PALAEONTOLOGICAL HERITAGE ASSESSMENT: COMBINED DESKTOP & FIELD-BASED STUDY

PROPOSED RIETKLOOF WIND ENERGY FACILITY NEAR LAINGSBURG, LAINGSBURG LOCAL MUNICIPALITY, WESTERN CAPE

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EXECUTIVE SUMMARY

Rietkloof Wind Farm (Pty) Ltd, a subsidiary of G7 Renewable Energies (Pty) Ltd (G7), is proposing to develop a wind energy facility (WEF) of up to 140 megawatt generation capacity on a site located some 35 km northwest of Laingsburg, Western Cape Province. Nine wind turbines have already been authorized for this project and an additional 51 turbine positions are proposed in the present application. The Rietkloof WEF study area lies in the mountainous Klein-Roggeveldberge region and is underlain by around twelve formations of potentially fossil-baring sedimentary rocks (Fig. 4). The majority of the bedrocks are of Palaeozoic age (Early to Middle Permian) and belong to the Karoo Supergroup which is internationally famous for its rich fossil record. Palaeontological field assessment of the Rietkloof WEF study area shows that in this portion of the south-western Karoo:

- Dwyka Group and Lower to Middle Ecca Group bedrocks in the low-lying, southern portion of the area are tectonically deformed and weathered, with low-diversity trace fossil assemblages of limited scientific interest. This also applies to the Whitehill Formation that elsewhere, outside the study area, may be of high palaeontological sensitivity.
- Waterford Formation (Upper Ecca Group) deltaic bedrocks underlying the mountainous southern portion of the main development footprint are generally fossil-poor, apart from low-diversity trace fossil assemblages. However, isolated blocks and rare logs of well-preserved petrified wood found within the eastern portion of the study area are of high scientific and conservation value.
- Abrahamskraal Formation (Lower Beaufort Group) fluvial bedrocks underlying the high-lying northern portion of the study area are generally considered to be of high palaeontological sensitivity. However, in this area of the SW Karoo they are fossil-poor, apart from occasional horizons with plant debris or low-diversity trace fossils, including unconfirmed large tetrapod (terrestrial vertebrate) burrows. Fossil vertebrate skeletal remains (bones, teeth) are very rare indeed in these lowermost Beaufort Group rocks. None have been recorded as yet within the Rietkloof WEF study area. Since isolated occurrences of probable small dicynodonts have recently been found just to the north (Brandvalley WEF project area) they may well be present here as well.
- Late Caenozoic superficial sediments (alluvium, colluvium, calcretes, soils, surface gravels *etc*) overlying the Palaeozoic bedrocks are of low palaeontological sensitivity. Pediment and surface gravels along the foot of the Klein-Roggeveld Escarpment locally contain numerous clasts of petrified wood reworked from the Karoo Supergroup outcrop area to the north.

The overall impact significance of the construction phase of the proposed wind energy project (2018 revised layout) is assessed as MODERATE (negative) without mitigation in terms of palaeontological heritage resources. This is a consequence of (1) the paucity of irreplaceable, unique or rare fossil remains within the development footprint, (2) the high levels of bedrock weathering and tectonic deformation in the southern part of the study area, as well as (3) the extensive superficial sediment cover overlying most potentially-fossiliferous bedrocks within the Rietkloof WEF study area. If the mitigation measures outlined here (Section 5) are followed-through, the impact significance of the proposed WEF would be reduced to LOW (negative). This assessment applies to the60 wind turbines (9 already authorized as well as 51 proposed new turbine

positions), hardstanding and laydown areas, access roads, on-site substation, underground cables, wind masts, construction camps including a concrete batching plant area, 33 kV powerlines and associated WEF infrastructure within the study area. A comparable low (negative) impact significance is inferred for all project infrastructure alternatives and layout options under consideration, including different options for routing of access roads, turbine layouts and siting of construction camps and substations. T**here are therefore no preferences on palaeontological heritage grounds for any particular layout among the various options under consideration.** No significant further impacts on fossil heritage are anticipated during the planning, operational and decommissioning phases of the WEF. The No-go alternative (*i.e.* no WEF development) will have a neutral impact on palaeontological heritage.

There **are no fatal flaws** in the revised Rietkloof WEF development proposal as far as fossil heritage is concerned. *Provided that* the recommendations for palaeontological monitoring and mitigation outlined below are followed through, there are no objections on palaeontological heritage grounds to authorisation of the revised Rietkloof WEF project. Cumulative impacts on palaeontological heritage resources that are anticipated as a result of the numerous alternative energy developments currently proposed or authorised for the Klein-Roggeveldberge region - including impacts envisaged for the Rietkloof WEF project – are predicted to be low (negative), *provided that* the proposed monitoring and mitigation recommendations made for these various projects are followed through. Unavoidable residual negative impacts may be partially offset by the improved understanding of Karoo palaeontology resulting from appropriate professional mitigation. This is regarded as a significant *positive* impact for Karoo palaeontological heritage. The developer's proposal to actively improve the management of surrounding land within the project site for conservation purposes is unlikely to have a significant impact on palaeontological heritage resources.

The great majority of the Rietkloof WEF study area is assessed as being of low palaeontological sensitivity due to the scarcity of significant fossil vertebrate, plant and other remains here. Highly sensitive no-go areas within the proposed development footprint itself have not been identified in this study. The concentration of blocks and logs of well-preserved petrified wood from the Waterford Formation that are exposed on the slopes of Kranskop, Wilgehout Fontein 87 constitute a notable exception (See area outlined in purple in Fig. 68). This highly-sensitive area, which lies well *outside* the proposed WEF development footprint, should *not* be disturbed. Pending the potential discovery of substantial new fossil remains during construction, specialist palaeontological mitigation is only recommended within two narrow upland areas of Waterford Formation outcrop close to Kranskop. These areas are outlined in orange in Fig. 68. Once the footprint for access roads and wind turbine placements within these two potentially sensitive areas is finalised, and *before* construction starts, they should be surveyed for fossil wood occurrences by a professional palaeontologist. 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). Where practicable, fossils remaining on site should be safeguarded, for example by moving them away from the development footprint.

The Environmental Control Officer (ECO) responsible for the WEF development should be made aware of the potential occurrence of scientifically-important fossil remains within the development footprint. During the construction phase all major clearance operations (*e.g.* for new access roads, turbine placements) and deeper (> 1 m) excavations should be monitored for fossil remains on an on-going basis by the ECO. Should substantial fossil remains - such as vertebrate bones and teeth, or petrified logs of fossil wood - be encountered at surface or exposed during construction, the ECO should safeguard these, preferably *in situ*. They should then alert Heritage Western Cape (HWC) as soon as possible (Contact details: Protea Assurance Building, Green Market Square, Cape Town 8000. Private Bag X9067, Cape Town 8001. Tel: 086-142 142. Fax: 021-483 9842. Email: hwc@pgwc.gov.za). This is to ensure that appropriate action (*i.e.* recording, sampling or collection of fossils, recording of relevant geological data) can be taken by a professional palaeontologist at the developer's expense (See Chance Fossil Finds Procedure tabulated in Appendix 2).

These mitigation recommendations should be incorporated into the Environmental Management Programme (EMPr) for the revised Rietkloof WEF alternative energy project. 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 Heritage Western Cape);
- The palaeontologist concerned with potential mitigation work will need a valid fossil collection permit from Heritage Western Cape and any material collected would have to be curated in an approved depository (*e.g.* museum or university collection);
- All palaeontological specialist work should 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 developed by SAHRA (2013).

1. INTRODUCTION & BRIEF

1.1. Project outline

The company Rietkloof Wind Farm (Pty) Ltd, a subsidiary of G7 Renewable Energies (Pty) Ltd (G7), is proposing to develop a wind energy facility (WEF) of up to 140 megawatt generation capacity on a site located some 35 km northwest of Laingsburg. The site lies within the Laingsburg Local Municipality, Western Cape Province (Fig. 1). The Rietkloof WEF study area extends over an area of some 27 200 ha and comprises the following land portions: Portion 1 of Barendskraal 76, The Remainder of Fortuin 74, Portion 3 of Fortuin 74, Remainder of Hartjieskraal 77, Portion 1 of Hartjieskraal 77, The Remainder of Nuwerus 284, Portion 1 of Rietkloof Annexe 88, The Remainder of Snyders Kloof 80, Portion 1 of Snyders Kloof 80, Vogelstruisfontein 81 and Remainder of Wilgehout Fontein 87 (Figs. 2a & 2b).

A wind energy facility with 9 turbine positions within the original Rietkloof project area has already been authorised by the Department of Environmental Affairs (DEA) (See below). A *revised* Rietkloof WEF project proposal with up to 60 turbine positions (*including* the previously authorised 9 turbine positions) is now being submitted for authorisation. The main infrastructural components of the revised Rietkloof WEF (estimated total footprint of 126.6 ha) that are relevant to the present palaeontological heritage assessment are as follows:

- Up to 51 potential new wind turbines (between 2 MW and 5.5 MW in capacity each), each with a foundation 25 m in diameter and 4 m in depth, in addition to the 9 turbines already authorised.
- The hub height of each turbine will be up to 125m, and the rotor diameter up to 160m.
- Permanent compacted hard-standing laydown areas for each wind turbine (70 m x 50 m, total 21 ha).
- Electrical turbine transformers (690 V/ 33 kV) adjacent to each turbine (typical footprint of 2 m x 2m, but can be up to 10 m x 10 m at certain locations).
- Underground 33 kV cabling between turbines, to be buried along access roads, where feasible.
- Internal access roads up to 9 m wide, including structures for storm-water control, required to access each turbine location and turning circles. Where possible, existing roads will be upgraded.
- 33 kV overhead power lines linking groups of wind turbines to the onsite 33 / 132 kV substation(s). A number of electrical 33 kV powerlines will be required in order to connect wind turbines to the preferred onsite substation.
- 33 / 132 kV onsite substation with a footprint of approximately 200 m x 200 m.
- Up to 4 x 120 m tall wind measuring lattice masts strategically placed within the wind farm development footprint.
- Temporary infrastructure, including a large construction camp (~10 ha) and an on-site concrete batching plant (~1 ha) for use during the construction phase.
- Fencing (4 m) around the construction camp and batching plant.
- Temporary infrastructure to obtain water from available local sources / new or existing boreholes, including a potential above ground pipeline (c. 35 cm diam.). Water will potentially be stored in

temporary water storage tanks. The necessary approvals from the DWS will be applied for separately to this Basic Assessment process.

Subject to authorisation of the revised Rietkloof WEF project, the applicant is proposing to actively improve the management of surrounding land within the project site for conservation in collaboration with y CapeNature, landowners, specialists and other interested parties within parts of the WEF project area, to be outlined in a the revised environmental management plan.

WEF layout alternatives considered during this revised assessment include:

1. The following access road options from the R354 to the turbine locations (See Figs. 2a & 2b):

- Ou Mure access road alternative 1 is an existing public gravel road located to the north of the project area.
- Fortuin access road alternative 2 (Preferred Alternative) follows an existing gravel access road from the R354 in a western direction along the north-eastern section of the project area before branching south into various side roads in order to connect the various ridges where turbines are proposed to the main access road.
- Southern access road alternative 3 is an existing public road located to the south of the project area and is also proposed to start from the R354 and follow an existing public gravel road in a western direction. From this alternative main access road various roads will branch to the north.

2. Three alternative construction camp layouts: construction camp 10 (preferred), construction camp 3 and construction camp 13.

3. On-site substation alternatives: alternative 5 (preferred) and alternative 6.

The Rietkloof WEF study area is located in a region that is underlain by potentially fossiliferous sedimentary rocks of Late Palaeozoic and younger, Late Tertiary or Quaternary, age (These are described in more detail in Sections 2 & 3 of this report). The construction phase of the proposed WEF will entail extensive surface clearance as well as excavations into the superficial sediment cover and underlying bedrock. The development may adversely affect potential fossil heritage within the study area by destroying, disturbing or permanently sealing-in fossils preserved at or beneath the surface of the ground that are then no longer available for scientific research or other public good. The planning, operational and decommissioning phases of the WEF are unlikely to involve further adverse impacts on local palaeontological heritage.

In response to a NID submitted by Cedar Tower Services, Mowbray, a palaeontological heritage assessment of the Rietkloof WEF was requested by Heritage Western Cape (HWC) as part of an integrated heritage assessment for this project (HWC letter of 3 March 2016, their Case No. 15110402GT0219E). A combined desktop and field-based palaeontological heritage assessment of the Rietkloof WEF project area (Almond 2016b) was accordingy submitted as part of the EIA for this development, co-ordinated on behalf of G7 by EOH Coastal & Environmental Services, Cape Town. A Palaeontological Heritage Comment regarding the associated 132 kV distribution lines was subsequently submitted by the author (Almond 2016c). The Department of Environmental Affairs (DEA) issued an environmental authorisation (EA) which only authorised 9 turbines out of the proposed total of 60.

The present palaeontological heritage report assesses a *revised* project description for the Rietkloof Wind Energy Facility, as outlined above. The proposed WEF lies within the formally gazetted Komsberg Renewable Energy Development Zone (REDZ) and is therefore now only subject to a Baasic Assessment (BA) process rather than a full Environmental Impact Assessment (EIA) in terms of the National Environmental Management Act (Act 107 of 1998) (NEMA) as amended, EIA Regulations 2014 (as amended in 2017). The BA process for this project is being co-ordinated by WSP, Environment & Energy, Africa (Contact details: Ms Bronwyn Fisher. WSP, Environment & Energy, Africa. Building C Knightsbridge, 33 Sloane Street, Bryanston 2191 South Africa. Tel: +27 11 361 1481. Fax: +27 11 361 1301, E-mail: Bronwyn.Fisher@wsp.com).

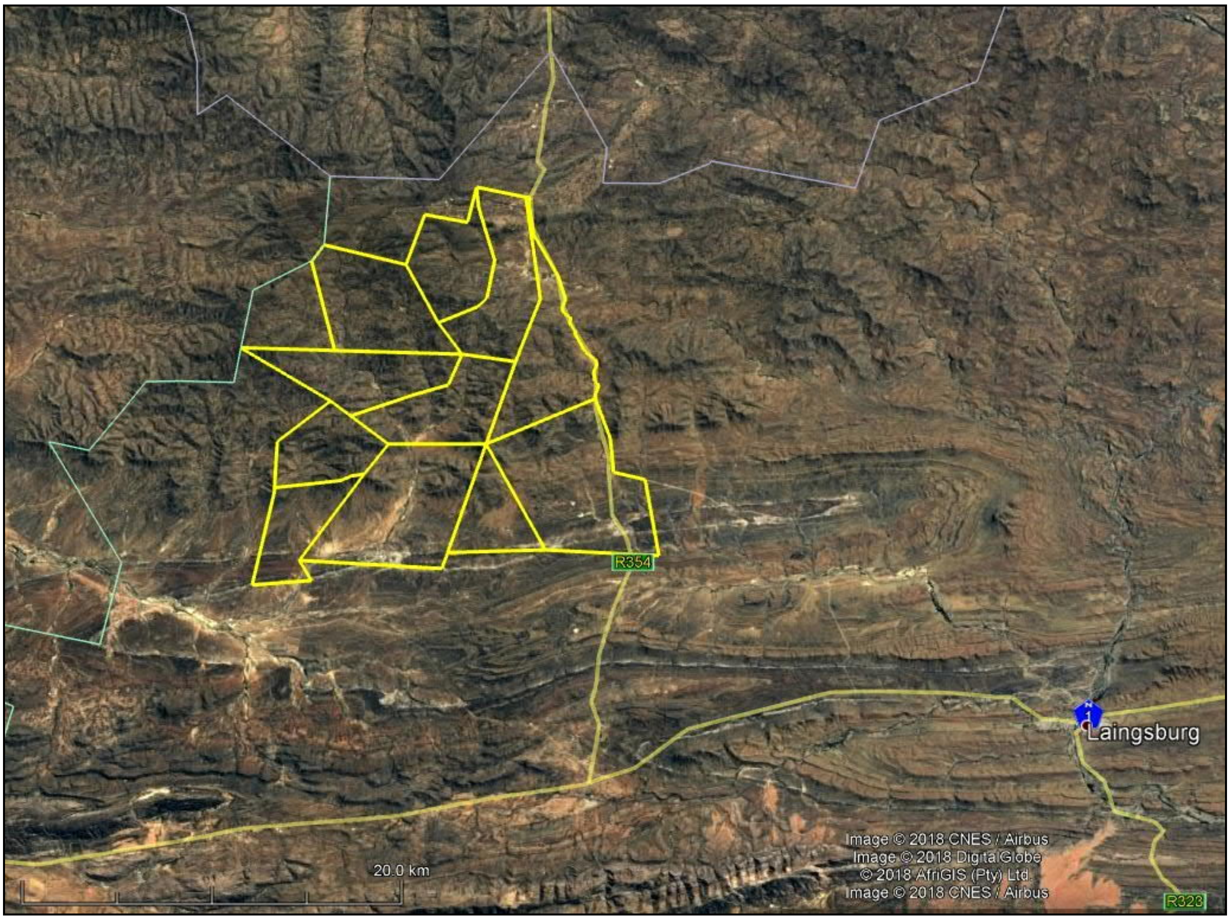
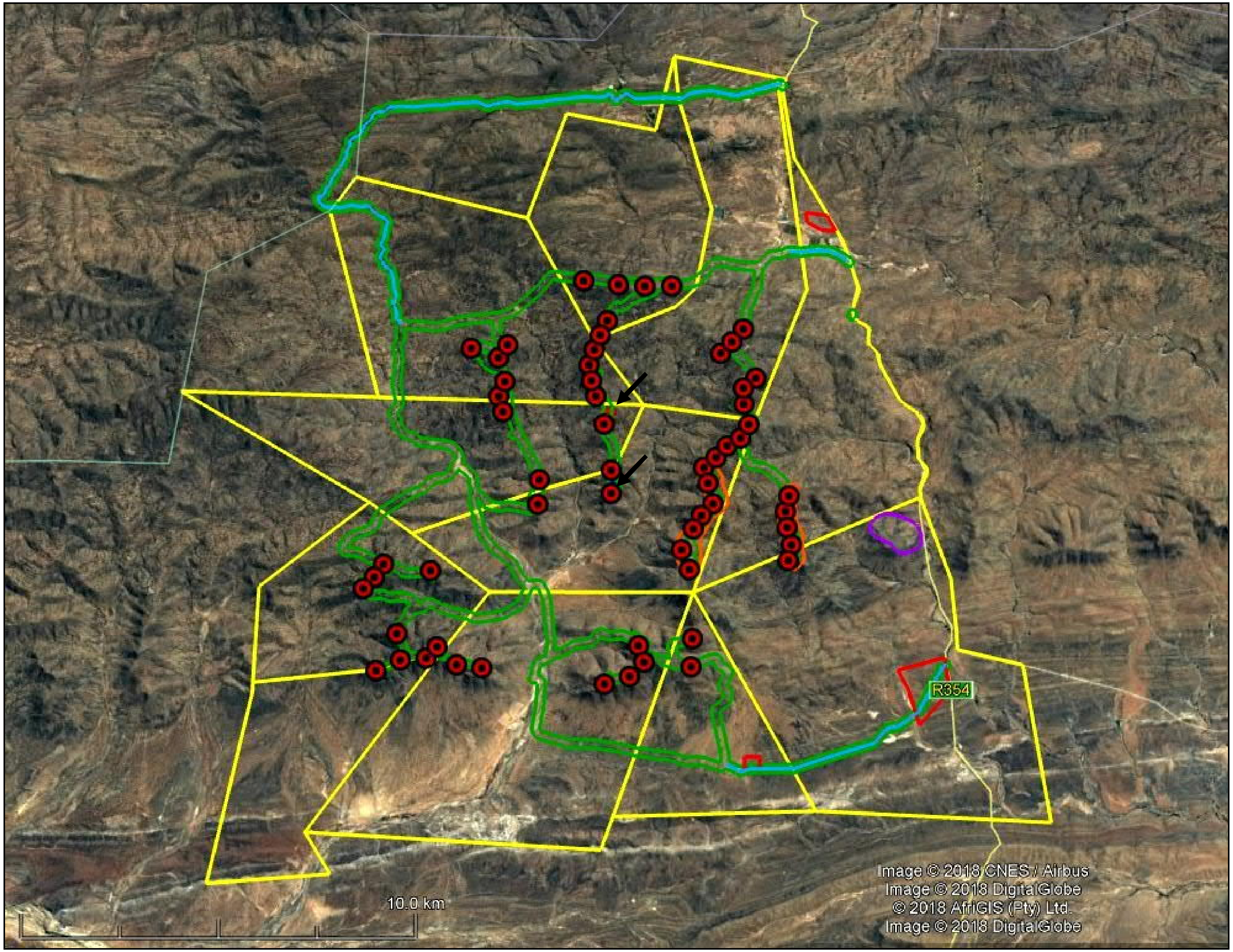


Figure 1. Google Earth© satellite image showing the approximate location of land parcels making up the Rietkloof WEF project area, situated *c.* 35 km NW of Laingsburg, Western Cape (yellow polygons) The study area lies within the mountainous Klein-Roggeveldberge region to the west of the R354 Matjiesfontein to Sutherland tar road and is bordered by the semi-arid lowlands of the Ceres Karoo in the south. The grey line demarcates the boundary between the Northern and Western Cape.

Figure 2a (following page). Overview Google Earth© satellite map of the *revised* Rietkloof WEF project layout showing the various land portions involved (yellow polygons), topography, internal access road corridors (green), access road options from the R354 (pale blue), alternative footprints of construction camp (red), alternative on-site substation sites (small red and blue squares, arrowed) as well as a layout of the 60 proposed turbine positions (red circles), including 9 which have already been authorised as well as up to 51 proposed new turbine positions.

The small area outlined in purple (Kranskop on Wilgehout Fontein 87) features palaeontologically important, well-preserved fossil wood from the Waterford Formation and should be safeguarded from development. It is recommended that, once the final WEF layout is determined and *before* construction commences, the two nearby areas of Waterford Formation outcrop outlined in orange are surveyed by a professional palaeontologist to record, safeguard and sample any well-preserved fossil wood exposed here (Please refer to Figure 68 for a close-up view of these palaeontologically-sensitive areas).


R354
Image © 2018 CNES / Airbus
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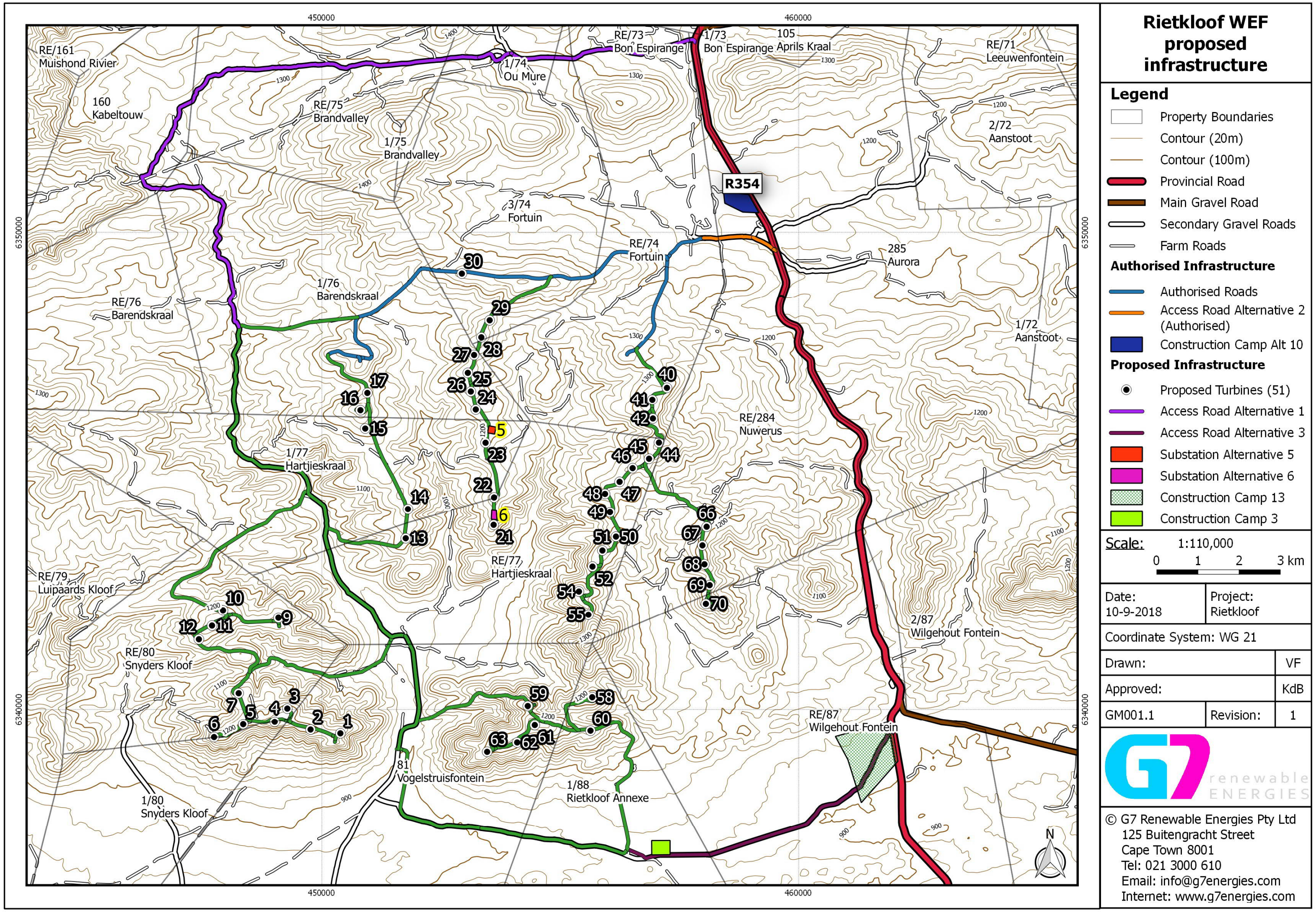

Figure 2b. Proposed layout of the Rietkloof WEF showing the 51 *new* turbine positions that form part of the present revised application (Image provided by G7 Renewable Energies Pty Ltd)

1.2. Legislative context for palaeontological assessment studies

The proposed Rietkloof WEF is located within the Komsberg Renewable Energy Development Zone (REDZ), one of the eight REDZ formally gazetted in South Africa for the purpose of development of solar and wind energy generation facilities. In line with the gazetted process for projects located within REDZ, the revised Rietkloof WEF will be subject to a Basic Assessment (BA) process instead of a full Environmental Impact Assessment (EIA) process in terms of the National Environmental Management Act (Act 107 of 1998) (NEMA) as amended, EIA Regulations 2014 (as amended in 2017).

The present combined desktop and field-based palaeontological heritage assessment report contributes to the consolidated heritage Basic Assessment for the proposed Rietkloof WEF and falls under the South African Heritage Resources Act (Act No. 25 of 1999). It will also inform the Environmental Management Programme (EMPr) for this alternative energy 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; and
- palaeontological objects and material, meteorites and rare geological specimens.

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

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

to undertake the development if no application for a permit is received within two weeks of the order being served.

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

1.3. Approach to the palaeontological heritage study

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 2008a, 2008b). The likely impacts of the proposed development on local fossil heritage are 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-based assessment study by a professional palaeontologist is usually warranted to identify any palaeontological hotspots and make specific recommendations for any mitigation or monitoring 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 planning, operational or decommissioning phases. Phase 2 mitigation by a professional palaeontologist – normally involving the recording and sampling of fossil material and associated geological information (*e.g.* sedimentological data) may be required (a) in the pre-construction phase where important fossils are already exposed at or near the land surface and / or (b) during the construction phase when fresh fossiliferous bedrock has been exposed by excavations. To carry out mitigation, the palaeontologist involved will need to apply for a palaeontological collection permit from the relevant heritage management authorities, *i.e.* SAHRA for the Northern Cape (Contact details: Mrs Colette Scheermeyer, P.O. Box 4637, Cape Town 8000. Tel: 021 462 4502. Email: cscheermeyer@sahra.org.za) and Heritage Western Cape for the Western Cape (Contact details: Heritage Western Cape. Protea Assurance Building, Green Market Square, Cape Town 8000. Private Bag X9067, Cape Town 8001. Tel: 086-142 142. Fax: 021-483 9842. Email: hwc@pgwc.gov.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.

In summary, the approach to a Phase 1 palaeontological heritage study is as follows. Fossil bearing rock units occurring within the broader study area are determined from geological maps and relevant geological sheet explanations as well as 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 using the same assessment methodology used to inform the 2016 assessment with recommendations for any further studies or mitigation. This PIA was undertaken in line with the SAHRA 2016 Minimum Standards for the palaeontological component of heritage impact assessment.

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 case of the Rietkloof WEF study area near Laingsburg in the Western Cape preservation of potentially fossiliferous bedrocks is favoured by the semi-arid climate and sparse vegetation. However, bedrock exposure is highly constrained by extensive superficial deposits, especially in areas of low relief, as well as pervasive Karoo *bossieveld* vegetation (Central Mountain Shale Renosterveld, Koedoesberg – Moordenaars Karoo, Tanqua Wash Riviere). The study area is very extensive and much of it is hilly or mountainous with few access roads, especially in rugged upland areas. However, sufficient bedrock exposures were examined during the course of the four-day field study to assess the palaeontological heritage sensitivity of the main rock units represented within the study area (See Appendix 1 for locality data). Comparatively few academic palaeontological studies have been carried out hitherto in the region, so any new data from impact studies here are of scientific interest. Palaeontological and geological data from the recent field study is usefully supplemented by those from several other field-based fossil heritage impact studies carried out in the Klein-Roggeveldberge and Ceres Karoo regions by the author in recent years (See reference list). Confidence levels for this impact assessment are consequently rated as moderate, despite the unavoidable constraints of limited exposure, time and access.

1.5. Information sources

The present combined desktop and field-based palaeontological study was largely based on the following sources of information:

1. A brief project outline supplied by WSP, Environment & Energy, Africa;

2. Relevant geological maps and sheet explanations (*e.g.* Theron 1983, Theron *et al.* 1991, Cole & Vorster 1999) as well as Google earth© satellite imagery;

3. Previous palaeontological assessment reports for the Rietkloof WEF project area (Almond 2016b, 2016c) as well as several palaeontological heritage assessment reports by the present author for proposed developments in the Ceres Karoo and Klein-Roggeveldberge regions between Sutherland, Matjiesfontein and Touwsrivier. These include palaeontological impact assessments (PIAs) for the Eskom Gamma – Omega 765 kV transmission line that runs just to the north of the study area (Almond 2010a) and those for several alternative energy facilities (*e.g.* Almond 2010a, 2010c, 2011a-b, 2014, 2015, 2015a-g, 2016b-f);

4. A four-day palaeontological field assessment of the Rietkloof WEF study area (April 2015) by the author and an experience field assistant within the context of a broader-based review of fossil heritage resources for this and the adjacent Brandvalley WEF project area;

5. The author's previous field experience with the formations concerned and their palaeontological heritage (*cf* Almond & Pether 2008 and references listed above).

GPS data and brief descriptive notes for all numbered geological or palaeontological localities mentioned in the text are provided in Appendix 1. Further field data directly relevant to the Rietkloof WEF study area is given in the separate palaeontological assessment of the adjoining Brandvalley WEF to the north (Almond 2016d).

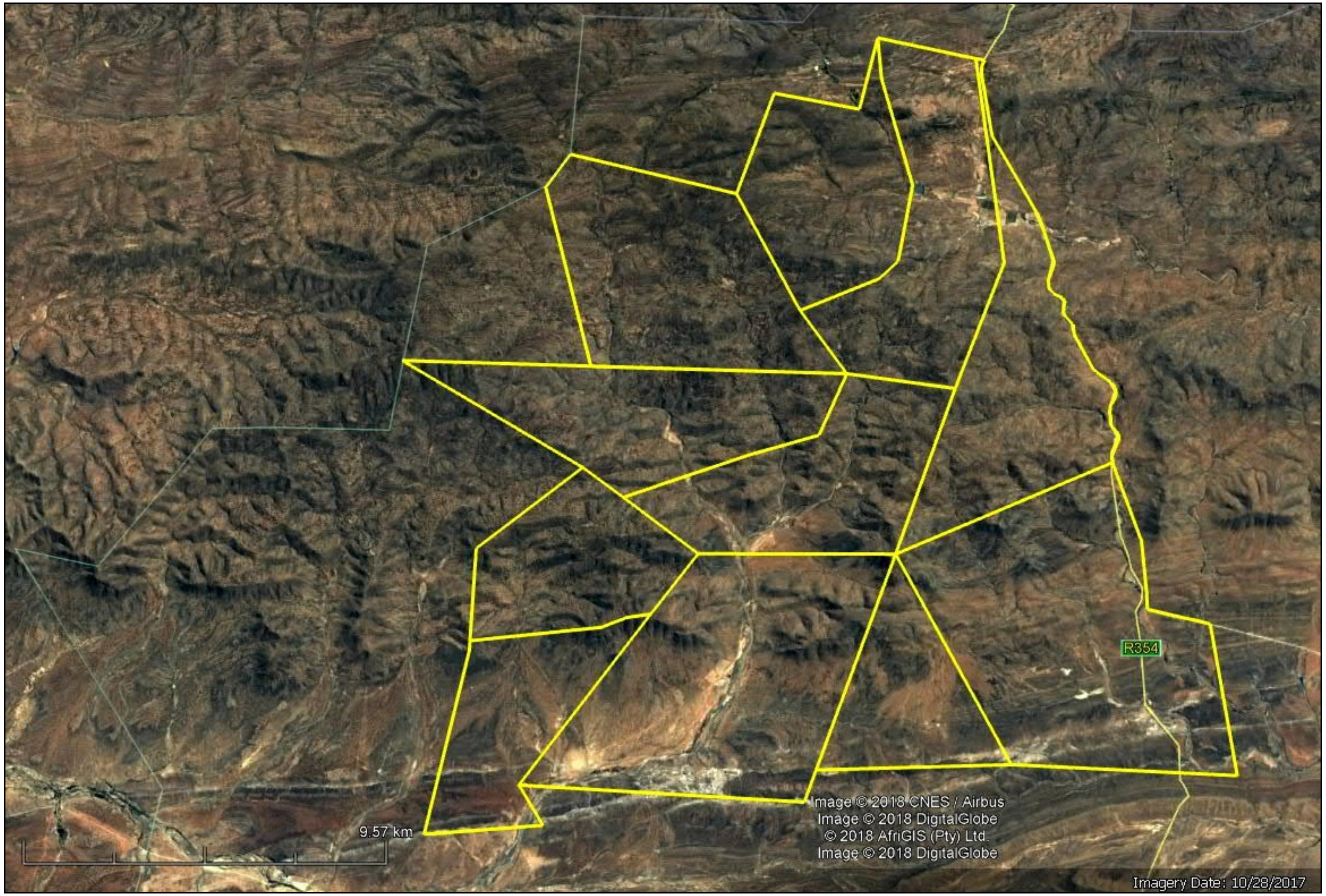

Figure 3. Google earth© satellite image of the Rietkloof WEF study area showing the constituent farm portions (yellow polygons) situated largely to the west of the R354 tar road between Matjiesfontein and Sutherland. The northern two thirds of the area comprises mountainous terrain of the Klein-Roggeveldberge. The southern third lies covers low-relief, semi-arid terrain in an eastern extension of the Ceres Karoo region, bordered in the south by the low, west-east trending hills of the Witrante. The study area is drained by tributaries of the Grootrivier to the southwest and the Wilgehoutrivier in the southeast.

2. GEOLOGICAL CONTEXT

The Rietkloof WEF study area is largely situated within hilly to mountainous terrain of the Klein-Roggeveldberge (Figs. 2 & 3). It forms part of the Great Karoo Region and lies some 35 km to the northwest of Lainsgburg, well to the south of the Great Escarpment. The R354 tar road between Matjiesfontein and Sutherland runs along or close to the eastern edge of the area. The core project area where most of the WEF infrastructure will be situated lies between the dashed yellow lines shown on the geological map below (Fig. 4). It comprises highly-dissected uplands with ridges and plateaux at elevations of around 1200-1350 m amsl; the highest point is Tafelkop at *c*. 1370 m amsl. Mountain slopes here are generally fairly gentle with prominent-weathering ridges or *kranzes* of Karoo Supergroup sandstones imparting a distinctive banded appearance (Figs. 6 to 8, 18, 24) that is well-seen on satellite images. The area is drained by (mostly unnamed) tributaries of the Grootrivier, feeding into the Tanquarivier drainage system to the west, and the Wilgeboschrivier that feeds into the Buffelsrivier drainage system to the southeast. An eastern extension of the arid Ceres Karoo region occupies the lower-lying southern portion of the study area at elevations of around 830-930 m amsl. These gently south-sloping lowlands are blanketed by karroid *bossieveld* and incised by numerous small, intermittently flowing streams. They lie between a west-east trending range of low hills of Dwyka and Lower Ecca Group rocks along the southern edge of the study area – the Witrantjies - and the steep, south-facing Klein-Roggeveldberge Escarpment built of Middle to Upper Ecca Group rocks with a crest at around 1000 - 1200 m amsl. Away from the numerous drainage lines and sandstone ridges, levels of bedrock exposure in the study area - notably that of the recessive-weathering mudrock facies - are generally very low. This is due to extensive cover by alluvial and colluvial deposits as well as karroid *bossieveld* vegetation (Central Mountain Shale Renosterveld, Koedoesberg – Moordenaars Karoo) (Figs. 6 to 8).

The geology of the Rietkloof WEF study area is outlined on the adjoining 1: 250 000 geology sheets 3320 Ladismith and 3220 Sutherland (Council for Geoscience, Pretoria; Theron 1983, Theron *et al.* 1991, Cole & Vorster 1999) (Fig. 4). Geologically it lies on the gently folded northern margin of the Permo-Triassic Cape Fold Belt (CFB). A total of thirteen mappable rock units or formations are represented within the study area (Fig. 4). The great majority of which belong to the **Karoo Supergroup** succession and are Early to Middle Permian in age (Johnson *et al.* 2006) (Fig. 5) (*N.B.* A few of these units, such as the Laingsburg and Vischkuil Formations, are very poorly exposed and lie well outside the main development footprint, so they are not treated further here. The study area overlies a basement palaeohigh between the Tanqua and Laingsburg Subbasins of the Main Karoo Basin (*cf* Hodgson *et al.* 2006 and refs. therein).

A narrow, west-east anticline along the Witrantjies range in the south is constructed of Permo-Carboniferous glacial tillites of the **Elandsvlei Formation** (**Dwyka Group**) as well as several formations of postglacial marine to lacustrine mudrocks of the **Lower Ecca Group** of Early to Middle Permian age, *viz*. the **Prince Albert**, **Whitehill** and **Collingham Formations**. The succeeding **Middle Ecca Group** mudrocks cropping out between the Witrantjie range and the Klein-Roggeveld Escarpment are largely assigned to the **Tierberg Formation**, although the stratigraphically correlated **Vischkuil** and **Laingsburg Formations** are separately mapped in the southeast. More resistant-weathering, sandstone-rich prodeltaic and deltaic sediments of the Middle Permian **Fort Brown** and **Waterford Formations** (**Middle & Upper Ecca Group**) build the central uplands, to the north of the escarpment. The major part of the northern uplands are underlain by continental (fluvial and lacustrine) mudrocks and sandstones forming the lowermost portion of the very thick **Abrahamskraal Formation** (**Lower Beaufort Group**). These continental sediments are also of Middle Permian age. Slightly older Waterford Formation bedrocks crop out in the cores of east-west orientated megasynclinal structures towards the northern edge of the study area. The Early Jurassic **Karoo Dolerite Suite** (*c*. 182 Ma = million years old; Duncan & Marsh 2006) is represented by a few narrow dolerite dykes which are intruded into the Lower Beaufort Group country rocks along W-E to WNW-ESE fracture lines. These fractures are clearly visible on satellite images but Karoo dolerite itself was not encountered during the present field study. The Karoo dolerites are entirely unfossiliferous and will therefore not be treated in any detail in this report. The Palaeozoic and Mesozoic bedrocks in the study area are very extensively overlain by a wide spectrum of **Late Caenozoic superficial deposits**. They include scree and other slope deposits (colluvium and hillwash), river and stream alluvium (including coarse pediment gravels), downwasted surface gravels, calcretes and various soils. These geologically youthful sediments are generally of low palaeontological sensitivity and are also only briefly treated in this study.

All of these rock units – with the exception of the very minor Karoo dolerites - are potentially fossiliferous, although only two – the Whitehill and Abrahamskraal Formations - are considered to be of high palaeontological sensitivity (*cf* Almond & Pether 2008a, 2008b, SAHRIS website). The rock succession broadly youngs towards the north and levels of tectonic deformation are generally low in the core project area, with dips of up to 50º along major west-east trending fold axes and only minor faulting (*e.g.* E-W fracture zones seen on satellite images). Much higher levels of deformation are concentrated along along the Witrantjies zone in the south. Here Lower Ecca Group rocks are intensely folded, thrust faulted (leading to tectonic repetition) and locally cleaved, with the complex juxtaposition of fault blocks.

A short, illustrated account of the main sedimentary rock units encountered within the study area during fieldwork is presented in this section of the report. Fossil material recorded within the study area from these various sediments is documented in Section 3. GPS data and brief descriptions for all numbered geological and palaeontological localities mentioned in the text are provided in Appendix 1.

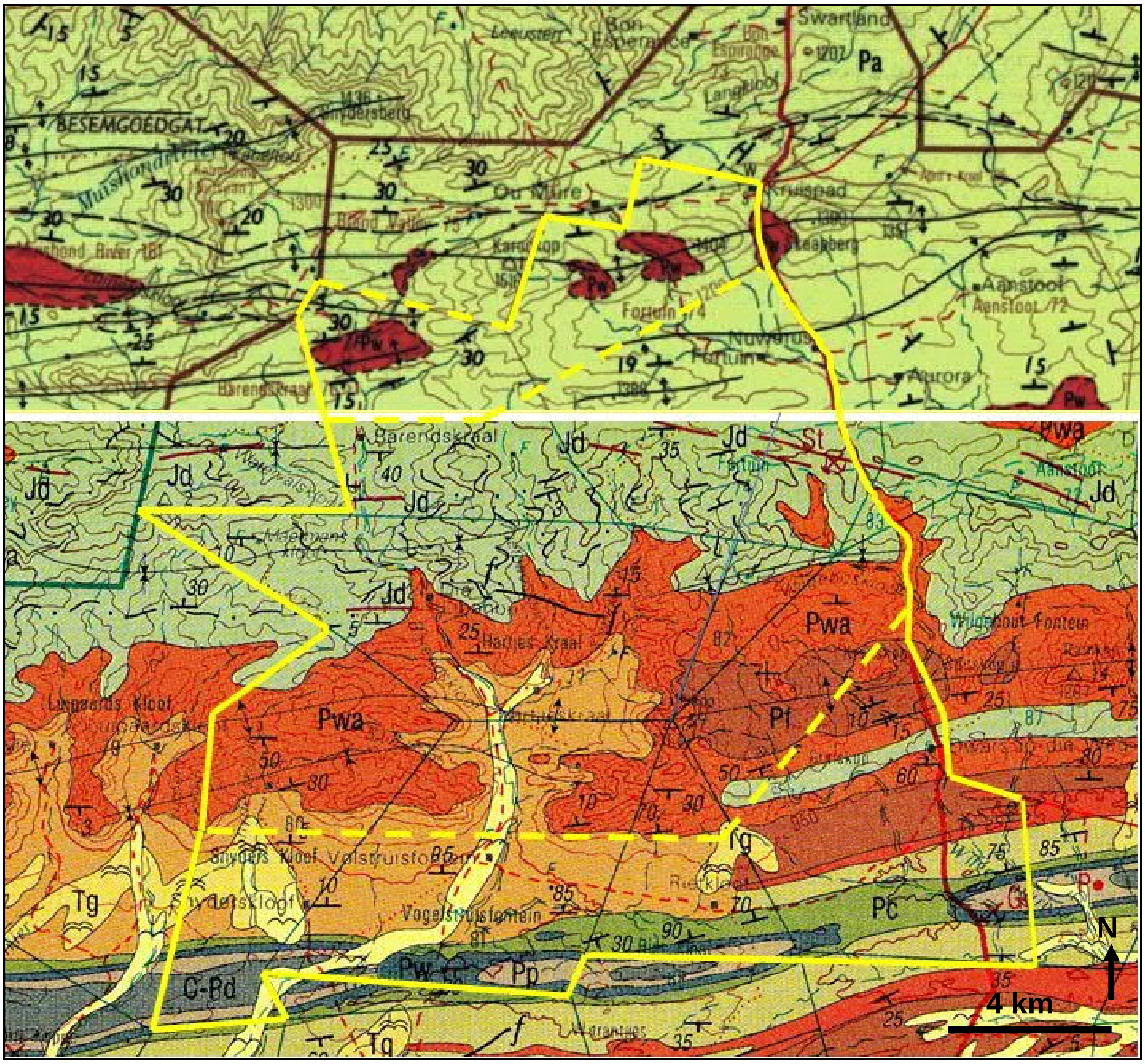

Figure 4. Extracts from adjoining 1: 250 000 scale geology sheets 3320 Ladismith (below) and 3220 Sutherland (above) showing the location of the proposed Rietkloof WEF study area, *c*. 35 km northwest of Langsburg, Western Cape Province (solid yellow polygon) (Maps published by Council for Geoscience, Pretoria). The core development area – where most of the key WEF infrastructure

(wind turbines, access roads *etc*) will be situated– lies between the yellow dashed lines and is the principal focus of the present study (Compare Fig. 2a).

The main mappable rock units (fm = formation) represented within the study area are:

DWYKA GROUP:	**Elandskloof Fm (C-Pd, grey)**
ECCA GROUP	**Prince Albert Fm (Pp, grey** **Whitehill Fm (Pw, blue-grey)** **Colllingham Fm (Pc, pea green)** **Vischkuil Fm Pv (Pv, pale green)** **Laingsburg Fm (Pl, dark orange)** **Tierberg Fm (Pt, pale orange)** **Fort Brown Fm (Pf, brown)** **Waterford Fm (Pwa, middle orange or dark brown)**
LOWER BEAUFORT GROUP	**Abrahamskraal Fm (Pa, pale green)**
KAROO DOLERITE SUITE	**Karoo dolerite (Jd, red lines)**
SUPERFICIAL DEPOSITS	**Pediment / alluvial fan gravels (Tg, dark yellow)** **Younger alluvium (pale yellow)**

Other Late Caenozoic superficial deposits that are not mapped at 1: 250 000 scale include colluvium (scree deposits, hillwash), downwasted surface gravels, pedocretes (calcretes) and soils.

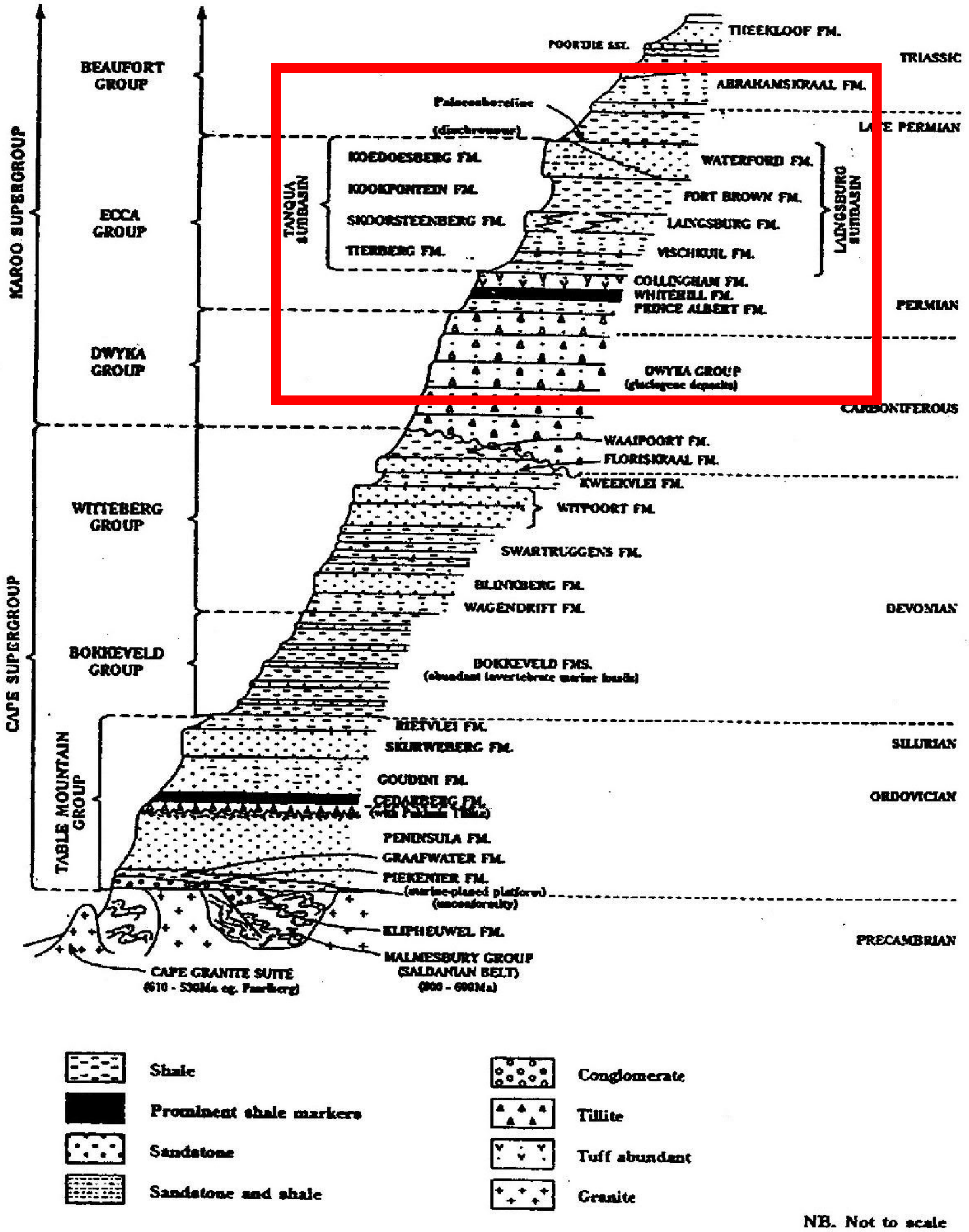

Figure 5. Schematic stratigraphic column for the Western Cape, the red box indicating the relative position of the various Late Palaeozoic sedimentary formations that crop out within the Rietkloof WEF study area (Modified from original figure by H. de V. Wickens).

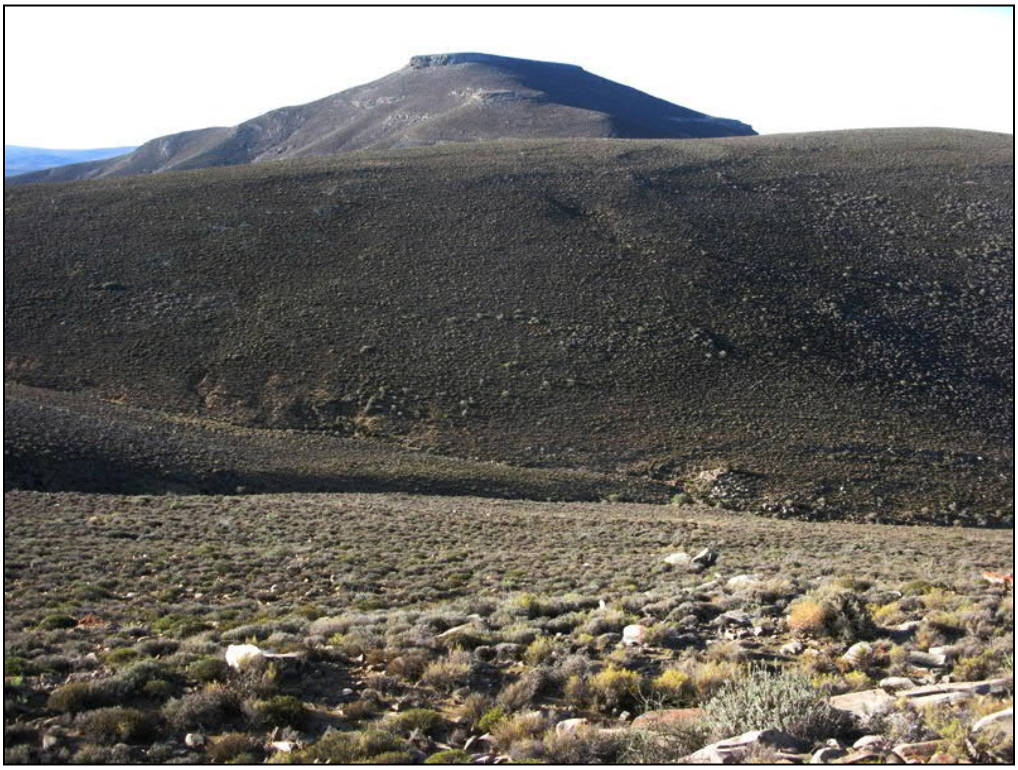

Figure 6. View northwards across Lower Beaufort Group and Waterford Formation outcrop areas showing Tafelkop in the distance. The viewpoint is close to the wind measuring mast on Rietkloof Annexe 88.

Figure 7. View north-westwards from Kranskop (Wilgehout Fontein 87) showing a ridge of north-dipping Waterford and Lower Beaufort Group beds on the skyline.

Figure 8. View towards Tafelkop from the northwest, with Voetpadskloof in the middle ground (Haartjies Kraal 77). Thick sandstone packages in the lower ground belong to the Waterford Formation, while the uplands are built of Lower Beaufort Group rocks.

2.1. Elandsvlei Formation (Dwyka Group)

Massive to crudely-bedded glacial diamictites of the Elandsvlei Formation dominate the Permo-Carboniferous Dwyka Group (C-Pd) along the southern margins of the Great Karoo and Ceres Karoo (Theron *et al.,* 1991, Visser 2003, Johnson *et al.* 2006, Cole & Wickens 1998, Cole & Smith 2008). These sediments were deposited beneath the base of floating ice sheets in the subsiding Main Karoo Basin during a major Late Palaeozoic glacial episode. A succession of four deglaciation cycles can be clearly recognized in this area (Visser 1997). They commence with thick, greyish-green diamictites ("tillites") containing a wide range of exotic glacial erratics and terminate in dark, well-laminated mudrocks with abundant gravel to boulder-sized dropstones ("dropstone laminites"). The thick (*c*. 1 km) Dwyka succession tends to weather recessively to form low-lying, drift-mantled *vlaktes*, but prominent *koppies* and ridges displaying a highly characteristic "tombstone weathering" pattern – reflecting the regional tectonic jointing / cleavage pattern - are also found in the Ceres Karoo area, for example at Toorberg (Almond 2015a).

Dwyka Group rocks crop out in the core of a thrusted anticline in the south-western corner of the study area. Due to the generally recessive-weathering character of these rocks, only limited, low-relief riverbed and bank exposures of massive, grey, clast-poor to finely-gravelly tillites are seen here (Fig. 9). No potentially fossiliferous interglacial mudrock packages were encountered.

Figure 9. Massive grey, clast-poor tillites of the Elandsvlei Formation (Dwyka Group) exposed in the banks of the Grootrivier, Vogel Struisfontein 81 (Loc. 143) (Hammer = 30 cm).

2.2. Prince Albert Formation

The Dwyka diamictites are sharply overlain by dark-hued, tabular-bedded mudrocks and fine-grained sandstones of the Prince Albert Formation (Pp) representing the base of the postglacial Ecca Group (Visser 1992, 1994, Cole 2005). These muddy sediments were deposited within a fairly deep basin on the southwestern margins of Gondwana. They contain a range of unusual rock types, including layers and lenses of chert, limestone or dolomite, phosphatic minerals, as well as abundant iron and manganese deposits. Thin layers of pale yellow tuff (volcanic ash) are frequent in parts of the succession.

Exposure of this formation in the present study area is generally poor, with the exception of extensive but tectonically deformed exposures of grey-green, tabular-bedded mudrocks and prominent-weathering ferruginised beds or lenticles along the southern banks of the Grootrivier on Vogelstruis Fontein 81 (Locs. 140, 142) (Fig. 10). Contacts with the stratigraphically overlying Whitehill Formation are locally faulted (Loc. 129). The Prince Albert Formation displays extensive small-scale deformation structures such as tight folds while a tectonic cleavage is often very well-developed.

Figure 10. Grey-green mudrocks with prominent-weathering, ferruginised beds or lenticles of the Prince Albert Formation, southern banks of the Grootrivier on Vogelstruis Fontein 81 (Loc. 142).

2.3. Whitehill Formation

The Whitehill Formation (Pw) is a thin (*c*. 30 m) succession of well-laminated, carbon-rich mudrocks of Early Permian (Artinskian) age that forms part of the lower Ecca Group. These sediments were laid down about 278 Ma in an extensive shallow, brackish to freshwater basin – the Ecca Sea – that stretched across southwestern Gondwana, from southern Africa into South America (McLachlan & Anderson 1971, Oelofsen 1981, 1987, Visser 1992, 1994, Cole & Basson 1991, MacRae 1999, McCarthy & Rubidge 2005, Johnson *et al*. 2006). Fresh Whitehill mudrocks are black and pyritic due to their high content of fine-grained organic carbon, probably derived from persistent or seasonal phytoplankton blooms that promoted anoxic conditions on the Ecca Sea bed. Near-surface weathering of the pyrite leads to the formation of gypsum, lending a pale grey colour to the Whitehill outcrop (hence informally known as the "*Witband*"). Large (meter-scale) diagenetic nodules and lenses of tough, greyish dolomite are common and often display a stromatolite-like fine-scale banding.

The outcrop area of the Whitehill Formation in the west-east trending Witrantjie anticline is unusually broad due to tectonic repetition (Fig. 11). It can be clearly seen as a pale band along the southern border of the study area in satellite images (Fig. 3). Most of the Whitehill Formation outcrop area is mantled with angular cherty colluvium from the overlying Collingham Formation. All surface exposures of the Whitehill Formation studied in the field area show evidence of deep chemical weathering, as suggested by the pale grey to multi-hued appearance at outcrop (*e.g.* Locs. 135, 136,138). The bedrocks are soft, crumbly and locally shot through with secondary mineral veins of ferro-manganese minerals and translucent gypsum (sheets and veins of selenite). No fresh carbonaceous mudrocks were seen. Large, boulder-sized, rounded concretions of dark grey diagenetic dolomite are common in this area where they weather-out prominently (Fig.12).

Figure 11. View westwards along the axis of the Witrantjie anticline on Vogelstruis Fontein 81 showing the wide, tectonically-repeated outcrop area of the pale-weathering Whitehill Formation.

Figure 12. Pale-weathering mudrocks of the Whitehill Formation with large dolomitic concretion in the foreground, Vogelstruis Fontein 81 (Loc. 135).

2.4. Collingham Formation

The tabular-bedded Collingham Formation is characterized by the regular “striped” alternation of thin-bedded, well-jointed siliceous mudrocks, thin, soft-weathering pale yellow tuffs (i.e. volcanic ash layers) and grey-green siltstone (Viljoen 1992, 1994). These tuffs have been radiometrically dated to 270 Ma or Mid Permian (More recent, albeit controversial, radiometric dates suggest a date of 275 Ma, i.e. Kungurian / end Early Permian; Fildani et al. 2007, 2009). Basinal mudrocks and tuffs deposited by suspension settling in the lower part of the Collingham give way higher up to thicker, tabular-bedded turbidite units deposited by sediment gravity flows. A prominent-weathering, highly tabular bed of pale grey chert or cherty mudrock characterizes the lower Collingham Formation for over 450 km along the southern Karoo margins and is known as the Matjiesfontein Member (c. 50-60 cm thick on average). Several thick cherty beds are seen at this level in the Ceres Karoo outcrop area between the Laingsburg and Tanqua Subbasins of the Lower Ecca Group (cf Almond 2015a) where they have been extensively exploited as a raw material for stone artefacts. According to J. Viljoen (pers. comm. 2016) the unusually high number and thickness of chert beds here probably reflects proximity to the source area.

The Collingham Formation is well exposed along the Witrantjies anticline along the southern margins of the study area where it extensively jointed and shows evidence of tectonic repetition by folding and faulting (Fig. 13). Downwasted angular colluvial rubble of chert and silicified mudrocks of the Collingham Formation mantle hillslopes below the chert band outcrop and appear as grey areas on satellite images.

Figure 13. Tabular beds of resistant, cherty mudrock and tuffs of the Collingham Formation overlying pale grey Whitehill Formation mudrocks on Vogelstruis Fontein 81 (Loc. 138).

2.5. Tierberg Formation

Laminated to thin-bedded, dark mudrocks and wackes of the Tierberg Formation were deposited in offshore basinal and distal submarine fan settings within the Early to Middle Permian Ecca Sea (Wickens 1984, 1994, 1996). Proximal, sand-dominated turbidite fan deposits of the Skoorsteenberg Formation, as mapped along the Roggeveld Escarpment to the north, have not been formally recognized in the present study area which is situated on a basinal high between the Tanqua and Laingsberg submarine fan depositories. The Tierberg succession here is therefore stratigraphically equivalent to the entire Tierberg / Skoorsteenberg / Kookfontein succession to the northwest, comprising mudrocks of basinal, submarine fan as well as distal deltaic provenance. According to recent radiometric dates published by Fildani *et al.* (2007) the Tierberg Formation in its more northern outcrop area (*i.e.* lower Tierberg in the study area) was deposited between 275 and 255 Ma, spanning most of the Middle and Late Permian; however, these dates are highly contested (*cf* Rubidge *et al.* 2010, 2013).

The mudrock-dominated, recessive-weathering Tierberg succession in the study area is very thick, its outcrop extending from the *vlaktes* of the Ceres Karoo into the gentle lower slopes of the Klein Roggeveld Escarpment to the north. However, exposure of this recessive-weathering unit is generally poor, apart from occasional incised stream sections and erosion gullies along the Klein-Roggeveld Escarpment (*e.g.* Locs. 146, 148,158 on Snyders Kloof 80). The succession consists predominantly of dark grey, massive to laminated or thin- to medium-bedded, hackly-weathering to pencil cleaved mudrocks (claystones, siltstones). Extensive bedding plane exposures are rarely developed. Good vertical sections display repeated upward-coarsening cycles of several to a few tens of meters in thickness, possibly representing prograding lobes of a turbidite fan (Fig. 14). These show a typical stepped weathering profile. The packages commence at the base with dark massive mudrocks passing up into laminated to thinly-bedded greyish siltstones and then thin- to medium-bedded, flaggy fine-grained sandstones or wackes. Thin (meter-scale) sandstones or wackes at the tops of the upward-coarsening packages are tabular, fine-grained, well-sorted, massive to thin-laminated and well-jointed, with a flaggy weathering pattern. Large oblate sphaeroidal nodules and lenses of rusty-brown ferruginous carbonate are locally common within the Tierberg mudrocks and sometimes develop internal septarian cracking. Strata-bound horizons of intense soft-sediment deformation with convolute lamination as well as ball-and-pillow structures are also seen.

Figure 14. Dark grey laminated to thin-bedded mudrocks and wackes of the Tierberg Formation building thin, upward-coarsening and –thickening packages, Klein- Roggeveld Escarpment, Snyders Kloof 80 (Loc. 158).

2.6. Fort Brown Formation

The Fort Brown Formation ("Middle Ecca"), with a thickness of up to 1400 m, consists mainly of dark grey, tabular-bedded mudrocks, with minor fine-grained sandstones or wackes becoming more important upwards towards the contact with the overlying Waterford Formation. Much of the mudrock succession is dominated by cyclically-banded rhythmitites building upward-coarsening and –thickening packages on the scale of a few meters to tens of meters in thickness. This rhythmic sedimentation pattern may reflect annual fluctuations in sediment supply to the Ecca Basin (Johnson 1976, Hill 1993, Johnson *et al.* 2006). Depositional processes in a prodeltaic setting include suspension settling as well as fine-grained turbidite and tempestite event beds. Soft-sediment deformation structures related to slumping and loading (*e.g.* recumbent folds, ball-and-pillow structures) as well as symmetrical wave ripples and ferruginous carbonate lenses or concretions are common within the upper part of the succession. Minor tuff layers are reported from the Darlington Dam area north of Port Elizabeth (Lock & Johnson 1974).

A brief account of the Fort Brown rocks on the Ladismith 1: 250 000 sheet, quoting an average thickness of 800 m for the formation, is given by Theron *et al.* (1991). In the present study area excellent exposures of thin-bedded, wave-rippled siltstones and wackes (rhythmitite facies) are seen on the lower slopes of Kranskop, including in deeply-incised stream cuttings and a sizeable borrow pit in the area (Wilgehout Fontein 87; Locs.181, 182, 186, 224, 231) (Figs. 15 to 17).

Figure 15. Upward-thickening packages of thin-bedded, grey rhythmitites of the Fort Brown Formation, banks of an incised stream on Wilgehout Fontein 87 (Loc. 182).

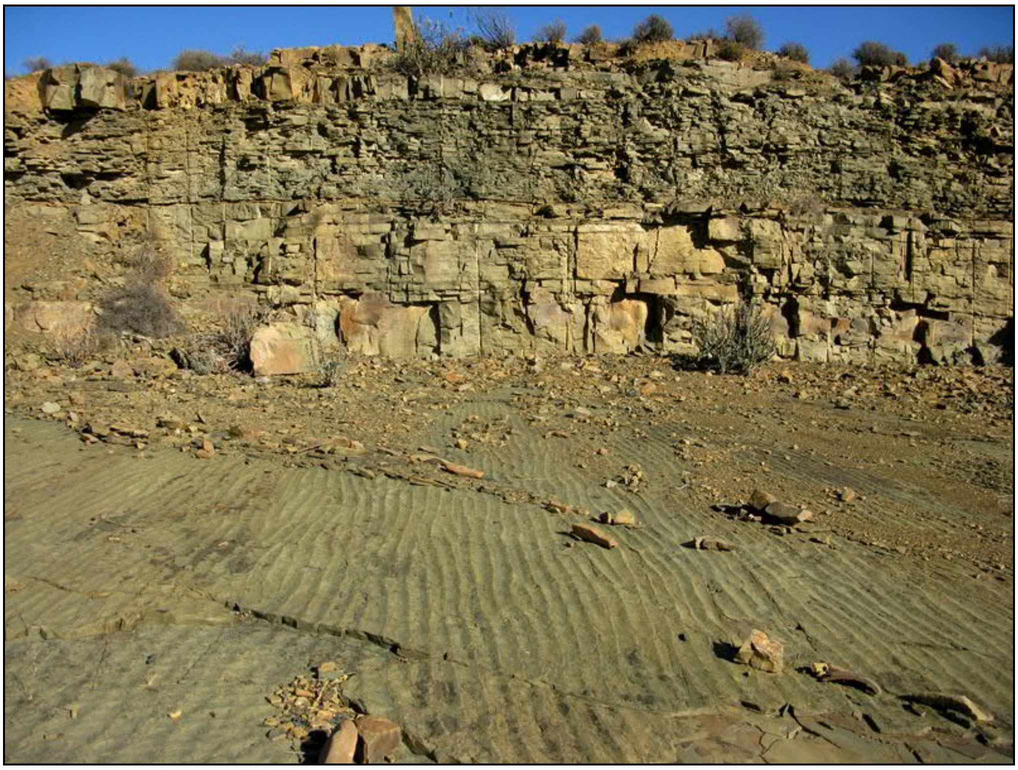

Figure 16. Thin-bedded wackes of the Fort Brown Formation exposed in a small quarry on Wilgehout Fontein 87 showing linear-crested wave ripples on bedding surfaces in the foreground (Loc. 224).

Figure 17. Typical thin-bedded rhythmitites of the Fort Brown Formation showing regular interbedding of brown, fine-grained wackes with rippled surfaces and grey siltstones (Hammer = 30 cm) (Wilgehout Fontein 87, Loc. 224).

2.7. Waterford Formation

The Waterford Formation (Pw) ("Upper Ecca") is a thick (*c*. 500-770 m), easterly- and northerly-thinning wedge of fine-grained deltaic deposits of Middle Permian age that represent the last phase of infilling of the Ecca Basin before the onset of continental sedimentation of the Lower Beaufort Group. Dominant lithologies include fine greyish to khaki, massive lithofeldspathic sandstones or wackes and dark grey mudrocks (often including thin-bedded rhythmitites) that are structured into sharp-topped, broadly coarsening-upwards prograding cycles. Shallow water prodelta and delta platform sandstones capping the cycles typically show well-developed wave-rippled bedding planes and extensive evidence of soft-sediment deformation including spectacular ball-and-pillow load structures and chaotic slump facies. Large, ovoid ferruginous carbonate concretions of diagenetic origin (*koffieklip*) are common. Theron et al. (1991) provide a short account of the Waterford Formation in the Ladismith 1: 250 000 sheet area where it is up to 550 m thick. A recent account of the Waterford Formation in the Eastern Cape has been given by Rubidge *et al.* (2012) while Rubidge *et al.* (2000) describe Waterford sediments and fossils along the south-western Karoo margin. New radiometric dates for tuffs within the lowermost Abrahamskraal Formation (Lanci *et al.* 2013) imply a Roadian (early Guadalupian, Middle Permian) age for the Waterford Formation, *i.e.* around 270 Ma.

The delta-top sediments of the Waterford Formation can be distinguished from the conformably overlying Lower Beaufort Group fluvial succession on the basis of sedimentological criteria. They include, among others, the predominance of upward-coarsening, sandstone-dominated packages, thin-bedded rhythmitites, common large-scale (dm) wave ripples, ball-and-pillow and chaotically slumped horizons, *plus* the absence of subaerial indicators such as arid-climate palaeosols marked by pedogenic calcrete, mudcracks, microbial mats, silicified gypsum pseudomorphs, purple-brown mudrocks and terrestrial vertebrate remains or trackways (*cf* Rubidge *et al.* 2000, Table 7). Plant fossils including petrified wood and equisetaleans occur in both the Waterford and Beaufort Groups. The plant material in the former case is usually transported and comminuted while *in situ* reedy horsetails (or casts of their stems) are associated with swampy facies in the latter succession (Rubidge 1995, Rubidge *et al.* 2000). Petrified wood is also absent to very rare in the basal Abrahamskraal Formation

The sandstone-rich, resistant-weathering Waterford Formation underlies the mountainous terrain along the Klein-Roggeveld Escarpment and in the uplands immediately to the north in the central part of the study area (Figs. 8, 18). Thick, amalgamated sandstone bodies within the upper part of the Waterford succession build prominent ridges, cliffs and *kranzes* in this area, contrasting with the smoother slopes underlain by the succeeding Lower Beaufort Group. These sandstone bodies are often sheet-like in geometry but on some slopes they appear to thicken and thin along strike, giving the impression that they are sometimes lenticular in section. The Rietkloof WEF study area contains several excellent exposures of these deltaic rocks that are of considerable geoscientific significance for the information they provide concerning the sedimentology of the Waterford Formation as well as the nature of the Ecca – Beaufort boundary in this part of the Main Karoo Basin. Examples include outstanding riverine cliff sections through amalgamated Waterford sandstones and mudrocks in Wilgeboskloof (Wilgehout Fontein 87) (Locs. 192, 192a) (Fig. 19) as well as classic examples of soft-sediment deformation (*e.g.* ball-and-pillow structures) along or close to the R354 to the north and southeast of Dwars in die Weg homestead (Wilgehout Fontein 87) (Loc. 233) (Fig. 21) and elsewhere (Fig. 20).

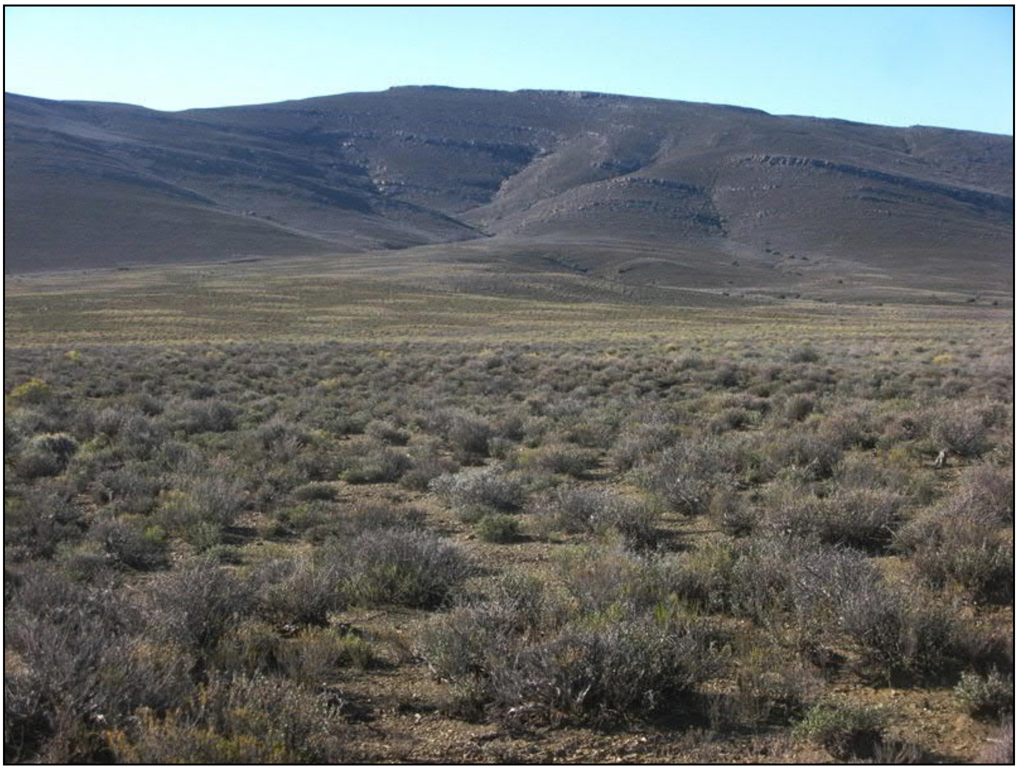

Figure 18. South-facing escarpment of the Klein-Roggeveldberge showing prominent-weathering, east-dipping sandstone package of the Waterford Formation.

Figure 19. Thick amalgamated sandstone package of the Waterford Formation exposed in a riverine cliff, Wilgeboskloof (Wilgehout Fontein 87) (Loc. 192). Note large scale cross-sets and load structures within the lower part of the cliff section.

Figure 20. Ball-and-pillow structures within a thick package of Waterford Formation wackes on Hartjies Kraal 77 (Loc. 173) (Hammer = 30 cm).

Figure 21. Spectacular soft-sediment deformation within the Waterford Formation (ball-and-pillow structures, chaotic bedding) produced by downslope gravity slumping on a delta front, R354 roadcutting on Wilgehout Fontein 87 (Loc. 233) (Hammer = 30 cm).

2.8. Lower Beaufort Group (Adelaide Subgroup)

A useful recent overview of the Beaufort Group continental succession has been given by Johnson *et al.* (2006). Geological and palaeoenvironmental analyses of the Lower Beaufort Group sediments in the western 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, 1987a, 1987b, 1988, 1989, 1990, 1993a, 1993b) and Stear (1978, 1980a, 1980b), as well as several informative field guides (*e.g.* Cole *et al.* 1990, Cole & Smith 2008) and two geological sheet explanations for the Sutherland area (Theron 1983, Cole & Vorster 1999). In brief, the thick Lower Beaufort Group succession of was laid down by a series of large, meandering rivers within a subsiding basin over a period of less than 20 million years, largely within the Middle to Late Permian Period (*c*. 268-251 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, reedy plant fossils).

Frequent development of fine-grained pedogenic (soil) limestone or calcrete as nodules and more continuous lenses or banks indicates that semi-arid, highly seasonal climates prevailed in the Middle Permian Karoo. This is also indicated by the common occurrence of sand-infilled mudcracks and silicified gypsum "desert roses" (Smith 1980, 1990, 1993a, 1993b, Almond 2010a). 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, Wilson *et al.* 2014).

2.8.1. Abrahamskraal Formation

The Abrahamskraal Formation is a very thick (*c*. 2.5 km) succession of fluvial deposits laid down in the Main Karoo Basin by meandering rivers on an extensive, low-relief floodplain during the Mid Permian Period, some 266-260 million years ago (Rossouw & De Villiers 1952, Johnson & Keyser 1979, Turner 1981, Theron 1983, Smith 1979, 1980, 1990, 1993a, 1993b, Smith & Keyser 1995a, Loock *et al*., 1994, Cole & Vorster 1999, McCarthy & Rubidge 2005, Johnson *et al*., 2006, Almond 2010a, Day 2013a, Day & Rubidge 2014, Wilson *et al.* 2014). These sediments include (a) lenticular to sheet-like channel sandstones, often associated with thin, impersistent intraformational breccio-conglomerates (larger clasts mainly of reworked mudflakes, calcrete nodules, *plus* sparse rolled bones, teeth, petrified wood), (b) well-bedded to laminated, grey-green, blue-grey to purple-brown floodplain mudrocks with sparse to common pedocrete horizons (calcrete nodules formed in ancient soils), (c) thin, sheet-like crevasse-splay sandstones, as well as more (d) localized playa lake deposits (*e.g.* wave-rippled sandstones, laminated mudrocks, limestones, evaporites). A number of greenish- to reddish-weathering, silica-rich "chert" horizons are also found. Many of these appear to be secondarily silicified mudrocks or limestones but at least some contain subaerial or reworked volcanic ash (tuffs, tuffites). Thin, fine-grained tuffs with a pale greenish, cherty appearance also occur here and are of value for radiometric dating (Lanci *et al.* 2013). A wide range of sedimentological and palaeontological observations point to deposition of the Abrahamskraal sediments under seasonally arid climates. These include, for example, the abundance of pedogenic calcretes and evaporites (silicified gypsum pseudomorphs or "desert roses"), reddened mudrocks, sun-cracked muds, "flashy" river systems, sun-baked fossil bones, well-developed seasonal growth rings in fossil wood, rarity of fauna, and little evidence for substantial bioturbation or vegetation cover (*e.g.* root casts) on floodplains away from the river banks.

Within the Rietkloof WEF study area the Abrahamskraal Formation is mapped as underlying the northern uplands (Fig. 25) as well as a narrow synclinal axis running west-east at the latitude of Dwars in die Weg (Fig. 24). As noted below, some of the upland terrain close to the Klein-Roggeveld Escarpment in the south might need re-assigning from the Waterford Formation to the Lower Beaufort Group (Fig. 26). The 1: 250 000 Sutherland and Ladismith geological sheets (Theron 1983, Theron *et al.* 1991) show a large area of undifferentiated Abrahamskraal Formation beds in the Matjiesfontein - Sutherland area (Fig. 4). There have since been a number of attempts, only partially successful, to subdivide the very thick Abrahamskraal Formation succession in both lithostratigraphic (rock layering) and biostratigraphic (fossil) terms (*cf* Day & Rubidge 2010, Day 2013a). Among the most relevant of these is the study by Loock *et al.* (1994) in the Moordenaarskaroo area north of Laingsburg. Detailed geological mapping here led to the identification of six lithologically-defined members within the Abrahamskraal Formation (Fig. 22). Several of the younger members have since been mapped in the Sutherland area by Cole and Vorster (1999). A slightly revised scheme has recently been published by Day & Rubidge (2014) (Fig. 23).

The precise stratigraphic range of the Lower Beaufort Group beds represented within the Rietkloof WEF study area has not been determined here with any confidence. On the basis of their proximity to the Ecca – Beaufort boundary, the presence of a basal sandstone-rich package as well as another sandstone package higher up along the crest of west-facing escarpment *plus* the abundance of maroon mudrocks within the upper part, it is concluded that much or most of the succession here belongs to the **Combrinkskraal Member** *sensu lato* and lower **Leeuvlei Member** of Loock *et al.* (1994) (Fig. 22) (The black dashed line running W-E through the northern part of the study area in Fig. 4 indicates the approximate incoming of maroon mudrocks within the Abrahamskraal Formation within the upper part of the Combinkskraal Member *s.l*. However, this is not regarded as accurate). The two sandstone packages might then correspond to the **Combrinkskraal** and **Grootfontein Members** of Day and Rubidge (2014) (Fig. 23), one or both of which are recorded to the southwest of Sutherland (Ouberg Pass and Verlatenkloof). This interpretation is supported by the discovery of possible *Eodicynodon* remains just to the north of the present study area (and above the first appearance of maroon mudrocks). This therapsid genus characterizes the Middle Permian (Wordian) *Eodicynodon* Assemblage Zone (See Section 3).

The Combrinkskraal Member *sensu lato* is not clearly differentiated by Loock *et al.* (1994), apart from to say that it comprises grey and maroon overbank mudrocks, with thin siltstone and sandstone interbeds and occasional calcareous concretions, while the channel sandstones are sheet-like. This description would apply to much of the lower Abrahamskraal Formation succession of the Klein-Roggeveldberge region. According to Loock *et al.* (1995) the *c*. 860 m-thick Leeuvlei Member is characterized by:

- Grey overbank mudrocks with calcrete concretions and thin pyritic horizons;
- Maroon mudrocks, locally with abundant equisetalean (arthrophyte) plant debris;
- Sheet-like channel sandstone bodies composed of very fine- to fine-grained sandstone showing horizontal lamination and ripple cross-lamination. Sandstone bases are erosional and in the upper part of the member they feature lag breccio-conglomerates composed of mudflake intraclasts, reworked calcrete nodules and fossil material (rolled tetrapod bone, arthrophyte stems);
- Well-developed palaeosurfaces on sharp upper sandstone surfaces showing ripple marks, ponds, rill marks *etc*;
- Heavy mineral laminations towards the tops of sandstone packages.
- Occasional thick channel packages with a multi-storey architecture and trough cross-bedding. These packages are locally associated with accumulations of plant debris and secondary uranium mineralization (*koffieklip*).

The sedimentology of the *Eodicynodon* Assemblage Zone beds at the base of the Abrahamskraal Formation has been outlined by Rubidge (1995; see also Rubidge *et al.* 2000, Smith *et al.* 2012). According to these authors, the depositional setting is interpreted as a subaerial delta plain featuring low-sinuosity perennial river channels with intervening floodplains and lakes. Sharp, erosively-based, upward-fining cycles are characteristic. Channel sandstones are fine-grained, single- to multi-storey with generally sharp, erosive bases, often associated with mudrock and calcrete intraclasts breccio-conglomerates. Mudrocks are thin-bedded or massive, predominantly grey to olive green in hue, and often feature small to sizeable reddish brown carbonate concretions.

The Abrahamskraal Formation in the Klein-Roggeveld study region as a whole is a succession of continental fluvial rocks characterized by numerous lenticular to (especially) laterally-extensive sheet-like sandstones with intervening, more recessive-weathering mudrocks (Stear 1980, Le Roux 1985, Loock *et al.* 1994, Cole & Vorster 1999, Wilson *et al.* 2014). The channel sandstone units are up to several (5 m or more) meters thick and vary in geometry from extensive, subtabular sheets to single-storey lenticles or multi-storey channel bodies. The prominent-weathering, laterally-persistent sandstone ledges generate a distinctive stepped or terraced topography on hill slopes in the area. The sheet sandstones are generally pale-weathering (enhanced by epilithic lichens), fine- to medium-grained, well-sorted and variously massive or structured by horizontal lamination (flaggy, with primary current lineation) or, more rarely, tabular to trough cross-bedding. Greyish hues of some freshly broken sandstone surfaces suggest an "impure" clay-rich mineralogy (*i.e.* wackes). Current ripple cross-lamination and horizontal lamination is common towards the tops of the sandstone beds. These may also feature well-preserved palaeosurfaces with swales or pools, wave ripples (locally variable wave crest azimuths), falling water marks, adhesion warts, microbial mat textures, trace fossils and rills; according to Loock *et al.* (1994, p. 189) these features are commonly seen in the Leeuvlei Member. The lower contacts of the sandstones are often gradational or erosive on a small scale, especially lower down in the Abrahamskraal succession. Channel sandstones higher in the succession may be associated with lenticular to sheet-like basal breccias of reworked mudflake and calcrete intraclasts that may infill small-scale erosive gullies; such breccias were not observed within the present study area, however.

Lower Beaufort Group bedrock exposure levels within the Rietkloof WEF study are generally very low, especially as far as the mudrock facies are concerned; surface exposure of these is mainly confined to limited stream and erosion gullies on steeper hillslopes (Figs. 24 & 25). Most of the upland outcrop area is mantled with colluvium, soils and vegetation, with the exception of prominent narrow ridges of sandstone that impart a striped appearance to the landscape. A moderately high but subordinate proportion of the Abrahamskraal overbank mudrocks within the study area are purple-brown to maroon, while non-reddish mudrocks may be more blue-green than greenish-grey, especially lower down in the succession. Horizons of small to large pedogenic calcrete concretions are moderately common within the overbank mudrock packages at all stratigraphic levels. Larger-scale pedogenic calcretes are usually ferruginous, rusty brown, and often sphaeroidal, lenticular to irregular in form (Fig. 28), while smaller sphaeroidal calcrete nodules are usually pale grey (Fig. 29). Occasional float blocks of pale greenish, fine-grained cherty tuff – *i.e.* volcanic ash, of high significance for radiometric dating - have been observed shortly to the north and northwest of the present study area (Almond 2014, 2015c) but similar rocks not seen during the recent field assessment.

It is notable that the majority of Lower Beaufort Group sandstone bodies within the study area show a markedly laterally-persistent, tabular geometry comparable to that of the underlying Waterford Formation. They are mostly fine- to very fine-grained with gradational rather than sharp, erosive bases and often cap small-scale (few m) upward-coarsening sedimentary packages (Figs. 26 & 27). Lenticles and large concretions of rusty-hued ferruginous carbonate are more ubiquitous within the dominantly grey, blue- to grey-green mudrock facies than pale grey calcrete nodules, although both may occur within the same exposures. Features such as basal gullying, well-developed channel breccio-conglomerates containing reworked calcrete nodules, silicified gypsum pseudomorphs or sand-infilled mudcracks are not commonly seen compared to higher members within the Abrahamskraal Formation. These characteristics, which contrast in several respects to the "typical" *Eodicynodon* AZ sediments described earlier, may suggest that the lowermost Abrahamskraal Formation in the study area was deposited in a more swampy delta plain setting with perennially high water tables. The transitional nature of such a setting, between deltaic and fluvial, might also partially explain the paucity of vertebrate fossils (and perhaps woody remains) in these beds, due to palaeoecological as well as preservational (diagenetic) constraints.

It is also noted here that the mapping of the Abrahamskraal and Waterford Formations in the Klein-Roggeveld study area, as shown in Fig. 4, may warrant revision in future, with some of the higher-lying outcrop areas towards the southern escarpment being re-assigned to the former rock unit. It is also possible that intertonging of subaqueous and subaerial delta platform facies may have occurred along the diachronous Ecca – Beaufort boundary in the SW Karoo, especially in areas favoring local subsidence of a thick, river-dominated delta prism (*cf* Theron 1983). Further detailed sedimentological studies and mapping that lie outside the scope of the present report are required to delineate and characterize the Ecca – Beaufort boundary in the study region.

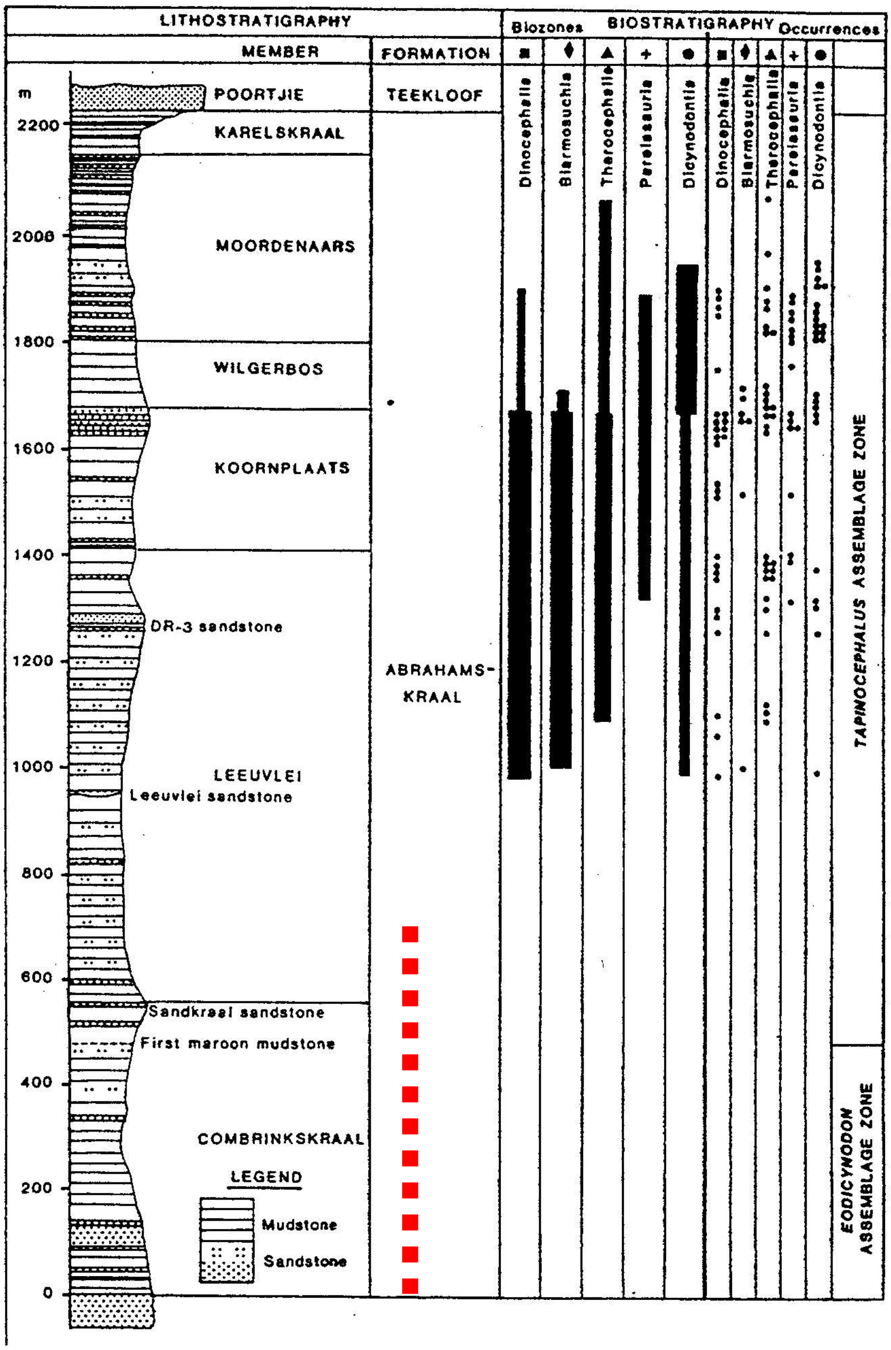

Figure 22. Chart showing the subdivision of the Abrahamskraal Formation in the western Karoo region with stratigraphic distribution of the major fossil vertebrate groups (Loock *et al*. 1994). The Rietkloof WEF study area is probably underlain by fossil-poor sediments within the Combrinkskraal Member *s.l.* and possibly the lower Leeuvlei Member (dotted red bar), above the first appearance of maroon mudstones.

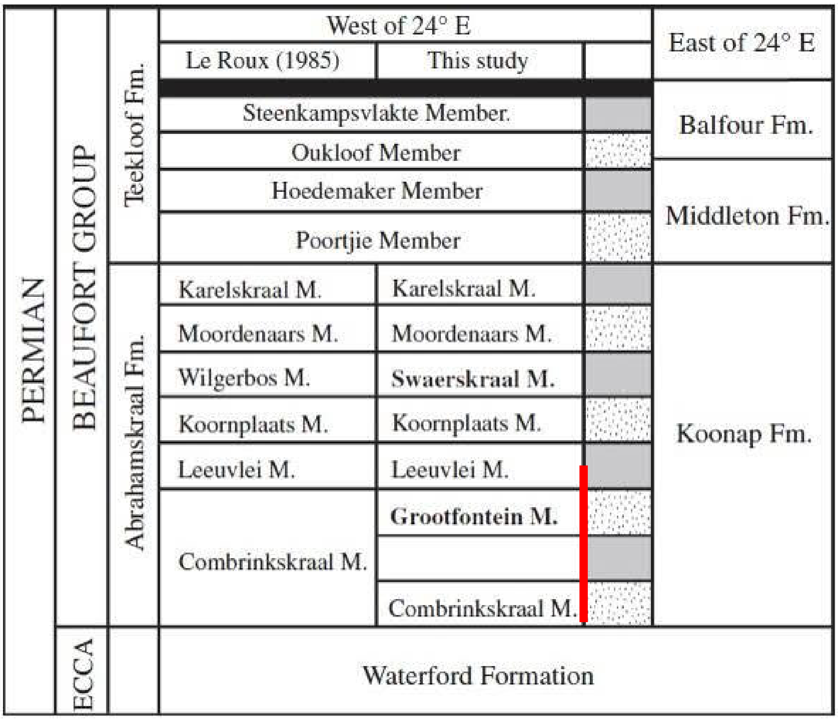

Figure 23. Revised subdivision of the Abrahamskraal Formation of Day and Rubidge (2014). The red bar indicates members that are probably represented within the Rietkloof WEF study area.

Figure 24. South-dipping succession of Abrahamskraal Formation beds within a narrow west-east syncline, western edge of Wilgehout Fontein 87. Note thin, laterally-persistent sandstone ridges and lack of mudrock exposure here.

Figure 25. Typical upland outcrop area of the Abrahamskraal Formation in the northern portion of the study area (Hartjies Kraal 77, looking SW). Note gentle slopes, downwasted rocky rubble and general lack of good bedrock exposures.

Figure 26. Gulley exposure of thin, upward-coarsening and –thickening packages within the Abrahamskraal Formation, Hartjies Kraal 77 (Loc. 168). The packages are capped by ill-defined, fine-grained sandstones / wackes with gradational bases.

Figure 27. Overbank mudrocks of the Abrahamskraal Formation with alternating maroon and grey-green colour bands, Hartjies Kraal 77 (close to Loc. 167).

Figure 28. Horizon of rusty-brown ferruginous carbonate concretions of pedogenic origin, Abrahamskraal Formation, Hartjies Kraal 77 (Loc. 171) (Hammer = 30 cm).

Figure 29. Palaeosol horizon within the Abrahamskraal Formation marked by abundant small, spheroidal, pale grey calcrete nodules, Hartjies Kraal 77 (Loc. 166) (Hammer = 30 cm). Such horizons are an important target for vertebrate fossil recording.

2.9. Karoo Dolerite Suite

A series of narrow, W-E to ENE-WSW orientated dolerite dykes is mapped intruding Lower Beaufort Group country rocks in the northern portion of the study area more or less at the latitude of Barendskraal (Fig. 4, thin red lines). These Early Jurassic dykes are associated with a swarm of linear fractures that are clearly seen on satellite images of the area, for example in the quarry area along the R354 on Fortuin 74. Examples of similar fracture-associated dykes from the Karusa WEF study area to the northeast have been illustrated by Almond (2015c). Dolerite dykes were not encountered during recent fieldwork and, since these rocks are of no palaeontological interest, they will not be treated further here.

2.10. Late Caenozoic Superficial Deposits

Late Caenozoic alluvial deposits in the Rietkloof WEF study area, as exposed in river or stream banks and erosion gulley sections, reach thicknesses of up to few meters and are dominated by well-bedded to massive pale buff silts, sands and gravelly sands, with lenticles of fine to coarse, poorly-sorted gravel. They are well seen along the banks of the Grootrivier, Wilgehoutrivier and their various unnamed tributaries, for example (Figs. 30 & 31). There is often a basal horizon of poorly-sorted, subangular to well-rounded gravels dominated by Waterford or Beaufort Group sandstone / wacke, indurated mudrock, minor ferruginous palaeocalcrete nodules, reworked younger (Quaternary – Recent) calcrete and vein quartz (*e.g.* Locs. 160, 175). The coarse basal gravels are usually semi-indurated, with partial to extensive calcrete cementation, and may show well-developed current imbrication. Flaked stone artefacts of Middle Stone Age origin embedded within semi-consolidated older alluvium indicate a Pleistocene or younger age for these deposits (*e.g.* Loc. 160). Terraces and abandoned bars of coarse bouldery to cobbly gravels are encountered locally along major drainage lines.

Thick (up to several meters) mixed alluvial, colluvial and sheetwash deposits on hillslopes are exposed by gulley or stream erosion where they are seen to consist of poorly-sorted sandy matrix as well as angular, blocky sandstone clasts (Figs. 33, 39). The colluvium may form a semi-consolidated rubbly, clast-supported breccia bed locally (Locs. 153, 158, 172). Elsewhere diamictites or matrix-suppported breccias consisting of angular, dispersed sandstone blocks within a poorly-sorted sandy to silty matrix (locally calcretised) may be debrites emplaced by gravity flow on steeper slopes (*e.g.* Locs. 150, 151). Upland hillslopes and plateaux above the escarpment, where most of the key WEF infrastructure will be concentrated, are generally mantled by angular downwasted rock debris - predominantly Karoo sandstones or wackes (Fig. 40) - but in some areas the bedrocks are mantled in fine gravels and sandy soils (Fig. 41). Prominent-weathering sandstone *kranzes* along and above the escarpment are associated with scree aprons of angular to well-rounded blocks and corestones of Ecca or Beaufort Group sandstone. Mixed fluvial and colluvial sandstone rubble overlies sandstone channel bodies of the Waterford and Abrahamskraal Formations exposed along stream beds and on hillslopes (Fig. 37).

Low-lying *vlaktes* in the southern portion of the study area, below the Klein-Roggeveld Escarpment, are mantled in sandy to finely-gravelly alluvial soils that may reach a depth of a few meters and show calcrete development at depth (Fig. 38). Nodular calcrete hardpans up to three meters in thickness are exposed along some drainage lines (Loc. 145) (Fig. 32). Bouldery to cobbly coarse surface gravels characterise several gently-sloping alluvial fans along the foot of the steep escarpment. The gravels consist mainly of angular to subrounded clasts of Karoo wacke with subordinate clasts of silicified mudrock, ferruginous carbonate, calcrete, vein quartz and petrified wood (Figs. 34 to 36). Relict pediment surfaces can be recognised where the alluvial fans have been dissected by younger incised drainage systems (Fig. 41b).

Figure 30. Well-consolidated older alluvial deposits exposed in Barendskloof, with calcretised basal breccio-conglomerates overlain by brown finer gravels and sands (Hammer = 30 cm) (Loc. 160).

Figure 31, Massive to laminated sandy alluvium overlying poorly-sorted and –consolidated coarse basal gravels on Hartjies Kraal 77 (Loc. 175).

Figure 32. Thick development of a nodular calcrete hardpan within sandy alluvial deposits exposed along an incised drainage line, Vogelstruis Fontein 81 (Loc. 145) (Hammer = 30 cm).

Figure 33. Immature, poorly-sorted sandy to gravelly colluvial or proximal alluvial fan deposits exposed in the banks of an incised stream, Riet Kloof 88 (Loc. 177).

Figure 34. Bouldery, moderately well-rounded pediment gravels of Karoo wacke perched on Tierberg Formation bedrocks several meters above modern stream level, Snyders Kloof 80 (Loc. 148).

Figure 35. Calcretised rubbly alluvial deposits perched on the banks of a deeply-incised stream, Wilgehout Fontein 87 (Loc. 182).

Figure 36. Downwasted distal alluvial fan gravels of reddish-brown weathering Karoo wacke overlying sandy to silty soils on Snyders Kloof 80 (near Loc. 146).

Figure 37. Streambank exposure of very coarse, poorly-sorted, semi-consolidated gravels of mixed alluvial and colluvial origin in Maermanskloof, Hartjies Kraal 77.

Figure 38. Donga exposures of thick sandy to finely gravelly hillwash deposits along the foot of the Klein-Roggeveld Escarpment, Snysders Kloof 80 (Loc. 157).

Figure 39. Imbriated, clast-supported fluvial breccias overlain by matrix-supported sandy breccias on Snyders Kloof 80 (Loc. 150) (Hammer = 30 cm).

Figure 40. Typical angular rock rubble of Karoo wackes overlying upland hillslopes and plateaux areas, especially in the vicinity of sandstone ridges, Snyders Kloof 80 (Loc. 153).

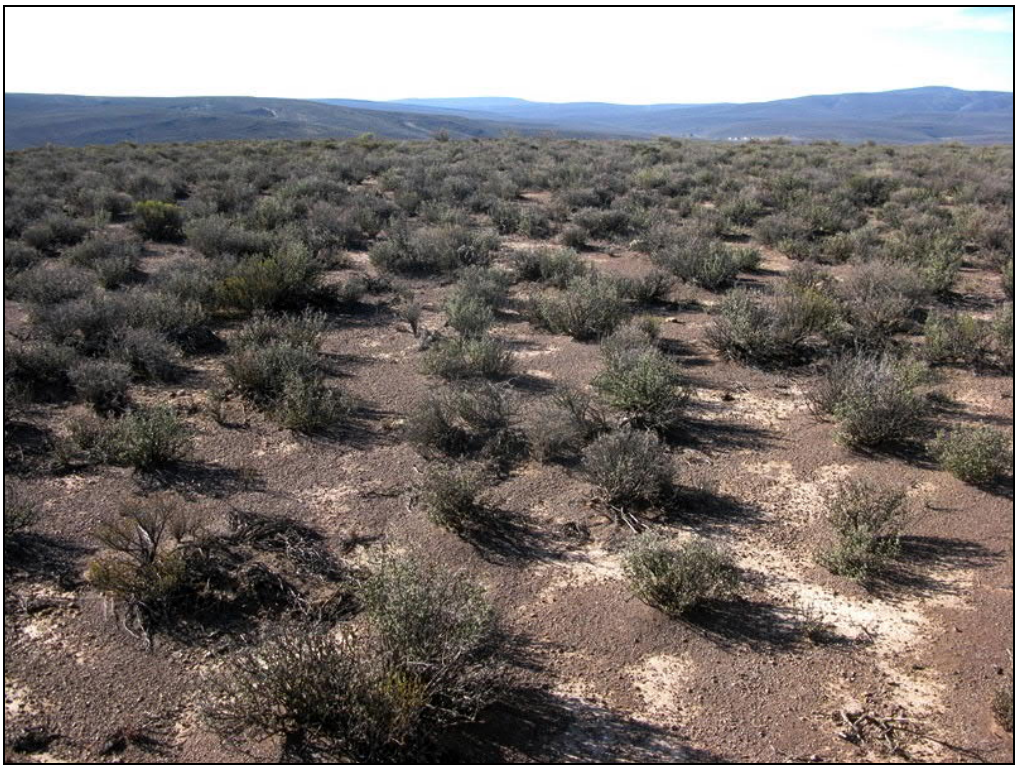

Figure 41a. Mantling of bedrocks by fine sandy to gravelly soils in some flat to gently-sloping upland areas, here overlying the Abrahamskraal Formation on Hartjies Kraal 77.

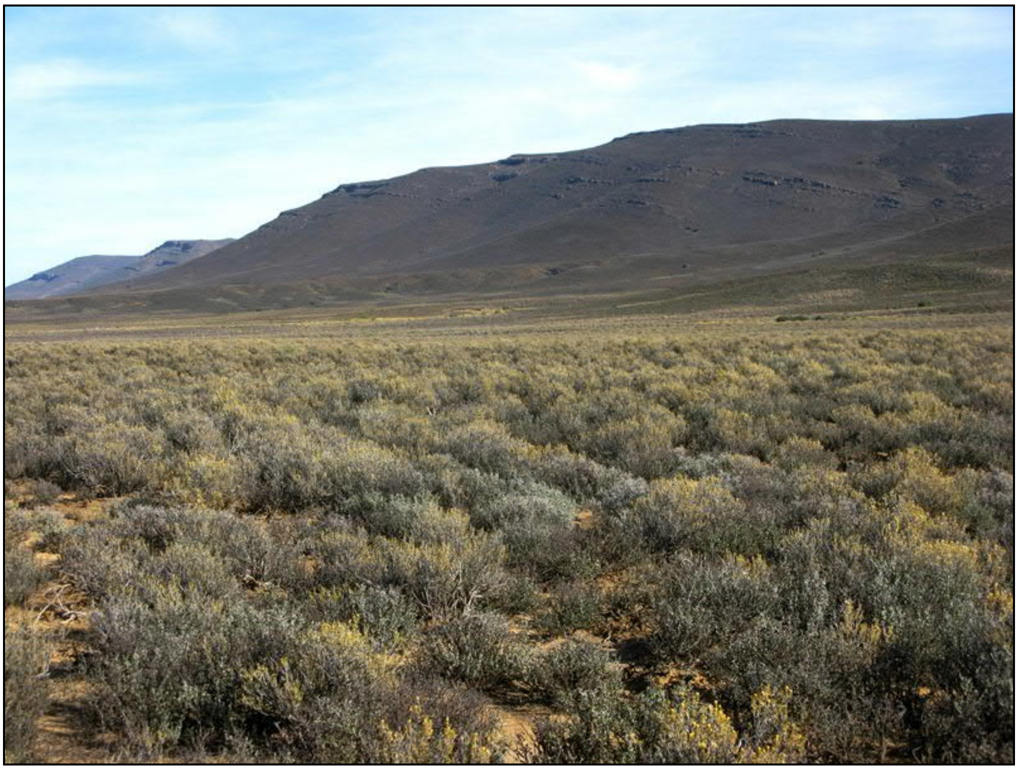

Figure 41b. Gently-sloping relict pediment surfaces extending out into the *vlaktes* at the foot of the Klein-Roggeveld Escarpment.

Table 1: Fossil record of the main sedimentary rock units represented within the Rietkloof WEF study area (modified from Almond & Pether 2008b). The colour code reflects palaeontological sensitivity: low (blue), medium (green), red (high).

ROCK UNIT		SEDIMENTS	FOSSIL ASSEMBLAGES
LATE CAENOZOIC FLUVIAL, LACUSTRINE & TERRESTRIAL DEPOSITS OF INTERIOR **(Most occurrences too small to be indicated on 1: 250 000 geological maps)** **Miocene to Holocene**		Fluvial, pan, lake and terrestrial sediments, including diatomite (diatom deposits), pedocretes, spring tufa / travertine, cave deposits, peats, colluvium	Bones and teeth of wide range of mammals (*e.g.* proboscideans, rhinos, bovids, horses, micromammals, hominins), reptiles (crocodiles, tortoises), ostrich egg shells, fish, freshwater and terrestrial molluscs (unionid bivalves, gastropods), crabs, trace fossils (*e.g.* termitaria, horizontal invertebrate burrows, stone artefacts), petrified wood, leaves, rhizoliths, diatom floras, peats and palynomorphs.
BEAUFORT GROUP Late Permian – Early Triassic *c.* 268 – 250 Ma	**Adelaide Subgroup Abrahamskraal Fm (Pa)** Middle Permian	Fluvial sediments with channel sandstones (meandering rivers), thin mudflake conglomerates interbedded with floodplain mudrocks (grey-green, purplish), pedogenic calcretes, playa lake and pond deposits, occasional reworked volcanic ashes	Diverse continental biota dominated by a variety of therapsids (*e.g.* dinocephalians, dicynodonts, gorgonopsians, therocephalians, cynodonts) and primitive reptiles (*e.g.* pareiasaurs), sparse *Glossopteris* Flora (petrified wood, rarer leaves of *Glossopteris*, horsetail stems), tetrapod trackways, burrows & coprolites. Freshwater assemblages include temnospondyl amphibians, palaeoniscoid fish, non-marine bivalves, phyllopod crustaceans and trace fossils (esp. arthropod trackways and burrows, "worm" burrows, fish fin trails, plant rootlet horizons).
ECCA GROUP Early – Middle Permian (290 – 266 Ma)	**Waterford Fm (Pwa)**	Prodelta to delta plain sediments	Low diversity non-marine trace assemblages (especially arthropod scratch burrow *Scoyenia*), locally common petrified wood (silicified/ calcified), twigs and other remains of *Glossopteris* Flora (*e.g.* horsetails), palaeoniscoid fish scales, rare rolled fragments of tetrapod bone (probably from large temnospondyl amphibians)
	Fort Brown Fm (Pf)	Distal prodeltaic mudrocks & wackes	Low diversity trace fossil assemblages, comminuted reworked vascular plant material, petrified wood, disarticulated fish remains (mainly scales), rare transported tetrapod bone (probably amphibian).
	Tierberg Fm (Pt)	Offshore non-marine mudrocks with distal turbidite beds, prodeltaic sediments	Disarticulated microvertebrate remains (*e.g.* fish teeth, scales), sponge spicules, spare vascular plants (leaves, petrified wood), moderate diversity trace fossil assemblages (as below *plus* variety of additional taxa such as large ribbed pellet burrows, arthropod scratch burrows, *Siphonichnus etc*)
	Collingham Fm (Pc)	Offshore non-marine mudrocks with numerous volcanic ashes, subordinate turbidites	Low diversiy but locally abundant ichnofaunas (horizontal "worm" burrows, arthropod trackways including giant eurypterids), vascular plant remains (petrified and compressed wood, twigs, leaves *etc*).
	Whitehill Fm (Pw)	Carbonaceous offshore non-marine mudrocks within minor volcanic ashes, dolomite nodules	Mesosaurid reptiles, rare cephalochordates, variety of palaeoniscoid fish, small eocarid crustaceans, insects, low diversity of trace fossils (*e.g.* king crab trackways, possible shark coprolites), palynomorphs, petrified wood and other sparse vascular plant remains (*Glossopteris* leaves, lycopods *etc*)
	Prince Albert Fm (Ppr)	Marine to hyposaline basin plain mudrocks, minor volcanic ashes, phosphates and ironstones, post-glacial mudrocks at base	Low diversity marine invertebrates (bivalves, nautiloids, brachiopods), palaeoniscoid fish, sharks, fish coprolites, protozoans (foraminiferans, radiolarians), petrified wood, palynomorphs (spores, acritarchs), non-marine trace fossils (especially arthropods, fish, also various "worm" burrows), possible stromatolites, oolites
DWYKA GROUP (C-Pd) Late Carboniferous – Early Permian *c.* 320-290 Ma	**Elandsvlei Fm** Late Carboniferous – Early Permian	Predominantly massive tillites, with interglacial mudrocks at intervals	Interglacial mudrocks occasionally with low diversity marine fauna of invertebrates (molluscs, starfish, brachiopods, coprolites *etc*), palaeoniscoid fish, petrified wood, leaves (rare) and palynomorphs of *Glossopteris* Flora. Well-preserved non-marine ichnofauna (traces of fish, arthropods) in laminated mudrocks. Possible stromatolites, oolites at top of succession.

3. PALAEONTOLOGICAL HERITAGE

In this section of the report fossil assemblages that are recorded from the main sedimentary rock units represented within the Rietkloof WEF study area are outlined (Table 1) while fossil material recorded during the present field assessment is listed and illustrated. GPS locality details and brief descriptions for numbered palaeontological sites are provided in Appendix 1. Please note that these sites are usually only representative of the relevant rock units as a whole; it is likely that comparable fossil occurrences occur elsewhere within the outcrop area of these units. The fossil sites listed in Appendix 1 do *not* therefore represent a comprehensive record of fossil sites within the study area.

3.1. Fossils in the Dwyka and Lower Ecca Group

A very short summary of the fossil record of the Dwyka Group (Elandsvlei Formation) and Lower Ecca Group (Prince Albert, Whitehill and Collingham Formations) is given in Table 1, largely based on Almond & Pether (2008b). More detailed reviews of these fossil assemblages with extensive references have been given in geological sheet explanations by Almond (2008a, 2008b) as well as palaeontological heritage assessments for the Ceres Karoo region by Almond (2010a, 2015a).

The **Dwyka Group**, cropping out in the south-western corner of the Rietkloof WEF study area, is represented by unfossiliferous tillites. No potentially fossiliferous interglacial mudrocks were recorded here.

Lower Ecca Group mudrocks cropping out along the southern margins of the study area are for the most part highly deformed (locally cleaved) and with little bedding plane exposure. The only fossils recorded from the Lower Ecca group here are low diversity trace fossil assemblages dominated by small, simple, intrastratal or epichnial horizontal burrows within the **Prince Albert** and **Collingham Formations**. In the latter formation, some horizons show dense concentrations of traces of wide-ranging diameter, some of which might be branching burrows systems of the ichnogenus *Chondrites* (Fig.42). Bilobed epichnial burrows (*c*. 2 cm wide) with a vaguely meniscate periphery and a central furrow have been referred to the ichnogenus *Scolicia* in the literature and are widely recorded from Collingham and Tierberg mudrocks along the SW Karoo margins (Fig. 43). No body fossils such as mesosaurid reptiles, palaeoniscoid fish or notocarid crustaceans, or indeed other fossil remains, were observed within the extensive **Whitehill Formation** outcrop area in the study area; the carbonaceous mudrocks here are highly weathered and locally cleaved. Dolomitic concretions with a fine stromatolite-like lamination occur here but apparently do not contain well-preserved pygocephalomorph crustaceans of the sort seen within similar diagenetic concretions in the Prince Albert area.

A wide range of non-marine ichnogenera, including various horizontal burrows (*e.g.* "*Scolicia*"), fish swimming trails, arthropod trackways (*Umfolozia*) and resting traces, as well as unnamed pellet-filled, strap shaped burrows (so called "*Plagiogmus*" *in lit*.), have been collected from the **Tierberg Formation**, many of them from the Ceres / Tanqua Karoo and Roggeveld regions (Wickens 1996, Almond 2008a, b, 2015a and refs. therein). Leaf compressions of the *Glossopteris* Flora and petrified woods have been collected from these rocks in the Tanqua Karoo region and elsewhere. Rare animal remains include disarticulated microvertebrates from calcareous concretions (Zawada 1992).

Only low-diversity intrastratal burrow assemblages were recorded from the Tierberg Formation in the present study area (Fig. 44), probably in part due to the lack of good bedding plane exposures here. Poorly preserved examples of "*Plagiogmus*" strap burrows ranging in diameter up to 4 cm also occur here (Fig. 45).

Figure 42. Intensely-bioturbated, dark grey mudrocks of the Collingham Formation showing a wide range of burrow diameters (up to 5 mm), Wilgehout Fontein 87 (Loc. 129).

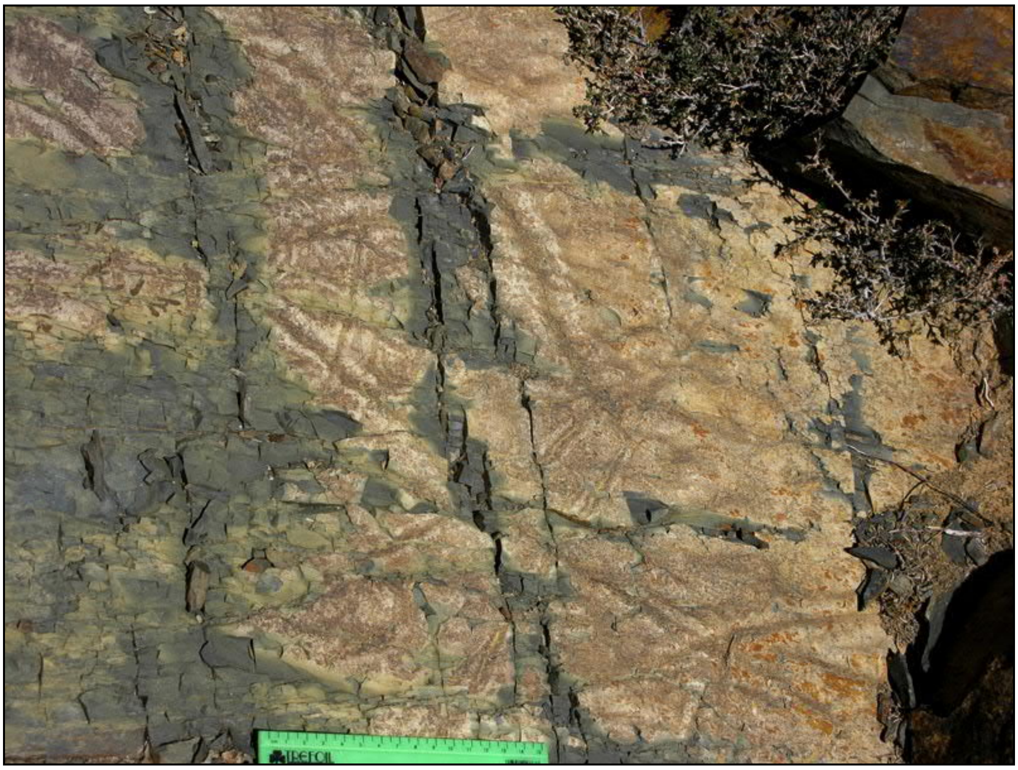

Figure 43. Bilobed epichnial horizontal burrows ("*Scolicia*") preserved at the interface between grey mudrocks and pale yellow tuffs, Collingham Formation, Wilgehout Fontein 87 (Loc. 129) (Scale in cm).

Figure 44. Narrow intrastratal burrows within olive-grey mudrocks of the Tierberg Formation, Snyders Kloof 80 (Loc. 146) (Scale in cm and mm).

Figure 45. Poorly-preserved example of the transversely-ribbed, strap-shaped burrow "Plagiogmus" from the Tierberg Formation, Snysders Kloof 80 (Loc. 159) (Scale in cm and mm).

3.2. Fossils in the Fort Brown and Waterford Formations

The palaeontological record of prodeltaic and delta front facies of the **Fort Brown Formation** is sparse and poorly known (Kingsley 1977, Wickens 1984, 1996, Theron *et al.* 1991, Rubidge *et al.* 2000, Johnson *et al.* 2006, Almond 2008b, Almond 2013). Trace fossil assemblages tend to be impoverished due to high sedimentation rates, fluctuating salinities and sediment instability, though levels of bioturbation may be locally very high. They include various horizontal interface burrows and distinctive, transversely-ribbed pellet burrows of an unnamed ichnogenus (so-called "*Plagiogmus*" of authors) as well as large *Teichichnus* spreiten burrows, undulose *Undichna* fish fin trails, and *Kouphichnium* (king crab trackways). Kingsley (1977) reports trace assemblages of the *Cruziana* and *Skolithos* ichnofacies in the shallower water settings towards the top of the Fort Brown Formation. Plant fragments (finely ground "tea leaves" or "coffee grounds", stem fragments), disarticulated palaeoniscoid fish scales and silicified wood are also common in Ecca delta front successions (Bamford 1999, Theron *et al.* 1991). Isolated tetrapod bones, presumably transported offshore by floods, have been recorded from the Fort Brown Formation in the Eastern Cape (Kingsley 1977, Rubidge & Oelofsen 1981). Some of these may belong to temnospondyl amphibians.

The only fossils recorded from the Fort Brown Formation in the Rietkloof WEF study area comprise a limited range of small-scale burrows variously preserved on bed tops, bed soles or within the beds themselves (Figs. 46 to 50).

The body fossil record of the deltaic facies of the **Waterford Formation** (*i.e.* western outcrop area, including the previously recognised Koedoesberg Formation) is sparse, but this may in part reflect comparative neglect by palaeontologists. Rare fragments of poorly-preserved tetrapod bone are recorded in channel lags within the upper Waterford Formation in the Williston sheet area (Viljoen 1989) and the southern Great Karoo. These probably belong to aquatic temnospondyl amphibians ("labyrinthodonts") but large fish and terrestrial therapsids might also be represented. Scattered palaeoniscoid fish scales and fish coprolites are common in the Waterford Formation, and several genera of non-marine bivalves have been described from the southern Karoo (Bender *et al*. 1991, Cooper & Kensley 1984).

Upper delta platform facies of the Waterford Formation contain abundant, low diversity trace assemblages of the *Scoyenia* ichnofacies. They are dominated by the rope-like, horizontal and oblique burrows of the ichnogenus *Scoyenia* that has been attributed to small arthropods (possibly insects) and / or earthworms. These tubular, meniscate back-filled scratch burrows characterise intermittently moist, firm substrates such as channel and pond margins on the upper delta platform (Smith & Almond 1998, Buatois & Mángano 2004, 2007). Good examples, often associated with wave-rippled surfaces, are recorded from Waterford thin-bedded sandstones and siltstones in the Roggeveld Escarpment zone by Wickens (1984, 1996) and Viljoen (1989). Offshore delta platform facies of the Waterford Formation have very impoverished, poorly-preserved ichnofaunas due to rapid sedimentation rates with abundant soft-sediment deformation and perhaps also to fluctuating salinities. Contrasting ichnoassemblages of the *Cruziana* ichnofacies are recorded from wave-dominated siliclastic shoreline facies of the Waterford Formation in the Northern Cape (previously known as the Carnarvon Formation) (Siebrits 1989, Rust *et al.* 1991, Almond 2016).

Petrified wood and other plant material of the *Glossopteris* Flora (*e.g. Glossopteris, Phyllotheca*) occurs widely in the Waterford Formation and is often reworked in associated pediment or downwasted surface gravels (Theron 1983, Anderson & Anderson 1985, Viljoen 1989, Wickens 1984, 1996, Theron *et al.* 1991, Rubidge *et al*. 2000, Almond 2016). Leaves and stems of arthrophytes (horsetails) such as *Schizoneura* have been observed in vertical life position. Substantial fossil logs (so-called "*Dadoxylon*") showing clearly developed seasonal growth rings are mostly permineralised with silica but partially or completely calcified material is also known (Viljoen 1989). At least two different genera of gymnospermous woods, *Prototaxoxylon* and *Australoxylon,* have been identified so far (Bamford 1999, 2004).

Low-diversity trace fossil assemblages, mainly comprising a small range of horizontal burrows, are commonly seen on wave-rippled bed tops of the Waterford Formation in the Rietkloof WEF study area. High bioturbation intensity may be reflected at some horizons. Many Waterford bedding surfaces are too deformed by soft-sediment deformation to favour trace fossil preservation, however, especially in the upper part of the succession. Sizeable rope-like burrows (*Palaeophycus striatus*) and possible infaunal bivalve burrows (*Lockeia*) preserved on yellowish-brown sandstone surfaces are identical to those that dominate ichnoassemblages within storm-dominated shoreface deposits of the Waterford Formation in the Williston – Carnarvon area of the Northern Cape (Almond 2016) (Fig. 51).

Petrified fossil wood material has been widely recorded within the Waterford Formation - including the previously separate Koedoesberg Formation - in the Ladismith and Sutherland 1: 250 000 sheet areas (Theron 1983, Theron *et al.* 1991). Tool marks made by current-entrained logs are also known from sandstone palaeosurfaces in the region; these have occasionally been mistaken for the actual fossil impressions or moulds of logs (Theron 1983, p. 8; Almond 2010a). Numerous dispersed pieces as well as concentrations of pale grey, finely-banded, angular blocks of silicified wood were encountered in the Rietkloof WEF study area, most notably on the slopes of Kranskop, *c*. 13 km NNW of Dwars in die Weg homestead, Wilgerhout Fontein 87 (Figs. 52 to 55) (See area outlined in purple in Fig. 68). The most impressive of these occurrences includes large pieces of one or more fossil logs whose original radius must have been greater than 35 cm (Figs. 54 & 55). As with the petrified wood material in the Koedoesberg Formation (Theron, 1983), the Waterford fossil logs are generally not encountered *in situ*, *i.e.* still embedded within sedimentary bedrock. However, it is clear from their size, freshness and absence of rounding that the locally concentrated blocks, as seen for example in Fig. 54, cannot have moved far from the beds within which they were originally preserved. These were probably major sand bodies such as distributary channels or sand bars within the Waterford Formation. Downwasted fossil wood blocks can be traced downslope from the same source. Preservation of the microscopic woody fabric (xylem) of the wood is very good, with the clear development of concentric growth lines suggesting a strongly seasonal growth pattern and palaeoclimate (Fig. 55). The petrified wood occurrences on Wilgerhout Fontein 87 are among the best known in the Waterford Formation and indeed in the South African Ecca Group as a whole; they are therefore of considerable scientific interest and worthy of *in situ* conservation (Much more impressive "petrified forests" are known in Lower Ecca beds of Namibia; *cf* Schneider & Marais 2004). It is quite possible that other unrecorded concentrations of well-preserved petrified wood are scattered across the less accessible mountainous uplands in the central portion of the Rietkloof WEF study area that are underlain by the Waterford Formation.

Figure 46. Simple interstratal horizontal burrows within laminated mudrocks of the Fort Brown Formation, Wilgehoutfontein 87 (Loc. 182). The burrows are *c*. 2 mm wide on average.

Figure 47. Small hypichnial burrows on the sole of a wave-rippled sandstone bed, Fort Brown Formation, Wilgehout Fontein 87 (Loc. 224) (Scale in cm).

Figure 48. Epichnial grooves on a wave-rippled sandstone bed top, Waterford Formation, Wilgehout Fontein 87 (Loc. 224) (Scale in mm and cm).

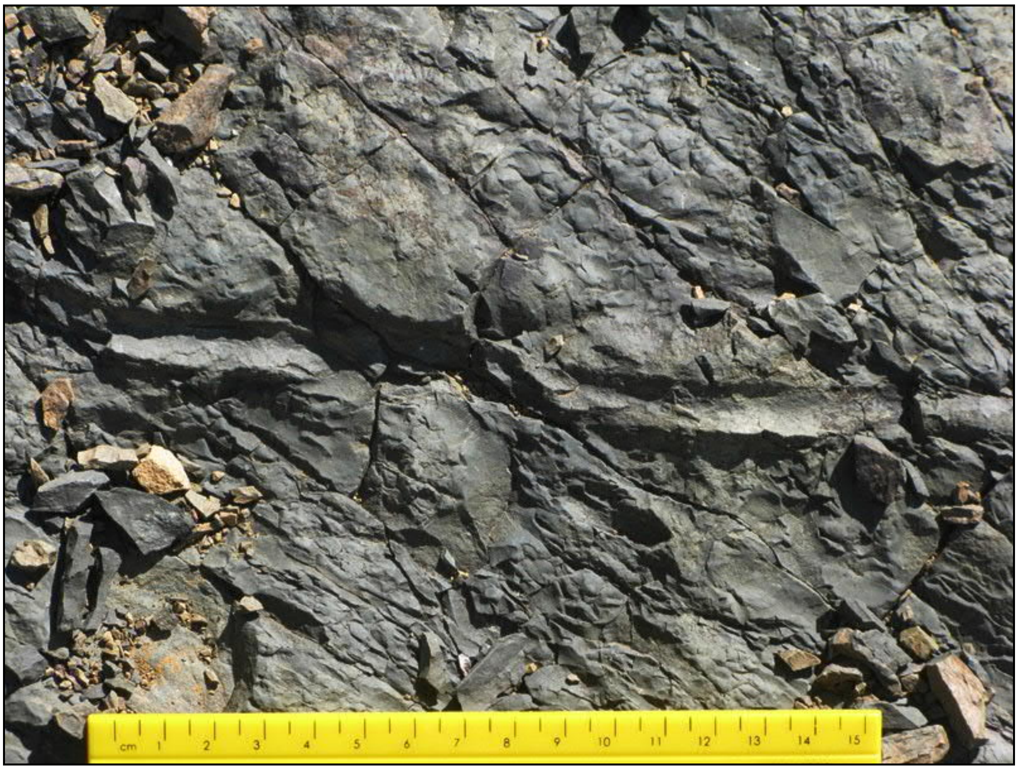

Figure 49. Sizeable horizontal spreiten burrow (possibly *Teichichnus*) within grey siltstones of the Fort Brown Formation, Wilgehout Fontein 87 (Loc. 186) (Scale in cm).

Figure 50. Horizontal intrastratal burrows (*Palaeophycus*) within thinly-interbedded sandstones and siltstones of the Fort Brown Formation, Wilgehout Fontein 87 (Loc. 224) (Scale in mm and cm).

Figure 51. Rope-like horizontal and oblique burrows ("*Palaeophycus striatus*") *plus* possible lenticular bivalve burrows (*Lockeia*) in a sandstone float block from the Waterford Formation, Wilgerhout Fontein 87 (Loc. 189).

Figure 52. Silicified log embedded within colluvial gravels overlying the Waterford Formation, Wilgerhout Fontein 87 (Loc. 187) (Hammer = 30 cm).

Figure 53. Sizeable float blocks of downwasted petrified wood on the lower slopes of Kranskop, Wilgehout Fontein 87 (Loc. 225) (Scale is *c*. 15 cm long).

Figure 54. Petrified log breaking up *in situ*, northern slopes of Kranskop, Wilgehout Fontein 87 (Loc. 229) (Scale is *c*. 15 cm long).

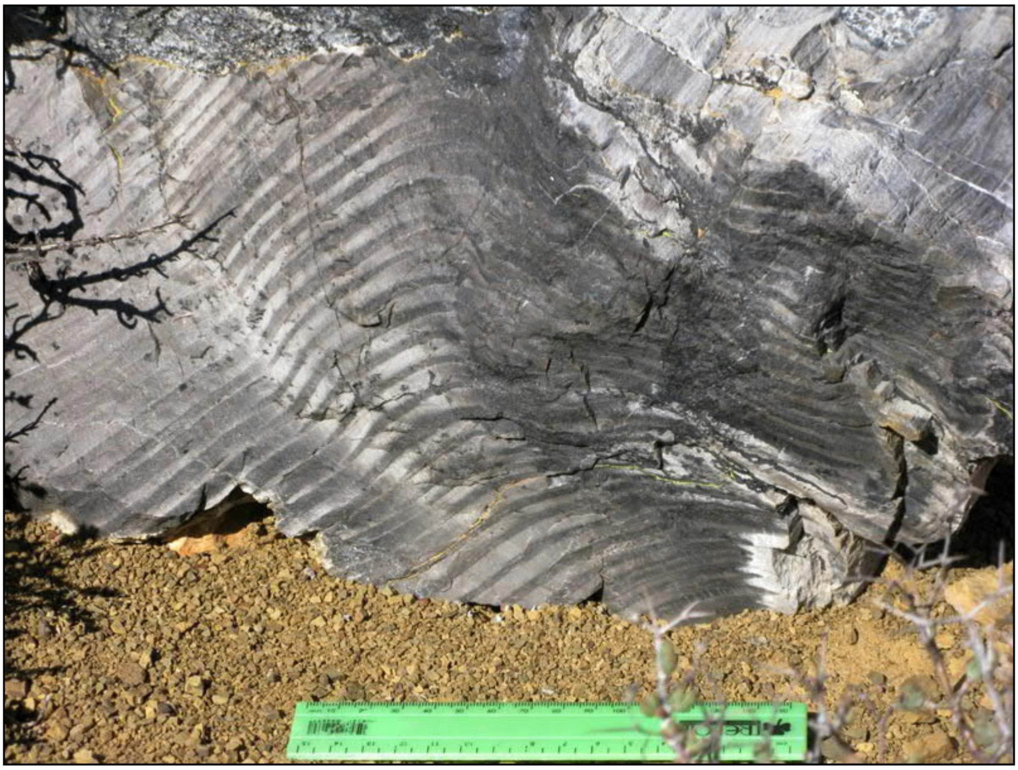

Figure 55. Close-up view of the largest petrified log fragment in the previous figure showing the very well-preserved seasonal growth lines (Scale in mm and cm).

3.3. Fossil biotas of the Lower Beaufort Group (Adelaide Subgroup)

The overall palaeontological sensitivity of the Lower Beaufort Group sediments is high to very high (Almond & Pether 2008b). 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 (MacRae 1999, Rubidge 2005, McCarthy & Rubidge 2005, Smith *et al.* 2012). Bones and teeth of Late Permian tetrapods have been collected in the western Great Karoo region since at least the 1820s and this area remains a major focus of palaeontological research in South Africa.

A chronological series of mappable fossil biozones or assemblage zones (AZ), defined mainly by their characteristic tetrapod faunas, has been established for the Main Karoo Basin of South Africa (Rubidge 1995, 2005, Van der Walt *et al.* 2010, Smith *et al.* 2012). Maps showing the distribution of the Beaufort Group assemblage zones within the Main Karoo Basin have been provided by Keyser and Smith (1979, Fig. 57 herein) and Rubidge (1995, 2005). A recently updated version is now available (Nicolas 2007, Van der Walt *et al.* 2010) (Fig. 56). This last – already outdated - map assigns the Abrahamskraal Formation beds in the present study area on the south-western margins of the Lower Beaufort Group outcrop area to the *Tapinocephalus* Assemblage Zone. However, recent magnetostratigraphic, radiometric and lithostratigraphic studies suggest that the Combrinkskraal Member *sensu lato* of the Abrahamskraal Formation belongs to the slightly older ***Eodicynodon* Assemblage Zone** of Middle Permian (Guadalupian / Wordian) age (*c*. 268-265 Ma) (Lanci *et al.* 2013, Day & Rubidge 2014, p. 233 and refs. therein).

Fossil biotas of the *Eodicynodon* Assemblage Zone have been usefully summarized by Rubidge (1995) and more recently by Smith *et al.* (2012). This early Middle Permian biota is characterized by a small variety of primitive therapsids, most notably the small dicynodont *Eodicynodon* (by far the commonest taxon), very rare large-bodied herbiovorous and carnivorous dinocephalians such as *Tapinocaninus* and anteosaurids, as well as equally rare gorgonopsians and scylacosaurid therocephalians (Fig. 59) (See also Rubidge & Oelofsen 1981, Rubidge 1987, Rubidge 1991, Rubidge *et al.* 1994, Rubidge 1995, Rubidge *et al.* 2000, Rubidge 2005, Govender 2002, Jinnah & Rubidge 2007, Abdala *et al.* 2008, Nicolas and Rubidge 2010). The fauna is of considerable biogeographic significance in that it includes some of the earliest and most primitive examples of several therapsid subgroups recorded anywhere in the world. Associated fossils include disarticulated palaeoniscoid fish and amphibians (rhinesuchid temnospondyls), freshwater bivalves, a small range of invertebrate ichnogenera such as the arthropod trackway *Umfolozia*, as well as glossopterids and the sphenophyte ferns *Equisetum* and *Schizoneura* (Anderson & Anderson 1985). Petrified wood is apparently – and perhaps surprisingly - absent in the lowermost Beaufort Group, in contrast to the underlying Waterford Formation (Rubidge *et al.* 2000); it is unclear why this is so. Vertebrate fossils – especially identifiable, articulated specimens - tend to be very rare indeed in this biozone, as indicated by the fossil chart of Loock *et al.* (1994) (Fig. 22) as well as the fossil site maps of Keyser & Smith (1977-78) (Fig. 57) and of Nicolas (2007) (Fig. 58). The fossils are also typically difficult to extract from their resistant rock matrix. They are mainly found within overbank, lake margin mudrocks in association with small pedogenic calcrete nodules or - in the case of the dinocephalians - within or at the base of channel sandstones.

Large (*c*. 15 cm wide) inclined tetrapod burrows, *possibly* associated with nearby skeletal remains of small-bodied dicynodonts, are reported from the *Eodicynodon* AZ in the adjoining Brandvalley WEF by Almond (2016, in prep.). These may represent the oldest known tetrapod burrows reported from the Karoo Supergroup of South Africa (and perhaps from Gondwana), although this claim remains to be confirmed. Several occurrences of possible, but unconfirmed, sand-cast tetrapod burrows have recently been noted from the lower Abrahamskraal Formation of the Klein-Roggeveldberge region (*e.g.* Almond 2015c, 2015d); some of these might be of amphibian rather than therapsid origin. In the Rietkloof WEF study area a couple of anomalous linear sandstone bodies of broadly elliptical to plano-convex cross section were noted within crumbly grey mudrocks overlying a wave-rippled sandstone palaeosurface on Hartjies Kraal 77 (Figs. 60 & 61). This is the same pond or lake margin depositional setting as that inferred for the convincing tetrapod burrows reported by Almond (2106, in prep.) as well as that with which *Eodicynodon* skeletal remains are most commonly associated (Smith *et al.* 2012). No fossil tetrapod bones of teeth were recorded from the Lower Beaufort Group during the field study for the Rietkloof WEF. However, very rare disarticulated tetrapod remains – probably *Eodicynodon* - have recently been found within the same succession just to the north (Almond 2016, in prep.).

Invertebrate trace fossils are not well represented within the Beaufort Group beds in present study area; damp substrate *Scoyenia* ichnofacies burrows, such as commonly seen higher within the Abrahamskraal succession, are apparently scarcer here. Assemblages of calcretised, subcylindrical structures with an oblique to vertical orientation were seen embedded within grey siltstones on Hartjies Kraal 77 (Fig. 62). These traces vary in diameter from 1.5 to 5 cm as well as along their length. They might be rhizocretions or invertebrate burrows (*e.g.* of crustaceans); no scratch marks were observed on their walls. Dense arrays of somewhat similar but larger-diameter, subcylindrical, sand-infilled vertical structures have been recorded from several horizons within the lower part of the Abrahamskraal Formation in the Klein-Roggeveld region (Almond 2010a, 2015c). They have been tentatively compared with gregarious lungfish aestivation burrows (ichnogenus *Dipnoichnus*; *cf* Hasiotis *et al.* 1993) although this fish group is not yet been recorded as body fossils from these beds (Rubidge 1995)

The only plant fossils recorded from the Lower Abrahamskraal Formation during the present field study comprise dispersed to concentrated, fragmentary impressions of equisetaleans (horsetail ferns and their relatives) preserved within overbank mudocks (*cf* Anderson & Anderson 1985, Rubidge *et al.* 2000). They include segmented stems of reedy horsetails (*Phyllotheca*) as well as strap-shaped, longitudinally-ridged leaves referred to the genus *Schizoneura* (Fig. 65). Dense concentrations of small cylindrical features exposed in cross-section on bedding planes of flaggy sandstones probably represent stem casts of reedy vegetation such as horsetails (Fig. 63). The apparent absence, or great scarcity, of petrified wood within the lowermost Abrahamskraal Formation is puzzling in view of the abundant well-preserved material seen within the underlying Waterford Formation (see above). However, sandstone palaeosurfaces in the earliest Beaufort Group beds not infrequently bear large linear tool marks that are plausibly attributed to current-entrained logs (Fig. 64). A good example is recorded from the Brandvalley WEF study area to the north (Almond 2010a).

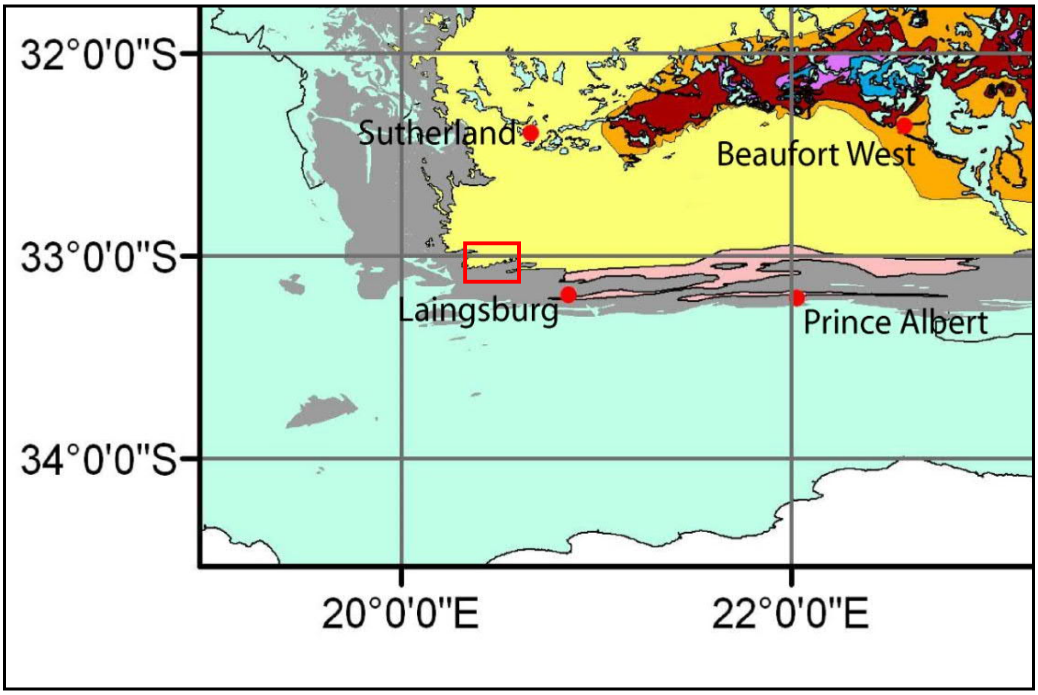

Figure 56. Recent - but already outdated - biozonation of the SW Karoo region showing restriction of the *Eodicynodon* Assemblage Zone (pink) to the southern margins of the Main Karoo Basin (Van der Walt 2010). Subsequent work suggests that this earliest Beaufort Group biozone extends further to the northwest along the Ecca – Beaufort Group boundary, including the present study area (red rectangle).

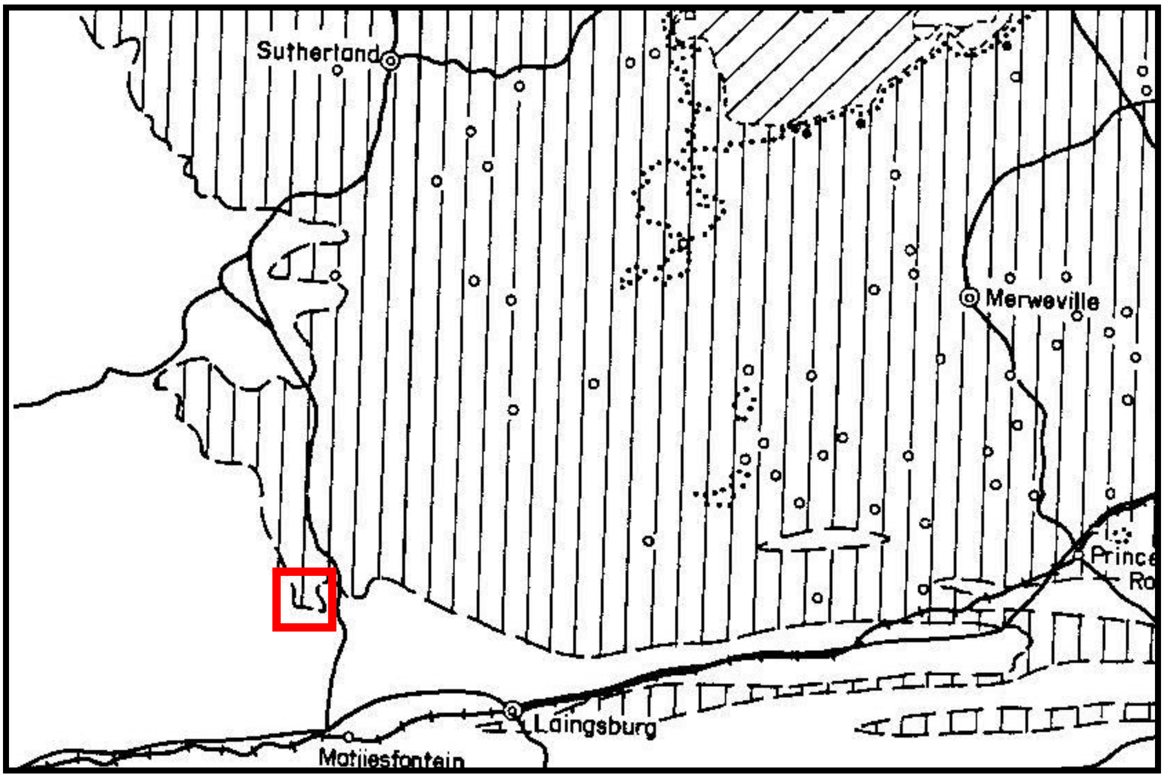

Figure 57. Vertebrate fossil localities within the Lower Beaufort Group in the south-western Karoo region (Map abstracted from Keyser & Smith 1977-78). Outcrop areas with a vertical lined ornament were originally assigned to the Middle Permian *Tapinocephalus* Assemblage Zone. Note the absence of fossil records from the lower part of the Abrahamskraal Formation in the present Rietkloof WEF study area between Matjiesfontein and Sutherland (red rectangle).

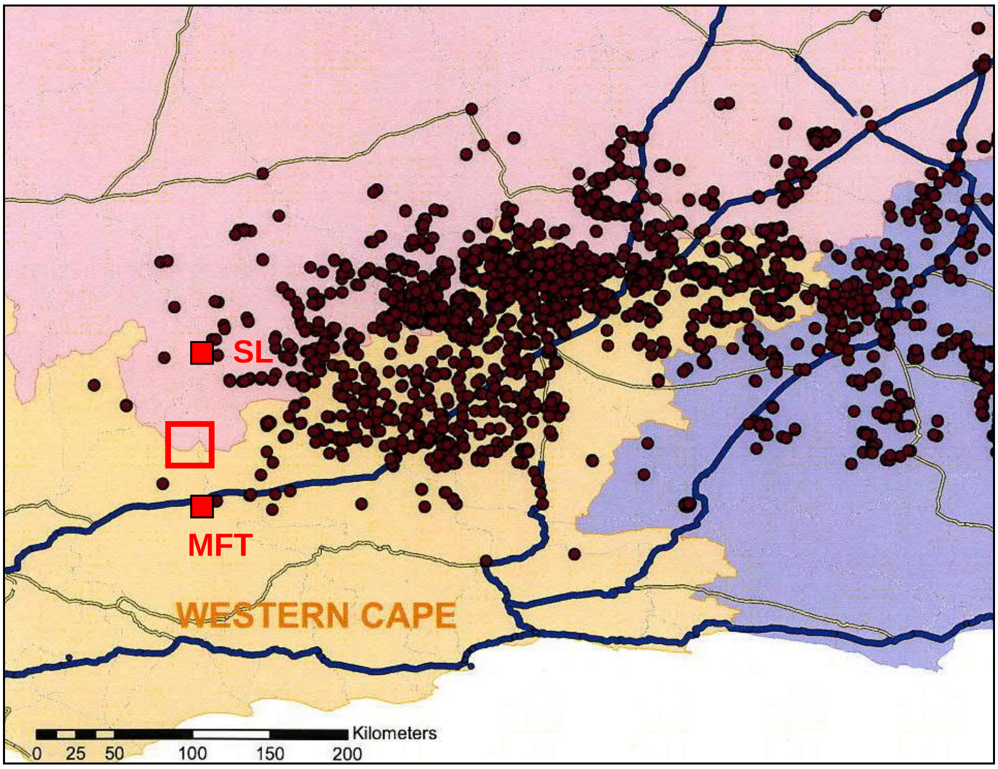

Figure 58. Distribution of recorded vertebrate fossil sites within the south-western portion of the Main Karoo Basin (modified from Nicolas 2007). The approximate location of the Rietkloof WEF and adjacent Brandvalley WEF study areas is approximately indicated by the open red square. Note the lack of known fossil sites in this part of the Karoo. SL = Sutherland. MFT = Matjiesfontein.

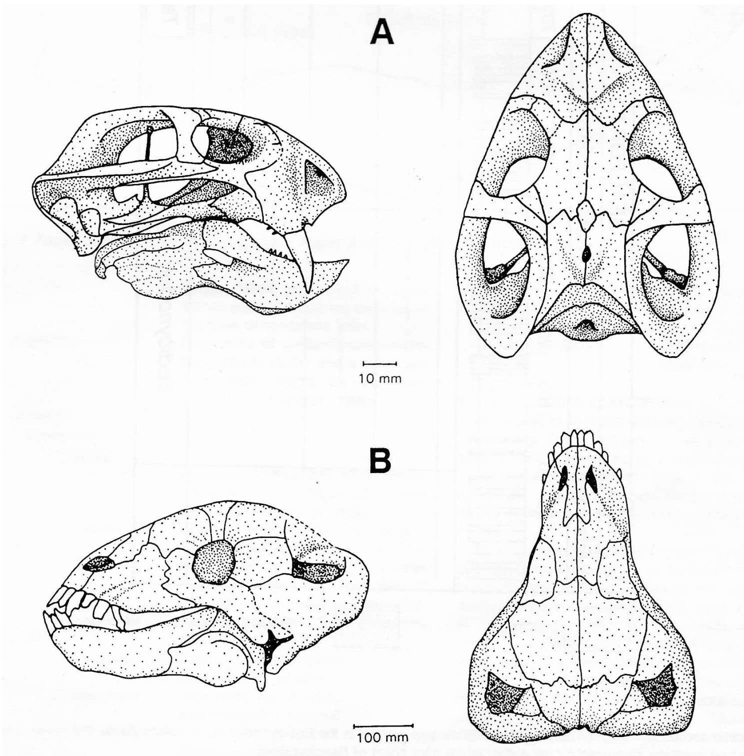

Figure 59. Skulls of two key fossil therapsids from the *Eodicynodon* Assemblage Zone: A – the small dicynodont *Eodicynodon*; B – the rhino-sized dinocephalian *Tapinocaninus* (From Rubidge 1995).

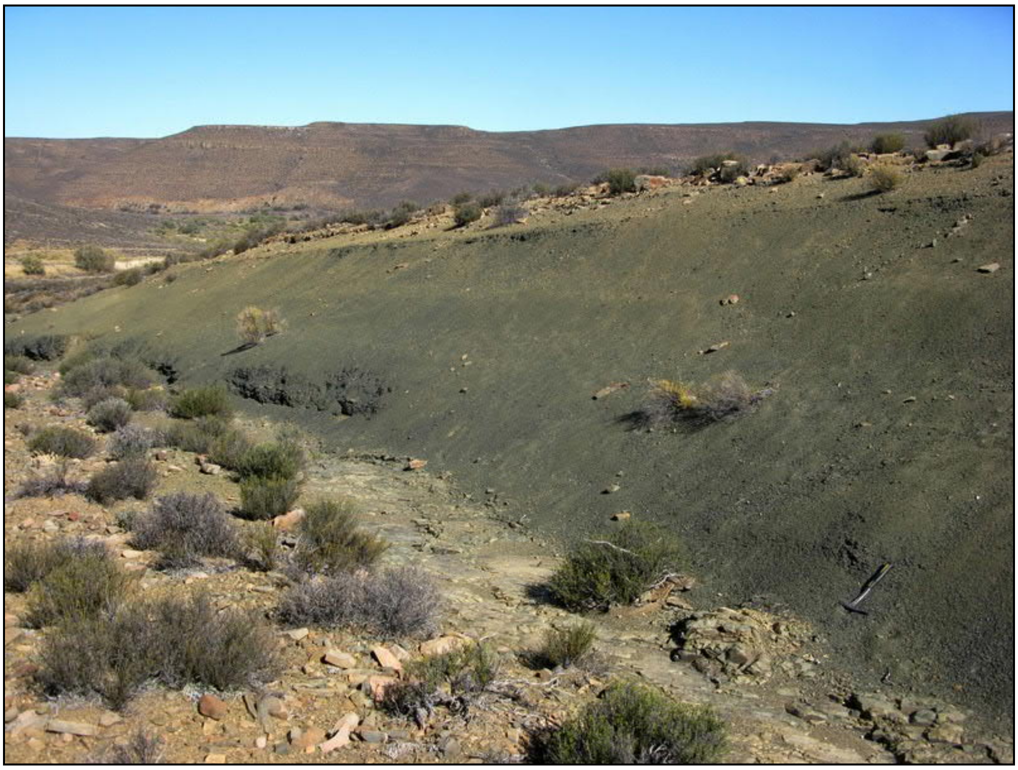

Figure 60. Hillslope exposure of crumbly, grey-green Lower Beaufort mudrocks overlying a sandstone palaeosurface on Hartjies Kraal 77 (Loc 221) (Hammer = 30 cm). The anomalous plano-convex sandstone body to the left of the hammer might a tetrapod burrow cast (See also following figure).

Figure 61. Close-up of the possible tetrapod burrow cast seen in the previous figure.

Figure 62. Subcylindrical calcretised bodies embedded within grey overbank mudrocks of the Lower Beaufort Group, Hartjies Kraal 164 (Loc. 164) (Scale in cm and mm). These are possibly rhizocretions (root casts) or invertebrate burrows.

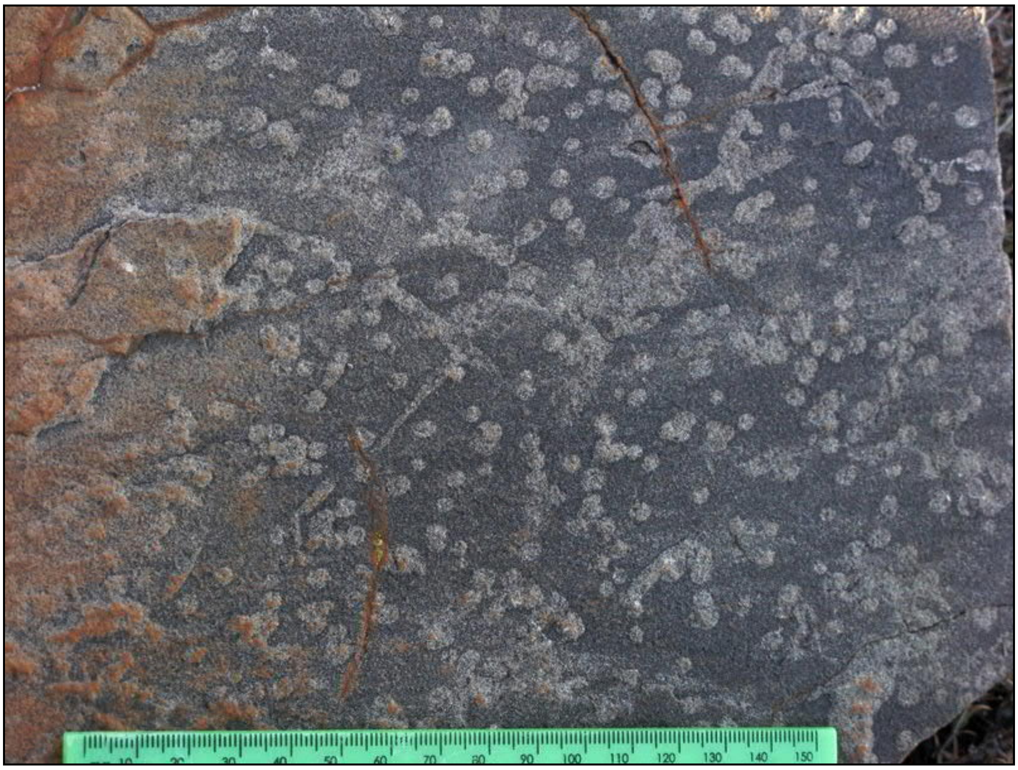

Figure 63. Flaggy Lower Beaufort Group sandstone featuring a dense assemblage of cylindrical structures, probably stem casts of reedy vegetation such as equisetaleans (horsetail ferns), Riet Kloof 88 (Loc. 178) (Scale in cm and mm).

Figure 64. Wave rippled sandstone palaeosurface in the Lower Beaufort Group transected by a linear tool mark (arrowed, possibly generated by a floating log, Hartsjies Kraal 77 (Loc. 167).

Figure 65. Impression of a narrowly, strap-shaped plant leaf – probably of the equisetalean *Schizoneura*, Lower Beaufort Group, Hartsjies Kraal 77 (Loc. 165) (Scale in cm and mm).

3.4. Fossils within Late Caenozoic superficial deposits

The diverse Late Caenozoic superficial deposits within the South African interior have been comparatively neglected in palaeontological terms. However, sediments associated with ancient drainage systems, springs and pans in particular may occasionally contain important fossil biotas, notably the bones, teeth and horn cores of mammals as well as remains of reptiles like tortoises (e.g. Skead 1980, Klein 1984b, 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 that may occur within these superficial deposits include non-marine molluscs (bivalves, gastropods), ostrich egg shells, trace fossils (e.g. calcretised termitaria, coprolites, invertebrate burrows, rhizocretions), and plant material such as peats or palynomorphs (pollens) in organic-rich alluvial horizons (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.

The only fossils observed within the various Late Caenozoic superficial deposits during the present field study comprise well-dispersed to occasionally concentrated clasts of petrified wood that occur among coarse surface gravels and pediment gravels along the foot of the Klein-Koedoesberge Escarpment (*e.g.* Locs. 155, 156, 176, 180) (Fig. 66). Some of the concentrated float blocks are angular, clearly having broken-up nearby, while others are slightly rounded as a result of fluvial transport and sheetwash. Most of the material has probably been reworked from the Waterford Formation (or upper Tierberg Formation) that builds the crest of the escarpment, but it is also possible that some blocks have a Lower Beaufort Group provenance. In contrast to the fresh-looking, pale grey, markedly-banded material observed in the Waterford Formation outcrop area (Figs. 50 to 55), some reworked fossil wood blocks show pervasive orange or brownish hues – perhaps due to long residence within pediment gravels. Still others lack well-marked growth bands or well-preserved xylem fabric and may have suffered partial decomposition prior to silicification.

Figure 66. Angular to slightly rounded clasts of petrified wood dispersed among coarse pediment gravels of Late Caenozoic age, Vogelstruis Fontein 81 (Loc. 155) (Scale in cm).

4. ASSESSMENT OF IMPACTS ON PALAEONTOLOGICAL RESOURCES

Desktop studies show that the Rietkloof WEF study area is underlain by around twelve mappable units of Palaeozoic to Late Caenozoic sedimentary rocks (Fig. 4), all of which contain fossils of some sort. Palaeontological field assessment of the area shows that:

- Dwyka Group and Lower to Middle Ecca Group bedrocks in the low-lying, southern portion of the area are tectonically deformed and weathered, with low-diversity trace fossil assemblages of limited scientific interest. This also applies to the Whitehill Formation that elsewhere, outside the study area, may be of high palaeontological sensitivity.

- Waterford Formation (Upper Ecca Group) deltaic bedrocks underlying the mountainous southern portion of the main development footprint are generally fossil-poor, apart from low-diversity trace fossil assemblages. However, isolated blocks and rare logs of well-preserved petrified wood found within the eastern portion of the study area are of high scientific and conservation value. Fossil wood material within the eastern part of the project footprint may be adversely impacted by the proposed WEF development.

- Abrahamskraal Formation (Lower Beaufort Group) fluvial bedrocks underlying the high-lying northern portion of the study area are generally considered to be of high palaeontological sensitivity. However, in this area of the SW Karoo they are fossil-poor, apart from occasional horizons with plant debris or low-diversity trace fossils, including unconfirmed large tetrapod (terrestrial vertebrate) burrows. Fossil vertebrate skeletal remains (bones, teeth) are very rare indeed in these lowermost Beaufort Group rocks. None have been recorded as yet within the Rietkloof WEF study area, but isolated occurrences of probable small dicynodonts have recently been found just to the north (Brandvalley WEF project area) (Almond 2016d). Significant impacts on well-preserved, scientifically valuable Beaufort Group fossil vertebrates within the WEF project area are considered unlikely.

- Late Caenozoic superficial sediments (alluvium, colluvium, calcretes, soils, surface gravels *etc*) overlying the Palaeozoic bedrocks are of low palaeontological sensitivity. Pediment and surface gravels along the foot of the Klein-Roggeveld Escarpment locally contain numerous clasts of petrified wood reworked from the Karoo Supergroup outcrop area to the north.

The potential impact of the proposed Rietkloof WEF development (*revised* layout) on local fossil heritage resources is evaluated in Table 2 below (summarized in Section 6). This assessment applies only to the construction phase of the WEF development since further impacts on fossil heritage during the planning, operational and decommissioning phases of the WEF are not anticipated. The assessment applies to all key infrastructure as described in Section 1 situated within the main WEF study area as shown in Figs. 2a & 2b, *i.e.* wind turbines and associated hardstanding areas, internal and external access roads, on-site substation, 33 kV overhead transmission lines, underground cables, wind masts, construction camps, concrete batching plant, and associated infrastructure. Separate Basic Assessment processes have been undertaken to assess grid connection alternatives, 132 kV overhead power lines (*e.g.* Almond 2011b, 2016c).

The destruction, damage or disturbance out of context of legally-protected fossils preserved at the ground surface or below ground that may occur during construction of the WEF entail direct *negative* impacts to palaeontological heritage resources that are confined to the development footprint (*localised*). These impacts can often be mitigated but cannot be fully rectified (*i.e.* they are *permanent*). All of the sedimentary formations represented within the study area contain fossils of some sort, so impacts *of some sort* on fossil heritage are *definite*. Most (but *not* all) of the fossils concerned are probably of widespread occurrence within the outcrop areas of the formations concerned, however. With the possible exception of small palaeontologically sensitive areas within the development footprint highlighted in Figure 68 (orange shapes) the likelihood of loss of *unique, well-preserved or rare* fossil heritage is therefore generally low (Rated *may occur* before mitigation to allow for the sensitive areas identified). Because of the generally sparse occurrence of scientifically important, well-preserved, unique or rare fossil material within the majority of the bedrock formations concerned here - notably those underlying the proposed wind turbine sites and access roads - as well as within the overlying superficial sediments (soil, alluvium, colluvium *etc*), the severity of these impacts before mitigation is conservatively rated as *moderate*. Should the proposed mitigation measures outlined in Section 5 of the report be fully implemented (so significant impacts are *unlikely*), the anticipated severity of impacts on palaeontological heritage would fall to *slight*.

As a consequence of (1) the paucity of irreplaceable, unique or rare fossil remains - as opposed to common, poorly-preserved fossil material of minimal scientific value - within the development footprint, (2) the high levels of bedrock weathering and tectonic deformation in the southern part of the study area, as well as (3) the extensive superficial sediment cover overlying most potentially-fossiliferous bedrocks within the Rietkloof WEF study area, the overall impact significance of the construction phase of the proposed wind energy project *before* mitigation is assessed as *MODERATE (negative).* The impact significance falls to *LOW (negative)* after mitigation. This assessment applies to the wind turbines, laydown areas, external access roads (three alternatives), substations (two alternatives), construction camps (3 alternatives) and all associated infrastructure within the WEF study area. A comparable moderate to low impact significance is inferred for all project infrastructure alternatives and layout options under consideration that are outlined in Section 1.1, including different options for routing of external access roads, turbine layouts and siting of construction camps and substations. There are therefore no preferences on palaeontological heritage grounds for any particular layout among the various options under consideration.

No significant further impacts on fossil heritage are anticipated during the planning, operational and de-commissioning phases of the WEF. The developer's proposal to actively improve the management of surrounding land within the project site for conservation purposes is unlikely to have a significant impact on palaeontological heritage resources. The No-go alternative (*i.e.* no WEF development) will have a neutral impact on palaeontological heritage (Potential benefits of successful mitigation of chance fossil finds would be partially offset by the natural weathering of fossils exposed in the *veld*, whether or not the WEF project goes ahead). There are no fatal flaws in the revised Rietkloof WEF development proposal as far as fossil heritage is concerned. *Providing that the proposed recommendations for palaeontological monitoring and mitigation are followed through* (See Section 5), there are no objections on palaeontological heritage grounds to authorisation of the revised Rietkloof WEF project.

Due to the generally low levels of bedrock exposure within the study area and the inevitably reconnaissance level of the brief field assessment undertaken, confidence levels for this palaeontological heritage assessment are only *moderate,* following the field assessment of numerous representative rock exposures (See Appendix 1). These conclusions are supported, however, by several previous palaeontological field assessments undertaken in the broader study region by the author (See References).

Table 1. Tabulated significance statement for the proposed Rietkloof WEF near Laingsburg (revised layout) with respect to scientifically valuable palaeontological heritage resources. This assessment applies to the construction phase and all layout options under consideration.

Impact	**IMPACTS ON PALAEONTOLOGICAL HERITAGE RESSOURCES**				
Impact Description	Destruction, damage or disturbance of fossil remains preserved at or beneath the ground surface during the construction phase as a result of ground clearance, excavations into superficial sediments or bedrock (*e.g.* for access roads, turbine footings, building foundations)				
Status of Impact (Positive/ Negative)	NEGATIVE (*N.B.* mitigation may have positive benefits)				
Impact	**Effect**			**Risk or Likelihood**	**Overall Significance**
	Temporal Scale	**Spatial Scale**	**Severity of Impact**		
Without Mitigation	Permanent	Localised	Moderate (-)	May occur	**MODERATE (-)**
With Mitigation	Permanent	Localised	Slight (-)	Unlikely	**LOW (-)**

No- Go Alternative:

It is mandatory to consider the “no-go” option in the BA process. The no development alternative option assumes there is construction of a 9 turbine WEF and associated infrastructure in the proposed project area. This alternative would not realise the positive impacts associated with the WEF.

4.1. Cumulative impacts

A considerable number of alternative energy developments have been proposed or already authorised in the broader south-western Karoo region within which the Rietkloof WEF study area is situated. Many, but not all, of these are shown in Figure 67 (abstracted from Almond 2016b). Additional WEF projects now shown here include the Esizayo WEF, Maralla East WEF and Maralla West WEF (Almond 2016e, 2016f). Desktop- and field-based assessments for a major proportion of these projects have been carried out by the author (See References) and colleagues (*e.g.* Miller 2011). It is noted that this region also falls within the shale gas prospecting area of Falcon Oil and Gas Ltd as well as the broader study area for the on-going Strategic Environmental Assessment for shale gas exploitation in the Karoo (fracking) that is being co-ordinated by the CSIR. Several of these projects entail impacts on comparable fossil heritage resources preserved within the same rock units of the Karoo Supergroup and overlying superficial sediments that are represented within the present study area (notably the Lower Beaufort Group). In all cases it was concluded by the author that, despite the undoubted occurrence of scientifically-important fossil remains (notably fossil vertebrates, vertebrate trackways and burrows, petrified wood), the overall impact significance of the proposed developments (including the new wind farms proposed in the area) was low because the probability of significant impacts on unique or rare fossils was slight.

Provided that the proposed monitoring and mitigation recommendations made for these various projects are effectively followed through, their cumulative impact on palaeontological heritage resources - including impacts envisaged for the revised Rietkloof WEF project – is predicted to be low (negative) following a similar rationale to that shown in Table 1. On the other hand, unavoidable residual negative impacts may be partially counterbalanced by an improved understanding of Karoo palaeontology resulting from appropriate professional mitigation for these projects. This is regarded as a significant *positive* impact for Karoo palaeontological heritage.

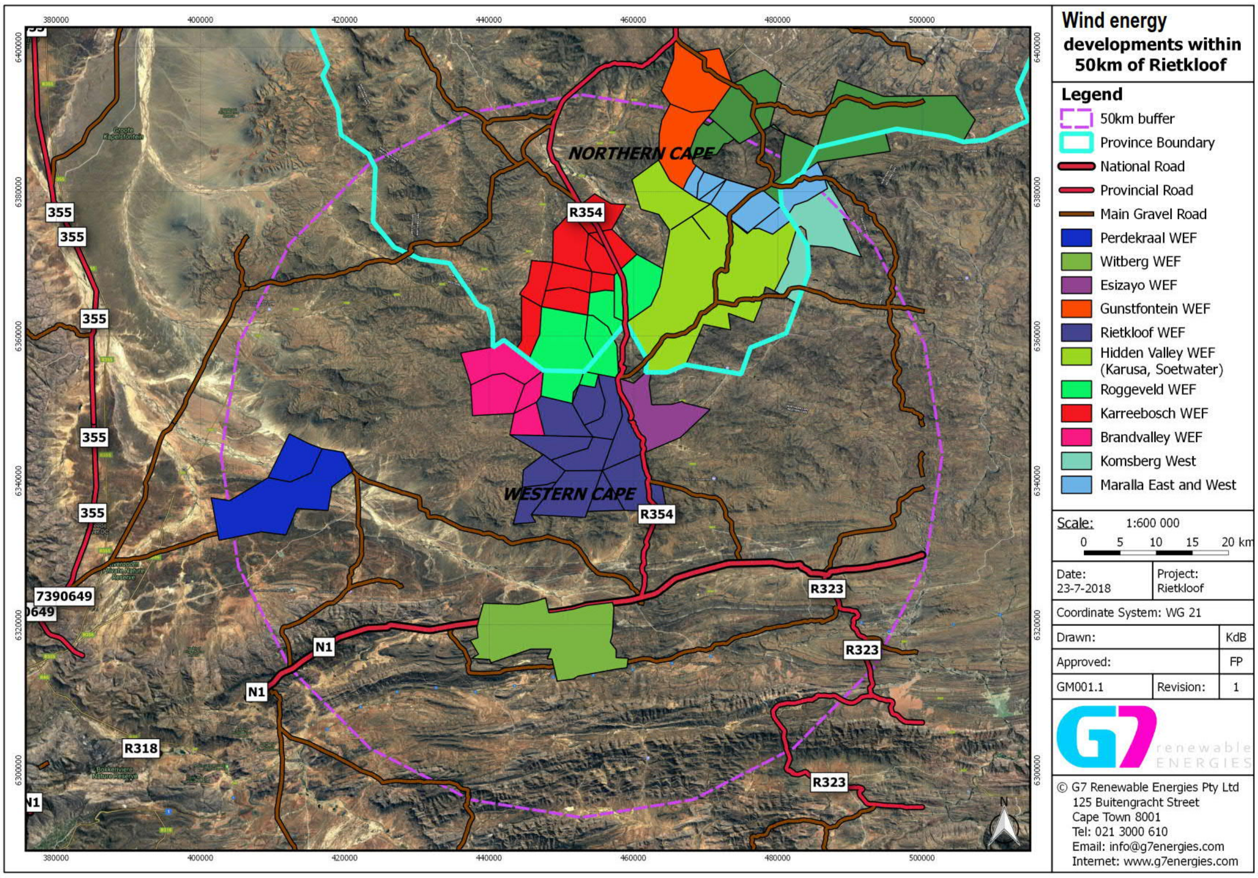

Figure 67. Map outlining proposed or approved alternative energy projects in the SW Karoo region surrounding the Rietkloof WEF project area (black polygon) (Image prepared byG9 Rewable Energies Pty Ltd (G9)).

5. MITIGATION & RECOMMENDATIONS FOR THE ENVIRONMENTAL MANAGEMENT PROGRAMME

The great majority of the Rietkloof WEF study area is assessed as being of low palaeontological sensitivity due to the paucity of irreplaceable, unique or rare fossil remains here. The concentration of blocks and logs of well-preserved petrified wood from the Waterford Formation exposed on the slopes of Kranskop, Wilgehout Fontein 87 (area outlined in *purple* in Figs. 2, 68) is a notable exception. This highly sensitive area, which lies well *outside* the WEF development footprint, should *not* be disturbed. Highly sensitive "no-go" areas within the proposed development footprint itself have not been identified in this study.

Pending the potential discovery of substantial new fossil remains during construction, specialist palaeontological mitigation is only recommended within two narrow upland areas of Waterford Formation outcrop close to Kranskop. These are outlined in *orange* in Figs. 2 and 68. Once the footprint for access roads and wind turbine placements within these two potentially sensitive areas is finalised, and *before* construction starts, these areas should be surveyed for fossil wood occurrences by a professional palaeontologist. 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). Where practicable, fossils remaining on site should be safeguarded, for example by moving them away from the development footprint.

The Environmental Control Officer (ECO) responsible for the WEF development should be made aware of the potential occurrence of scientifically-important fossil remains within the development footprint. During the construction phase all major clearance operations (*e.g.* for new access roads, turbine placements) and deeper (> 1 m) excavations should be monitored for fossil remains on an on-going basis by the ECO. Should substantial fossil remains - such as vertebrate bones and teeth, or petrified logs of fossil wood - be encountered at surface or exposed during construction, the ECO should safeguard these, preferably *in situ*. They should then alert Heritage Western Cape (HWC) as soon as possible (Contact details: Protea Assurance Building, Green Market Square, Cape Town 8000. Private Bag X9067, Cape Town 8001. Tel: 086-142 142. Fax: 021-483 9842. Email: hwc@pgwc.gov.za). This is to ensure that appropriate action (*i.e.* recording, sampling or collection of fossils, recording of relevant geological data) can be taken by a professional palaeontologist at the developer's expense. Please refer to the tabulated Chance Fossil Finds procedure is provided in Appendix 2.

The palaeontologist concerned with mitigation work will need a valid fossil collection permit from Heritage Western Cape 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 developed by SAHRA (2013).

These monitoring and mitigation recommendations should be incorporated into the Environmental Management Programme (EMPr) for the Rietkloof WEF. The operational and decommissioning phases of the development are unlikely to have further significant impacts on palaeontological heritage and no recommendations are made in this regard.

It should be noted that, should fossils be discovered before or during construction and reported by the responsible ECO to the responsible heritage management authority (HWC) for professional recording and collection, as recommended here, the overall impact significance of the project would remain low (negative). However, residual negative impacts from inevitable loss of fossil heritage would be partially offset by an improved palaeontological database 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 of the Great Karoo would constitute a useful addition to our scientific understanding of the fossil heritage here.

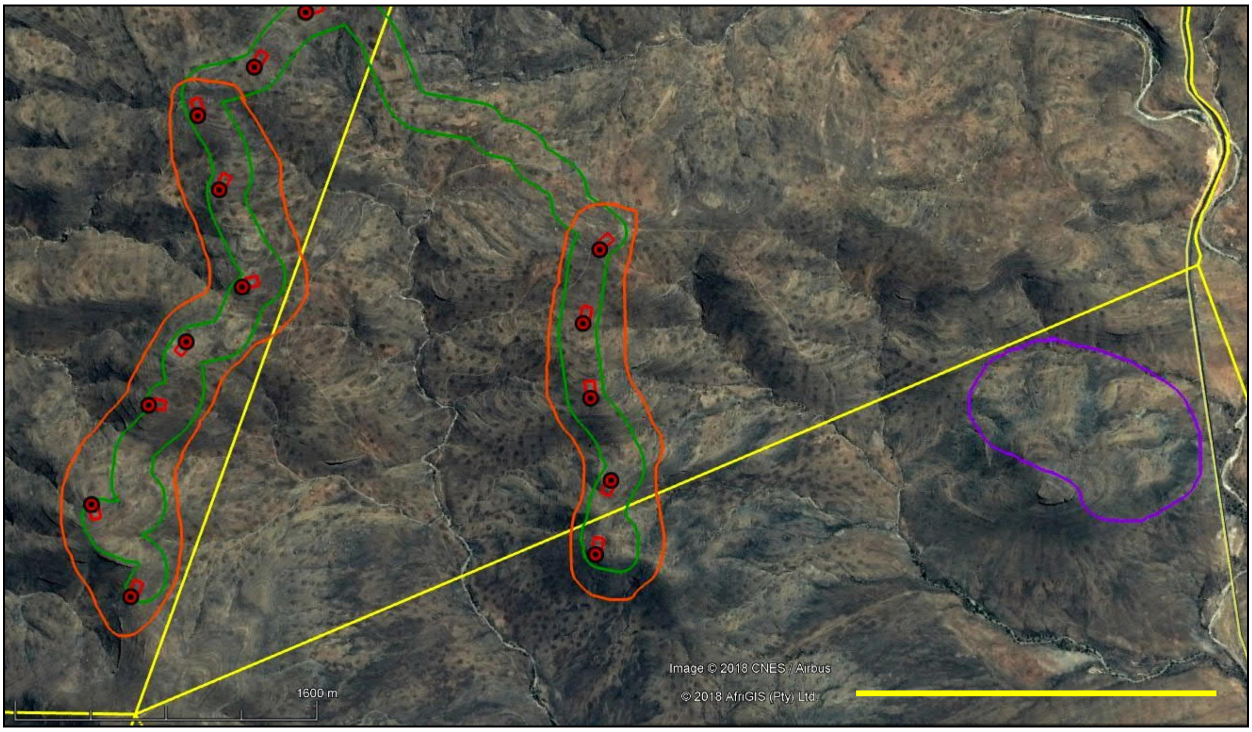

Figure 68. Google Earth© satellite image showing in detail the identified palaeontologically-sensitive areas within the eastern portion of the Rietkloof WEF project area (Please refer to Figure 2 for context). Scale bar = 2 km. N towards the top of the image. The small area outlined in *purple* (Kranskop on Wilgehout Fontein 87) features palaeontologically important, well-preserved fossil wood from the Waterford Formation and should be safeguarded from development. It is recommended that, once the final WEF layout is determined and *before* construction commences, the two nearby areas of Waterford Formation outcrop outlined in *orange* (located on farms Hartjieskraal RE/77, Nuwerus RE/284 & Wilgehout Fontein RE/87) are surveyed by a professional palaeontologist to record, safeguard and sample any well-preserved fossil wood exposed here. The turbines proposed within the orange areas can be authorised by DEA on condition that the mitigation measure as outlined above are implemented.

6. SUMMARY STATEMENT ON FOSSIL HERITAGE IMPACTS AND PROPOSED MITIGATION

IMPACT: Disturbance, damage or destruction of fossil heritage during the construction phase of the WEF

Cause and comment:

The Rietkloof WEF study area is underlain by several (*c*. 13) Palaeozoic to Late Caenozoic sedimentary formations that contain legally-protected fossil heritage. The construction phase of the proposed wind energy facility will entail substantial surface clearance (*e.g.* for access roads, wind turbine placements) as well as excavations into the superficial sediment cover (soils, surface gravels *etc*) and the underlying bedrock. The latter include excavations for the wind turbine foundations and transmission line pylon footings, underground cables, new internal access roads, construction camps and foundations for associated infrastructure such as the on-site substation and any control / storage buildings. In addition, sizeable areas of potentially fossiliferous bedrock may be sealed-in or sterilized by infrastructure such as hard standing areas for each wind turbine, lay down areas and access roads. All these developments may adversely affect fossils exposed at the surface or preserved underground within the development footprint. Fossil material here may be damaged, destroyed, disturbed from its original geological context or permanently sealed- in and is then no longer available for scientific research or other public good. Once constructed, the operational and decommissioning phases of the wind energy facility will not involve further adverse impacts on palaeontological heritage.

Significance Statement

Impacts associated with the disturbance, damage or destruction of fossil heritage during the construction phase of the WEF are direct, definite and permanent in effect. However, *significant* impacts (*i.e*. those affecting scientifically-important fossils that are of conservation value) are likely to be limited to small portions of the development footprint (localised) - for example the two areas outlined in orange in Fig. 68 - since such fossils are otherwise very scarce within the project area. It is concluded that, while such significant palaeontological impacts are possible (may occur), the overall severity of anticipated impacts without mitigation is moderate. The overall significance of the impacts without mitigation is assessed as MODERATE NEGATIVE. Impact significance can be meaningfully reduced to LOW NEGATIVE through implementation of the proposed monitoring and mitigation. Improved understanding of local fossil heritage through professional palaeontological mitigation can be viewed as a positive impact, however. Significant impacts on fossil heritage are not anticipated during the operational and decommissioning phases of the development. The developer's proposal to actively improve the management of surrounding land within the project site for conservation purposes is unlikely to have a significant impact on palaeontological heritage resources.

Impact Mitigation

- Pre-construction survey by a professional palaeontologist of two small areas in the eastern portion of the WEF project area (indicated in orange in Fig. 68) to record, sample and safeguard any significant well-preserved fossil wood or other fossil material here.

- Monitoring of all major surface clearance and deeper (> 1m) excavations for fossil material (bones, teeth, petrified wood *etc*) by the ECO on an on-going basis during the construction phase. Significant fossil finds to be reported to Heritage Western Cape for recording and sampling by a professional palaeontogist (See tabulated Chance Fossil Finds Procedure in Apppendix 2).

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9. QUALIFICATIONS & EXPERIENCE OF THE AUTHOR

Dr John Almond has an Honours Degree in Natural Sciences (Zoology) as well as a PhD in Palaeontology from the University of Cambridge, UK. He has been awarded post-doctoral research fellowships at Cambridge University and in Germany, and has carried out palaeontological research in Europe, North America, the Middle East as well as North and South Africa. For eight years he was a scientific officer (palaeontologist) for the Geological Survey / Council for Geoscience in the RSA. His current palaeontological research focuses on fossil record of the Precambrian - Cambrian boundary and the Cape Supergroup of South Africa. He has recently written palaeontological reviews for several 1: 250 000 geological maps published by the Council for Geoscience and has contributed educational material on fossils and evolution for new school textbooks in the RSA.

Since 2002 Dr Almond has also carried out palaeontological impact assessments for developments and conservation areas in the Western, Eastern and Northern Cape, Limpopo, Northwest, KwaZulu-Natal and the Free State under the aegis of his Cape Town-based company *Natura Viva* cc. He has served as a long-standing member of the Archaeology, Palaeontology and Meteorites Committee for Heritage Western Cape (HWC) and an advisor on palaeontological conservation and management issues for the Palaeontological Society of South Africa (PSSA), HWC and SAHRA. He is currently compiling technical reports on the provincial palaeontological heritage of Western, Northern and Eastern Cape for SAHRA and HWC. Dr Almond is an accredited member of PSSA and APHP (Association of Professional Heritage Practitioners – Western Cape).

Declaration of Independence

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

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APPENDIX 1: GPS LOCALITY DATA

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

Loc	GPS data	Comments
129	S33° 05' 56.1" E20° 35' 05.0"	Wilgehout Fontein 87. Ridge composed of several uncomformable packages of steeply-dipping, locally folded mudrocks, thin yellowish tuffs and ferruginous lenses of Collingham Fm, with several closely-spaced, prominent-weathering "Matjiesfontein Chert" beds. Deformation due to faulting and possibly also downslope megaslumps. Faulted contact with probable Prince Albert Fm mudrocks with ferruginous lenticles. Low diversity trace fossil assemblages of horizontal burrows ("*Chondrites*", "*Scolicia*").
131	S33° 05' 49.3" E20° 34' 32.5"	Wilgehout Fontein 87. Prominent-weathering ridge of thin-bedded, wavy-undulose wackes, ferruginous carbonate lenticles; probably Fort Brown Fm.
132	S33° 05' 56.8" E20° 34' 25.0"	Wilgehout Fontein 87.Thin-bedded, wavy-undulose, brownish wackes and tabular pale grey, fine-grained sandstones / wackes forming small upward-thickening packages; probably Fort Brown Fm.. Low diversity assemblages of small horizontal burrows.
133	S33° 06' 10.7" E20° 33' 31.6"	Wilgehout Fontein 87. Downwasted and sheetwash surface gravels overlying Lower Ecca Group bedrocks, dominated by angular clasts of silicified mudrock, vein quartz. Prominent-weathering beds or lenses of ferromagnesian mudrocks with Liesegang rings..
134	S33° 06' 16.8" E20° 31' 51.1"	Rietkloof 88. Shallow streambed exposure of Tierberg Fm, laminated to thin-bedded, dark grey to greenish-grey, highly tabular / laterally-persistent wackes plus thin-bedded, ripple cross-laminated sandstones with flat bases, wavy tops. Discrete, strata-bound zones of soft-sediment deformation, e.g. convolute bedding. Local development of cleavage quartz veining also.
135	S33° 07' 16.6" E20° 28' 04.4"	Vogelstruis Fontein 81. Very extensive exposure of Whitehill Fm white-weathering mudrocks and large (sev. m diameter), dark grey dolomite nodules in and around roadside borrow pit and surrounding Witrantjies area. Probable tectonic repetition by thrust faulting.
136	S33° 07' 15.9" E20° 28' 19.7"	Narrow, steeply-dipping zone of convolute-laminated, silicified Whitehill Fm mudrocks. Float blocks have misleading fossil wood-like appearance (*i.e.* pseudofossils).
137	S33° 07' 20.8" E20° 28' 05.5"	Vogelstruis Fontein 81. Multiple Matjiesfontein Chert-like beds associated with locally abundant stone artefacts, human quarrying of chert material.
138	S33° 07' 15.7" E20° 27' 56.3"	Vogelstruis Fontein 81.Dark grey, stromatolite-like laminated, calcite-veined dolomite concretion within Whitehill Fm. No fossil crustaceans seen.
139	S33° 06' 44.8" E20° 27' 57.7"	Vogelstruis Fontein 81. Buff silty to gravelly alluvial deposits of the Grootrivier (probably Holocene).
140	S33° 06' 47.6" E20° 27' 55.6"	Vogelstruis Fontein 81. Tectonically-deformed, NE-dipping Lower Ecca beds (Prince Albert, Whitehill & Collingham Fms) along southern bank of Grootrivier. Prince Albert Fm with interbedded tabular grey mudrocks and olive-brown wackes.
141	S33° 06' 52.3" E20° 27' 18.0"	Vogelstruis Fontein 81. Good riverbank sections through coarse gravely to silty alluvium (probably Pleistocene – Holocene) of Grootrivier. Clasts mainly of Ecca Group wackes, subangular to well-rounded, poorly-sorted, pebbly to bouldery.
142	S33° 06' 55.4" E20° 27' 12.3"	Vogelstruis Fontein 81. Good riverbank sections through coarse gravely to silty alluvium (probably Pleistocene – Holocene) of Grootrivier.Locally well-developed pebble imbrication. Good views of tectonised exposures of grey-green Prince Albert Fm along southern banks of Grootrivier in this area. Prominent-weathering, blackish to olive-brown beds and lenticles of ferruginised mudrock.

143	S33° 07' 03.0" E20° 26' 31.1"	Vogelstruis Fontein 81. Riverbed exposures of massive, grey, clast-poor to finely-gravelly diamictites of the Dwyka Group (Elandsvlei Fm), Grootrivier
144	S33° 07' 08.9" E20° 26' 07.8"	Vogelstruis Fontein 81. Well-jointed exposures of clast-poor Dwyka tillite on southern banks of Grootriver.
145	S33° 06' 52.1" E20° 25' 48.9"	Vogelstruis Fontein 81. Thick (2-3 m), pale cream, sparsely gravelly hardpan of nodular calcrete along drainage line (possibly Quaternary in age). Pale buff Holocene alluvial soils in region with surface gravels dominated by reworked calcrete clasts.
146	S33° 06' 33.8" E20° 25' 02.9"	Snyders Kloof 80. Extensive exposures of NW-dipping Tierberg Fm mudrocks and fine-grained sandstones / wackes along incised, north-south trending drainage line. Series of thin, upwards-coarsening and thickening packages with grey or grey-green, massive and hackly-weathering to laminated silty mudrocks at base, ferruginous carbonate concretions and lenses, thin-bedded, highly tabular grey-green wackes at top. Highly bioturbated horizons with fine-scale intrastratal horizontal burrows at intervals. Stratiform horizons of soft sediment deformation (*e.g.* load balls and pillows, convolute lamination). Margins of riverbanks mantled with coarse cobbly to bouldery alluvial gravels up to a few meters above present day stream level.
148	S33° 06' 41.0" E20° 25' 03.4"	Snyders Kloof 80. Same incised stream section as above, here showing good upper bedding plane exposures of tabular, NW-dipping Tierberg Fm wackes with interbedded packages of massive, hackly-weathering grey mudrocks. Adjacent *vlaktes* mantled with coarse, subrounded alluvial gravels of brown-weathering Ecca wacke.
150	S33° 04' 39.4" E20° 25' 19.9"	Snyders Kloof 80. Coarse, clast-inbricated basal alluvial gravels along stream valley overlain by matrix-supported breccio-conglomerates with angular wacke clasts suspended within brownish sandy to gritty matrix. Lower parts of succession are partially calcretised.
151	S33° 04' 39.5" E20° 25' 22.1"	Snyders Kloof 80. Calcretised breccias of Waterford Fm wackes, probably of debris flow origin, overlying deeply-weathered Waterford wacke and mudrock bedrocks with calcrete veining.
152	S33° 04' 27.9" E20° 25' 41.4"	Snyders Kloof 80. Streambank exposure of thick-bedded, flat-based Waterford Fm wacke, chaotic zone of balls and pillows, heterolithic, thin-bedded facies with interbedded grey mudrocks and thin sandstones showing complex soft sediment deformation (slump structures).
153	S33° 04' 57.8" E20° 26' 25.5"	Snyders Kloof 80, viewpoint along southern edge of escarpment (near bat mast) showing low levels of bedrock exposure (especially mudrocks, seen only along occasional stream valleys and erosion gulllies) in hilly upland areas, prominent-weathering, upward-coarsening packages of Waterford Fm wackes along upper edge of escarpment. Upland slopes mainly mantled with gravelly colluvial deposits dominated by angular clasts of Karoo wacke, fine-grained sandstones, clasts of dark rusty-brown diagenetic ferruginous carbonate (sometimes finely laminated)
154	S33° 04' 55.7" E20° 26' 33.3"	Snyders Kloof 80. Narrow hillslope exposure of grey-green massive, hackly-weathering mudrocks of the Waterford Fm. Diagenetic ferruginous carbonate concretions associated with both mudrock and wacke facies. Ball-and-pillow sandstone load structures within mudrocks, linear-crested wave rippled tops on sandstone beds. Lenticular sandstone bodies are possibly small distributary channel infills. No palaeocalcrete concretions.
155	S33° 06' 20.2" E20° 27' 25.2"	Vogelstruis Fontein 81. Coarse alluvial surface gravels of subrounded, orange-brown Ecca wacke cobbles, occasional boulders, on periphery of alluvial fan. Locally abundant angular clasts of reworked well-preserved petrified wood.
156	S33° 06' 15.6" E20° 27' 32.3"	Vogelstruis Fontein 81.Locally abundant silicified wood fragments among coarse alluvial gravels.
157	S33° 05' 23.9" E20° 25' 23.3"	Snyders Kloof 80. Erosion donga sections through fine gravelly alluvial deposits on footslopes of escarpment (mainly platy mudrock clasts). Calcretised coarser alluvial gravels

		at base.
158	S33° 05' 23.3" E20° 24' 35.2"	Snyders Kloof 80. Extensive erosion gully exposures through upper part of N-dipping, massive to thin-bedded Tierberg Fm succession in S-facing escarpment slopes. Succession of thin (c. 10 m-scale) sharp-topped upward-coarsening and –thickening packages. Horizons with abundant ferruginous carbonate oblate concretions & lenses, thin zones of soft-sediment deformation. Bedrocks mantled with partially calcretised colluvial gravels of angular Waterford wacke clasts in gritty matrix (probably debrites).
159	S33° 05' 20.3" E20° 24' 31.7"	Snyders Kloof 80. Large (c. 4 cm-wide) horizontal burrow of "*Plagiogmus*" type within silty grey-green silty mudrocks within top of upward-coarsening package, Tierberg Fm. Similar but smaller scale (1-2 cm wide) burrows seen in adjacent erosion gulley.
160	S33° 04' 40.4" E20° 29' 08.1"	Vogelstruis Fontein 81, Barendskloof just south of large dam. Erosion gulley exposures of thick (several m) pale brown, well-consolidated, sandy to coarse gravelly older alluvial deposits (Pleistocene – Holocene) on valley floor. Capped by cobbly surface gravels (perhaps reworked terrace gravels from valley margins). Lower gravelly horizons well-calcretised. Abundant stone artefacts (*e.g.* MSA tools of wacke, hornfels), some embedded within consolidated sandy to silty alluvium; some tools retain thin calcrete patina.
163	S33° 02' 38.3" E20° 26' 23.3"	Hartjies Kraal 77. Extensive hillslope exposure of upper surface of channel sandstone body, Lower Beaufort Group. Associated mudrocks poorly exposed in upland regions, associated with dark brown ferruginous calcrete nodules. Sandstone bodies laterally extensive, tabular.
164	S33° 02' 34.4" E20° 26' 19.4"	Hartjies Kraal 77. Stream gulley exposure of blue-grey and purple-brown overbank mudrocks, crevasse-splay sandstones of Lower Beaufort Group. Grey calcrete nodules, possible rhizoliths / stem casts or casts of lungfish burrows (vertical to oblique calcretised cylinders), concentrations of sphenophyte fern debris, possible gypsum lenticles.
165	S33° 01' 36.9" E20° 25' 24.7"	Hartjies Kraal 77. Stream bank exposure of Lower Beaufort Group grey-green to olive-weathering, hackly to crumbly overbank mudrocks, upper reaches of Maermanskloof. Ferruginous calcrete nodules. Horizons with arthrophyte plant debris (probably *Schizoneura*).
166	S33° 01' 27.3" E20° 24' 29.9"	Hartjies Kraal 77. Extensive hillslope stream gulley exposure of grey-green and purple-brown, hackly-weathering Lower Beaufort Group mudrocks with horizons of small greyish and larger rusty-brown pedocrete nodules, thin crevasse-splay sandstones..
167	S33° 01' 29.1" E20° 24' 27.2"	Hartjies Kraal 77. Lower Beaufort Group wave-rippled sandstone palaeosurface with linear tool marks – possibly biogenic. Fine-grained, well-sorted sandstone facies.
168	S33° 01' 37.2" E20° 24' 25.9"	Hartjies Kraal 77. Hillslope stream gulley exposure of Lower Beaufort Group. Thin-bedded siltstones (distal floodplain / playa lake) coarsen-up into grey-green wacke with ill-defined base. Local development of tectonic cleavage.
169	S33° 01' 40.6" E20° 24' 28.6"	Hartjies Kraal 77. Streambed and bank exposures of Lower Beaufort Group grey-green hackly mudrocks and tabular to lenticular, fine-grained sandstones. Horizons of large ferruginous carbonate pedocrete concretions. Sandstone facies variously (a) dark, fine-grained, well-sorted and well-consolidated with gradational bases or (b) medium-grained, friable, less well-cemented with sharper bases.
170	S33° 01' 39.4" E20° 24' 30.9"	Hartjies Kraal 77. Hillslope exposure of succession of tabular, sharp-based, upward-coarsening grey-green to purple-brown mudrock to fine sandstone cycles of Lower Beaufort Group.
171	S33° 01' 28.9" E20° 24' 33.7"	Hartjies Kraal 77. Gulley and hillslope exposure of Lower Beaufort Group sandstones, grey-green and purple-brown mudrocks. Horizons of large ferruginous pedocrete nodules. Upward-thickening sandstone package sharply overlain by overbank mudrocks.
172	S33° 01' 37.8" E20° 26' 10.5"	Hartjies Kraal 77. Lower Maermanskloof, extensive streambed exposure of swaley, well-jointed and well-consolidated upper surface of thick channel sandstone body, Lower Beaufort Group. Overlain by several meters semi-consolidated, very coarse, poorly-sorted mixed alluvial and colluvial deposits (angular to subrounded clasts, mainly sandstone), partially

		calcretised.
173	S33° 02' 24.4" E20° 27' 56.9"	Hartjies Kraal 77. Riverbank and cliff section through upper Waterford Formation. Thick amalgamated wacke / sandstone packages (laminated to massive, sharp, erosive base) overlying thin-bedded heterolithic package of grey mudrocks and wave-rippled sandstones. Beneath these are thicker wackes showing boulder-sized load balls / pillows, chaotic mélange or slump facies with complex inter-tonguing of sandstone and mudrock (flame structures *etc*). Probable steeply-inclined fault to the south, sudden change in dip associated with minor quartz veining, mineral lineation (See also swarm of W-E fractures here on satellite images).
174	S33° 03' 09.8" E20° 30' 16.4"	Hartjies Kraal 77. Hillslope and river bank exposures of thick packages of Waterford Fm wackes east of Hartjieskraal homestead (laterally extensive but *possibly* thicken and thin along strike in this region). Good exposures of wave-rippled, thin-bedded heterolithic facies (bioturbated bed tops, low diversity ichnoassemblages) overlain by thick-bedded, brownish, sharp-based wackes with large-scale load balls and pillows.
175	S33° 03' 08.6" E20° 30' 25.1"	Hartjies Kraal 77. Good riverbank sections through buff silty to sparsely gravelly, laminated to masssive Holocene alluvium, well-consolidated below, overlying coarse, poorly-sorted basal alluvial gravels
176	S33° 06' 12.7" E20° 31' 30.3"	Riet Kloof 88. Coarse, downwasted alluvial surface gravels with sparse clasts of reworked petrified wood.
177	S33° 05' 19.6" E20° 32' 04.4"	Riet Kloof 88. Stream gulley section through coarse, poorly-sorted alluvial fan debris overlying bedrock. Mainly angular clasts of Karoo wacke, partially calcretised below.
178	S33° 04' 51.0" E20° 31' 19.9"	Riet Kloof 88. Probable lowermost Beaufort Group, flaggy sandstone surface with dense rounded casts of plant stems (possibly reedy equisetaleans).
179	S33° 04' 55.9" E20° 31' 25.5"	Riet Kloof 88. Hillslope erosion gulley exposure of Lower Beaufort Group grey-green mudrocks, large ferruginous calcrete concretions.
180	S33° 05' 46.9" E20° 31' 54.3"	Riet Kloof 88. Coarse downwasted alluvial gravels with sparse petrified wood clasts.
181	S33° 03' 33.4" E20° 34' 15.9"	Wilgehout Fontein 87, SW side of Kranskop. Stream gulley exposure of Fort Brown Fm thin-bedded, wave-rippled sandstones / wackes and grey to khaki siltstones forming thin upward-coarsening packages. Occasional small-scale channel infill features. Ferruginous carbonate concretions. Low diversity ichnoassemblages (horizontal burrows, possible *Lockeia* bivalve burrows).
182	S33° 03' 27.1" E20° 34' 07.1"	Wilgehout Fontein 87. Excellent, extensive,incised stream bank exposure of Fort Brown Fm showing upward-coarsening packages. Highly tabular laminated to thin-bedded grey-green siltstones, fine-grained wackes, thin (10 cm) parallel-laminated sandstones. Low diversity ichnoassemblages (dense epichnial horizontal burrows, occasional larger – 0.5cm - burrows). Wave-rippled bed tops. Bedrocks overlain by calcretised coarse alluvium / colluvium of angular sandstone / wacke clasts with interbeds of finer gravels and grits.
183	S33° 03' 15.9" E20° 34' 19.7"	Wilgehout Fontein 87. Isolated float clast of well-preserved silicified wood, Fort Brown / Waterford Fm, Kranskop.
184	S33° 03' 12.4" E20° 34' 25.3"	Wilgehout Fontein 87. Isolated float clast of well-preserved silicified wood, Fort Brown / Waterford Fm, Kranskop.
185	S33° 03' 10.2" E20° 34' 32.2"	Wilgehout Fontein 87. Several float clasts of well-preserved silicified wood, Fort Brown / Waterford Fm, Kranskop.
186	S33° 03' 09.8" E20° 34' 43.9"	Wilgehout Fontein 87. Stream gulley exposure of thin-bedded, grey Fort Brown Fm siltstones and wackes. Large (c. 1cm wide) horizontal furrows or burrows. Isolated small float block of petrified wood, Kranskop.

187	S33° 03' 02.1" E20° 34' 40.8"	Wilgehout Fontein 87. Fragment of well-preserved petrified log embedded within colluvial gravels of Waterford Fm, Kranskop.
188	S33° 03' 06.8" E20° 34' 33.6"	Wilgehout Fontein 87. Float block of well-preserved petrified log on colluvial gravels of Waterford Fm, Kranskop.
189	S33° 03' 12.4" E20° 34' 24.6"	Wilgehout Fontein 87, NW slopes of Kranskop. Sandstone float block with numerous rope-like burrows of "*Palaeophycus striatus*", possible *Lockeia* bivalve burrows, Waterford Fm.
190	S33° 02' 55.3" E20° 33' 46.3"	Wilgehout Fontein 87. Concentration of petrified wood blocks in surface float above Waterford Fm
191	S33° 01' 50.4" E20° 33' 39.1"	Annex Hartjes Kraal 82, Wilgerboskloof. Stream bed and bank exposure of Lower Beaufort Group purple-brown and grey-green mudrocks and sandstones. Large ferruginous carbonate concretions. Local development of closely-spaced jointing within sandstones.
192	S33° 01' 53.4" E20° 34' 33.7"	Wilgerhout Fontein 87, Wilgerboskloof. Excellent south-facing cliff sections through thick Waterford Formation sandstone package (probably lenticular along strike). Predominantly tabular bedding with large load features.
192a	S33° 02' 12.3" E20° 34' 57.2"	Wilgerhout Fontein 87, Wilgerboskloof. Northeast-facing riverine cliff section through sandstone packages and mudrocks of the Waterford Fm (close to and visible from R354 tar road). Good sedimentological features (upward-coarsening packages, loading, lenticular channels *etc*).
221	S33° 01' 22.6" E20° 26' 38.0"	Hartjies Kraal 77. Stream gulley and bank exposure of Lower Beaufort Group sandstones and crumbly grey-green mudrocks. Poorly-preserved horizontal burrows on sandstone bed tops (including possible *Teichichnus*). Finely-rippled sandstone palaeosurface with microbial mat textures, adhesion warts. Overlying mudrocks with *possible* sandstone casts of vertebrate burrows.
222	S33° 01' 39.8" E20° 27' 07.5"	Hartjies Kraal 77. Erosion gulley and hillslope exposures of Lower Beaufort Group sandstones and hackly grey-green mudrocks.
223	S33° 01' 42.9" E20° 29' 18.4"	Hartjies Kraal 77, Lower Beaufort Group exposures in stream bed and banks in Voetpadskloof. Large scale sandstone bedforms (trough crossbeds) on channel sandstone top. Ferruginous calcrete horizons within overbank mudrocks.
224	S33° 03' 04.6" E20° 34' 55.9"	Wilgehout Fontein 87, sizeable quarry excavated into thin-bedded, wave-rippled siltstones and fine sandstones as well as tabular, medium-bedded wackes of the Fort Brown Fm (as mapped) / lower Waterford Fm. Well-exposed ladder-backed, interference and linear-crested ripples (*NB* contrasting ripple crest azimuths), thin mudflake intraclast horizons. Poorly-preserved low diversity trace fossil assemblages (indeterminate horizontal burrows, furrows and positive hypichnia, some washed-out, on soles) on upper bedding planes.
225	S33° 03' 04.6" E20° 34' 53.7"	Hartjies Kraal 77, NE slopes of Kranskop. Float blocks of well-preserved petrified wood among surface gravels, Waterford Fm.
226	S33° 03' 05.0" E20° 34' 43.7"	Hartjies Kraal 77, NE slopes of Kranskop. Float block of well-preserved petrified wood among surface gravels, Waterford Fm .
227	S33° 03' 05.1" E20° 34' 41.9"	Hartjies Kraal 77, NE slopes of Kranskop. Float block of well-preserved petrified wood among surface gravels, Waterford Fm. Several additional blocks upslope.
228	S33° 03' 05.2" E20° 34' 40.7"	Hartjies Kraal 77, NE slopes of Kranskop. Several float blocks of well-preserved petrified wood among surface gravels, Waterford Fm
229	S33° 03' 06.1" E20° 34' 35.3"	Hartjies Kraal 77, concentration of petrified wood, partial logs (Radius ≥ 35 cm) on northern slopes of Kranskop, Waterford Fm. Occasional additional fragments occur downslope to the north.
230	S33° 03' 06.2"	Hartjies Kraal 77, sizeable petrified log on NE slopes of Kranskop, Waterford Fm.

	E20° 34' 41.6"	
231	S33° 15' 25.2" E20° 34' 21.7"	Hartjies Kraal 77, good streambed exposures on lower slopes of Kranskop of Fort Brown / Waterford Fm thin bedded mudrocks and wave-rippled sandstones.
232	S33° 03' 07.6" E20° 34' 49.9"	Hartjies Kraal 77, wave-rippled sandstone palaeosurface in streambed just uphill from quarry, Fort Brown Fm. Vague curving horizontal burrows, enigmatic impressions.
233	S33° 02' 38.2" E20° 35' 07.0"	Wilgehout Fontein 87. Road cuttings along the R354 showing spectacular soft-sediment deformation within the Waterford Formation (ball-and-pillow structures).

<table>
<tr><td colspan="3">APPENDIX 2: CHANCE FOSSIL FINDS PROCEDURE: RIETKLOOF WIND ENERGY FACILITY NEAR LAINGSBURG</td></tr>
<tr><td>Province & region:</td><td colspan="2">Western Cape, Laingsburg Local Municipality</td></tr>
<tr><td>Responsible Heritage Management Authority</td><td colspan="2">HERITAGE WESTERN CAPE. Protea Assurance Building, Green Market Square, Cape Town 8000. Private Bag X9067, Cape Town 8001. Tel: 086-142 142. Fax: 021-483 9842. Email: hwc@pgwc.gov.za</td></tr>
<tr><td>Rock unit(s)</td><td colspan="2">Ecca Group (esp. Waterford Fm), Abrahamskraal Formation (L. Beaufort Group); Caenozoic alluvium.</td></tr>
<tr><td>Potential fossils</td><td colspan="2">Petrified wood (incl. well-preserved logs), mesosaurid reptiles, trace fossils in Ecca Group. Rare vertebrate skeletal remains, vertebrate burrows and trackways, petrified wood and other plant material in Abrahamskraal FmFossil bones, teeth and horn cores within Late Caenozoic alluvium.</td></tr>
<tr><td rowspan="5">ECO protocol</td><td colspan="2">1. Once alerted to fossil occurrence(s): alert site foreman, stop work in area immediately (N.B. safety first!), safeguard site with security tape / fence / sand bags if necessary.</td></tr>
<tr><td colspan="2">2. Record key data while fossil remains are still in situ:
• Accurate geographic location – describe and mark on site map / 1: 50 000 map / satellite image / aerial photo
• Context – describe position of fossils within stratigraphy (rock layering), depth below surface
• Photograph fossil(s) in situ with scale, from different angles, including images showing context (e.g. rock layering)</td></tr>
<tr><td>3. If feasible to leave fossils in situ:
• Alert Heritage Resources Authority and project palaeontologist (if any) who will advise on any necessary mitigation
• Ensure fossil site remains safeguarded until clearance is given by the Heritage Resources Authority for work to resume</td><td>3. If not feasible to leave fossils in situ (emergency procedure only):
• Carefully remove fossils, as far as possible still enclosed within the original sedimentary matrix (e.g. entire block of fossiliferous rock)
• Photograph fossils against a plain, level background, with scale
• Carefully wrap fossils in several layers of newspaper / tissue paper / plastic bags
• Safeguard fossils together with locality and collection data (including collector and date) in a box in a safe place for examination by a palaeontologist
• Alert Heritage Resources Authority and project palaeontologist (if any) who will advise on any necessary mitigation</td></tr>
<tr><td colspan="2">4. If required by Heritage Resources Authority, ensure that a suitably-qualified specialist palaeontologist is appointed as soon as possible by the developer.</td></tr>
<tr><td colspan="2">5. Implement any further mitigation measures proposed by the palaeontologist and Heritage Resources Authority</td></tr>
<tr><td>Specialist palaeontologist</td><td colspan="2">Record, describe and judiciously sample fossil remains together with relevant contextual data (stratigraphy / sedimentology / taphonomy). Ensure that fossils are curated in an approved repository (e.g. museum / university / Council for Geoscience collection) together with full collection data. Submit Palaeontological Mitigation report to Heritage Resources Authority. Adhere to best international practice for palaeontological fieldwork and Heritage Resources Authority minimum standards.</td></tr>
</table>