PALAEONTOLOGICAL IMPACT ASSESSMENT: BASIC ASSESSMENT STUDY & PROPOSED EXEMPTION FROM FURTHER SPECIALIST PALAEONTOLOGICAL STUDIES

PROPOSED KLOOFSIG SOLAR PV FACILITY ON THE REMAINDER OF FARM KALK POORT 18, RENOSTERBERG LOCAL MUNICIPALITY NEAR COLESBERG, NORTHERN CAPE

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

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1. EXECUTIVE SUMMARY

It is proposed to develop a solar PV facility of approximately 450 MW generation capacity on the Farm Kloofsig (Remainder of Farm Kalk Poort 18), situated in the Renosterberg Local Municipality *c*. 60 km SE of Hopetown and *c*. 95 km NW of Colesberg, Northern Cape. The development would take place in six phases on privately owned agricultural land and is currently in an early planning stage so a proposed layout of the infrastructure is not yet available. The present baseline assessment study of the entire study area has been commissioned by SRK Consulting (South Africa) (Pty) Ltd, Port Elizabeth.

The study area for the proposed Kloofsig Solar PV Facility near Colesberg is underlain by (1) potentially fossiliferous basinal sediments of the marine to lacustrine Tierberg Formation (Ecca Group, Karoo Supergroup) of Middle Permian age that are locally intruded by (2) unfossiliferous Early Jurassic igneous rocks of the Karoo Dolerite suite. The Tierberg mudrocks are very poorly exposed due to the pervasive cover by Late Caenozoic superficial sediments (calcrete, soils, surface gravels, alluvium *etc*). These younger deposits are most thickly developed in association with drainage areas and small dams in the north-western portion of the study area. Here the Ecca mudrocks are generally weathered and extensively calcretised near-surface. Well-exposed bedding planes that might reveal fossil material are not seen. The numerous large concretions of rusty-brown iron carbonate and silicified mudstone encountered at some horizons within the Tierberg succession are apparently unfossiliferous; complex stromatolite-like features seen within them are not of biological origin. Baking by dolerite intrusion has probably further compromised fossil preservation within the Ecca mudrocks. No fossil material, such as mammalian bones or teeth or calcretised termitaria, was recorded within the moderately thick (up to *c*. 1.5 m) calcrete hardpan that overlies older bedrocks over much of the flat-lying portion of the Kloofsig study area. The silty to sandy alluvial deposits associated with shallow drainage lines (especially in the northwest) are also calcretised at depth and contain dispersed gravel clasts, some of which are anthropogenically flaked (*i.e.* probably Pleistocene or younger). No other fossil remains were observed within the alluvial deposits, apart from local concentrations of sun-cracked mammalian bones and teeth close to the old ruined *opstal* that are probably subfossil (historical) in nature. Widespread dispersed surface gravels within the study area are dominated by hornfels (baked mudrock), dolerite, reworked Ecca concretionary material and calcrete. The only fossil recorded within them was a single, small fragment of petrified wood, probably reworked from the Ecca Group bedrocks in the area.

In conclusion, no significant fossil heritage resources have been recorded within the Kloofsig Solar PV Facility study area. The area is inferred to be of low sensitivity in terms of palaeontological heritage and no sensitive or no-go areas have been identified within it during the present field assessment. The proposed solar energy facility on RE/18 (Farm Kalk Poort) near Colesberg is of

LOW impact significance with respect to palaeontological heritage resources. Pending the discovery of substantial new fossil remains during development, no further specialist palaeontological studies or mitigation are considered necessary for this project.

In the case of any substantial 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: Mrs Colette Scheermeyer, P.O. Box 4637, Cape Town 8000. Tel: 021 462 4502. Email: cscheermeyer@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 development.

2. INTRODUCTION & BRIEF

The company Africoast Energy, Port Elizabeth, is proposing to develop a solar PV facility of approximately 450 MW generation capacity on the Farm Kloofsig (Remainder of Farm Kalk Poort 18), known as the Kloofsig Solar PV Facility, which is situated in the Renosterberg Local Municipality *c*. 60 km SE of Hopetown and *c*. 95 km NW of Colesberg, Northern Cape (Fig. 1). The development would take place in six phases on privately owned agricultural land and is currently in an early planning stage so a proposed layout of the infrastructure is not yet available.

The required Environmental Impact Assessment process associated with the development is being co-ordinated by SRK Consulting (South Africa) (Pty) Ltd, Port Elizabeth (Contact details: Ms Nicola Rump, SRK Consulting (South Africa) (Pty) Ltd. Ground Floor, Bay Suites, 1a Humewood Rd, Humerail, Port Elizabeth, 6000. P O Box 21842, Port Elizabeth, 6000. Tel: +27-041-5094800. Fax: +27-041-5094850. Email: NRump@srk.co.za).

The present palaeontological heritage basic assessment study of the proposed development area has been commissioned by SRK Consulting as part of a spectrum of heritage assessment studies. The brief for the field assessment was to assess the whole site and to flag any sensitive or no-go areas to inform the final layout.

Fieldwork for the palaeontological heritage assessment was carried out over two days during the period 17 to 19 June 2015.

1.3. Legislative context for palaeontological assessment studies

The present combined desktop and field-based palaeontological heritage report falls under Sections 35 and 38 (Heritage Resources Management) of the South African Heritage Resources Act (Act No. 25 of 1999), and it will also inform the Environmental Management Plan for this project.

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

- geological sites of scientific or cultural importance;
- palaeontological sites;
- 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).

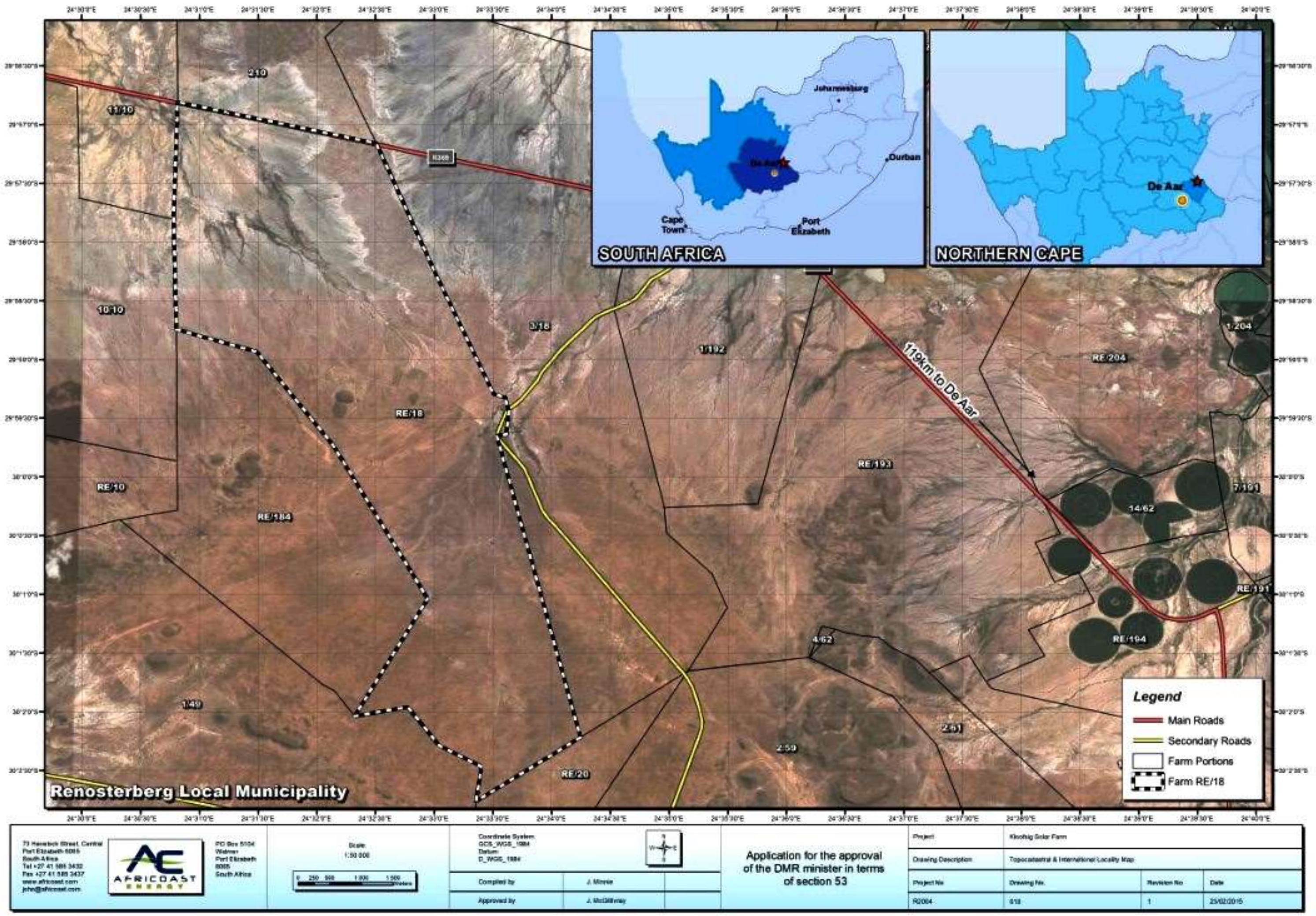

Fig. 1. Map showing the location (dashed outline) of the proposed Kloofsig Solar PV Facility study area on Farm RE/18, situated *c*. 95 km to the northwest of Colesberg, Northern Cape (Image kindly provided by SRK Consulting, Port Elizabeth).

2.1. General approach used for this palaeontological impact study

This PIA report provides an assessment of the observed or inferred palaeontological heritage within the broader study area, with recommendations for specialist palaeontological mitigation where this is considered necessary. The report is based on (1) a review of the relevant scientific literature, including previous palaeontological impact assessments in the area (*e.g.* Almond 2013a, 2013b), (2) published geological maps and accompanying sheet explanations, (3) a two-day field study in the area near Colesberg (17 to 19 June 2015) as well as (4) the author's extensive field experience with the formations concerned and their palaeontological heritage (*e.g.* Almond & Pether 2008).

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 scoping during the compilation of the final report). This data is then used to assess the palaeontological sensitivity of each rock unit to development (Provisional tabulations of palaeontological sensitivity of all formations in the Western, Eastern and Northern Cape have already been compiled by J. Almond and colleagues; *e.g.* Almond & Pether 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 notably the extent of fresh bedrock excavation envisaged. When rock units of moderate to high palaeontological sensitivity are present within the development footprint, a field assessment study by a professional palaeontologist is usually warranted.

The focus of palaeontological field assessment is *not* simply to survey the development footprint or even the development area as a whole (*e.g.* farms or other parcels of land concerned in the development). Rather, the palaeontologist seeks to assess or predict the diversity, density and distribution of fossils within and beneath the study area, as well as their heritage or scientific interest. This is primarily achieved through a careful field examination of one or more representative exposures of all the sedimentary rock units present (*N.B.* Metamorphic and igneous rocks rarely contain fossils). The best rock exposures are generally those that are easily accessible, extensive, fresh (*i.e.* unweathered) and include a large fraction of the stratigraphic unit concerned (*e.g.* formation). These exposures may be natural or artificial and include, for example, rocky outcrops in stream or river banks, cliffs, quarries, dams, dongas, open building excavations or road and railway cuttings. Uncemented superficial deposits, such as alluvium, scree or wind-blown sands, may occasionally contain fossils and should also be included in the field study where they are well-represented in the study area. It is normal practice for impact palaeontologists to collect representative, well-localized (*e.g.* GPS and stratigraphic data) samples of fossil material during field assessment studies. In order to do so, a fossil collection permit from SAHRA is required and all fossil material collected must be properly curated within an approved repository (usually a museum or university collection).

Note that while fossil localities recorded during field work within the study area itself are obviously highly relevant, most fossil heritage here is embedded within rocks beneath the land surface or obscured by surface deposits (soil, alluvium *etc*) and by vegetation cover. In many cases where levels of fresh (*i.e.* unweathered) bedrock exposure are low, the hidden fossil resources have to be *inferred* from palaeontological observations made from better exposures of the same formations elsewhere in the region but outside the immediate study area. Therefore a palaeontologist might reasonably spend far *more* time examining road cuts and borrow pits close to, but outside, the study area than within the study area itself. Field data from localities even further afield (*e.g.* an adjacent province) may also be adduced to build up a realistic picture of the likely fossil heritage within the study area.

On the basis of the desktop and field 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. Mitigation by a professional palaeontologist – normally involving the recording and sampling of fossil material and associated geological information (*e.g.* sedimentological and taphonomic data) – is usually most effective 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, SAHRA (Contact details: Mrs Colette Scheermeyer, P.O. Box 4637, Cape Town 8000. Tel: 021 462 4502. Email: cscheermeyer@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.

3. GEOLOGICAL BACKGROUND

The study area on Farm RE/18 Kalk Poort comprises semi-arid, predominantly flat-lying terrain some 6 km or more to the southwest of the Orange River (Fig. 1). The R369 tar road to Orania runs along the northern boundary. A west-east trending row of several low, isolated dolerite *koppies* lies approximately due west of the Kloofsig farmstead. To the south of the *koppies* the terrain shows very little relief, lying between c. 1200 and 1245 m amsl., with the occasional very shallow drainage course. The area to the north of the *koppies* comprises a gently north-sloping, flat plateau at *c*. 1160 to 1200 m amsl that has been incised along the western and eastern edges by dendritic networks of drainage lines flowing to the northwest and northeast respectively; these intermittent-flowing streams feed into south bank tributaries of the Orange River.

The geology of the study area is outlined on 1: 250 000 geology sheet 2924 Koffiefontein and the adjoining northern margin of sheet 3024 Colesberg (Council for Geoscience, Pretoria) (Fig. 2), with accompanying short sheet explanations by Zawada (1992) and Le Roux (1993) respectively. The study area lies within the northern margins of the Main Karoo Basin and is largely underlain by sedimentary bedrocks of the Permian **Ecca Group** (Karoo Supergroup), notably by dark basinal shales of the **Tierberg Formation** (Pt).

The Tierberg Formation is a thick, recessive-weathering, mudrock-dominated succession consisting predominantly of dark, often brown to grey, well-laminated, carbonaceous shales with subordinate thin, fine-grained sandstones (Prinsloo 1989, Le Roux 1993, Viljoen 2005, Johnson *et al*., 2006). The Tierberg shales are Early to Middle Permian in age and were deposited in a range of offshore, quiet water environments below wave base. These include basin plain, distal turbidite fan and distal prodelta in ascending order (Viljoen 2005, Almond *in* Macey *et al.* 2011). Thin coarsening-upwards cycles occur towards the top of the formation with local evidence of soft-sediment deformation, ripples and common calcareous concretions. Thin water-lain tuffs (volcanic ash layers) are also known. A restricted, brackish water environment is reconstructed for the Ecca Basin at this time. Close to the contact with Karoo dolerite intrusions the Tierberg mudrocks are often baked to a dark grey hornfels with a reddish-brown crust (Prinsloo 1989).

The Karoo Supergroup sedimentary bedrocks within the study area are largely undeformed, with low, subhorizontal bedding dips except perhaps in the immediate vicinity of igneous intrusions. Exposure levels of the Tierberg mudrocks are generally poor due to the low topographic relief and extensive cover by superficial calcrete, alluvium, soils and surface gravels. Extensive bedding planes – a prime focus for fossil recording - were not encountered. Most of the better exposures are associated with shallow water courses and steeper hillslopes, such as seen in the north-western portion of the study area (Figs. 5 to 8, 11). Here the Tierberg mudrocks are extensively weathered and disrupted by calcrete veins as well as irregular calcrete bodies near-surface. Abundant large, prominent-weathering, sphaeroidal diagenetic concretions occur at several horizons. These may reach diameters of a meter or more and often consist of a softer core of rusty-brown ferruginous carbonate surrounded by a rim of pale grey, tough, silicified mudrock. The carbonate core frequently shows well-developed cone-in-cone structures indicating mineral growth under a substantial overburden pressure (Fig. 21). Laterally extensive lenses or bands of grey silicified mudrock up to a couple of dm thick may be associated with the concretionary horizons. Thin (few cm) pale yellowish-grey cherty beds might be tuffitic in nature, *i.e.* originally comprising an admixture of volcanic ash and fine-grained siliciclastic material. Good vertical sections through fresher, thin-bedded to laminated mudrocks of the Tierberg Formation can be seen in road cuttings in the vicinity of the Vanderkloof Dam, some 16 km east of the Kloofsig study area (Fig. 3) as well as in borrow pits just east and north of the study area.

The Tierberg mudrocks in the Kloofsig study area are extensively intruded by dolerites of the **Karoo Dolerite Suite** (Jd). These form part of a suite of basic igneous bodies (dykes, sills) that were intruded into sediments of the Main Karoo Basin in the Early Jurassic Period, about 183 million years ago (Duncan & Marsh 2006, Cole *et al.* 2004). These dolerites form part of the Karoo Igneous Province of Southern Africa that developed in response to crustal doming and stretching preceding the break-up of Gondwana. Close to the margins of the intrusions the country mudrocks have been thermally metamorphosed or baked to form tough, splintery hornfels.

The precise extent of dolerite intrusion beneath the study area is currently unclear due to the widespread cover of the ancient bedrocks by calcrete hardpans and other superficial sediments (alluvium / soil / gravels *etc*). Dolerite is mapped at or close to the surface in the central and south-western portions of the study area, building the series of small bouldery *koppies* to the west of Kloofsig farmstead (Fig. 4), and is clearly also present locally beneath parts of the north-eastern plateau, as shown by locally abundant doleritic rubble at surface here.

Various types of **superficial deposits** of Late Caenozoic (Miocene / Pliocene to Recent) age occur widely throughout the Karoo study region (*e.g.* Holmes & Marker 1995, Cole *et al.* 2004, Partridge *et al.* 2006). They include pedocretes (*e.g*. calcretes), colluvial slope deposits, down-wasted surface gravels, river alluvium, wind-blown sands as well as spring and pan sediments. This mantle of superficial deposits obscures the Palaeozoic and Mesozoic bedrock geology in most parts of the Kloofsig study area. Furthermore, deep chemical weathering in the Late Cretaceous to Tertiary interval has probably converted some of the near-surface Ecca rocks to *in situ* weathered saprolite (Fig. 6). Useful geological overviews of talus deposits, alluvium and calcrete occurrences in a semi-arid Karoo region are given by Cole *et al.* (2004).

A well-developed **calcrete hardpan** (Qc) of Neogene (probably Quaternary) age mantles the older bedrocks over large portions of the study area, although it is only mapped as such in the northeast where a thin white calcrete rim can be seen running along the relict plateau in satellite images. Good vertical sections through the calcrete hardpan are seen along the eastern and western plateau edges (in part just outside the study area itself) (Figs. 8 to 10). Here the hardpan is up to 1.5 m thick, with a solid to rubbly or cavernous texture. Towards the base the hardpan incorporates abundant angular shards of mudrock indicating *in situ* brecciation during calcrete formation. Basal gravels were not observed. Numerous irregular veins and bodies of calcrete extend down into the underlying weathered Tierberg mudrocks (Fig. 4). Weathering and erosion of the hardpan has generated calcrete rubble that mantles the plateau surface and has been reworked downslope as an extensive colluvial apron (Figs. 7 & 8).

Thin to moderately thick (few m) deposits of silty, sandy and gravelly **alluvium** of Late Caenozoic age (< 5 Ma) are found in association with shallow stream beds in the lower-lying north-western sector of the study area where they are sometimes well-exposed in vertical section by *donga* erosion (Figs. 16 to 19). In some areas semi-consolidated, pale (calcretised) older alluvial deposits with abundant dispersed gravels or thin gravel lenticles can be clearly distinguished from overlying unconsolidated, pale brown younger alluvial deposits with fewer gravels, apart from a surface concentration of downwasted material. The older alluvium may contain flaked artefacts of pale grey quartzite or hornfels (especially concentrated near old spring eyes), indicating a Pleistocene or younger age for these deposits. It is locally cross-bedded and may contain thick lenticles of reworked calcrete glaebules. Deeper weathering of Tierberg bedrocks in the neighbourhood of the old ruined *opstal* has generated poorly-consolidated, pale, calcretised saprolite beneath a thin, harder capping of relict pediment gravels (mainly dolerite, hornfels, concretionary rubble) (Fig. 6).

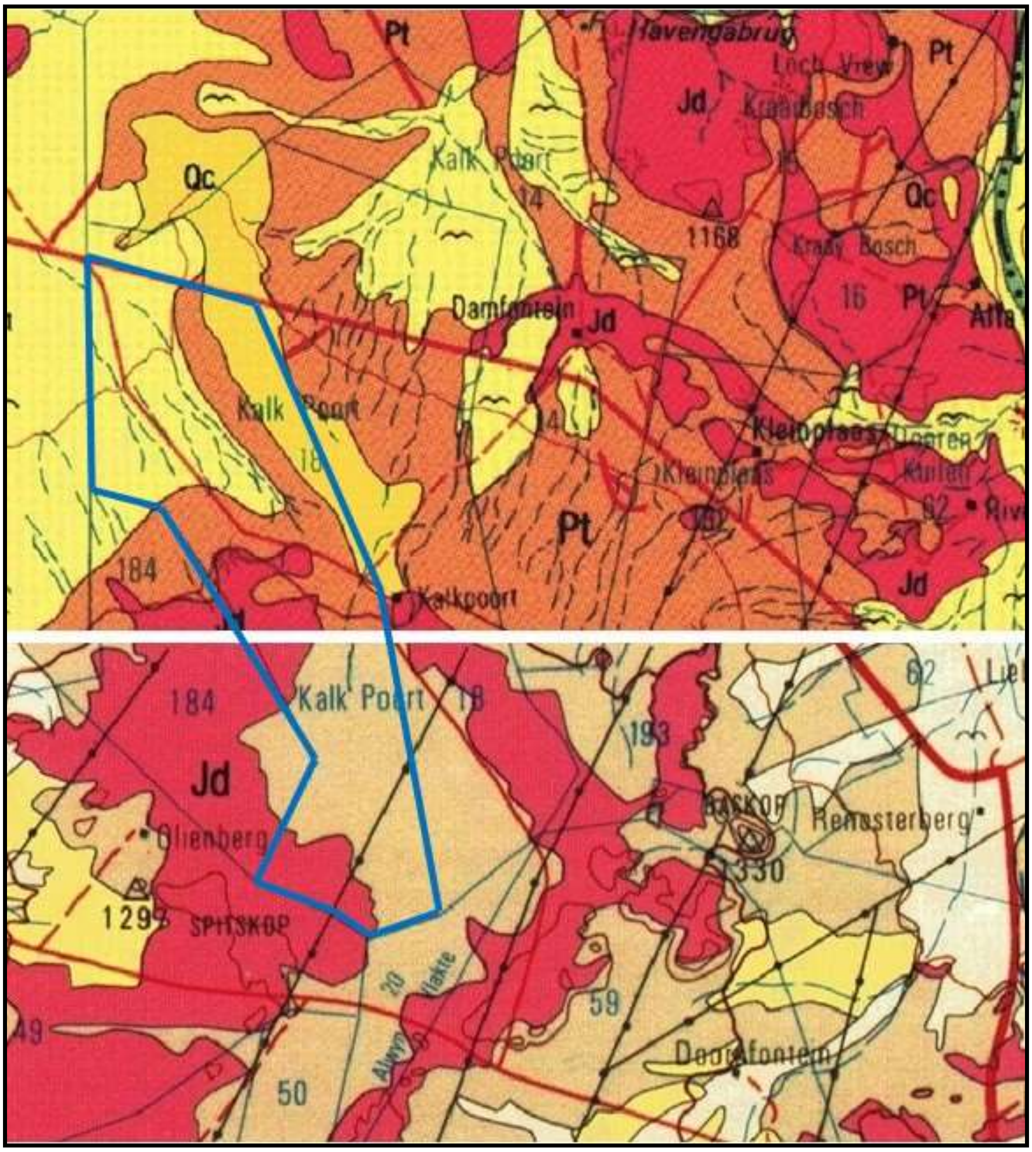

Fig. 2. Extracts from the southern margin of 1: 250 000 geology sheet 2924 Koffiefontein and the adjoining northern margin of sheet 3024 Colesberg showing the geology of the Kloofsig Solar PV Facility study area study area on farm RE/18 (blue polygon, approximate boundaries only), *c*. 95 km northwest of Colesberg, Northern Cape (Council for Geoscience, Pretoria). The main rock units represented within the study area are:

1. KAROO SUPERGROUP (ECCA GROUP)

Tierberg Formation (Pt, orange / pale brown)

2. KAROO DOLERITE SUITE

Dolerite sills and dykes (J-d, pink)

3. LATE CAENOZOIC SUPERFICIAL SEDIMENTS

Stream and river alluvium (pale yellow with flying bird symbol), calcrete hardpans (Qc, dark yellow)

A sparse to thin veneer of **downwasted surface gravels** is present overlying reddish-brown silty to sandy soils and exposed calcrete hardpan throughout much of the study area (Figs. 12 to 14). Clasts are predominantly angular to poorly-rounded and of local origin, consisting mainly of rusty-patinated hornfels (often anthropogenically flaked), calcrete, quartzite, dolerite, ferruginous carbonate and siliceous mudrock of concretionary origin, together with much rarer exotic cherts (*e.g.* reddish banded ironstone chert, probably transported from the Orange River). Pale rounded patches speckling flat-lying plateau areas, especially in the north east, are often associated with intensely mammalian-burrowed soils overlying calcrete on the ground (Fig. 15). At least some of these patches may represent *heuweltjies, i.e.* patches of preferentially-cemented, erosion-resistant ground at the sites of pre-existing bush clumps (Cramer *et al.* 2012).

Fig. 3. Road cutting exposure of Tierberg Formation mudrocks and concretionary horizons near Vanderkloof Dam, *c*. 16 km east of the Kloofsig study area.

Fig. 4. Dolerite corestones littering the outcrop area of the Karoo Dolerite suite to the west of Kloofsig homestead. Dolerite is an unfossiliferous igneous rock.

Fig. 5. Riverbank exposure of grey Tierberg mudrocks with large, prominent-weathering diagenetic concretions, showing the rusty-brown ferruginous carbonate core. North-western portion of Kloofsig.

Fig. 6. Riverbank exposure of weathered Tierberg mudrocks veined with calcrete and mantled with downwasted ferruginous concretions. In the background pale calcretised older alluvium is overlain by brownish younger alluvial deposits. Area just north of the *ou opstal*, Kloofsig (Hammer = 30 cm).

Fig. 7. Western slopes of the calcrete plateau in the north-eastern portion of Kloofsig showing grey Tierberg bedrocks largely mantled in downwasted calcrete colluvial gravels.

Fig. 8. Calcrete hardpan capping weathered, calcretised Tierberg bedrocks along the eastern edge of the plateau, just outside and east of the Kloofsig study area.

Fig. 9. Detail of the site seen in the previous figure showing the rubbly, weathered fabric of the thick calcrete hardpan (Hammer = 30 cm).

Fig. 10. Vertical section through the calcrete hardpan along the western margin of the calcrete plateau, NE Kloofsig (Hammer = 30 cm). Note the angular shale fragments incorporated into the lower portion of the hardpan.

Fig. 11. Calcrete veins and rubble as well as weathered-out ferruginous concretion overlying the Tierberg Formation bedrocks just east of the Kloofsig study area (Hammer = 30 cm).

Fig. 12. General view of the flat-lying terrain with thin surface gravels, sandy soils and karroid bossies that characterises the southern portion of the Kloofsig study area. Note total lack of bedrock exposure in the *vlaktes* here.

Fig. 13. General view of the flat-lying terrain with thin surface gravels, reddish-brown sandy soils and karroid bossies that characterises the northeastern portion of the Kloofsig study area. Note total lack of bedrock exposure here.

Fig. 14. Surface exposure of calcrete hardpan with dispersed downwasted angular gravels (mainly hornfels) in the area illustrated in the preceding figure (Scale = *c*. 15 cm).

Fig. 15. Pale, sparsely-vegetated patches of calcrete-rich soil that typify the calcrete plateau in the north-eastern sector of Kloofsig. These patches tend to be heavily burrowed by small mammals and are visible on satellite images.

Fig. 16. Riverbank section in the north-western part of Kloofsig showing grey, weathered Tierberg mudrocks enclosing large diagenetic nodules and overlain by thick, gravelly alluvial deposits (Hammer = 30 cm).

Fig. 17. Alluvial *vlaktes* associated with wooded stream courses and thin sheetwash gravels in north-western Kloofsig.

Fig. 18. Detail of downwasted, sheet-washed alluvial gravels of reworked hornfels, dolerite, calcrete *etc* in the area illustrated in the previous figure (Hammer = 30 cm). Note rounding of many larger clasts.

Fig. 19. Erosional gulley exposure of thick alluvial deposits to the west of the *ou opstal*, Kloofsig. Here Tierberg bedrocks are sharply overlain by pale, well-consolidated older alluvium rich in reworked calcrete clasts, capped in turn by pale brown, unconsolidated younger silty to sandy alluvium.

4. PALAEONTOLOGICAL HERITAGE

The fossil heritage within each of the major sedimentary rock units that are represented within the Kloofsig study area has been summarized in previous desktop and field-based palaeontological studies by the author for the region near Hopetown (*e.g.* Almond 2013a, 2013b). The dolerite outcrops in the study area are in themselves of no palaeontological significance. These are high temperature igneous rocks emplaced at depth within the Earth's crust so they do not contain fossils.

4.1. Fossil heritage within the Tierberg Formation

The fossil record of the Tierberg Formation in the Loeriesfontein sheet area and elsewhere within the Main Karoo Basin has been reviewed in detail by Almond *in* Macey *et al.* (2011). Rare body fossil records include disarticulated microvertebrates (*e.g.* fish teeth and scales) from calcareous concretions in the Koffiefontein sheet area (Zawada 1992) and allochthonous plant remains (leaves, petrified wood). The latter become more abundant in the upper, more proximal (prodeltaic) facies of the Tierberg succession (*e.g.* Wickens 1984). Prinsloo (1989) records numerous plant impressions and unspecified "fragmentary vertebrate fossils" within fine-grained sandstones in the Britstown sheet area. Dark carbonaceous Ecca mudrocks are likely to contain palynomorphs (*e.g.* pollens, spores, acritarchs).

The commonest fossils by far in the Tierberg Formation are sparse to locally concentrated assemblages of trace fossils that are often found in association with thin event beds (*e.g.*distal turbidites, prodeltaic sandstones) within more heterolithic successions. A modest range of ten or so different ichnogenera have been recorded from the Tierberg Formation (*e.g.* Abel 1935, Anderson 1974, 1976, Wickens 1980, 1984, 1994, 1996, Prinsloo 1989, De Beer *et al*., 2002, Viljoen 2005, Almond *in* Macey *et al.* (2011)). These are mainly bedding parallel, epichnial and hypichnial traces, some preserved as undertracks. Penetrative, steep to subvertical burrows are rare, perhaps because the bottom sediments immediately beneath the sediment / water interface were anoxic. Most Tierberg ichnoassemblages display a low diversity and low to moderate density of traces. Apart from simple back-filled and / or lined horizontal burrows (*Planolites, Palaeophycus*) they include arthropod trackways (*Umfolozia*) and associated resting impressions (*Gluckstadtella*), undulose fish swimming trails (*Undichna*) that may have been generated by bottom-feeding palaeoniscoids, horizontal epichnial furrows (so-called *Scolicia*) often attributed to gastropods (these are also common in the co-eval Collingham Formation; Viljoen 1992, 1994), arcuate, finely striated feeding excavations of an unknown arthropod (*Vadoscavichnia*), beaded traces ("*Hormosiroidea*" or "*Neonereites*"), small sinusoidal surface traces (*Cochlichnus*), small star-shaped feeding burrows (*Stelloglyphus*) and zigzag horizontal burrows (*Beloraphe*), as well as narrow (< 1cm) *Cruziana carbonaria* scratch burrows. The symmetrical, four-pronged trace *Broomichnium* (= *Quadrispinichna* of Anderson, 1974 and later authors) often occurs in groups of identical size (*c*. 3.5cm wide) and similar orientation on the bedding plane. This trace has frequently been misinterpreted as a web-footed tetrapod or arthropod trackway (*e.g.* Van Dijk *et al*. 2002 and references therein). However, Braddy and Briggs (2002) present a convincing case that this is actually a current-orientated arthropod resting trace (cubichnion), probably made by small crustaceans that lived in schools of similar-sized individuals and orientated themselves on the seabed with respect to prevailing bottom currents. Distinctive broad (3-4 cm), strap-shaped, horizontal burrows with blunt ends and a more-or-less pronounced transverse ribbing occur widely within the Tierberg mudrocks. They have been described as "fucoid structures" by earlier workers (*e.g.* Ryan 1967) by analogy with seaweeds, and erroneously assigned to the ichnogenera *Plagiogmus* by Anderson (1974) and *Lophoctenium* by Wickens (1980, 1984). Examples up to one metre long were found in Tierberg mudrocks near Calvinia in 1803 by H. Lichtenstein, who described them as "eel fish". These are among the first historical records of fossils in South Africa (MacRae 1999). These as yet unnamed burrows are infilled with organized arrays of faecal pellets (Werner 2006). Sandstone sole surfaces with casts of complex networks of anastomosing (branching and fusing) tubular burrows have been attributed to the ichnogenus *Paleodictyon*

(Prinsloo 1989) but may more appropriately assigned to *Megagrapton* (Almond 1998). These so-called graphoglyptid burrows are associated with turbidite facies from the Ordovician to Recent times and have been interpreted as gardening burrows or *agrichnia* (Seilacher, 2007). Microbial mat textures, such as *Kinneyia*, also occur in these offshore mudrocks but, like the delicate grazing traces with which they are often associated, are generally under-recorded.

No fossils were recorded directly from the Tierberg Formation in the Kloofsig study area. However, an isolated small fragment of silicified wood showing well-developed seasonal growth banding that was recognised among surface gravels on the north-eastern plateau has probably been reworked from the Tierberg bedrocks in the region (Fig. 20). Complex, stromatolite-like ribbed structures frequently seen within ferruginous carbonate concretions are abiogenic cone-in-cone structures and not true fossils (Fig. 21). The concretions appear to be late diagenetic in origin and no macroscopic fossil remains were observed within them (although various microfossils might be preserved here).

4.2. Fossil heritage within the 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). Other late Caenozoic fossil biotas from these superficial deposits include non-marine molluscs (bivalves, gastropods), ostrich egg shells, trace fossils (*e.g.* calcretised termitaria, coprolites), and plant remains such as peats or palynomorphs (pollens, spores) in organic-rich alluvial horizons (Scott 2000) and siliceous 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). Stone artefacts of Pleistocene and younger age may additionally prove useful in constraining the age of superficial deposits such as gravelly alluvium within which they are occasionally embedded (Fig. 19).

No fossil remains were recorded within superficial deposits of the Kloofsig Solar PV Facility study area during the present field assessment. Local concentrations of mammalian bones and teeth observed with and overlying younger alluvium in the vicinity of the *ou opstal* (NW study area) are frequently highly sun-cracked and probably subfossil (historical) in nature (Figs. 22 to 23).

Fig. 20. Isolated fragment (*c*. 4 cm across) of silicified fossil wood – probably reworked from the Middle Permian Tierberg Formation – recorded from surface gravels overlying the calcrete plateau, north-eastern Kloofsig.

Fig. 21. Stromatolite-like texture seen within many ferruginous carbonate concretions of the Tierberg Formation (Scale in cm and mm). This is an abiogenic structure, not a true fossil.

Fig. 22. Scatter of disarticulated, sun-cracked mammalian bones and teeth weathering out from soft younger alluvium close to the *ou opstal*, NW Kloofsig (Hammer = 30 cm).

Fig. 23. Close-up of unidentified larger, suncracked mammalian tooth seen in the previous figure (Scale in cm and mm).

5. SUMMARY & RECOMMENDATIONS

The study area for the proposed Kloofsig Solar PV Facility near Colesberg is underlain by (1) potentially fossiliferous basinal sediments of the marine to lacustrine Tierberg Formation (Ecca Group, Karoo Supergroup) of Middle Permian age that are locally intruded by (2) unfossiliferous Early Jurassic igneous rocks of the Karoo Dolerite suite. The Tierberg mudrocks are very poorly exposed due to the pervasive cover by Late Caenozoic superficial sediments (calcrete, soils, surface gravels, alluvium *etc*). These younger deposits are most thickly developed in association with drainage areas and small dams in the north-western portion of the study area. Here the Ecca mudrocks are generally weathered and extensively calcretised near-surface. Well-exposed bedding planes that might reveal fossil material are not seen. The numerous large concretions of rusty-brown iron carbonate and silicified mudstone encountered at some horizons within the Tierberg succession are apparently unfossiliferous; complex stromatolite-like features seen within them are not of biological origin. Baking by dolerite intrusion has probably further compromised fossil preservation within the Ecca mudrocks. No fossil material, such as mammalian bones or teeth or calcretised termitaria, was recorded within the moderately thick (up to *c*. 1.5 m) calcrete hardpan that overlies older bedrocks over much of the flat-lying portion of the Kloofsig study area. The silty to sandy alluvial deposits associated with shallow drainage lines (especially in the northwest) are also calcretised at depth and contain dispersed gravel clasts, some of which are anthropogenically flaked (*i.e.* probably Pleistocene or younger). No other fossil remains were observed within the alluvial deposits, apart from local concentrations of sun-cracked mammalian bones and teeth close to the old ruined *opstal* that are probably subfossil (historical) in nature. Widespread dispersed surface gravels within the study area are dominated by hornfels (baked mudrock), dolerite, reworked Ecca concretionary material and calcrete. The only fossil recorded within them was a single, small fragment of petrified wood, probably reworked from the Ecca Group bedrocks in the area.

In conclusion, no significant fossil heritage resources have been recorded within the Kloofsig Solar PV Facility study area. The area is inferred to be of low sensitivity in terms of palaeontological heritage and no sensitive or no-go areas have been identified within it during the present field assessment. The proposed solar energy facility on RE/18 (Farm Kalk Poort) near Colesberg is of LOW impact significance with respect to palaeontological heritage resources. Pending the discovery of substantial new fossil remains during development, no further specialist palaeontological studies or mitigation are considered necessary for this project.

In the case of any substantial 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: Mrs Colette Scheermeyer, P.O. Box 4637, Cape Town 8000. Tel: 021 462 4502. Email: cscheermeyer@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 development.

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8. QUALIFICATIONS & EXPERIENCE OF THE AUTHOR

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

Since 2002 Dr Almond has also carried out palaeontological impact assessments for developments and conservation areas in the Western, Eastern and Northern Cape 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 project, application or appeal in respect of which I was appointed other than fair remuneration for work performed in connection with the activity, application or appeal. There are no circumstances that compromise the objectivity of my performing such work.

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