Palaeontological specialist assessment: combined desktop and field-based study

PROPOSED MODDERFONTEIN WIND ENERGY FACILITY NEAR VICTORIA WEST, CENTRAL KAROO AND PIXLEY KA-SEME DISTRICTS, WESTERN CAPE & NORTHERN CAPE PROVINCES

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EXECUTIVE SUMMARY

It is proposed to develop the Modderfontein WEF on farms Modderfontein 228 and Phaisant Kraal 1, situated *c*. 40 km SSE of Victoria West in the Pixley Ka-Seme and Central Karoo Districts of the Northern and Western Cape respectively. Environmental Authorisation has already been granted for a WEF project on the same site involving up to 67 wind turbines and a total generation capacity of 201 MW. An amended Modderfontein WEF project proposal comprising up to 34 wind turbines with a total generation capacity of up to 190.4 MW is the focus of the present palaeontological heritage study. Assessment of a grid connection for the Modderfontein WEF does not form part of this study.

The Modderfontein WEF project area is underlain by continental sediments of the Teekloof Formation (Lower Beaufort Group, Karoo Supergroup) of Late Permian age. These sedimentary bedrocks have yielded important fossil vertebrate faunas of the *Endothiodon* Assemblage Zone (incorporating the previous *Pristerognathus* and *Tropidostoma* Assemblage Zones) *plus* younger assemblages in the area south of Victoria West. In particular, vertebrate fossil sites in the vicinity of Biesiespoort railway station (Farm Noblesfontein 227, Matjiesfontein 220 and Modderfontein 228), situated just west of the present WEF project area, have been studied by several prominent Karoo palaeontologists since the early C20. Fossils collected here include several holotype specimens of herbivorous and carnivorous therapsids (“mammal-like reptiles”) and continue to make a key contribution to the biostratigraphic zonation of the Beaufort Group (Day & Rubidge 2020a).

The palaeosensitivity of the Modderfontein WEF project area is provisionally rated as Very High in standard screening studies. A three-day palaeontological site visit, focussing mainly on the limited areas with good Teekloof mudrock exposure, shows that vertebrate fossils are locally common here with over 50 new fossil sites recorded (Appendix 1). Some of the stratigraphically lower mudrock horizons are apparently only sparsely fossiliferous, however well-exposed, while most of the fossils recorded comprise common forms of small-bodied dicynodonts of limited scientific interest. Other fossil groups recorded include fragmentary material of larger therapsids (mostly unidentified), various vertebrate burrows, low-diversity invertebrate trace fossil assemblages and very occasional plant material (moulds of glossopterid leaves, equivocal woody plant stems). Fossils are rare within sandstone facies while those recorded within thermally metamorphosed (“baked”) Teekloof Formation bedrocks adjacent to dolerite intrusions are very poorly preserved. The Karoo dolerites, where a high proportion of wind turbines will be sited, are unfossiliferous and most lower-lying

areas are mantled by thin to thick alluvial and colluvial deposits of Late Caenozoic age that are of low palaeosensitivity.

It is concluded that the majority of the Modderfontein WEF project area is, in practice, of Low palaeosensitivity with scattered, and to some extent unpredictable, islands of High sensitivity. No palaeontological Very High Sensitivity / No-Go areas have been identified or designated here and the WEF project proposal is not fatally flawed from a palaeontological heritage viewpoint. None of the recorded fossil sites overlaps directly with the amended turbine locations and no exclusion or re-siting of the amended turbine sites on palaeontological grounds is proposed here.

The anticipated impact significance of the amended turbine layout in terms of palaeontological heritage is substantially *lower* compared with the original, authorized turbine layout principally due to (1) the much smaller number of amended turbine sites and (2) the siting of a high proportion of these sites on unfossiliferous doleritic ridges and plateaux, or on adjoining thermally-metamorphosed sedimentary bedrocks of low palaeosensitivity. Construction phase excavations and surface clearance for associated infrastructure such as access roads and hard stand areas pose a more serious threat to local palaeontological heritage than wind turbine footings. The overall palaeontological impact significance of amended Modderfontein WEF project – and hence the level of proposed mitigation - can only be formally assessed when the complete finalized layout (including grid connection corridor) becomes available but in any event will be markedly lower than that of the authorized WEF project.

Micro-siting of turbine positions and other WEF infrastructure in relation to known fossil sites is generally not recommended. Inevitable negative impacts within the final WEF footprint can usually be effectively mitigated by pre-construction palaeontological surveying of potentially sensitive sectors of the WEF footprint (including the grid connection corridor). This would entail specialist recording and judicious sampling of any fossil specimens of scientific and / or conservation value *plus* specific, realistic recommendations for any necessary, targeted mitigation during the construction phase. During the construction phase itself a Chance Finds Fossil Procedure driven by the responsible environmental site officers and ECO should be implemented (see Appendix 2).

These palaeontological heritage recommendations are broadly in line with those made by in 2011 by Heritage Western Cape with respect to the original Karoo Renewable Energy Facility project area of which the Modderfontein WEF project area forms a part. SAHRA's (2011) additional requirement that fresh excavations undertaken into the Teekloof Formation should be inspected by a palaeontologist during the construction phase is considered to be unduly onerous and unlikely to yield much useful palaeontological material or data. Furthermore, finding suitably qualified palaeontologists willing or able to undertake such work for long stretches during the WEF construction phase would be very challenging. For these reasons, mitigation through targeted pre-construction fossil recording and collection supplemented by a fully-implemented Chance Fossil Finds Procedure during the construction phase is preferred here.

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 palaeontological heritage studies developed by SAHRA (2013) and

HWC (2021). The palaeontological assessment reports must be submitted for consideration to both Heritage Western Cape and SAHRA.

1. INTRODUCTION

1.1. Project outline and brief

It is proposed to develop a wind energy facility (WEF), known as the Modderfontein Wind Energy Facility (WEF), on farms Modderfontein 228 (Northern Cape Province, Pixley Ka-Seme District) and Phaisant Kraal 1 (Western Cape Province, Central Karoo District), situated some 20 km NE of Three Sisters and 40 km SSE of Victoria West (Fig. 1). The WEF project area is located in highly dissected, hilly to mountainous terrain of the semi-arid Great Karoo between the N1, N12 and R63 roads and just east of the Biesiespoort Railway Station on the Beaufort West to Hutchinson railway line. Environmental Authorisation (DEA 12/12/20/1993) has already been granted for an original WEF project on the same site involving up to 67 wind turbines and a total generation capacity of 201 MW (Fig. 2). An amended Modderfontein WEF project proposal comprising up to 34 wind turbines with a total generation capacity of up to 190.4 MW is the focus of the present palaeontological heritage study (Fig. 3). The Modderfontein WEF lies within the recently gazetted Beaufort West Renewable Energy Development Zone (REDZ).

The proposed Modderfontein WEF project area is underlain by potentially fossiliferous sedimentary rocks of Late Permian and Late Caenozoic age (Sections 2 and 3). The construction phase of the WEF development will entail substantial surface clearance as well as excavations into the bedrocks and superficial sediment cover (*e.g.* for wind turbine footings, laydown areas, underground cables, substation and building foundations, internal access roads, electrical pylon footings). All these activities may adversely affect potential fossil heritage preserved at or beneath the surface of the ground within the study area by destroying, disturbing or permanently sealing-in fossils that are then no longer available for scientific research or other public good.

A desktop palaeontological heritage report for the Modderfontein WEF project area, originally part of the much more extensive Karoo Renewable Energy Facility project area, was submitted by Rossouw (2011). This short study recognised the palaeontological sensitivity of the Permian sedimentary bedrocks of the Teekloof Formation (Lower Beaufort Group, Karoo Supergroup) as well as of the Quaternary (Late Caenozoic) alluvial deposits within the project area. Rossouw (2011) accordingly recommended that:

> *Future development that calls for trench or pit excavations, exposing fresh Teekloof Formation bedrock or intact superficial deposits in the area will require a Phase 1 palaeontological impact assessment.*

Heritage Western Cape's response (Case ID 1256, letter of May 2011) to the responsible EAP. Savannah Environmental (Pty) Ltd, referring to the original Karoo Renewable Energy Facility, included the following requirements relevant to local palaeontological heritage resources:

4. A pre-excavation palaeontological survey of selected sites and access roads is necessary involving any fossiliferous exposures existing within the broader footprint of the proposed development, fresh cuttings along new access roads, substantial bedrock excavations as well as foundation excavations - this report must be submitted to HWC

SARAH's review comment to Savannah Environmental (Pty) Ltd, also dated May 2011, was along similar lines, as follows:

- A Phase 1 Palaeontological Impact Assessment in the form of field survey of the area is requested, the assessment must be then submitted to SAHRA for comments. If deemed necessary after the survey, a Phase 2 rescue operation might also be requested.
- A palaeontologist must inspect fresh excavations undertaken in the fossil-bearing Teekloof Formation.

This response was reiterated by SAHRA in their Interim Comment of June 2013 (SAHRA Ref: 9/2/100/0001) followed by a written request from SAHRA for outstanding information dated May 2015. Although, to the author's knowledge, no field-based PIA of the Karoo Renewable Energy Facility project area was ever conducted or submitted, the development nevertheless received Environmental Authorization from the DEA (DEA Ref. No. 12/12/20/1993, dated 22 February 2012). The Conditions for Authorization itemised by the DEA, who reference input from SAHRA, included the following requirements relevant to the present palaeontological heritage study:

18. The holder of this authorisation must appoint a qualified heritage specialist to ground-truth every infrastructure footprint and their recommendation must inform the final layout of the facility and the EMP to be submitted to the Department for approval.

100. [Regarding palaeontological resources] If there are any changes to the layout of the turbines from the approved layout plan, then additional survey work will be required to ensure that no sites are directly impacted and / or to identify the need for an excavation permit.

102. A walk-through survey of the final power line corridor must be undertaken by a heritage specialist to identify areas where mitigation may be required.

The Karoo Renewable Energy Facility project was subsequently split into three components – namely the Noblesfontein, Highlands and Modderfontein WEFs – the first of which, including a grid connection, has already been constructed and is now fully operational. It appears that no pre-construction or construction phase palaeontological mitigation or monitoring were undertaken for the Noblesfontein WEF project or the associated grid connection. In the interim, two additional relevant desktop PIA reports for the Noblesfontein 2 and Noblesfontein 3 WEF proposals, situated in closely comparable (geologically and palaeontologically) terrain outside but close to the original Karoo Renewable Wind Energy Facility project area, were submitted to the EAP Terramanzi Group (Pty) Ltd by Almond (2015a, 2015b).

The currently authorized Modderfontein WEF (67 turbines, 201 MW) has not yet been fully assessed in terms of palaeontological heritage resources. In support of the Part 2 Amendment application for the revised Modderfontein WEF (25 turbines, 140 MW) the present combined desktop and field-based palaeontological heritage report has been commissioned and will contribute to the broad-based heritage assessment of the amended project under the aegis of CTS Heritage, Cape Town (Contact details: Ms Jenna Lavin. CTS Heritage. 16 Edison Way, Century City, RSA. Tel: +27 (0)87 073 5739. Cell: +27 (0)83 619 0854. E-mail: info@ctsheritage.com). The independent EAP responsible for the Part 2 Amendment Application process is the Terramanzi Group (Pty) Ltd (Address: 5 Devon Air Close, Crofters Valley, Noordhoek 7975, RSA. Tel: 021 701 5228. E-mail: info@terramanzi.co.za).

Figure 1: Google Earth© satellite image showing the location (orange polygon) of the Modderfontein WEF project area on adjoining farms Modderfontein 228 and Phaisant Kraal 1. The project area lies to the north of the N1 and spans the boundary between the Western and Northern Cape Provinces (lilac line), *c*. 40 km SSE of Victoria West and 20 km NE of Three Sisters.

1.2. Legislative context for palaeontological assessment studies

All palaeontological heritage resources in the Republic of South Africa are protected by the National Heritage Resources Act (Act 25 of 1999). Heritage resource management in the Western Cape is the responsibility of Heritage Western Cape (HWC) (3rd Floor, Protea Assurance Building, Green Market Square, Cape Town 8000. Private Bag X9067, Cape Town 8001. Tel: 021 483 9598. Fax: 021 483 9845. E-mail: hwc.hwc@westerncape.gov.za). For the Northern Cape Province the responsible body is SAHRA (Contact details: SAHRA, 111 Harrington Street, Cape Town. PO Box 4637, Cape Town 8000, South Africa. Phone: +27 (0)21 462 4502. Fax: +27 (0)21 462 4509. Web: www.sahra.org.za).

The various categories of heritage resources recognised as part of the National Estate in Section 3 of the National Heritage Resources Act (Act 25 of 1999) include, among others:

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

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

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

(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 agency, or to the nearest local agency offices or museum, which must immediately notify such heritage resources Agency.

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

(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 agency 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 agency 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) and Heritage Western Cape (2021).

1.3. Approach to the palaeontological heritage study (PIA)

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

In preparing a palaeontological desktop study the potentially fossiliferous rock units (groups, formations *etc.*) represented within the study area are determined from geological maps and satellite images. The known fossil heritage within each rock unit is inventoried from the published scientific literature, previous palaeontological impact studies in the same region, and the author's field experience (consultation with professional colleagues as well as examination of institutional fossil collections may play a role here, or later following field assessment during the compilation of the final report). This data is then used to assess the palaeontological sensitivity of each rock unit to a 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 impact of the proposed development on local fossil heritage is then determined on the basis of (1) the palaeontological sensitivity of the rock units concerned, and (2) the nature and scale of the development itself, most significantly the extent of fresh bedrock excavation envisaged. When rock units of moderate to high palaeontological sensitivity are present and exposed within the development footprint, a Phase 1 field assessment study by a professional palaeontologist is usually warranted to identify any palaeontological hotspots and make specific recommendations for any mitigation required before or during the construction phase of the development.

On the basis of the desktop and Phase 1 field assessment studies, the likely impact of the proposed development on local fossil heritage and any need for specialist mitigation are then determined. Adverse palaeontological impacts normally occur during the construction rather than the operational or decommissioning phase. Phase 2 mitigation by a professional palaeontologist – normally involving the recording and judicious 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 Agency (*i.e.* Heritage Western Cape for the Western Cape, SAHRA for the Northern Cape). It should be emphasized that, *provided that appropriate mitigation is carried out*, the majority of developments involving bedrock excavation can make a *positive* contribution to our understanding of local palaeontological heritage.

1.4. Assumptions & limitations

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

1. Inadequate database for fossil heritage for much of the RSA, given the large size of the country and the small number of professional palaeontologists carrying out fieldwork here. Most development study areas have never been surveyed by a palaeontologist.
2. Variable accuracy of geological maps which underpin these desktop studies. For large areas of terrain these maps are largely based on aerial photographs alone, without ground-truthing. The maps generally depict only significant ("mappable") bedrock units as well as major areas of superficial "drift" deposits (alluvium, colluvium) but for most regions give little or no idea of the level of bedrock outcrop, depth of superficial cover (soil *etc.*), degree of bedrock weathering or levels of small-scale tectonic deformation, such as cleavage. All of these factors may have a major influence on the impact significance of a given development on fossil heritage and can only be reliably assessed in the field.
3. Inadequate sheet explanations for geological maps, with little or no attention paid to palaeontological issues in many cases, including poor locality information.
4. The extensive relevant palaeontological "grey literature" - in the form of unpublished university theses, impact studies and other reports (*e.g*. of commercial mining companies) - that is not readily available for desktop studies.
5. Absence of a comprehensive computerized database of fossil collections in major RSA institutions which can be consulted for impact studies. A Karoo fossil vertebrate database is now accessible for impact study work.

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

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

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

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

In the case of the present study area near Victoria West the main constraint for fossil heritage studies is the limited surface exposure of potentially fossiliferous bedrocks (especially readily-weathered mudrocks) due to cover by superficial sediments such as colluvium (scree), eluvial gravels and alluvium. This limitation is partially offset by the long (> 100 years) history of scientific fossil collection in this palaeontologically important subregion of the Main Karoo Basin (Day & Rubidge 2020a). A number of good exposures of bedrock and superficial sedimentary rock units were examined during the course of the present field survey so confidence levels for this assessment are rated as Medium.

1.5. Information sources

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

1. A short project outline, maps and kmz files kindly provided by CTS Heritage, Cape Town;
2. A review of the relevant scientific literature (especially Day & Rubidge 2020 and refs. therein), including published geological maps and accompanying sheet explanations (*e.g.* Le Roux & Keyser 1988) as well as several desktop and field-based palaeontological assessment studies in the broader Victoria West region of the Northern Cape by the author and others (*e.g.* Almond 2010a, 2010b, 2012a, 2012b, 2013c, 2015a, 2016b, Rossouw 2011);
3. Examination of relevant topographical maps (*e.g.* 1: 250 000 sheet 3122 Victoria West, 1: 50 000 sheets 3123CA, CB, CC, CD) and Google Earth© satellite images;
4. A three-day palaeontological site visit by the author and an experienced assistant (4-6 May 2021) which focussed on a representative sample of potentially-fossiliferous exposures of bedrock units (especially good mudrock exposures) and older - probably Pleistocene - alluvial deposits within the broader project area. Note that the survey did *not* focus on proposed turbine positions, many of which are situated on unfossiliferous dolerite or thermally-metamorphosed sediments, since these do not constitute the most important potential threat to local fossil heritage resources.
5. The author's previous field experience with the formations concerned and their palaeontological heritage (See also reviews of Western and Northern Cape fossil heritage by Almond & Pether 2008a and 2008b respectively).

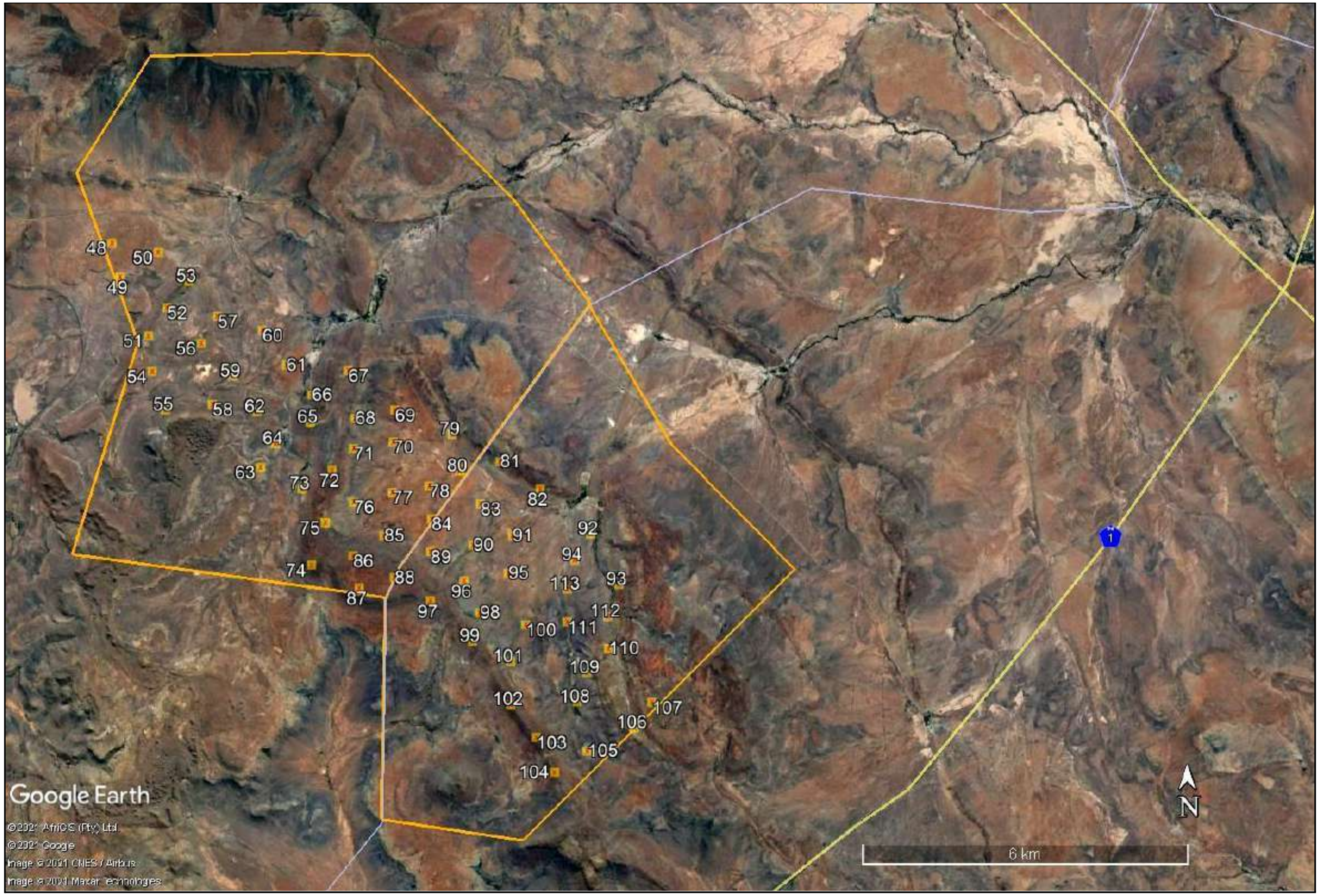

Figure 2: Google earth© satellite image showing the Modderfontein WEF project area near Victoria West (orange polygon) as well as the original, *authorized* layout for up to 67 wind turbines with a total generation capacity of 201 MW (small numbered yellow squares).

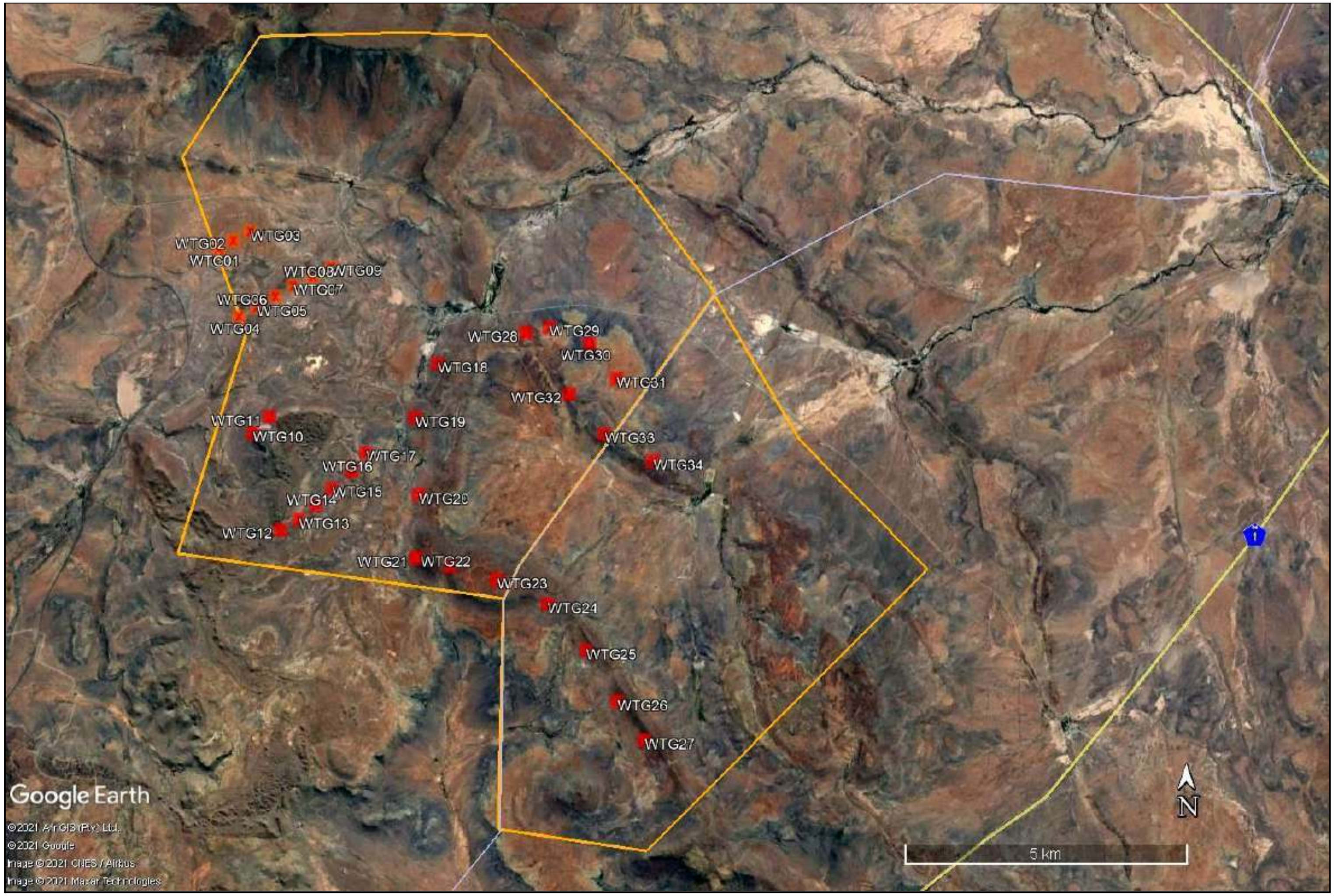

Figure 3: Google earth© satellite image showing the Modderfontein WEF project area near Victoria West (orange polygon) as well as the *amended* layout for up to 25 wind turbines with a total generation capacity of 140 MW (small numbered red squares). Note that many of the proposed turbine

locations are aligned along or close to dolerite intrusions (rusty brown) while impacts by turbines on areas of good Beaufort Group mudrock exposure (dark grey) are very limited. These areas might be significantly impacted by other WEF infrastructure such as access roads, however.

2. GEOLOGICAL OUTLINE OF THE STUDY AREA

The Modderfontein WEF project area on farms Modderfontein 228 and Phaisant Kraal 1 lies within the semi-arid Upper Karoo region of the RSA and features scenically attractive, dissected, mountainous to hilly terrain with rocky doleritic ridges, stepped sandstone surfaces and intervening gravelly to sandy *vlaktes* or alluvial plains (Figs. 4 to 14). The vegetation is typical karroid *bossieveld* vegetation, often grassy in doleritic areas, while trees are largely restricted to intermittently-flowing watercourses. The highest terrain lies in the north, outside the WEF project area, where the Horse Shoe reaches elevations of 1813 at Gys Roosberg while the conical peak of Rondekop in the southwest lies at 1587 m amsl. Doleritic ridges and narrow plateaux traversing the area lie up to *c*. 1500 m amsl. The area is drained towards the east and northeast by shallowly incised tributaries of the Brakrivier including the Gabrielspruit. Proposed WEF infrastructure is confined to the region due south of the unpaved road from the N1 trunk road to Biesiespoort railway station. Sedimentary bedrock exposure levels – especially as far as the potentially fossiliferous mudrocks are concerned - are variable and usually low due to extensive, thick alluvial sands and gravels in the lower-lying areas *plus* colluvium (scree) and eluvial (downwasted / relictual) gravels on steeper hillslopes and their marginal alluvial fans. However, occasional good exposures of potentially fossiliferous bedrocks are present locally, as indicated by dark grey areas on satellite images (Figs. 2 & 3).

Figure 4: Typical gravelly alluvial plains seen in the central sector of Phaisant Kraal 1, here looking northwards with dolerite ridges on the skyline. Bedrock exposure in such low-lying areas is minimal.

Figure 5: View northwards from the Gamma-Omega powerline along a shallow stream valley incised into Teekloof Formation bedrocks, Phaisant Kraal 1. Numerous small mudrock exposures occur along the incised lower hill slopes flanking the valley.

Figure 6: Typical upland dolerite scenery, seen here along the Gamma-Omega powerline on Phaisant Kraal 1, with ruiniform heaps of dolerite corestones and well-developed dark patination of many well-rounded boulders.

Figure 7: Rubbly dolerite ridge on the SW portion of Modderfontein 228 with low-relief *vlaktes* in the foreground largely mantled by alluvial and eluvial gravels and sands. Bedrock exposure in the *vlaktes* is very limited (bottom LHS).

Figure 8: Dissected north-eastern slopes of the main doleritic turbine ridge on the SW portion of Phaisant Kraal 1. Outside occasional deeper *klowe*, sedimentary bedrock exposure along the ridge flanks is minimal due to colluvial gravel and vegetation cover.

Figure 9: Stepped, north-east facing escarpment of Teekloof Formation bedrocks capped by dolerite on the eastern margins of Phaisant Kraal 1. Good exposures of mudrocks are confined to deeply-incised stream gorges or *klowe* and are frequently thermally metamorphosed to dark hornfels.

Figure 10: Stepped lower valley slopes in the central portion of Phaisant Kraal 1 with a rugged dolerite ridge in the background to the SW (Note wind mast). Exposure levels of fossiliferous dark Teekloof Formation mudrocks are high in this area.

Figure 11: Deeply-incised stream valley on the western margins of Phaisant Kraal 1 with Rondekop on the skyline to the south. The purple-brown Teekloof mudrocks exposed on the valley slopes are baked and capped by collapsed blocks of paler baked channel sandstone.

Figure 12: Rondekop in the SW corner of Phaisant Kraal 1 viewed from the south. According to the geological map, the smooth lower hillslopes with few thin intercalated sandstone packages are built of Hoedemaker Member mudrocks capped by dolerite along the eastern hillcrest.

Figure 13: View northwards towards the approximately W-E trending dolerite ridge running along the southern edge of Modderfontein 228 into Phaisant Kraal 1. Several turbine locations are sited here. The dissected hilly terrain in the foreground includes palaeontologically promising mudrock exposures.

Figure 14: North-facing escarpment of Teekloof Formation bedrocks close to Modderfontein homestead showing extensive dark mudrock exposures along the lower slopes with thin intercalated channel sandstone packages. These exposures are only sparsely fossiliferous, however.

The geology of the Modderfontein WEF project area is outlined on the 1: 250 000 geology sheet 3122 Victoria West (Fig. 15) with a short accompanying sheet explanation by Le Roux & Keyser (1988). The project area is almost entirely underlain by Late Permian continental sediments of the **Lower Beaufort Group** (Adelaide Subgroup, Karoo Supergroup) (Johnson *et al.* 2006). According to the published geological map two subunits or members of the **Teekloof Formation** are represented within the study area, namely the basal sandstone-dominated **Poortjie Member** (**Ptp**) and the overlying mudrock-dominated **Hoedemaker Member** (**Pth**) (See stratigraphic table Fig. 16). The Poortjie Member mainly crops out in lower-lying terrain and builds the lower portions of stepped hillslopes, low-lying sandstone plateaux and their fringing escarpments (*e.g.* Fig. 14). The Hoedemaker Member, as mapped, builds the smoother slopes of Rondekop (Fig. 12) in the southwest as well as the lower slopes (largely obscured by colluvium) of the Horse Shoe range on the northern margins of Farm Modderfontein 228.

As noted in the recent, well-documented biostratigraphical study of the Biesiespoort area by Day and Rubidge (2020), however, the published geological mapping may require considerable revision. In the present author's view, the outcrop area of the Hoedemaker Member is probably much more extensive here than mapped. Some of the thin, often yellowish sandstone packages currently referred to the Poortjie Member may in fact belong to the lower Hoedemaker Member, as also seen further west near Loxton (See stratigraphic columns in Smith & Keyser 1995, Day & Smith 2020). Thicker sandstone packages observed at high elevations in the western-central sector of the project area (Fig. 26) *might* belong to the overlying Oukloof Member which is mapped just beneath the dolerite sill capping the Horse Shoe. Such lithostratigraphic revision is beyond the scope of the present PIA study but has important implications for the biostratigraphic zonation of the Main Karoo Basin (Section 3).

Bedding dips of sedimentary bedrocks are not indicated on the Victoria West geology sheet, probably because the Beaufort Group succession here is largely flat-lying and undeformed, favouring fossil preservation. However, these Permian sediments are extensively intruded and thermally metamorphosed (baked) by a network of substantial dolertic sills and dykes of the Early Jurassic **Karoo Dolerite Suite** (Jd) that are themselves unfossiliferous (*e.g.* many portions of the proposed turbine footprint; *cf* rusty-brown areas in Figs. 2 & 3).

Geological and palaeoenvironmental analyses of the Lower Beaufort Group sediments in the Great Karoo region have been conducted by a number of workers. Key references within an extensive scientific literature include various papers by Roger Smith (*e.g.* Smith 1979, 1980, 1986, 1987a, b, 1988, 1989, 1990, 1993a, 1993b, Smith *et al.* 2012) and Stear (1978, 1980), as well as several informative field guides (*e.g.* Cole & Smith 2008). In brief, these thick successions of clastic sediments were laid down by a series of large, meandering rivers within a subsiding basin over a period of some ten or more million years within the Middle to Late Permian Period (*c*. 265-251 Ma). Sinuous sandstone bodies of lenticular cross-section represent ancient channel infills, while thin (<1.5m), laterally-extensive sandstone beds were deposited by crevasse splays during occasional overbank floods. The bulk of the Beaufort sediments are greyish-green to reddish-brown or purplish mudrocks (“mudstones” = fine-grained claystones and slightly coarser siltstones) that were deposited over the floodplains during major floods. Thin-bedded, fine-grained playa lake deposits also accumulated locally where water ponded-up in floodplain depressions and are associated with distinctive fossil assemblages (*e.g.* fish, amphibians, coprolites or fossil droppings, arthropod, vertebrate and other trace fossils).

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

Compared with the underlying Abrahamskraal Formation succession the **Teekloof Formation** has a generally higher proportion of sandstones and reddish mudrocks are more abundant here (Johnson & Keyser 1979, Le Roux & Keyser 1988). Multi-storied channel sandstones are common in the basal arenaceous **Poortjie Member**, as are thin, impersistent lenses of pinkish “cherts” that are probably altered volcanic ashes (Johnson & Keyser 1979, Smith & Keyser 1995a), though these were not observed in the present study area. This member is about 80 m thick in the Victoria West area, thinning eastwards. In the Beaufort West area several economically interesting uranium ore deposits occur within the Poortjie Member in association with brown-weathering, ferruginous channel sandstones (“*koffieklip*”) and transported plant material.

Interesting accounts of the sedimentology and palaeontology of the Poortjie Member in the southern Karoo are given by Stear (1978) as well as by Cole and Smith (2008). In general, the Poortjie Member purple-brown and grey-green mudrocks encountered in the project area show less vibrant, more “dusky” hues than those seen in the overlying Hoedemaker Member (Figs. 18, 21 & 22). A succession of orange-brown, grey-green and yellowish channel sandstone packages seems to be typical for this area within the Poortjie Member (Fig. 17). Well-developed horizons or lenses of large (cobble-sized) calcrete concretions, often secondarily ferruginised, are common within the mudrock facies, as are sandstone-infilled mudcracks and veins or “desert roses” of silicified gypsum. Thick (up to 1-2 m), sometimes multiple or cross-bedded lenses of coarse breccio-conglomerate may be present towards the base of the channel sandstone packages (especially the highest, yellow-weathering one) and consist of reworked mudflakes and calcrete nodules with very sparse fossil bone / teeth (Fig. 19). These features, together with the general paucity of fossil remains, all suggest episodes of intense aridity and episodic erosional gullying of the ancient Karoo floodplain.

The geology of the **Hoedemaker Member**, which is up to 240 m thick, is outlined by Smith (1980, 1993a, b) and later by Smith and Keyser (1995b) as well as Cole and Smith (2008). The Hoedemaker succession is dominated by greenish-grey to purple-brown overbank mudrocks, with occasional single-storey sheet sandstones that are generally finer-grained and less friable (biscuit-like) than those in the Poortjie Member. Palaeosol (ancient soil) horizons characterized by small calcrete nodules (Fig. 24) and rhizocretions (root casts) are common, as are also lacustrine (transient to long-lived playa lake) sediments deposited in depressions on the Late Permian floodplain. These last are associated with limestone crusts, gypsum crystals ("desert roses") as well as a range of fine-scale sedimentary features such as wave rippled sandstones, falling water marks, mudcracks, and trace fossils (Stear 1978, Smith 1980, 1986, 1993a). The overbank mudrocks of the Hoedemaker Member often display vibrant or luminous purple-brown to grey-green or blue-grey hues (Fig. 23).

An irregular network of resistant-weathering **Karoo dolerite** bodies intrude the Beaufort Group sedimentary country rocks within the WEF project area (Fig. 15). The subhorizontal sills and steeply inclined dykes, as well as resistant-weathering metasediments generated by thermal metamorphism of the adjacent country rocks, build much of the higher ground in the region south of Victoria West. These Early Jurassic (*c*. 183 Ma) basic intrusions were emplaced during crustal doming and stretching that preceded the break-up of Gondwana (Duncan and Marsh 2006). The hot dolerite magma plus associated hot circulating fluids baked and mineralised adjacent Beaufort mudrocks and sandstones to form tough, splintery hornfels and quartzites respectively which are typically densely spotted with pale-rimmed irregular cavities or vugs (Fig. 20). Voluminous blocky colluvium and corestones released by weathering and erosion of the dolerites and associated tough metasediments blanket many mountain slopes, obscuring the underlying fossiliferous Beaufort Group sediments, as clearly seen in satellite images and field photos of the study area (*e.g.* Figs. 8 & 9). Areas of dolerite intrusion are typically associated with ferruginous lateritic soils and calcrete formation. In upland areas rounded dolerite corestones often display a very dark brown to black patina of desert varnish which has often been exploited by rock engravers in pre-historical as well as early historical times (Fig. 6).

Various types of **superficial deposits** of Late Caenozoic (Miocene / Pliocene to Recent) age occur widely throughout the Great Karoo region, including the present study area. They include pedocretes (*e.g*..calcretes or soil limestones), colluvial slope deposits (sandstone and dolerite scree, downwasted or eluvial gravels *etc*), sheet wash, river channel alluvium and terrace gravels, soils, as well as spring and pan sediments (Johnson & Keyser 1979, Le Roux & Keyser 1988, Cole *et al.,* 2004, Partridge *et al*. 2006).

The intervening lower-lying areas are for the most part thickly blanketed in **Quaternary alluvium** (Figs. 4, 5 & 7) but, apart from a small area due east of Phesantkraal homestead associated with the Gabrielspruit drainage line, these younger superficial deposits are not mapped at 1: 250 000 scale. The older alluvial deposits (possibly Pleistocene in age) are often semi-consolidated by calcrete cementation (Fig. 27). The gravel facies is dominated by angular to subrounded clasts of quartzite, hornfels and dolerite. No identifiable stone artefacts or reworked fossil bones / teeth which might constrain their age were encountered during the field survey. Apart from occasional deeply-incised stream gullies or *klowe*, sedimentary bedrock exposure along mountain slopes and foothills is usually very poor due to the pervasive thick apron of **colluvial rock debris** (*i.e.* scree), mainly of baked sandstone (quartzite), hornfels and dolerite *plus* finer-grained hillwash (Fig. 9). Rubbly doleritic debris is frequently stabilized by calcrete (soil limestone) on hillslopes and along water courses. Thin veneers of calcareous flowstone locally coat bedrocks exposed in overhangs in the vicinity of dry waterfalls (*e.g.* stream valley N of Rondekop).

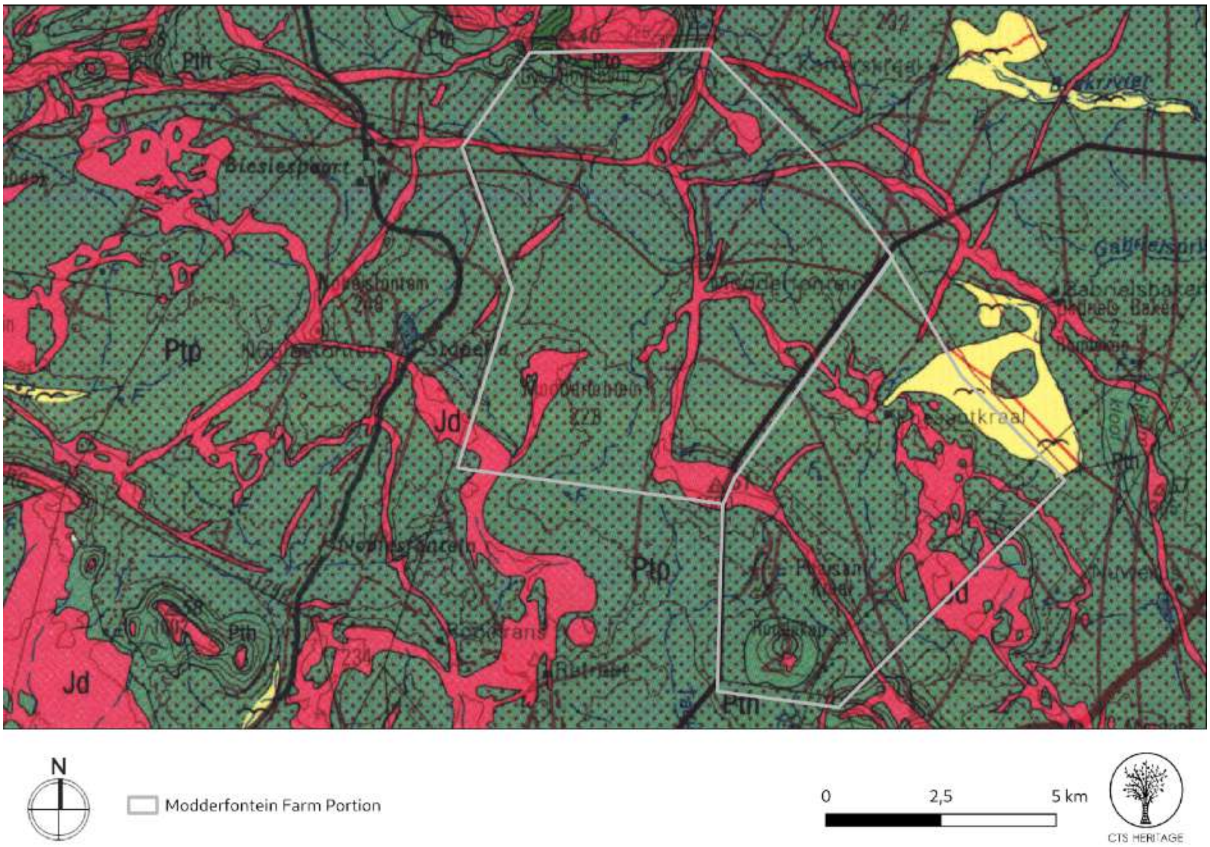

Figure 15: Extract from 1: 250 000 geology sheet 3122 Victoria West showing the outline of the Modderfontein WEF project area on farms Modderfontein 228 and Phaisant Kraal 1 (white polygons) (Base map published by the Council for Geoscience, Pretoria. Image prepared by CTS Heritage). The main rock units represented here include:

Ptp (middle green with stipple) = Middle to Late Permian Poortjie Member, Teekloof Formation (Adelaide Subgroup). Pth (middle green without stipple) = Late Permian Hoedemaker Member, Teekloof Formation (Adelaide Subgroup). Pto (dark green) = Late Permian Oukloof Member, Teekloof Formation (Adelaide Subgroup). Jd (red) = sills and dykes of the Early Jurassic Karoo Dolerite Suite. Pale yellow with flying bird symbol = Late Caenozoic (Neogene / Pleistocene to Recent) alluvium.

***N.B.* The mapping of the various members within the Teekloof Formation shown here is currently contested. In particular, the Hoedemaker Member outcrop area has probably been underestimated while thick sandstone packages of the overlying Oukloof Member might be present at higher elevations in the south.**

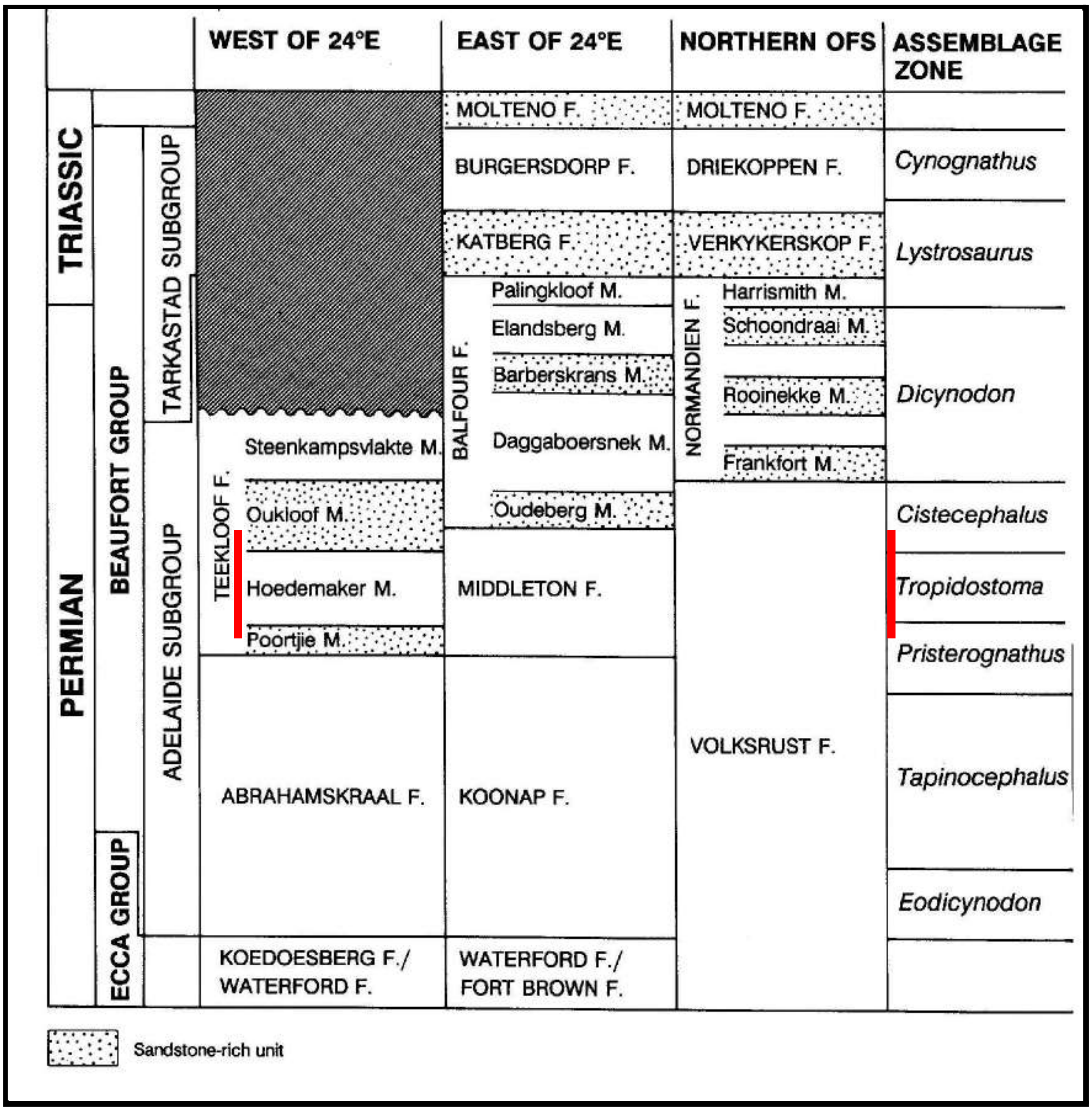

Figure 16: Stratigraphy and biostratigraphic zonation of the Beaufort Group of the Main Karoo Basin (From Rubidge (Ed.) 1995). The vertical red lines indicate the Lower Beaufort subunits and fossil assemblage zones that are represented in the Modderfontein WEF study area. However, the mapping of these subunits may require future revision while the precise, and apparently anomalous, relationship between the lithostratigraphy and successive fossil assemblages in the area south of Victoria West is currently unclear (*cf* Day & Rubidge 2020). Note that the *Pristerognathus* and *Tropidostoma* Assemblage Zones (AZ) have recently been combined within a redefined *Endothiodon* AZ.

Figure 17: Stepped, NE-facing escarpment on the eastern margins of Modderfontein 228 showing three thin, closely-spaced channel sandstone packages (orange-brown, grey-brown and yellowish in ascending order) that are currently mapped within the Poortjie Member at the base of the Teekloof Formation.

Figure 18: Very well-exposed purple-brown and grey-green mudrocks with thin crevasse splay sandstone interbeds of the Poortjie Member exposed along the incised, north-facing escarpment due east of Modderfontein homestead. Such areas are ideal for fossil-hunting, and yet have yielded comparatively few fossil remains during the site visit.

Figure 19: Thick, multiple packages of mudrock clast-dominated basal channel breccia intercalated within the base of a yellowish channel sandstone package of the Poortjie Formation near Modderfontein homestead. Such breccias may contain sparse and highly fragmentary reworked bone and tooth material.

Figure 20: Stream bed and bank exposure of baked Teekloof Formation sediments showing typical spotting by pale-rimmed cavities (vugs), some of which may represent metamorphosed pedogenic calcrete concretions. Note thick alluvial deposits in the background on the right.

Figure 21: Stepped hillslopes of intercalated Teekloof sandstone and mudrock in the south central portion of Modderfontein 228 that probably belong to the Poortjie Member (as mapped) and have yielded several vertebrate fossils.

Figure 22: Thin-bedded, purple-brown overbank mudrocks of the Poortjie Member capped by a channel sandstone package. The thin (10-20 cm) greenish-horizon is a breccia or diamictite containing reworked calcrete concretions and sparse fragmentary fossil vertebrate material (Hammer = 30 cm). See also Figure 51.

Figure 23: Well-exposed, colour-banded overbank mudrocks of the Teekloof Formation exposed in the central portion of Phaisant Kraal 1 that are mapped within the Poortjie Member but probably belong to the overlying Hoedemaker Member. These beds have yielded several vertebrate fossils.

Figure 24: Palaeosol horizon marked by numerous subrounded pedogenic calcrete concretions (Hammer = 30 cm). Such ancient soil horizons are an important focus for fossil

recording and occur frequently within both the Poortjie and Hoedemaker Members in the WEF project area.

Figure 25: Relictual, downwasted blocks of ferruginised basal channel breccio-conglomerate exposed south of Rondekop on Phaisant Kraal 1. These beds may lie along the Poortjie / Hoedemaker contact or perhaps within the Hoedemaker Member. They do not contain obvious skeletal remains but these, like the associated calcrete nodules, may have been leached out during metamorphosis.

Figure 26: Closely-spaced, comparatively thick channel sandstone packages overlying a thick mudrock package and capped by dolerite, SW portion of Modderfontein 228. The sandstones here might belong to the Oukloof Member overlying Hoedemaker Member mudrocks.

Figure 27: Thick, stratified gravelly and sandy alluvial deposits associated with the Gabrielspruit exposed by gulley erosion northeast of the Phesantkraal homestead (Hammer = 30 cm). The basal beds are partially calcretised and might be Pleistocene in age.

Figure 28: Thick mantle of unconsolidated fine gravelly alluvium incised by erosion gullies on the southern portion of Modderfontein 228.

3. PALAEONTOLOGICAL HERITAGE WITHIN THE WEF PROJECT AREA

The Late Permian Teekloof Formation bedrocks in the Modderfontein WEF project area are characterised by fossil assemblages of what have, until recently, been termed the *Pristerognathus* and *Tropidostoma* Assemblage Zones (Kitching 1977, Keyser & Smith 1977-78, Rubidge 1995, Van der Walt *et al.* 2010, Smith *et al.* 2012) (Figs. 16 & 29). Recent revision of the Lower Beaufort Group biostratigraphic zonation has incorporated both these assemblages into the *Endothiodon* Assemblage Zone (Day & Smith 2020). They include a wide range of fossil vertebrates – especially reptiles and therapsids ("mammal-like reptiles" or protomammals"") – as well as fish, amphibians, plant remains, microfossils and trace fossils (Rubidge 1995, Rubidge 2005, Smith *et al.* 2012, Day & Smith 2020). Le Roux and Keyser (1988) briefly mention fossil vertebrate taxa recorded in the Teekloof Formation in the Victoria West sheet area. In addition Kitching (1977) provides palaeofaunal lists for specific localities within the Great Karoo region, including several near Victoria West. The recent review of Beaufort Group vertebrate fossil sites by Nicolas (2007) shows a high concentration of finds along the N1 to the northeast of Three Sisters and south of Victoria West (Fig. *30). In the vicinity of dolerite intrusions the preservation of vertebrate fossils has been seriously compromised due to baking and chemical alteration, while voluminous doleritic and metasedimentary colluvium often masks the nearby fossiliferous sedimentary bedrocks. Thick deposits of older, semi-consolidated alluvium in the Karoo region may occasionally contain important assemblages of fossil vertebrates (*e.g.* mammal bones and teeth) as well as reworked petrified wood, trace fossils (*e.g.* calcretised termitaria, rhizoliths) and freshwater molluscs such as unionid bivalves (swan mussels).

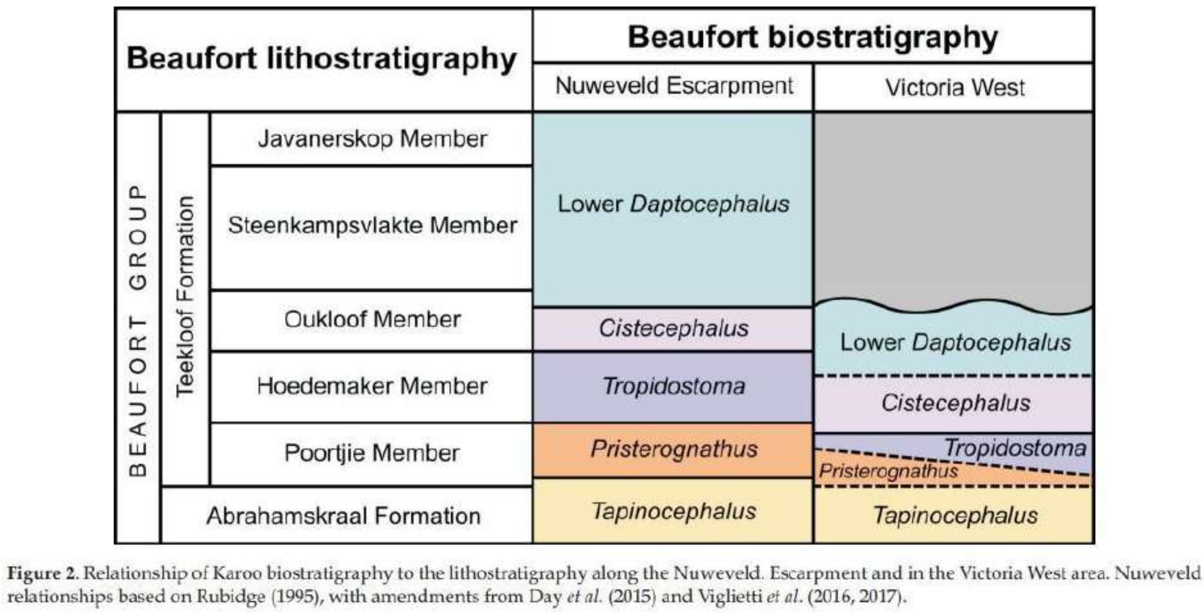

Figure 29: Table from Day and Rubidge (2020a) illustrating possible differences in the distribution of Lower Beaufort Group fossil assemblage zones in relation to the lithostratigraphy along the Nuweveld Escarpment *versus* the Victoria West region. Some of these real or apparent contrasts might be resolved by detailed geological re-mapping and palaeontological surveying in the latter area.

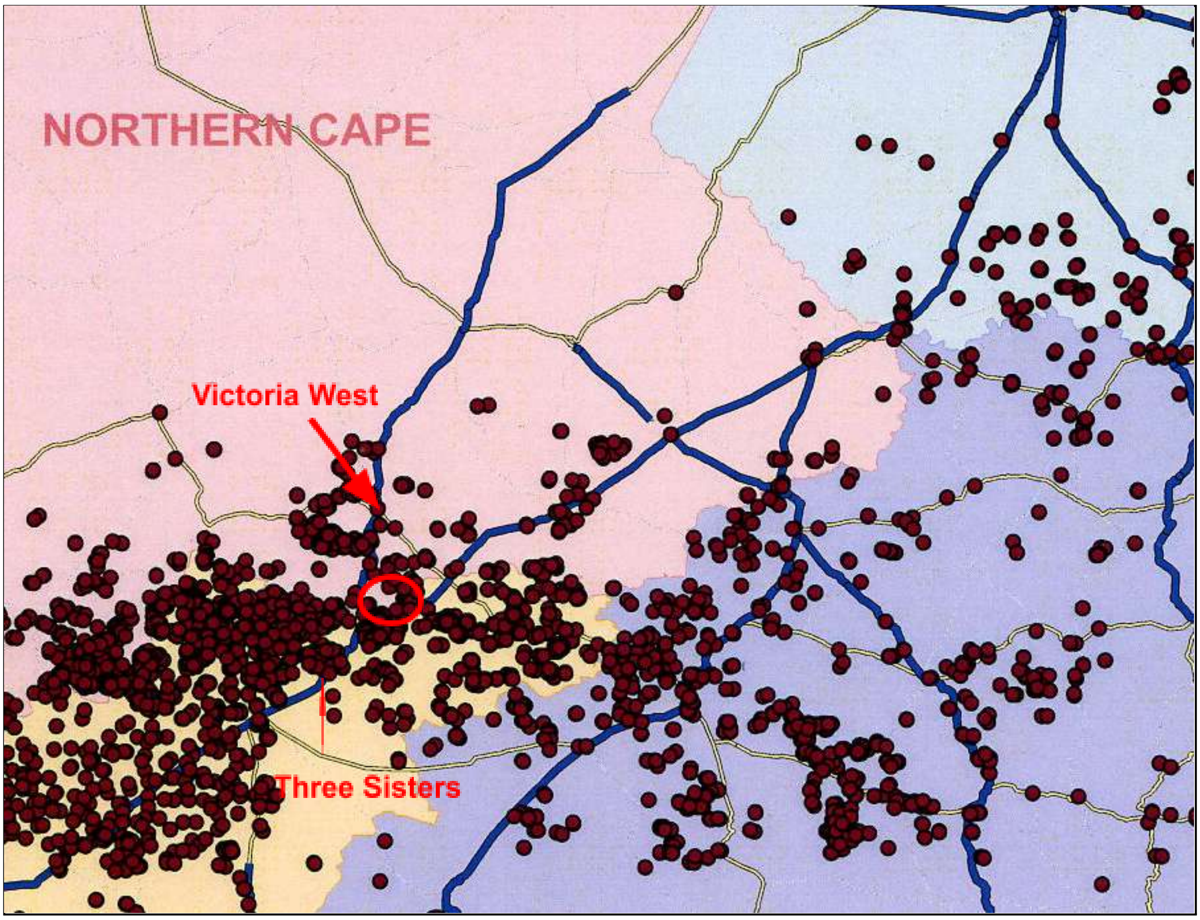

Figure 30: Distribution map of recorded vertebrate fossil sites within the Beaufort Group of the Great Karoo around the junction of the Western, Northern and Eastern Cape and the Free State (From Nicolas 2007). Note the abundance of known fossil sites in the vicinity of the present WEF project area (red ellipse) close to the N1 to the northeast of Three Sisters and south of Victoria West. This reflects in part the long history (> 100 years) of fossil collection by both academic palaeontologists as well as knowledgeable amateurs at sites close to Biesiespoort Station (See following figure

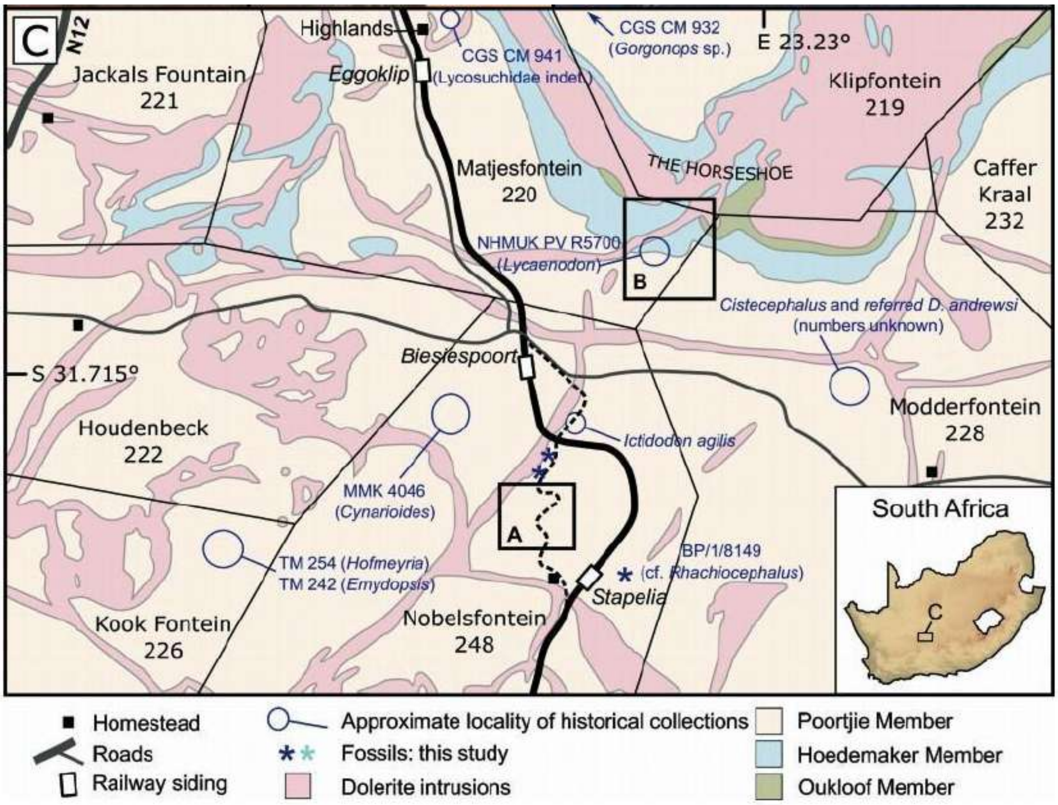

Figure 31: Map compiled by Day & Rubidge (2020a) illustrating the location of key historical sites of Beaufort Group fossil vertebrates in the vicinity of Biesiespoort Station, just west of the Modderfontein WEF project area. The lithostratigraphic mapping reflects the published geological map which may require substantial revision (See Fig. 15 herein). Note that a few historical records – including those of two dicynodont genera – are located within the Modderfontein WEF project area.

3.1. Fossil biotas within the Teekloof Formation : Poortjie Member

The arenaceous Poortjie Member as well as the uppermost beds of the underlying Abrahamskraal Formation are characterised palaeontologically by fossils of what was until recently termed the *Pristerognathus* Assemblage Zone (Smith & Keyser 1995a) which now forms the lower portion of a new *Endothiodon* Assemblage Zone (Day & Smith 2020). This important Late Permian, low-diversity (post-extinction recovery phase) terrestrial biota is dominated by various therapsids ("mammal-like reptiles") such as the moderate-sized therocephalian carnivore *Pristerognathus* as well as several gorgonopsian predators / scavengers and herbivorous dicynodonts. The commonest genus by far is the small burrowing dicynodont *Diictodon* (Keyser and Smith 1977-78, Smith & Keyser 1995a, MacRae 1999, Cole *et al*., 2004, Rubidge 2005, Almond 2010a, 2014a, Smith *et al.* 2012; Fig. 32 herein). There are also large, rhino-sized herbivorous reptiles (*Bradysaurus* spp.), the small parareptile *Eunotosaurus* (Day *et al.* 2013), crocodile-like temnospondyl amphibians (*Rhinesuchus*), palaeoniscoid fish, vascular plant fossils of the *Glossopteris* Flora (fossil wood, leaves *etc*) and various trace fossils, including invertebrate burrows and tetrapod trackways. Rare relict dinocephalians recorded recently within the lowermost Poortjie Member are now assigned to the impoverished post-extinction biota at the top of the revised *Tapinocephalus* Assemblage Zone (Day *et al.* 2015a, 2015b, Day & Rubidge 2020b).

Most fossils in the *Pristerognathus* Assemblage Zone are found in the softer-weathering mudrock facies (floodplain sediments) that are usually only exposed on steeper hill slopes and in stream gullies. Fossils here are often associated with pedogenic limestone nodules or calcretes (Smith 1993a, Smith & Keyser 1995a). The mudrocks lie between the more resistant-weathering channel sandstones, which in the classic Poortjie Member sections along the Nuweveld Escarpment often display a distinctive "golden yellow" tint. Fossil skeletal remains also occur in the lenticular channel sandstones, especially in intraformational lag conglomerates towards the base, but are usually very fragmentary and water-worn ("rolled bone").

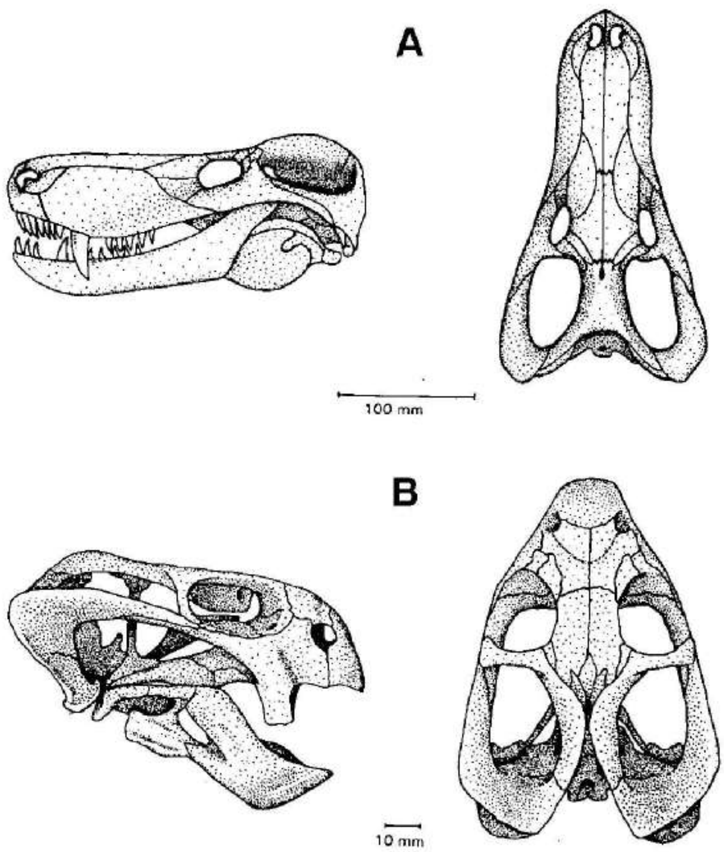

Figure 32: Skulls of typical therapsids from the *Pristerognathus* Assemblage Zone (now the lower part of the *Endothiodon* Assemblage Zone): A. the dog-sized carnivorous therocephalian *Pristerognathus* and B. the small herbivorous dicynodont *Diictodon* (From Smith & Keyser 1995a).

3.2. Fossil biotas within the Teekloof Formation: Hoedemaker Member

The *Tropidostoma* Assemblage Zone (AZ) characterizes the Hoedemaker Member of the Teekloof Formation along the Great Escarpment (Le Roux & Keyser 1988, Smith & Keyser, 1995b). This faunal assemblage is assigned to the early Lopingian (Wuchiapingian) Age of the Late Permian Period. It has recently been incorporated into the upper part of a revised *Endothiodon* Assemblage Zone (Day & Smith 2020).

The following major categories of fossils have been recorded within *Tropidostoma* AZ sediments in well-collected sections along the Nuweveld Escarpment and elsewhere (Kitching 1977, Keyser & Smith 1977-78, Le Roux & Keyser 1988, Anderson & Anderson 1985, Smith & Keyser 1995, MacRae 1999, Cole *et al*., 2004, Almond 2010a, 2014b, Smith *et al.* 2012, Day & Smith 2020):

- isolated petrified bones as well as rare articulated skeletons of terrestrial vertebrates (tetrapods) such as true reptiles (notably large herbivorous pareiasaurs) and therapsids or "mammal-like reptiles" (*e.g.* diverse herbivorous dicynodonts, flesh-eating gorgonopsians, and insectivorous therocephalians) (Fig. 33)
- aquatic vertebrates such as large temnospondyl amphibians (*Rhinesuchus* spp., usually disarticulated), and palaeoniscoid bony fish (*Atherstonia*, *Namaichthys*, often represented by scattered scales rather than intact fish)
- freshwater bivalves (*e.g. Palaeomutela*)
- trace fossils such as worm, arthropod and tetrapod burrows and trackways, coprolites (fossil droppings), fish swimming trails
- vascular plant remains including leaves, twigs, roots and petrified woods ("*Dadoxylon*") of the *Glossopteris* Flora (usually sparse, fragmentary), especially glossopterid trees and arthrophytes (horsetails).

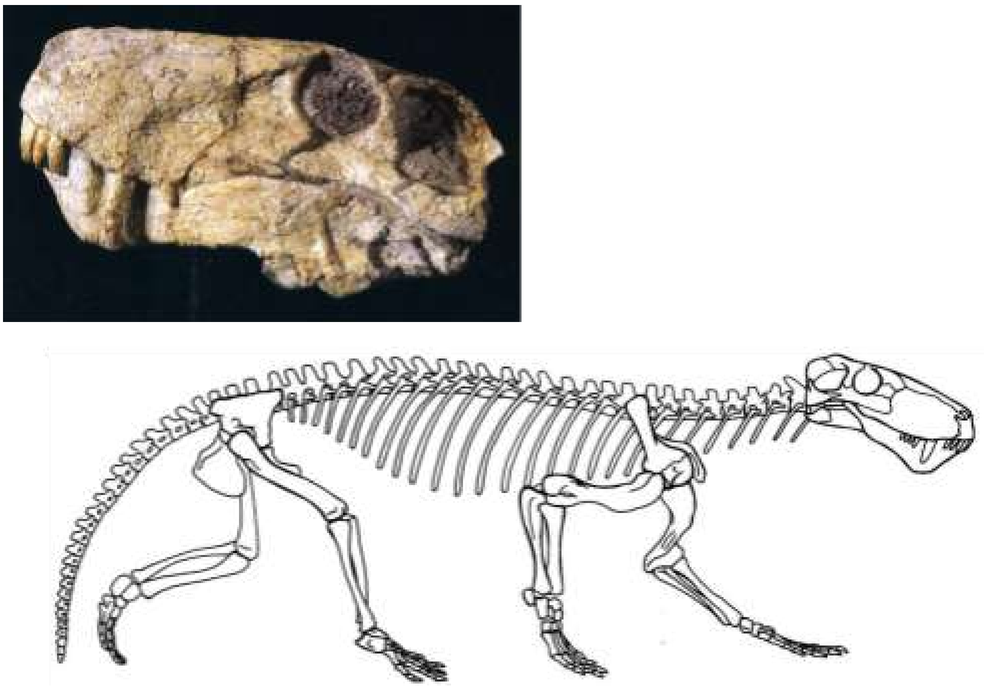

Figure 33: Skull and skeleton of a saber-toothed carnivore, the gorgonopsian *Lycaenops* – a typical, albeit rare, member of the *Tropidostoma* (now upper *Endothiodon*) Assemblage Zone. The best known specimen of the genus was collected near Biesiespoort station (Fig. 34).

According to Smith and Keyser (1995b) the tetrapod fauna of the *Tropidostoma* Assemblage Zone is dominated by the small burrowing dicynodont *Diictodon* that constitutes some 40% of the fossil remains recorded here. There are several genera of small-bodied toothed dicynodonts (*e.g. Emydops, Pristerodon*) as well as medium-sized forms like *Rachiocephalus* and *Endothiodon* (*cf* Cluver & King

1983, Botha & Angielczyk 2007 for more details about these genera). Carnivores are represented by medium-sized gorgonopsians (*e.g. Lycaenops, Gorgonops*; Fig. 33) as well as smaller, insectivorous therocephalians such as *Ictidosuchoides*. Among the large (2.3-3 m long), lumbering pareiasaur reptiles the genus *Pareiasaurus* replaces the more primitive *Bradysaurus* seen in older Beaufort Group assemblages.

As far as the biostratigraphically important tetrapod remains are concerned, the best fossil material within the Hoedemaker Member succession is generally found within overbank mudrocks, whereas fossils preserved within channel sandstones tend to be fragmentary and water-worn (Rubidge 1995, Smith 1993b). Many vertebrate fossils are found in association with ancient soils (palaeosol horizons) that can usually be recognised by bedding-parallel concentrations of calcrete nodules. Smith and Keyser (1995b) report that in the *Tropidostoma* Assemblage Zone / Hoedemaker Member most tetrapod fossils comprise isolated disarticulated skulls and post-cranial bones, although well-articulated skeletons of the small dicynodont *Diictodon* are locally common, associated with burrows (See also Smith 1993b for a benchmark study of the taphonomy of vertebrate remains in the Hoedemaker Member near Loxton).

3.3. Teekloof fossils in the Modderfontein WEF project area

The recent review by Day and Rubidge (2020a) of Teekloof Formation fossils from the classic Bieiespoort area south of Victoria West is highly relevant to the present PIA study. The authors point that:

- A considerable proportion of Beaufort Group fossils in institutional collections, especially as far as the Upper Karoo is concerned, has been collected in the Victoria West area.
- There is an unusually long history of fossil collection by prominent Karoo palaeontologists from sites near Biesiespoort Station (Farms Noblesfontein 248, Matjiesfontein 220, Modderfontein 228), from the famous Robert Broom in the 1920s until the present day (See locality map Fig. 31). Consequently fossil specimens from the area are now curated at several museums both in South Africa and abroad.
- A number of holotype Karoo tetrapod specimens come from the Biesiespoort area, including taxa of herbivorous dicynodonts and carnivorous forms such as gorgonopsians (Fig. 34).
- The region south of Victoria West is of key biostratigraphic interest because of the apparent mismatch between the Teekloof Formation lithostratigraphy and the recorded vertebrate fossil assemblages, compared with the better known sections along the Nuweveld Escarpment (Fig. **). This anomaly is currently unresolved and might be real or, at least in part, stem from mis-mapping of the various members on the published geological maps. Palaeontological field data acquired during PIA studies of the broader Karoo Renewable Energy Facility project area might contribute usefully to resolving some of these palaeontological research issues.

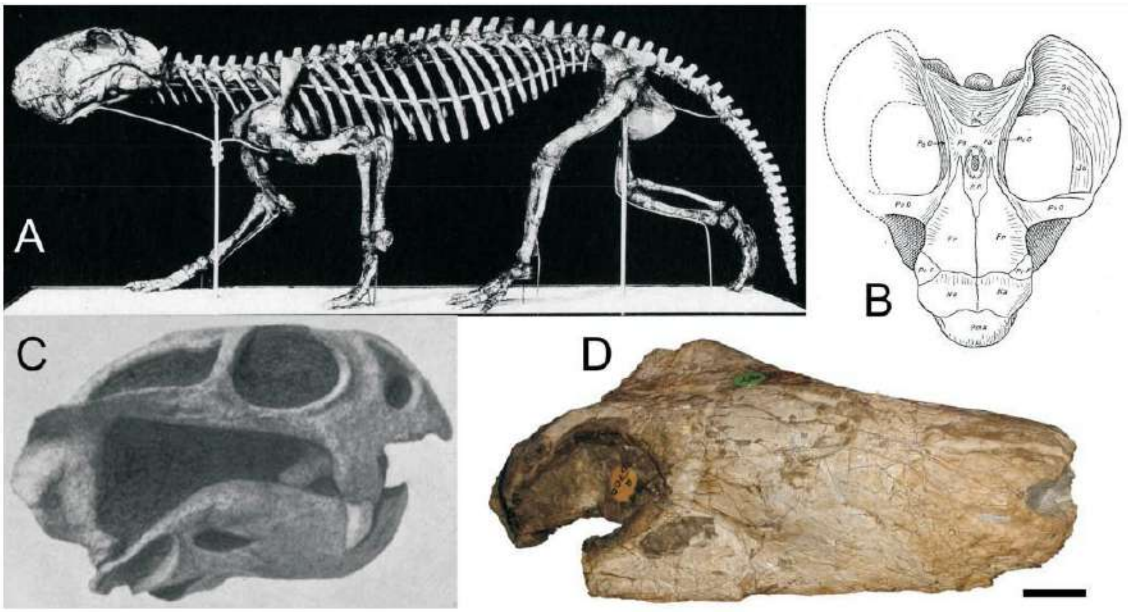

Figure 3. Some historical collections from Biesiespoort area. **A**, Mounted skeleton of the holotype of *Lycaenops ornatus* Broom (AMNH FARB 2240), from Colbert (1948). **B**, Illustration of the allegedly lost holotype of *Bainia peavoti* Broom (MMK 4237; = *'Aulacephalodon' peavoti*), from Broom (1921). **C**, Photograph of referred specimen of *Dicynodon sollasi* Broom (= *Diictodon feliceps*), from Janensch (1952a). **D**, Photograph of the holotype of *Lycaenodon longiceps* Broom (NHMUK PV R 5700). Scale bar equals: 2 cm.

Figure 34: Image from Day and Rubidge (2020a) illustrating holotype specimens of Teekloof Formation therapsids that have been collected near Biesiespoort station. They include carnivorous gorgonopsians (one of the most complete skeletons known) as well as small- to large-bodied herbivorous dicynodonts.

Fossil material recorded during the recent palaeontological site visit to the Modderfontein WEF project area near Victoria West is tabulated in Appendix 1, together with GPS locality data, a brief description and recommended mitigation (if any). These sites are mapped in relation to the authorized and amended turbine layouts in Figures A1 to A2 and A3 to A4 respectively (See Appendix 1). Please note that:

- The fossil sites recorded represent only a representative fraction of the sites present at surface. The absence of recorded sites in an area does *not* imply that no fossils are present here, at or beneath the land surface.
- Given current uncertainties concerning the mapping and lithostratigraphy of the Lower Beaufort Group bedrocks in the project area (*cf* Day & Rubidge 2020a), the fossils listed here are not referred to a specific subunit or member of the Teekloof Formation.

The palaeosensitivity of the Modderfontein WEF project area (dolerites, thermally metamorphosed Teekloof bedrocks, alluvial and colluvial deposits) is generally low but there are also small regions of high palaeosensitivity associated with good exposures of Teekloof mudrock facies. Few, and then generally fragmentary, fossil remains are recorded within sandstone facies of the Teekloof Formation. Taking into account the limited area and sporadic distribution of the palaeontologically more promising mudrock exposures, the recent palaeontological site survey suggests that vertebrate fossils within the Modderfontein WEF project area are common locally while some mudrock horizons, even where well exposed, are apparently fossil-poor. Unfossiliferous mudrocks tend to occur lower down within the Teekloof succession - within the probable Poortjie Member – and may reflect an early phase of the faunal recovery following the end Middle Permian Mass Extinction event of *c*. 260 Ma. Many of the richer fossil vertebrate localities recorded probably lie within the Hoedemaker Member (although currently not mapped as such) which is well known elsewhere for occasional high concentrations of fossils, including skeletal remains as well as vertebrate burrows, which were perhaps associated with long-standing ponds or playa lakes on the ancient Karoo floodplain (*e.g.* Smith 1993b)

The great majority of Lower Beaufort Group fossils recorded during the palaeontological field survey comprise isolated partial skulls, with or without articulated lower jaws, of **small-bodied (dassie-sized) dicynodonts**, as is typical for vertebrate fossil assemblages from the *Endothiodon* Assemblage Zone (Figs. 40, 41, 43 to 47). Most of these 2-tusked or tuskless skulls are probably *Diictodon* but several other small dicynodonts have been recorded from the lower part of the Teekloof Formation, some with small teeth. Preparation of the fossils is often required to identify them to generic level. The majority of specimens are enclosed within calcrete concretions of pedogenic origin while a few are embedded within sandstone (Fig. 35). A very few specimens – such as the carnivore tooth row illustrated in Figure ** (possibly **therocephalian**) - represent larger, **medium-sized therapsids**, some of which might be of biostratigraphic interest, but in general these particular specimens are highly fragmentary and in most cases probably unidentifiable (Figs. 37 & 38). A number of fossil occurrences comprise **partially-articulated postcranial skeletons**, with or without attached skulls (Figs. 39, 48 & 50). At least some of these animals may have been preserved curled-up in their burrows. Several probable **small vertebrate burrow casts** are recorded (while a considerable number of equivocal examples were also seen), showing a straight, curved or helical morphology (Figs. 52 to 55). They are usually cast in sandstone which weathers-out more positively than the surrounding friable mudrock but examples incised into sandstone bed tops are also found. Other fossil groups recorded include low-diversity **invertebrate trace fossil assemblages** (some possibly associated with organic-rich vertebrate burrow floors) (Fig. 46), the casts of **reedy plant stems** (probably horsetails), isolated moulds of **glossopterid leaves** (Fig. 57), and possible but unconfirmed moulds of **woody plant axes** within channel sandstones (these last occurrences require confirmation) (Fig. 58). No petrified wood material was seen.

The majority of the fossils recorded represent common taxa (notably the small dicynodont *Diictodon*) and are not sufficiently well-preserved to warrant special mitigation. A few of the better preserved or unusual specimens are of potential scientific interest (*e.g.* for biostratigraphy) and should be collected in the pre-construction phased if threated by the proposed WEF development (See Appendix 1 for proposed mitigation measures in the event that the fossil site falls within or close to the final WEF footprint).

Figure 35: Disarticulated postcranial skeleton of a small tetrapod (mainly showing ribs), preserved unusually within a channel sandstone bed, probably of the Poortjie Member (Loc. 400) (Scale in cm).

Figure 36: Small float blocks of robust bones as well as (above) partial tooth row of a small carnivore, possibly a therocephalian from the Poortjie Member (Loc. 399) (Scale in cm and mm).

Figure 37: Several palaoecalcrete concretions with fragmentary / disarticulated bony remains of small- to medium-sized tetrapods, probably from the Poortjie Member (Loc. 396) (Scale in cm and mm).

Figure 38: Partial skull and postcrania of medium-sized therapsid embedded within mudrock, probably Poortjie Member (Loc. 389) (Scale in cm).

Figure 39: Skull with articulated lower jaw and associated postcrania of small-bodied dicynodont embedded within grey-green mudrock (Loc. 365) (Scale in cm and mm).

Figure 40: Weathered-out calcrete concretion showing the faint outline of a small dicynodont skull with orbits (O) (Loc. 411) (Scale in mm). This specimen demonstrates how readily many fossils may pass unnoticed due to being completely enveloped by pedogenic calcrete (See also following figure).

Figure 41: Freshly broken transverse sections through the fossiliferous grey micritic concretion seen in the previous figure showing the delicate skull bones inside (Loc. 411) (Scale in cm and mm).

Figure 42: Elliptical, flattened pedocrete concretion containing disarticulated postcrania of a small tetrapod (Loc. 366) (Scale in cm and mm).

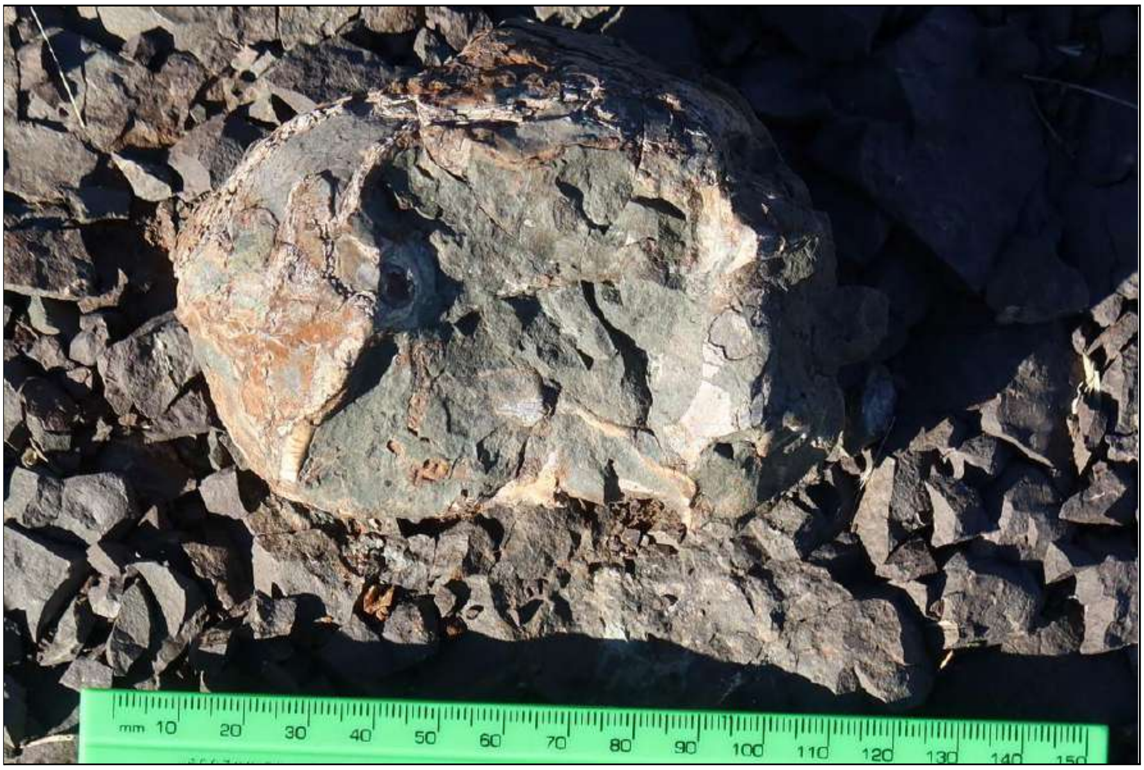

Figure 43: Well-preserved skull of a small-bodied, tusked dicynodont with articulated lower jaw, preserved within a palaeocalcrete concretion (Loc. 383) (Scale in cm and mm).

Figure 44: Isolated skull (10.5 cm long) with articulated lower jaw of a small-bodied dicynodont that was preserved side-upwards within grey-green overbank mudrocks and consequently somewhat laterally-compressed (Loc. 373).

Figure 45: Weathered-out skull with articulated lower jaw of small-bodied dicynodont seen in ventral view and preserved within ferruginised palaeocalcrete concretion (Loc. 359) (Scale in cm and mm).

Figure 46: *In situ* small dicynodont skull preserved ventral side upwards within palaeocalcrete concretion (Loc. 344) (Scale in cm).

Figure 47: Partial snout and skull roof of small-bodied dicynodont showing broad intertemporal region (*i.e.* not *Diictodon*) preserved in float block (Loc. 408) (Scale in cm and mm).

Figure 48: Skull (ventral-up) and curved vertebral column of a small-bodied dicynodont embedded within grey-green mudrock and *possibly* preserved within a burrow (Loc. 395) (Scale = 15 cm).

Figure 49: Partial, fragmentary skull and some postcrania of a small-bodied therapsid, *possibly* not a dicynodont, preserved within mottled, baked mudrock (Loc. 356) (Scale in cm).

Figure 50: Curled-up skeleton of a small-bodied tetrapod embedded within mottled, baked mudrock (Loc. 357) (Scale in cm and mm).

Figure 51: Thin, greenish to purple-hued breccio-conglomerate of reworked pebbly pedocrete concretions, mudflakes and sparse bone material (fragmentary, sun-cracked – see arrow (Loc. 364) (Scale = 15 cm). See also Figure 22.

Figure 52: Bioturbated "lumpy-weathering" purple-brown and grey-green mudrock horizon (yellow bar) containing several equivocal, prominent-weathering casts of vertebrate burrows (Loc. 376). See also following figure.

Figure 53: Possible helical vertebrate burrow cast (arrowed) weathering-out of the bioturbated mudrock horizon illustrated above (Loc. 376) (Hammer = 30 cm).

Figure 54: Possible (but equivocal) vertebrate burrow cast weathering out of crumbly overbank mudrocks (Loc. 344) (Scale = 15 cm).

Figure 55: Probable smoothed floor of a small vertebrate burrow preserved within pale. baked tabular-bedded quartzites (Loc. 429) (Scale = 15 cm).

Figure 56: Small-scale invertebrate trace fossils preserved on an otherwise smooth quartzite surface (Loc. 428) (Scale = 15 cm). Vertebrate burrow floors are often preferentially bioturbated.

Figiure 57: Sandstone float block containing the concave mould of an isolated glossopterid leaf with pronounced midrib (arrowed) (Loc. 418) (Scale in cm and mm).

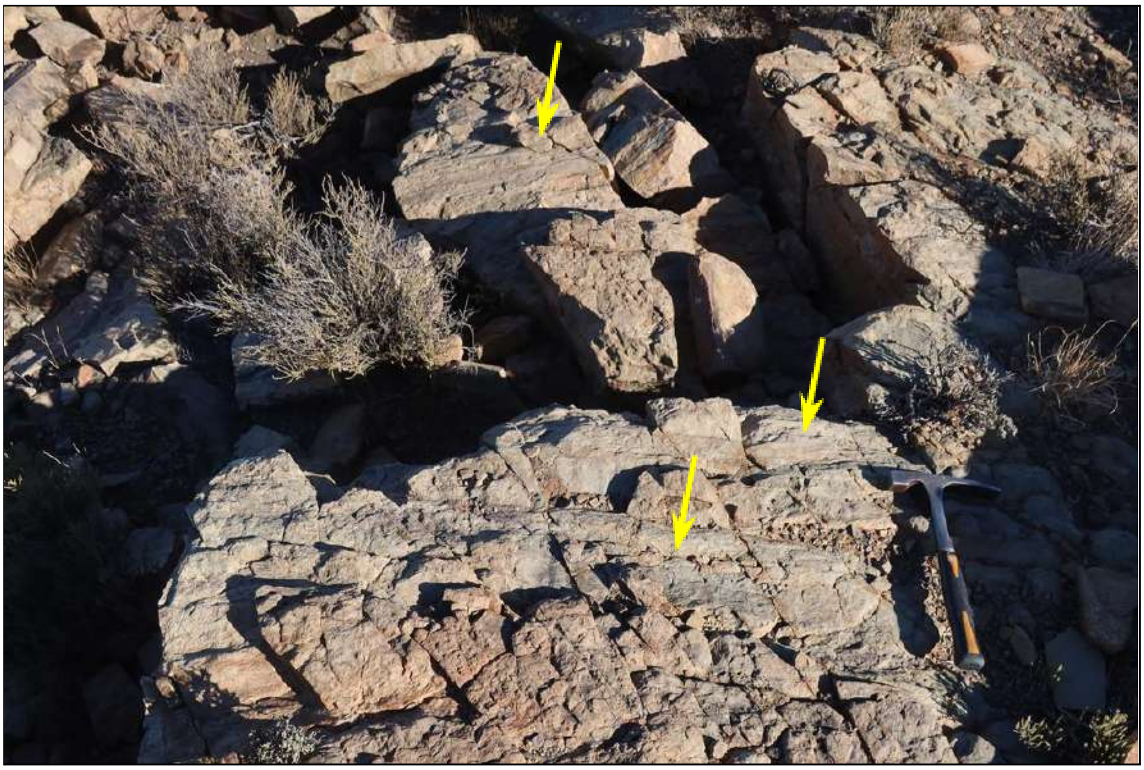

Figure 58: Several puzzling, subparallel, longitudinally-striated features within a channel sandstone (arrowed). These might be the moulds of woody plant stems or perhaps a soft-sediment deformation feature (Loc. 403) (Hammer = 30 cm).

3.4. Fossils within the Karoo Dolerite Suite

The dolerite outcrops criss-crossing the Modderfontein WEF project area are in themselves of no direct palaeontological significance since these are high temperature igneous rocks emplaced at depth within the Earth's crust. However, as a consequence of their proximity to large dolerite intrusions, the Lower Beaufort Group sediments in the vicinity have to a great extent been thermally metamorphosed or "baked" (*ie*. recrystallised, impregnated with secondary minerals). Embedded fossil material of phosphatic composition, such as bones and teeth, has frequently been altered by baking and hot, mineral-rich circulating groundwaters – bones may become whitened and brittle or powdery, for example - and can be very difficult to extract from the hard matrix by mechanical preparation (Smith & Keyser, p. 23 *in* Rubidge 1995). Several examples of poorly preserved, thermally-altered vertebrate fossils have been recorded within the Modderfontein project area (*e.g.* Figs. 48 & 50). Thermal metamorphism by dolerite intrusions has therefore tended to substantially reduce the palaeontological heritage potential of adjacent Beaufort Group sediments. In addition, the large volumes of colluvial gravels of dolerite and resistant, baked metasediments (hornfels and quartzite) associated with dolerite intrusions tend to seal-in adjacent outcrop areas of Beaufort Group bedrocks whose fossils are consequently no longer inaccessible.

3.5. Fossil biotas within Late Caenozoic superficial deposits

The Quaternary to Recent superficial deposits of the Great Karoo region have been comparatively neglected in palaeontological terms for the most part. However, they may occasionally contain important fossil biotas, notably the bones, teeth and horn cores of mammals (*e.g.* Skead 1980, Klein 1984, MacRae 1999, Partridge & Scott 2000). These may include ancient human remains of considerable palaeoanthropological significance (*e.g*. Grine *et al.* 2007). Other late Caenozoic fossil biotas from these superficial deposits include non-marine molluscs (bivalves, gastropods), ostrich egg shells, trace fossils (*e.g.* calcretised termitaria, coprolites, rhizoliths or plant root casts), and plant remains such as peats or palynomorphs (pollens) in fine-grained, organic-rich alluvial horizons. Quaternary alluvial sediments may contain reworked Stone Age artifacts that are useful for constraining their maximum age.

The only fossil remains recorded from the Late Caenozoic superficial deposits within the WEF project area are cylindrical calcretized rhizoliths (root casts) within older, semi-consolidated alluvial deposits associated with major drainage lines (Figs. 27 & 59). No special mitigation is recommended for these very common fossils. No reworked petrified wood or freshwater molluscs were observed.

Figure 59: Resistent-weathering calcretised rhizoliths (root casts) projecting from sandy to finely-gravelly older alluvial deposits along the Gabrielspruit drainage line near the Phesantkraal Homestead (Loc. 347) (Hammer = 30 cm). See also Figure 27 for context.

4. CONCLUSIONS AND RECOMMENDATIONS

The fluvial to lacustrine sedimentary bedrocks of Late Permian Teekloof Formation (Lower Beaufort Group, Karoo Supergroup) in the Modderfontein WEF project area are characterised by important low- to moderate-diversity fossil assemblages of the *Pristerognathus* and *Tropidostoma* Assemblage Zones (now combined within the new *Endothiodon* Assemblage Zone) following the major End Guadalupian Mass Extinction Event of 260 million years ago (Ma). Fossil taxa recorded from these rock units include a wide range of terrestrial vertebrates – especially reptiles and therapsids ("mammal-like reptiles") – as well as fish, amphibians, petrified wood and other plant remains, microfossils and trace fossils (Rubidge 1995, Rubidge 2005, Smith *et al.* 2012, Day & Smith 2020). Numerous fossil vertebrate sites have been recorded by previous workers in the Great Karoo region to the northeast of Three Sisters and south of Victoria West (*cf* Kitching 1977, Nicolas 2007). In particular several important sites in the vicinity of Biesiespoort railway station, located just west of the Modderfontein WEF project area, have been sampled for a period of over a century by a succession of prominent Karoo palaeontologists (Day & Rubidge 2020a). The fossils collected here include important holotype specimens of herbivorous dicynodonts and carnivorous gorgonopsians, now curated in several museums in South Africa and abroad. This fossil material plays a key role in resolving outstanding questions concerning the biostratigraphic zonation of the Beaufort Group.

In the vicinity of dolerite intrusions fossil preservation has largely been compromised due to baking and chemical alteration. Thick deposits of older, semi-consolidated alluvium might contain important assemblages of mammalian fossils (*e.g.* horn cores, bones and teeth) as well as reworked petrified wood and trace fossils (*e.g.* calcretised termitaria). No fossil wood has been recorded so far within the present WEF project area. Doleritic and sandstone colluvial rock rubble mantling the steeper mountain slopes is unlikely to be fossiliferous.

During the recent 3-day palaeontological site visit to the Modderfontein WEF project area some 50 or so new fossil sites were recorded, despite generally very low levels of bedrock exposure (Appendix 1). Most of these comprise the skulls and/or incomplete postcranial skeletons of small-bodied dicynodonts which are locally common within the lower Teekloof Formation bedrocks. Rare skeletal remains (often unidentifiable) of larger animals also occur as well as vertebrate burrow casts, low-diversity invertebrate trace fossil assemblages, occasional glossoperid leaf impressions and possible (but unconfirmed) moulds of substantial woody plant axes. No petrified wood was observed.

No palaeontological Very High Sensitivity / No-Go areas have been identified or designated here and the WEF project proposal is not fatally flawed from a palaeontological heritage viewpoint. None of the recorded fossil sites overlaps directly with the amended turbine locations and no exclusion or re-siting of turbine sites on palaeontological grounds is proposed here. Given the size of the project area as well as the challenging terrain for fossil finding, the fossil sites recorded so far are likely to represent only a small fraction of those actually present at surface. Important fossil sites tend to be small in area (few square meters), sparse, scattered and to some extent unpredictable (*e.g.* they occur in both sandstone and mudrock bedrocks). It is important to appreciate that the preliminary fossil site maps in Figures A1-A4 *do NOT show all potential sites*. All the fossil sites recorded so far could be effectively mitigated through specialist palaeontological collection and recording of associated geological data, and this is likely to be the case for the great majority of unrecorded fossil sites as well.

The anticipated impact significance of the amended turbine layout is substantially lower compared with the authorized turbine layout principally due to (1) the far smaller number of amended turbine sites and (2) the siting of a high proportion of these sites on unfossiliferous doleritic ridges and plateaux, or on adjoining thermally-metamorphosed sedimentary bedrocks of low palaeosensitivity. Construction phase excavations and surface clearance for associated infrastructure such as access roads and hard stand areas pose a more serious potential threat to local palaeontological heritage than wind turbine footings. The overall impact significance of amended Modderfontein WEF project – and hence the level of proposed mitigation - can only be formally assessed when the complete finalized layout (including grid connection corridor) becomes available but in any event will be markedly lower than that of the authorized WEF project.

Micro-siting of turbine positions and other WEF infrastructure in relation to known fossil sites is generally not recommended. Inevitable negative impacts within the final WEF footprint can be effectively mitigated, to a large extent, by pre-construction palaeontological surveying of potentially sensitive sectors of the WEF footprint (including the grid connection corridor). This would entail specialist recording and judicious sampling of any fossil specimens of scientific and / or conservation value *plus* specific, realistic recommendations for any necessary, targeted mitigation during the construction phase (See also comments below). During the construction phase itself a Chance Finds Fossil Procedure driven by the responsible environmental site officers and ECO should be implemented (see Appendix 2).

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 palaeontological heritage studies developed by SAHRA (2013) and HWC (2021). The palaeontological assessment reports must be submitted for consideration to both Heritage Western Cape and SAHRA.

These palaeontological heritage recommendations are broadly in line with those made by in 2011 by Heritage Western Cape with respect to the original Karoo Renewable Energy Facility project area of which the Modderfontein WEF project area forms a part. In the author's view, however, SAHRA's (2011) additional requirement that fresh excavations undertaken into the Teekloof Formation should be inspected by a palaeontologist during the construction phase is unduly onerous and unlikely to yield much useful palaeontological material or data; fossils within freshly-excavated mudrock are usually very hard to discern due to adherent dust or mud, as well as being highly fragmented. Furthermore, finding suitably qualified palaeontologists willing or able to undertake such work for long stretches during the WEF construction phase would be very challenging. For these reasons, mitigation through targeted pre-construction fossil recording and collection supplemented by a fully-implemented Chance Fossil Finds Procedure during the construction phase is preferred.

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8. QUALIFICATIONS & EXPERIENCE OF THE AUTHOR

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

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

Declaration of Independence

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

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

APPENDIX 1: GPS DATA FOR NEWLY RECORDED FOSSIL SITES WITHIN THE MODDERFONTEIN WEF PROJECT AREA

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

Please note that:

- The fossil sites recorded represent only a representative fraction of the sites present at surface. The absence of recorded sites in an area does not imply that no fossils are present here, at or beneath the land surface.
- Given current uncertainties concerning the mapping and lithostratigraphy of the Lower Beaufort Group bedrocks in the project area (*cf* Day & Rubidge 2020a), the fossils listed here are not referred to a specific member of the Teekloof Formation.

Loc.	GPS data	Comments
340	S31° 45' 19.0" E23° 18' 04.8"	Phaisant Kraal 1. Partial snout of small dicynodont. Proposed Field Rating IIIC. No mitigation recommended.
343	S31° 45' 18.7" E23° 18' 02.0"	Phaisant Kraal 1. Small palaeocalcrete concretion containing the tusk of a small therapsid (probably dicynodont). Proposed Field Rating IIIC. No mitigation recommended.
344	S31° 45' 18.6" E23° 18' 01.4"	Phaisant Kraal 1. Small dicynodont skull preserved ventral side upwards within palaeocalcrete concretion. Also possible (but equivocal) vertebrate burrow cast *c*. 15-20 cm wide. Proposed Field Rating IIIB. Skull specimen to be collected if it falls within 10 m of development footprint.
347	S31° 45' 26.0" E23° 18' 04.0"	Thick (up to 6m) Late Caenozoic alluvial deposits, the older horizons partially calcretised with dispersed cylindrical calcretised rhizoliths (root casts). Proposed Field Rating IIIC. No mitigation recommended.
352	S31° 47' 40.3" E23° 16' 30.3"	Phaisant Kraal 1. Package of medium-bedded, interbedded, baked, mottled mudrocks and pale yellowish sandstones. Poorly-preserved bones (probably ribs) of small-bodied tetrapod within speckled sandstone. Proposed Field Rating IIIC. No mitigation recommended.
353	S31° 47' 40.7" E23° 16' 30.4"	Phaisant Kraal 1. Incomplete skull table and two other incomplete skulls of small-bodied therapsids (probably dicynodonts) within mottled, baked mudrocks. Proposed Field Rating IIIC. No mitigation recommended.
356	S31° 47' 49.6" E23° 16' 41.5"	Phaisant Kraal 1. Partial, fragmented skull (*c*. 7 cm long) and some postcrania of a small-bodied therapsid, *possibly* not dicynodont, preserved within mottled, baked mudrock. Proposed Field Rating IIIB. Specimen to be collected if it falls within 10 m of development footprint.
357	S31° 47' 50.4" E23° 16' 41.1"	Phaisant Kraal 1. Curled-up skeleton of small-bodied tetrapod embedded within mottled, baked mudrock. Possibly includes skull with teeth (unconfirmed). Proposed Field Rating IIIB. Specimen to be collected if it falls within 10 m of development footprint.
359	S31° 47' 43.5" E23° 16' 23.6"	Phaisant Kraal 1. Skull including articulated lower jaw of small-bodied dicynodont preserved within ferruginised palaeocalcrete concretion, in float. Second small concretion containing disarticulated postcrania of a small tetrapod. Proposed Field Rating IIIB.Specimens to be collected if they fall within 10 m of development footprint.
362	S31° 47' 15.1" E23° 17' 08.7"	Phaisant Kraal 1. Baked pedocrete concretion containing unidentified white bones. Proposed Field Rating IIIC. No mitigation recommended.
363	S31° 46' 51.1" E23° 17' 41.6"	Phaisant Kraal 1. Occipital region of skull of small dicynodont weathered out in float. Proposed Field Rating IIIC. No mitigation recommended.
364	S31° 46' 51.2" E23° 17' 41.1"	Phaisant Kraal 1. Thin (*c*. 5-10 cm), greenish breccio-conglomerate of reworked pedocrete concretions, mudflakes and sparse bone material (fragmentary, sun-cracked) within thin-bedded, purple-brown mudrock succession. Proposed Field Rating IIIC. No mitigation recommended.
365	S31° 46' 50.8" E23° 17' 39.3"	Phaisant Kraal 1. Skull (with articulated lower jaw) and associated postcrania of small-bodied dicynodont embedded within grey-green mudrock. Proposed Field Rating IIIB. Specimen to be collected if it falls within 10 m of development footprint.
366	S31° 46' 50.9" E23° 17' 39.2"	Phaisant Kraal 1. Pedocrete concretion containing disarticulated postcrania of small tetrapod. Proposed Field Rating IIIC. No mitigation recommended.

367	S31° 46' 51.9" E23° 17' 39.4"	Phaisant Kraal 1. Isolated skull with articulated deep lower jaw of small dicynodont preserved side-upwards within grey-green overbank mudrocks, somewhat laterally compressed. Proposed Field Rating IIIB. Specimen to be collected if it falls within 10 m of development footprint.
368	S31° 46' 51.9" E23° 17' 38.6"	Phaisant Kraal 1. Several small blocks of mudrock and pedogenic concretion containing very fragmentary skeletal remains of small tetrapods. Proposed Field Rating IIIC. No mitigation recommended.
370	S31° 46' 50.2" E23° 17' 39.4"	Phaisant Kraal 1. Isolated lower jaw of small dicynodont embedded within grey-green mudrock. Proposed Field Rating IIIC. No mitigation recommended.
372	S31° 47' 08.9" E23° 17' 46.4"	Phaisant Kraal 1. Small pedogenic calcrete nodule with disarticulated postcranial remains of a small-bodied tetrapod. Proposed Field Rating IIIC. No mitigation recommended.
373	S31° 47' 09.8" E23° 17' 46.1"	Phaisant Kraal 1. Isolated snout of small-bodied dicynodont. Proposed Field Rating IIIC. No mitigation recommended.
374	S31° 47' 10.1" E23° 17' 46.3"	Phaisant Kraal 1. Skull of small dicynodont embedded within grey-green mudrock and partially exposed in lateral view. Proposed Field Rating IIIB. Specimen to be collected if it falls within 10 m of development footprint.
375	S31° 47' 09.8" E23° 17' 46.5"	Phaisant Kraal 1. Possible, but equivocal. Sandstone cast of curved vertebrate burrow (*c*. 15 cm wide). Proposed Field Rating IIIC. No mitigation recommended.
376	S31° 47' 11.0" E23° 17' 45.7"	Phaisant Kraal 1. Bioturbated “lumpy-weathering” purple-brown and grey-green mudrock horizon with several equivocal casts of vertebrate burrows, including possible helical burrows (requires confirmation). Proposed Field Rating IIIC. No mitigation recommended.
377	S31° 47' 11.5" E23° 17' 44.7"	Phaisant Kraal 1. Poorly-preserved skull of small dicynodont, side-upwards, within grey-green, possibly vertebrate-burrowed mudrock horizon. Proposed Field Rating IIIC. No mitigation recommended.
379	S31° 47' 17.4" E23° 17' 51.7"	Phaisant Kraal 1. Possible, but equivocal, inclined, grey-green vertebrate burrow cast (*c*. 5 cm wide) within purple-brown mudrocks. Proposed Field Rating IIIC. No mitigation recommended.
380	S31° 47' 17.8" E23° 17' 51.2"	Phaisant Kraal 1. Float blocks of grey-green siltstone with fragmenmtary postcfrania (backbone, pelvis) of a small-bodied tetrapod. Proposed Field Rating IIIC. No mitigation recommended.
383	S31° 45' 33.2" E23° 12' 46.4"	Modderfontein 228. Well-preserved skull of small-bodied dicynodont with articulated lower jaw, second incomplete skull and postcrania, all preserved within palaeocalcrete concretions. Proposed Field Rating IIIB. Specimens to be collected if they fall within 10 m of development footprint.
384	S31° 45' 31.9" E23° 12' 45.5"	Modderfontein 228. Small dicynodont skull, lateral side upwards, embedded within grey-green siltstone bedrocks in stream gulley. Proposed Field Rating IIIC. No mitigation recommended.
385	S31° 45' 31.9" E23° 12' 45.5"	Modderfontein 228. Probable skull and postcrania (ribs, vertebrae) of small tetrapod (probably dicynodont) within grey-green siltstone bedrocks, poorly preserved. Proposed Field Rating IIIC. No mitigation recommended.
386	S31° 45' 31.9" E23° 12' 45.4"	Modderfontein 228. Poorly-preserved dicynodont skull within loose palaeocalcrete concretion. Proposed Field Rating IIIC. No mitigation recommended.
387	S31° 45' 31.8" E23° 12' 44.8"	Modderfontein 228. Two loose palaeocalcrete nodules in surface fvloat containing postcrania of small tetrapods. Proposed Field Rating IIIC. No mitigation recommended.
388	S31° 45' 37.7" E23° 12' 40.3"	Modderfontein 228. Gentle low hillslope exposure of purple-brown and grey-gfreen overbank mudrocks with probable vertebrate burrow cast, several fossil bone scraps. Proposed Field Rating IIIC. No mitigation recommended.
389	S31° 45' 38.1" E23° 12' 41.0"	Modderfontein 228. Probable partial skull of medium-sized therapsid embedded within mudrock. Proposed Field Rating IIIB. Specimen to be collected if it falls within 10 m of development footprint.
392	S31° 45' 34.8" E23° 12' 46.2"	Modderfontein 228. Small dicynodont skull exposure dorsum-up in stream gulley exposure of grey-green mudrocks. Proposed Field Rating IIIC. No mitigation recommended.
393	S31° 45' 34.7" E23° 12' 46.2"	Modderfontein 228. Poorly-preserved skull of small tetrapod within ferruginous calcrete concretion, stream gulley exposure of grey-green mudrocks. Proposed Field Rating IIIC. No mitigation recommended.
395	S31° 45' 17.9" E23° 14' 23.0"	Modderfontein 228. Skull (ventral-up) and curved vertebral column of small dicynodont embedded within grey-green mudrock (*possibly* preserved within a burrow). Proposed Field Rating IIIB. Specimen to be collected if falls within 10 m of development footprint.

396	S31° 45' 18.0" E23° 14' 22.9"	Modderfontein 228. Several palaoecalcrete concretions with fragmentary / disarticulated bony remains of small- to medium-sized tetrapods. Proposed Field Rating IIIB. Specimens to be collected if they fall within 10 m of development footprint.
397	S31° 45' 16.8" E23° 14' 23.2"	Modderfontein 228. Isolated vertebra (centrum plus incomplete neaural arch) of medium-sized tetrapod. Proposed Field Rating IIIB. Specimen to be collected if it falls within 10 m of development footprint.
398	S31° 45' 17.3" E23° 14' 14.4"	Modderfontein 228. Scrap of fossil bone within siltstone float. Proposed Field Rating IIIC. No mitigation recommended.
399	S31° 45' 17.1" E23° 14' 14.0"	Modderfontein 228. Several small, loose float fragments of medium-sized tetrapod, including a partial tooth row, probably of a therocephalian therapsid. Proposed Field Rating IIIB. Specimens to be collected if they fall within 10 m of development footprint.
400	S31° 45' 16.6" E23° 14' 12.7"	Modderfontein 228. Several disarticulated fine ribs of small-bodied tetrapod preserved within sandstone. Proposed Field Rating IIIC. No mitigation recommended.
403	S31° 46' 08.0" E23° 14' 00.3"	Modderfontein 228, pale cross-bedded sandstone *krans* near kraal complex with (1) mottled, bioturbated textures; (2) subparallel, longitudinally striated / ridged and grooved negative features – possibly moulds of large woody plant stems or soft-sediment deformation structures, (3) local development of smoothed surfaces (possibly floors of vertebrate burrows), (4) mud-lined elongate structures with transverse, comb-like ridges (possibly casts of burrow scratches). Proposed Field Rating IIIB. Features to be recorded if they fall within 10 m of development footprint.
405	S31° 43' 56.6" E23° 16' 35.8"	Modderfontein 228. Float specimen of small dicynodont skull. Proposed Field Rating IIIC. No mitigation recommended.
406	S31° 44' 09.0" E23° 16' 50.0"	Modderfontein 228. Float specimen of small dicynodont snout. Proposed Field Rating IIIC. No mitigation recommended.
407	S31° 44' 09.3" E23° 16' 50.2"	Modderfontein 228. Float block of mudflake basal channel breccia containing isolated fossil tusk. Proposed Field Rating IIIC. No mitigation recommended.
408	S31° 44' 09.4" E23° 16' 50.8"	Modderfontein 228. Partial snout and skull roof of small-bodied dicynodont showing broad intertemporal region. Proposed Field Rating IIIB. Specimen to be collected if it falls within 10 m of development footprint.
411	S31° 44' 03.9" E23° 16' 19.7"	Modderfontein 228. Two small pedogenic calcrete nodules respectively containing postcrania of small tetrapod as well as skul of small dicynodont (latter almost completely enveloped by calcrete). Proposed Field Rating IIIB. Specimens to be collected if they fall within 10 m of development footprint.
413	S31° 44' 05.5" E23° 16' 18.8"	Modderfontein 228. Float fragment of palaeocalcrete concretion containing sun-cracked tetrapod bone. Proposed Field Rating IIIC. No mitigation recommended.
414	S31° 44' 06.4" E23° 16' 18.6"	Modderfontein 228. Snout of small-bodied dicynodont. Proposed Field Rating IIIC. No mitigation recommended.
416	S31° 44' 05.9" E23° 16' 27.3"	Modderfontein 228. Snout (palatal view) of small tetrapod skull, *possibly* with tiny teeth, probably sun-cracked and associated with mudflakes within float block of grey-green sandstone. Simple horizontal cylindrical burrows associated with wave-rippled palaeosurface. Probable sandstone cast of vertebrate burrow with elliptical cross-section (*c*. 15-20 cm wide). Proposed Field Rating IIIC. No mitigation recommended.
417	S31° 44' 07.4" E23° 16' 27.6"	Modderfontein 228. Fragment of well-preserved, partially crushed rib or limb bone of medium-sized tetrapod among float. Proposed Field Rating IIIC. No mitigation recommended.
418	S31° 44' 05.7" E23° 16' 29.8"	Modderfontein 228. Incomplete glossopterid leaf with clear midrib but indistinct venation, preserved within yellowish sandstone float block. Proposed Field Rating IIIC. No mitigation recommended.
428	S31° 45' 47.7" E23° 17' 58.4"	Phaisant Kraal 1. Pale brown, fine-grained tabular sandstones with local wave rippling, showing areas of smooth surfaces within fine mud cracking, wrinkled microbial mat textures, small-scale invertebrate burrows (possibly undermat miners such as insects), probable casts of reedy plant stems. Proposed Field Rating IIIB. Specimens already protected within riverine area downstream of farm dam.
429	S31° 45' 49.6" E23° 17' 57.0"	Phaisant Kraal 1. Same setting as above with several probable tetrapod burrows (*c*. 15-20 cm across), variously preserved as shallow troughs, low ridges or smooth, straight to sinuous strips on sandstone bed tops. Proposed Field Rating IIIB. Specimens already protected within riverine area downstream of farm dam.

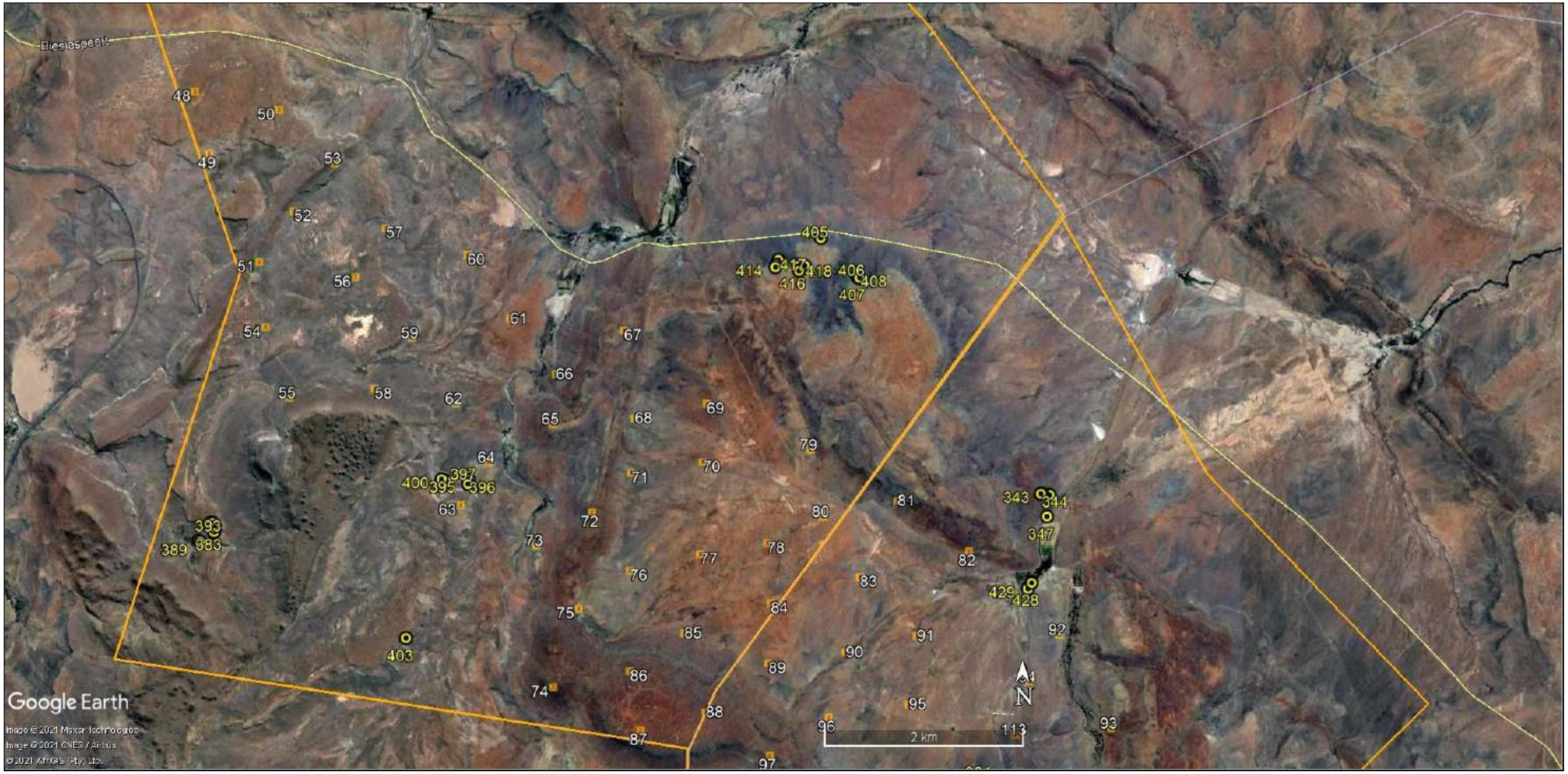

Figure A1: Google Earth© satellite image of the NW sector of the Modderfontein WEF project area (orange polygons) showing the authorized turbine locations (numbered small orange squares) as well as new fossil sites recorded during the present palaeontological site visit (numbered yellow circles). In this original layout a large number of turbine sites overlie potentially fossiliferous sedimentary bedrocks of the Teekloof Formation (grey hues). Excavations for turbine footings and (especially) surface clearance and excavations for associated infrastructure such as access roads and hard stand areas (not shown here) are likely to have significant negative impacts on local fossil heritage preserved at or near-surface, most of which remains unrecorded.

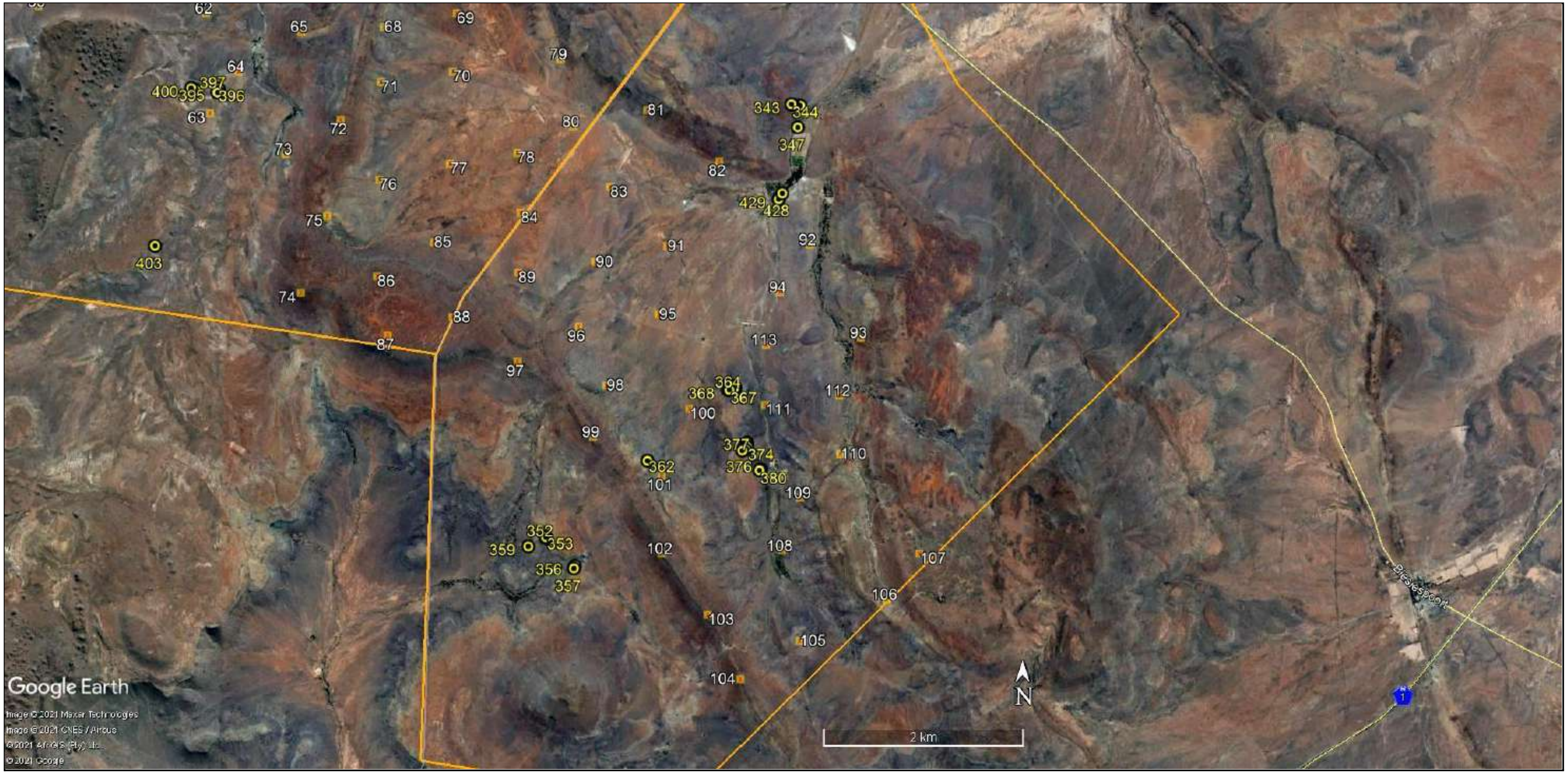

Figure A2: Google Earth© satellite image of the SE sector of the Modderfontein WEF project area (orange polygons) showing the authorized turbine locations (numbered small orange squares) as well as new fossil sites recorded during the present palaeontological site visit (numbered yellow circles). In this original layout a large number of turbine sites overlie potentially fossiliferous sedimentary bedrocks of the Teekloof Formation (grey hues). Excavations for turbine footings and (especially) surface clearance and excavations for associated infrastructure such as access roads and hard stand areas (not shown here) are likely to have significant negative impacts on local fossil heritage preserved at or near-surface, most of which remains unrecorded.

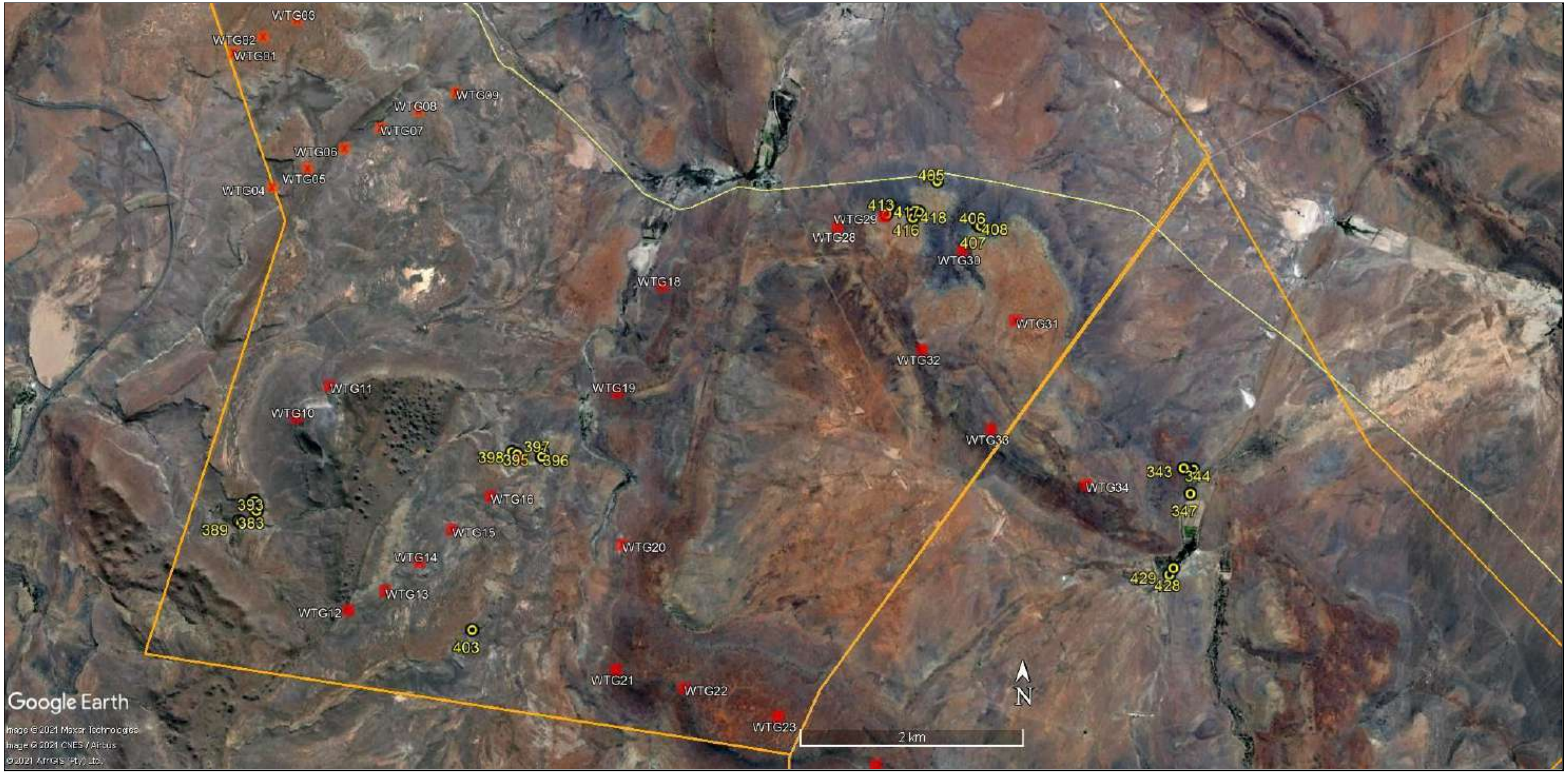

Figure A3: Google Earth© satellite image of the NW sector of the Modderfontein WEF project area (orange polygons) showing the proposed amended turbine locations (numbered small red squares) as well as new fossil sites recorded during the present palaeontological site visit (numbered yellow circles). No fossil sites are recorded at the turbine locations. In this amended layout a high proportion of the turbine sites overlie unfossiferous dolerite, doleritic colluvium (both showing rusty brown hues in the image) or thermally metamorphosed Teekloof Formation bedrocks that are of low palaeosensitivity. Excavations for most turbine footings are therefore likely to have low impacts on palaeontological heritage. Surface clearance and excavations for associated infrastructure such as access roads and hard stand areas (not shown here) might have significant negative impacts on local

fossil heritage preserved at or near-surface, most of which remains unrecorded, so a focussed pre-construction survey of potentially fossiliferous sectors of the final WEF footprint is recommended. In any event the overall impact significance is markedly *lower* than for the authorized WEF layout.

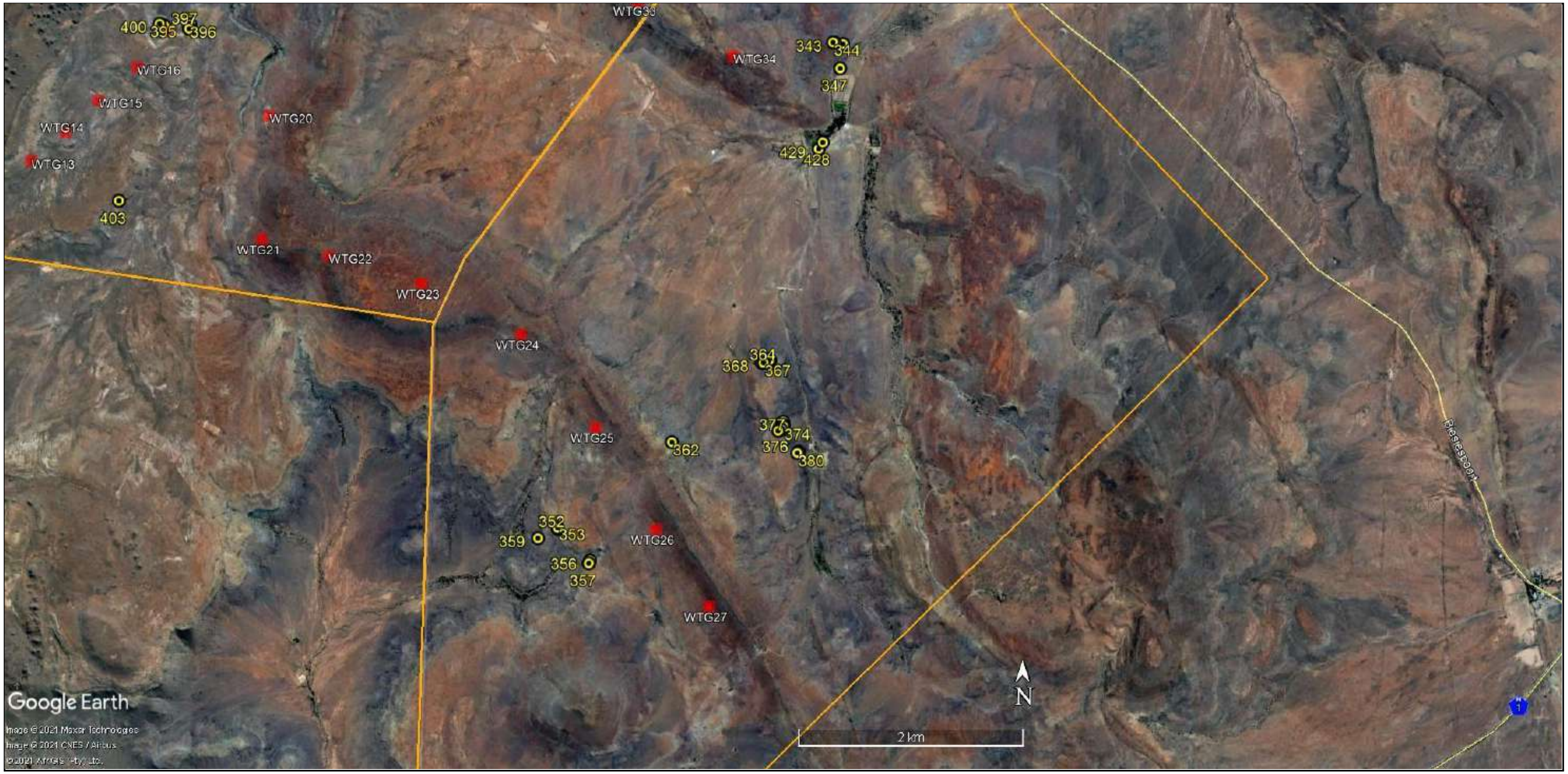

Figure A4: Google Earth© satellite image of the SE sector of the Modderfontein WEF project area (orange polygons) showing the proposed amended turbine locations (numbered small red squares) as well as new fossil sites recorded during the present palaeontological site visit (numbered yellow circles). No fossil sites are recorded at the turbine locations. In this amended layout a high proportion of the turbine sites overlie unfossiferous dolerite, doleritic colluvium (both showing rusty brown hues in the image) or thermally metamorphosed Teekloof Formation bedrocks that are of low palaeosensitivity. Excavations for most turbine footings are therefore likely to have low impacts on palaeontological heritage. Surface clearance and

excavations for associated infrastructure such as access roads and hard stand areas (not shown here) might have significant negative impacts on local fossil heritage preserved at or near-surface, most of which remains unrecorded, so a focussed pre-construction survey of potentially fossiliferous sectors of the final WEF footprint is recommended. In any event the overall impact significance is markedly *lower* than for the authorized WEF layout.

<table>
<tr><td colspan="3">APPENDIX 2. CHANCE FOSSIL FINDS PROCEDURE: Modderfontein WEF on farms Modderfontein 228 and Phaisant Kraal 1 near Victoria West</td></tr>
<tr><td>Province & region:</td><td colspan="2">Western Cape (Central Karoo District) & Northern Cape (Pixley Ka-Seme District)</td></tr>
<tr><td>Responsible Heritage Management Agencies</td><td colspan="2">HERITAGE WESTERN CAPE. Protea Assurance Building, Green Market Square, Cape Town 8000. Private Bag X9067, Cape Town 8001. Tel: 021 483 9598. E-mail: ceoheritage@westerncape.gov.za
SAHRA: SAHRA, 111 Harrington Street, Cape Town. PO Box 4637, Cape Town 8000, South Africa. Phone: +27 (0)21 462 4502. Fax: +27 (0)21 462 4509. Web: www.sahra.org.za</td></tr>
<tr><td>Rock unit(s)</td><td colspan="2">Teekloof Formation (Lower Beaufort Group), Late Caenozoic alluvium.</td></tr>
<tr><td>Potential fossils</td><td colspan="2">Fossil skulls, postcrania of tetrapods, amphibians, fish as well as rare petrified wood, vertebrate and invertebrate burrows within bedrocks. Mammalian bones, teeth & horn cores, freshwater molluscs, calcretised trace fossils & rhizoliths and plant material in alluvium.</td></tr>
<tr><td rowspan="5">ECO protocol</td><td colspan="2">1. Once alerted to fossil occurrence(s): alert site foreman, stop work in area immediately (N.B. safety first!), safeguard site with security tape / fence / sand bags if necessary.</td></tr>
<tr><td colspan="2">2. Record key data while fossil remains are still in situ:
● Accurate geographic location – describe and mark on site map / 1: 50 000 map / satellite image / aerial photo
● Context – describe position of fossils within stratigraphy (rock layering), depth below surface
● Photograph fossil(s) in situ with scale, from different angles, including images showing context (e.g. rock layering)</td></tr>
<tr><td>3. If feasible to leave fossils in situ:
● Alert Heritage Resources Agency and project palaeontologist (if any) who will advise on any necessary mitigation
● Ensure fossil site remains safeguarded until clearance is given by the Heritage Resources Agency for work to resume</td><td>3. If not feasible to leave fossils in situ (emergency procedure only):
● Carefully remove fossils, as far as possible still enclosed within the original sedimentary matrix (e.g. entire block of fossiliferous rock)
● Photograph fossils against a plain, level background, with scale
● Carefully wrap fossils in several layers of newspaper / tissue paper / plastic bags
● Safeguard fossils together with locality and collection data (including collector and date) in a box in a safe place for examination by a palaeontologist
● Alert Heritage Resources Agency and project palaeontologist (if any) who will advise on any necessary mitigation</td></tr>
<tr><td colspan="2">4. If required by Heritage Resources Agency, ensure that a suitably-qualified specialist palaeontologist is appointed as soon as possible by the developer.</td></tr>
<tr><td colspan="2">5. Implement any further mitigation measures proposed by the palaeontologist and Heritage Resources Agency</td></tr>
<tr><td>Specialist palaeontologist</td><td colspan="2">Record, describe and judiciously sample fossil remains together with relevant contextual data (stratigraphy / sedimentology / taphonomy). Ensure that fossils are curated in an approved repository (e.g. museum / university / Council for Geoscience collection) together with full collection data. Submit</td></tr>
</table>

	Palaeontological Mitigation report to Heritage Resources Agency. Adhere to best international practice for palaeontological fieldwork and Heritage Resources Agency minimum standards.