Palaeontological specialist assessment: combined desktop and field-based study

Umsobomvu 1 Wind Energy Facility near Middelburg, Pixley ka Seme & Chris Hani District Municipalities, Northern and Eastern Cape

John E. Almond PhD (Cantab.)
***Natura Viva* cc, PO Box 12410 Mill Street,**
Cape Town 8010, RSA
naturaviva@universe.co.za

September 2018

EXECUTIVE SUMMARY

InnoWind (Pty) Ltd is proposing to develop a wind energy facility (WEF) of up to 220 MW generation capacity in the mountainous Agter-Renosterberg region of the eastern Karoo, situated some 25 km to the northwest of Middelburg, on the border between the Northern Cape and Eastern Cape Provinces. The present palaeontological heritage assessment report concerns the project design for the Umsobomvu 1 WEF as amended in 2018 that is outlined in Section 1.1 as well as in Figure 3 herein. Land parcels concerned in the proposed WEF total just over 8000 hectares and include eight portions of the farms Elands Kloof 135, Uitzicht 3, Leuwe Kop 120 and Winterhoek 136, falling under the Pixley ka Seme & Chris Hani District Municipalities. The access road to the site from the N10, also assessed here, will be on Winterhoek RE/118. The electrical energy generated by the WEF will be fed directly into 400 kV power lines (to be assessed separately) from a small on-site substation.

The proposed Umsobomvu 1 WEF project area is largely underlain by continental (fluvial, lacustrine) sediments of the Beaufort Group (Karoo Supergroup). These include (1) latest Permian to earliest Triassic rocks forming the uppermost portion of the Adelaide Subgroup (equivalents of the Balfour Formation of the eastern Main Karoo Basin) that crop out in low-lying, hilly terrain around the periphery of the Agter-Renosterberg massif, as well as (2) Early Triassic sediments of the Katberg Formation (Tarkastad Group) that build the Agter-Renosterberg escarpment and large parts of the upland plateau. The Karoo Supergroup sediments have been extensively intruded by Early Jurassic dykes and sills of the Karoo Dolerite Suite that have baked the adjacent country rocks and also underlie large areas of the plateau. The upper Adelaide Subgroup and Katberg Formation are well-known for their important continental biotas spanning the Permo-Triassic boundary, including diverse fossil vertebrates (therapsids, reptiles, amphibians), trace fossils (*e.g.* invertebrate and vertebrate burrows, trackways) and rarer vascular plants. These fossil faunas provide key data for understanding the impact of the catastrophic end-Permian Mass Extinction at 251 Ma (million year ago) on the terrestrial life of Gondwana. The Beaufort Group and Karoo dolerite bedrocks are extensively mantled by a variety of Late Caenozoic superficial deposits such as colluvial rock rubble (scree), alluvium, surface gravels, soils and pedocretes.

Previous workers have recorded a number of Late Permian and Early Triassic vertebrate fossil sites in the Agter-Renosterberg (*cf* Kitching 1977, Nicolas 2007). Recent fieldwork shows that the mudrock-dominated Adelaide Subgroup succession around the base of the escarpment is generally very poorly exposed, due to a thick prism of colluvial sediment cover, and often deeply weathered. Only sparse fossil vertebrate remains (isolated bones, one semi-articulated skeleton close to but outside the project area) as well as low-diversity trace fossil assemblages (*Scoyenia*) were recorded

here. Better exposures just 20 km southwest of the study area yielded numerous, unusually large vertebrate burrows of possible dicynodont origin. Most of the fossil material recorded from the Katberg Formation within and close to the study area comes from small exposures of mudrock-dominated sediment packages within the lower part of the succession (The precise stratigraphic position of these finds remains ambiguous due to low exposure levels here). It includes well-articulated skeletal material of the medium-sized dicynodont *Lystrosaurus* embedded within mudrock or pedogenic calcrete outside and west of the study area (Almond 2018b) as well as fairly common, disarticulated and rolled bones and teeth variously associated with mudflake / calcrete basal breccias or channel sandstones. Several large vertebrate burrows are recorded in excellent road cutting exposures of lower Katberg rocks along the N10, just outside the study area, as well as along a stream bed exposure over 100 m SW of the proposed access route into the Umsobomvu 1 WEF project area on Farm Winterhoek 118/RE. Small, oblique cylindrical burrows (*Katbergia*), of probable crustacean origin are locally abundant within mudrock and sandstone facies. Rare occurrences of poorly-preserved plant material (unidentified stems and woody fragments) as well as possible tetrapod tracks from high up within the Katberg Formation were reported from farm Uitzicht 3. The intrusive dolerites that are likely to underlie a substantial fraction of the development footprint on higher ground are unfossiliferous. Furthermore, baking of the surrounding sediments during dolerite intrusion has probably compromised some of the fossils originally preserved here. No fossil remains were observed within the Late Caenozoic superficial sediments in the study area.

There are no fatal flaws in the Umsobomvu 1 WEF development proposal as far as fossil heritage is concerned. Due to (1) the general scarcity of fossil remains, especially in the upland areas where the majority of the infrastructure will be situated, (2) the moderately high levels of near-surface bedrock weathering and baking of sediments by dolerite intrusions, as well as (3) the extensive superficial sediment cover observed within most of the study area, the overall impact significance of the construction phase of the proposed alternative energy project is assessed as LOW. The no-go option (*i.e.* no development of the wind farm) is of neutral impact significance for fossil heritage. This assessment applies to the construction phase of the development since further impacts on fossil heritage during the planning, operational and decommissioning phases of the facilities are not anticipated. Cumulative impacts on fossil heritage resources posed by several alternative energy developments proposed in the wider Middelburg – Noupoort region are assessed as *low*. Confidence levels for the assessment are rated as medium, given the necessarily superficial palaeontological field coverage of the large, mountainous project area.

All scientifically-significant, conservation-worthy fossil sites recorded within the Umsobomvu 1 WEF project area lie outside the development footprint. Given the low impact significance of the proposed Umsobomvu 1 WEF near Middelburg as far as palaeontological heritage is concerned, no further specialist palaeontological heritage studies or mitigation are considered necessary for this project, pending the potential discovery or exposure of substantial new fossil remains during development. There are no objections on palaeontological heritage grounds to authorization of the amended WEF development.

During the construction phase all deeper (> 1 m) bedrock excavations should be monitored for fossil remains by the responsible ECO. Should substantial fossil remains such as vertebrate bones, teeth or trackways, plant-rich fossil lenses or dense fossil burrow assemblages be exposed during construction, the responsible Environmental Control Officer should safeguard these, preferably *in situ*, and alert the responsible heritage management authority (ECPHRA for the Eastern Cape, SAHRA for the Northern Cape) so that appropriate action can be taken by a professional palaeontologist, at the developer's expense (Contact details: ECPHRA: Mr Sello Mokhanya, 74 Alexander Road, King Williams Town 5600; Email: smokhanya@ecphra.org.za. 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). Mitigation would normally involve the scientific recording and judicious sampling or collection of fossil material as well as associated geological data (*e.g.* stratigraphy, sedimentology, taphonomy) by a professional palaeontologist. A Chance Fossil Finds Procedure is appended to this report.

These mitigation recommendations should be incorporated into the Construction Environmental Management Programme (EMPr) for the Umsobomvu 1 Wind Energy Facility. *Provided that* the recommended mitigation measures are carried through, it is likely that any potentially negative impacts of the proposed development on local fossil resources will be substantially reduced. Furthermore, they will be partially offset by the *positive* impact represented by our increased understanding of the palaeontological heritage of the Great Karoo region.

Please note that:

- All South African fossil heritage is protected by law (South African Heritage Resources Act, 1999) and fossils cannot be collected, damaged or disturbed without a permit from SAHRA or the relevant Provincial Heritage Resources Agency (in this case, ECPHRA for the Eastern Cape and SAHRA for the Northern Cape);

- The palaeontologist concerned with mitigation work will need a valid fossil collection permit from ECPHRA / SAHRA and any material collected would have to be curated in an approved depository (*e.g.* museum or university collection);

- All palaeontological specialist work would have to conform to international best practice for palaeontological fieldwork and the study (*e.g.* data recording fossil collection and curation, final report) should adhere as far as possible to the minimum standards for Phase 2 palaeontological studies recently developed by SAHRA (2013).

1. INTRODUCTION

1.1. Outline of the proposed development

The company InnoWind (Pty) Ltd is proposing to develop a wind energy facility (WEF) in the mountainous Agter-Renosterberg region of the eastern Karoo, situated some 25 km to the northwest of Middelburg, on the border between the Northern Cape and Eastern Cape Provinces (Figs. 1 & 2). The Northern Cape portion of the proposed Umsobomvu 1 WEF falls within the Umsobomvu Local Municipality in the Pixley ka Seme District Municipality while the Eastern Cape portion lies within the Inxuba Yethemba Local Municipality and Chris Hani District Municipality. The present report assesses palaeontological heritage impacts for the revised Umsobomvu 1 WEF project design, as amended in 2018.

The Umsobomvu 1 WEF will consist of up to approximately forty wind turbines, each with potential power output of 5.5 megawatts (MW) giving a total generation capacity of up to 220 MW (Fig. 3). The eight separate land parcels that are concerned in the proposed WEF are as follows: Elands Kloof 135/1 and 135/0 (RE); Uitzicht 3/(RE), 3/2, 3/3, 3/4, 3/7 & 3/8; Leuwe Kop 120/0 (RE)and Winterhoek 136/0 (RE) (Fig. 3). The access road to the site, also assessed here, will be on Winterhoek RE/118. These land parcels have a total area of just over 8000 hectares, but the development footprint of the wind turbines and associated infrastructure will potentially occupy less than 2% of this area. The electrical energy generated by the WEF will be fed directly from a small on-site IPP substation *via* an Eskom MTS Substation and new 400 kV power lines (to be assessed separately) to the existing Hydra / Poseidon Eskom Powerline.

The main infrastructural components of the proposed Umsobomvu 1 WEF of relevance to the present study (See Fig. 3) include:

- Up to 40 wind turbines of 5.5 MW generation capacity whose size will depend on technical assessments of the wind data gathered on site;
- Concrete foundations to support the wind towers;
- Approximately 6 meter-wide internal access roads to each turbine;
- Underground cables *plus* multiple internal 33 kV overhead cables, each approximately 1.5 km long, connecting the turbines with one another and to the small on-site substation;
- An OMS building to house the control instrumentation and interconnection elements, as well as a storeroom for maintenance equipment;
- Temporary batching plant laydown areas and construction compounds (x 2);
- A small on-site substation together with the MTS/IPP system (total footprint *c*. 600 m x 600 m) at 31°21'21.95"S, 24°49'21.88"E to facilitate connection of the WEF with the Eskom electricity grid.
- A 132 kV overhead transmission line of up to 1 km in length connecting the On-site Substation to the Eskom MTS Substation.

EOH Coastal & Environmental Services, East London (Contact details: Caroline Evans. EOH Coastal & Environmental Services. 16 Tyrell Road, Berea, East London 5241. P.O Box 8145, Nahoon, 5210. Tel: (043) 726 7809/8313. Fax: (043) 726 8352. Email: c.evans@cesnet.co.za) have been appointed by InnoWind (Pty) Ltd as the independent consultants to assess the environmental impacts of the proposed development in terms of the National Environmental Management Act 107 of 1998 (NEMA).

1.2. Scope of this palaeontological heritage study

The Umsobomvu 1 WEF project study area near Middelburg is underlain by potentially fossiliferous sedimentary rocks of the Beaufort Group (Adelaide and Tarkastad Subgroups) of Late Permian to Early Triassic age as well as Late Caenozoic superficial deposits (Figs. 4 to 7). This combined desktop and field-based palaeontological specialist report provides an assessment of the observed or inferred palaeontological heritage within the study area, with recommendations for further specialist palaeontological studies and / or mitigation where considered necessary.

The Specialist Terms of Reference (ToR) for the Palaeontological Impact Assessment, as determined by EOH Coastal & Environmental Services, are as follows:

> The Paleontological Impact Assessment will focus on the identification and evaluation of sites, features and objects of fossil significance located in the area of the proposed development.
>
> Preparation and submission of a Phase 1 Palaeontological Impact Report, as determined by the National Heritage Resources Act, by:
>
> 1. undertaking a site visit to the proposed location of the windfarm as per the coordinates provided by CES;
>
> 2. determining the likelihood of there being palaeontological sites of significance within the development area;
>
> 3. identifying and mapping (as far as may be possible in a four day site visit) any sites of palaeontological significance exposed at surface within the footprint of the proposed development;

4. indicating the sensitivity and conservation significance of potential palaeontological sites that may be affected by the proposed development;

5. identifying mitigation measures to protect any such sites, and

6. making recommendations for inclusion in the Construction Environmental Management Plan for the proposed excavations, as to how the identified potential heritage impacts should be mitigated and minimised.

The present palaeontological heritage assessment report concerns the project design for the Umsobomvu 1 WEF, as amended in 2018, that is outlined in Section 1.1 as well as in Figure 3.

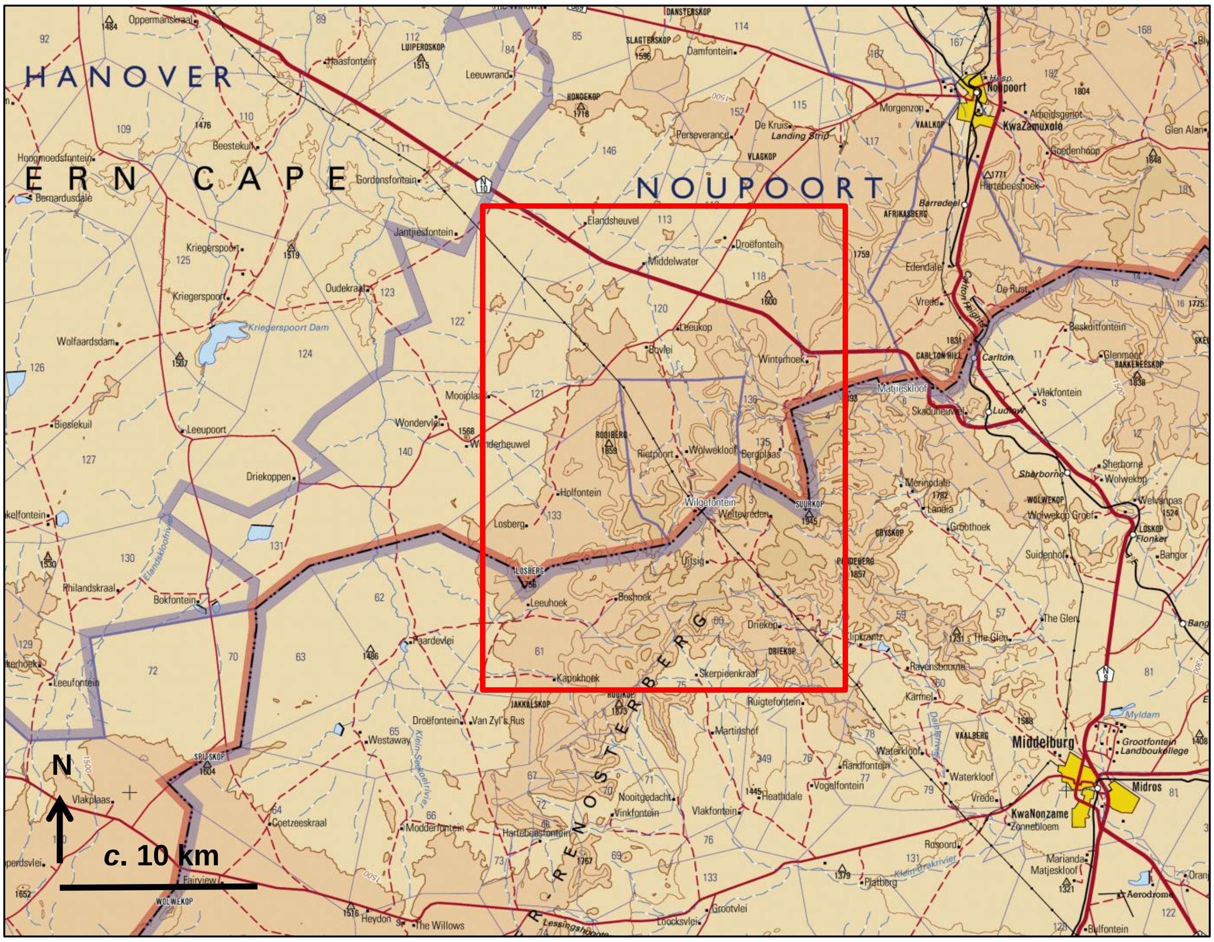

Fig. 1. Extract from 1: 250 000 topographical sheet 3124 Middelburg (Courtesy of the Chief Directorate: National Geo-spatial Information, Mowbray) showing the *approximate* location of the proposed Umsobomvu 1 WEF project area in the Agter-Renosterberg region of the Eastern Karoo, *c*. 25 km NW of Middelburg, Eastern Cape Province (red rectangle). Note that the project area spans the Eastern and Northern Cape provincial boundary.

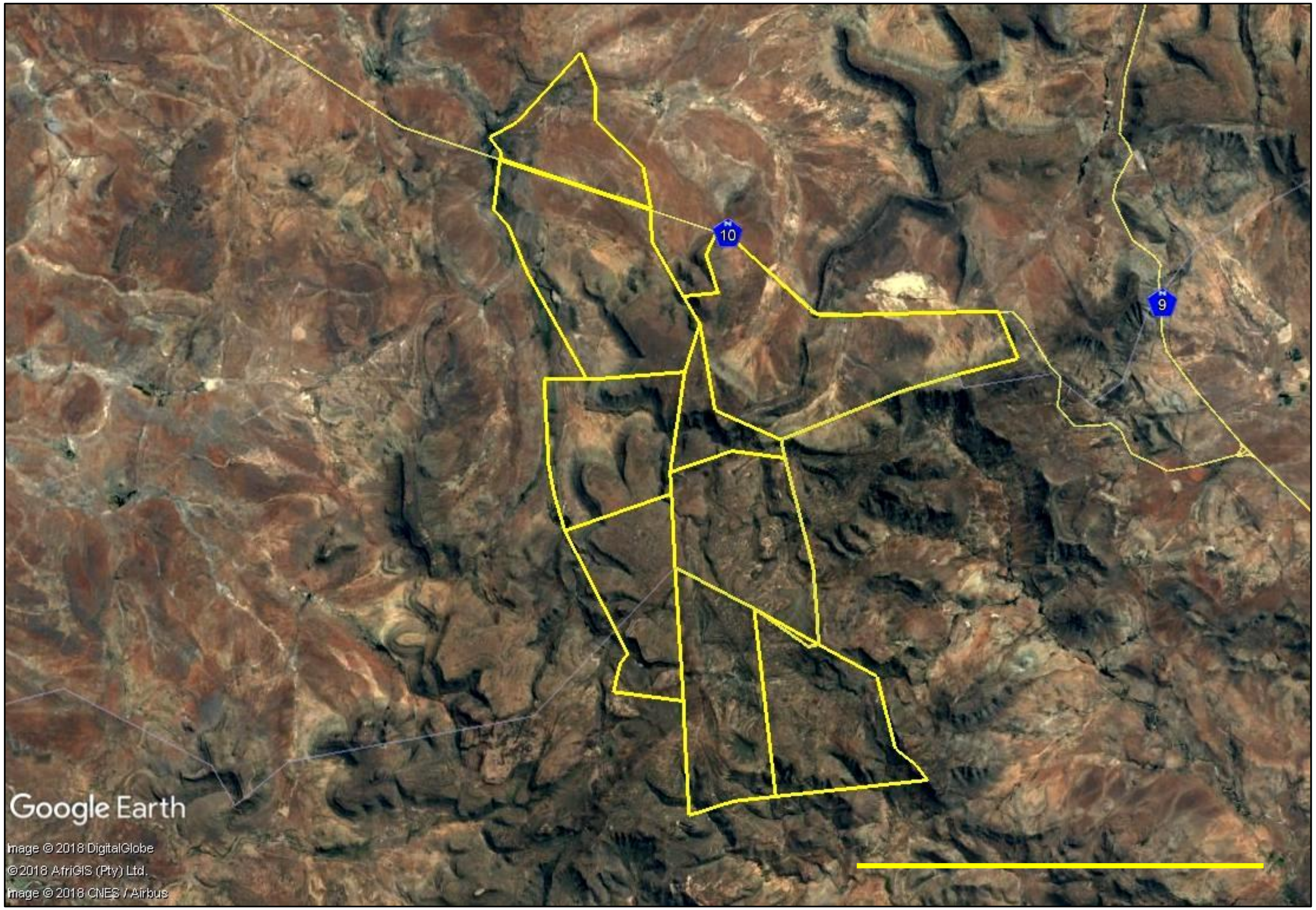

Fig. 2. Google earth© satellite image of the Umsomobvu 1 WEF project area, Eastern Cape (yellow polygons outlining the separate land parcels), showing the semi-arid, rugged mountainous terrain of the Agter-Renosterberg region to the NW of Middelburg and south of the N10 trunk road. Scale bar = 10 km. N towards the top of the image

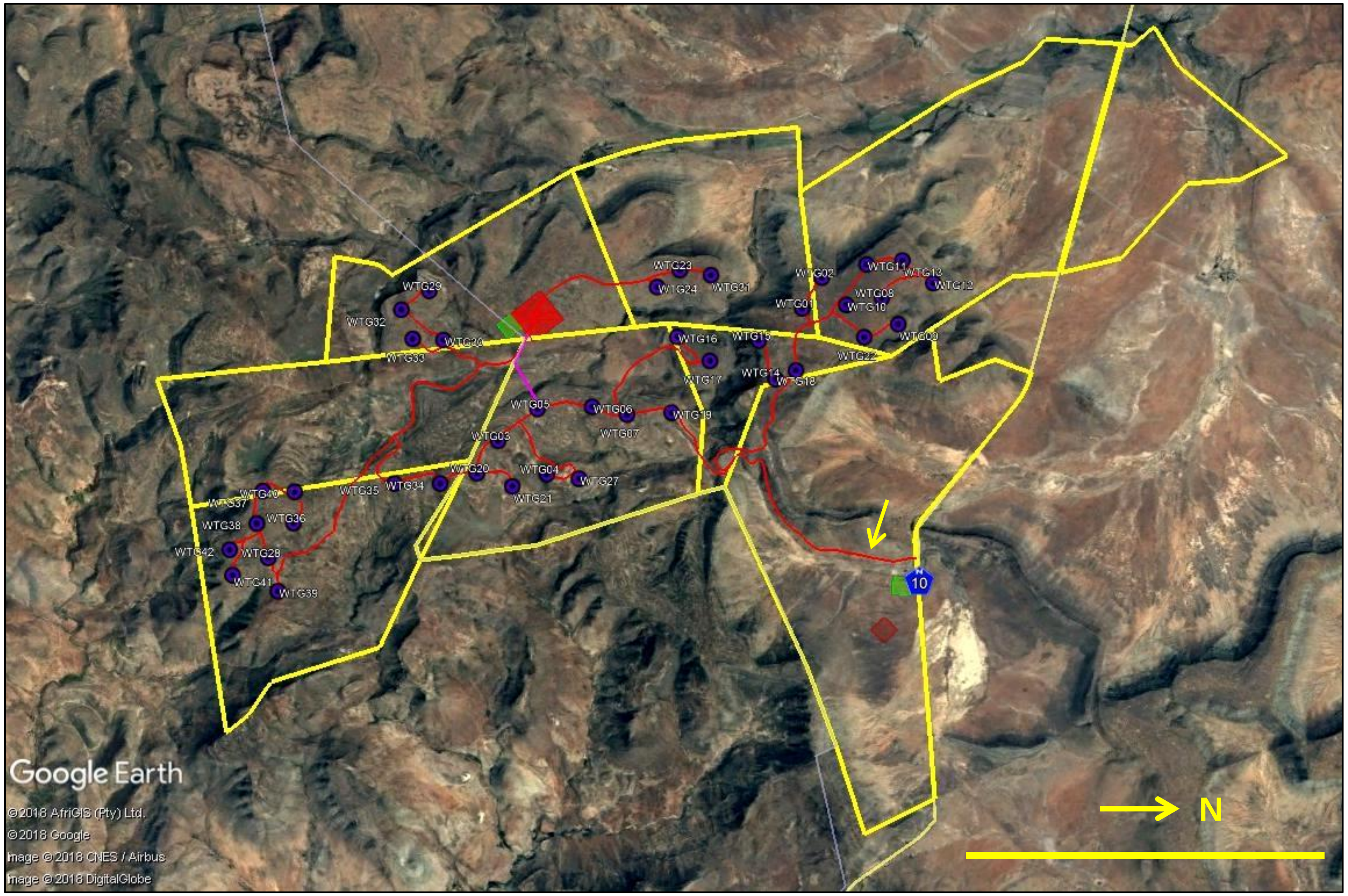

Fig. 3. Google earth© satellite image of the Umsomobvu 1 WEF project area showing the main infrastructural components, *viz*: 40 wind turbine sites (blue circles); internal access roads (red lines); on-site substation (large red square); temporary laydown areas and construction compounds (green squares); 33 kV overhead cables (lilac).The access road to the WEF project area on Winterhoek RE/118 is arrowed. Scale bar = 6 km. N towards the RHS of the figure.

Fig. 4. North-western escarpment area of the Agter-Renosterberg showing steep *krans* of upper Katberg Formation sandstones along the crest, lower escarpment slopes mantled with colluvium with only small exposures of potentially fossiliferous mudrocks (grey, middle ground).

Fig. 5. Deeply-dissected uplands of the Agter-Renosterberg, here looking NW towards Wilgefontein homestead. The valley rims are built of tough-weathering Katberg sandstone and intrusive dolerite.

Fig. 6. Typical dolerite upland scenery on the western portion of Uitzicht 3, with well-jointed dolerite in the foreground.

Fig. 7. Subhorizontal Katberg sandstones (foreground and middle ground) overlain and baked by an intrusive dolerite sill (background), western portion of Uitzicht 3.

1.3. Legislative context for palaeontological assessment studies

The proposed Umsobomvu 1 Wind Energy Facility project is located in an area of the eastern Karoo that is underlain by potentially fossil-rich sedimentary rocks of the Karoo Supergroup that are of Late Permian to Early Triassic age and that are internationally famous for their rich fossil record (Sections 2 and 3). The construction phase of the WEF development will entail excavations into the superficial sediment cover (soils, alluvium, surface gravels *etc*) and also into the underlying fossiliferous bedrock. These notably include site clearance activities as well as excavations for the wind turbine foundations, laydown and mounting areas, buried cables, new internal access roads, transmission line pylon footings, on-site substation, office / workshop area and any associated borrow pits. All these developments may adversely affect potential fossil heritage within the study area by destroying, disturbing or permanently sealing-in fossils that are then no longer available for scientific research or other public good. Once constructed, the operational and decommissioning phases of the WEF will not involve further adverse impacts on palaeontological heritage, however.

The present combined desktop and field-based palaeontological heritage report falls under Sections 35 and 38 (Heritage Resources Management) of the South African Heritage Resources Act (Act No. 25 of 1999), and it will also inform the Construction 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).

1.4. 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 (provisional tabulations of palaeontological sensitivity of all formations in the Western, Eastern and Northern Cape have already been compiled by J. Almond and colleagues; *e.g.* Almond & Pether 2008, Almond *et al.* 2008). The likely impact of the proposed development on local fossil heritage is then determined on the basis of (1) the palaeontological sensitivity of the rock units concerned and (2) the nature and scale of the development itself, most significantly the extent of fresh bedrock excavation envisaged. When rock units of moderate to high palaeontological sensitivity are present within the development footprint, a Phase 1 field assessment study by a professional palaeontologist is usually warranted to identify any palaeontological hotspots and make specific recommendations for any mitigation required before or during the construction phase of the development.

On the basis of the desktop and Phase 1 field assessment studies, the likely impact of the proposed development on local fossil heritage and any need for specialist mitigation are then determined.

Adverse palaeontological impacts normally occur during the construction rather than the operational or decommissioning phase. Phase 2 mitigation by a professional palaeontologist – normally involving the recording and sampling of fossil material and associated geological information (*e.g.* sedimentological data) may be required (a) in the pre-construction phase where important fossils are already exposed at or near the land surface and / or (b) during the construction phase when fresh fossiliferous bedrock has been exposed by excavations. To carry out mitigation, the palaeontologist involved will need to apply for palaeontological collection permits from the relevant heritage management authorities, *i.e.*. ECPHRA for the Eastern Cape (Contact details: Mr Sello Mokhanya, 74 Alexander Road, King Williams Town 5600; Email: smokhanya@ecphra.org.zaso) 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.

1.4. Assumptions & limitations

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

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

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

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

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

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

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

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

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

Since most areas of the RSA have not been studied palaeontologically, a palaeontological desktop study usually entails *inferring* the presence of buried fossil heritage within the study area from relevant fossil data collected from similar or the same rock units elsewhere, sometimes at localities far away. Where substantial exposures of bedrocks or potentially fossiliferous superficial sediments are present in the study area, the reliability of a palaeontological impact assessment may be significantly enhanced through field assessment by a professional palaeontologist. In the present case, site visits to the various loop and borrow pit study areas in some cases considerably modified our understanding of the rock units (and hence potential fossil heritage) represented there.

In the case of the Umsobomvu 1 WEF study area exposure of potentially fossiliferous bedrocks is often very poor due to soil, scree, alluvium and vegetation cover (Figs. 4 to 7). Several useful exposures are available in borrow pits, road cuttings, stream beds and river banks as well as on steeper hillslopes, that, together with previous studies on local fossils, permit a reasonably informed assessment of the palaeontological heritage sensitivity of the area. Confidence levels for this assessment are necessarily only moderate, however.

1.5. Information sources

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

1. A brief project outline provided by EOH Coastal & Environmental Services;

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

3. The author's previous field experience with the formations concerned and their palaeontological heritage (See also reviews of Northern and Eastern Cape fossil heritage by Almond & Pether 2008 and Almond *et al.* 2008 respectively);

4. A five-day field assessment of the original Umsobomvu WEF project area on 4-8 January 2015 by the author and two assistants (Almond 2015).

2. GEOLOGICAL OUTLINE OF THE BROADER STUDY REGION NEAR NOUPOORT

The following illustrated account of the geology of the Agter-Renosterberg region to the southwest of Noupoort and northwest of Middelburg is abstracted *verbatim* from the palaeontological assessment report for the original Umsobomvu WEF project area by the author (Almond 2015). It covers the entire amended project area for the Umsobomvu 1 WEF *as well as* project areas for the adjoining Coleskop WEF and for the additional electrical infrastructure associated with these two WEFs. GPS locality data and brief notes regarding numbered sites mentioned in the text are given in Appendix 2 to this report.

The original Umsobomvu WEF study area, of which the present Umsobomvu 1 WEF project area forms only a part, is centred on the highly dissected upland plateau of the Agter-Renosterberg, a NNE-SSW trending mountain range that is situated in the eastern Karoo region some 25 km northwest of Middelburg. It lies north of the R398 dust road between Middelburg and Richmond and extends northwards up to and just beyond the N10 tar road from Hanover to Middelburg. The rugged, rocky plateau where the bulk of the WEF infrastructure will be situated reaches elevations of *c*. 1875 m amsl (*e.g.* Rooikop, Rooiberg) while the *vlaktes* along its steep western escarpment lie at around 1500 m amsl. The plateau area is drained to the southeast by tributaries of the Klein-Brakrivier and to the west by tributaries of the Klein-Seekoeirivier. Most of the terrain is rocky, semi-arid and mantled by sparse *bossieveld* vegetation with grassier vegetation on the dolerite-dominated upland plateau (Figs. 4 to 7).

The geology of the study area to the northwest of Middelburg is shown on 1: 250 000 sheet 3124 Middelburg (Council for Geoscience, Pretoria) (Cole *et al.* 2004) (Fig. 9). Most of the higher-lying terrain is underlain by Early Triassic (*c*. 250 Ma = million years old) fluvial sediments of the **Katberg Formation** of the Tarkastad Subgroup, Upper Beaufort Group, Karoo Supergroup (**TRk**, pale yellow with red stipple in Fig. 9). These are the potentially fossiliferous sediments that will be most affected by the proposed WEF development. A small area of slightly older Lower Beaufort Group sediments assigned to the underlying **Adelaide Subgroup** (**Pa**, pale blue-green in Fig. 9) is mapped within the study area in the western and northern foothills of the Agter-Renosterberg range. As discussed below, it is likely that these rocks belong to the uppermost portion of the Adelaide Subgroup, namely the **Elandsberg** and **Palingkloof Members** of Latest Permian to Earliest Triassic age (See stratigraphic chart in Fig. 8). Given their location at the foot of the sandstone-dominated and dolerite-intruded Katberg escarpment, the Adelaide Subgroup rocks here are largely covered by Late Caenozoic colluvial debris (scree, hillwash *etc*). Furthermore, direct impacts of the Umsomobvu WEF development on this lower-lying portion of the study area are likely to be minimal (*e.g.* access roads, transmission line pylon footings). For these reasons, the pre-Katberg rocks will not be treated in any detail in this report. It should be noted, however, that the upper Adelaide Subgroup sediments and fossils are of considerable palaeontological significance elsewhere in the Main Karoo Basin since they record the catastrophic end-Permian mass extinction event and subsequent 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, Viglietti *et al.* 2015, Viglietti 2016).

The Karoo Supergroup sedimentary rocks in the Agter-Renosterberg 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). The sills and dykes have thermally metamorphosed or baked the adjacent sediments. The presence of resistant-weathering bedrocks such as dolerite as well as baked, silicified country rocks is largely responsible for the elevated topography and steep slopes of the mountains here. Levels of tectonic deformation in this region are generally low, as shown by recorded dips here of only two to three degrees within the Beaufort Group bedrocks; locally higher dips within the sedimentary country rocks are a consequence of subterranean displacement by voluminous dolerite magma during Early Jurassic times (Fig. 43).

In most parts of the study area, including the flatter-lying plateaux and *vlaktes* as well as steeper hillslopes, the ancient sedimentary and igneous bedrocks are mantled with a variety of **superficial deposits** of probable Late Caenozoic (Quaternary to Recent) age. They include pedocretes (*e.g*. calcretes, ferricretes), slope deposits (rubbly scree, hillwash *etc*), river alluvium, diverse soils and surface gravels (*cf* Partridge *et al*. 2006). As a result of these deposits as well as pervasive grassy or dwarf shrubby vegetation cover, surface exposure of fresh Karoo Supergroup rocks within the region is usually poor, apart from occasional stream banks and beds, erosional gullies or *dongas* and steeper hill slopes as well as artificial exposures in road cuttings, farm dams and borrow pits or quarries. The hill slopes are typically mantled with a thin to thick layer of **colluvium** or slope deposits (*e.g.* sandstone and dolerite scree, finer-grained hill wash) and soil. Thicker accumulations of silty, sandy, gravelly and bouldery **alluvium** of Late Caenozoic age (< 5 Ma) are found in streams and river valleys. These colluvial and alluvial deposits may be extensively calcretised (*i.e.* cemented with soil limestone or calcrete), especially in the neighbourhood of dolerite intrusions. Apart from the more extensive areas of river alluvium in lower lying areas in the west and north of the Agter-Renosterberg (pale yellow areas with “flying bird” symbol in Fig. 9), most of these geologically youthful deposits are not mapped at 1: 250 000 scale. Exposure levels of potentially fossiliferous Beaufort Group bedrocks are therefore far lower than implied by the geological map. During palaeontological fieldwork, attention necessarily focused on small, dispersed exposures of sedimentary bedrock in road-cuttings, borrow pits, erosion gullies and stream beds that were identified beforehand on satellite images. More extensive exposures, especially of the prominent-weathering sandstone facies, were also available on steeper slopes along the western escarpment of the Agter-Renosterberg massif and elsewhere (Figs. 10 & 11).

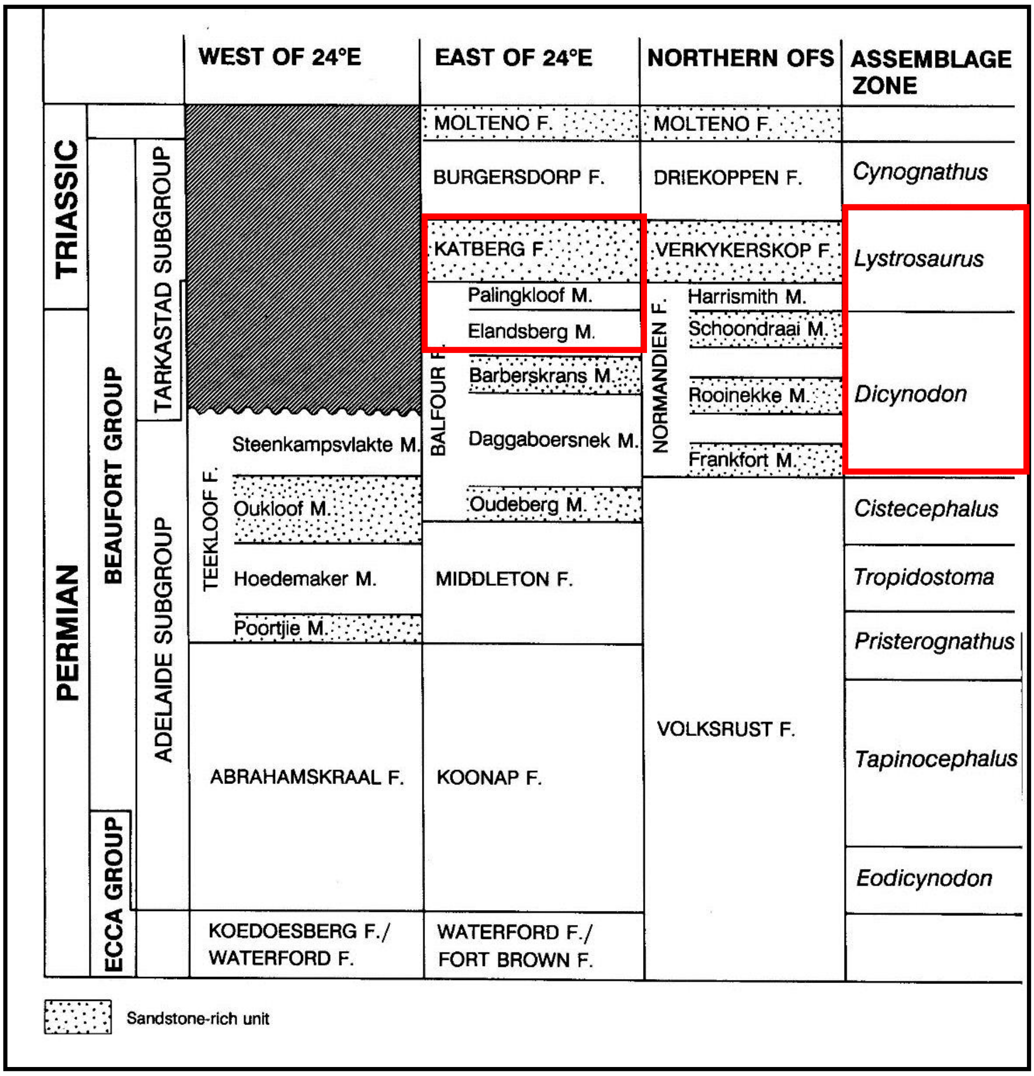

Fig. 8: Chart showing the lithostratigraphic (rock-based) and biostratigraphic (fossil-based) subdivisions of the Beaufort Group with rock units and fossil assemblage zones relevant to the present study outlined in red (Modified from Rubidge 1995). Note that these include subdivisions of the Adelaide and Tarkastad Subgroups and range in age from Late Permian to Early Triassic. Due to insufficient field data, the precise subunits of the Balfour Formation represented in the study area have not yet been determined (See text for discussion).

Fig. 9 (following page). Extract from 1: 250 000 geology sheet 3124 Middelburg (Council for Geoscience, Pretoria) showing *approximate* outline of the Umsobomvu 1 WEF project area in the Agter-Renosterberg region to the northwest of Middelburg, Northern and Eastern Cape (blue polygon). The main geological units represented here are: Pa (pale blue-green) = Late Permian to Earliest Triassic Adelaide Subgroup (Lower Beaufort Group, Karoo Supergroup); TRk (pale orange with red dots) = Early Triassic Katberg Formation of the Tarkastad Subgroup (Upper Beaufort Group, Karoo Supergroup); Jd (red) = intrusive sills and dykes of the Early Jurassic Karoo Dolerite Suite. Pale yellow 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.

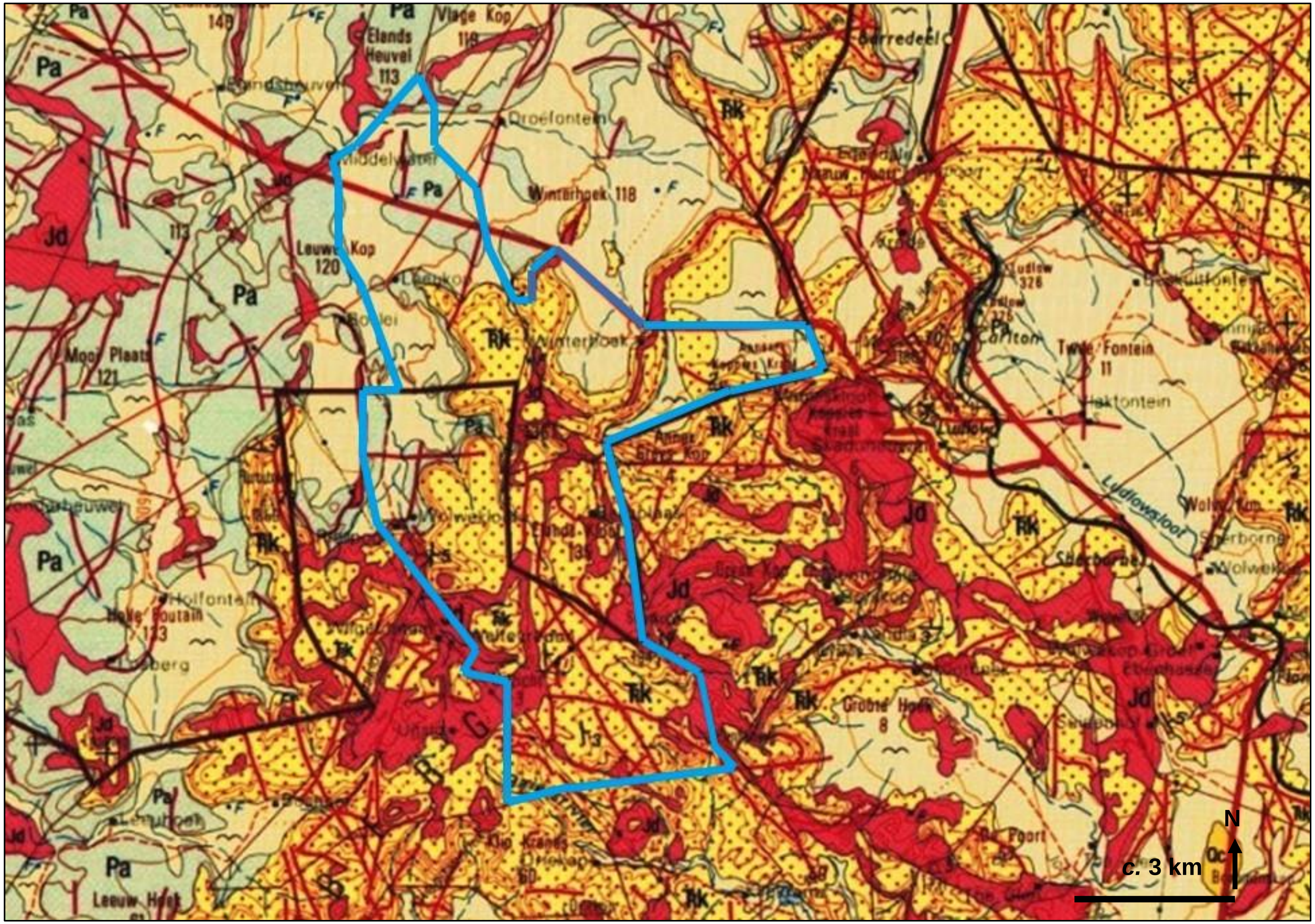
Elands Heuvel 113
Droefontein
Winterhoek 118
Leeuw Kop 120
Winterhoek
Mooi Plaats 121
Twee Fontein 11
Ludlowsloot
Pa
Jd
Trk
N
c. 3 km

Fig. 10. The steep NW slopes of the Rooiberg. Closely-spaced sandstone packages extending down the hillslope are mapped as Katberg Formation while the grey-green mudrocks in the foreground are assigned to the upper Adelaide Subgroup. The base of the Katberg here is not well-defined and may be gradational.

Fig. 11. West-facing Katberg escarpment to the southeast of Bovlei homestead, Elandskloof 135. The majority of the steep, sandstone-dominated slope seen here is mapped as Katberg Formation, with Adelaide Subgroup rocks only at the base.

2.1. Adelaide Subgroup

The oldest rocks in the study area comprise Late Permian fluvial sediments of the **Lower Beaufort Group** (**Adelaide Subgroup**; Pa in geological map Figure 9). Geological and palaeoenvironmental analyses of the Lower Beaufort Group sediments in the Great Karoo region have been conducted by a number of workers. Key references within an extensive scientific literature include various papers by Roger Smith (*e.g.* Smith 1979, 1980, 1986, 1987, 1988, 1989, 1990, 1993a, 1993b) and Stear (1978, 1980), as well as several informative field guides (*e.g.* Smith *et al.* 2002, Cole & Smith 2008). In brief, these thick successions of clastic sediments were laid down by a series of large, meandering rivers within a subsiding basin over a period of some ten or more million years within the Late Permian Period (*c*. 265-251 Ma). Sinuous sandstone bodies of lenticular cross-section represent ancient channel infills, while thin (<1.5 m), laterally-extensive sandstone beds were deposited by crevasse splays during occasional overbank floods. The bulk of the Beaufort sediments are greyish-green to reddish-brown or purplish mudrocks ("mudstones" = fine-grained claystones and slightly coarser siltstones) that were deposited over the floodplains during major floods. Thin-bedded, fine-grained playa lake deposits also accumulated locally where water ponded-up in floodplain depressions and are associated with distinctive fossil assemblages (*e.g.* fish, amphibians, coprolites or fossil droppings, arthropod, vertebrate and other trace fossils).

Frequent development of fine-grained pedogenic (soil) limestone or calcrete as nodules and more continuous banks indicates that semi-arid, highly seasonal climates prevailed in the Late Permian Karoo. This is also indicated by the frequent occurrence of sand-infilled mudcracks and silicified gypsum "desert roses", especially in the western outcrop area (Smith 1980, 1990, 1993a, 1993b). Highly continental climates can be expected from the palaeogeographic setting of the Karoo Basin at the time – embedded deep within the interior of the Supercontinent Pangaea and in the rainshadow of the developing Gondwanide Mountain Belt. Fluctuating water tables and redox processes in the alluvial plain soil and subsoil are indicated by interbedded mudrock horizons of contrasting colours. Reddish-brown to purplish mudrocks probably developed during drier, more oxidising conditions associated with lowered water tables, while greenish-grey mudrocks reflect reducing conditions in waterlogged soils during periods of raised water tables. However, diagenetic (post-burial) processes also greatly influence predominant mudrock colour (Smith 1990).

Due to the absence of unambiguous sandstone marker horizons, the Adelaide Subgroup is not subdivided into individual formations or members on the 3124 Middelburg sheet but these subdivisions are discussed in the accompanying sheet explanation by Cole *et al.* (2004). It is apparent from biostratigraphic (*i.e.* fossil-based) mapping, however, that only the upper, Late Permian to Early Triassic, portion of the Adelaide Subgroup is present within the present study area, corresponding to the *Dicynodon* and lowermost *Lystrosaurus* Assemblage Zones (Rubidge 2005, Van der Walt *et al.* 2010, Smith *et al.* 2012). The succession here is therefore broadly equivalent to the uppermost part of the **Balfour Formation** that is recognised at the top of the Adelaide Subgroup succession within the Main Karoo Basin to the east of 24º East (Rubidge 2005) (Fig. 8).

The fluvial Balfour Formation comprises recessive weathering, grey to greenish-grey overbank mudrocks with subordinate resistant-weathering, grey, fine-grained channel sandstones deposited by large meandering river systems in the Late Permian to Earliest Triassic Period (Hill 1993, Cole *et al.* 2004). The formation reaches a maximum thickness of over 2000 m in the Fort Beaufort area but is only 650 m near Graaff-Reinet (Johnson 1976, Visser & Dukas 1979). Thin wave-rippled sandstones were laid down in transient playa lakes on the flood plain. Reddish mudrocks are comparatively rare, but increase in abundance towards the top of the Adelaide Subgroup succession near the upper contact with the Katberg Formation. Key recent reviews of the Balfour Formation fluvial succession have been given by Visser and Dukas (1979), Catuneanu and Elango (2001), Katemaunzanga (2009) and Oghenekome (2012). Catuneanu and Elango (2001) identified six upward-fining depositional sequences within the Balfour succession that are separated by subaerial unconformities and lasted on average about 0.7 Ma (million years). The sequences were generated by tectonic processes within the Cape Fold Belt. Fluvial deposition by sandy braided rivers in the early part of each sequence was followed by more mixed channel sandstones and overbank mudrocks laid down by meandering rivers higher in the sequence. Sedimentological data, such as the comparative rarity of palaeosols (fossil soils, desiccation cracks, red beds), suggest that palaeoclimates during this period were predominantly temperate to humid and water tables were generally high.

The Balfour Formation of the Eastern Cape has been subdivided into five successive members (Kitching 1995) (Fig. 8). These stratigraphic units are not separately mapped on the 1: 250 000 scale geological map (Fig. 9) but they are briefly discussed for the Middelburg sheet area by Cole *et al.* (2004) and by Oghenekome (2012) for the Bedford – Adelaide area to the south. Only the uppermost three members relevant to the present Agter-Renosterberg study area will be discussed here. The **Barberskrans Member** is a sandstone-dominated package within the upper Adelaide Subgroup that is situated *c*. 100-150 m below the base of the Katberg Formation. In the western part of the Middelburg sheet area it reaches 150 m in thickness. At Klein Tafelberg, *c*. 30 km west of the present study area, it is 40 m thick but thins towards the northeast. This sandstone package is therefore probably not represented within the Umsobomvu 1 WEF study area itself. The overlying **Elandsberg Member** consists predominantly of greenish-grey to grey mudrocks with subordinate sandstone units up to 5 m thick. It reaches a thickness of *c*. 100 m on Klein Tafelberg and is inferred to underlie the *vlaktes* to the west of the Agter-Renosterberg. The uppermost subunit of the Balfour Formation, the **Palingkloof Member**, is characterised by a dominance of red mudrocks and directly underlies the Katberg Formation. It is 70 m thick to the NW of Nieu-Bethesda (*c*. 40 km SW of the present study area), where the massive siltstone-dominated Palingkloof succession includes several thin sandstone units. The Palingkloof Member is over 20 m thick at Carlton Siding *c*. 20 km NE of the study area but is absent on Klein Tafelberg, *c*. 30 km west of the Agter-Renosterberg (Cole *et al.* 2004). Although a red mudrock horizon was not observed beneath the Katberg Formation within the study area itself, this comparatively thin unit may be present but obscured by scree. A thick package of reddish mudrocks was noted, however, along a Katberg-capped ridge just north of the N10 on Winterhoek 118, less than 10 km NE of the study area (31º 18' S, 24º 54' E).

The lower portion of the Katberg Formation in the Agter Renosterberg consists of a series of prominent-weathering, tabular sandstone packages with thin intervening mudrocks, giving a step-like appearance to the escarpment slopes (Figs. 10 & 11). Since bedrock exposure of the lower escarpment slopes is generally very poor due to colluvial cover, the basal contact of the Katberg and Adelaide successions could not be precisely defined during the present field study, nor was it possible to identify with any confidence the subunits of the uppermost Balfour Formation represented here. For these reasons, the stratigraphic position of several fossil sites remains ambiguous at this stage; further fieldwork would be needed to resolve these uncertainties. In the interim, the published 1: 250 000 map (Fig. 9) is the primary resource used here.

Interbedded grey-green mudrocks and thin channel sandstones of the upper Adelaide Subgroup are well seen on the slopes of Wonderheuwel, some 10 km west of the study area (Fig. 12). If the capping sandstone seen here is indeed an outlier of the Katberg Formation, the underlying beds may belong to the Elandsberg Member, with intervening red mudrocks of the Palingkloof Member absent (as at Klein Tafelberg, *c*. 30 km to the southwest). A few small natural and borrow pit exposures of grey-green and subordinate purple-brown, hackly-weathering mudrocks and thin sandstones of the upper Adelaide Subgroup on the *vlaktes* bordering the Agter-Renosterberg are seen at Locs. 125, 126, 142, 151, 152 (Figs. 13 to 17). Rusty-brown ferruginous calcrete nodules and laterally-coalescent lenticles are a common occurrence within these beds, reflecting ancient soil horizons that are a target for fossil hunting. A fibrous ferruginous mineral encountered at Loc. 151 may be a secondary pseudomorph after gypsum, suggesting arid climatic intervals with high evaporation rates. Sandstone palaeosurfaces locally display mudcracking, adhesion warts and algal mat textures and were probably associated with shallow playa lakes or ponds on the ancient floodplain (*cf* Smith 1993).

Fig. 12. Grey-green overbank mudrocks and thin channel sandstones of the Adelaide Subgroup at Wonderheuwel, *c*. 10 km W of the Umsobomvu 1 WEF study area. The thick sandstone capping seen here might be an outlier of the Katberg Formation that occurs 5 km to the east.

Fig. 13. Shallow stream exposure of grey-green Adelaide Subgroup mudrocks in front of the Katberg Escarpment (Holle Fontein 133, Loc. 127). Note extensive mantle of poorly-sorted alluvium covering the bedrocks here.

Fig. 14. Large sphaeroidal ferruginous calcrete concretions marking an ancient palaeosol within the Adelaide Subgroup (Holle Fontein 133) (Hammer = 30 cm).

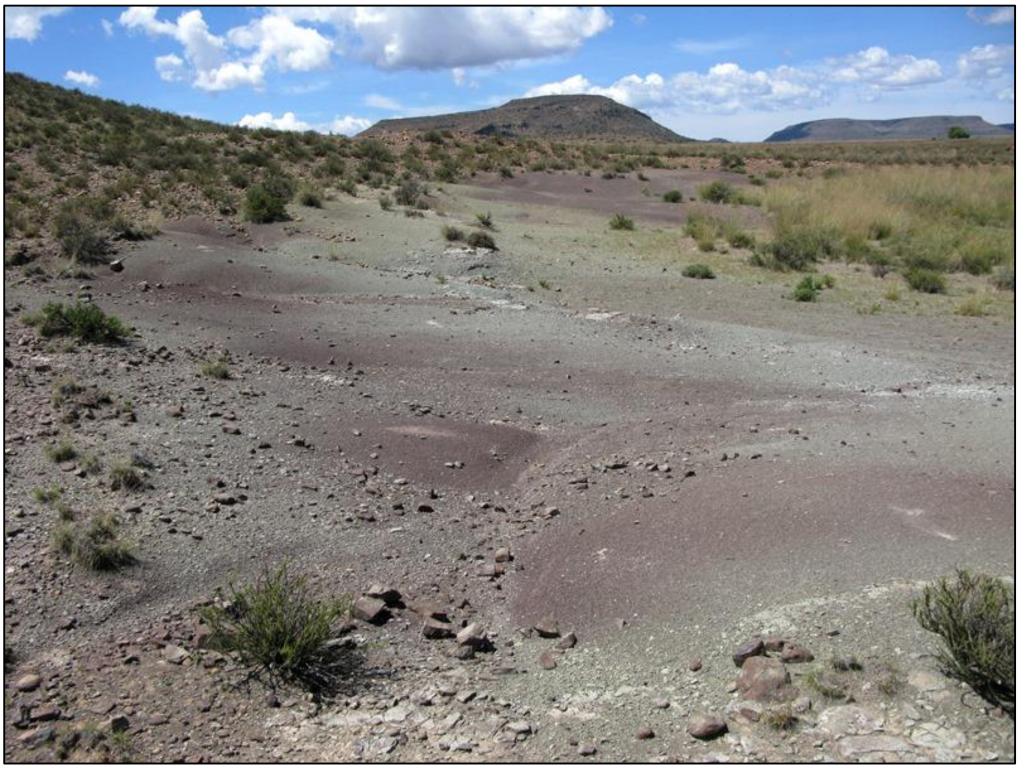

Fig. 15. Exposure of grey-green and purple-brown Adelaide Subgroup overbank mudrocks with calcrete nodules, borrow pit on Farm 121 (Loc. 126).

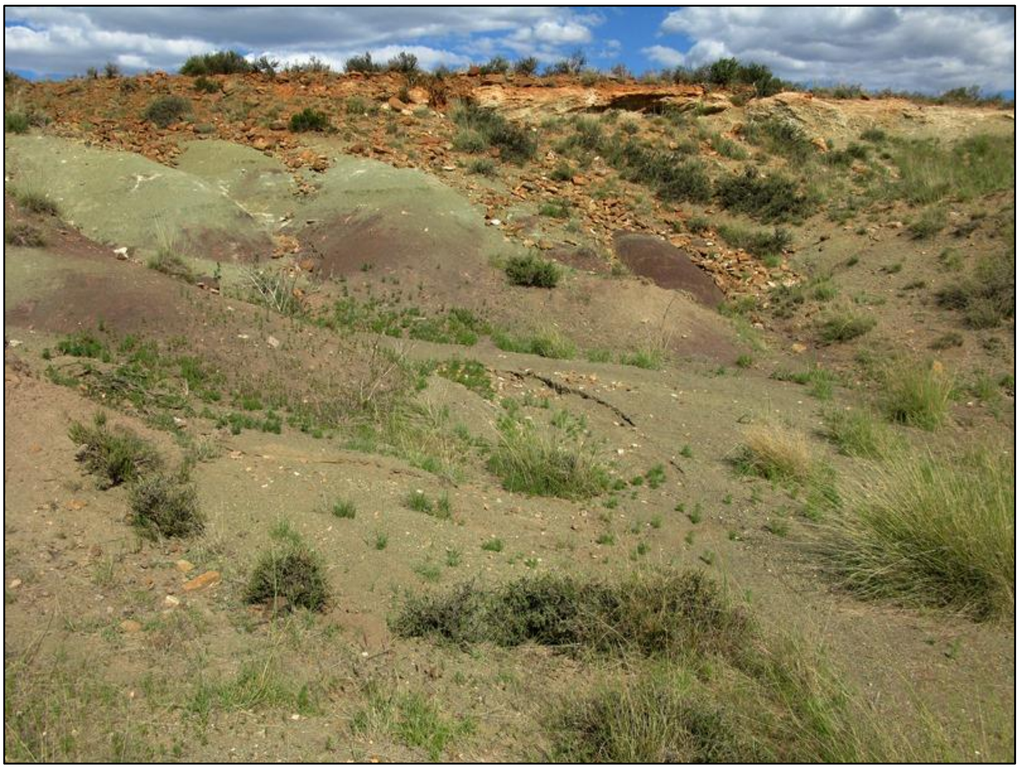

Fig. 16. Weathered, partially calcretised, massive mudrocks of the Adelaide Subgroup, borrow pit exposure on Leeukop 120 (Loc. 153).

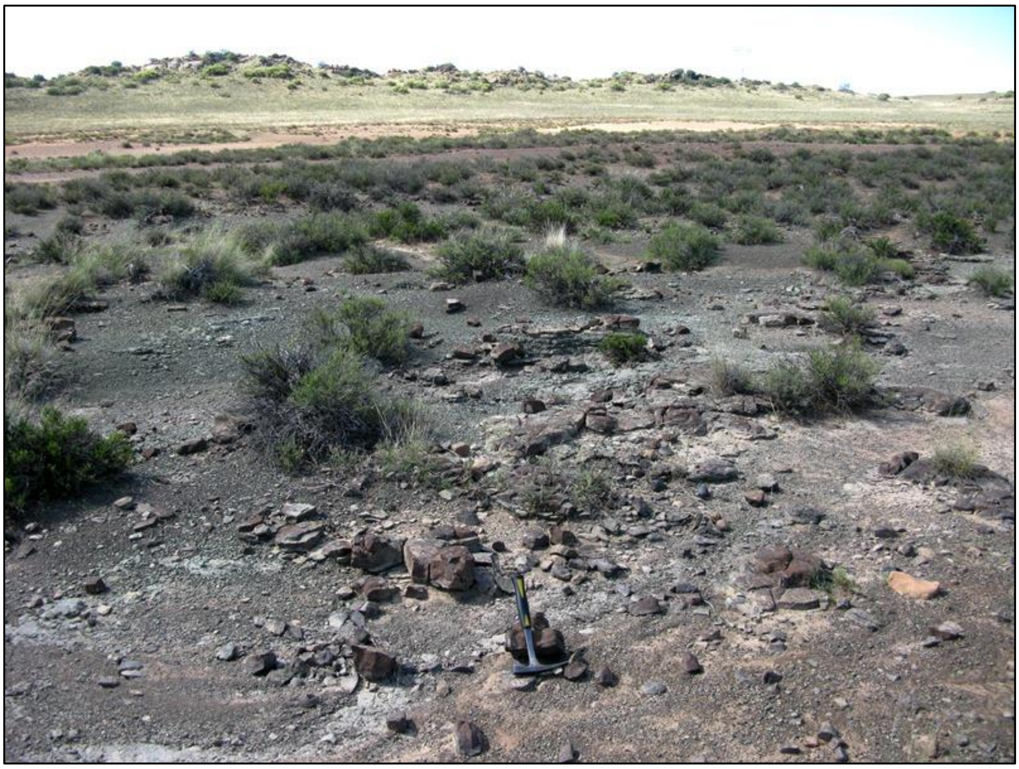

Fig. 17. Dense nodules and lenticles of ferruginous carbonate marking a pedocrete horizon, shallow erosion gulley exposure of Adelaide Subgroup bedrocks, Mooi Plaats 122 (Loc. 152) (Hammer = 30 cm).

2.2. Katberg Formation

The thick succession of pale brown to buff fluvial sandstones of the Early Triassic Katberg Formation dominates the western escarpment as well as large portions of the high-lying plateau of the Agter-Renosterberg range (Figs. 4, 5 & 7). Following the geological map (Fig. 9) as well as the observation of thick, closely-spaced sandstone packages down most of the western escarpment, where exposure permits, the bulk of the slope as well as the solid sandstone *krans* along the escarpment crest are considered to belong to the Katberg Formation, at least in the northern portion of the study area (Figs. 10 & 11). Useful geological descriptions of the Katberg Formation are given by Johnson (1976), Hancox (2000), Johnson *et al.* (2006), Smith *et al.* (2002) and for the Middelburg sheet area in particular by Cole *et al.* (2004). The more detailed sedimentological accounts by Stavrakis (1980), Hiller and Stavrakis (1980, 1984), Haycock *et al.* (1994), Groenewald (1996) and Neveling (1998) are also relevant to the present study area.

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. A thickness of 400 m more of grey to greenish-grey sandstone beds with minor reddish- or greenish-grey mudrock interbeds is reported by Cole *et al.* (2004) in the Middelburg sheet area, thinning to 260 m at Carlton Heights. The predominant sediments are (a) prominent-weathering, pale buff to greyish, tabular or ribbon-shaped sandstones up to 30 m thick that are interbedded with (b) recessive-weathering, reddish or occasionally green-grey mudrocks with subordinate thin sandstone beds. In some areas up to four discrete sandstone packages can be identified within the succession. Katberg channel sandstones are typically rich in feldspar and lithic grains (*i.e*. lithofeldspathic). They build laterally extensive, multi-storey units with an erosional base that is often marked by intraformational conglomerates up to one meter thick consisting of mudrock pebbles, reworked calcrete nodules and occasional rolled fragments of bone. The basal Katberg succession is often marked by a major cliff-forming sandstone unit, but in the some areas, such as to the west of Noupoort, there is a transitional relationship with the underlying Adelaide Subgroup that is marked by an upward-thickening series of sandstone sheets (Figs. 10 & 11). Internally the moderately well-sorted sandstones are variously massive, horizontally-laminated or cross-bedded and heavy mineral laminae occur frequently. Sphaeroidal carbonate concretions up to 10 cm across are common. The predominantly reddish Katberg mudrocks are typically massive with horizons of pedocrete nodules (calcretes), and mudcracks. Natural mudrock exposure within the study area is very limited due to extensive mantling of these recessive-weathering rocks by superficial sediments.

Katberg sandstone deposition was mainly due to intermittently flooding, low-sinuosity braided river systems flowing northwards from the rising Cape Fold Belt mountains in the south into the subsiding Main Karoo Basin (Fig. 18). Mudrocks were largely laid down by suspension settling within overbank areas following episodic inundation events, while other fine-grained sediments are associated with lakes and temporary playas in lower-lying areas on the arid floodplain, especially in the northern Katberg outcrop area and its lateral correlatives in the Burgersdorp Formation. Palaeoclimates inferred for the Early Triassic Period in the Main Karoo Basin were arid with highly seasonal rainfall and extensive periods of drought. This is suggested by the abundant oxidised ("rusty red") mudrocks, desiccation cracks, and palaeosols associated with well-developed calcretes. Arid settings are also supported by taphonomic and behavioural evidence such as pervasive carbonate encrustation of fossil bones, mummification of postcrania, bone-bed death assemblages associated with water holes and the frequency of burrowing habits among tetrapods, including large dicynodonts like *Lystrosaurus* (Groenewald 1991, Smith & Botha 2005, Viglietti 2010, Smith *et al.* 2012).

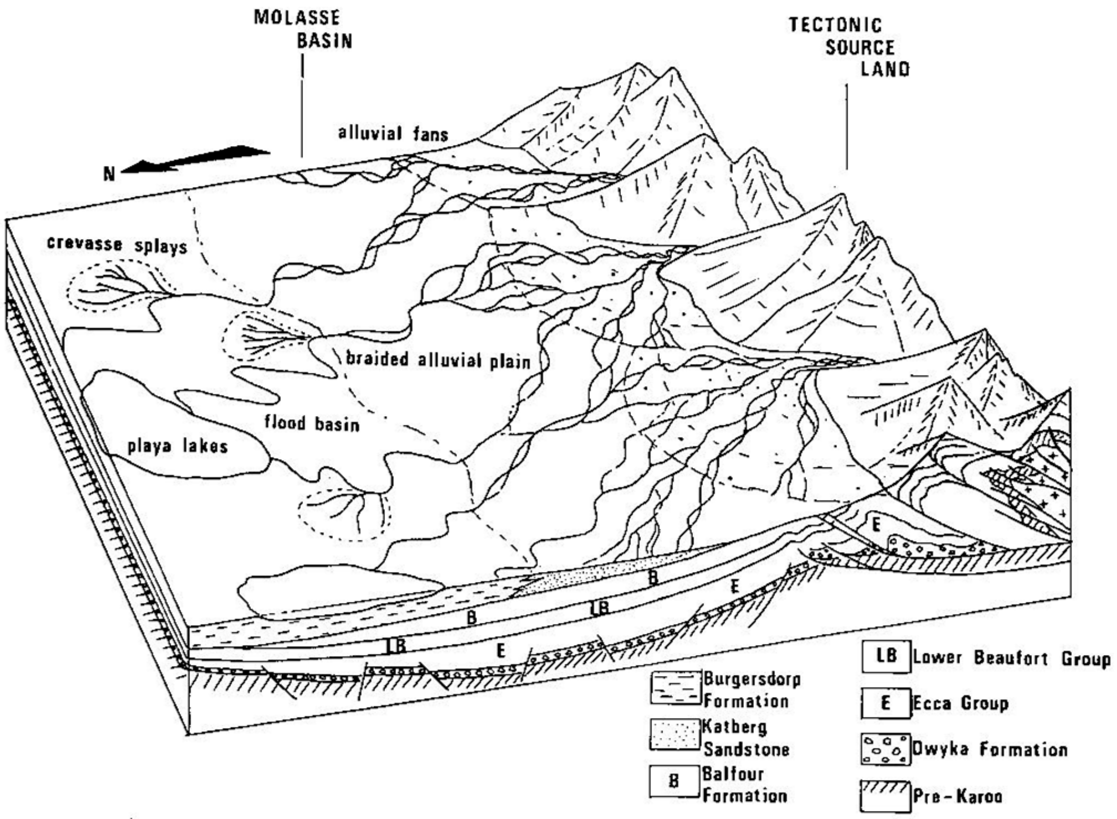

Fig. 18. Reconstruction of the south-eastern part of the Main Karoo Basin in Early Triassic times showing the deposition of the sandy Katberg Formation near the mountainous source area in the south. The mudrock-dominated Burgersdorp Formation was deposited on the distal floodplain where numerous playa lakes are also found (From Hiller & Stavrakis 1984).

Good exposures of thick packages of resistant-weathering, greyish to buff Katberg sandstones are seen both along the marginal escarpments of the Agter-Renosterberg as well as in the high-lying plateau areas where they have often been thermally metamorphosed by nearby dolerite intrusions (Figs. 7, 23). Mudrock intervals some 5 to 10 m in thickness occur between the lower Katberg sandstone packages, generating a stepped topography, but these recessive intervals are rarely well-exposed due to the pervasive sandstone colluvium (*e.g.* Locs. 133-134, 154-155, 162) (Figs. 24 to 28). The mudrocks are grey-green, blue-grey or purplish-brown, massive to thin-bedded with ferruginised calcrete concretionary nodules and lenses. They may contain locally common oblique invertebrate burrows of the distinctive ichnogenus *Katbergia* (Fig. 60). The mudrocks often pass up into thinly interbedded mudrock / sandstone packages that may display casts of mudcracks, fine mudflake breccias, algal mat textures, possible adhesion warts, transported plant debris and abundant small-scale (0.5 to 1 cm wide) vertical burrows (or perhaps reedy plant stem casts) (Fig. 61). This facies association may be associated with playa lakes on the semi-arid floodplain. Some greyish-hued zones between channel sandstone packages consist mainly of thin-bedded, tabular fine-grained sandstones rather than mudrock.

The upper portion of the Katberg succession in the Agter-Renosterberg comprises amalgamated major channel sandstone packages that form a steep cliff or *krans* at the top of the surrounding escarpment (Figs. 4, 5 & 11). Internally the sandstones are massive, finely laminated horizontally, or structured by trough or tabular cross-sets (Figs. 29 & 30). Flaggy, thin-bedded packages display well-developed primary current lineation on bedding planes. Large scale (megaripple) current bedforms as well as small scale current rippled bedding planes are preserved locally in plateau areas (Locs. 157, 161 Figs. 31 & 35). Lenticular basal or internal breccias may reach thicknesses of a half to one meter or more and variously consist of angular mudstone intraclasts, rounded calcrete glaebules, or a mixture of the two (Locs. 155, 161) (Figs. 36 to 39). Extensive, prominent-weathering, pale grey beds of cross-bedded calcrete glaebule conglomerate on Uitzicht 3 (Loc. 156) point towards episodes of dramatic denudation of the arid floodplain with reworking of resistant clasts (including occasional vertebrate bones and teeth) from overbank muds into river channels. The calcrete conglomerates are locally secondarily ferruginised, probably as a consequence of dolerite intrusion. The Katberg exposures in higher-lying regions of the Agter-Renosterberg show several features of karst (*i.e.* solution) weathering, probably of late Tertiary age, including crusty, polygonally-cracked surfaces, solution hollows, widened joints, and secondary case-hardening by silica (Figs. 32 & 33). Rounded pebble- to cobble-sized siliceous bodies (often hollow) within the sandstones are probably a result of hot circulating silica-rich fluids following dolerite intrusion. Well-developed sets of linear joints within Katberg sandstones on Klip Krands 60 have been misinterpreted as historical “wagon tracks” (Fig. 34).

The most informative exposures of lower Katberg Formation sediments are found in several extensive road cuttings along the N10 tar road to the northeast of the Umsobomvu 1 WEF study area (Locs. 166 to 168 on Naauw Poort 1, Koppies Kraal 6) (Figs. 19 to 21). Good vertical sections through grey-green, grey and purple-brown overbank mudrocks, packages of thin-bedded sandstones, heterolithic facies (interbedded sandstone and siltstone) as well as packages of pale grey to buff channel sandstones are seen here. Bedding geometries are predominantly tabular. Channel sandstone packages are multi-storey with relict mudrock interbeds or composed of amalgamated massive, horizontally-laminated to cross-bedded sandstone beds. Sandstone bases are often markedly erosive and gullied with associated with lenticles of mudflake intraclasts. Occasionally the last comprise cross-bedded mudflake breccias. Concentrations of sizeable angular blocks of overbank mudrock suspended within channel sandstones reflect local bank collapse (Fig. 21). Overbank mudrocks may show sand-infilled mudcracks, isolated lenticles of sandstone, rusty brown calcrete pedocrete horizons and locally abundant oblique invertebrate burrows (*Katbergia*). Equally good sections through similar tabular-bedded lower Katberg rocks are seen in steep river banks on Klip Krands 60 (Locs. 162 to 164) (Fig. 22). Here extensively mud-cracked surfaces associated with thin-bedded sandstones are associated with algal mat textures and dense assemblages of vertical, cylindrical sand-infilled structures that might be either invertebrate burrows (*Skolithos*) or perhaps casts of plant stems.

Fig. 19. N10 road cutting through the lower part of the Katberg Formation on Naauw Poort 1 (Loc. 168). Shown here are tabular channel sandstones (see erosional, channeled base towards bottom of photo) as well as grey-green, thinly-bedded siltstone or fine sandstone facies.

Fig. 20. Erosive-based channel sandstone overlying grey-green and purple-brown overbank mudrocks with rusty ferruginous carbonate lenticles, lower Katberg Formation N10 road cutting on Naauw Poort 1 (Loc. 166).

Fig. 21. Interbedded pale brown channel sandstones and grey-green mudrocks within the lower Katberg Formation, N10 road cutting on Koppies Kraal 6 (Loc. 167). Note coarse channel collapse breccia of dark mudrock blocks indicated by yellow arrow.

Fig. 22. Tabular-bedded, mudrock-rich interval within the lower Katberg Formation, riverbank cliffs on Uitzicht 3 (Loc. 161)

Fig. 23. Steep valley wall exposure of Katberg Formation channel sandstones in Kamferkloof (Uitzicht 3). Most sandstone bodies are tabular, but erosive-based lenticular channel infills are also seen here (yellow arrow).

Fig. 24. Roadside exposure of weathered grey-green Katberg mudrocks and thin sandstone interbeds on Uitzicht 3 (Loc. 154).

Fig. 25. Package of grey-green and purple-brown mudrocks passing up into thin-bedded heterolithic zone incised by channel sandstone, Katberg escarpment, Holle Fountain 133 (Loc. 133).

Fig. 26. Detail of upper portion of succession seen in previous figure showing mudcracked heterolithic beds beneath cross-bedded channel sandstone, Katberg Formation (Loc. 133).

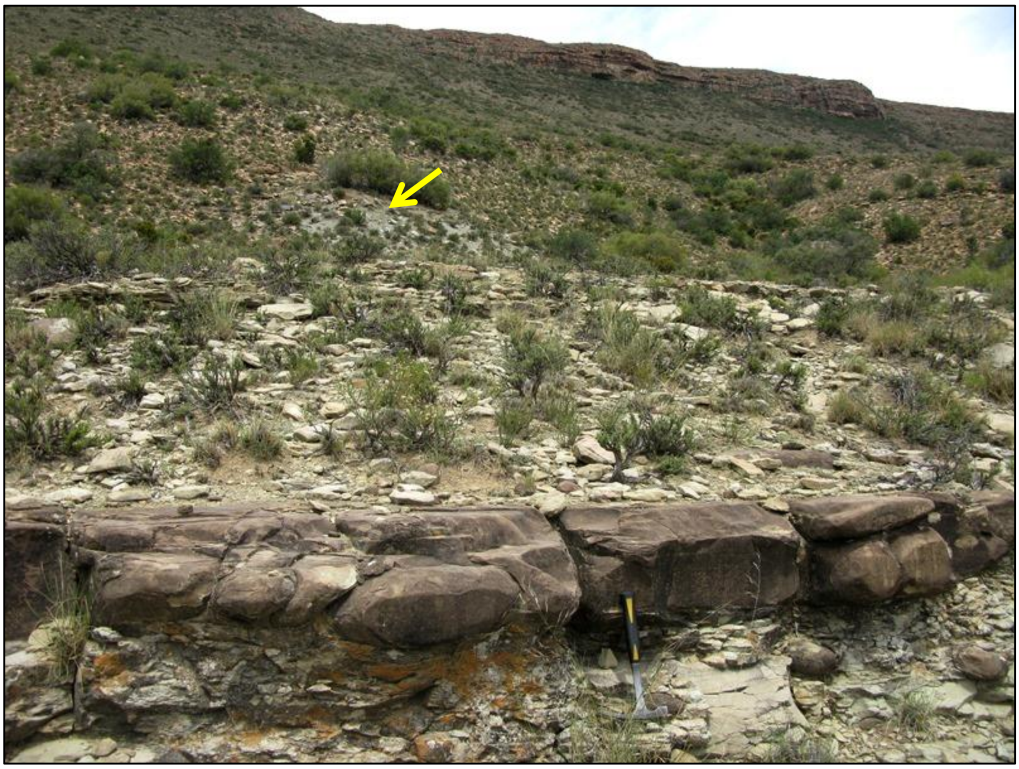

Fig. 27. Grey-green sandstones with brown ferruginous carbonate lenticle, probably within lowermost Katberg Formation (but possibly uppermost Adelaide Subgroup), Holle Fountain 133 (Loc. 136) (Hammer = 30 cm). Yellow arrow indicates stratigraphic level of grey-green siltstone containing the *Lystrosaurus* skeleton recorded by Almond (2018).

Fig. 28. Boulder-sized ferruginous carbonate nodules at same stratigraphic level as that arrowed in the previous figure, Holle Fountain 133 (Loc. 136) (Hammer = 30 cm).

Fig. 29. Typical package of pale brown, amalgamated, cross-bedded channel sandstones of the Katberg Formation, Holle Fountain (near Loc. 137).

Fig. 30. Large scale, low-angle trough cross-bedding within the Katberg Formation, Leeuw Hoek 61 (Loc. 139) (Hammer = 30 cm).

Fig. 31. Large current megaripples on a Katberg sandstone bedding surface, Uitzicht 3 (Loc. 157). The emergent crest and flank of the nearest megaripple may have been trampled by tetrapods such as therapsids (possible tetrapod trackway).

Fig. 32. Karstic solution features in Katberg sandstones on Uitzicht 3 (Loc. 157) including polygonal surface weathering pattern and solution hollows (Hammer = 30 cm).

Fig. 33. Karst-weathered, polygonally-cracked sandstone bedding surface of the Katberg Formation showing irregular vugs or hollows with silicified walls, Uitzicht 3 (Loc. 157).

Fig. 34. Well-jointed Katberg sandstone surface, probably baked by dolerite, on Uitzicht 3 (Hammer = 30 cm). The rectilinear markings here have been misinterpreted as ancient oxwagon tracks (*ossewaspoor*)

Fig. 35. Current-rippled sandstone surface on Ultzicht 3 (near Loc. 161), correctly promoted as an ancient river bed (Hammer = 30 cm).

Fig. 36. Secondarily ferruginised basal breccia within the lower Katberg Formation, Holle Fountain 133 (Loc. 128) (Hammer = 30 cm). The breccia contains isolated fragments of reworked fossil bones and teeth (See Fig. 74).

Fig. 37. Prominent-weathering, laterally-persistent, erosive-based bed of pale grey calcrete glaebule conglomerate, Katberg Formation on Uitzicht 3 (Loc. 156) (Scale = 15 cm).

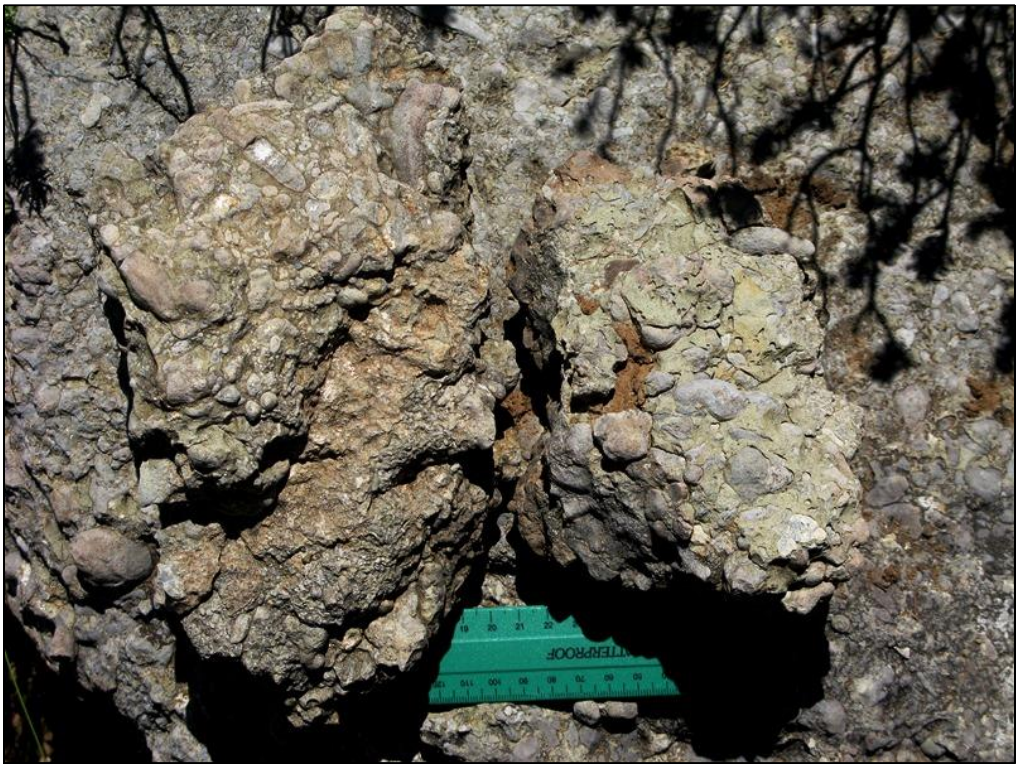

Fig. 38. Close-up of the poorly-sorted calcrete glaebule conglomerate shown in the previous figure, Katberg Formation on Uitzicht 3 (Loc. 156) (Scale in cm and mm).

Fig. 39. Silicified basal channel breccia unit containing both mudflakes and calcrete glaebules, Katberg Formation overlying a major dolerite sill on Uitzicht 3 (Near Loc. 161) (Hammer = 30 cm).

2.3. Karoo Dolerite Suite

Numerous sills and dykes of Karoo dolerite intruding the continental sediments of the Adelaide and Tarkastad Subgroups are mapped in the broader Umsobomvu – Coleskop WEF study area (Cole *et al.* 2004, Duncan & Marsh 2006) (Fig. 9). These igneous rocks are only treated briefly here because they are unfossiliferous. Major subhorizontal to sloping, transgressive dolerite sills are seen cutting across the Katberg Formation rocks building the upland areas of the Agter-Renosterberg as well seen, for example, in the valley sides between Wilgepoort and Rietpoort homesteads (Figs. 40 to 42). Extensive areas of Katberg bedrocks on the Agter-Renosterberg plateau have been baked by dolerite. These upland regions feature classic Karoo dolerite scenery with well-jointed, masonry-like corestones, reddish-brown lateritic soils and rubbly doleritic surface gravels (Figs. 6 & 44). The thicker sills often show well-developed large scale columnar jointing (Figs. 41 & 42). Intrusion of large volumes of magma has displaced the country rocks, which locally show substantial dips that are not of tectonic origin (Fig. 47). Deeply weathered dolerite (locally known as *sabunga* in the Eastern Cape) containing boulder-sized corestones of fresh rock are can be seen in road cuttings near Uitsig farmstead (Fig. 45).

Beaufort Group mudrocks in the vicinity of dolerite intrusions have been thermally metamorphosed to very dark, flinty hornfels that has often been exploited for Stone Age artefacts. A good example of a hornfels “factory site” with abundant stone tools associated with outcropping vuggy hornfels is seen, for example, on Paarde Valley 62 (Locs. 145-146) (Fig. 46). Rounded, mineral-infilled cavities or *vugs* are seen within the thermal aureole of a dolerite intrusion on Elands Kloof 135 (Fig. 47). Baked pale quartzites and dark hornfels overlying a dolerite sill are exposed on the margins of a dam near the Paardevlei homestead (Loc. 149). Hot mineralising fluids associated with dolerite intrusion were probably responsible for the secondary ferruginisation of lime-rich sediments within the country rocks, such as pedocretes and calcrete conglomerates. Related silicification has caused rounded pebble- to cobble-sized or even larger, hollow structures to develop within the Katberg sandstone.

Fig. 40. Thick, massive dolerite sill (darker brown, in foreground) intruding baked, bedded sediments of the Katberg Formation, *kloof* between Rietpoort and Wilgefontein, Uitzicht 3.

Fig. 41. Subhorizontal dolerite sill showing clear columnar jointing and overlain by baked sediments of the Katberg Formation, view east of Wilgefontein homestead, Uitzicht 3.

Fig. 42. Well-developed columnar jointing in inclined sill, view north of Wilgefontein homestead, Uitzicht 3.

Fig. 43. Inclined bedding of Katberg Formation associated with dolerite intrusion, view east of Wilgefontein homestead, Uitzicht 3.

Fig. 44. Typical dolerite scenery with masonry-like weathering patterns and downwasted corestones, western plateau area on Uitzicht 3.

Fig. 45. Deeply-weathered dolerite (*sabunga*) containing relict boulder-sized corestones, road cutting east of Uitsig homestead, on Uitzicht 3.

Fig. 46. Outcrop of dark hornfels that is associated with a high concentration of flaked stone artefacts, Paarde Valley 62 (Loc 146) (Hammer = 30 cm).

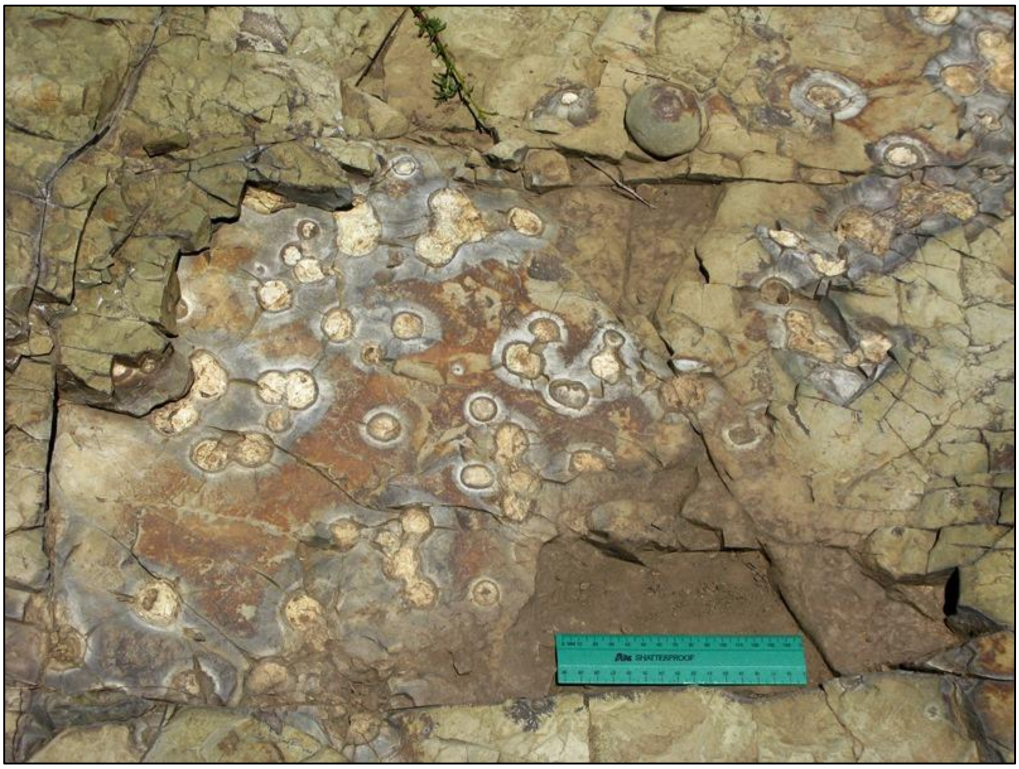

Fig. 47. Baked Katberg Formation mudrocks containing rounded, mineral-infilled vugs produced by hydrothermal fluids following dolerite intrusion, stream bed on Elands Kloof 135 (Loc 170) (Scale in cm).

2.4. Late Caenozoic superficial deposits

The Karoo Supergroup and Karoo dolerite bedrocks within the Umsobomvu 1 WEF study area are largely mantled by a wide range of superficial deposits of Late Caenozoic age, some of which are potentially fossiliferous. A mantle of poorly-sorted, fine to coarse colluvial and alluvial debris forms an extensive apron up to several meters thick overlying bedrocks along the face and foot of the escarpment as well as the numerous valleys incising the Agter-Renosterberg (Fig. 4). The rocky debris consists mainly of angular blocks and gravels of Katberg sandstone as well as dolerite, together with soils and hillwash. Good vertical sections are seen along the banks of *dongas* (erosion gullies) and incised stream beds (Figs. 48 & 49).

Polymict surface gravels overlying the Adelaide Subgroup outcrop area around the margins of the Agter-Renosterberg consist mainly of reworked, downwasted sandstone, ferruginous calcrete nodules, dolerite corestones, hornfels, quartzite, *koffieklip* as well as vuggy, silicified sediments from the metamorphic aureoles adjacent to dolerite intrusions (*e.g.* silicified mudflake breccio-conglomerates). Locally, matrix-supported diamictite-like bodies of colluvial blocks embedded within a much finer-grained, well-consolidated sandy matrix may be of debris flow origin (*i.e.* sediment-gravity flows); some of these deposits are calcretised (*e.g.* Loc. 129) (Figs. 49, 50 & 51).

Much of the higher plateau areas within the Agter-Renosterberg are mantled with sandstone and dolerite surface gravels as well as thin, skeletal, gravelly soils (Fig. 9). Gentler slopes away from the escarpment are largely covered in various alluvial deposits, often with a coarse, poorly-sorted gravelly base (Figs. 52 to 54). The overlying older alluvial deposits are up top several meters thick, usually semi-consolidated, orange-brown sands with dispersed gravels and gravel lenticels. They are overlain by paler grey-brown sandy to silty younger alluvial with sparse gravels that are in turn overlain by darker brown modern soils and downwasted surface gravels. The older alluvium and soils may be incipiently calcretised, with thin calcrete veins, especially in the vicinity of dolerite intrusions. Coarser bodies of calcretised gravels may represent ancient fluvial channel deposits.

Fig. 48. Thick prism of coarse, poorly-sorted colluvial deposits mantling Beaufort Group bedrocks, riverbank on Klip Krands 60 (Loc. 162).

Fig. 49. Bouldery diamictite-like colluvial deposits overlying Adelaide Subgroup bedrocks, erosion gulley on Holle Fountain 133 (Loc. 129).

Fig. 50. Close-up of well-consolidated diamictites of possible debris-flow origin overlying weathered Adelaide Subgroup mudrocks on Leeukop 120 (Loc. 153) (Hammer = 30 cm).

Fig. 51. Calcretised gravels (possible fluvial channel infill) overlying weathered Adelaide Subgroup mudrocks, Leeukop 120 (Loc. 153) (Hammer = 20 cm).

Fig. 52. *Donga* exposures of thick valley alluvium succession on Winterhoek 118 showing basal gravels, orange-brown older alluvium and grey-brown younger alluvial soils.

Fig. 53. Thick, crudely-bedded silty alluvial deposits with horizons of poorly-sorted gravels, erosion *donga* on Klip Krands 60 (Loc. 163).

Fig. 54. Erosional gully exposure of sandy alluvial deposits with abundant sandstone blocks, base of escarpment on Holle Fountain 133 (Loc. 137).

3. PALAEONTOLOGICAL HERITAGE WITHIN THE STUDY REGION

The overall palaeontological sensitivity of the Beaufort Group sediments in the Main Karoo Basin of South Africa is high (Rubidge 1995, Rubidge 2005, Almond *et al*. 2008, Smith *et al.* 2012). These continental sediments have yielded one of the richest fossil records of land-dwelling plants and animals of Permo-Triassic age anywhere in the world. A chronological series of mappable fossil biozones or assemblage zones (AZ), defined mainly on their characteristic tetrapod faunas, has been established for the Main Karoo Basin of South Africa (Rubidge 1995, 2005). Maps showing the distribution of the Beaufort assemblage zones within the Main Karoo Basin have been provided by Kitching (1977), Keyser and Smith (1977-78), Rubidge (1995) and Van der Walt *et al* (2010). The 1: 250 000 geological maps as well as a recently updated biozone map based on a comprehensive GIS fossil database (Van der Walt *et al.* 2010) suggests that two Permo-Triassic vertebrate-based biozones are represented within the Umsobomvu 1 WEF study region near Middelburg, *viz.* the *Dicynodon* Assemblage Zone within the upper Adelaide Subgroup at lower elevations round the Agter-Renosterberg plateau and the Early Triassic *Lystrosaurus* Assemblage Zone within the Katberg Formation at higher elevations (Fig. 56). A number of known *Dicynodon* AZ and *Lystrosaurus* AZ vertebrate fossil sites in the Agter-Renosterberg region are shown on the map presented by Kitching (1977) (Fig. 55). A recent compilation map of known fossil vertebrate sites from the Beaufort Group of the Main Karoo Basin (Nicolas 2007) also indicates a concentration of fossil sites to the northwest of Middelburg (Fig. 57) (See also previous palaeontological assessment studies in the broader Middelburg – Noupoort region by Almond (2012, 2015, 2017a, 2017b),, Gess (2012) and Butler (2014).

As a consequence of their proximity to large dolerite intrusions, the Beaufort Group sediments in parts of the study area been thermally metamorphosed or “baked” (*i.e*. recrystallised, impregnated with secondary minerals). Embedded fossil material of phosphatic composition, such as bones and teeth, is frequently altered by baking – bones may become blackened, for example - and can be very difficult to extract from the hard matrix by mechanical preparation (Smith & Keyser *in* Rubidge 1995). Thermal metamorphism by dolerite intrusions therefore tends to reduce the palaeontological heritage potential of Beaufort Group sediments.

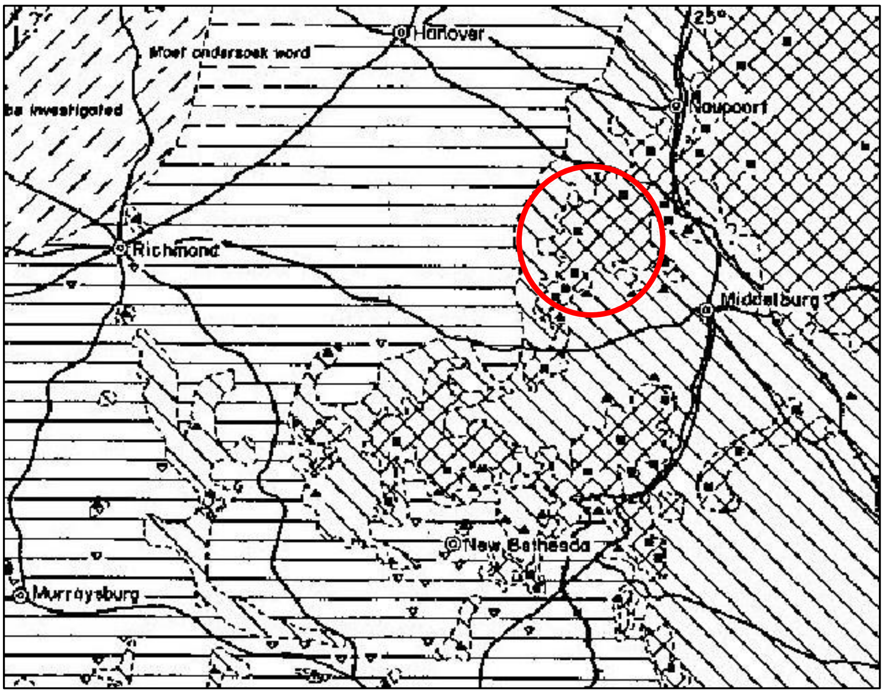

Fig. 55. Early fossil zonation map of the Middelburg – Richmond region showing the occurrence of several fossil localities in the broader Umsobomvu 1 WEF study area area to the northwest of Middelburg, Eastern Cape (red ellipse). Black squares here refer to fossils of the Early Triassic *Lystrosaurus* Assemblage Zone (mainly within the Katberg Formation) while triangles are *Dicynodon* AZ fossil sites within Late Permian rocks of the Adelaide Subgroup. Figure modified from Karoo biozonation map of Kitching (1977).

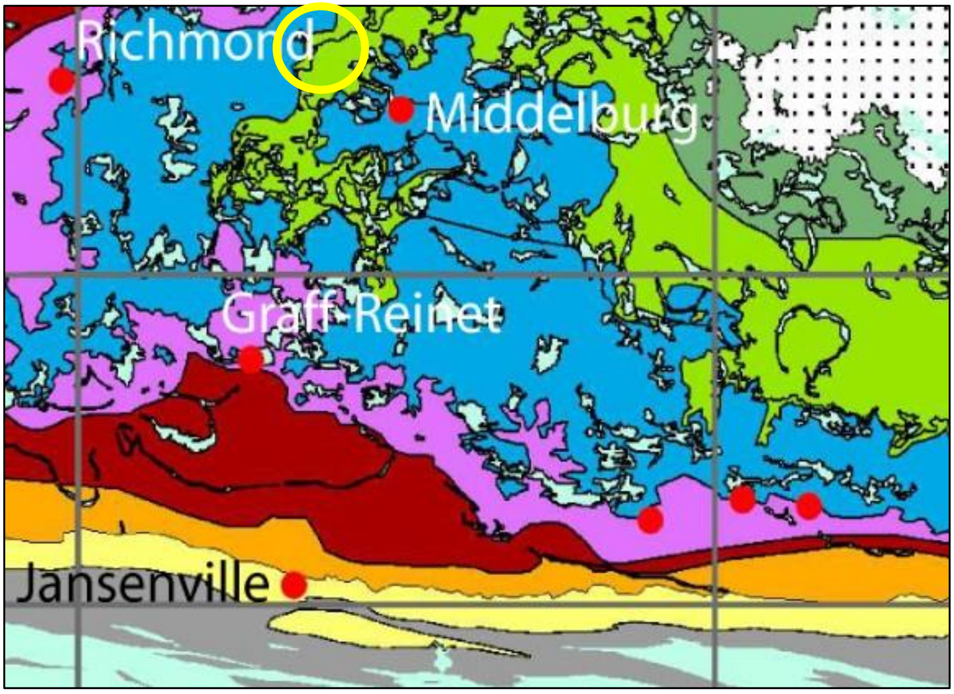

Fig. 56. Extract from the latest fossil biozonation map for the Main Karoo Basin (Van der Walt *et al.* 2010) showing the approximate location of the Umsobomvu 1 WEF study area NW of Middelburg, Eastern Cape (yellow ellipse). The biozones represented here include the Late Permian *Dicynodon* (blue) and Early Triassic *Lystrosaurus* (pale green) Assemblage Zones.

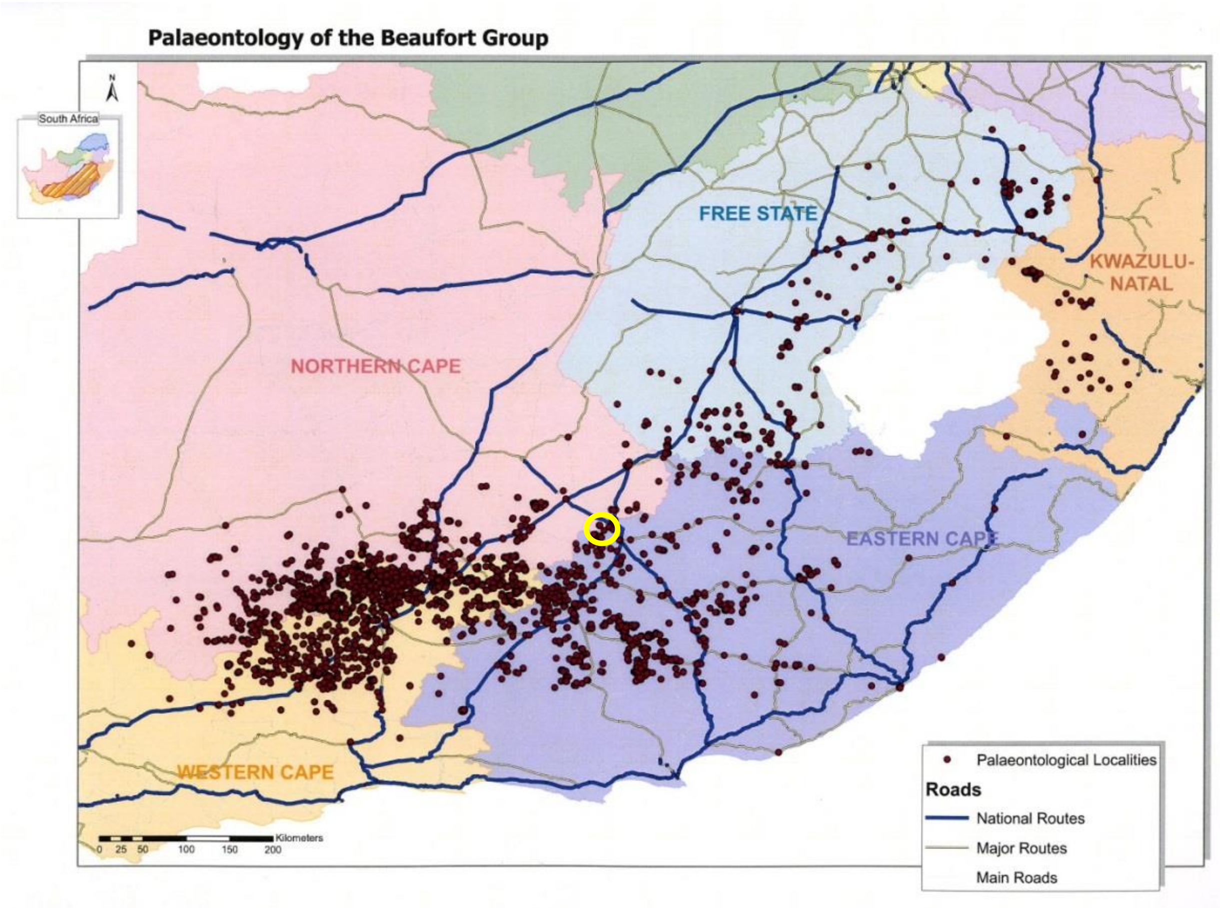

Fig. 57. Distribution of recorded fossil vertebrate localities within the Beaufort Group (Main Karoo Basin) showing the concentration of sites to the northwest of Middelburg, Eastern Cape (yellow circle) (Map abstracted from Nicolas 2007).

3.1. Fossils within the uppermost Adelaide Subgroup

Adelaide Subgroup sediments close to the Katberg sandstone lower contact can be correlated with the Balfour Formation recognised elsewhere in the eastern portion of the Main Karoo Basin, the greater part of is characterised by Late Permian fossil biotas of the ***Dicynodon* Assemblage Zone** (Fig. 8). This biozone has been assigned to the Changhsingian Stage (= Late Tartarian) right at the end of the Permian Period, with an approximate age range of 253.8-251.4 million years (Rubidge 1995, 2005). Good accounts, with detailed faunal lists, of the fossil biotas of the *Dicynodon* Assemblage Zone have been given by Kitching (*in* Rubidge 1995) and by Cole *et al*. (2004). See also the reviews by Cluver (1978), MacRae (1999), McCarthy & Rubidge (2005), Almond *et al*. (2008) and Smith *et al.* (2012) as well as recent papers on Permo-Triassic boundary tetrapod faunas of the Main Karoo Basin by Smith and Botha (2005), Botha and Smith (2006, 2007), Viglietti *et al.* (2015) and Viglietti (2016). In general, the following broad categories of fossils might be expected within the Balfour Formation near Middelburg:

- isolated petrified bones as well as articulated skeletons of terrestrial vertebrates such as true **reptiles** (notably large pareiasaurs, small millerettids) and **therapsids** (diverse dicynodonts such as *Dicynodon* and the much smaller *Diictodon*, gorgonopsians, therocephalians such as *Theriognathus*, primitive cynodonts like *Procynosuchus*, and biarmosuchians) (Fig. 58);
- aquatic vertebrates such as large temnospondyl **amphibians** like *Rhinesuchus* (usually disarticulated), and palaeoniscoid **bony fish** (*Atherstonia*, *Namaichthys*);

- freshwater **bivalves;**
- **trace fossils** such as worm, arthropod and tetrapod burrows and trackways, coprolites;
- **vascular plant remains** including leaves, twigs, roots and petrified woods ("*Dadoxylon*") of the *Glossopteris* Flora (usually sparse, fragmentary), especially glossopterids and arthrophytes (horsetails).

From a palaeontological viewpoint, these diverse *Dicynodon* Assemblage Zone biotas are of extraordinary interest in that they provide some of the best available evidence for the last flowering of ecologically-complex terrestrial ecosystems immediately preceding the catastrophic end-Permian mass extinction (*e.g.* Smith & Ward, 2001, Rubidge 2005, Retallack *et al*., 2006, Smith & Botha 2005, Botha & Smith 2006, 2007). The faunal turnover at the Permian – Triassic boundary, which has been identified within the Palingkloof Member of the Balfour Formation, is discussed in some detail by Smith and Botha (2005), Botha and Smith (2007) as well as more recently by Smith *et al.* (2012), Viglietti *et al.* (2015) and Viglietti (2016)..

As far as the biostratigraphically important tetrapod remains are concerned, the best fossil material is generally found within overbank mudrocks, whereas fossils preserved within channel sandstones tend to be fragmentary and water-worn (Rubidge 1995, Smith 1993). Many fossils are found in association with ancient soils (palaeosol horizons) that can usually be recognised by bedding-parallel concentrations of calcrete nodules. The abundance and variety of fossils within the *Dicynodon* Assemblage Zone decreases towards the top of the succession (Cole *et al*., 2004).

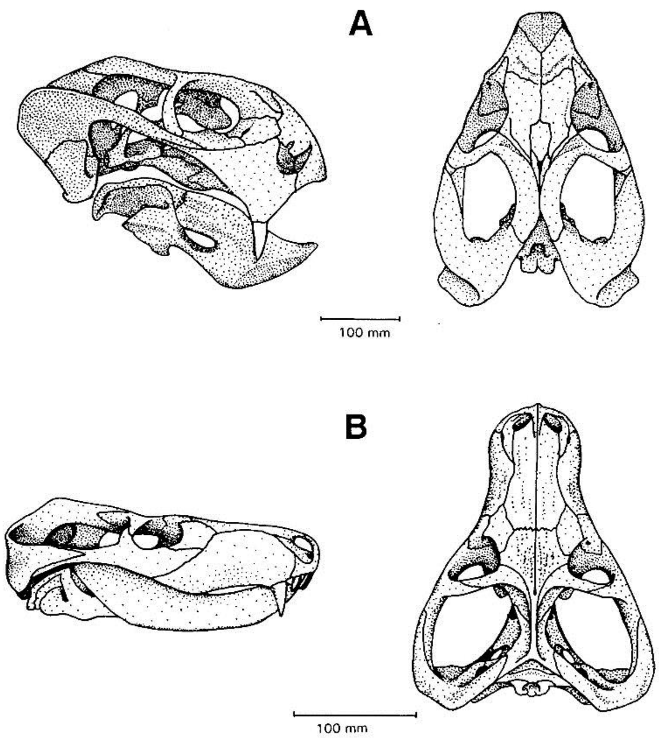

Fig. 58. Skulls of key therapsids ("mammal-like reptiles") from the Late Permian *Dicynodon* Assemblage Zone: the dicynodont *Dicynodon* and the therocephalian *Theriognathus* (From Kitching *in* Rubidge 1995).

Dicynodon Assemblage Zone fossils have been reported by previous workers along the southern margins of the Agter-Renosterberg uplands to the west of Middelburg (*cf* Fig. 55, abstracted from Kitching 1977 who gives detailed faunal lists).

Very few new fossil sites were recorded within uppermost Adelaide Subgroup rocks during the present field study (See Satellite maps in Figs. 67 & 68 as well as palaeontological data in Appendix 1); this is probably due, at least in part, to the very poor levels of bedrock exposure.

Thin-bedded, fine-grained sandstones on Farm Mooi Plaats 121, due west of the present study area, are characterised by locally common small arthropod scratch burrows of the ichnogenus *Scoyenia* that characterises damp, subaerially-exposed substrates such as playa lake and river margins in the Permo-Triassic Main Karoo Basin. The distinctive oblique, subcylindrical burrow *Katbergia* with its pelleted cortex occurs within upper Adelaide Group sandstones and mudrocks in a large borrow pit situated on the south side of the R389, just west of Lessingshoogte (Locs. 171-172), some 20 km southwest of the present study area. Also of palaeontological interest at this locality are numerous unusually large vertebrate burrows (40-50 cm wide), possibly attributable to medium-sized dicynodonts, preserved as subcylindrical, dorso-ventrally flattened sandstone casts within overbank mudrocks (Almond 2018a). The burrows are subcylindrical, slope gently downwards and are straight to gently curved in plan view. Some examples show oblique scratch marks on their upper and / or lower surfaces, while patches with a peculiar pustulose texture are seen on the base of one example. While some burrow casts are isolated, others are aggregated into dense “warrens”. Small isolated bone fragments and sandstone bedding planes displaying mudcrack infills were also recorded from this locality, outside the burrows.

The only other Adelaide Subgroup vertebrate skeletal fossils recorded during the present field study include sparse, fragmentary bones within overbank mudrocks on Farm Mooi Plaats 121 (Loc. 126), several isolated bones embedded within ferruginous calcrete nodules on Leeuw Hoek 61 (Loc. 143), as well as a semi-articulated small therapsid postcranial skeleton, also embedded within calcrete (Loc. 144; Almond 2018a). The stratigraphic horizon of these last specimens probably lies within the uppermost Adelaide Subgroup (narrow mudrock zone beneath base of Katberg on satellite images), but this would need to be checked by further fieldwork. None of these fossil localities fall within the Umsobomvu 1 WEF project area but comparable fossils are also likely to occur here within the same stratigraphic horizon.

3.2. Fossils within the Katberg Formation

The Katberg Formation is well known for its low-diversity but palaeontologically important terrestrial fossil biota of Early Triassic (Scythian / Induan - Early Olenekian) age, *i.e.* around 250 million years old (Groenewald & Kitching 1995, Rubidge 2005, Smith *et al.* 2012). The biota is dominated by a small 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 impoverished fossil assemblage characterizes Early Triassic successions of the upper part of the Palingkloof Member (Adelaide Subgroup) as well as the overlying Katberg Formation and - according to some earlier authors – the lowermost Burgersdorp Formations of the Tarkstad Subgroup. Recent research has emphasized the rapidity of faunal turnover during the transition between the sand-dominated Katberg Formation (*Lystrosaurus* Assemblage Zone) and the overlying mudrock-dominated Burgersdorp Formation (*Cynognathus* Assemblage Zone) (Neveling *et al.* 2005). In the proximal (southern) part of the basin the abrupt faunal turnover occurs within the uppermost sandstones of the Katberg Formation and the lowermost sandstones of the Burgersdorp Formation (*ibid*., p.83 and Neveling 2004). This work shows that the *Cynognathus* Assemblage Zone correlates with the entire Burgersdorp Formation; previous authors had proposed that the lowermost Burgersdorp beds belonged to the *Lystrosaurus* Assemblage Zone (*e.g.* Keyser & Smith 1977-78, Johnson & Hiller 1990, Kitching 1995). It should also be noted that the dicynodont *Lystrosaurus* has now been recorded from the uppermost beds of the Latest Permian *Dicynodon* Assemblage Zone but only becomes super-abundant in Early Triassic times (*e.g.* Smith & Botha 2005, Botha & Smith 2007, Viglietti *et al.* 2015, Viglietti 2016 and refs. therein).

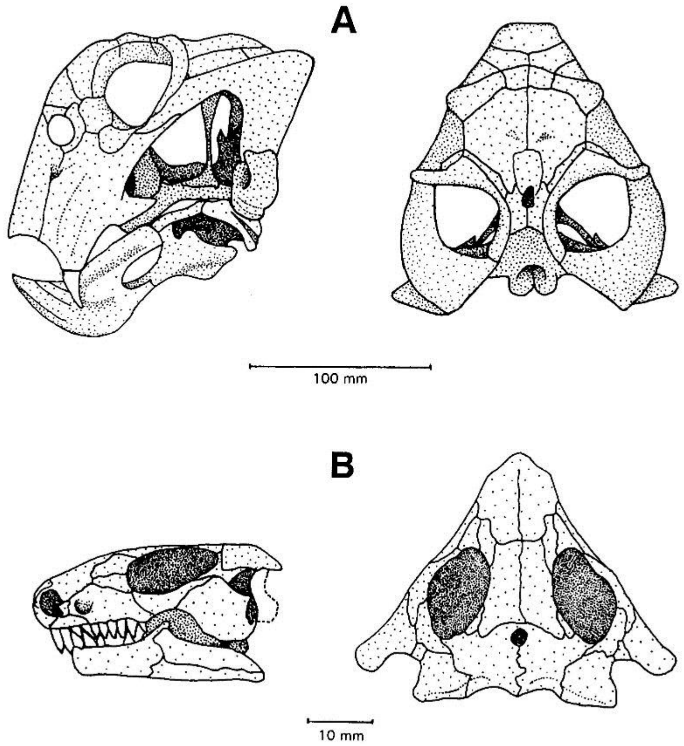

Fig. 59. Skulls of two key tetrapod genera from the Early Triassic *Lystrosaurus* Assemblage Zone of the Main Karoo Basin: the pig-sized dicynodont *Lystrosaurus* (A) and the small primitive reptile *Procolophon* (B) (From Groenewald and Kitching, 1995).

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), Viglietti *et al.* (2015) and Viglietti (2016), 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 251.4 million years ago (*e.g.* Smith & Botha 2005, Botha & Smith 2007 and refs. therein). 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 (*cf* Viglietti 2010).

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* (Fig. 59). 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* scratch burrows), as well as several subgroups of fossorial tetrapods such as cynodonts, procolophonids and even *Lystrosaurus* itself (*e.g.* Groenewald 1991, Damiani *et al.* 2003b, Abdala *et al.* 2006, Modesto & Brink 2010, Bordy *et al.* 2009, 2011). 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 Katberg 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 breccio-conglomerates at the base of some of the channel sandstones.

The great majority of the sparse fossil material recorded from the Katberg Formation in the present study area, including trace fossils as well as skeletal remains, comes from mudrock and fine sandstones between the major sandstone packages within the lower portion of the succession. The commonest trace fossils are obliquely-inclined, subcylindrical invertebrate burrows of possible crustacean origin known as *Katbergia* (Gastaldo & Rolerson 2008, Bordy *et al.* 2011). The burrows are slightly elliptical in cross secton, *c*. 1 – 1.5 cm across, and the wall often shows a distinctive pelleted or scratched surface texture (Fig. 66). These traces are up to several dm long are locally abundant at several localities within or close to the present WEF project area (*e.g.* Locs. 130, 166, 168, 169) and penetrate both mudrock and sandstone facies, often within thin-bedded heterolithic facies with horizons of pedogenic calcrete.

Supposed *Skolithos* ichnofacies trace fossil assemblages were also recorded within thin sandstone interbeds that form part of grey-green mudrock-dominated packages within the Katberg Formation (Locs. 154, 155, 162, 164). The cylindrical vertical "burrows" are *c*. 0.5 cm wide, penetrating through thin sandstone beds, are locally abundant and often associated with mudcracks, synaeresis cracks, possible algal mat textures, adhesion warts, small scale wave and current ripples and vague horizontal burrows (Fig. 61). They may have been formed on the margins of shallow playa lakes and ponds. An alternative interpretation of the vertical cylindrical structures is that they are sandstone casts of reedy plant stems (*e.g.* sphenophyte ferns) that might be expected in such damp settings.

Locally abundant large vertebrate burrows, preserved as sandstone casts, can be seen in vertical sections through the lower Katberg Formation along the N10, just outside the present project area (Naauw Poort 1, Loc. 166) (*cf* Bordy *et al.* 2011) (Figs. 62 to 64). These are comparable in scale to those described earlier from the upper Adelaide Subgroup to the south of the present study area (Almond 2015) and in both cases may have been excavated by moderately large-bodied therapsids such as *Lystrosaurus*. Most of the burrows are cut into thin-bedded grey-green overbank mudrocks and thin-bedded fine sandstones. They appear to be concentrated at certain horizons within the succession. In some cases, oblique scratch marks on their lower surfaces can be made out.

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 fairly close to the main access road to the Umsobomvu 1 WEF (Locs. 119, 120, 122 and 123, Fig. 66; see also satellite map in Fig. 68). One of the burrow casts is associated with disarticulated postcranial bones (Fig. 66 E-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. In practice, these burrows lie > 100 m outside and in elevation well below the project footprint so they are not directly threatened by the development.

Skeletal remains within the lower Katberg succession are often associated with ferruginous pedogenic calcrete horizons and enclosed within the calcrete itself (*e.g.* Loc. 168, 143). Good examples are the semi-articulated cranial and postcranial skeletal remains of *Lystrosaurus* preserved within ferruginous carbonate on Holle Fountain 133, just west of the present study area (Loc. 136) (Almond 2018b). *Possible* but vague tetrapod trackways were observed on the crest and flanks of a megaripple on Uitzicht 3, perhaps reflecting trampling during a period of emergence (Fig. 31).

A rare occurrence of earliest Triassic plant remains Katberg Formation was found in a small borrow pit on Uitzicht 3 (Loc. 158) (*cf* Gastaldo *et al.* 2005). The plant material is poorly-preserved and comprises indeterminate, ferruginised plant stem moulds up to 3 cm across, including woody material (Fig. 65). The moulds are associated with medium-coarse buff sandstones interbedded within a weathered grey-green mudrock package quite high up within the Katberg succession, on the Agter-Renosterberg plateau. The sandstone beds here show fine mudflake breccias on their basal surfaces, and sometimes also on bed tops. Erosional sandstone bases with scours and flutes also occur here.

3.3. Fossils within Late Caenozoic superficial deposits

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. Good examples are the Pleistocene mammal faunas at Florisbad, Cornelia and Erfkroon in the Free State and elsewhere (Wells & Cooke 1942, Cooke 1974, Skead 1980, Klein 1984, Brink, J.S. 1987, Bousman *et al.* 1988, Bender & Brink 1992, Brink *et al*. 1995, MacRae 1999, Meadows & Watkeys 1999, Churchill *et al*. 2000, Partridge & Scott 2000, Brink & Rossouw 2000, Rossouw 2006). 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 (Scott 2000) and diatoms in pan sediments. In Quaternary deposits, fossil remains may be associated with human artefacts such as stone tools and are also of archaeological interest (*e.g.* Smith 1999 and refs. therein). Ancient solution hollows within extensive calcrete hardpans may have acted as animal traps in the past. As with coastal and interior limestones, they might occasionally contain mammalian bones and teeth (perhaps associated with hyaena dens) or invertebrate remains such as snail shells.

No fossil remains were recorded from the various Late Caenozoic superficial deposits examined during the present field assessment.

Fig. 60. Sandstone casts of *Katbergia* arthropod scratch burrows, Katberg Formation on Annex Winterhoek 186 (Loc. 169). The burrows are *c*. 1.5 cm wide.

Fig. 61. Sole surface of thin sandstone bed showing mudcrack infill as well as numerous vertical cylindrical structures – either *Skolithos* invertebrate burrows or - more probably - casts of reedy plant stems Uitzicht 3 (Loc. 155). The burrows / stems are *c*. 5 mm across.

Fig. 62. N10 road cutting through the lower Katberg Formation showing large inclined vertebrate burrow (arrowed) cutting through thin-bedded, grey-green overbank mudrocks, Naauw Poort 1 (Loc. 168).

Fig. 63. Close-up of the sandstone cast of a large vertebrate burrow seen in the previous figure, Naauw Poort 1 (Loc. 168).

Fig. 64. Grey-green overbank mudrocks in lower Katberg Formation road cutting showing two separate horizons with abundant sand-cast vertebrate burrows, Naauw Poort 1 (Loc. 168).

Fig. 65. Casts of fragmentary fossil plant material preserved within a thin sandstone bed in association with reworked mudflakes, upper Katberg Formation on Uitzicht 3 (Loc. 158) (Scale in cm and mm). Fossil plant remains are generally rare within the Katberg Formation.

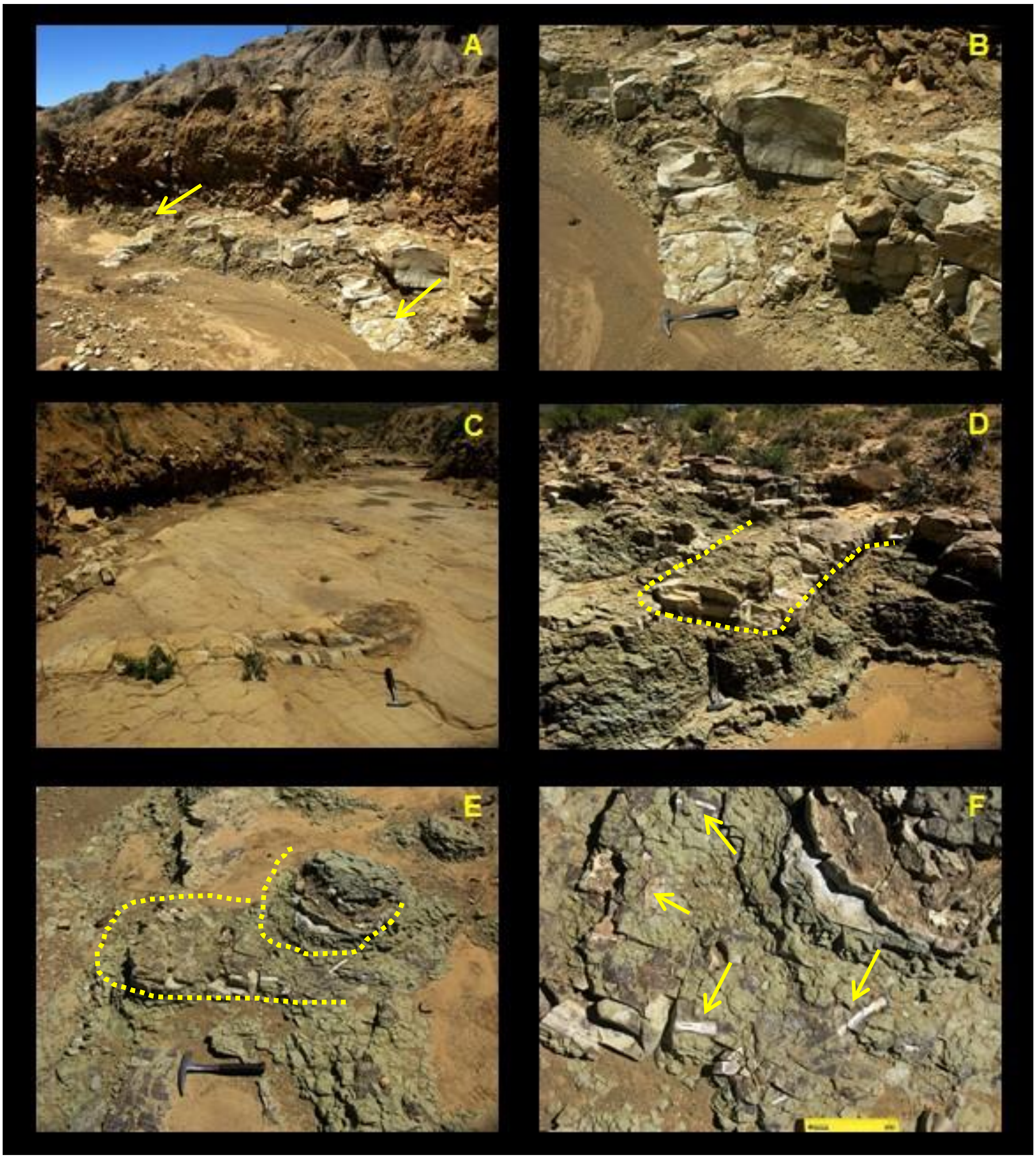

Fig. 66. Large vertebrate burrows within the lower Katberg Formation exposed in the base of a *donga* on Winterhoek 118 (Hammer = 27 cm): (A-B) Two inclined, 30 cm-wide burrow casts (arrowed) embedded in grey-green mudrock (Loc. 119); (C) Subhorizontal, convex-topped burrow (30-40 cm wide) exposed at 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) (Images abstracted from Almond 2017a).

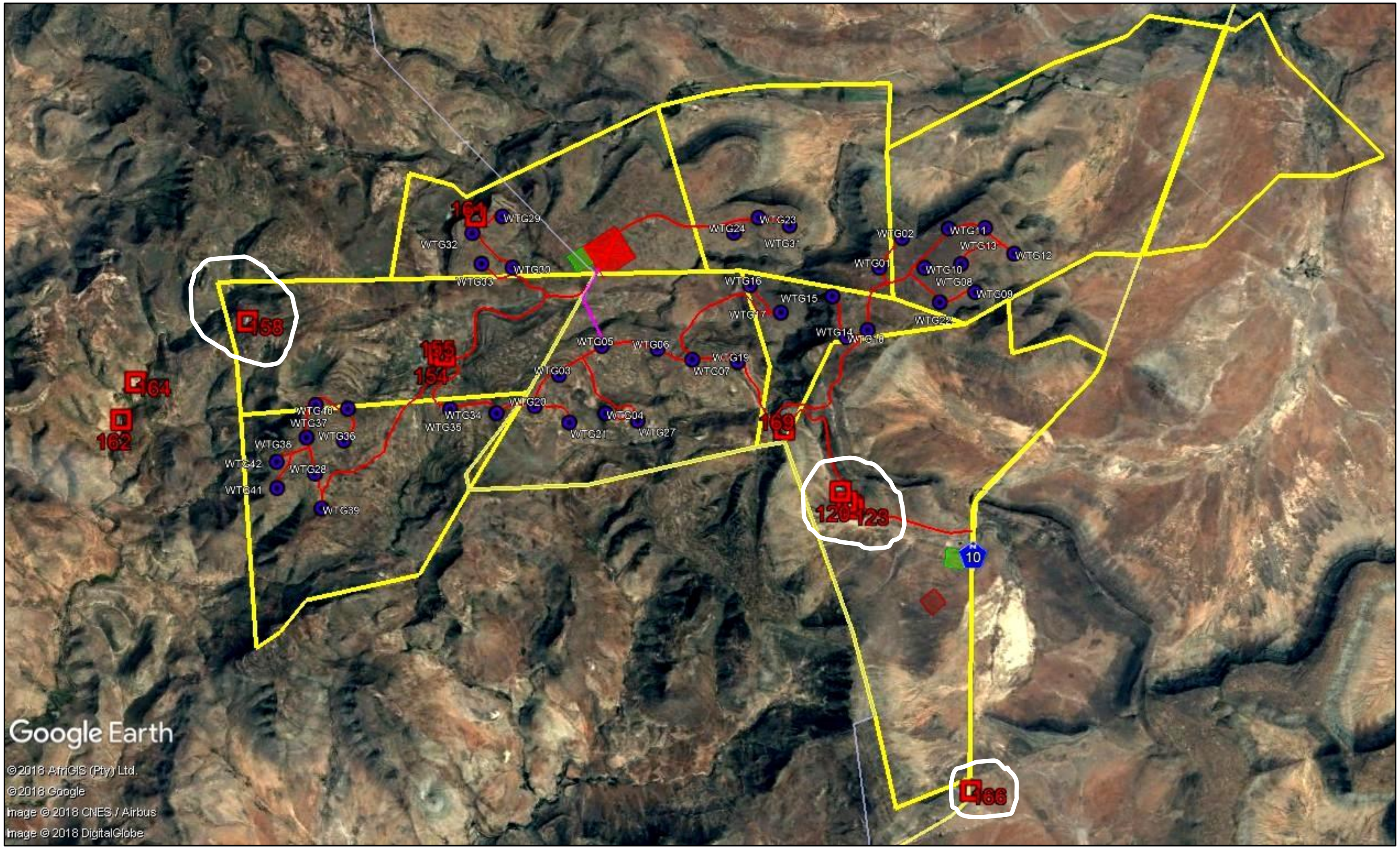

Fig. 67. Google Earth© satellite image of the Umsobomvu 1 WEF project area (yellow polygons) showing known fossil sites (numbered in red) in relation to the revised project footprint. Scientifically important sites 158 (plant debris) and 166, 119-123 (vertebrate burrows and skeletal remains) outlined in white for emphasis lie outside (> 50 m) the project footprint (See also Fig. 69). The remaining sites are of low scientific / conservation value and / or lie well outside the project footprint. None of these sites therefore warrants palaeontological mitigation for this development.

Fig. 68. Satellite image showing the fossil vertebrate skeletal material and burrow sites 119-123 on Farm Winterhoek 118/RE (data from Almond 2017a) in relation to the proposed WEF main access road from the N10 (in red). The sites lie over 100 m from the access road (blue shape depicts a *c.* 50 m–radius buffer zone) and at a much lower elevation so they will not be impacted by the proposed development.

4. PALAEONTOLOGICAL HERITAGE IMPACT ASSESSMENT

The study area for the proposed Umsobomvu 1 WEF near Middelburg is underlain by potentially fossiliferous sedimentary rocks of Permo-Triassic and younger, Quaternary to Holocene age (Sections 2 & 3). The construction phase of the proposed WEF will entail surface clearance as well as substantial excavations into the superficial sediment cover and into the underlying bedrock as well. These notably include site clearance activities as well as excavations for the wind turbine foundations, laydown and mounting areas, buried cables, new internal access roads, transmission line pylon footings, on-site substation, office / workshop area and any associated borrow pits. 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 planning, operational and decommissioning phases of the wind energy facility are unlikely to involve further adverse impacts on local palaeontological heritage, however.

The Umsobomvu 1 WEF study area, centred on the Agter-Renosterberg mountains to the northwest of Middelburg, is largely underlain by continental (fluvial, lacustrine) sediments of the Beaufort Group (Karoo Supergroup). These include (1) latest Permian to earliest Triassic rocks forming the uppermost portion of the Adelaide Subgroup (equivalents of the Balfour Formation of the eastern Main Karoo Basin) that crop out in low-lying, hilly terrain around the periphery of the Agter-Renosterberg massif, as well as (2) Early Triassic sediments of the Katberg Formation (Tarkastad Group) that build the Agter-Renosterberg escarpment and large parts of the upland plateau. The Karoo Supergroup sediments have been extensively intruded by Early Jurassic dykes and sills of the Karoo Dolerite Suite that have baked the adjacent country rocks and also underlie large areas of the plateau. The upper Adelaide Subgroup and Katberg Formation are well-known for their important continental biotas spanning the Permo-Triassic boundary, including diverse fossil vertebrates (therapsids, reptiles, amphibians), trace fossils (*e.g.* invertebrate and vertebrate burrows, trackways) and rarer vascular plants. These fossil faunas provide key data for understanding the impact of the catastrophic end-Permian Mass Extinction at 251 Ma (million years ago) on the terrestrial life of Gondwana. The Beaufort Group and Karoo dolerite bedrocks are extensively mantled by a variety of Late Caenozoic superficial deposits such as colluvial rock rubble (scree), alluvium, surface gravels, soils and pedocretes.

Previous workers have recorded a number of Late Permian and Early Triassic vertebrate fossil sites in the Agter-Renosterberg (*cf* Kitching 1977, Nicolas 2007). Recent fieldwork shows that the mudrock-dominated Adelaide Subgroup succession around the base of the escarpment is generally very poorly exposed, due to a thick prism of colluvial sediment cover, and often deeply weathered. Only sparse fossil vertebrate remains (isolated bones, one semi-articulated skeleton just outside the present project area) as well as low-diversity trace fossil assemblages (*Scoyenia*) were recorded here. Better exposures just 20 km southwest of the study area yielded unusually large vertebrate burrows, however. Most of the fossil material recorded from the Katberg Formation within the study area comes from small exposures of mudrock-dominated sediment packages within the lower part of the succession (The precise stratigraphic position of these finds remains ambiguous due to low exposure levels here). It includes well-articulated skeletal material of the medium-sized dicynodont *Lystrosaurus* embedded within mudrock or pedogenic calcrete (Almond 2018b) as well as fairly common, disarticulated and rolled bones and teeth variously associated with mudflake / calcrete basal breccias or channel sandstones. Several large vertebrate burrows are recorded in excellent road cutting exposures of lower Katberg rocks along the N10, just outside the study area, as well as along a stream bed exposure on Winterkoek 118/RE while small, oblique cylindrical burrows (*Katbergia*), of probable crustacean origin are locally abundant within mudrock and sandstone facies. Rare occurrences of poorly-preserved plant material (unidentified stems and woody fragments) as well as possible tetrapod tracks from high up within the Katberg Formation were reported from farm Uitzicht 3. The intrusive dolerites that are likely to underlie a substantial fraction of the development footprint on higher ground are unfossiliferous. Furthermore, baking of the surrounding sediments during dolerite intrusion has probably compromised some of the fossils originally preserved here. No fossil remains were observed within the Late Caenozoic superficial sediments in the study area.

It is concluded that palaeontologically valuable fossil remains are widely distributed within the Beaufort Group sedimentary bedrocks of the study area but they are sparsely distributed and for most part protected against impacts by the thick superficial sediment cover. Only deep, high-volume excavations into fresh sedimentary bedrock are therefore likely to have any significant impact on local fossil heritage resources within the Umsobomvu 1 WEF study area.

The inferred impact of the proposed wind energy development on local fossil heritage resources is analysed in Table 1 below, based on the system used by EOH Coastal & Environmental Services. This assessment applies only to the construction phase of the development since further 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 (*localised*). Such impacts can usually be mitigated but cannot be fully rectified or reversed (*i.e. permanent, irreversible*). Most of the sedimentary formations represented within the study area contain fossils of some sort, so impact on fossil heritage are *probable*. However, because of (a) the generally sparse occurrence of fossils within the bedrocks concerned here, as well as within the overlying superficial sediments (soil, alluvium, colluvium *etc*), (b) the widespread occurrence of the fossils concerned and (c) the mantling of the bedrocks with thick superficial sediments in many areas so that major impacts on potentially-fossiliferous fresh (*i.e.* unweathered) bedrock are limited, the severity of these impacts is conservatively rated as *low (negative)*. However, should fossil sites with well-articulated vertebrate remains, vertebrate burrows or well-preserved plant material be destroyed without mitigation, these impacts would be locally *high* (*negative*). Given the generally low levels of bedrock exposure within the study area, the degree of confidence for this assessment is rated as moderate (*possible*).

Apart from (1) the area around Locs. 119 to 123 (Winterhoek 118/RE), where several large burrows and disarticulated skeletal remains of therapsids (mammal-like reptiles) have recently been recorded (Almond 2017a; Fig. 68 herein), and (2) Loc. 158 (Uitzicht 3) featuring rare Early Triassic fossil plants in an existing borrow pit, no areas or fossil sites of exceptional fossil heritage sensitivity or significance were identified during the field assessment within the Umsobomvu 1 WEF study area (*N.B.* Given time constraints and the huge area involved, only a geologically representative sample of the area could be surveyed). The fossil remains identified in this study are mostly of widespread occurrence within the study area itself as well as within the outcrop area of the formations concerned (*i.e.* not unique to the study area). Irreplaceable loss of fossil heritage is therefore not anticipated. Should fossil remains be discovered or exposed during the construction phase of the proposed WEF development, these impacts can usually be mitigated, at least in part, as outlined in the following section of the report.

There are no fatal flaws in the Umsobomvu WEF development proposal as far as fossil heritage is concerned. Due to (1) the general scarcity of fossil remains, especially in the higher-lying areas where the majority of the infrastructure will be situated, (2) the moderately high levels of near-surface bedrock weathering and baking of sediments by dolerite intrusions, as well as (3) the extensive superficial sediment cover observed within most of the study area, the overall impact significance of the construction phase of the proposed alternative energy project is assessed as LOW. The no-go option (*i.e.* no development of the wind farm) is of neutral impact significance for fossil heritage. Confidence levels for the assessment are rated as medium, given the necessarily superficial palaeontological field coverage of the large, mountainous project area. There are no objections on palaeontological heritage grounds to authorisation of the amended WEF project.

It should be noted that should new fossil remains be discovered before or during construction and reported by the responsible ECO to the relevant heritage management authority (ECPHRA for the Eastern Cape and SAHRA for the Northern Cape) for professional recording and collection, as recommended below, the overall impact significance of the project would remain LOW. Residual negative impacts from loss of 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 under-recorded region would constitute a useful addition to our scientific understanding of the fossil heritage here.

4.1. Cumulative impacts

Previous palaeontological assessments (PIAs) for several proposed or authorized alternative energy projects within a 50 km radius of the Umsobomvu 1 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 original Umsobomvu WEF (Almond 2015 – covering the amended Umsobomvu 1 and Coleskop WEF project areas), the Phezukomoya WEF (Almond 2017a) and the San Kraal WEF (Almond 2017b) 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 have been, or are likely to be, 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 (1) the comparative rarity of well-preserved, scientifically important fossil material in the region and (2) 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 in the main Karoo Basin, the cumulative impact significance of the Umsobomvu 1 WEF is assessed as LOW.

4.2. Recommended mitigation and management actions

All scientifically-significant, conservation-worthy fossil sites recorded within the Umsobomvu 1 WEF project area lie outside the development footprint (Figs. 67 & 68). Given the low impact significance of the proposed Umsobomvu 1 WEF near Middelburg as far as palaeontological heritage is concerned, no further specialist palaeontological heritage studies or mitigation are considered necessary for this project, pending the potential discovery or exposure of substantial new fossil remains during development.

During the construction phase all deeper (> 1 m) bedrock excavations should be monitored for fossil remains by the responsible ECO. Should substantial fossil remains such as vertebrate bones and teeth, plant-rich fossil lenses or dense fossil burrow assemblages be exposed during construction, the responsible Environmental Control Officer should safeguard these, preferably *in situ*, and alert the responsible heritage management authority (ECPHRA for the Eastern Cape, SAHRA for the Northern Cape) so that appropriate action can be taken by a professional palaeontologist, at the developer's expense (Contact details: ECPHRA: Mr Sello Mokhanya, 74 Alexander Road, King Williams Town 5600; Email: smokhanya@ecphra.org.za. 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). Mitigation would normally involve the scientific recording and judicious sampling or collection of fossil material as well as associated geological data (*e.g.* stratigraphy, sedimentology, taphonomy) by a professional palaeontologist. A tabulated Chance Fossil Finds Procedure has been appended to this report (Appendix 2).

These mitigation recommendations should be incorporated into the Construction Environmental Management Programme (EMPr) for the Umsobomvu 1 Wind Energy Facility.

Provided that the recommended mitigation measures are carried through, it is likely that any potentially negative impacts of the proposed transmission line development on local fossil resources will be substantially reduced. Furthermore, they will be partially offset by the *positive* impact represented by increased understanding of the palaeontological heritage of the Great Karoo region.

Please note that:

- All South African fossil heritage is protected by law (South African Heritage Resources Act, 1999) and fossils cannot be collected, damaged or disturbed without a permit from SAHRA or the relevant Provincial Heritage Resources Agency (in this case, ECPHRA for the Eastern Cape and SAHRA for the Northern Cape);

- The palaeontologist concerned with mitigation work will need a valid fossil collection permit from ECPHRA / SAHRA and any material collected would have to be curated in an approved depository (*e.g.* museum or university collection);

- All palaeontological specialist work would have to conform to international best practice for palaeontological fieldwork and the study (*e.g.* data recording fossil collection and curation, final report) should adhere as far as possible to the minimum standards for Phase 2 palaeontological studies recently developed by SAHRA (2013).

Table 1: Assessment and mitigation of impacts (Construction Phase): Umsobomvu 1 WEF.

DESCRIPTION OF IMPACTS	SPATIAL SCALE	TEMPORAL SCALE (DURATION)	CERTAINTY SCALE/ LIKELIHOOD	SEVERITY/ BENEFICIAL SCALE	SIGNIFICANCE PRE-MITIGATION	MITIGATION MEASURES	SIGNIFICANCE POST-MITIGATION
Issue: Fossil heritage resources							
Disturbance, damage, destruction or sealing-in of fossil remains preserved at or beneath the ground surface within the development area, especially during ground clearance or bedrock excavations during the construction phase.	Localised (WEF footprint)	Permanent	Possible	LOW NEGATIVE (but might be locally HIGH NEGATIVE)	LOW/ NEGATIVE	Monitoring of all substantial bedrock excavations for fossil remains by ECO, with reporting of new palaeontological finds (notably fossil vertebrate bones & teeth) to ECPHRA (E. Cape) or SAHRA (N. Cape) for possible specialist mitigation.	LOW/ NEGATIVE (but professional recording and collection of new fossil finds is compensatory positive outcome)

5. CONCLUSIONS AND RECOMMENDATIONS

The Umsobomvu WEF study area, centred on the Agter-Renosterberg mountains to the northwest of Middelburg, is largely underlain by continental (fluvial, lacustrine) sediments of the Beaufort Group (Karoo Supergroup). These include (1) latest Permian to earliest Triassic rocks forming the uppermost portion of the Adelaide Subgroup (equivalents of the Balfour Formation of the eastern Main Karoo Basin) that crop out in low-lying, hilly terrain around the periphery of the Agter-Renosterberg massif, as well as (2) Early Triassic sediments of the Katberg Formation (Tarkastad Group) that build the Agter-Renosterberg escarpment and large parts of the upland plateau. The Karoo Supergroup sediments have been extensively intruded by Early Jurassic dykes and sills of the Karoo Dolerite Suite that have baked the adjacent country rocks and also underlie large areas of the plateau. The upper Adelaide Subgroup and Katberg Formation are well-known for their important continental biotas spanning the Permo-Triassic boundary, including diverse fossil vertebrates (therapsids, reptiles, amphibians), trace fossils (*e.g.* invertebrate and vertebrate burrows, trackways) and rarer vascular plants. These fossil faunas provide key data for understanding the impact of the catastrophic end-Permian Mass Extinction at 251 Ma (million year ago) on the terrestrial life of Gondwana. The Beaufort Group and Karoo dolerite bedrocks are extensively mantled by a variety of Late Caenozoic superficial deposits such as colluvial rock rubble (scree), alluvium, surface gravels, soils and pedocretes.

Previous workers have recorded a number of Late Permian and Early Triassic vertebrate fossil sites in the Agter-Renosterberg (*cf* Kitching 1977, Nicolas 2007). Recent fieldwork shows that the mudrock-dominated Adelaide Subgroup succession around the base of the escarpment is generally very poorly exposed, due to a thick prism of colluvial sediment cover, and often deeply weathered. Only sparse fossil vertebrate remains (isolated bones, one semi-articulated skeleton close to but outside the present project area) as well as low-diversity trace fossil assemblages (*Scoyenia*) were recorded here. Better exposures just 20 km southwest of the study area yielded unusually large vertebrate burrows, however. Most of the fossil material recorded from the Katberg Formation within the Agter-Renosterberg region comes from small exposures of mudrock-dominated sediment packages within the lower part of the succession (The precise stratigraphic position of these finds remains ambiguous due to low exposure levels here). Well-articulated skeletal material of the medium-sized dicynodont *Lystrosaurus* embedded within mudrock or pedogenic calcrete is recorded just west of the present study area (Almond 2018b) as well as fairly common, disarticulated and rolled bones and teeth variously associated with mudflake / calcrete basal breccias or channel sandstones. Several large vertebrate burrows are recorded in excellent road cutting exposures of lower Katberg rocks along the N10, just outside the study area, as well as along a stream bed exposure on Winterhoek 118/RE while small, oblique cylindrical burrows (*Katbergia*), of probable crustacean origin are locally abundant within mudrock and sandstone facies. Rare occurrences of poorly-preserved plant material (unidentified stems and woody fragments) as well as possible tetrapod tracks from high up within the Katberg Formation were reported from farm Uitzicht 3. The intrusive dolerites that are likely to underlie a substantial fraction of the development footprint on higher ground are unfossiliferous. Furthermore, baking of the surrounding sediments during dolerite intrusion has probably compromised some of the fossils originally preserved here. No fossil remains were observed within the Late Caenozoic superficial sediments in the study area.

There are no fatal flaws in the Umsobomvu 1 WEF development proposal as far as fossil heritage is concerned. Due to (1) the general scarcity of fossil remains, especially in the upland areas where the majority of the infrastructure will be situated, (2) the moderately high levels of near-surface bedrock weathering and baking of sediments by dolerite intrusions, as well as (3) the extensive superficial sediment cover observed within most of the study area, the overall impact significance of the construction phase of the proposed alternative energy project is assessed as LOW. The no-go option (*i.e.* no development of the wind farm) is of neutral impact significance for fossil heritage. This assessment applies only to the construction phase of the development since further impacts on fossil heritage during the planning, operational and decommissioning phases of the facilities are not anticipated. Confidence levels for the assessment are rated as medium, given the necessarily superficial palaeontological field coverage of the large, mountainous project area.

Cumulative impacts on fossil heritage resources posed by several alternative energy developments proposed in the wider Middelburg – Noupoort region are assessed as *low*.

All scientifically-significant, conservation-worthy fossil sites recorded within the Umsobomvu 1 WEF project area lie outside the development footprint. Given the low impact significance of the proposed Umsobomvu 1 WEF near Middelburg as far as palaeontological heritage is concerned, no further specialist palaeontological heritage studies or mitigation are considered necessary for this project, pending the discovery or exposure of substantial new fossil remains during development. There are no objections on palaeontological heritage grounds to authorisation of the amended WEF project.

During the construction phase all deeper (> 1 m) bedrock excavations should be monitored for fossil remains by the responsible ECO. Should substantial fossil remains such as vertebrate bones and teeth, plant-rich fossil lenses, vertebrate trackways or dense fossil burrow assemblages be exposed during construction, the responsible Environmental Control Officer should safeguard these, preferably *in situ*, and alert the responsible heritage management authority (ECPHRA for the Eastern Cape, SAHRA for the Northern Cape) so that appropriate action can be taken by a professional palaeontologist, at the developer's expense (Contact details: ECPHRA: Mr Sello Mokhanya, 74 Alexander Road, King Williams Town 5600; Email: smokhanya@ecphra.org.za. 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). Mitigation would normally involve the scientific recording and judicious sampling or collection of fossil material as well as associated geological data (*e.g.* stratigraphy, sedimentology, taphonomy) by a professional palaeontologist. A tabulated Chance Fossil Finds Procedure is appended to this report (Appendix 2).

These mitigation recommendations should be incorporated into the Construction Environmental Management Plan (EMPr) for the Umsobomvu 1 Wind Energy Facility. *Provided that* the recommended mitigation measures are carried through, it is likely that any potentially negative impacts of the proposed transmission line development on local fossil resources will be substantially reduced. Furthermore, they will be partially offset by the *positive* impact represented by our increased understanding of the palaeontological heritage of the Great Karoo region.

Please note that:

- All South African fossil heritage is protected by law (South African Heritage Resources Act, 1999) and fossils cannot be collected, damaged or disturbed without a permit from SAHRA or the relevant Provincial Heritage Resources Agency (in this case, ECPHRA for the Eastern Cape and SAHRA for the Northern Cape);

- The palaeontologist concerned with mitigation work will need a valid fossil collection permit from ECPHRA / SAHRA and any material collected would have to be curated in an approved depository (*e.g.* museum or university collection);

- All palaeontological specialist work would have to conform to international best practice for palaeontological fieldwork and the study (*e.g.* data recording fossil collection and curation, final report) should adhere as far as possible to the minimum standards for Phase 2 palaeontological studies recently developed by SAHRA (2013).

6. ACKNOWLEDGEMENTS

I would like to thank Ms Caroline Evans of EOH Coastal & Environmental Services for commissioning this study and for kindly proving the necessary background information. The various land owners concerned in the project area are also thanked for facilitating our palaeontological fieldwork. I am especially grateful to Hedi and Erwin Stummer for their good company, logistical support and assistance with recording fossils in the field. Indeed, it must be acknowledged that majority of the important fossils finds on this project were found by Hedi Stummer.

7. 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. 2010. Borrow pit near Encobo Local Municipality, Chris Hani District Municipality, Eastern Cape Province. Palaeontological impact assessment: desktop study, 13 pp. Natura Viva cc, Cape Town.

ALMOND, J.E. 2011a. 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. 2011b. Proposed iNca Energy wind facility on the farms Cathcarts Gift 311 and Latham 205 near Queenstown, Eastern Cape Province. palaeontological impact assessment: combined desktop and scoping study, 30 pp. Natura Viva cc, Cape Town.

ALMOND, J.E. 2011c. Upgrading and construction of water supply schemes in Cluster 2, Chris Hani District Municipality, Eastern Cape Province: Phase 2 (Regional Scheme 5). Palaeontological impact assessment: desktop study, 14 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. 2013. Rehabilitation of National Route R61 (Section 3, km 24.2 to km 75) between Cradock and Tarkastad, Eastern Cape. Palaeontological specialist assessment: combined desktop and field-based study, 46 pp. Natura Viva cc, Cape Town.

ALMOND, J.E. 2014a. Proposed subdivision and rezoning of Portions on Remainder Erf 1 and Erf 176, Cofimvaba, Chris Hani District Municipality, Eastern Cape. Palaeontological specialist assessment: combined desktop and field-based study, 34 pp. Natura Viva cc, Cape Town.

ALMOND, J.E. 2014b. Proposed upgrade of DR08376 from R61 at St Marks to Sabalele Village near Cofimvaba, Chris Hani District Municipality, Eastern Cape. Palaeontological specialist assessment: combined desktop and field-based study, 46 pp. Natura Viva cc, Cape Town.

ALMOND, J.E. 2014c. Proposed development of three borrow pits near Lady Frere, Eastern Cape. Palaeontological impact assessment: combined desktop and field study, 19 p. 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. 2017a. Proposed Mainstream Phezukomoya Wind Energy Facility near Noupoort, Northern & Eastern Cape. Palaeontological heritage report, 59 pp. Natura Viva cc.

ALMOND, J.E. 2017b. Proposed Mainstream San Kraal Wind Energy Facility near Noupoort, Northern & Eastern Cape. Palaeontological heritage report, 59 pp. Natura Viva cc.

ALMOND 2018a. Umsobomvu 1 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, 79 pp. Natura Viva cc, Cape Town.

ALMOND 2018b. Coleskop 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, 83 pp. Natura Viva cc, Cape Town.

ALMOND, J.E. & PETHER, J. 2008. Palaeontological heritage of the Northern Cape. Interim SAHRA technical report, 124 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.

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

BAMFORD, M. 1999. Permo-Triassic fossil woods from the South African Karoo Basin. Palaeontologia africana 35, 25-40.

BAMFORD, M.K. 2004. Diversity of woody vegetation of Gondwanan southern Africa. Gondwana Research 7, 153-164.

BENDER, P.A. & BRINK, J.S. 1992. A preliminary report on new large mammal fossil finds from the Cornelia. South African Journal of Science 88, 512-515.

BENDER, P.A. & HANCOX, P.J. 2003. Fossil fishes of the *Lystrosaurus* and *Cynognathus* Assemblage Zones, Beaufort Group, South Africa: correlative implications. Council for Geoscience, Pretoria, Bullletin 136, 1-27.

BENDER, P.A. & HANCOX, P.J. 2004. Newly discovered fish faunas from the Early Triassic, Karoo Basin, South Africa, and their correlative implications. Gondwana Research 7, 185-192.

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.

BOTHA, J. & SMITH, R.M.H. 2006. Rapid vertebrate recuperation in the Karoo Basin of South Africa following the End-Permian extinction. Journal of African Earth Sciences 45, 502–514.

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.

BOUSMAN, C.B. et al. 1988. Palaeoenvironmental implications of Late Pleistocene and Holocene valley fills in Blydefontein Basin, Noupoort, C.P., South Africa. Palaeoecology of Africa 19: 43-67.

BRINK, J.S. 1987. The archaeozoology of Florisbad, Orange Free State. Memoirs van die Nasionale Museum 24, 151 pp.

BRINK, J.S. et al. 1995. A new find of *Megalotragus priscus* (Alcephalini, Bovidae) from the Central Karoo, South Africa. Palaeontologia africana 32: 17-22.

BRINK, J.S. & ROSSOUW, L. 2000. New trial excavations at the Cornelia-Uitzoek type locality. Navorsinge van die Nasionale Museum Bloemfontein 16, 141-156.

BRINK, J.S., BERGER, L.R. & CHURCHILL, S.E. 1999. Mammalian fossils from erosional gullies (dongas) in the Doring River drainage. Central Free State Province, South Africa. *In*: C. Becker, H. Manhart, J. Peters & J. Schibler (eds.), Historium animalium ex ossibus. Beiträge zur Paläoanatomie, Archäologie, Ägyptologie, Ethnologie und Geschichte der Tiermedizin: Festschrift für Angela von den Driesch. Rahden/Westf : Verlag Marie Leidorf GmbH, 79-90.

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, Bloemfontein.

CATUNEANU, O. AND ELANGO, H.N. 2001. Tectonic control on fluvial styles: the Balfour Formation of the Karoo Basin, South Africa. Sedimentary Geology 140, 291-313.

CHURCHILL, S.E. et al. 2000. Erfkroon: a new Florisian fossil locality from fluvial contexts in the western Free State, South Africa. South African Journal of Science 96: 161-163.

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

COLE, D. & SMITH, R. 2008. Fluvial architecture of the Late Permian Beaufort Group deposits, S.W. Karoo Basin: point bars, crevasse splays, palaeosols, vertebrate fossils and uranium. Field Excursion FT02 guidebook, AAPG International Conference, Cape Town October 2008, 110 pp.

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.

COOKE, H.B.S. 1974. The fossil mammals of Cornelia, O.F.S., South Africa. In: Butzer, K.W., Clark, J.D. & Cooke, H.B.S. (Eds.) The geology, archaeology and fossil mammals of the Cornelia Beds.

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.W. 2013. Palaeontological impact assessment for proposed establishment of a Solar Energy facility on farm Naauwpoort near Noupoort, Eastern Cape, 13 pp. Rob Gess Consulting, Bathurst.

GROENEWALD, G.H. 1984. Stratigrafie en Sedimentologie van die Groep Beaufort in die Noordoos Vrystaat. Unpublsihed Ph.D. Thesis, Rand Afrikaans University, Johannesburg, 174 pp.

GROENEWALD, G.H., 1989. Stratigrafie en sedimentologie van die Groep Beaufort in die Noordoos-Vrystaat. Bulletin of the Geological Survey of South Africa 96, 1–62.

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

GROENEWALD, G.H. 1996. Stratigraphy of the Tarkastad Subgroup, Karoo Supergroup, South Africa. Unpublished PhD thesis, University of Port Elizabeth, South Africa.

GROENEWALD, G.H. 2011. Palaeontological impact assessment report: the proposed Thomas River Wind Energy Facility, Stutterheim, Eastern Cape Province, South Africa, 11 pp. Metsi Metseng Geological Services cc, Bethlehem.

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., J. WELMAN, AND J. A. MACEACHERN. 2001. Vertebrate burrow complexes from the Early Triassic *Cynognathus* Assemblage Zone (Driekoppen Formation, Beaufort Group) of the Karoo Basin, South Africa. Palaios16,148–160.

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.

HILL, R.S. 1993. The geology of the Graaff-Reinet area. Explanation of Sheet 3224, scale 1: 250 000. 31pp. Geological Survey / Council for Geoscience, Pretoria.

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. 1984. The geology of the Queenstown area. Explanation to 1: 250 000 geology Sheet 3126 Queenstown, 21 pp. Council for Geoscience, Pretoria.

JOHNSON, M.R. & HILLER, N. 1990. Burgersdorp Formation. South African Committee for Stratigraphy, Catalogue of South African Lithostratigraphic Units 2, 9-10. Council for Geoscience, Pretoria.

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.

KARPETA, W.P. & JOHNSON, M.R. 1979. The geology of the Umtata area. Explanation to 1: 250 000 geology Sheet 3128 Umtata, 16 pp. Council for Geoscience, Pretoria.

KATEMAUNZANGA, D. 2009. Lithostratigraphy, sedimentology and provenance of the Balfour Formation (Beaufort Group) in the Fort Beaufort-Alice, Eastern Cape Province, South Africa. Unpublished M.Sc. Thesis, University of Fort Hare, 1-140.

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. 1963. Notes on some fossil pockets and bone beds in the *Cynognathus*-Zone in the Burghersdorp and Lady Frere Districts. Palaeontologia Africana 8, 113-118.

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).

KITCHING, J.W. 1995. Biostratigraphy of the Cynognathus Assemblage Zone. Pp. 13-17 in Rubidge, B.S. (ed.) Biostratigraphy of the Beaufort Group (Karoo Supergroup). South African Committee for Stratigraphy, Biostratigraphic Series No. 1. Council for Geoscience, Pretoria.

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.

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.

MEADOWS, M.E. & WATKEYS, M.K. 1999. Palaeoenvironments. In: Dean, W.R.J. & Milton, S.J. (Eds.) The karoo. Ecological patterns and processes, pp. 27-41. Cambridge University Press, Cambridge.

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. 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., 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., 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.

OGHENEKOME, M.E. 2012. Sedimentary environments and provenance of the Balfour Formation (Beaufort Group) in the area between Bedford and Adelaide, Eastern Cape Province, South Africa. Unpublished MSc thesis, University of Fort Hare, 132 pp.

ORTIZ, D., LEWIS, P.J., KENNEDY, A.M., BHULLAR, B.S. & HANCOX, J. 2010. Preliminary analysis of lungfish (Dipnoi) tooth plates from Driefontein, South Africa. Proceedings of the 16th Conference of the PSSA, Howick, Umgeni Valley Nature Reserve, 72-74.

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.

PREVEC, R. 2011. Xhonxa Dam water supply project (Qam-Xon),former Transkei, Eastern Cape, RSA. Palaeontological heritage assessment for Eskom Environmental Management, 41 pp.

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.

SHONE, R.W. 1978. Giant *Cruziana* from the Beaufort Group. Transactions of the Geological Society of South Africa 81, 327-329.

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.M.H. 1979. The sedimentology and taphonomy of flood-plain deposits of the Lower Beaufort (Adelaide Subgroup) strata near Beaufort West, Cape Province. Annals of the Geological Survey of South Africa 12, 37-68.

SMITH, R.M.H. 1980. The lithology, sedimentology and taphonomy of flood-plain deposits of the Lower Beaufort (Adelaide Subgroup) strata near Beaufort West. Transactions of the Geological Society of South Africa 83, 399-413.

SMITH, R.M.H. 1986. Trace fossils of the ancient Karoo. Sagittarius 1 (3), 4-9.

SMITH, R.M.H. 1987a. Morphological and depositional history of exhumed Permian point bars in the southwestern Karoo, South Africa. Journal of Sedimentary Petrology 57, 19-29.

SMITH, R.M.H. 1987b. Helical burrow casts of therapsid origin from the Beaufort Group (Permian) of South Africa. Palaeogeography, Palaeoclimatology, Palaeoecology 60, 155-170.

SMITH, R.M.H. 1988. Fossils for Africa. An introduction to the fossil wealth of the Nuweveld mountains near Beaufort West. Sagittarius 3, 4-9. SA Museum, Cape Town.

SMITH, R.M.H. 1989. Fossils in the Karoo – some important questions answered. Custos 17, 48-51.

SMITH, R.M.H. 1990. Alluvial paleosols and pedofacies sequences in the Permian Lower Beaufort of the southwestern Karoo Basin, South Africa. Journal of Sedimentary Petrology 60, 258-276.

SMITH, R.M.H. 1993a. Sedimentology and ichnology of floodplain paleosurfaces in the Beaufort Group (Late Permian), Karoo Sequence, South Africa. Palaios 8, 339-357.

SMITH, R.M.H. 1993b. Vertebrate taphonomy of Late Permian floodplain deposits in the southwestern Karoo Basin of South Africa. Palaios 8, 45-67.

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., 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.

STEAR, W.M. 1978. Sedimentary structures related to fluctuating hydrodynamic conditions in flood plain deposits of the Beaufort Group near Beaufort West, Cape. Transactions of the Geological Society of South Africa 81, 393-399.

STEAR, W.M. 1980. Channel sandstone and bar morphology of the Beaufort Group uranium district near Beaufort West. Transactions of the Geological Society of South Africa 83: 391-398.

VAN DER WALT, M., DAY, M., RUBIDGE, B., COOPER, A.K. & NETTERBERG, I. 2010. A new GIS-based biozone map of the Beaufort Group (Karoo Supergroup), South Africa. Palaeontologia Africana 45, 1-5.

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.

WELLS, L.H. & COOKE, H.B.S. 1942. The associated fauna and culture of Vlakkraal thermal springs, O.F.S.; III, the faunal remains. Transactions of the Royal Society of South Africa 29: 214-232.

WELMAN, J., GROENEWALD, G.H. & Kitching, J.W. 1991. Confirmation of the occurrence of Cynognathus Zone (Kannemeyeria – Diademodon Assemblage-Zone) deposits (uppermost Beaufort Group) in the northeastern Orange Free State, South Africa. South African Journal of Geology 94, 245-248.

8 . 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 1: GPS LOCALITY DATA FOR NUMBERED SITES MENTIONED IN TEXT

This table provides field data relating to the entire original Umsobomvu WEF project area (*cf* Almond 2015) *plus* several relevant fossil sites in the broader Middelburg – Noupoort region. Data for fossil sites 119-123 were abstracted from the palaeontological assessment report by Almond (21017a) for the Mainstream Phezukomoya Wind Energy Facility.

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

N.B. Given the sensitivity and conservation importance of fossil sites in the RSA, this data is *not* for public release.

Locality number	South	East	Comments
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.
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.
125	31 18 53.3	24 44 08.2	Farm 121, Adelaide Subgp mudrocks, ferruginous calcrete nodules
126	31 19 19.8	24 44 02.6	Farm 121, borrow pit exposure of Adelaide Subgp mudrocks, silicified surface clasts of hornfels, quartzite. Small bone fragments, *Scoyenia* Ichnofacies trace fossils. Proposed Field Rating IIIC. No mitigation required.
127	31 20 07.3	24 44 38.5	Holle Fountain 133, stream bed exposure of Adelaide Subgp palaeosurface with mudcracks, adhesion warts, algal mat textures
128	31 20 05.3	24 44 41.1	Holle Fountain 133, thin sandstone packages with thick calcrete glaebule conglomerates containing sparse rolled bone, teeth. Lower Katberg Fm. Proposed Field Rating IIIC. No mitigation required.
129	31 20 03.9	24 44 42.2	Holle Fountain 133, stream bank exposure of poorly sorted sand-supported boulder diamictite; probably debris flow deposit overlying Adelaide Subgp.
130	31 20 04.1	24 44 40.7	Holle Fountain 133, streambed exposure of hackly-

			weathering grey-green mudrocks with locally abundant *Katbergia* invertebrate burrows. Mudflake breccias associated with thin sandstone packages. Proposed Field Rating IIIC. No mitigation required.
131	31 19 53.0	24 45 02.1	Holle Fountain 133, thick package of pale-grey, sheet-like sandstones low down on escarpment slope, ferruginous pedocrete nodules abundant. Lower Katberg Fm.
132	31 19 51.4	24 45 06.7	Holle Fountain 133, calcrete breccia lenses within sandstone package. Lower Katberg Fm.
133	31 19 54.2	24 45 09.4	Holle Fountain 133, heterolithic package within lower Katberg Fm, thin-bedded pale grey sandstones and grey-green mudrocks, prominent-weathering pedogenic calcrete horizons.
134	31 20 10.6	24 44 57.3	Holle Fountain 133, as above. Recessive-weathering band within lower Katberg escarpment. Grey-green and purple-brown mudrocks, possible sand-infilled mudcracks within thin-bedded heterolithic package. Mudflake basal breccias within thicker channel sandstones.
135	31 20 11.6	24 44 59.5	Holle Fountain 133, thin-bedded, pale grey sandstone with grey-green mudrock interbeds, calcrete glaebule breccio-conglomerates,ferruginous pedocrete lenticles and large boulder-sized concretions, *Lystrosaurus* skull and associated postcrania embedded in siltstone. Probably lower Katberg Fm (needs confirmation). Proposed Field Rating IIIB.
136	31 20 11.5	24 44 57.8	Holle Fountain 133, articulated skull & postcranial remains within ferruginous calcrete concretions. Few meters below *in situ Lystrosaurus* skeleton. Probably lower Katberg Fm (needs confirmation). Proposed Field Rating IIIB.
136a	31 20 13.9	24 44 54.6	Holle Fountain 133, small bone fragments associated with ferruginous pedocrete. Probably lower Katberg Fm (needs confirmation). Proposed Field Rating IIIC. No mitigation required.
137	31 21 30.9	24 45 04.6	Holle Fountain 133, colluvial and alluvial deposits dominated by flaggy sandstone blocks.
138	31 23 57.1	24 45 50.3	Leeuw Hoek 61, viewpoint down western Katberg and dolerite escarpment.
139	31 24 06.2	24 45 09.9	Leeuw Hoek 61, cross-bedded Katberg Fm sandstones.
140	31 24 30.9	24 45 14.4	Leeuw Hoek 61, 4x4 trail near Boshoek farmstead, small hillslope exposures of purple-brown Katberg mudrocks.
141	31 24 33.0	24 45 14.9	Leeuw Hoek 61, 4x4 trail near Boshoek farmstead, erosion gulley exposures of weathered purple-brown mudrocks. Katberg Fm.
142	31 25 23.6	24 41 56.0	Leeuw Hoek 61, borrow pit and erosion gulley exposure of grey-green and purple brown mudrocks. Adelaide Subgroup.
143	31 25 28.1	24 41 57.1	Leeuw Hoek 61, fragments of disarticulated bone within ferruginous pedocrete concretions. Adelaide Subgroup. Proposed Field Rating IIIC. No mitigation required.
144	31 25 28.0	24 41 57.2	Leeuw Hoek 61, articulated postcrania of small tetrapod within calcrete concretion. Adelaide Subgroup. Proposed Field Rating IIIB.
145	31 25 21.8	24 41 15.6	Paarde Valley 62, hornfels gravels associated with dolerite on slopes of koppie. Adelaide Subgroup.
146	31 25 20.8	24 41 15.6	Paarde Valley 62, *in situ* hornfels. Adelaide Subgroup.
147	31 25 28.7	24 40 46.9	Paarde Valley 62, dense patch of angular hornfels surface gravels.
148	31 25 40.6	24 39 23.5	Paarde Valley 62, near-surface calcrete development over dolerite, close to Paardevlei homestead.
149	31 25 35.8	24 39 18.4	Paarde Valley 62, baked, vuggy tabular sandstone package, close to Paardevlei homestead. Adelaide Subgroup.
150	31 24 45.3	24 38 51.7	Paarde Valley 62, borrow pit into grey-green Adelaide Subgroup mudrocks north of Paardevlei homestead.
151	31 23 32.1	24 38 28.4	Paarde Valley 62, borrow pit into grey-green Adelaide Subgroup mudrocks north of Paardevlei homestead. Fibrous

			ferruginous concretionary minerals (possibly pseudomorphs after gypsum).
152	31 18 25.0	24 45 08.1	Mooi Plaats 122, borrow pit into purple-brown to grey-green Adelaide Subgroup mudrocks, extensive development of ferruginous carbonate concretions. Sheetwash surface gravels.
153	31 16 30.3	24 48 08.5	Leeukop 120, weathered Adelaide Subgp. mudrocks, calcretised near-surface, overlain by calcretised and semi-consolidated alluvial gravels, debris flow diamictites.
154	31 22 43.5	24 50 24.4	Uitzicht 3, roadside borrow pit exposure of grey-green Katberg mudrocks and thin sandstone interbeds, basal mudclast breccias with small bone fragments. Calcretised subcylindrical invertebrate burrow infills (1-2 cm diameter). Propoed Field Rating IIIC. No mitigation required.
155	31 22 40.3	24 50 25.4	Uitzicht 3, roadside borrow pit exposure of grey-green Katberg mudrocks and thin sandstone interbeds with dense assemblages of vertical burrows or – more probably – sandstone casts of reedy plant stems (*e.g.* equisetaleans). Baked channel breccio-conglomerates. Proposed Field Rating IIIC. No mitigation required.
156	31 22 41.7	24 50 36.3	Uitzicht 3, thick, laterally extensive greyish lenticles of cross-bedded calcrete glaebule conglomerate. Katberg Fm.
157	31 23 15.9	24 51 49.4	Uitzicht 3, current megaripples and karst weathering in Katberg sandstones near Kamferkloof. Some ripple crests show *possible* evidence for trampling by tetrapods during period of subaerial exposure (equivocal).
158	31 24 24.4	24 50 08.2	Uitzicht 3, roadside borrow pit with reworked, fragmentary ferruginised plant compressions (*e.g.* longitudinally-ridged stems) within pale flaggy sandstones, upper Katberg Formation. Proposed Field Rating IIIB (given general rarity of Katberg Formation plant fossils). No mitigation required.
159	31 23 42.4	24 49 53.3	Uitzicht 3, roadside exposure of thin-bedded to laminated, flaggy Katberg sandstones, possible pyrite pseudomorphs.
160	31 22 01.8	24 48 46.0	Uitzicht 3, low cliff exposure of baked Katberg quartzite and hornfels overlying dolerite sill near Wilgerfontein.
161	31 22 27.0	24 48 59.2	Uitzicht 3, thinly-laminated Katberg channel sandstone basal breccias with sparse small (cm-scale) fragments of reworked bone and teeth teeth. Close to "petrified riverbed" rippled sandstones. Proposed Field Rating IIIC. No mitigation required.
162	31 25 31.4	24 51 11.3	Klip Krands 60, riverside cliff exposure of lower Katberg sandstones and mudrocks near Driekop farmstead. Sandstone sole surfaces with pustular algal mat textures, fine horizontal burrows, vertical burrows. Proposed Field Rating IIIC. No mitigation required.
163	31 25 40.0	24 51 08.2	Klip Krands 60, erosion gulley exposure of older alluvial silts, sands and gravels near Driekop farmstead. Downwasted sandstone surface gravels.
164	31 25 24.3	24 50 47.7	Klip Krands 60, extensive exposure of lower Katberg grey-green mudrocks, desiccation-cracked surfaces with vertical burrow assemblages near dam overflow. Abandoned riverside cliff exposure through Katberg sandstones and mudrocks.
165	31 25 30.4	24 49 45.1	Klip Krands 60, baked Katberg sandstone and adjacent dolerite intrusions, sandstone and dolerite surface gravels.
166	31 17 57.7	24 54 41.1	Naauw Poort 1, extensive N10 road cutting through lower Katberg Fm channel sandstones and overbank mudrocks. Possible *Katbergia* burrows. Proposed Field Rating IIIB.
167	31 18 46.7	24 55 26.6	Koppies Kraal 6, extensive N10 road cutting through lower Katberg Fm channel sandstones and overbank mudrocks. Channel collapse breccias, cross-bedded basal-breccias.
168	31 19 27.6	24 56 18.0	Naauw Poort 1, extensive N10 road cutting through lower Katberg Fm channel sandstones and overbank mudrocks. *Katbergia* invertebrate burrows, large vertebrate burrows, rolled bone within channel basal breccio-conglomerates as well as channel sandstones, postcranial bones in pedocrete

			horizons within overbank mudrocks. Proposed Field Rating IIIB.
169	31 19 42.0	24 51 03.1	Annex Winterhoek 186, hillslope exposure of Katberg Fm grey-green mudrocks, pedocrete nodules, thin sandstones. Locally abundant *Katbergia* burrows. Proposed Field Rating IIIC. No mitigation required.
170	31 20 03.9	24 50 52.8	Elands Kloof 135, stream bed exposure of baked Katberg mudrocks and sandstones with rounded mineral-infilled vesicles, dolerite intrusion.
170a	31 19 47.98	24 51 01.37	Elands Kloof 135, small hillslope exposure of grey-green Katberg mudrocks.
171	31 33 18.5	24 42 38.2	Extensive borrow pit into grey-green and purple-brown Adelaide Subgroup mudrocks on S side of R398 just west of Lessingshoogte, *c*. 27 km WSW of Middelburg. Several large-scale, gently sloping vertebrate burrows, locally common *Katbergia* burrows in sandstones, sparse bone fragments. Proposed Field Rating IIIB.
172	31 33 19.0	24 42 39.2	As above, site of vertebrate burrow warren. Proposed Field Rating IIIB.

<table>
<tr><td colspan="3">APPENDIX 2: CHANCE FOSSIL FINDS PROCEDURE: Umsobomvu 1 WEF near Middelburg</td></tr>
<tr><td>Province & region:</td><td colspan="2">Northern and Eastern Cape: Pixley ka Seme & Chris Hani District Municipalities</td></tr>
<tr><td>Responsible Heritage Management Authority</td><td colspan="2">E Cape - ECPHRA: Mr Sello Mokhanya, 74 Alexander Road, King Williams Town 5600; Email: smokhanya@ecphra.org.za.
N. Cape - 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</td></tr>
<tr><td>Rock unit(s)</td><td colspan="2">Adelaide Subgroup, Katberg Formation (Beaufort Group), Late Caenozoic alluvium</td></tr>
<tr><td>Potential fossils</td><td colspan="2">Vertebrate bones, teeth and burrows (esp. therapsids), plant remains, invertebrate burrows in Beaufort Group bedrocks. Mammalian bones, teeth & horn cores, freshwater molluscs, trace fossils and plane debris in older alluvial sediments.</td></tr>
<tr><td rowspan="4">ECO protocol</td><td colspan="2">1. Once alerted to fossil occurrence(s): alert site foreman, stop work in area immediately (N.B. safety first!), safeguard site with security tape / fence / sand bags if necessary.</td></tr>
<tr><td colspan="2">2. Record key data while fossil remains are still in situ:
• Accurate geographic location – describe and mark on site map / 1: 50 000 map / satellite image / aerial photo
• Context – describe position of fossils within stratigraphy (rock layering), depth below surface
• Photograph fossil(s) in situ with scale, from different angles, including images showing context (e.g. rock layering)</td></tr>
<tr><td>3. If feasible to leave fossils in situ:
• Alert Heritage Management Authority and project palaeontologist (if any) who will advise on any necessary mitigation
• Ensure fossil site remains safeguarded until clearance is given by the Heritage Management Authority for work to resume</td><td>3. If not feasible to leave fossils in situ (emergency procedure only):
• Carefully remove fossils, as far as possible still enclosed within the original sedimentary matrix (e.g. entire block of fossiliferous rock)
• Photograph fossils against a plain, level background, with scale
• Carefully wrap fossils in several layers of newspaper / tissue paper / plastic bags
• Safeguard fossils together with locality and collection data (including collector and date) in a box in a safe place for examination by a palaeontologist
• Alert Heritage Management Authority and project palaeontologist (if any) who will advise on any necessary mitigation</td></tr>
<tr><td colspan="2">4. If required by Heritage Management Authority, ensure that a suitably-qualified specialist palaeontologist is appointed as soon as possible by the developer.</td></tr>
</table>

	5. Implement any further mitigation measures proposed by the palaeontologist and Heritage Management Authority
Specialist palaeontologist	Record, describe and judiciously sample fossil remains together with relevant contextual data (stratigraphy / sedimentology / taphonomy). Ensure that fossils are curated in an approved repository (e.g. museum / university / Council for Geoscience collection) together with full collection data. Submit Palaeontological Mitigation report to Heritage Resources Authority. Adhere to best international practice for palaeontological fieldwork and Heritage Management Authority minimum standards.