PALAEONTOLOGICAL IMPACT ASSESSMENT

PROPOSED MINERAL SANDS RESOURCES (PTY) LTD PROSPECTING ON PORTIONS 1, 2, 3 & RE/153 OF THE FARM KLIPVLEY KAROO KOP 153

MATZIKAMA MUNICIPALITY, VREDENDAL DISTRICT, WESTERN CAPE PROVINCE

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Prepared at the Request of

Mineral Sands Resources (Pty) Ltd.

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EXECUTIVE SUMMARY

1. Project Name

Proposed Mineral Sands Resources (Pty) Ltd. Prospecting on Portions 1, 2, 3 & Re/153 of the Farm Klipvley Karoo Kop 153, Vredendal District, Western Cape Province.

2. Location

The farm Klipvley Karoo Kop 153 is located in the Matzikama Municipality, Vredendal Magisterial District. It is situated at the coast to the west of Lutzville town, from where it is ~30 km distant by road via Koekenaap to Skaapvlei homestead and the old Weskus Mynbou premises (Figure 1).

3. Locality Plan

The locations of the prospecting sampling and drilling will be determined on the basis of the Phase 1 analysis of existing data and the Phase 2 field survey and mapping.

4. Proposed Development

The prospecting is to evaluate the occurrence and abundances in the coastal-plain deposits of the Heavy Minerals (HM):

- Rutile (Rt), Ilmenite (Il), Leucoxene (Lx). For Titanium (Ti) and iron slag.
- Zircon (Zr). For glazes, pigments, high-temperature casting and Zirconium.
- Garnet (Gn). For abrasive.
- Monazite (Mz). For Rare Earth (RE) elements (Th, Ce, La, Nd, Y..
- Diamonds (DA). Marine placer diamonds.

Activities affecting the subsurface involve:

- ~200 surface sampling pits with 0.5 m sides and 1 m deep
- ~100 small-diameter, man-portable auger drill holes to ~4 m depth.
- ~50 air-core drilling rig boreholes to an average depth of ~ 20 m.

5. Affected Formations

The surface sampling in small pits (~1 m) will primarily affect the late Quaternary surficial sands of the Koekenaap and Hardevlei formations. Sampling to depth by auger and air-core drilling will intersect the "Dorbank", Olifantsrivier, Graauw Duinen and later Miocene aeolianite formations. The marine Kleinzee, Avontuur and Hondeklipbaai formations will also be intersected. Alluvium and colluvium in the local drainages, and possibly the Koingnaas Formation, may be intersected.

6. Palaeontological Resources

The fossil content of the aeolian formations is presumed to be typical of that observed in correlative formations in the wider area. Fossil material most commonly seen is the ambient fossil content of dune sands: land snails, tortoise shells and mole bones. The bones of larger animals are sparse, but are more persistently present along palaeosurfaces which separate units. Rare caches of bones in large burrows are due to the bone-collecting behaviour of hyaenas. Interbedded pan deposits may occur, possibly with aquatic fossils and organic-rich layers. Fossil shells and sparse marine mammal bones occur in the marine formations and rare patches of offshore muds which sometimes include fossil pollens. Alluvia and colluvia in drainages may also include potential fossil pollen-bearing mud layers. The Koingnaas Fm. includes organic peaty beds with fossil pollen and plant remains.

7. Anticipated Impact

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

Mud beds in any of the formations are important as potentially containing fossil plant pollen.

In the process of the field survey and during the sampling and drilling programme, late Quaternary fossil and archaeological material, including larger mammal bones, may be encountered in deflation areas not discovered during archaeological surveys, or may be noticed in old prospecting excavations and surrounding spoil.

8. 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 fossils occur in obvious abundance. The palaeontological resources are predominantly subsurface and consequently considerations of fossil potential do not result in preferred sites and the particular locations of surface sampling and drilling do not affect this assessment.

Under supervision of the Environmental Control Officer (ECO) and as part of Environmental and Health & Safety awareness training, personnel involved in the **shallow pit sampling** must be instructed to be alert for the occurrence of fossil bones. Fossil bones may also be noticed weathering out in the sides of old prospecting excavations, or exposed in the adjacent spoil heaps of excavated material. In the event of such discoveries the **Fossil Finds Procedure** provided below (Section 10.2), for incorporation into the Environmental Management Programme for the proposed prospecting, must be followed.

Although the palaeontological impact of the **auger and air-core drilling** is minimal due to the small volumes affected, it is proposed that a degree of mitigation is feasible and could have a positive benefit for the geological interpretation of the stratigraphy of the deposits. It is recommended that fossil material extracted from the boreholes, or later separated during sample analysis, be kept and bagged for identification by a palaeontologist. For preliminary analysis, quality images of the fossil material should be forwarded by email for examination by a specialist, in order to identify specimens of importance for stratigraphic diagnosis, and specimens requiring further examination and diagnosis.

Samples of mud beds from any formation, which may contain fossil pollen, are highly desirable due to their scientific importance and are a standing request from the fossil pollen specialists.

These mitigation measures are deemed adequate for the prospecting sampling and drilling operation. 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.

CONTENTS

ABBREVIATIONS

asl.	above (mean) sea level.
bsl.	below (mean) sea level.
CD-NGI	Chief Directorate – national geo-spatial Information.
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.
MTS	Main Transmission Substation.
OSL	Optically stimulated luminescence.
PIA	Palaeontological Impact Assessment.
SAHRA	South African Heritage Resources Agency.
SRTM	Shuttle Radar Topography Mission – NASA.
SS	Substation.

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).

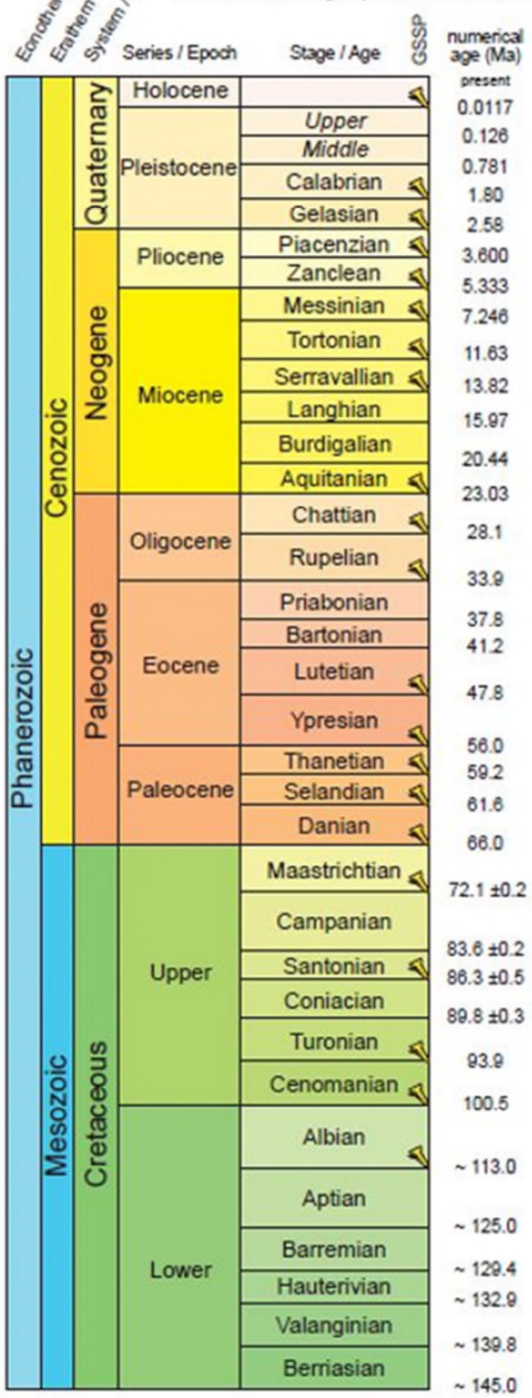
GEOLOGICAL TIME SCALE TERMS

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.

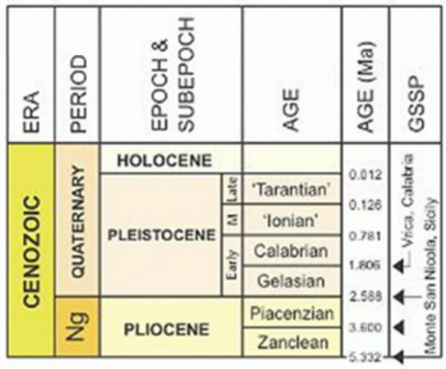
Ma: Millions years, mega-annum (10^6 years). Implicitly means “Ma ago” *i.e.* duration from the present, but “ago” is omitted. The “Present” refers to 1950 AD. Not used for durations not extending from the Present. For a duration only “Myr” is used.

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, Mineral Sands Resources (Pty) Ltd. (MSR) 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 various Heavy Minerals (HM) on four portions of the farm Klipvley Karoo Kop 153 on the coastal plain of southern Namaqualand (Figure 1). Jomela Consulting (Pty) Ltd. is undertaking the environmental authorisation process for the proposed prospecting. This report forms part of the Heritage Impact Assessment (HIA) 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 Construction Phase of the project.

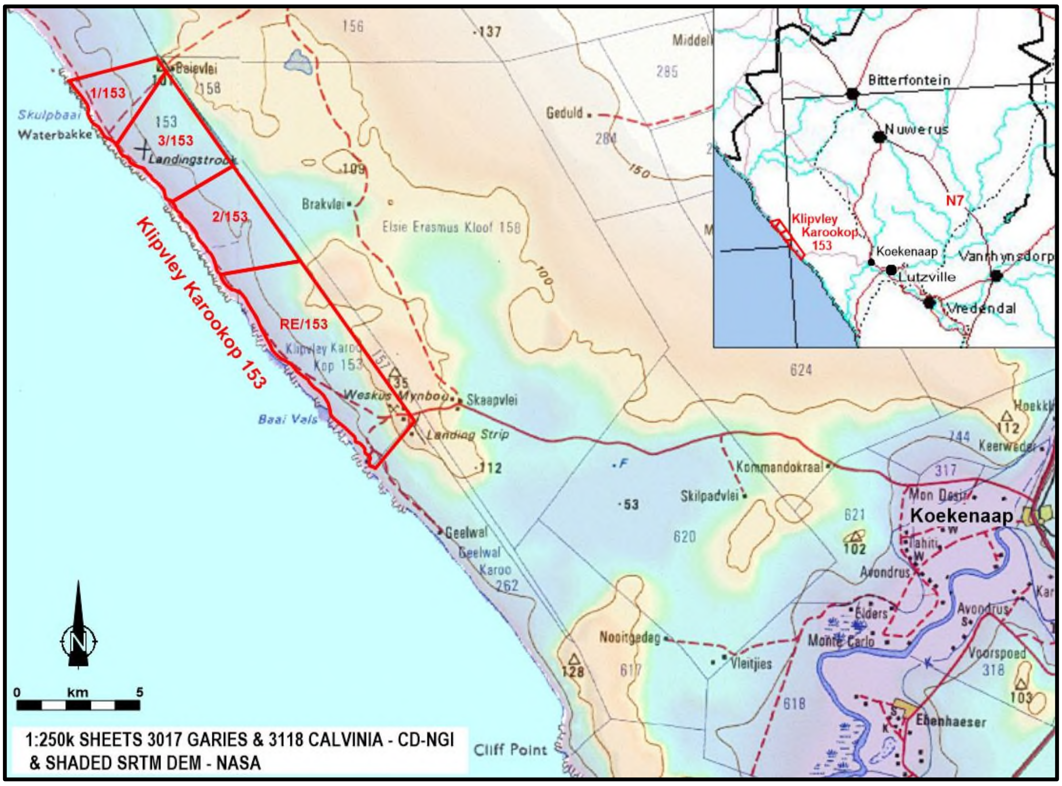


Figure 1. Location of Klipvley Karoo Kop 153 Project Area for the proposed prospecting.

2 LOCATION

The farm Klipvley Karoo Kop 153 is located in the Matzikama Municipality, Vredendal Magisterial District, Western Cape Province. It is situated at the coast to the west of Lutzville town, from where it is ~30 km distant by road via Koekenaap to Skaapvlei homestead and the old Weskus Mynbou premises (Figure 1). The properties involved are:

KLIPVLEY KAROO KOP 153	
Farm Portions	**Area ha**
Portion 1	451.4
Portion 2	777.7
Portion 3	809.9
Remainder	1596.1
TOTAL AREA	**3635**

CD-NGI Topo-cadastral Mapsheets:

- 1:50000 3117BD BAIEVLEI; 3118AC LANDPLAAS; 3118CA PAPENDORP.
- 1:250000 3017 GARIES; 3118 CALVINIA.

Council for Geoscience Geological Sheets:

- 1:250000 3017 GARIES, 3118 CALVINIA.

The Tormin Mineral Sands Mine, owned by MSR, is located on the adjacent farm Geelwal Karoo 262 where the HM-rich beach sands and the "Western Strandline" deposits just inland are mined.

3 LOCALITY PLAN

The locations of the prospecting sampling and drilling will be determined on the basis of the Phase 1 analysis of existing data and the Phase 2 field survey and mapping.

4 PROPOSED ACTIVITIES

The prospecting is to evaluate the occurrence and abundances in the coastal-plain deposits of the Heavy Minerals (HM):

- Rutile (Rt), Ilmenite (Il), Leucoxene (Lx). For Titanium (Ti) and iron slag.
- Zircon (Zr). For glazes, pigments, high-temperature casting and Zirconium.
- Garnet (Gn). For abrasive.
- Monazite (Mz). For Rare Earth (RE) elements (Th, Ce, La, Nd, Y..
- Diamonds (DA). Marine placer diamonds.

Phase 1 involves desktop activities, *viz*. data sourcing and evaluation of existing geological and prospecting data, satellite imagery and terrain data, in order to inform the choice of prospecting programme targets.

Phase 2 entails surface mapping traverses and the sampling of mineral occurrences by 25 litre samples extracted from ~200 pits with 0.5 m sides and 1 m deep. The pits will be backfilled after sampling.

Phase 3 entails the layout of sampling grids (~500 by 500 m) in areas of interest for shallow drilling and sampling using a small-diameter, man-portable auger drill. Approximately 100 auger holes to ~4 m depth are envisaged initially, but additional holes may be required for improved definition.

Phase 4 involves deeper drilling with an air-core drilling rig mounted on a small truck to acquire samples up to ~20 m depth . Approximately 50 air-core drill holes are planned, but additional holes may be required to follow up on results.

The surface, auger-drill and air-core drill samples will be analysed for their heavy mineral contents and the grades of potentially economic constituents.

Phase 5 entails the evaluation of the sampling results to estimate the mineral resources, the compilation of the prospecting geological report and the economic assessment, and the planning of the next phase of evaluation, if required.

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

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. Reports on previous prospecting are not readily available.

A account of the literature sources, the stratigraphy and the palaeontology of the coastal exposures between Graauw Duinen 152 and De Punt is given in Pether (2017) to which the reader is referred for more detail:

The relevant 1:250 000 Council for Geoscience geological maps and their explanations are Sheet 3118 CALVINIA (De Beer e*t al*., 2002) and Sheet 3017 GARIES (De Beer, 2010). The annotated and modified pertinent parts of these sheets are presented in Figure 5. The new stratigraphic terminology proposed by De Beer (2010) is mainly used, but is elaborated and modified according to the author's own observations.

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 along the shore of Klipvley Karoo Kop 153 consists of various gneisses of the Namaqualand Metamorphic Province (2000-1000 Ma; Ma = million years ago). These previously-molten, crustal basement rock formations are not of palaeontological interest.

7.2 THE WEST COAST GROUP

The bedrock gneisses are 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 2).

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.

TABLE 2. 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 Aeoliannites*	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.		

Ongoing erosion has removed nearly all traces of early 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

Deeply weathered, kaolinized (white china clay) bedrock is a feature of the older, higher parts of the coastal plain, with silcrete cappings in places. The silcretes are silicified bedrock and overlying deposits which originally formed in poorly-drained low spots in the pre-existing landscape, but with erosion these low areas are now "inverted" and occur as silcrete cappings on hills which are remnants of the old palaeosurface. The deep weathering and silcrete formation occurred during humid, tropical weathering such as thought typical of the palaeoclimates during Cretaceous and earlier Cenozoic (Paleeogene) times. 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. These silcretes mark an older palaeosurface of the coastal plain and represent talus and colluvial deposits. The fossil potential of these silicified colluvia is low, except perhaps for plant impressions.

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. Interestingly, the buried channel topography is partly registered in the surface topography (Figure 2).

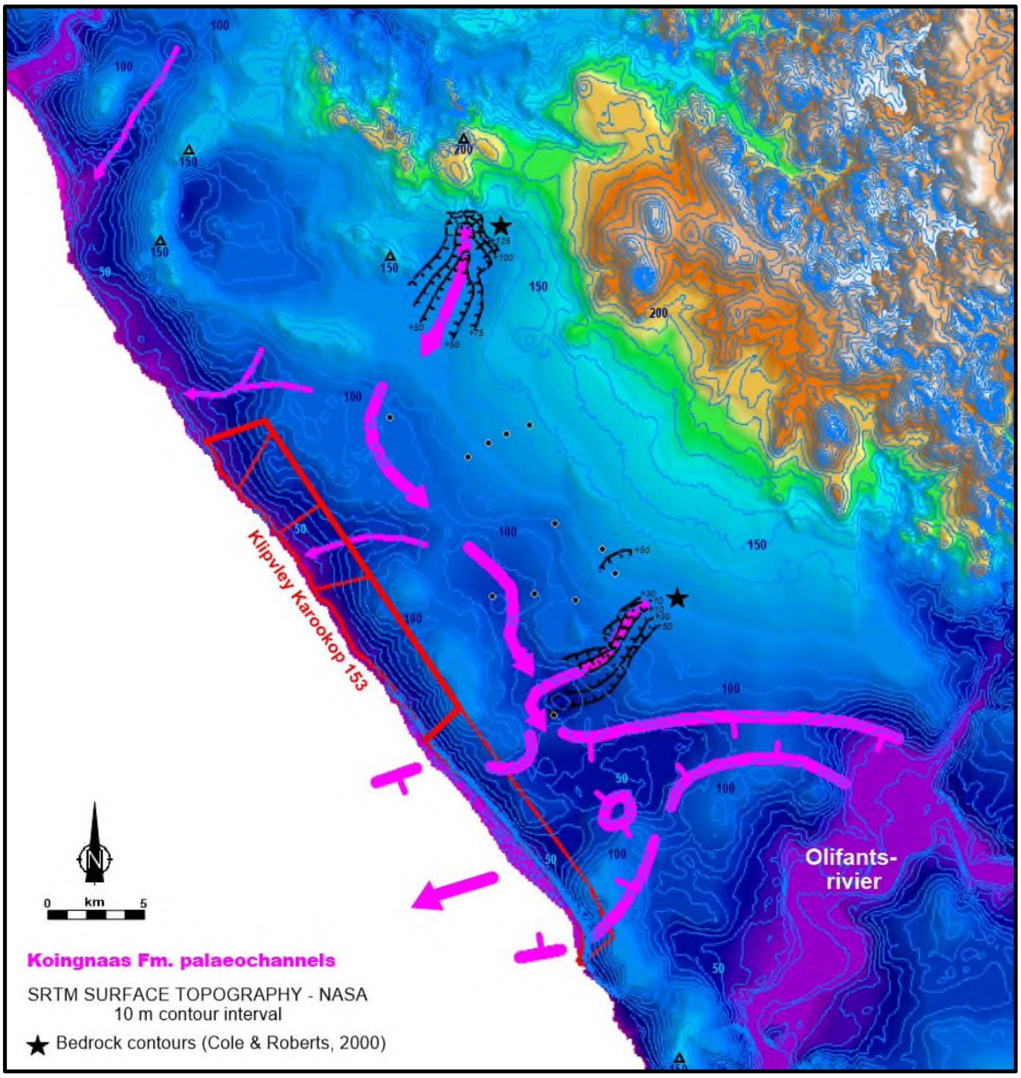


Figure 2. Surface topography (SRTM DEM) of the surrounds of the Project Area and buried palaeochannels of the Koingnaas Formation.

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 as 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 3), with the aggradation of fluvial deposits in the palaeochannels likely correlating with times of rising sea levels between 44-34 Ma. However, due to the pervasive kaolinitic weathering of the palaeochannel deposits it is possible that remnants of older, late Cretaceous and/or early 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.

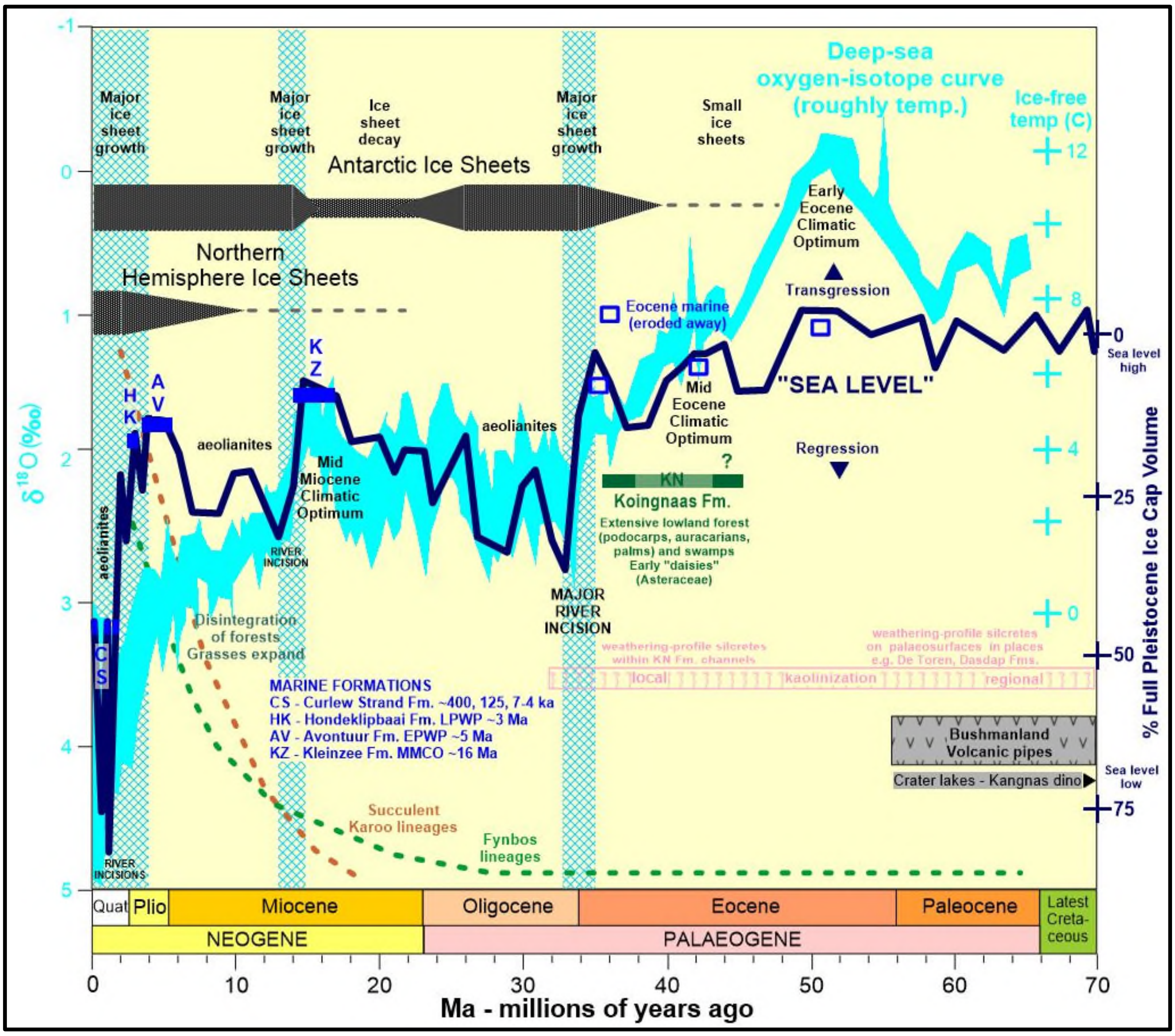


Figure 3: The Cenozoic Era (66 Ma to present) showing global palaeoclimate proxies, aspects of regional vegetation history and the context of marine formations of the West Coast Group, Alexander Bay Subgroup.

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.

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 3), 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 3), 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.

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** ~17-14 Ma (Figure 3). 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 ~90 m asl. When sea level receded again the marine **Kleinzee Formation** was deposited on the inner, high part of the coastal bevel and extends seawards from ~90 m asl. (also called the 90 m Package).

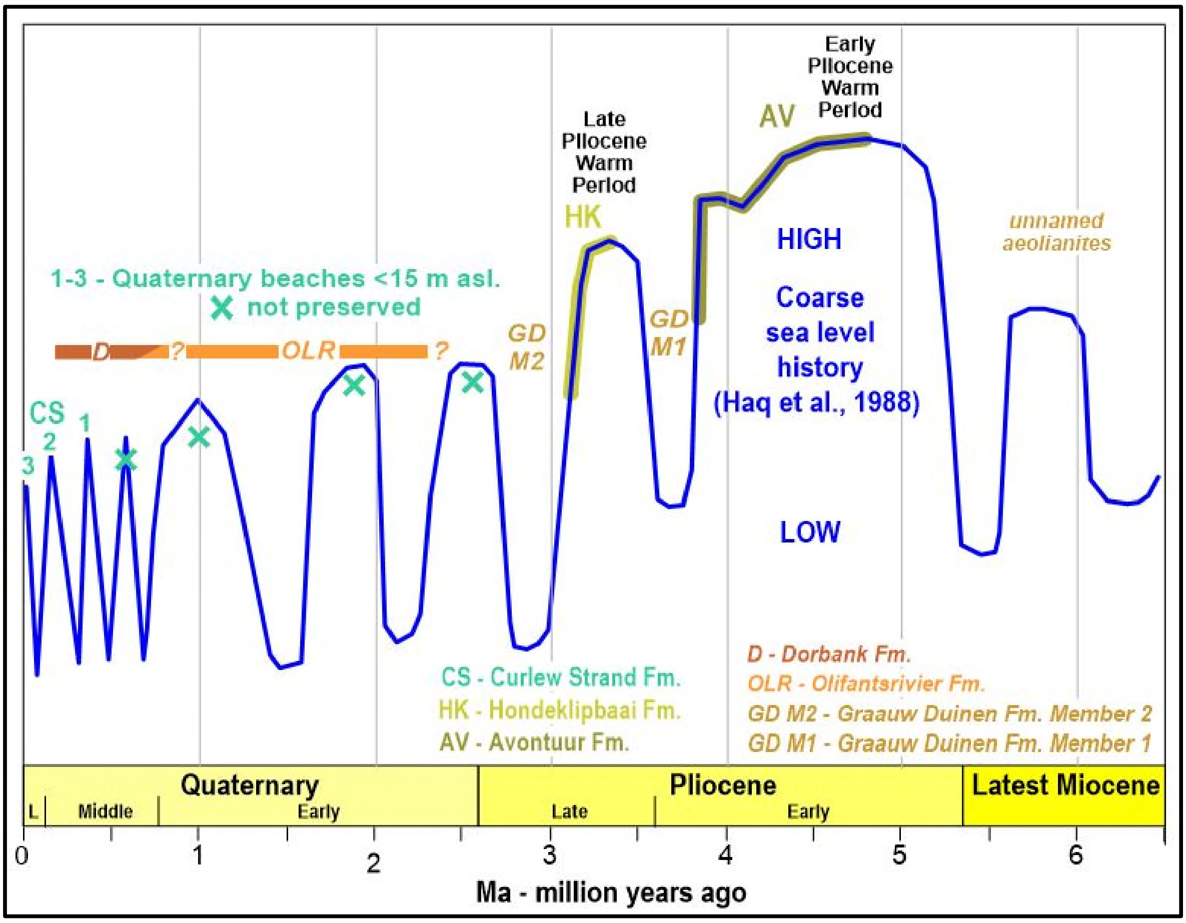


Figure 4. Context of latest Miocene, Pliocene and Quaternary marine and aeolian formations correlated with coarse-scale sea-level history based on major margin unconformities.

The Avontuur Formation

The previous Miocene marine beds were eroded during rising sea-level of the **Early Pliocene Warm Period** and the **Avontuur Formation** (the 50 m Package) was deposited 5-4 Ma as sea-level receded from the transgression maximum of about 50 m asl. and the shoreline prograded seawards (Figure 4).

The Hondeklipbaai Formation

The Avontuur Formation in turn was eroded by yet another rising sea-level associated with the **Late Pliocene Warm Period** 3.3-3.0 Ma (Figure 4). The **Hondeklipbaai Formation** or 30 m Package was deposited as sea level declined from a high of about 30-33 m asl. and a substantial, prograded marine formation built out seawards. This formation, up to a few km wide, underlies the outer part of the coastal plains of the West Coast. The actual sea levels were not at the absolute elevations mentioned above – the ancient palaeoshorelines have attained their present elevations due to uplift of the continental margin. Fossil shells are found in places in these Miocene and Pliocene marine formations and each contains warm-water species and also important extinct fossil shell species which are characteristic of that formation and which facilitate correlation of formations over wide regions.

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. It comprises 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 4, CS 1, 2, 3). The fossil shells in these "raised beaches" are predominantly the cold-water fauna of modern times.

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.

Our embryonic knowledge of the stratigraphic context of these older, buried aeolianite formations comes from the huge mine pits created by diamond and heavy-mineral mining, but these observations are mainly confined to the lower coastal plain (<~100 m asl.) where the dated marine formations underlie or are interbedded with the aeolian formations. The major pedocretes present in the mining pits are regional in extent and will also occur within the unexposed and unknown aeolian sequences of the higher coastal plain, and should be of stratigraphic utility for correlation.

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 into nearly massive units cemented by partly-silicified, neoformed interstitial clays. They may be basically pale units with extensive mottling and thus superficially similar to underlying Miocene marine deposits, or are extensively pedocreted, with many post-depositional features. 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 the bear-dog *Agnotherium* sp. (13 - 12 Ma) and the gomphothere *Tetralophodon* (12 - 9 Ma) in the basal gravels of the early Pliocene Avontuur Formation at Hondeklipbaai indicate the pre-existence of terrestrial deposits of this later Miocene age range (Figure 3).

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 4). 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 4). 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 6). 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 (Figure 4), while the upper part which includes ESA material is latest early Quaternary/earliest middle Quaternary (Figure 6). 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**.

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.

Notably, where thickly developed this formation generally lacks the development of distinct, laterally continuous, evolved calcareous pedocretes, most likely due to low original calcareous bioclastic content. However, as is the case with all aeolian formations, where the Dorbank Fm. thins out at its edges, the condensed sequence there has been subjected to more pervasive pedogenic alteration and cementing, and where the addition of elements to the soil by dust has had a greater relative role.

Figure 5. Surface geology of the Project Area.

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 6).

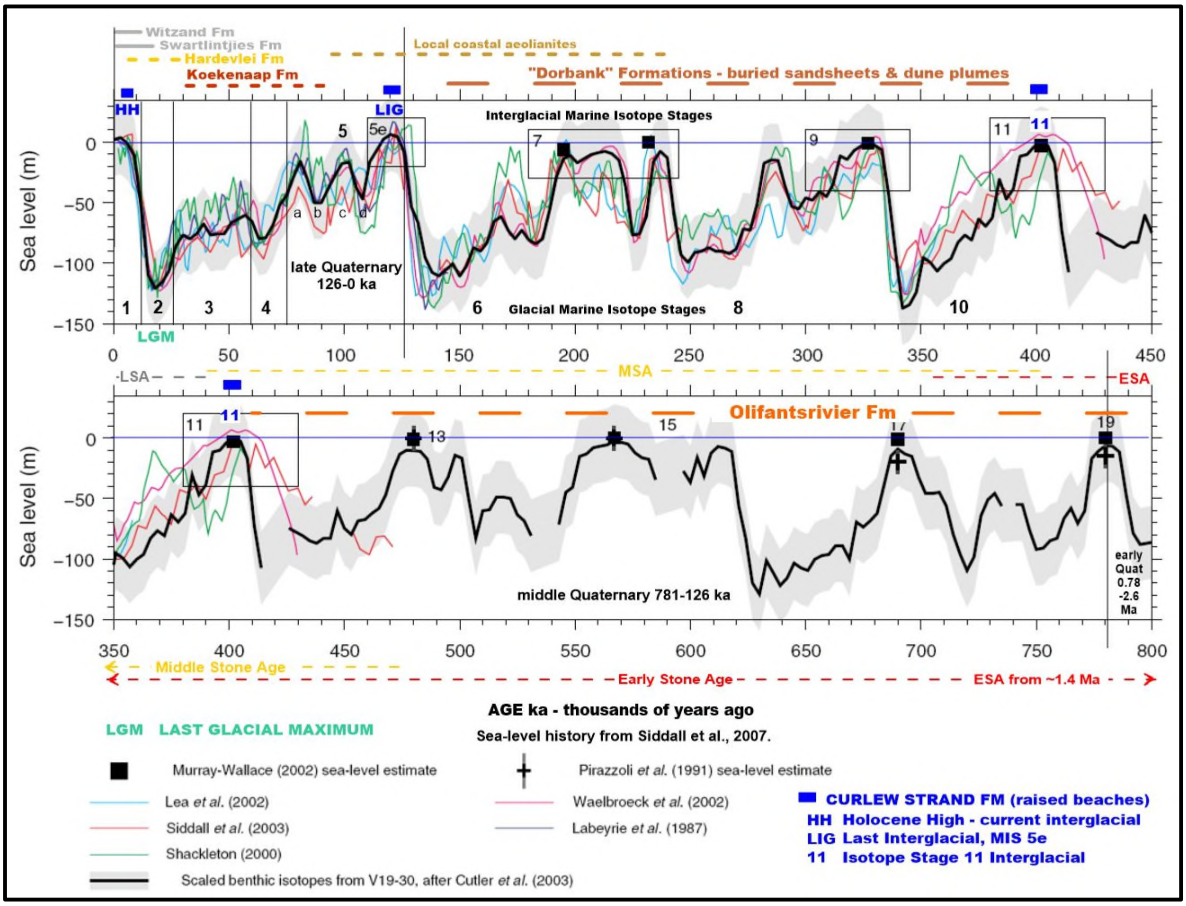


Figure 6. Sea-level history (from Siddall *et al.*, 2007) and the age ranges of middle and late Quaternary formations of Namaqualand.

The "Panvlei Formation" Surfaces

Proposed by De Beer (2010), the **Panvlei Formation** (**Qpa**) "(Figures 5 & 7) 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 are mapped as Q-r$_2$, "calcareous and gypsiferous soil", on the Calvinia geological map. 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 6). During some of these stages shoreline aeolianite units were deposited at places along the coast, herein called **Local Coastal Aeolianites**. For example, the Last Interglacial (LIG, ~125 ka) raised beach deposits along this stretch of coast are overlain by compact aeolian deposits, beneath the surficial, loose Witzand Fm. sands, that differ from place to place, *i.e.* rubified pink sands, or yellow sands, or grey sands, which are more locally confined to the coast and which are apparently of different ages. These 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 6) exhibit variations of pedogenesis and incipient pedocrete development indicative of their relative ages, but lack substantial pedocrete horizons.

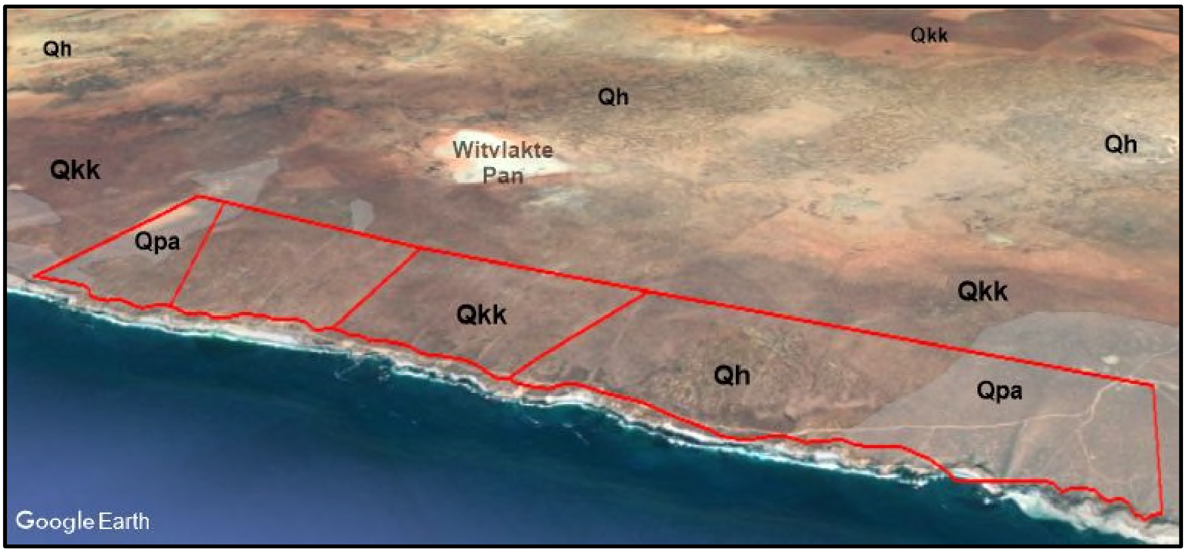


Figure 7. Klipvley Karoo Kop 153 and surrounds. Simulated oblique aerial image showing surficial formations.

The Koekenaap Formation

The **Koekenaap Formation** (**Qkk**) (Roberts *et al.*, 2006; De Beer, 2010) refers to the variously-reddened, unconsolidated coversands and low, degraded dunes which mantle much of the surface of the coastal plain (Figures 5 & 7)), overlying the hard surface of the Dorbank Formation. This surficial unit is depicted as "Red Aeolian Sand" (**Ç-s)** on the Calvinia geological map and denoted as the "RAS" at Namakwa Sands mine. Where thicker, subunits can be distinguished by subtle variations in hue and grain adhesion. The red sands are underlain by scatters of MSA material on top of the palaeosurface formed on the Dorbank 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 6) 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.

The Hardevlei Formation

Subsequent aeolian activity is manifested in the yellow dunes of the **Hardevlei Formation** (**Qh**) (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 (Figures 5 & 7). 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 geological maps do not depict the entire area of Hardevlei Fm. dunes and therefore it has been added to Figure 5, as seen in satellite images. 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). A nearby core in a Hardevlei Fm. dune produced an OSL date of ~14 ka near its base (2.5 m depth), ~6.7 ka at 1 m depth and ~2.2 ka at 0.5 m depth (WK03-15; Chase & Thomas, 2006).

The Swartlintjies Formation

The name **Swartlintjies Formation** (**Qsw**) 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). Similarly, large dune plumes blew inland from the coast in the deeper past and are evident as broad low ridges of the Dorbank Fm. in the landscape.

The Witzand Formation

The **Witzand Formation** (**Qwi**) 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

Surface elevations of ~100 m asl. pertain along the eastern boundary of Klipvley Karoo Kop 153 (Figure 1) and evidently reflect relatively steeply-rising underlying bedrock. The high ground is divided by a broad valley trending across Portion 2, Brakvlei se Laagte, which speculatively may mark a palaeochannel possibly preserving Koingnaas Fm. deposits (Figure 2). However, this drainage must have been active during subsequent times, reworking previous deposits and transporting quartz-gravelly sediments derived from the weathered bedrock. Similarly, other minor drainages may host locally-derived colluvium and alluvium. The episodically active drainages very likely later eroded gaps in the Miocene and Pliocene marine deposits along their courses.

Most of the Project Area would have been inundated during the Mid-Miocene Climatic Optimum sea-level transgression to ~90 m asl. The associated Kleinzee Fm. marine deposits are poorly preserved in general and erosion has particularly affected the thin, high edge of the formation above ~70 m asl. Often only residual rounded marine gravels may remain, but in places heavy-mineral-rich, laminated foreshore (beach) deposits are preserved seaward of the ~90 m asl. cliff line, as seen in the exposures north of Kleinzee. Farther seawards the deposits of the early Pliocene Avontuur Fm. overlie the bedrock and are in turn overlapped by the late Pliocene Hondeklipbaai Fm. The Hondeklipbaai Fm. crops out along the coast (Figure 5) where exposures just inland reveal shoreface deposits and indicate that the sea level was about 20 m higher than present at the time when the late Pliocene shoreline prograded past the position of the present shoreline.

The surface sampling in shallow pits (~1 m) will primarily affect the surficial sands of the Koekenaap Fm. There is a patch of dunes named Kolduin which resembles the Hardevlei Fm. type, situated somewhat anomalously adjacent to the coast (Figures 5 & 7). The auger drilling will primarily intersect the underlying, compact, older aeolianites. The drilling depths could be several metres, but may be limited in places by hard layers such as pedocretes. It is likely that the "Dorbank" Formation will primarily be intersected over most of the area by auger drilling, but the pedocreted, older aeolianites equivalent to Olifantsrivier and Graauw Duinen formations may be close to the surface in places, such as beneath the "Panvlei Surfaces" in the southern and northern parts of the Project Area.

The air-core drilling, with the intention to drill sufficiently deep to intersect the potential heavy mineral content of the marine formations, will intersect most of the coastal-plain aeolianite sequence, *i.e.* the Dorbank, Olifantsrivier and Graauw Duinen aeolian formations, and possibly the Later Miocene Aeolianites below the higher elevations in the Project Area, although the presence and thicknesses of the formations will vary across the area.

9 PALAEONTOLOGICAL IMPACT OF THE PROSPECTING

The proposed surface pit sampling will involve the late Quaternary surficial coversand and dune formations and, where the coversands are thin, will expose the uppermost part of the compact "Dorbank" Fm. Fossils are very sparse in the Hardevlei and Koekenaap formations. Fossil bone material that may occur is likely to be in an archaeological context and both artefacts and fossil bones are most often found on the compact palaeosurface of the "Dorbank" Fm. beneath the surficial sands. These occurrences usually only come to light when large areas of the surficial sands have been blown or mined away, whereas small pits over a large area have a low probability of chancing upon such finds. The impact of the surface pitting is therefore considered to be LOW.

Sampling to depth by auger and air-core drilling will intersect the "Dorbank", Olifantsrivier and Graauw Duinen aeolianite formations and pedocretes, and possibly aeolianites equivalent to the unnamed later Miocene aeolianite formation. The most common fossil material is the ambient fossil content of sparsely-scattered land snails, tortoise bones and mole bones, but little of this material is expected in the relatively small-volume samples. Even if the drill intersects a cluster of fossil bones only fragments will be produced. These older aeolianites have also been extensively decalcified and drilling will have LOW to MARGINAL impact due to the near absence of fossil material at the scale of drill holes.

The marine deposits are generally quite decalcified except for robust, thick shells, but pockets or zones of well-preserved shell fossils do occur in an unpredictable manner. However, the drilled material will likely be fragmentary and any fossil shell species that may be encountered are unlikely to be new discoveries. Other fossils which are occasionally brought up in boreholes include smaller petrified fossils such as shark and other fish teeth and casts of shells (steinkerns). This material is of interest, although usually not particularly age-diagnostic. The impact of the prospecting on marine fossils is considered to be LOW.

Although it is not intended to drill into the Koingnaas Fm. (which may not be present), it is nevertheless worth mentioning that drilling intersections may produce samples of organic-rich clays containing fossil pollen and lignitic material of plant macrofossils such as leaf and wood fragments. The plant fossils from these ancient rivers and swamps are of ongoing research interest and therefore the palaeontological sensitivity of the Koingnaas Formation may be regarded as HIGH. This is mentioned "just in case" as any opportunity to obtain such samples should not be overlooked.

Organic-rich mud layers may also occur in the younger deposits. Plant fossils are known to occur in the deeper-water, muddy deposits which are locally preserved in the basal beds of the marine formations. Mud beds may occur in association with interdune pond/vlei deposits in the aeolianite formations and may possibly be associated with younger deposits within the drainage lines. Samples of any such material are of similar high scientific importance, due to the large spans of geological time for which there are no fossil pollen samples available to shed more light on the evolution of the modern biomes.

In the process of the field survey and during the sampling and drilling programme, late Quaternary fossil and archaeological material, including larger mammal bones, may be encountered in deflation areas not discovered during archaeological surveys, or may be noticed in old prospecting excavations and surrounding spoil.

9.1 IMPACT SUMMARY TABLE

Due to the limited disturbance involved in the proposed prospecting, as compared with bulk sampling or mining, the overall impact of the proposed prospecting programme on all formations is considered to be LOW.

TABLE 3. SUMMARY IMPACT TABLE.

<table>
<tr><th></th><th>Extent</th><th>Intensity</th><th>Duration</th><th>Probability</th><th>Impact</th><th>Significance</th><th>Status</th><th>Confidence</th></tr>
<tr><td rowspan="2">Without mitigation</td><td>Local</td><td>Low</td><td>Permanent</td><td>Possible</td><td>Low</td><td rowspan="2">MEDIUM</td><td rowspan="2">-ve</td><td rowspan="2">Medium</td></tr>
<tr><td>1</td><td>1</td><td>4</td><td>2</td><td>8</td></tr>
<tr><td colspan="9">Essential mitigation measures:
▪ Retain fossils (especially bone & teeth fragments) that are unearthed during pitting and drilling and record the details of the find.
▪ Submit images of finds to a palaeontologist to assess their scientific value and conservation worthiness.
▪ Submit finds deemed by a palaeontologist to be of significant scientific value or conservation worthiness to a curatorial institution.</td></tr>
<tr><td rowspan="2">With mitigation</td><td>Local</td><td>Low</td><td>Permanent</td><td>Possible</td><td>Low</td><td rowspan="2">LOW</td><td rowspan="2">+ve</td><td rowspan="2">Medium</td></tr>
<tr><td>1</td><td>1</td><td>4</td><td>2</td><td>8</td></tr>
</table>

10 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 and which are not marked as an archaeological site. The palaeontological resources are predominantly subsurface and consequently considerations of fossil potential do not result in preferred sites and the particular locations of surface sampling and drilling do not affect this assessment.

10.1 MITIGATION

It is recommended that a requirement to be alert for fossil materials and archaeological material uncovered during the shallow pitting, or brought up by drilling, 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 **shallow pit sampling** must be instructed to be alert for the **occurrence of fossil bones**. Fossil bones may also be noticed weathering out in the sides of **old prospecting excavations**, or exposed in the adjacent spoil heaps of excavated material. In the event of such discoveries the **Fossil Finds Procedure** provided below, for incorporation into the Environmental Management Programme for the proposed prospecting, must be followed. Due to the scarcity of fossil bones in the affected formations it is important that such ephemeral opportunities to rescue fossil bones must not be overlooked.

Although the palaeontological impact of the **auger and air-core drilling** is minimal due to the small volumes affected, it is proposed that a degree of mitigation is feasible and could have a positive benefit for the geological interpretation of the stratigraphy of the deposits. The accomplishment of this proposed mitigation requires the participation of the geologists supervising the drilling sampling and the personnel carrying out the subsequent processing of the samples.

Larger-size fossils, such as shells and smaller bones, may be noticed in the field when material is extracted from the boreholes for sampling and must be retained along with the contextual information (borehole no., location, depth in hole). Subsequently, the laboratory analysis of the borehole samples initially entails sieving in order to separate coarse material, such as pebbles and small fossils, from the sand fractions containing the heavy minerals. **It is recommended that fossil material extracted from the boreholes, or later separated during sample analysis, be kept and bagged for identification by a palaeontologist**, recording the details of the sample such as its borehole number, depth and the lithology of the material, with such included in the borehole log. For preliminary analysis, quality images of the fossil material should be forwarded by email for examination by a specialist, in order to identify specimens of importance for stratigraphic diagnosis, and specimens requiring further examination and diagnosis.

Organic-rich, dark, peaty layers intersected in boreholes which may contain fossil pollens and plant remains are particularly important, irrespective of which formation in which they may occur. Samples of such material, which lacking heavy minerals is not of economic interest, must be collected, along with the relevant details of the contexts. The possible availability of such material from southern Africa is of international scientific interest and is a standing request from the fossil pollen specialists.

These mitigation measures are deemed adequate for the prospecting sampling and drilling operation. 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.

10.2 FOSSIL FINDS PROCEDURE

Fossil bones in excavations

Should fossil bones and teeth be encountered in the shallow prospecting pits, work must cease at the site and the works foreman and the ECO for the project must be informed immediately. Scattered, unearthed parts/fragments of the find must be retrieved and returned to the main find site which must be protected from further disturbance. It should be possible to continue with the sampling at other sites.

Fossil bones which may be noticed in old excavations must also be protected from possible loss and be reported.

HWC and/or an appropriate specialist palaeontologist must be informed and supplied with contextual information:

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

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

Fossils from borehole samples

The geologists and laboratory personnel must retain small fossil material (teeth, bones, shell) sieved from the samples and liaise with a palaeontologist for identification and possible stratigraphic significance.

All fossils deemed important must be deposited in an appropriate, approved curatorial institution.

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12 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

13 APPENDIX 2- SPECIALIST DECLARATION

Palaeontological Impact Assessment.

Proposed Mineral Sands Resources (Pty) Ltd. Prospecting on Portions 1, 2, 3 & Re/153 of the Farm Klipvley Karoo Kop 153.

Matzikama Municipality, Vredendal District, Western Cape Province.

File Reference Number SAMRAD: 30/5/1/1/2/10307PR.

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: 2 February 2021

14 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.