Palaeontological specialist assessment: desktop study

PROPOSED DEVELOPMENT OF THE BOULEVARD PRECINCT, BRAM FISCHER AIRPORT, SUBDIVISION 3 OF THE FARM SUNNYSIDE NO. 2620 NEAR BLOEMFONTEIN, MANGAUNG METROPOLITAN MUNICIPALITY, FREE STATE

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EXECUTIVE SUMMARY

The Airports Company South Africa (ACSA) is proposing to construct a series of developments within the Boulevard Precinct, a site of 53 ha extent on Subdivision 3 of the Farm Sunnyside No. 2620, situated adjacent to Bram Fischer Airport on the eastern outskirts of Bloemfontein, Free State. The study area is underlain at depth by continental sediments of the Adelaide Subgroup (Karoo Supergroup) that can probably be assigned to the Normandien Formation of Late Permian age. This formation is known for its rich fossil plant assemblages of the *Glossopteris* Flora of Gondwana, together with associated insects and other invertebrates, trace fossils and rare vertebrate remains, such as dicynodont therapsids. In the flat-lying study area these potentially fossiliferous bedrocks are mantled by fossil-poor superficial sediments (soils, residual gravels *etc*) of much younger, Quaternary to Recent age.

The proposed development is accordingly assessed as of MEDIUM significance in terms of potential impacts on fossil heritage here. There is a significant possibility that scientifically valuable fossil remains (*e.g.* vertebrate bones and teeth, plant-rich horizons) are exposed during deeper excavations into Karoo Supergroup sedimentary bedrocks during the construction phase. It is therefore recommended that a professional palaeontologist be commissioned to monitor all, or at least a representative sample of, large scale, deep excavations into bedrocks. It is important that the opportunity for professional monitoring and mitigation is given while the bedrock excavations are fresh and *before* they are infilled, covered over or degraded by weathering and plant growth. Before development starts a realistic programme of monitoring and mitigation should therefore be negotiated between the developer and the palaeontologist contracted for the project to maximize the scientific and conservation benefits of the work, while minimizing disruption of the construction programme.

Monitoring and mitigation by a qualified palaeontologist should entail (a) the field examination of new bedrock excavations, (b) the recording of sedimentological and palaeontological data, (c) the judicious sampling and curation of fossil material as well as (d) recommendations for any further action required to safeguard fossil heritage. The palaeontologist involved in monitoring and mitigation work will need to obtain a fossil collection permit from SAHRA (Contact details: Mrs Colette Scheermeyer, P.O. Box 4637, Cape Town 8000. Tel: 021 462 4502. Email: cscheermeyer@sahra.org.za) and to make arrangements with an approved repository (*e.g.* museum, university) to store and curate any fossil material collected. All palaeontological specialist work should conform to international best practice for palaeontological fieldwork and the study (*e.g.* data recording fossil collection and curation, final report) should adhere as far as possible to the minimum standards for Phase 2 palaeontological studies recently developed by SAHRA (2013).

The following generic palaeontological monitoring and mitigation measures should also be implemented during the construction phase of the Boulevard Precinct development:

- The Site Engineer and /or Environmental Control Officer (ECO) responsible for monitoring environmental compliance of the development must remain aware that all sedimentary deposits have the potential to contain fossils and he/she should thus monitor all substantial excavations into sedimentary bedrock for fossil remains. If any substantial fossil remains (*e.g.* vertebrate bones, teeth, horn cores, fossil plant-rich beds) are found during construction SAHRA should be notified immediately (Contact details: SAHRA, 111 Harrington Street, Cape Town. PO Box 4637, Cape Town 8000, South Africa. Phone: +27 (0)21 462 4502. Fax: +27 (0)21 462 4509. Web: www.sahra.org.za) so that appropriate mitigation (*i.e.* recording, sampling or collection) by a palaeontological specialist can be considered and implemented, at the developer's expense.

- A chance-find procedure should be implemented so that, in the event of fossils being uncovered, the ECO and /or Site Engineer will take the appropriate action, which includes:
    - Stopping work in the immediate vicinity and fencing off the area with tape to prevent further access;
    - Reporting the discovery to the provincial heritage agency and/or SAHRA;
    - Appointing a palaeontological specialist to inspect, record and (if warranted) sample or collect the fossil remains;
    - Implementing further mitigation measures proposed by the palaeontologist; and
    - Allowing work to resume only once clearance is given in writing by the relevant authorities.
- During maintenance and servicing of infrastructure, if excavation is required, it shall be limited to the disturbed footprint as far as practicable. Should bulk works exceed the currently proposed development footprint, as outlined in Fig. 1 of this report, SAHRA should be notified.

If the mitigation measures outlined above are adhered to, the residual impact significance of any construction and operational phase impacts on local palaeontological resources is considered to be LOW.

1. INTRODUCTION, PROJECT OUTLINE AND BRIEF

The Airports Company South Africa (ACSA) is proposing to construct a series of developments within the Boulevard Precinct, a site of 53 ha extent on Subdivision 3 of the Farm Sunnyside No. 2620, situated adjacent to Bram Fischer Airport on the eastern outskirts of Bloemfontein (Figs. 1 to 3). The following brief project outline has kindly been provided by Vidamemoria Heritage Consultants, Cape Town:

> Bram Fischer Airport (formerly known as Bloemfontein Airport) site, subdivision 3 of the Farm Sunnyside No. 2620, is located approximately 8 km to the east of Bloemfontein CBD. The site, owned by the Airports Company South Africa (ACSA) is located within the urban edge and is zoned Special Use Zone Cxxi in terms of the Bloemfontein Town Planning Scheme No. 1 of 1954. The site is located along the N8 Corridor and has been identified by the Mangaung Metropolitan Municipality as one of the corridor nodes, and is perceived as a catalyst to the successful development of the corridor. The Bloemfontein Airport Development Framework (2010) conceptually divides the site into five precincts: Terminal, Boulevard, General Aviation, Airport Industria and Grasslands. The focus of this application is on The Boulevard Precinct, which measures approximately 53 ha in extent.
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> In 2009, the entire Subdivision 3 of the Farm Sunnyside No. 2620 was rezoned to a Special Use Zone with specific rights to accommodate the existing development including the road lodge hotel which was constructed in 2010. In 2012, the Special Use Zone was amended to include additional developments (hospital, warehousing, self-storage and business premises) within the Boulevard Precinct. ACSA will apply for a further amendment to the Special Zone Cxxi in the form of the Basket of Rights application to accommodate further developments on the Boulevard Precinct. The proposed land uses will have a total bulk of approximately 176 500 m^2 and will comprise:
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> a) Offices
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> b) Commercial
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> c) Motor car dealer and showroom
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> d) 2 x service station and convenience shop
>
> e) Retail / shops
>
> f) Auctioneer business
>
> g) 100 bed hotel with 80 seat conferencing facility
>
> h) 300 seat conferencing facility and showground
>
> i) Medical facilities
>
> j) Industry, including industrial shops
>
> k) Warehousing and distribution centres / warehouse wholesale
>
> l) Car rental
>
> m) Logistics centre

In addition to the above bulk and associated land uses, approximately 100 000 m^2 of bulk will in the future be accommodated on The Boulevard Precinct. The land use composition of this additional bulk has not been defined at this stage, given that this development will occur in the long term.

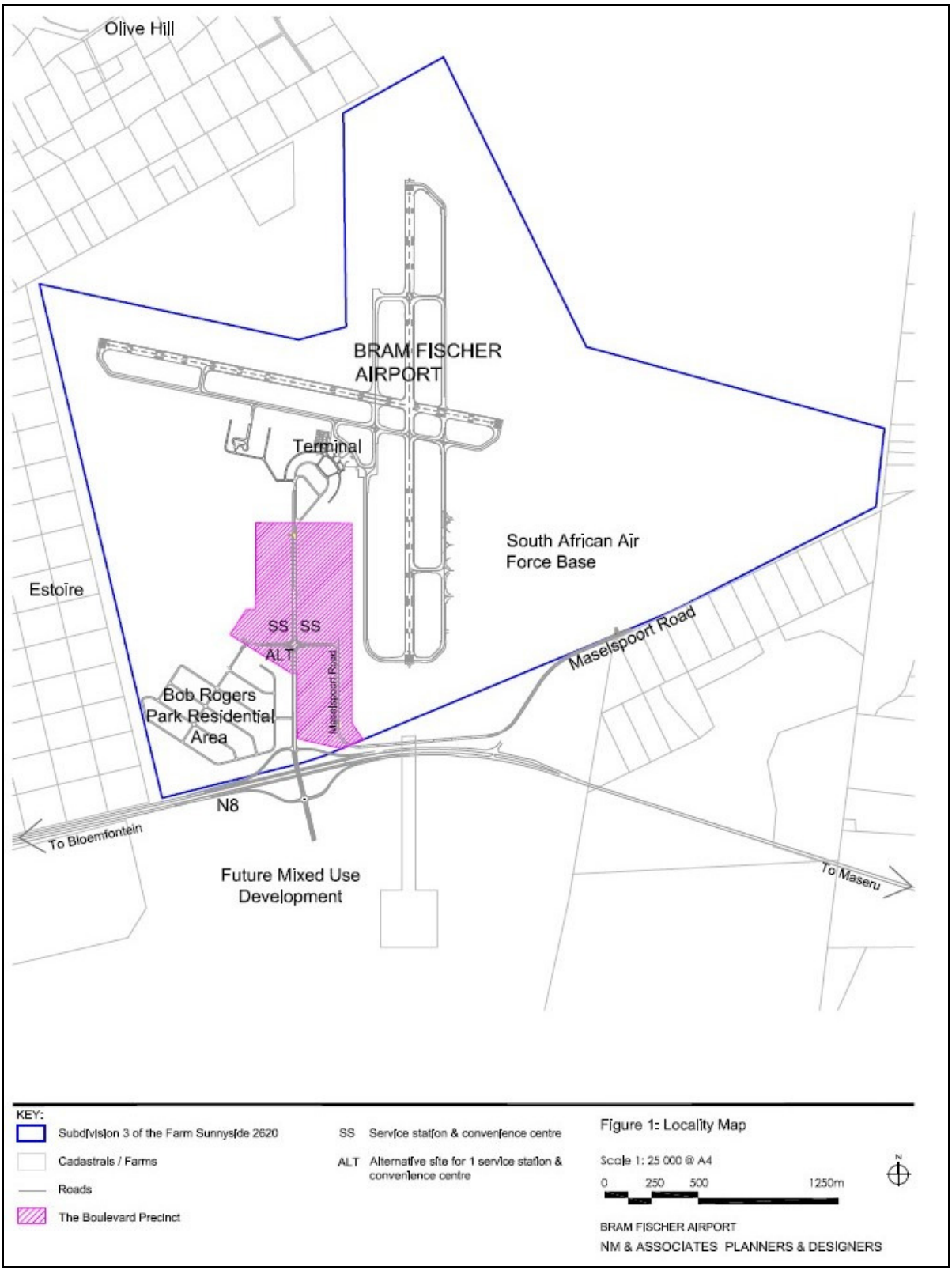

Fig. 1. Locality map for the proposed Boulevard Precinct development adjacent to the Bram Fischer Airport, Bloemfontein (Subdivision 3 of the farm Sunnyside No. 2620) (Image kindly provided by Vidamemoria Heritage Consultants, Cape Town).

The Boulevard Precinct development area is underlain by potentially fossiliferous sedimentary rocks of Late Palaeozoic age (Sections 2 and 3). The construction phase of the development will entail substantial excavations into the superficial sediment cover (*e.g.* for building foundations, roads, pipelines and other services). In addition, sizeable areas will be sealed-in or sterilized beneath the various commercial / industrial developments. All these developments may adversely affect potential fossil heritage 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.

All palaeontological heritage resources in the Republic of South Africa are protected by the National Heritage Resources Act (Act 25 of 1999) (See Section 1.1 below). Heritage resource management in the Free State is the responsibility of the South African Heritage Resources Agency or SAHRA (Contact details: SAHRA, 111 Harrington Street, Cape Town. PO Box 4637, Cape Town 8000, South Africa. Phone: +27 (0)21 462 4502. Fax: +27 (0)21 462 4509. Web: www.sahra.org.za).

The following palaeontological heritage comment was prepared by the author in April 2013 as part of the NID for the Boulevard Precinct development submitted to SAHRA by Vidamemoria Heritage Consultants:

> The Bram Fischer Bloemfontein Airport study area is underlain by continental sediments of the Lower Beaufort Group (Adelaide Subgroup, Karoo Supergroup). These rocks are characterised by diverse fossil assemblages of the *Dicynodon* Assemblage Zone of Late Permian Age, including terrestrial and freshwater tetrapods (amphibians, true reptiles and synapsids, especially therapsids), palaeoniscoid fish, freshwater bivalves, trace fossils (including tetrapod trackways), sparse to rich assemblages of vascular plants (*Glossopteris* Flora, including petrified logs) and insects. A desktop palaeontological heritage assessment is therefore recommended for the proposed Boulevard Precinct project. Pre-construction field assessment is considered unnecessary due to the disturbed context and low level of surface bedrock exposure in the study area.

The present palaeontological heritage desktop assessment has been commissioned by Vidamemoria Heritage Consultants as part of a Heritage Impact Assessment requested for the development by SAHRA (Contact details: Ms Quahnita Samie. Vidamemoria Heritage Consultants, Cape Town. 3rd Floor, Guarantee House, 37 Burg Street, Greenmarket Square, Cape Town. Tel: 021-424 8432. E-mail: Quahnita@vidamemoria.co.za).

1.1. Legislative context for palaeontological assessment studies

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

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

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

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

(2) All archaeological objects, palaeontological material and meteorites are the property of the State.

(3) Any person who discovers archaeological or palaeontological objects or material or a meteorite in the course of development or agricultural activity must immediately report the find to the responsible heritage resources authority, or to the nearest local authority offices or museum, which must immediately notify such heritage resources authority.

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

(a) destroy, damage, excavate, alter, deface or otherwise disturb any archaeological or palaeontological site or any meteorite;

(b) destroy, damage, excavate, remove from its original position, collect or own any archaeological or palaeontological material or object or any meteorite;

(c) trade in, sell for private gain, export or attempt to export from the Republic any category of archaeological or palaeontological material or object, or any meteorite; or

(d) bring onto or use at an archaeological or palaeontological site any excavation equipment or any equipment which assist in the detection or recovery of metals or archaeological and palaeontological material or objects, or use such equipment for the recovery of meteorites.

(5) When the responsible heritage resources authority has reasonable cause to believe that any activity or development which will destroy, damage or alter any archaeological or palaeontological site is under way, and where no application for a permit has been submitted and no heritage resources management procedure in terms of section 38 has been followed, it may—

(a) serve on the owner or occupier of the site or on the person undertaking such development an order for the development to cease immediately for such period as is specified in the order;

(b) carry out an investigation for the purpose of obtaining information on whether or not an archaeological or palaeontological site exists and whether mitigation is necessary;

(c) if mitigation is deemed by the heritage resources authority to be necessary, assist the person on whom the order has been served under paragraph *(a)* to apply for a permit as required in subsection (4); and

(d) recover the costs of such investigation from the owner or occupier of the land on which it is believed an archaeological or palaeontological site is located or from the person proposing to undertake the development if no application for a permit is received within two weeks of the order being served.

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

1.4. Approach to the desktop palaeontological heritage study

The approach to this desktop palaeontological heritage study is briefly as follows.

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

In preparing a palaeontological desktop study the potentially fossiliferous rock units (groups, formations *etc.*) represented within the study area are determined from geological maps and satellite images. The known fossil heritage within each rock unit is inventoried from the published scientific literature, previous palaeontological impact studies in the same region, and the author's field experience (consultation with professional colleagues as well as examination of institutional fossil collections may play a role here, or later following field assessment during the compilation of the final report). This data is then used to assess the palaeontological sensitivity of each rock unit to a development (Provisional tabulations of palaeontological sensitivity of all formations in the Western, Eastern and Northern Cape have already been compiled by J. Almond and colleagues; *e.g.* Almond & Pether 2008).

The likely impact of the proposed development on local fossil heritage is then determined on the basis of (1) the palaeontological sensitivity of the rock units concerned, and (2) the nature and scale of the development itself, most significantly the extent of fresh bedrock excavation envisaged. When rock units of moderate to high palaeontological sensitivity are present 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 (*e.g.* SAHRA for the Free State). It should be emphasized that, *provided that appropriate mitigation is carried out*, the majority of developments involving bedrock excavation can make a *positive* contribution to our understanding of local palaeontological heritage.

1.5. Assumptions & limitations

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

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

2. Variable accuracy of geological maps which underpin these desktop studies. For large areas of terrain these maps are largely based on aerial photographs alone, without ground-truthing. The maps generally depict only significant ("mappable") bedrock units as well as major areas of superficial "drift" deposits (alluvium, colluvium) but for most regions give little or no idea of the level of bedrock

outcrop, depth of superficial cover (soil *etc.*), degree of bedrock weathering or levels of small-scale tectonic deformation, such as cleavage. All of these factors may have a major influence on the impact significance of a given development on fossil heritage and can only be reliably assessed in the field.

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

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

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

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

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

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

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

In the case of the study area near Bloemfontein a major limitation for fossil heritage studies is the very low level of surface exposure of potentially fossiliferous bedrocks, as well as the paucity of previous specialist palaeontological field studies in the region as a whole.

1.6. Information sources

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

1. A brief project outline, field photos and maps kindly provided by Vidamemoria Heritage Consultants, Cape Town;

2. A review of the relevant scientific literature, including published geological maps and accompanying sheet explanations as well as several desktop and field-based palaeontological assessment studies in the Bloemfontein area (*e.g.* Groenewald 2013, Rossouw 2013);

3. Examination of relevant topographical maps and satellite images;

4. The author's previous field experience with the formations concerned and their palaeontological heritage.

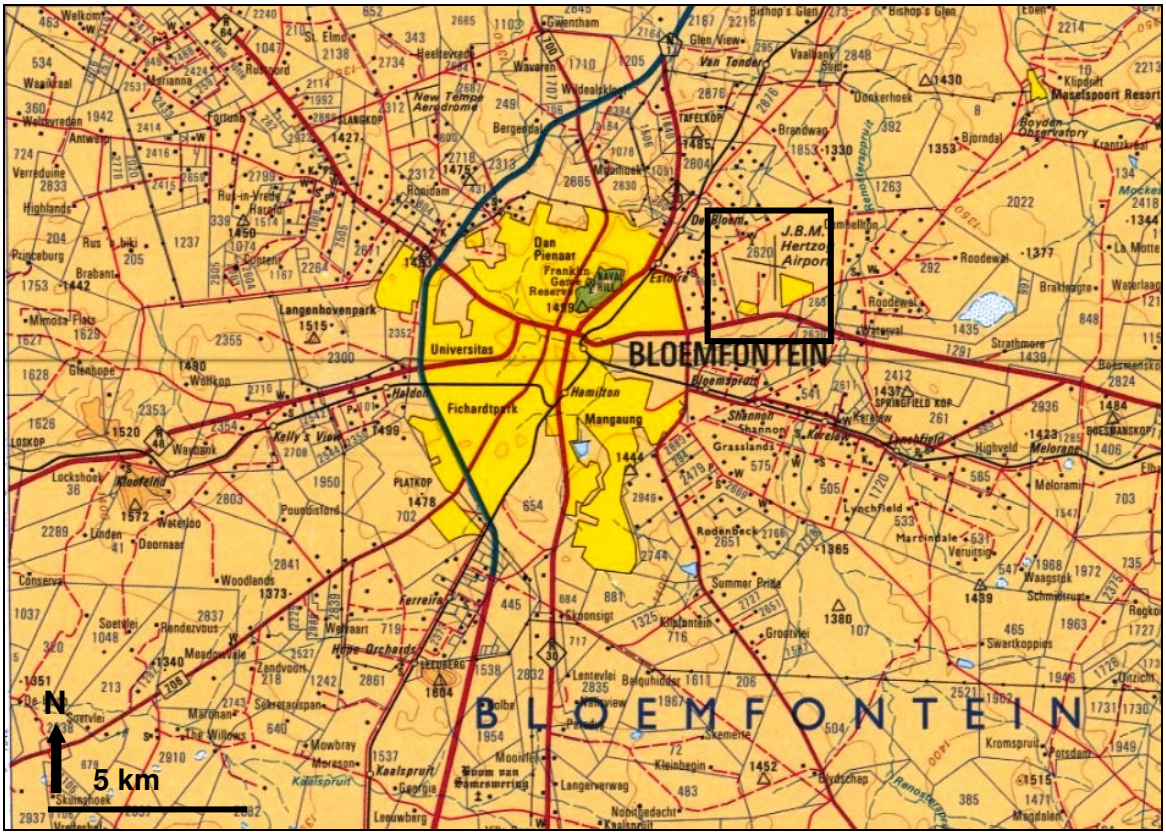

Fig. 2. Map showing the approximate location (black rectangle) of the Boulevard Precinct study area adjacent to Bram Fischer Airport on farm Sunnyside No. 2620, on the eastern outskirts of Bloemfontein, Free State (Extract from 1: 250 000 topographical map 2926 Bloemfontein, Courtesy of the Chief Directorate Surveys and Mapping, Mowbray).

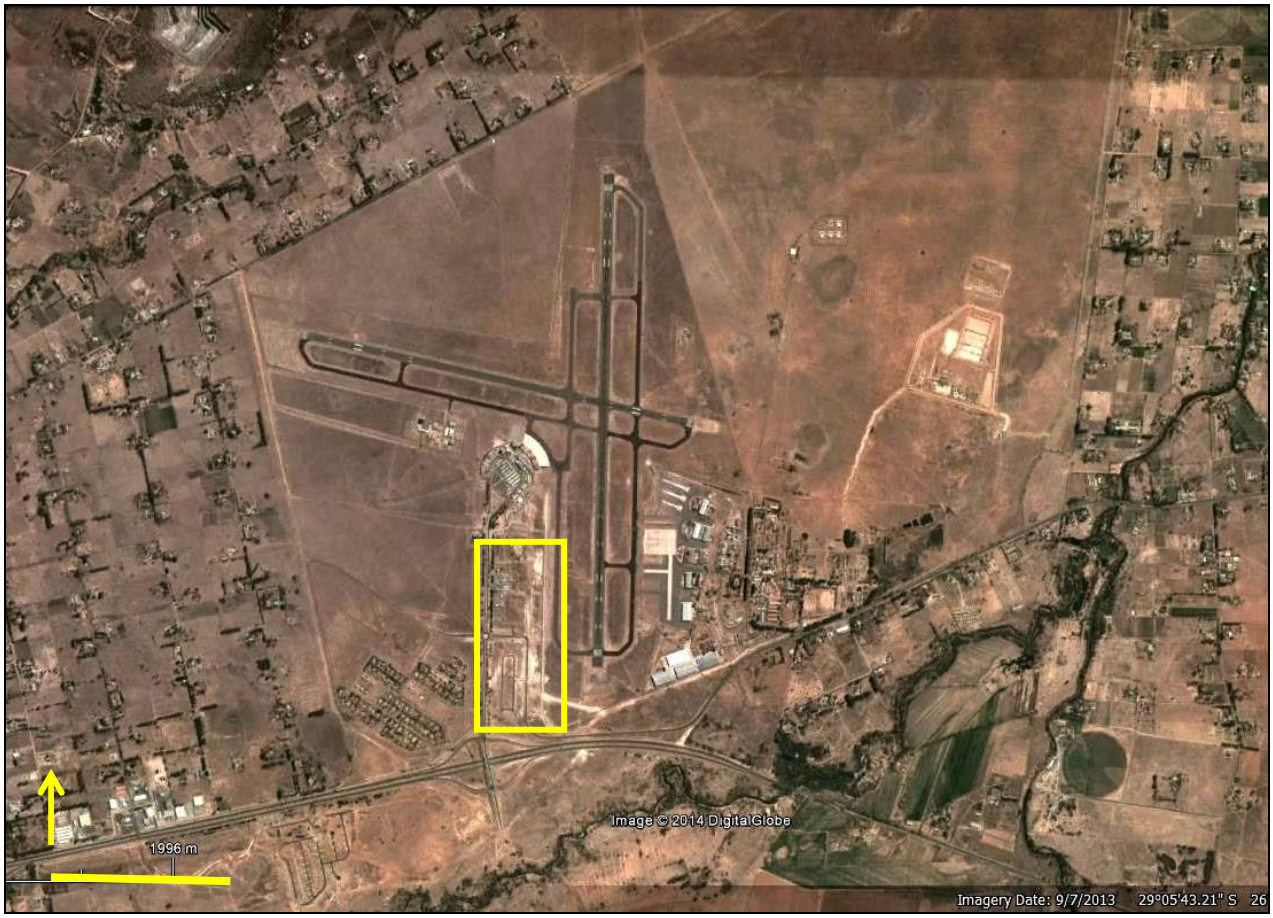

Fig. 3. Google earth© satellite image of the Bram Fischer airport east of Bloemfontein showing the flat-lying Boulevard Precinct study area (yellow rectangle) between the airport terminal and the N8. Yellow scale bar (bottom LHS) = *c.* 1 km. Arrow points north.

Fig. 4. Field image of flat-lying, grassy terrain in the Boulevard Precinct study area (Image kindly provided by Vidamemoria Heritage Consultants, Cape Town).

Fig. 5. Shallow drainage ditch in the Boulevard Precinct study area showing lack of bedrock exposure beneath superficial sediments (soils, gravels *etc*).

2. GEOLOGICAL OUTLINE OF THE STUDY AREA

The Boulevard Precinct study site near Bram Fischer Airport on the eastern outskirts of Bloemfontein, Free State, is situated in a flat-lying area at *c*. 1350 m amsl between the airport terminal and the N8 Bloemfontein – Maseru tar road (Figs. 1 to 3). Satellite images and field photos (Figs. 4 & 5) show that the area is largely grass-covered and partially disturbed with little or no bedrock exposure. The winding course of a small tributary of the Renosterspruit drainage system runs less than one kilometre to the south.

The geology of the study region is shown on the 1: 250 000 geological sheet 2926 Bloemfontein (Council for Geoscience, Pretoria) (Fig. 6 herein). This map is not accompanied by a detailed sheet explanation (A brief explanation is printed on the map itself, however). The Bram Fischer airport region is entirely underlain by continental sediments – predominantly fluvial mudrocks and sandstones – of the Lower Beaufort Group (**Adelaide Subgroup** of the Beaufort Group, Karoo Supergroup) of Permian age (Johnson *et al.* 2006). Elsewhere in the Bloemfontein area these sedimentary bedrocks are extensively intruded by Early Jurassic intrusions of the **Karoo Dolerite Suite** (Duncan & Marsh 2006).

In the north-eastern portion of the Main Karoo Basin, including the Bloemfontein area, the Adelaide Subgroup is represented by the **Normandien Formation** of Late Permian age (Groenewald 2013). The Normandien Formation as now redefined includes continental facies beds that were previously assigned to the Estcourt Formation in western KZN and southern Mpumalanga. In its type area (Kroonstad – Memel – Escourt in the northern Free State and KZN) the formation is 100 to 320 m thick and comprises greyish to reddish mudrocks with prominent-weathering sandstone interbeds (Groenewald 1984, 1989, Johnson 1994). In the more southern "Escourt Formation" outcrop area the sandstones are coarser and occasionally pebbly with rare thin (1-10 cm) coal seams at the top of upward-fining cycles (Johnson 1994, Lindström 1987). The lower contact with basinal mudrocks of the Volksrust Formation is conformable, while the upper boundary with the Tarkastad Subgroup (Upper Beaufort Group) is an erosional unconformity.

The "Escourt Formation" beds in the Vryheid sheet area, which are some 90 m thick, have been briefly described by Turner (1977) and Lindström (1987). Broadly upwards-fining successions are attributed to deposition by meandering rivers. Freshwater settings are implied by mudrock units containing conchostracan crustaceans. A detailed study of Normandien Formation meandering fluvial sediments and associated fossil biotas near Escourt, KZN, has been published by Prevec *et al.* (2009). A Late Permian (Changhsingian) age for the Normandien Formation is inferred by these last authors on the basis of the sparse fossil vertebrates (*e.g.* the dicynodont *Oudenodon*) supported by glossopterid floras, palynomorphs and insect faunas. Equivalent Late Permian coal-bearing beds in the Lebombo Basin to the east are referred to the separate Emakwezini Formation and have recently been described by Bordy and Prevec (2008). Selover and Gastaldo (2005) provide sedimentological evidence for turbidite fan sedimentation within the Late Permian "Estcourt Formation" near Escourt, KZN.

In the flat-lying Boulevard Precinct study area near Bloemfontein the Adelaide Subgroup sedimentary bedrocks are largely to entirely mantled by a range of **Quaternary to Recent superficial sediments** such as soils, residual gravels, and perhaps alluvium related to the Renosterspruit drainage system the runs just to the south (Figs. 3 to 5). The thickness of these post-Karoo sediments is unclear, but it is likely to be substantial (perhaps up to several meters) (*cf.* previous palaeontological heritage assessments in the Bloemfontein area by Rossouw 2013, Groenewald 2013)..

Fig. 6. Extract from 1: 250 000 geological map 2926 Bloemfontein (Council for Geoscience, Pretoria) showing the *approximate* location of the Boulevard Precinct study area on farm Sunnyside 2620, *c.* 8 km east of Bloemfontein CBD (black polygon). Note that the road network shown here is out of date.

Geological units represented within the broader study region include the Late Permian Lower Beaufort Group (Adelaide Subgroup) (K3l, pea green) and Early Jurassic dolerite intrusions (dark red). Superficial sediment cover is not mapped at this scale.

3. POTENTIAL PALAEONTOLOGICAL HERITAGE WITHIN THE STUDY AREA

Fossil biotas recorded from each of the main rock units mapped at surface within the study region (Fig. 6) are briefly reviewed in this section of the report.

3.1. Fossils in the Adelaide Subgroup

The diverse vertebrate, invertebrate and plant fossil assemblages of the Beaufort Group are reknowned worldwide for their rich record of continental biotas on the supercontinent Gondwana during the Permo-Triassic interval (*cf* Cluver 1978, MacRae 1999, McCarthy & Rubidge, 2005). The palaeontological sensitivity of these rocks is therefore generally assessed as HIGH. Pervasive calcretisation and chemical weathering of near-surface bedrocks in the Great Karoo has compromised their original fossil heritage in many areas, however.

The Adelaide Subgroup sediments in the Bloemfontein study area are assigned to the ***Dicynodon* Assemblage Zone** (Rubidge 1995, Van der Walt 2010) (Fig. 7). This youngest biozone of the Adelaide succession has been assigned to the Changhsingian Stage (= Late Tartarian), right at the end of the Permian Period, with an approximate age range of 253.8-251.4 million years (Rubidge 1995, 2005, Rubidge *et al.* 2013). Good accounts, with detailed faunal lists, of the rich Late Permian fossil biotas of the *Dicynodon* Assemblage Zone have been given by Keyser and Smith (1979). Kitching (1995), MacRae (1999) and by Cole *et al*. (2004).

From a palaeontological viewpoint, these diverse *Dicynodon* Assemblage Zone biotas are of extraordinary interest in that they provide some of the best available evidence for the last flowering of ecologically-complex terrestrial ecosystems immediately preceding the catastrophic end-Permian mass extinction (*e.g.* Smith & Ward, 2001, Rubidge 2005, Gastaldo *et al.* 2005, Retallack *et al.,* 2006).

In general, the following broad categories of fossils might be expected within the Adelaide Subgroup (*Dicynodon* Assemblage Zone) in the Bloemfontein study area:

- isolated petrified bones as well as articulated skeletons of terrestrial vertebrates such as true **reptiles** (notably large herbivorous pareiasaurs, small lizard-like millerettids and younginids) and **therapsids** (diverse dicynodonts such as *Dicynodon* and the much smaller *Diictodon*, carnivorous gorgonopsians, therocephalians such as *Theriognathus* (= *Whaitsia*), primitive cynodonts like *Procynosuchus*, and biarmosuchians) (See Figs. 8 & 9 herein);

- aquatic vertebrates such as large, crocodile-like temnospondyl **amphibians** like *Rhinesuchus* (usually disarticulated), and palaeoniscoid **bony fish** (*Atherstonia*, *Namaichthys*);

- freshwater **bivalves** (*Palaeomutela*);

- **trace fossils** such as worm, arthropod and tetrapod burrows and trackways, coprolites (fossil droppings);

- **vascular plant remains** including leaves, twigs, roots and petrified woods ("*Dadoxylon*") of the *Glossopteris* Flora (usually sparse, fragmentary), especially glossopterids and arthrophytes (horsetails);

As far as the biostratigraphically important tetrapod remains are concerned, the best fossil material is generally found within overbank mudrocks, whereas fossils preserved within channel sandstones tend to be fragmentary and water-worn (Rubidge 1995, Smith 1993a, 1993b). Many fossils are found in association with ancient soils (palaeosol horizons) that can usually be recognised by bedding-parallel concentrations of calcrete nodules. The abundance and variety of fossils within the *Dicynodon* Assemblage Zone decreases towards the top of the succession (Cole *et al.,* 2004).

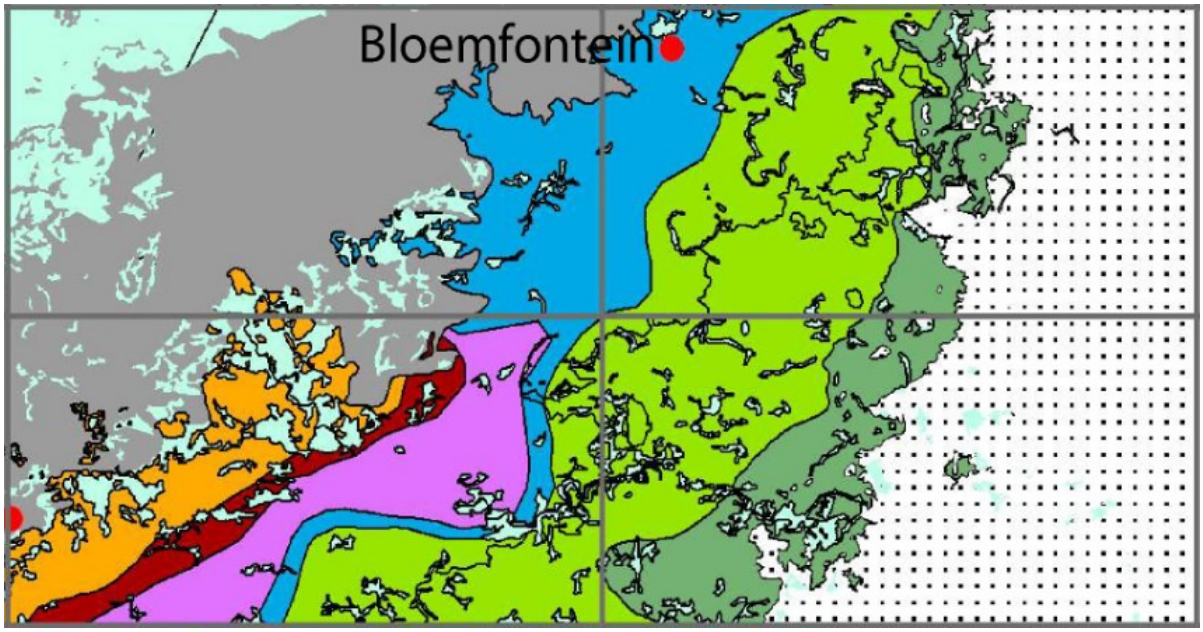

Fig. 7. Extract from the most recent fossil assemblage zone map for the Main Karoo Basin showing the zones represented in the Free State study region (Modified from Van der Walt *et al.* 2010). The Adelaide Subgroup sediments beneath the development footprint near Bloemfontein are situated within the latest Permian *Dicynodon* Assemblage Zone (blue area).

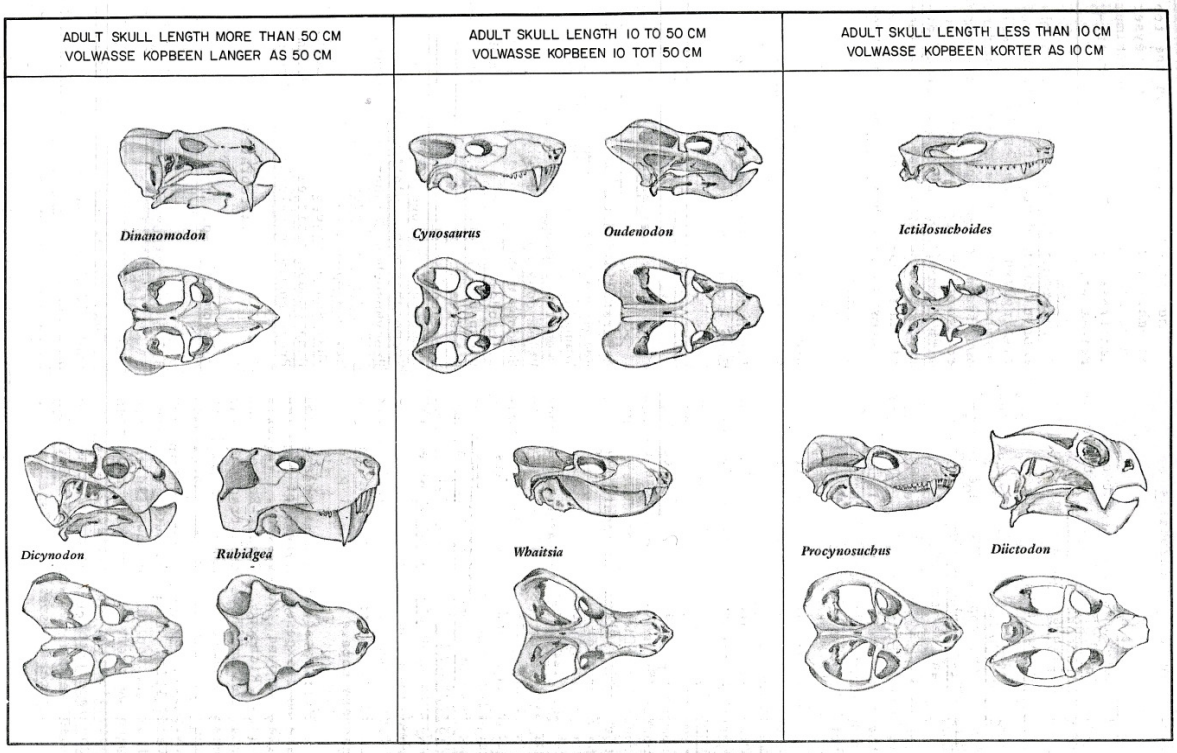

Fig. 8. Skulls of characteristic fossil vertebrates – all therapsids - from the *Dicynodon* Assemblage Zone (From Keyser & Smith 1979). Among the dominant therapsids ("mammal-like reptiles"), *Rubidgea* and *Cynosaurus* are carnivorous gorgonopsians, *Whaitsia* (now *Theriognathus*) is a predatory therocephalian while *Ictidosuchoides* is a small insectivorous member of the same group, *Procynosuchus* is a primitive cynodont, and the remainder are large- to small-bodied dicynodont herbivores.

Fig. 9. Skull of the two-tusked dicynodont *Dicynodon* from the Late Permian Period (Gondwana Studios, Internet image). Skull length in this genus is approximately 13 cm.

Late Permian (Lopingian / Changhsingian) fluvio-deltaic sediments of the **Normandien Formation** (including the previously recognised Estcourt Formation) in the eastern and north-eastern portion of the Main Karoo Basin are well-known for their rich fossil plant assemblages of the *Glossopteris* Flora, some of which are unusually well preserved. Key accounts of these palaeofloras include those by Lacey (1974, 1978), Lacey *et al.* (1985), Anderson and Anderson (1985 – Estcourt Formation, pp. 32-35), Van Dijk (2000 and earlier papers) and Claassen (2008). The excellent recent study by Prevec *et al.* (2009) has a strong palaeoecological emphasis, highlighting plant-insect interactions on the basis of diverse trace fossil data. Plant groups recorded from the Normandien succession include possible mosses, sphenophytes, other ferns, possible lycopods, a range of glossopterids represented by remains of leaves, axes, fertile structures and seeds, as well as several coniferophytes. Petrified wood has been assigned to the genus *Agathoxylon*. Microfossils include a limited range of palynomorphs. Most of the plant fossil remains are associated with finely-laminated shale intervals within the Normandien succession; these are interpreted as in-channel slack-water deposits in the case studied by Prevec *et al.* (2009). Comparable fossil floras are also recorded from the (in part) co-eval Emakwezeni Formation of the Lebombo Basin (Bordy & Prevec 2008).

Fossil insect assemblages as well as insect-caused trace fossils (*e.g.* traces of herbivory) are well-represented at some localities (Van Dijk *et al.* 2000, Prevec *et al.* 2009 and refs. therein). Conchostracans (clam shrimps) are represented within freshwater mudrocks (Lindström 1987). Vertebrate remains recorded from the Normandien succession include the dicynodont therapsids *Oudenodon* and *Dicynodon*, supporting correlation with the latest Permian *Dicynodon* Assemblage Zone (Rubidge *et al.* 1995, Claassen 2008, Prevec *et al.* 2009).

Palaeontological data for the type area of the Normandien Formation (Kroonstad – Memel – Escourt area, northern Free State and western KZN) is given in the seminal accounts by Groenewald (1984, 1989; not seen).

3.2. Fossils within Late Caenozoic superficial deposits

The central Karoo "drift" deposits have been comparatively neglected in palaeontological terms. However, they may occasionally contain important fossil biotas, notably the bones, teeth and horn cores of mammals as well as remains of reptiles like tortoises. Good examples are the Pleistocene mammal faunas at Florisbad, Cornelia and Erfkroon in the Free State and elsewhere (Wells & Cooke 1942, Cooke 1974, 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 from these superficial deposits include non-marine molluscs (bivalves, gastropods), ostrich egg shells, tortoise remains, trace fossils (*e.g.* calcretised termitaria, coprolites, invertebrate burrows), 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.

4. PALAEONTOLOGICAL HERITAGE IMPACT ASSESSMENT

During construction of the Boulevard Precinct development the disturbance, damage or destruction of fossil remains preserved at or beneath the ground surface within the project footprint are negative impacts that may potentially compromise legally – protected fossil heritage here. Activities undertaken predominantly during the preparation and construction phases of the project will have the greatest potential to disturb or damage palaeontological resources on site. These activities include:

- Site and vegetation clearance;
- Levelling, compacting and grading activities;
- Trenching and excavations for infrastructure and pipelines; and
- The laying of foundations for buildings and structures.

At an operational phase, maintenance and servicing activities may result in forms of excavation, but will be limited to previously disturbed footprints.

Potential impacts in fossil heritage resources within the Boulevard Precinct study area near are assessed in Table 1 below.

Judging from satellite images and site photos, exposure levels of Adelaide Subgroup bedrocks within the study area near Bloemfontein are very low. The Quaternary to Recent superficial deposits (soils, gravels, possibly alluvium from the Renostespruit drainage system *etc*) that mantle the bedrocks here are of very low palaeontological sensitivity.

It is concluded that the overall impact significance of the proposed development is MEDIUM as far as palaeontological heritage is concerned. Cumulative impacts are likely to be of LOW significance, given the scarcity of important fossils (mainly vertebrate remains) within the sedimentary rock units concerned as well as the huge outcrop area of the Normadien Formation as a whole. The degree of confidence for this assessment is rated as MEDIUM due to (a) the uncertainty regarding the thickness of comparatively insensitive (*i.e.* fossil-poor) superficial sediments mantling the potentially fossilferous Karoo Supergroup bedrocks in the study area; (b) the abundance and quality of preservation of vertebrate and plant fossil remains within Adelaide Subgroup rocks in the Bloemfontein area.

Table 1: Impact assessment for the Boulevard Precinct development, Bram Fisher Airport, Bloemfontein: Disturbance, Damage or Destruction of Palaeontological Heritage Resources

CRITERIA	RATING	COMMENTS
Extent of impact	LOW	Limited to development footprint (which is albeit large)
Duration of impact	PERMANENT	
Intensity of impact	MEDIUM	Significant fossil resources within the rocks underlying the development footprint are generally rare. However, if well-preserved fossil vertebrate remains are present subsurface, the impact intensity would be locally HIGH. The impact intensity if accordingly assessed as MEDIUM here, applying the precautionary principle.
Probability of impact	HIGH	Trace fossils (invertebrate burrows, plant root casts *etc.*), plant remains *etc* are likely to occur within the development footprint. Vertebrate remains are probably uncommon but may well be present.
Degree of reversibility	LOW	Damage, destruction of fossil material and loss of contextual geological data is irreversible.
Irreplaceability of resource	HIGH	This applies to the rarer vertebrate remains or well-preserved plant remains.
Cumulative impacts	LOW	Cumulative impacts cannot be accurately assessed in the absence of data on other developments in the broader study region. However, given the large outcrop area of the Normandien Formation in the northern Free State, cumulative impacts are provisionally assessed as LOW.
Significance rating	**MEDIUM**	This rating applies pending the exposure of any significant fossil vertebrate remains (*e.g.* bones, teeth, horn cores) during the construction phase of the development. Such findings would increase the significance of the potential impacts to HIGH.

4.1. Recommended monitoring and mitigation measures during the construction phase

Since the potentially fossiliferous Karoo Supergroup bedrocks beneath the Boulevard Precinct study area are currently covered by relatively unfossiliferous superficial deposits (soil *etc*), no further specialist studies or mitigation are recommended for the pre-construction phase.

There is a significant possibility that scientifically important fossil remains (*e.g.* vertebrate bones and teeth, plant-rich horizons) are exposed during deeper excavations into Karoo Supergroup sedimentary bedrocks during the construction phase. It is therefore recommended that a professional palaeontologist be commissioned to monitor all, or at least a representative sample of, large scale, deep excavations into bedrocks. It is important that the opportunity to for monitoring and mitigation is given while the bedrock excavations are fresh and *before* they are infilled, covered over or degraded by weathering and plant growth. Before development starts a realistic programme of monitoring and mitigation should therefore be negotiated between the developer and the palaeontologist contracted for the project to maximize the scientific and conservation benefits of the work, while minimizing disruption of the construction programme.

Monitoring and mitigation by a qualified palaeontologist should entail (a) the field examination of new bedrock excavations, (b) the recording of sedimentological and palaeontological data, (c) the judicious sampling and curation of fossil material and (d) recommendations for any further action required to

safeguard fossil heritage. The palaeontologist involved in mitigation work will need to obtain a fossil collection permit from SAHRA (Contact details: Mrs Colette Scheermeyer, P.O. Box 4637, Cape Town 8000. Tel: 021 462 4502. Email: cscheermeyer@sahra.org.za) and to make arrangements with an approved repository (*e.g.* museum, university) to store and curate any fossil material collected. All palaeontological specialist work should conform to international best practice for palaeontological fieldwork and the study (*e.g.* data recording fossil collection and curation, final report) should adhere as far as possible to the minimum standards for Phase 2 palaeontological studies recently developed by SAHRA (2013).

The following generic palaeontological monitoring and mitigation measures should also be implemented during the construction phase of the Boulevard Precinct development:

- The Site Engineer and /or Environmental Control Officer (ECO) responsible for monitoring environmental compliance of the development must remain aware that all sedimentary deposits have the potential to contain fossils and he/she should thus monitor all substantial excavations into sedimentary bedrock for fossil remains. If any substantial fossil remains (*e.g.* vertebrate bones, teeth, horn cores, fossil plant-rich beds) are found during construction SAHRA should be notified immediately (Contact details: SAHRA, 111 Harrington Street, Cape Town. PO Box 4637, Cape Town 8000, South Africa. Phone: +27 (0)21 462 4502. Fax: +27 (0)21 462 4509. Web: www.sahra.org.za) so that appropriate mitigation (*i.e.* recording, sampling or collection) by a palaeontological specialist can be considered and implemented, at the developer's expense.

- A chance-find procedure should be implemented so that, in the event of fossils being uncovered, the ECO and /or Site Engineer will take the appropriate action, which includes:

    - Stopping work in the immediate vicinity and fencing off the area with tape to prevent further access;

    - Reporting the discovery to the provincial heritage agency and/or SAHRA;

    - Appointing a palaeontological specialist to inspect, record and (if warranted) sample or collect the fossil remains;

    - Implementing further mitigation measures proposed by the palaeontologist; and

    - Allowing work to resume only once clearance is given in writing by the relevant authorities.

- During maintenance and servicing of infrastructure, if excavation is required, it shall be limited to the disturbed footprint as far as practicable. Should bulk works exceed the currently proposed development footprint, as outlined in Fig. 1 of this report, SAHRA should be notified.

If the mitigation measures outlined above are adhered to, the residual impact significance of any construction and operational phase impacts on local palaeontological resources is considered to be LOW.

5. CONCLUSIONS AND RECOMMENDATIONS

The Boulevard Precinct study area near Bram Fischer Airport, Bloemfontein, is underlain at depth by continental sediments of the Adelaide Subgroup (Karoo Supergroup) that can probably be assigned to the Normandien Formation of Late Permian age. This formation is known for its rich fossil assemblages of plants of the *Glossopteris* Flora of Gondwana, together with associated insects and other invertebrates, trace fossils and rare vertebrate remains such as dicynodont therapsids. In the flat-lying study area these potentially fossiliferous bedrocks are mantled by fossil-poor superficial sediments (soils, residual gravels *etc*) of much younger, Quaternary to Recent age.

The proposed development is accordingly assessed as of MEDIUM significance in terms of potential impacts on fossil heritage here. There is a significant possibility that scientifically valuable fossil remains (*e.g.* vertebrate bones and teeth, plant-rich horizons) are exposed during deeper excavations into Karoo Supergroup sedimentary bedrocks during the construction phase. It is therefore recommended that a professional palaeontologist be commissioned to monitor all, or at least a representative sample of, large scale, deep excavations into bedrocks. It is important that the opportunity for professional monitoring and mitigation is given while the bedrock excavations are fresh and *before* they are infilled, covered over or degraded by weathering and plant growth. Before development starts a realistic programme of monitoring and mitigation should therefore be negotiated between the developer and the palaeontologist contracted for the project to maximize the scientific and conservation benefits of the work, while minimizing disruption of the construction programme.

Monitoring and mitigation by a qualified palaeontologist should entail (a) the field examination of new bedrock excavations, (b) the recording of sedimentological and palaeontological data, (c) the judicious sampling and curation of fossil material as well as (d) recommendations for any further action required to safeguard fossil heritage. The palaeontologist involved in monitoring and mitigation work will need to obtain a fossil collection permit from SAHRA (Contact details: Mrs Colette Scheermeyer, P.O. Box 4637, Cape Town 8000. Tel: 021 462 4502. Email: cscheermeyer@sahra.org.za) and to make arrangements with an approved repository (*e.g.* museum, university) to store and curate any fossil material collected. All palaeontological specialist work should conform to international best practice for palaeontological fieldwork and the study (*e.g.* data recording fossil collection and curation, final report) should adhere as far as possible to the minimum standards for Phase 2 palaeontological studies recently developed by SAHRA (2013).

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  - Allowing work to resume only once clearance is given in writing by the relevant authorities.

- During maintenance and servicing of infrastructure, if excavation is required, it shall be limited to the disturbed footprint as far as practicable. Should bulk works exceed the currently proposed development footprint, as outlined in Fig. 1 of this report, SAHRA should be notified.

If the mitigation measures outlined above are adhered to, the residual impact significance of any construction and operational phase impacts on local palaeontological resources is considered to be LOW.

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7. REFERENCES

ALMOND, J.E., DE KLERK, W.J. & GESS, R. 2008. Palaeontological heritage of the Eastern Cape. Draft report for SAHRA, 20 pp. *Natura Viva* cc, Cape Town.

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

BAMFORD, M. 1999. Permo-Triassic fossil woods from the South African Karoo Basin. Palaeontologia africana 35, 25-40.

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

BENDER, P.A. 2004. Late Permian actinopterygian (palaeoniscid) fishes from the Beaufort Group, South Africa: biostratigraphic and biogeographic implications. Bulletin 135, 84pp. Council for Geoscience, Pretoria.

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.

BENTON, M.J. 2003. When life nearly died. The greatest mass extinction of all time, 336 pp. Thames & Hudson Ltd., London.

BOTHA, J. & ANGIELCZYK, K.D. 2007. An integrative approach to distinguishing the Late Permian dicynodont species *Oudenodon bainii* and *Tropidostoma microtrema* (Therapsida: Anomodontia). Palaeontology 50, 1175-1209.

BORDY, E.M. & PREVEC, R. 2008. Sedimentology, palaeontology and palaeo-environments of the Middle (?) to Upper Permian Emakwezini Formation (Karoo Supergroup, South Africa). South African Journal of Geology 111, 429-456.

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.

CATUNEANU, O., WOPFNER, H., ERIKSSON, P.G., CAIRNCROSS, B., RUBIDGE, B.S., SMITH, R.M.H. & HANCOX, P.J. 2005. The Karoo basins of south-central Africa. Journal of African Earth Sciences 43, 211-253.

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.

CLAASSEN, M. 2008. A note on the biostratigraphic application of Permian plant fossils of the Normandien Formation (Beaufort Group, Northeastern Main Karoo Basin), South Africa. South African Journal of Geology 111, 263-280.

COOKE, H.B.S. 1974. The fossil mammals of Cornelia, O.F.S., South Africa. In: Butzer, K.W., Clark, J.D. & Cooke, H.B.S. (Eds.) The geology, archaeology and fossil mammals of the Cornelia Beds, O.F.S. Memoirs of the National Museum, Bloemfontein 9: 63-84.

CLUVER, M.A. 1978. Fossil reptiles of the South African Karoo, 54pp. South African Museum, Cape Town.

COLE, D.I., NEVELING, J., HATTINGH, J., CHEVALLIER, L.P., REDDERING, J.S.V. & BENDER, P.A. 2004. The geology of the Middelburg area. Explanation to 1: 250 000 geology Sheet 3124 Middelburg, 44 pp. Council for Geoscience, Pretoria.

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.

DUNCAN & MARSH 2006. The Karoo Igneous Province. In: Johnson, M.R., Anhaeusser, C.R. & Thomas, R.J. (Eds.) The geology of South Africa, pp. 501-520. Geological Society of South Africa, Marshalltown.

GASTALDO, R. *et al.* 2005. Taphonomic trends of macrofloral assemblages across the Permian–Triassic Boundary, Karoo Basin, South Africa. Palaios 20, 479-497.

GROENEWALD, G.H. 1984. Stratigrafie en Sedimentologie van die Groep Beaufort in die Noordoos Vrystaat. Unpublsihed Ph.D. Thesis, Rand Afrikaans University, Johannesburg, 174 pp.

GROENEWALD, G.H., 1989. Stratigrafie en sedimentologie van die Groep Beaufort in die Noordoos-Vrystaat. Bulletin of the Geological Survey of South Africa 96, 1–62.

GROENEWALD, G. 2013. Palaeontological desktop assessment for the construction of two 5MW photovoltaic power plants on the farm Spes Bona 2355, Bloemfontein, Manguang Metro Municipality, Free State Province, 12 pp. PGS Heritage.

HILL, R.S. 1993. The geology of the Graaff-Reinet area. Explanation to 1: 250 000 geology Sheet 3224 Graaff-Reinet, 31 pp. Council for Geoscience, Pretoria.

JOHNSON, M.R. 1976. Stratigraphy and sedimentology of the Cape and Karoo sequences in the Eastern Cape province. Unpublished PhD thesis, Rhodes University, Grahamstown, 336 pp.

JOHNSON, M.R. (Ed.) 1994. Lexicon of South African stratigraphy. Part 1: Phanerozoic units, 56 pp. South African Committee for Stratigraphy, Council for Geoscience, Pretoria.

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.

KEYSER, A.W. & SMITH, R.M.H. 1979. Vertebrate biozonation of the Beaufort Group with special reference to the western Karoo Basin. Annals of the Geological Survey of South Africa 12, 1-35.

KITCHING, J.W. 1977. The distribution of the Karroo vertebrate fauna, with special reference to certain genera and the bearing of this distribution on the zoning of the Beaufort beds. Memoirs of the Bernard Price Institute for Palaeontological Research, University of the Witwatersrand, No. 1, 133 pp (incl. 15 pls).

KITCHING, J.W. 1995. Biostratigraphy of the *Dicynodon* Assemblage Zone. Pp. 29-34 *in* Rubidge, B.S. (ed.) Biostratigraphy of the Beaufort Group (Karoo Supergroup). South African Committee for Stratigraphy, Biostratigraphic Series No. 1. Council for Geoscience, Pretoria.

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.

LACEY, W.S. 1974. New Permian Glossopteris flora from Natal South African Journal of Science 70, 154-156.

LACEY, W.S. 1978. A review of the Upper Permian Glossopteris flora in western Natal. Palaeobotanist 25, 185-189.

LACEY, W.S., VAN DIJK, D.E. & GORDON-GRAY, K.D. 1975. Fossil plants from the Upper Permian in the Mooi River district of Natal, South Africa. Annals of the Natal Museum 22, 349-420.

LINDSTRŐM, W. 1987. Die geologie van die gebied Vryheid. Explanation to 1: 250 000 sheet area 2730, 48 pp. Council for Geoscience, Pretoria.

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

MCCARTHY, T. & RUBIDGE, B. 2005. The story of Earth and life: a southern African perspective on a 4.6-billion-year journey. 334pp. Struik, Cape Town.

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.

MUNTINGH, D. J. 1997. Sedimentologie en stratigrafie van die Ecca-Beaufort-oorgang in die noordoostelike gedeelte van die hoof Karookom. Geological Survey of South Africa Bulletin 121, 46 pp, maps. Council for Geoscience, Pretoria.

NICOLAS, M. & RUBIDGE, B.S. 2010. Changes in Permo-Triassic terrestrial tetrapod ecological representation in the Beaufort Group (Karoo Supergroup) of South Africa. Lethaia 43, 45-59.

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.

PONOMARENKO, A.G. & MOSTOVSKI, M.B. 2005. New beetles (Insecta: Coleoptera) from the Late Permian of South Africa. African Invertebrates 46, 253–260.

PREVEC, R., LABANDEIRA, C.C., NEVELING, J., GASTALDO, R.A., LOOY, C.V. & BAMFORD, M. 2009. Portrait of a Gondwana ecosystem: a new late Permian fossil locality from Kwazulu-Natal, South Africa. Review of Palaeobotany and Palynology. doi:10.1016/j.revpalbo.2009.04.012

NICOLAS, M.V. 2007. Tetrapod diversity through the Permo-Triassic Beaufort Group (Karoo Supergroup) of South Africa. Unpublished PhD thesis, University of Witwatersrand, Johannesburg.

RETALLACK, G.J., METZGER, C.A., GREAVER, T., HOPE JAHREN, A., SMITH, R.M.H. & SHELDON, N.D. 2006. Middle-Late Permian mass extinctions on land. GSA Bulletin 118, 1398-1411.

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

ROSSOUW, L. 2013. Exemption of Phase 1 Archaeological and Palaeontological Impact Assessment of a 5 ha site on portion 2 of Farm Pundisford 2903, Bloemfontein, Free State Province, 6 pp.

RUBIDGE, B.S. (Ed.) 1995. Biostratigraphy of the Beaufort Group (Karoo Supergroup). 46pp. South African Committee for Stratigraphy, Biostratigraphic Series No. 1. Council for Geoscience, Pretoria.

RUBIDGE, B.S. 2005. Re-uniting lost continents – fossil reptiles from the ancient Karoo and their wanderlust. South African Journal of Geology 108: 135-172.

RUBIDGE, B.S., ERWIN, D.H., RAMEZANI, J., BOWRING, S.A. & DE KLERK, W.J. 2010. The first radiometric dates for the Beaufort Group, Karoo Supergroup of South Africa. Proceedings of the 16th conference of the Palaeontological Society of Southern Africa, Howick, August 5-8, 2010, pp. 82-83.

RUBIDGE, B.S., ERWIN, D.H., RAMEZANI, J., BOWRING, S.A. & DE KLERK, W.J. 2013. High-precision temporal calibration of Late Permian vertebrate biostratigraphy: U-Pb zircon constraints from the Karoo Supergroup, South Africa. Geology published online 4 January 2013. doi: 10.1130/G33622.1.

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

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

SELOVER, R.W. & GASTALDO, R.A. 2005. A reinterpretation of the Wagendrift Quarry, Estcourt, KwaZulu-Natal Province, and its implications for Karoo Basin paleogeography. South African Journal of Geology 108, 16–26.

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.

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.

SMITH, R.M.H. 1993a. Sedimentology and ichnology of floodplain paleosurfaces in the Beaufort Group (Late Permian), Karoo Sequence, South Africa. Palaios 8, 339-357.

SMITH, R.M.H. 1993b. Vertebrate taphonomy of Late Permian floodplain deposits in the southwestern Karoo Basin of South Africa. Palaios 8: 45-67.

SMITH, R.M.H. & ALMOND, J.E. 1998. Late Permian continental trace assemblages from the Lower Beaufort Group (Karoo Supergroup), South Africa. Abstracts, Tercera Reunión Argentina de Icnologia, Mar del Plata, 1998, p. 29.

SMITH, R.H.M. & WARD, P.D. 2001. Pattern of vertebrate extinction across an event bed at the Permian-Triassic boundary in the Karoo Basin of South Africa. Geology 29, 1147-1150.

TURNER, J.R. 1977. Palaeoenvironmental study of the Lower Beaufort in the northeast Karoo basin. Unpublished MS Thesis, University of Natal, 138 pp.

VAN DER WALT, M., DAY, M., RUBIDGE, B., COOPER, A.K. & NETTERBERG, I. 2010. A new GIS-based biozone map of the Beaufort Group (Karoo Supergroup), South Africa. Palaeontologia Africana 45, 1-5.

VAN DIJK, D.E. 1981. A study of the type locality of Lidgettonia africana Thomas 1958. Palaeontologia africana 24, 43-61.

VAN DIJK, D.E. 1998. Insect faunas of South Africa from the Upper Permian and the Permian / Triassic boundary. Palaeontologia Africana 34, 34-48.

VAN DIJK, D.E. 2000. Contributions to knowledge of some southern African fossil sites and their fossils. M.Sc. Thesis, University of Stellenbosch, Cape Town, 167 pp.

WELLS, L.H. & COOKE, H.B.S. 1942. The associated fauna and culture of Vlakkraal thermal springs, O.F.S.; III, the faunal remains. Transactions of the Royal Society of South Africa 29: 214-232.

8. QUALIFICATIONS & EXPERIENCE OF THE AUTHOR

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

Since 2002 Dr Almond has also carried out palaeontological impact assessments for developments and conservation areas in the Western, Eastern and Northern Cape under the aegis of his Cape Town-based company *Natura Viva* cc. He is 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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