PALAEONTOLOGICAL HERITAGE ASSESSMENT: COMBINED DESKTOP & FIELD-BASED STUDY

PROPOSED BRANDVALLEY WIND ENERGY FACILITY NEAR LAINGSBURG, WESTERN & NORTHERN CAPE PROVINCES

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EXECUTIVE SUMMARY

Brandvalley 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 45 km northwest of Laingsburg, Western and Northern Cape Provinces. The Brandvalley WEF study area lies in the mountainous Klein-Roggeveldberge region and is underlain by several formations of potentially fossil-baring sedimentary rocks (Fig. 4). The majority of the bedrocks are of Late Palaeozoic age (Middle Permian) and belong to the Karoo Supergroup which is internationally famous for its rich fossil record. Palaeontological field assessment of the Brandvalley WEF study area shows that in this portion of the south-western Karoo:

- Waterford Formation (Upper Ecca Group) deltaic bedrocks have small outcrop areas crossing the central part of the study area. These small areas lie largely outside the main development footprint and are generally fossil-poor, apart from low-diversity trace fossil assemblages. However, isolated blocks and rare logs of well-preserved petrified wood recorded from this formation just to the south of the study area (Rietkloof WEF project area) are of high scientific and conservation value and similar material might also be present in the Brandvalley WEF study area.
- Abrahamskraal Formation (Lower Beaufort Group) fluvial bedrocks underlying the great majority of the study area are generally considered to be of high palaeontological sensitivity. However, in this area of the south-western Karoo they are generally fossil-poor, apart from occasional horizons with plant debris or low-diversity trace fossils. A few examples of large tetrapod (*i.e.* terrestrial vertebrate) burrows as well as disarticulated skeletal remains (dispersed bones, teeth) recorded from these beds during the present field assessment are of considerable scientific interest but are very rare indeed.
- 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 and elsewhere locally contain numerous clasts of petrified wood reworked from the Karoo Supergroup (probably Waterford Formation).

The overall impact significance of the construction phase of the proposed wind energy project is assessed as LOW (negative) 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 as well as (2) the extensive superficial sediment cover overlying most potentially-fossiliferous bedrocks within the Brandvalley WEF study area. This assessment applies to the wind turbines, laydown areas, access roads, substations, construction camps including a batching plant area, 33kV powerlines and associated WEF infrastructure within the study area. A comparable low 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.

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 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 Brandvalley WEF development proposal as far as fossil heritage is concerned. Providing 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 Brandvalley 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 Brandvalley 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 great majority of the Brandvalley WEF study area is assessed as being of low palaeontological sensitivity due to the scarcity of significant fossil vertebrate, plant and other remains here. Sensitive no-go areas within the proposed development footprint itself have not been identified in this study. The occurrence of very rare tetrapod (*i.e.* terrestrial vertebrate) burrows and associated skeletal remains within the Abrahamskraal Formation along the Kabeltou Pass (Muishond Rivier 161) is a notable exception. This highly sensitive area (outlined in green in Fig. 2), which lies within the Western Cape and *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 not recommended for the Brandvalley WEF project.

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 the relevant provincial heritage management authority as soon as possible - *i.e.* Heritage Western Cape for the Western Cape (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) and 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). 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.

These mitigation recommendations should be incorporated into the Environmental Management Plan (EMP) for the Brandvalley 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 / SAHRA 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 Brandvalley 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 45 km northwest of Laingsburg. The site lies within the Karoo Hoogland, Witzenberg (Ceres) and Laingsburg Local Municipalities, which in turn fall within the Namakwa, the Cape Winelands and the Central Karoo District Municipalities of the Western and Northern Cape Provinces (Fig. 1).

The Brandvalley WEF project area extends over an area of some 25 500 ha and comprises the following land portions: The Remainder of Barrendskraal 76, Portion 1 of Barendskraal 76, the Remainder of Brandvalley 75, Portion 1 of Brandvalley 75, the Remainder of Fortuin 74, Portion 3 of Fortuin 74, the Remainder of Kabeltouw 160, the Remainder of Muishondrivier 161, Portion 1 of Muishondrivier 161, Portion 1 of Fortuin 74 (Ou Mure) and the Farm Rietfontein 197 (Fig. 2).

The main infrastructural components of the Brandvalley WEF that are relevant to the present palaeontological heritage assessment are as follows:

- Up to 70 potential wind turbines (between 1.5 MW and 4 MW in capacity each), each with a foundation 25 m in diameter and 4 m in depth.
- Permanent compacted hard-standing laydown areas for each wind turbine (70 m x 50 m, total 24.5 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 12 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.
- Borrow pits and quarries for locally sourcing aggregates required for construction (~4.5 ha) in addition to onsite turbine excavations where required. All materials excavated will eventually be used on the compacting of the roads and hard-standing areas. The number and size of the borrow pits depends on suitability of the subsurface soils and the requirement for granular material for access road construction and other earthworks. Alternative borrow pit locations will be assessed in a separate BA process.
- Fencing around the construction camp.
- Temporary infrastructure to obtain water from available local sources / new or existing boreholes. Water will potentially be stored in temporary water storage tanks. The necessary approvals from the DWS will be applied for separately to this EIA process.

The following alternative options for aspects of the Brandvalley WEF are under consideration in the EIA Phase (Fig. 2b):

1. Fundamental alternatives:
    1.1 Project area location alternative: One project location alternative, namely Brandvalley Wind Farm

1.2 Access road location alternatives: two access road alternatives, namely access road alternative 1 and access road alternative 2
1.3 Construction camp alternatives, namely construction camp 1, 2 or 3
1.4 Four onsite substation location alternatives, namely substation alternatives 1, 2, 3 or 4.
1.5 Technology alternative: One technology alternative, namely a WEF

2. Incremental alternatives:
   2.1 Turbine layout alternatives
   2.2 200 m buffer on access roads for sensitivity alternatives

3. No-go alternative

As a result of input from specialists, the following changes to the original layout for the Brandvalley WEF (as shown in Fig. 2) have been proposed and are assessed in this report. The area near Snydersberg (located in the northern section of the project area, comprising 12 proposed turbines) has been identified as a very sensitive area. The access roads have therefore been re-routed to follow existing roads and two turbines (38 and 42) have been taken out. The footprint within this area has therefore been reduced by approximately 40%.

It is planned to develop the Brandvalley WEF in parallel with a second 140 MW WEF just to the south, known as the Rietkloof WEF (See Almond 2016b). The latter alternative energy project is being proposed by Rietkloof Wind Farm (Pty) Ltd, another subsidiary of G7. The Rietkloof WEF project area is situated on adjacent properties to the Brandvalley WEF, some of which overlap in this application for Environmental Authorisation (EA). A separate Environmental Impact Assessment (EIA) process is being undertaken for each of the two WEFs, running in parallel. Two separate Basic Assessments (BAs) will also be undertaken to assess the grid connection alternatives and overhead power lines for the WEFs.

The Brandvalley 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 those portions of the Brandvalley WEF falling within the Western Cape has been requested by Heritage Western Cape (HWC) as part of an integrated heritage assessment for this project (HWC letters of 1 March 2016, their Case Nos. 15110409AS0219E and 16021701AS0219E). With reference to those portions of the project area falling within the Northern Cape, SAHRA has requested a palaeontological impact assessment (PIA) (their letter of 25 February 2016, Case ID: 9103). The heritage report must clearly state which heritage resources are located within the Northern Cape and Western Cape Provinces to allow the relevant Heritage Resource Authority (HRA) to provide comments. The report must also clearly state the distance between each proposed project activity and identified resources *via* detailed descriptions and a map.

The present combined desktop and field-based palaeontological heritage assessment of the Brandvalley WEF project area has accordingly been commissioned as part of the EIA for this development that is being co-ordinated on behalf of G7 by EOH Coastal & Environmental Services, Cape Town (Contact details: Ms Belinda Huddy. EOH Coastal & Environmental Services. The Point, Suite 408, 4th Floor, 76 Regent Road, Sea Point, Cape Town RSA. Tel: +27 (021) 045 0904. Fax: +27 (46) 622 6564. E-mail: b.huddy@cesnet.co.za).

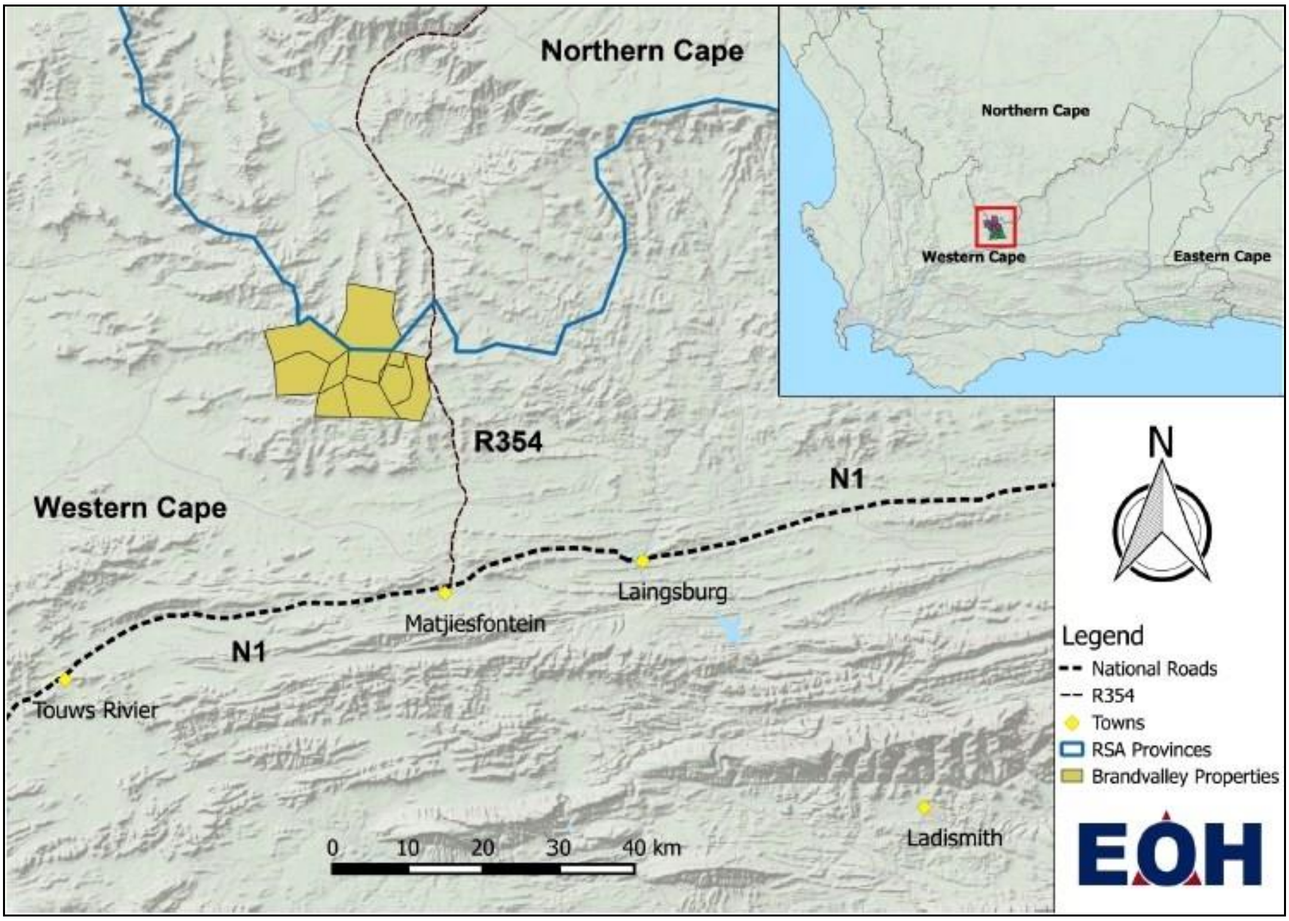
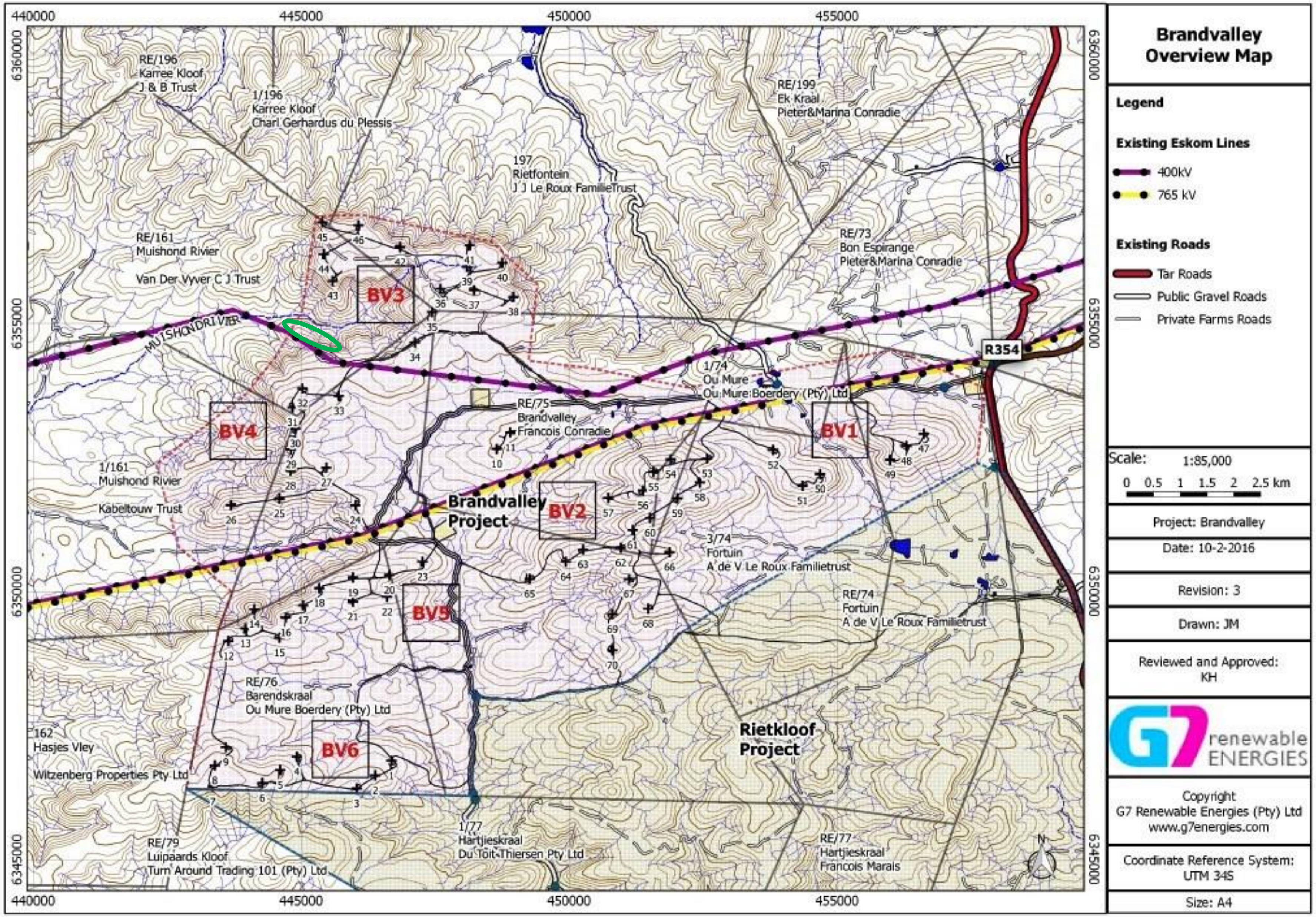


Figure 1. Map showing the approximate location of land parcels making up the Brandvalley WEF project area, situated *c*. 45 km NW of Laingsburg, Western and Northern Cape (purple polygon) (Image abstracted from the Draft Scoping Report by EOH, January 2016). The study area lies within the mountainous Klein-Roggeveldberge region to the west of the R354 Matjiesfontein to Sutherland tar road. The blue line demarcates the boundary between the Northern and Western Cape.

Figure 2a (following page). Overview map of the Brandvalley WEF project area showing the various land portions involved, topography, roads as well as a provisional layout of turbine positions. Note that this original layout in the area referred to as BV3 has subsequently been slightly modified in the light of specialist input (See text Section 1.1 for discussion).

The small area outlined in green (Kabeltouw Pass on Muishond Rivier 161, Western Cape) features palaeontologically important tetrapod burrows ad skeletal remains in the Abrahamskraal Formation and should be safeguarded from disturbance or development.



Brandvalley Overview Map
Legend
Existing Eskom Lines
400kV
765 kV
Existing Roads
Tar Roads
Public Gravel Roads
Private Farms Roads
Scale: 1:85,000
0 0.5 1 1.5 2 2.5 km
Project: Brandvalley
Date: 10-2-2016
Revision: 3
Drawn: JM
Reviewed and Approved: KH
renewable ENERGIES
Copyright
G7 Renewable Energies (Pty) Ltd
www.g7energies.com
Coordinate Reference System: UTM 34S
Size: A4
BV1
BV2
BV3
BV4
BV5
BV6
Brandvalley Project
Rietkloof Project
R354
MUISHOND RIVIER
RE/196 Karree Kloof J & B Trust
1/196 Karree Kloof Charl Gerhardus du Plessis
197 Rietfontein J J Le Roux FamilieTrust
RE/199 Ek Kraal Pieter&Marina Conradie
RE/161 Muishond Rivier
Van Der Vyver C J Trust
RE/73 Bon Espirange Pieter&Marina Conradie
1/74 Ou Mure Ou Mure Boerdery (Pty) Ltd
RE/75 Brandvalley Francois Conradie
1/161 Muishond Rivier
Kabeltouw Trust
3/74 Fortuin A de V Le Roux Familietrust
RE/74 Fortuin A de V Le Roux Familietrust
RE/76 Barendskraal Ou Mure Boerdery (Pty) Ltd
162 Hasjes Vley
Witzenberg Properties Pty Ltd
1/77 Hartjieskraal Du Toit-Thiersen Pty Ltd
RE/77 Hartjieskraal Francois Marais
RE/79 Luipaards Kloof Turn Around Trading 101 (Pty) Ltd
440000
445000
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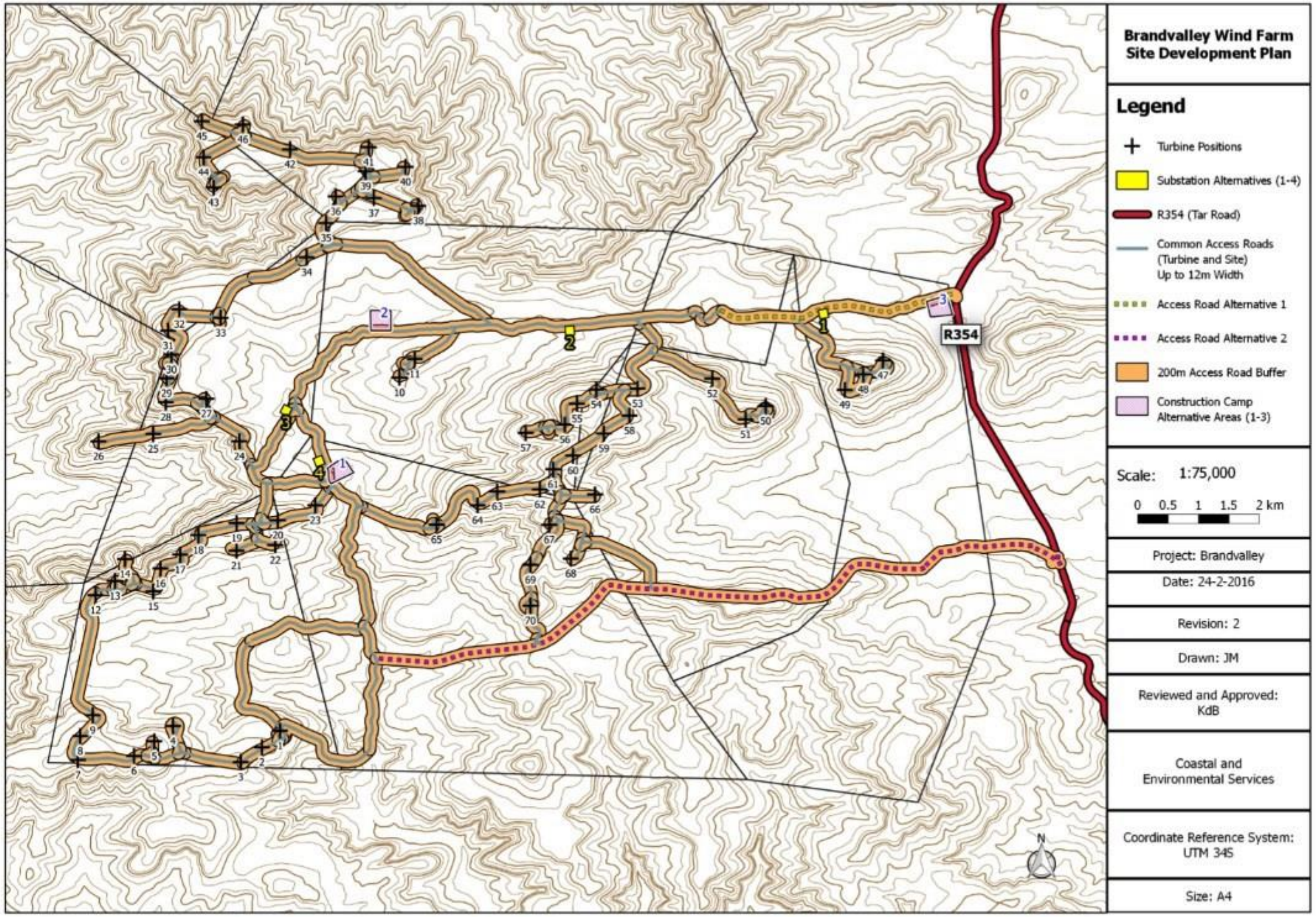

Figure 2b. Map of the site development plan for the proposed Brandvalley WEF showing alternative access roads as well as sites for construction camps and substations.

1.2. Legislative context for palaeontological assessment studies

The present combined desktop and field-based palaeontological heritage assessment report contributes to the consolidated heritage assessment for the proposed Brandvalley WEF and falls under the South African Heritage Resources Act (Act No. 25 of 1999). It will also inform the Environmental Management Programme (EMP) 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 CES assessment methodology 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 Brandvalley WEF study area near Laingsburg in the Western and Northern 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 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 region 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 kindly supplied by EOH Coastal & Environmental Services;
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. 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, 2011, 2014, 2015, 2015a-g, Almond 2016b). Note that the 2014 study area for the Kareebosch WEF overlaps the northernmost portion of the Brandvalley WEF. Relevant geological and palaeontological data (including photographs) from the former have therefore been made use of in this later report.

4. A four-day palaeontological field assessment of the Brandvalley 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 the Appendix. Further field data directly relevant to the Brandvalley WEF study area is given in the separate palaeontological assessment of the adjoining Rietkloof WEF to the south (Almond 2016b.).

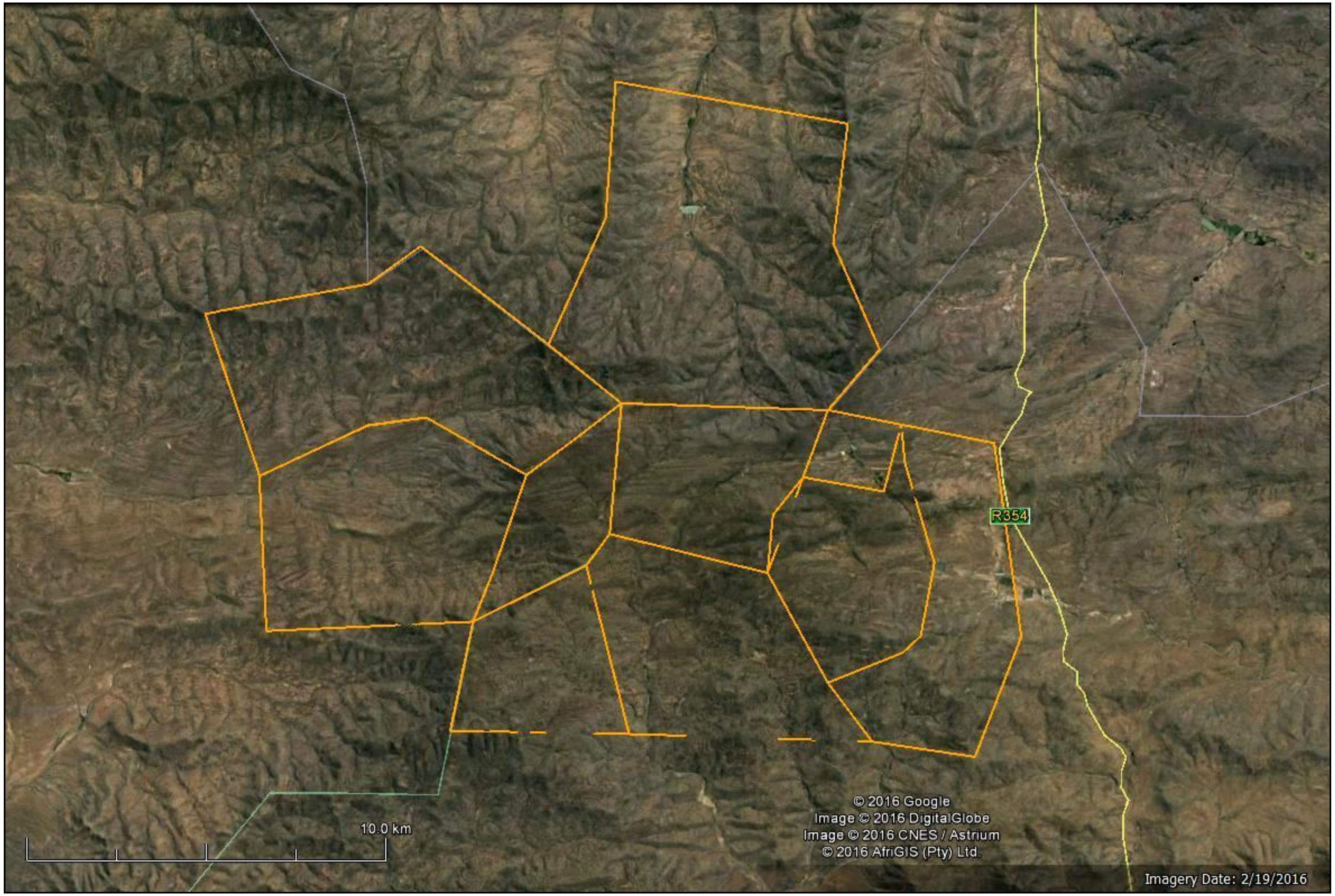

Figure 3. Google earth© satellite image of the Bradvalley WEF study area showing the constituent farm portions (orange polygons), situated to the west of the R354 tar road between Matjiesfontein and Sutherland. The study area comprises mountainous terrain of the Klein-Roggeveldberge with a steep, = escarpment towards the north and west. This region of the Karoo is drained towards the west by tributaries of the Muishondrivier, towards the north by the Wilgebosrivier as well as towards the south by tributaries of the Grootrivier and Wilgehoutrivier.

2. GEOLOGICAL CONTEXT

The Brandvalley 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 45 km to the northwest of Lainsgburg, well to the south of the Great Escarpment. The R354 tar road between Matjiesfontein and Sutherland runs along 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 1400-1515 m amsl in the north (*e.g.* Brandkop, Snydersberg) and 1300-1350 amsl in the south. Above the steep, north- and west-facing escarpment areas mountain slopes are generally fairly gentle with prominent-weathering ridges or *kranzes* of Karoo Supergroup sandstones imparting a distinctive banded appearance (Figs.8 & 9) that is also well-seen on satellite images. The area is drained by (mostly unnamed) tributaries of the Grootrivier as well as the Muishondrivier, both feeding into the Tanquarivier drainage system to the west, and by the Wilgeboschrivier that feeds into the Buffelsrivier drainage system to the southeast. Below the Klein-Roggeveld Escarpment lie the valleys of the Muishondrivier, Luiperdskloof and Wilgebosrivier (floors at *c*. 900 m amsl) that are blanketed by karroid *bossieveld* and incised by numerous small, intermittently flowing streams (Fig. 7). 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 (Figs. 6 & 9). This is due to extensive cover by alluvial and colluvial deposits as well as karroid *bossieveld* vegetation (Central Mountain Shale Renosterveld, Koedoesberg – Moordenaars Karoo).

The geology of the Brandvalley 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). Only two major sedimentary rock units or formations are represented within the study area on 1: 250 000 scale geological maps (Fig. 4), *viz* the **Waterford Formation** (Pwa, brown or orange in Fig. 4) and the **Abrahamskraal Formation** (Pa, pale green in Fig. 4), both of which belong to the **Karoo Supergroup** succession of the Main Karoo Basin of South Africa and are Middle Permian in age (Johnson *et al.* 2006) (Fig. 5). Deltaic sediments of the Waterford Formation (upper **Ecca Group**) only crop out in the core of a major anticlinal structure whose axis runs west-east through the project area at a latitude of around 32º 57-58'. The great majority of study area is underlain by continental (fluvial and lacustrine) mudrocks and sandstones forming the lowermost portion of the very thick **Abrahamskraal Formation** (**Lower Beaufort Group**). 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 (See thin red lines, marked Jd, in southern part of the project area, Fig. 4). 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), down-wasted 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. Most are not mapped at 1: 250 000 scale.

All of these rock units – with the exception of the very minor Karoo dolerites - are potentially fossiliferous, although only the Abrahamskraal Formation is 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. Dips of up to 30º are mapped along major west-east trending fold axes, but locally may be steeper , and faulting is minor (*e.g.* E-W fracture zones seen on satellite images) (Fig. 16). Levels of Karoo Supergroup bedrock exposure are generally low to very low due to cover by superficial sediments and karroid bossieveld vegetation. A short, illustrated account of the main sedimentary rock units encountered within the study area during fieldwork is presented below 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 the Appendix.

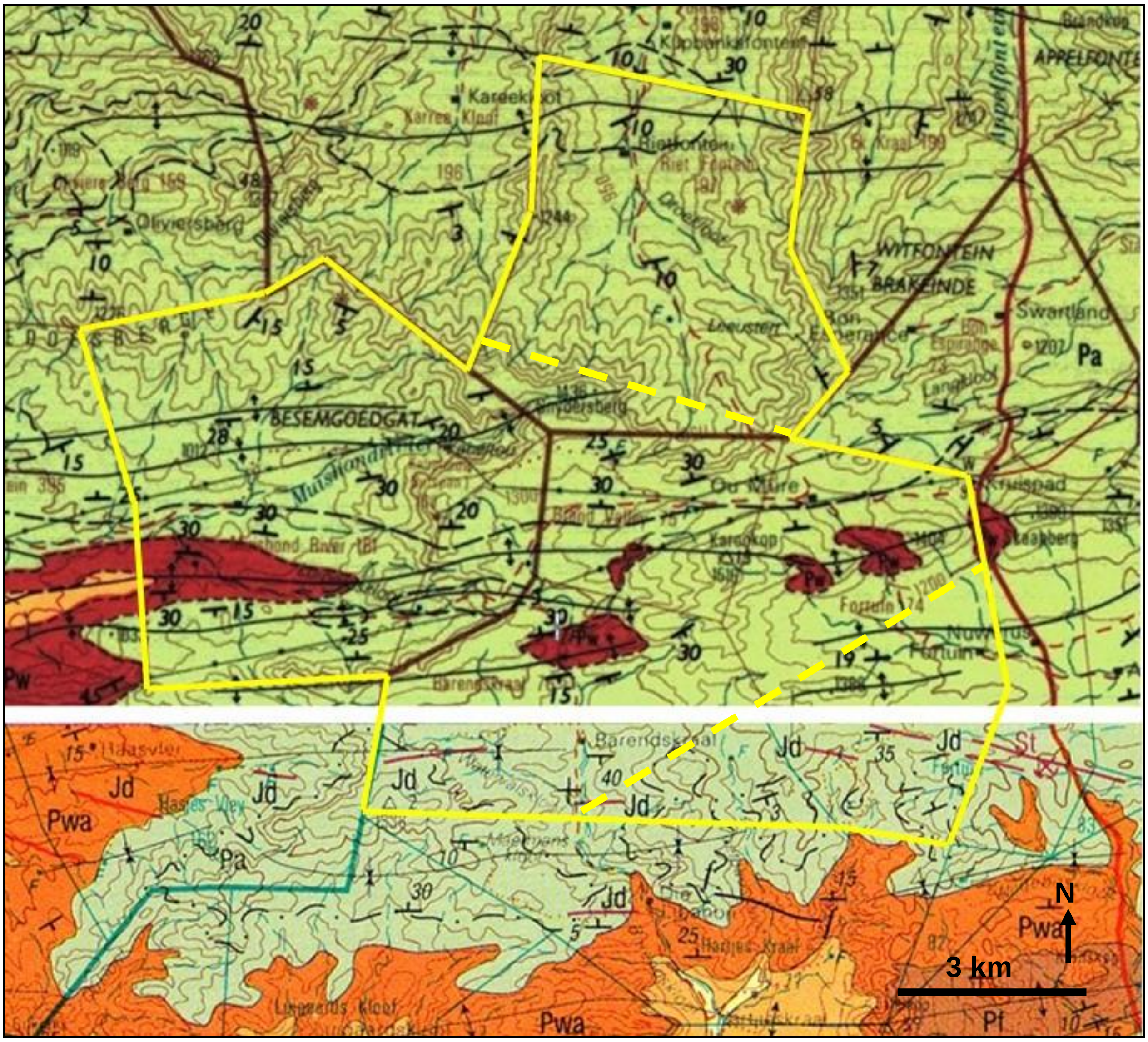

Figure 4. Extracts from adjoining 1: 250 000 scale geology sheets 3320 Ladismith (below) and 3220 Sutherland (above) showing the location of the proposed Brandvalley WEF study area, *c*. 45 km northwest of Langsburg, Western and Northern Cape Provinces (solid yellow polygon) (Maps published by Council for Geoscience, Pretoria). The core development area – where most of the key WEF infrastructure (wind turbines, access roads *etc*) will be situated – lies in the region between the yellow dashed lines and is the principal focus of the present study (Compare Fig. 2).

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

ECCA GROUP	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	Younger alluvium (pale yellow)

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

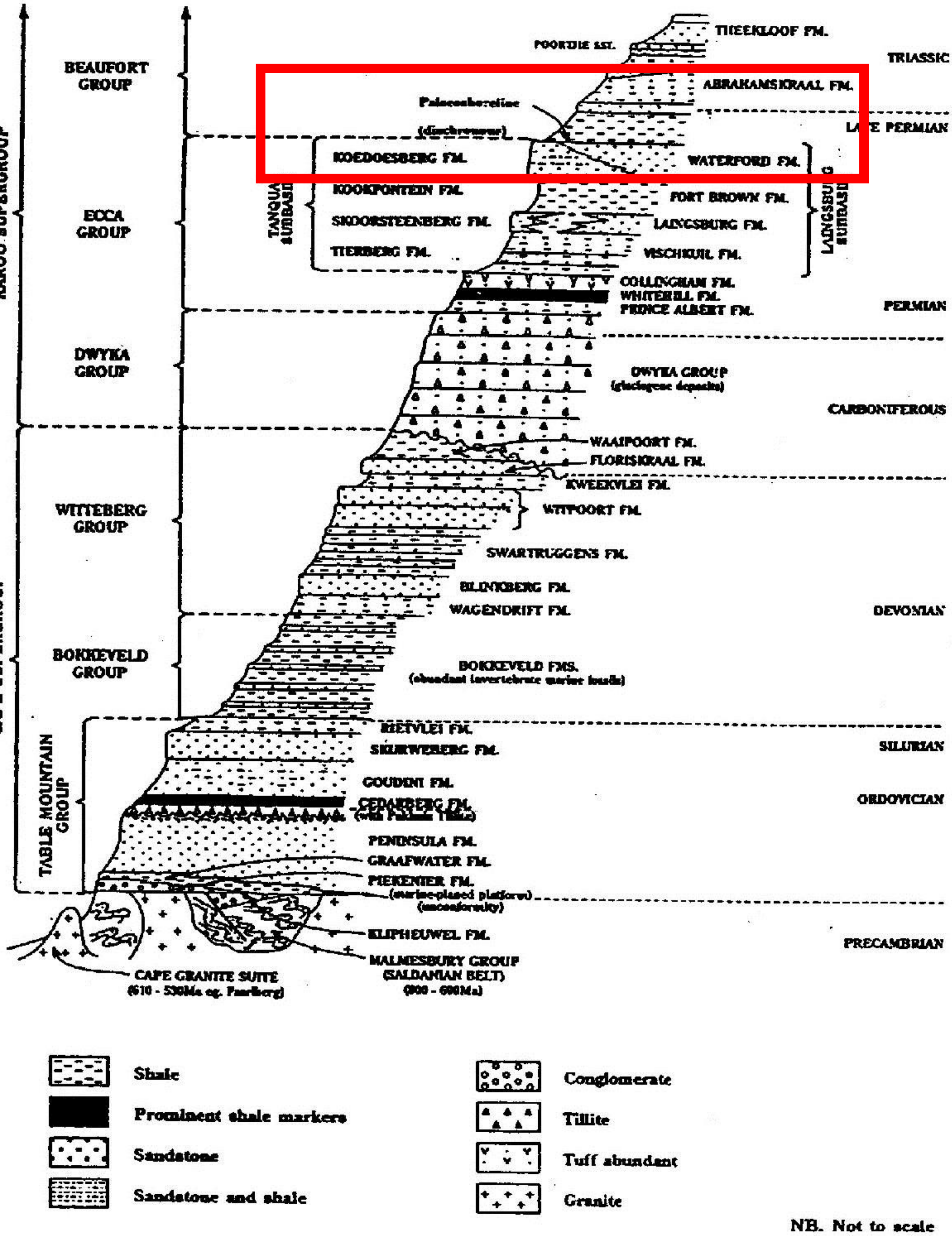

Figure 5. Schematic stratigraphic column for the Western Cape, the red box indicating the position of the various Late Palaeozoic sedimentary formations that crop out within the Brandvalley WEF study area (Modified from original figure by H. de V. Wickens).

Figure 6. Undulating uplands in the northern part of the study area, looking north towards the wind mast on Snysdersberg, Rietfontein 197. Note the paucity of bedrock exposure here.

Figure 7. Low-lying hilly terrain at the foot of the west-facing Klein-Roggeveld escarpment, Muishond Rivier 161, with the Kabeltou Pass in the foreground.

Figure 8. Riverine cliff exposures of Lower Beaufort Group rocks in Barendskloof, Barendskraal 76.

Figure 9. Hilly upland terrain in the southern portion of the study area (Barendskraal 76), looking southeast towards Tafelkop (This mountain is capped by Waterford Formation beds according to the geological map, but the gentle upper slopes and upper sandstone *krans* probably belong to the Lower Beaufort Group).

2.1. 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 (often speckled) 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 (1983) provides a short account of the Waterford Formation in the Sutherland 1: 250 000 sheet where it thins northwards from 75 m just south of the map area. 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 absent to very rare in the basal Abrahamskraal Formation.

The sandstone-rich, resistant-weathering Waterford Formation crops out in the core of a west-east mega-anticline running through the central part of the study area (Fig. 4). 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 (Figs. 12 & 13). 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. Thin-bedded, wave-rippled heterolithic packages within the lower parts of progradational cycle are far less well exposed (Figs. 10 & 11). The Brandvalley and Rietkloof WEF study areas 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 (*cf* Almond 2016b).

Figure 10. Thinly interbedded, wave-rippled Waterford Formation wackes and siltstones in a stream bank exposure on Muishond Rivier 161 (Loc. 203). These beds are rich in trace fossils (See Figs. 34 to 36 below).

Figure 11. Thin-bedded, wave-rippled wackes in the lower part of a prograding deltaic package, Waterford Formation, Muishond Rivier 161 (Loc. 200) (Hammer = 30 cm).

Figure 12. Cliff section through dark grey mudrocks and thin- to thick-bedded wackes of the Waterford Formation, Muishond Rivier 161 (Loc. 200). Large ball-and-pillow structures are seen above the lower sandstone here.

Figure 13. Riverine cliff exposure of a thick package of wackes of the Waterford Formation, locally showing high levels of soft-sediment deformation and disrupted bedding, Barendskloof, Barendskraal 76 (Loc. 213).

2.2. 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 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).

2.2.1. 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 Middle 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.

The Abrahamskraal Formation is mapped as underlying the great majority of the Brandvalley WEF study area where the succession broadly youngs towards the north (Figs. 4 & 16). 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. 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. 15). 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. 14).

The precise stratigraphic range of the Lower Beaufort Group beds represented within the Brandvalley 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. 15) (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 since maroon mudrocks occur along the Muishondrivier very close to the mapped Ecca – Beaufort boundary). The two sandstone packages might then correspond to the **Combrinkskraal** and **Grootfontein Members** of Day and Rubidge (2014) (Fig. 14), 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 Brandvalley 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 as well as along major drainage lines such as Barendskloof (Figs.6 to 9, 16 to 23, 25 to 26). 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 (Fig. 23). 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, while smaller sphaeroidal calcrete nodules are usually pale grey (Fig. 27). 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.

Lenticular channel sandstone bodies – some of which are composite - are well seen in cross section within the lowermost Beaufort Group succession exposed in Barendskloof (Figs. 20 & 21). The thick sandstone packages seen here might belong to the Combrinkskraal Member *sensu stricto* of Day and Rubidge (2014) (Fig. 14). It is notable that the majority of overlying 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 (Fig. 18). 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 frequently found compared to higher members within the Abrahamskraal Formation. Extensive development of soft-sediment loading at the base of thicker sandstone units, or entailing the complete break-up into balls-and-pillows of thinner beds, is commonly seen within the lowermost Abrahamskraal Formation beds, some of which may include maroon mudrocks (Figs. 19 & 22). These characteristics, which are shared in part with the deltaic Waterford Formation, contrast in several respects to the "typical" fluvial *Eodicynodon* AZ sediments described earlier. This 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. A thick sandstone-rich package that runs along the crest of the Klein-Roggeveld Escarpment in the western and northern part of the study area (*e.g.* Snydersberg area) may belong to the Grootfontein Member of Day and Rubidge (2014) (Figs. 24 & 25).

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 Klein-Roggeveld escarpment being re-assigned to the Lower Beaufort Group (*cf.* Fig. 9). 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 (This is also implied by Theron 1983, p. 8). 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.

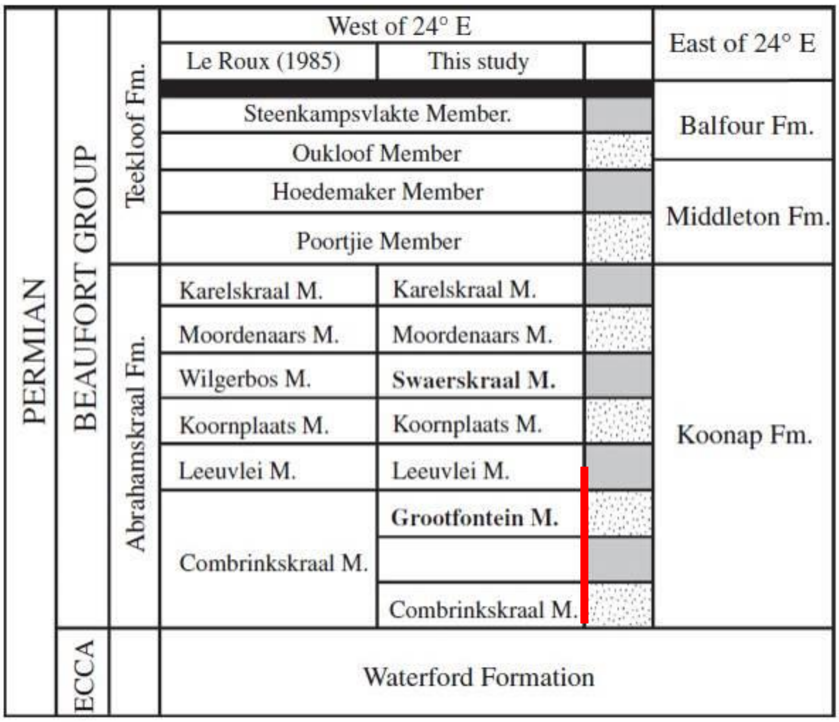

Figure 14. Revised subdivision of the Abrahamskraal Formation of Day and Rubidge (2014). The red bar indicates members that are probably represented within the Brandvalley WEF study area.

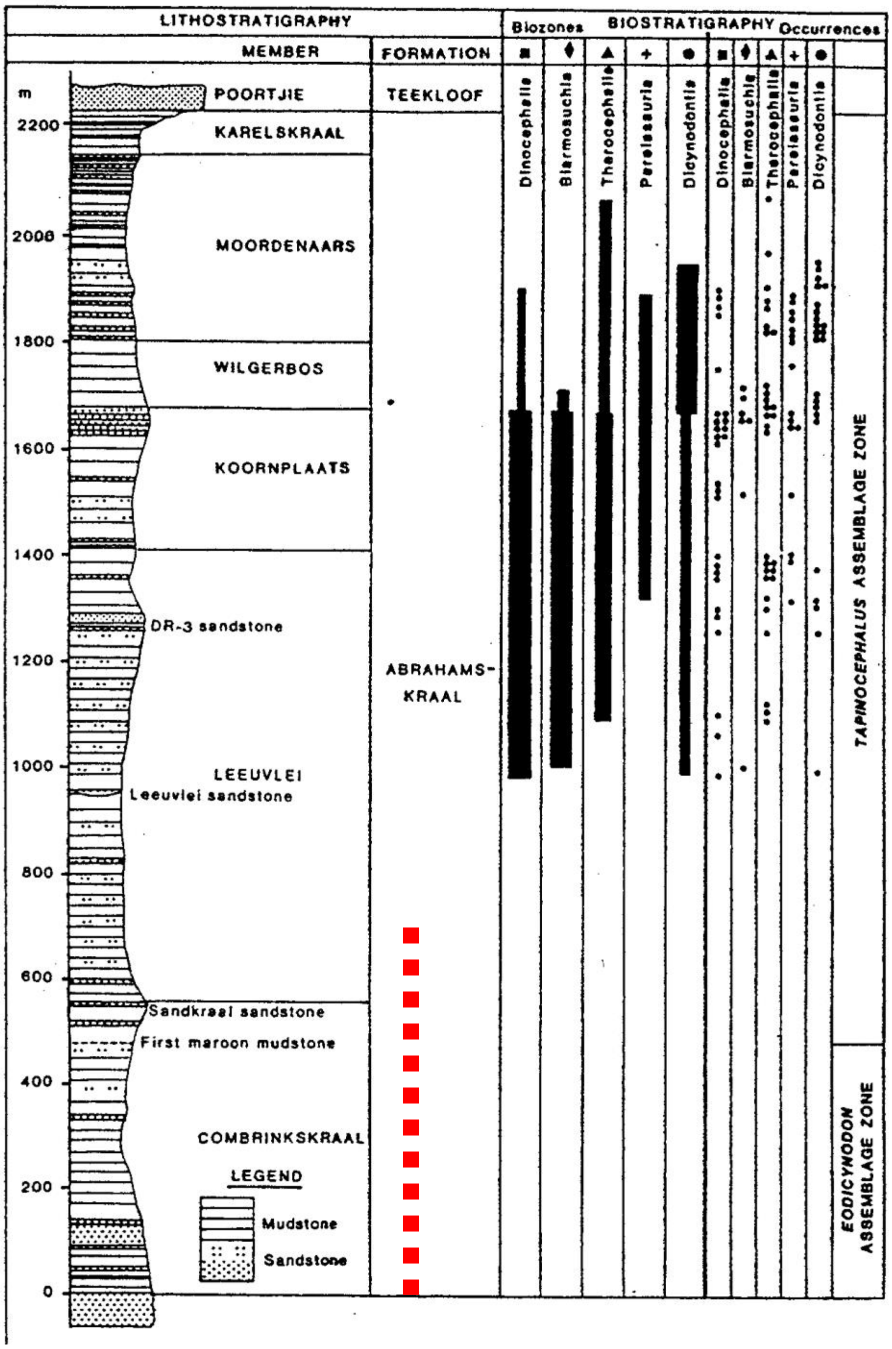

Figure 15. Chart showing the subdivision of the Abrahamskraal Formation in the western Karoo region with stratigraphic distribution of the major fossil vertebrate groups (Loock *et al*. 1994). The Brandvalley WEF study area is probably underlain by fossil-poor sediments within the Combrinkskraal Member *s.l.* and possibly the lower Leeuvlei Member (dotted red bar), above the first appearance of maroon mudstones.

Figure 16. West-facing escarpment of the Klein-Roggeveldberge on Muishond Rivier 161 showing the very thick, north-dipping succession of Lower Beaufort Group rocks here.

Figure 17. Thin-bedded tabular sandstones and grey mudrocks of the Lower Beaufort Group overlying a major channel sandstone body, stream exposure on Barendskloof 76 (Loc. 218).

Figure 18. Tabular, upward-coarsening mudrock to sandstone cycles, Lower Beaufort Group on Barendskraal 76 (Loc. 218). The sandstone caps show gradational bases and sharp tops.

Figure 19. Extensive soft-sediment deformation (ball-and-pillow structures) within the lowermost Abrahamskraal Formation along the Muishondrivier on Muishond Rivier 161 (Loc. 204). The upper package of mudrocks seen here are purple-brown.

Figure 20. Composite, lenticular channel sandstone bodies incised into a highly tabular succession of interbedded sandstones and mudrocks, Lower Beaufort Group, Barendskloof on Barendskraal 76 (Loc. 218).

Figure 21. Thick sandstone package towards the base of the Abrahamskraal Formation showing basal lenticular channel sandstone, Barendskloof on Barendskraal 76 (Loc. 218).

Figure 22. Large scale loading at the base of the lenticular channel body shown in the previous figure, Barendskloof (Loc. 218).

Figure 23. Typical, laterally-persistent, highly-tabular channel sandstone horizons within the Lower Beaufort Group, Hartjies Kraal 77/1.

Figure 24. Numerous small exposures of maroon and grey-green overbank mudrocks close to the northern transmission line on Muishond Rivier 161 (Besemgoedgat Valley). These Abrahamskraal Formation beds correspond to the succession between sandstone-rich packages on the skyline.

Figure 25. Sandstone package (possibly the Grootfontein Member) building the crest of the escarpment on the southern flank of Snydersberg, Abrahamskraal Formation, Rietfontein 197 (Loc. 194).

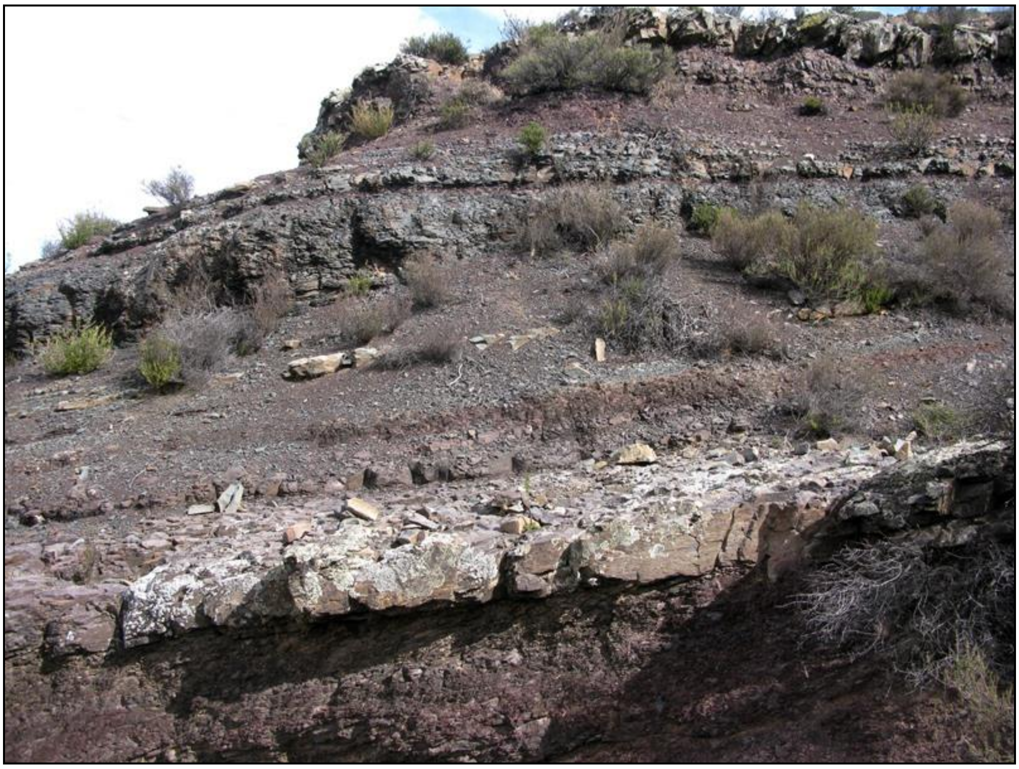

Figure 26. Good exposure of tabular-bedded sandstones interbedded with maroon or grey-green overbank mudrocks, Abrahamskraal Formation on Rietfontein 197 (Loc. 194).

Figure 27. Small, greyish calcrete nodules marking a palaeosol horizon within grey-green, hackly-weathering overbank mudrocks of the Abrahamskraal Formation on Snydersberg, Rietfontein197 (Loc. 195) (Hammer = 30 cm).

Figure 28. Rippled sandstone palaeosurface overlain by colour-banded succession of Abrahamskraal overbank mudrocks, Kabeltou Pass on Muishond Rivier 161 (Loc. 210) (See also Figs. 47 to 51).

Figure 29. Close-up of the sandstone palaeosurface with pond margin ripples shown in the previous figure. Note also partially-effaced invertebrate burrows (Hammer = 30 cm) (Loc. 210) (See also Fig. 48).

2.3. 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 near quarry areas 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.

2.4. Late Caenozoic Superficial Deposits

Late Caenozoic alluvial deposits in the Brandvalley 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 Muishondrivier, Wilgebosrivier and their various unnamed tributaries, for example (Fig. 32). 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. 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. 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 (Fig. 30). The colluvium may form a semi-consolidated rubbly, clast-supported breccia bed locally. 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. 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 - but in some areas the bedrocks are mantled in fine gravels and sandy soils. 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.

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. Nodular calcrete hardpans up to three meters in thickness are exposed along some drainage lines. 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 (Fig. 33). Relict pediment surfaces can be recognised where the alluvial fans have been dissected by younger incised drainage systems. Calcretised, vuggy spring deposits occur at intervals along drainage lines in Luiperdskloof (Muishond Rivier 161).

Figure 30. Thick package of coarse, rubbly breccias of mixed alluvial and colluvial origin along a stream valley on Barendskraal 76 (Loc. 215) (Hammer = 30 cm).

Figure 31. Calcretised fluvial breccias overlying dark Waterford Formation bedrocks exposed along a stream bank on Muishond Rivier 161 (Loc. 202) (Hammer = 30 cm).

Figure 32. Coarse alluvial gravels overlain by younger sandy alluvium in the banks of the Wilgebosrivier, Riet Fontein 197 (Loc. 036) (Hammer = 30 cm).

Figure 33. Surface gravels of subrounded Waterford Formation wacke on Barendskraal 76 (Loc. 214). These gravels contain locally common reworked clasts of petrified wood (See Fig. 52).

Table 1: Fossil record of the main sedimentary rock units represented within the Brandvalley 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)

3. PALAEONTOLOGICAL HERITAGE

In this section of the report fossil assemblages that are recorded from the main sedimentary rock units represented within the Brandvalley WEF study area are outlined (See also Table 1 above) 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 the Appendix. 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 the Appendix do *not* therefore represent a comprehensive record of fossil sites within the study area.

3.1. Fossils in the Waterford Formation

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 2016a).

Petrified wood and other plant material of the *Glossopteris* Flora (*e.g. Glossopteris, Phyllotheca*) occurs widely in the Waterford Formation and is often reworked into 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) (Fig. 52). 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 from the Waterford Formation so far (Bamford 1999, 2004). 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) (*cf* Fig. 42).

Numerous dispersed pieces as well as concentrations of pale grey, finely-banded, angular blocks of silicified wood have been recorded in the Rietkloof WEF study area just to the south (See Almond 2016b) but were not seen during the field assessment of the Brandvalley WEF study area. Transported plant debris preserved as ferruginised impressions of woody stems and leaves, is found locally here within khaki-hued Waterford Formation wackes (Loc. 030) (Fig. 37).

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 Brandvalley WEF study area (e.g. Locs. 200, 203) (Figs. 34 to 36). They include a small range of horizontal burrows, the larger examples sometimes showing meniscate backfill, as well as occasional small arthropod scratch burrows (*Rusophycus* "bilobites") that are probably attributable to non-marine crustaceans. 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. Occasonal 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 2016a, 2016b).

Figure 34. Small hypichnial horizontal burrows on the sole of a thin-bedded Waterford Formation wacke, Muishond Rivier 161 (Loc. 203) (Scale in cm) (See also Fig. 10 for sedimentary setting).

Figure 35. Sole surface of Waterford Formation wacke showing fine tool marks as well as small arthropod resting traces (*Rusophycus*, arrowed), Muishond Rivier 161 (Loc. 203).

Figure 36. Block of medium-bedded Waterford Formation wacke showing horizontal burrows with meniscate backfill (*c*. 1 cm wide), ruined house on Muishond Rivier 161 (Loc. 203).

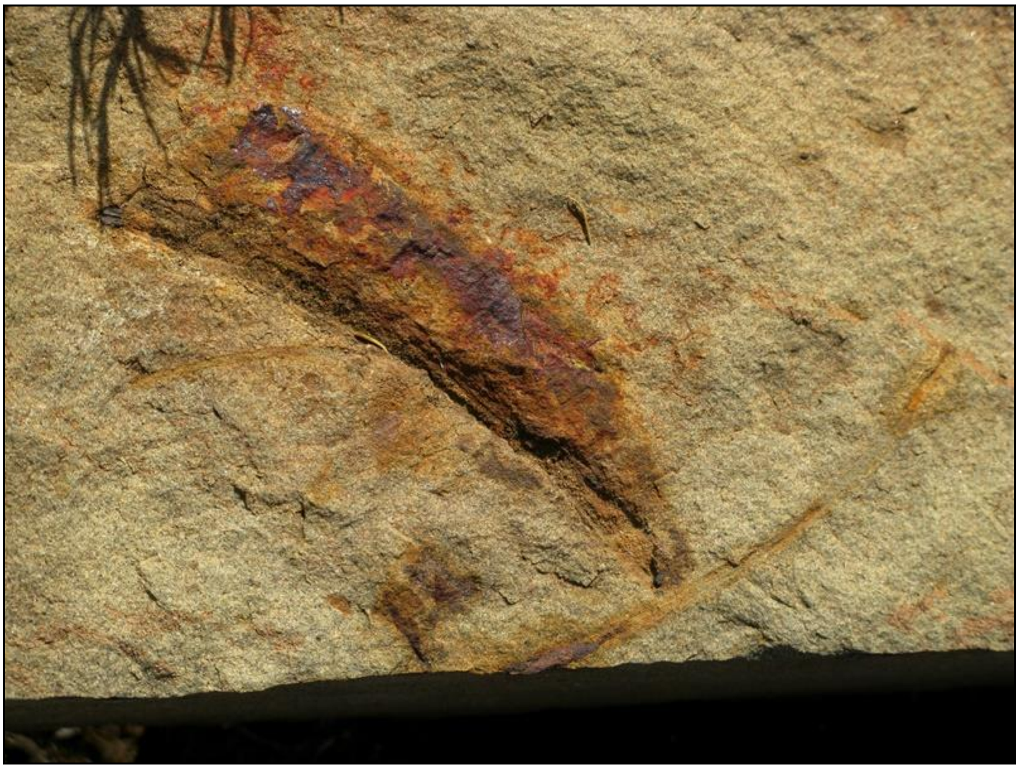

Figure 37. Ferruginised, comminuted plant debris within a speckled Waterford Formation wacke, Muishond Rivier 161 (Loc. 030). The largest fragment is 3.5 cm across.

3.2. 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. 39 herein) and Rubidge (1995, 2005). A recently updated version is now available (Nicolas 2007, Van der Walt *et al.* 2010) (Fig. 38). 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. 41) (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, Rubidge *et al.* 2000). Petrified wood is apparently – and perhaps surprisingly - absent in the lowermost Beaufort Group, in contrast to the underlying Waterford Formation; 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. 15) as well as the fossil site maps of Keyser & Smith (1977-78) (Fig. 39) and of Nicolas (2007) (Fig. 40). 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 (Smith *et al.* 2012).

Casts of large (*c*. 15 cm wide), subhorizontal to gently-inclined, straight tetrapod burrows are reported here for the first time from the *Eodicynodon* AZ in the Brandvalley WEF (Figs. 47, 49, 50). The burrows have a broadly elliptical cross section and show possible scratch marks on the lateral wall. One of the burrows tapers and flattens distally; there is no evidence of a broader terminal chamber. They directly overlie a wave-rippled sandstone palaeosurface with small-scale invertebrate burrows (probably *Scoyenia*) (Fig. 48) and reedy plant stem casts. Impressions of equisetalean stems (Fig. 45) as well as sizeable ferruginous carbonate concretions are found in the overlying mudrocks. This suggests a pond or lake margin depositional setting similar to that with which *Eodicynodon* skeletal remains are most commonly associated (Smith *et al.* 2012). The burrows reported here occur within the sandstone package along the crest of the Klein-Roggeveld Escarpment on Muishond Rivier 161 (possible the Grootfontein Member of Day & Rubidge 2014). They may represent the oldest known tetrapod burrows reported from the Karoo Supergroup of South Africa (and even perhaps from Gondwana), although this claim remains to be confirmed. Several occurrences of possible, but unconfirmed, sand-cast tetrapod and possible lungfish burrows have recently been noted from the lower Abrahamskraal Formation - *i.e.* the Combrinkskraal *sensu lato* and Leeuvlei Members - in the Klein-Roggeveldberge region, including the Rietkloof WEF project area just to the south of the present study area (*e.g.* Almond 2010, 2015c, 2015d, 2016b). The marked scarcity of fossil tetrapods and woody plants combined with widespread vertebrate burrowing might reflect environmentally-challenging conditions in the Karoo Basin in Middle Permian (Wordian) times.

A local concentration of disarticulated skeletal remains of a small tetrapod, including a limb bone and tusks (Fig. 51), occurs at the same horizon as the tetrapod burrows, and indeed within two meters of one of these. The skeletal remains are most likely to belong to the small dicynodont *Eodicynodon* which may well have been the burrow-maker. The teeth comprise two similar-sized tusks *plus* a smaller one; this is reminiscent of the double-tusked *Eodicynodon* skull described by Jinnah and Rubidge (2007). The latter specimen, which also occurs above the incoming of maroon mudrocks within the lower Abrahamskraal Formation, was interpreted by these authors as pathological. Perhaps the two-tusked condition was a fairly common feature among these very early dicynodonts.

The only plant fossils recorded from the Lower Abrahamskraal Formation during the present field study comprise dispersed to concentrated, fragmentary impressions of sphenophytes (horsetail ferns and their relatives) preserved within overbank mudocks and sandstone bed tops (*cf* Anderson & Anderson 1985, Rubidge *et al.* 2000). They include segmented stems of reedy horsetails (*Phyllotheca*) (Fig. 45) as well as strap-shaped, longitudinally-ridged leaves referred to the genus *Schizoneura* (Figs. 43 & 44). 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. 46). 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. A good example is recorded from just outside the Brandvalley WEF study area on Klip Banks Fontein 395 (Almond 2010a) (Fig. 42).

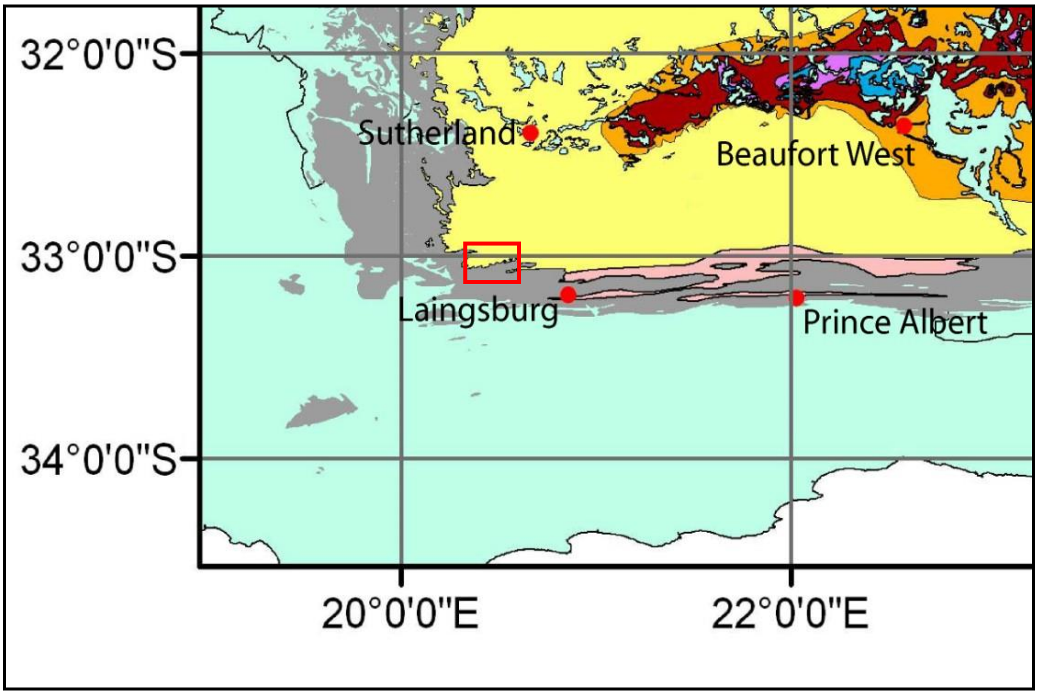

Figure 38. Recent - but already outdated - biozonation of the SW Karoo region showing restriction of the *Eodicynodon* Assemblage Zone (pink) to the southern margins of the Main Karoo Basin (Van der Walt 2010). Subsequent work suggests that this earliest Beaufort Group biozone extends further to the northwest along the Ecca – Beaufort Group boundary, including the present study area (red rectangle).

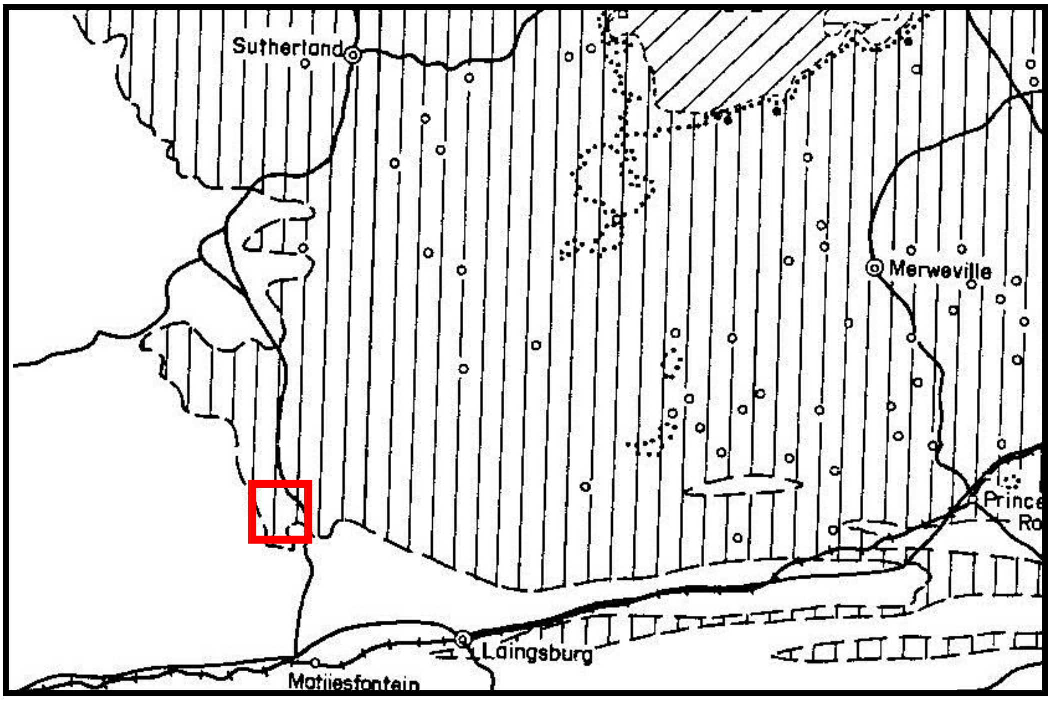

Figure 39. Vertebrate fossil localities within the Lower Beaufort Group in the south-western Karoo region (Map abstracted from Keyser & Smith 1977-78). Outcrop areas with a vertical lined ornament were originally assigned to the Middle Permian *Tapinocephalus* Assemblage Zone. Note the absence of fossil records from the lower part of the Abrahamskraal Formation in the present Brandvalley WEF study area between Matjiesfontein and Sutherland (red rectangle).

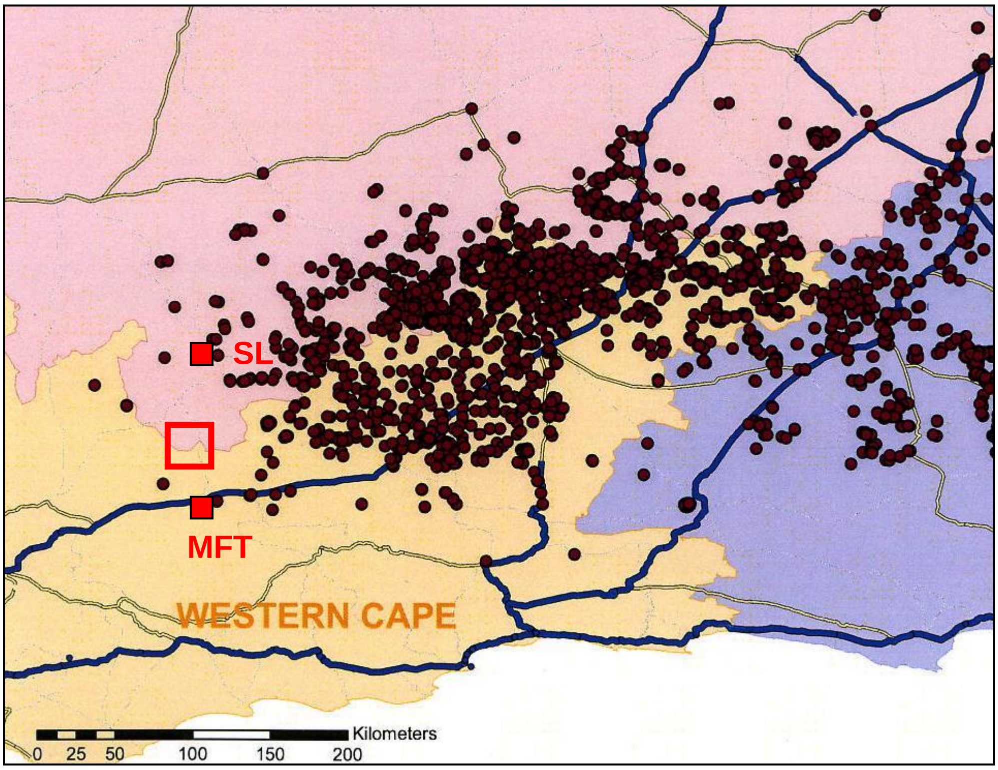

Figure 40. Distribution of recorded vertebrate fossil sites within the south-western portion of the Main Karoo Basin (modified from Nicolas 2007). The approximate location of the Brandvalley WEF and adjacent Rietkloof WEF study areas is approximately indicated by the open red square. Note the lack of known fossil sites in this part of the Karoo. SL = Sutherland. MFT = Matjiesfontein.

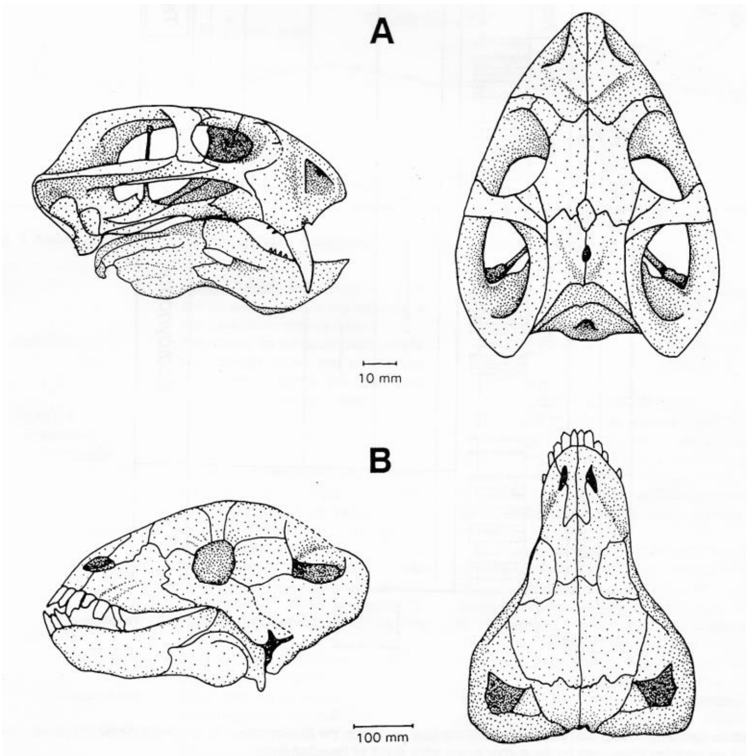

Figure 41. Skulls of two key fossil therapsids from the *Eodicynodon* Assemblage Zone: A – the small dicynodont *Eodicynodon*; B – the rhino-sized dinocephalian *Tapinocaninus* (From Rubidge 1995).

Figure 42. Impression or drag mark of a sizeable log exposed on a current-rippled sandstone palaeosurface on Klipbanks Fontein 395, just outside the present study area (Loc. 029) (From Almond 2010a).

Figure 43. Float block of khaki-hued Lower Beaufort or Waterford wacke with the impression of a strap-shaped sphenophyte plant leaf (*Schizoneura*), Barendskraal 76 (Loc. 217) (Scale in cm).

Figure 44. Concentration of *Schizoneura* leaf impressions within grey-green overbank mudrocks, Kabeltouw Outspan 160 (Loc. 198) (Scale in cm and mm).

Figure 45. Impression of longitudinally-striated, segmented equisetalean fern stem ("horsetail"), from mudrocks overlying a sandstone palaeosurface on Muishond Rivier 121 (Loc. 210) (Scale in cm and mm).

Figure 46. Concentrated assemblage of reedy plant stem casts – probably equisetaleans – on a mudrock-veneered sandstone bed top, Muishond Rivier 161 (Loc. 209) (Scale in cm).

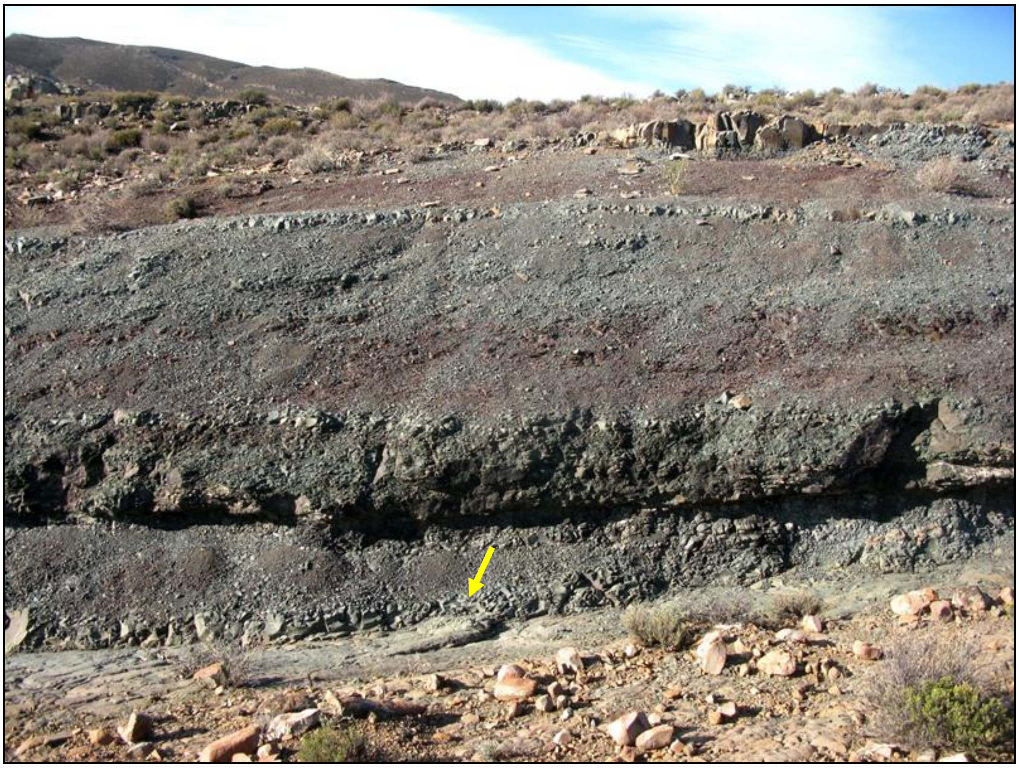

Figure 47. Pair of tetrapod burrow casts (arrowed) at the base of an exposure of Abrahamskraal Formation overbank mudrocks, Kabeltou Pass, Muishond Rivier 121 (Loc. 211).

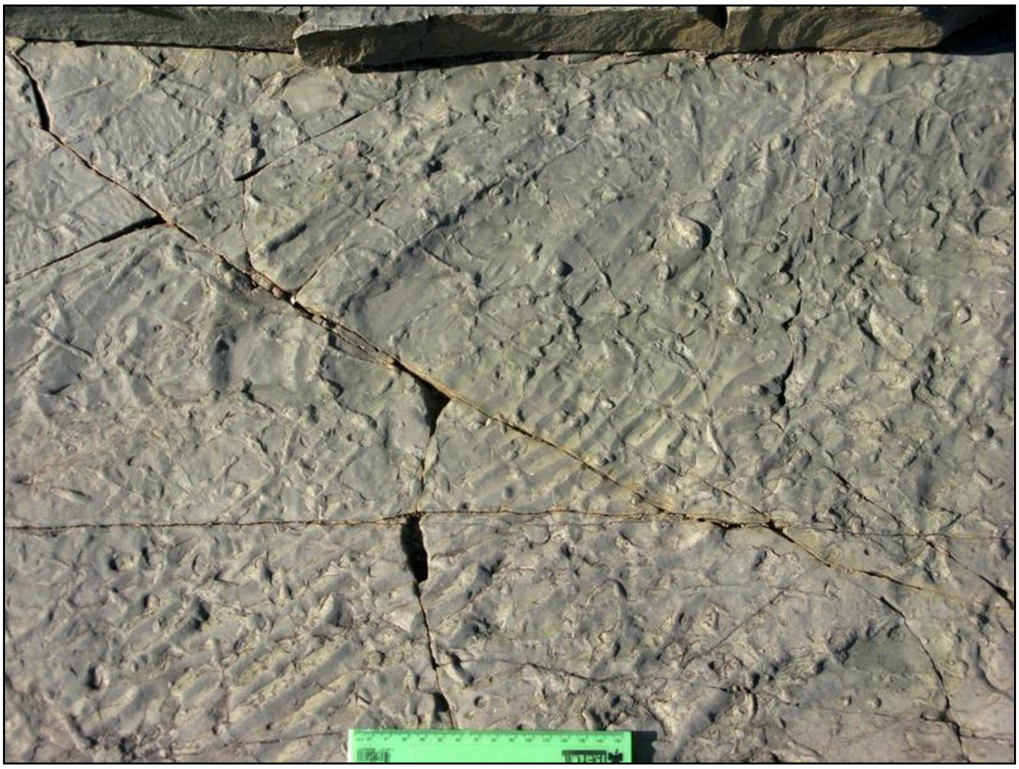

Figure 48. Close-up of wave-rippled sandstone palaeosurface seen in Fig. 29 showing small invertebrate burrows – probably *Scoyenia* - Muishond Rivier 161 (Loc. 210) (Scale in cm).

Figure 49. Subhorizontal tetrapod burrow cast, Lower Abrahamskraal Formation, Muishond Rivier 161 (Loc. 212) (Scale is *c*. 15 cm across).

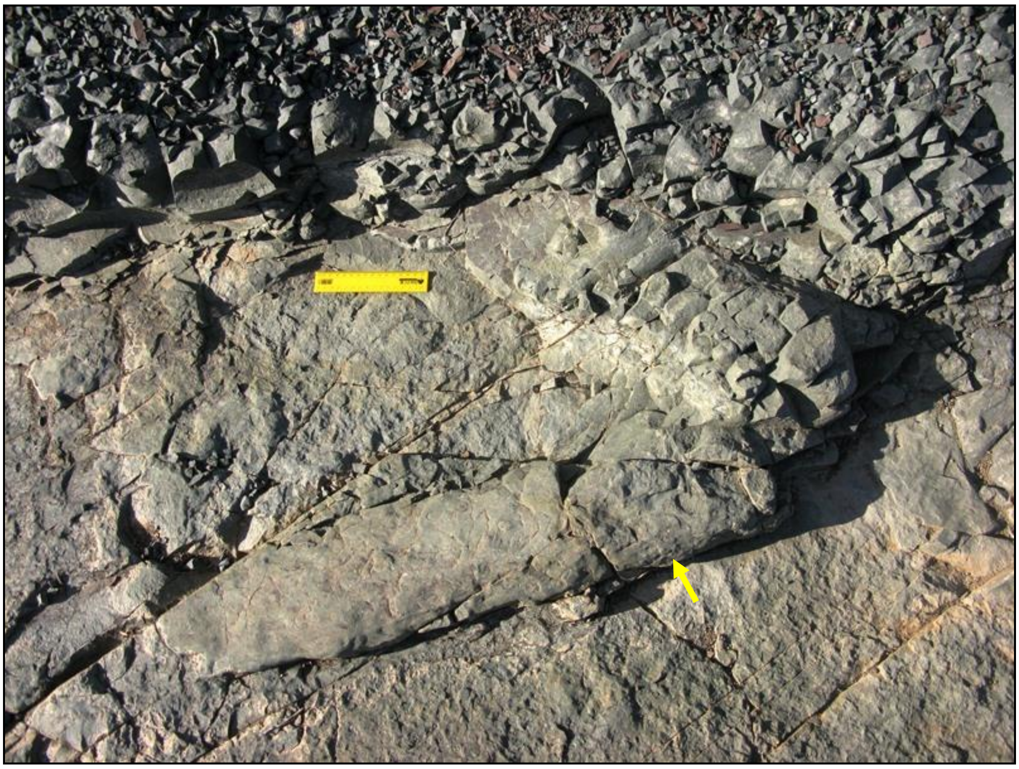

Figure 50. Pair of inclined tetrapod burrow casts overlying the sandstone palaeosurface shown in Fig. 45, Muishond Rivier 161 (Loc. 211) (Scale is *c*. 15 cm long). Arrow indicates possible scratch marks on the lateral surface of one burrow.

Figure 51. Disarticulated skeletal remains of a small tetrapod (possibly *Eodicynodon*) embedded within green-grey fine sandstone of the lower Abrahamskraal Formation, Muishond Rivier 161 (Loc. 212). Seen here are a limb long bone (orange arrow) and three tusks (yellow arrow).

3.3. 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 as well as above the Klein-Koedoesberge Escarpment (Fig.52). 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 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 (*cf* Almond 2016b), 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 52. Angular to slightly rounded clasts of reworked petrified wood dispersed among coarse pediment gravels of Late Caenozoic age, Barendskraal 76 (Loc. 214) (Scale in cm).

4. ASSESSMENT OF IMPACTS ON PALAEONTOLOGICAL RESOURCES

Desktop studies show that the Brandvalley WEF study area is underlain by two mappable units of Late Palaeozoic sedimentary rocks of the Karoo Supergroup *plus* unmapped Late Caenozoic superficial sediments such as alluvium and colluvium (scree, surface gravels) (Fig. 4), all of which contain fossils of some sort. Palaeontological field assessment of the area shows that:

- Waterford Formation (Upper Ecca Group) deltaic bedrocks have small outcrop areas crossing the central part of the study area. These small areas lie largely outside the main development footprint and are generally fossil-poor, apart from low-diversity trace fossil assemblages. However, isolated blocks and rare logs of well-preserved petrified wood recorded from this formation just to the south of the study area (Rietkloof WEF project area) are of high scientific and conservation value and similar material might also be present in the Brandvalley WEF study area.

- Abrahamskraal Formation (Lower Beaufort Group) fluvial bedrocks underlying the great majority of the study area are generally considered to be of high palaeontological sensitivity. However, in this area of the SW Karoo they are generally fossil-poor, apart from occasional horizons with plant debris or low-diversity trace fossils. A few examples of large tetrapod (*i.e.* terrestrial vertebrate) burrows as well as disarticulated skeletal remains (dispersed bones, teeth) recorded from these beds during the present field assessment are of considerable scientific interest but are very rare indeed.

- 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 and elsewhere locally contain numerous clasts of petrified wood reworked from the Karoo Supergroup (probably Waterford Formation).

The potential impact of the proposed Brandvalley WEF development on local fossil heritage resources is evaluated in Table 2 below (Chapter 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 key infrastructure as described in Section 1 situated within the main WEF study area as shown in Figs. 2 and 2b, *i.e.* wind turbines, access roads, substations, 33 kV transmission lines and associated infrastructure. Separate Basic Assessment processes are to be undertaken to assess grid connection alternatives, 132kV overhead power lines and quarries or borrow pits for this project.

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 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; the likelihood of loss of *unique or rare* fossil heritage is therefore low. Because of the generally sparse occurrence of scientifically important, well-preserved, unique or rare fossil material within 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 is conservatively rated as *slight*.

As a consequence of (1) the paucity of irreplaceable, unique or rare fossil remains within the development footprint, as well as (2) the extensive superficial sediment cover overlying most potentially-fossiliferous bedrocks within the Brandvalley WEF study area, the overall impact significance of the construction phase of the proposed wind energy project is assessed as LOW (negative). This assessment applies to the wind turbines, laydown areas, access roads (both alternatives), substations (the four alternatives), construction camps (the three alternatives) and associated infrastructure within the WEF study area. A comparable 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 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 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 Brandvalley WEF development proposal as far as fossil heritage is concerned. Providing that the proposed recommendations for palaeontological monitoring and mitigation are followed through, there are no objections on palaeontological heritage grounds to authorisation of the Brandvalley 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). These conclusions are supported, however, by several previous palaeontological field assessments undertaken in the broader study region by the author (See References).

4.1. Cumulative impacts

A considerable number of alternative energy developments have been proposed or authorised in the broader south-western Karoo region within which the Brandvalley WEF study area is situated (See Fig. 53).

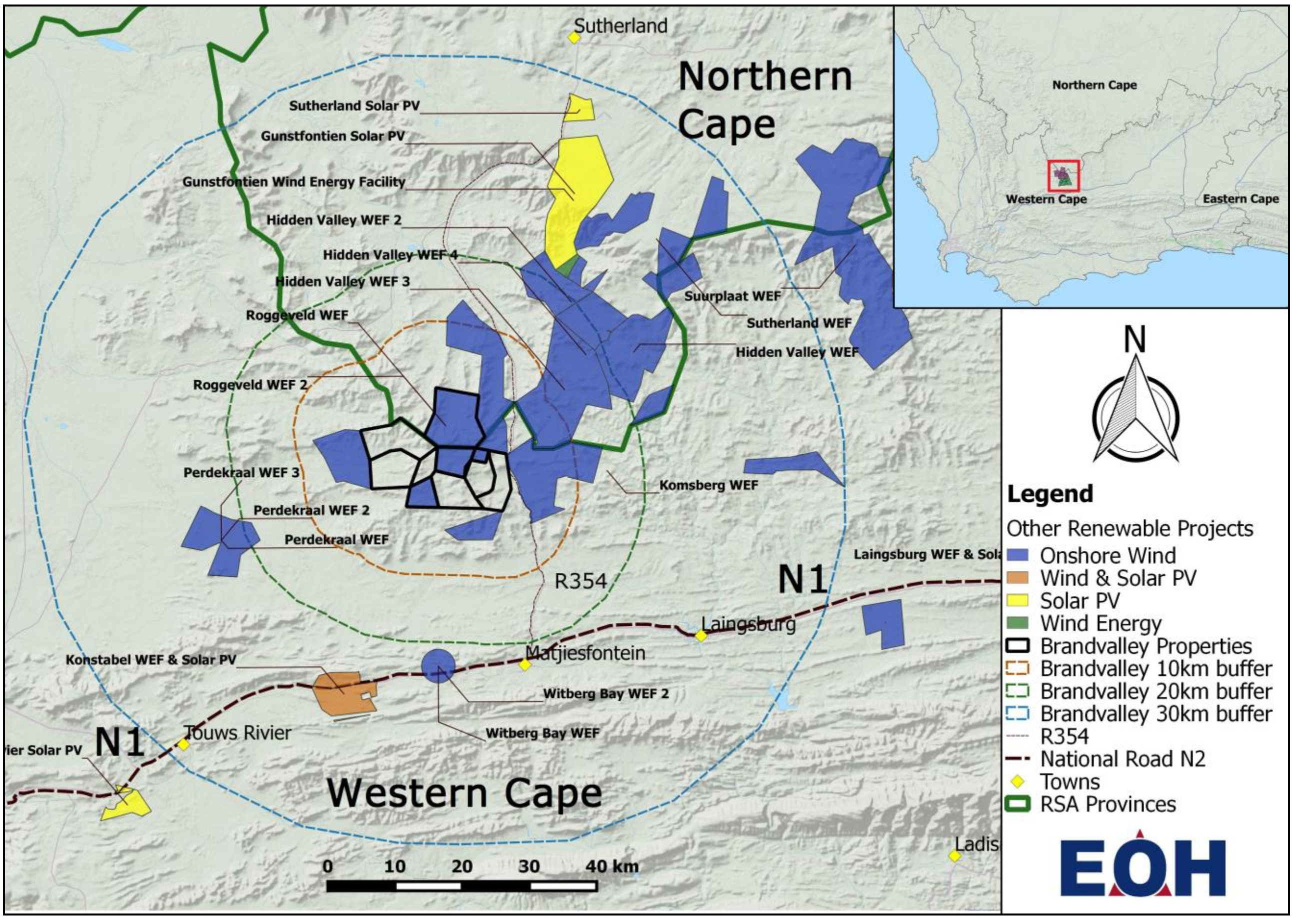

Figure 53. Map outlining proposed or approved alternative energy projects in the SW Karoo region surrounding the Brandvalley WEF project area (black polygon) (Image kindly supplied by EOH).

Several of these projects entail impacts on 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. 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. 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).

For example, field assessments of the Rietkloof WEF and Kareebosch WEF (Roggeveld Phase 2) project areas situated immediately south and north of, as well as overlapping with, the Brandvalley WEF study area have recently been completed (Almond 2014, Almond, 2016b). 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 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 followed through, their cumulative impact on palaeontological heritage resources - including impacts envisaged for the Brandvalley WEF project – is predicted to be low (negative). 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.

5. MITIGATION & RECOMMENDATIONS FOR THE ENVIRONMENTAL MANAGEMENT PLAN

The great majority of the Brandvalley WEF study area is assessed as being of low palaeontological sensitivity due to the paucity of irreplaceable, unique or rare fossil remains here. The occurrence of very rare tetrapod burrows and associated skeletal remains within the Abrahamskraal Formation along the Kabeltou Pass (Muishond Rivier 161) is a notable exception. This highly sensitive area (outlined in green in Fig. 2), which lies within the Western Cape and *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 therefore not recommended for the Brandvalley WEF project.

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 the relevant provincial heritage management authority as soon as possible - *i.e.* Heritage Western Cape for the Western Cape (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) and 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). 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.

The palaeontologist concerned with mitigation work will need a valid fossil collection permit from Heritage Western Cape (sites in the Western Cape) or SAHRA (sites in the Northern 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 Plan (EMP) for the Brandvalley 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 the Western Cape, SAHRA for the Northern Cape) 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.

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 Brandvalley WEF study area is underlain by Palaeozoic to Late Caenozoic sedimentary rocks 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 very small portions of the development footprint (local) since such fossils are 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 is slight. The overall significance of the impacts without mitigation is assessed as LOW NEGATIVE. Impact significance can be meaningfully reduced through the proposed monitoring and mitigation but will still remain low negative. 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.

Table 2: Assessment of impacts of the proposed Brandvalley WEF on local fossil heritage resources (construction phase)

Impact	Effect			**Risk or Likelihood**	**Overall Significance**
	Temporal Scale	Spatial Scale	Severity of Impact		
Impact : **Disturbance, damage or destruction of fossil heritage within development footprint during the construction phase of the WEF**					
Without Mitigation	Permanent	Localised	Slight	Unlikely	LOW -
With Mitigation	Permanent	Localised	Slight	Unlikely	LOW -

Impact Mitigation

- 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 (Western Cape sites) or SAHRA (Northern Cape sites) for recording and sampling by a professional palaeontogist;

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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 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: 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
029	S32 59 32.7 E20 19 50.0	Klip Banks Fontein 395 (just outside study area). Current-rippled sandstone surface with drag mark or impression of large fossil log. Large ferruginous carbonate septarian concretion nearby.
030	S32 59 6.4 E20 20 0.5	Muishond Rivier 101. Comminuted plant fossil compressions, Waterford Fm sandstones.
031	S32 56 25.2 E20 29 26.3	Rietfontein 197. Hill slope exposure of Abrahamskraal Fm mudrocks. Possible soft-sediment deformation of fine -grained sandstones.
032	S32 55 51.1 E20 28 51.5	Rietfontein 197. Hill slope exposure of Abrahamskraal Fm mudrocks.
034	S32 55 26.2 E20 28 40.0	Rietfontein 197. Narrow gulley exposure of Abrahamskral mudrocks and heterolithic packages.
035	S32 54 53.8 E20 28 20.4	Rietfontein 197. Extensive stream bank exposures of massive and thin-bedded grey-green mudrocks, Abrahamskraal Fm.
036	S32 54 14.3 E20 27 45.3	Rietfontein 197. Alluvial gravels and silts of the Wilgebosrivier,
193	S32° 56' 45.2" E20° 27' 23.3"	Brand Valley 75, Keerwater stream valley. Hillslope and stream bank exposures of Abrahamskraal maroon and grey-green to blue-green mudrocks (locally mottled) and thin tabular sandstones.
194	S32° 55' 50.5" E20° 25' 59.9"	Rietfontein 197. Lower Beaufort thick channel sandstone cliffs capping possible sandstone package at the head of the Muishondrivier Valley, Snydersberg. Extensive exposure of grey-green and maroon overbank mudrocks with interbedded thin tabular sandstones. Narrow west-east fold zone associated with mineral lineation, bedding plane slippage. Plant stem casts or burrows within maroon fine-grained sandstone.
195	S32° 56' 07.9" E20° 26' 22.1"	Rietfontein 197, Snydersberg. Hillslope exposure of tabular-bedded, hackly-weathering maroon and grey-green overbank mudrocks of Lower Beaufort Group with small, pale grey calcrete nodules, thin tabular sandstone interbeds.
196	S32° 58' 34.9" E20° 25' 26.8"	Kabeltouw Outspan 160. Hillslope and erosion gulley exposure of khaki-hued, weathered Lower Beaufort mudrocks.
197	S32° 58' 35.4" E20° 24' 46.1"	Kabeltouw Outspan 160. Hillslope and track exposures of blue-grey and maroon mudrocks of Lower Beaufort Group, locally with Late Caenozoic calcrete veining. Downwasted gravels composed of rounded corestones of Beaufort Group sandstone.
198	S32° 58' 43.2" E20° 24' 16.5"	Kabeltouw Outspan 160. Extensive riverbank exposures of Lower Beaufort Group grey-green mudrocks, thin tabular sandstones, locally loaded. Thin upward-coarsening packages. Laterally persistent horizon of grey-green

		siltstones with fragmentary impressions of strap-shaped sphenophyte leaves (*Schizoneura*). Small pale grey palaeocalcrete nodules.
199	S32° 58' 46.2" E20° 23' 42.6"	Muishond Rivier 161. Streambed exposure of well-jointed sandstone body – possibly Waterford Fm. Overlain by calcretised coarse gravelly alluvium with gritty orange-brown matrix.
200	S32° 58' 17.7" E20° 21' 19.1"	Muishond Rivier 161. South-facing cliff (with rock art shelter) of thick-bedded Waterford Fm sandstones and grey massive mudrocks with, large-scale soft-sediment deformation of sandstones (*e.g.* balls-and-pillows). Cliff underlain by thin-bedded, wave-rippled wackes. Low-diversity assemblages of small-sized trace fossils on sandstone soles.
202	S32° 58' 10.3" E20° 20' 48.5"	Muishond Rivier 161. Calcrete-cemented alluvial gravels overlying Waterford Fm bedrocks in vicinity of spring.
203	S32° 58' 08.7" E20° 20' 48.7"	Muishond Rivier 161. Streambank exposure of massive to thin-bedded, wave-rippled Waterford Fm wackes with abundant small-scale trace fossils, fine linear toolmarks on sole surfaces, wavy bed tops. Some washed-out traces on bedsoles. Small, non-marine arthropod scratch burrows and possible comb-like scratch marks (bilobites" - *Rusophycus*). Hypichnial burrows (incl. rope-like *Palaeophycus striatus*) also seen on stone blocks in walls of nearby ruins. Semi-consolidated spring-associated vlei deposits.
204	S32° 57' 29.6" E20° 20' 20.3"	Muishond Rivier 161.Exposures along Muishondrivier. Lowermost Abrahamskraal Fm massive grey-green and minor maroon mudrocks, sharp-based tabular-bedded channel sandstones, interbedded thin sandstones and grey-green or maroon mudrocks with persistent horizons of sandstone load structures.
205	S32° 57' 34.9" E20° 20' 15.1"	Muishond Rivier 161.Lower Beaufort Group exposures along southern banks of Muishondrivier. Hackly-weathering blue-grey to khaki-weathered mudrocks, tabular, fine-grained, well-jointed channel sandstones.
205a	S32° 57' 31.3" E20° 20' 20.5"	Muishond Rivier 161. Road cutting and riverbank exposures through well-bedded Quaternary – Holocene sandy to boulder alluvium of Muishondrivier. Older coarse gravelly horizons calcretised.
206	S32° 57' 14.8" E20° 21' 35.8"	Muishond Rivier 161. Package of predominantly Lower Beaufort maroon mudrocks and fine-grained sandstones exposed along banks of Muishondrivier. Irregular lenses of greyish-green pedogenic calcrete mark palaeosols. Also horizon of rusty-brown ferruginous carbonate concretions.
208	S32° 57' 00.8" E20° 21' 34.4"	Muishond Rivier 161. Multiple extensive exposures of Lower Beaufort Group interbedded hackly-weathering mudrocks (grey-green and purple-brown), thin, well-jointed, fine-grained tabular sandstones along stream cuttings close to transmission line. Thin-bedded and heterolithic sediment packages (possibly lacustrine). Common small pale grey calcrete nodules. Cylindrical burrows or plant stem casts in grey siltstones.
209	S32° 56' 47.8" E20° 21' 51.9"	Muishond Rivier 161. Extensive gulley exposure of Lower Beaufort Group sediments just N of transmission line. Tabular, fine-grained, often mottled sandstones with vague, gradational bases. Possible upward-coarsening packages. Mudrocks predominantly blue-grey but some horizons with subequal proportions of blue-grey and maroon mudrocks. Probably reedy plant stem casts on tops of sandstone beds. Large ferruginous carbonate concretions

		common, as well as small grey calcrete nodules.
210	S32° 56' 35.4" E20° 24' 35.5"	Muishond Rivier 161, Kabeltouw Pass near transmission line route. Hillslope and gulley exposures of Abrahamskraal Fm. Grey-green to blue-grey and maroon murocks, thin tabular crevasse splay sandstones. Sandstone palaeosurface with small-scale wave ripples, reedy stem casts, linear tool marks (possible logs or amphibians), invertebrate burrows (possibly *Scoyenia*). Overlying mudrocks with oblate ferruginous carbonate concretions, fragmentary equisetalean stem impressions.
211	S32° 56' 36.3" E20° 24' 37.4"	Muishond Rivier 161, Kabeltouw Pass. Pair of inclined tetrapod burrow casts (*c*. 15-20 cm wide, elliptical cross-section, narrowing and flattening distally) immediately overlying sandstone palaeosurface at previous locality – probably palaeosol horizon surrounding playa lake.
212	S32° 56' 34.0" E20° 24' 34.9"	Muishond Rivier 161, Kabeltouw Pass. Sparse disarticulated skeletal remains of a small tetrapod, probably comprising the tusks and limb bone of a small dicynodont therapsid (*e.g. Eodicynodon*), embedded in fine grey-green sandstone. Linear subhorizontal tetrapod burrow (c. 15 cm wide) nearby (< 2m) at the same horizon.
213	S32° 58' 58.6" E20° 26' 32.0"	Barendskraal 76. Riverine cliff exposure of package of thick Waterford Fm wackes showing high levels of soft-sediment deformation (convolute bedding), overlying grey-green mudrocks with load balls.
214	S32° 58' 55.2" E20° 26' 36.3"	Barendskraal 76. Downwasted and alluvial surface gravels with locally common reworked blocks of pale grey petrified wood from the Waterford Fm.
215	S32° 58' 53.8" E20° 26' 38.1"	Barendskraal 76. Stream gulley exposure of wave-rippled Waterford Fm sandstones, sharp-based, and heterolithic thin-bedded facies. Overlain by thick unit of poorly-sorted, partially calcretised alluvial gravels (mainly Waterford wacke clasts).
216	S33° 00' 08.0" E20° 26' 40.3"	Barendskraal 76. Stream bed exposure of large, well-jointed (NW-SE) sandstone channel body of Lower Beaufort Group with current-rippled top. Primary current lineation, horizontal lamination, large scale trough cross-sets.
217	S33° 00' 23.5" E20° 27' 07.1"	Barendskraal 76. Strap-shaped sphenophyte leaf impression (*Schizoneura*) within sandstone float block, mapped as L. Beaufort Group.
218	S33° 00' 24.1" E20° 27' 04.0"	Barendskraal 76, SE of farmstead. Extensive stream gulley exposure of Lower Beaufort Group (as mapped) – or perhaps upper Waterford Fm – sediments, close to Ecca-Beaufort boundary. Thick, tabular amalgamated sandstone along skyline to the south. Heterolithic packages of thin-bedded sandstones and siltstones. Sharp-based channel sandstones, laminated towards base, overlying thin-bedded, grey-green mudrocks. Local loading of sandstone bases. Thin, upward-coarsening siltstone – sandstone packages capped by fine sandstones with gradational bases. Horizons with abundant large ferruginous carbonate concretions, sandstone load balls.
219	S33° 00' 37.5" E20° 26' 41.7"	Barendskraal 76, Barendskloof. Excellent riverine cliff sections through lowermost Abrahamskraal Fm (as mapped) – possibly basal Combrinkskraal Member *sensu stricto* sandstone package. Thick lenticular channel sandstones downcutting into heterolithic, thinner-bedded tabular succession > sandstone lloading and upward-coarsening seen at base of exposure but wave-rippled sandstone surfaces, maroon mudrocks, calcrete nodules apparently absent. Subvertical W-E running fault plane visible on both sides of valley (beds

		downfaulted to the south).
220	S33° 00' 55.6" E20° 26' 43.3"	Barendskraal 76, southern part of Barendskloof. Riverine cliff sections through thick, lenticular (or thickening and thinning), amalgamated channel sandstone bodies of lowermost Abrahamskraal Fm (possibly = Combrinkskraal Member *sensu stricto*), close to Ecca – Beaufort boundary. Bases of thick sandstone packages are loaded on a large scale. Between cliff-forming sandstone bodies are medium-bedded, tabular to lenticular, fine-grained, sharp-based sandstones and grey-green massive to thin-bedded mudrocks. No maroon mudrocks or wave rippled surfaces seen. Basal package of khaki-brown, hackly-weathering mudrocks and brownish tabular sandstones beneath major cliff-forming sandstone in the south. Above zone of major sandstone packages the Lower Beaufort Group shows stepped outcrop with much thinner, tabular, laterally-persistent sandstone bodies (*e.g.* southern end of Barensdkloof).