PALAEONTOLOGICAL IMPACT ASSESSMENT

DANSILE NXIKWE DIAMONDS CC PROSPECTING RIGHT APPLICATION WITH BULK SAMPLING ON A PORTION OF PLOT 516, PLOT 678 AND PLOT 668, PORT NOLLOTH

RICHTERSVELD LOCAL MUNICIPALITY, NAMAKWA DISTRICT MUNICIPALITY

NAMAKWALAND MAGISTERIAL DISTRICT, NORTHERN CAPE

DMR REFERENCE NUMBER: NC 30/5/1/1/2/12672 PR

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For

Dansile Nxikwe Diamonds CC

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EXECUTIVE SUMMARY

1. Project Name

Dansile Nxikwe Diamonds CC Prospecting Right Application to prospect for the occurrence of diamonds on parts of Port Nolloth Township land.

2. Location

The Prospecting Right Application Area (NC 30/5/1/1/2/12672 PR) occupies the Port Nolloth Township land surrounding the town and the extent of ~2212 ha mainly includes part of the Remainder Plot 516, the triangular Plot 678 and the small Plot 668 in the south (Figure 1).

3. Locality Plan

Dansile Nxikwe Diamonds has an existing Prospecting Right NC30/5/1/1/2/11976PR on part of Plot RE/516 (Figure 1). This application proposes to extend the existing prospecting right to include the larger area indicated in Figures 1 and 2. The preliminary prospecting target areas are indicated in Figures 1 and 2 and the Diamond Processing Plant is to be located in the north-western corner of the application area in an existing, historical mining pit ~500 m from the seashore.

4. Proposed Prospecting

- PHASE 1 involves data compilation, field assessment and a Ground Resistivity geophysical survey, in order to further inform the choice of prospecting programme targets.
- PHASE 2 involves Preliminary Evaluation by Pitting (Figure 3). It is anticipated that no more than 30 prospecting pits will be excavated. The prospecting pitting is intended to characterise the deposits by logging the pits and basal gravels and collecting small samples.
- PHASE 3 involves Trench Bulk Sampling whereby the surface footprint of a trench is a rectangular area of 100 by 50 m. Between 5-10 bulk sampling sites are envisaged.
- Phases 4 and 5 entail the interpretation and evaluation of the prospecting data.

Due to the unavoidable general nature of the assessment of hidden, subsurface palaeontological resources the precise locations of the pits and trenches do not affect the gist and recommendations of this assessment.

5. Affected Formations

The prospecting Project Area is located on the Middle Terrace and the Lower Terrace (Figure 8, as mapped by Keyser, 1972). The late Pliocene, marine Hondeklipbaai Formation (30 m Package) overlies most the of area of the Middle Terrace bedrock. The three Quaternary raised beaches of the Curlew Strand Fm. occupy most of the Lower Terrace. Patches of the older, marine, early Pliocene Avontuur Fm. and of the mid-Miocene Kleinzee Fm. may be preserved in places beneath the Hondeklipbaai Fm. basal gravels.

The Port Nolloth area has been subject to aeolian erosion during the Quaternary and the older, Pliocene-early Quaternary aeolian formations are absent. The Hondeklipbaai Fm. is overlain by a unit of hard aeolian sands in which a calcrete has formed and which may be a condensed approximate equivalent of the Olifantsrivier Fm. or the Dorbank Fm. The calcrete is overlain by a thin aeolian sandsheet of compact brown sands, speculatively equivalent to the Koekenaap Fm. The latter is succeeded by geologically-recent, pale-grey and white sand dunes with slightly pink/brown sands in interdune areas (Figure 4, Q-s3). In the north (Pit Areas 1, 2) are the coastal dunes of the Witzand Fm. (Figure 4, Q-s1). The pan is rimmed by pan carbonate deposits of a much expanded pan and other “fossil” pan deposits occur in the area.

6. Anticipated Impacts

The fossil shell fauna of the early Pliocene Avontuur Fm. in central Namaqualand (Hondeklipbaai area) is fairly well sampled due to fortuitous preservation (Carrington & Kensley, 1969; Kensley & Pether, 1986). However, the sample is spatially and biogeographically restricted. Due to the poor preservation of shell in most of the decalcified Hondeklipbaai Fm. the sample is relatively small and biased toward robust shells. These shortcomings are illustrated by the fact that several species found by Carrington & Kensley (1969) have not been found again. If well-preserved shell beds are uncovered it is expected that the list of known species will be lengthened and more extinct shell species, and warm-water species, will be found, some of which are ancestral to the endemic modern fauna. The Avontuur and Hondeklipbaai formations are thus of MODERATE sensitivity with respect to shell fossils.

The Curlew Strand Fm. is dominated by shell species still living today and is of LOW sensitivity with respect to shell fossils. Notwithstanding, sheltered embayments may have pertained in the Port Nolloth area, such as in the main pan locations, and these deposits will include the warm-water, extralimital "guests" of West African origin not yet recorded from Namaqualand.

Very sparsely scattered bones occur within these marine deposits, such as bones of whales, dolphins, seals and seabirds, while terrestrial mammal bones are found in estuarine deposits. The abraded, brown-coloured, petrified bones and teeth of older marine taxa, as well as those of terrestrial vertebrates, occur in basal marine gravels. The smaller petrified teeth are found in the rotary pan heavy concentrates from gravels and have provided critical age constraints for our understanding of coastal-plain geohistory (Pickford & Senut, 1997). In these marine formations the bones are mainly of extinct species and are of HIGH palaeontological importance.

Due to the apparent lack of older, Pliocene to early Quaternary aeolianite formations in the Project Area the fossil terrestrial faunas which may be discovered are expected to be younger, *i.e*. later mid-Quaternary and late Quaternary, and are accorded a MODERATE palaeontological sensitivity.

7. Recommendations

There are no known outcrops of sensitive fossiliferous strata in the Project Area that require protection as NO-GO sites, such as spots where fossil bones occur in obvious abundance.

There will only be three prospecting pits open at any given time, one being backfilled, one that is operational and one being excavated. Similarly, only one bulk sample trench will be open at any given time. The duration of the prospecting is not specified, but presumably will take place over a few years. It is not feasible for a specialist to routinely monitor the excavation of the pits and trenches. Routine monitoring can only be achieved by the co-operation of the people on the ground. By these are meant personnel in supervisory/inspection roles, such as the geologist, surveyor, pit foremen, etc., who are willing and interested to look out for occurrences of fossils. A monitoring presence is critical for spotting a major "strike" of fossil bones and stopping further damaging excavation.

It is recommended that a requirement to be alert for fossil materials and archaeological material uncovered during the prospecting be included in the Environmental Management Programme (EMPr) for the proposed prospecting operations. Under supervision of the Environmental Control Officer (ECO) and as part of Environmental and Health & Safety awareness training, personnel involved in the prospecting excavations must be instructed to be alert particularly for the occurrence of fossil bones. Due to the scarcity and importance of fossil bones in the affected formations it is important that such ephemeral opportunities to rescue fossil bones must not be overlooked. In the event of such discoveries the **Fossil Finds Procedure** (FFP) provided below, for incorporation into the Environmental Management Programme for the proposed prospecting, must be followed.

Very importantly, mine staff must be empowered to rescue the fossil material that appears sporadically, but quite routinely during excavation and must be promptly rescued from loss. For instance, as fossil tortoises are quite common, they should be in the category of "allowed" rescue by mine staff *cf*. isolated bone finds in the FFP below. It is highly recommended that mine staff must be empowered to rescue the petrified fossil material, usually teeth, that is retained in the rotary pan concentrates and which is seen during their sorting.

In the event of the uncovering of fossil bones, or fortuitously-preserved very shelly beds, which on consultation are deemed to be significant finds, a professional palaeontologist must be appointed to excavate the fossil bones and sample the shell beds. Said palaeontologist must also undertake the recording of the stratigraphic context and sedimentary geometry of the exposure and the compilation of the report to SAHRA and the relevant curatorial institution, *e.g.* the IZIKO S.A. Museum.

A contribution to mitigation which is of great importance is the creation of a systematic archive of the pit and trench exposures over the duration of the prospecting, and later possible mining. Involving the Project Geologist, or perhaps a student doing fieldwork for a thesis, a systematic archive of the pit and trench exposures will be a significant positive contribution to the geoscience and geoheritage of the Namaqualand coastal-plain formations in this area. Also in this context, in co-operation and liaison with the Project Geologist, it may be mutually beneficial that the consulting palaeontologist carry out field inspections of the large prospecting trenches.

The proposed mitigation actions for the prospecting programme are relatively easily accomplished and their implementation will result in a positive impact for palaeontology arising from the proposed prospecting operation. The Director, Project Geologist and ECO for Dansile Nxikwe Diamonds CC are welcome to contact me about any clarifications or advice.

CONTENTS

ABBREVIATIONS

asl.	above (mean) sea level.
bsl.	below (mean) sea level.
CD-NGI	Chief Directorate – national geo-spatial Information.
EMPr	Environmental Management Programme.
EPWP	Early Pliocene Warm Period.
ESA	Early Stone Age.
Fm.	Formation.
HM	Heavy Minerals.
HWC	Heritage Western Cape.
LIG	Last Interglacial.
LPWP	Late Pliocene Warm Period.
MIS	Marine Isotope Stage.
MMCO	Mid Miocene Climatic Optimum.
MSA	Middle Stone Age.
OSL	Optically stimulated luminescence.
PIA	Palaeontological Impact Assessment.
SAHRA	South African Heritage Resources Agency.
SRTM	Shuttle Radar Topography Mission – NASA.

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.

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

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.

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.

Conglomerate: A cemented gravel deposit.

Coversands: Aeolian blanket deposits of sandsheets and smaller 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, gypcrete, sepiocrete etc.

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

Fossil: The remains of parts of animals and plants found in sedimentary deposits. Most commonly hard parts such as bones, teeth and shells which in lithified sedimentary rocks are usually altered by petrification (mineralization). Also impressions and mineral films in fine-grained sediments that preserve indications of soft parts. Fossils plants include coals, petrified wood and leaf impressions, as well as microscopic pollen and spores. Marine sediments contain a host of microfossils that reflect the plankton of the past and provide records of ocean changes. Nowadays also includes molecular fossils such as DNA and biogeochemicals such as oils and waxes.

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).

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-day interglacial which is MIS 1, stages with odd numbers represent warm interglacial intervals and stages with even numbers represent cold glacial periods.

Optically-stimulated Luminescence (OSL). 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 formed on a palaeosurface. The soil 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.

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.

Rhizolith: Fossil root. Most commonly formed by pedogenic carbonate deposition around the root and developed in palaeosols.

Sepiocrete: A duricrust with a high content of the magnesian clay mineral sepiolite.

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

Stratotype locality: The place where deposits regarded as defining the characteristics of a particular geological formation occur.

Tectonic: Relating to the structure of the earth's crust and the large-scale processes which take place within it (faulting and earthquakes, crustal uplift or subsidence.

Trace fossil: A structure or impression in sediments that preserves the behaviour of an organism, such as burrows, borings and nests, feeding traces (sediment processing), farming structures for bacteria and fungi, locomotion burrows and trackways and traces of predation on hard parts (tooth marks on bones, borings into shells by predatory gastropods and octopuses).

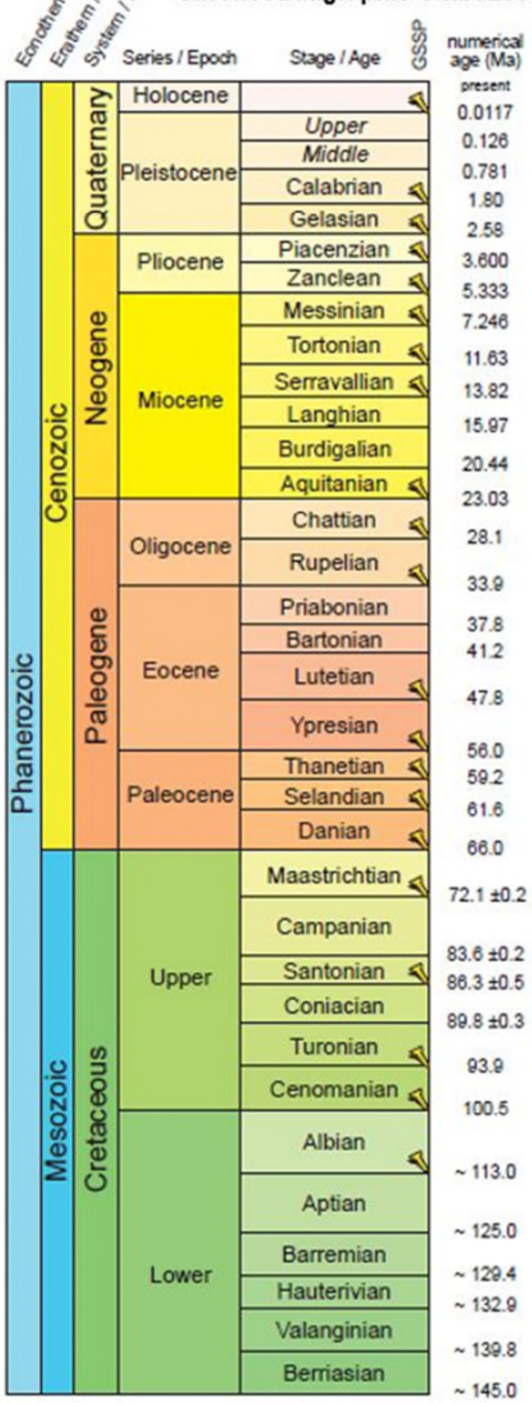
GEOLOGICAL TIME SCALE TERMS

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. Not used for durations not extending from the Present. For a duration only “kyr” is used.

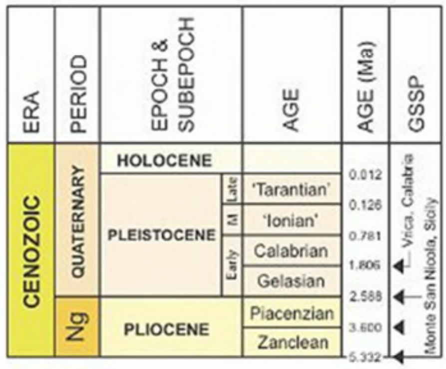
Ma: Millions years, mega-annum (10^6 years). Implicitly means “Ma ago” *i.e.* duration from the present, but “ago” is omitted. The “Present” refers to 1950 AD. Not used for durations not extending from the Present. For a duration only “Myr” is used.

For more detail see www.stratigraphy.org.

Mesozoic and Cenozoic Chronostratigraphy
From: International Commission on Stratigraphy.
Chronostratigraphic Chart 2016-12.pdf



ICS-approved 2009 Quaternary (SQS/INQUA) proposal



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

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.

Quaternary: The current Period, from 2.6 Ma to the present, in the Cenozoic Era.
The Quaternary includes both the Pleistocene and Holocene epochs. As used herein, early and middle Quaternary correspond with the Pleistocene divisions, but late Quaternary includes the Late Pleistocene and the Holocene.

1 INTRODUCTION

The Applicant, Dansile Nxikwe Diamonds CC (DND), is applying for a Prospecting Right in terms of the Mineral and Petroleum Resources Development Act 28 of 2002 (as amended), to prospect for the occurrence of diamonds on parts of Port Nolloth Township land on the coastal plain of northern Namaqualand (Figure 1). Green Direction Sustainability Consulting (Pty) Ltd has undertaken the Scoping Report for the environmental authorisation process for the proposed prospecting. ASHA Consulting (Pty) Ltd is undertaking the Heritage Impact Assessment (HIA) of which this report forms part and its brief is to inform about the palaeontological sensitivity of the Project Area and the probability of palaeontological materials (fossils) being uncovered in the subsurface and being disturbed or destroyed in the process of prospecting, and to provide recommendations for palaeontological mitigation to be included in the Environmental Management Programme (EMPr) for the proposed prospecting.

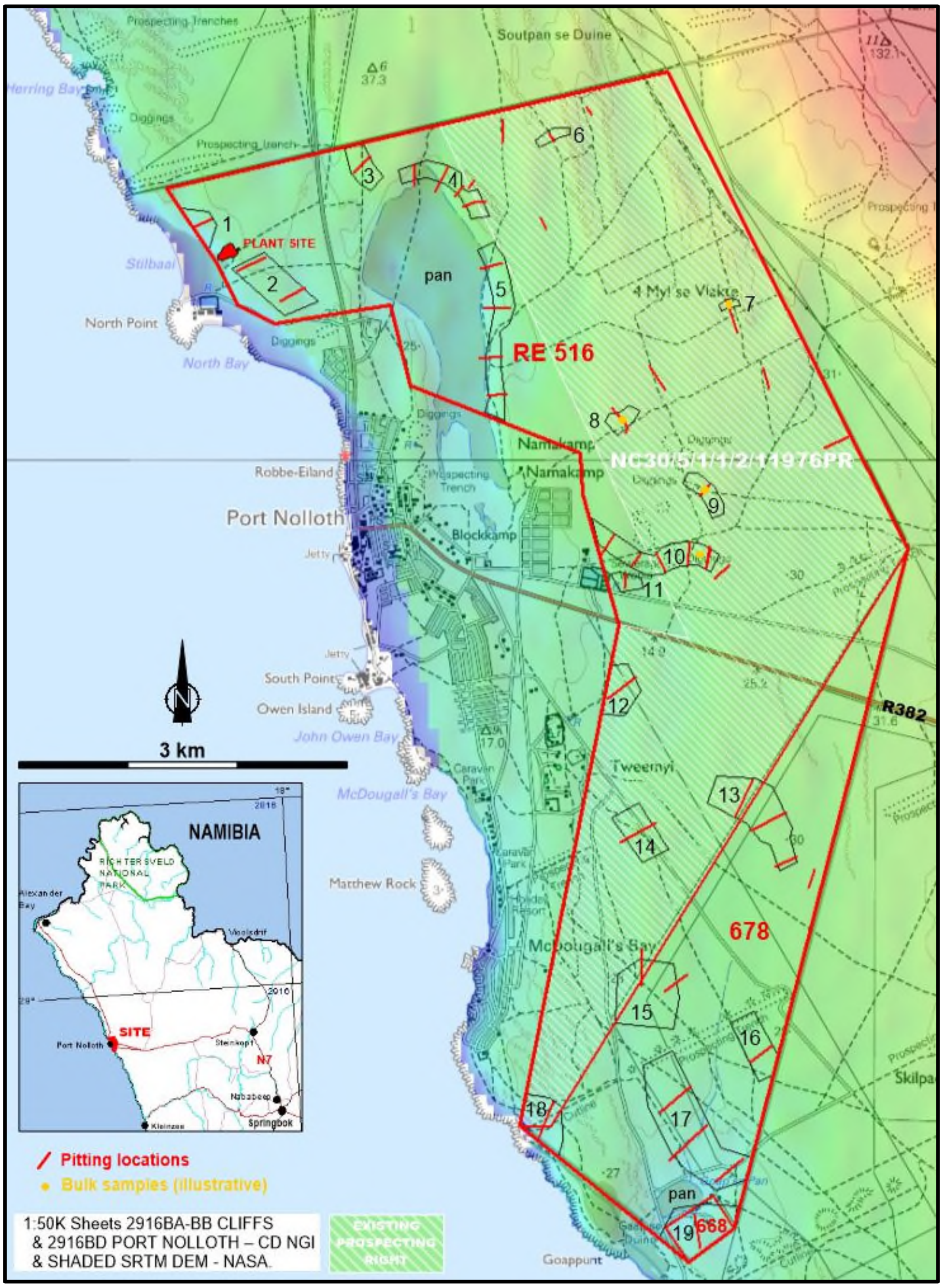


Figure 1. The Port Nolloth Prospecting Right Application Area for diamond prospecting.

2 LOCATION

The DND Prospecting Right Application Area (NC 30/5/1/1/2/12672 PR) occupies the Port Nolloth Township land surrounding the town and the extent of ~2212 ha mainly includes part of the Remainder Plot 516, the triangular Plot 678 and the small Plot 668 in the south (Figure 1).

CD-NGI Topo-cadastral Mapsheets:

- 1:50000 2916BA-BB CLIFFS and 2916BD PORT NOLLOTH.

Council for Geoscience Geological Sheet:

- 1:250000 2916 SPRINGBOK.

3 LOCALITY PLAN

Dansile Nxikwe Diamonds has an existing Prospecting Right NC30/5/1/1/2/11976PR on part of Plot RE/516 (Figure 1). This application proposes to extend the existing prospecting right to include the larger area indicated in Figures 1 and 2, in order to investigate additional exploration targets and create a potentially viable mining area. The target areas of interest and proposed locations of the prospecting pits and bulk sampling trenches are indicated in Figures 1 and 2.

Figure 2. Landscape context of the Prospecting Right Application Area.

4 PROPOSED ACTIVITIES

The prospecting is to evaluate the occurrence and abundances of gem diamonds in the coastal-plain deposits.

PHASE 1 involves **Field assessment follow-up** on previous desktop activities (data sourcing and evaluation of existing geological and prospecting data, satellite imagery and terrain data), and **Ground Resistivity geophysical survey**, in order to further inform the choice of prospecting programme targets.

PHASE 2 involves **Preliminary Evaluation by Pitting**. The prospecting pitting is intended to characterise the deposits by logging the pits and basal gravels and collecting small samples. The typical section through the deposits comprises:

- 0.0 - 0.5 m Surficial sands/topsoil.
- 0.5 – 5.5 m Overburden - aeolian and marine sands (~5 m thick).
- 5.5 – 6.5 m Basal gravel (~1 m thick).

The surface footprint of a prospecting pit is a rectangular area of 11 by 8 m, with the excavation sides sloping down to an area of exposed gravel at ~5 m depth of 5 by 2 m (Figure 3).

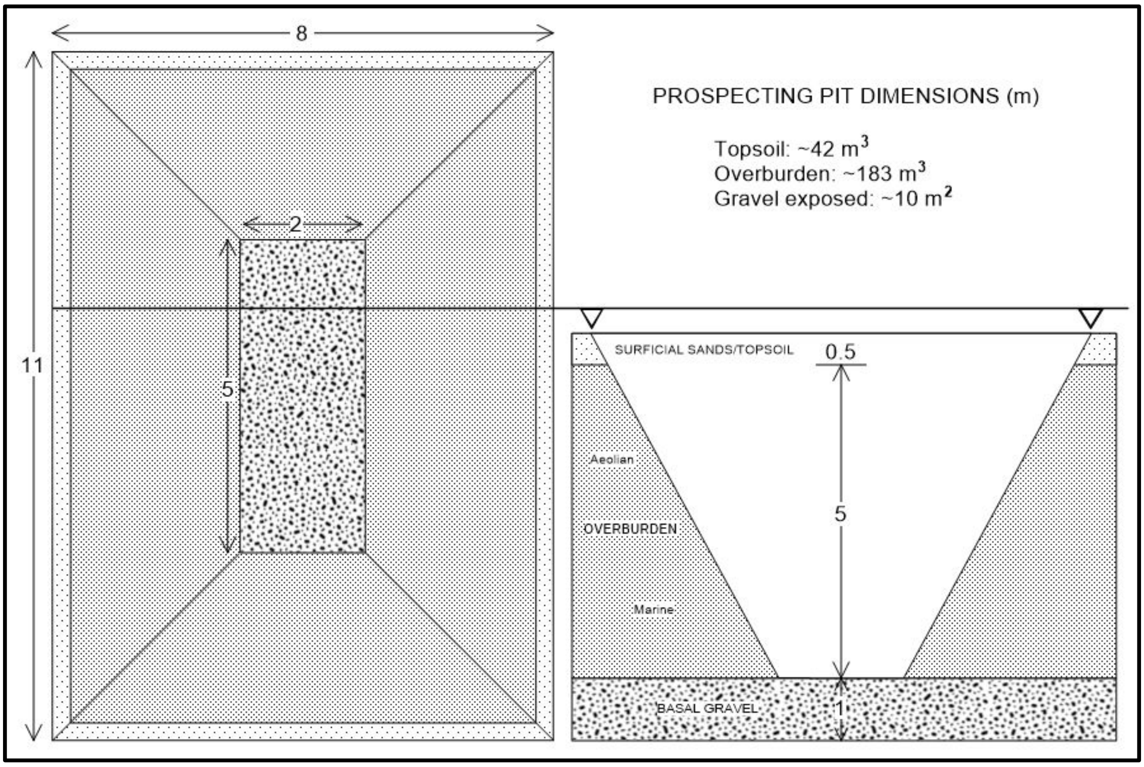


Figure 3. Prospecting pit in typical deposit thicknesses.

It is anticipated that no more than 30 prospecting pits will be excavated. After logging and sampling each pit will be backfilled before moving to the next pit site.

PHASE 3 involves **Trench Bulk Sampling** whereby the surface footprint of a trench is a rectangular area of 100 by 50 m, with the excavation sides sloping down to an area of exposed gravel at ~5 m depth of 94 by 44 m. The excavated trench volume to the basal gravel is ~22 800 m^3 (97x47x5 m), on top of ~4136 m^3 of gravel (~1 m thick). Between 5-10 bulk sampling sites are envisaged.

The gravel will be screened (sieved) on site with 2 mm and 25 mm meshes to remove sand and large pebbles (~90% of the gravel) and the ~10% of gravel between 2-25 mm will be trucked to the diamond processing plant.

The **Diamond Processing Plant** is to be located in the north-western corner of the application area in an existing, historical mining pit ~500 m from the seashore (Figure 1), due to the plant requirement for seawater. The screened fine pebble gravel from the bulk sample trench will be fed into rotary pans for concentration of the heavier small pebbles and diamonds. The concentrate will be passed through an X-ray diamond sorter (FLOW SORT X-Ray Media Separator) to separate the diamonds.

Phases 4 and 5 entail the ongoing **interpretation and evaluation of the prospecting and sampling data**, in order to optimise the prospecting programme and to estimate the diamond resources present and ultimately the feasibility of mining the deposits.

5 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).

6 APPROACH AND METHODOLOGY

6.1 AVAILABLE INFORMATION

Historically, Port Nolloth is famous for being nearby the site of the initial definite discovery of diamonds on the Namaqualand coast. This was in 1925, when Jack Carstens investigated basal marine gravels exposed in an abandoned and dune-blocked channel of the Kammarivier, about 9 km south of Port Nolloth. The early prospects near Port Nolloth were examined by Wagner & Merensky (1928) and Haughton (1926, 1928, 1932) described the fossil faunas. The profusion of fossil oysters in the deposits led to the popular perception of an “Oyster Line” associated with diamonds and the realization that sea temperatures along the west coast were once warmer than at present. Much later, Keyser (1972) summarized the results of an extensive drilling and trenching campaign by the State Alluvial Diggings (now Alexkor), which included the Port Nolloth area.

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. The relevant 1:250 000 Council for Geoscience geological maps and their explanations are Sheet 2916 SPRINGBOK (Marais e*t al*., 2001) and Sheet 3017 GARIES (De Beer, 2010). The annotated pertinent part of Sheet 2916 is presented in Figure 4. The new stratigraphic terminology proposed by De Beer (2010) is mainly used, but is elaborated and modified according to the author’s own observations.

The coastal-plain history of Namaqualand, as then variously understood, has been described and discussed in De Villiers & Söhnge (1959), Hallam (1964), Carrington & Kensley (1969), Keyser (1972), Hendey (1981, 1983a, 1983b, 1983c), Dingle *et al*. (1983), Pether (1986), Gresse (1988) and Rogers *et al*. (1990). Additions to the fossil faunas are described by Kensley & Pether (1986), Pether (1990) and Brunton & Hiller (1990). Pether (1994) provided detail on the exposures and palaeontology at Hondeklipbaai. Summary texts have been published (Pether *et al*., 2000; Roberts *et al*., 2006).

The author has looked into several of the prospecting holes in the vicinity of the site and has made diagnoses of the biostratigraphy (fossils and the formation) and the sedimentology (type of deposits/palaeodepth).

Relevant aspects of the regional geology are described in summary below. References are cited in the normal manner and are included in the References section.

6.2 METHODOLOGY

Deposits or formations are rated in terms of their potential to include fossils of scientific importance, *viz*. their palaeontological sensitivity. Palaeontological sensitivity refers to the likelihood of finding significant fossils within a geologic unit, which informs the Intensity/Magnitude/Severity rating in an impact assessment. The rating criteria are included in Appendix 3.

6.3 ASSUMPTIONS AND LIMITATIONS

The assumption is that the fossil potential of a formation will be typical of its genesis/depositional environment and more specifically, similar to that observed in equivalent deposits near the project areas. Scientifically important fossil material is expected to be very sparsely scattered in the coastal-plain deposits and much depends on spotting this material as it is uncovered during digging *i.e.* by monitoring excavations. The relatively few fossils from the Namaqualand coastal plain have been vital to our current understanding of the coastal-plain geological history, not only of Namaqualand, but the fossil findings are also relevant to the coastal plains of the wider southern Africa.

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.

7 REGIONAL STRATIGRAPHY OF THE NAMAQUALAND COASTAL PLAIN

7.1 THE BEDROCK

The bedrock beneath the Port Nolloth area is the Vredefontein Formation (Figure 4, Nvr) of the Stinkfontein Subgroup, Port Nolloth Group, Gariep Supergroup. The Vredefontein Formation consists of alluvial sandstones (quartzites) and siltstones deposited in a rift zone 770-740 Ma (Ma = million years ago) . No fossils are recorded and this bedrock is not of concern here.

7.2 THE WEST COAST GROUP

The bedrock is overlain by much younger formations deposited during the last 66 million years of the **Cenozoic Era**. The **West Coast Group** is the name proposed to encompass the various named formations comprising the Cenozoic coastal deposits between the Orange River and Elandsbaai (Roberts *et al*., 2006), of both marine and terrestrial origin (Table 1).

7.3 THE EARLY COASTAL PLAIN

The formation of the coastal plain begins with the rifting of the Gondwana supercontinent and the opening of the Atlantic Ocean in the early Cretaceous, 130-120 Ma, which was accompanied by the inception of numerous rivers draining to the new coastline. A few kilometres thickness of Nama and Karoo formations have been stripped off the continental edge, exposing the coastal bedrock of metasediments and gneisses and building up the continental margin wedge offshore.

Ongoing erosion has removed nearly all traces of Cretaceous deposits from the present-day West Coast coastal pain. A rare instance dating from the early Cretaceous rifting is preserved just north of the Buffelsrivier mouth and is evidently the surviving, deepest part of a fault-bounded lake. Rounded cobbles of petrified, early Cretaceous *Podocarpoxylon* woods are found in the onshore marine gravels, having been reworked successively from now nearly-vanished Cretaceous fluvial deposits of the early coastal plain.

The De Toren Formation

Remnants of an ancient surface marked by silcrete cappings are preserved in places on the higher parts of the coastal plain. The De Toren Formation mapped on the Garies geological sheet (De Beer, 2010) is an example and comprises silcreted angular gravels and sands that overlie deeply-weathered bedrock and which occur as mesa-like features on high ground 200-400 m asl. The deep weathering and silcrete formation occurred during humid, tropical weathering such as thought typical of the palaeoclimates during Cretaceous and earlier Cenozoic (Paleeogene) times. The fossil potential of the silicified colluvia is low, except perhaps for plant impressions.

TABLE 1. NAMAQUALAND COASTAL STRATIGRAPHY – THE WEST COAST GROUP.

Formation Name	Deposit type	Age
Witzand	Aeolian pale dunes & sandsheets.	Holocene, <~12 ka.
Curlew Strand, Holocene High	**Marine, 2-3 m Package.**	**Holocene, 7-4 ka.**
Swartlintjies & Swartduine	Aeolian dune plumes.	Latest Quat., <20 ka.
Hardevlei	Aeolian, semi-active surficial dunes, >100 m asl.	Latest Quat., <25 ka.
Koekenaap	Aeolian, surficial red aeolian sands.	later late Quat., 80-30 ka.
Local Coastal Aeolianites*	Aeolianites, limited pedogenesis, weak pedocrete	Mid-late Quat., ~250-80 ka.
Curlew Strand, MIS 5e, LIG.	**Marine, 4-6 m Package.**	**earliest late Quat., ~125 ka.**
Fossil Heuweltjiesveld palaeosurface on Olifantsrivier & Dorbank fms.		
Dorbank*	Aeolian, reddened, semi-lithified.	later mid-Quat., ~400-140 ka.
Curlew Strand, MIS 11.	**Marine, 8-12 m Package.**	**mid Quat., ~400 ka.**
Olifantsrivier	Aeolianite, colluvia, pedocrete.	early-mid Quat., ~2-0.4 Ma.
Graauw Duinen Member 2	Aeolianite, colluvia, pedocrete.	latest Plio-early Quat.
Hondeklipbaai	**Marine, 30 m Package, LPWP.**	**late Pliocene, ~3 Ma.**
Graauw Duinen Member 1	Aeolianite, colluvia, pedocrete.	mid Pliocene.
Avontuur	**Marine, 50 m Package, EPWP.**	**early Pliocene, ~5 Ma.**
Later Miocene Aeolianites*	Aeolianites, weathered.	later Miocene (14-5 Ma)
Kleinzee	**Marine, 90 m Package, MMCO.**	**mid Miocene, ~16 Ma.**
Unnamed*	Aeolianites, leached, faulted.	Oligocene
Koingnaas	Fluvial, kaolinized gravels, sands, plant fossils.	late Eocene
De Toren	Silcreted colluvial palaeosurfaces 200-400 m asl.	Paleocene - Eocene
* - Informal		
MMCO – Mid Miocene Climatic Optimum. EPWP – Early Pliocene Warm Period. LPWP – Late Pliocene Warm Period. MIS – Marine Isotope Stage.		

The Koingnaas Formation

Buried between the existing, ephemeral Namaqualand rivers are ancient river channels that attest to the wetter climates of the early Cenozoic when more rivers drained the coastal plain. These locally-diamondiferous palaeochannels have fluvial deposit infills that have also been kaolinized and silcrete has formed within the waterlogged channel deposits in places. The deposits in the palaeochannels consist of basal, subangular to subrounded vein-quartz conglomerates overlain by beds of clayey sand, clay and carbonaceous, peaty material containing plant fossils, in a pale matrix of kaolinite (Molyneux, in Rogers *et al*., 1990), with yellow and red ochreous staining in places. 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. The locations of the ancient channels were influenced by faulting in the bedrock, causing coast-parallel courses in places.

The fossil pollen from the peaty beds has provided evidence of the vegetation type present and the age of the Koingnaas Formation. Yellowwood forest with auracaria conifers, ironwoods and palms dominated the West Coast. Fossil wood similar to tropical African mahogany has been found. The presence of early forms of pollen of the Asteraceae (daisy family) previously indicated that the age of the deposits was no older than Oligocene (34 Ma). Now new fossil evidence indicates that the Asteraceae have an earlier origin in the Eocene (Mandel *et al*., 2019). The age of Koingnaas Formation is therefore revised to later Eocene (Figure 5), with the aggradation of fluvial deposits in the palaeochannels likely correlating with times of rising sea levels. However, due to the pervasive kaolinitic weathering of the palaeochannel deposits it is possible that remnants of older, late Cretaceous and/or earlier Cenozoic deposits may be disguised in places in the bases of the channels. 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). The Koingnaas Formation deposits are remainders of a fossil landscape when the wooded Namaqualand coast approximately resembled the forests of the South Coast.

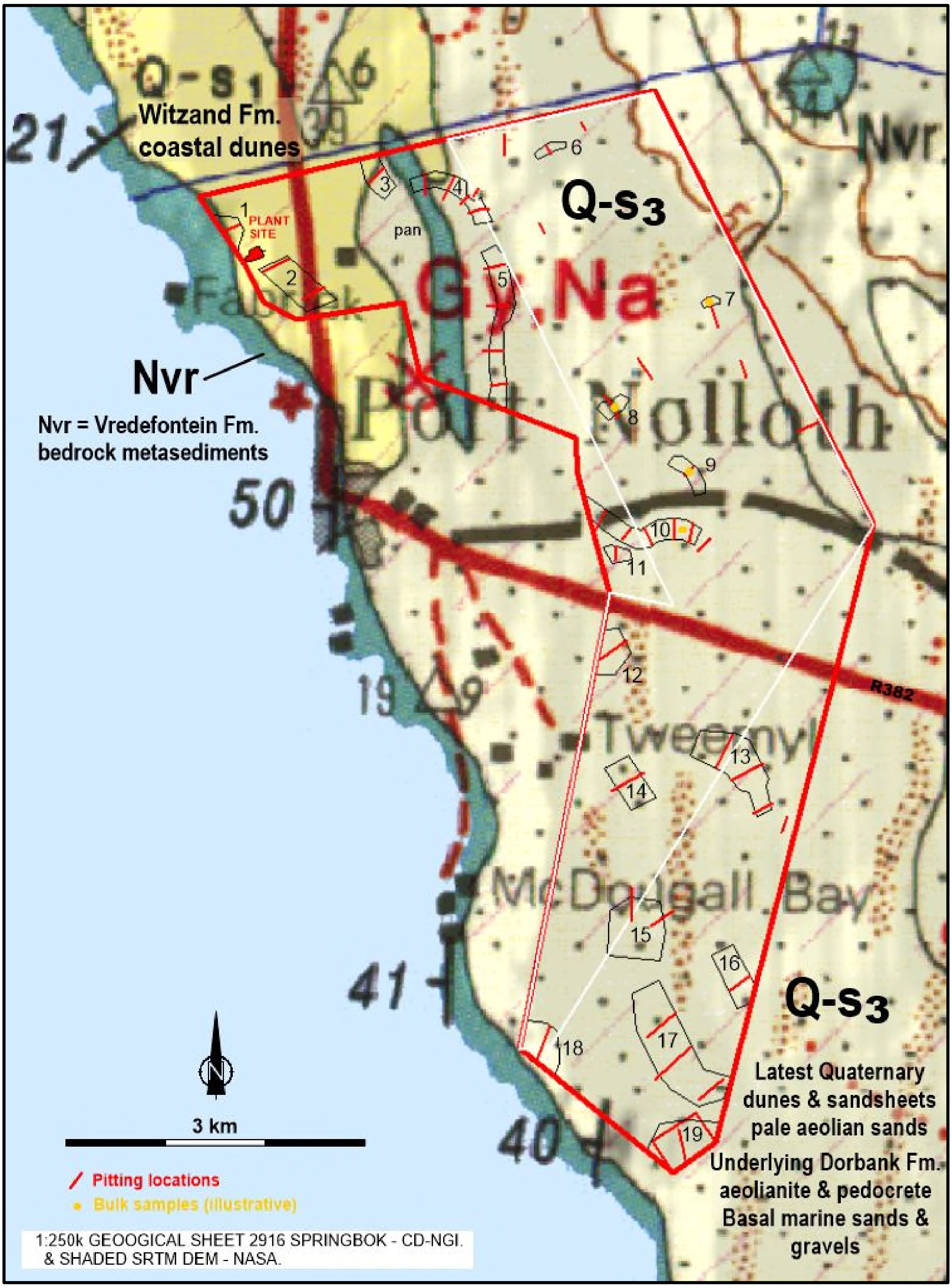


Figure 4. Surface geology of the Prospecting Application Area.

As elsewhere on the Namaqualand coastal plain, thin eroded remnants of these ancient, kaolinitic vein-quartz gravels may occur in places in the Port Nolloth area beneath the marine gravels and parts of equivalent palaeochannels are likely to occur along the Kammarivier drainage.

7.4 The Marine Formations

The early coastal plain would have been transgressed by the sea during high sea-levels associated with peak global warming intervals during the Paleocene and Eocene (Figure 5), but no deposits of this earlier marine history are known to remain along Namaqualand. Eocene marine remnants are preserved on the southern Namibian coast and in the Eastern Cape and must also have been present on the Namaqualand coastal plain, but were evidently later flushed off into rivers during the late Eocene and Oligocene.

Towards the end of the Eocene and during the Oligocene the global climate underwent major cooling and polar ice built up on the Antarctic continent, lowering sea level significantly (Figure 5), while drier climatic conditions likely pertained along the West Coast. This "**Oligocene Regression**" is thought to have had an impact on the coastal plain by the incision and entrenchment of the present-day river courses and further erosion back into the Escarpment.

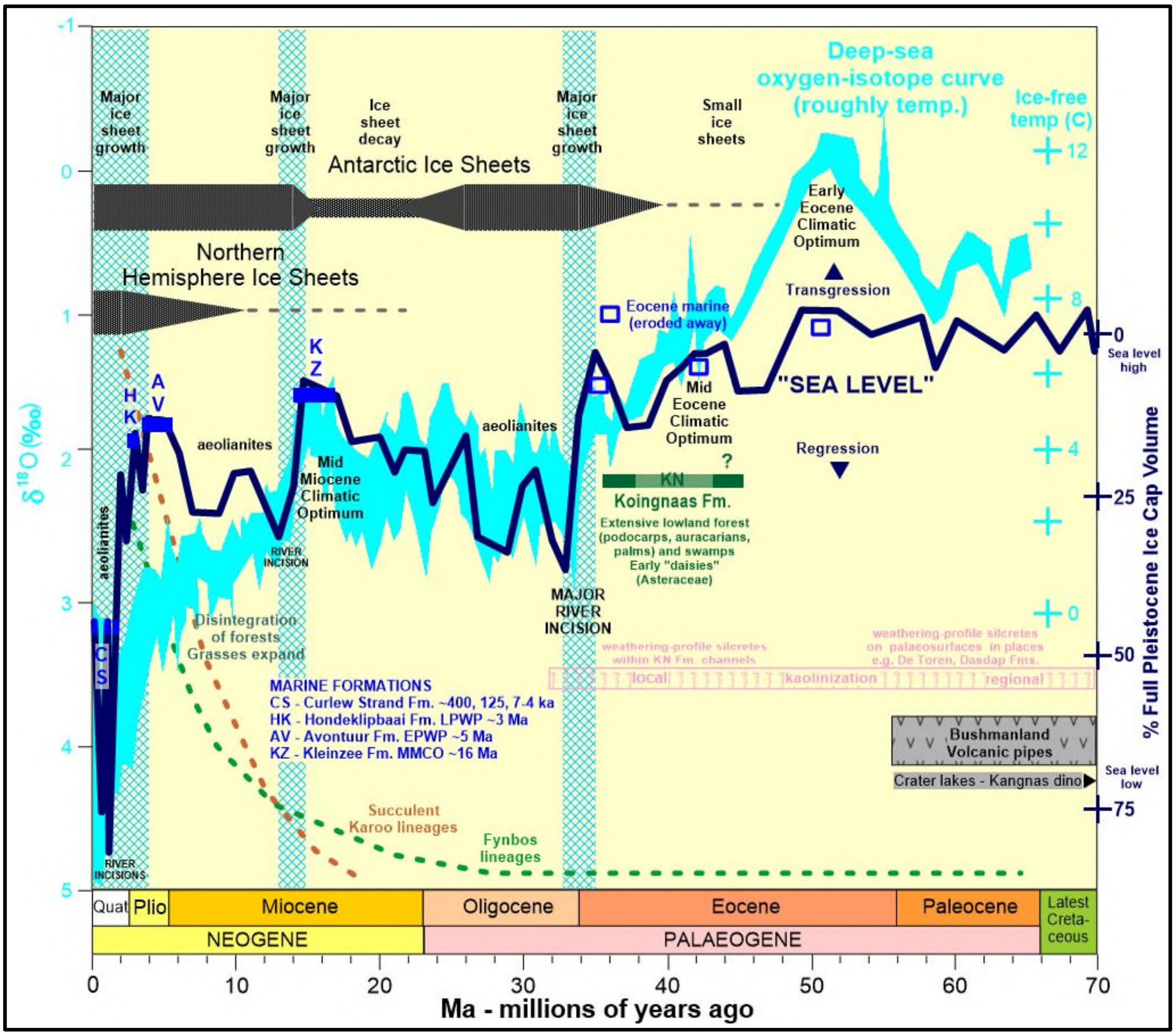


Figure 5: The Cenozoic Era (66 Ma to present) showing global palaeoclimate proxies, aspects of regional vegetation history and the context of marine formations of the West Coast Group, Alexander Bay Subgroup.

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). MMCO – Mid Miocene Climatic Optimum. EPWP – Early Pliocene Warm Period. LPWM - Late Pliocene Warm Period.

Three extensive marine formations containing warm-water mollusc assemblages occur beneath the aeolian coversands of the Namaqualand coastal plain. The genesis of these formations is due to periods of global warmth, when partial melting of polar ice raised sea level globally during the mid-Miocene ~16 Ma, during the early Pliocene ~5 Ma and again during the late Pliocene ~3 Ma. At those times the high sea levels lapped over the present-day coastal plain and reached highest inland levels of about 90 m asl., ~50m asl. and ~30 m asl., respectively. These maximum palaeo-shoreline elevations (transgressive maxima) are the sum of the actual higher sea levels and the amount the coast has been uplifted in the intervening time. When sea level receded again from each of these maximum elevations shallow marine deposits were left behind on the coastal plain. The three formations are informally named the **Kleinzee**, **Avontuur** and **Hondeklipbaai** formations, respectively (previously known as the 90, 50 and 30 m Packages, resp.). These formations are currently all subsumed in the **Alexander Bay Formation** as members. 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 coastal plain has been couched in terms of a steplike progression of marine terraces, for example, those described in the State Alluvial Diggings (SAD)/Alexkor (Keyser, 1972, Gresse, 1988): the Grobler, Upper, Middle and Lower terraces. 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 fossil shells unique to each formation and, importantly, on the basis of sedimentary features which provide a depth-of-deposition diagnosis (palaeo-depth), such as distinguishing beach, upper shoreface, lower shoreface and inner shelf environments of deposition.

TABLE 2. MARINE FORMATIONS ON THE MARINE TERRACES.

Alexkor terraces	Main formation present	Older formations present
LOWER 0-10 m asl.	Curlew Strand Formation / <12 m asl.	Underlain by 30 m P in embayments.
MIDDLE 17-26 m asl.	Hondeklipbaai Formation / 30 m Package	Partly overlain by 50 m P wedge. Underlying patches of 90 m P shelf deposits.
UPPER 34-47 m asl.	Avontuur Formation / 50 m Package	Partly overlain by 90 m P wedge Underlying patches of 90 m P shelf deposits.
GROBLER 64-84 m asl.	Kleinzee Formation / 90 m Package	Older marine formation not present.

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 and well above the bedrock topography of cliffs and platforms, which had mainly been formed during earlier sea-level stillstands and are composite in origin, to be last only modified during the immediately preceding transgression. The misfit between bedrock topography (*e.g.* cliffs) and the overlying sedimentary geometry was first noticed by De Villiers & Söhnge (1959, fig. 12, p. 235). For instance, the deposits which overlie the Upper Terrace (Avontuur Fm.) continue onto the Middle Terrace at the places where they were not eroded away by the subsequent sea-level transgression ~3 Ma across the Middle Terrace up to ~30 m asl. The deposits of an earlier regression from a high sea level were not totally removed by the succeeding transgression, thus much older deposits may occur locally at low elevations (Table 2). Notwithstanding the important distinction between the earlier formed bedrock topography and the overlying shoreline deposits which built out seawards over the topography, there is a general correspondence between the marine terraces and the overlying marine formations (Table 2).

The Kleinzee Formation

Towards the end of the Oligocene the cooler global climate began to ameliorate and with large fluctuations this warming trend continued through the early Miocene and peaked in the middle Miocene during the warm **Mid-Miocene Climatic Optimum** (MMCO) ~17-14 Ma (Figure 5). Melting of the Antarctic ice cap raised sea level and the outer part of the coastal plain was inundated by the sea up to an elevation which is now uplifted to ~90 m asl. By the beginning of the Miocene the basic topography of the coastal plain was in place, but the slow, fluctuating transgression of the sea during the late Oligocene and early Miocene (Figure 5) must have left a major erosional imprint. As sea level rose the Orange River and Namaqualand river valleys, including the Kammarivier valley, were "backed up" and fluvio-marine gravels and sands aggraded in their embayed lower reaches, while gravels were deposited upstream of which the edges later became flanking terraces.

During the mid-Miocene high sea level the submerged coastal plain to the seawards was mantled by deep-water, muddy shelf deposits. When sea level receded again the marine **Kleinzee Formation** was deposited and extends seawards from ~90 m asl. On the inner, high part of the coastal bevel these are beach and shoreface deposits overlying bedrock, while as the sea level continued to fall the offshore muddy deposits were partly eroded before being covered by the prograded, shallow-water shoreface deposits.

Subsequently, during the next ~10 million years sea level was at lower levels (Figure 5) and the subaerially-exposed marine deposits were subject to terrestrial processes involving deflation erosion by wind, mantling by aeolian sandsheets and dunes (the *Later Miocene Aeolianites*), with enhanced erosion along water courses and deposition of alluvium and colluvium in the eroded areas. The erosion of the Kleinzee Fm. during this long interval was quite advanced as these terrestrial deposits are preserved in places beneath the Avontuur Fm.

The Avontuur Formation

During the rising sea-level of the **Early Pliocene Warm Period** (EPWP) ~5 Ma (Figures 5 & 6), the previous mid-Miocene Kleinzee Fm. marine beds, and the intervening, later-Miocene terrestrial deposits, were eroded up to the transgression maximum of about 50 m asl. As during the mid-Miocene transgression, the river valleys were "backed up" with aggraded fluvial gravels, while in the offshore, muddy marine shelf deposits were accumulated on top of the local erosional remnants of the Kleinzee Fm. shelf muds. The offshore environment during the EPWP was characterized by the periodic formation of chocolate-brown phosphorite mud drapes which evidently lithified (hardened) soon after deposition, forming rinds capping intervals of the shelf storm deposits.

When sea-level receded 5-4 Ma (Figure 6) the shoreline prograded seawards, building out the shallow-marine shoreface deposits of the **Avontuur Formation**. The overall water depths pertaining during the regression from ~50 m asl. were now more limited (*cf*. the regression from 90 m asl.) and the earlier, deeper-water muddy deposits were extensively reworked as they came with wave base. The draping phosphorite interbeds were eroded to form the brown phosphorite pebbles typical of the basal gravels of the Avontuur Fm. During subsequent subaerial exposure the Avontuur Fm. was similarly eroded and overlain by aeolian sandsheets and dunes (the *Graauw Duinen Fm., Member 1*) and colluvial deposits also occur in places beneath the Hondeklipbaai Fm.

The Hondeklipbaai Formation

The Avontuur Formation in turn was eroded up to ~30 m asl. by yet another rising sea-level associated with the **Late Pliocene Warm Period** (LPWP) 3.3-3.0 Ma (Figure 6). Again, around the transgressive maximum, gravels aggraded along the river valleys and muddy deposits accumulated in the offshore shelf depths. The **Hondeklipbaai Formation** was deposited as sea level declined and a substantial, prograded marine formation built out seawards. Due to even more limited palaeodepths during the regression the LPWP inner- shelf deposits are evidently not generally preserved, but the local remnants of mid-Miocene shelf deposits remained in the bedrock depressions. The Hondeklipbaai Fm., up to a few km wide, underlies the outer part of the coastal plains of the West Coast and usually extends quite close to the modern shoreline, where it has been cliffed by the Quaternary high sea levels. Its deflated and eroded top is overlain by aeolian sandsheets and dunes (the *Graauw Duinen Fm., Member 2*).

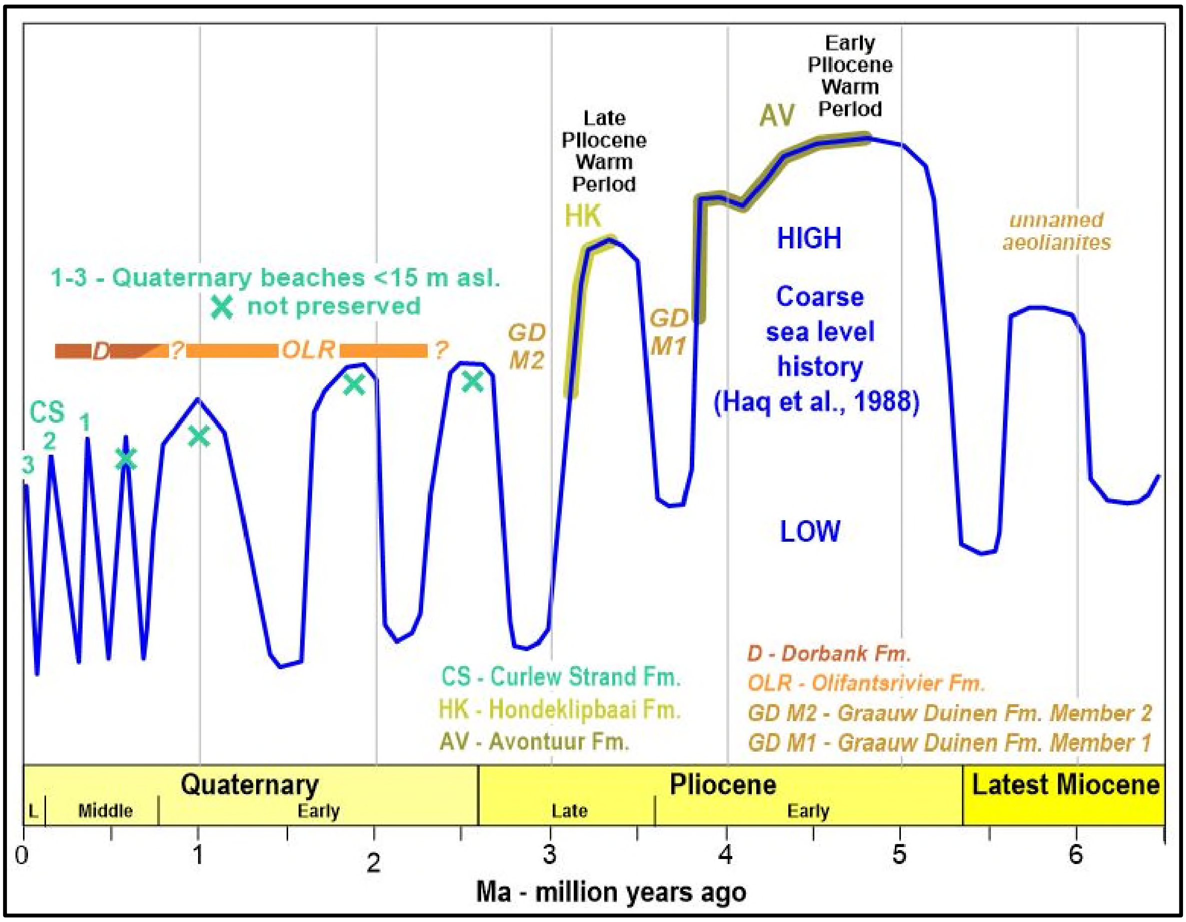


Figure 6. Context of latest Miocene, Pliocene and Quaternary marine and aeolian formations correlated with coarse-scale sea-level history based on major margin unconformities.

The Curlew Strand Formation

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 **Curlew Strand Formation** has been proposed for this composite of raised beaches, equivalent to the Velddrif Formation of the SW Cape Coast, and which are also known locally as the “Recent Emergence Terraces” (RETs). It comprises three members: the **8 - 12 m Package** dating to ~400 ka (ka = thousand years ago) during Marine Isotope Stage 11 (MIS 11), the **4 - 6 m Package** of the Last Interglacial (LIG) ~125 ka and the **2 - 3 m Package** (mid-Holocene High, 7-4 ka) (Figure 6, CS 1, 2, 3).

Notably, most of the earlier Quaternary sea-level record has not been preserved and was presumably eroded away by the younger highstands (Figure 6). The older 8 - 12 m Package is poorly known and the few examples preserved may not always be deposits of identical age. However, it is expected that these deposits mostly relate to the MIS 11 highstand recognized globally (Figure 7). The LIG beach (Figure 7) is the best-preserved and is almost continuous along the coast, occurring within embayments and on low bedrock platforms along rocky coast. The Holocene High beach is usually preserved beneath young dunes along sandy coast, but is often eroded away along rocky coast.

Palaeontology of the Marine Formations

The importance of fossil bones and teeth is that they provide indications of the age of a formation by comparison with fossils from dated sites elsewhere in Africa. Extinct fossil shells facilitate the correlation of marine formations between locations.

In the basal gravels of the **Kleinzee Fm**. have been found the petrified teeth of extinct pigs (suids) and an extinct hominoid tooth which have an age range of ~18 - 17.5 Ma (Pickford & Senut, 1997). These fossils were evidently reworked from preceding terrestrial deposits of Arrisdrift Formation age. The Kleinzee Fm. deposits are decalcified and generally lack all but the most robust shell macrofossils such as oysters and the curious, thick-shelled bivalve *Isognomon gariesensis* which is the zone-fossil for this formation (Appendix 6). The thin (~0.5 m) patches of offshore muddy shelf deposits preserved at low elevations contain a poorly-preserved, fragile shell fossil fauna of which a few species have been described.

The **Avontuur Fm**. 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 in the basal assemblage are the bear-dog *Agnotherium* (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 early Pliocene Varswater Formation exposed at the West Coast Fossil Park near Saldanha. Much of the fine-sandy 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* (Appendix 6).

The **Hondeklipbaai Fm**. is the last, major formation of the coastal plain, deposited during a high sea-level never since exceeded. An age-diagnostic fossil vertebrate assemblage directly associated with the Hondeklipbaai Formation has not yet been discovered and so its age is not well-constrained by vertebrate datums. However, with its warm-water molluscan fauna it is unlikely to postdate the inception of major cooling in the Benguela System from after ~3 Ma. Accordingly, the 30 m Package is not likely to be younger than ~3.0 Ma and corresponds with the Late Pliocene Warm Period and the second, major Pliocene sea-level highstand in the late Pliocene at ~3.0 to 3.3 Ma (Figure 6). 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* (Appendix 6).

In open-coast settings the fossil shells in the **Curlew Strand Fm**. Quaternary raised beaches are predominantly the cold-water fauna of modern times. However, during the Last Interglacial several West African tropical taxa ranged down the coast as they are found in equivalent LIG deposits of the Southern Cape. These warm-water species evidently inhabited the warm waters of sheltered embayments. Along the Namaqualand shoreline, the LIG beach deposits are poorly examined and sampled for fossil shells. Extinct species and subspecies occur in LIG deposits of the southern Cape (Kilburn & Tankard, 1975) and may occur in the Namaqualand LIG and MIS 11 deposits. Rare surprises have come to light in the mid-Holocene beach deposits, such as isolated occurrences of species dispersed from South America and the mid-Atlantic islands. The sparse fossil bones in the Quaternary Curlew Strand Formation (*e.g.* seabirds, marine mammals) are likely to be closely related or identical to modern marine species, but may include species that we would not expect nowadays and finds may be of scientific importance.

7.5 THE AEOLIAN FORMATIONS

A variety of terrestrial deposits also make up the coastal plain of Namaqualand. These are predominantly extensive aeolian dune and sandsheet deposits that overlie the eroded tops of the marine sequences near the coast, and as dune plumes extending inland. A glance at the satellite images of the coast show that the dune plumes of various ages occur in specific areas and are linked to topography, sea-level oscillations, the changing 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. More locally there are colluvial (sheetwash) and ephemeral stream deposits associated with nearby hillslopes; these dominate the thinner cover of the hills of the higher, inner coastal plain. Formed within the terrestrial sequences are pedocretes and palaeosols of a variety of types, compositions and degrees of development which mark times of surface stability and relate to times of reduced aeolian activity (less windy) and/or more humid climatic intervals.

The Later Miocene Aeolianites

The mid-Miocene, marine Kleinzee Formation has been extensively eroded and has been largely reworked into aeolian sands. These old aeolian deposits, the **Later Miocene Aeolianites**, are now quite altered by pedogenic and groundwater processes, transforming them pale, leached sands or nearly-massive, cemented units. These later-Miocene aeolianites occupy the higher part of the coastal notch where they overlie residuals of the Kleinzee Formation and extend into the hinterland. Locally they occur beneath the inner part of the Avontuur Formation (early Pliocene) marine wedge. The occurrence of petrified teeth of age range 13-9 Ma (*Agnotherium*, *Tetralophodon*) in the basal gravels of the early Pliocene Avontuur Formation at Hondeklipbaai indicates the pre-existence of terrestrial deposits of this later Miocene age.

The Graauw Duinen Formation

The **Graauw Duinen Formation** 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, but temporarily, exposed in coast-normal mining faces. Based on personal observations of the aeolianites exposed at Graauw Duinen 152 (Namakwa Sands) there are actually three main, distinct aeolian formations in the subsurface there. The first main aeolianite formation (Member 1) overlies/postdates the marine early Pliocene Avontuur Fm. and is overlain in the west by the marine late Pliocene Hondeklipbaai Fm., *i.e*. it is broadly of mid-Pliocene age (Figure 6). The second aeolian formation ("Member 2") overlies/postdates the Hondeklipbaai Fm. in the west and overlies the pedocreted palaeosurface of the first aeolian formation inland, *i.e*. it is of latest Pliocene to early Quaternary age (Figure 6). The third aeolian formation overlies the pedocreted palaeosurface of Member 2. Notably, this formation contains rare Early Stone Age (ESA) material and is referred to the Olifantsrivier Formation.

The Olifantsrivier Formation

The **Olifantsrivier Formation** (Roberts *et al*., 2006) 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 7). 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 ~1.9 Ma and extends from the earliest Quaternary (max. age 2.5 Ma), while the upper part which includes ESA material is latest early Quaternary/earliest middle Quaternary (Figure 7). This broad age range constraint is reflected by the several included member units separated by pedocretes.

The Dorbank Formation

The older aeolian formations, such as the Graauw Duinen and Olifantsrivier formations are rarely exposed on the higher coastal plain inland from ~100 m asl., except as outcrops of their cappings of well-developed pale pedocretes (calcrete, sepiocrete) in places. For the most part, these older formations are buried beneath more aeolianites of varying ages and thicknesses, from several metres thick up to ~15 m thick, which have been transformed by pedogenesis into yellow-brown to red-brown, semi-cemented beds colloquially called "dorbank". For practical purposes these "dorbank" units are lumped together and referred to as the **Dorbank Formation**.

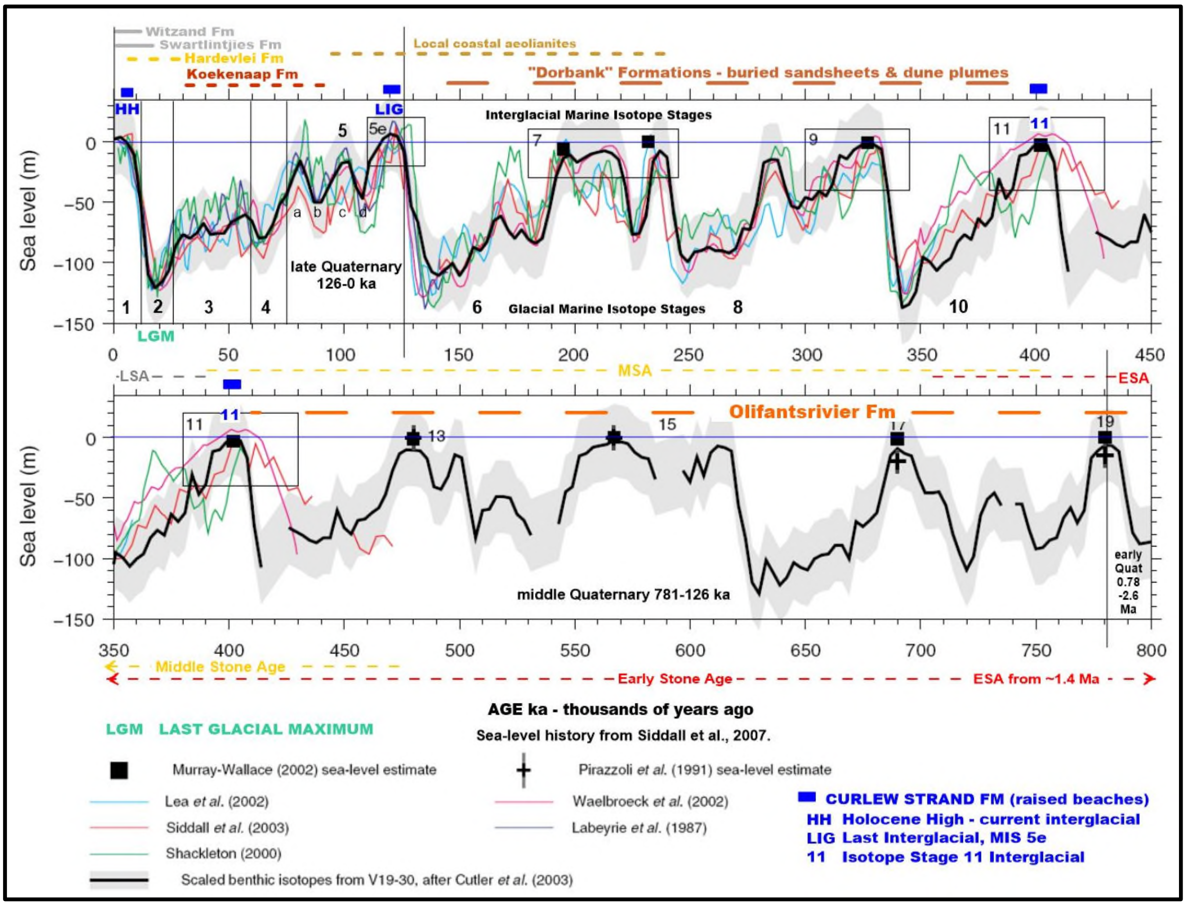


Figure 7. Sea-level history (from Siddall *et al*., 2007) and the age ranges of middle and late Quaternary formations of Namaqualand.

The Dorbank Formation is typically a stack of successive sand sheet and dune beds forming units 0.5 m to ~2 m thick, with differing yellowish to reddish-brown hues of the interstitial neoformed pedogenic clays. Due to the pedogenic clays the dorbank is quite hard and incipiently to variously cemented. Many individual units appear initially to be massive, lacking obvious sedimentary structures, but closer inspection reveals features defined by grain-size contrasts, such as bioturbation mixing, wind ripples of coarser sand and relict dune slipface crossbedding in thicker units. Interbedded lenses of pan muds occur, formed from pedogenic clays washed-out into interdune ponds, as well as occasional lenses of white, alkaline pan carbonates with varying silicification and rare diatomaceous pan deposits.

The Dorbank Formation is widespread along the Namaqualand coast where it occupies a spatio-temporal context as the youngest consolidated aeolianite beneath the weakly-compacted to loose surface sand formations mentioned below. Where thickly developed the formation is expressed in the present-day landscape as topographically positive areas, most notably the long, wide ridges of buried dune plumes. The landscape during accumulation of the Dorbank Formation basically resembled that of the present day, with the distribution of aeolian environments (sand sheets, dune fields and transgressive dune plumes) reflecting the roles of the sandy beaches and riverbeds as sand sources for southerly wind.

Notably, Middle Stone Age (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. Dating of the overlying Koekenaap Fm. surficial sands (see below), together with some few dates from the top of the Dorbank Fm. farther south, indicates that the Dorbank Fm. is older than ~130 ka, pre-dating the Last Interglacial (Figure 7).

The "Panvlei Formation" Surfaces

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 to depict those surface areas that are closely underlain by the capping pedocrete of the underlying formation, or by the hard top of pedogenically partly-cemented "dorbank" sands. 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 are clearly of differing ages.

These "Panvlei" areas could be referred to instead as "Panvlei Surfaces". The Panvlei Fm. areas near the coast are consequently areas closely underlain by older aeolianite units, such as the calcreted top of the Olifantsrivier Fm. mentioned above, or by the top of the Dorbank Fm. Panvlei-type surfaces also occur extensively on the slopes of the bedrock hills of the coastal hinterland, where pedocreted colluvia underlie the surficial sands and where the typical vegetation is Namaqualand Heuweltjieveld on mounded sands.

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). During some of these stages shoreline aeolianite units were deposited at places along the coast, herein called **Local Coastal Aeolianites**. For example, beneath the surficial, loose Witzand Fm. sands, the Last Interglacial (LIG, ~125 ka) raised beach deposits are usually overlain by compact aeolian deposits which differ from place to place, *i.e*. rubified pink sands, or yellow sands, or grey sands. These units are more locally confined to the coast and are apparently of different ages. These units represent discrete phases of local accumulation, compared with the much larger dune plumes extending inland from the vicinity of river mouths, or the widespread sand sheets or fields of degraded small dunes inland on the wider coastal plain. These coastal units of later mid-Quaternary to earlier late-Quaternary age (Figure 7) exhibit variations of pedogenesis and incipient pedocrete development indicative of their relative ages, but lack substantial pedocrete horizons.

The Koekenaap Formation

The **Koekenaap Formation** (Roberts *et al.*, 2006; De Beer, 2010) refers to "Red Aeolian Sand", the variously-reddened, unconsolidated coversands and low, degraded dunes which mantle much of the surface of the coastal plain, overlying the hard surface of the Dorbank Formation. The red sands are underlain by scatters of MSA material on top of the palaeosurface formed on the Dorbank Fm. or older aeolian formations. Results of Optically-Stimulated-Luminescence (OSL) dating of some reddened coversands (Chase & Thomas, 2006, 2007) produced late Quaternary ages between ~80 ka and ~20 ka (Figure 7) and suggest phases of accumulation which differ between areas. Sand sources include the coast and the reworking of older sands, while the older red sands on the higher, inner coastal plain have apparently been sourced from the local rivers. The typical vegetation types are Namaqualand Strandveld and Namaqualand Heuweltjie Strandveld.

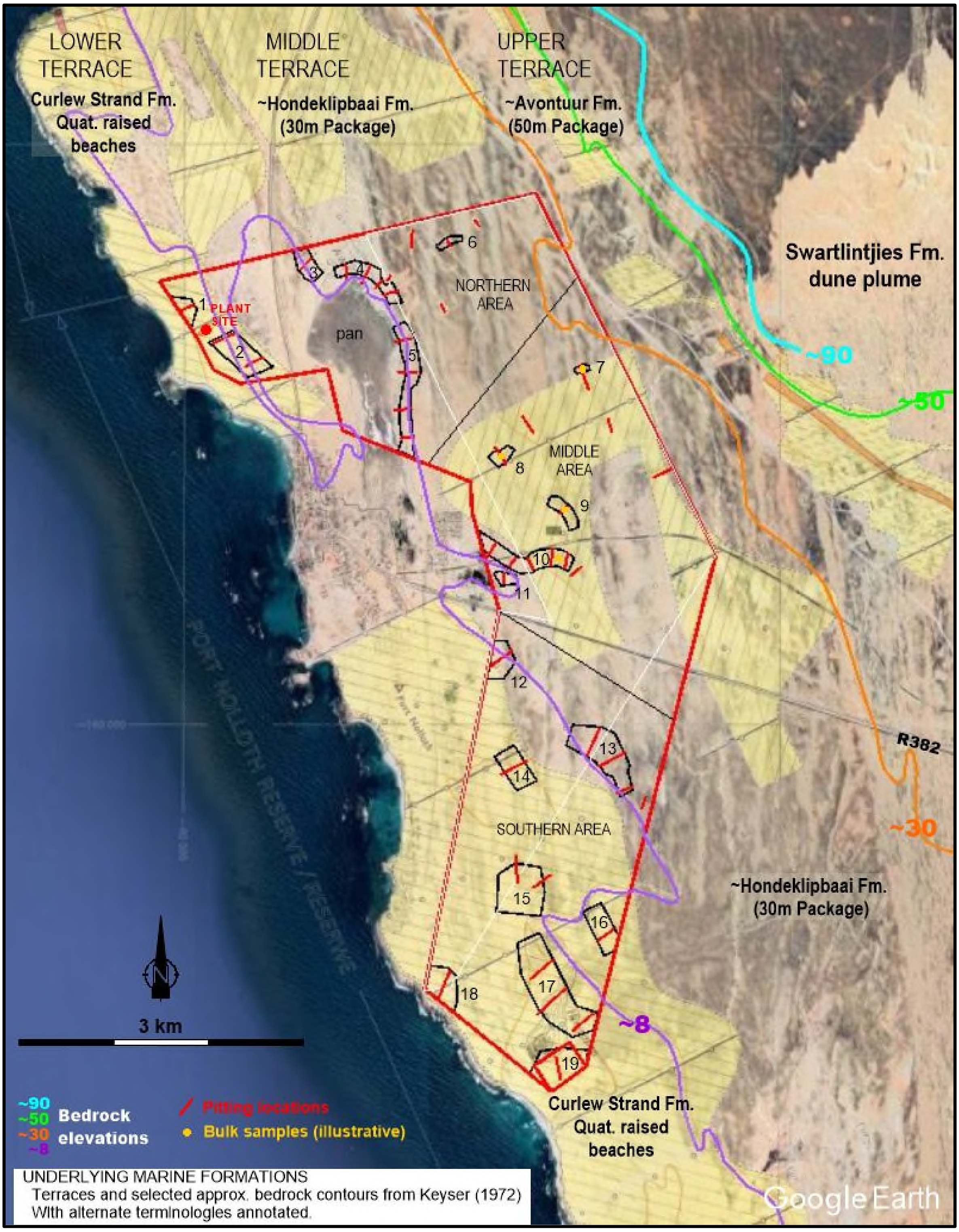


Figure 8. Marine formations beneath the Prospecting Application Area.

The Hardevlei Formation

Subsequent aeolian activity is manifested in the yellow dunes of the **Hardevlei Formation** (De Beer, 2010) which encompasses fields of low, pale-yellow dunes of varied morphology overlying the Koekenaap-type red sands or the local Dorbank Fm., and which are developed inland from the coast on the higher, inner parts of the coastal plain. Dune types include both parallel, longitudinal sand ridges formed by the northward migration of vegetation-impeded, parabolic, “hairpin” dunes, and transverse, barchanoid (crescentic) dunes. Both morphologies are combined to form reticulate dune fields formed by directionally-variable winds. The veld type is mainly Namaqualand Sand Fynbos, with Inland Duneveld in places. Dating by the OSL technique indicates ages generally less than ~20 ka (Chase & Thomas, 2006, 2007). The complex Hardevlei Fm. inland dune fields occur mainly on the southern Namaqualand coastal plain, whereas north of Kleinzee linear dunes forms dominate.

The Swartlintjies and Swartduine Formations

The name **Swartlintjies Formation** is proposed for the large, pale plumes of semi-stabilized parabolic dunes that extend far inland northwards from the beaches north of the main rivers (Roberts *et al.*, 2006; De Beer, 2010) and which are the latest large-volume additions to the coastal plain. The Swartlintjies dune plume is the type example. The plume sands were blown by south winds from the beaches now submerged by rising sea levels since the Last Ice Age maximum ~20 ka (Figure 7, LGM), when the shoreline was ~120 m below present (Tankard & Rogers, 1978). A related unit, the **Swartduine Formation**, has been proposed to accommodate somewhat muddy, light brown to green sands in interdune areas between the major late Quaternary dunes (De Beer, 2010).

The Witzand Formation

The **Witzand Formation** 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 attached small dune plumes transgressing inland. The coast-attached Witzand Fm. dunes are the modern analogue of the older Local Coastal Aeolianites.

8 AFFECTED FORMATIONS IN THE PROJECT AREA

It is possible that patches of the Koingnaas Fm. may be locally preserved in locally-incised palaeochannel remnants, but these basal quartz gravels are not expected to be fossiliferous.

From the shoreline of the Port Nolloth area the bedrock extends inland at a low gradient so that the ~8 m asl. contour is up to ~2 km from the coast and the ~30 m asl. bedrock contour is 4-5 km from the coast (Figure 8). This antecedent topography has determined that the Hondeklipbaai Fm. (30 m Package) occupies most the area of the marine coastal plain corresponding generally to the Middle Terrace. Similarly, the Quaternary raised beaches (Curlew Strand Fm.) extend farther than usual inland as the Lower Terrace (Figure 8).

The prospect pit target areas 6, 7, 8, 9 10 and 13 will intersect the **Hondeklipbaai Fm**. It may also be intersected in the pit areas 10-West, 11 and 12. A trench exposure in the vicinity of Pit Area 9 (Figures 9-12) shows the vertical section in the area and also the degree of fossil preservation. Most of the Hondeklipbaai Fm. is typically decalcified and fossil shells were only preserved in two trenches. Figure 9 shows the main fossiliferous trench. Basal gravels were deposited far offshore via megarips during very major storms. These are overlain by “normal” deposits of the offshore lower shoreface (LSH), *viz*. muddy, bioturbated sands with pebble “stringers and isolated small cobbles, the latter coarser clasts also introduced during storms, while the mixed-in mud content reflects fairweather conditions. As the shoreline builds out the offshore sands are succeeded by deposits of the breaker and surf zone or the upper shoreface (USH). The LSH muddy sands are sharply overlain by poorly-sorted rip-channel fan conglomerates, in turn overlain by complexly cross-bedded coarse and fine sands deposited under combined wave and current action.

The thickness of the preserved USH is only about 2 m, whereas at other locations (*e.g.* Hondeklipbaai) much more section is preserved and its thickness is 4 – 6 m. The original thickness of the USH at these localities (Figures 9 & 10) was at least 4 m. Only the lower part of the USH is preserved. The foreshore deposits, ~3 m thick, are also missing. Thus ~5 m of the top of the Hondeklip Bay Formation has been eroded away here, blown away into the old dunes to the north.

Figure 9. The Hondeklipbaai Fm. exposed in a prospecting trench near Pit Area 9, with depositional environments indicated.

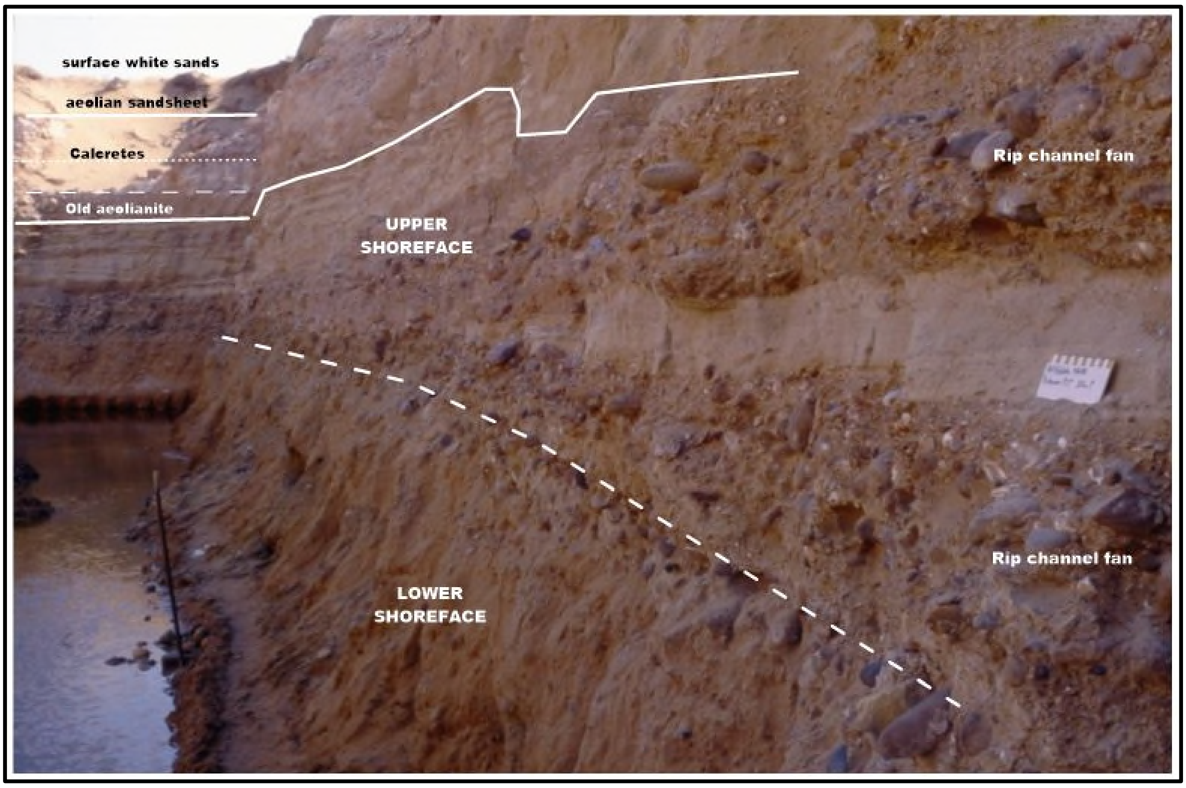


Figure 10. Hondeklipbaai Fm. - opposite face of same trench.

In the trench where fossil shell was preserved, the shell content is residual. Only the larger, more robust shells remain; the small species and shell fragments are effectively absent (Figures 11 & 12). The remaining shell is chalky and fragile and softer than the enclosing, partially-cemented matrix. Due to their original calcitic, dense shells, oysters are preferentially preserved. This is illustrated at another spot where an *in situ* oyster bed is preserved, but all other shell is gone (Figure 12). The context is the rip-channel fan conglomerates in the base of the USH. A fan depositional unit, now cemented by groundwater calcrete, has an armoured top produced by wave-winnowing. This was colonized by the oysters, living beneath the outer breaker zone in several metres of water. Deposition of another rip-channel fan unit was catastrophic.

Figure 11. Hondeklipbaai Fm. The residual nature of the fossil shell content.

Figure 12. Hondeklipbaai Fm. A rare, *in situ* oyster bed. Other shells have been dissolved away.

As mentioned above, patches of shelf deposits of both the **Avontuur** and **Kleinzee** formations may be preserved in places beneath the Hondeklipbaai Fm. basal gravels. It is probable that the eroded edge of the Avontuur Fm. is present along the inland, higher part of the “Middle Terrace”, where it is overlain by the Hondeklipbaai Fm. deposits close to the ~30 m asl. transgressive maximum (*e.g.* at Pit Area 7 and pits nearby the eastern edge of the Northern and Middle areas (Figure 8).

Figure 13. Cobbles of the “8-12 m Raised Beach” overlying the decalcified and reddened deposits of the Hondeklipbaai Formation at ~11 m asl., ~600 m inland from the shoreline.

The oldest Quaternary raised beach/member of the **Curlew Strand Fm**. is expected along the inner edge of the “Lower Terrace” (Pits 10-West, 11, 12, 14, 16), where its deposits lap onto the eroded edge of the Hondeklipbaai Fm. This “8-12 m Raised Beach” (Figure 13) is expected to date from MIS 11 (~400 Ma), with an associated sea-level high of 12-13 m asl. Notably, the “Lower Terrace” is largely circumscribed by the ~8 m asl. bedrock contour (Figure 8) and thus could theoretically have been largely occupied by the high sea level of the Last Interglacial of up to 6-7 m asl. However, the extent to which the “8-12 m Raised Beach” is preserved varies along the coast and it may be altogether removed by erosion during the LIG where the bedrock gradient is relatively steep. Nevertheless, in view of the apparent low bedrock gradient in the Port Nolloth area it is expected that large part of the “Lower Terrace” will be occupied by the older, “8-12 m Raised Beach” deposits, with the LIG and “Holocene High” members deposits more confined to the coast (Figure 14) and likely intersected at Pits Areas 1, 2, 18 and 19.

The salt pan to the north of Port Nolloth is located in a bedrock depression wherein saline groundwater accumulated and has apparently formed by a combination of salt weathering and deflation, which has exposed the bedrock on its floor and where gypsum and salt were collected (Figure 4, Gy, Na). The pan is rimmed by what appears to be bioturbated pan carbonate deposits of a much expanded pan (Figure 15) and most probably postdates the Last Interglacial high sea level, but the proposed pits situated along its edge (Pit Areas 3, 4, & 5) may shed further light on its history.

A smaller pan in the south (Pit Areas 17, 19) is possibly associated with a palaeochannel of the Kammarivier and also appears to have pale, rimming pan deposits.

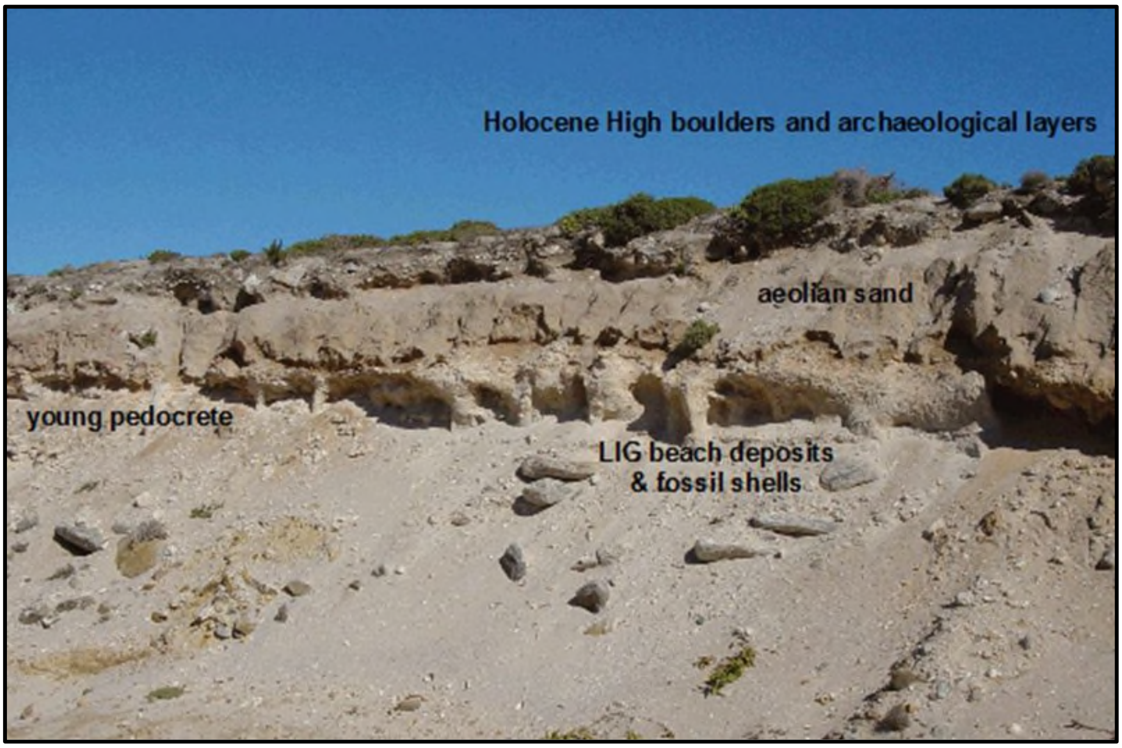


Figure 14. Scattered boulders of the Holocene High are partly covered with aeolian sand bearing cultural layers. An underlying unit of aeolian sand is altered by pedogenesis. Beneath this is a pedocrete formed in shelly deposits of the LIG. West (seaward) end of pit.

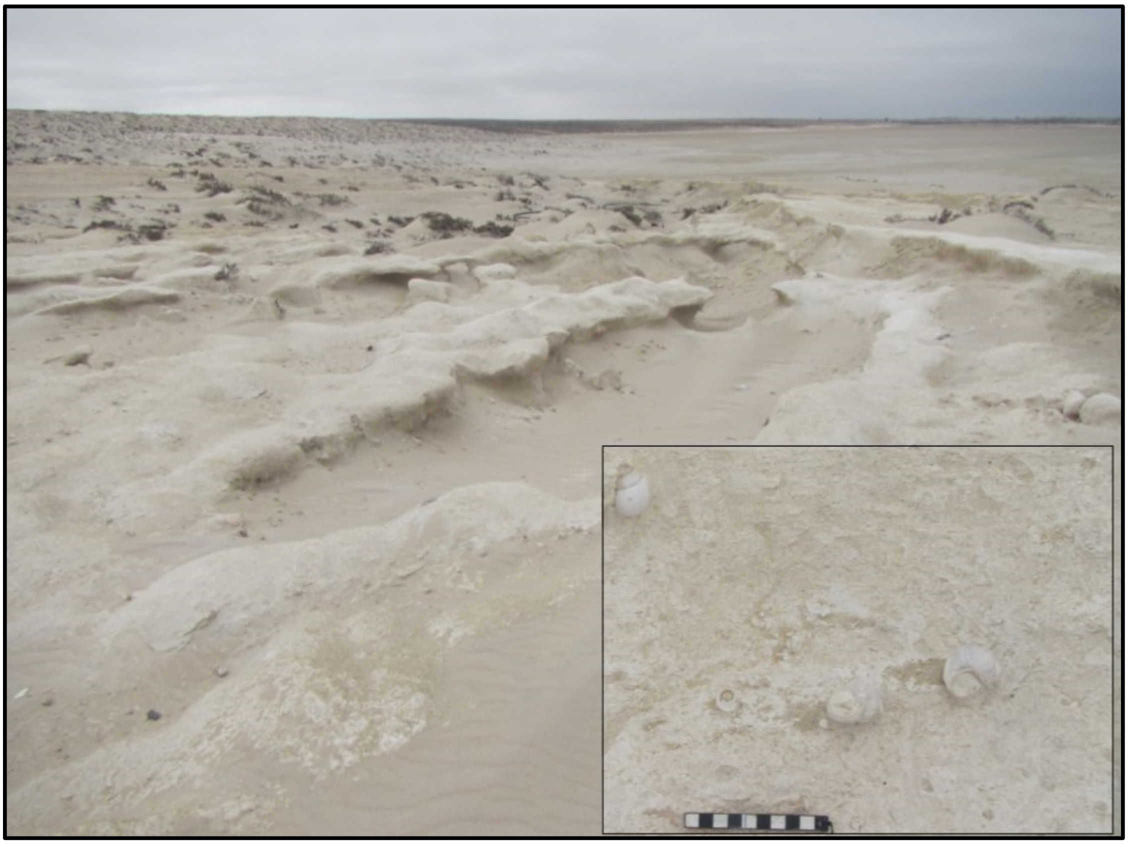


Figure 15. Eroded pan deposits on the edge of Port Nolloth Saltpan. Inset close-up shows burrowed texture and land snails *Trigonephrus*. Images courtesy J. Orton.

It is evident that the Port Nolloth area has been subject to aeolian erosion during the Quaternary and the older, Pliocene-early Quaternary aeolian formations are absent. For instance, near Pit Area 9, the eroded surface on the Hondeklipbaai Fm. is overlain by a unit of hard, brown aeolian sands in which a polyphase calcrete has formed (Figure 10). Very speculatively, this unit may be a condensed approximate equivalent of the Olifantsrivier Fm. or the Dorbank Fm. The top of the calcrete has been exposed by deflation and is overlain by an aeolian sandsheet of compact brown sands, speculatively equivalent to the Koekenaap Fm. However, the surficial aeolian formations recognized south of Kleinzee, such as the classic red aeolian sand of the Koekenaap Fm. and its characteristic veld type, are not well-defined in this more arid area. The geological map depicts the area as “Q-s3 - white to light pink sand” (Figure 4) and three generations of geologically-recent sands appear to be present, *viz*. slightly pink/brown interdune areas and pale grey and white sand dunes (Figure 2), with vegetation classified as “Richtersveld Coastal Duneveld” (Cape Farm Mapper). In the north (Pit Areas 1, 2) the plumes of coastal dunes emanating from the beaches of North Bay and from the pan are depicted as the Witzand Fm. (Figure 4, Q-s1).

9 PALAEONTOLOGICAL IMPACT OF THE PROSPECTING

The prospecting pitting and bulk sampling will expose the entire sequences at the various locations.

9.1 FOSSILS IN THE TERRESTRIAL FORMATIONS

For the most part the aeolian formations have a sparse fossil bone content. 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 (Figure 16A, B, C). The ambient fossil content is more abundant in association with palaeosurfaces and their associated soils (palaeosols and pedocretes), formed during periods of dune stabilization and which define aeolian packages and larger formations. Other palaeosurfaces are formed by wind deflation exposing and concentrating fossils, and by dune migration wherein the ambient fossil content is concentrated on the palaeosurface the dunes are traversing, leaving their fossil content behind in a deflation lag. Importantly, the bones of larger animals (*e.g.* antelopes) are also more persistently present along palaeosurfaces which separate the major aeolianite units, and on the major palaeosurface formed on top of the eroded marine deposits.

The most spectacular bone concentrations found in aeolianites are due to the bone-collecting behaviour of hyaenas which store them in and around their lairs (Figure 16F). The hard pedocretes embedded in the aeolianites form ledges on the eroding coastal slopes and these can be exploited as the roofs for lairs of hyaenas and other carnivores dug below. The large burrows made by aardvarks are also appropriated by the hyaenas. Such bone accumulations are, of course, younger than the aeolianite into which the burrow was made.

The late Quaternary surficial coversands and dunes (Q-s1 and Q-s3) are expected to mainly enclose fossil bones and material in an archaeological context, such as buried middens and ephemeral occupation scatters. In view of the generally deflationary, migrating dune history, both artefacts and fossil bones may be expected on the palaeosurface of the more compact sands beneath the loose surficial sands. Another important palaeosurface is that beneath the aforementioned compact sands and formed on top of the calcrete developed in an earlier aeolian formation, or in the marine deposits. These concentrations of material on deflation palaeosurfaces, including both artefacts and fossils, are important for rough chronostratigraphic (age) control of the poorly-known aeolianites in the Port Nolloth area. While Late Stone Age (LSA) artefacts are expected in the surficial sands, it is possible that MSA and ESA material may be buried in the underlying deposits.

Pan deposits and the surrounding palaeosurfaces are expected to have more abundant fossil bone occurrences, due to their being a focus of activity in the landscape. On local scales, interdune areas are the sites of ponding of water seeping from the dunes, leading to the deposits of springs and vleis. These may include muddy beds, with dark organic content and plant fossils, pan-carbonate layers with microfossils, and diatomaceous layers. Fossil aquatic snails and the remains of other pan life such as insects, frogs and birds may occur, along with their trace fossils. The bones of large mammals are more prevalent due to predator activity around water sources, including Stone Age hunters.

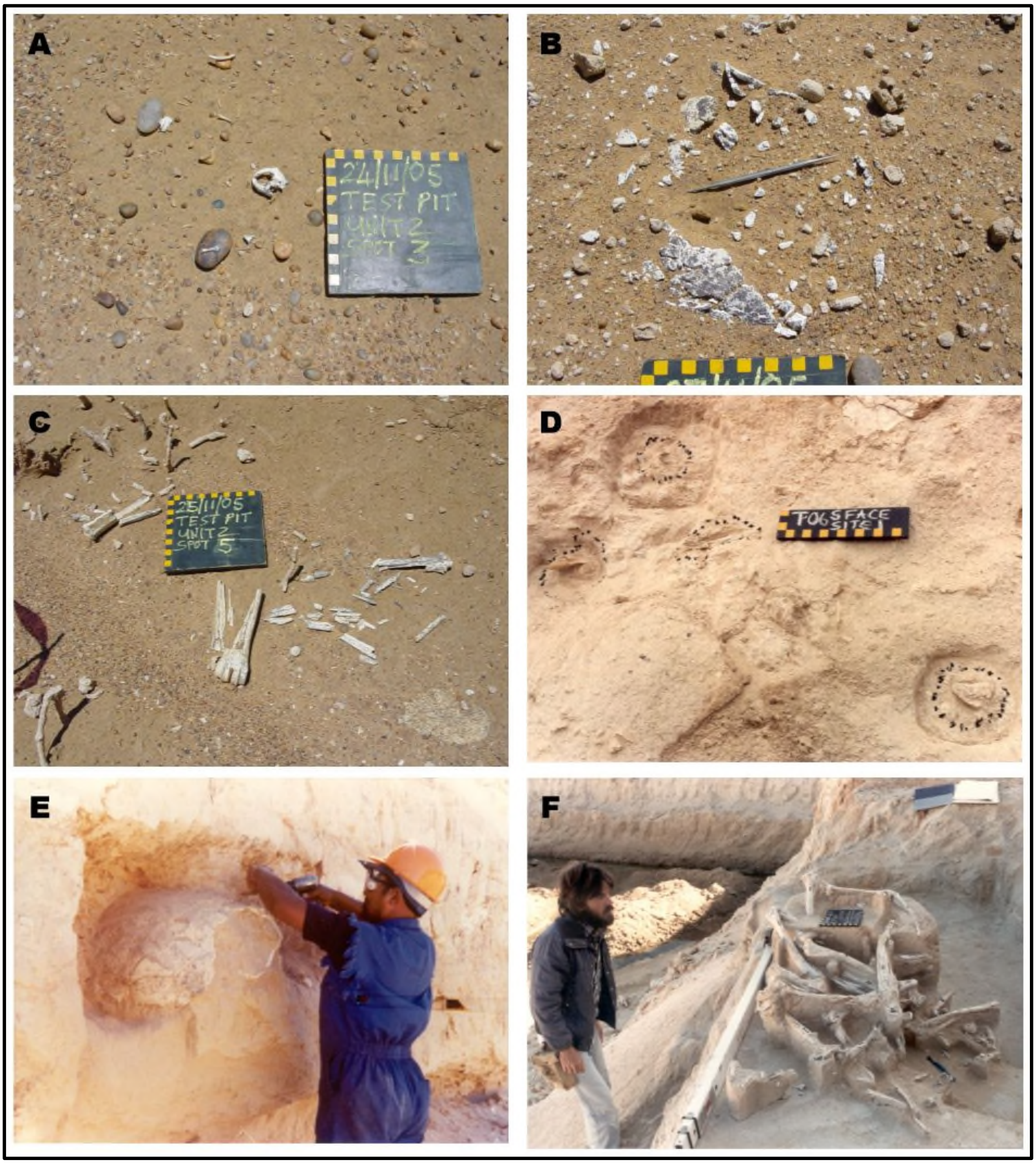


Figure 16. Examples of fossil bones in aeolianites. A, B & C: Ambient fossil content exposed on palaeosurface on floor of trench. A: Mole jaws. B: Tortoise. C: Small antelope limb bones. Scattered bones in vertical section through pedocrete likely indicative of a bone accumulation in a burrow. E: Giant tortoise. F: Hyaena bone accumulation in a burrow just below the pit sidewall bench and which could be excavated from above.

In addition to the main pan and the pan in the south, there are apparently other locations with thin pan-carbonate deposits of more ephemeral pans within the Project Area. Where exposed by erosion, the hard pan-carbonates, like calcrete, also furnish roofs for burrow lairs made in the underlying softer sands.

The published information is about a pan deposit just farther inland on Kannikwa with diatomaceous and peaty deposits which have been radiocarbon-dated to ~28 ka and, together with dates from the

Namib Desert, indicate wetter conditions along the West Coast during the Last Ice Age ~40 to ~20 ka.

A late Quaternary fauna was obtained from calcareous interdune deposits (Swartduine Fm.) 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).

Due to the apparent lack of older, Pliocene to early Quaternary aeolianite formations in the Project Area the fossil terrestrial faunas which may be discovered are expected to be younger, *i.e*. later mid-Quaternary and late Quaternary, and are accorded a MODERATE palaeontological sensitivity.

9.2 FOSSILS IN THE MARINE FORMATIONS

The mid-Miocene fauna of the Kleinzee Fm. which occurs at low elevations in thin patches of offshore muddy shelf deposits is incompletely known due to poor preservation. Due to very localized occurrences the likelihood of these "*Isognomon* Beds" being intersected is low. If encountered, the fragile shells are best sampled by means of large lumps or blocks reinforced by a plaster jacket, for preparation in a laboratory.

The fossil shell fauna of the early Pliocene Avontuur Fm. in central Namaqualand (Hondeklipbaai area) is fairly well sampled due to fortuitous preservation (Carrington & Kensley, 1969; Kensley & Pether, 1986). However, the sample is spatially and biogeographically restricted. Due to the poor preservation of shell in most of the decalcified Hondeklipbaai Fm. the sample is relatively small and biased toward robust shells. These shortcomings are illustrated by the fact that several species found by Carrington & Kensley (1969) have not been found again.

Some fossil shells selected from exposures in the study area featured in the earliest palaeontological findings about the marine deposits (Haughton, 1926, 1928, 1932) and are kept at the IZIKO South African Museum, but lack precise locations. If fortuitously-preserved shelly beds are encountered they should be sampled in bulk in order to obtain representative faunal assemblages, as faunal assemblage data are lacking for the marine formations in northern Namaqualand. If well-preserved shell beds are uncovered it is expected that the list of known species will be lengthened and more extinct shell species, and warm-water species, will be found, some of which are ancestral to the endemic modern fauna. Certainly, efforts to increase the overall fossil sample size from both Pliocene formations, from wider afield along the West Coast, will inform about the nature of the coastal palaeoenvironments and biogeographic transitions during of those times of extended global warmth and deglaciation. The Avontuur and Hondeklipbaai formations are thus of MODERATE sensitivity with respect to shell fossils.

The Curlew Strand Fm., as mentioned, is dominated by shell species still living today and is of LOW sensitivity with respect to shell fossils. Notwithstanding, sheltered embayments may have pertained in the Port Nolloth area, such as in the main pan locations, and these deposits will include the warm-water, extralimital "guests" of West African origin which ranged down the coast during LIG and earlier times.

Very sparsely scattered bones occur within these marine deposits, such as bones of whales, dolphins, seals and seabirds, while terrestrial mammal bones are found in estuarine deposits. These bones are white, fragile and not strongly mineralized. The hard, abraded, brown-coloured, petrified (phosphatized) bones and teeth of older marine taxa, as well as those of terrestrial vertebrates, occur in basal marine gravels (Figure 17). The smaller petrified teeth are found in the rotary pan heavy concentrates from gravels (Figure 18) and have provided critical age constraints for our understanding of coastal-plain geohistory (Pickford & Senut, 1997). Though fossil bone or tooth finds might appear to be nondescript-looking fragments, a specialist is often able to make an identification, as evident in Figures 17 and 18. In these marine formations the bones are mainly of extinct species and are of HIGH palaeontological importance.

ELEPHANTS & KIN
1: Anancus kenyensis. Latest Miocene - Early Pliocene gomphothere.
2: Loxodonta sp. Lukeino stage, Late Miocene -Early Pliocene elephant.
3 & 4: Proboscidae indeterminate. Petrified, phosphatized ivory, with asymmetrical X-sections.
TOOTHED WHALES & DOLPHINS
5 & 6: Incredibly large teeth of extinct giant sperm whales that cruised the Miocene oceans.
OSTRICHES & KIN
7: ?Diamantornis sp. Tarso-metatarsus of extinct giant ostrich.
RHINOCEROTIDAE
Diceros praecox. Teeth of extinct white rhino, Late Miocene - Early Pliocene.
PINNIPEDIA - SEALS
9: Homiphoca. Flipper bone of extinct Langebaanian seal.
EQUIDAE - HORSES, ZEBRAS
10: Eurygnathohippus cornelianus. Tooth of extinct horse, 6-7 Ma.
CARNIVORES
11: Canine tooth of an unknown, large carnivore.
12: Amphicyonidae. Bear-dogs - Agnotherium sp. Carnassial tooth, Miocene 13 - 12 Ma.
FISH TEETH
13: Various petrified shark and fish teeth, including half tooth of giant Pliocene shark C. megalodon

Figure 17. Fossils from the basal marine gravels, petrified by phosphatization processes in marine muds when submerged on shelf.

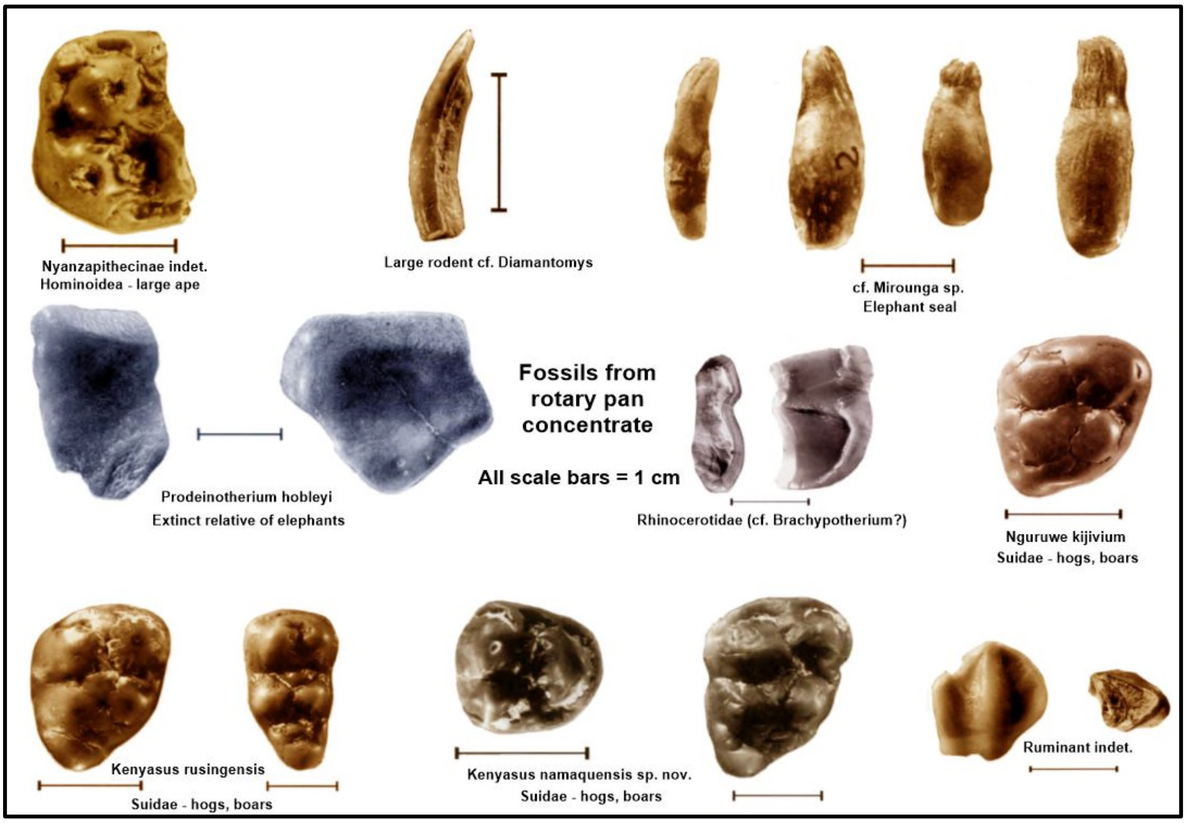


Figure 18. Examples of fossil mammal teeth collected from gravel rotary pan concentrates.

10 ASSESSMENT OF PALAEONTOLOGICAL IMPACTS

10.1 NATURE OF FOSSIL HERITAGE

Fossils are rare objects, often preserved due to unusual circumstances. This is particularly applicable to vertebrate fossils (fossil bones), which tend to be sporadically preserved and have high value with respect to palaeoecological and biostratigraphic (dating) information. Such fossils are non-renewable resources. Provided that no subsurface disturbance occurs, the fossils remain sequestered there.

Overall the palaeontological sensitivity of coastal deposits is HIGH (Almond & Pether, 2009) due to previous fossil finds of high scientific importance. When excavations are made they furnish the "windows" into the coastal plain depository that would not otherwise exist and thereby provide access to the hidden fossils. The impact is positive for palaeontology, if efforts are made to watch out for and rescue the fossils.

The very scarcity of fossils makes for the added importance of looking out for them. Fossils and significant observations will be lost in the absence of management actions to mitigate such loss. There remains a medium to high risk of valuable fossils being lost despite management actions to mitigate such loss. Machinery involved in excavations may damage or destroy fossils, or they may be hidden in "spoil" of excavated material. This loss of the opportunity to recover them and their contexts when exposed at a site is irreversible.

The status of the potential impact for palaeontology is not neutral or negligible. It depends on the long term interest and involvement of all personnel involved in the prospecting and mining operations, and particularly, those observing the deposit exposure faces during excavation. Support and co-operation between mining companies and academia, in the interpretation of the deposits of the coastal plain, as informed by fossils discovered and rescued by mining/prospecting people, has been fundamental to the development of the basic, "roughed-out" current geological model for the West Coast. This basic geological model needs to be tested against the geological record in the different antecedent bedrock topographies of the coastal compartments along the coast, such as the unstudied Port Nolloth embayment.

10.2 Impact Rating Criteria

The impact on palaeontological resources takes place during all earthmoving activities. The criteria for the rating of significance are according to the scheme provided in Appendix 4.

10.3 Extents

The physical extent of impacts on potential palaeontological resources relates directly to the extents of subsurface disturbance involved in the installation of infrastructure and buildings during the Construction Phase, *i.e.* limited to the SITES of construction activity.

However, unlike an impact that has a defined spatial extent (*e.g.* loss of a portion of a habitat), the cultural, heritage and scientific impacts are of regional to national extent, as is implicit in the National Heritage Resources Act No. 25 (1999) and, if scientifically important specimens or assemblages are uncovered, are of INTERNATIONAL interest. This is evident in the amount of foreign-funded palaeontological research that takes place in South Africa by scientists of other nationalities.

10.4 Duration

The initial duration of the impact is SHORT TERM (<5 years) and primarily related to the Construction Phase when excavations for infrastructure are made. This is the “time window” for mitigation.

The impact of both the finding and the loss of fossils is permanent. The found fossils must be preserved “for posterity”, the lost, overlooked or destroyed fossils are lost to posterity. The duration of impact is therefore PERMANENT with or without mitigation.

10.5 Intensity/Magnitude

The intensity or magnitude of impact relates to the palaeontological sensitivities of the affected formations (Appendix 3) and the degree or volume of disturbance. In this case the total volume of the excavations is substantial due to the intention to expose the basal gravels and fossils are likely to be exposed in the overlying sequences at several locations. From the discussion above:

In the marine formations the bones are mainly of extinct species and are of HIGH palaeontological importance.

The terrestrial formations, mainly of later mid-Quaternary and late Quaternary age, are accorded a MODERATE palaeontological sensitivity with respect to fossil bones.

The Pliocene Avontuur and Hondeklipbaai formations are of MODERATE sensitivity with respect to shell fossils.

The Quaternary Curlew Strand Fm. raised beaches are of LOW sensitivity with respect to shell fossils.

10.6 Consequence of Impact

Permanent loss of material palaeontological heritage (fossil specimens) and the scientific discovery and knowledge implicit in their origin and context.

10.7 Probability of Occurrence

Notwithstanding that fossil bones are overall sparse in the formations in this area, it is PROBABLE that fossil bones could be discovered, in view of the excavation volume involved.

10.8 IRREPLACEABLE LOSS OF RESOURCES

Without mitigation and rescue of unearthed fossils there will be a COMPLETE LOSS OF RESOURCES within the footprints of the development.

10.9 REVERSIBILITY

Palaeontological resources are unique and their loss is IRREVERSIBLE.

10.10 INDIRECT IMPACTS

The material fossil evidence of “deep time” is embedded in the creation of the sacred landscape and contributes to the “sense of place” cultural aesthetic of the region. The loss of fossils and concomitant interpreted knowledge impoverishes the tangible testimony of the prehistoric landscape and ecological context of ancient humans.

10.11 CUMULATIVE IMPACTS

The cumulative impact of coastal developments and coastal mining is the inevitable and permanent loss of fossils and the associated scientific implications. As mentioned, the impact of both the finding and the loss of fossils is permanent. Diligent and successful mitigation contributes to a positive cumulative impact as the rescued fossils are preserved and accumulated for scientific study. Even though just a very minor portion of the bone fossils exposed in coastal excavations has been seen and saved, the rescued fossils have proved to be of fundamental scientific value.

10.12 DEGREE TO WHICH IMPACT CAN BE AVOIDED

There is a risk of valuable fossils being lost despite management actions to mitigate such loss. The avoidance of impact is LOW.

10.13 DEGREE TO WHICH IMPACT CAN BE MANAGED

Experience of coastal developments and mining has shown that the impact is difficult to manage and will require significant mitigation co-operation and effort on the part of excavation contractors and supervisors. Seldom are fossil bone finds reported from contexts where they are expected to occur. The conclusion is that the monitoring of digging is generally inadequate for the capture of small-scale fossil bone occurrences as the fossils are only briefly exposed, while large bones or bone clusters are seen. The success of management is thus LOW to MODERATE.

10.14 DEGREE TO WHICH AN IMPACT CAN BE MITIGATED

Given unavoidable loss of fossils the impact can only be partly mitigated, *i.e*. MODERATE.

10.15 RESIDUAL IMPACTS

Negative residual impact arises from the unavoidable loss of fossils of unknown significance in spite of mitigation efforts. Positive residual impact arises from the successful rescue of fossil material for posterity, resulting in material for future research, employment opportunities for budding, young researchers and enhanced insights into the prehistory of the Northern Cape.

10.16 Impact Summaries

10.16.1 Fossil Bones in the Marine Formations

Loss of fossil bones from excavations in the marine Avontuur, Hondeklipbaai and Curlew Strand formations.							
	Extent	**Duration**	**Intensity**	**Status**	**Probability**	**Significance**	**Confidence**
Without mitigation	Local 1	Permanent 5	High 8	Negative	Probable 3	MEDIUM 42	Medium
Essential mitigation measures: • Prospecting personnel to be alert for rare fossil bones and follow "Fossil Finds Procedure". • Cease construction on discovery of fossil bones and protect fossils from further damage. • Contact appointed palaeontologist providing information and images. • Palaeontologist will assess information and establish suitable response, such as the importance of the find and recommendations for preservation, collection and record keeping.							
With mitigation	Local 1	Permanent 5	High 8	Positive	Probable 3	MEDIUM 42	Medium

10.16.2 Fossil Bones in the Terrestrial Formations

Loss of fossil bones from excavations in the aeolian formations, included pedocretes and pan deposits.							
	Extent	**Duration**	**Intensity**	**Status**	**Probability**	**Significance**	**Confidence**
Without mitigation	Local 1	Permanent 5	Medium 6	Negative	Probable 3	MEDIUM 36	Medium
Essential mitigation measures: • Prospecting personnel to be alert for rare fossil bones and follow "Fossil Finds Procedure". • Cease construction on discovery of fossil bones and protect fossils from further damage. • Contact appointed palaeontologist providing information and images. • Palaeontologist will assess information and establish suitable response, such as the importance of the find and recommendations for preservation, collection and record keeping.							
With mitigation	Local 1	Permanent 5	Medium 6	Positive	Probable 3	MEDIUM 36	Medium

10.16.3 Fossil Shells in the Marine Pliocene Formations

Loss of fossil shells from excavations in the Avontuur and Hondeklipbaai formations.							
	Extent	**Duration**	**Intensity**	**Status**	**Probability**	**Significance**	**Confidence**
Without mitigation	Local 1	Permanent 5	Medium 6	Negative	Probable 3	MEDIUM 36	Medium
Essential mitigation measures: • Prospecting personnel and ECO to be aware that a substantial temporary exposure of marine shelly beds may require sampling and recording. • In the event of a large exposure of shell beds, the appointed palaeontologist must be notified and provided with information and images. Palaeontologist will assess information and establish suitable response, such as the importance of the find and recommendations for sample collection and record keeping. • Selected exposed fossiliferous sections in earthworks recorded and sampled by appointed palaeontologist.							
With mitigation	Local 1	Permanent 5	Medium 6	Positive	Probable 3	MEDIUM 36	Medium

10.16.4 Fossil Shells in the Quaternary Raised Beaches

Loss of fossil shells from excavations in the marine Curlew Strand Formation raised beaches.							
	Extent	**Duration**	**Intensity**	**Status**	**Probability**	**Significance**	**Confidence**
Without mitigation	Local 1	Permanent 5	Low 4	Negative	Probable 4	MEDIUM 40	Medium
Essential mitigation measures: • Prospecting personnel and ECO to be aware that a substantial temporary exposure of marine shelly beds may require sampling and recording. • In the event of a large exposure of shell beds, the appointed palaeontologist must be notified and provided with information and images. Palaeontologist will assess information and establish suitable response, such as the importance of the find and recommendations for sample collection and record keeping. • Selected exposed fossiliferous sections in earthworks recorded and sampled by appointed palaeontologist.							
With mitigation	Local 1	Permanent 5	Low 4	Positive	Probable 4	MEDIUM 40	Medium

11 CONCLUSIONS AND RECOMMENDATIONS

There are no known outcrops of sensitive fossiliferous strata in the Project Area that require protection as NO-GO sites, such as spots where fossil bones occur in obvious abundance. The palaeontological resources are subsurface and consequently considerations of fossil potential do not result in preferred sites and the precise locations of the prospecting pits and trenches do not affect this assessment.

11.1 MITIGATION

There will only be three prospecting pits open at any given time, one in the process of backfilling and rehabilitation, one that is operational for logging and one in the process of excavation. Similarly, only one bulk sample trench will be open at any given time. The duration of the prospecting is not specified, but presumably will take place over a few years.

It is not feasible for a specialist to routinely monitor the excavation of the pits and trenches. Routine monitoring can only be achieved by the co-operation of the people on the ground. By these are meant personnel in supervisory/inspection roles, such as the geologist, surveyor, pit foremen, etc., who are willing and interested to look out for occurrences of fossils. A monitoring presence is critical for spotting a major “strike” of fossil bones and stopping further damaging excavation.

It is recommended that a requirement to be alert for fossil materials and archaeological material uncovered during the prospecting be included in the Environmental Management Programme (EMPr) for the proposed prospecting operations. Under supervision of the Environmental Control Officer (ECO) and as part of Environmental and Health & Safety awareness training, personnel involved in the prospecting excavations must be instructed to be alert particularly for the occurrence of fossil bones. Due to the scarcity and importance of fossil bones in the affected formations it is important that such ephemeral opportunities to rescue fossil bones must not be overlooked. In the event of such discoveries the **Fossil Finds Procedure** (FFP) provided (Appendix 5), for incorporation into the Environmental Management Programme for the proposed prospecting, must be followed.

Fossils that were not seen during excavation may also be revealed when overburden spoil is returned to the excavation when backfilling. Fossil bones may also be noticed weathering out in the sides of old prospecting excavations, or exposed in the adjacent wind-eroded spoil heaps of excavated material.

Very importantly, mine staff must be empowered to rescue the fossil material that appears sporadically, but quite routinely during excavation and must be promptly rescued from loss. For instance, as fossil tortoises are quite common, they should be in the category of "allowed" rescue by mine staff *cf.* isolated bone finds in the FFP below (Appendix 5).

As mentioned above, finds of petrified teeth in rotary pan concentrates have provided critical age constraints for the ages of formations. Importantly, the previous finds have come from small-scale, "hands-on" operations using rotary pans to concentrate heavy mineral pebbles, such as the proposed operation herein. Whereas, in the larger mines, high-throughput concentration systems using Heavy Media Separation (HMS) plants and X-ray Sortex-type machines to extract diamonds in a "hands off" security regime, the petrified fossils in the concentrate are not captured.

It is highly recommended that mine staff must be empowered to rescue the petrified fossil material, usually teeth, that is retained in the rotary pan concentrates and which is seen during their sorting.

In the event of the uncovering of fossil bones, or fortuitously-preserved very shelly beds, which on consultation are deemed to be significant finds, a professional palaeontologist must be appointed to excavate the fossil bones and sample the shell beds. Said palaeontologist must also undertake the recording of the stratigraphic context and sedimentary geometry of the exposure and the compilation of the report to SAHRA and the relevant curatorial institution, *e.g.* the IZIKO S.A. Museum.

A contribution to mitigation which is of great importance is the creation of a systematic archive of the pit and trench exposures over the duration of the prospecting, and later possible mining. With modern technology such as smartphones and cameras capable of recording high-resolution images inexpensively, accompanied by GPS positioning, and freely available software that enables the stitching together of image mosaics of the pit faces, the creation of systematic records of the pit faces is now greatly facilitated. Involving the Project Geologist, or perhaps a student doing fieldwork for a thesis, a systematic archive of the pit and trench exposures will be a significant positive contribution to the geoscience and geoheritage of the Namaqualand coastal-plain formations in this area.

In this endeavour of diligent mitigation this consulting palaeontologist/stratigrapher can play a collaborating role in assisting with the interpretation of the exposures and identifying emailed images of fossil shells on an *ad hoc* basis. Also in this context, in co-operation and liaison with the Project Geologist, it may be mutually beneficial that the consulting palaeontologist carry out field inspections of the large prospecting trenches. Involving a day or two of fieldwork, the aim of field inspection is to examine the various formations exposed in the excavations, recording context and geometry, any shell fossil content, take fossil samples, and contribute to the archive of the exposures.

The proposed mitigation actions for the prospecting programme are relatively easily accomplished and their implementation will result in a positive impact for palaeontology arising from the proposed prospecting operation. The Director, Project Geologist and ECO for Dansile Nxikwe Diamonds CC are welcome to contact me about any clarifications or advice.

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13 APPENDIX 1 – 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) (~300 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 Environmental 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 (Cape Environmental Assessment Practitioners).	Sharples Environmental Services cc
CCA Environmental (Pty) Ltd.	Site Plan Consulting (Pty) Ltd.
Centre for Heritage & Archaeological Resource Management (CHARM).	SRK Consulting (South Africa) (Pty) Ltd.
Chand Environmental Consultants.	Strategic Environmental Focus (Pty) Ltd.
CK Rumboll & Partners.	UCT Archaeology Contracts Office (ACO).
CNdV Africa	UCT Environmental Evaluation Unit
CSIR - Environmental Management Services.	Urban Dynamics.
Digby Wells & Associates (Pty) Ltd.	Van Zyl Environmental Consultants
Enviro Logic	Western Cape Environmental Consultants (Pty) Ltd, t/a ENVIRO DINAMIK.
Environmental Resources Management SA (ERM).	Wethu Investment Group Ltd.
Greenmined Environmental	Withers Environmental Consultants.

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

14 APPENDIX 2 - SPECIALIST DECLARATION

PALAEONTOLOGICAL IMPACT ASSESSMENT.

DANSILE NXIKWE DIAMONDS CC PROSPECTING RIGHT APPLICATION WITH BULK SAMPLING ON A PORTION OF PLOT 516, PLOT 678 AND PLOT 668, PORT NOLLOTH, RICHTERSVELD LOCAL MUNICIPALITY, NAMAKWA DISTRICT MUNICIPALITY, NAMAKWALAND MAGISTERIAL DISTRICT, NORTHERN CAPE.

DMR REFERENCE NUMBER: NC 30/5/1/1/2/12672 PR

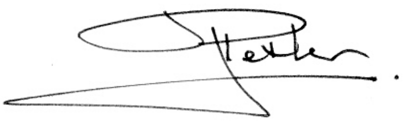
Terms of Reference

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 and 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: 29 March 2021

15 APPENDIX 3 - PALAEONTOLOGICAL SENSITIVITY RATING

Palaeontological Sensitivity refers to the likelihood of finding significant fossils within a geologic unit.

VERY HIGH: Formations/sites known or likely to include vertebrate fossils pertinent to human ancestry and palaeoenvironments and which are of international significance.

HIGH: Assigned to geological formations known to contain palaeontological resources that include rare, well-preserved fossil materials important to on-going palaeoclimatic, palaeobiological and/or evolutionary studies. Fossils of land-dwelling vertebrates are typically considered significant. Such formations have the potential to produce, or have produced, vertebrate remains that are the particular research focus of palaeontologists and can represent important educational resources as well.

MODERATE: Formations known to contain palaeontological localities and that have yielded fossils that are common elsewhere, and/or that are stratigraphically long-ranging, would be assigned a moderate rating. This evaluation can also be applied to strata that have an unproven, but strong potential to yield fossil remains based on its stratigraphy and/or geomorphologic setting.

LOW: Formations that are relatively recent or that represent a high-energy subaerial depositional environment where fossils are unlikely to be preserved, or are judged unlikely to produce unique fossil remains. A low abundance of invertebrate fossil remains can occur, but the palaeontological sensitivity would remain low due to their being relatively common and their lack of potential to serve as significant scientific resources. However, when fossils are found in these formations, they are often very significant additions to our geologic understanding of the area. Other examples include decalcified marine deposits that preserve casts of shells and marine trace fossils, and fossil soils with terrestrial trace fossils and plant remains (burrows and root fossils)

MARGINAL: Formations that are composed either of volcaniclastic or metasedimentary rocks, but that nevertheless have a limited probability for producing fossils from certain contexts at localized outcrops. Volcaniclastic rock can contain organisms that were fossilized by being covered by ash, dust, mud, or other debris from volcanoes. Sedimentary rocks that have been metamorphosed by the heat and pressure of deep burial are called metasedimentary. If the meta sedimentary rocks had fossils within them, they may have survived the metamorphism and still be identifiable. However, since the probability of this occurring is limited, these formations are considered marginally sensitive.

NO POTENTIAL: Assigned to geologic formations that are composed entirely of volcanic or plutonic igneous rock, such as basalt or granite, and therefore do not have any potential for producing fossil remains. These formations have no palaeontological resource potential.

Adapted from Society of Vertebrate Paleontology. 1995. Assessment and Mitigation of Adverse Impacts to Nonrenewable Paleontologic Resources - Standard Guidelines. News Bulletin, Vol. 163, p. 22-27.

16 APPENDIX 4 - METHODOLOGY FOR ASSESSING THE SIGNIFICANCE OF IMPACTS

EFFECT	**Extents/Spatial Scale**		**E**
	Localized	At localized scale and a few hectares in extent.	1
	Study area	The proposed site and its immediate environs.	2
	Regional	District and Provincial level.	3
	National	Country.	4
	International	Internationally.	5
	Duration/Temporal Scale		**D**
	Very short	Less than 1 year.	1
	Short term	Between 2 to 5 years.	2
	Medium term	Between 5 and 15 years.	3
	Long term	Exceeding 15 years and from a human perspective almost permanent.	4
	Permanent	Resulting in a permanent and lasting change.	5
	Magnitude/Intensity (Palaeontological Sensitivity)		**M**
	No potential	Formations entirely lacking fossils such as igneous rocks.	0
	Marginal	Limited probability for producing fossils from certain contexts at localized outcrops.	2
	Low	Depositional environment where fossils are unlikely to be preserved, or are judged unlikely to produce unique fossil remains.	4
	Medium	Strong potential to yield fossil remains based on stratigraphy and/or geomorphologic setting.	6
	High	Formations known to contain palaeontological resources that include rare, well-preserved fossil materials.	8
	Very high	Formations/sites known or likely to include vertebrate fossils pertinent to human ancestry and palaeoenvironments and which are of international significance.	10
	Probability/Likelihood		**P**
	Very improbable	Probably will not happen.	1
	Improbable	Some possibility, but low likelihood.	2
	Probable	Distinct possibility of these impacts occurring.	3
	Highly probable	The impact is most likely to occur.	4
	Definite	The impact will definitely occur regardless of prevention measures.	5

SIGNIFICANCE = (E+D+M)P		
< 30	LOW	The impact would not have a direct influence on the decision to develop in the area
30-60	MEDIUM	The impact could influence the decision to develop in the area unless it is effectively mitigated
>60	HIGH	The impact must have an influence on the decision process to develop in the area

17 APPENDIX 5 - FOSSIL FINDS PROCEDURE

In the context under consideration, it is improbable that fossil finds will require delineation of "No Go" zones. At most a temporary pause in activity at a limited locale may be required. The strategy is to rescue the fossil material as quickly as possible.

The procedures suggested below are in general terms, to be adapted as befits a context. They are couched in terms of finds of fossil bones that usually occur sparsely. However, they may also serve as a guideline for other fossil material that may occur.

Bone finds can be classified as two types: isolated bone finds and bone cluster finds.

17.1 Isolated Bone Finds

In the process of digging excavations, isolated bones may be spotted in the hole sides or bottom, or as they appear during subsequent handling of material, such as appearing on the overburden dump or at the oversize screen. By this is meant bones that occur singly, in different parts of the excavation. If the number of distinct bones at a spot exceeds 6 pieces, the finds must be treated as a Bone Cluster Find (below).

Response by personnel in the event of isolated bone finds

- **Action 1:** An isolated bone exposed in an excavation or subsequently during material handling/processing must be retrieved before it is obscured and lost and set aside.
- **Action 2:** The pit supervisor and Environmental Control Officer (ECO) must be informed.
- **Action 3:** The responsible field person (pit supervisor or ECO) must take custody of the fossil. The following information to be recorded:
  - Location co-ordinates (such as obtained by GPS in decimal degrees).
  - Digital images of excavation showing vertical section (mine face) and position of the find (estimated if recovered from *ex-situ* gravel).
  - Digital images of fossil.
  - Geological context obtained from the mine geologist.
- **Action 4:** The fossil should be placed in a bag (*e.g.* a Ziplock bag), along with any detached fragments. A label must be included with the date of the find, position info., depth.
- **Action 5:** ECO contacts the standby archaeologist and/or palaeontologist. ECO to describe the occurrence and provide images asap. by email.

Response by Palaeontologist in the event of isolated bone finds

The palaeontologist will assess the information and liaise with Dansile Nxikwe Diamonds and the ECO and a suitable response will be established.

Ex-situ fossil finds in concentrates

Petrified teeth which occur in the rotary pan concentrates must be collected and placed in labelled bags with information on the date, approximate source location and geological context, and images of the fossil must be recorded.

As above, images of finds must be emailed to the standby palaeontologist who will preliminarily evaluate the find.

On the discovery of conservation-worthy fossils, a collection permit must be applied for from the South African Heritages Resources Agency (SAHRA).

With the passage of time arrangements must be made to transport fossil material deemed worthy of conservation and study to an appropriate curatorial institution.

17.2 BONE CLUSTER FINDS

A bone cluster is a major find of bones, *i.e*. several bones in close proximity or bones resembling part of a skeleton. These bones will likely be seen in broken sections of the sides of the hole and as bones appearing in the bottom of the hole and in excavated material.

Response by personnel in the event of a bone cluster find

- **Action 1:** Immediately stop excavation in the vicinity of the potential material. Mark (flag) the position and also excavated material that may contain fossils.
- **Action 2:** Inform the pit supervisor and the ECO.
- **Action 3:** ECO contacts the standby archaeologist and/or palaeontologist. ECO to describe the occurrence and provide images asap. by email.

Response by Palaeontologist in the event of a bone cluster find

The palaeontologist will assess the information and liaise with Dansile Nxikwe Diamonds and a suitable response will be established. It is likely that a Field Assessment by the palaeontologist will be carried out asap.

It will probably be feasible to “leapfrog” the find and continue the excavation farther along, or proceed to the next excavation, so that the work schedule is minimally disrupted. The response time/scheduling of the Field Assessment is to be decided in consultation with Dansile Nxikwe Diamonds and the environmental consultant.

The field assessment could have the following outcomes:

- If a human burial, the appropriate authority is to be contacted. The find must be evaluated by a human burial specialist.
- If the fossils are in an archaeological context, an archaeologist must be contacted to evaluate the site and decide if Rescue Excavation is required.
- If the fossils are in a palaeontological context, the palaeontologist must evaluate the site and decide if Rescue Excavation is required.

17.3 RESCUE EXCAVATION

Rescue Excavation refers to the removal of the material from the excavation. This would apply if the amount or significance of the exposed material appears to be relatively circumscribed and it is feasible to remove it without compromising contextual data. The time span for Rescue Excavation should be reasonably rapid to avoid any undue delays to the mining schedule.

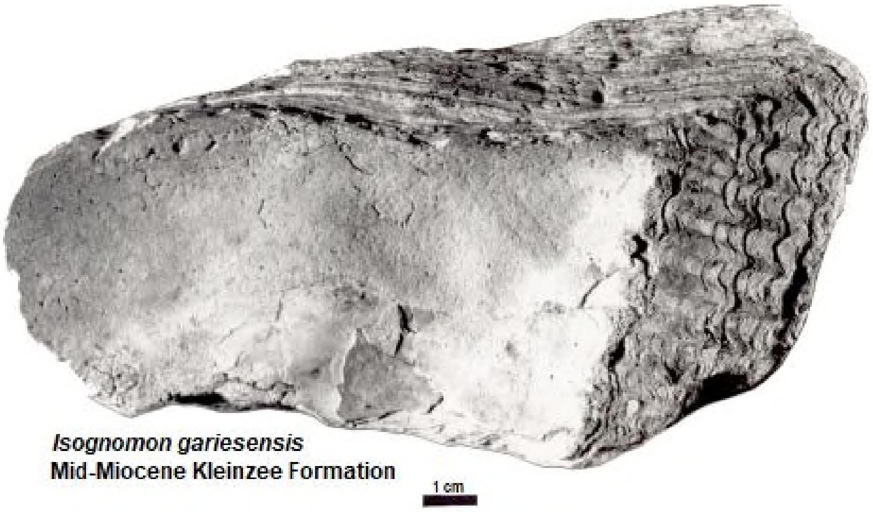
In principle, the strategy during mitigation is to “rescue” the fossil material as quickly as possible. The strategy to be adopted depends on the nature of the occurrence, particularly the density of the fossils. The methods of collection would depend on the preservation or fragility of the fossils and whether in loose or in lithified sediment. These could include:

- On-site selection and sieving in the case of robust material enclosed in loose material.
- Fragile material in loose/crumbly sediment would be encased in blocks using Plaster-of Paris or reinforced mortar and removed for preparation in a laboratory.
- Chunks of cemented rock with embedded fossils would be carefully trimmed of unnecessary excess rock and removed for preparation in a laboratory.

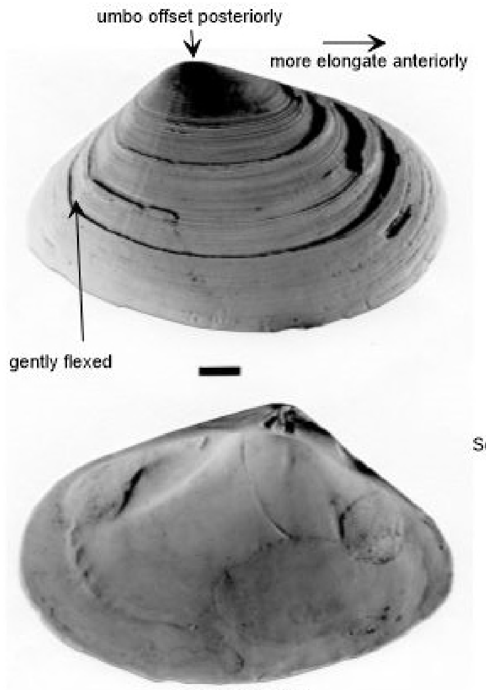
If the fossil occurrence is dense and is assessed to be a significant find then carefully controlled excavation is required.

18 APPENDIX 6 – SOME EXTINCT FOSSIL SHELLS FROM THE MIO-PLIOCENE MARINE FORMATIONS

Scale bars are 1 cm.

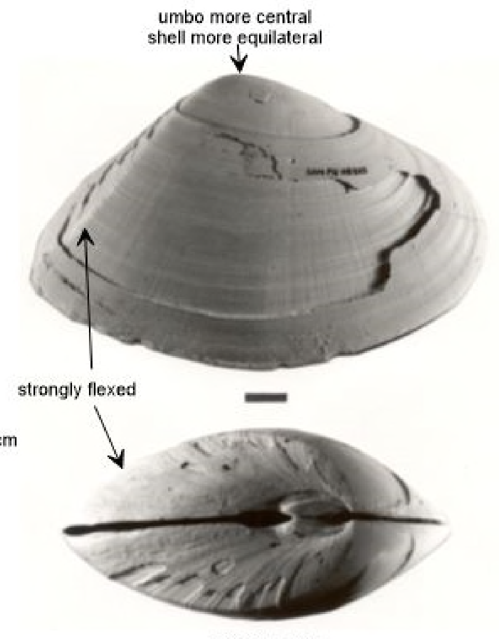


Isognomon gariesensis
Mid-Miocene Kleinzee Formation

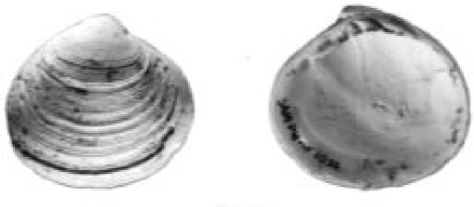


Donax haughtoni
Avontuur Formation (50 m Package) Early Pliocene ~5 Ma

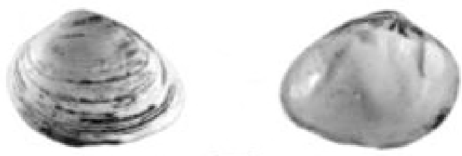
Scale bar = 1 cm



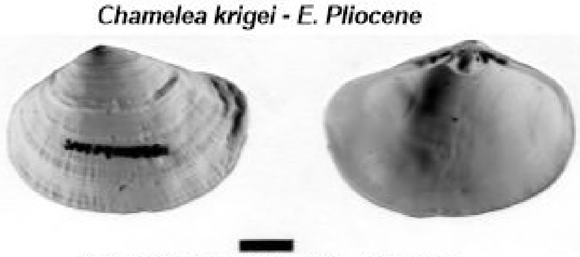
Donax rogersi
Late Pliocene ~3 Ma
Hondeklipbaai Formation (30 m Package)



***Chamelea krigei* - E. Pliocene**

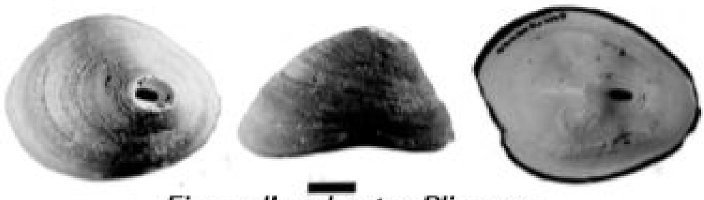


***Notocallista schwarzi* - E. Pliocene**



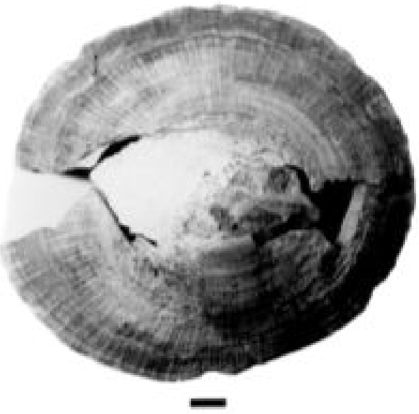
***Standella namaquensis* - Pliocene**

***Dosinia sicarisinus* - Pliocene**

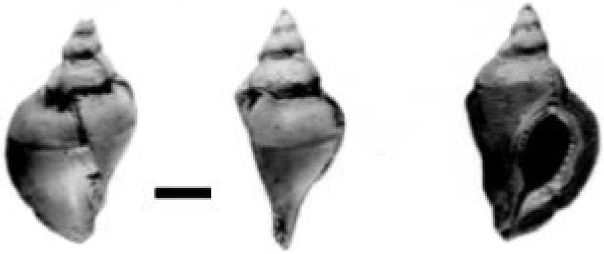


Fissurella robusta - Pliocene

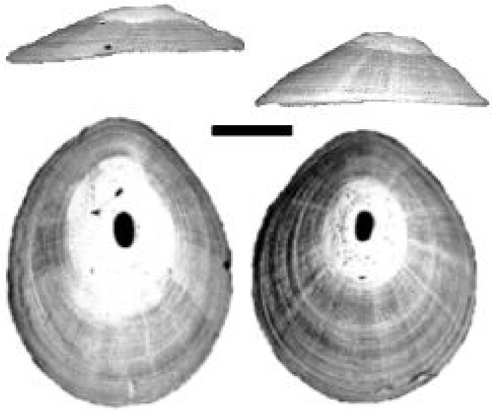
Patella hoffmani - E. Pliocene



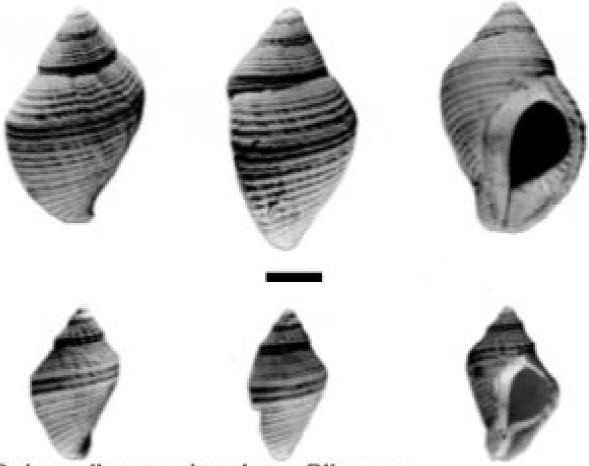
Patella hendeyi - Pliocene



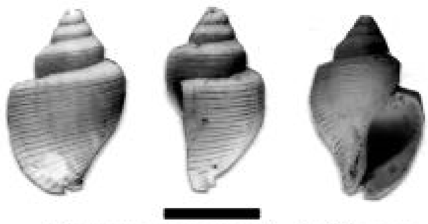
Namamurex odontostoma - Pliocene



Fissurella glarea - L. Pliocene



Spinucella praecingulata - Pliocene



Burnupena rogersi - L. Pliocene

Calliostoma depressa - E. Pliocene

Clanculus murrayi - Pliocene