PALAEONTOLOGICAL ASSESSMENT
(Desktop Study)

SAXON HEAVY MINERALS (PTY) LTD.

PROPOSED HEAVY MINERAL SAND PROSPECTING ON THE NAMAQUALAND COASTAL FARMS LANG KLIP 489, MITCHELLS BAY 495 AND FARM 496

Kamiesberg Local Municipality, Namakwa District Municipality
Namaqualand Magisterial District, Northern Cape

By

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CTS HERITAGE

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SUMMARY

Background

Saxon Heavy Minerals (Pty) Ltd intends to apply for a Prospecting Right, in terms of the Mineral and Petroleum Resources Development Act 28 of 2002 (MPRDA), to prospect for the presence of economic deposits of heavy mineral sands on three farms on the Namaqualand coast (Figure 1). The application involves the former De Beers Namaqualand Mines properties south of Hondeklipbaai, *viz*. Lang Klip 489, Mitchells Bay 495 and Farm 496, in the Kamiesberg Local Municipality, Namakwa District Municipality, Namaqualand Magisterial District.

CTS HERITAGE has prepared a Heritage Screener and Desktop Heritage Assessment for the proposed prospecting programme. This addendum document expands the palaeontological assessment section and describes the formations and expected palaeontological resources (fossils) likely to be uncovered in the subsurface in the process of prospecting the heavy mineral content of the aeolian and marine sand deposits.

Description of the proposed activity

The prospecting involves drilling to depth for samples by both auger and Reverse Circulation (RC) drilling methods.

Heritage resources identified

The drilling will penetrate coastal-plain aeolian and marine formations of the West Coast Group, of various Miocene, Pliocene and Quaternary ages (Figure 2).

Anticipated impact

The prospecting drilling involves small vertical volumes and the impact relative to mining is marginal. The fossil material likely to be encountered in drill samples from aeolianites is the ambient fossil content of land snails, tortoise bones and mole bones. Fossil marine shell is not well-preserved in most of the marine deposits, but fossil shell will be encountered in some drill holes. Though likely fragmentary, it may be diagnostic of the marine formation penetrated. Other fossils which are brought up in boreholes include smaller petrified material such as shark and other fish teeth and casts of shells (steinkerns).

In the process of the prospecting drilling programme displaced fossil bones may be found on the overburden dumps or be exposed in the eroding sides of mine pits.

Recommendations

The impact of the prospecting drilling programme is considered to be LOW.

It is recommended that a requirement to be alert for possible fossil materials and archaeological material be included in the Environmental Management Plan (EMP) for the proposed prospecting operations which is to include:

- Implementation of an archaeological and palaeontological awareness programme.
- Implementation of the Fossil Finds Procedure (FFP) in the event of fossil bone material being encountered on overburden dumps or in mine pits.
- In addition to the above proposed mitigatory measures, all core samples will be sifted on site to separate heavy minerals from the

matrix. At this point, all palaeontological or archaeological material contained in the cores will be identified by the on site geologist who will bag the finds, recording the GPS co-ordinates of the core sample from which they are derived. This material will then be sent to Cape Town for analysis by professional researchers. In the event that subsurface archaeological deposits are encountered, these can be red flagged, and then avoided to prevent further damage. For the palaeontological samples, this coring will serve to positively identify the location of sensitive fossils within a landscape of highly sensitivity geological deposits.

These mitigation measures are deemed adequate for the prospecting drilling, in particular, the collection of coarse-fraction fossiliferous material for analysis.

Upon notification of a potential fossil find, SAHRA and an appropriate specialist palaeontologist will assess the information and liaise with the developer, the environmental consultants and the ECO and a suitable response will be established.

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CURRICULUM VITAE

John Pether, M.Sc., Pr. Sci. Nat. (Earth Sci.)

Independent Consultant/Researcher recognized as an authority with 37 years' experience in the field of coastal-plain and continental-shelf palaeoenvironments, fossils and stratigraphy, mainly involving the West Coast/Shelf of southern Africa. Has been previously employed in academia (South African Museum) and industry (Trans Hex, De Beers Marine). At present an important involvement is in Palaeontological Impact Assessments (PIAs) and mitigation projects in terms of the National Heritage Resources Act 25 (1999) (~250 PIA reports to date) and is an accredited member of the Association of Professional Heritage Practitioners (APHP). Continues to be involved as consultant to offshore and onshore marine diamond exploration ventures. Expertise includes:

- Coastal plain and shelf stratigraphy (interpretation of open-pit exposures, on/offshore cores and exploration drilling).
- Sedimentology and palaeoenvironmental interpretation of shallow marine, aeolian and other terrestrial surficial deposits.
- Marine macrofossil taxonomy (molluscs, barnacles, brachiopods) and biostratigraphy.
- Marine macrofossil taphonomy.
- Sedimentological and palaeontological field techniques in open-cast mines (including finding and excavation of vertebrate fossils (bones).

Membership of Professional Bodies

- South African Council of Natural Scientific Professions. Earth Science. Reg. No. 400094/95.
- Geological Society of South Africa.
- Palaeontological Society of Southern Africa.
- Southern African Society for Quaternary Research.
- Association of Professional Heritage Practitioners (APHP), Western Cape. Accredited Member No. 48.

Past Clients Palaeontological Assessments

AECOM SA (Pty) Ltd.	Guillaume Nel. Env. Management Consultants.
Agency for Cultural Resource Management (ACRM).	Klomp Group.
AMATHEMBA Environmental.	Megan Anderson, Landscape Architect.
Anél Blignaut Environmental Consultants.	Ninham Shand (Pty) Ltd.
Arcus Gibb (Pty) Ltd.	PD Naidoo & Associates (Pty) Ltd.
ASHA Consulting (Pty) Ltd.	Perception Environmental Planning.
Aurecon SA (Pty) Ltd.	PHS Consulting.
BKS (Pty) Ltd. Engineering and Management.	Resource Management Services.
Bridgette O'Donoghue Heritage Consultant.	Robin Ellis, Heritage Impact Assessor.
Cape Archaeology, Dr Mary Patrick.	Savannah Environmental (Pty) Ltd.
Cape EAPrac.	Sharples Environmental Services cc
CCA Environmental (Pty) Ltd.	Site Plan Consulting (Pty) Ltd.
Centre for Heritage & Archaeological Resource Management	Strategic Environmental Focus (Pty) Ltd.
Chand Environmental Consultants.	UCT Archaeology Contracts Office (ACO).
CK Rumboll & Partners.	UCT Environmental Evaluation Unit
CNdV Africa	Urban Dynamics.
CSIR - Environmental Management Services.	Van Zyl Environmental Consultants
Digby Wells & Associates (Pty) Ltd.	ENVIRO DINAMIK.
Enviro Logic	Wethu Investment Group Ltd.
Environmental Resources Management SA (ERM).	Withers Environmental Consultants.
Greenmined Environmental	

Stratigraphic consulting including palaeontology

Afri-Can Marine Minerals Corp	Council for Geoscience
De Beers Marine (SA) Pty Ltd.	De Beers Namaqualand Mines.
Geological Survey Namibia	IZIKO South African Museum.
Namakwa Sands (Pty) Ltd	NAMDEB

DECLARATION OF INDEPENDENCE

PALAEONTOLOGICAL ASSESSMENT (DESKTOP STUDY)

SAXON HEAVY MINERALS (PTY) LTD. PROPOSED HEAVY MINERAL SAND PROSPECTING ON THE NAMAQUALAND COASTAL FARMS LANG KLIP 489, MITCHELLS BAY 495 AND FARM 496. Kamiesberg Local Municipality, Namakwa District Municipality, Namaqualand Magisterial District, Northern Cape.

Terms of Reference

This assessment forms part of the Heritage Assessment and it assesses the overall palaeontological (fossil) sensitivities of formations underlying the Project Area in terms of the proposed prospecting drilling.

Declaration

I …**John Pether**……, as the appointed independent specialist hereby declare that I:

- act/ed as the independent specialist in the compilation of the above report;
- regard the information contained in this report as it relates to my specialist input/study to be true and correct, and
- do not have and will not have any financial interest in the undertaking of the activity, other than remuneration for work performed in terms of the NEMA, the Environmental Impact Assessment Regulations, 2014 and any specific environmental management Act;
- have and will not have any vested interest in the proposed activity proceeding;
- have disclosed to the EAP any material information that has or may have the potential to influence the decision of the competent authority or the objectivity of any report, plan or document required in terms of the NEMA, the Environmental Impact Assessment Regulations, 2014 and any specific environmental management act;
- have provided the EAP with access to all information at my disposal regarding the application, whether such information is favourable to the applicant or not; and
- am aware that a false declaration is an offence in terms of regulation 48 of the 2014 NEMA EIA Regulations.

Signature of the specialist

Date: 6 February 2018

1 INTRODUCTION

1.1 BACKGROUND

Saxon Heavy Minerals (Pty) Ltd intends to apply for a Prospecting Right, in terms of the Mineral and Petroleum Resources Development Act 28 of 2002 (MPRDA), to prospect for the presence of economic deposits of heavy mineral sands on three farms on the Namaqualand coast (Figure 1). The application involves the former De Beers Namaqualand Mines properties south of Hondeklipbaai, *viz.* Lang Klip 489, Mitchells Bay 495 and Farm 496, in the Kamiesberg Local Municipality, Namakwa District Municipality, Namaqualand Magisterial District.

CTS HERITAGE has prepared a Desktop Heritage Assessment for the proposed prospecting programme. This addendum document expands the palaeontological assessment section and describes the formations and expected palaeontological resources (fossils) likely to be uncovered in the subsurface in the process of prospecting the heavy mineral content of the aeolian and marine sand deposits.

1.2 THE PROSPECTING PROGRAMME

The proposed prospecting will take place over a 60-month (five year) period and will initially comprise non-invasive methods (Phase 1), which will include surface mapping and surveying of the deposits. Phase 2 will comprise invasive prospecting methods and will include auger and RC drilling of material. Phases 3 and 4 will involve off-site sample processing, data analysis and decision making. Phase 5 will include rehabilitation. Some of these phases will be undertaken in parallel. If economically recoverable resources can be proven on the properties, the Applicant may decide to apply for a Mining Right in terms of the MPRDA.

2 APPLICABLE LEGISLATION

The National Heritage Resources Act (NHRA No. 25 of 1999) protects archaeological and palaeontological sites and materials, as well as graves/cemeteries, battlefield sites and buildings, structures and features over 60 years old. The South African Heritage Resources Agency (SAHRA) administers this legislation nationally, with Heritage Resources Agencies acting at provincial level. According to the Act (Sect. 35), it is an offence to destroy, damage, excavate, alter or remove from its original place, or collect, any archaeological, palaeontological and historical material or object, without a permit issued by the South African Heritage Resources Agency (SAHRA) or applicable Provincial Heritage Resources Agency. Notification of SAHRA or the applicable Provincial Heritage Resources Agency is required for proposed developments exceeding certain dimensions (Sect. 38).

Perhaps here it is appropriate to note that, in the National Heritage Resources Act, "palaeontological" is defined to mean "any fossilised remains other than fossil fuels or fossiliferous rock intended for industrial use" (*e.g.* limestone made up of fossil shells). In the case of heavy-mineral sands and diamond mining, fossils are not the primary component intended for industrial use. However, there are rare shell and bone macrofossils sparsely scattered and locally concentrated within both overburden and orebodies. Fortunately, this is generally recognized and it has been primarily due to the large excavations made by mining, and the support of mining companies, that much of the present-day knowledge of the coastal-plain record has been rendered possible. Notwithstanding, there is much scope for improvement in this collaboration.

Figure 1. Location of the Project Area.

3 APPROACH TO THE STUDY

3.1 LITERATURE REVIEW

This assessment is based on the published scientific literature on the origin and palaeontology of the Namaqualand coastal-plain deposits and the author's comprehensive field experience of the formations involved and their fossil content. An important advance for the stratigraphy of Namaqualand coastal deposits was Carrington and Kensley's (1969) article describing new mollusc fossils from the central Namaqualand area and in which marine deposits of different ages were distinguished based on fossil shells. Research on the succession at Hondeklipbaai (Trans Hex exposures) led to considerable additions to the marine fossil fauna (Kensley & Pether, 1986; Pether, 1990; Brunton & Hiller, 1990) and refinement of the stratigraphy (Pether, 1986, 1994). Further notes on the deposits of central Namaqualand were provided by Davies (1973) and by Tankard (1975a, 1975b). Syntheses emphasizing Cenozoic palaeoclimates, biogeography and sea-level history which are pertinent to Namaqualand coastal stratigraphy are Tankard and Rogers, 1978; Siesser and Dingle, 1981; Hendey, 1983a, 1983b, 1983c and Dingle *et al.*, 1983). Summary texts of the coastal-plain deposits are Pether *et al*. (2000) and Roberts *et al*. (2006).

The relevant 1:250 000 Council for Geoscience geological maps and their explanations are Sheet 2816 Alexander Bay (Minnaar *et al.*, 2011), Sheet 2917 Springbok (Marais *et al.*, 2001) and Sheet 3017 Garies (De Beer, 2010). The new stratigraphic terminology proposed by De Beer (2010) is mainly used, but is elaborated and modified according to the author’s own observations.

3.2 ASSUMPTIONS AND LIMITATIONS

The assumption is that the fossil potential of a formation in the study area will be typical of that found in the region and more specifically, similar to that already observed the study area. Scientifically important fossil shell and bone material is expected to be sparsely scattered in these deposits and much depends on spotting this material as it is uncovered during digging *i.e.* by monitoring excavations. A limitation on predictive capacity exists in that it is not possible to predict the buried fossil content of an area or formation other than in such general terms. Certain processes/agents can produce significant concentrations of fossil bones, but the possibility of these specific buried palaeoenvironments being present may only be revealed once the formation is exposed in excavations.

4 STRATIGRAPHY OF THE NAMAQUALAND COASTAL PLAIN

4.1 THE BEDROCK

The geology of the region is summarised, as by convention, from the oldest bedrock to the youngest deposits. The basement gneisses of the Namaqualand Metamorphic Province crop out along the shore (Figure 2). These are intrusive gneisses of the Little Namaqualand Suite of gneisses which are older than 1000 Ma (Ma = million years ago) and include the Hunboom Gneiss (Ɲhb), the Mesklip Gneiss (Ɲme) and the Langklip Gneiss (Ɲlan) (Figure 2). These bedrock gneisses are unfossiliferous.

4.2 THE EARLY COASTAL PLAIN

The strata of the Palaeozoic and Mesozoic eras have been mostly eroded from the western margin of the subcontinent during and subsequent to the rifting of the Gondwana supercontinent and the opening of the Atlantic Ocean

130-120 Ma. The early coastal plain would have been inundated or transgressed by the sea during times of late Cretaceous high sea-levels. Transgressive Eocene events also affected the coastal plain (Figure 3). Marine deposits of these ages are found in southern Namibia, but little evidence of this earlier marine history remains along Namaqualand. This earlier marine record, with palaeoshorelines that now would have been uplifted to 150-200 m asl., has been eroded from the Namaqualand coastal plain.

Figure 2. Surface geology of the Project Area.

Deeply weathered, kaolinized (white china clay) bedrock is a feature of the older parts of the coastal plain, with silcrete cappings in places. The silcretes originally formed in poorly-drained low spots in the pre-existing landscape, but with erosion these low areas are now "inverted" and occur as silcrete cappings on hills which are remnants of the old palaeosurface. The deep weathering and silcrete formation occurred during humid, tropical weathering such as thought typical for the latest Cretaceous and earlier Cenozoic palaeoclimates.

The **West Coast Group** is the name proposed to accommodate the Cenozoic coastal deposits between the Orange River and Elandsbaai (Roberts *et al*., 2006). The context of the West Coast Group in terms of global Cenozoic palaeoclimatic and sea-level trends is shown in Figure 3.

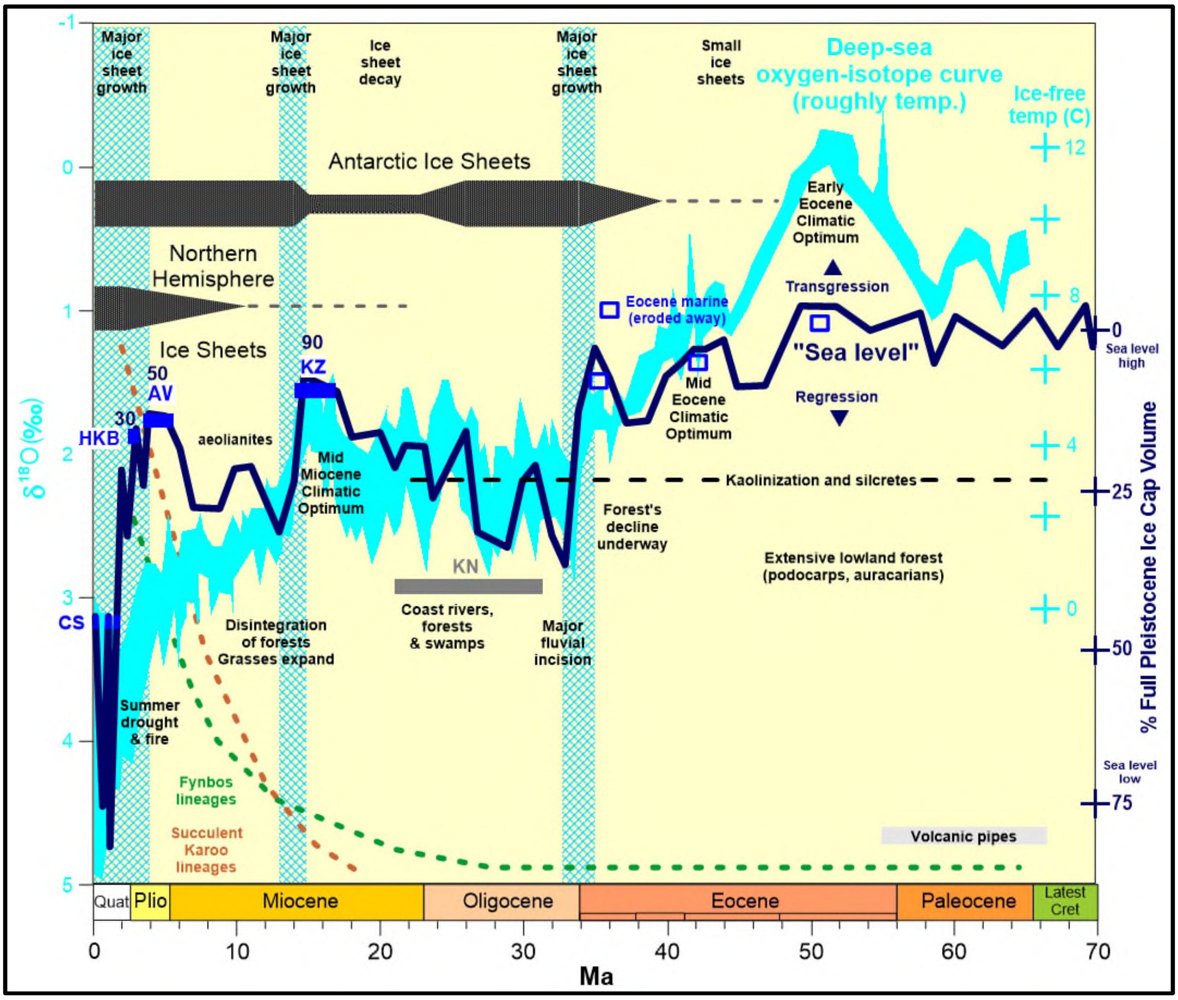

Figure 3: The Cenozoic Era (65.5 Ma to present) showing global palaeoclimate proxies, aspects of regional vegetation history and the context of marine formations of the West Coast Group, Alexander Bay Subgroup.

Cyan curve - history of deep-ocean temperatures, adapted from Zachos *et al*. (2008). **Blue curve** is an estimate of global ice volumes, adapted from Lear *et al*. (2000). Global ice volumes roughly indicate sea-level history caused by the subtraction from the sea of water as land-ice. The expansion of Fynbos and Karoo floras is adapted from Verboom *et al*. (2009).

Formations: KN – Koingnaas Fm. KZ - Kleinzee Fm. AV – Avontuur Fm. HK – Hondeklipbaai Fm. CS – Curlew Strand Fm.

4.2.1 The Koingnaas Formation

Buried between the main Namaqualand rivers are ancient river channels that attest to the wetter climates of the early Cenozoic, when more rivers drained the coastal plain. These diamondiferous palaeochannels have fluvial infills that have also been kaolinized and silcrete has formed within the channel deposits in places. Beds of carbonaceous, peaty material containing plant fossils also occur. Previously referred to as the "**Channel Clays**" by diamond miners, these deposits are now proposed as the **Koingnaas Formation** (De Beer, 2010). It is not shown on the geological maps, being covered by younger deposits.

Fossil pollen from the organic-rich beds has provided evidence of the vegetation type present and the age of the Koingnaas Formation. Yellowwood forest with auracaria conifers and ironwoods dominated the West Coast. The presence of Oleaceae (ironwoods) and Asteraceae (daisies) indicate an age not older than Oligocene (Muller, 1981). Fossil wood similar to tropical African mahogany has been found and also supports an Oligocene maximum age. This suggests that the Koingnaas Formation is Oligocene to earliest Miocene, and that humid weathering (kaolinization) continued to ensue during the earliest Miocene.

Notably, the Koingnaas pollen assemblage, with many extinct types of uncertain affinity and no analogues elsewhere, indicates that the uniqueness of the Cape Floristic Region is rooted in "deep time" (De Villiers & Cadman, 2002) (Figure 3). The Koingnaas Formation deposits are remainders of a fossil landscape when the wooded Namaqualand coast more resembled the forests of the south coast.

An important occurrence of the kaolinitic, quartzose gravels of the Koingnaas Formation, with abundant plant fossils, occurred in a coast-parallel palaeochannel entering the north side of Rooiwalbaai (now mined away) (Figure 2).

4.3 THE MARINE RECORD – ALEXANDER BAY SUBGROUP

Three extensive marine formations containing warm-water mollusc assemblages occur beneath the aeolian coversands of the Namaqualand coastal plain. These are currently all subsumed in the **Alexander Bay Formation** as members (Kleinzee, Avontuur and Hondeklipbaai members, previously known as the 90, 50 and 30 m Packages, resp.). However, these marine formations each occupy a specific spatial position in the stratigraphic geometry, have distinctly different fossil faunas and are of distinctly different ages. They are therefore worthy of full formation status. Concomitantly the Alexander Bay Formation is promoted to Subgroup rank and incorporates all the marine formations, including the Quaternary Curlew Strand Formation.

The traditional stratigraphy of the Namaqualand coast mining area is couched in terms of the bedrock topography of marine terraces (Keyser, 1972, Gresse, 1988). In this geomorphological approach the marine deposits on each successively lower, younger terrace are assumed to have been deposited on the terrace soon after it was formed by erosion during a sea-level highstand. In contrast, the marine formations mentioned above can be recognized independent of bedrock morphology, on the basis of fossils and sedimentary features which provide a depth-of-deposition diagnosis.

The key finding is that the marine sediments comprising each formation were deposited as sea level retreated from transgressive maxima and these regressive deposits built out seawards (prograded) over the topography of cliffs and platforms, which had been formed during earlier sea-level stillstands and are partly composite in origin. The deposits of an earlier regression from a high sea level are not totally removed by the succeeding transgression, thus much older deposits may occur locally at low elevations.

4.3.1 The Kleinzee Formation - Mid-Miocene Climatic Optimum

The oldest marine formation is the **Kleinzee Formation** which is found extending seawards from ~90 m asl. (also called the **90 m Package**). Petrified teeth of suids and a hominoid tooth have been found in the basal gravels (Pickford & Senut, 1997). These were reworked from preceding terrestrial deposits of Arrisdrift Formation age.(ca. 18 - 17.5 Ma). The deposits are decalcified and generally lack all but the most robust macrofossils such as oysters. However, a shelly, more distal marine (shelf) facies of pebbly muddy sands and clays is very locally preserved at lower elevations, beneath the younger marine deposits. Strontium isotope ages of 16-15 Ma have been obtained from foraminifera sealed in clay at one such occurrence in the Hondeklip area (Langklip), consistent with deposition during the decline from the high sea level of the warm Mid-Miocene Climatic Optimum *ca*. 17 to 15 Ma (Figure 3).

The shelly fauna from the Kleinzee Formation is poorly preserved, sparse and mainly unstudied, but the curious, thick-shelled bivalve *Isognomon gariesensis* is the zone-fossil for this formation..

4.3.2 The Avontuur Formation - Early Pliocene Warm Period

The previous Miocene marine beds were eroded during rising sea-level of the Early Pliocene Warm Period and the fine sands of the **Avontuur Formation** (the **50 m Package**) were deposited 5-4 Ma as sea-level receded from the transgression maximum of about 50 m asl. and the shoreline prograded seawards (Figures 3 & 4). The Avontuur Formation also contains a basal concentration of petrified and abraded vertebrate remains inherited from earlier periods. This “Basal, petrified, mixed assemblage” or *remanié* fauna includes shark teeth and the bones and teeth of extinct whales, proboscideans, rhinocerotids, bovids and equids. The oldest fossils present are the bear-dog *Agnotherium* sp. (13 - 12 Ma) and the gomphothere *Tetralophodon* (12 - 9 Ma), but the age indicated by most of the material is terminal Miocene (7.5 - 5 Ma). These youngest taxa in the reworked basal assemblage constrain the maximum age of the 50 m Package. The important, unpetrified finds from within the deposits are the Langebaanian (Varswater) phocid (seal) *Homiphoca capensis* and the suid (bushpig) *Nyanzachoerus kanamensis*. This deposit is broadly contemporaneous with the Varswater Formation exposed at the West Coast Fossil Park near Saldanha. Much of the Avontuur Formation is also decalcified, but it must have been very shelly originally and in places shell fossils are abundant so that the shell fauna is quite well-known. The zone fossil is the extinct “surf clam” *Donax haughtoni*.

4.3.3 The Hondeklipbaai Formation – “Mid-Pliocene Warm Period”

The Avontuur Formation in turn was eroded by yet another rising sea-level associated with a warm period later on during the Pliocene Epoch. The **Hondeklipbaai Formation** or **30 m Package** was deposited as sea level declined from a high of about 30-33 m asl. and a substantial, prograded marine formation built out seawards (Pether, 1994; Pether, in Roberts *et al*., 2006). This formation, up to a few km wide, underlies the outer part of the coastal plains of the West Coast.

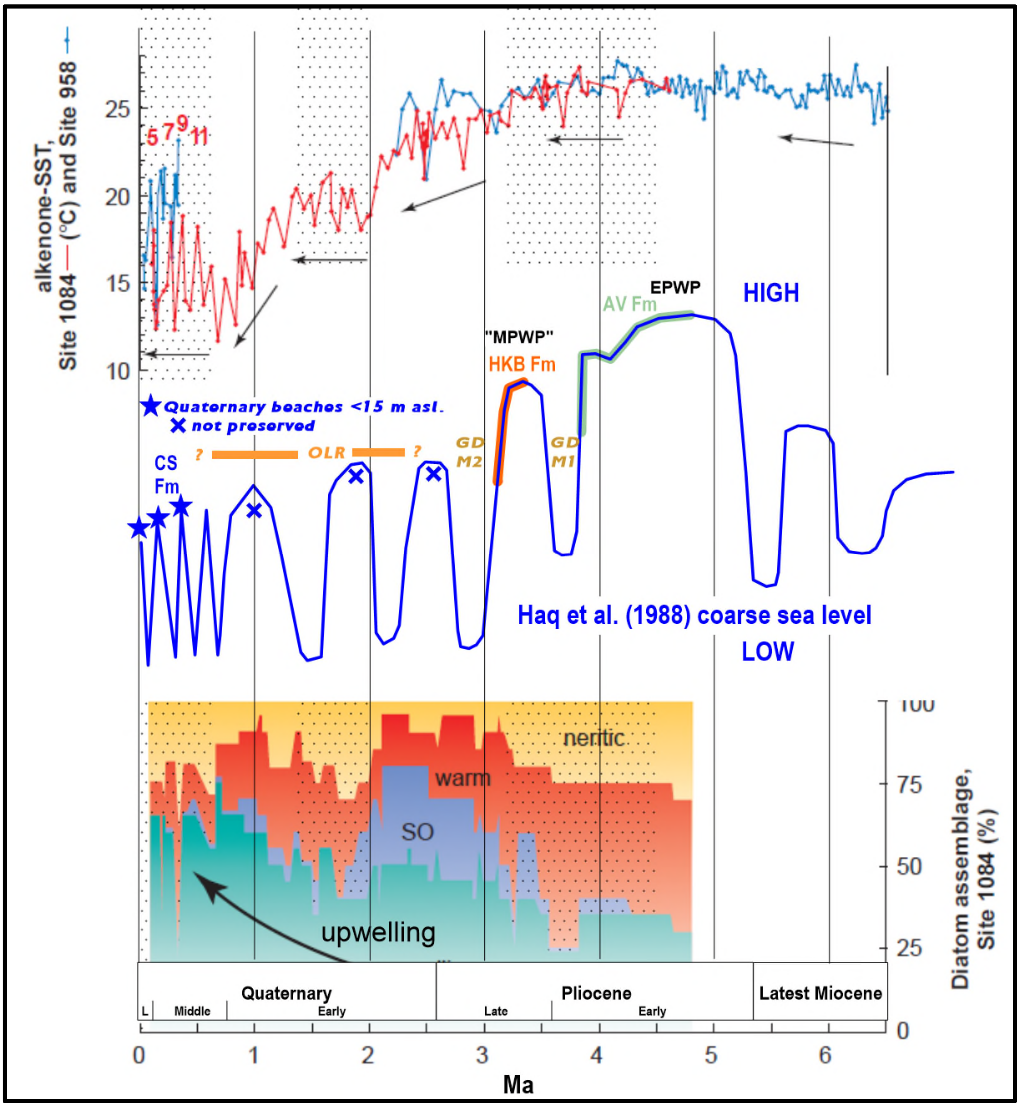

Figure 4. Coarse-scale sea-level history based on major margin unconformities (from Haq et al., 1988), shown together with palaeoceanographic data from deep-sea core 1084 off Luderitz (from Marlow et al., 2000).

TOP: Sea Surface Temperature (SST) history showing stepwise cooling after 3 Ma.
MIDDLE: Sea Level history and Formations: AV – Avontuur Fm. HKB – Hondeklipbaai Fm. CS – Curlew Strand Fm. EPWP – Early Pliocene Warm Period. "MPWP" Mid-Pliocene Warm Period (now in late Pliocene). GD M1 – Graauw Duinen Fm., Member 1. GD M2 - Graauw Duinen Fm., Member 2. OLR – Olifantsrivier Formation.
BOTTOM: Diatom assemblages showing increase in upwelling species and decrease in warm water species during the Quaternary. SO – Southern Ocean species abundant during initial cooling transition and growth of polar ice caps.

An age-diagnostic fossil vertebrate assemblage directly associated with the Hondeklipbaai Formation has not yet been recovered and so its age is not constrained by vertebrate datums. Notwithstanding, it is the last, major formation of the coastal plain, deposited during a high sea-level never since exceeded. With its warm-water molluscan fauna, it is unlikely to postdate the inception of major cooling in the Benguela System (Figure 4). Accordingly, the 30 m Package is not likely to be younger than ~3.0 Ma and corresponds with the "*Mid-Pliocene Warm Period" and the second, major Pliocene sea-level highstand in the late Pliocene at ~3.0 to 3.4 Ma (Figure 4). (* - see Glossary)

The Hondeklipbaai Formation is mainly coarse-sandy and extensively decalcified and reddened. Shell fossils are quite sparse and more need to be found. The zone fossil is the large extinct "surf clam" *Donax rogersi*.

4.3.4 The Curlew Strand Formation – mid-late Quaternary interglacials

Close to the seaside, the Hondeklipbaai Formation is eroded and overlain by the younger, Quaternary "raised beaches" that extend up to about 12-15 m asl. The name has been proposed for this composite of old beaches, equivalent to the Velddrif Formation of the SW Cape Coast. It comprises the **8 - 12 m Package** (~400 ka?), the **4 - 6 m Package** (Last Interglacial (LIG) ~125 ka) and the **2 - 3 m Package** (mid-Holocene High 6-4 ka). The LIG beach is the best-preserved, but the older unit is poorly known and may not always be deposits of identical age. Notably, most of the earlier Quaternary sea-level record has not been preserved and was presumably eroded away by the younger highstands (Figure 4). Along the Namaqualand shoreline, these beaches are poorly sampled for fossil shells, but West African tropical taxa ranged down the coast as they are found in equivalent deposits of the SW Cape. Rare surprises have come to light in the mid-Holocene beach deposits, such as isolated occurrences of South American and mid-Atlantic island species.

4.4 THE TERRESTRIAL RECORD

A variety of terrestrial deposits also make up the coastal plain of the Namaqualand. For the most part these are extensive aeolian dune and sandsheet deposits that overlie the eroded tops of the marine sequences. More locally there are colluvial (sheetwash) and ephemeral stream deposits associated with nearby hillslopes; sometimes these underlie or are interbedded between the marine formations, but are more usually found interbedded with aeolian deposits. Formed within the upper parts of the marine formations and capping terrestrial sequences are major pedocreted palaeosols of a variety of types, compositions and degrees of development.

A glance at the satellite images of the coast show that the pale swathes of modern and Holocene aeolian activity occur in specific areas, linked to antecedent topography, sea-level oscillations, locations of sandy beaches and fluvial sediment inputs. Similarly, the deeper-time aeolian record is expected to comprise buried dune fields, dune plumes and sand sheets that accumulated at different times in various areas of the coastal plain.

The sorting out and stratigraphic formalization of the aeolian record of the coastal plain is still very much in its infancy and thus the formations proposed hitherto have been very broadly defined. It is quite apparent, on the basis of interleaving marine deposits of different ages, well-developed pedocretes marking intervals of regional extent within currently-defined formations, and interbedded fluvial and colluvial deposits, that at this stage the aeolian formations currently proposed are comprised of and subsume major units that, as fieldwork and fossil discoveries ensue, will in time become formations in their own right, in a sequence-stratigraphic framework linked to global and continental palaeoclimatic cycles and their regional outcomes.

4.4.1 Later Miocene Aeolianite

The mid-Miocene, marine Kleinzee Formation has been extensively eroded and has been largely reworked into aeolian sands. These old aeolian deposits are now quite altered by pedogenic and groundwater processes, transforming them into nearly massive units cemented by partly-silicified, neoformed interstitial clays. They may be basically pale units with extensive mottling and thus superficially similar to underlying Miocene marine deposits, or extensively pedocreted, or appear as evolved red/brown dorbank with many post-depositional features.

In Namaqualand, this is effectively an unnamed formation, partly due to the difficulty of diagnosis when lateral exposure is lacking. These later-Miocene aeolianites occupy the higher part of the coastal notch where they overlie residuals of the Kleinzee Formation and extend into the immediate hinterland. Locally they occur beneath the inner part of the Avontuur Formation (early Pliocene) marine wedge. Colluvial interbeds are quite common. They are sharply overlain by younger aeolianites (*e.g.* Graauw Duinen Formation, see below) which are in a distinctly different, less evolved state of alteration.

The occurrence of petrified teeth of the bear-dog *Agnotherium* sp. (13 - 12 Ma) and the gomphothere *Tetralophodon* (12 - 9 Ma) in the basal gravels of the early Pliocene Avontuur Formation at Hondeklipbaai hints at the pre-existence of terrestrial deposits of this later Miocene age range.

4.4.2 The Graauw Duinen Formation

This name has been proposed to accommodate the aeolianites as exemplified in the Namakwa Sands excavations on Graauw Duinen 152 (Roberts *et al.*, 2006; De Beer, 2010) where the aeolianites are excellently exposed in coast-normal mining faces. Based on personal observations of the aeolianites exposed at Graauw Duinen (Namakwa Sands), the first main aeolianite unit postdates the marine early Pliocene Avontuur Formation. Also exposed at Graauw Duinen are younger aeolianites that postdate the late Pliocene Hondeklipbaai Formation. Traced inland, these younger aeolianites overlie the aforementioned aeolianites that directly overlie the Avontuur Formation.

Accordingly, on the basis of the Graauw Duinen exposures, this formation has a lower unit (Member 1) that overlies early Pliocene marine deposits (Avontuur Formation) (Figure 4, GD-M1) and can be traced laterally therefrom. In the west this lower unit is transgressed and eroded beneath the marine late Pliocene Hondeklipbaai Formation where it pinches out. Its age is about 4.5 – 3.5 Ma. A younger large aeolian unit (Member 2) overlies and postdates the ~3 Ma Hondeklipbaai Formation and Member 1 (Figure 4, GD-M2). Other than this maximum ~3 Ma age, the age of Member 2 is not yet well constrained. However, Stone Age artefacts are apparently absent in Member 2 at Graauw Duinen/Namakwa Sands. The immediately overlying aeolianite formation contains rare Early Stone Age (ESA) material and is referred to the Olifantsrivier Formation.

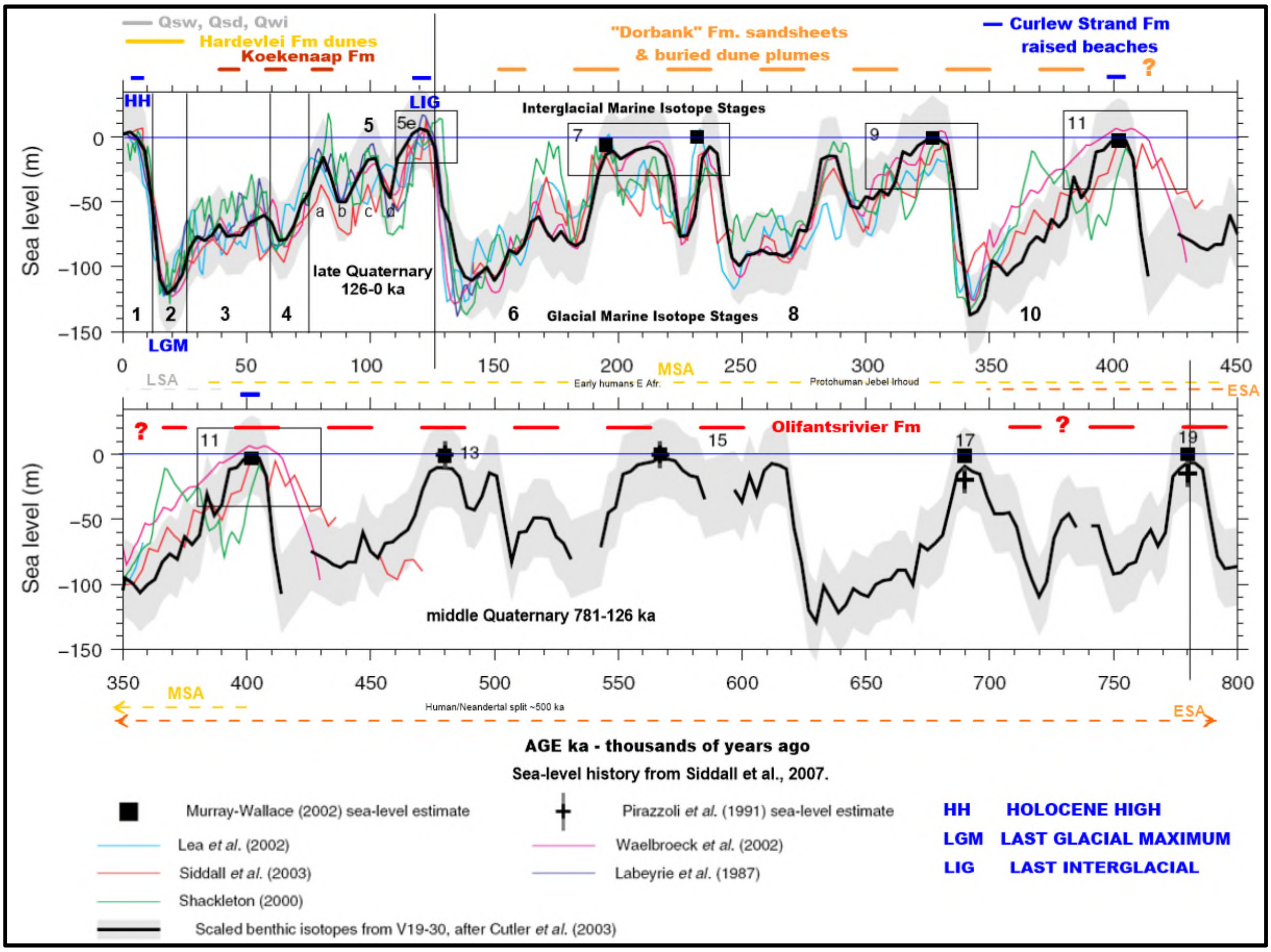

Figure 5. Sea-level history (from Siddall et al., 2007) and the age ranges of middle and late Quaternary formations of Namaqualand.

4.4.3 The Olifantsrivier Formation

This formation is a typical, variously reddened aeolianite with interbedded palaeosols, pedocretes, abundant root casts and termite burrows (pers. obs.), as exemplified in cliff exposures up to 30 m thick north of the Olifants River mouth and in the Namakwa Sands mine pit. Isolated cobble manuports and ESA/Acheulean handaxes and cleavers are found within the formation. Middle Stone Age (MSA) artefacts are also reported, but these occur on the eroded surfaces and slopes of the formation.

The ESA artefacts indicate an age range from ~1 Ma to ~350 ka (Figure 5). Fossils eroding out of a channel fill within the aeolianite succession on Geelwal Karoo 262 include *Numidocapra crassicornis*, a bovid hitherto found only in North Africa and Ethiopia where the age range for this fossil species is 2.5-1.7 Ma. Also found were teeth of *Dinofelis barlowi*, an extinct sabre-toothed felid, indicating an age range of 2.5-1.9 Ma. (Stynder & Reed, 2015). These finds suggest that the lower part of the Olifantsrivier Formation is older than ~1.7 Ma and extends from the earliest Quaternary (Figure 4), while the upper part which includes ESA material is latest early Quaternary/earliest middle Quaternary. This broad age range constraint is reflected by the several included member units separated by pedocretes.

4.4.4 The "Dorbank" Formation

There are unnamed units that post-date the capping pedocrete of the Olifantsrivier Fm. and precede the uppermost, unconsolidated formations described below. For example, thick "dorbank" comprised of several metres of reddened and semi-lithified, medium and coarse sands are typically exposed in excavations somewhat inland of the coast, overlying the eroded surfaces on Miocene and Pliocene marine deposits or older pedocreted aeolianites. This "dorbank" formation is a stack of successive sand sheets forming beds, 0.5 to ~1 m thick, with slightly differing hues of the neoformed pedogenic clays. The "dorbank" is quite hard and incipiently to variously cemented, but notably, this formation lacks the development of distinct, laterally continuous, pale pedocrete horizons, other marked, post-depositional features and also lacks an upper pedocrete capping. It may represent phased, but semi-continuous deposition over wide areas. Alternatively, the palaeoclimatic conditions were not conducive to the formation of pedocreted palaeosols. Interestingly, in the Graauw Duinen area the top of the "Dorbank" Formation includes discrete lenses of calcrete that are fossil heuweltjiesveld-type termitaria cf. the pre-LIG Q2 surface of the southwestern Cape. The "Dorbank" Formation is widespread along the Namaqualand coast where it occupies a spatio-temporal context as the youngest consolidated aeolianite beneath weakly-compacted to loose surface sands. Notably, MSA artefacts occur within its upper portion and on its top surface, these suggesting that the age is in the later part of the middle Quaternary, younger than about 400 ka (Figure 5).

4.4.5 The "Panvlei Formation" Surface

Proposed by De Beer (2010), the Panvlei Formation "represents sands, fluvial deposits and soils derived from bedrock erosion and reworking of Cenozoic sediments of all ages". Semi-silicified dorbank and calcretized and pedocreted deposits are included. The formation is overlain by "unconsolidated sands of Pleistocene to Holocene age". Its purpose is apparently to depict those surface areas that are closely underlain by the capping pedocrete or "dorbank" of the underlying formation. Clearly such a broad definition, based on surface outcrop, is a mapping practicality when it is not possible to determine the stratigraphic position of the underlying deposits, which could then be of differing ages.

The Panvlei Fm. on the 3017 Garies Sheet is depicted in two spatial contexts. The first is mainly distributed around the hills of the coastal hinterland which is mapped by botanists as "Namaqualand Heuweltjieveld" and is a "heuweltjiesveld" terrain of stabilized soil cover on thin colluvia and older, pedocreted aeolian & colluvial deposits. At lower elevations on the coastal plain the surface areas mapped as the Panvlei Fm. also correspond with areas of "kolletjiesveld" patterned, established vegetation where the red sands and younger coversands have not been accumulating. They are consequently areas closely underlain by older aeolianite units, such as the pedocreted or semi-lithified tops of the preceding formations – which could be referred to instead as "Panvlei-type Surfaces".

4.4.6 The Local Coastal Aeolianites

At the coast the aeolianites overlying the Quaternary raised beaches include smaller units that reflect local permutations of aeolian deposition during highstands of MISs 11 and 5e and at other times when sea levels were close to, but did not exceed, the present level *viz*. MISs 9, 7, 5c and 5a (Figure 7). Conceivably, at such times local shoreline aeolianite units were deposited at places along the coast. For example, the LIG raised beach is overlain by compact aeolian deposits, beneath the surficial, loose sands, that differ from place to place, i.e. rubified pink sands, or yellow sands, or grey sands, and that are apparently more locally confined to the coast and probably of different ages. These may not be of the same age as the much larger dune plumes extending inland from the vicinity of river mouths, or the widespread sand sheets or fields of degraded small dunes forming the "Dorbank" Formation inland on the wider coastal plain. These coastal units of later mid-Quaternary to earlier late-Quaternary age (Figure 5) exhibit variations of pedogenesis and pedocrete development, but lack substantial pedocrete horizons.

4.4.7 The Late Quaternary Surficial Aeolianites

The late Quaternary aeolianites include the following surface formations that have a distinguishable appearance in aerial imagery and that are present over wide areas. Nevertheless, their boundaries and extents are sometimes indistinct and their depiction on geological maps a matter of individual interpretation. Differing approaches and interpretations have been applied by the various authors, resulting in complexities and inconsistencies across maps (Table 1 below). While some maps depict only broad surface units (*e.g.* 2916 Springbok), others attempt to depict units that are buried beneath the younger coversands (*e.g.* 3017 Garies and 2816 Alexander Bay with respect to the Graauw Duinen Formation (Tgr)). The current limitations reflect the work required to produce a more seamless Quaternary surface unit classification. This state of affairs is not important for the purposes of this general report.

4.4.7.1 The Koekenaap Formation

Overlying the hard surface of the dorbank are compact, but unconsolidated markedly-red sands, the "Red Aeolian Sand" or RAS that is exploited at Namakwa Sands mine, now proposed as the Koekenaap Fm. (Roberts *et al*., 2006; De Beer, 2010). The red sands of the Koekenaap Fm. occupy most of the surface of the Namaqualand coastal plain and underlie the following formations described below. These younger formations obscure surface features of the red sands over large areas, but it seems reasonable to assume that the red sands accumulated in similar modes. Where thicker, subunits can be distinguished by subtle variations in hue and grain adhesion. The red sands are underlain by scatters of MSA material on top of the palaeosurface formed on the "Dorbank" or older aeolian formations. Preliminary results of Optically-Stimulated-Luminescence (OSL) dating of reddened coversands (Chase, 2006; Chase & Thomas, 2006, 2007) indicate late Quaternary ages between ~80 ka and ~30 ka and are presumed to reflect depositional ages of the red aeolian sands (Figure 5).

4.4.7.2 The Hardevlei Formation

Comprised of unconsolidated, pale-red to pale-yellow coversand deposits (sand sheets and degraded small dunes) that are younger that the RAS of the Koekenaap Formation (De Beer, 2010), this formation encompasses wide swathes of pale sand blown northwards from both river and shoreline sources, as well as patches inland that reflect the reworking of older sands or sands blown far from their sources. Aerial images show the complex morphology of these low, relict dunes which exhibit a reticulate pattern of linear dunes linked by numerous transverse, barchanoid elements. The complex pattern reflects a polyphase history and a varying wind regime. The OSL dates from the yellowish, inland reticulate dunes (Chase & Thomas, 2006, 2007) are generally less than ~20 ka and are probably representative of the aeolian activity/deposition of the Hardevlei Formation . Outlier ages of ~40 and ~80 ka at the bottom of 2 dune cores must reflect the ages of the underlying coversands (= Koekenaap Fm.) that were reworked into the patches of reticulate dunes.

Table 1. Labels applied to surficial deposits on geological maps.

Quaternary surficial aeolian formations - labels on 250k map sheets					
GEOMAP 250k	**White/pale-hued dune sands**	**Grey to pale yellow & red coversands**	**Red aeolian sands**	**Loam and sandy soil, heuweltjiesveld**	**Brak calc & gyp soils**
3318 Cape Town	Qw	Qs		Qg	Qb
Formation	Witzand	Springfontyn		Springfontyn	
3218 Clanwilliam	Q5	Q1		Q2	Q4
Formation	Witzand	Springfontyn		Springfontyn	
3118 Calvinia	Q-s	Q-r1	Ç-s	Ç-r1	Q-r2
Formation	Witzand	Springfontyn	Koekenaap	Springfontyn	
3017 Garies	Qwi & Qsw	Qh & Qd	Koekenaap	Qpa	
Formation	Witzand & Swartlintjies	Hardevlei & Swartduine	Koekenaap	Panvlei (surface)	
2916 Springbok	Q-s1	Q-s3	Q-s4	Q-s2	
Formation	Witzand & Swartlintjies	Pale sands incl. Hardevlei & Swartduine	Koekenaap	Panvlei (surface)	
2816 Alexander Bay	Qsw	Q39 unconsol sands?	Qkk	Q15 older sands, calcrete	Q-so
Formation	Swartlintjies	Surficial sandy soils, incl. Hardevlei & Swartduine?	Koekenaap? Mainly inland	Panvlei? (surface)	pans
AGE	**<20 ka**	**<25 ka**	**30 - 80 ka**	**>130 ka**	**Various ages**

4.4.7.3 The Swartlintjies Formation

The Swartlintjies Formation is proposed for the large, pale plumes of semi-stabilized parabolic dunes that extend from the beaches north of the main rivers (Roberts *et al*., 2006; De Beer, 2010). It has been suggested that these dune plumes originated during lower ice-age sea levels and were blown from the lower reaches of the rivers that then extended across the inner shelf (Tankard & Rogers, 1978). A few OSL dates are Holocene rather than of Last

Ice Age time. The OSL data are too few for conclusions, especially given that the dune plumes are clearly comprised of generations of smaller plumes and that sand mobility in the plumes is ongoing.

4.4.7.4 The Swartduine Formation

Proposed to accommodate somewhat muddy, light brown to green sands in areas between the major Late Quaternary dune plumes (De Beer, 2010). As interdune areas, these spaces will also have received sheetwash from the surrounding dunes and are damp longer after rainfall events due to surrounding seepage. The Swartduine Fm. as depicted on the 3017 Garies Sheet also includes thin, grey sandsheets and small dunes close to the coast, with a smooth vegetation texture that fades out landwards with thinning onto the red sands of the Koekenaap Fm. Broader swathes of similar pale coversand occur farther inland.

4.4.7.5 The Witzand Formation

This formation is extrapolated northward from the Sandveld Group of the southwestern Cape, where it accommodates sand and shell fragments blown from sandy beaches during the Holocene, in the form of partly-vegetated dune cordons backing the beach and the dune plumes transgressing inland. In the 3017 Garies Sheet the major dune plumes are separated as the Swartlintjies Fm. and thus the Witzand Fm. therein entails only the smaller dune plumes adjacent to the coast. These include active dunes and the more-vegetated, pale-grey dunes that are the origin of the name “Graauw Duinen” for some of these properties along the coast.

5 FORMATIONS IN THE PROJECT AREA

The subsurface inland extent of the three main coastal-plain marine formations is very approximately indicated by dashed lines in Figure 2 (KZ = Kleinzee, AV = Avontuur, HKB = Hondeklipbaai formations). The marine formations overlap and their actual extent in these zones is determined by the bedrock topography and the subsequent erosion of the upper part of the marine formations. The three Quaternary raised beaches are beneath dunes and dorbank close to the coast.

The Graauw Duinen Fm. is extensively depicted on the 3017 geological sheet/map (Figure 2, Tgr) as a formation comprising much of the surface. This is the result of a wide definition of the formation wherein it is regarded as encompassing all the aeolianites that overlie the marine formations (later Miocene, earlier Pliocene and later Pliocene) (De Beer, 2010). Subsequently, Roberts & Mthembi (2015) have proposed that the Graauw Duinen Fm. be restricted to West Coast Group aeolianites of Pliocene age. Its nature in the type area, based on personal observations, has been described above.

Observations and fossil finds from the Trans Hex Hondeklipbaai mine to the immediate north of Lang Klip 489 indicate that the deflated early Pliocene Avontuur Fm. there is overlain by thick, reddened aeolianites that post-date the Pliocene and are of probable mid-Quaternary age. Notwithstanding, it is quite possible that units equivalent to the Pliocene Graauw Duinen Fm. occur locally in the Project Area, but they are buried beneath younger aeolian formations where their presence and extent cannot be estimated without detailed stratigraphic interpretation of open pits. To sum up, the area depicted as the Graauw Duinen Formation (Tgr) in Figure 2 should rather be mapped as surficial red sands (Koekenaap Fm., Qkk) and it is underlain by the aeolianites that broadly correlate with the Quaternary Olifantsrivier and "Dorbank" formations.

The red Koekenaap Fm. sands occupying the higher, inland part of Lang Klip 489 are partly covered by patches of the complex dunes of the Hardevlei Formation. A small plume of partly-vegetated dunes of the Swartlintjies Fm. extends north from Langklipbaai (Figure 2). A similar, partly-vegetated plume extends north from the Spoegrivier mouth. Active dunes of the Witzand Fm. mark the downwind source areas of these plumes. A broad, diffuse zone of pale sands, the Swartduine Fm., has spread inland from the coast.

6 ASPECTS OF NAMAQUALAND VERTEBRATE PALAEONTOLOGY

The vertebrate fossils (bones, teeth) found in the coastal plain deposits are absolutely critical for the provision of age constraints. The sample of identifiable fossil bones and teeth from coastal Namaqualand is small (see tables in Pickford & Senut, 1997) and currently is just sufficient to provide age constraints that support correlations with gross sea-level/ice-volume history. Nevertheless, study of the Hondeklip exposures have demonstrated that there are more bone/teeth fossils in the deposits than is generally perceived, as has been revealed by dedicated searching. These occur in the following contexts:

- Basal, petrified, mixed assemblage: petrified (phosphatized), variously abraded, reworked fossils found the basal gravels and that pre-date the enclosing marine deposits. Includes both terrestrial and marine vertebrates.

- The marine assemblage: cetacean, seabird and seal fossils contemporaneous with the enclosing marine deposits. Input of terrestrial bones is associated with local back-barrier environments (lagoons, tidal channel lags).

- The capping, terrestrial assemblage: Bones of land animals common on the extensive palaeosurface erosively formed on the marine deposits.

- Overlying terrestrial deposits: Mainly aeolianites (dune, interdune/pan and sandsheet deposits), locally with colluvial and ephemeral streamwash deposits. Rare bones occur on palaeosurfaces within these sequences. Fossils are more common in interdune deposits.

In aeolianites, the fossil material most commonly seen is the ambient fossil content of dune sands: land snails, tortoise shells and mole bones. Other small bones occur very sparsely such as bird and small mammal bones. The fossil content is more abundant in association with palaeosurfaces and their soils (palaeosols), formed during periods of dune stabilization and which define aeolian packages and larger formations. Importantly, the bones of larger animals (*e.g.* antelopes) are more persistently present along palaeosurfaces formed on top of marine deposits and the palaeosurfaces which separate the major aeolianite units.

The deposits on slopes adjacent to the coast have a higher content of fossil bones due to the attraction of the shoreline for foraging and scavenging. For example, jackals and hyaenas scavenge seabird, seal and other carcasses, carrying remains onto the sand slopes. The most spectacular bone concentrations found in aeolianites are due to the bone-collecting behaviour of hyaenas which store bones in and around their lairs.

In younger aeolianites it is more likely that fossil bones may occur in an archaeological context, with artefacts and shell. The fossil material in these deposits is a sample of the middle and late Quaternary fauna of the Namaqualand coast. For example, fossil bones in aeolianite near the Swartlintjiesrivier were associated with ESA artefacts and include large species (elephant, sivathere, zebra). *Sivatherium maurusium* was a large, heavily-built short-necked giraffid common in Africa between ~5 to ~0.4 Ma. In addition small species were collected (hare, squirrel, moles, snake). The estimated age is mid-Quaternary and the large mammals indicate that the coast was better watered than the present-day (Pickford & Senut, 1997).

A late Quaternary fauna was obtained from calcareous interdune deposits exposed between the dunes of the Swartlintjies Formation. The presence of frogs indicates a damp environment. Larger species include ostrich, zebra and steenbok and oddly, giraffe, a browser. A variety of small rodent taxa occurred. Other than the giraffe the fauna is essentially modern. The giraffe suggests that woodland still occurred in Namaqualand as recently as the late Quaternary, probably related to riverine settings and wetter conditions associated with ice age climate (Pickford & Senut, 1997).

The fossil bone finds from excavations in aeolianites demonstrate that this sparse material, of both small (rodents, birds) and larger animals (antelopes, carnivores), is important to on-going palaeoclimatic, palaeobiological and biostratigraphic studies. Consequently, the palaeontological sensitivity of the aeolian formations is HIGH with respect to fossil bones.

7 PALAEONTOLOGICAL IMPACT OF THE PROSPECTING

The prospecting drilling involves small vertical volumes and the impact relative to mining is marginal. The fossil material likely to be encountered in drill samples from aeolianites is the ambient fossil content of land snails, tortoise bones and mole bones. Fossil marine shell is not well-preserved in most of the marine deposits, but fossil shell will be encountered in some drillholes. Though likely fragmentary, it may be diagnostic of the marine formation penetrated. Other fossils which are brought up in boreholes include smaller petrified material such as shark and other fish teeth and casts of shells (steinkerns).

In the process of the prospecting drilling programme displaced fossil bones may be found on the overburden dumps or may be exposed in the eroding sides of mine pits.

8 CONCLUSIONS AND RECOMMENDATIONS

The impact of the prospecting programme is considered to be LOW.

It is recommended that a requirement to be alert for possible fossil materials and archaeological material be included in the Environmental Management Plan (EMP) for the proposed prospecting operations.

The mitigation measures proposed in the Desktop Heritage Impact Assessment by CTS include:

- Implementation of an archaeological and palaeontological awareness programme.
- Implementation of the Fossil Finds Procedure.
- In addition to the above proposed mitigatory measures, all core samples will be sifted on site to separate heavy minerals from the matrix. At this point, all palaeontological or archaeological material contained in the cores will be identified by the on site geologist who will bag the finds, recording the GPS co-ordinates of the core sample from which they are derived. This material will then be sent to Cape Town for analysis by professional researchers. In the event that subsurface archaeological deposits are encountered, these can be red flagged, and then avoided to prevent further damage. For the palaeontological samples, this coring will serve to positively identify the location of sensitive fossils within a landscape of highly sensitivity geological deposits.

These mitigation measures are deemed adequate for the prospecting drilling, in particular, the collection of coarse-fraction fossiliferous material for analysis.

8.1 FOSSIL FINDS PROCEDURE

In the event that scientifically valuable fossil bones are noticed in the overburden dumps or in the mining areas, any further disturbance must be prevented at the site and the Environmental Control Officer (ECO) for the project must be informed immediately. Scattered, parts/fragments of the find must be retrieved and returned to the main find site which must be protected.

The ECO or representative must then inform SAHRA immediately and provide:

- A description of the nature of the find.
- Detailed images of the finds (with scale included).
- Position of the find (GPS) and depth.
- Digital images of the context. *i.e*. the excavation or site (with scales).

SAHRA and an appropriate specialist palaeontologist will assess the information and liaise with the developer, the environmental consultants and the ECO and a suitable response will be established.

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10 GLOSSARY

~ (tilde): Used herein as "approximately" or "about".

Aeolian: Pertaining to the wind. Refers to erosion, transport and deposition of sedimentary particles by wind. A rock formed by the solidification of aeolian sediments is an aeolianite.

AIA: Archaeological Impact Assessment.

Alluvium: Sediments deposited by a river or other running water.

Archaeology: Remains resulting from human activity which are in a state of disuse and are in or on land and which are older than 100 years, including artefacts, human and hominid remains and artificial features and structures.

asl.: above (mean) sea level.

Bedrock: Hard rock formations underlying much younger sedimentary deposits.

Calcareous: sediment, sedimentary rock, or soil type which is formed from or contains a high proportion of calcium carbonate in the form of calcite or aragonite.

Calcrete: An indurated deposit (duricrust) mainly consisting of Ca and Mg carbonates. The term includes both pedogenic types formed in the near-surface soil context and non-pedogenic or groundwater calcretes related to water tables at depth.

Clast: Fragments of pre-existing rocks, *e.g.* sand grains, pebbles, boulders, produced by weathering and erosion. Clastic – composed of clasts.

Colluvium: Hillwash deposits formed by gravity transport downhill. Includes soil creep, sheetwash, small-scale rainfall rivulets and gullying, slumping and sliding processes that move and deposit material towards the foot of the slopes.

Coversands: Aeolian blanket deposits of sandsheets and dunes.

Duricrust: A general term for a zone of chemical precipitation and hardening formed at or near the surface of sedimentary bodies through pedogenic and (or) non-pedogenic processes. It is formed by the accumulation of soluble minerals deposited by mineral-bearing waters that move upward, downward, or laterally by capillary action, commonly assisted in arid settings by evaporation. Classified into calcrete, ferricrete, silcrete.

ESA: Early Stone Age. The archaeology of the Stone Age between ~1.4 Ma and ~300 ka.

EIA: Environmental Impact Assessment.

EMP: Environmental Management Plan.

Facies: Sedimentary facies are bodies of sediment that possess a suite of characters that reflect particular processes of the depositional environment. Ichnofacies are the assemblages of trace fossils typical of certain environments.

Ferricrete: Indurated deposit (duricrust) consisting predominantly of accumulations of iron sesquioxides, with various dark-brown to yellow-brown hues. It may form by deposition from solution or as a residue after removal of silica and alkalis. Like calcrete it has pedogenic and groundwater forms. Synonyms are laterite, iron pan or “koffieklip”.

Fluvial deposits: Sedimentary deposits consisting of material transported by, suspended in and laid down by a river or stream.

Fm.: Formation.

Fossil: Mineralised bones of animals, shellfish, plants and marine animals. A trace fossil is the disturbance or structure produced in sediments by organisms, such as burrows and trackways.

Heritage: That which is inherited and forms part of the National Estate (Historical places, objects, fossils as defined by the National Heritage Resources Act 25 of 1999).

HIA: Heritage Impact Assessment.

LSA: Late Stone Age. The archaeology of the last ~40 ka associated with fully modern people.

LIG: Last Interglacial. Warm period 128-118 ka. Relative sea-levels higher than present by 4-6 m. Also referred to as Marine Isotope Stage 5e or “the Eemian”.

Midden: A pile of debris, normally shellfish and bone that have accumulated as a result of human activity.

MIS: Marine isotope stages (MIS), marine oxygen-isotope stages, or oxygen isotope stages (OIS), are alternating warm and cool periods in the Earth's paleoclimate, deduced from oxygen isotope data reflecting changes in temperature derived from data from deep sea core samples. Working backwards from the present, MIS 1 in the scale, stages with even numbers representing cold glacial periods, while the odd-numbered stages represent warm interglacial intervals.

MSA: Middle Stone Age. The archaeology of the Stone Age between ~400 and ~40 ka associated with early humans.

OSL: Optically stimulated luminescence. One of the radiation exposure dating methods based on the measurement of trapped electronic charges that accumulate in crystalline materials as a result of low-level natural radioactivity from U, Th and K. In OSL dating of aeolian quartz and feldspar sand grains, the trapped charges are zeroed by exposure to daylight at the time of deposition. Once buried, the charges accumulate and the total radiation exposure (total dose) received by the sample is estimated by laboratory measurements. The level of radioactivity (annual doses) to which the sample grains have been exposed is measured in the field or from the separated minerals containing radioactive elements in the sample. Ages are obtained as the ratio of total dose to annual dose, where the annual dose is assumed to have been similar in the past.

Palaeontology: The study of any fossilised remains or fossil traces of animals or plants which lived in the geological past and any site which contains such fossilised remains or traces.

Palaeosol: An ancient, buried soil whose composition may reflect a climate significantly different from the climate now prevalent in the area where the soil is found. Burial reflects the subsequent environmental change.

Palaeosurface: An ancient land surface, usually buried and marked by a palaeosol or pedocrete, but may be exhumed by erosion (*e.g.* wind erosion/deflation) or by bulk earth works.

Peat: partially decomposed mass of semi-carbonized vegetation which has grown under waterlogged, anaerobic conditions, usually in bogs or swamps.

Pedogenesis/pedogenic: The process of turning sediment into soil by chemical weathering and the activity of organisms (plants growing in it, burrowing animals such as worms, the addition of humus *etc.*).

Pedocrete: A duricrust formed by pedogenic processes.

PIA: Palaeontological Impact Assessment.

SAHRA: South African Heritage Resources Agency – the compliance authority, which protects national heritage.

Stone Age: The earliest technological period in human culture when tools were made of stone, wood, bone or horn. Metal was unknown.

Type locality: The specific geographic locality where the stratotype of a layered stratigraphic unit is situated. The name also refers to the locality where the unit was originally described and/or named.

10.1 GEOLOGICAL TIME SCALE TERMS (YOUNGEST TO OLDEST).

ka: Thousand years or kilo-annum (10^3 years). Implicitly means "ka ago" *i.e.* duration from the present, but "ago" is omitted. The "Present" refers to 1950 AD. Generally not used for durations not extending from the Present. Sometimes "kyr" is used instead.

Ma: Millions years, mega-annum (10^6 years). Implicitly means "Ma ago" *i.e.* duration from the present, but "ago" is omitted. The "Present" refers to 1950 AD. Generally not used for durations not extending from the Present.

Holocene: The most recent geological epoch commencing 11.7 ka till the present.

Mid Pliocene Warm Period (MPWP): An interval of warm climate and high sea level around ~3 Ma. When this interval was referred to as "mid-Pliocene" the boundary between the Pliocene and Quaternary was set younger, at 1.8 Ma at the beginning of the Calabrian (see figure below). Now that the Pliocene/Quaternary boundary is set further back in time by international agreement to the beginning of the Gelasian at ~2.6 Ma, the MPWP at ~3 Ma is no longer "mid", but is in the late Pliocene. However, for continuity it is still being referred to as the MPWP.

Pleistocene: Epoch from 2.6 Ma to 11.7 ka. Late Pleistocene 11.7–126 ka. Middle Pleistocene 135–781 ka. Early Pleistocene 781–2588 ka (0.78-2.6.Ma).

Quaternary: The current Period, from 2.6 Ma to the present, in the Cenozoic Era. The Quaternary includes both the Pleistocene and Holocene epochs. The terms early, middle or late in reference to the Quaternary should only be used with lower case letters because these divisions are informal and have no status as divisions of the term Quaternary. As used herein, early and middle Quaternary correspond with the

Pleistocene divisions, but late Quaternary includes the Late Pleistocene and the Holocene.

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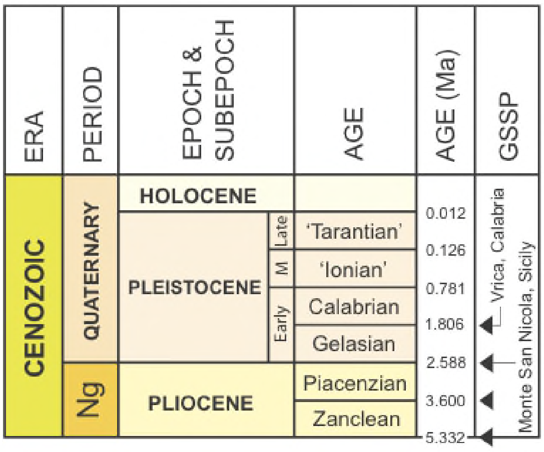

Pliocene: Epoch from 5.3-2.6 Ma.

Miocene: Epoch from 23-5 Ma.

Neogene: Period comprising the Miocene and Pliocene epochs.

Oligocene: Epoch from 34-23 Ma.

Eocene: Epoch from 56-34 Ma.

Paleocene: Epoch from 65-56 Ma.

Cenozoic: Era from 65 Ma to the present. Includes Paleocene to Holocene epochs.

Cretaceous: Period in the Mesozoic Era, 145-65 Ma.

Jurassic: Period in the Mesozoic Era, 200-145 Ma.

Precambrian: Old crustal rocks older than 542 Ma (pre-dating the Cambrian).

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