PALAEONTOLOGICAL ASSESSMENT

(DESKTOP STUDY)

PROSPECTING RIGHT APPLICATION FOR SEA CONCESSION 12B

INNER CONTINENTAL SHELF OFF OLIFANTSRIVIER MOUTH, WESTERN CAPE

By

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Prepared at the Request of

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Client

Nisarox (Pty) Ltd.

For

13 February 2023

SUMMARY

Site

Diamond Sea Concession 12B off the central Namaqualand coast. Prospecting Right Application by Nisarox (Pty) Ltd.

Location

Sea Concession 12B (~11167 ha) is located just north of the Olifantsrivier (Figure 1) and extends northwards from the Olifantsrivier mouth for ~34 km, is ~1 to ~5 km offshore and ~2 to ~4 km wide and encompasses inner-shelf water depths ranging from ~-20 m to ~-80 m below sea level (bsl.) (Figure 2).

Proposed Activities

The proposed prospecting is intended to be accomplished in phases:

- Phase 1 - Geophysical Survey – Multibeam Swath Bathymetry to derive a high-resolution map of the topography of the seabed and shallow seismics to acquire sub-bottom profiles.
- Phase 2a – Vibracoring and Grab Sampling – In depths shallower than ~100 m a vibracorer will be deployed at 100-200 sites to acquire cores of ~10 cm in diameter and up to ~3 m in length. Surface sediments may be sampled at 20-50 sites using a Van Veen grab sampler.
- Phase 2b – Drillship Sampling – To be undertaken by a chartered drillship with a capability of drilling a cased hole 2.5 m in diameter (5 m^2) and up to 12 m deep in weakly-lithified sediments.
- Phase 3 - Up to 10 bulk sampling trenches, each 180 m long, 20 m wide and 5 m deep.
  - Phase 3a – Remote Dredge Pump Mining – Shallow water.
  - Phase 3b – Remote Seabed Crawler Mining – Deeper water.
- Phase 4 - Feasibility Studies - Involves consideration of all factors and potential costs of defining and exploiting the diamond resource.

Impacted Palaeontological Resources

For the most part the affected sediments are those of the **Last Transgression Sequence** (**LTS**) deposited since 12 thousand years ago when sea level rose across the inner-shelf Precambrian bedrock from the low levels of the Last Ice Age and consisting of basal gravels and subsequent sands to muddy fine sands deposited with increasing depths.

Reworked petrified Cretaceous and Miocene fossil wood is sparsely present in the LTS gravels in the form of transported, worn cobbles and pebbles. Medium Significance.

Fossil shells transported from offshore Cenozoic formations (Eocene and Miocene) may occur sparsely in the form of black, phosphatic shell casts, but are usually in poor condition. Low Significance.

Fossil bones and teeth reworked from the older formations also occur in the LTS gravels. This material is scarce, but the large volumes involved increase the probability that some will be encountered and are of high scientific value. Medium-high Significance.

The marine shell “subfossils” which occur in the LTS are predominantly the species expected on the West Coast Shelf. However, unexpected species and “extralimitals” (species beyond their normal home range) are quite common and include Algoa and West African species which populated the western shelf at times when the Benguela Upwelling System was subjected to changed conditions due to climatic/oceanographic oscillations during the last deglaciation. These specimens are of considerable scientific interest. Medium Significance.

Recommendations

The Environmental Management Plans for offshore prospecting and mining must include provisions for the collection of representative examples of the fossils that occur. 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 vibracores, grabs and the gravel oversize screen during bulk sampling by large-diameter airlift drilling, remote dredging and seabed crawler. 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 legislation.

The palaeontological impact of the vibracoring and grab sampling in Concession 12B is considered to be negligible, in view of the minimal volumes of sediment affected. 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. 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.

During bulk sampling by a drillship, dredger and seabed crawler, as part of the normal sampling/mining process, the material crossing the oversize screen (Figure 6) must be monitored for the occurrence of the various fossil types. Potential fossil material should be collected for later identification and evaluation, with labelling and recording of the find data.

Collected samples are to be 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.

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

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CONTENTS

SPECIALIST DETAILS, EXPERTISE AND DECLARATION

CURRICULUM VITAE

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

Independent Consultant/Researcher recognized as an authority with 37 years' experience in the field of coastal-plain and continental-shelf palaeoenvironments, fossils and stratigraphy, mainly involving the West Coast/Shelf of southern Africa. Has been previously employed in academia (South African Museum) and industry (Trans Hex, De Beers Marine). At present an important involvement is in Palaeontological Impact Assessments (PIAs) and mitigation projects in terms of the National Heritage Resources Act 25 (1999) (~300 PIA reports to date) and is an accredited member of the Association of Professional Heritage Practitioners (APHP). Continues to be involved as consultant to offshore and onshore marine diamond exploration ventures. Expertise includes:

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

Membership of Professional Bodies

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

Past Clients Palaeontological Assessments

AECOM SA (Pty) Ltd.	Guillaume Nel Environmental Management Consultants.
Agency for Cultural Resource Management (ACRM).	Klomp Group.
AMATHEMBA Environmental.	Megan Anderson, Landscape Architect.
Anél Blignaut Environmental Consultants.	Ninham Shand (Pty) Ltd.
Arcus Gibb (Pty) Ltd.	PD Naidoo & Associates (Pty) Ltd.
ASHA Consulting (Pty) Ltd.	Perception Environmental Planning.
Aurecon SA (Pty) Ltd.	PHS Consulting.
BKS (Pty) Ltd. Engineering and Management.	Resource Management Services.
Bridgette O'Donoghue Heritage Consultant.	Robin Ellis, Heritage Impact Assessor.
Cape Archaeology, Dr Mary Patrick.	Savannah Environmental (Pty) Ltd.
Cape EAPrac (Cape Environmental Assessment Practitioners).	Sharples Environmental Services cc
CCA Environmental (Pty) Ltd.	Site Plan Consulting (Pty) Ltd.
Centre for Heritage & Archaeological Resource Management (CHARM).	SRK Consulting (South Africa) (Pty) Ltd.
Chand Environmental Consultants.	Strategic Environmental Focus (Pty) Ltd.
CK Rumboll & Partners.	UCT Archaeology Contracts Office (ACO).
CNdV Africa	UCT Environmental Evaluation Unit
CSIR - Environmental Management Services.	Urban Dynamics.
Digby Wells & Associates (Pty) Ltd.	Van Zyl Environmental Consultants
Enviro Logic	Western Cape Environmental Consultants (Pty) Ltd, t/a ENVIRO DINAMIK.
Environmental Resources Management SA (ERM).	Wethu Investment Group Ltd.
Greenmined Environmental	Withers Environmental Consultants.

Stratigraphic consulting including palaeontology

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

DECLARATION OF INDEPENDENCE

PALAEONTOLOGICAL ASSESSMENT

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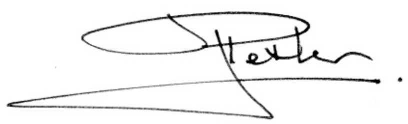
Terms of Reference

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: 13 February 2023

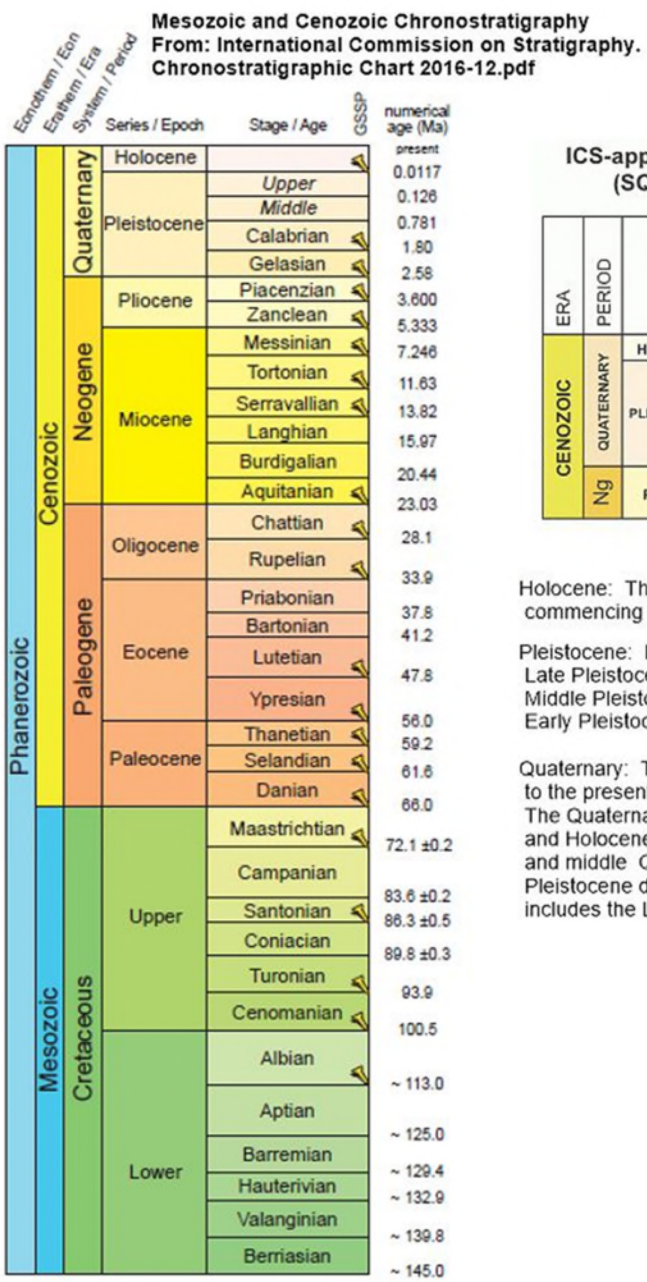
GEOLOGICAL TIME SCALE TERMS

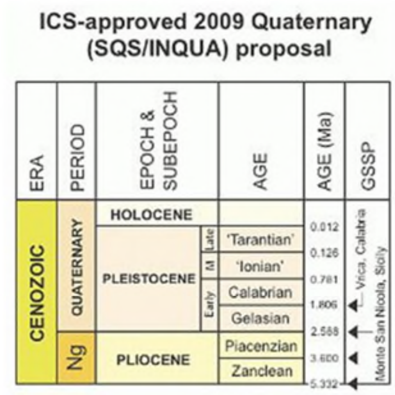
For more detail see www.stratigraphy.org.

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

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





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, Nisarox (Pty) Ltd., proposes to carry out geological exploration for diamonds in Sea Concession 12B off southern Namaqualand (Figure 1). Consultant Philip le Roux has been appointed to facilitate the Prospecting Right Application process for the proposed exploration activities. Maritime Archaeologist Vanessa Maitland has been appointed to undertake the Heritage Study to inform the application process. This report is the contribution to the Heritage Impact Assessment and it describes the potential palaeontological heritage which may be affected by the proposed activities.

2 LOCATION

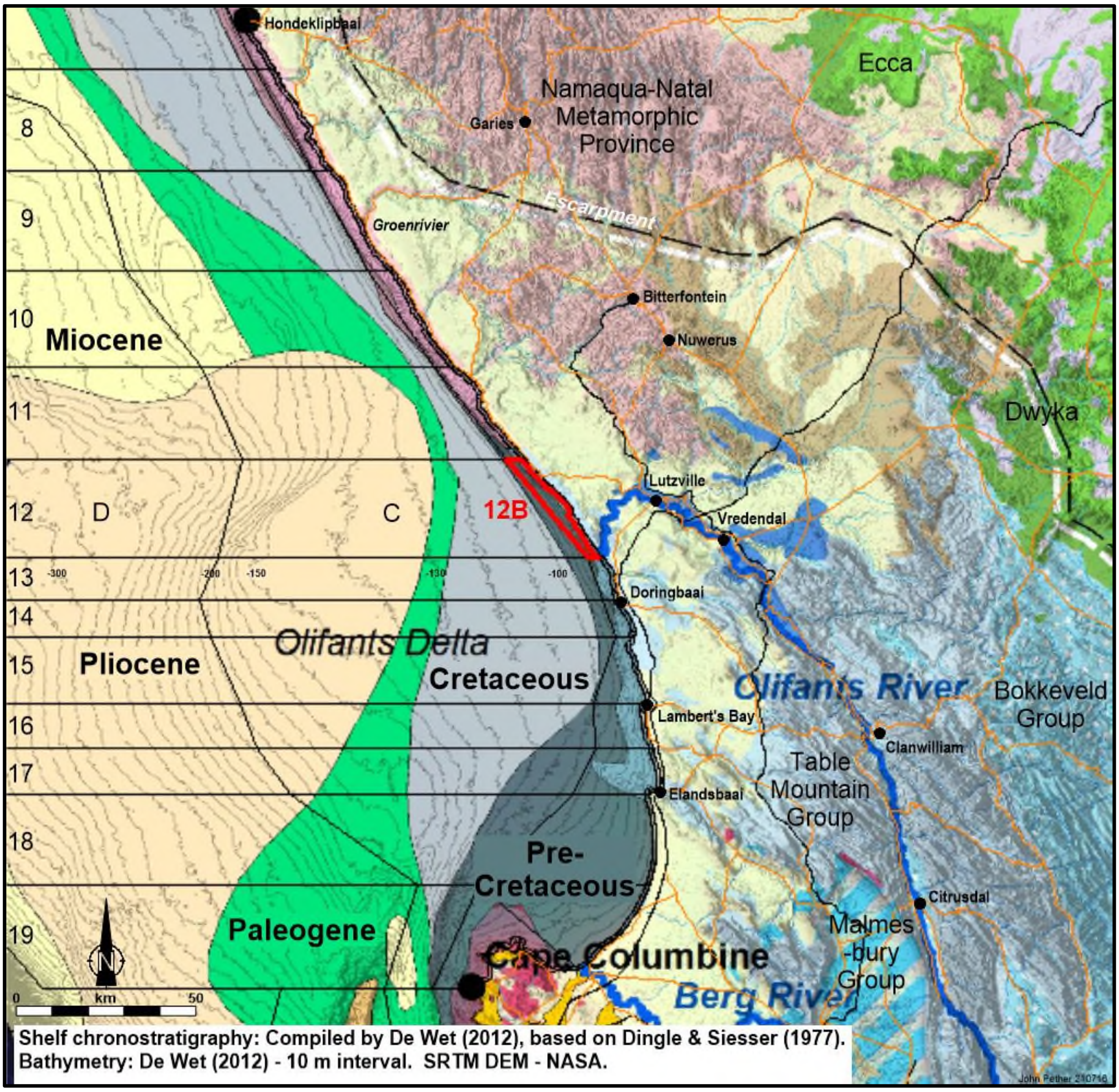


Figure 1. Location of Sea Concession 12B and regional geological context.

Sea Concession 12B (~11167 ha) is located just north of the Olifantsrivier (Figure 1) and extends northwards from the Olifantsrivier mouth for ~34 km opposite the coastal farms De Punt, Geelwal Karoo and Klipvley Karoo Kop, is ~1 to ~5 km offshore and ~2 to ~4 km wide and encompasses inner-shelf water depths ranging from ~-20 m to ~-80 m below sea level (bsl.) (Figure 2).

3 PROPOSED ACTIVITIES

The proposed prospecting is intended to be accomplished in phases:

PHASE 1 - GEOPHYSICAL SURVEY

A geophysical survey vessel will undertake acquisition of Multibeam 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. The data will be interpreted and targets for sampling will be defined.

PHASE 2 – EXPLORATION SAMPLING

Phase 2a – Vibracoring and Grab Sampling – In depths shallower than ~30 m a vibracorer will be deployed at 100-200 sites to acquire cores of ~10 cm in diameter and up to ~3 m in length. Surface sediments may be sampled at 20-50 sites using a Van Veen grab sampler.

Phase 2b – Drillship Sampling – Deeper water. To be undertaken by a chartered drillship with dynamic positioning and operating a large-diameter airlift drill making cased hole 2.5 m in diameter (5 m^2) and up to 12 m deep in weakly-lithified sediments. Effective airlift dredging requires deeper water (>~40 m depth). A maximum of 4 800 drillship sample sites are envisaged.

PHASE 3 – BULK SAMPLING

It is proposed that up to 10 bulk sampling trenches, each 180 m long, 20 m wide and 5 m deep would be excavated within the concession area.

Phase 3a – Remote Dredge Pump Mining – Shallow water. Dredging using powerful pumps and suspended hoses and digging heads

Phase 3b – Remote Seabed Crawler Mining – Deeper water. A seabed mining vessel equipped with a subsea crawler will be deployed to undertake bulk sampling.

PHASE 4 – FEASIBILITY ANALYSIS

Involves consideration of all factors and potential costs of exploiting the mineral resource including sampling grades obtained, mining vessel costs, financial modelling, market risks, taxes, environmental impacts, mitigation *etc*., in order to ascertain the portion of the mineral resource which is a “bankable” mineral reserve which is profitable to mine.

4 GEOLOGICAL SETTING

The seabed geology of the continental shelf in the surrounding area is depicted in Figure 1 which shows overall successively younger formations seawards. The Cretaceous and Paleogene units comprise the main bulk of the Olifants Delta and are succeeded by cappings of Miocene and Pliocene units.

Sea Concession 12B is on the inner shelf where the Pre-Cretaceous bedrock slopes relatively steeply seawards down to the gentle slope developed on the Cretaceous formations (Figure 2A). Extrapolating from the seashore exposures, the inner-shelf bedrock is expected to be mainly comprised of highly deformed, metasedimentary schists, quartzites and limestones of the Gifberg Group which were originally deposited in a rifted ocean basin between 780-760 million years ago (Ma) during the late Precambrian Eon. Older crustal basement gneisses occur in the north while in the southern portion it is possible that some minor outliers of basal Table Mountain Group conglomerates, sandstones and shales could be preserved.

These bedrock formations comprise the “footwall” to overlying, much younger late Quaternary to present-day deposits which for the most part are a veneer over the continental shelf, but are much thicker where they have accumulated in the accommodation provided by the slope break between the steeper inner shelf and the nearly flat middle shelf (Figure 3) where they constitute the “mudbelt”, as illustrated in Figure 2B which shows in excess of 10 m of Holocene mudbelt deposits offshore of 12B. The mudbelt is a composite feature with a lower portion composed of coarse shallow-water sediments deposits during low sea level, overlain by muds accumulated under subsequent deeper water depths.

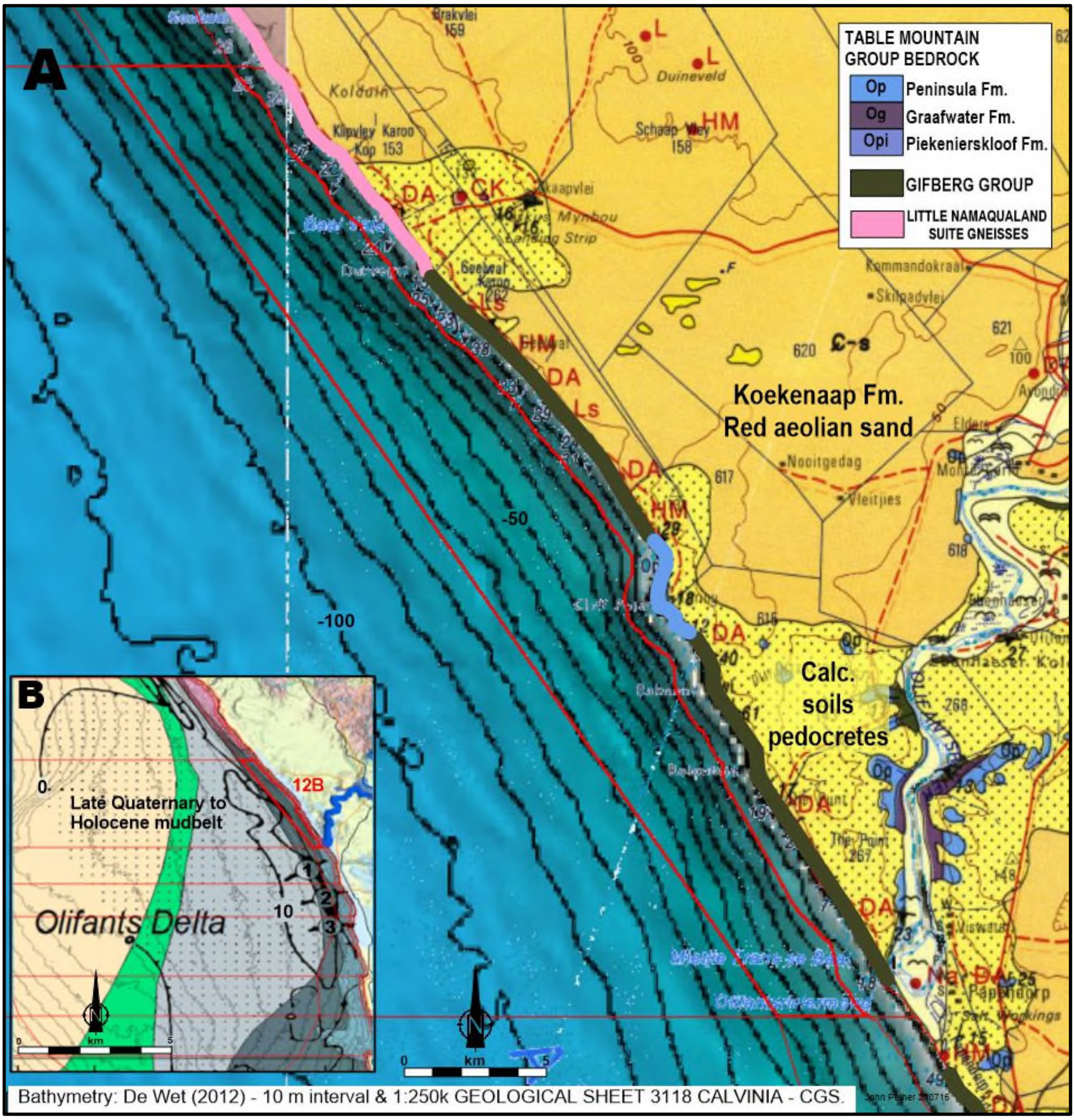


Figure 2. A - Bathymetry of Sea Concession 12B and coastal bedrock geology. B – Basic Quaternary sediment thickness (stippled area) and locations of Figure 3 seismic profiles.

On most of the B-concession inner shelf the sediment distribution is patchy and largely determined by the topography of the bedrock, with gullies and basins with sediment fills interspersed by bedrock high outcrops. The oldest deposits are preserved in deeper and larger bedrock depressions, beneath the latest Quaternary basal gravels which were deposited during the last rise in sea level after the Last Ice Age (Figure 4). The larger bedrock depressions are usually palaeochannels in the Precambrian bedrock and are often the seaward extensions of buried palaeochannels and river valleys on land on the coastal plain.

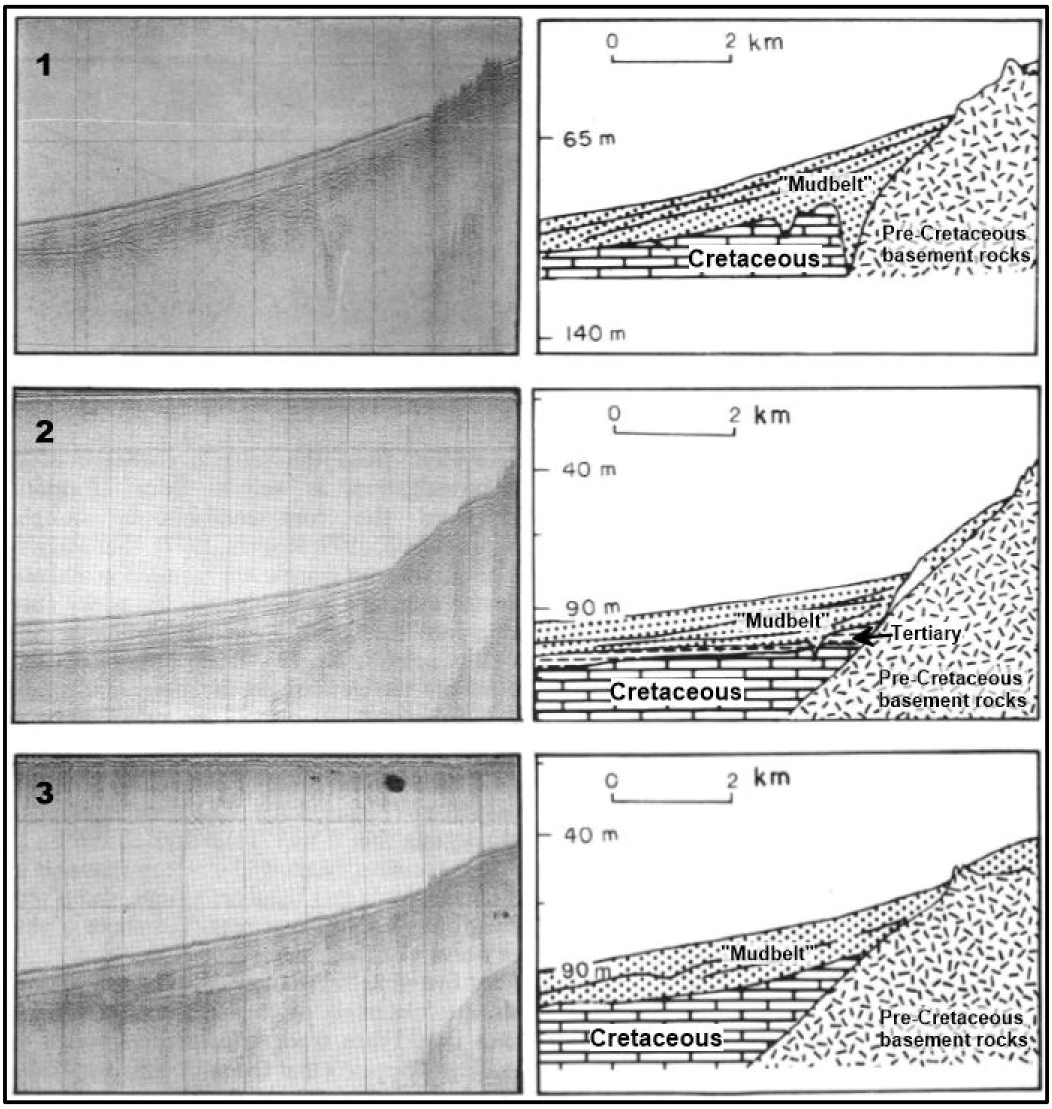


Figure 3. Examples of geophysical seismic profiles illustrating the "mudbelt" sediment wedge overlying the inner to midshelf transition. Adapted from Birch *et al.*, 1991.

For the most part the sediments overlying the inner-shelf bedrock 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 4). 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/basins 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. Large deposits of sediments can also cause the preservation of the underlying, older beds. As shown in Figure 5 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 (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).

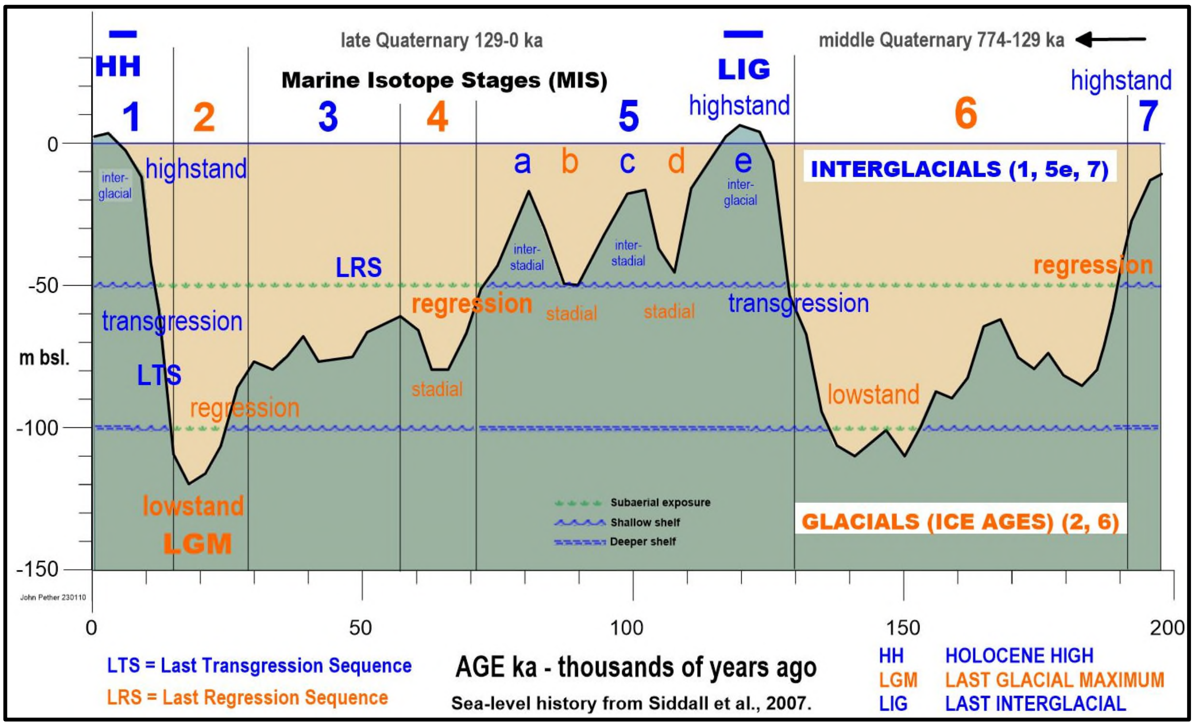


Figure 4. Sea level history and palaeoclimatic nomenclature for the last 200 ka.

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, complete sequence in a bedrock depression at a particular depth can be predicted from Figure 4. For example, a site at -100 m depth would have been submerged since 135 ka and was only subaerially exposed as land near the seashore for a short time of ~10 thousand years (10 kyr) during the LGM. In contrast, a site at ~-50 m depth was emergent and terrestrial for much of the last 200 kyr, being terrestrial for ~60 kyr during the MIS 6 ice age, and again for ~60 kyr during MISs 4, 3 and 2 (Figure 4). A site at -50 m will likely include land deposits with soils and pedocretes, while a site at -100 m would have more limited evidence of subaerial exposure. An idealized sequence in a deeper bedrock depression around -50 m depth on the inner shelf may include all or part of the following (refer to Figure 4):

1. During the **MIS5/6 transgression** the terrestrial deposits of the shoreline were eroded and shoreface gravels and coarse sands were deposited ~130 ka.
2. Succeeding shelf sands deposited during the LIG highstand MIS 5e and the 5c and 5a interstadials would have been reworked during the 5d and 5b regressions and after 5a.
3. Shelly gravels and sandstones deposited ~70 ka during the 5a/4 regression, constituting the base of the **Last Regression Sequence** (LRS).
4. Subaerial exposure for ~60 kyr during MISs 4, 3, 2 and early MIS 1, with deposition of upper LRS terrestrial deposits which may include colluvium, pan deposits and dune sands, with land snails, possible animal remains and perhaps archaeological material, capped by a calcrete.
5. An erosion surface overlain by the basal gravel of the **Last Transgression Sequence** (LTS) (early MIS 1, ~12 ka).
6. Succeeding shelly sand fining up to muddy shelf sand (current interglacial highstand, later MIS 1).

On the inner shelf the thickest terrestrial deposits of the Last Regression Sequence are found in larger, deeper palaeochannels and include aeolian dune sands. More commonly the LRS basal gravels are preserved in some gullies due to cementing under the influence of rain-sourced meteoric groundwater and/or preserved by an overlying calcreted soil, beneath the LTS erosion surface and unconsolidated LTS gravels.

The inner shelf of Sea Concession 12B has more extensive sediment cover than is typical of the inner shelf farther north, due to the sediments delivered by the Olifantsrivier (Figure 3, profiles 2 & 3). The sediment bodies could include the eroded lower beds of barrier beaches, lagoons and dunes formed on top of the deposits of the previous regression, and occurrences possibly associated with meltwater pulses MWP-1B and 1C (Figure 5).

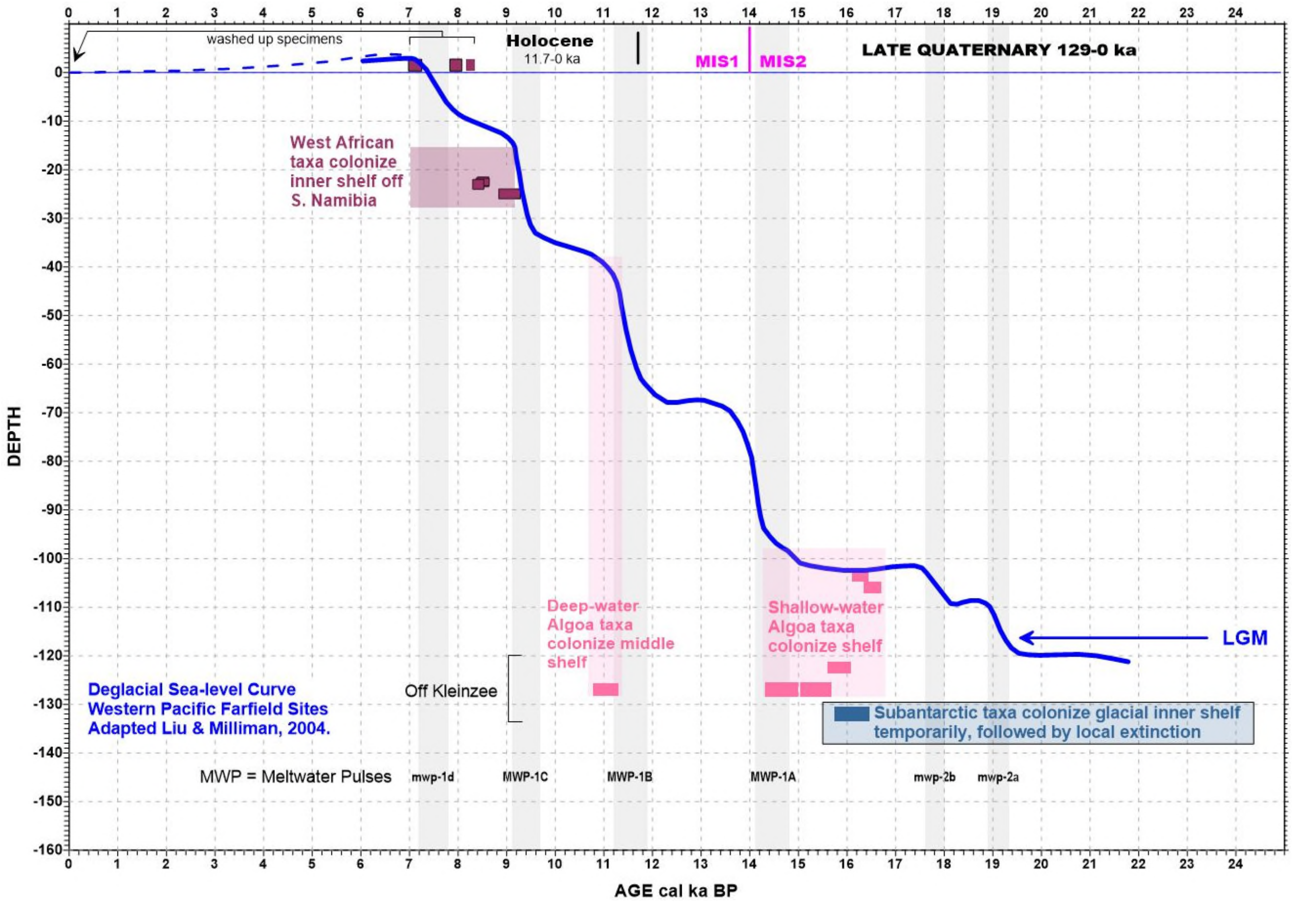


Figure 5. Sea-level curve for the last deglaciation, showing contexts of dated shells from the West Coast Shelf.

5 PALAEONTOLOGICAL HERITAGE

5.1 PETRIFIED FOSSIL WOOD

Cretaceous fossil wood, mainly dating between 120 to 80 Ma, 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, the "Fossil Forests". 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). Rounded cobbles and pebbles of petrified wood are sometimes noticed in gravels on the Precambrian inner-shelf bedrock to where they have been transported during rising sea levels, but are quite rare there and far from the source formation.

Petrified fossil wood also occurs on land in the Olifantsrivier river terrace gravels of mid-Miocene age (20-16 Ma) and the forest tree types present indicate tropical conditions in the Cape during those warm-period times (Bamford, 1999). Most of the mid-Miocene deposits which once infilled the Olifantsrivier valley have been flushed out to sea and may be present on the neighbouring inner shelf.

5.2 CENOZOIC SHELLY MACROFAUNA

The Cenozoic shelly macrofauna comprises black phosphatic shell casts 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.

5.3 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.

5.4 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 4). 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 5). 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. Exploration sampling in 12B in depths of -40 to -70 m will test for the occurrence of Algoa species associated with the second incursion of warm-water species around 12 to 11 ka (Figure 5).

6 ANTICIPATED IMPACT

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 palaeontological impact of the coring and grab sampling in Concession 12B is considered to be negligible, in view of the minimal volumes of sediment affected. 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 grab samples are purposed for obtaining the upper, modern fauna and are unlikely to capture fossils which are usually lower down.

The target areas and number of drillship sample sites will be determined on the basis of interpretation of the geophysical survey. For each metre drilled a 5 m^2 drill footprint delivers ~5 m^3 of material to the gravel screening plant on the vessel. Ignoring the variable thickness of "overburden", each drill hole includes a basal, potentially fossiliferous 5 m^3 of material and up to 24 000 m^3 for up to 4 800 holes.

The bulk sampling involves a considerable volume of the inner shelf deposits and the 10 sampling trenches are "trial mining blocks", each of which involves 180 X 20 m = 3 600 m^2 which, at an average sediment depth of 5 m, entails 18 000 m^3 and 180 000 m^3 for 10 trenches. Ignoring the variable thickness of "overburden", each trench includes a basal, potentially fossiliferous 3 600 m^3 of material and 36 000 m^3 in total.

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 fossil wood, reworked old fossil shells, bones and teeth in the gravels. Older Quaternary deposits of the Last Regression Sequence may be preserved in places.

6.1 EXTENTS

In sampling and 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 sampling and 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 discoveries of the Cretaceous fossil woods, the Miocene petrified whale fossils and the Subantarctic, Algoa and West

African molluscan taxa in the Last Transgression Sequence, are all published in the international scientific literature.

6.2 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.

6.3 INTENSITY

The intensity of the potential impact of mining 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. Overall, the palaeontological sensitivity of marine deposits is HIGH (Almond & Pether, 2009) due to a few, crucial fossil bone finds of high scientific importance that provided the age constraints for the formations. However, there are complications as marine formations usually contain more than one type of fossil of differing importance, *e.g.* common shells and rare bones. Quaternary fossil shell assemblages consist mainly of well-known, usual taxa and it is the unexpected, out of range or unknown, new shell species which are important to distinguish from the expected, common species.

6.3.1 Petrified Fossil Wood

Although reworked petrified Cretaceous fossil wood is sparsely present in the inner-shelf LTS gravels it is in the form of transported, abraded cobbles and pebbles, while the valuable specimens are large well-preserved chunks more directly derived from the Cretaceous formations exposed on the middle shelf. Similarly, Miocene petrified wood is also expected to be much abraded clasts. This impact is therefore LOW.

CRITERIA	WITHOUT MITIGATION	WITH MITIGATION
Extent	National 4	National 4
Duration	Permanent 5	Permanent 5
Intensity	Low 4	Low 4
Probability	Probable 3	Probable 3
Confidence	Medium	Medium
Significance	**Medium negative 39**	**Medium positive 39**
Reversibility	Irreversible	
Mitigation potential	Medium	

6.3.2 Cenozoic Shelly Macrofauna

The 12B inner shelf is far removed from the offshore source area of these fossils which are expected to be very sparse and mostly in the form of worn shell casts, of which only some with distinctive shapes are identifiable. The impact of sampling and mining on the ex-situ Cenozoic shelly macrofauna is considered to be LOW.

CRITERIA	WITHOUT MITIGATION	WITH MITIGATION
Extent	Regional 3	Regional 3
Duration	Permanent 5	Permanent 5
Intensity	Low 4	Low 4
Probability	Improbable 2	Improbable 2
Confidence	Medium	Medium
Significance	**Low negative 24**	**Low positive 24**
Reversibility	Irreversible	
Mitigation potential	Medium	

6.3.3 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 fish and seals are common and are excluded. The fossil material is phosphatized (petrified) to various degrees and 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.

CRITERIA	WITHOUT MITIGATION	WITH MITIGATION
Extent	National 4	National 4
Duration	Permanent 5	Permanent 5
Intensity	High 8	High 8
Probability	Probable 3	Probable 3
Confidence	High	High
Significance	**Medium-high - negative 51**	**Medium-high - positive 51**
Reversibility	Irreversible	
Mitigation potential	Medium	

6.3.4 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 12B has a strong potential to yield fossil shells of extralimital Algoa species and is accorded MODERATE palaeontological sensitivity.

CRITERIA	WITHOUT MITIGATION	WITH MITIGATION
Extent	National 4	National 4
Duration	Permanent 5	Permanent 5
Intensity	Medium 6	Medium 6
Probability	Probable 3	Probable 3
Confidence	High	High
Significance	**Medium - negative 45**	**Medium - positive 45**
Reversibility	Irreversible	
Mitigation potential	Medium	

See Appendices 1 and 2 for Impact Rating Criteria.

6.4 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.

7 RECOMMENDATIONS

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 EMPs for the prospecting and mining rights areas 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 vibracores, grab samples and the gravel oversize screens of the drillship, dredge-ship and crawler vessels.

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.

7.1 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 “sub-fossil” 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 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. 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).

7.2 COLLECTION OF FOSSIL MATERIAL DURING PROSPECTING AND MINING

As part of the normal drillship sampling and bulk sampling processes the material crossing the oversize screen (Figure 6) must be monitored for the occurrence of the various fossil types. Potential fossil material should be collected for later identification and evaluation.

For overall monitoring purposes it is suggested that a few small bulk samples of shells (~5 litres) be collected on occasion. The idea is to sample the typical assemblage at a few points in the sampling/mining area. It is possible that an uncommon assemblage may be encountered, such as a shallow-water fauna or a lagoonal fauna, in which case it should also be sampled.

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.

Figure 6. The gravel oversize screen on a typical diamond sampling vessel where the geological personnel monitor the material being dredged and where fossil collection takes place.

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.

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

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9 APPENDIX 1. 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

10 APPENDIX 2. 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.