SAHRA CASE ID: 13224

PALAEONTOLOGICAL ASSESSMENT

OENA DIAMOND MINE PROSPECTING AND MINING

FOR UPDATE OF THE ENVIRONMENTAL MANAGEMENT PROGRAMME

AFRICAN STAR MINERALS (PTY) LTD.

MINERAL LEASE AREA, FARM 18, RICHTERSVELD MUNICIPALITY, NAMAKWALAND MAGISTERIAL DISTRICT, NORTHERN CAPE

SAMRAD REFERENCE NCS 30/5/1/2/3/2/1(553) MR

By

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For

African Star Minerals (Pty) Ltd.

17 JULY 2020

EXECUTIVE SUMMARY

1. Site Name

Oena Diamond Mine. African Star Minerals (Pty) Ltd.

2. Location

The Oena Diamond Mine is situated on the left bank of the Orange River in the northern part of Farm 18 in the rugged Richtersveld terrain. The mine is comprised of five alluvial deposit areas of preserved terraces separated by intervals where the bedrock descends steeply to the river's edge, called Oena Proper, Sandberg, Blokwerf, Visrivier and Kabies (Figures 1 & 2).

MAP: 1:50 000 Topo-cadastral Sheet 2817AA XONAS – CD NGI.

3. Locality Plan

Figures 3 and 4 show the five mining areas.

4. Proposed Development

The outlines of the deposits shown in Figures 3 and 4 depict the maximum areas of bulk sampling and possible mining, but the actual areas mined will depend on the ongoing evaluation of payable ore based on sampling and mining results and will be smaller areas. Mine pits will be backfilled with processed material. The life of mine based on the Oena, Sandberg and Blokwerf deposits is estimated to be about 15 years during which about 34.42 million tons of material will be excavated and ~15.5 million tons will be processed for diamond content. Due to environmental concerns the Visrivier and Kabies alluvial terraces are presently excluded from consideration for mine developments, but may be the subject of a separate application in the future.

5. Affected Formations

The alluvial deposits of the lower Orange River mainly comprise a mid-Miocene (19-17 Ma) **Proto Terrace Suite** and a Pliocene **Meso Terrace Suite** (Figures 5 & 6). The affected formations include a mid-Miocene Proto deposit (or Intermediate?) and early Pliocene Upper Meso deposits (Oena Proper), while all areas of interest involve Lower Meso deposits of late Pliocene age.

6. Palaeontological Resources Identified

The Proto Suite deposits have also been called the **Arries Drift Formation** due to the spectacular fossil finds at that locality which have revealed the importance of southern Africa in the evolution of the wider African fauna (Pickford & Senut, 2003). The more than 10 000 fossils from Arrisdrift include worm tubes and shark teeth indicative of the proximity of the estuary, 13 reptiles incl. the ancestor of the Nile Crocodile, 13 birds and more than 35 mammal species, while upstream at Auchas fossil finds in Proto-Orange" deposits include large tree trunks, 3 reptiles, a bird and 8 mammals. On the basis of mammal biochronology an age of ~19 Ma is indicated for the Auchas fossils and an age of ~17 Ma for the Arrisdrift assemblage (Pickford & Senut, 2003).

To the writer's knowledge, there have not been any fossil finds from the Pliocene Meso Suite deposits which have been made known in the published literature.

7. Anticipated Impact

The major fossil finds have concerned conspicuous fossil bone occurrences, such as many bones (Arrisdrift) or large fossils (Auchas). It is not altogether impossible that similar occurrences may yet be discovered in the Proto and Meso deposits. It can be predicted that isolated fossil bones and teeth are sparsely scattered in the gravel deposits, as is witnessed by the many fossil finds in Vaal River gravels during the early times of the diamond diggings, when gravel processing was manual and observed at close range. Nevertheless, it is evident that fossils are overall sparse in the Orange River alluvial deposits and consequently the impact of bulk sampling and mining is considered to be

LOW (Appendix 1). However, as is shown by Figure 10, the similar finding of a few small fossil teeth from the hitherto unfossiliferous Meso Suite fluvial deposits would change the low negative impact to a high positive impact of regional to international scientific extent.

8. Recommendations

Unlike surficial archaeological material which can be recorded and collected prior to disturbance by mining, the mitigation of palaeontological resources must take place over the entire lifetime of the mine (15 years).

Open-pit mine excavations are a scientific and fossil resource and have been the major contributor to the understanding of the deposits and palaeontology of the West Coast. Mine personnel have played a critical role in bringing fossil finds (Figures 9 & 10) to the attention of the international scientific community.

As it is impractical for a specialist to routinely monitor the mine pit and mined material, routine monitoring can only be achieved by the co-operation of the people on the ground. By these are meant personnel in supervisory/inspection roles, such as the pit supervisor, geologist, surveyor and environmental monitoring officer, who are willing and interested to look out for occurrences of fossils. A monitoring presence is critical for spotting fossils as they are uncovered and stopping further damaging excavation.

It is recommended that a requirement to be alert for fossil materials and archaeological material be included in the Environmental Management Plan (EMP) for the sampling and mining operations. The Environmental Control Officer (ECO) and mining manager must inform staff of the need to watch for potential fossil occurrences. In the event of a discovery of fossil bone material a Fossil Finds Procedure" (FFP) is provided in Appendix 2. It is expected that such finds would be in the category of "allowed" rescue by mine staff, *i.e*. as for isolated bone finds in the FFP.

As mentioned above, finds of petrified teeth in concentrates hold the most promise for a diagnostic fossil find from the Orange River deposits. Importantly, vital previous finds have come from small-scale, "hands-on" operations using rotary pans to concentrate heavy minerals, such as the proposed operations by Oena Diamond Mine. It is highly recommended that mine staff must be empowered to rescue the petrified fossil material that is retained in the rotary pan concentrates and which is seen during their sorting.

The sampling and mining could have a positive impact with respect to understanding the stratigraphy and to palaeontological heritage, providing that adequate mitigation measures are in place and duly performed over the duration of the mining.

The creation of a systematic archive of the mine exposures over the duration of the mining will be a significant positive contribution to geoscience and geoheritage.

CONTENTS

DECLARATION OF INDEPENDENCE

THE SPECIALIST

I, **John Pether**, as the appointed specialist hereby declare/affirm the correctness of the information provided or to be provided as part of the application, and that I:

- in terms of the general requirement to be independent:
  - o other than fair remuneration for work performed/to be performed in terms of this application, have no business, financial, personal or other interest in the activity or application and that there are no circumstances that may compromise my objectivity; or
  - o am not independent, but another specialist that meets the general requirements set out in Regulation 13 have been appointed to review my work (Note: a declaration by the review specialist must be submitted);
- in terms of the remainder of the general requirements for a specialist, am fully aware of and meet all of the requirements and that failure to comply with any the requirements may result in disqualification;
- have disclosed/will disclose, to the applicant, the Department and interested and affected parties, all material information that have or may have the potential to influence the decision of the Department or the objectivity of any report, plan or document prepared or to be prepared as part of the application;
- have ensured/will ensure that information containing all relevant facts in respect of the application was/will be distributed or was/will be made available to interested and affected parties and the public and that participation by interested and affected parties was/will be facilitated in such a manner that all interested and affected parties were/will be provided with a reasonable opportunity to participate and to provide comments;
- have ensured/will ensure that the comments of all interested and affected parties were/will be considered, recorded and submitted to the Department in respect of the application;
- have ensured/will ensure the inclusion of inputs and recommendations from the specialist reports in respect of the application, where relevant;
- have kept/will keep a register of all interested and affected parties that participate/d in the public participation process; 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:

Name of company: Sole Proprietor

Date: 17 JULY 2020

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

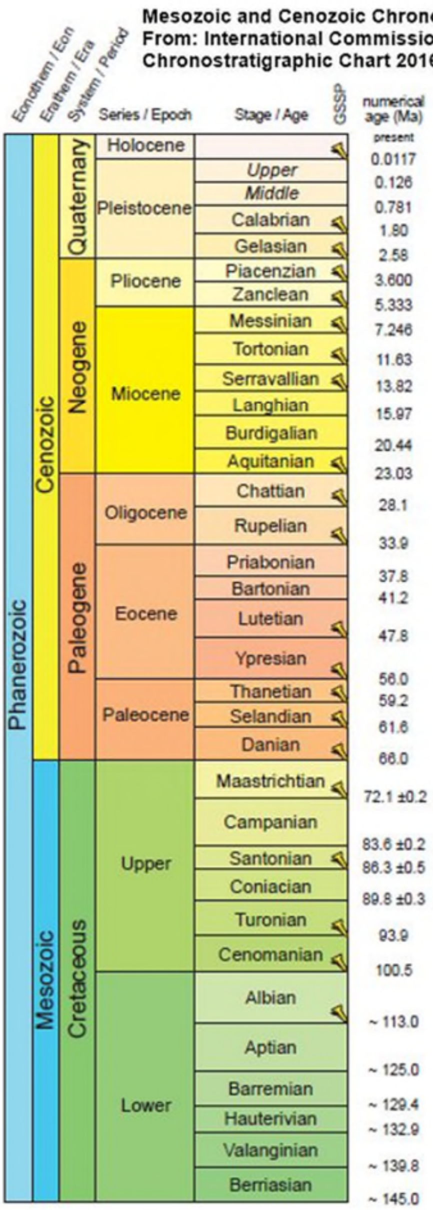
GEOLOGICAL TIME SCALE TERMS

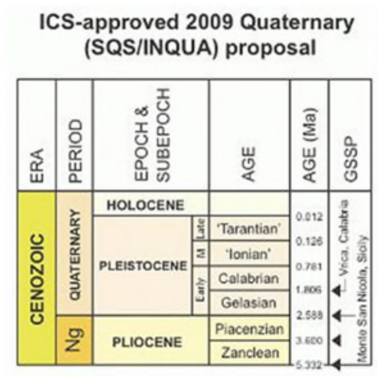
For more detail see www.stratigraphy.org.

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

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

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





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

Pleistocene: Epoch from 2.6 Ma to 11.7 ka.
Late Pleistocene 11.7–126 ka.
Middle Pleistocene 135–781 ka.
Early Pleistocene 781–2588 ka.

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

1 INTRODUCTION

African Star Minerals (Pty) Ltd. operates the Oena Diamond Mine Mineral Lease Area on the Orange River banks in the Richtersveld National Park (Figures 1 & 2) Site Plan Consulting has been appointed to update the existing Environmental Management Programme (EMP) for the mine. ASHA Consulting (Pty) Ltd. has been appointed to undertake the Archaeological Mitigation of the affected areas, based on the findings of the previous Archaeological Impact Assessment (Orton & Webley, 2009). As part of the EMP update, the South African Heritage Resources Agency (SAHRA) has requested that a desktop Palaeontological Study be submitted (not previously done), as the mining involves alluvial deposits of moderate palaeontological sensitivity as per the SAHRIS PalaeoSensitivity Map (Figure 2, inset) (SAHRA Case ID 13224, 19 Dec. 2018).

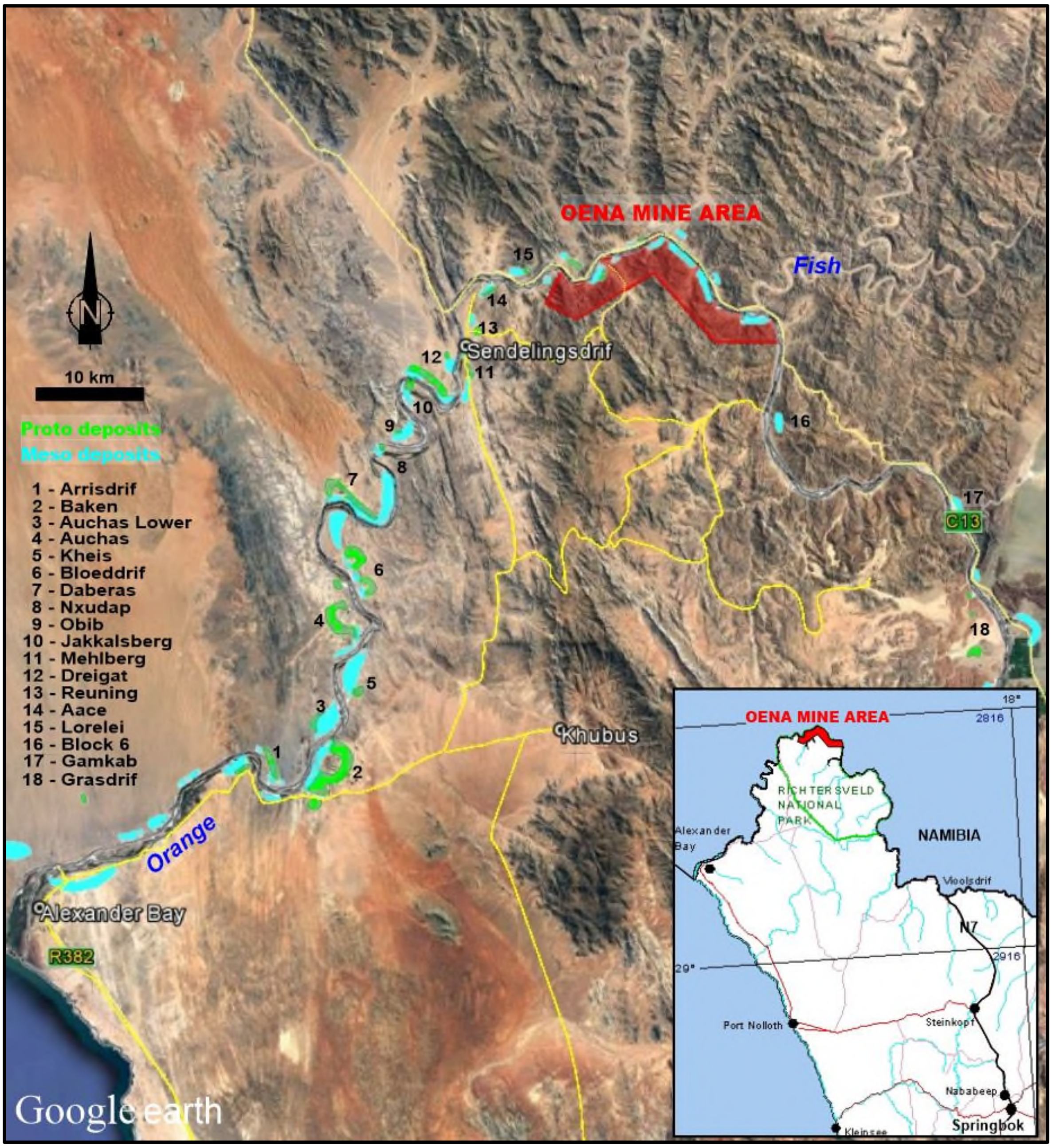


Figure 1. Location of the Oena Mine Area and the mined alluvial terraces in the valley of the lower Orange River.

This report forms part of the HIA and its brief is to inform about the palaeontological sensitivity of the Project Area and the probability of palaeontological materials (fossils) being uncovered in the subsurface and being disturbed or destroyed in the process of prospecting and mining, and to provide recommendations for palaeontological mitigation to be included in the Environmental Management Plan (EMP) for the prospecting and mining.

2 LOCATION

The Oena Diamond Mine Mineral Lease Area is situated on the left bank of the Orange River in the northern part of Farm 18 in the rugged Richtersveld terrain. It is approached from Sendelingsdrif (Figure 1) via a 4x4 track proceeding up a drainage line valley to the dividing watershed surmounted by the "Halfmens Pass" and then down the Kouamsrivier drainage to Oena.

MAP: 1:50 000 Topo-cadastral Sheet 2817AA XONAS – CD NGI.

The name "Xonas" is evidently an alternative to "Oena". Other usages in the literature include "Oenas" and Oona.

The Oena Diamond Mine is comprised of five alluvial deposit areas of preserved terraces separated by intervals where the bedrock descends steeply to the river's edge, called Oena Proper, Sandberg, Blokwerf, Visrivier and Kabies (Figure 2).

3 PROPOSED ACTIVITIES

The envisaged future prospecting and mining activities are broadly summarized below, based on information in the Environmental Impact Assessment Report and Environmental Management Programme Report (Site Plan Consulting, Jan. 2019). The outlines of the deposits shown in Figures 3 and 4 depict the maximum areas of possible mining, but the actual areas mined will depend on the ongoing evaluation of payable ore based on sampling and mining results and will be smaller areas. Existing mine pits will be backfilled with processed material. The proposed activities entail the following:

Oena Proper: Continuation of mining of mining blocks 1 to 8 with processing at the existing plant (Figure 3A).

Sandberg: The mine blocks shown in Figure 3B have been outlined on the basis of drilling. A new mine plant will be placed adjacent to the existing pit in the south, with a possible plant location in the north.

Blokwerf: This deposit has been bulk-sampled in places and a plant has been established in the south (Figure 4A). Further assessment is intended by a drilling programme covering the northern section. Possible future plant sites could be located centrally and in the north.

Visrivier: Mapping of the deposits (Figure 4B) and a drilling programme to establish the bedrock topography and the extent and nature of gravel beds. Subsequent bulk sampling with a possible plant in the area, or alternatively a field screening plant with plantfeed transported to a future plant on Blokwerf.

Kabies: Mapping of the deposits (Figure 4C) and a drilling programme to establish the bedrock topography and the extent and nature of gravel beds. Subsequent bulk sampling with a possible plant in the Visrivier area, or alternatively a field screening plant with plantfeed transported to a future plant on Blokwerf.

Due to environmental concerns the Visrivier and Kabies alluvial terraces are presently excluded from consideration for mine developments, but may be the subject of a separate application in the future.

The life of mine based on the Oena, Sandberg and Blokwerf deposits is estimated to be about 15 years during which about 34.42 million tons of material will be excavated and ~15.5 million tons will be processed for diamond content.

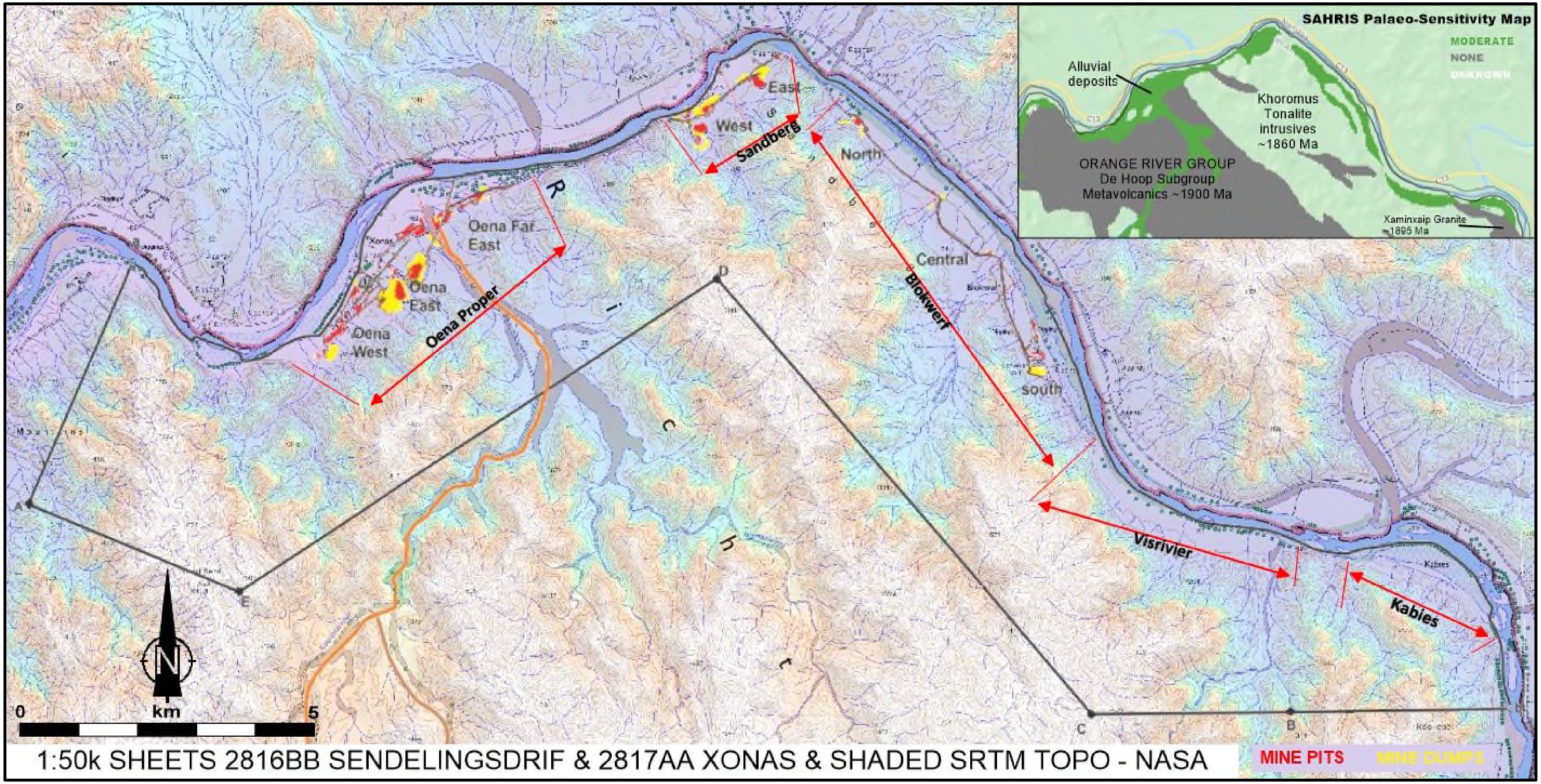


Figure 2. The Oena Mine Mineral Leases Area and the alluvial deposits. Previous mining areas (red) and mine dumps (yellow) are indicated. Inset shows the SAHRIS palaeontological sensitivity rating and the unfossiliferous bedrock lithologies.

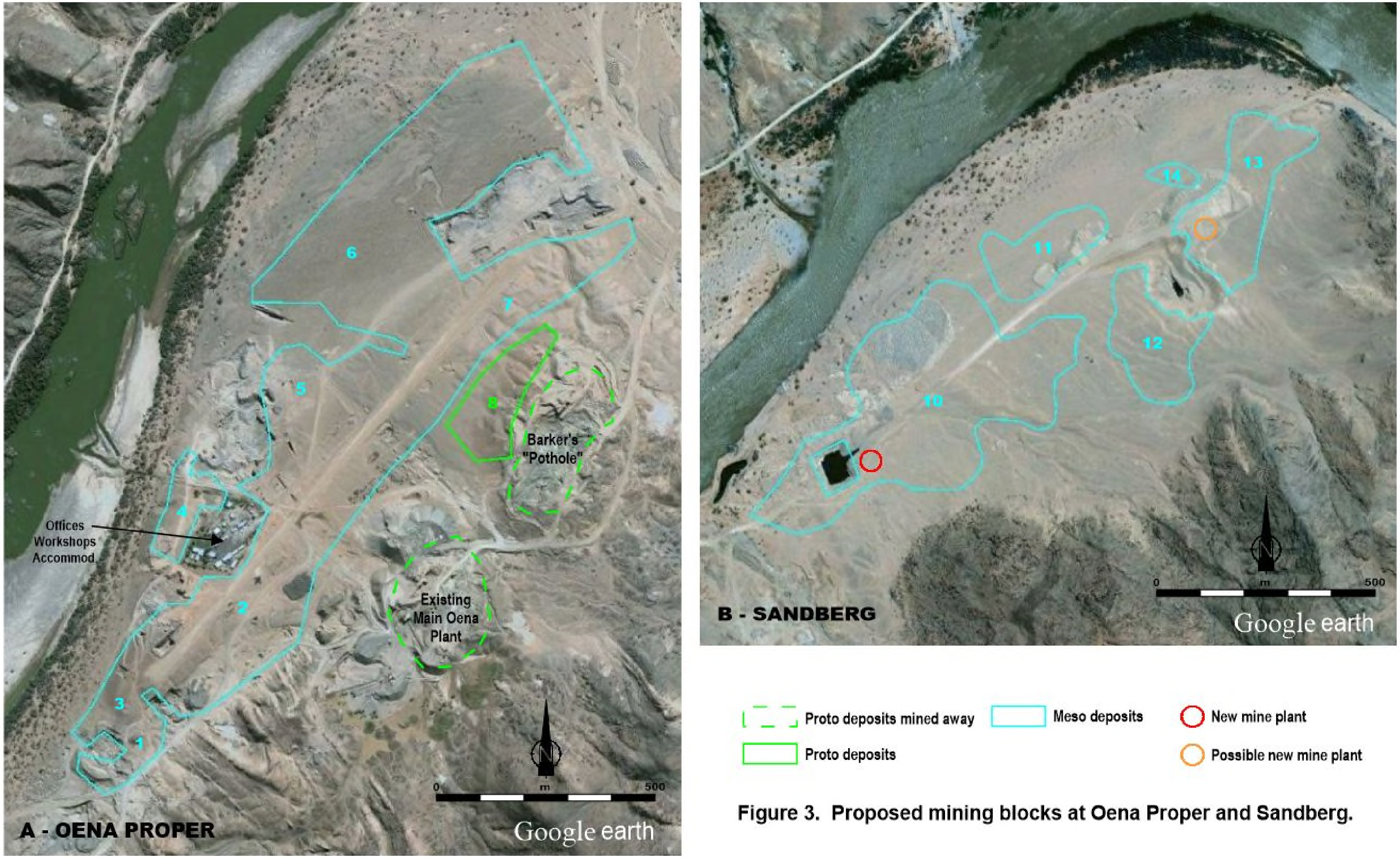


Figure 3. Proposed mining blocks at Oena Proper and Sandberg.

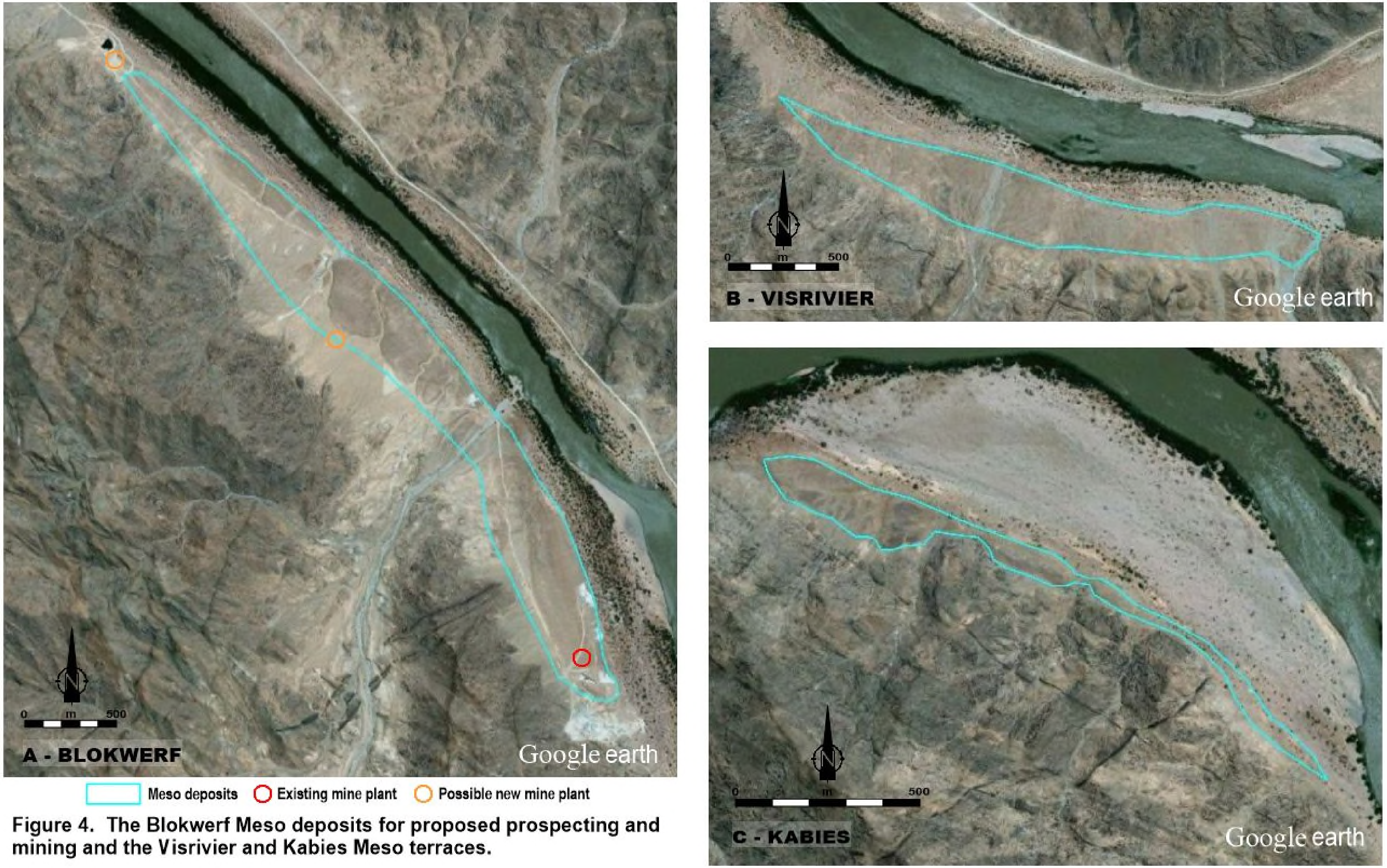


Figure 4. The Blokwerf Meso deposits for proposed prospecting and mining and the Visrivier and Kabies Meso terraces.

4 APPROACH AND METHODOLOGY

Deposits or formations are rated in terms of their potential to include fossils of scientific importance, *viz*. their palaeontological sensitivity. Palaeontological Sensitivity refers to the likelihood of finding significant fossils within a geologic unit, which informs the Intensity/Magnitude/Severity rating in an impact assessment. The criteria for rating are in Appendix 1.

4.1 AVAILABLE INFORMATION

A considerable literature exists about the alluvial terraces of the lower Orange River, due to their diamond content and especially about the world-reknowned fossil discoveries in the deposits. Descriptions of geological aspects of the deposits include De Villiers & Söhnge (1959), Fowler (1976, 1982), Steyn (1982), Van Wyk & Pienaar (1986), Jacob *et al*. (1999), Pickford & Senut (2000), De Wit *et al*. (2000), Jacob (2005) and Van der Westhuizen (2012). Initial descriptions of the fossil finds at Arrisdrift and Auchas on the Namibian bank include Corvinus & Hendey (1978), Hendey (1978, 1984) and Pickford et al. (1995), to be succeeded by many articles by palaeontological specialists diagnosing the fossil species discovered (Pickford & Senut (eds.), 2003).

4.2 ASSUMPTIONS AND LIMITATIONS

The assumption is that the fossil potential of a formation will be typical of its genesis/depositional environment and more specifically, similar to that observed in equivalent deposits nearby the Project Area. Scientifically important fossils are expected to be very sparsely scattered in these deposits and much depends on spotting fossils as they are uncovered during digging *i.e.* by monitoring excavations, or spotting fossils during processing of mined material. A limitation on predictive capacity exists in that it is not possible to predict the buried fossil content of an area or formation other than in such general terms.

5 THE GEO-HISTORY OF THE ORANGE RIVER

5.1 CRETACEOUS AND PALAEOGENE RIVERS

The geological history of the rivers of the West Coast is an intriguing topic and impinges upon several overlapping fields of study which converge on syntheses of the post- Gondwana-breakup history of the erosion of the southern African subcontinent, as informed by fossil discoveries, geomorphology, crustal cooling erosion histories and stratigraphy, both offshore and onshore. The various scenarios for the courses of palaeodrainages (ancient rivers) are the abiding interest of alluvial diamond prospectors. Some broad aspects are mentioned below.

The rifting of the Gondwana supercontinent and the opening of the Atlantic Ocean in the early Cretaceous, 130-120 Ma, was accompanied by the inception of numerous rivers draining to the new coastline. After the rifting phase with its volcanoes, faulting and terrestrial/lacustrine sedimentation, the rifted landscape was covered by sediments delivered to the expanding Cretaceous South Atlantic Ocean. Wide coastal plains and deltas formed as many coastal rivers, and the early major rivers eroding the sub-continental interior, deposited enormous volumes of sediments eroded from the well-watered hinterland. Marine processes spread the finer sands and muds further to form the continental shelf extending seawards. Slumping at the shelf edges carried sediments downslope into deep water. Successive continental shelves built out and upwards as the underlying crust subsided. These now fill what is called the Orange Basin offshore, which includes an accumulation of Cretaceous sediments exceeding 6 km thickness off the Namaqualand coast.

Ongoing erosion has removed nearly all traces of early Cretaceous deposits from the present-day West Coast coastal pain. A rare instance dating from the early Cretaceous rifting is preserved just north of the Buffelsrivier mouth and is evidently the surviving, deepest part of a fault-bounded lake. Discovered by drilling, the lake deposits contain fossil pollen of the early Cretaceous flora (Molyneux, in Rogers *et al*., 1990), indicating deposition 145-130 Ma. Rounded cobbles of petrified, early Cretaceous *Podocarpoxylon* woods are found in the onshore marine gravels of the Quaternary raised beaches near Kleinzee and south of Port Nolloth (Bamford & Corbett, 1995), reworked successively from the now-vanished fluvial deposits of the early coastal plain.

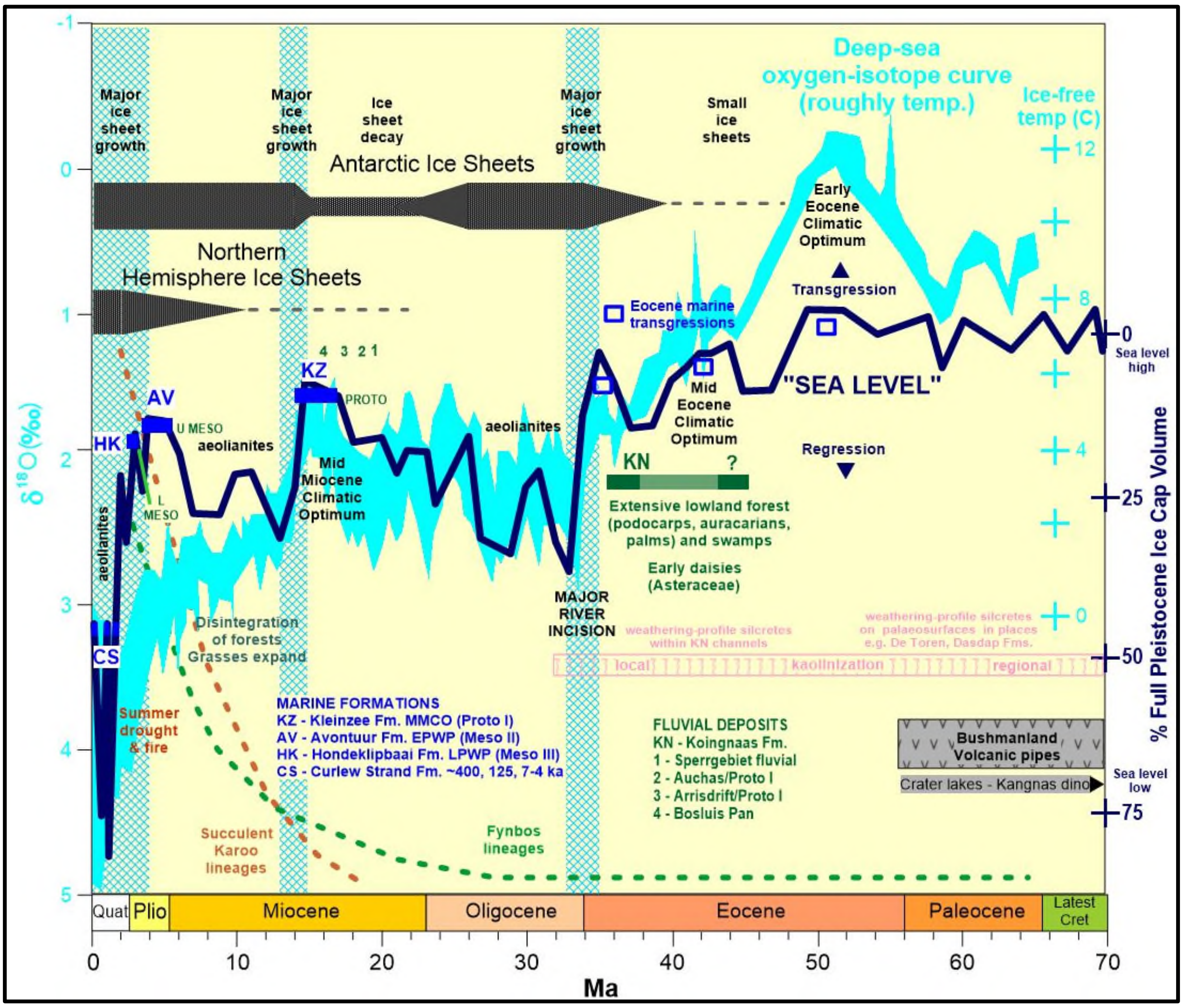


Figure 5: The Cenozoic Era (66 Ma to present) showing global palaeoclimate proxies, the context of marine formations of the West Coast Group and the Orange River alluvial deposits and aspects of regional vegetation history.

Cyan curve - history of deep-ocean temperatures, adapted from Zachos *et al*. (2008). **Blue curve** is an estimate of global ice volumes, adapted from Lear *et al*. (2000). Global ice volumes roughly indicate sea-level history caused by the subtraction from the sea of water as land-ice. The expansion of Fynbos and Karoo floras is adapted from Verboom *et al*. (2009). EPWP – Early Pliocene Warm Period. LPWM - Late Pliocene Warm Period.

The ongoing erosion by rivers during the Cretaceous bevelled the new continental edge, abetted by its uplift in response to the subsiding crust bending beneath the sediment load offshore. A few kilometres thickness of Karoo and Nama formations had been stripped off, exposing the bedrock of gneisses, metasediments and granites whose various erodibilities and structural features then influenced the river courses. However, this exhumed bedrock had a pre-formed palaeo-topography, carved out beneath the glaciers of Dwyka times ~300 Ma, which then also influenced parts of the river courses, such as in the major valleys of the Orange, Olifants and Buffels rivers. The developing coastal plain, backed by a “Great Escarpment”, approached its present configuration. Headward erosion by these larger rivers encroached into the subcontinental interior, capturing drainages there and directing their eroded sediment load to the West Coast.

The interior of southern Africa also underwent major erosion during the Cretaceous by large rivers ancestral to the Orange-Vaal rivers which meandered across the landscape, delivering sediments to the West Coast. Various interesting reconstructions of the Cretaceous and Cenozoic palaeo-drainages of the interior have been mooted (Dingle & Hendey, 1984; Malherbe *et al*. (1986), De Wit, 1993,1999; Van der Westhuizen, 2012), but these are not reviewed here. The salient observation is the meandering nature of the Orange-Vaal rivers and some major tributaries (*e.g*. Fish River), indicating that a mature, low-gradient, large-discharge river system has been superimposed by subsequent incision into the landscape, so that the modern rivers occupy inherited, "misfit" courses incongruent with their current steeper gradients and much lower discharge (Ward & Bluck, 1997).

The meandering system reflects the mature, later Cretaceous landscape created by earlier Cretaceous denudation, with the Orange-Vaal delivering sand and mud to the continental shelf. The occurrence of exotic pebbles and cobbles, derived from the far interior, in gravels of Eocene age north of the Orange on the Namibian coastal plain, indicates that the incision, steepening and rejuvenation of the Orange-Vaal drainage had occurred by Eocene times, ~50-40 Ma (Bluck *et al*., 2005). Estimates of the timing of the causal uplift, based on shelf sedimentation rates derived from analysis of offshore oil exploration data, or thermo-chronologic data derived from the cooling history crustal rocks (fission track dating) (https://en.wikipedia.org/wiki/Fission_track_dating), vary somewhat, but overall indicate later Cretaceous times (*e.g*. Baby *et al*., 2020).

Within the lower Orange River valley there is no sedimentary record of this late Cretaceous and Palaeogene history and except for isolated, limited occurrences of gravel with compositions of Eocene aspect (Jacob, 2005) the valley was flushed of these earlier deposits. However, a glimpse of conditions during the Eocene is provided by the record of the local coastal drainages of the Namaqualand coastal plain to the south. Incised into the bedrock along the outer edge of the coastal plain and extending onto the inner shelf are many buried, old river palaeochannels which may attest to the erosion during the later Cretaceous. It is possible that late Cretaceous fluvial deposits once filled the palaeochannels, but it seems that the palaeochannels were occupied by subsequent river systems and underwent cycles of infilling and flushing out with fluctuations of sea level during the early Cenozoic, until the deposits finally occupying them are mainly of late Eocene age (**Koingnaas Formation**). Nevertheless, due to the pervasive kaolinitic weathering of the palaeochannel deposits it is possible that remnants of the older, late Cretaceous to early Eocene deposits may be disguised in places in the bases of the channels.

The kaolinized **Koingnaas Formation** (De Beer, 2010) "white-clay" channel sediments consist of subangular quartz conglomerates, locally rich in diamonds, overlain by beds of clayey sand, clay and carbonaceous material containing plant fossils (Molyneux, in Rogers *et al*., 1990). The fossil pollen has provided evidence of the vegetation type present and the age of the Koingnaas Formation. Yellowwood forest with auracaria conifers, ironwoods and palms dominated the West Coast. Fossil wood identified as tropical African mahogany has been found. The presence of pollen of early Asteraceae (daisies) (Mutisieae-type, Scott *et al*., 2006) indicates that the age of the Koingnaas Formation is later Eocene, with the aggradation of fluvial deposits in the palaeochannels likely correlating with times of rising sea levels ~36 Ma or possibly ~45 Ma (Figure 5). Ultimately the channels became waterlogged due to high water tables and a humid climate regime, and the feldspar content weathered to kaolinite, with microcrystalline silcrete forming locally beneath swampy places. The Koingnaas Formation fluvial channel deposits are part of the later Eocene fossil landscape at the coast of Namaqualand, when it was last under the influence of a globally-expanded tropical climate. Subsequent to the Eocene most of these coastal drainages were abandoned and "fossilized" between the remaining, more widely spaced rivers that have persisted through Neogene times to the present.

Towards the end of the Eocene ~35 Ma and during the Oligocene the global climate underwent major cooling and polar ice built up on the Antarctic continent, lowering sea level significantly (Figure 5). This "**Oligocene Regression**" had an impact on the coastal plain by the further incision and entrenchment of the river courses and further erosion back into the Escarpment. The Orange River valley was deepened by downcutting and widened by the expansion of the local tributaries, accompanied by erosion of the older, deeply-weathered Paleocene-Eocene surface in the surrounds.

5.2 THE NEOGENE ORANGE RIVER

5.2.1 Proto Orange River Terrace Suite

Towards the end of the Oligocene the cooler global climate began to ameliorate and, with large fluctuations, this warming trend continued through the early Miocene and peaked in the middle Miocene in a period of global warmth known as the **Mid-Miocene Climatic Optimum** (MMCO) (Figure 5). The gradual melting of Antarctic ice raised sea level and the outer edge of the coastal plain was "transgressed" by the sea. Coastal rivers responded to the rising base level and fluvial deposits accumulated within their courses, the earliest deposits of which occur in the Sperrgebiet of southern Namibia (*e.g*. Grillental) and which are dated on the basis of fossils to 20-18 Ma (Pickford, 2008) (Figure 5).

The lower reaches of the Orange River were inundated, forming a large estuary, whilst upstream the river valley was "backed up" with aggrading fluvial deposits. Some of these Miocene deposits are now preserved as high level terraces in cut-off meander loops along the flanks of the valley and were called the "**Proto-Orange I Terrace**" deposits in older De Beers geologist terminology, but more recently, on the basis of mine exposures which revealed complexities, are referred to as the "**Proto Orange River Terrace Suite**" (Jacob, 2005) (Figure 6).

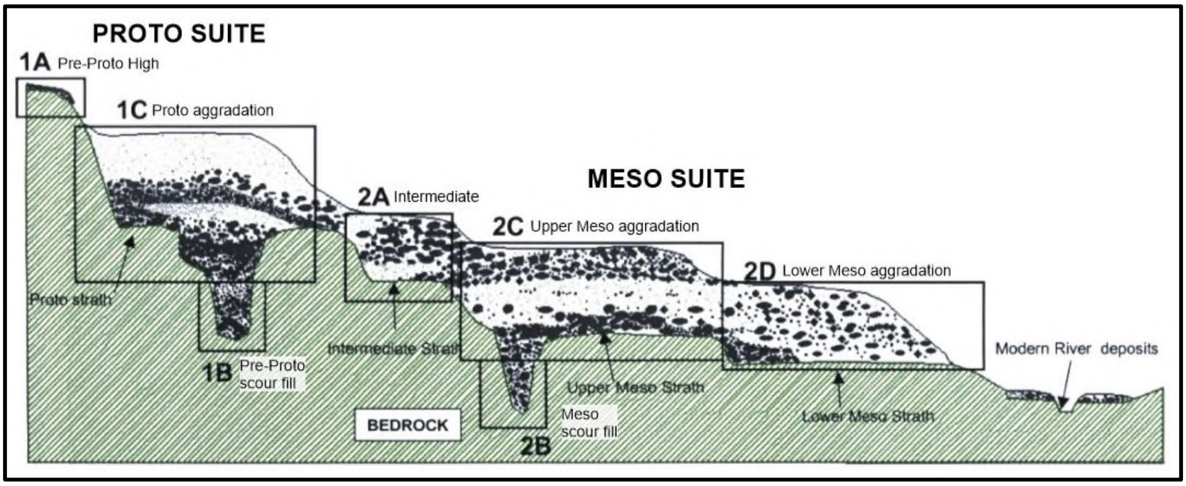


Figure 6. The Orange River Alluvial Deposits. Adapted from Jacob (2005), fig. 4.7.

These deposits have also been called the **Arries Drift Formation** due to the spectacular fossil finds at that locality which have revealed the importance of southern Africa in the evolution of the wider African fauna (Pickford & Senut, 2003). The more than 10 000 fossils from Arrisdrift include worm tubes and shark teeth indicative of the proximity of the estuary, 13 reptiles incl. the ancestor of the Nile Crocodile, 13 birds and more than 35 mammal species, while upstream at Auchas fossil finds in Proto-Orange" deposits include large tree trunks, 3 reptiles, a bird and 8 mammals. On the basis of mammal biochronology an age of ~19 Ma is indicated for the Auchas fossils and an age of ~17 Ma for the Arrisdrift assemblage (Pickford & Senut, 2003).

The wood anatomy of the fossil tree trunks from Auchas show that they grew all year round, but with some water stress, in a warm subtropical climate (Bamford, 2003), which is consistent with the subtropical, summer rainfall palaeoclimate inferred from the Arrisdrift fossil fauna, with riverside gallery forests and woody savannah wider afield.

Above the escarpment the Koa Valley was an active tributary river of the Orange, as shown by fossils from the bottom of Bosluis Pan in western Bushmanland which include catfish, crocodiles, tortoises, giraffids, bovids, a rhinocerotid and a small proboscidean (Elephantida) *Choerolophodon pygmaeus* which had a lifestyle similar to hippos. Most of the species also occur at Arrisdrift, but a slightly younger age of ~16 Ma has been estimated (Senut *et al*., 1996; Pickford, 2005).

By the time of the peak of the MMCO about 16 Ma (Figure 5) the palaeoshoreline of the transgressive maximum sea level was at ~90 m asl., as is evident south of the Orange River by impressive sea cliffs cut into the bedrock. This high elevation is a combination of the meltwater added to the oceans (~30-40 m equivalent), as well as uplift of the continental margin (by ~50-60 m since ~16 Ma).

The MMCO was ended by global cooling and major build-up of polar ice and when the sea receded again the regressive, shallow-marine **Kleinzee Formation** (aka 90 m Package) was deposited (Figure 5). The lowering sea level resulted in the Orange River incising into the previous Proto-age valley fills along the central valley during the later Miocene, with straightening of its course in the valley, preserving the Proto Suite deposits locally in deep scours, in the inherited meander loops and as terraces in places along the wider valley flanks.

During the later Miocene major changes in the ocean and atmospheric circulations led to dryer climates in Africa, with decline of forests and the expansion of savannah grasslands, while along the West Coast the influence of cold Subantarctic waters increased, together with the onset of the early Benguela upwelling regime and the expansion of arid conditions.

5.2.2 The Meso Orange River Terrace Suite

A temporary return of global warming, the **Early Pliocene Warm Period** (EPWP) (Figure 5), resulted in rising sea level and erosion of the edge of the Miocene Kleinzee Fm. as the sea approached the transgression maximum at about 50 m asl. In the Orange River valley the "**Meso-Orange II Terrace**" or **Upper Meso** gravels aggraded along the more confined river course (Figure 6). At the coast the marine **Avontuur Formation** (the 50 m Package) was deposited 5-4 Ma as sea-level receded from ~50 m asl. and the shoreline prograded seawards (Figure 5), while the Meso II deposits were incised as the regression proceeded.

The Avontuur Formation in turn was eroded by yet another episode of rising sea-level associated with the **Late Pliocene Warm Period** ~3.2 Ma (LPWP) (Figure 5). In the Orange River valley the lower "**Meso-Orange III Terrace**" or **Lower Meso** gravels accumulated (Figures 6 & 7). At the coast the **Hondeklipbaai Formation** or 30 m Package was deposited as sea level declined from a high of about 30-33 m asl. and a substantial, prograded marine formation built out seawards.

With the onset of the **Quaternary Ice Ages** (glacials) since about 2.6 Ma the sea level oscillated mainly between elevations of -20 to -80 m bsl., with drops to between -100 to -140 m bsl. during the numerous Ice Age glacial maxima. The Orange River ran in an entrenched course, with the estuarine mouth and delta being constantly re-positioned and reworked as sea level traversed repeatedly up and down the inner shelf during the numerous Quaternary glacials and interglacials. Present sea level was rarely exceeded, as is evident in only three "raised beaches" being preserved close to the coast. The name **Curlew Strand Formation** encompasses this composite of raised beaches, equivalent to the Velddrif Formation of the SW Cape Coast. Below sea level in the incised river mouths are interbedded fluvial and estuarine deposits, the latter deposited when rising sea levels entered the incised valley. The latest and best-preserved estuarine deposits date to the last transgression after the Last Ice Age when sea level was approaching present level between 14-8 thousand years ago (ka).

6 THE GEOLOGY OF THE PROJECT AREA

The alluvial gravel deposits in the Oena Diamond Mine Mineral Lease Area are mainly those of the Meso Orange River Terrace Suite (Figure 6).

In the Oena Proper area the Proto deposits at high level (approx. 40-50 m above river level (arl.) have been mined away (Figure 3A, *e.g.* Barkers "Pothole"). Block 8 is a deposit below the Proto level with its surface at approx. 20-30 m arl. Although considered to be a Proto deposit (Site Plan Consulting, Jan. 2019), it is also possible that it may be a small patch of the Upper Meso deposits or possibly the Intermediate deposits of the Meso Suite (Figure 6). These alternatives can be resolved on the basis of the different gravel compositions between the Proto and Meso suites, as detailed by Jacob (2005). The main area of the Oena Proper mining blocks comprises Lower Meso Suite deposits (Figures 3A, 7).

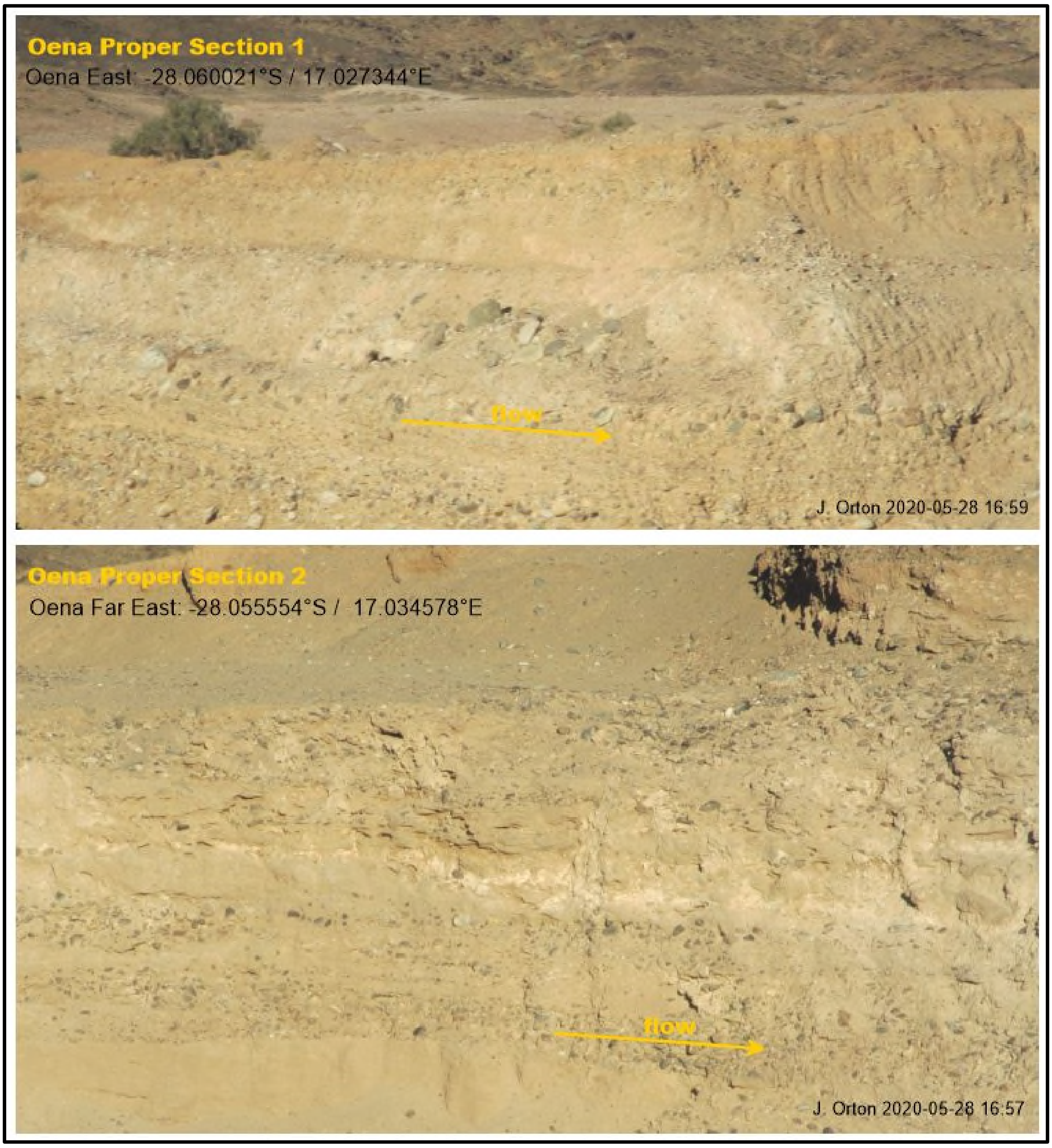


Figure 7. Examples of the Meso deposits of the Orange River at Oena Proper. Top: Earlier Meso deposits with irregular, pale cementing. Bottom: Later Meso deposits at lower elevation. Images courtesy J. Orton.

The deposits on Sandberg, Blokwerf, Visrivier and Kabies principally involve the Lower Meso terrace (*e.g.* Figures 3B, 4, 8), although there may be underlying Upper Meso gravels in places. The terrace deposits are locally dissected by drainages exiting the mountains and are also partly overlapped by alluvial fans, while flood-plain sands have been reworked into an aeolian sand cover of varying thicknesses.

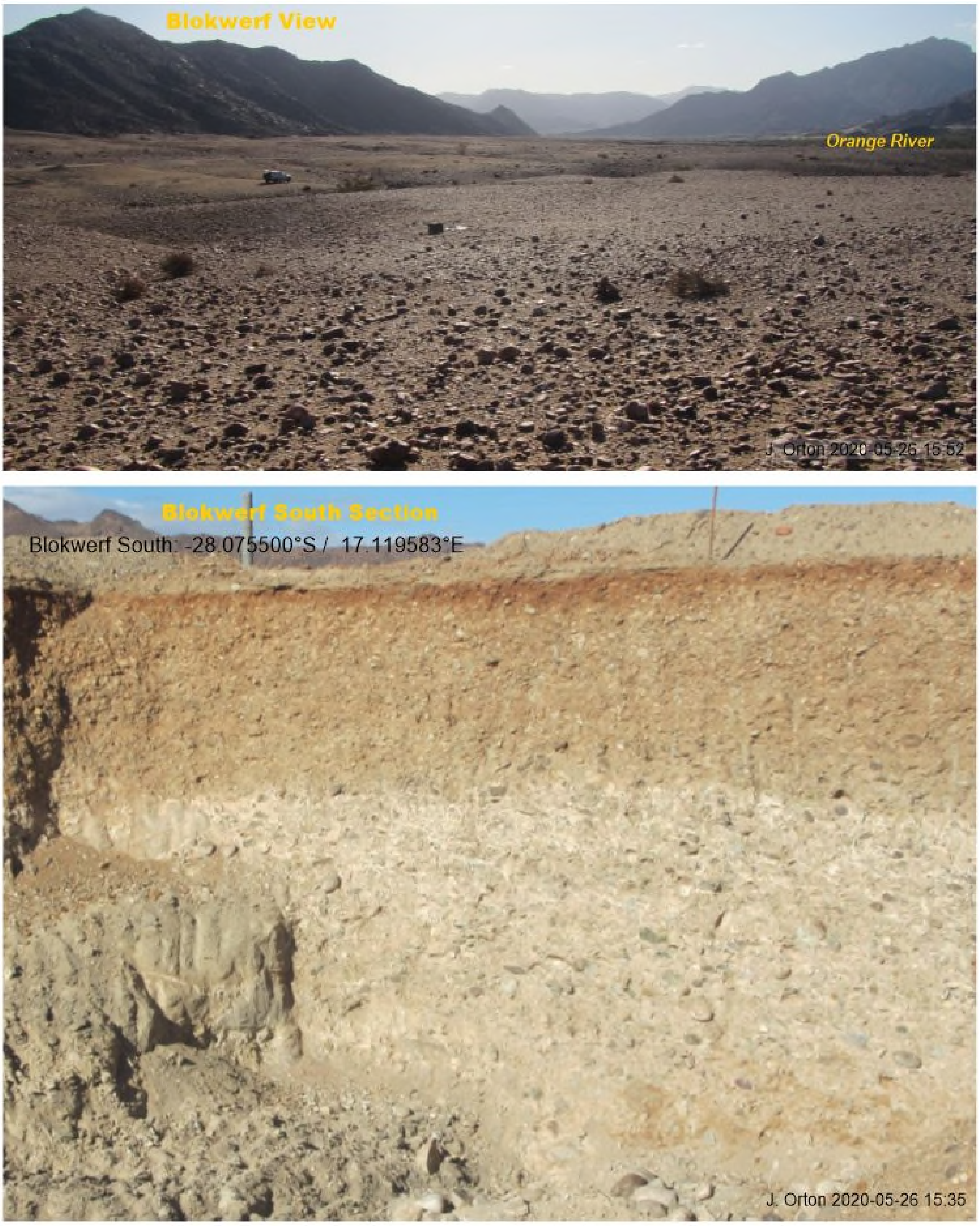


Figure 8. Top: View over the Meso Terrace at Blokwerf. Bottom: Section at Blokwerf South showing two distinct units. Images courtesy J. Orton.

An exposure at Blokwerf South shows a pale, cobbly lower unit ,evidently cemented by a groundwater calcrete, and an upper, brown, pebbly unit (Figure 8). Speculatively, these may represent the older, Upper Meso Terrace deposits and the younger, Lower Meso deposits, respectively.

7 PALAEONTOLOGICAL ASPECTS OF THE ORANGE RIVER ALLUVIAL DEPOSITS

The major fossil discoveries, as briefly summarized above, have been in the mid-Miocene Proto Suite aggradational deposits. To the writer's knowledge, there have not been any fossil finds from the Pliocene Meso Suite deposits which have been made known in the published literature.

This may be partly due to the more lucrative Proto Suite deposits having been the main target for mining hitherto. However, a most likely more important aspect are differences in the nature of the Proto and Meso deposits with respect to sub-environments developed in their fluvial systems. The Auchas and Arrisdrift fossil occurrences are in abandoned meanders of the Proto-Orange when it occupied a wider valley and was meandering in its own unconsolidated, accumulating alluvium and prone to switches in its course (avulsions).

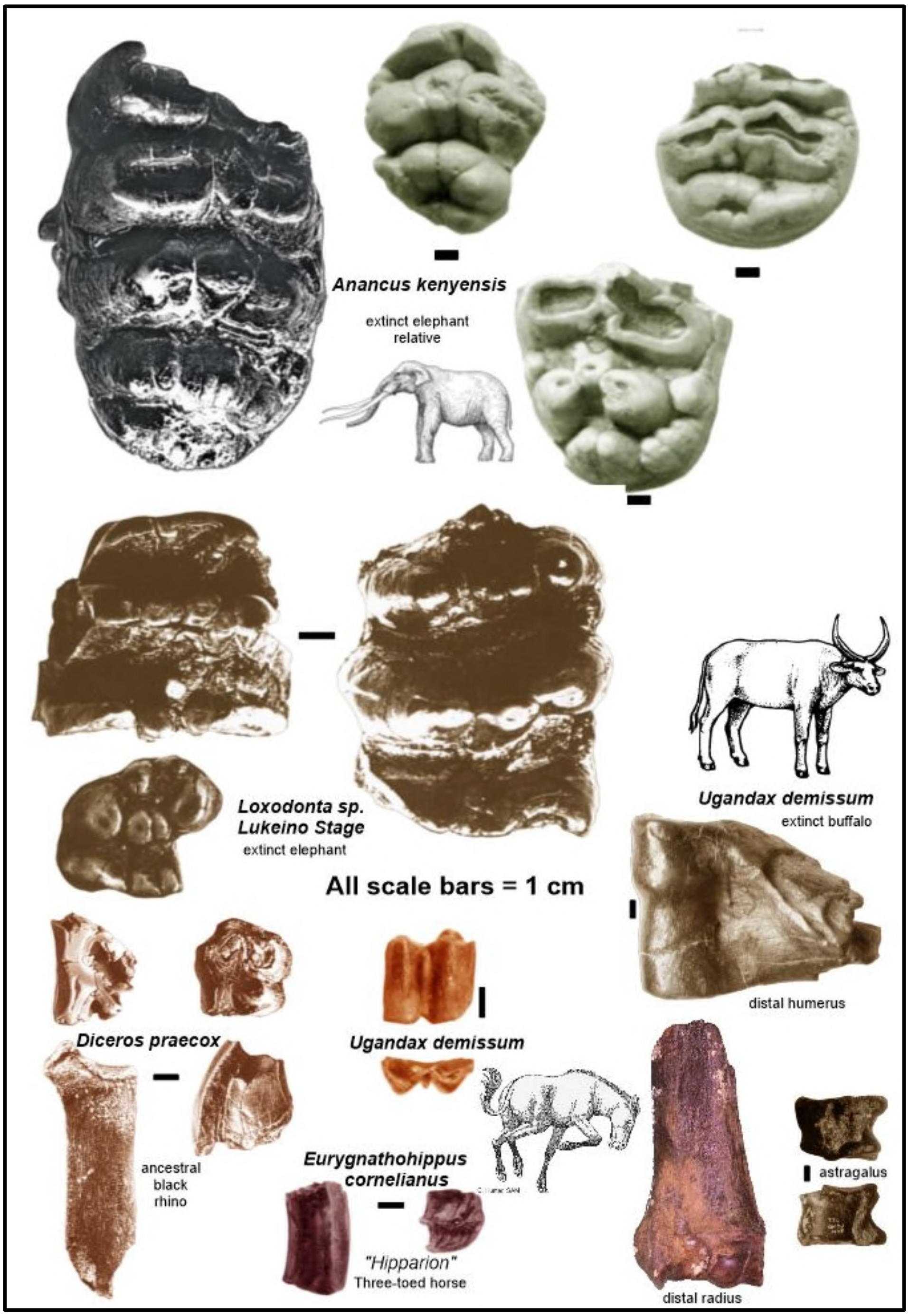


Figure 9. Examples of larger, abraded fossils of land mammals found in gravels.

At Auchas the skulls and jaws of probocideans (ancient relatives of elephants), rhino bones, giant tortoise carapaces and crocodile teeth were scattered randomly in deposits of a laterally-accreting point bar, while large tree logs in approximately parallel orientation evidently lay along the river bank.

At Arrisdrift an abundance of fossil bones occurred in an abandoned channel which was later episodically infilled with clay, sands and gravel in cut & fill structures during higher water levels. Notably, the bones are generally not articulated and many bear evidence of lying exposed on the river banks prior to final deposition. Some have tooth marks that were likely made by crocodiles. Bone breakage due to initial trampling, or subsequent, post-depositional compaction, are aspects of preservation and the precipitation of gypsum has also been deleterious (Pickford *et al.*, 1995; Pickford & Senut, 2003).

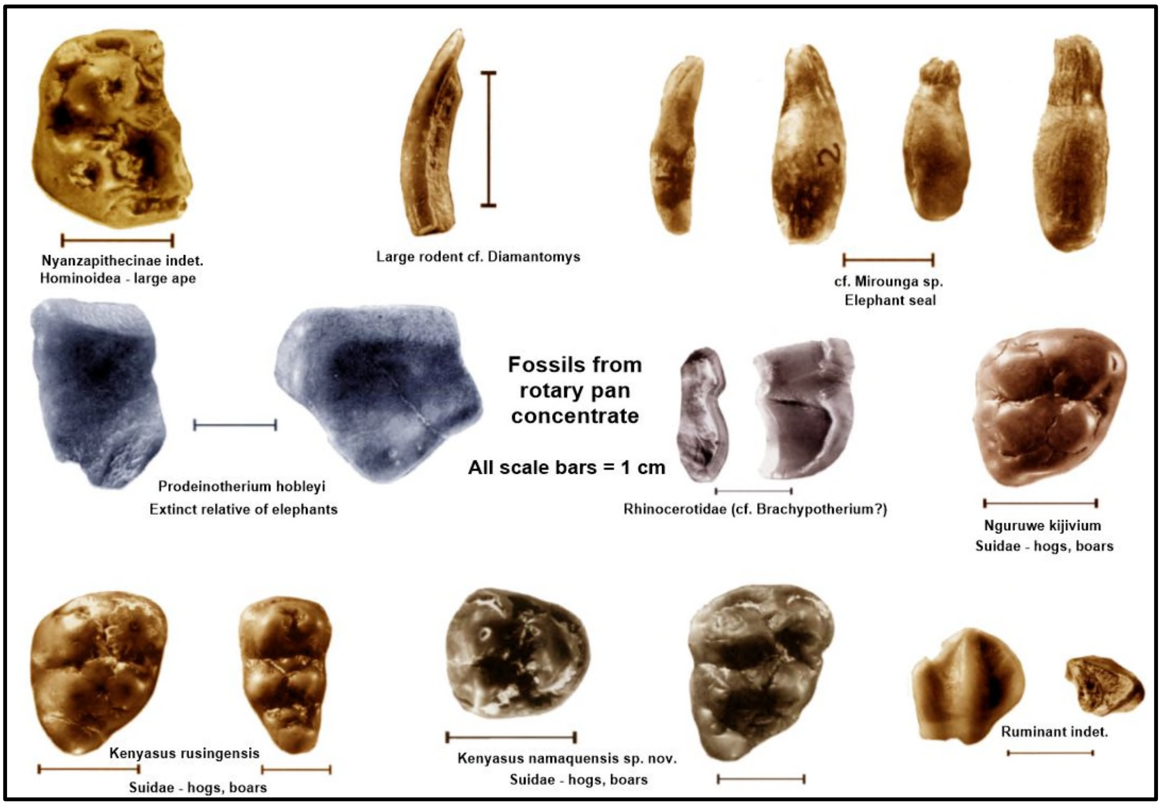


Figure 10. Examples of fossil mammal teeth collected from gravel rotary pan concentrates.

In contrast, the Meso Suite deposits, accumulated in a more confined valley, are dominated by matrix-rich, poorly-sorted gravels which represent “bulk” deposition during flood wane, with intercalations of armoured gravel bar tops due to subsequent winnowing, and evidence of point-bar meander deposits, and abandoned-channel, “cul-de sac” infills, is relatively rare (pers. obs.). This generally more energetic fluvial regime is less favourable for the deposition of skeletal remains in sufficient quantities to be noticeable during mining. Notwithstanding, there can be no doubt that fossils are present which, like the diamond content, are in low concentration. For instance, upstream the lower Vaal River gravels produced some reworked fossils of broadly coeval Pliocene, Meso Suite age (Helgren, 1977).

The fossils from the Upper Meso deposits are expected to be species of the early Pliocene Langebaanian Land Mammal Age, so named for the defining, very large faunal assemblage discovered in the phosphate mine at Langebaanweg, now the West Coast Fossil Park. The Lower Meso deposits would include species from the Early Makapanian Land Mammal Age, of late Pliocene and earliest Quaternary time range, ~3.5-1.8 Ma. The southern African fauna of late Pliocene age is chiefly known from the karstic cave-cavern deposits of Makapansgat and Sterkfontein in the eastern part of the subcontinent, while a fossil mammal fauna of late Pliocene age (3.5-2.6 Ma) has not yet been discovered from the West Coast or lower Orange River deposits.

An example of the kind of fossil material that could occur in the Meso Suite gravels is shown in Figure 9. These larger fossils, which would be found in the excavations or noticed at the oversize screen (grizzly), are biased towards denser skeletal elements such as petrified teeth and the more robust articulating ends of limb bones.

The petrified teeth are found in the heavy concentrates from gravels of the coastal diamond mines (Figure 10) and have provided critical age constraints for our understanding of coastal-plain geohistory (Pickford & Senut, 1997). Similarly, it seems that finds in concentrates hold the most promise for a diagnostic fossil find from the Meso Suite deposits.

Notwithstanding the apparent paucity of fossils in the Orange River Meso Suite fluvial deposits, the possibility that some could be discovered cannot be dismissed. In view of the lack of age constraints from fossil mammal bones, any identifiable find would be of scientific importance. Though fossil bone or tooth finds might appear to be nondescript-looking fragments, a specialist is often able to make an identification, as evident in Figures 9 and 10.

Note that Figures 9 and 10 are intended to illustrate the nature of fossils from gravels and are not suggesting that the actual fossil species depicted are expected to occur. Although the depicted fossils are from marine gravels, they were reworked from pre-existing terrestrial deposits (except *cf. Mirounga* sp, Figure 10). Nevertheless, Figure 10 shows mid-Miocene, Proto-age fossil teeth and Figure 9 shows early Pliocene, Langebaanian, Upper Meso-age fossils.

8 GEOHERITAGE ASPECTS

African Star Minerals proposes to preserve the historically mined-out area of the Proto Terrace on Oena Proper, known as “Barker’s Pothole”, as a Geoheritage Site (geosite). Here the swept, potholed and fissured bedrock, where “jackpots” rich in diamonds were excavated, is still exposed (Figure 11). Boardwalks, signage and viewpoints are proposed and the site will form an added attraction to the Ai-Ais/Richtersveld Transfrontier Park.

Figure 11. Diamond trapsite microtopography. Images courtesy J. Orton.

Geology/geoscience is a fundamental part of nature, and geoheritage is an integral part of the global natural heritage – it encompasses the special places and objects that have a key role in our understanding of the history of the Earth – its rocks, minerals, fossils and landscapes. The preservation of a geoheritage site/attraction at the Oena mine is commendable. However, the exposed bedrock essentially shows the aftermath of the mining and the emptied potholes convey only limited information. Geoheritage and geoscience would be greatly enhanced by the creation of an archive of the exposures in the mine pits systematically recorded throughout the lifetime of the mine. The mining and backfilling permanently destroys the natural geological archive of the alluvial deposits and thus the impact of mining on geology, in the absence of such mitigation, is of high negative significance. The extent is international, as is evident in the interest of geoscientists of wide nationalities, and the loss of a sufficiently detailed record of the irreplaceable deposits is irreversible.

9 ANTICIPATED IMPACT ON POTENTIAL FOSSIL RESOURCES

The affected formations include a mid-Miocene Proto deposit (or Intermediate?) and/or early Pliocene Upper Meso deposits (Oena Proper), while all areas of interest involve Lower Meso deposits of late Pliocene age.

The major fossil finds have concerned conspicuous fossil bone occurrences, such as many bones (Arrisdrift) or large fossils (Auchas). It is not altogether impossible that similar occurrences may yet be discovered in the Proto and Meso deposits. It can be predicted that isolated fossil bones and teeth are sparsely scattered in the gravel deposits, as is witnessed by the many fossil finds in Vaal River gravels during the early times of the diamond diggings, when gravel processing was manual and observed at close range. Nevertheless, it is evident that fossils are overall sparse in the Orange River alluvial deposits and consequently the impact of bulk sampling and mining is considered to be LOW (Appendix 1). However, as is shown by Figure 10, the similar finding of a few small fossil teeth from the hitherto unfossiliferous Meso Suite fluvial deposits would change the low negative impact to a high positive impact of regional to international scientific extent.

10 IMPACT ASSESSMENT

10.1 GENERAL IMPACT OF BULK EARTH WORKS ON FOSSILS

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 there.

When excavations are made they furnish the “windows” into the deposits that would not otherwise exist and thereby provide access to the hidden fossils. The impact is positive for palaeontology, provided that efforts are made to watch out for and rescue the fossils. Fossils and significant observations will be lost in the absence of management actions to mitigate such loss. This loss of the opportunity to recover them and their contexts when exposed at a particular site is irreversible. The very scarcity of fossils makes for the added importance of looking out for them.

There remains a medium to high risk of valuable fossils being lost in spite of management actions to mitigate such loss. Machinery involved in excavation may damage or destroy fossils, or they may be hidden in “spoil” of excavated material.

This impact assessment, according to the rating scheme in Appendix 3, addresses the occurrence of the high-value fossil bones in the deposits. It does not differentiate between the formations as the palaeontological sensitivities of the affected formations with respect to the occurrence of fossil bones are similarly low.

10.2 EXTENTS

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

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

10.3 DURATION

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

10.4 INTENSITY

As mentioned above, due to the overall very sparse distribution of fossils in the affected formations the intensity/sensitivity is considered to be LOW. Conversely, when fossils are found in such poorly fossiliferous formations, they provide very significant advances in the geological understanding of the stratigraphy of a region.

10.5 PROBABILITY

It is probable that isolated fossil bones and teeth are sparsely scattered in the gravel deposits and it is POSSIBLE that fossils could be discovered during sampling and mining operations at the Oena Diamond Mine, especially if concentrates are inspected for fossil teeth.

10.6 IMPACT ASSESSMENT TABLE

TABLE 3. PALAEONTOLOGICAL IMPACT – SAMPLING AND MINING

Potential impact description: Impacts to palaeontological resources.
Destruction of or damage to fossil bones or resources by sampling and mining.

	Extent	Duration	Intensity	Consequence	Probability	Significance	Status	Confidence
Without Mitigation	Local 1	Long term 3	Low 1	Low 5	Possible	VERY LOW	Negative	Medium
With Mitigation	Local 1	Long-term 3	Low 1	Low 5	Possible	VERY LOW	Positive	Medium

Can the impact be reversed?	NO, because palaeontological resources are unique and their loss is irreversible.
Will impact cause irreplaceable loss or resources?	YES, valuable fossils may be lost in spite of management actions to mitigate such loss.
Can impact be avoided, managed or mitigated?	Although they cannot be avoided, impacts can be managed and/or mitigated during the mining.

Mitigation measures to reduce residual risk or enhance opportunities:

- Identify and appoint stand-by palaeontologist should paleontological finds be uncovered.
- Mine personnel to be alert for rare fossil bones and follow "Fossil Finds Procedure" (Appendix 2).
- On discovery of *in situ* fossil bones during sampling/mining, cease excavation and protect fossils from further damage.
- On discovery of potential fossils in ex-situ gravels, collect to labelled bag/box for safekeeping.
- On discovery of fossils in rotary pan concentrate, collect to labelled bag for safekeeping.
- Contact appointed palaeontologist providing information and images.
- Palaeontologist will assess information and establish suitable response, such as the importance of the find and recommendations for preservation, collection and record keeping.

Cumulative Impact: For prospecting and mining excavations in coastal-plain marine and alluvial formations the impact of both the finding and the loss of fossils is permanent. The loss of fossils would be of uncertain significance. Diligent and successful mitigation contributes to a positive cumulative impact as the rescued fossils are preserved and accumulated for scientific study. Positive impacts would continue to be felt with successful mitigation because of the scientific implications of the resulting research opportunities. Even though just a very minor portion of the bone fossils exposed in coastal-plain excavations has been seen and saved, the rescued fossils proved to be of fundamental scientific value.

Residual impact: It will never be possible to spot and rescue all fossils which means that there will always be loss and therefore a cumulative negative impact.

11 IMPACT OF MINING ON GEOSCIENCE AND GEOHERITAGE

The alluvial deposits of the middle and lower reaches of the Orange River have been mined for the last ~60 years. The published scientific literature emanated is actually relatively small (*e.g.* compared with that about kimberlite pipes) and is mainly of an interpretational, broad-scale nature – there is a lack of systematic illustration and description of the actual sedimentary geometries and stratigraphies of the individual mine pits in the public domain and much of this record is now permanently gone. The archival status of the records of the many mining companies involved over the years is undetermined.

With modern technology such as smartphones and cameras capable of recording high-resolution images, accompanied by GPS positioning, and freely available software that enables the stitching together of image mosaics of the mine faces, the creation of systematic records of the mine pit faces is now greatly facilitated.

In view of the importance of the mine exposures for geoscience and geoheritage, the significance of the impact of the mining is considered to be HIGH without mitigation, as reflected in the amendments below to the Geology part of the Impact Table in the Oena Diamond Mine EIA & EMP Report, page 68 (Site Plan Consulting, 2019).

TABLE 4. AMENDED IMPACT TABLE – ADAPTED FROM SITE PLAN CONSULTING, 2019.

Activity	Nature	Extent	Duration	Probability	Significance	Extent to which impact can cause or be:		
						Reversed	Irreplacea-ble loss of resource	Avoided, managed or mitigated
2.2. Clearing of overburden where present as backfill to previously-mined area *and mining of the underlying alluvial gravels*								
2.2.1. Geology	Removal of subsoil will impact on local geological stratigraphy	~~Local~~ Inter-national	Permanent	Definite	~~Insignificant~~ High	~~Yes~~ No	~~No~~ Yes	Mitigated By the creation of an archive of the mine pits strati-graphies

12 RECOMMENDATIONS

Unlike surficial archaeological material which can be recorded and collected prior to disturbance by mining, the mitigation of palaeontological resources must take place over the entire lifetime of the mine (15 years).

Open-pit mine excavations are a scientific and fossil resource and have been the major contributor to the understanding of the deposits and palaeontology of the West Coast. Mine personnel have played a critical role in bringing fossil finds to the attention of the international scientific community. These have generally been rare, more noticeable finds. Scattered finds and small fossils sparsely distributed in the deposits are generally missed or overlooked, as has probably been the case for the Orange River fluvial deposits. Most coastal diamond mine exposures also seem to lack fossils, but these are discovered during the occasions when mine geologists and guest scientists doing research projects have undertaken systematic, close-range scrutiny of the pit walls, which is not a routine mining activity.

As it is impractical for a specialist to routinely monitor the mine pit and mined material, routine monitoring can only be achieved by the co-operation of the people on the ground. By these are meant personnel in supervisory/inspection roles, such as the pit supervisor, geologist, surveyor and environmental monitoring officer, who are willing and interested to look out for occurrences of fossils. A monitoring presence is critical for spotting fossils as they are uncovered and stopping further damaging excavation.

It is recommended that a requirement to be alert for fossil materials and archaeological material be included in the Environmental Management Plan (EMP) for the sampling and mining operations. The Environmental Control Officer (ECO) and mining manager must inform staff of the need to watch for potential fossil occurrences. In the event of a discovery of fossil bone material a Fossil Finds Procedure" (FFP) is provided in Appendix 2. It is expected that such finds would be in the category of "allowed" rescue by mine staff, *i.e.* as for isolated bone finds in the FFP.

As mentioned above, finds of petrified teeth in concentrates hold the most promise for a diagnostic fossil find from the Orange River deposits. Importantly, the previous finds have come from small-scale, "hands-on" operations using rotary pans to concentrate heavy minerals, such as the proposed operations by Oena Diamond Mine. Whereas, in the larger mines, high-throughput concentration systems using Heavy Media Separation (HMS) plants and X-ray Sortex-type machines to extract diamonds in a "hands off" security regime, the petrified fossils in the concentrate are not captured.

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

The sampling and mining could have a positive impact with respect to understanding the stratigraphy and to palaeontological heritage, providing that adequate mitigation measures are in place and duly performed over the duration of the mining.

The creation of a systematic archive of the mine exposures over the duration of the mining will be a significant positive contribution to geoscience and geoheritage.

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14 APPENDIX 1 - PALAEONTOLOGICAL SENSITIVITY RATING

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

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

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

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

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

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

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

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

15 APPENDIX 2 - FOSSIL FIND PROCEDURES

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

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

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

15.1 ISOLATED BONE FINDS

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

Response by personnel in the event of isolated bone finds

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

Response by Palaeontologist in the event of isolated bone finds

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

Ex-situ fossil finds in concentrates

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

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

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

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

15.2 BONE CLUSTER FINDS

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

Response by personnel in the event of a bone cluster find

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

Response by Palaeontologist in the event of a bone cluster find

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

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

The field assessment could have the following outcomes:

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

15.3 RESCUE EXCAVATION

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

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

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

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

16 APPENDIX 3 - IMPACT SIGNIFICANCE RATING METHODOLOGY

The **significance** of an impact is defined as a combination of the **consequence** of the impact occurring and the **probability** that the impact will occur. The criteria used to determine impact consequence are presented in the Table below.

Criteria used to determine the Consequence of the Impact

Rating	Definition of Rating	Score
A. ***Extent***– *the area in which the impact will be experienced*		
None		0
Local	Confined to project or study area or part thereof (*e.g.* site)	1
Regional	The region, which may be defined in various ways, *e.g.* cadastral, catchment, topographic	2
(Inter) national	Nationally or beyond	3
B. ***Intensity***– *the magnitude or size of the impact*		
None		0
Low	Natural and/or social functions and processes are negligibly altered	1
Medium	Natural and/or social functions and processes continue albeit in a modified way	2
High	Natural and/or social functions or processes are severely altered	3
C. ***Duration***– *the time frame for which the impact will be experienced*		
None		0
Short-term	Up to 2 years	1
Medium-term	2 to 15 years	2
Long-term	More than 15 years	3

The combined score of these three criteria corresponds to a **Consequence Rating**, as set out in the Table below:

Method used to determine the Consequence Score

***Combined Score* (A+B+C)**	0 – 2	3 – 4	5	6	7	8 – 9
Consequence Rating	Not significant	Very low	Low	Medium	High	Very high

Once the consequence is derived, the probability of the impact occurring will be considered, using the probability classifications presented in the Table below.

Probability Classification

Probability of impact – the likelihood of the impact occurring	
Improbable	< 40% chance of occurring
Possible	40% - 70% chance of occurring
Probable	> 70% - 90% chance of occurring
Definite	> 90% chance of occurring

The overall s**ignificance** of impacts will be determined by considering consequence and probability using the rating system prescribed in the table below.

Impact Significance Ratings

Significance Rating	***Consequence***		***Probability***
Insignificant	Very Low	&	Possible
	Very Low	&	Improbable
Very Low	Very Low	&	Definite
	Very Low	&	Probable
	Low	&	Possible
	Low	&	Improbable
Low	Low	&	Definite
	Low	&	Probable
	Medium	&	Possible
	Medium	&	Improbable
Medium	Medium	&	Definite
	Medium	&	Probable
	High	&	Possible
	High	&	Improbable
High	High	&	Definite
	High	&	Probable
	Very High	&	Possible
	Very High	&	Improbable
Very High	Very High	&	Definite
	Very High	&	Probable

Finally the impacts will also be considered in terms of their status (positive or negative impact) and the confidence in the ascribed impact significance rating. The prescribed system for considering impacts status and confidence (in assessment) is laid out in the Table below.

Impact Status and Confidence Classification

Status of impact	
Indication whether the impact is adverse (negative) or beneficial (positive).	+ ve (positive – a 'benefit')
	– ve (negative – a 'cost')
	Neutral
Confidence of assessment	
The degree of confidence in predictions based on available information, SRK's judgment and/or specialist knowledge.	Low
	Medium
	High

The impact significance rating should be considered by the competent authorities in their decision-making process based on the implications of ratings ascribed below:

- **Insignificant**: the potential impact is negligible and **will not** have an influence on the decision regarding the proposed activity/development.
- **Very Low**: the potential impact **should not** have any meaningful influence on the decision regarding the proposed activity/development.
- **Low**: the potential impact **may not** have any meaningful influence on the decision regarding the proposed activity/development.
- **Medium**: the potential impact **should** influence the decision regarding the proposed activity/development.
- **High**: the potential impact **will** affect the decision regarding the proposed activity/development.
- **Very High**: The proposed activity should **only** be approved under special circumstances.

In the EIA practicable mitigation measures are recommended and impacts rated in the prescribed way both without and with the assumed effective implementation of mitigation measures.