Palaeontological heritage assessment: combined desktop & field-based study

PROPOSED EXTENSION OF AN EXISTING BORROW PIT ON PORTION 5 OF FARM HOL PADS LEEGTE NUMBER 32 NEAR BRANDVLEI, HANTAM LOCAL MUNICIPALITY, NORTHERN CAPE

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EXECUTIVE SUMMARY

Hantam Local Municipality is proposing to develop an existing gravel borrow pit situated some 2.5 km east of Brandvlei on Portion 5 of Farm Hol Pads Leegte Number 32, Brandvlei, Northern Cape.

The proposed borrow pit study area near Brandvlei, Northern Cape, is underlain by basinal mudrocks of the Prince Albert Formation (lower Ecca Group) of Early Permian age. Elsewhere in the Main Karoo Basin these mudrocks have yielded a range of fossil fish, marine to non-marine invertebrates and petrified wood, often preserved within diagenetic nodules, as well as various trace fossils (*e.g.* invertebrate burrows, coprolites, fish swimming trails and arthropod trackways). However, only low-diversity trace fossil assemblages (mainly horizontal burrows) were recorded within and on the outskirts of the Brandvlei borrow pit study area during field assessment. These fossil borrows are of widespread occurrence while the overlying suface gravels are apparently unfossiliferous. Ancient (Tertiary) elevated alluvial gravels of the Sakrivier drainage system do not occur in the study area itself, although these are mapped a few kilometres to the north. Unique or rare fossil heritage resources are therefore not threatened by the proposed development.

The overall impact significance of the proposed borrow pit development at Brandvlei is rated as LOW. Given the low impact significance of the proposed development, no further specialist palaeontological heritage studies or mitigation are recommended for this project, pending the discovery of substantial new fossil material during borrow pit excavation.

The responsible Environmental Control Officer (ECO) should monitor all substantial (> 1 m deep) excavations for fossil material. In the case of any significant fossil finds during construction (*e.g.* vertebrate teeth, bones, burrows, petrified wood, shells), these should be safeguarded - preferably *in situ* - and reported by the ECO as soon as possible to SAHRA (Contact details: Dr Ragna Redelstorff, SAHRA, P.O.Box 4637, Cape Town 8000. Tel: 021 202 8651. Email: rredelstorff@sahra.org.za, so that appropriate mitigation (*i.e.* recording, sampling or collection) by a palaeontological specialist can be considered and implemented.

These recommendations should be incorporated into the Environmental Management Plan (EMP) for this borrow pit development.

1. INTRODUCTION AND BRIEF

Hantam Local Municipality is proposing to extend an exisiting borrow pit situated some 2.5 km east of Brandvlei on Portion 5 of Farm Hol Pads Leegte Number 32 (approx. GPS co-ordinates 30 28 18 S, 20 31 12.5 E). The development site lies on the eastern side of the Sakrivier, just to the north of the R353 gravel road to Vanwyksvlei (Figs. 1 & 2). Gravel material extracted from the borrow pit will be used for the development of the new Brandvlei waste water treatment works. A short access road (less than 4 m wide) from the new pit to the R353 will have to be established as well as an access gate (3 m wide). The access road will be located east of the floodplain.

The present palaeontological heritage assessment was commissioned by EnviroAfrica cc, Somerset West (Contact details: Mnr. Bernard de Witt. EnviroAfrica cc. Cell: +27 82 448999. Office tel: +27 21 851 1616. Fax: 0865120154. Postal address: P. O. Box 5367, Helderberg, 7135. Street address: 29 St James St, Somerset West) as part of a broad-based heritage assessment for the project which falls under Sections 35 and 38 (Heritage Resources Management) of the South African Heritage Resources Act (Act No. 25 of 1999).

The approach to this palaeontological heritage study is briefly as follows. Fossil bearing rock units occurring beneath the development footprint are determined from geological maps and satellite images (Section 2). Known fossil heritage from each rock unit is inventoried from scientific literature, previous assessments of the broader study region (*e.g.* Almond 2013. 2016), a short site visit (17 May 2017) as well as the author's field experience and palaeontological database (Section 3). Based on this data the palaeontological heritage sensitivity of the proposed development is assessed, with recommendations for any further specialist studies (Section 4).

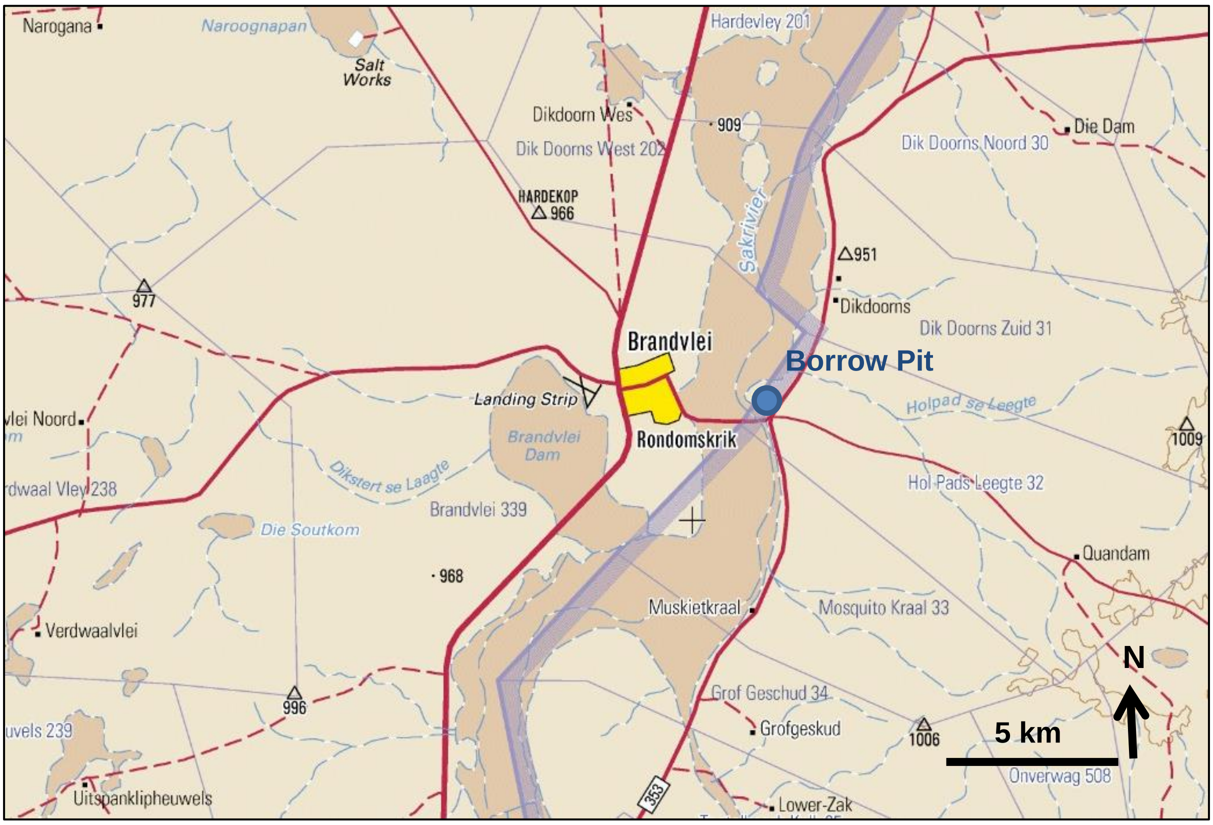

Figure 1. Extract from 1: 250 000 topographical map 3020 Sakrivier (Courtesy of the Chief Directorate: National Geo-spatial Information, Mowbray) showing the location of the borrow pit on Hol Pads Leegte 32 near Brandvlei, Hantam Local Municipality, Northern Cape.

Figure 2. Google earth© satellite image of the borrow pit study area on the eastern sie of the Sakrivier near Brandvlei, Northern Cape (red polygon), showing the location of the existing pit as well as the proposed new excavation area to the north (orange rectangle) as well as the access road to the tar road to Vanwyksvlei.

1.1. Legislative context of this palaeontological study

The proposed Brandvlei borrow pit development footprint overlies areas that are underlain by potentially fossil-rich sedimentary rocks of Palaeozoic and younger, Quaternary to Holocene age (Sections 2 and 3). The construction phase of the development will entail substantial surface clearance and excavations into the superficial sediment cover as well as locally into the underlying bedrock. 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 (Table 1. Provisional tabulations of palaeontological sensitivity of all formations in Northern Cape Province have already been compiled by J. Almond & John Pether (2008, unpublished data). 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.* SAHRA for the Northern Cape (Contact details: Dr Ragna Redelstorff, SAHRA, P.O.Box 4637, Cape Town 8000. Tel: 021 202 8651. Email: rredelstorff@sahra.org.za). It should be emphasized that, *providing appropriate mitigation is carried out*, the majority of developments involving bedrock excavation can make a *positive* contribution to our understanding of local palaeontological heritage.

1.4. Assumptions & limitations

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

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

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

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

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

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

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

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

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

Since most areas of the RSA have not been studied palaeontologically, a palaeontological desktop study usually entails *inferring* the presence of buried fossil heritage within the study area from relevant fossil data collected from similar or the same rock units elsewhere, sometimes at localities far away. Where substantial exposures of bedrocks or potentially fossiliferous superficial sediments are present in the study area, the reliability of a palaeontological impact assessment may be significantly enhanced through field assessment by a professional palaeontologist.

In the case of the Brandvlei study area a major limitation for fossil heritage studies is the paucity of previous specialist palaeontological studies in the region as a whole. Little palaeontological data is available in the relevant geological sheet map explanation (Siebrits 1989).

1.5. Information sources

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

1. A short project outline and maps provided by EnviroAfrica cc, Somerset West;

2. A review of the relevant scientific literature, including published geological maps and accompanying sheet explanations as well as previus palaeontological assessment reports for the region (*e.g.* Almond 2013, 2016);

3. A short site visit on 17 May 2017;

4. The author’s database on the formations concerned and their palaeontological heritage.

2. GEOLOGICAL OUTLINE OF THE STUDY AREA

The borrow pit study area on the eastern banks of the Sakrivier near Brandvlei lies at an elevation of arund 920 m amsl, a few meters above the modern river bed (Figs. 2, 4 & 6). The terrain is semi-arid, sparsely-vegetated and traversed by small stream gullies. Low, SW-facing cliffs of Ecca Group bedrocks buld the riverbank just to the northwest.

The geology of the study area at Brandvlei is shown on 1: 250 000 sheet map 3020 Sakrivier (Siebriets 1989) (Fig. 3). This region of Bushmanland is entirely underlain by Early to Middle Permian “marine” sediments of the Lower **Ecca Group** (Karoo Supergroup), namely the Prince Albert Formation (Pp), Whitehill Formation (Pw) and Tierberg Formation (Pt), that are extensively intruded by dolerite sills of Early Jurassic age (Jd). Of these older bedrock units, only the **Prince Albert Formation** will be directly impacted by the prosed borrow pit development and will be considered further here.

The Prince Albert Formation mudrocks appear as dark grey areas in satellite images (Fig. 2; Pp in Fig. 3). The post-glacial basinal mudrocks of the **Prince Albert Formation** (**Pp**) form the lowermost subunit of the Ecca Group. 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. The brittle rocks are well-jointed and often display a well-developed tectonic cleavage that results in sharp, elongate cleavage flakes ("pencil cleavage"). Extensive bedding planes are therefore rarely encountered in the southern outcrop area close to the Cape Fold Belt while Northern Cape outcrops are much less deformed.

The Prince Albert Formation in the study region consists predominantly of dark grey to grey-green, well-laminated mudrocks (shales, siltstones) with minor thin-bedded, fine-grained sandstone and siltstone interbeds. These basinal rocks build small-scale upward-coarsening and - shallowing cycles on the scale of a few meters to decimetres (Figs. 5 & 7). The mudrocks are sometimes micaceous, carbonaceous or pyritic and typically contain a variety of diagenetic concretions enriched in iron and carbonate minerals (Visser *et al.* 1977-1978, Siebrits 1989, Zawada 1992, Bosch 1993). Some of these carbonate concretions reach diameters of over a meter are in some areas of the Main Karoo Basin they are richly fossilferous (See Section 3 below). Concretionary material within the borrow pit study area often displays a fibrous texture and may be easily mistaken for petrified wood.

These Ecca Group bedrocks are mantled by surface gravels generated by downwasting, sheet wash and shallow streams (Figs. 8 & 9). The surface gravels are dominated by platy clasts of Ecca mudrocks and paler, fine-grained sandstone as well as fragments of diagenetic ferruginous carbonate concretions weathered out locally from the Prince Albert Formation. Pale grey and other coloured cherty clasts within the surface gravels (as well as some coarser gravels of fine-graiend sandstone) show extensive anthropogenic flaking and reflect Stone Age human activity in the area. Possible sources of cherty parent material include alluvial gravels of the Sakrivier, thin siliceous beds within the Prince Albert and lower Tierberg Formation of tuffaceous or diagenetic origin, as well as local concentrations of opaline Magadi-type cherts that may be associated with alkaline pans or much older volcanic crfater lake deposits in the Bushmanland region (See discussion in Almond 2016b). Modern silty **alluvium** of the Sakrivier (pale buff in satellite image Fig. 2) is found to the west of an outside the area. Elevated older (Pio-Pleistocene) alluvial gravels occur on the eastern banks of the Sakrivier a few kilometres to the north, on Farm Dik Doorns Noord 30 (De Wit & Bamford 1993, Bamford & De Wit 1993) (Fig. 13), but not within the present study area.

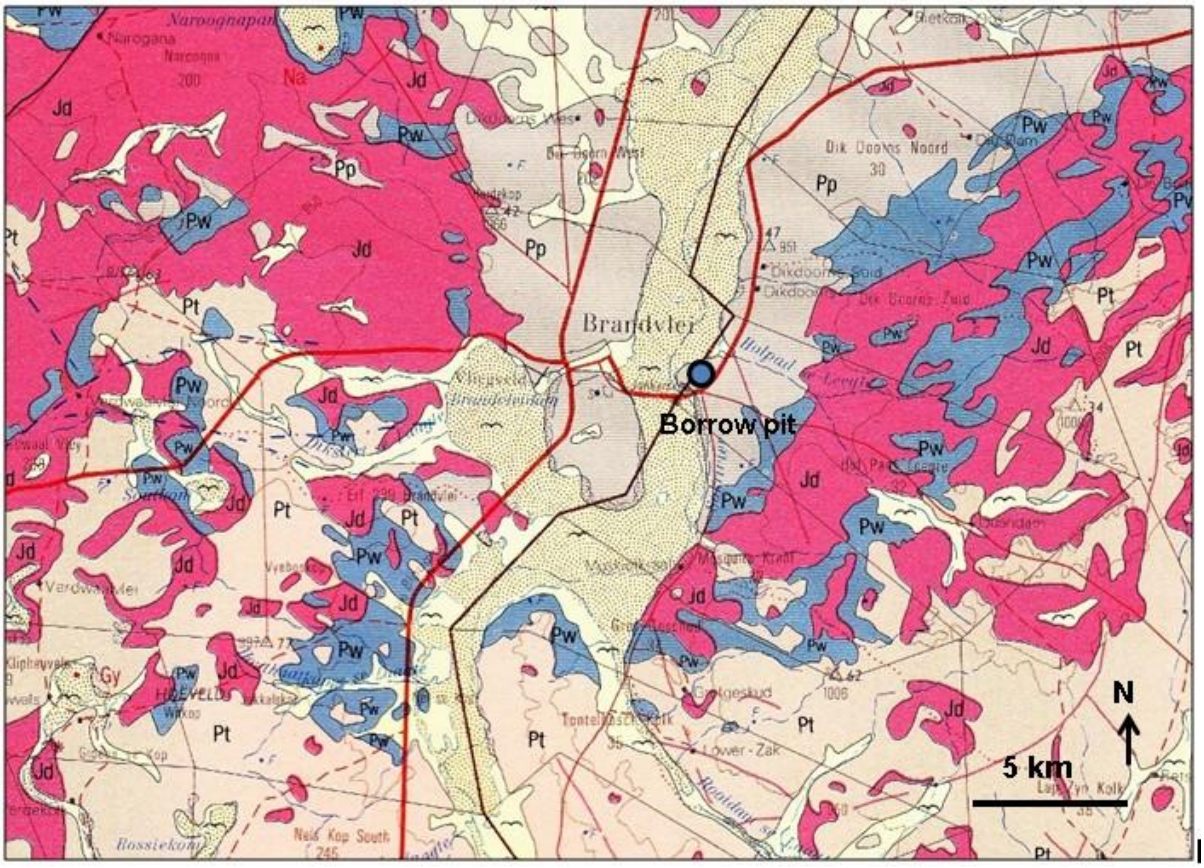

Figure 3. Extract from 1: 250 000 geology sheet 3010 Sakrivier (Council for Geoscience, Pretoria) showing the approximate location of the borrow pit study area near Brandvlei, Northern Cape. The bedrocks mapped in the study region are assigned to the Prince Albert Formation (Pp, grey) of the Ecca Group (Early Permian) that are overlain to the west by Quaternary to Holocene alluvial deposits of the present Sakrivier. Small outliers of Tertiary to Quaternary alluvium occur along the eastern banks of the Sakrivier to the north of the study area (Dik Doorns Nooord 30), but these are not mapped at 1: 250 000 scale (See also Fig. 13).

Figure 4. View to the northwest across the borrow pit study area showing low riverine cliffs of Prince Albert Formation mudrocks in the background and extensive ferruginous concretions in the foreground.

Figure 5. Vertical section through grey silty mudrocks of the Prince Albert Formation building small-scale upward-coarsening cycles, exposed in the cut face of the existing borrow pit (Hammer = 30 cm). A pale concretionary lens is seen towards the top of the succession.

Figure 6. Platy surface gravels and ferruginous concretions of the Prince Albert Formation within the new borrow pit study area (Hammer = 30 cm).

Figure 7. Prominent-weathering siltstones and fine-grained sandstones forming the upper part of an upward-shallowing cycle within the Prince Albert Formation that builds the low cliffs just NW of the study area (Hammer = 30 cm).

Figure 8. Surface gravels of platy clasts of fine-grained pale sandstone within the western sector of the borrow pit study area. Some of the clasts are anthropogenically flaked.

Figure 9. Fine mudrock surface gravels alongside a small stream in the central part of the borrow pit study area showing admixture of flaked grey chert and ostrich egg shell (Later Stone Age).

3. OVERVIEW OF PALAEONTOLOGICAL HERITAGE WITHIN THE STUDY AREA

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, 2008 b, Almond *in* Macey *et al.* 2011). Diagenetic nodules containing the remains of palaeoniscoids (primitive bony fish), sharks, spiral bromalites (coprolites *etc*) and 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 only fossils reported from the Prince Albert Formation in the Sakrivier sheet area are invertebrate trace fossils assigned to the ichnogenera *Chondrites* and *Thalassinoides* (Siebrits 1989). 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. During the present site visit prolific assemblages of flattened, bedding-parallel, straight to gently-curving, unbranched, strap-shaped burrows were recorded within siltstone and fine sandstone facies on the floor and above the cut face of the existing borrow pit (Figs. 10 to 12) as well as on steeper slopes just to the northwest of the new borrow pit study area. Smaller scale, *Chondrites*-like burrows are also seen within the sandy matrix. The burrow coloration varies from pale grey to rusty brown and may depend on different burrow infills and / or diagenetic influences (including baking by dolerite intrusions).

Figure 10. Rusty-brown, strap-shaped horizontal burrows within siltstones exposed on the floor of the existing borrow pit. The burrows range up to *c*. 1cm in width.

Figure 11. Pale strap-shaped horizontal burrows (*c*. 1 cm wide) with smaller-scale, dark *Chondrites*-like burrow systems within the fine-grained silty sandstone matrix, steeper hillslope exposures of the Prince Albert Formation just to the NW of the borrow pit study area.

Figure 12. Well-consolidated, laminated, fine-grained sandstones of the Prince Albert Formation exposed in hillslopes just NW of the borrow pit study area showing pale strap-shaped burrows at several successive horizons (Scale in cm).

3.2. Fossils within the Late Caenozoic superficial sediments

The diverse superficial deposits within the South African interior have been comparatively neglected in palaeontological terms. However, sediments associated with ancient drainage systems, springs and pans in particular may occasionally contain important fossil biotas, notably the bones, teeth and horn cores of mammals as well as remains of reptiles like tortoises (*e.g.* Skead 1980, Klein 1984, Brink, J.S. 1987, Bousman *et al.* 1988, Bender & Brink 1992, Brink *et al*. 1995, MacRae 1999, Meadows & Watkeys 1999, Churchill *et al*. 2000, Partridge & Scott 2000, Brink & Rossouw 2000, Rossouw 2006). Other late Caenozoic fossil biotas that may occur within these superficial deposits include non-marine molluscs (bivalves, gastropods), ostrich egg shells, trace fossils (*e.g.* calcretised termitaria, coprolites, invertebrate burrows, rhizocretions), and plant material such as peats or palynomorphs (pollens) in organic-rich alluvial horizons (Scott 2000) and diatoms in pan sediments. In Quaternary deposits, fossil remains may be associated with human artefacts such as stone tools and are also of archaeological interest (*e.g.* Smith 1999 and refs. therein). Ancient solution hollows within extensive calcrete hardpans may have acted as animal traps in the past. As with coastal and interior limestones, they might occasionally contain mammalian bones and teeth (perhaps associated with hyaena dens) or invertebrate remains such as snail shells.

Diverse fossils associated with the ancient Tertiary drainage systems of the Karoo have been summarized by Almond in Macey *et al.* (2011). In the Brandvlei area lies the north-south trending Geelvloer Palaeo-valley, a Mid Tertiary palaeodrainage system that links up with the Commissioners Pan – Koa Valley system to the northwest. Here calcretised basal alluvial facies contain bones of hippopotamus-like artiodactyls called anthracotherids indicating a Miocene age (De Wit 1993, 1999, De Wit *et al*. 2000). Anthracotherids are an extinct group of amphibious mammalian herbivores only distantly related to true hippos that were widespread in the Miocene of Africa (Schneider & Marais

2004). Early to Mid Miocene silicified woods from Brandvlei are referable to a number of extant tree families, including the Dipterocarpaceae that mainly inhabit tropical forests in Africa and Asia today. The fossil woods and associated sediments indicate that warm, tropical to subtropical climates prevailed in the Mid Miocene and that perennial, low-sinuousity braided river systems supported lush riparian forests (De Wit & Bamford 1993, Bamford & De Wit 1993, Bamford 2000b). Wet, weakly seasonal climates are suggested by the structure (indistinct growth rings) and dimensions (trunk diameters of over 50 cm) of the fossil woods (Bamford 2000).

Abraded Plio-Pleistocene fossil woods from relict alluvial terraces of the Sak River just north of Brandvlei (Dik Doorns Noord 30) (Fig. 13) include members of the Family Polygalaceae and also indicate humid growth conditions (Bamford & De Wit 1993, De Wit & Bamford 1992). These terraces were formed by meandering rivers during intermittent pluvial (*i.e.* wetter), but still semi-arid, episodes following the onset of generally arid conditions in the western portion of southern Africa towards the end of the Miocene. The abrasion and polishing of the fossil wood material from alluvial gravels Dik Doorns Noord suggests that it was probably reworked from older (Miocene) alluvial deposits.

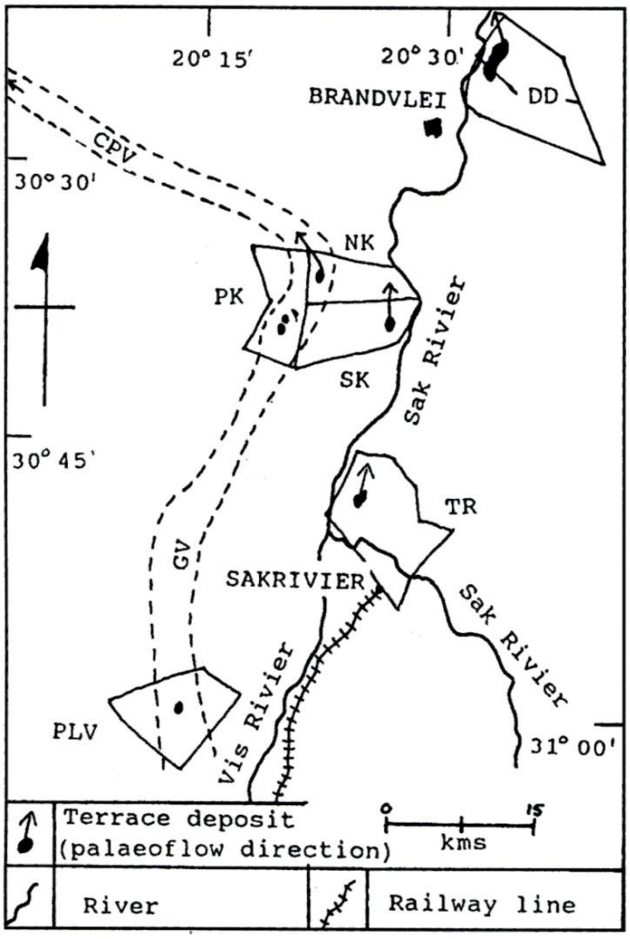

Figure 13. Map showing small relict patches of ancient alluvial gravels in the Brandvlei area (De Wit & Bamford 1993). The fossiliferous deposits on Dik Doorns Noord 30 (DD on map) lie outside and to the north of the present study area to the east of Brandvlei.

4. CONCLUSIONS & RECOMMENDATIONS

The proposed borrow pit study area near Brandvlei, Northern Cape, is underlain by basinal mudrocks of the Prince Albert Formation (lower Ecca Group) of Early Permian age. Elsewhere in the Main Karoo Basin these mudrocks have yielded a range of fossil fish, marine to non-marine invertebrates and petrified wood, often preserved within diagenetic nodules, as well as various trace fossils (*e.g.* invertebrate burrows, coprolites, fish swimming trails and arthropod trackways). However, only low-diversity trace fossil assemblages (mainly horizontal burrows) were recorded within and on the outskirts of the Brandvlei borrow pit study area during field assessment. These fossil borrows are of widespread occurrence while the overlying suface gravels are apparently unfossiliferous. Ancient (Tertiary) elevated alluvial gravels of the Sakrivier drainage system do not occur in the study area itself, although these are mapped a few kilometres to the north. Unique or rare fossil heritage resources are therefore not threatened by the proposed development.

The overall impact significance of the proposed borrow pit development at Brandvlei is rated as LOW. Given the low impact significance of the proposed development, no further specialist palaeontological heritage studies or mitigation are recommended for this project, pending the discovery of substantial new fossil material during borrow pit excavation.

The responsible Environmental Control Officer (ECO) should monitor all substantial (> 1 m deep) excavations for fossil material. In the case of any significant fossil finds during construction (*e.g.* vertebrate teeth, bones, burrows, petrified wood, shells), these should be safeguarded - preferably *in situ* - and reported by the ECO as soon as possible to SAHRA (Contact details: Dr Ragna Redelstorff, SAHRA, P.O.Box 4637, Cape Town 8000. Tel: 021 202 8651. Email: rredelstorff@sahra.org.za, so that appropriate mitigation (*i.e.* recording, sampling or collection) by a palaeontological specialist can be considered and implemented. These recommendations should be incorporated into the Environmental Management Plan (EMP) for this borrow pit development.

5. ACKNOWLEDGEMENTS

Mnr Bernard de Witt (EnviroAfrica cc, Somerset West) as well as Jonathan Kaplan (Agency for Cultural Resource Management, Rondebosch) are both thanked for commissioning this study and for kindly providing the necessary background information.

6. REFERENCES

ALMOND, J.E. 2008a. Fossil record of the Loeriesfontein sheet area (1: 250 000 geological sheet 3018). Unpublished report for the Council for Geoscience, Pretoria, 32 pp.

ALMOND, J.E. 2008b. Palaeozoic fossil record of the Clanwilliam sheet area (1: 250 000 geological sheet 3218). Unpublished report for the Council for Geoscience, Pretoria, 49 pp. (To be published by the Council in 2009).

ALMOND, J.E. 2009. Contributions to the palaeontology and stratigraphy of the Alexander Bay sheet area (1: 250 000 geological sheet 2816), 117 pp. Unpublished technical report prepared for the Council for Geoscience by Natura Viva cc, Cape Town.

ALMOND, J.E. 2013. Proposed development and operation of a reverse osmosis plant, brine evaporation ponds and associated infrastructure at Brandvlei, Northern Cape. Palaeontological heritage assessment: desktop study, 13 PP. Natura Viva cc, Cape Town.

ALMOND, J.E. 2016a. SKA Core and Phase 1 development area, Great Karoo, Northern Cape - palaeontological heritage. Reconnaissance scoping report, 38 pp. Natura Viva cc.

ALMOND, J.E. 2016b. Proposed Kokerboom 2 Wind Farm near Loeriesfontein, Namaqua District Municipality, Northern Cape. Palaeontological heritage assessment: combined desktop & field-based scoping study, 62 pp. Natura Viva cc, Cape Town.

ALMOND, J.E. & PETHER, J. 2008. Palaeontological heritage of the Northern Cape. Interim SAHRA technical report, 124 pp. Natura Viva cc., Cape Town.

ANDERSON, A.M. 1974. Arthropod trackways and other trace fossils from the Early Permian lower Karoo Beds of South Africa. Unpublished PhD thesis, University of Witwatersrand, Johannesburg, 172 pp.

ANDERSON, A.M. 1975. Turbidites and arthropod trackways in the Dwyka glacial deposits (Early Permian) of southern Africa. Transactions of the Geological Society of South Africa 78: 265-273.

ANDERSON, A.M. 1976. Fish trails from the Early Permian of South Africa. Palaeontology 19: 397-409, pl. 54.

ANDERSON, A.M. 1981. The *Umfolozia* arthropod trackways in the Permian Dwyka and Ecca Groups of South Africa. Journal of Paleontology 55: 84-108, pls. 1-4.

ANDERSON, A.M. & MCLACHLAN, I.R. 1976. The plant record in the Dwyka and Ecca Series (Permian) of the south-western half of the Great Karoo Basin, South Africa. Palaeontologia africana 19: 31-42.

ANDERSON, J.M. 1977. The biostratigraphy of the Permian and the Triassic. Part 3: A review of Gondwana Permian palynology with particular reference to the northern Karoo Basin, South Africa. Memoirs of the Botanical Survey of South Africa 45, 14-36.

ANDERSON, J.M. & ANDERSON, H.M. 1985. Palaeoflora of southern Africa. Prodromus of South African megafloras, Devonian to Lower Cretaceous, 423 pp, 226 pls. Botanical Research Institute, Pretoria & Balkema, Rotterdam.

BAMFORD, M.K. 2000a. Fossil woods of Karoo age deposits in South Africa and Namibia as an aid to biostratigraphical correlation. Journal of African Earth Sciences 31, 119-132.

BAMFORD, M.K. 2000b. Cenozoic macro-plants. In: Partridge, T.C. & Maud, R.R. (Eds.) The Cenozoic of southern Africa, pp.351-356. Oxford University Press, Oxford.

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

BAMFORD, M.K. & DE WIT, M.C.J. 1993. Taxonomic description of fossil wood from Cainozoic Sak River terraces, near Brandvlei, Bushmanland, South Africa. Palaeontologia africana 30: 71-80.

BANGERT, B., STOLLHOFEN, H., LORENTZ, V. & ARMSTRONG, R. 1999. The geochronology and significance of ash-fall tuffs in the glacigenic Carboniferous – Permian Dwyka Group of Namibia and South Africa. Journal of African Earth Sciences 29: 33-49.

BANGERT, B., STOLHOFEN, H., GEIGER, M. & LORENZ, V. 2000. Fossil record and high resolution tephrostratigraphy of Carboniferous glaciomarine mudstones, Dwyka Group, southern Namibia. Communications of the Geological Survey of Namibia 12, 235-245.

BANGERT, B. & BAMFORD, M. 2001. Carboniferous pycnoxylic woods from the Dwyka Group of southern Namibia. Palaeontologia africana 37, 13-23.

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

BOSCH, P.J.A. 1993. Die geologie van die gebied Kimberley. Explanation to 1: 250 000 geology Sheet 2824 Kimberley, 60 pp. Council for Geoscience, Pretoria.

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

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

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

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

BUATOIS, L. & MANGANO, M.G. 1995. The paleoenvironmental and paleoecological significance of the lacustrine *Mermia* ichnofacies: an archetypal subaqueous nonmarine trace fossil assemblage. Ichnos 4: 151-161.

BUATOIS, L. & MANGANO, M.G. 2004. Animal-substrate interactions in freshwater environments: applications of ichnology in facies and sequence stratigraphic analysis of fluvio-lacustrine successions. In: McIlroy, D. (Ed.) The application of ichnology to palaeoenvironmental and stratigraphic analysis. Geological Society, London, Special Publications 228, pp 311-333.

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

COLE, D.I. 2005. Prince Albert Formation. SA Committee for Stratigraphy, Catalogue of South African Lithostratigraphic Units 8: 33-36.

COOKE, H.B.S. 1949. Fossil mammals of the Vaal River deposits. Memoirs of the geological Survey of South Africa 35, 1-117.

DE WIT, M.C.J. 1990. Palaeoenvironmental interpretation of Tertiary sediments at Bosluispan, Namaqualand. Palaeoecology of Africa and the surrounding islands 21: 101-118.

DE WIT, M.C.J. 1993. Cainozoic evolution of drainage systems in the north-western Cape. Unpublished PhD thesis, University of Cape Town, Cape Town, 371 pp.

DE WIT, M.C.J. 1999. Post-Gondwana drainage and the development of diamond placers in western South Africa. Economic Geology 94: 721-740.

DE WIT, M.C.J. & BAMFORD, M.K. 1993. Fossil wood from the Brandvlei area, Bushmanland as an indication of palaeoenvironmental changes during the Cainozoic. Palaeontologia africana 30: 81-89.

DE WIT, M.C.J., MARSHALL, T.R. & PARTRIDGE, T.C. 2000. Fluvial deposits and drainage evolution. In: Partridge, T.C. & Maud, R.R. (Eds.) The Cenozoic of southern Africa, pp.55-72. Oxford University Press, Oxford.

DINGLE, R.V., SIESSER, W.G. & NEWTON, A.R. 1983. Mesozoic and Tertiary geology of southern Africa. viii + 375 pp. Balkema, Rotterdam.

DU TOIT, A. 1954. The geology of South Africa. xii + 611pp, 41 pls. Oliver & Boyd, Edinburgh.

EVANS, F.J.E. 2005. Taxonomy, palaeoecology and palaeobiogeography of some Palaeozoic fish of southern Gondwana. Unpublished PhD thesis, University of Stellenbosch, 628 pp.

GRILL, H. 1997. The Permo-Carboniferous glacial to marine Karoo record in southern Namibia: sedimentary facies and sequence stratigraphy. Beringeria 19: 3-98, 1 pl.

HERBERT, C.T. & COMPTON, J.S. 2007. Depositional environments of the lower Permian Dwyka diamictite and Prince Albert shale inferred from the geochemistry of early diagenetic concretions, southwest Karoo Basin, South Africa. Sedimentary Geology 194: 263-277.

JOHNSON, M.R., VAN VUUREN, C.J., VISSER, J.N.J., COLE, D.I., De V. WICKENS, H., CHRISTIE, A.D.M., ROBERTS, D.L. & BRANDL, G. 2006. Sedimentary rocks of the Karoo Supergroup. In: Johnson, M.R., Anhaeusser, C.R. & Thomas, R.J. (Eds.) The geology of South Africa, pp. 461-499. Geological Society of South Africa, Marshalltown.

KLEIN, R.G. 1984. The large mammals of southern Africa: Late Pliocene to Recent. In: Klein, R.G. (Ed.) Southern African prehistory and paleoenvironments, pp 107-146. Balkema, Rotterdam.

MACEY, P.H., SIEGFRIED, H.P., MINNAAR, H., ALMOND, J. & BOTHA, P.M.W. 2011. The geology of the Loeriesfontein area. Explanation to 1: 250 000 geology sheet 3018, 139 pp. Council for Geoscience, Pretoria.

MACRAE , C. 1999. Life etched in stone. Fossils of South Africa. 305 pp. The Geological Society of South Africa, Johannesburg.

MALHERBE, S.J., KEYSER, A.W., BOTHA, B.J.V., CORNELISSEN, A., SLABERT, M.J. & PRINSLOO, M.C. 1986. The Tertiary Koa River and the development of the Orange River drainage. Annals of the Geological Survey of South Africa 20, 13-23.

MCLACHLAN, I.R. & ANDERSON, A. 1973. A review of the evidence for marine conditions in southern Africa during Dwyka times. Palaeontologia africana 15: 37-64.

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

MILLER, R.M. 2008. Karoo Supergroup, pp. 16-1 to 16-115 *in* Miller, R.G. The geology of Namibia. Volume 3. Upper Palaeozoic to Cenozoic. Geological Survey, Namibia.

OELOFSEN, B.W. 1986. A fossil shark neurocranium from the Permo-Carboniferous (lowermost Ecca Formation) of South Africa. In: Uyeno, T, Arai, R., Taniuchi, T & Matsuura, K. (Eds.) Indo-Pacific fish biology. Proceedings of the Second International Conference on Indo-Pacific Fishes. Ichthyological Society of Japan, Tokyo, pp 107-124.

PARTRIDGE, T.C. & SCOTT, L. 2000. Lakes and pans. In: Partridge, T.C. & Maud, R.R. (Eds.) The Cenozoic of southern Africa, pp.145-161. Oxford University Press, Oxford.

PARTRIDGE, T.C., BOTHA, G.A. & HADDON, I.G. 2006. Cenozoic deposits of the interior. In: Johnson, M.R., Anhaeusser, C.R. & Thomas, R.J. (Eds.) The geology of South Africa, pp. 585-604. Geological Society of South Africa, Marshalltown.

PICKFORD, M. & SENUT, B. 2002. The fossil record of Namibia. 39 pp. The Geological Survey of Namibia.

PLUMSTEAD, E.P. 1969. Three thousand million years of plant life in Africa. Alex Du Toit Memorial Lectures No. 11. Transactions of the Geological Society of South Africa, Annexure to Volume 72, 72pp. 25 pls.

POTGIETER, G.J.A. 1974. The geology of an area south of Kimberley, 91 pp. Unpublished MSc Thesis, University of the Orange Free State.

PRINSLOO, M.C. 1989. Die geologie van die gebied Britstown. Explanation to 1: 250000 geology Sheet 3022 Britstown, 40 pp. Council for Geoscience, Pretoria.

ROSSOUW, L. 2006. Florisian mammal fossils from erosional gullies along the Modder River at Mitasrust Farm, Central Free State, South Africa. Navorsinge van die Nasionale Museum Bloemfontein 22, 145-162.

SAHRA 2013. Minimum standards: palaeontological component of heritage impact assessment reports, 15 pp. South African Heritage Resources Agency, Cape Town.

SAVAGE, N.M. 1970. A preliminary note on arthropod trace fossils from the Dwyka Series in Natal. IUGS Second Gondwana Symposium, South Africa, 1970, Proceedings and Papers, pp 627-635, pls. 1-5.

SAVAGE, N.M. 1971. A varvite ichnocoenosis from the Dwyka Series of Natal. Lethaia 4: 217-233.

SCHNEIDER, G. & MARAIS, C. 2004. Passage through time. The fossils of Namibia. 158 pp. Gamsberg MacMillan, Windhoek.

SCOTT, L. 2000. Pollen. In: Partridge, T.C. & Maud, R.R. (Eds.) The Cenozoic of southern Africa, pp.339-35. Oxford University Press, Oxford.

SEILACHER, A. 2007. Trace fossil analysis, xiii + 226pp. Springer Verlag, Berlin.

SENUT, B., PICKFORD, M., WARD, J., DE WIT, M., SPAGGIARI, R. & MORALES, J. 1996. Biochronology of the Cainozoic sediments at Bosluis Pan, Northern Cape Province, South Africa. South African Journal of Science 92: 249-251.

SIEBRITS, L.B. 1989. Die geologie van die gebied Sakrivier. Explanation of 1: 250 000 geology sheet 3020, 19 pp. Council for Geoscience, Pretoria.

SKEAD, C.J. 1980. Historical mammal incidence in the Cape Province. Volume 1: The Western and Northern Cape. 903pp. Department of Nature and Environmental Conservation, Cape Town.

SLABBERT, M.J., MOEN, H.F.G. & BOELEMA, R. 1999. Die geologie van die gebied Kenhardt. Explanation to 1: 250 000 geology Sheet 2920 Kenhardt, 123 pp. Council for Geoscience, Pretoria.

SMITH, A.B. 1999. Hunters and herders in the Karoo landscape. Chapter 15 in Dean, W.R.J. & Milton, S.J. (Eds.) The Karoo; ecological patterns and processes, pp. 243-256. Cambridge University Press, Cambridge.

STAPLETON, R.P. 1977. Carboniferous unconformity in southern Africa. Nature 268, 222-223.

STEPHENSON, M.H. 2008. A review of the palynostratigraphy of Gondwanan Late Carboniferous to Early Permian glacigene successions. In: Fielding, C.R., Frank, T.D. & Isbell, J.L. (eds). Resolving the Late Paleozoic Ice Age in time and space. Geological Society of America Special Paper 441, 317-330.

STOLLHOFEN, H., STANISTREET, I.G., BANGERT, B. & GRILL, H. 2000. Tuffs, tectonism and glacially-related sea-level changes, Carboniferous-Permian, southern Namibia. Palaeogeography, Palaeoclimatology, Palaeoecology 161: 127-150.

VEEVERS, J.J., COLE, D.I. & COWAN, E.J. 1994. Southern Africa: Karoo Basin and Cape Fold Belt. Geological Society of America, Memoir 184: 223-279.

VISSER, J.N.J. 1992. Deposition of the Early to Late Permian Whitehill Formation during a sea-level highstand in a juvenile foreland basin. South African Journal of Geology 95: 181-193.

VISSER, J.N.J. 1997. Deglaciation sequences in the Permo-Carboniferous Karoo and Kalahari Basins of southern Africa: a tool in the analysis of cyclic glaciomarine basin fills. Sedimentology 44: 507-521.

VISSER, J.N.J., LOOCK, J.C., VAN DER MERWE, J., JOUBERT, C.W., POTGIETER, C.D., MCLAREN, C.H., POTGIETER, G.J.A., VAN DER WESTHUIZEN, W.A., NEL, L. & LEMER, W.M.

1977-78. The Dwyka Formation and Ecca Group, Karoo Sequence, in the northern Karoo Basin, Kimberley-Britstown area. Annals of the Geological Survey of South Africa 12, 143-176.

ZAWADA, P.K. 1992. The geology of the Koffiefontein area. Explanation of 1: 250 000 geology sheet 2924 Koffiefontein, 30 pp. Council for Geoscience, Pretoria.

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

Declaration of Independence

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

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