PALAEONTOLOGICAL IMPACT ASSESSMENT

(Desktop Study)

PROPOSED RICHWILL DIAMONDS PROSPECTING ON THE FARM KAROETJIES KOP 150

PART OF PORTION 1/150 & SEAWARD PART OF RE/150

NAMAQUALAND, MATZIKAMA LOCAL MUNICIPALITY, WEST COAST DISTRICT

VREDENDAL MAGISTERIAL DISTRICT, WESTERN CAPE

WC10430PR

By

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

Geological and Palaeontological Consultant

P. O. Box 48318, Kommetjie, 7976
Tel./Fax (021) 7833023
Cellphone 083 744 6295
jpether@iafrica.com

Prepared at the Request of

ASHA Consulting (Pty) Ltd

40 Brassie Street, Lakeside, 7945
Tel: (021) 788 1025 | 083 272 3225
Email: jayson@asha-consulting.co.za

For

N.J. van Zyl (EAP)

Client

Richwill Diamonds (PTY) LTD.

29 JUNE 2023

EXECUTIVE SUMMARY

1. Site Name

Prospecting Right Application WC10430PR for pitting and drilling (without bulk sampling) on parts of the farm Karoetjies Kop 150, Matzikama Local Municipality, West Coast District, by Richwill Diamonds (Pty) Ltd. (Figure 1).

2. Location

The Farm Karoetjies Kop 150 is approached via Vredendal, Lutzville and Koekenaap and the road to Brand se Baai and the Namakwa Sands mine (Figure 1). At Namakwa Sands mine a gravel road continues north to Salt Pan, *i.e*. the mouth of the Soutrivier, from where a track links to the coastal track crossing the mouth and onto Karoetjies Kop. The site can also be reached via farm roads from Nuwerus or Bitterfontein.

3. Locality Plan

The prospecting application area involves the northern part of Portion 1/150 which is the state-owned seashore strip and the northern seaward part RE/150, extending variably from low-water mark to about 200 to 500 metres inland (Figure 1), depending on headlands and bays, and involving about 412 ha.

4. Proposed Activities

The prospect of the application area on Karoetjies Kop 150 for the presence of diamonds in the marine deposits will be ascertained by industry-established consecutive phases of evaluation activities such as:

- **Phase 1a: Gathering of existing data** *e.g*. published and proprietary data from previous geological exploration and mapping, geophysical surveys) and registering of data in a Geographic Information System and databases for analysis and formulation of initial geological models.
- **Phase 1b: Geophysical Survey**. Ground resistivity measurements will be used to identify potential target areas.
- **Phase 2: Exploration pitting and drilling**. Twenty small prospecting pits (11x8 m) and possibly large diameter auger (LDA) drill holes, but drilling not specified.
- **Phase 3: Bulk Sampling**. If the preliminary results are favourable, prospecting may advance to bulk sampling. Bulk sampling will be done as an extension to the initial prospecting phase in terms of Section 102 and is not included as part of this application.
- **Phase 4: Analytical Desktop Studies**. Each phase of prospecting is followed by interpretation and modelling of all data acquired. These studies will determine if the prospecting is to proceed to bulk sampling, mining or to discontinue activities.

5. Affected Formations

The initial prospecting along the seashore and will affect the modern beach deposits and the raised beach deposits of the **Curlew Strand Fm**., such as the Holocene High raised beach deposits and most likely also the Last Interglacial raised beach. The overlying dune sands of the **Witzand Fm**. will also be disturbed, and possibly the **Local Coastal Aeolianites**. Prospecting inland of the immediate beach will affect the coversands of **the Koekenaap Fm**. Farther inland, as shown by the old prospecting trenches, pitting and drilling will mainly intersect the **Dorbank** and **Hondeklipbaai** formations. Inland sites may also intersect the older aeolianites (**Olifantsrivier** and/or **Graauw Duinen** fms.), as well as marine deposits of the **Avontuur Fm**., beneath well-developed pedocretes.

6. Anticipated Impacts

The intensity/magnitude of a palaeontological impact is determined by the palaeontological sensitivity of the affected geological formation, together with the extent or volume of excavations made into the formation. In all formations any fossil bones and teeth are the main focus of concern, due to their scientific importance. The fossil bone material in the younger aeolianites, *viz*. the Witzand, Koekenaap, Local Coastal Aeolianites and Dorbank formations is a sample of the middle and late Quaternary fauna of the Namaqualand coast and is expected to mainly comprise representatives of the extant fauna, but unexpected species may occur, as well as species which became extinct during the termination of the Last Ice Age. Fossil bone occurrences may also be associated with important archaeological evidence of the early human inhabitants of the coast.

In the Quaternary Curlew Strand Fm. raised beaches the fossil bones of marine mammals (cetaceans, seals) and seabirds are of HIGH palaeontological sensitivity, but are very sparse. In the Pliocene marine Hondeklipbaai and Avontuur formations, and the Olifantsrivier and Graauw Duinen aeolianite formations the fossil bones and teeth are mainly of extinct terrestrial and marine species and are of HIGH palaeontological sensitivity and importance. However, given the limited subsurface disturbance of the proposed prospecting, fossil bones are unlikely to be unearthed due to their sparse distribution and the palaeontological impact of the prospecting for all formations is similarly LOW.

Fossil shells in the Curlew Strand Fm. raised beaches are predominantly extant species and an impact is not anticipated. The Pliocene marine Hondeklipbaai and Avontuur formations are generally of MODERATE sensitivity with respect to well-preserved shell fossil beds. However, intersections of shelly beds are expected to be limited in small excavations and drill holes, due to widespread decalcification. Consequently, a significant impact on the fossil shells in the Pliocene marine formations is not expected.

In the possible event of the deployment of an LDA drill, it is improbable that fossil bones will be intersected at depth due to the relatively small footprint at a few widely separated sites. The fossil material which may be encountered in drill samples from aeolianites is the ambient fossil content of land snails, tortoise bones and mole bones. Fossil marine shell is not well-preserved in most of the marine deposits, but fossil shell could be encountered in some drillholes. Other fossils which are brought up in boreholes include smaller petrified material such as shark and other fish teeth and casts of shells (steinkerns). Petrified mammal bones and loose mammal teeth in the marine gravels are rare and unlikely to be unearthed in a few auger holes.

8. Recommendations

There are no known outcrops of sensitive fossiliferous strata in the Project Area that require protection as NO-GO sites. The palaeontological resources are predominantly subsurface and consequently considerations of fossil potential do not result in preferred sites and the particular locations of drilling sites do not affect this assessment. The relatively modest subsurface disturbance of the proposed prospecting renders the discovery of fossil bones unlikely, but not altogether impossible.

It is recommended that a requirement to be alert for fossil bones and archaeological material which may be uncovered during the prospecting be included in the Environmental Management Programme (EMP) 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 must be instructed to be alert for the occurrence of fossil bones. In the event of such discoveries the provided Fossil Finds Procedure, for incorporation into the Environmental Management Programme for the proposed prospecting, must be followed.

In the possible event of the deployment of an LDA drill, fossil material brought up by the auger drill must be collected and placed in labelled bags with information on the date, position, depth and geological context, and images of the fossil must be recorded and emailed to the standby palaeontologist who will preliminarily evaluate the find.

The Project Geologist is welcome to contact the writer by email with images for preliminary opinions about potential finds and stratigraphy, at no initial cost.

---oooOOOooo---

CONTENTS

DECLARATION OF INDEPENDENCE

PALAEONTOLOGICAL IMPACT ASSESSMENT (Desktop Study)

PROPOSED DIAMOND PROSPECTING ON THE FARM KAROETJIES KOP 150

PART OF PORTION 1/150 & SEAWARD PART OF RE/150

NAMAQUALAND, MATZIKAMA LOCAL MUNICIPALITY, WEST COAST DISTRICT

VREDENDAL MAGISTERIAL DISTRICT, WESTERN CAPE

WC10430PR

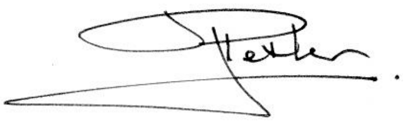
Terms of Reference

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 development.

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 June 2023

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) (~350 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

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.
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 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.
Colluvium	Hillwash deposits formed by gravity transport downhill. Includes soil creep, sheetwash, small-scale rainfall rivulets and gullying, slumping and sliding processes that move and deposit material towards the foot of the slopes.
Coversands	Aeolian blanket deposits of sandsheets and small dunes.
Fluvial deposits	Sedimentary deposits consisting of material transported by, suspended in and laid down by a river or stream.
MIS - Marine Isotope Stages	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.
OSL - Optically stimulated luminescence	One of the radiation exposure dating methods based on the measurement of trapped electronic charges that accumulate in crystalline materials as a result of low-level natural radioactivity from U, Th and K. In OSL dating of aeolian quartz and feldspar sand grains, the trapped charges are zeroed by exposure to daylight at the time of deposition. Once buried, the charges accumulate and the total radiation exposure (total dose) received by the sample is estimated by laboratory measurements.
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.
Pedocrete	A cemented soil formed by pedogenic processes, such as calcrete, silcrete and laterite.
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.*).
Rhizolith	Fossil root. Most commonly formed by pedogenic carbonate deposition around the root and developed in palaeosols.

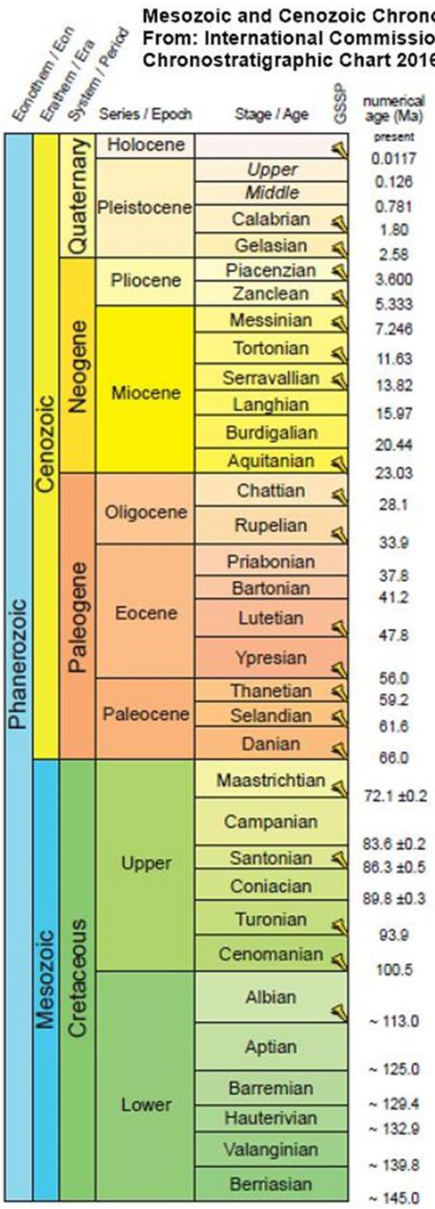
GEOLOGICAL TIME SCALE TERMS

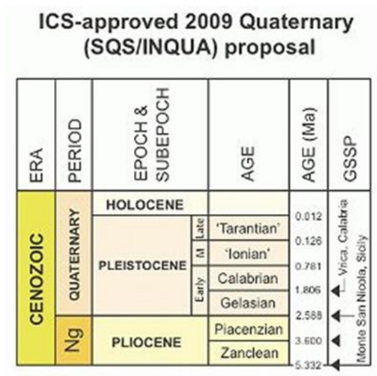
For more detail see www.stratigraphy.org.

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: Million 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.

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





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, Richwill Diamonds (Pty) Ltd., proposes to prospect for diamonds on parts of the farm Karoetjies Kop 150 in southern Namaqualand in the northwestern Western Cape Province (Figure 1). N.J. van Zyl is the EAP consultant undertaking the Environmental Impact Assessment (EIA) process and has appointed ASHA Consulting to undertake the Heritage Impact Assessment (HIA) for the application. This Palaeontological Impact Assessment (PIA) report forms part of the HIA and its brief is to inform about the palaeontological sensitivity of the application area and the probability of palaeontological materials (fossils) being disturbed or destroyed in the process of the proposed prospecting.

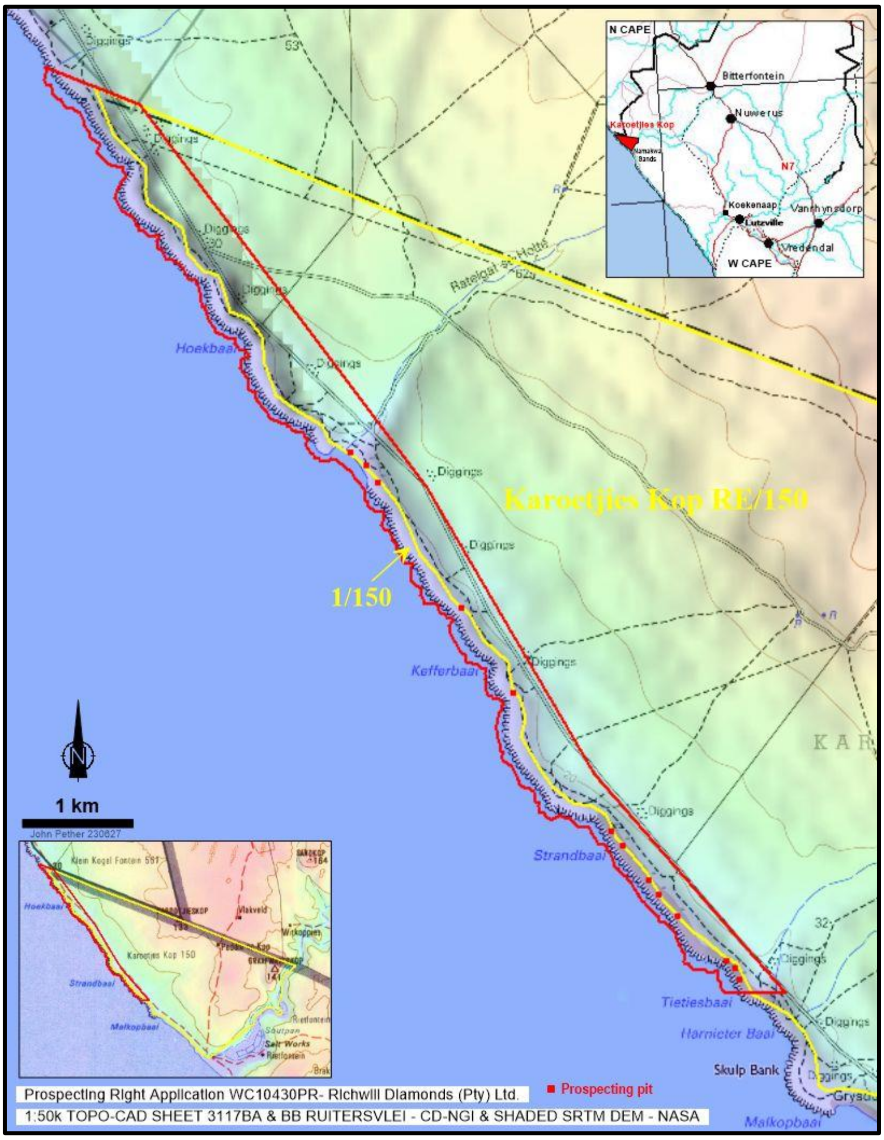


Figure 1. Location of Karoetjies Kop 150 and the proposed prospecting application area.

2 LOCATION

The Farm Karoetjies Kop 150 occupies the utmost northwestern corner of the Western Cape Province in the shape of a triangular property of 5461 ha bordered by the coast and the valley of the Soutrivier (Figure 1). It is approached via Vredendal, Lutzville and past Koekenaap on the road to Nuwerus, along which the tar road continues to Brand se Baai and the Namakwa Sands mine. At Namakwa Sands mine a gravel road continues north to Salt Pan, *i.e*. the mouth of the Soutrivier, from where a track links to the coastal track crossing the mouth and onto Karoetjies Kop. The site can also be reached via farm roads from Nuwerus or Bitterfontein.

The prospecting application area involves the northern part of Portion 1/150 which is the state-owned seashore strip and the northern seaward part RE/150, extending variably from low-water mark to about 200 to 500 metres inland (Figure 1), depending on headlands and bays, and involving about 412 ha.

3 PROPOSED ACTIVITIES

The prospect of the application area on Karoetjies Kop 150 for the presence of diamonds in the marine deposits will be ascertained by industry-established consecutive phases of evaluation activities such as:

PHASE 1a – Desktop Study (Literature Study, Imagery Analysis, Geological Mapping)

This will comprise a desktop review of all information and data gathered by previous exploration in the surrounding area, as well as review of aerial photography and satellite imagery to aid with structural and geological mapping of the prospecting area and surrounds.

PHASE 1b: Geophysical Survey

Ground resistivity measurements will be used to identify potential target areas. Any anomalous features such as due to saline groundwater pooled in bedrock lows will be mapped in detail. The final purpose of Phase 1 will be to estimate bedrock elevation contours and potential diamond traps.

PHASE 2 – Preliminary Evaluation

This phase will determine a ballpark estimate of grade and size and thus the potential *in-situ* value of the deposit by sampling. Due to the relatively shallow overburden prospecting pits will be employed in areas where bedrock elevation is less than 5 metres.

Prospecting Pits

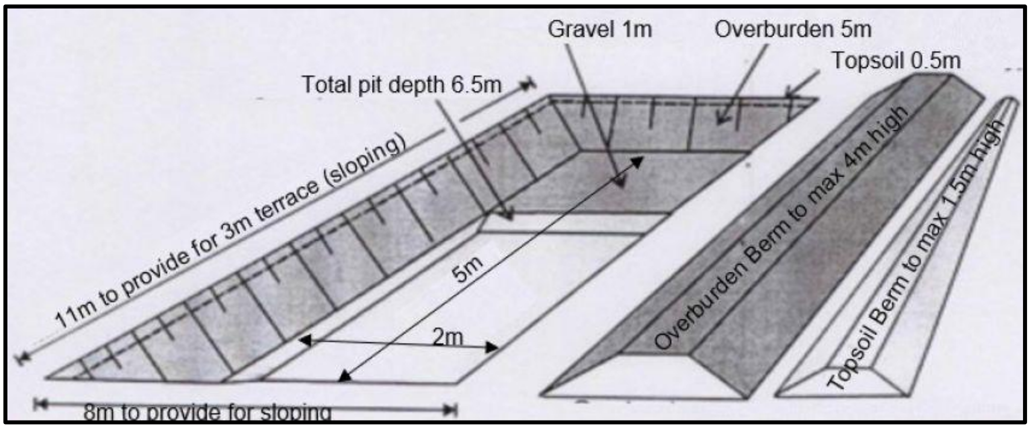


Figure 2. Typical prospecting pit (from Prospecting Work Programme.

The footprint of a prospecting pit is about 11 by 8 m and up to 6.5 m deep Figure 2). It is anticipated that 20 pits will be excavated. Some 13 preliminary sites are indicated in Figures 1 & 7).

Exploration Drilling

Exploration drilling, such as by large diameter auger (LDA), is not specified in the Prospecting Work Programme, but is presumably an option for the prospecting.

PHASE 3 - Bulk Sampling

If the preliminary results are favourable, prospecting may advance to the bulk sampling or trial mining phase to establish orebody diamond grades and as a Measured Resource. If this project moves on to evaluation-phase bulk sampling it will be done as an extension to the initial prospecting phase in terms of Section 102 and is not included as part of this application.

PHASE 4 - Analytical Desktop Studies

The project geologist continuously monitors the program and consolidates and interprets the data and amends the program depending on the results. Each phase of prospecting is followed by interpretation and modelling of all data acquired. A GIS based database will be constructed capturing all exploration data. These studies will determine the manner in which the work program is to proceed in terms of activity, quantity, resources, expenditure and duration, such as to proceed to mining or discontinue activities.

PHASE 5 – Application for a Mining Right or Closure

Mining Right or Closure Certification.

4 APPROACH AND 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 geological formation, which informs the Intensity/Magnitude/Severity rating in a Palaeontological Impact Assessment. The criteria for rating are in Appendix 1. The palaeontological sensitivity, together with the extent or volume of excavations into the geological formation, determines the palaeontological impact.

Note that different types of fossils occur in a single formation which differ in their scientific/palaeontological importance. The fossil bones and teeth of vertebrate animals are always of high palaeontological sensitivity and scientific importance and generally occur quite sparsely in deposits. For example, in aeolian formations the scarce fossil bones are rated HIGH, while fossil shells of land snails and the trace fossils made by termites are commonly present and are of LOW sensitivity.

4.1 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. Relevant aspects of the regional geology are described. References are cited in the normal manner and are included in the References section. The relevant 1:250 000 Council for Geoscience (CGS) geological map is Sheet 3017 GARIES and Explanation (De Beer, 2010). The annotated pertinent part of the map is presented in Figure 3.

4.2 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 nearby the Project Area. Scientifically important fossil material is expected to be very sparsely scattered in these deposits and much depends on spotting this material as it is uncovered during digging *i.e.* by monitoring excavations. A limitation on predictive capacity exists in that it is not possible to predict the buried fossil content of an area or formation other than in such general terms.

5 THE REGIONAL GEOLOGY

5.1 THE BEDROCK

The older bedrock of the coastal plain in this area is comprised of various hard rocks of the **Namaqualand Metamorphic Province** including gneisses, quartzites and schist metasediments of the **Kamiesberg Group** and intrusive gneisses of the **Little Namaqualand Suite** and the granites **Spektakel Suite**. These are old, unfossiliferous rocks ranging in age from about 1600 to ~1000 million years ago (million years ago = Ma). The younger **Jakkalshoek Granite** of the Spektakel Suite (Ŋjk/purple, ~1080 Ma) is exposed at the seashore along part of Karoetjies Kop (Figure 3).

Outcrops of metasediments of the **Gariep Supergroup**, **Gifberg Group**, occur along the southern shore of Karoetjies Kop and include the conglomerates and quartzites of the **Karoetjies Kop Formation** (Nkr/green) (being the type/example area) and the marbles and limestones of the **Widouw Formation** (Nwi/pale blue) (Figure 3). These metasediments are of Late Proterozoic age (Cryogenian – Ediacaran) and were deposited between ~800 to ~600 Ma. The first basic multicellular animals were evolving around this time, but such fossils are unlikely to have been preserved, due to the metamorphism subsequently undergone by these old sediments.

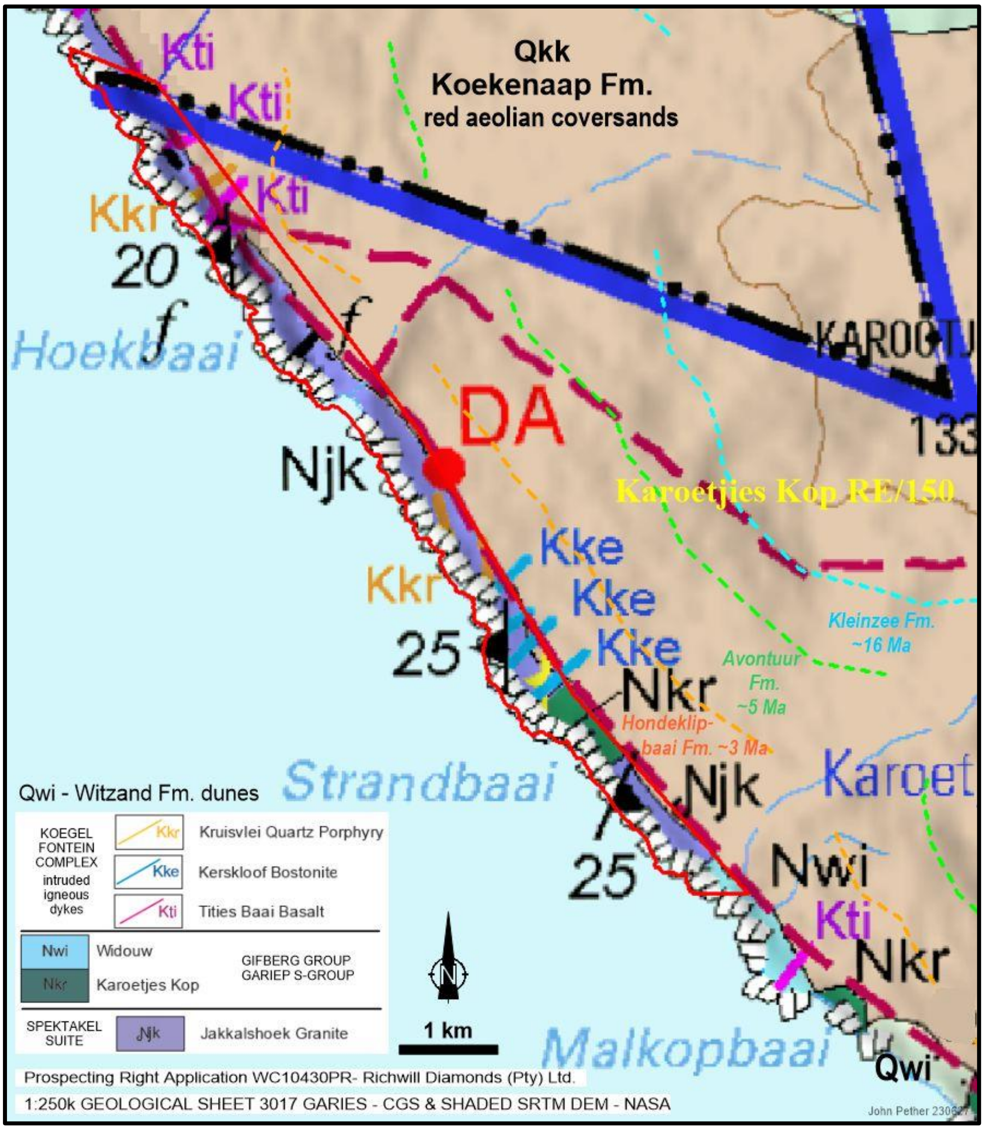


Figure 3. Surface geology of the Project Area and surrounds. The approximate subsurface extents of the underlying marine formations are also indicated.

Much later, during the early Cretaceous ~145 to ~130 Ma, rifting of the supercontinent of Gondwana and the opening of the South Atlantic Ocean between southern African and South America was under way. The continental breakup was accompanied by widespread volcanic activity along the rifting margin . The volcanoes have been eroded away and are now represented by “feeder” dolerite dykes around the coasts. In southern Namaqualand in particular, the rifting volcanic activity had more complex counterparts at depth involving the intrusion of numerous dykes, plugs and granites of varied compositions. This **Koegel Fontein Complex** (De Beer, 2010) consists principally of the Rietpoort Granite, dated at ~133 Ma and which is exposed northeast of the study area. The Koegel Fontein Complex is represented along the Karoetjies Kop shoreline by black dykes of the Tities Baai Basalt (Kti), pale brown dykes of the Kersklo of Bostonite (Kke) and orange dykes of the Kruisvlei Quartz Porphyry (Kkr) (Figure 3) (De Beer 2010). These igneous intrusions are not fossiliferous.

This part of the Namaqualand coast has had a unique post-Gondwana geological history and its complexities are of considerable scientific interest. Many of the various outcrops and their features, that informed the unravelling of their relationships by Coenie de Beer and his predecessors, are worthy sites of geoheritage and geotourism.

Between the rocky coast and the bedrock hills of the “Hardeveld” inland is the sand-covered “Sandveld” made up of much younger buried and surface deposits known collectively as the **West Coast Group** (Table 1).

5.2 The West Coast Group

The **West Coast Group** is the name proposed to accommodate 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). The stratigraphic terminology proposed by Pether *et al*. (2000), Roberts *et al*. (2006) and De Beer (2010) is mainly used, but is elaborated and modified according to the author’s own observations.

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.
Unnamed coastal fms.	Aeolianites, limited pedogenesis, weak pedocrete	earlier late Quat., 125-80 ka.
Curlew Strand, MIS 5e, LIG.	**Marine, 4-6 m Package.**	**earliest late Quat., ~125 ka.**
Fossil Heuweltjiesveld palaeosurface on Olifantsrivier & Dorbank fms.		
Unnamed “Dorbank” fms.	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.**
Unnamed	Aeolianites, weathered.	later Miocene (14-5 Ma)
Kleinzee	**Marine, 90 m Package, MMCO.**	**mid Miocene, ~16 Ma.**
Unnamed	Aeolianites, leached. Faulting.	Oligocene
Koingnaas	Fluvial, kaolinized gravels, sands, plant fossils.	late Eocene, ~44-34 Ma
De Toren	Silcreted colluvial palaeosurfaces 200-400 m asl.	Paleocene - Eocene
MMCO – Mid Miocene Climatic Optimum. EPWP – Early Pliocene Warm Period. LPWP – Late Pliocene Warm Period. MIS – Marine Isotope Stage.		

5.2.1 The Early Coastal Plain

Silcreted angular gravels and sands that overlie deeply-weathered bedrock and which occur as mesa-like features on high ground 100-400 m asl. are mapped as the **De Toren Formation** on the Garies geological sheet (De Beer, 2010). These silcretes mark an older palaeosurface of the coastal plain and represent talus and colluvial deposits. The age of these palaeosurfaces is uncertain, but is broadly of early Cenozoic age. Silcrete formed in weathered bedrock is a feature of the valley flanks of the Soutrivier, suggesting that the valley is of considerable age. Many more rivers traversed the ancient coastal plain and their buried channels (palaeo-channels) and deposits have been discovered during diamond exploration.

The **Koingnaas Formation** (De Beer, 2010), infills the ancient river channels buried between the main, now ephemeral Namaqualand rivers. These deposits have also been kaolinized, disguising their presence. Silcrete has also formed in places within the waterlogged channels. The "white-clay" channel sediments consist of subangular quartz conglomerates, locally rich in diamonds, overlain by beds of clayey sand, clay and carbonaceous material containing plant fossils (Molyneux, in Rogers *et al*., 1990). The fossil pollen 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 identified as tropical African mahogany has been found. Importantly, the fossil pollen includes pollen of the earliest Asteraceae (daisies).

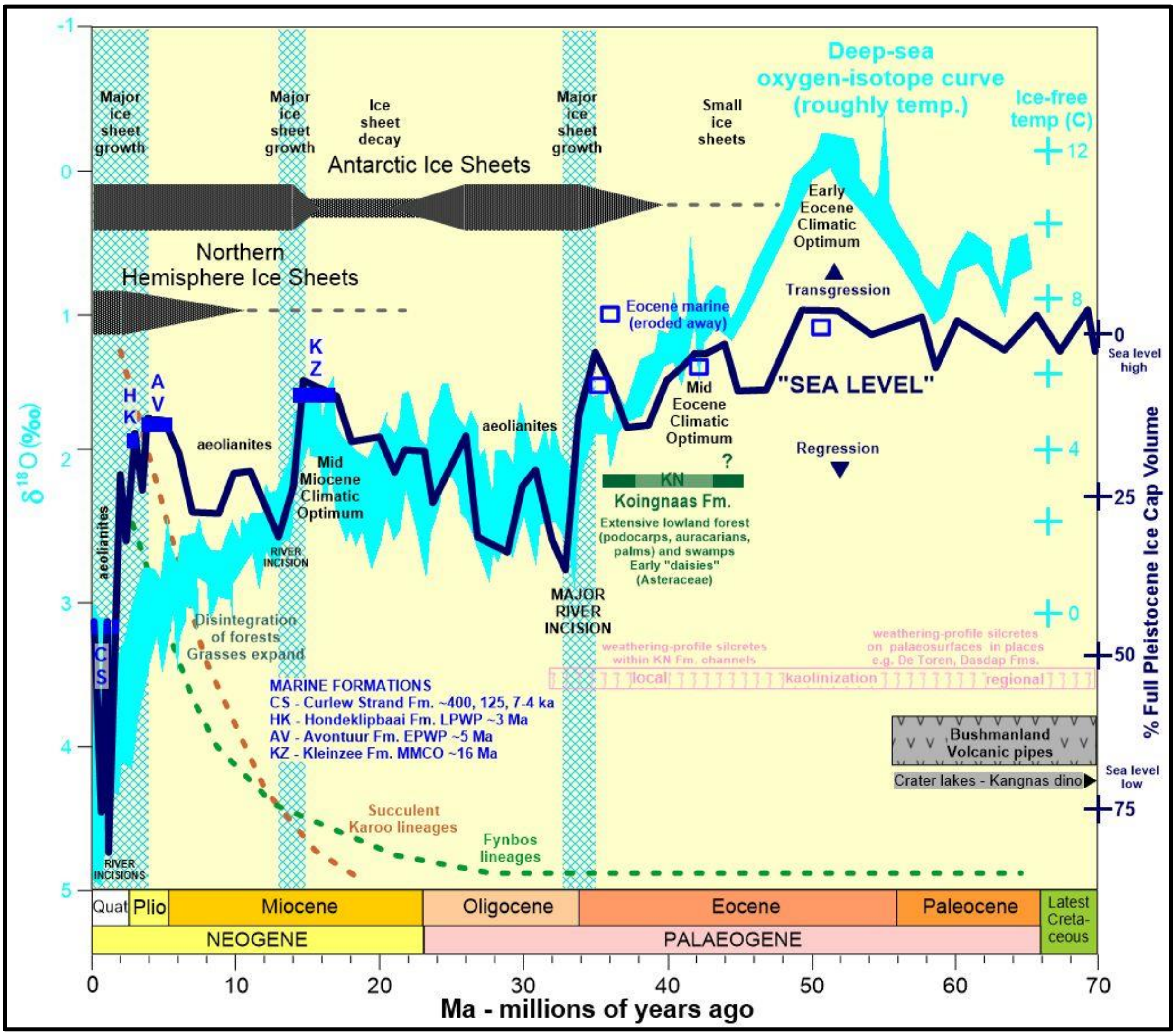


Figure 4. The Cenozoic Era (66 Ma to present) showing the context of formations of the West Coast Group with respect to global sea-level history, palaeoclimate proxies and aspects of regional vegetation history.

Cyan curve - history of deep-ocean temperatures, adapted from Zachos *et al*. (2008). **Dark 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).

The age of the Koingnaas Formation is most likely late Eocene, between 44-34 Ma (Figure 4). 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 tropical wooded Namaqualand coast more nearly resembled the forests of the south coast.

5.2.2 The Fossiliferous Marine Deposits

At times during the Cretaceous and Palaeogene Periods (66-34 Ma) the higher part of the coastal plain was occupied by the sea, but marine deposits from these times have been eroded away, or remain as undiscovered residual patches beneath the thick cover.

During the Neogene Period the outer part of the coastal plain below ~100 m asl. was inundated by the sea during periods of global warmth when melting of the Antarctic ice cap raised sea level. The oldest marine formation is the **Kleinzee Formation** which occupies the inner, high part of the coastal bevel and extends seawards from ~90 m asl. (also called the 90 m Package). It was deposited during the decline from the high sea level of the warm **Mid-Miocene Climatic Optimum** ~16 Ma (Figure 4). 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 5). 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 5). 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. 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.

Close to the seaside, the Hondeklipbaai Formation is eroded and overlain by the younger, Quaternary "raised beaches" that extend from about 12-15 m asl. (Figures 5 & 6). The name **Curlew Strand Formation** has been proposed for this composite of raised beaches, equivalent to the Velddrif Formation of the SW Cape Coast. Three successive raised beaches are recognized at 8-12, 4-6 and 2-3 m asl., with ages of ~400 ka (ka = thousand years ago), ~125 ka and 7-4 ka, respectively. The fossil shells in these raised beaches are predominantly the cold-water fauna of modern times.

It is important to note that the formations of the marine **Alexander Bay Subgroup** mentioned above consist of shallow-marine sand and gravel deposits and are not geomorphological "marine terraces" (see Appendix 3).

5.2.3 The Aeolian Formations

A variety of terrestrial deposits also make up the coastal plain of Namaqualand. For the most part these are extensive aeolian dune and sandsheet deposits that overlie the eroded tops of the marine sequences. More locally there are colluvial (sheetwash) and ephemeral stream deposits associated with nearby hillslopes. Formed within the upper parts of the marine and terrestrial sequences are pedocretes and palaeosols of a variety of types, compositions and degrees of development. A glance at the satellite images of the coast show that the pale swathes of modern and Holocene aeolian activity occur in specific areas, linked to antecedent topography, sea-level oscillations, locations of sandy beaches and fluvial sediment inputs. Similarly, the deeper-time aeolian record is expected to comprise buried dune fields, dune plumes and sand sheets that accumulated at different times in various areas of the coastal plain.

Later Miocene Aeolianites

The mid-Miocene, marine Kleinzee Formation has been extensively eroded and has been largely reworked into aeolian sands. The later-Miocene aeolianites occupy the higher part of the coastal notch where they overlie residuals of the Kleinzee Formation and extend into the hinterland. These old aeolian deposits are quite altered by pedogenic and groundwater processes. They may be basically pale, leached units with mottling and thus superficially similar to underlying Miocene marine deposits, or extensively pedocreted, appearing as evolved red/brown, silicified dorbank. The occurrence of reworked 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 indicates the pre-existence of terrestrial deposits of this later Miocene age range (Figure 4).

The Graauw Duinen Formation

This name has been proposed to accommodate the aeolianites as exemplified in the Namakwa Sands excavations on Graauw Duinen 152 (Roberts *et al*., 2006; De Beer, 2010) where the aeolianites are excellently exposed in coast-normal mining faces. Based on personal observations of the aeolianites exposed at Graauw Duinen 152 (Namakwa Sands) there are actually three 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 5). 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 earliest Quaternary age. 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 (Figure 5).

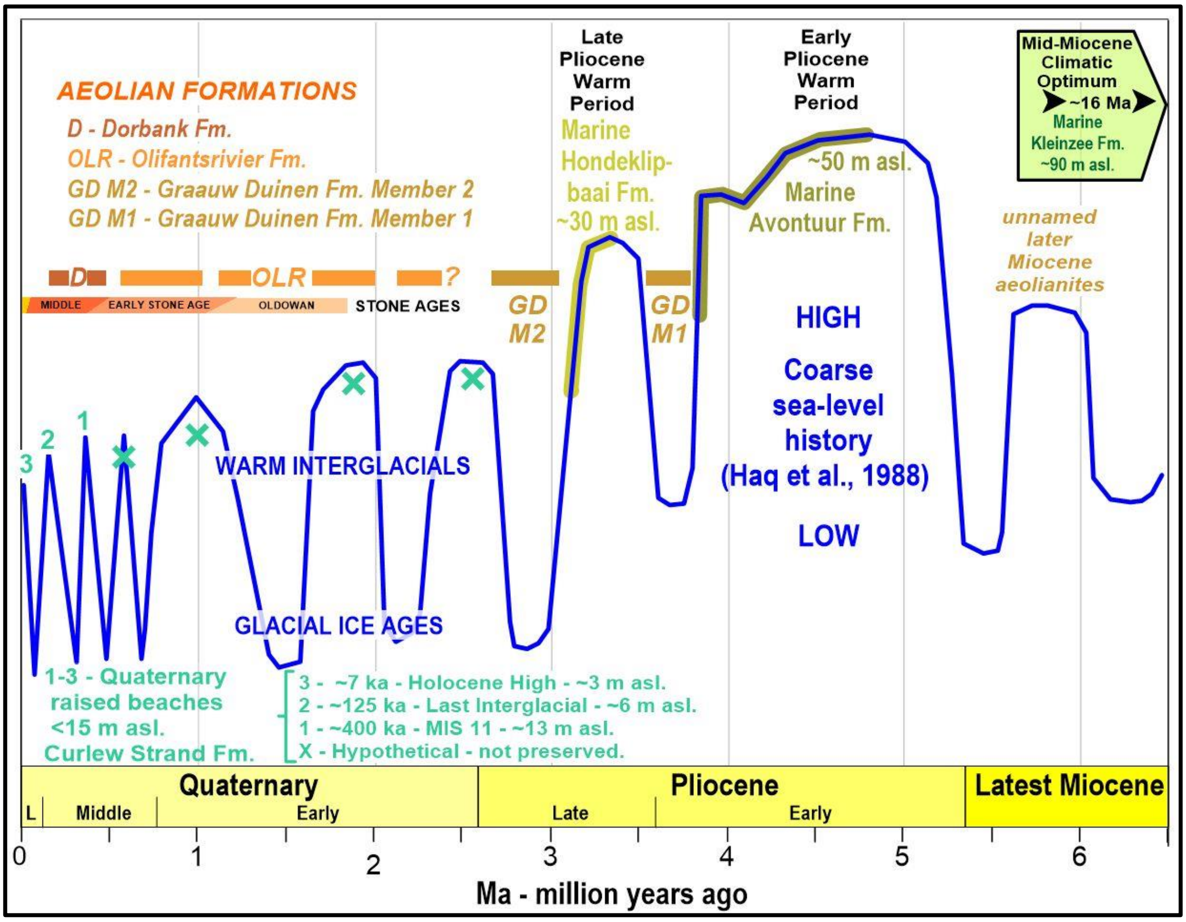


Figure 5. Context of latest Miocene, Pliocene and Quaternary marine and aeolian formations correlated with coarse-scale sea-level history based on major margin unconformities.

The Olifantsrivier Formation

This formation is a typical, variously reddened aeolianite with interbedded palaeosols, pedocretes, abundant root casts and termite burrows (pers. obs.), as exemplified in cliff exposures up to 30 m thick north of the Olifants River mouth and in the Namakwa Sands mine pit. Isolated cobble manuports and ESA/Acheulean handaxes and cleavers are found within the formation. Middle Stone Age (MSA) artefacts are also reported, but these occur on the eroded surfaces and slopes of the formation. The ESA artefacts indicate an age range from ~1.4 Ma to ~350 ka (Figure 5). Fossils eroding out of a channel fill within the aeolianite succession on Geelwal Karoo 262 include *Numidocapra crassicornis*, a bovid hitherto found only in North Africa and Ethiopia where the age range for this fossil species is 2.5-1.7 Ma. Also found were teeth of *Dinofelis barlowi*, an extinct sabre-toothed felid, indicating an age range of 2.5-1.9 Ma. (Stynder & Reed, 2015). These finds suggest that the lower part of the Olifantsrivier Formation is older than ~1.7 Ma and extends from the earliest Quaternary (Figure 5), while the upper part which includes ESA material is latest early Quaternary/earliest middle Quaternary (Figure 5). This broad age range constraint is reflected by the several included member units separated by pedocretes.

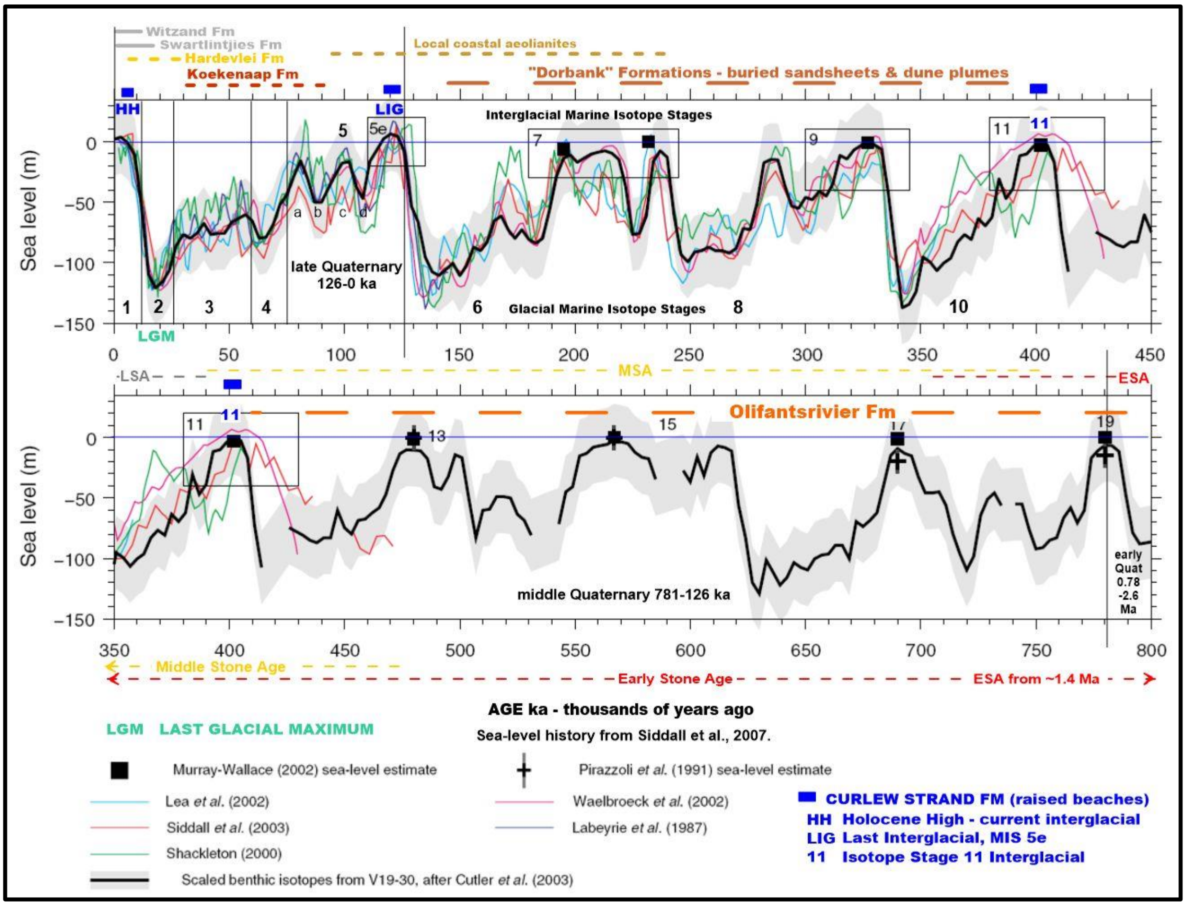


Figure 6. Sea-level history (from Siddall *et al*., 2007) and the age ranges of middle and late Quaternary formations of Namaqualand.

The "Panvlei Formation" Surfaces

Proposed by De Beer (2010), the Panvlei Formation "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 compact surface of the "dorbank" aeolian sands with pedogenic clay. Clearly such a broad definition, based on surface outcrop, is a mapping practicality when it is not possible to determine the stratigraphic position of the underlying deposits, which could be 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 pedocreted or semi-lithified tops of the preceding formations mentioned above, most typically the Olifantsrivier Fm. capping calcrete. The vegetation of these areas is usually Namaqualand Heuweltjie Strandveld. Panvlei-type surfaces are also depicted inland 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.

The Dorbank Formation

There are unnamed units that post-date the capping pedocrete of the Olifantsrivier Fm. and precede the uppermost, unconsolidated formations described below. For example, thick "dorbank" comprised of up to several metres of reddened and semi-lithified, decalcified, medium and coarse sands are typically exposed in excavations somewhat inland of the coast, overlying the eroded surfaces on Miocene and Pliocene marine deposits or older pedocreted aeolianites. This Dorbank Formation is typically a stack of successive sand sheets forming beds, 0.5 to ~1 m thick, with slightly differing hues of the neoformed pedogenic clays. The dorbank is quite hard and incipiently to variously cemented, but notably, this formation lacks the development of distinct, laterally continuous, pale pedocrete horizons, other marked, post-depositional features and generally also lacks an evolved pedocrete capping. The Dorbank Formation is widespread along the Namaqualand coast where it occupies a spatio-temporal context as the youngest consolidated aeolianite beneath weakly-compacted to loose surface sands. Notably, MSA artefacts occur within its upper portion and on its top surface, these suggesting that the age is in the later part of the middle Quaternary, younger than about 400 ka (Figure 6). Dating of the overlying Koekenaap Fm. surficial sands, 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).

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.

The Koekenaap Formation

Overlying the hard surface of the dorbank are compact, but unconsolidated, red sands, the "Red Aeolian Sand" or RAS that is exploited at Namakwa Sands mine, proposed as the Koekenaap Fm. (Roberts *et al*., 2006; De Beer, 2010). The red sands of the Koekenaap Fm. occupy much of the surface of the Namaqualand coastal plain (Figure 7) and underlie the following formations described below. Where thicker, subunits can be distinguished by subtle variations in hue and grain adhesion. The red sands are underlain by scatters of MSA material on top of the palaeosurface formed on the "Dorbank" or older aeolian formations. Preliminary results of Optically-Stimulated-Luminescence (OSL) dating of reddened coversands (Chase, 2006; Chase & Thomas, 2006, 2007) indicate late Quaternary ages between ~80 ka and ~30 ka and are presumed to reflect depositional ages of the red aeolian sands (Figure 6). The typical vegetation type is Namaqualand Heuweltjie Strandveld.

The Hardevlei Formation

Comprised of unconsolidated, pale-red to pale-yellow coversand deposits (sand sheets and small dunes) that are younger that the RAS of the Koekenaap Formation (De Beer, 2010). This formation encompasses wide swathes of pale sand blown northwards from both river and shoreline sources, as well as patches inland that reflect the reworking of older sands of the Koekenaap Fm. The

Hardevlei Fm. is also mined at Namakwa Sands. Aerial images show the complex morphology of these low, relict dunes which in places exhibit a reticulate pattern of linear dunes linked by transverse, barchanoid elements. The complex pattern reflects a polyphase history and a varying wind regime. The OSL dates from the yellowish, inland reticulate dunes (Chase & Thomas, 2006, 2007) are generally less than ~20 ka and are probably representative of the aeolian activity/deposition of the Hardevlei Formation (Figure 6). The associated veld types are Namaqualand Sand Fynbos and Inland Duneveld.

The Swartlintjies Formation

The Swartlintjies Formation is proposed for the large, pale plumes of semi-stabilized parabolic dunes that extend from the beaches north of the main rivers (Roberts *et al*., 2006; De Beer, 2010). It has been suggested that these dune plumes originated during lower ice-age sea levels (Figure 6, ~20 ka) and were blown from the lower reaches of the rivers that then extended across the inner shelf (Tankard & Rogers, 1978). The dune plumes are clearly comprised of superimposed generations of smaller plumes and sand mobility in the plumes is currently ongoing in places. The typical vegetation is Namaqualand Coastal Duneveld.

The Witzand Formation

This formation accommodates sand and shell fragments blown from sandy beaches mainly during the Holocene, in the form of partly-vegetated dune cordons backing the beach and the attached small dune plumes transgressing inland. As the major dune plumes are separated as the Swartlintjies Fm., the Witzand Fm. entails only the smaller dune cordons and plumes adjacent to the coast. These include active dunes and the more-vegetated, pale-grey dunes that are the origin of the name “Graauw Duinen” for some of the properties along the coast where these dunes occur. . The typical vegetation is Namaqualand Seashore Vegetation. The local coastal occurrences of the Witzand Fm. are the modern analogue for the older, buried patches of the Local Coastal Aeolianites.

6 THE LOCAL GEOLOGY

From the shore elevations rise quite rapidly to 20-25 m asl. From the south the inland boundary of the application area approximately follows the coastal road and rises gradually from ~20 m asl. to ~25 m asl. towards the Ratelgat se Holte drainage (Figure 7). Just north of there the boundary is farther inland, with elevations rising to~30 m asl., probably as a reflection of buried aeolianites blown from the sandy beach associated with the Ratelgat se Holte mouth, and/or higher bedrock. The latter drainage is likely associated with an ancient palaeochannel. Father north the inland boundary elevations decline again to about 20 m asl.

The approximate subsurface extents of the successive marine formations are shown in Figures 3 and 7, but considerable erosion, mainly by wind and also locally along drainages, has often reduced their extents and thickness. Old prospecting trenches have intersected the late Pliocene Hondeklipbaai Fm. which is extensively decalcified (Figure 8), but fossil shells are preserved in places as is evident in spoil from some drill holes and in some bulk-sample trenches (Figure 9). The extinct “white mussel” *Donax rogersi*, which is typical of the Hondeklipbaai Fm., is abundant, along with oyster shells. Due to the limited inland extent of the application area it is mainly underlain by the Hondeklipbaai Fm. Thin patches of both the Avontuur Fm. and the Miocene Kleinzee Fm. may occur in bedrock depressions below the Hondeklipbaai Fm.

The Koekenaap Fm. coversands which mantle most of the area of Karoetjies Kop (Figure 7). The subsurface, older aeolian formations with calcretes, typical of the coastal plain to the south, *viz*. the Graauw Duinen and Olifantsrivier fms., may occur in places inland. However, the old collapsed prospecting trenches close to the coast expose only the Dorbank Fm. (Figure 8), beneath of which is the Hondeklipbaai Fm. At the coast the Hondeklipbaai and Dorbank formations are truncated by the Quaternary raised beaches of the Curlew Strand Fm. (Figure 10) which may overlain in places by units of the Local Coastal Aeolianites, the latter usually hidden beneath foredunes of the Witzand Fm. The more substantial occurrences of the raised beach deposits have been targeted by uncontrolled mining in the past and are much disturbed in places.

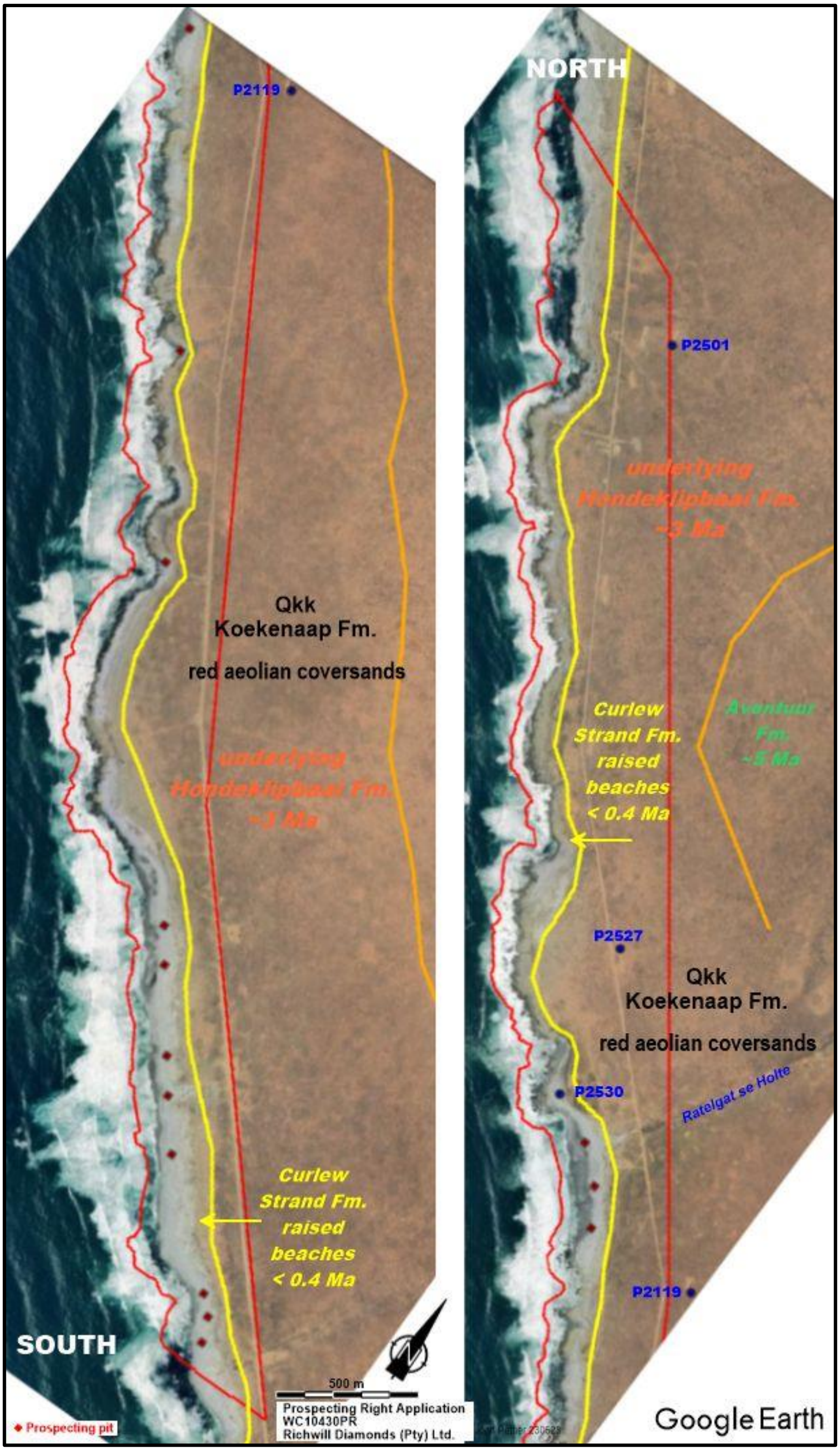


Figure 7. Aerial aspect of the surficial sand cover and the approximate maximum palaeo-shoreline of the Hondeklipbaai Fm. Blue points are image locations by J. Orton.

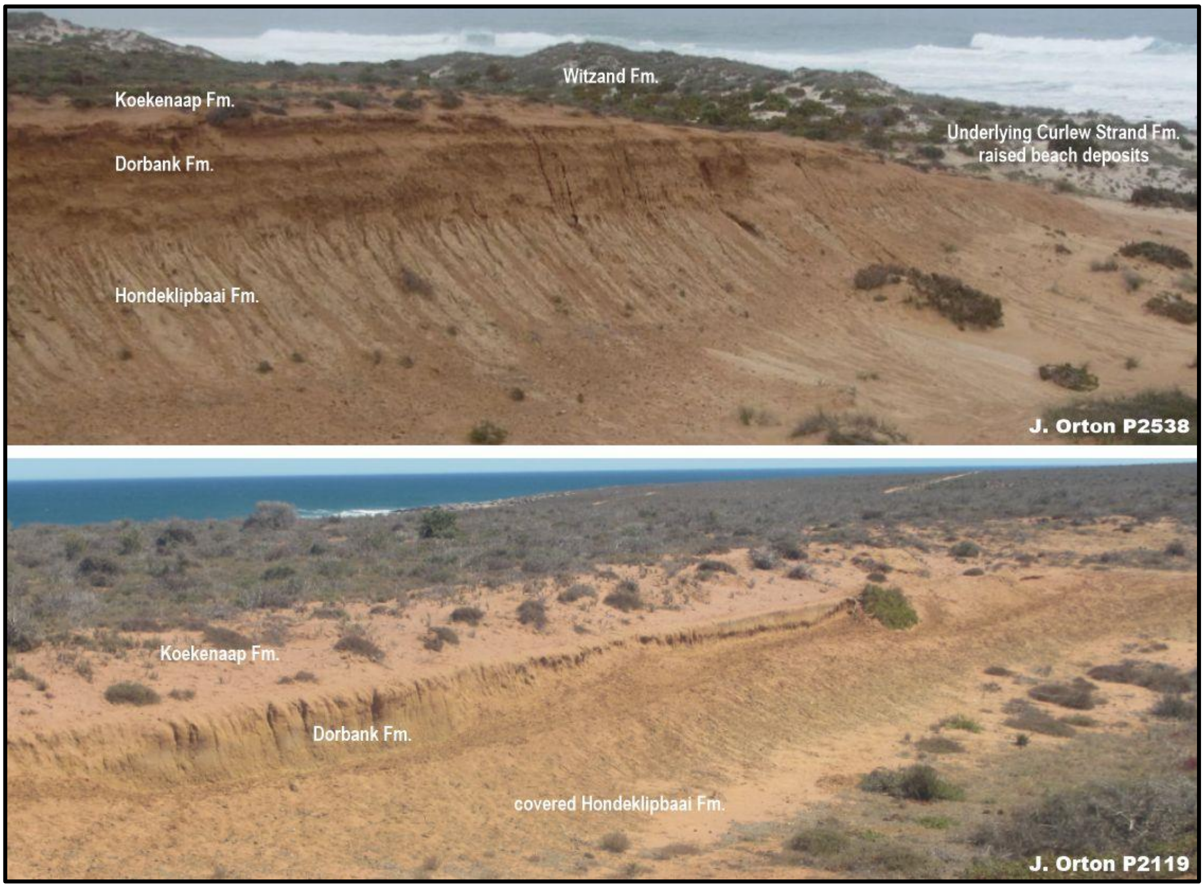


Figure 8. Old prospecting trenches. Image P2538 is in the south part of Karoetjies Kop.

7 AFFECTED FORMATIONS

This application area covers portions of the Lower and Middle Terrace*, i.e*. the Curlew Strand and Hondeklipbaai formations (SAD terraces, Appendix 3). The initial prospecting will take place along the seashore and may later extend to sites inland in the Prospecting Right Area.

The initial prospecting along the seashore and will affect the modern beach deposits and the raised beach deposits of the **Curlew Strand Fm**., such as the Holocene High raised beach deposits and most likely also the Last Interglacial raised beach. The overlying dune sands of the **Witzand Fm**. will also be disturbed. Note that the coarse-scale 1:250 000 geological map (Figure 3) only depicts the large areas occupied by the Witzand Fm.

The prospecting pitting and possible drilling involves the making of tracks for vehicles access to sites and the disturbance at the sites, both of a surficial nature affecting the coversands of **the Koekenaap Fm**. Farther inland, as shown by the old prospecting trenches, pitting and drilling will mainly intersect the **Dorbank** and **Hondeklipbaai** formations. Inland sites may also intersect the older aeolianites (**Olifantsrivier** and/or **Graauw Duinen** fms.), as well as marine deposits of the **Avontuur Fm**., beneath well-developed pedocretes. There is some small possibility that buried palaeochannel remnants with infills of the kaolinized and locally silcreted **Koingnaas Fm**. could occur and be intersected by the drilling. The palaeochannels are usually associated with bays and sandy beaches at the coast.

The schematic stratigraphy illustrated in Figure 10 is but one permutation of the formations which may occur and represents most of the formations. However, usually there are “missing” formations at any particular site. For instance, as seen in old trenches, the Olifantsrivier Fm. may be absent, with the Hondeklipbaai Fm. overlain by the Dorbank Fm. The MIS 11 raised beach is preferentially preserved where the bedrock gradient is low and the deposits extend far inland. On steeper bedrock it may be eroded away and absent, with the LIG raised beach directly abutting the cliffed Hondeklipbaai and Dorbank fms. The Local Coastal Aeolianites are only present in places

Figure 9. Old prospecting trench exposing shoreface deposits of the Hondeklipbaai Fm., decalcified and cemented by groundwater. Shells are preserved higher in the section. An interval of reworked sand is overlain by a young Dorbank Fm. sandsheet.

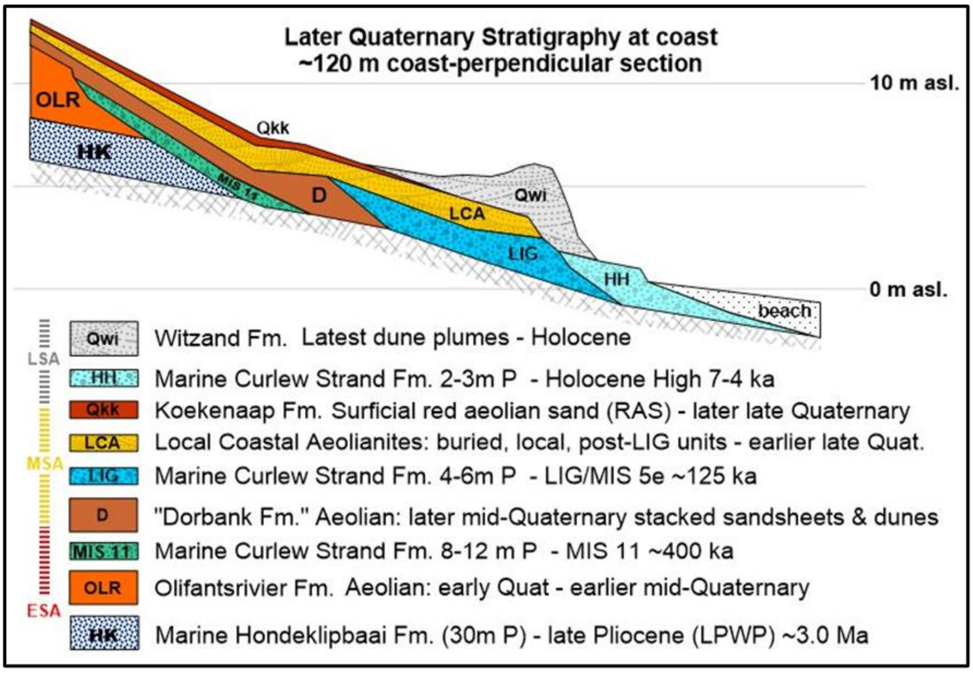


Figure 10. Schematic geological section of one permutation of the stratigraphy at the coast.

Sandy beaches situated above exhumed palaeochannels with no bedrock outcrop may be underlain by the seawards extentions of the Curlew Strand Fm. and/or consolidated aeolianites, often with calcrete cappings. In places the local drainages have delivered alluvial deposits to the shoreline, which occur interbedded between the marine and aeolian deposits. In some instances the Koingnaas Fm. kaolinitic quartz gravels in a major palaeochannel have not been eroded away and occur at depth beneath the beaches.

8 ANTICPATED PALAEONTOLOGICAL IMPACT OF THE PROSPECTING

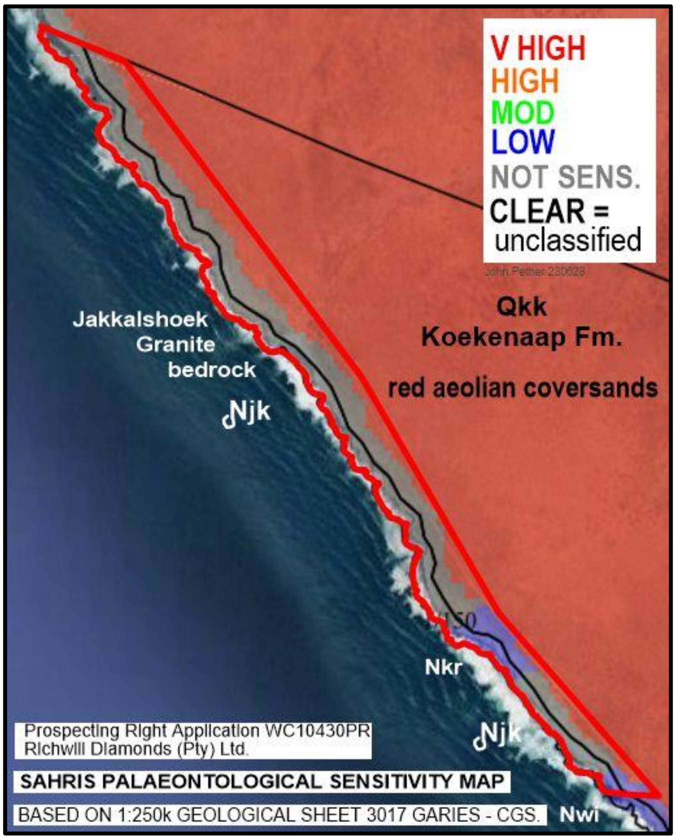


Figure 11. Palaeontological Sensitivity of the Project Area. Refer to Figure 3.

According to the SAHRIS Palaeontological Sensitivity map (Figure 11) it appears that just the inland part of the application area is rated VERY HIGH/RED. However, at the small scale of the geological map (Figure 3) the extents of the “Not sensitive” or “Low” bedrock are a depiction only and not an accurate mapping of the actual bedrock outcrop which is restricted to the seashore.

In open-coast settings the fossil shells in the **Curlew Strand Formation** Quaternary raised beaches are the mainly of 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.

The Witzand Formation has a Moderate sensitivity rating. Fossil bones in the subsurface of the **Witzand Formation** are expected to be in an archaeological context and their loss will be rated as highly negative from that perspective. Palaeontologically, the formation is recent and is judged unlikely to produce unique fossil remains. The “subfossil” bones are likely to be extant species. However, unexpected species could occur. Nevertheless, here the archaeological concerns take precedence.

Fossils are very sparse in the surficial **Koekenaap Formation** aeolian coversands. Fossil bone and marine shell material that may occur are likely to be in an archaeological context and both artefacts and fossil bones are most often found on the compact palaeosurface of the underlying Dorbank Fm. These occurrences usually only come to light when large areas of the surficial sands have been blown away by the wind or mined away. The palaeontological sensitivity of the Koekenaap Fm. coversands is rated Very High (Figure 11) which is applicable close to the coast in view that archaeological material and fossil bones are more common there compared to further inland. However, this rating is also a default for the West Coast Group in general which has an overall Very High palaeontological sensitivity rating due to previous fossil finds of high scientific importance (Almond & Pether, 2009). As the geological maps only depict formations at the surface, the Very High sensitivity rating of the surficial Koekenaap Fm. coversands is a “stand-in” which effectively also represents the fossil content of the underlying aeolianites, marine deposits and associated intervening palaeosurfaces.

The fossil bone material in the younger aeolianites, *viz*. the Witzand, Koekenaap, Local Coastal Aeolianites and Dorbank formations is a sample of the middle and late Quaternary fauna of the Namaqualand coast and is expected to mainly comprise representatives of the extant fauna, but unexpected species may occur, as a result of phases of different ecological and palaeoclimatic conditions in the past, as well as species which became extinct during the termination of the Last Ice Age. Fossil bone occurrences may also be associated with important archaeological evidence of the early human inhabitants of the coast.

The anticipated impact of the proposed prospecting is limited by the few sites and the relatively minor subsurface disturbance involved. These is some chance that fossil material could be unearthed in the small prospecting pits, but only 20 pit sites are envisaged.

In the possible event of the deployment of an LDA drill, it is improbable that fossil bones will be intersected at depth due to the relatively small footprint at widely separated sites. Should it occur it is likely that only fragments will be obtained from the subsurface formations. The fossil material which may be encountered in drill samples from aeolianites is the ambient fossil content of land snails, tortoise bones and mole bones. Fossil marine shell is not well-preserved in most of the marine deposits, but fossil shell could be encountered in some drillholes. Other fossils which are brought up in boreholes include smaller petrified material such as shark and other fish teeth and casts of shells (steinkerns). Petrified mammal bones and loose mammal teeth in the marine gravels are rare and unlikely to be unearthed in a few auger holes.

A significant impact by the prospecting on the fossils of the older formations, such as the Olifantsrivier Fm. aeolianites and the marine deposits of the Hondeklipbaai Fm., is not anticipated.

9 IMPACT ASSESSMENT RATING

9.1 EXTENTS

The physical extent of impacts on potential palaeontological resources relates directly to the extents of subsurface disturbance, *i.e.* LOCAL.

9.2 DURATION

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.

9.3 INTENSITY

The intensity/magnitude of a palaeontological impact is determined by the palaeontological sensitivity of the affected geological formation, together with the extent or volume of excavations made into the formation. In all formations any fossil bones and teeth are the main focus of concern, due to their scientific importance.

The Quaternary Curlew Strand Fm. raised beaches are of LOW sensitivity with respect to shell fossils. Fossil bones of marine mammals (cetaceans, seals) and seabirds are rare in the Quaternary Curlew Strand Fm. raised beaches and are of HIGH palaeontological sensitivity.

The fossil bone material in the younger aeolianites, *viz*. the Witzand, Koekenaap, Local Coastal Aeolianites and Dorbank formations, is overall sparsely distributed and the relatively few minor sites of subsurface disturbance at prospecting pit and drill sites have a low probability of chancing upon such finds and the impact is therefore considered to be LOW.

In the Pliocene marine Hondeklipbaai and Avontuur formations the fossil bones and teeth are mainly of extinct terrestrial and marine species and are of HIGH palaeontological sensitivity and importance. However, given the limited subsurface disturbance of the proposed prospecting, fossil bones are unlikely to be unearthed. The palaeontological impact on the older Olifantsrivier and Graauw Duinen aeolianite formations, if at all intersected, is similarly LOW.

The Pliocene marine Hondeklipbaai and Avontuur formations are generally of MODERATE sensitivity with respect to well-preserved shell fossil beds. However, intersections of shelly beds are expected to be limited in the small excavations, due to widespread decalcification and preferential preservation of the thicker, larger shells. Consequently fossil shells in the Pliocene marine formations are of LOW sensitivity due to the limited prospecting disturbance.

9.4 PROBABILITY

As mentioned above, the relatively modest subsurface disturbance of the proposed prospecting, compared to bulk sampling and mining, renders the discovery fossil bones in the abovementioned formations unlikely, but not altogether impossible.

9.5 IMPACT ASSESSMENT TABLE

For simplicity, the assessment table below refers in general only to the discovery of fossil bones and teeth in pits and drill holes, in any formation.

<table>
<tr><td colspan="8">E = Extent, D = Duration, I = Intensity, P = Probability of occurrence.
Where Significance = (E + D + I) x P.</td></tr>
<tr><td></td><td>E</td><td>D</td><td>I</td><td>P</td><td>Significance</td><td>Status</td><td rowspan="3">Prospecting personnel to be alert for unearthing of fossil bones in the pits and drill holes and follow the Fossil Finds Procedure.</td></tr>
<tr><td>Without Mitigation</td><td>1</td><td>5</td><td>8</td><td>2</td><td>28 – LOW (upper)</td><td>Negative</td></tr>
<tr><td>With Mitigation</td><td>1</td><td>5</td><td>8</td><td>2</td><td>28 – LOW (upper)</td><td>Positive</td></tr>
<tr><td colspan="8">Rating scheme according to Appendix 2.</td></tr>
</table>

10 RECOMMENDATIONS

There are no known outcrops of sensitive fossiliferous strata in the drilling 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 pit and drill sites do not affect this assessment.

10.1 MITIGATION

It is recommended that a requirement to be alert for fossil bones and archaeological material which may be uncovered during the prospecting be included in the Environmental Management Programme (EMP) 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 must be instructed to be alert for the occurrence of fossil bones. 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.

10.2 FOSSIL FINDS PROCEDURE

Should fossil bones and teeth be encountered in pits and drill holes the unearthed bones, teeth and fragments must be retrieved for safekeeping and the works foreman and the ECO for the project must be informed immediately. If a concentration of bones is unearthed in a pit work must cease at the site, the works foreman and the ECO must be informed immediately, and the find site must be protected from further disturbance. It should be feasible to relocate the prospecting site to an adjacent spot and thus avoid machine downtime.

Heritage Western Cape (HWC) and/or an appropriate specialist archaeologist or palaeontologist must be informed and supplied with contextual information by email:

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

In the possible event of the deployment of an LDA drill, fossil material brought up by the auger must be collected and placed in labelled bags with information on the date, position, depth 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.

HWC and the palaeontologist will assess the information provided for fossil finds and liaise with the ECO, the environmental consultants and the developer and a suitable response will be established.

On the discovery of conservation-worthy fossils, a collection permit must be applied for from HWC. The applicant should be the qualified specialist responsible for assessment, collection and reporting. Should fossils be found that require rapid collecting, application for a palaeontological permit must be made to HWC immediately. Arrangements must be made to transport rescued fossil material deemed worthy of conservation and study to an appropriate curatorial institution.

In addition to the information and images of the find, the application requires details of the registered owners of the sites, their permission and a site-plan map. All fossils must be deposited at a HWC-approved institution. The rescue and reporting of discovered archaeological or palaeontological remains by a contracted specialist shall be at the Developer’s expense.

The Project Geologist is welcome to contact the writer by email with images for preliminary opinions about potential finds and stratigraphy at no initial cost.

11 REFERENCES

Almond, J.E. & Pether, J. 2009. Palaeontological Heritage of the Northern Cape. SAHRA Palaeotechnical Report, Natura Viva cc., Cape Town.

Chase, B. 2006. *Late Quaternary palaeoenvironments of the west coast of South Africa: the aeolian record*. Unpublished D.Phil. Thesis, The University of Oxford.

Chase, B.M. & Thomas, D.S.G. 2006. Late Quaternary dune accumulation along the western margin of South Africa: distinguishing forcing mechanisms through the analysis of migratory dune forms. *Earth and Planetary Science Letters* **251**: 318–333.

Chase, B.M. & Thomas, D.S.G. 2007. Multiphase late Quaternary aeolian sediment accumulation in western South Africa: timing and relationship to palaeoclimatic changes inferred from the marine record. Quaternary International 166: 29–41.

De Beer, C.H. 2010. The geology of the Garies area. Explanation: 1:250000 Sheet 3017 Garies. Council for Geoscience South Africa. 100 pp

De Villiers, S. E. & Cadman, A. 2002. An analysis of the palynomorphs obtained from Tertiary sediments at Koingnaas, Namaqualand, South Africa. Journal of African Earth Sciences 33:17–47.

Haq, B.U., Hardenbol, J. & Vail, P.R. 1988. Mesozoic and Cenozoic chronostratigraphy and cycles of sea-level change. In: *Sea-level Changes: an Integrated Approach*. Special Publication of the Society for Economic Paleontologists and Mineralogists, **42**, 71-108.

Lear, C.H, Elderfield, H. & Wilson, P.A. 2000. Cenozoic Deep-Sea Temperatures and Global Ice Volumes from Mg/Ca in Benthic Foraminiferal Calcite. *Science* **287**: 269-272.

Pether, J, Roberts, D.L. & Ward, J.D. 2000. Deposits of the West Coast (Chapter 3). In: Partridge, T.C. & Maud, R.R. eds. The Cenozoic of Southern Africa. *Oxford Monographs on Geology and Geophysics No. 40. Oxford University Press*: 33-55.

Roberts, D.L., Botha, G.A., Maud, R.R. and Pether, J. 2006. Coastal Cenozoic Deposits (Chapter 30). In: Johnson, M. R., Anhaeusser, C. R. and Thomas, R. J. (eds.), The Geology of South Africa. Geological Society of South Africa, Johannesburg/Council for Geoscience, Pretoria: 605-628.

Rogers, J., Pether, J., Molyneux, R., Hill, R.S., Kilham, J.L.C., Cooper, G. and Corbett, I. 1990. Cenozoic geology and mineral deposits along the west coast of South Africa and the Sperrgebiet. Guidebook Geocongress '90 Geological Society of South Africa PR1: 1-111.

Siddall, M., Chappell, J. and Potter, E.-K. 2007. Eustatic sea level during past interglacials. The Climate of Past Interglacials: Developments in Quaternary Science ***7****: 75-92.*

Stynder, D & Reed, K. 2015. Permit application for archaeological and palaeontological excavations at CP-537 on the farm Geelwal Karoo 262.

Tankard, A.J. and Rogers, J. 1978. Late Cenozoic palaeoenvironments on the west coast of southern Africa. *Journal of Biogeography,* **5**, 319-337.

Verboom, G. A., Archibald, J. K., Bakker, F. T., Bellstedt, D. U., Conrad, F., Dreyer, L. L., Forest, F., Galley, C., Goldblatt, P., Henning, J. F., Mummenhoff, K., Linder, H. P., Muasya, A. M., Oberlander, K. C., Savolainen, V., Snijman, D. A., van der Niet, T. & Nowell, T. L. 2009 Origin and diversification of the Greater Cape flora: Ancient species repository, hot-bed of recent radiation, or both? Molecular Phylogenetics and Evolution 51: 44–53.

Zachos, J. C., Dickens G. R., Zeebe, R. E. 2008. An early Cenozoic perspective on greenhouse warming and carbon cycle dynamics. Nature 451: 279–283.

12 APPENDIX 1 - 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.

13 APPENDIX 2. 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

The context of the historical "marine terraces" with respect to formations recognized.

Terrace Record - Erosion mainly during sea-level rises (transgressions).		
Alexkor/State Alluvial Diggings[1]	**Kleinzee[2]/De Beers Namaqualand**	**Overlying Deposits**
SAD Lower 0-15 m asl.	Recent Emergence Terraces (RETs) <15 m asl.	Raised beaches overlying bedrock, or aeolianites, or Hondeklipbaai Fm.
SAD Middle 15-30 m asl.	Lower Terrace Local slope-breaks at ~30 m asl.	Occupied by Hondeklipbaai Fm. Partly occupied Avontuur Fm. Patches of Kleinzee Fm.
SAD Upper 30-60 m asl.	L. Middle Terrace 30-45 m asl. (K-LMT) U. Middle Terrace 45-65 m asl. (K-UMT)	Occupied by Avontuur Fm. Partly overlain by Kleinzee Fm.
Grobler Terrace 75-90 m asl.	Upper Terrace 75-95 m asl.	Kleinzee Fm.

Depositional Record - Coastal deposits progradation during sea-level falls (regressions).			
C & K, 1969[3]	**Regressive marine deposits from highstands[4]**	**Alexander Bay Subgroup[5]**	**Age**
~2 m T.C. ~5 m T.C. 7-8 m T.C.	2-3 m Package. 4-6 m Package. 8-12 m Package.	Curlew Strand Fm. raised beaches. (equiv. to Velddrif Fm., SW Cape)	Mid-Holocene, 7-4 ka. LIG MIS 5e,~125 ka. MIS 11, ~400 ka.
17-21 m T.C. 29-34 m Beach.	30 m Package.	Hondeklipbaai Fm.	Late Pliocene, ~3 Ma..
45-50 m T.C. Phosphatic siltstones.	50 m Package. (includes shelf phosphorites)	Avontuur Fm.	Early Pliocene, 5-4 Ma.
75-90 m T.C.	90 m Package.	Kleinzee Fm.	Middle Miocene, 16-15 Ma

1. Hill, in Rogers *et al*., 1990.
2. Molyneux, in Rogers *et al*., 1990.
3. Carrington and Kensley, 1969. T.C. = "Transgression Complex", but are actually regressive deposits.
4. Pether, in Pether *et al*., 2000. Approximate highstand maxima, with regressive, prograded deposits extending seawards.
5. Roberts *et al.*, 2006 (but with the Alexander Bay Fm. raised to subgroup rank with constituent formations and revised ages).

The occurrence of patches of the mid-Miocene Kleinzee formation on lower "terraces", as low as 10 m asl., indicates that the basic bedrock topography was already in place by the mid-Miocene. The basic terrace bedrock geomorphology was formed before the deposition of the overlying marine deposits, such as during the early Miocene and Eocene highstands (Figure 4, this report).

Carrington, A.J. and Kensley, B.F. 1969. Pleistocene molluscs from the Namaqualand coast. *Annals of the South African Museum,* 52, 189-223.

Pether, J, Roberts, D.L. & Ward, J.D. 2000. Deposits of the West Coast (Chapter 3). In: Partridge, T.C. & Maud, R.R. eds. The Cenozoic of Southern Africa. *Oxford Monographs on Geology and Geophysics No. 40. Oxford University Press*: 33-55.

Roberts, D.L., Botha, G.A., Maud, R.R. and Pether, J. 2006. Coastal Cenozoic Deposits (Chapter 30). In: Johnson, M. R., Anhaeusser, C. R. and Thomas, R. J. (eds.), *The Geology of South Africa*. Geological Society of South Africa, Johannesburg/Council for Geoscience, Pretoria: 605-628.

Rogers, J., Pether, J., Molyneux, R., Hill, R.S., Kilham, J.L.C., Cooper, G. and Corbett, I. 1990. Cenozoic geology and mineral deposits along the west coast of South Africa and the Sperrgebiet. *Guidebook Geocongress '90 Geological Society of South Africa*, **PR1**: 1-111.

15 APPENDIX 4. ADDITIONAL IMAGES FROM THE WC10430PR APPLICATION AREA