PALAEONTOLOGICAL ASSESSMENT: DESKTOP STUDY

Tourism and event-related developments at Hakskeen Pan, Dawid Kruiper Local Municipality, ZF Mgcawu District Northern Cape

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

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EXECUTIVE SUMMARY

The Northern Cape Provincial Government (NCPG) is supporting the Bloodhound Super Sonic Car (SSC) Landspeed Record Project based at Hakskeen Pan near Rietfontein, Dawid Kruiper Local Municipality, ZF Mgcawu District. Land parcels concerned are Gordonia RD Farms 222.0, 585.0 and 585.107. The current and planned infrastructure for the project has a comparatively small footprint – including several temporary structures - and is largely confined to the pan area and its margins, most of which is probably of low palaeontological sensitivity. While the palaeontology of this region is currently poorly-known, there are several sedimentary rock units represented around the margins of Hakskeen Pan that are either already known to contain fossils or that might prove fossiliferous.

Dwyka Group glacially-related bedrocks cropping out along the western and eastern margins of Hakskeen Pan have previously been reported to contain fossil Permo-Carboniferous plants - *e.g. Glossopteris* leaves, with petrified wood also a possibility - but precise locality details are not available (Thomas *et al.* 1988). The overlying postglacial Prince Albert Formation (Ecca Group), cropping out along the southern pan margins, is unusually well-exposed in the region (*e.g.* western edge of Koppieskraal Pan) but in this area its palaeontology is unknown. It might contain trace fossils, invertebrates and plant remains, for example. Baking of the Ecca mudrocks by Karoo dolerite intrusions may have enhanced or compromised fossil preservation. Surface gravels in pan areas might contain reworked blocks of petrified wood and teeth reworked from older sediments by erosional downwasting and sheetwash. Elsewhere in the Northern Cape (*e.g.* Bushmanland) dense concentrations of Pleistocene freshwater molluscs as well as disarticulated remains of fishes, birds, crabs and undetermined teeth have been reported along pan margins (Kent & Gribnitz 1985, Almond *in* Macey 2011). Calcrete hardpans, which are especially well-developed in areas with dolerite intrusions, might contain trace fossils as well as rare vertebrate remains.

Event infrastructure as well as tourism project-related activities might disturb or damage valuable fossil heritage around the pan margins. There has already been a degree of surface disturbance entailed by the landspeed record project (*e.g.* collection of surface rocks, infilling of borrow pits). As a precautionary measure, it is therefore recommended that a short specialist palaeontological field assessment of the Hakskeen Pan project area takes place with special focus on the pan margins (*cf* Figs. 4 & 5 herein) and rock dumps. The resulting report to SAHRA (South African Heritage Resources Agency) should document and briefly assess any fossil remains found as well as make recommendations for any mitigation measures for the remaining phases of the development.

1. INTRODUCTION & BRIEF

As part of their strategy to market the Northern Cape Province as an extreme sport destination, the Northern Cape Provincial Government (NCPG) is supporting the current Bloodhound Super Sonic Car (SSC) Landspeed Record Project. A land speed record attempt is planned to take place on Hakskeen Pan which is located close to the RSA / Namibia border on the eastern side of the R31 and *c*. 15 km east of the small community of Rietfontein in the Dawid Kruiper (formerly Mier) Local Municipality, ZF Mgcawu District (Fig. 1). Land parcels concerned are Gordonia RD Farms 222.0, 585.0 and 585.107 (Fig. 2).

The following project description for ongoing developments at Hakskeen Pan is abstracted from the Heritage Impact Assessment by Morris (2016) (See also Figs. 3 to 7):

The majority of the infrastructure is to be on the eastern side, at the existing MTN containers (Speedweek/Landside camp/Media Centre). In addition there are to be a technical camp at the MTN tower next to the R31, as well as proposed sites for the fuel depot. The infrastructure includes the following:

- *A 20 km long, 500 m wide track that has been constructed, including a 300m wide safety buffer on either side of the track. Construction here consists of the following:*
    - *317 workers cleared by hand an area of 20km x 1,1km of all surface stones and pebbles.*
    - *Rehabilitation of the pan in the form of removing an existing causeway which was previously the main road between Mier and Rietfontein. This road which was 1m high was removed and the pan restored to its original surface and level.*
    - *Material removed from the road was placed back in the borrow pits created many years ago when this road was first built.*
    - *In certain areas it was necessary to remove stones which protruded above the surface but which extended to below the surface of the pan. These cases only represent a total estimated area of 500 m x 300 m when combined; thus only 0,68% of the total amount of stones removed were unearthed by machines, the remainder having been removed by hand.*
    - *The only place where grading has and will take place is to repair man-made indentations and elevations in the form of old tracks created by locals or in the case of the elevated causeway which was removed.*

- *Temporary structures (mostly shipping containers) placed on the edge of the pan for various functions such as control, storage, hospitality, showers and toilets etc.) located at the landside / Speedweek camp.*

- *A 110kVa diesel generator, with a 3500l diesel tank and bund, also housed within a portable shipping container on site.*

- *Two telecommunications masts placed at the landside camp and next to the R31.*

- *6 x 10 000l jo-jo tanks have been constructed for the storage of water on site.*

- *Water is sourced from local borehole near the site, via a 16m long, 40mm diameter pipeline.*

- *There is also a 110kVa diesel generator, with a 3500l diesel tank and bund, also housed within a portable shipping container on site.*

- *A 44 000l sewerage septic/holding tank has also been constructed at the landside/ Speedweek camp for the temporary storage of all effluent (to be disposed of by road to the Mier Sewerage Works).*

- *No new roads constructed for the activities, and only existing tracks on the pan used.*

The ongoing development involves disturbance or excavations into potentially fossiliferous sediments of the Karoo Supergroup as well as surface gravels and pan sediments. The present palaeontological impact assessment of the project as part of a comprehensive HIA has therefore been commissioned by the Department of Economic Development and Tourism Northern Cape in accordance with the requirements of the National Heritage Resources Act, 1999 (Contact details: Ms Nadia Miller, Tourism Officer: Tourism Development, Department of Economic Development and Tourism Northern Cape. Address: Cnr Kekewhich & Memorial Road, Block No. 6, Monridge Office Park, Monuments Hights, Kimberley 8300. Tel: 053 830 4810. Fax: 086 603 7400. Email: millern@ncpg.gov.za).

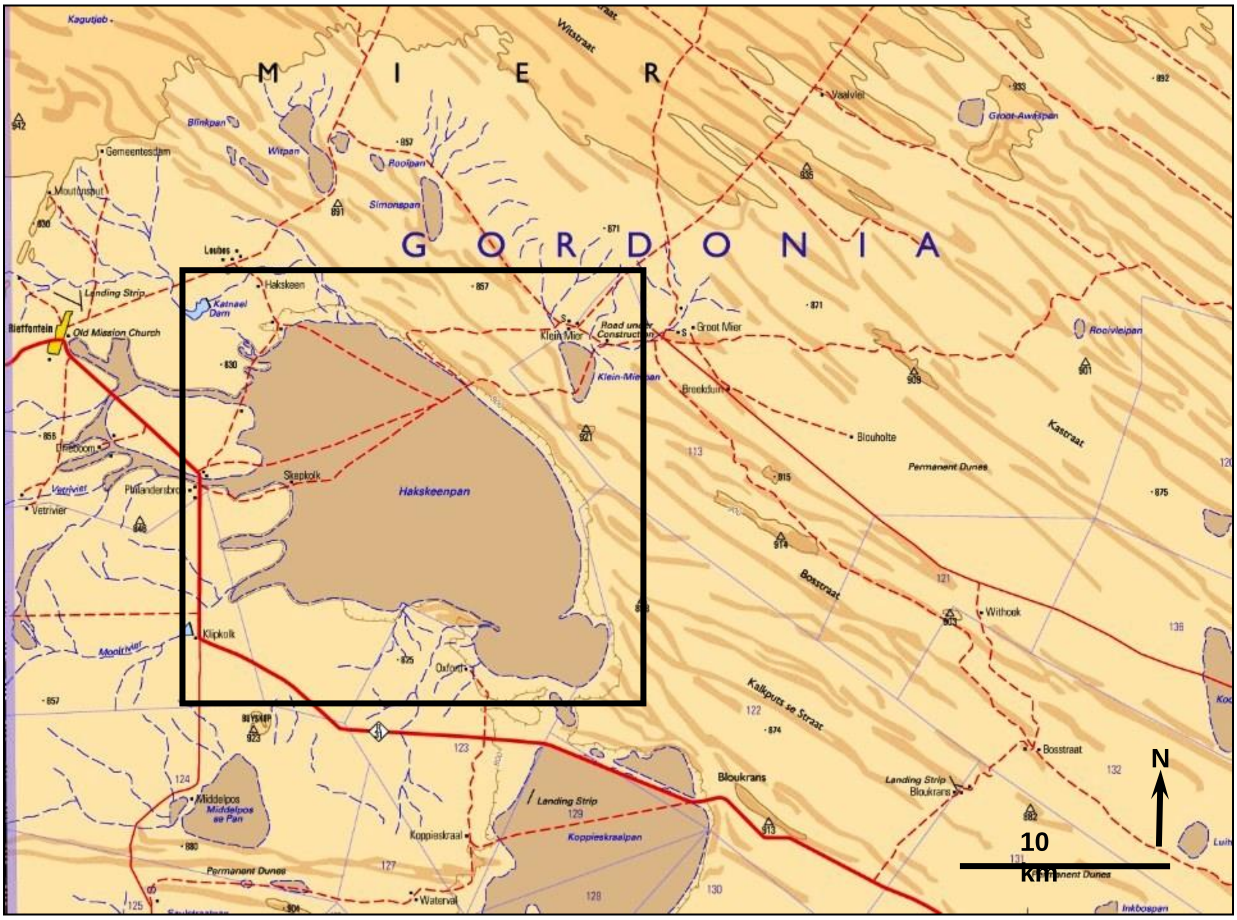

Figure 1. Extract from 1: 250 000 topographical sheet 2620 Twee Rivieren (courtesy of The Chief Directorate: National Geo-spatial Information, Mowbray) showing the location of Hakskeen Pan, *c*. 20 k east of the RSA / Namibia border and 15 km east of Rietfontein, Dawid Kruiper Local Municipality, Northern Cape (black rectangle).

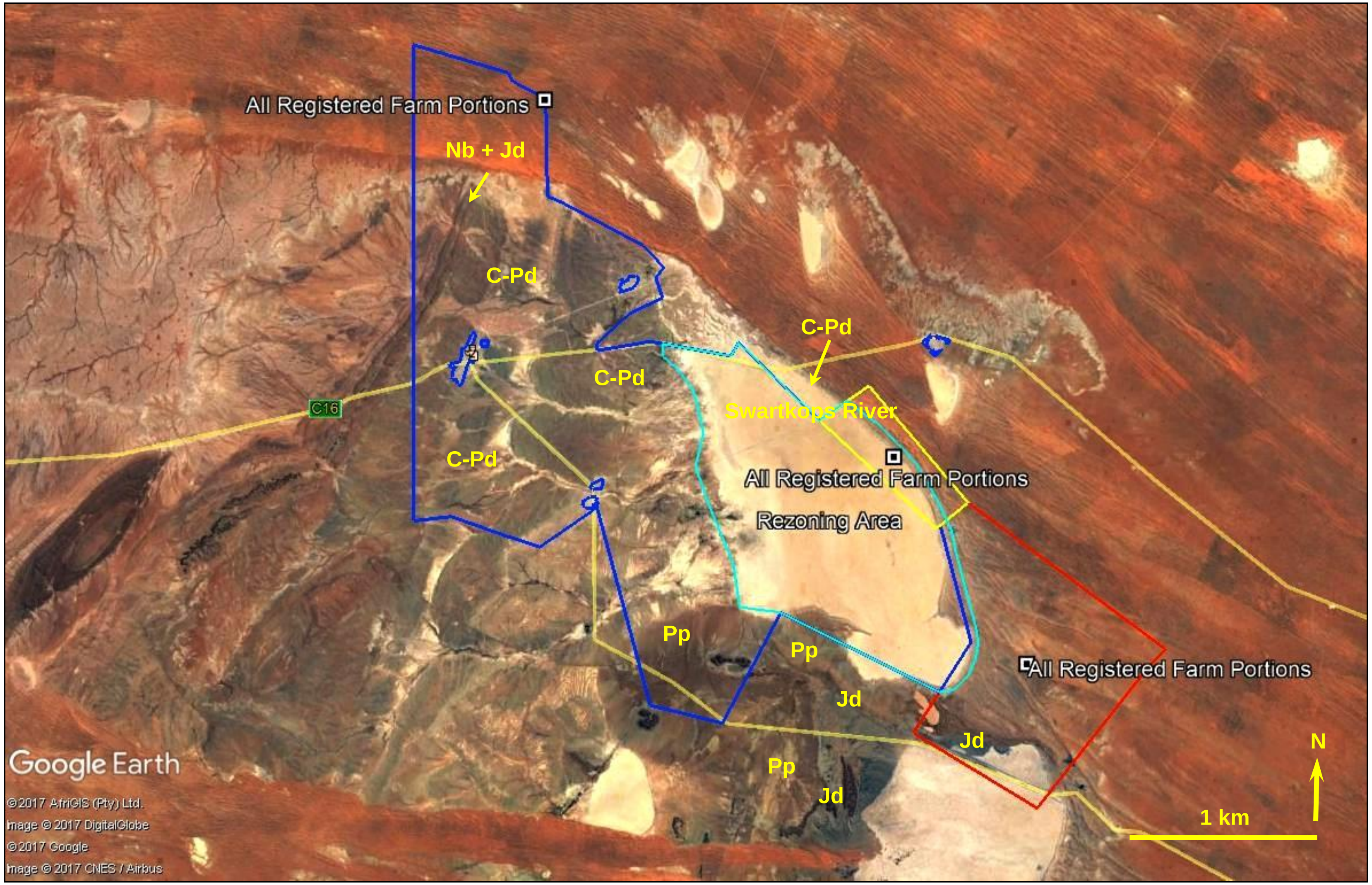

Figure 2. **Google Earth© satellite image of the Hakskeen Pan study area, Northern Cape. Gordonia RD land parcels concerned include Farm 222.0 (red polygon), 585.0 (blue polygon) and 585.107 (yellow polygon). Major bedrock units represented here include: Nb (Fish River Subgroup), C-Pd (Dwyka Group), Pp (Ecca Group) and Jd (Karoo Dolerite Suite) (See geological map. Fig. 7).**

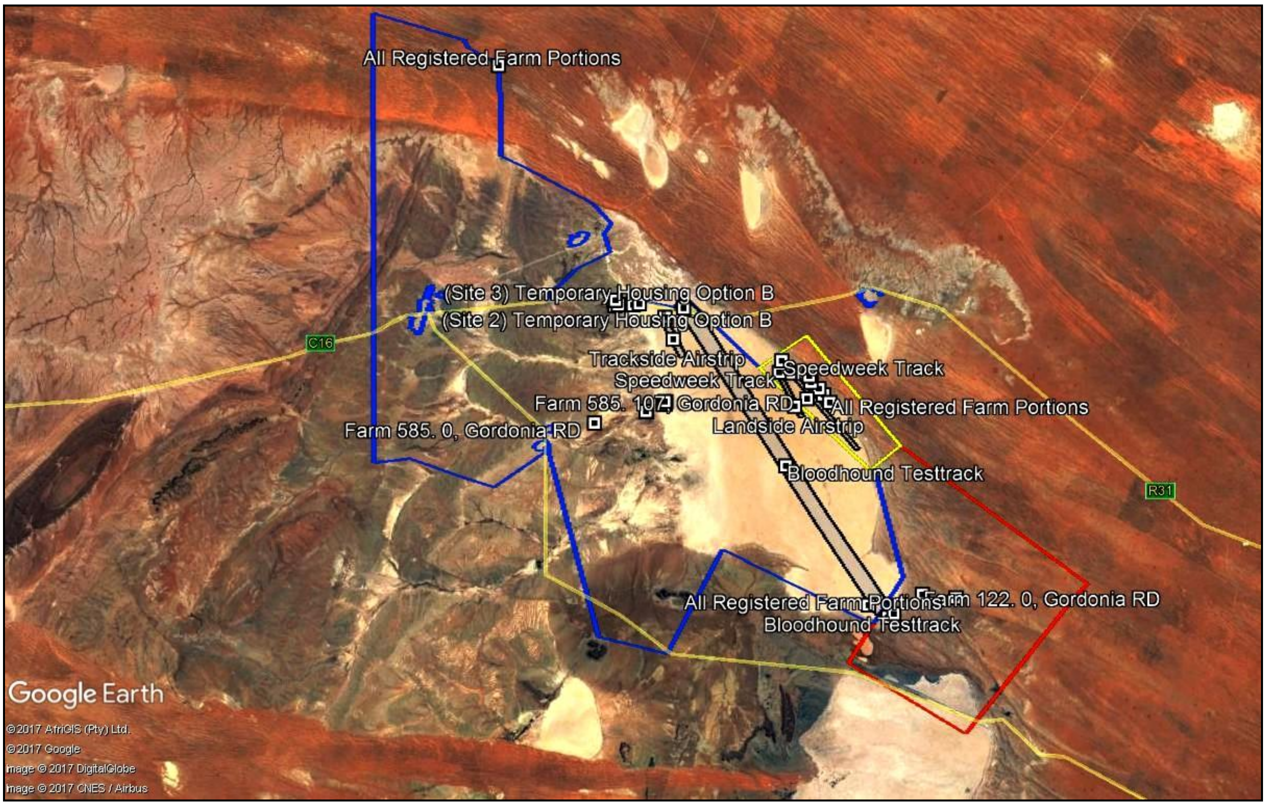

Figure 3. Google Earth© satellite image of the Hakskeen Pan study area showing the distribution of infrastructure for the Bloodhound Super Sonic Car (SSC) Landspeed Record Project. See following three images for more detail.

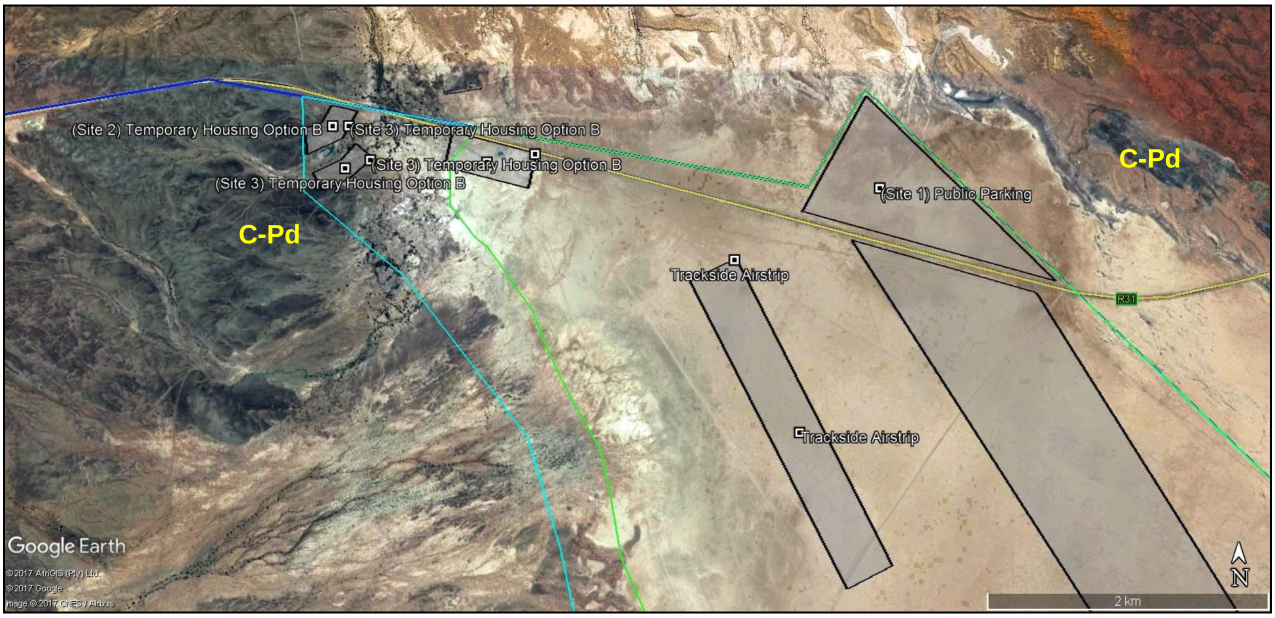

Figure 4. Google Earth© satellite image showing the location of infrastructure in the north-western portion of Hakskeen Pan. Dwyka Group bedrocks and surface gravels appear as dark grey (C-Pd).

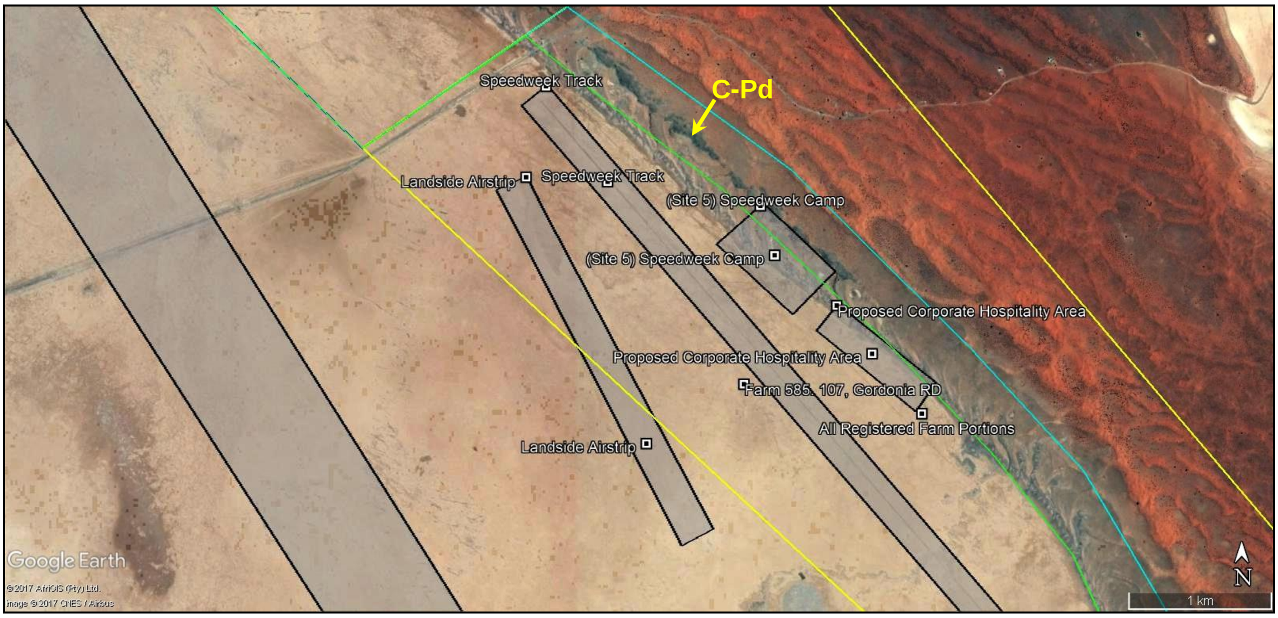

Figure 5. Google Earth© satellite image showing the location of infrastructure along the north-eastern margin of Hakskeen Pan. A ridge of Dwyka Group bedrocks and surface gravels appears as dark grey (C-Pd), Kalahari aeolian sands to the northeast are orange.

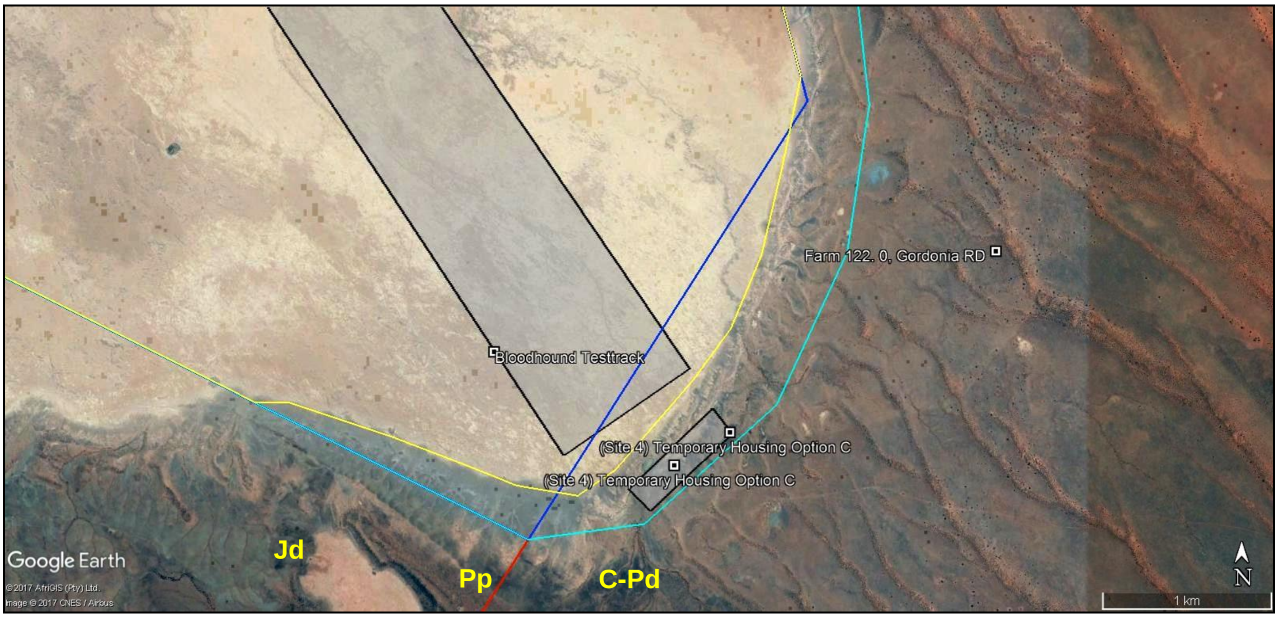

Figure 6. Google Earth© satellite image showing the location of infrastructure along the south-eastern margin of Hakskeen Pan. Bedrocks in the south include representatives of the Dwyka Group (dark grey, C-Pd), Ecca Group (brown, Pp) and Karoo Doerite Suite (Jd). Kalahari aeolian sands extend up to the edge of the pan elsewhere.

1.1. Legislative context of this palaeontological study

The development footprint is situated in an area that is underlain by potentially fossiliferous sedimentary rocks of Palaeozoic to Caenozoic age (Sections 2 and 3). The construction phase of the development entails surface clearance and small excavations into the superficial sediment cover and perhaps locally into the underlying bedrock as well. All these developments may adversely affect 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.

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

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

1.2. Approach to the palaeontological heritage assessment

In preparing a palaeontological desktop study the potentially fossiliferous rock units (groups, formations *etc*) represented within the study area are determined from geological maps. The known fossil heritage within each rock unit is inventoried from the published scientific literature, previous palaeontological impact studies in the same region, and the author's field experience (Consultation with professional colleagues as well as examination of institutional fossil collections may play a role here, or later following field assessment during the compilation of the final report). This data is then used to assess the palaeontological sensitivity of each rock unit to development

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

On the basis of the desktop and Phase 1 field assessment studies, the likely impact of the proposed development on local fossil heritage and any need for specialist mitigation are then determined. Adverse palaeontological impacts normally occur during the construction rather than the operational or decommissioning phase. Phase 2 mitigation by a professional palaeontologist – normally involving the recording and sampling of fossil material and associated geological information (*e.g.* sedimentological data) may be required (a) in the pre-construction phase where important fossils are already exposed at or near the land surface and / or (b) during the construction phase when fresh fossiliferous bedrock has been exposed by excavations. To carry out mitigation, the palaeontologist involved will need to apply for a palaeontological collection permit from the relevant heritage management authority, *i.e.* the South African Heritage Resources Agency, SAHRA. It should be emphasized that, *providing appropriate mitigation is carried out*, the majority of developments involving bedrock excavation can make a *positive* contribution to our understanding of local palaeontological heritage.

1.3. Information sources

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

1. A short project outline (Morris 2016) and kmz files kindly provided by Macroplan Town & Regional Planners, Upington;

2. A review of the relevant scientific literature, including published geological maps and accompanying sheet explanations (Thomas *et al.* 1988) as well as previous palaeontological assessment reports for the broader region (*e.g.* Almond 2015, 2017);

3. The author's database on the geological formations concerned and their palaeontological heritage (See Almond & Pether 2008).

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.

To the author’s knowledge, there have been no specialist palaeontological field studies in this part of the Kalahari region. Confidence levels for this palaeontological assessment are therefore only MODERATE.

2. GEOLOGICAL BACKGROUND

The Hakskeen Pan study area lies within the Kalahari Geomorphic Province (Partridge *et al.* 2010) of the Northern Cape. According to Morris (2016), Hakskeen Pan represents one of the largest isolated or closed pans in the South African Kalahari with an area of approximately 140 km^2 at an elevation of about 800 m above sea level. The geology of the region is shown on 1: 250 000 geology sheet 2620 Twee Rivieren (Council for Geoscience, Pretoria; Thomas *et al.* 1988). Hakskeen Pan, as well as Koppieskraal Pan just to the southeast, are located on the eastern side of an extensive, broadly oval (W-E) patch of bedrock exposure spanning the RSA / Namibia border and surrounded by Kalahari dune sands (Fig. 2). The bedrocks in the study region east of Rietfontein belong to the Karoo Supergroup succession on the southern margins of the Kalahari Basin (*not* the Main Karoo Basin) with representatives of the Permo-Carboniferous, glacially influenced Dwyka Group as well as overlying Early Permian post-glacial mudrocks of the Ecca Group. North of Rietfontein the Karoo beds unconformably overlie reddish-brown Early Cambrian sandstones of the Fish River Subgroup (Nama Group). According to the geological map, Hakskeen Pan largely overlies Dwyka sediments that crop out along its western and eastern margins and also lie beneath the pan itself. The southern margins of the pan are underlain by Prince Albert Formation mudrocks which are extensively intruded and baked here by Early Jurassic sills and dykes of the Karoo Dolerite Suite. A single kimberlite pipe of the Late Cretaceous Gordonia Province intrudes the Dwyka Group bedrocks *c*. 1 km east of Rietfontein (black diamond symbol in Fig. 7).

Orange-hued dune sands of the Pleistocene to Recent **Gordonia Formation** (**Kalahari Group**) extend up to the north-eastern edge of the pan, with NW-SE trending linear dunes clearly visible on satellite images. Dark grey hues on satellite images of the Rietfontein study area suggest that parts of the Dwyka Group outcrop area are mantled by downwasted gravels of the **Obogorogop Formation** (Kalahari Group). Well-developed Plio-Pleistocene calcretes of the **Mokalanen Formation** (Kalahari Group) (T-Qm, pale yellow in Fig. 7) are mapped capping the Dwyka Group north of Rietfontein and may extend into the present study area further to the east.

2.1. Dwyka Group

The geology of the Dwyka Group has been summarized by Visser (1989), Visser *et al.* (1990) and Johnson *et al.* (2006), among others. According to maps in Visser *et al.* (1990) and Von Brunn and Visser (1999), as well as the field descriptions of Thomas *et al.* (1988) for the Twee Rivieren 1: 250 000 sheet area. The Dwyka Group rocks in the Mier area, close to the southern edge of the Kalahari (Botswana) Karoo Basin, are probably very similar in facies and origin to the **Mbizane Formation** of the Main Karoo Basin. This is equivalent to the "Northern (valley and inlet) Facies" of Visser *et al*. (1990). The Mbizane Formation, up to 190 m thick, is recognized across the entire northern margin of the Main Karoo Basin where it may variously form the whole or only the *upper* part of the Dwyka succession. It is characterized by its extremely heterolithic nature, with marked vertical and horizontal facies variation (Von Brunn & Visser 1999). The proportion of diamictite and mudrock is often low, the former often confined to basement depressions. Orange-tinted sandstones (often structureless or displaying extensive soft-sediment deformation, amalgamation and mass flow processes) may dominate the succession.

In the Rietfontein area the Dwyka succession is 50 m or more thick and very heterolithic, showing considerable lateral as well as vertical facies variation. The upper sandstone-dominated portion of the succession, comprising conglomerates, grits, sandstones, calcarenites and brown nodular limestones overlies older beds of polymict boulder diamictite (tillite) and grey-green shales with occasional dropstones (Thomas *et al.* 1988). These last authors report extensive outcrops of ferruginous flaggy sandstones, locally ripple-marked, cross-bedded and with soft-sediment deformation structures, at the top of the Dwyka succession on the northwest side of Hakskeen Pan.

2.2. Ecca Group

The Ecca Group in the study area is represented by post-glacial basinal mudrocks of the **Prince Albert Formation** (**Pp**). This thin-bedded to laminated, mudrock-dominated succesion of Early Permian (Asselian / Artinskian) age was previously known as "Upper Dwyka Shales". Key geological accounts of this formation are given by Visser (1992) and Cole (2005). The Prince Albert succession consists mainly of tabular-bedded mudrocks of blue-grey, olive-grey to reddish-brown colour with occasional thin (dm) buff sandstones and even thinner (few cm), soft-weathering layers of yellowish water-lain tuff (*i.e.* volcanic ash layers). Extensive diagenetic modification of these sediments has led to the formation of thin cherty beds, pearly-blue phosphatic nodules, rusty iron carbonate nodules, as well as beds and elongate ellipitical concretions impregnated with iron and manganese minerals. In the Mier study region the Prince Albert Formation reaches a thickness of 30-50 m and is especially well-exposed along the western edge of Koppieskraal Pan. In the vicinity of Hakskeen Pan the thin-bedded micaceous shales with minor arkoses are locally carbonaceous and extensively baked by dolerite intrusions to form dark grey, flinty hornfels (Thomas *et al.* 1988).

2.3. Kalahari Group

The geology of the Late Cretaceous to Recent Kalahari Group is reviewed by Thomas (1981), Dingle *et al.* (1983), Thomas & Shaw 1991, Haddon (2000) and Partridge *et al.* (2006). The unconsolidated, reddish aeolian sands of the **Gordonia Formation** ("Kalahari sands") at the top of the Kalahari Group succession are considered to range in age from the Late Pliocene / Early Pleistocene to Recent, dated in part from enclosed Middle to Late Stone Age stone tools (Dingle *et al*., 1983, p. 291). Note that the recent extension of the Pliocene - Pleistocene boundary from 1.8Ma back to 2.588 Ma places the Gordonia Formation entirely within the Pleistocene Epoch. Most of the sand is considered to be of local origin (Partridge *et al.* 2006). In the Mier study area the sands build sparsely-vegetated linear dunes with a pronounced NW-SE orientation that may have originated in Pleistocene times. Along water courses and inter-dune areas the sands are reworked by stream action and sheet wash; leached sands here may appear greyish or white. In the Twee Rivieren 1: 250 000 sheet area the sands are 10 to 20 m thick on average, but may be up to 40 m thick in some areas (Thomas *et al.* 1988). These unconsolidated sands are locally to extensively underlain by thin surface gravels equivalent to the Obobogorop Formation, formed from down-wasted (residual) or water-transported clasts weathered out of the Dwyka tillites or other bedrocks, as well as by calcretes of Plio-Pleistocene or younger age (Mokalanen Formation) (Fig. 8). Calcrete formation is often prevalent in low-lying areas associated with dolerite intrusions.

The Hakskeen Pan itself contains extensive deposits of sandy or silty to muddy material brought in by endorheic drainage systems as well as by wind action (Partridge & Scott 2000). According to Thomas *et al*. (1988) the pan sediments are "relatively young" and consist mainly of the minerals quartz, calcite, montmorillonite (clay) and feldspar, with salt deposits near-surface. Alluvial sands and gravels occur along shallow drainage lines traversing the Dwyka bedrocks west of the pan as well as along the outer pan margins on this side.

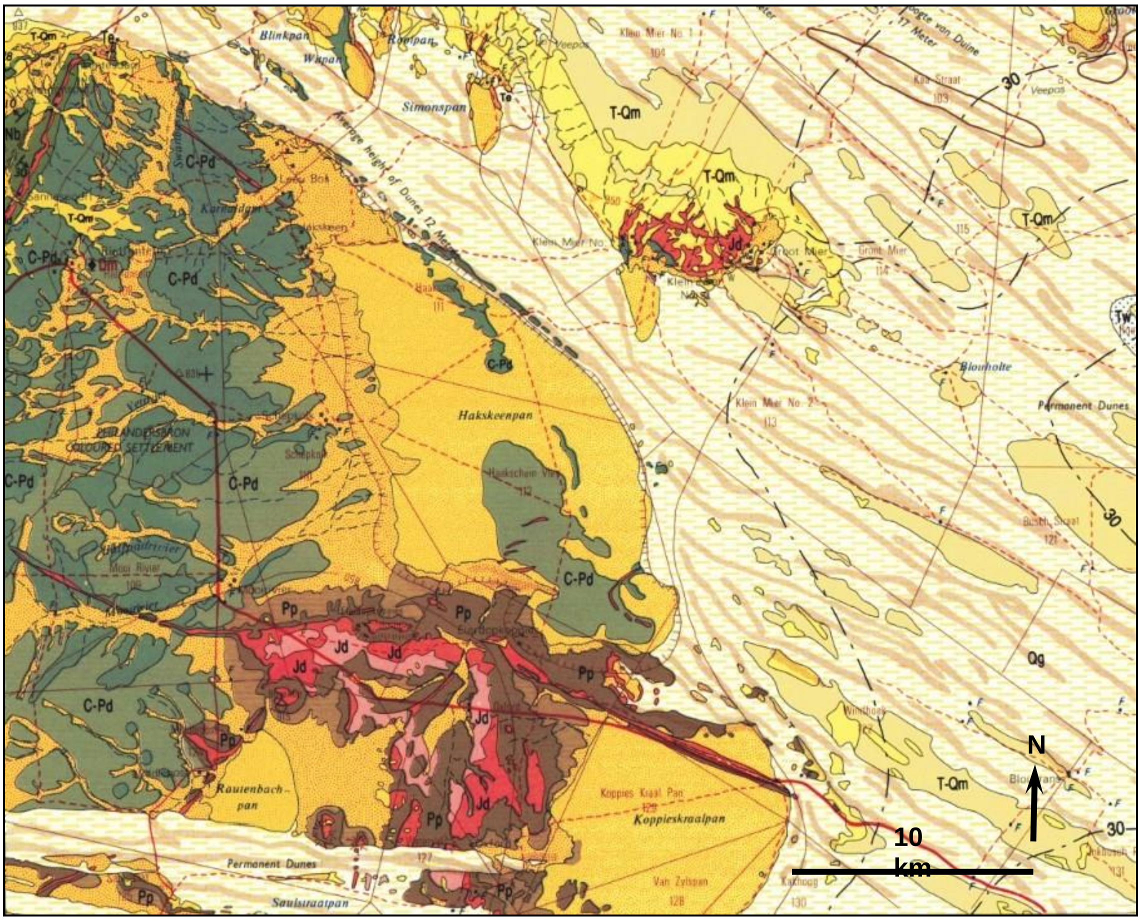

Figure 7. Extract from the 1: 250 000 map 2620 Twee Rivieren (Council for Geoscience, Pretoria) showing the geology of the Hakskeen Pan area near Rietfontein, Northern Cape. Rock units mapped in the region include: Dwyka Group (C-Pd, grey); Prince Albert Formation (Ecca Group) (Pp, brown); Karoo Dolerite Suite (Jd, red & pink); Late Caenozoic

alluvium and pan sediments (dark yellow); Gordonia Formation aeolian sands (Kalahari Group) (white and pale brown).

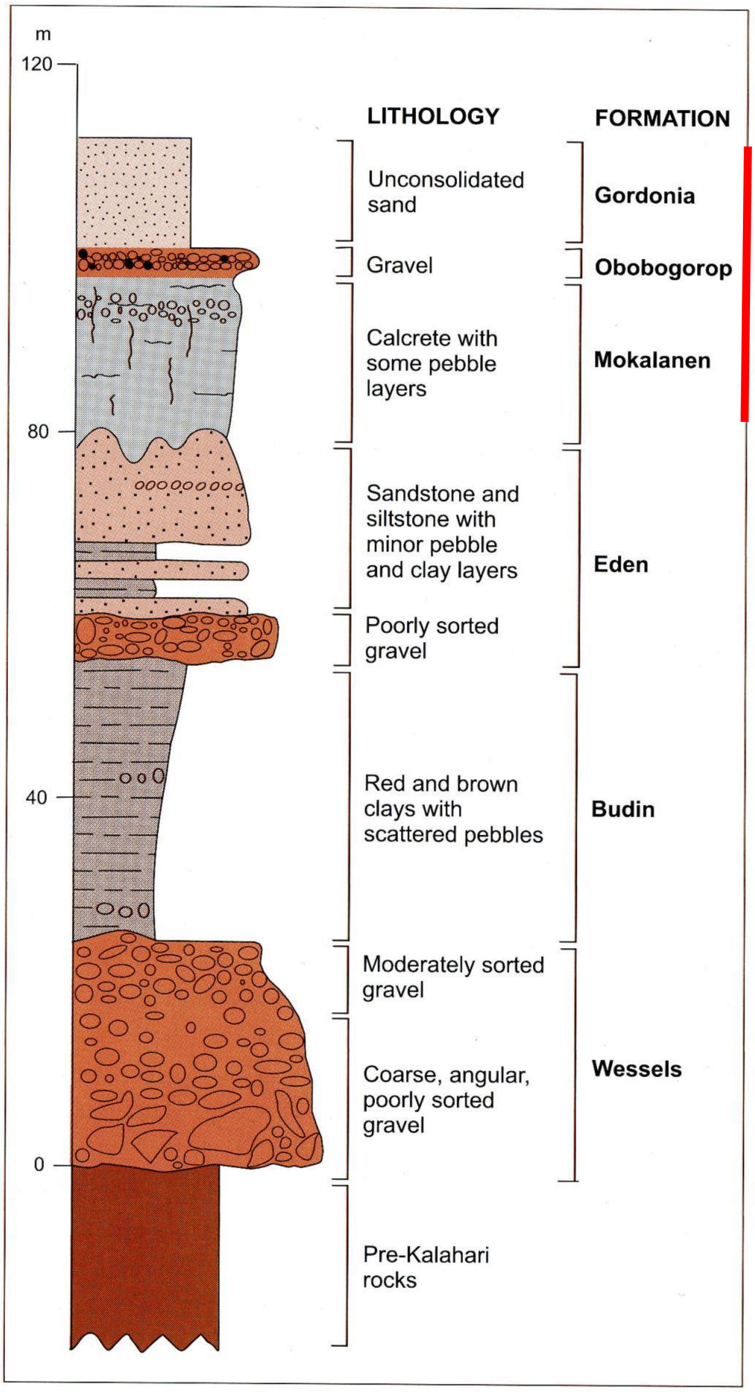

Figure 8. Generalised stratigraphy of the Kalahari Group (From Partridge *et al.* 2006). Rock units mapped near Rietfontein are indicated by the red bar.

3. PALAEONTOLOGICAL HERITAGE

The fossil record of the major sedimentary rock packages that are represented in the Hakskeen Pan area is outlined in this section of the report.

3.1. Dwyka Group fossils

The generally poor fossil record of the **Dwyka Group** (McLachlan & Anderson 1973, Anderson & McLachlan 1976, Visser 1989, Visser *et al*., 1990, Von Brunn & Visser 1999, Visser 2003, Almond & Pether 2008) is hardly surprising given the glacial climates that prevailed during much of the Late Carboniferous to Permian Periods in southern Africa. However, most Dwyka sediments were deposited during periods of glacial retreat associated with climatic amelioration. Sparse, low diversity fossil biotas from the **Mbizane Formation** in particular mainly consist of arthropod trackways associated with interglacial to post-glacial dropstone laminites and sporadic vascular plant remains (drifted wood and leaves of the *Glossopteris* Flora), while palynomorphs (organic-walled microfossils) are also likely to be present within finer-grained mudrock facies. Glacial diamictites (tillites or "boulder mudstones") are normally unfossiliferous but do occasionally contain fragmentary transported plant material as well as palynomorphs in the fine-grained matrix. Thomas *et al.* (1988, p. 4; after Meyer 1953) report *Glossopteris* leaf impressions within flaggy sandstones on the north-western side of Hakskeen Pan. Such rocks might also contain petrified wood (*cf* Bangert & Bamford 2001, Bamford 2004) which may then be weathered out and concentrated in surface gravels.

3.2. Ecca Group fossils

The fossil biota of the **Prince Albert Formation** is usefully summarized by Cole (2005). The typical *Umfolozia / Undichna* – dominated trace fossil assemblages of the non-marine *Mermia* Ichnofacies commonly found in basinal mudrock facies of the Prince Albert Formation throughout the Ecca Basin have been briefly reviewed by Almond (2008a, 2008b, Almond *in* Macey *et al.* 2011). Diagenetic nodules containing the remains of palaeoniscoids (primitive bony fish), sharks, spiral bromalites (coprolites *etc*) and petrified wood have been found in the Ceres Karoo and rare shark remains (*Dwykaselachus*) near Prince Albert on the southern margin of the Great Karoo (Oelofsen 1986). Microfossil remains in this formation include sponge spicules, foraminiferal and radiolarian protozoans, acritarchs and miospores.

The most diverse as well as biostratigraphically, palaeobiogeographically and palaeoecologically interesting fossil biota from the Prince Albert Formation is that described from calcareous concretions exposed along the Vaal River in the Douglas area of the Northern Cape (McLachlan and Anderson 1973, Visser *et al.,* 1977-78). The important Douglas biota contains petrified wood (including large tree trunks), palynomorphs (miospores), orthocone nautiloids, nuculid bivalves, articulate brachiopods, spiral and other "coprolites" (probably of fish, possibly including sharks) and fairly abundant, well-articulated remains of palaeoniscoid fish. Most of the fish have been assigned to the palaeoniscoid genus *Namaichthys* but additional taxa, including a possible acrolepid, may also be present here (Evans 2005). The invertebrates are mainly preserved as moulds.

The fossil record of the Prince Albert Formation in the NW Karoo / Bushlmanland region has been reviewed by Almond in Macey *et al.* (2011). The commonest fossils encountered are low-diversity trace fossil assemblages dominated by locally prolific, strap-shaped to branching networks of smooth, flattened invertebrate burrows. These were informally referred to in the older literature as "fucoids" because they were originally mistaken for fossil seaweeds. Almond (2016) recently reported that good examples can be seen in the banks of the Sakrivier near Brandvlei and that preservation of these burrow assemblages is often enhanced by nearby dolerite intrusion.

3.3. Kalahari Group fossils

The fossil record of the **Kalahari Group** is generally sparse and low in diversity. Despite their inferred lacustrine origin, no fossil remains (*e.g.* fish, molluscs, plant debris, microfossils) have been reported from the **Budin Formation** to the author's knowledge, apart from calcified rhizoliths in the Sishen area (Partridge *et al.* 2006, p. 591). This may be because the lakes were shallow and saline, or perhaps due to very poor exposure for palaeontological studies. Fossil remains have not been recorded from the coarse, downwasted gravels of the **Obogorogop Formation** that are largely derived from erosion of Dwyka Group bedrocks. The **Gordonia Formation** dune sands were mainly active during cold, drier intervals of the Pleistocene Epoch that were inimical to most forms of life, apart from hardy, desert-adapted species. Porous dune sands are not generally conducive to fossil preservation. However, mummification of soft tissues may play a role here and migrating lime-rich groundwaters derived from the underlying bedrocks (including, for example, dolerite) may lead to the rapid calcretisation of organic structures such as burrows and root casts. Occasional terrestrial fossil remains that might be expected within this unit include calcretized rhizoliths (root casts) and termitaria (*e.g. Hodotermes*, the harvester termite), ostrich egg shells (*Struthio*) and shells of land snails (*e.g. Trigonephrus*) (Almond *in* Macey *et al.* 2011, Almond & Pether 2008). Other fossil groups such as freshwater bivalves and gastropods (*e.g. Corbula, Unio*) and snails, ostracods (seed shrimps), charophytes (stonewort algae), diatoms (microscopic algae within siliceous shells) and stromatolites (laminated microbial limestones) are associated with local watercourses and pans (Thomas *et al.* 1988). Microfossils such as diatoms may be blown by wind into nearby dune sands. These Kalahari fossils (or subfossils) can be expected to occur sporadically but widely, and the overall palaeontological sensitivity of the Gordonia Formation is therefore considered to be low. Underlying calcretes of the **Mokolanen Formation** might also contain trace fossils such as rhizoliths, termite and other insect burrows, or even mammalian trackways. Mammalian bones, teeth and horn cores (also tortoise remains, and fish, amphibian or even crocodiles in wetter depositional settings such as pans) may be expected occasionally expected within Kalahari Group sediments and calcretes, notably those associated with ancient, Plio-Pleistocene alluvial gravels. However, such fossil sites are likely to be sparsely distributed and their locations difficult to predict, given the extensive younger sedimentary cover.

Consolidated older alluvium, calcrete hardpans as well as spring and pan deposits may occasionally contain important fossil biotas, notably the bones, teeth and horn cores of mammals as well as remains of reptiles like tortoises (Kiberd 2006). Impressive concentrations of intact or comminuted, tiny non-marine snails are found along the edge of the pan Swartkolkvloer, 50 km southwest of Brandvlei (Kent & Gribnitz 1985, Almond *in* Macey 2011). They are associated with fossil remains of fishes, birds, crabs and undetermined teeth that remain unsampled and unstudied (*ibid*.). The well-known Kathu Pan site in the Kalahari Region has yielded important Pleistocene mammalian remains, peats as well as Acheulean and MSA stone tools (Klein 1984, 1988, Beaumont *et al.* 1984, Beaumont 1990, Beaumont 2004, MacRae 1999, Partridge & Scott 2000). Other late Caenozoic fossil biotas that may occur within these superficial deposits include non-marine molluscs (bivalves, gastropods), ostrich egg shells, trace fossils (*e.g.* calcretised termitaria, coprolites, invertebrate burrows, rhizocretions), and plant material such as peats or palynomorphs (pollens) in organic-rich alluvial horizons and diatoms in pan sediments. In Quaternary deposits, fossil remains may be associated with human skeletal material or artefacts such as stone tools of palaeontological as well as archaeological interest. Surface gravels concentrated by sheetwash and downwasting may contain resistant clasts of silicified wood as well as bones and teeth that have been reworked from older sediments (*e.g.* petrified wood blocks from the Karoo Supergroup).

4. CONCLUSIONS & RECOMMENDATIONS

The sensitivity of the study area is difficult to gauge at present since the palaeontology of Hakskeen Pan and its surrounds is currently very poorly-known. Most of the pan itself is probably of low sensitivity but there are several sedimentary rock units represented around the margins of the pan that are either already known to contain fossils or that might prove fossiliferous.

Dwyka Group glacially-related bedrocks cropping out along the western and eastern margins of Hakskeen Pan have previously been reported to contain fossil Permo-Carboniferous plants - *e.g. Glossopteris* leaves, with petrified wood also a possibility - but precise locality details are not available (Thomas *et al.* 1988). The overlying postglacial Prince Albert Formation (Ecca Group), cropping out along the southern pan margins, is unusually well-exposed in the region (*e.g.* western edge of Koppieskraal Pan) but in this area its palaeontology is unknown. It might contain trace fossils, invertebrates and plant remains, for example. Baking of the Ecca mudrocks by Karoo dolerite intrusions may have enhanced or compromised fossil preservation. Surface gravels in pan areas might contain reworked blocks of petrified wood and teeth reworked from older sediments by erosional downwasting and sheetwash. Elsewhere in the Northern Cape (*e.g.* Bushmanland) dense concentrations of Pleistocene freshwater molluscs as well as disarticulated remains of fishes, birds, crabs and undetermined teeth have been reported along pan margins (Kent & Gribnitz 1985, Almond *in* Macey 2011). Calcrete hardpans, which are especially well-developed in areas with dolerite intrusions, might contain trace fossils as well as rare vertebrate remains.

Event infrastructure as well as tourism project-related activities might disturb or damage valuable fossil heritage around the pan margins. There has already been a degree of surface disturbance entailed by the landspeed record project (*e.g.* collection of surface rocks, infilling of borrow pits). As a precautionary measure, it is therefore recommended that a short specialist palaeontological field assessment of the Hakskeen Pan project area takes place with special focus on the pan margins (*cf* Figs. 4 & 5 herein) and rock dumps. The resulting report to SAHRA (South African Heritage Resources Agency) should document and briefly assess any fossil remains found as well as make recommendations for any mitigation measures for the remaining phases of the development.

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7. QUALIFICATIONS & EXPERIENCE OF THE AUTHOR

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

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

Declaration of Independence

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

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