TRANS ATLANTIC DIAMONDS

# APPENDIX 7: Palaeontology Impact Assessment

## FINAL BASIC ASSESSMENT REPORT

## APPLICATION FOR ENVIRONMENTAL AUTHORISATION AND PROSPECTING RIGHTS FOR PROSPECTING IN OFFSHORE SEA CONCESSION AREA 6C, NORTHERN CAPE, BY TRANS ATLANTIC DIAMONDS (PTY) LTD

**EA Application Ref. No.: NC30/5/1/1/2/14851 PR**

**September 2026**

ANCHOR environmental | PART OF SLR

**DMRE Ref: NC30/5/1/1/2/14851 PR**

# PALAEONTOLOGICAL IMPACT ASSESSMENT

# (DESKTOP STUDY)

# PROSPECTING RIGHT APPLICATION SEA CONCESSION 6C

# TRANS ATLANTIC DIAMONDS (PTY) LTD.

# MIDDLE CONTINENTAL SHELF OFF NAMAQUALAND

By

**John Pether, M.Sc., Pr. Sci. Nat. (Earth Sci.)**
**Geological and Palaeontological Consultant**
Cellphone 083 744 6295
jpether@iafrica.com

Prepared at the Request of

**Anchor Environmental Consultants**

Tel: 021 701 3420
www.anchorenvironmental.co.za

**FOR**

**Trans Atlantic Diamonds (Pty) Ltd.**

**2 July 2026**

**SUMMARY**

**Name**

Trans Atlantic Diamonds (Pty) Ltd. Prospecting Right Application in Sea Concession 6C off the central Namaqualand coast.

**Location**

Sea Concession 6C (~345 648 ha) is located on the middle continental shelf of the Namaqualand coast (Figure 1). Its southern boundary is approximately opposite the ex DBNM diamond mine village of Koingnaas and ~32.2 km to the north the northern boundary of 6C is approximately opposite the border between the coastal farms Samsons Bak 330 and Brazil 329.

**Proposed Activities**

The application is for a large variety of mineral commodities. The proposed prospecting is intended to be accomplished in phases:

**Phase 1:**
a) Desktop Study (Non-invasive)
b) Geophysical survey and seafloor mapping (Non-invasive)
c) Data acquisition and synthesis and Geological modelling (Non-invasive)

**Phase 2:**
a) Van Veen grab sampling (part of ecological baseline survey) (Invasive)
b) Core sampling using either a Vibracore, Gravity core or Sonic core (Invasive)

**Phase 3:**
a) Drillship sampling using a large-diameter specialised drilling tool (Invasive)

**Phase 4:**
a) Feasibility study and resource estimation (Non-invasive)

**Palaeontological Resources**

Seaward from the inner shelf successively younger formations of Cretaceous, Paleogene and Miocene age comprise the middle shelf of 6C (Figures 2 & 3). These "footwall" formations are the sources of fossils, which mostly are eroded out and occur as objects in the overlying Quaternary gravels deposited since about 300 ka (ka=thousand years ago),

- **Cretaceous fossil wood** in both petrified and lignitic forms occurs primarily in the gravels which directly overlie the source Cretaceous formations.
- **Cenozoic Shelly Macrofauna**. The Paleogene (Eocene) and Miocene shelly macrofauna comprises phosphatic shell casts, and more rarely intact shells, from these formations. Mainly unstudied due to lack of suitable specimens.
- **Fossil Bones and Teeth**. Phosphatized/petrified bones and skulls of extinct marine mammal species, the teeth of sharks and other fishes, and the occasional bones and teeth of land-living animals that roamed the exposed shelf during Ices Ages.
- **Shells from the Last Transgression Sequence**. Exotic or extralimital seashells from the Last Transgression Sequence occur in the sediments accumulated on the shelf during the last 20 thousand years, as it was submerged following the low sea level of the Last Ice Age, are evidence for temporary changes in oceanographic conditions affecting the West Coast shelf, such as intrusions of subtropical currents. Important for radiocarbon dating.

**Anticipated Impacts**

The main Impact is drillship sampling involving a considerable volume of the shelf deposits (up to 1500 sites). For the most part the excavated material is the Last Transgression Sequence deposits with expected "subfossil" extant shell species and a 'sprinkling' of scientifically important extralimital species and rare reworked old fossil shells, bones and teeth in the gravels.

The grab samples are purposed for obtaining the upper, modern fauna and are unlikely to capture fossils which are usually lower down. Notwithstanding, the grabs may capture poorly-known modern species.

In the vibracores the small volumes involved greatly reduce to likelihood of capturing the sparse fossils and the "extralimitals" in the Last Transgression Sequence. However, should extralimital Subantarctic and Agulhas species occur in the cores they are more important specimens than those selected from the loose, mixed shells crossing the oversize screens during drillship sampling, as they have context in the geological and faunal succession in the core and the expense to have specimens radiocarbon dated is more worthwhile.

**Recommendations**

The EMPr for the prospecting must include provisions for the collection of representative examples of the fossils that occur therein. As part of Environmental Awareness Training, geological staff involved in logging must be informed of the need to watch for fossil material and rescue such from the gravel oversize screen during drillship sampling. Potential fossil material should be collected for later identification and evaluation, with labelling and recording of the find context data.

Fossils may be found during the processing of the vibracores and grab samples. All material of potential interest must have the details of context recorded and be kept for identification by an appropriate specialist and if significant, to be deposited in a curatorial institution such as the IZIKO SA Museum. The best outcome for a set of cores from this poorly-known area is that they are the subject of a detailed study, such as for a B.Sc. Honours or M.Sc. project, with radiocarbon dates. The vibracores are valuable in that they capture the context of fossil shells, such as extralimital species, in the sedimentary sequence.

Collected samples are to be stored by the company. When a collection of fossil material has been accumulated, an appointed palaeontologist should undertake the identification and evaluation of the fossil material and compile the report for submission to SAHRA. A selection of material could be removed for further study. The Environmental Manager/Officer is to liaise with the appointed palaeontologist on the progress of the fossil collection and the scheduling of the evaluation.

During all operations, personnel can send queries and images by email to an appointed palaeontologist for evaluation and prompt feedback.

---oooOOOooo---

**CONTENTS**

**DECLARATION OF INDEPENDENCE**

**DMRE Ref: NC30/5/1/1/2/14851 PR**

**PALAEONTOLOGICAL IMPACT ASSESSMENT**

**(DESKTOP STUDY)**

**PROSPECTING RIGHT APPLICATION SEA CONCESSION 6C**

**TRANS ATLANTIC DIAMONDS (PTY) LTD.**

**MIDDLE CONTINENTAL SHELF OFF NAMAQUALAND**

**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: 2 July 2026

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

South African Council of Natural Scientific Professions. Earth Science. Reg. No. 400094/95.

Association of Professional Heritage Practitioners (APHP), Western Cape. Accredited Member No. 48.

Independent Consultant/Researcher recognized as an authority with 40+ years' experience in the field of coastal-plain and continental-shelf palaeoenvironments, fossils and stratigraphy, mainly involving the West Coast and its shelf off southern Africa. Has been previously employed in academia (South African Museum), in industry (Trans Hex, De Beers Marine), and subsequently as consultant to offshore and onshore marine diamond exploration ventures. 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).

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).

---oooOOOooo---

## ABBREVIATIONS

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

| | |
|---|---|
| asl. | above (mean) sea level. |
| bsl. | below (mean) sea level. |
| CD-NGI | Chief Directorate – National Geo-spatial Information. |
| DBNM | De Beers Namaqualand Mines. |
| EMPr | Environmental Management Programme. |
| Fm. | Formation. |
| HWC | Heritage Western Cape. |
| ka | Thousand years ago. |
| LIG | Last Interglacial. |
| Ma | Million years ago. |
| MIS | Marine Isotope Stage. |
| OSL | Optically stimulated luminescence. |
| PIA | Palaeontological Impact Assessment. |
| SAHRA | South African Heritage Resources Agency. |
| SAHRIS | South African Heritage Resources Information System. |
| SRTM-NASA | Shuttle Radar Topography Mission - National Aeronautics and Space Administration. |

## GLOSSARY

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, such as shells and shell fragments.

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.

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.

Deflation: The removal of sand by wind, producing a deflation surface on which heavier objects are concentrated, such as heavy mineral grains, pebbles, bones and snail shells.

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

Footwall: The unmineralized strata underlying an ore deposit.

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).

MIS: Marine isotope stages (MIS), marine oxygen-isotope stages, or oxygen isotope stages (OIS), are alternating warm and cool periods in the Earth's paleoclimate, deduced from oxygen isotope data reflecting changes in temperature derived from data from deep sea core samples. Working backwards from the present, MIS 1 in the scale, stages with even numbers representing cold glacial periods, while the odd-numbered stages represent warm interglacial intervals (see Figure 7).

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

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

Palaeosol: An ancient, buried soil 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.

Stone Age: The earliest 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.

Terrigenous: Sediments derived from erosion of the land mass by rivers, wind and glaciers.

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

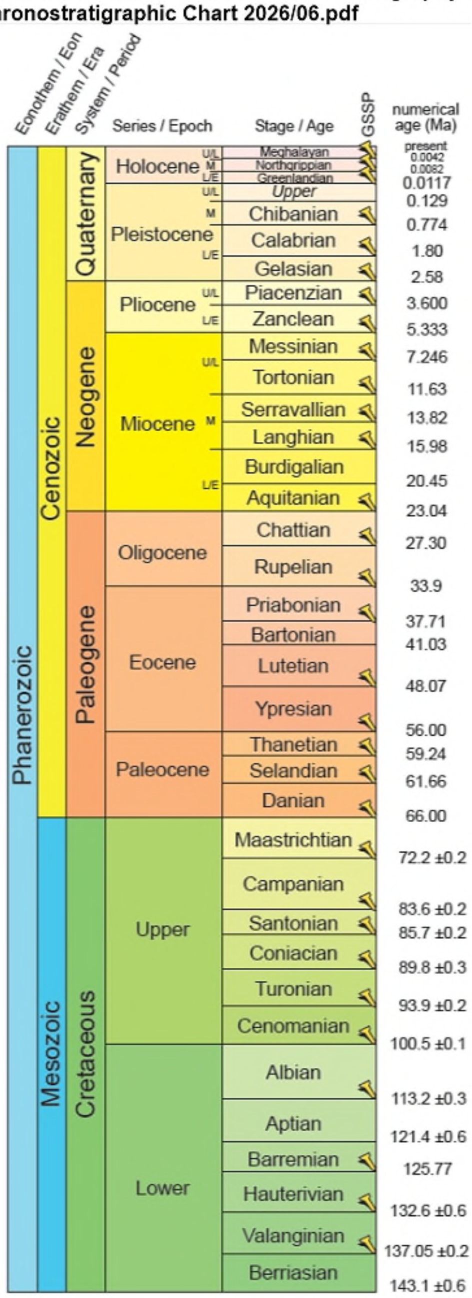
For more detail see www.stratigraphy.org.

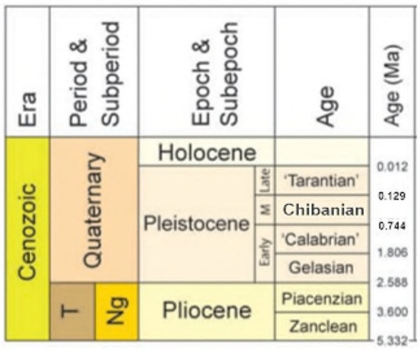
ka: Thousand years or kilo-annum ($10^3$ years). Implicitly means “ka ago” *i.e.* duration from the present, but “ago” is omitted. The “Present” refers to 1950 AD. Not used for durations not extending from the Present. For a duration “ky” or “kyr” is used.

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 “My” or “Myr” is used.

Tertiary Period: Refers to the Paleogene and Neogene Periods together. Supposed to be obsolete, but still widely in use.

**Mesozoic and Cenozoic Chronostratigraphy**
**From: International Commission on Stratigraphy.**
**Chronostratigraphic Chart 2026/06.pdf**




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 11.7–129 ka.
Middle Pleistocene 129–744 ka.
Early Pleistocene 744–2588 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, Trans Atlantic Diamonds (Pty) Ltd., proposes to carry out geological exploration for a variety of mineral commodities in South African Sea Concession 6C off Namaqualand (Figure 1). Anchor Environmental Consultants (Pty) Ltd. have been appointed to facilitate the Environmental Impact Assessment (EIA) process for the proposed exploration activities. TerraMare Archaeology (Pty) Ltd. have been appointed to undertake the Heritage Study to inform the EIA process. This report is the contribution to the Heritage Impact Assessment and it describes the palaeontological heritage which may be affected by the proposed prospecting activities.

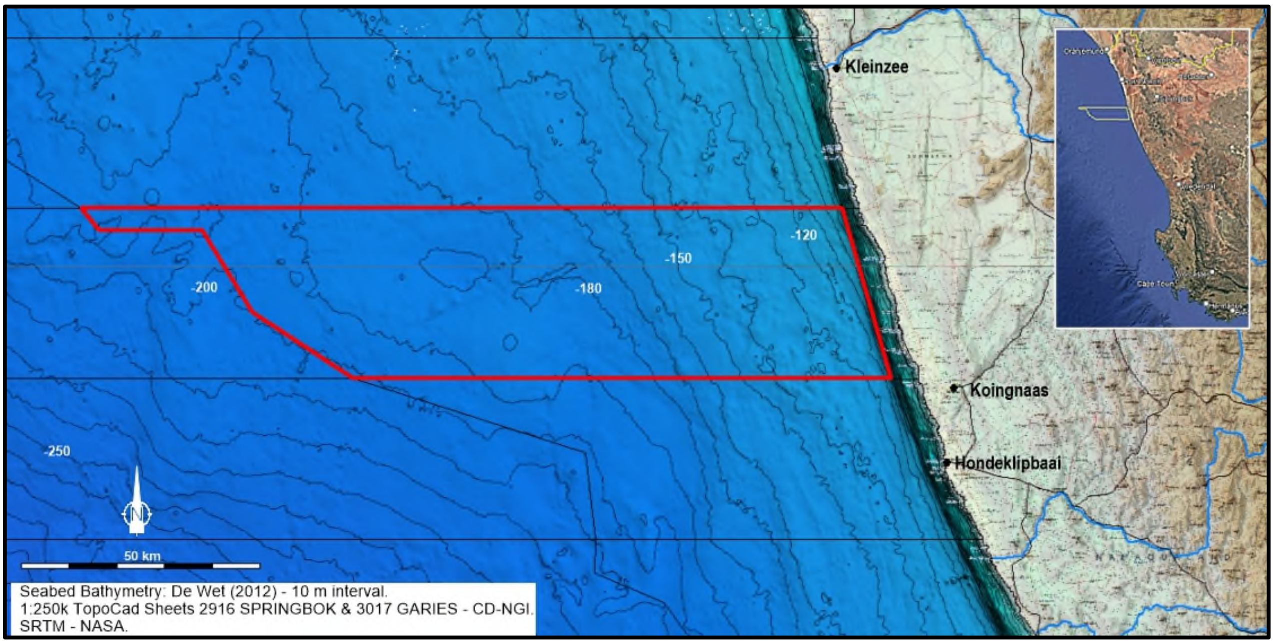



**Figure 1. Location and bathymetry of Sea Concession 6C.**

# 2 LOCATION

Sea Concession 6C (~345 648 ha) is located on the middle continental shelf of the Namaqualand coast (Figure 1). Its southern boundary is approximately opposite the ex DBNM diamond mine village of Koingnaas and ~32.2 km to the north the northern boundary of 6C is approximately opposite the border between the coastal farms Samsons Bak 330 and Brazil 329.

The distance of the inshore boundary from the coast is about 2.3 km in the north, increasing to about 5 km in the south. The depths along the inshore boundary are about -100 m in the south and decrease in the north to -90 to -70 m depth, this northward shallowing being due to the increasing thickness of the "Mudbelt" sediment body beneath the offshore 6B/6C boundary. The offshore boundary approximates the -200 m isobath (Figure 1).

# 3 PROPOSED ACTIVITIES

The Prospecting Right Application within Sea Concession Area 6C, is Northern Cape EA Application Ref. No. NC30/5/1/1/2/14851 PR.

The Application, in terms of the Mineral and Petroleum Resources Development Act (MPRDA; Act No. 28 of 2002), is for a basket of mineral commodities including Chrome, Copper, Corundum, Diamonds (general), Garnet (abrasive), Gemstones, Gold Ore, Heavy Minerals (general), Iron Ore, Lithium Ore, Platinum Group Metals, Rare Earths, Silver Ore, as well as Titanium and Uranium Ore.

The proposed prospecting is intended to be accomplished in 4 phases.

### 3.1 PHASE 1

- **Desktop Studies** – A review of published literature and the obtaining and compiling of available prospecting data from previous surveys and sampling, in order to pre-inform the prospecting programme as to potential targets and issues.
- **Geophysical Survey** – A geophysical survey vessel with hull-mounted equipment will use the Multibeam Echo Sounder (MBES) to acquire MB Swath Bathymetry to derive a high-resolution map of the topography of the seabed (DEM). Sub-bottom profiles are to be acquired using a CHIRP shallow seismic system to reveal the sedimentary units and their geometry within local sediment basins. Deployment of a Magnetometer may detect concentrations of heavy minerals (and also unmapped shipwrecks).
- **Data Synthesis** - The geophysical data will be interpreted to produce digital maps and targets for grab sampling and shallow coring (*e.g*. vibracores) will be defined.

### 3.2 PHASE 2

**Grab sampling** - A Van Veen grab with a sampling capacity of approximately 50 kg will be used to collect baseline environmental data on sediment benthic macrofauna from 20–50 sites. Subsamples will be subject to geotechnical analyses (compositions, shear strengths).

**Coring** – Cores for stratigraphic and geotechnical analyses will be collected at 100-200 sites using either vibracoring, gravity coring or sonic coring. Such cores are 8-10 cm in diameter, penetrating to 3-8 m depth. The cores will be processed at a facility on land.

### 3.3 PHASE 3

**Drill Sampling** – Typical drillship large-diameter sampling will be performed in target areas involving 300 initial sample sites. For example, the MV The Explorer with its large diameter airlift drill (5 $m^2$) which can penetrate the seabed to 8 or 12 m depths. For diamond sampling the material is passed over an oversize screen (15 - 22 mm apertures) to remove coarser gravel, falling onto the undersize screen (1.5 – 2.0 mm apertures) where sand is washed out, while the plantfeed fraction of fine gravel is fed onwards to the Dense Media Separator (DMS) plant to separate the dense particles including diamonds.

Should the sampling indicate targets for additional sampling for resource estimation, an additional 1200 sampling sites is envisaged.

### 3.4 PHASE 4

**Feasibility Study** – A Feasibility Study will be conducted to assess the likely magnitude of the resource and the economic viability of mining in the proposed prospecting area. The report will include the Geological Model, which includes seafloor topography, sediment stratigraphy and geological units; distribution of potentially mineralized deposits; an evaluation of the drill samples; resource evaluation of areas that are mineralized; an estimate of the extent and size of the resource present, and the potential costs of exploiting the mineral resource (mining vessel costs, financial modelling, market risks, taxes, environmental impacts, mitigation and end of mine life rehabilitation *etc*.), in order to ascertain the portion of the mineral resource which is a "bankable" mineral reserve which is profitable to mine.

## 4 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.

Notification of SAHRA or the applicable Provincial Heritage Resources Agency is required for proposed developments exceeding certain dimensions (Sect. 38), upon which they will decide whether or not the development must be assessed for heritage impacts (an HIA) that may include an assessment of palaeontological heritage (a PIA). Below High Water Mark the management of maritime and underwater cultural heritage resources under the NHRA is the responsibility of the national agency, SAHRA. The heritage resources include "Any movable property of cultural significance which may be protected in terms of any provisions of the NHRA, including any archaeological artefact or palaeontological specimen" (Section 2(xxix)).

In the case of heavy-mineral sands and diamond mining there are rare shell and bone macrofossils sparsely scattered and locally concentrated within both overburden and orebodies. Fortunately, this is generally recognized and it has been primarily due to the large excavations made by mining, and the support of mining companies and their geologists, that much of the present-day knowledge of the coastal-plain record has been rendered possible. Similarly, geologists active on the offshore shelf have contributed valuable specimens to museum collections.

# 5 APPROACH AND METHODOLOGY

## 5.1 INFORMATION SOURCES

Exploration for fossil fuels has been the main driver for determining the large-scale litho-, bio- and chrono-stratigraphy of continental shelves to depth. The palaeontology (fossil life forms and their evolution) of a variety of microscopic remains of both marine and terrestrial animals and plants provide the means to divide up long cores through kilometres of the offshore sediment pile into formations of different origins and ages. Mapping of the shelf bathymetry and the nature of seabed sediments in increasing detail is an ongoing endeavour, for both ecological and mineral resource purposes. Sediment bodies on the shelf have been cored to access their sea-level change and palaeoclimatic records. This has generated a considerable marine geological literature by the collaborative efforts of scientists in employ of companies, the state and in academia. The contributions relevant to this assessment are cited in the normal manner as references in the text and are included in the References section. However, the published literature specifically on shell macrofossils from the shelf off Namaqualand is relatively limited. This assessment also benefits from the author's personal observations of fossils from the shelf during exploration sampling for diamonds.

## 5.2 ASSUMPTIONS, LIMITATIONS AND INFORMATION GAPS

The main assumption is that the fossil potential of a formation in the study area will be typical of that found in the region and more specifically, similar to that already observed in the study areas. A limitation on predictive capacity exists in that it is not possible to predict the fossil content of an area or formation other than in such general terms. The information gaps are the proprietary, confidential observations contained in geological reports and logs of the sampling and prospecting that has been undertaken in the prospecting and mining right areas.

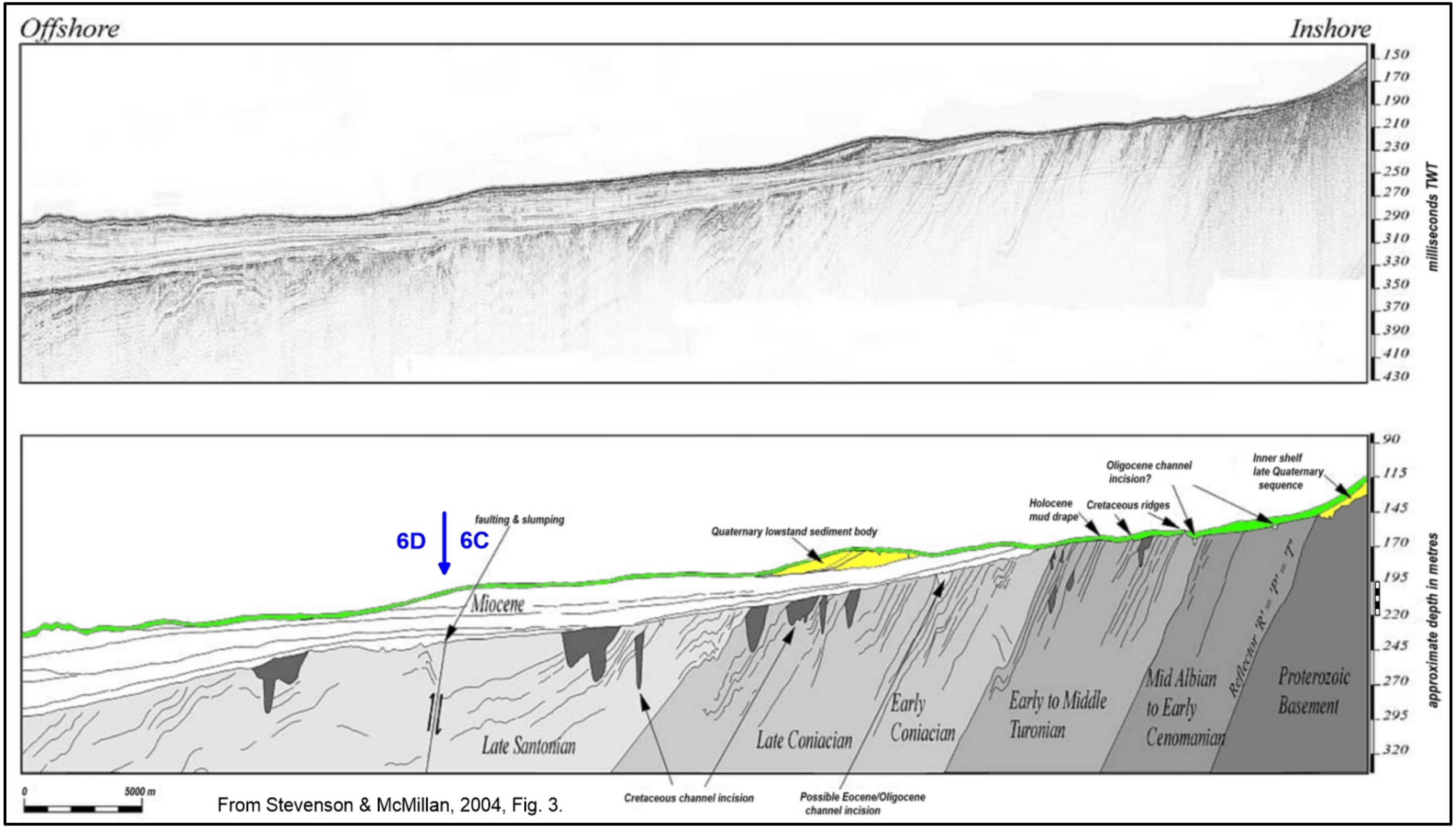



Figure 2. Interpreted geophysical (seismic) profile seawards off Hondeklipbaai showing the Pre-Quaternary geology and the generally thin, overlying Quaternary deposits (in colour). The section is vertically exaggerated - true Cretaceous reflector dips are only 1.5 degrees.

# 6 GEOLOGICAL SETTING

## 6.1 GENERAL ASPECTS

The inner shelf of Sea Concession 6 slopes relatively steeply seawards down to the very gentle slope developed across the middle and outer shelf (Figures 1 & 2). The inner-shelf bedrock is comprised of the **Precambrian** "basement rock" gneisses and metasediments of the NAMAQUALAND METAMORPHIC PROVINCE (Figure 3), dating to 1200 – 800 Ma (Ma = million years ago). These Precambrian bedrock formations are not of palaeontological concern.

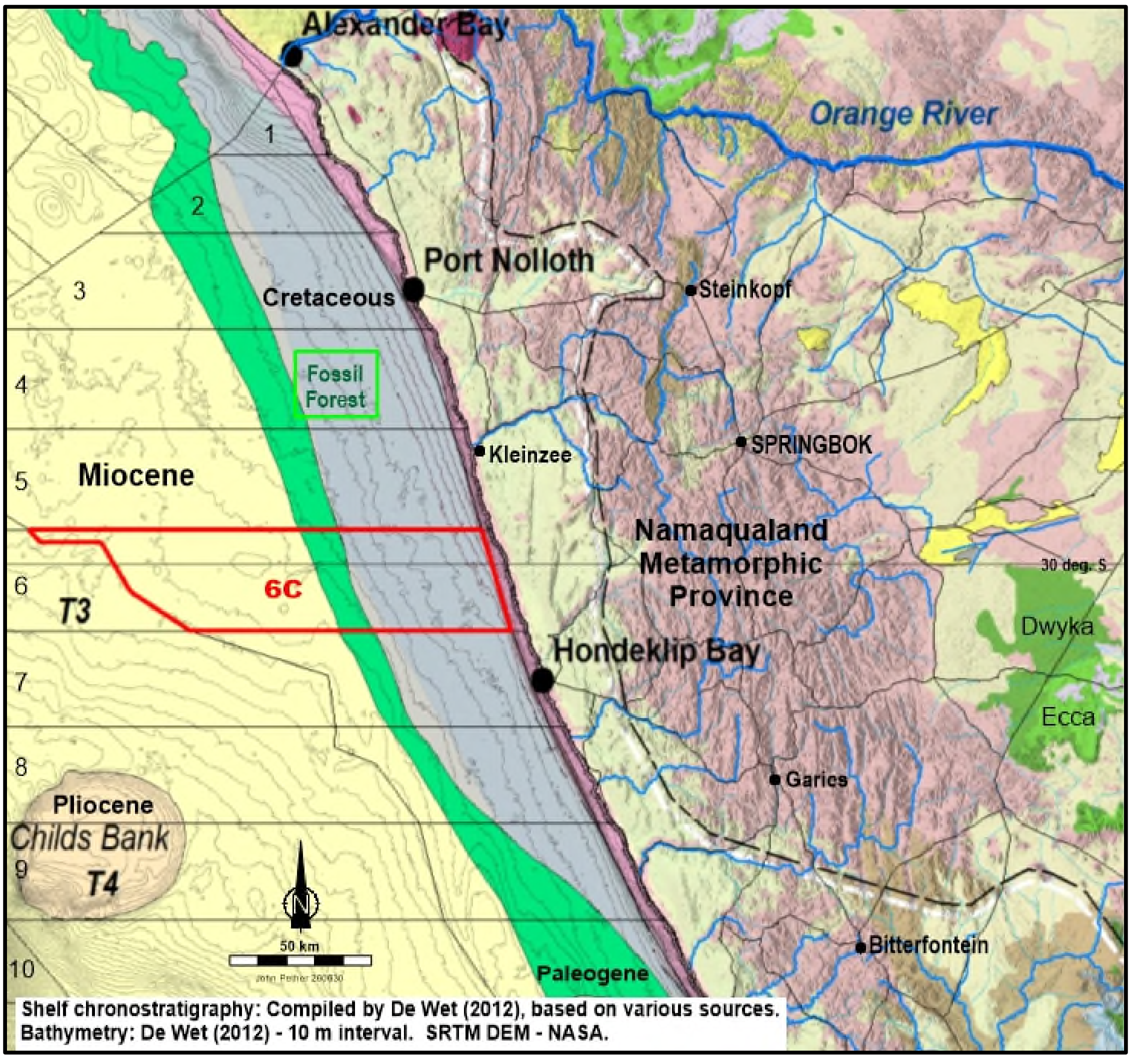



**Figure 3. Regional onshore and offshore geological setting of Sea Concession 6C.**

The hard seabed geology of the continental shelf, beneath unconsolidated sediments, is depicted in Figures 2 & 3 which shows overall successively younger chronological formations seawards as the continental margin was built out by the muds and sands delivered to the opening Atlantic Ocean by the numerous rivers which eroded the subcontinent since the breakup the supercontinent Gondwana 130-120 Ma. The Cretaceous and Paleogene units comprise the main bulk of the continental shelf and are succeeded by cappings of overlapping Miocene and Pliocene units.

The eroded surfaces of the inner-shelf bedrock and the offshore Cretaceous, Paleogene and Miocene formations are the bottom or "footwall" to overlying, much younger Quaternary to present-day deposits (Figure 2). For the most part the Quaternary deposits are a veneer over the continental shelf, but are much thicker where they have accumulated in the accommodation space provided by the slope break between the steeper inner shelf and the nearly flat middle shelf where they constitute the "Mudbelt" (Figure 4).

The Mudbelt is a composite feature with a lower portion composed of coarse shallow-water sediments deposited during low sea level, overlain by thick muds accumulated under subsequent deeper water depths. The terrigenous mud was delivered by the Orange/Gariep River and has been transported southwards by the Benguela Undercurrent and has accumulated since about 11 thousand years ago (11 ka) when sea level approached its current level. The Mudbelt extent and thickness narrows and thins southwards past Concession 6 and most of it is located in the shallow portion of 6C where the muds form the seabed (Figure 4).

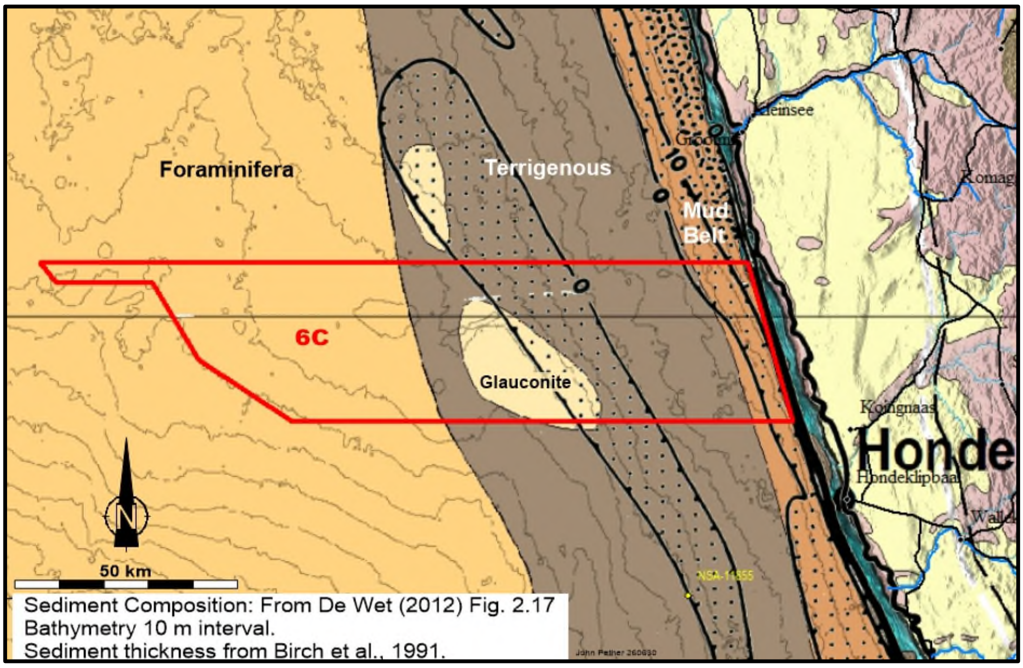



**Figure 4. Surficial sediment compositions and Quaternary sediment thickness.**

The Quaternary veneer in the shallow half of 6C is mainly comprised of terrigenous (land-derived) sands and silts. A large area which is glauconite-rich is identified (Figure 4). Known as "greensands" due to the colour of the sand grains, glauconite is an iron-rich mineral which forms in the marine environment, infilling the pore spaces in sediments. These greensands have been derived from the erosion and reworking of older formations on the shelf, such as the underlying Paleogene formations. Further offshore the sediment cover is dominated by the calcareous, sand-sized shells of microfossil foraminifera, settling out of the water column onto the seabed.

The coarse-scale sediment thicknesses shows an offshore Quaternary sediment body (Figure 4) which corresponds to the lowstand sediment body shown in Figure 2, which was deposited mainly during the Last Ice Age when sea level was about -125 m bsl.

## 6.2 PRE-QUATERNARY FORMATIONS

The pre-Quaternary footwall geology shown in Figure 3 is based on very broad-scale, early surveys and is now superseded. The updated offshore geology shown in Figure 5 comes from a published extract (McMillan, 2003) of the unpublished, proprietary map produced by the De Beers Marine (DBM) diamond exploration geologists over many years and at considerable expense. The buried stratigraphy and surface outcroppings are mapped on the basis of geophysical profiles acquired by DBM surveys and geophysical profiles and borehole data from oil and gas exploration (e.g. SOEKOR/PetroSA). The ground-truthing of outcrop and the ages of the formations are based on samples from the seabed obtained during diamond sampling and mining and from vibracoring campaigns specifically intended for stratigraphic and age-control purposes.

The main difference between Figure 3 and the later Figure 5 is that the onlapping Miocene formation extends further inshore. The Cretaceous is subdivided into formations which are named according to their ages in terms of international chronostratigraphic nomenclature (see Geological Time Scale, page viii).

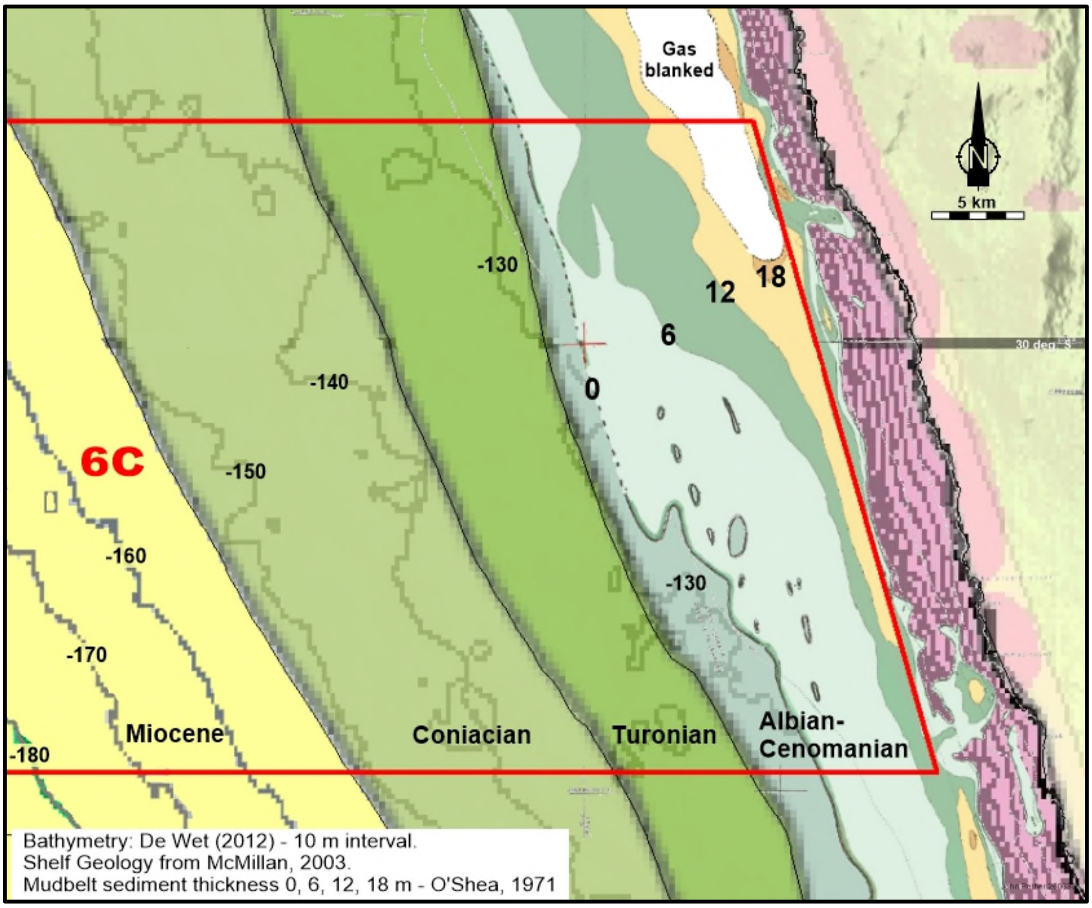



**Figure 5. Updated shelf geology showing Cretaceous formations and the thicknesses of the Mudbelt sediments.**

The Albian to Cenomanian Fm. (~108-97 Ma) is of fluvial origin and consists of white, kaolinitic muds, well-sorted sandstones and well-sorted, sub-angular to sub-rounded, exclusively vein-quartz gravels with kaolinitic matrixes. The kaolinite clays and local silicification indicate advanced weathering under humid climatic conditions. No marine microfossils are present. Worn pebbles of black lignite are derived from this formation.

The Turonian Fm. (~94-92 Ma) is comprised of cycles of thick fluvial muds, locally with incised valley fills and interbedded with thinner grey muds with microfossils indicative of brackish (hyposaline), estuarine environments.

The Coniacian Fm. (~89-86 Ma) is a thick fluvial succession characterised by numerous incised valleys associated with erosion surfaces and subsequent valley fills which terminate in marine incursions, indicate of falling and rising cycles of sea level. Ferruginized sandstones and conglomerates are associated with the major palaeosurfaces and were cemented from groundwater high in dissolved iron, with Fe-oxide precipitated by fluctuation of water table levels beneath the alluvial floodplains. These harder, cemented strata now stand proud as ridges on the seabed (Stevenson & McMillan, 2004).

The Santonian Fm. (~86-83 Ma) is fluvial in origin and also characterised by incised valley fills with brown claystones, minor sandy clays and land-plant microfossils (spores, seeds).

The Palaeogene is represented by Eocene formations of Bartonian age (41-38 Ma) and consists of deep-water green marine clays.

The Miocene Fm. in 6C is of Burdigalian age (20-16 Ma) and is pale grey and pale yellow limestone mainly consisting of biogenic carbonate such as forams, bryozoans and shell fragments, with very minor terrigenous input.

In the deeper part of 6C (>-180 m bsl.) unpublished data indicates there are “windows” in the Miocene exposing Santonian and Eocene footwall.

### 6.3 QUATERNARY DEPOSITS

Figure 5 also shows the thicknesses of the Holocene Mudbelt which mainly overlies the middle-shelf Albian-Cenomanian footwall and which is thickest in the angle between the steep Precambrian inner shelf and the flat middle shelf, exceeding 18 m thick in the northeastern corner of 6C where gas in the sediment has blanked out the echoes from underlying sound (seismic) reflectors. Also of note are sediment-filled depressions in the Precambrian inner-shelf bedrock opposite the northern and southern corners of 6C which are often the seaward extensions of buried palaeochannels and river valleys on land on the coastal plain.

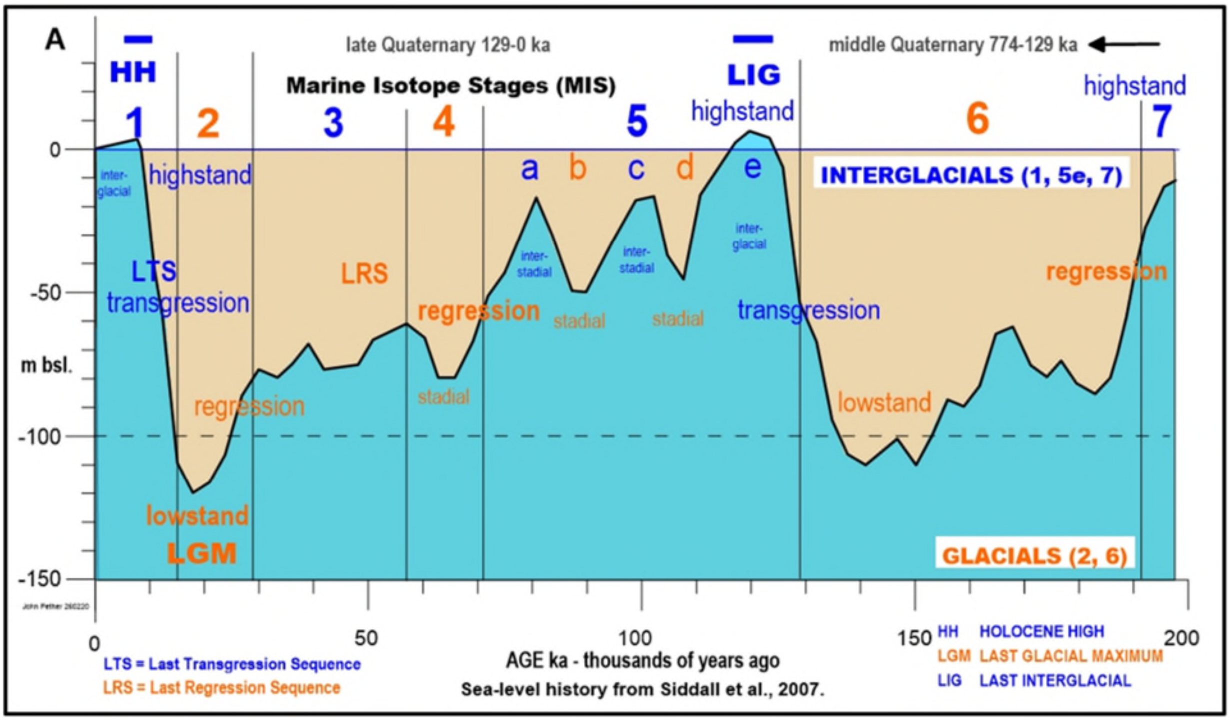



**Figure 6. Sea level history and palaeoclimatic nomenclature for the last 200 kyr.**

For the most part the Quaternary sediments overlying the Cretaceous footwall in the inshore of 6C involve only the **Last Transgression Sequence** (**LTS**) which was deposited during and subsequent to the last rise in sea level from the **Last Glacial Maximum** (**LGM**) lowstand ~20 ka (Figure 6). The shoreface of the rising, advancing shoreline is very effective at eroding and redistributing the previous shoreline and dune deposits it encroaches upon, due to the high wave energy impinging on the West Coast. The lower LTS is comprised of basal gravel units left behind in the deepening shoreface and innermost shelf where they were partly reworked during major storms. With ongoing deepening the basal gravels are overlain by an upward-fining unit of pebbly and shelly shelf sands, fine sands, and finally the bioturbated muds of the modern shelf seabed.

Bedrock depressions and sheltered sites landward of high bedrock ridges may include earlier Quaternary marine conglomerates and sandstones as local remnants that escaped erosion during the latest transgression from the LGM low sea level. As shown in Figure 7 the rate of the last deglacial rise in sea level was not uniform, but with periods of slow rise or stillstand succeeded by rapid rises due to pulses of polar meltwaters (Meltwater Pulses, MWPs). Provided that sediment is available, barrier beaches with spits, lagoons and dunes form on top of the deposits of the previous regression and these deposits are then overstepped and incompletely eroded by the subsequent Meltwater Pulse rapid rise in sea level (Runds *et al.*, 2019).

Based on personal observations there are several permutations for what type and age of deposits might be preserved, which are dependent on the depth/elevation of the site relative to sea-level history and the space within bedrock depressions. The observed beds are sensible in terms of sea-level history and an idealized sequence in a bedrock depression or overstepped elevation interval at ~-100 m depth may include all or some of the following generic units (refer to Figure 6).

1. After ~15 kyr of being on the shore of the MIS 6 lowstand, shoreface gravels and coarse sands were deposited during the **MIS5/6 transgression** ~135 ka.
2. Succeeding muddy fine sands and muds deposited during the **LIG highstand MIS 5e** and the continuing higher levels for the remainder of MIS 5 (5d-5a). Subsequent shallowing during MISs 4, 3 and 2 then reworked the deeper-water sediments at -100 m depth, but not totally, as is evident in their preservation in places.
3. Shelly gravels and sandstones deposited during the ongoing regression (MIS 2), constituting the base of the **Last Regression Sequence (LRS)** dating to 25 ka.
4. **Subaerial exposure** for ~10 thousand years (kyr) during the **LGM** and deposition of terrestrial deposits comprising the upper LRS which may include colluvium, pan deposits and dune sands, with land snails, possible animal remains and perhaps archaeological material, capped by a soil and/or incipient calcrete.
5. An erosion surface overlain by the basal gravel of the **Last Transgression Sequence (LTS)** (MIS 1/2, ~14 ka).
6. Succeeding shelly sand fining up to muddy shelf sand and muds (current interglacial highstand, later MIS 1).

In contrast, the shelf deeper than the LGM sea level lowstand remained submerged and will not include terrestrial deposits. Over much of the middle shelf the Quaternary is a veneer about 0.5 m thick, representing a condensed sequence with a basal winnowed shell lag gradationally overlain by a fining-upwards unit of muddy sand to mud, representing shallow shelf deepening to middle shelf depths. Where accommodation is available thicker deposits are comprised of 2 or 3 such sequences, formed during the last 2 or 3 glacial/interglacial sea-level cycles.

# 7 PALAEONTOLOGICAL HERITAGE

## 7.1 CRETACEOUS FOSSIL WOOD

Cretaceous fossil wood occurs primarily in the gravels on the flat middle shelf which directly overlie the source Cretaceous formations. Petrified wood is common and includes areas where petrified logs litter the seabed, *e.g.* the “Fossil Forest” protected area (Figure 3). Sections of silicified tree trunks were encountered during ground-truthing inspection of the seabed from the manned submersible JAGO by De Beers Marine. Specimens obtained via diamond exploration are providing valuable insights into the palaeo climates of the Cretaceous West Coast, when wide, well-watered coastal plains were covered by forests of primitive yellow wood (podocarp) trees (Bamford & Corbett, 1994; Bamford & Stevenson, 2002; Stevenson & Bamford, 2003). The best samples are those which are minimally abraded and of the largest size that passes through the drill apertures (large cobble to small boulder size), as these should generally be close to their position in the shelf stratigraphic sequence. Abraded, very reworked Cretaceous fossil wood also occurs onshore (App. 3, A3-1).

## 7.2 Cenozoic Shelly Macrofauna

The Cenozoic shelly macrofauna comprises black phosphatic shell casts (App.3, A3-2) and more rarely partly intact shells of various ages, mainly of Eocene and early Miocene ages. During later Neogene and Quaternary times the shelf was dominated by upwelling processes, with high organic productivity and authigenic mineralization of seabed rocks, clays and biogenic particles by phosphatization and glauconization. Extensive cemented crusts or "hardgrounds" formed on formations exposed at the seabed. Sea level oscillated repeatedly, dropping to ice-age palaeoshorelines as much as 140 m below present sea level. The hardgrounds were eroded during the ice-age/glacial shallowing episodes, releasing these fossils for incorporation into the LTS gravels.

## 7.3 Fossil Bones and Teeth

Fossil bones and teeth include the bones and teeth of sharks and other fishes, the skulls of extinct whale species and the occasional remains of land-living animals that roamed the ice-age exposed shelf are also phosphatized and reworked into the latest, loose Last Transgression Sequence sediments on the seabed. A sample of this reworked material turns up in bottom-trawl fishnets, scientific dredging and during diamond-mining operations and the specimens which have been donated to scientific institutions have been invaluable contributions (*e.g*. Bianucci, Lambert & Post, 2007; Bianucci, Post & Lambert, 2007). All such material should be collected.

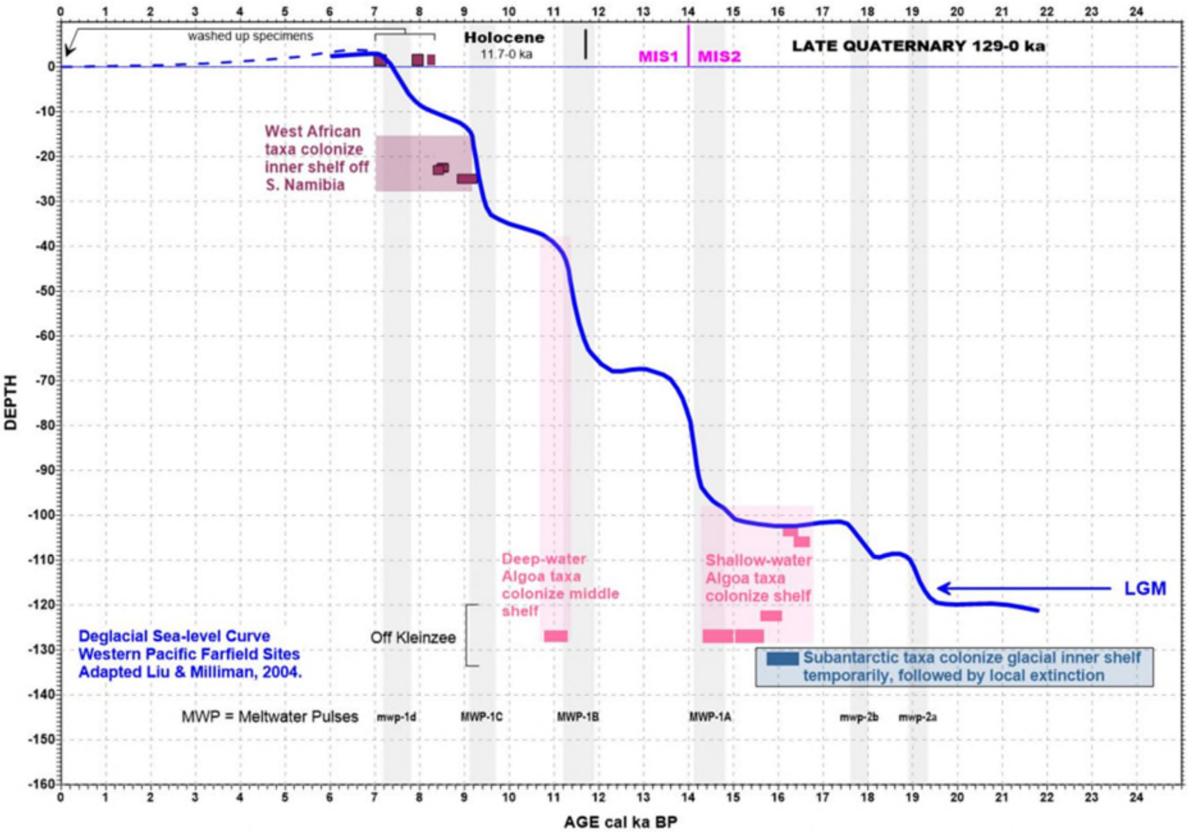



**Figure 7. Sea-level curve for the last deglaciation, showing contexts of dated shells from the West Coast Shelf.**

## 7.4 Shells from the Last Transgression Sequence

Shells from the Last Transgression Sequence refers to the "subfossil" shells that occur abundantly in the sediments accumulated on the shelf during the last 20 thousand years as it was submerged to increasing depths. The marine shell fossils which occur in the LTS are predominantly the species expected on the West Coast Shelf, in a deepening-water faunal succession with littoral epifaunal species in the basal gravels, succeeded by infaunal bivalves in clean sands, succeeded by bivalves adapted to dwelling in the capping sulphidic muds. However, unexpected species and "extralimitals" (species beyond their normal home range) are actually quite common.

For instance, the Last Ice Age palaeoshoreline gravels are dominated by a "Venus shell" clam, *Tawera philomela* (Figure 7). This Subantarctic cold-water species, along with others, reached the Cape coast from the mid-Atlantic islands of Tristan da Cunha and Gough, apparently thrived here and then became extinct locally during the last deglaciation (Pether, 1993). During the subsequent deglaciation/warming, several warm-water species from the south and east coasts "invaded" the western shelf temporarily (Figure 7). This shows a more marked influence of Agulhas water rounding the Cape and affecting the Benguela System during the global-warming steps of the last deglaciation (Pether, 1994). These Agulhas extralimitals have mainly been found during diamond exploration sampling off northern Namaqualand off Kleinzee in the inner part of Concession 5C.

# 8 ANTICIPATED IMPACTS

Fossils are rare objects, often preserved due to unusual circumstances. This is particularly applicable to vertebrate fossils (bones), which tend to be sporadically preserved and have high value with respect to palaeoecological and biostratigraphic (dating) information. Such fossils are non-renewable resources. Provided that no subsurface disturbance occurs, the fossils remain sequestered. The absence of management and operator mitigatory actions to be alert for fossils and retrieve them will result in their loss. This loss of the opportunity to recover fossils and record their contexts when exposed at a particular site is a negative, irreversible impact.

If mitigatory efforts are made to watch out for and rescue the fossils then the impact is positive for palaeontology. However, there remains a medium to high risk of valuable fossils being lost in spite of management actions to mitigate such loss. The fossils may simply not be noticed or not recognized. Even the most diligent attempts at mitigation can only hope to acquire some fraction of the fossils. This is particularly the case if the fossils are sparsely distributed in the deposits, which is generally the case for scientifically-valuable fossil bone material. A misperception exists that if fossils are sparse in a deposit then the intensity of impact will be low. This is not the case as it is the valuable fossils that are usually scarce, such as fossil bones. The very scarcity of such fossils makes for the added importance of watching for them.

The grab samples are purposed for obtaining the upper, modern fauna and are unlikely to capture fossils which are usually lower down. Notwithstanding, the grabs may capture poorly-known modern species.

In the vibracores the small volumes involved greatly reduce to likelihood of capturing the sparse fossils reworked from the older, pre- late Quaternary formations and the "extralimitals" in the Last Transgression Sequence. However, should extralimital Subantarctic and Agulhas species occur in the cores they are more important specimens than those selected from the loose, mixed shells crossing the oversize screens on sampling/mining vessels, as they have context in the geological and faunal succession in the core and the expense to have specimens radiocarbon dated is more worthwhile.

The drillship sampling involves a considerable volume of the shelf deposits (up to 1500 sites). For the most part the excavated material is the Last Transgression Sequence deposits with expected "subfossil" extant shell species and a 'sprinkling" of scientifically important extralimital species and rare reworked old fossil shells, bones and teeth in the gravels.

## 8.1 EXTENTS

In mining the fossil content of a prescribed volume of deposit is destroyed which is the physical extent of the impact. *i.e*. the extent is local.

On the other hand, fossils uncovered during mining of the coastal plain and offshore are often of sufficient note to publish about them which is a scientific impact on a national to international scale.

For example, the occurrence of fossil woods, the whale fossils, and the Subantarctic, Algoa and West African subfossil shells, are published in the international scientific literature.

## 8.2 DURATION

The impact of both the finding or the loss of fossils is permanent. Destroyed fossils are lost to posterity. The found fossils must be preserved for posterity.

## 8.3 INTENSITY

The intensity/magnitude of the potential impacts of subsurface excavations on fossil resources is determined by the palaeontological sensitivity of the affected formations - the potential scientific value of the fossils which are included in it (Appendix 1), together with the degree or volume of disturbance.

### 8.3.1 Cretaceous Fossil Wood

During sampling and mining on the middle shelf, pebbles, cobbles and small boulders of both silicified wood and black lignitic wood, which occur in the Latest Quaternary basal gravels, are fairly routinely sucked up from the seabed, rattle rapidly over the oversize screen and then disappear back overboard again. Although the fossil wood is not *in situ* in the source formation, the specimens are accorded a MODERATE palaeontological sensitivity due to the scientific value.

### 8.3.2 Cenozoic Shelly Macrofauna

The moulds of dissolved shells in cobbles and boulders derived from Miocene and Eocene formations preserve the external sculpture and are generally identifiable. The loose internal moulds of shells such as gastropod coils and bivalve casts (endocasts, also called steinkerns), which are quite common in the Quaternary gravels, are less easy to identify when worn, unless of taxa with very distinctive shapes. In rare places on the middle shelf practically pristine fossil shells are drilled up in from sample sites penetrating Miocene footwall. The impact of sampling on the Cenozoic shelly macrofauna is considered to be MODERATE.

### 8.3.3 Fossil Bones and Teeth

This category includes fossil bones and teeth of any origin as there is no purpose for distinctions when they must be captured before going overboard. Recent “fresh” bones such as those of seals and fish, and pieces of freshly-broken whalebone ribs, are common and are excluded. This fossil material is phosphatized (petrified) to various degrees and probably also worn by transport and/or pitted by boring organisms. This material is scarce, but the large volumes involved increase the probability that some will be encountered and could be of HIGH scientific value.

### 8.3.4 Shells from the Last Transgression Sequence

Quaternary fossil shell assemblages consist mainly of well-known, usual taxa and it is the unexpected, out of range or unknown shell species which are important. The concern here are shell species which are not typical of the normal faunal assemblages of the Namaqua shelf and are generally sparse, although several may occur in the same area. It is important to obtain a comprehensive sample of the Algoa species extralimital occurrences for future study. In addition to radiocarbon dating the incursions on Agulhas influence, the individual shells are snapshot archives of the palaeoceanographic conditions at the time, as revealed by incremental analyses of the shell stable isotopes and trace elements. Sampling in Concession 6C has a strong potential to yield fossil shells of extralimital Algoa species and is accorded MODERATE palaeontological sensitivity.

## 8.4 REVERSIBILITY

Palaeontological resources are unique and their loss is IRREVERSIBLE.

### 8.5 IRREPLACEABILITY

Without mitigation and rescue of fossils there will be a COMPLETE LOSS OF RESOURCES within the footprints of sampling and mining. Valuable fossils will be lost despite management actions to mitigate such loss.

### 8.6 CUMULATIVE IMPACT

The cumulative impact of coastal and offshore sampling and mining is the inevitable and permanent loss of fossils and the associated scientific implications. As mentioned, the impact of both the finding and the loss of fossils is permanent. Diligent and successful mitigation contributes to a positive cumulative impact as some fossils are rescued and preserved and accumulated for scientific study.

### 8.7 IMPACT SUMMARY TABLES

The following impact tables primarily refer to drillship sampling.

| **Cretaceous Fossil Wood** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Extent** | **Duration** | **Intensity** | **Consequ.** | **Probability** | **Significance** | **Status** | **Confidence** |
| **Without mitigation** | Local 1 | Permanent 3 | Medium 2 | Medium 6 | Probable | MEDIUM | -'ve | M |
| Essential mitigation measures<br>• Prospecting EMPr must include provisions for the collection of representative examples of the fossils.<br>• Geological staff involved in logging to be informed of the need to watch for fossil wood and rescue such from the gravel oversize screen.<br>• Fossils to be labelled and bagged, with recording of context data, and stored.<br>• Appointed palaeontologist to evaluate fossils collected and compile report for company and SAHRA. | | | | | | | | |
| **With mitigation** | Local 1 | Permanent 3 | Medium 2 | Medium 6 | Probable | MEDIUM | +'ve | M |

| **Cenozoic Shelly Macrofauna** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Extent** | **Duration** | **Intensity** | **Consequ.** | **Probability** | **Significance** | **Status** | **Confidence** |
| **Without mitigation** | Local 1 | Permanent 3 | Medium 2 | Medium 6 | Probable | MEDIUM | -'ve | M |
| Essential mitigation measures<br>• Prospecting EMPr must include provisions for the collection of representative examples of the fossils.<br>• Geological staff involved in logging to be informed of the need to watch for fossil shells and rescue such from the gravel oversize screen.<br>• Fossils to be labelled and bagged, with recording of context data, and stored.<br>• Appointed palaeontologist to evaluate fossils collected and compile report for company and SAHRA. | | | | | | | | |
| **With mitigation** | Local 1 | Permanent 3 | Medium 2 | Medium 6 | Probable | MEDIUM | +'ve | M |

| **Fossil Bones and Teeth** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Extent** | **Duration** | **Intensity** | **Consequ.** | **Probability** | **Significance** | **Status** | **Confidence** |
| **Without mitigation** | Local 1 | Permanent 3 | High 3 | High 7 | Improbable | MEDIUM | -'ve | M |
| Essential mitigation measures<br>• Prospecting EMPr must include provisions for the collection of representative examples of the fossils.<br>• Geological staff involved in logging to be informed of the need to watch for fossil bones and teeth and rescue such from the gravel oversize screen.<br>• Fossils to be labelled and bagged, with recording of context data, and stored.<br>• Appointed palaeontologist to evaluate fossils collected and compile report for company and SAHRA. | | | | | | | | |
| **With mitigation** | Local 1 | Permanent 3 | High 3 | High 7 | Probable | MEDIUM | +'ve | M |

| Shells from the Last Transgression Sequence | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Extent** | **Duration** | **Intensity** | **Consequ.** | **Probability** | **Significance** | **Status** | **Confidence** |
| **Without mitigation** | Local 1 | Permanent 3 | Medium 2 | Medium 6 | Possible | LOW | -'ve | M |
| Essential mitigation measures<br>• Prospecting EMPr must include provisions for the collection of representative examples of the fossils.<br>• Geological staff involved in logging to be informed of the need to watch for unusual shells and rescue such from the gravel oversize screen, as well as from grab samples and vibracores.<br>• Fossils to be labelled and bagged, with recording of context data, and stored.<br>• Appointed palaeontologist to evaluate fossils collected and compile report for company and SAHRA. | | | | | | | | |
| **With mitigation** | Local 1 | Permanent 3 | Medium 2 | Medium 6 | Possible | LOW | +'ve | M |

# 9 RECOMMENDATIONS

**Figure 8. The gravel oversize screen on a typical diamond mining vessel where the geological personnel monitor the material being dredged and where fossil collection takes place.**

The exploration and mining for diamonds in the marine environment is a once-off, never to be repeated opportunity to obtain fossils from various areas of the continental shelf, from deposits of various ages. It is cutting-edge, commercially-driven exploration at a scale and detail unaffordable by the state. In order to not overlook such opportunity to advance science co-operatively, the ambit of contemporary environmental management includes such concerns. The additional input from fossil information will be of benefit for the geological interpretation of the deposits. A find of an important fossil can generate favourable publicity. In the longer term, the offshore fossil heritage should also be made available in more permanent exhibitions at an appropriate facility.

The EMPr for the prospecting must therefore include provisions for the collection of representative examples of the fossils that occur therein. As part of Environmental Awareness Training, geological staff involved in logging must be informed of the need to watch for fossil material and rescue such from the gravel oversize screen.

The prospecting/mining company must apply to SAHRA for a general permit to destroy, damage, excavate, disturb and collect fossils identified during sampling and mining, as per the NHRA.

### 9.1 MITIGATION - VIBRACORES AND GRAB SAMPLES

Fossils may be found during the processing of the vibracores and grab samples. These may be obvious, such as petrified bone and teeth and shell casts, usually phosphatic. All material of potential interest must have the details of context recorded and be kept for identification by an appropriate specialist and if significant, to be deposited in a curatorial institution such as the IZIKO SA Museum.

The identification of extralimital, Agulhas/Algoa "subfossil" shell species in the loose shells of the Last Transgression Sequence requires a level of seashell knowledge. The best outcome for a set of cores is that they are the subject of a detailed study, such as for a B.Sc. Honours or M.Sc. project, with radiocarbon dates. It is possible that a core or two might intersect rarely preserved lagoonal deposits which are important for providing points on the sea-level curve applicable to the West Coast (Runds *et al*., 2019).

### 9.2 MITIGATION - COLLECTION OF FOSSIL MATERIAL DURING BULK SAMPLING

As part of the normal sampling and mining process the material crossing the oversize screen (Figure 8) must be monitored for the occurrence of the various fossil types. Potential fossil material should be collected for later identification and evaluation.

Data to be recorded during fossil collection includes:

- Date
- Company name
- Sample no.
- Collector's name
- Position (co-ordinates)
- Water depth
- Sample subsurface depth
- Vessel
- Brief description and photographs
- A copy of the graphic log of the sample drill hole or mining face showing the vertical sequence of units and the estimated location of the fossil in the sequence.
- A map of the fossil finds in the particular sampling/mining area, such as a contoured multibeam bathymetric image showing the context of samples in relation to the bedrock topography and sediment bodies.

During all operations, personnel can send queries and images by email to an appointed palaeontologist for evaluation and prompt feedback.

Collected samples are to be temporarily stored by the company.

When a collection of fossil material has been accumulated, the appointed palaeontologist should undertake the identification and evaluation of the fossil material and compile the report for submission to SAHRA. A selection of material could be removed for further study. The Environmental

Manager/Officer) is to liaise with the appointed palaeontologist on the progress of the fossil collection and the scheduling of the evaluation.

## 10 REFERENCES


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

Bamford M.K. & Stevenson I.R. 2002. A submerged Late Cretaceous podocarpaceous forest, west coast, South Africa. S. Afr. J. Sci. 98, 181–185.

Bamford, M.K. & Corbett, I.B. 1994. Fossil wood of Cretaceous age from the Namaqualand continental shelf, South Africa. Palaeontologia Africana 31: 83-95.

Bianucci, G., Lambert. O. & Post, K. 2007. A high diversity in fossil beaked whales (Odontoceti, Ziphiidae) recovered by trawling from the sea floor off South Africa. Geodiversitas 29(4); 5–62.

Bianucci, G., Post K. & Lambert, O. 2007. Beaked whale mysteries revealed by seafloor fossils trawled off South Africa. South African Journal of Science 104; 140-142.

Birch, G.F., Day, R.W. & Du Plessis, A. 1991. Nearshore Quaternary sediments on the West Coast of southern Africa. Geological Survey of South Africa Bulletin 101. 14 pp.

De Wet, W. M. 2012. Bathymetry of the South African continental shelf. M.Sc thesis, Department of Geological Sciences, University of Cape Town. 255 pp.

Dingle, R.V. & Siesser, W.G. 1977. Geology of the continental margin between Walvis Bay and Ponto do Ouro. Map - Geological Survey of South Africa Marine Geoscience Series.

McMillan, I.K. 2003. Foraminiferally defined biostratigraphic episodes and sedimentation pattern of the Cretaceous drift succession (Early Barremian to Late Maastrichtian) in seven basins on the South African and southern Namibian continental margin. South African Journal of Science 99: 537-576.

O'Shea, D. O'C. 1971. An outline of the inshore submarine geology of southern South West Africa and Namaqualand. MSc thesis, University of Cape Town.

Pether, J. 1993. Relict shells of Subantarctic Mollusca from the Orange Shelf, Benguela Region, off southwestern Africa. The Veliger 36 (3): 276-284.

Pether, J. 1994. Molluscan evidence for enhanced deglacial advection of Agulhas water in the Benguela Current, off southwestern Africa. Palaeogeography, Palaeoclimatology, Palaeoecology 111: 99-117.

Runds, M.J., Bordy, E.M. & Pether, J. 2019. Late Quaternary sedimentological history of a submerged gravel barrier beach complex, southern Namibia. Geo-Marine Letters 39: 469-491.

Pether, J. 1995. *Belichnus* new ichnogenus, a ballistic trace on mollusc shells from the Holocene of the Benguela region, South Africa. Journal of Paleontology 69: 171-181.

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

Stevenson I.R. & Bamford, M. 2003. Submersible-based observations of in situ fossil tree trunks in Late Cretaceous seafloor outcrops, Orange Basin, western offshore, South Africa. South African Journal of Geology 106: 315-326.

Stevenson, I.R. & McMillan, I.K. 2004. Incised valley fill stratigraphy of the Upper Cretaceous succession, proximal to the Orange Basin, Atlantic margin of southern Africa. Journal of the Geological Society, London, 161, 185-208.


---oooOOOooo---

## 11 APPENDIX 1 - PALAEONTOLOGICAL SENSITIVITY RATING

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

Applicable to the Intensity/Magnitude rating in Palaeontological Assessments.

**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.*

## 12 APPENDIX 2 - CURRICULUM VITAE

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

Independent Consultant/Researcher recognized as an authority with 40+ 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). 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**

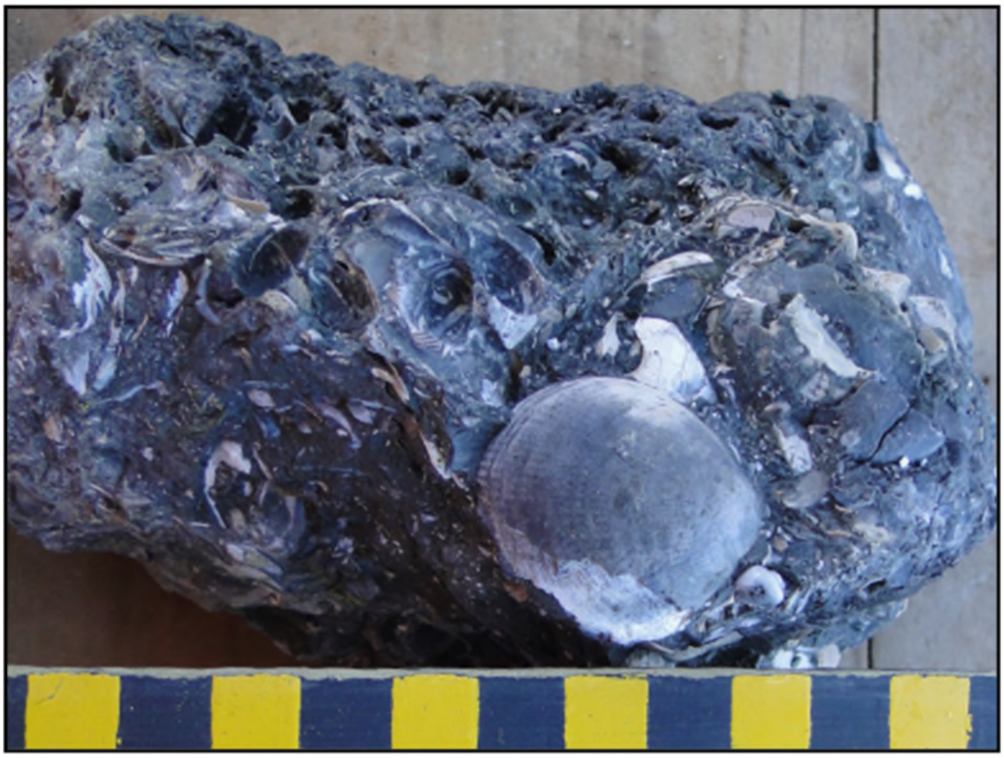
| | |
|---|---|
| AECOM SA (Pty) Ltd. | Guillaume Nel Environmental Management Consultants. |
| Agency for Cultural Resource Management (ACRM). | Klomp Group. |
| AMATHEMBA Environmental. | Megan Anderson, Landscape Architect. |
| Anél Blignaut Environmental Consultants. | Ninham Shand (Pty) Ltd. |
| 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**

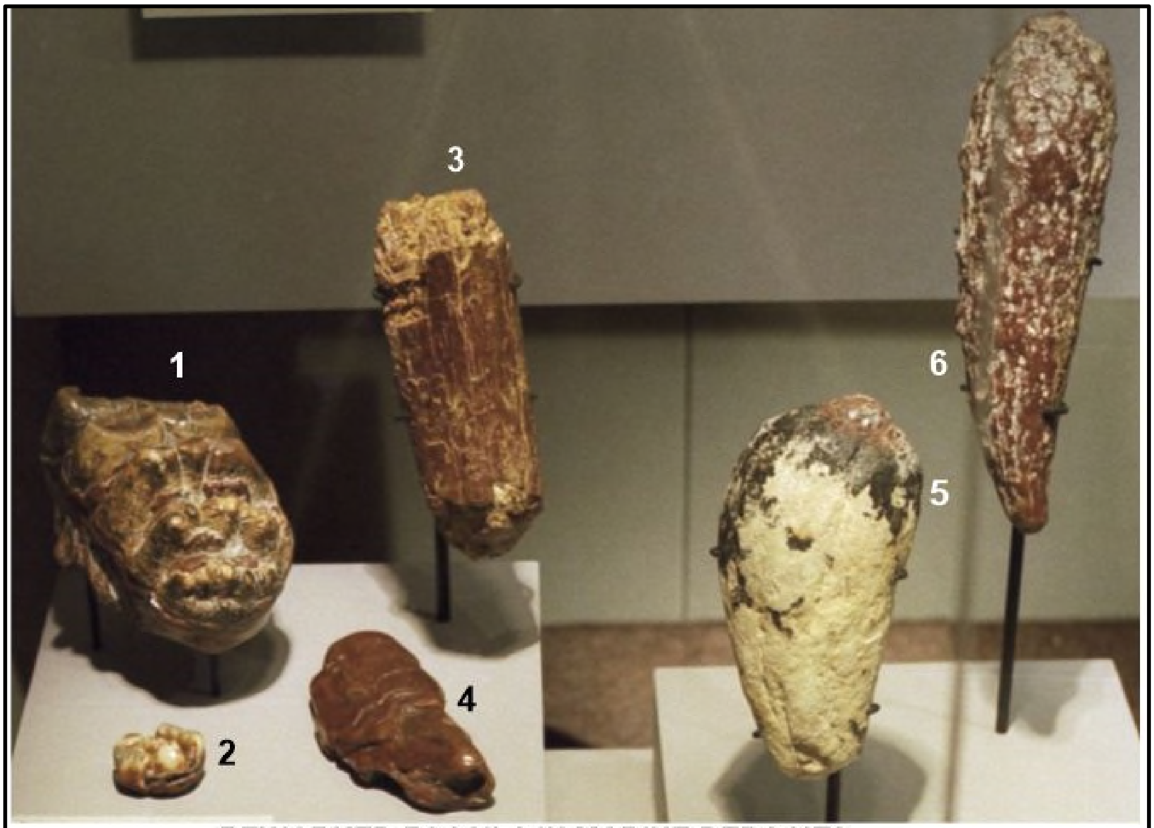
| | |
|---|---|
| Afri-Can Marine Minerals Corp | Council for Geoscience |
| De Beers Marine (SA) Pty Ltd. | De Beers Namaqualand Mines. |
| Geological Survey Namibia | IZIKO South African Museum. |
| Namakwa Sands (Pty) Ltd | NAMDEB |

## 13 APPENDIX 3. EXAMPLES OF FOSSILS

**A3-1. Beach cobbles of petrified fossil wood, together with some small cobbles of black lignitic wood.**



**A3-2. Example of cemented Miocene hardground with shell moulds.**



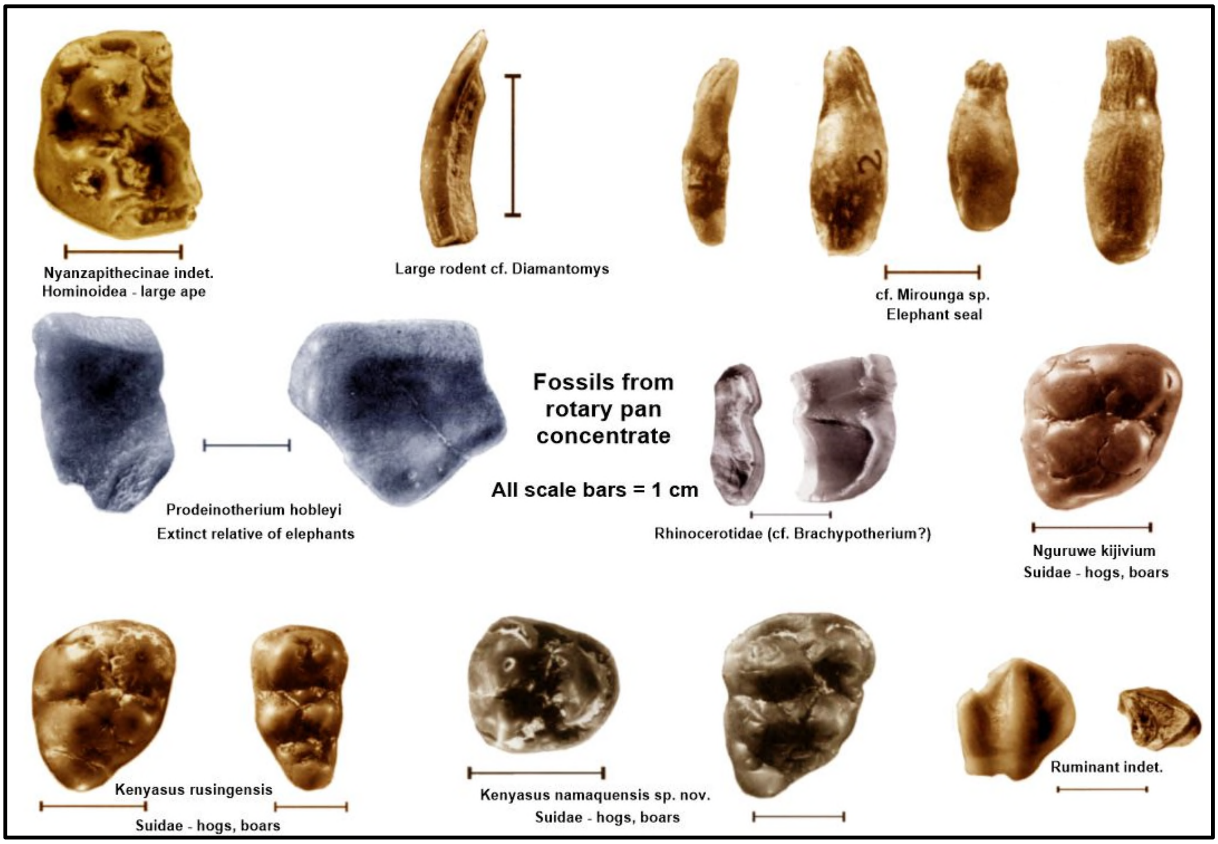

**REWORKED FOSSILS IN MARINE DEPOSITS**


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

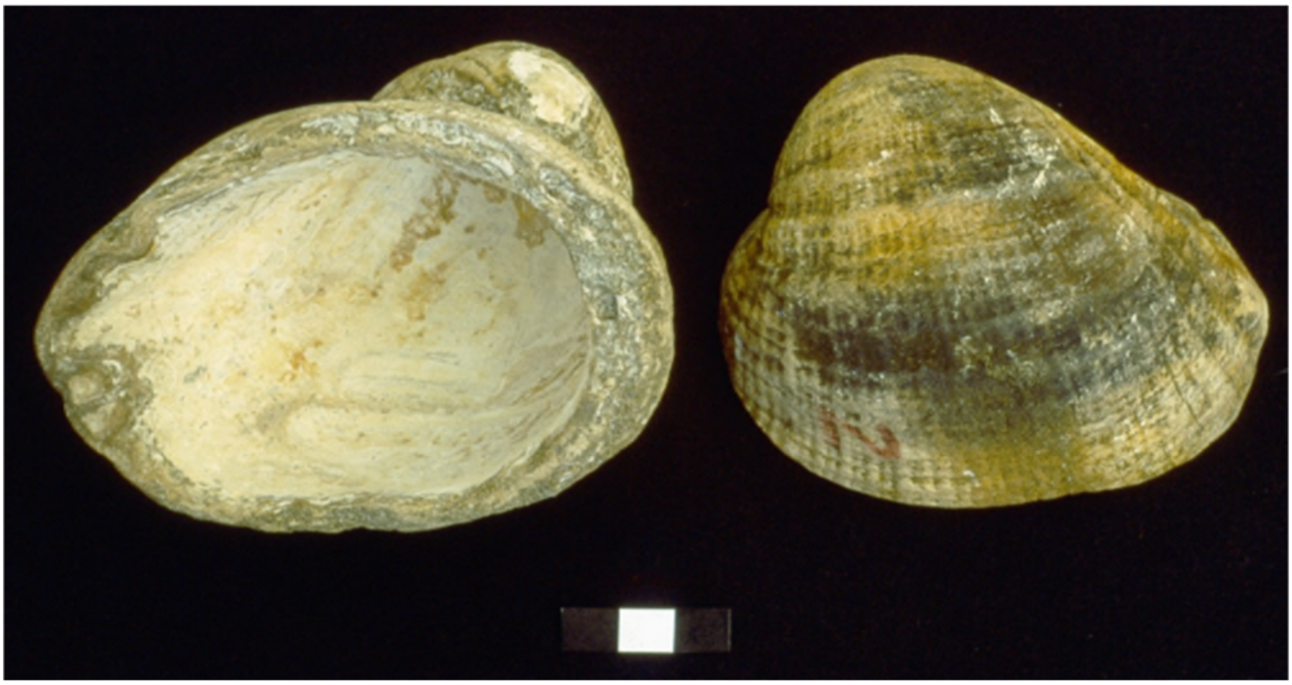
**A3-3. Examples of reworked petrified bones in marine basal gravels.**

**A3-4. Example of a fossil whale tympanic earbone.**

**A3-5. The extinct giant sperm whale *Livyatan melvillei* – similar teeth occur in marine basal gravels cf. A2-3 5 & 6. Reconstructed skull at the Natural History Museum of the University of Pisa, Italy. (https://en.wikipedia.org/wiki/Livyatan).**




**A3-6: Examples of abraded, small petrified teeth from concentrate which are nevertheless identifiable and of very high scientific importance.**



**A3-7: *Concholepas concholepas*, a large gastropod which at present lives along the coasts of Peru and Chile in South America. Found by diamond divers below sea-level near the Orange River and also just south of the Olifants River mouth.**


**A3-8. Extralimital Algoa species found off Namaqualand which are not expected on the West Coast.**



**A3-9. Extralimital Algoa species found off Namaqualand which are not expected on the West Coast.**