PALAEONTOLOGICAL ASSESSMENT: DESKTOP STUDY

PROPOSED NELSON MANDELA BAY MUNICIPALITY SEWAGE GRIT AND SLUDGE TREATMENT FACILITY, PORT ELIZABETH, EASTERN CAPE

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

September 2017

1. SUMMARY

Nelson Mandela Bay Municipality (NMBM) is proposing to construct a sewage grit and sludge treatment facility in the Swartkops area on the northern outskirts of Port Elizabeth, Eastern Cape. Three site options are currently under consideration.

The site at the existing Brickfields Waste Water Treatment Works (WWTW) to the north of the Swartkops River overlies highly fossiliferous estuarine to marine sediments of the Sundays River Formation and possibly also the Alexandria Formations. In the unlikely event that this site is authorised, a specialist palaeontological field assessment would be required and monitoring might be needed during excavation.

The two southern site options at or close to the existing Fish Water Flats WWTW south of the Swartkops River overlie potentially fossil-bearing coastal and fluvial sediments of Early Cretaceous to Quaternary and younger age. Estuarine to shallow marine rocks of the Quaternary to Holocene Salnova Formation that are mapped at surface in the study areas might contain rich assemblages of molluscs and other invertebrates such as recorded from Brighton Beach *c*. 0.5 km to the southeast. Cretaceous fluvial sediments of the Kirkwood Formation are present beneath the surface mantle of Swartkops Formation deposits and might be intersected by deeper (> 3 m) excavations made during construction. Plant fossils, petrified wood and even rare dinosaur bones may be present in the Kirkwood rocks. There is a preference on palaeontological grounds for the site within the existing Fish Water Flats WWTW because this area is probably more disturbed, judging from satellite images.

For both the southern site options it is concluded that, *provided that* the chosen site for the sewage grit and sludge treatment facility overlies highly-disturbed terrain with little prospect of fresh, fossiliferous bedrocks being intersected during construction, then the impact significance would be LOW and no further specialist input or mitigation is recommended here. However, any substantial excavations into *previously undisturbed* bedrocks made during the construction phase of the proposed development – as will be the case for the preferred site option - are quite likely to expose, disturb and destroy fossil heritage of high palaeontological significance. In this case, the impact significance of this project without mitigation would be rated as MODERATE; *i.e.* an important impact which requires mitigation. Mitigation by a professional palaeontologist during the construction phase when fresh fossiliferous bedrock has already been exposed by excavations would then be recommended for this project. Professional mitigation should involve the monitoring of substantial excavations for newly-exposed fossil material *plus* the recording and sampling of fossil material and associated geological information (*e.g.* sedimentological and taphonomic data). The detailed scope of work and timeframes for palaeontological mitigation should be defined by the specialist concerned in consultation with the developer and the Eastern Cape Provincial Heritage Resources Agency, ECPHRA (Contact details: ECPHRA. Mr Sello Mokhanya, 74 Alexander Road, King Williams Town 5600; smokhanya@ecphra.org.za). Following mitigation, the impact

significance of the project should be reduced to LOW. The palaeontologist concerned with mitigation work will need a valid collection permit from ECPHRA. All work would have to conform to international best practice for palaeontological fieldwork and the study (*e.g.* data recording fossil collection and curation, final report) should adhere to the minimum standards for Phase 2 palaeontological studies developed by SAHRA (2013). It should be emphasized that, *providing appropriate mitigation is carried out*, the majority of developments involving fossiliferous bedrock excavation can make a *positive* contribution to our understanding of local palaeontological heritage.

It is further recommended that:

- The ECO responsible for the development should be aware of the possibility of important fossils being present or unearthed on site and should monitor at suitable intervals (*e.g.* daily) all substantial excavations into fresh (*i.e.* unweathered, undisturbed) sedimentary bedrock for fossil remains;

- In the case of any significant chance fossil finds (*e.g.* vertebrate teeth, bones, shells, petrified wood) during construction, these should be safeguarded - preferably *in situ* - and reported by the ECO as soon as possible to the relevant heritage management authority (ECPHRA). This is so that any appropriate mitigation (*i.e.* recording, sampling or collection) by a palaeontological specialist can be considered and implemented, at the developer's expense;

- These recommendations should be incorporated into the EMPr for the Nelson Mandela Bay Municipality sewage grit and sludge treatment facility project.

Provided that these mitigation measures are followed through, there are no objections on palaeontological heritage grounds to authorisation of the proposed development.

2. INTRODUCTION & BRIEF

Nelson Mandela Bay Municipality (NMBM), Eastern Cape, is proposing to construct a sewage grit and sludge treatment facility. At present sewage grit is classified as a hazardous waste and therefore should be disposed of at a hazardous waste landfill site. The aim of the proposed treatment facility is to treat the grit to a degree where it can be disposed of at one of the NMBM's general waste landfill sites. The facility will treat grit which is removed from sewer lines and pump stations during cleaning operations and from WWTW inlet works. The facility will utilise reclaimed water from the Fish Water Flats WWTW.

Three potential sites for the proposed sewage grit and sludge treatment facility that are situated both north and south of the Swartkops River are currently under consideration (See Figs. 1 & 2):

- A new site opposite the existing Fish Water Flats waste water treatment works (preferred option). This option would entail substantial new excavations in the construction phase.

- Existing Fish Water Flats Site (FWF) where there is an existing bucket treatment facility in the Fish Water Flats WWTW. This is being considered as an alternative option but it may not be feasible due to space constraints. This site would be located within the existing footprint of the WWTW.

- Existing Brickfields WWTW. This site was considered during the planning phase but is not the preferred alternative because its operation would require the use of potable water

GIBB, Port Elizabeth has been appointed by Nelson Mandela Bay Municipality to undertake a basic assessment (BA) for the proposed treatment facility (Contact details: Ms Kate Parkinson. GIBB. Port Elizabeth. 2nd Floor, Greyville House, Cnr Greyville & Cape Rd, Greenacres, Port Elizabeth 6001. PO Box 63703, Greenacres 6057. Tel: +27 41 392 7500. Fax: +27 41 363 9300. E-mail: kparkinson@gibb.co.za).

Since the proposed development will involve excavations into potentially fossiliferous bedrock of the Uitenhage and Algoa Groups, the present palaeontological impact assessment of the development has been commissioned by GIBB in accordance with the requirements of the National Heritage Resources Act, 1999.

Figure 1. Google Earth© satellite image of the Swartkops area on the northern outskirts of Port Elizabeth, Eastern Cape showing the locations (yellow markers) of the three site options for the proposed Nelson Mandela Bay sewage grit and sludge treatment facility: the existing Brickfields WWTW north of the Swartkops River, the existing Fish Water Flats WWTW on the west side of the N2 trunk road to the south of the Swartkops River (FWF), and the preferred new site opposite the latter. See also Fig. 2 for more detail of the southern site options.

Figure 2. Google Earth© satellite image showing in more detail the locations (yellow markers) of the two southern site options for the proposed Nelson Mandela Bay sewage grit and sludge treatment facility: the existing Fish Water Flats WWTW (FWF) and the new site shortly to the south.

1.1. Legislative context of this palaeontological study

The development footprint of the proposed facility overlies areas that are underlain by potentially fossil-rich sedimentary rocks of Mesozoic to Caenozoic age (Sections 2 and 3). The construction phase of the development may entail substantial surface clearance and excavations into the superficial sediment cover as well as locally into the underlying bedrock. All these developments may adversely affect fossil heritage preserved at or beneath the surface of the ground within the study area by destroying, disturbing or permanently sealing-in fossils that are then no longer available for scientific research or other public good.

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

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

According to Section 35 of the National Heritage Resources Act, dealing with archaeology, palaeontology and meteorites:
(1) The protection of archaeological and palaeontological sites and material and meteorites is the responsibility of a provincial heritage resources authority.
(2) All archaeological objects, palaeontological material and meteorites are the property of the State.

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

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

1.2. Approach to the palaeontological heritage assessment

In preparing a palaeontological desktop study the potentially fossiliferous rock units (groups, formations *etc.*) represented within the study area are determined from geological maps. The known fossil heritage within each rock unit is inventoried from the published scientific literature, previous palaeontological impact studies in the same region, and the author's field experience (Consultation with professional colleagues as well as examination of institutional fossil collections may play a role here, or later following field assessment during the compilation of the final report). This data is then used to assess the palaeontological sensitivity of each rock unit to development Provisional tabulations of palaeontological sensitivity of all formations in Eastern Cape have already been compiled by Almond *et al.* (2008). The potential impact of the proposed development on local fossil heritage is then determined on the basis of (1) the palaeontological sensitivity of the rock units concerned and (2) the nature and scale of the development itself, most significantly the extent of fresh bedrock excavation envisaged. When rock units of moderate to high palaeontological sensitivity are present within the development footprint, a Phase 1 field assessment study by a professional palaeontologist is usually warranted to identify any palaeontological hotspots and make specific recommendations for any mitigation required before or during the construction phase of the development.

On the basis of the desktop and Phase 1 field assessment studies, the likely impact of the proposed development on local fossil heritage and any need for specialist mitigation are then determined. Adverse palaeontological impacts normally occur during the construction rather than the operational or decommissioning phase. Phase 2 mitigation by a professional palaeontologist –

normally involving the recording and sampling of fossil material and associated geological information (*e.g.* sedimentological data) may be required (a) in the pre-construction phase where important fossils are already exposed at or near the land surface and / or (b) during the construction phase when fresh fossiliferous bedrock has been exposed by excavations. To carry out mitigation, the palaeontologist involved will need to apply for a palaeontological collection permit from the relevant heritage management authority, *i.e.* the Eastern Cape Provincial Heritage Resources Authority, ECPHRA (Contact details: ECPHRA. Mr Sello Mokhanya, 74 Alexander Road, King Williams Town 5600; smokhanya@ecphra.org.za). It should be emphasized that, *providing appropriate mitigation is carried out*, the majority of developments involving bedrock excavation can make a *positive* contribution to our understanding of local palaeontological heritage.

1.3. Information sources

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

1. A short project outline and kmz files provided by GIBB;

2. A review of the relevant scientific literature, including published geological maps and accompanying sheet explanations (Le Roux 2000) as well as previous palaeontological assessment reports for the broader Port Elizabeth region (*e.g.* Almond 2010, 2012);

3. The author's database on the formations concerned and their palaeontological heritage (See Almond *et al.* 2008).

1.4. Assumptions & limitations

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

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

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

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

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

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

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

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

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

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

The geology of the Swartkops area on the northern outskirts of Port Elizabeth has been mapped in some detail (Le Roux 2000) (Figs. 3 & 4 herein) and the palaeontology of the underlying sedimentary rocks is comparatively well known (Section 4). Confidence levels for this palaeontological assessment are therefore HIGH.

2. GEOLOGICAL BACKGROUND

The three site options for the proposed Nelson Mandela Bay sewage grit and sludge treatment facility are all located on the low-lying (0-50 m amsl), gently-sloping coastal plain in the Swartkops region of Port Elizabeth (Fig. 1). The area forms part of the Eastern Coastal Lowlands region of Partridge *et al.* (2010) which is incised across readily-eroded Cretaceous bedrocks of the Algoa Basin. The geology of the study area is presented on the 1: 50 000 geological map 3325DC & DD, 3425BA Port Elizabeth (Council for Geoscience, Pretoria) (Figs. 3 & 4 below).

The Brickfields WWTW is located some 1.6 km NE of the Swartkops River and 3.6 km from the coast within or adjoining an existing brick quarry which is exploiting marine mudrocks of the Early Cretaceous **Sundays River Formation** (**Uitenhage Group**) (Ks, red in Fig. 3). The Sundays River beds here are unconformably capped by Miocene to Pliocene estuarine to marine limestones and conglomerates of the Alexandria Formation at the base of the Algoa Group (Ta, pink in Fig. 3).

The two southern site options are both situated on the west side of N2 trunk road and approximately one kilometer from the present day coast (Fig. 4). The Swartkops River mouth lies only 2 km to the northeast and branches of the Swartkops estuarine system extend close to the northern edge of the study areas.

The area south of the Swartkops River estuary is mantled by a thin blanket of Late Caenozoic alluvial (river) deposits of the Swartkops drainage system and, towards the modern coast, by shallow marine to estuarine sediments of the Pleistocene to Holocene **Salnova Formation** (**Algoa Group**) (Qs, yellow in Fig. 4). Early Cretaceous fluvial sediments of the **Kirkwood Formation** (**Uitenhage Group**) (J-Kk, dark yellow in Fig. 4) crop out at surface to the southwest and west of the study area and underlie the surface veneer of Late Caenozoic sediments on the coastal plain. The mean thickness of the Salnova succession near Port Elizabeth is estimated to be only 3.5 m (Le Roux 2000), so deeper excavations during the construction phase of the proposed development may intersect the Cretaceous bedrocks. The geology and palaeontology of these rocks units have been outlined by Engelbrecht *et al*. (1962), Toerien and Hill (1989) and Le Roux (2000), as well as more recently by Almond (2010).

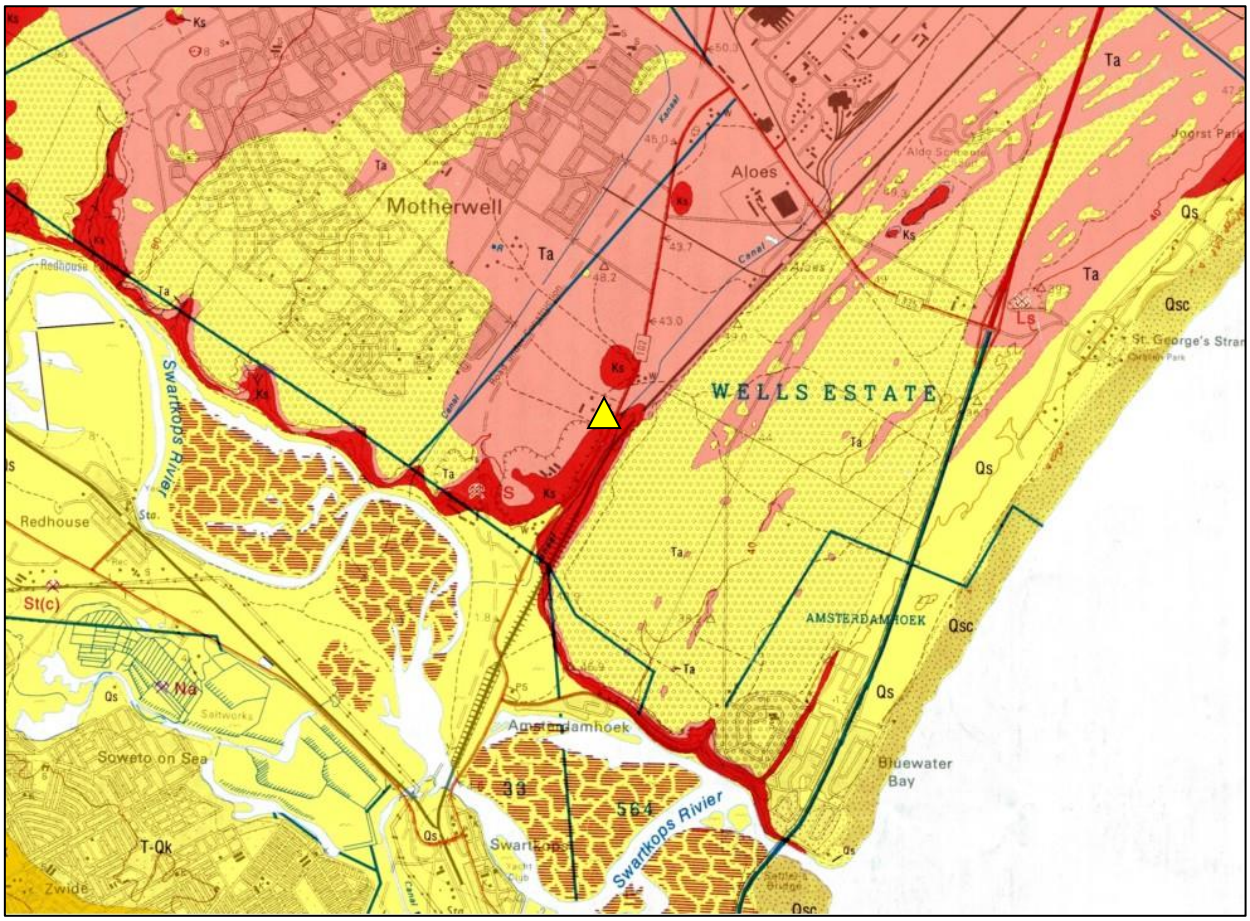

Figure 3. Extract from 1: 50 000 geological map 3325DC & DD, 3425BA Port Elizabeth (Council for Geoscience, Pretoria) showing the approximate location of the existing Brickfields WWTW to the north of the Swartkops River (yellow triangle). Rock units represented here include Ks (red) = Sundays River Formation (Uitenhage Group); Ta (pink) = Alexandria Formation (Algoa Group); T-Qk (pale yellow with stipple) = Pliocene to Quaternary fluvial deposits; Qsc (pale brown with stipple) = aeolian and beach sand, soils, middens; Qs (pale yellow) = Pleistocene to Holocene Salnova Formation (Algoa Group).

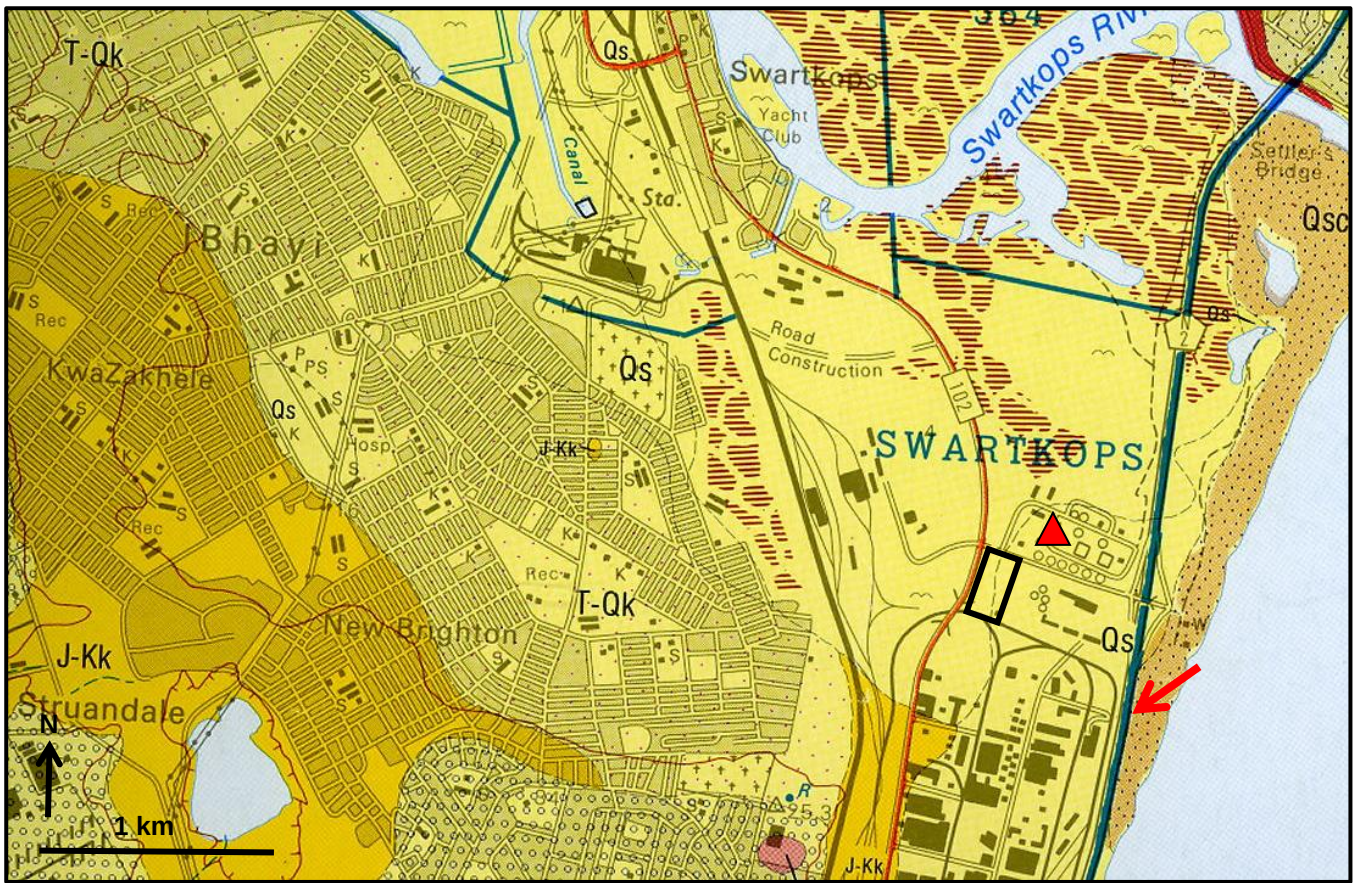

Figure 4. Extract from 1: 50 000 geological map 3325DC & DD, 3425BA Port Elizabeth (Council for Geoscience, Pretoria) showing the location at Swartkops of the Fish Water Flats WWTW alternative site (red triangle) as well as the preferred new site just to the south (black rectangle). The red arrow indicates location of the Stratotype A section of the Salnova Formation at Brighton Beach, some 0.5 km SE of the study area. Rock units represented within the broader study region include; J-Kk (dark yellow) = Early Cretaceous Kirkwood Formation (Uitenhage Group); T-Qk (pale yellow with stipple) = Pliocene to Quaternary fluvial deposits; Qsc (pale brown with stipple) = aeolian and beach sand, soils, middens; Qs (pale yellow) = Pleistocene to Holocene Salnova Formation (Algoa Group). Recent estuarine muds of the Swartkops River are shown by fine brown hatching.

The **Kirkwood Formation** (Uitenhage Group) in the Algoa Basin area comprises readily-weathered silty mudrocks and subordinate sandstones of fluvial origin and Early Cretaceous (Berriasian / Valanginian) age, *i.e.* some 140 million years old. These sediments crop out extensively south of the Swartkops River but are largely obscured here by urban development as well as a veneer of Late Caenozoic sediments, so any major new excavations into these rocks are of geological as well as palaeontological interest (Le Roux 2000). Key geological accounts of the Kirkwood beds include those by Rigassi & Dixon (1972), Winter (1973), McLachlan & McMillan (1976), Tankard *et al.* (1982), Dingle *et al.,* (1983) and Shone (2006). Early geologists called these rocks the "Variegated Marls" referring to the distinctive reddish-brown, pinkish and greenish-grey colour spectrum shown by the sediments (*NB* "marl" is a misnomer, technically referring only to calcareous, clay-rich mudrocks). Another older name for the same succession was the "Wood Beds", referring to the abundant petrified wood recorded in the Algoa Basin and elsewhere (see fossil record below). At the time that these Uitenhage sediments were being deposited, some 140 million years ago, Africa and South America – previously united within the West Gondwana supercontinent - were starting to pull apart. Uplift, faulting and erosion of the youthful southern African continent led to the rapid deposition of huge amounts of alluvium by systems of meandering rivers and estuaries fringing a new Mediterranean-sized seaway that was opening up in the southern Cape area.

The **Sundays River Formation** is of Early Cretaceous (Valanginian-Hauterivian) age, *ie* around 136 Ma (million years old). It comprises a thick (up to 2 km) succession of grey sandstones, siltstones and finer-grained mudrocks that are often highly fossiliferous (Shone 2006, Almond 2010). Depositional settings range from estuarine through littoral (shoreline) to marine outer shelf (McMillan 2003). Key geological accounts of the Sundays River Formation include those by McLachlan & McMillan (1976), Dingle *et al.,* (1983), McMillan (2003) and Shone (2006). Fine-grained mudrocks of the Sundays River beds are extensively exploited for brick making in the Port Elizabeth – Swartkops – Coega region.

The estuarine to coastal marine **Alexandria Formation** (Algoa Group) consists of a basal conglomerate rich in oyster shells overlain by calcareous sandstones, shelly coquinas and thin conglomerates (Le Roux 1987a). It represents a composite product of several marine transgression (invasion) / regression (retreat) cycles across the Algoa coastal plain in Late Miocene-Pliocene times, *i.e.* roughly around 7-5 Ma ago (Maud & Botha 2000, Roberts *et al.* 2006). The Alexandria Formation overlies a series of marine terraces incised into older (mainly Cretaceous) rocks in the hinterland of the Algoa Basin. The Alexandria Bay Formation ranges from three to 13 m in thickness, with an average of 9 to10 m, reaching its greatest thickness between the Swartkops and Sundays Rivers.

The **Salnova Formation** comprises a spectrum of well-indurated shallow marine to intertidal deposits, including calcareous beach sands, coquinites (shelly lenses or hash), shell-rich gravels and pebbly to bouldery conglomerates (Le Roux 2000, Maud & Botha 2000, Roberts *et al.* 2006, Almond 2010). These marine rocks typically crop out along the modern coast at low elevations - less than 18 m amsl according to Le Roux (1991). Intraformational clasts of older Algoa Group coquinite (shelly hash) and conglomerate are common. Finer-grained estuarine and lagoonal sediments are also found, such as the stratotype D locality designated by Le Roux (1991) near Salnova saltworks in the Coega estuary area north of Port Elizabeth; comparable mudrocks are probably associated with the Swartkops estuary in the present study area. The Salnova sediments were formed during a series of several Mid to Late Pleistocene transgressions (sea level rises). Some authors now extend the scope of this formation to include shoreline sediments of post-Pleistocene (Holocene) age. These include shell-rich cobbly and bouldery beds up to 2-3 m amsl that may reflect the Mid Holocene highstand (= sea level peak) of 4000 to 3000 BP. In the Swartkops area the Salnova beds overlie the Uitenhage Group (Kirkwood and Sundays River Formations) and are generally overlain by modern aeolianites of the Schelm Hoek Formation (Qsc in Fig. 4). Exposures of the Salnova Formation in the study area are also limited due to recent urban development. A key (Stratotype A) section through sandstones and coquinites (shell beds) of the Salnova Formation showing estuarine or lagoonal affinities has been designated by Le Roux (1991) at low cliffs on the coast at Brighton Beach, only about half a kilometer southeast of the Fish Water Flats WWTW study area (red arrow in Fig. 4).

A variety of **Late Tertiary to Recent fluvial deposits** (**T-Qk**) is preserved along the margins of the Swartkops River in the broader study region, but west of the Fish Water Flats WWTW. Detailed accounts of these deposits in the Algoa Bay region have been provided by Engelbrecht *et al*. (1962), Hattingh (1994, 1996, 2001) and Hattingh and Goedhart (1997). The fluvial sediments range from “High Level Gravels” of Miocene / Late Pliocene age situated on elevated terraces (60-15 m amsl) through to finer-grained alluvial sands and silts of Pleistocene / Holocene age close to modern river levels (10-2 m amsl; Goedhart & Hattingh 1997, Le Roux 2000). The Algoa Bay alluvial deposits comprise a range of gravels, cross-bedded and horizontally-laminated sand and silt that, in the case of the older examples, are often cemented by pedocretes such as calcrete, ferricrete or silcrete (Le Roux 2000). Fine grained **estuarine alluvium** occurs along the lower reaches of the Swartkops River Valley, and may locally reach thicknesses of over 20 m (Le Roux 2000). These deposits extend up to the northern edge of the Fish Water Flats WWTW study areas (brown-hatched patches in map Fig. 4).

3. PALAEONTOLOGICAL HERITAGE

The **Kirkwood Formation** is the most palaeontologically productive unit in southern Africa that yields terrestrial biotas of Early Cretaceous age. Its overall palaeontological sensitivity is rated as high (Almond *et al.* 2008). Fossils include vascular plants (including concentrations of petrified logs, lignite beds, charcoal), tetrapod vertebrates (notably dinosaurs) and freshwater invertebrates, among others (Du Toit 1954, Engelbrecht *et al*. 1962, McLachlan & McMillan 1976, Toerien and Hill 1989, MacRae 1999, Le Roux 2000, Almond 2010 and extensive references listed therein). Recent palaeontological research has yielded a number of new dinosaur taxa, for the most part from the Algoa Basin to the northeast of Port Elizabeth, but also from the Oudtshoorn Basin of the Little Karoo (De Klerk 2008, Rubidge *et al*., 2008). These include a range of sauropods, stegasaurs, iguanadontids and rare theropods such as the new genus of small coelurasaur *Nquebasaurus* (De Klerk 1995, 2000, 2008, De Klerk *et al.* 1998, 2000; Fig. 3). Most of the Kirkwood dinosaur fossils found so far are highly fragmentary, however. Other vertebrate fossil groups from the Kirkwood Formation include frogs, crocodiles, turtles, sphenodontid and other lizards, mammals and freshwater fish such as garfish.

The palaeobotanically famous "Variegated Marls" and "Wood Beds" of the Kirkwood Formation in the Eastern Cape have yielded a diverse fossil flora. Woody vegetation was dominated by gymnosperms including conifers such as *Araucaria* and *Podocarpus*, extinct cycad-like bennettitaleans like *Zamites*, as well as true cycads. In addition there are charophytes (stoneworts, an advanced group of freshwater algae), bryophytes (liverworts) and pteridophytes such as ferns. Angiosperms (flowering plants), which first radiated during this period, are not represented, however. Plant microfossils include pollens, spores and cuticular fragments, while amber and charcoal are locally common. So far no inclusions such as fossil insects have been recorded within the amber, which represents the oldest Cretaceous material recorded from Gondwana. Non-marine invertebrate fossils in the Kirkwood Formation are represented by freshwater or estuarine molluscs (*e.g.* unionid bivalves), rare insects such as beetles, and several groups of small crustaceans including ostracods (seed shrimps), conchostracans (clam shrimps) and notostracans (tadpole shrimps). Trace fossils include borings into petrified tree trunks that are variously attributed to bivalves (*Gastrochaena*) and insects (possibly beetles).

In palaeontological terms the **Sundays River Formation** contains one of the most prolific and scientifically important marine biotas of Mesozoic age in southern Africa. Fossils have been recorded from the Sundays River beds in the Algoa Basin since the early nineteenth century (1837). Cooper (1981) provides a good review of the earlier literature Among the key papers are those by Spath (1930), Engelbrecht *et al*. (1962), McLachlan & McMillan (1976), Klinger & Kennedy (1979), Cooper (1981, 1991), Dingle *et al*. (1983), McMillan (2003) and Shone (2006). An accessible, well-illustrated account of Sundays River fossils has recently been given by MacRae (1999). They include a wealth of Early Cretaceous molluscs (*e.g.* ammonites, bivalves) and other shelly invertebrates, microfossils, trace fossils as well as very rare marine reptiles (plesiosaurs). The ammonites and microfossils are of particular biostratigraphic importance, while the foraminiferans (a group of protozoans) are useful for palaeoenvironmental analysis.

The Miocene - Pliocene **Alexandria Formation** limestones as a whole are highly fossiliferous. A wide range of shelly marine fossils are recorded from the Alexandria Formation (Engelbrecht *et al*. 1962, Dingle *et al*., 1983, Le Roux 1987a, 1987b, 1990b, 1993). These are mainly molluscs (bivalves, gastropods, scaphopods), but also include serpulid worm tubes, sea urchins (the "sea pansy" *Echinodiscus*), solitary and colonial corals, bryozoans, brachiopods, barnacles and crab claws and benthic foraminifera. Sharks' teeth and rare fish vertebrae are also known. Diverse trace fossil assemblages occur in the Alexandria sediments but have not yet been described in detail in the palaeontological literature.

The **Salnova Formation** is characterized by the rich, shallow marine to estuarine "Swartkops" fossil biota that comprises over three hundred taxa (Engelbrecht *et al*. 1962, Le Roux 1990b, 1991, 1993, 2000 and references therein, Almond 2010). Fossil assemblages are dominated by a wide

range of molluscs, especially gastropods and bivalves. Many of these taxa are mainly found in finer-grained, estuarine facies that are probably well-represented in the study area south of the Swartkops estuary. Note that the majority of mollusc species in these Pleistocene fossil faunas are still alive today, though they are sometimes represented by different subspecies and not all of them are still native to the south coast. Compared with the older, Miocene / Pliocene Alexandria Formation of the Algoa Group, crab and sea urchin remains are more abundant in the Salnova Formation, while corals, brachiopods (lamp shells) and sharks' teeth are generally absent (Le Roux 1991). Trace fossils include pellet-walled crustacean burrow systems of the ichnogenus *Ophiomorpha* and bivalve burrows. Vertebrate remains such as the bones and teeth of marine mammals or fish may also be present but are not well recorded. The overall palaeontological sensitivity of the Salnova Formation is judged to be high, although many occurrences – especially the coarser-grained facies - are not especially shell-rich, or mainly contain fragmentary fossil remains. The Stratotype A locality of the Salnova Formation at Brighton Beach, on the coast just southeast of the study area, contains shelly coquinas with a variety of bivalve molluscs (often intact), gastropods as well echinoids and *Ophiomorpha* burrows (Le Roux 1991).

Little palaeontological work has been carried out on the **Tertiary to Recent fluvial and estuarine deposits** of the Port Elizabeth area. The coarser-grained, high energy gravels are unlikely to contain recognizable fossil remains, apart from, perhaps, rolled vertebrate teeth and bones and reworked robust shells or petrified wood eroded out from the Uitenhage Group beneath. In the Coega IDZ area to the north of Port Elizabeth, for example, apart from occasional reworked Early Cretaceous shelly fossils derived from the Sundays River beds upstream, no fossils were seen in the younger alluvial siltstones (Almond 2010). However, a careful search of finer-grained facies might well yield well-preserved skeletal remains of mammals, reptiles, fish, mollusks, crabs as well as plant material (wood, lignites, roots) and trace fossils (*e.g.* termitaria, ostrich egg shells).

4. CONCLUSIONS & RECOMMENDATIONS

The northern Brickfields WWTW site option for the proposed Nelson Mandela Bay sewage grit and sludge treatment facility it is no longer considered to be a viable option and has therefore not been assessed in any detail as part of the present palaeontological heritage assessment (PIA). In the unlikely event that this site is authorised a specialist palaeontological field assessment would be required and monitoring might be needed during excavation due to the presence here of Sundays River Formation mudrocks, and possibly also of Alexandria Formation limestones, both of which are highly fossiliferous (*e.g.* rich marine shell assemblages, rare reptile remains).

The two southern site options at or close to the existing Fish Water Flats WWTW south of the Swartkops River overlie potentially fossil-bearing coastal and fluvial sediments of Early Cretaceous to Quaternary and younger age. Estuarine to shallow marine rocks of the Quaternary to Holocene Salnova Formation that are mapped at surface in the study areas might contain rich assemblages of molluscs and other invertebrates such as recorded, for example, from the Brighton Beach stratotype section on the coast only 0.5 km to the southeast. Cretaceous fluvial sediments of the Kirkwood Formation are present beneath the surface mantle of Swartkops Formation deposits and might well be intersected by deeper (> 3 m) excavations made during construction. Plant fossils, petrified wood and even rare dinosaur bones may be present in the Kirkwood rocks. There is a preference on palaeontological grounds for the site within the existing Fish Water Flats WWTW because this area is probably already more disturbed, judging from satellite images.

For both the southern site options it is concluded that, *provided that* the chosen site for the sewage grit and sludge treatment facility overlies highly-disturbed terrain with little prospect of fresh, fossiliferous bedrocks being intersected during construction, then the impact significance would be LOW and no further specialist input or mitigation is recommended here.

However, any substantial excavations into *previously undisturbed* bedrocks made during the construction phase of the proposed development – as will be the case for the preferred site option -

are quite likely to expose, disturb and destroy fossil heritage of high palaeontological significance. In this case, the impact significance of this project without mitigation would be rated as MODERATE; *i.e.* an important impact which requires mitigation. Mitigation by a professional palaeontologist during the construction phase when fresh fossiliferous bedrock has already been exposed by excavations would then be recommended for this project. Professional mitigation should involve the monitoring of substantial excavations for newly-exposed fossil material *plus* the recording and sampling of fossil material and associated geological information (*e.g.* sedimentological and taphonomic data). The detailed scope of work and timeframes for palaeontological mitigation should be defined by the specialist concerned in consultation with the developer and the Eastern Cape Provincial Heritage Resources Agency, ECPHRA (Contact details: ECPHRA. Mr Sello Mokhanya, 74 Alexander Road, King Williams Town 5600; smokhanya@ecphra.org.za). Following mitigation, the impact significance of the project should be reduced to LOW. The palaeontologist concerned with mitigation work will need a valid collection permit from ECPHRA. All work would have to conform to international best practice for palaeontological fieldwork and the study (*e.g.* data recording fossil collection and curation, final report) should adhere to the minimum standards for Phase 2 palaeontological studies developed by SAHRA (2013). It should be emphasized that, *providing appropriate mitigation is carried out*, the majority of developments involving fossiliferous bedrock excavation can make a *positive* contribution to our understanding of local palaeontological heritage.

It is further recommended that:

- The ECO responsible for the development should be aware of the possibility of important fossils being present or unearthed on site and should monitor at suitable intervals (*e.g.* daily) all substantial excavations into fresh (*i.e.* unweathered, undisturbed) sedimentary bedrock for fossil remains;

- In the case of any significant fossil finds (*e.g.* vertebrate teeth, bones, shells, petrified wood) during construction, these should be safeguarded - preferably *in situ* - and reported by the ECO as soon as possible to the relevant heritage management authority (ECPHRA). This is so that any appropriate mitigation (*i.e.* recording, sampling or collection) by a palaeontological specialist can be considered and implemented, at the developer's expense;

- These recommendations should be incorporated into the EMPr for the Nelson Mandela Bay Municipality sewage grit and sludge treatment facility project.

Provided that these mitigation measures are followed through, there are no objections on palaeontological heritage grounds to authorisation of the proposed development.

5. ACKNOWLEDGEMENTS

Ms Kate Parkinson of GIBB, Port Elizabeth is thanked for commissioning this study and for kindly providing the necessary background information.

6. REFERENCES

ALMOND, J.E. 2010. Palaeontological heritage assessment of the Coega IDZ, Eastern Cape Province, 112 pp. Natura Viva cc, Cape Town.

ALMOND, J.E. 2012. Proposed upgrade of the Fish Water Flats Wastewater Treatment Works, Nelson Mandela Bay Municipality, Port Elizabeth, Eastern Cape. Palaeontological assessment: desktop study, 11 pp. Natura Viva cc, Cape Town.

ALMOND, J.E., DE KLERK, W.J. & GESS, R. 2008. Palaeontological heritage of the Eastern Cape. Interim technical report for SAHRA, 25 pp.

COOPER, M.R. 1981. Revision of the Late Valanginian Cephalopoda from the Sundays River Formation of South Africa, with special reference to the Genus *Olcostephanus*. Annals of the South African Museum 83: 147-366, 206 figs.

COOPER, M.R. 1991. Lower Cretaceous Trigonioida (Mollusca, Bivalvia) from the Algoa Basin, with a revised classification of the order. Annals of the South African Museum 100:1-52.

DE KLERK, W.J. 1995. The naming of *Paranthodon*. The Phoenix. Magazine of the Albany Museum 8, 30-33.

DE KLERK, W.J., 2000 South Africa's first dinosaur revisited - history of the discovery of the stegosaur *Paranthodon africanus* (Broom). Annals of the Eastern Cape Museums 1, 54-60.

DE KLERK, W.J. 2008. A review of the occurrence of disarticulated Early Cretaceous sauropod dinosaur fossils from the Kirkwood Formation of the Oudtshoorn and Algoa Basins. Programme and abstracts, Biennial Conference of the Palaeontological Society of South Africa, Matjiesfontein September 2008, 90-91.

DE KLERK, W. J., FORSTER, C. A., ROSS, C. F., SAMPSON, S. D. & CHINSAMY, A. 1998. A review of recent dinosaur and other vertebrate discoveries in the Early Cretaceous Kirkwood Formation in the Algoa Basin, Eastern Cape, South Africa. Journal of African Earth Sciences 27:p55.

DE KLERK, FORSTER, C.A., SAMPSON, S.D., CHINSAMY, A. and ROSS, C.F. 2000. A new coelurosaurian dinosaur from the Early Cretaceous of South Africa. Journal of Vertebrate Paleontology, 20(2), 324-332.

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

DU TOIT, A.L. 1954. The geology of South Africa (3rd edition). 611 pp, 41 pls, geological map insert.

ENGELBRECHT, L.N.J., COERTZE, F.J. & SNYMAN, A.A. 1962. Die geologie van die gebied tussen Port Elizabeth en Alexandria, Kaapprovinsie. Explanation to geology sheet 3325 D Port Elizabeth, 3326 C Alexandria and 3425 B, 54pp., 8 pls. Geological Survey of South Africa / Council for Geosciences, Pretoria.

GOEDHART, M.L. & HATTINGH, J. 1997. The geology of the Coega river mouth and proposed adjacent industrial development zone, Eastern Cape. Report No. 1997-0008, 1-6 pp including appendices, maps. Council for Geoscience, Pretoria.

HATTINGH, J. 1994. Depositional environment of some gravel terraces in the Sundays River Valley, Eastern Cape. South African Journal of Geology 97, 156-166.

HATTINGH, J. 1996. Late Cenozoic drainage evolution in the Algoa Basin with special reference to the Sundays River Valley. Unpublished PhD thesis, University of Port Elizabeth, 181 pp.

HATTINGH, J. 2001. Late Cenozoic drainage evolution in the Algoa Basin with special refence to the Sundays River Valley. Bulletin 128, 141 pp. Council for Geoscience, Pretoria.

HATTINGH, J. & GOEDHART, M.L. 1997. Neotectonic control on drainage evolution in the Algoa Basin, Eastern Cape. South African Journal of Geology 100, 43-52.

KLINGER, H.C. & KENNEDY, W.J. 1979. Cretaceous faunas from southern Africa: Lower Cretaceous ammonites, including a new bochianitid genus from Umgazana, Transkei. Annals of the South African Museum 78: 11-19.
LE ROUX, F.G. 1987a. Tertiary macrofossils of the Alexandria Formation - a supplementary list. Annals of the Geological Survey of South Africa 21: 65-74.

LE ROUX, F.G. 1987b. Lithostratigraphy of the Alexandria Formation. Lithostratigraphic Series, South African Committee for Stratigraphy, 1, 18 pp. Council for Geoscience, Pretoria.

LE ROUX, F.G. 1990a. Algoa Group. In: Johnson, M.R. (Ed.) Catalogue of South African Lithostratigraphic Units, 2, 1-2. South African Committee for Stratigraphy. Council for Geoscience, Pretoria.

LE ROUX, F.G. 1990b. Palaeontological correlation of Cenozoic marine deposits of the southeastern, southern and western coasts, Cape Province. South African Journal of Geology 93: 514-518.

LE ROUX, F.G. 1991. Lithostratigraphy of the Salnova Formation (Algoa Group). Lithostratigraphic Series, South African Committee for Stratigraphy, 11, 20 pp. Council for Geoscience, Pretoria.

LE ROUX, F.G. 1993. Updated macrofossil checklists for Cenozoic marine deposits along the south-eastern and southern Cape coasts, South Africa. South African Journal of Science 89: 375 – 386.

LE ROUX, F.G. 2000. The geology of the Port Elizabeth – Uitenhage area. Explanation of 1: 50 000 geology Sheets 3325 DC and DD, 3425 BA Port Elizabeth, 3325 CD and 3425 AB Uitenhage, 3325 CB Uitenhage Noord and 3325 DA Addo, 55pp. Council for Geoscience, Pretoria.

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

MAUD, R.R. & BOTHA, G.A. 2000. Deposits of the South Eastern and Southern Coasts. Pp. 19-32 *in* Partridge, T.C. & Maud, R.R. (Eds.) The Cenozoic of Southern Africa. Oxford Monographs on Geology and Geophysics No 40. Oxford University Press. Oxford, New York.

McLACHLAN, I.R. & McMILLAN, I.K. 1976. Review and stratigraphic significance of southern Cape Mesozoic palaeontology. Transactions of the Geological Society of South Africa. 79: 197-212.

McMILLAN, I. K., 2003. The Foraminifera of the Late Valanginian to Hauterivian (Early Cretaceous) Sundays River Formation of the Algoa Basin, Eastern Cape Province, South Africa. Annals of the South Africa Museum 106:1-274, 84 figs, 4 tables.

PARTRIDGE, T.C., DOLLAR, E.S.J., MOOLMAN, J. & DOLLAR, L.H. 2010. The geomorphic provinces of South Africa, Lesotho and Swaziland: a physiographic subdivision for earth and environmental scientists. Transactions of the Royal Society of South Africa 65, 1-47.

RIGASSI, D.A. & DIXON, G.E. 1972. Cretaceous of the Cape Province, Republic of South Africa. Proceedings, Conference on African geology, Ibadan Dec. 1970, pp. 513-527.

ROBERTS, D.L., BOTHA, G.A., MAUD, R.R. & PETHER, J. 2006. Coastal Cenozoic deposits. Pp. 605 – 628 *in* Johnson, M.R., Anhaeusser, C.R. & Thomas, R.J. (Eds.) The geology of South Africa. Geological Society of South Africa, Johannesburg & Council for Geoscience, Pretoria.

RUBIDGE, B.S., DE KLERK, W.J. & ALMOND, J.E. 2008. Southern Karoo Margins, Swartberg and Little Karoo. Palaeontological Society of South Africa, 15th Biennial Meeting, Matjiesfontein. Post-conference excursion guide, 35 pp.

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

SHONE, R.W. 1986. A new ophiuroid from the Sundays River Formation (Lower Cretaceous), South Africa. Journal of Paleontology 60, 904-910.

SHONE, R.W. 2006. Onshore post-Karoo Mesozoic deposits. In: Johnson, M.R., Anhaeusser, C.R. & Thomas, R.J. (Eds.) The geology of South Africa, pp. 541-552. Geological Society of South Africa, Marshalltown.

SPATH, L. F. 1930. On the Cephalopoda of the Uitenhage beds. Annals of the South African Museum 28(2):131-157, pls. 13-15, 1 text fig.

TANKARD, A.J., JACKSON, M.P.A., ERIKSSON, K.A., HOBDAY, D.K., HUNTER, D.R. & MINTER, W.E.L. 1982. Crustal evolution of southern Africa – 3.8 billion years of Earth history, xv + 523 pp., pls. Springer Verlag, New York.

TOERIEN, D.K. & HILL, R.S. 1989. The geology of the Port Elizabeth area. Explanation to 1: 250 000 geology Sheet 3324 Port Elizabeth, 35 pp. Council for Geoscience. Pretoria.

WINTER, H. DE LA R. 1973. Geology of the Algoa Basin, South Africa. In: Blant, G. (Ed.) Sedimentary basins of the African coast. Part, 2 South and East Coast, pp. 17-48. Association of African Geological Surveys, Paris.

7. QUALIFICATIONS & EXPERIENCE OF THE AUTHOR

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

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

Declaration of Independence

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

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