PALAEONTOLOGICAL ASSESSMENT

(DESKTOP STUDY)

APPLICATION FOR DRILLING PROSPECTING RIGHT ON FARMS DUYKER EILAND 6 AND SCHUITJES KLIP 22, SALDANHA BAY MUNICIPALITY, VREDENBURG MAGISTERIAL DISTRICT, WESTERN CAPE

Western Cape Department of Mineral Resources Reference WC 30/5/1/1/2/10292 PR

By

John Pether, M.Sc., Pr. Sci. Nat. (Earth Sci.)
Geological and Palaeontological Consultant
P. O. Box 48318, Kommetjie, 7976
Tel./Fax (021) 7833023
Cellphone 083 744 6295
jpether@iafrica.com

Prepared at the Request of

Agency for Cultural Resource Management (ACRM)
5 Stuart Road, Rondebosch, 7700
Ph/Fax: 021 685 7589
Mobile: 082 321 0172
E-mail: acrm@wcaccess.co.za

For

Coastal and Environmental Services (CES)

Client

K2017432278 (South Africa) (Pty) Ltd.

25 January 2019

EXECUTIVE SUMMARY

1. Site Name

Application for Drilling Prospecting Right on Farms Duyker Eiland 6 and Schuitjes Klip 22.

2. Location

The proposed Prospecting Right area entails ~2889 hectares and is located on the northern part of the Vredenburg Peninsula in the Saldanha Bay Local Municipality, Vredenburg Magisterial District, Western Cape Province (Figure 1). The portions of farm Duyker Eiland 6 involved are parts of Portions 4, 5, 7, 11 and 14 (Figure 1). Of farm Schuitjes Klip 22 the portions 1 and 3 are included.

The relevant map sheet is 1:50 000 SHEET 3217DB & DD VREDENBURG.

Proposed borehole locations are scattered over the entire application area, but most are concentrated in the area of known phosphate mineralisation on the eastern flank of the hill called Soetlandskop (Figure 2) around the location of -32.753217°S / 17.964089°E.

3. Locality Plan

Figure 2 shows the proposed prospecting programme drill hole purposes and locations.

4. Proposed Development

The proposed prospecting programme primary intention is to establish the extent and quantity of phosphatic minerals in the project area with more confidence. In addition to the phosphatic content, the drill hole samples will also be analysed for the heavy minerals leucoxene/ilmenite, rutile, monazite and zircon.

The project is divided into four phases:

- Phase 1 – geological desktop consolidation of existing data and surface geological survey – 1 year.
- Phase 2 – drilling of ~49 reconnaissance boreholes – 1 year.
- Phase 3 – drilling of ~89 resource estimation boreholes – 2 years.
- Phase 4 – desktop resource determination – 1 year.

The drill drilling technique to be employed is waterless, using compressed air instead. The Wallis Mantis 75 hydraulic top-drive drill rig and the compressor are mounted on a Toyota Landcruiser. Surface disturbance is minimal as the making of drill rig pads and water sump pools are not required. Each metre of drill core will be logged by a geologist, placed in a numbered sample bag, and will be sent to an accredited assay laboratory.

5. Palaeontological Heritage Resources Identified

The proposed prospecting drilling operation will penetrate the following fossiliferous formations of the Neogene Sandveld Group: the marine Saldanha, Varswater and Uyekraal formations and the calcareous aeolianites of the Prospect Hill and Langebaan formations.

6. Anticipated Impacts

The fossil material likely to be encountered in drill samples from aeolianites is the ambient fossil content of land snails, tortoise bones, mole bones and rodents/micromammals. It is also possible that organic-rich, peaty material is encountered, such as the deposits of interdune seeps and ponds.

Fossil shell will be encountered in drill holes through the marine deposits. Though likely fragmentary, it may be diagnostic of the marine formation penetrated. Other fossils which are brought up in boreholes include smaller petrified/phosphatized material such as shark and other fish teeth and casts of shells (steinkerns).

The marine deposits and the aeolianites derived from them will both include marine microfossils. If present in sufficient quantity and diversity of species, these should differentiate the formations present.

In the process of field survey of outcrops and during the drilling programme it is possible that fossil material may be noticed in the outcrops.

The prospecting drilling involves small vertical volumes and the impact on the fossil content of the formations is therefore considered to be LOW.

7. Recommendations

Although the impact of the prospecting drilling is low relative to a mining operation, there is potential that a high positive impact can be achieved if fossil material is separated from the samples and made available for scientific analysis.

Small fossils may be encountered when sieving the sand samples prior to analysis. It is recommended that such coarse fraction material be kept and bagged, recording the details of the sample as for a fossil find. These samples should be examined by a specialist and finds of importance deposited in a curatorial institution. It is also desirable that a small subsample of unsieved material be collected from different units and/or at regular intervals down hole, for the purposes of checking for marine microfossil content, and also deposited in a curatorial institution.

It is recommended that a requirement to be alert for fossils in outcrops be included in the Environmental Management Plan (EMP) for the proposed prospecting operations. In the event that fossil shells and bones are noticed in outcrops, the following basic Fossil Finds Procedure must be implemented.

The geologist or Environmental Control Officer (ECO) must inform Heritage Western Cape (HWC) and standby palaeontologist and provide:

- A description of the nature of the find.
- Detailed images of the find (with scale included).
- Position of the find (GPS).

Heritage Western Cape and an appropriate specialist palaeontologist will assess the information and a suitable response will be established. For instance, if the exposed fossil is potentially valuable and in danger of degradation and damage, it will require collecting fairly promptly. A permit from HWC issued to a qualified palaeontologist is required to excavate fossils, who must record the context in detail and deposit the fossils at a HWC-approved curatorial institution.

DECLARATION OF INDEPENDENCE

PALAEONTOLOGICAL ASSESSMENT (DESKTOP STUDY)

APPLICATION FOR DRILLING PROSPECTING RIGHT ON FARMS DUYKER EILAND 6 AND SCHUITJES KLIP 22, SALDANHA BAY MUNICIPALITY, VREDENBURG MAGISTERIAL DISTRICT, WESTERN CAPE

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: 25 January 2019

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

CONTENTS

GLOSSARY

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

Aeolian: Pertaining to the wind. Refers to erosion, transport and deposition of sedimentary particles by wind. A rock formed by the solidification of aeolian sediments is an aeolianite.

Alluvium: Sediments deposited by a river or other running water (alluvial).

Archaeology: Remains resulting from human activity which are in a state of disuse and are in or on land and which are older than 100 years, including artefacts, human and hominid remains and artificial features and structures.

asl.: above (mean) sea level.

Bedrock: Hard rock formations underlying much younger sedimentary deposits.

Calcareous: sediment, sedimentary rock, or soil type which is formed from or contains a high proportion of calcium carbonate in the form of calcite or aragonite.

Calcrete: An indurated deposit (duricrust) mainly consisting of Ca and Mg carbonates. The term includes both pedogenic types formed in the near-surface soil context and non-pedogenic or groundwater calcretes related to water tables at depth.

Clast: Fragments of pre-existing rocks, *e.g*. sand grains, pebbles, boulders, produced by weathering and erosion. Clastic – composed of clasts.

Colluvium: Hillwash deposits formed by gravity transport downhill. Includes soil creep, sheetwash, small-scale rainfall rivulets and gullying, slumping and sliding processes that move and deposit material towards the foot of the slopes.

Conglomerate: A cemented gravel deposit.

Coversands: Aeolian blanket deposits of sandsheets and smaller dunes.

Duricrust: A general term for a zone of chemical precipitation and hardening formed at or near the surface of sedimentary bodies through pedogenic and (or) non-pedogenic processes. It is formed by the accumulation of soluble minerals deposited by mineral-bearing waters that move upward, downward, or laterally by capillary action, commonly assisted in arid settings by evaporation. Classified into calcrete, ferricrete, silcrete, gypcrete, sepiocrete etc.

Ferricrete: Indurated deposit (duricrust) consisting predominantly of accumulations of iron sesquioxides, with various dark-brown to yellow-brown hues. It may form by deposition from solution or as a residue after removal of silica and alkalis. Like calcrete it has pedogenic and groundwater forms. Synonyms are laterite, iron pan or "koffieklip".

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

Fm.: Formation.

Fossil: The remains of parts of animals and plants found in sedimentary deposits. Most commonly hard parts such as bones, teeth and shells which in lithified sedimentary rocks are usually altered by petrification (mineralization). Also impressions and mineral films in fine-grained sediments that preserve indications of soft parts. Fossils plants include coals, petrified wood and leaf impressions, as well as microscopic pollen and spores. Marine sediments contain a host of microfossils that reflect the plankton of the past and provide records of ocean changes. Nowadays also includes molecular fossils such as DNA and biogeochemicals such as oils and waxes.

Heritage: That which is inherited and forms part of the National Estate (Historical places, objects, fossils as defined by the National Heritage Resources Act 25 of 1999).

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

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

Palaeosol: An ancient, buried soil formed on a palaeosurface. The soil composition may reflect a climate significantly different from the climate now prevalent in the area where the soil is found. Burial reflects the subsequent environmental change.

Palaeosurface: An ancient land surface, usually buried and marked by a palaeosol or pedocrete, but may be exhumed by erosion (*e.g.* wind erosion/deflation) or by bulk earth works.

Pedogenesis/pedogenic: The process of turning sediment into soil by chemical weathering and the activity of organisms (plants growing in it, burrowing animals such as worms, the addition of humus *etc.*).

Pedocrete: A duricrust formed by pedogenic processes.

PIA: Palaeontological Impact Assessment.

Rhizolith: Fossil root. Most commonly formed by pedogenic carbonate deposition around the root and developed in palaeosols.

Sepiocrete: A duricrust with a high content of the magnesian clay mineral sepiolite.

Stone Age: The earliest technological period in human culture when tools were made of stone, wood, bone or horn.

Stratotype locality: The place where deposits regarded as defining the characteristics of a particular geological formation occur.

Tectonic: Relating to the structure of the earth's crust and the large-scale processes which take place within it (faulting and earthquakes, crustal uplift or subsidence.

Trace fossil: A structure or impression in sediments that preserves the behaviour of an organism, such as burrows, borings and nests, feeding traces (sediment processing), farming structures for bacteria and fungi, locomotion burrows and trackways and traces of predation on hard parts (tooth marks on bones, borings into shells by predatory gastropods and octopuses).

GEOLOGICAL TIME SCALE TERMS

For more detail see www.stratigraphy.org.

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

Mesozoic and Cenozoic Chronostratigraphy
From: International Commission on Stratigraphy.
Chronostratigraphic Chart 2016-12.pdf

Eonothem / Eon	Erathem / Era	System / Period	Series / Epoch	Stage / Age	GSSP	numerical age (Ma)
Phanerozoic	Cenozoic	Quaternary	Holocene			present – 0.0117
			Pleistocene	*Upper*		0.126
				Middle		0.781
				Calabrian		1.80
				Gelasian		2.58
		Neogene	Pliocene	Piacenzian		3.600
				Zanclean		5.333
			Miocene	Messinian		7.246
				Tortonian		11.63
				Serravallian		13.82
				Langhian		15.97
				Burdigalian		20.44
				Aquitanian		23.03
		Paleogene	Oligocene	Chattian		28.1
				Rupelian		33.9
			Eocene	Priabonian		37.8
				Bartonian		41.2
				Lutetian		47.8
				Ypresian		56.0
			Paleocene	Thanetian		59.2
				Selandian		61.6
				Danian		66.0
	Mesozoic	Cretaceous	Upper	Maastrichtian		72.1 ±0.2
				Campanian		83.6 ±0.2
				Santonian		86.3 ±0.5
				Coniacian		89.8 ±0.3
				Turonian		93.9
				Cenomanian		100.5
			Lower	Albian		~ 113.0
				Aptian		~ 125.0
				Barremian		~ 129.4
				Hauterivian		~ 132.9
				Valanginian		~ 139.8
				Berriasian		~ 145.0

ICS-approved 2009 Quaternary (SQS/INQUA) proposal

ERA	PERIOD	EPOCH & SUBEPOCH		AGE	AGE (Ma)	GSSP
CENOZOIC	QUATERNARY	HOLOCENE			0.012	
		PLEISTOCENE	Late	'Tarantian'	0.126	
			M	'Ionian'	0.781	
			Early	Calabrian	1.806	Vrica, Calabria
				Gelasian	2.588	Monte San Nicola, Sicily
	Ng	PLIOCENE		Piacenzian	3.600	
				Zanclean	5.332	

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 for a Prospecting Right, K2017432278 (South Africa) (Pty) Ltd., proposes to carry out a prospecting programme by borehole drilling on the farms Duyker Eiland 6 and Schuitjes Klip 22 (Figure 1) where phosphatic sand deposits occur. has initiated a Mining Right Application for the proposed new Zandheuvel Phosphate Mine near Saldanha Bay (Figure 1). Coastal and Environmental Services (CES) has been appointed to undertake the Environmental Assessment for the proposed prospecting and has appointed the Agency for Cultural Resource Management (ACRM) to conduct the Heritage Assessment, of which this Palaeontological Assessment report forms part. Its brief is to inform about the palaeontological sensitivities of the Project Area and the probability of fossils being uncovered in the subsurface and being disturbed or destroyed in the process of the prospecting.

Figure 1. The Project Area for the proposed Prospecting Right and the parts of the included properties. From the Background Information Document issued by CES.

2 LOCATION

The proposed Prospecting Right area entails ~2889 hectares and is located on the northern part of the Vredenburg Peninsula in the Saldanha Bay Local Municipality, Vredenburg Magisterial District, Western Cape Province (Figure 1). The portions of farm Duyker Eiland 6 involved are parts of Portions 4, 5, 7, 11 and 14 (Figure 1). Of farm Schuitjes Klip 22 the portions 1 and 3 are included.

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Proposed borehole locations are scattered over the entire application area, but most are concentrated in the area of known phosphate mineralisation on the eastern flank of the hill called Soetlandskop (Figure 2) around the location of -32.753217°S / 17.964089°E.

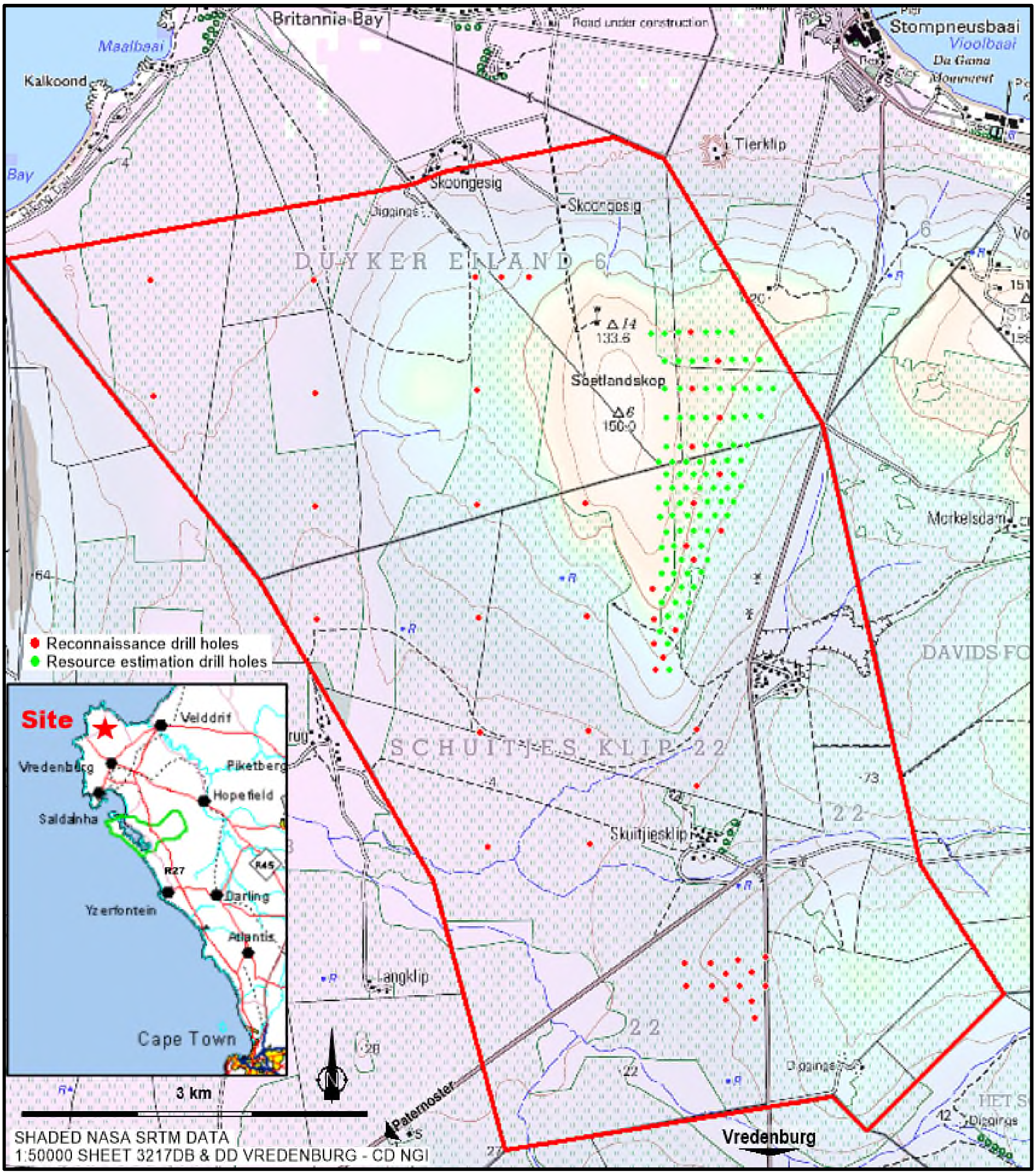

Figure 2. Proposed drill hole locations.

3 LOCALITY PLAN

Figure 2 shows the proposed prospecting programme drill hole purposes and locations.

4 PROPOSED PROSPECTING PROGRAMME

The proposed prospecting programme follows on from previous prospecting drilling carried out by Montero Mining and Exploration Ltd. (Simón & González, 2011). The applicant's primary intention is to establish the extent and quantity of phosphatic minerals in the project area with more confidence. In addition to the phosphatic content, the drill hole samples will also be analysed for the heavy minerals leucoxene/ilmenite, rutile, monazite and zircon.

The project is divided into four phases:

- Phase 1 – geological desktop consolidation of existing data and surface geological survey – 1 year.
- Phase 2 – drilling of ~49 reconnaissance boreholes – 1 year.
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The drill drilling technique to be employed is waterless, using compressed air instead in a reverse circulation drill stem, with the air being pumped down the outer tube while cuttings are forced up the inner tube. The Wallis Mantis 75 hydraulic top-drive drill rig and the compressor are mounted on a Toyota Landcruiser. Surface disturbance is minimal as the making of drill rig pads and water sump pools are not required. A rig-mounted rotary splitter will be used to collect a representative sample of the drilled rock. Each metre of drill core will be logged by a geologist, placed in a sample bag, numbered and moved to an off-site location where it will be prepared to be sent to an accredited testing laboratory.

5 APPLICABLE LEGISLATION

The National Heritage Resources Act (NHRA No. 25 of 1999) protects archaeological and palaeontological sites and materials, as well as graves/cemeteries, battlefield sites and buildings, structures and features over 60 years old. According to the Act (Sect. 35), it is an offence to destroy, damage, excavate, alter of remove from its original place, or collect, any archaeological, palaeontological and historical material or object, without a permit issued by the South African Heritage Resources Agency (SAHRA) or applicable Provincial Heritage Resources Agency, *viz*. Heritage Western Cape (HWC).

Notification of SAHRA or the applicable Provincial Heritage Resources Agency is required for proposed developments exceeding certain dimensions (Sect. 38). If the areal scale of subsurface disturbance and exposure exceeds 300 m in linear length and 5000 m^2 (NHRA 25 (1999), Section 38 (1)), the development must be assessed for heritage impacts (an HIA) that may include an assessment of palaeontological heritage (a PIA).

6 APPROACH AND METHODOLOGY

6.1 AVAILABLE INFORMATION

A considerable volume of scientific literature (several hundred published articles) has issued from the fossil finds made in the Saldanha area, most famously from finds in the old Langebaanweg phosphate mine that is now the West Coast Fossil Park. The important information for this report is in the articles dealing with the broader stratigraphy, palaeoenvironments, fossils and ages of the formations. These are, *inter alia*, Visser & Schoch (1972, 1973), Tankard (1974, 1975a,b), Dingle *et al.* (1979), Rogers (1980), Hendey (1981a,b,), Dingle *et al.* (1983), Hendey (1983a,b,c), Hendey and Dingle (1990), Pether *et al*. (2000), Roberts & Brink (2002), Roberts *et al*. (2006), Roberts *et al*. (2011) and Roberts & Siegfried (2014),. Other references are cited in the normal manner and included in the References section.

Some differences in the interpretation of the coastal-plain stratigraphy of the Saldanha area exist between researchers. This partly reflects the growth of observations as well as different approaches in stratigraphic classification. Historically the approach has been lithostratigraphic, based on lithology (sediment composition and texture). For example, phosphatic marine deposits in the southwestern Cape have previously all been subsumed in the Varswater Formation. However, it is now apparent that the Varswater Formation thus defined included marine deposits of different ages. Now that the history of global ice volumes, concomitant sea-level fluctuations and palaeoclimate/palaeoceanography are much better established it is possible to apply the sequence stratigraphic approach (dynamic stratigraphy) to coastal-plain deposits. In this approach, a marine formation includes that package of deposits that relates to a particular sea-level cycle of rising and falling sea level. In effect this results in a finer-scale stratigraphy (Table 1). The outline of the geological history presented below reflects the author's perspective, based on research and field observations of coastal-plain deposits between northern Namibia and the southern Cape.

6.2 ASSUMPTIONS AND LIMITATIONS

The assumption is that the fossil potential of a formation in the study area will be typical of that found in the region and more specifically, similar to that already observed the study area. In many cases the information on fossil content is limited to the basics, such as in the case of geological mapping when the fossils are not the immediate focus. Scientifically important fossil shell and bone material is expected to be sparsely scattered in these coastal-plain deposits, but unless large and obvious, is not generally seen, under-estimating the fossil prevalence. Much depends on careful scrutiny of exposures and on spotting fossils as they are uncovered during digging *i.e.* by monitoring excavations. A limitation on predictive capacity exists in that it is not possible to predict the buried fossil content of an area or formation other than in general terms.

7 REGIONAL GEOLOGICAL HISTORY

The bedrock of the wider region consists of **Malmesbury Group** shales, impure limestones and volcanics that were deposited ~600 Ma (Ma = million years ago, Mega-anna) and were later intruded at depth by molten magmas ~550 Ma that solidified and crystallized to become the **Cape Granites**. These granites form the hills and exposed rocky coasts of the Vredenburg Peninsula and underlie the Project Area at depth. Beneath much of the coastal plain the softer shale bedrock of the Malmesbury Group has been eroded away by ancient rivers to well below sea level and is deeply buried beneath the sediments of the **Sandveld Group** (Table 1) (Roberts *et al.*, 2006). These sediments are of later Cenozoic age, deposited during the Neogene and Quaternary periods, *i.e*. during the last 23 million years. The older marine formations of the Sandveld group are the primary hosts of the phosphatic sands in the region.

The buried valleys eroded in the Malmesbury shales are filled with the **Elandsfontyn Formation**, the oldest formation of the Sandveld Group, consisting of sandy fluvial and muddy marsh deposits laid down by meandering rivers under humid climatic conditions (Rogers, 1980, 1982). The formation has abundant plant fossils in places, including lignified logs and plant material. Fossil pollen is indicative of forest vegetation with palms and is considered to be early to middle Miocene in age (Coetzee, 1978; Rogers, 1982; Hendey, 1981b, Roberts *et al*., 2017). This was an interval 23-16 Ma of slow global warming and episodically rising sea level which culminated in the Mid-Miocene Climatic Optimum ~16 Ma.

The oldest marine deposits of the southwestern coastal plain, the **Saldanha Formation,** were laid down during and just after the Mid-Miocene Climatic Optimum ~16-14 Ma. The ancient shoreline of the transgression maximum (highest level reached by the sea) is now found about 90-120 m asl., to which it has been uplifted by the continental edge bobbing up slightly. The Saldanha Formation is buried beneath the younger deposits in the Saldanha region. Residual marine gravels and sands above ~50 m asl. belong to this formation, while patches of it are likely preserved in places beneath the younger, Pliocene marine deposits. The equivalent of the Saldanha Formation in Namaqualand is the marine Kleinzee Formation (aka 90 m Package), which extends seawards from a maximum ancient shoreline which is now is now uplifted to ~90 m asl. along the West Coast, with prograded, diamondiferous marine gravels occurring seaward of a prominent slope "nick" or even vertical "fossil" sea cliffs.

Subsequent Pliocene palaeoshoreline deposits (5-3 Ma) are found below ~50 m asl. (Pether *et al*., 2000). In the southwestern Cape, these marine deposits are collectively known as the **Varswater Formation**. The stratotype locality is at the West Coast Fossil Park, where the extensive fossil bone assemblage recovered from the phosphate quarry indicates the early Pliocene age (Hendey, 1981a). These fossils were deposited in an estuarine setting during the transgression to ~50 m asl., about 5 Ma during the global warming of the Early Pliocene Warm Period. In the wider area, when sea level later receded from ~50 m asl., fossiliferous shallow-marine deposits were left mantling the emerged coastal plain. These deposits correlate with the Avontuur Formation (aka 50 m Package) of the West Coast, from which "Langebaanian Age" terrestrial and marine mammal fossils have been recovered. These deposits have largely been eroded off the steeper, more elevated bedrock coastal gradients of the Vredenburg Peninsula, but residuals occur in places.

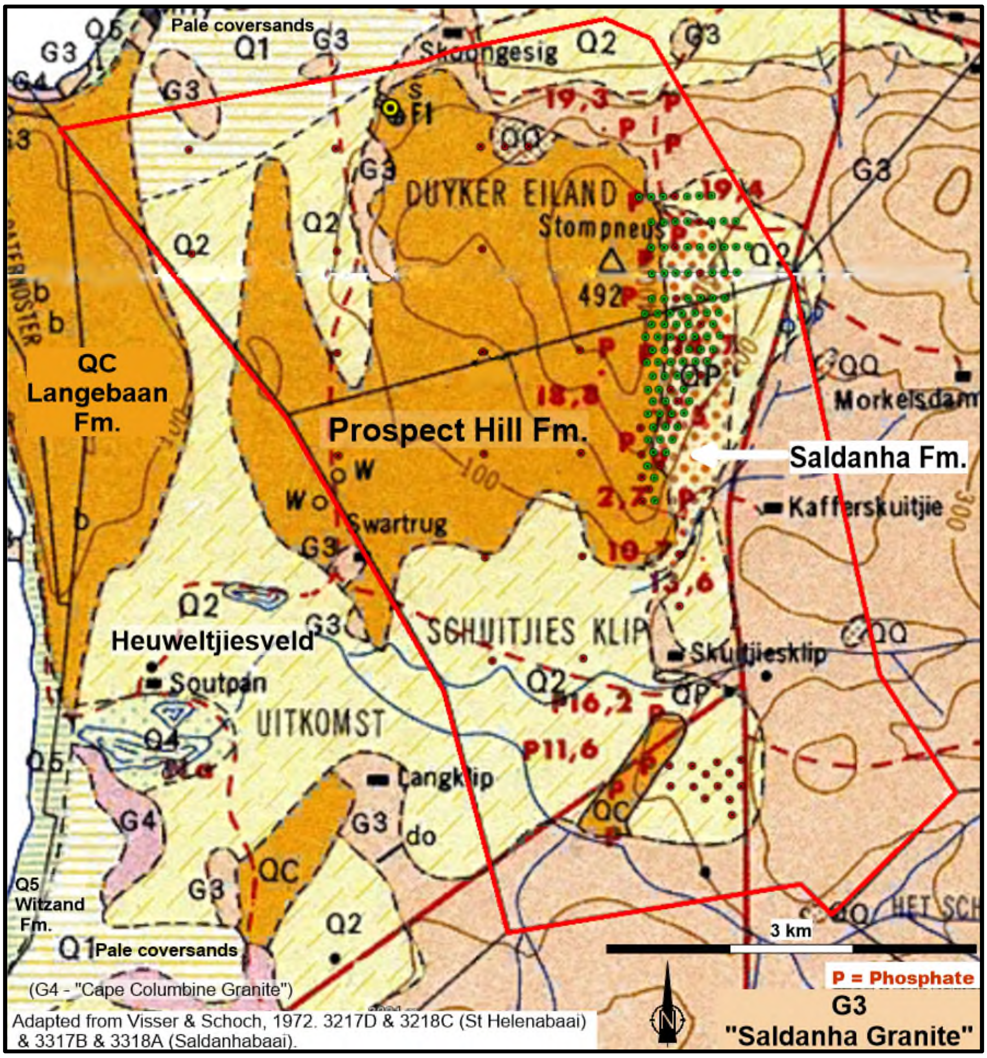

Figure 3. Older map of the surface geology of the Project Area and surrounds, updated to show the Prospect Hill and Saldanha formations.

Sea level rose again during the warming of the Late Pliocene Warm Period (~3.0 Ma), to a level now ~30 m asl. In the Saldanha embayment west of the West Coast Fossil Park, the flat plain extending towards the coast is underlain by these deposits which were previously a member of the Varswater Formation, but are now separated as the "**Uyekraal Formation**", after Rogers (in Rogers *et al*., 1990). The Uyekraal marine beds are spatially consistent with being equivalent to the Hondeklipbaai Formation (aka 30 m Package), seen in Namaqualand diamond mines as a substantial, prograded marine formation built out seawards from a sea-level maximum of 30-35 m asl. (Pether, 1994; Pether, in Roberts *et al*., 2006). This formation, up to a few km wide, underlies the outer part of the coastal plains of the West Coast.

TABLE 1. Formations of the Sandveld Group – revised stratigraphy.

FORMATION	Age and description	Sensitivity
WITZAND	Holocene and recently active dune fields and cordons <~12 ka.	Mainly archaeological sites.
SPRINGFONTYN	Mainly Quaternary to Holocene, mainly quartzose dune and sandsheet deposits, interbedded palaeosols, basal fluvial deposits <~2 Ma.	Fossil bones very sparse, high signif. Basal Baards QF-type deposits locally. Elandsfontein Fossil Beds.– v high signif.
LANGEBAAN	Late Quaternary aeolianites <~3 Ma.	Fossil bones mod. common, local to high signif.
VELDDRIF	Quaternary raised beaches & estuarine deposits, <~1.2 Ma. Sea-levels below ~15 m asl.	Shell fossils common, local signif. Fossil bones very sparse, high signif.
Marine erosion surfaces below ~15 m asl.		
Old indet. sands		
LANGEBAAN	Late Pliocene to mid-Quaternary aeolianites <~3 Ma.	Fossil bones mod. common, local to high signif.
UYEKRAAL SHELLY SAND (2)	Mid-Pliocene marine deposits ~3 Ma. Sea-level max. ~35 m asl	Shell fossils common, local signif. Fossil bones very sparse, high signif.
Marine erosion surface to ~35 m asl.		
Old indet. sands?		
LANGEBAAN	Earlier Pliocene aeolianites <~3 Ma.	Fossil bones mod. common, local to high signif.
VARSWATER	Later early Pliocene regressive deposits of wider area. 5-4 Ma. Sea-level max. ~50-60 m asl	Fossil bone rare, high signif. Poorly known, fossil shells of high signif.
VARSWATER	Early Pliocene transgressive marine deposits in embayments (upper KGM?, LQSM and MPPM members	Fossil bone common locally, high signif. Shells very sparse, high signif.
Marine erosion surface to ~60 m asl.		
Very old indet. sands??		
PROSPECT HILL	Miocene aeolianite 12-9 Ma?	Fossils very sparse – high signif.
SALDANHA	Mid-Miocene marine deposits (predicted presence), 17-14 Ma. Sea-level max. ~90 m asl. May Include the lower KGM?	Very few fossils recovered, high signif. if found.
Marine erosion surface to ~100 m asl.		
LANGEENHEID CLAYEY SAND (1)	Mid Miocene early-transgression estuarine deposits (prev. LCSM Member in lower Varswater Fm.). 18-17 Ma.	Plant microfossils – high signif.
ELANDSFONTYN	Oligocene-early Miocene fluvial muds, peats, sands and gravels, ~23-18 Ma.	Plant fossils – high signif.
PRE-SANDVELD GROUP BEDROCK		
(1) Previously a member of the LVF.	(2) Previously subsumed in the UVF.	UVF: Upper Varswater Fm. LVF: Lower Varswater Fm.

These older, phosphatic marine formations are mostly buried beneath aeolianite formations and are usually only exposed in excavations or intersected in boreholes. However, the eroded outer edge of the Uyekraal Formation is exposed at places around the Saldanha Bay shoreline (Hoedjiespunt, Elandspunt, Leentjiesklip).

Further shallow-marine beds occur along the coast below ~15 m asl. in a narrow fringe around the coast where they are exposed as shelly gravels and sands on terraces. These “raised beaches” were deposited at various times during the Quaternary Period and are collectively called the **Velddrif Formation**.

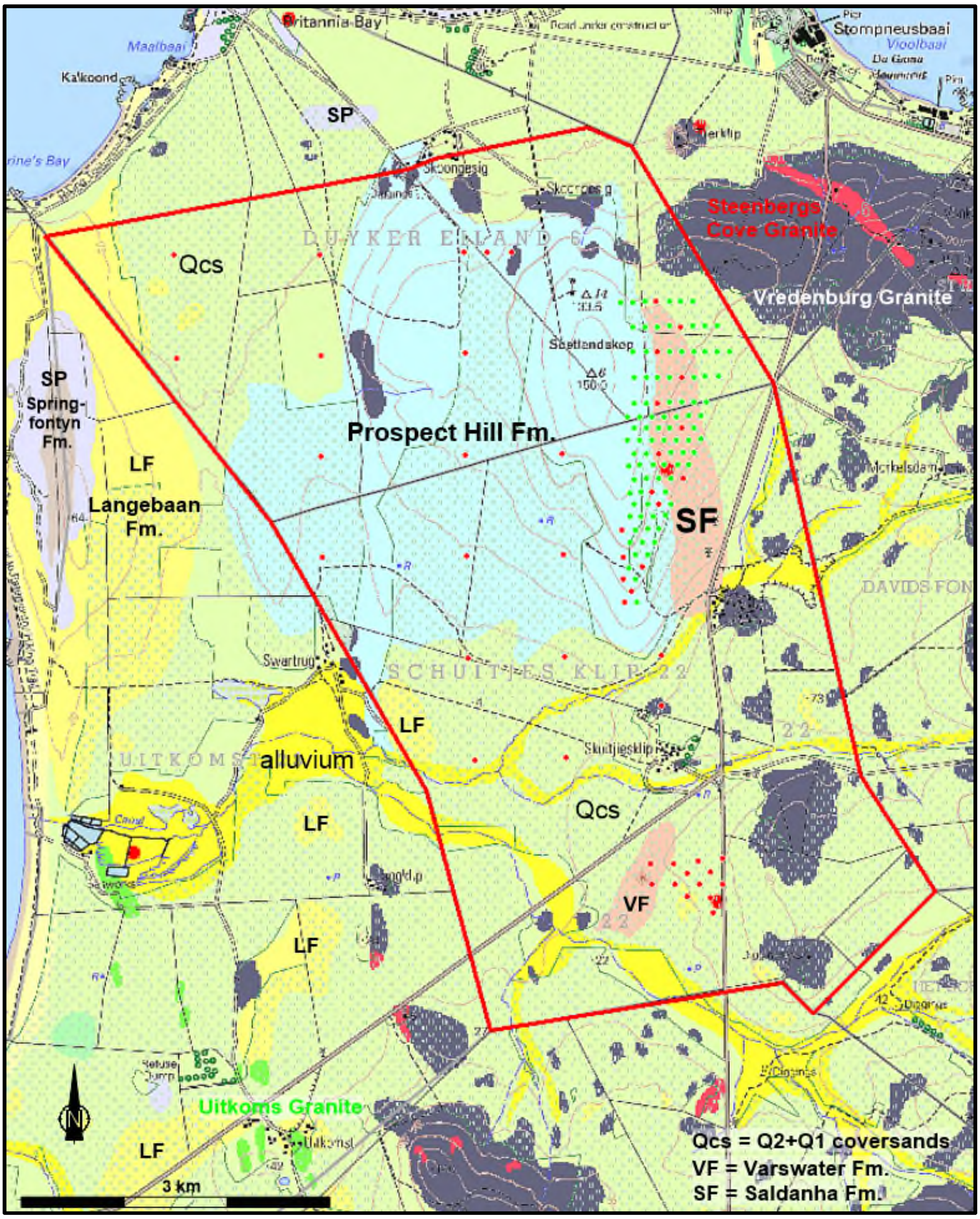

Figure 4. Adapted from 1:50 000 Geological Sheets 3217DB & DD Vredenburg and 3218CA & CC Velddrif, Council for Geoscience.

Extensive dune plumes and sand sheets were blown inland from the ancient shorelines by southerly winds and sands were also reworked from the underlying marine deposits. These calcareous dunes, mainly composed of tiny shell fragments, are evident in the coastal landscape as the ridges, low hills and mounds beneath a capping calcrete crust. The aeolianites overlie the wind-deflation erosion surfaces formed on the marine deposits.

The aforementioned mid-Miocene marine Saldanha Fm. was succeeded by aeolianites of later Miocene age (post ~16 Ma) which are expected to be preserved on the higher elevation part of the coastal plain. These older aeolianites would have been considerably altered by groundwater action and are now evidently represented by an unnamed formation comprised of significant thicknesses of leached "glass sands" which are encountered in boreholes, beneath the calcareous aeolianites in the Elandsfontein phosphate mine area.

Along the Vredenburg coast the high aeolianite ridge backing the narrow coastal terrace northwards from Saldanha (Prospect Hill) to Paternoster and Duyker Eiland is mainly comprised of slightly iron-oxide stained, cemented marine shell fragments. Terrestrial fossils such as extinct forms of land snails, sparse bones and ostrich eggshell fragments of the extinct ostrich *Diamantornis wardi* occur at the Prospect Hill quarry. Based on dated occurrences of fossil ostrich eggshell in the Namib, East Africa and Arabia, an age of 12-9 Ma is indicated for these calcareous aeolianites (Stidham, 2008) which have been named the **Prospect Hill Formation** (Roberts & Brink, 2002) (Figures 3 & 4). However, this age is controversial as these aeolianites might be underlain by early Pliocene marine deposits (Varswater Fm.) which are exposed near the quarry and are dated by shells and microfossils and thus the aeolianites would be no older than early Pliocene. For current purposes the Miocene age is accepted, but the issue is still to be resolved.

Surface outcrops of the younger, calcified aeolianites of the **Langebaan Formation** occupy large areas of the landscape (Figures 3 & 4). At this stage the Langebaan Formation includes various aeolianites of different ages and is an "amalgam" of the dune plumes that formed on the coastal plain, at differing places and times, mainly during the last ~4 Ma (Pliocene to the late Quaternary) (Table 1). This is reflected in the different ages indicated from fossils found at various places:

- a late Pliocene or younger age (Diazville lower quarry, Roberts & Brink, 2002).
- early Quaternary (Skurwerug, Hendey & Cooke, 1985).
- middle and late Quaternary ages (Kraal Bay Member) are indicated by relationships to Last Interglacial (~125 ka) and earlier shoreline deposits and by dating of aeolianites by luminescence methods (OSL) (Roberts *et al*., 2009).

The **Springfontyn Formation** accommodates the mainly non-calcareous, unconsolidated windblown sand sheets and dunes that have covered parts of the coastal landscape during the Quaternary. Local patches of dune sands have formed from the erosion and deflation of older deposits such as coversands, colluvia and alluvia and the Langebaan Formation. More generally distributed in the landscape are loose coversands with varying degrees of soil development. These coversands are not differentiated in the latest geological map (Figure 4), but in the older map (Figure 3) are distinguished as surficial units **Q2** (older "heuweltjiesveld" cover) and overlying **Q1** younger cover of pale sands. Chase & Thomas (2007) have cored Q1-type coversands in a regional survey of various settings along the West Coast and applied optically stimulated luminescence (OSL) dating techniques to establish the timing of sand accumulation. Their results indicate several periods of deposition of Q1 sands during the last 100 ka (late Quaternary), with activity/deposition at 63–73, 43–49, 30–33, 16–24 and 4–5 ka. Notably, underlying soils produced dates from ~150 to ~600 ka, reflecting the accumulation of Q2 sands during the middle Quaternary.

The latest addition of dunes to the coastal plain is known as the **Witzand Formation** (Rogers, 1980), comprising sands blown from the beach in the last several thousand years of the Holocene and accumulated in the form of a narrow dune cordon or "sand wall" parallel to the coast, or as dune plumes transgressing several kilometres inland.

8 LOCAL GEOLOGY AND PALAEONTOLOGY

8.1 Fossils in the Marine Formations

Fossil shells (snails, clams, barnacles, corals) are common to abundant in well-preserved marine deposits, but may be limited or dissolved away completely in deposits that have been subject to decalcification by groundwaters. Distinct faunas are associated with the various marine environments such as foreshore, surf-zone, shoreface and shelf deposits. Each marine formation also includes important extinct fossil shell species which are characteristic of that formation and which facilitate correlation of formations over wide regions.

The remains of marine mammals (whales, dolphins, seals), and of seabirds, occur sparsely in the marine deposits. Rolled, petrified bones and teeth of land mammals, which were eroded from older, pre-existing terrestrial deposits, occur in the marine gravels. Fish teeth are quite common, especially shark teeth. The hard parts of crustaceans, such as crab claws, are often present. A large array of trace fossils occur, made by the many animals that dwell within or forage in the sediments.

Microfossils, the minute, sand grain-size shells of the unicellular foraminifera, are an important component of marine sediments. Analysis of microfossils from coastal marine and aeolian formations on the west and south coasts by micropalaeontologist Dr Ian McMillan has shown that the coastal-plain marine formations, and the aeolianites derived from them, can be distinguished on the basis of foraminiferal assemblages and key species.

8.2 The Miocene Saldanha Formation

The oldest, potentially fossil-bearing marine sediments occur on Duyker Eiland and Schuitjes Klip where **Saldanha Formation** phosphatic sediments form the eastern flank of Soetlandskop, between 40-100 m asl. (Figures 3 & 4). Higher up the flank of Soetlandskop the phosphatic deposits are overlain by the later Miocene Prospect Hill Formation aeolianite. Roberts & Siegfried (2014) have assigned the phosphatic deposits to the Muishond Fontein Phosphorite Member of the early Pliocene Varswater Fm. However, this correlation is untenable, accepting that the overlying aeolianite is indeed the much older, Miocene Prospect Hill Formation. Furthermore, the high elevation of these deposits is incompatible with Pliocene sea-level history. The correlation of these deposits with the Saldanha Formation is indicated in Figures 3 & 4.

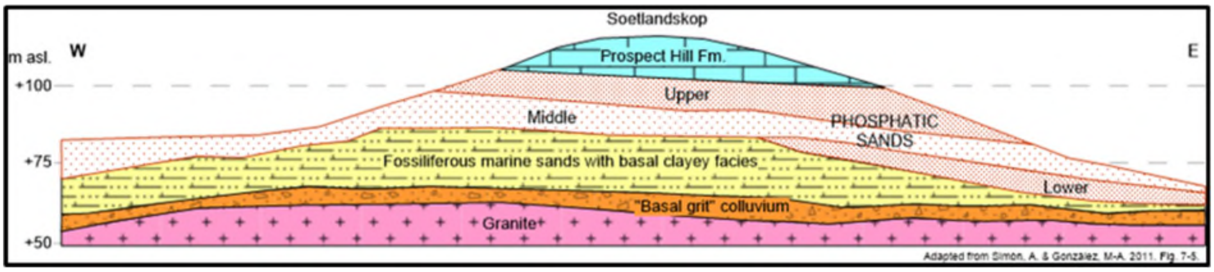

Figure 5. Section through Soetlandskop. Adapted from Simón & González, 2011.

The phosphatic material comprises brown sandstones, brown nodules and friable, sandy phosphatic limestone, interbedded with layers of shelly limestone (Visser & Schoch, 1973). More information on the nature of the strata comprising Soetlandskop has been provided in a phosphate exploration report by Simón & González (2011). The drilling results indicate that the deposits, up to ~30 m thick, will be intersected on the hill flanks (Figure 5). Overlying a "Basal Grit" unit of probable colluvial origin is a fossiliferous marine unit which includes beds with marine shell. Aeolian deposits with terrestrial snail shells also occur. The overlying Phosphatic Sands are divided into three units based on phosphatic content, with a phosphate-poor "Middle Zone" separating the Lower and Upper, phosphate-richer zones. It is possible that the Phosphatic Sands include marine sands that have been reworked into aeolianites.

8.2.1 Significance

As mentioned, hitherto the phosphatic deposits comprising Soetlandskop have been correlated with the early Pliocene Varswater Formation, but it is suggested that instead these deposits relate to the high sea levels of the mid-Miocene Warm Period ~16 Ma. The recovery of marine fossils from the Soetlandskop area will resolve the issue and is of importance because the existence of mid-Miocene marine deposits in the Saldanha region, the postulated and elusive Saldanha Formation, has long been debated.

8.3 The Pliocene Marine Formations

Marine deposits of the early Pliocene Varswater Formation may be preserved in places below ~50 m asl. but are usually buried beneath the aeolianites of the Langebaan Formation. Notably however, the new mapping by Roberts & Siegfried (2014) shows outcrop assigned to the Varswater Formation in the centre of Schuitjes Klip 3/22 (Figure 4, VF). They assigned this outcrop was to the Muishond Fontein Phosphorite Member and described it as “phosphatic, shelly limestone of uncertain stratigraphic affinity drapes a rare marine-cut surface sloping from 20 to 38 m asl.”. Situated on the flanks of a drainage interfluve, this outcrop had previously been mapped as phosphatic Langebaan Formation aeolianite (Figure 3).

The correlation of this outcrop with the Varswater Formation by Roberts & Siegfried (2014) is clearly tentative. Nevertheless, marine deposits preserved at these elevations are feasibly of early Pliocene age, but in this context are likely to have been deposited during the retreat of sea level from the early Pliocene sea-level maximum, *i.e*. are regressive, prograded shoreline deposits. Although this outcrop is correlated with the Muishond Fontein Phosphorite Member by Roberts & Siegfried (2014), on the basis of its phosphatic nature, this unit at the Langebaanweg type locality was evidently deposited in a low-gradient embayment during the preceding rising sea level and is not strictly equivalent to the subsequent regressive deposits that mantled the coastal plain where steeper bedrock gradients and open-coastal, exposed conditions prevailed.

The late Pliocene Uyekraal Formation will be intersected in reconnaissance boreholes in the lower-elevation, western portion of the Project Area.

8.3.1 Significance

The new mapping by Roberts & Siegfried (2014) has drawn attention to the presence of an outcrop that has potential to provide new insight into the geological history and fossil heritage of the Saldanha region, in particular the nature of the early Pliocene marine record preserved on the Vredenburg Peninsula, in a setting different to that of the Varswater Formation type locality. The recovery of marine fossils from this outcrop is of importance as these may resolve the issue of the nature and age of this deposit. Similarly, fossil material may identify and confirm the presence of the Uyekraal Fm. beneath the western part of the Project Area.

8.4 Fossils in the Aeolian Formations

In aeolianites, the fossil material most commonly seen is the ambient fossil content of dune sands: land snails, tortoise shells and mole bones. Other small bones occur very sparsely such as bird and small mammal bones. The fossil content is more abundant in association with palaeosurfaces and their soils (palaeosols), formed during periods of dune stabilization and which define aeolian packages and larger formations. Importantly, the bones of larger animals (e.g. antelopes) are more persistently present along palaeosurfaces formed on top of marine deposits and the palaeosurfaces which separate the major aeolianite units. Blowout or deflation erosional palaeosurfaces carry fossils concentrated by the removal of sand by the wind, such as land snails and tiny rodent fossils which reflect the palaeoenvironment such as the vegetation type. The interdune areas between dune ridges may host deposits associated with small springs/seeps and marshy vleis which are richly fossiliferous, including fossil plant material, aquatic snails and frogs. The most spectacular bone concentrations found in aeolianites are due to the bone-collecting behaviour of hyaenas which store bones in and around their lairs.

8.5 THE PROSPECT HILL FORMATION

The fossils recorded hitherto are the aforementioned eggshell fragments of the extinct ostrich *Diamantornis wardi* of later Miocene age, some fossil bones including the extinct three-toed horse *Hipparion*, also of later Miocene age, and poorly-preserved, indeterminate antelope bones. Roberts (1997) notes that the abundance of fossil tortoises in the Prospect Hill Formation Member far exceeds that in the younger, Langebaan Formation aeolianites. Extinct land snails occur, including a giant form of the common land snail *Trigonephrus*.

8.5.1 Significance

The fossil content of the Prospect Hill Formation is based on finds in the Prospect Hill area near Saldanha and no finds are specifically recorded from the formation where it comprises Soetlandskop in and around the northern Project Area. Therefore additional fossil evidence to support the correlation of these Soetlandskop calcreted aeolianites with the Prospect Hill Formation is required. Notably, extinct fossil tortoises are known from the Miocene of Namibia and from the early Pliocene Varswater Formation and tortoises are therefore useful for dating and correlation purposes. However, the identity of the fossil tortoises in the Prospect Hill Formation has not been established.

8.6 THE LANGEBAAN FORMATION

This formation is expected to be present beneath the coversands of the lower elevation terrain on these properties. On the later map a more extensive distribution is indicated and denoted as the younger, late Quaternary Kraal Bay Member of the Langebaan Fm. (Roberts & Siegfried, 2014) (Figure 4). However, older aeolianites overlying the Pliocene marine formations are also likely to be present. Patches of calcrete on the hills of the granitic terrain are also depicted as the Langebaan Formation, but although some of these may be remnant patches of aeolianite, some may just be calcrete formed in the weathering profile of the granite.

8.6.1 Significance

The aeolianites of the Langebaan Fm. have been a prime source of information on the Quaternary faunas and archaeology of the Western Cape and the fossils that have been found are of profound scientific value, raising international interest in the region. The boreholes may produce reworked marine microfossils, extinct land snails and micromammal fossils that may shed light on the age of the Langebaan Fm. aeolianite beneath the Project Area.

8.7 THE SPRINGFONTYN FORMATION COVERSANDS

The coversands are very poorly fossiliferous and an impact from drilling is not expected.

9 ANTICIPATED IMPACT OF THE PROSPECTING

The fossil material likely to be encountered in drill samples from aeolianites is the ambient fossil content of land snails, tortoise bones, mole bones and rodents/micromammals. It is also possible that organic-rich, peaty material is encountered, such as the deposits of interdune seeps and ponds.

Fossil shell will be encountered in drill holes through the marine deposits. Though likely fragmentary, it may be diagnostic of the marine formation penetrated. Other fossils which are brought up in boreholes include smaller petrified/phosphatized material such as shark and other fish teeth and casts of shells (steinkerns).

The marine deposits and the aeolianites derived from them will both include marine microfossils. If present in sufficient quantity and diversity of species, these should differentiate the formations present.

In the process of field survey of outcrops and during the drilling programme it is possible that fossil material may be noticed in the outcrops.

The prospecting drilling involves small vertical volumes and the impact on the fossil content of the formations is therefore considered to be LOW.

10 RECOMMENDATIONS

Although the impact of the prospecting drilling is low relative to a mining operation, there is potential that a high positive impact can be achieved if fossil material is separated from the samples and made available for scientific analysis.

Small fossils may be encountered when sieving the sand samples prior to analysis. It is recommended that such coarse fraction material be kept and bagged, recording the details of the sample as for a fossil find. These samples should be examined by a specialist and finds of importance deposited in a curatorial institution. It is also desirable that a small subsample of unsieved material be collected from different units and/or at regular intervals down hole, for the purposes of checking for marine microfossil content, and also deposited in a curatorial institution.

It is recommended that a requirement to be alert for fossils in outcrops be included in the Environmental Management Plan (EMP) for the proposed prospecting operations. In the event that fossil shells and bones are noticed in outcrops, the following basic Fossil Finds Procedure must be implemented.

The geologist or Environmental Control Officer (ECO) must inform Heritage Western Cape (HWC) and standby palaeontologist and provide:

- A description of the nature of the find.
- Detailed images of the find (with scale included).
- Position of the find (GPS).

Heritage Western Cape and an appropriate specialist palaeontologist will assess the information and a suitable response will be established. For instance, if the exposed fossil is potentially valuable and in danger of degradation and damage, it will require collecting fairly promptly.

A permit from HWC is required to excavate fossils. The applicant should be the qualified specialist responsible for assessment, collection and reporting (palaeontologist). Should fossils be found that require rapid collecting, application for a palaeontological permit must be made to HWC immediately. In addition to the information and images of the find, the application requires details of the registered owners of the sites, their permission and a site-plan map. All fossils must be deposited at a HWC-approved curatorial institution.

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