Annex G.14

Palaeontological Specialist Report

Project Reference Number 0164903

Environmental and Social Impact Assessment [ESIA] for the Gamsberg Zinc Mine and Associated Infrastructure, Northern Cape Province

PALAEONTOLOGICAL IMPACT ASSESSMENT
Desktop Study

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

Environmental Resources Management
Southern Africa (PTY) Ltd
Private Bag X12, Tokai, 7945
Tel: +27 21 702-9100, Fax: +27 21 701-7900
Mel.pillay@erm.com

For

BLACK MOUNTAIN MINING (Pty) Ltd

20 March 2013

CONTENTS

SUMMARY

Black Mountain Mining (Pty) Ltd proposes to establish a new open pit mine to exploit the zinc ore in the Gamsberg inselberg (*Figure 1*). Environmental Resources Management Southern Africa (Pty) Ltd (ERM) has been appointed to undertake the Environmental and Social Impact Assessment (ESIA) for the construction and operation of the new Gamsberg zinc mine.

This palaeontological assessment forms part of the Heritage Impact Assessment in the ESIA and its purposes are to:

- Outline the nature of possible palaeontological/fossil heritage resources in the subsurface of the Study Area.
- Suggest the mitigatory actions to be taken with respect to the occurrence of fossils during bulk earth works.

The Study Area is situated in the northern part of the Bushmanland Plateau where inselbergs and ridges of bedrock project steeply above the sandy plains (*Figure 2*). These are rocks of the **Namaqua Metamorphic Province** and the specific strata comprising Gamsberg belong to a meta-volcanosedimentary succession named the **Aggeneys Subgroup** of the **Bushmanland Group** (Figure 3). The age of the Bushmanland Group is between 1640 and 1200 Ma. The mining of the zinc ore in unfossiliferous Bushmanland Group bedrock strata does not have an impact on fossil heritage.

Between the inselbergs is a buried bedrock topography of ancient drainages that are now filled with a variety of deposits, including fluvial, local pan deposits, alluvial fan deposits, colluvial deposits and aeolian sands. These deposits can be broadly assigned to the younger strata of the **Kalahari Group** deposits of the interior. The uppermost, superficial deposits that form the surface of the plains are mapped as Quaternary to Recent Units Q-s2 and Q-s1 (Figure 3). Q-s2 is comprised of coversands and soils, ephemeral stream deposits and colluvial deposits. Unit Q-s1 is the red aeolian dunes, otherwise known as the **Gordonia Formation.** Fluvial deposits occur along the larger watercourses.

A direct impact is associated with the **Construction Phase** bulk earth works for infrastructure that will be excavated into the surficial Kalahari Group sediments that surround the Gamsberg amphitheatre, mainly the Q-s2 coversands and colluvial deposits and the fluvial deposits in watercourses.

No areas of particular palaeontological sensitivity are identified. Due to the sparse, very patchy distribution of fossils in the subsurface, the probability of a significant fossil find is rated UNLIKELY. The assigning of an intensity rating for palaeontological impact is guided by the 'Sensitivity Rating' provided in *Appendix 3*. The deposits of the initial 1-3 metres subsurface are

expected to be young (late Quaternary Q-s2) and very poorly fossiliferous, particularly since most of the material appears to be colluvial in origin. The botanical and faunal sensitivities of the watercourse environments will act to limit earthworks in the potentially more fossiliferous fluvial/stream deposits. Accordingly the intensity is rated as LOW. Notwithstanding, when fossils are found in these formations, they are often very significant additions to the geologic understanding of the area (*Appendix 3*).

Nature: Construction Phase bulk earth works for infrastructure may result in a **negative direct** impact on the fossil content of the surficial deposits (Kalahari Group).
Impact Magnitude: Small
Extent: Direct – Construction Sites.
Duration: Permanent.
Intensity: LOW.
Likelihood: Unlikely.
IMPACT SIGNIFICANCE (PRE-MITIGATION): NEGLIGIBLE.
Degree of Confidence: Medium.

The potential impact has a moderate influence upon the proposed project, consisting of implemented mitigation measures recommended below, to be followed during the Construction Phase.

- The monitoring of excavations by on-site personnel is recommended during construction of the infrastructure, under supervision of the Environmental Site Officer (ESO). Appendices 1 and 2 outline monitoring by construction personnel and provide general Fossil Find Procedures for incorporation into the Construction Phase EMP.
- A professional palaeontologist must be appointed to respond to queries about possible or definite fossil finds (*see Appendix 2*). In the event of a significant fossil find, a palaeontologist must supervise the excavation of the fossils and record their contexts.

It is probable that sparse, valuable bone fossils will go undetected, even with the most diligent mitigation practicable. On the other hand, the finding and recovery of fossils will have a positive impact ranging from regional to international in extent, depending on the nature of the finds.

Provided that no further bulk earth works in the surficial deposits take place there should not be an impact during the **Operational Phase** or the **Decommissioning Phase** . However, it is possible that with time further infrastructure may be required and earthmoving involved with rehabilitation and landscaping might entail excavation into undisturbed deposits. The EMPs for such must retain the requirement to monitor for fossil occurences.

1 *INTRODUCTION*

Black Mountain Mining (Pty) Ltd (Black Mountain) currently mines zinc, lead, copper and silver at the underground Black Mountain Deeps Mine near Aggeneys (*Figure 1*). A similar zinc-sulphide deposit is hosted in the strata forming Gamsberg, an inselberg east of Aggeneys rising 220-250 m above the Bushmanland Plateau. This deposit is currently exploited by underground mining, with the ore being transported to the Black Mountain Deeps plant for processing.

Black Mountain proposes to establish a new 10 Million tpa open pit mine to exploit the zinc ore in the Gamsberg inselberg, together with a concentrator plant and associated infrastructure. Environmental Resources Management Southern Africa (Pty) Ltd (ERM) has been appointed to undertake the Environmental and Social Impact Assessment (ESIA) for the construction and operation of the new Gamsberg zinc mine.

The proposed new mine, comprising the open pit, waste rock dump sites, haul roads, the zinc concentrator plant, a tailings dam and other infrastructure, is located on the following properties:

- Bloemhoek 61 Portion 1
- Gams 60 Portion 1
- Gams 60 Portion 4
- Aroams 57 RE

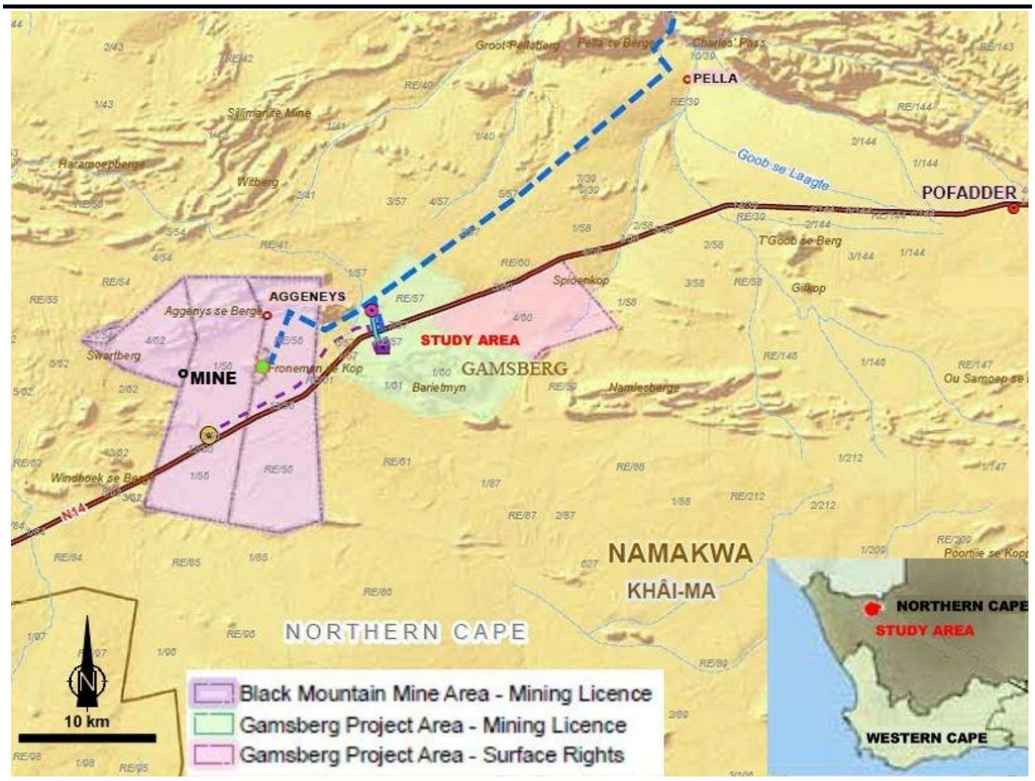
The zinc ore is within strata of the Bushmanland Group metasediments which form the bedrock of the region. These bedrock strata are not fossiliferous. Overlying the bedrock on the plains are much younger deposits that fill in the valleys in the bedrock topography. These deposits are sparsely fossiliferous. They will be intersected during the installation of infrastructure for the mine.

Palaeontological interventions mainly happen once fossil material is exposed at depth, ie once the ESIA process is done and construction commences. The purposes of this assessment are to:

- Outline the nature of possible palaeontological/fossil heritage resources in the subsurface of the Study Area.
- Suggest the mitigatory actions to be taken with respect to the occurrence of fossils during bulk earth works.

The action plans and protocols for palaeontological mitigation must therefore be *included in the Environmental Management Plan (EMP)* for the proposed project. Included herein is a general fossil-finds procedure for the appropriate responses to the discovery of palaeontological materials during construction of the infrastructure for the proposed new mine.

Figure 1 Location of the Study Area (adapted from figure supplied by ERM)



2 APPLICABLE LEGISLATION

The National Heritage Resources Act (NHRA No. 25 of 1999) protects archaeological and palaeontological sites and materials, as well as graves/cemeteries, battlefield sites and buildings, structures and features over 60 years old. The South African Heritage Resources Agency (SAHRA) administers this legislation nationally, with Heritage Resource Agencies acting at provincial level. According to the Act (Sect. 35), it is an offence to destroy, damage, excavate, alter or 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.

Notification of SAHRA or the applicable Provincial Heritage Resources Agency is required for proposed developments exceeding certain dimensions (Sect. 38). If the extent of subsurface disturbance and exposure exceeds 300 m in linear length and 5000 m2 (NHRA 25 (1999), Section 38 (1)), it must be assessed for heritage impacts including assessment of potential palaeontological heritage (a PIA).

3 APPROACH AND METHODOLOGY

3.1 AVAILABLE INFORMATION

The geology of the Study Area is depicted on Sheet 1: 250 000 Geological Series 2918 Pofadder (Council for Geoscience, 2007), an extract of which is shown in *Figure 3*. The publications relevant to this assessment are cited in the normal manner as references in the text and are included in the References section.

3.2 ASSUMPTIONS AND LIMITATIONS

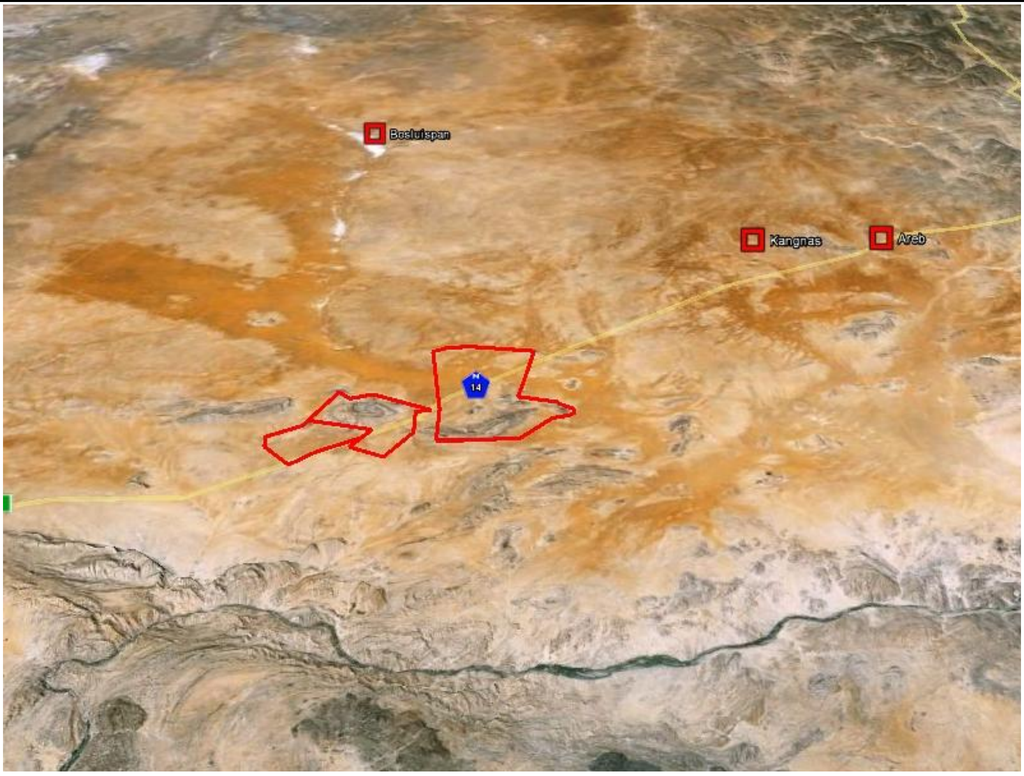
The assumption is that the fossil potential of the formations underlying the road route will be typical of that found in the region and more specifically, similar to that already discovered nearer to the site. Scientifically important fossil bone material is expected to be sparsely scattered in these deposits and much depends on spotting this material as it is uncovered during digging ie by monitoring excavations.

A limitation on predictive capacity exists in that it is not possible to predict the buried fossil content of an area or formation other than in such general terms. Certain processes/agents can produce significant concentrations of fossil bones, but the possibility of these specific buried palaeoenvironments being present is only hinted at by the general setting of a site.

4 GEOLOGICAL SETTING

The Study Area is situated in the northern part of the Bushmanland Plateau where inselbergs and ridges of bedrock granites, gneisses and metamorphic rocks project steeply above the sandy plains (*Figure* 2). These are rocks of the **Namaqua Metamorphic Province** and the specific strata comprising Gamsberg belong to the **Aggeneys Subgroup** of the **Bushmanland Group** (*Figure 3*). The Aggeneys Subgroup is a meta-volcanosedimentary succession that overlies ~1800 Ma gneiss of the Gladkop Suite. The age of the Bushmanland Group is between 1640 and 1200 Ma when it was deposited in a setting similar to that of the present-day Red Sea where active geothermal venting is depositing base metals in clayey muds accumulating in depressions on the sea floor (Bailie et al, 2007). Subsequently the sediments and volcanic exhalatives were metamorphosed and deformed. Gamsberg is now a concave synform feature folded into the granitic gneiss. These rocks are not fossiliferous.

Figure 2. The Study Area in context of the wider surrounds. Simulated oblique aerial view looking south. From Google Earth.

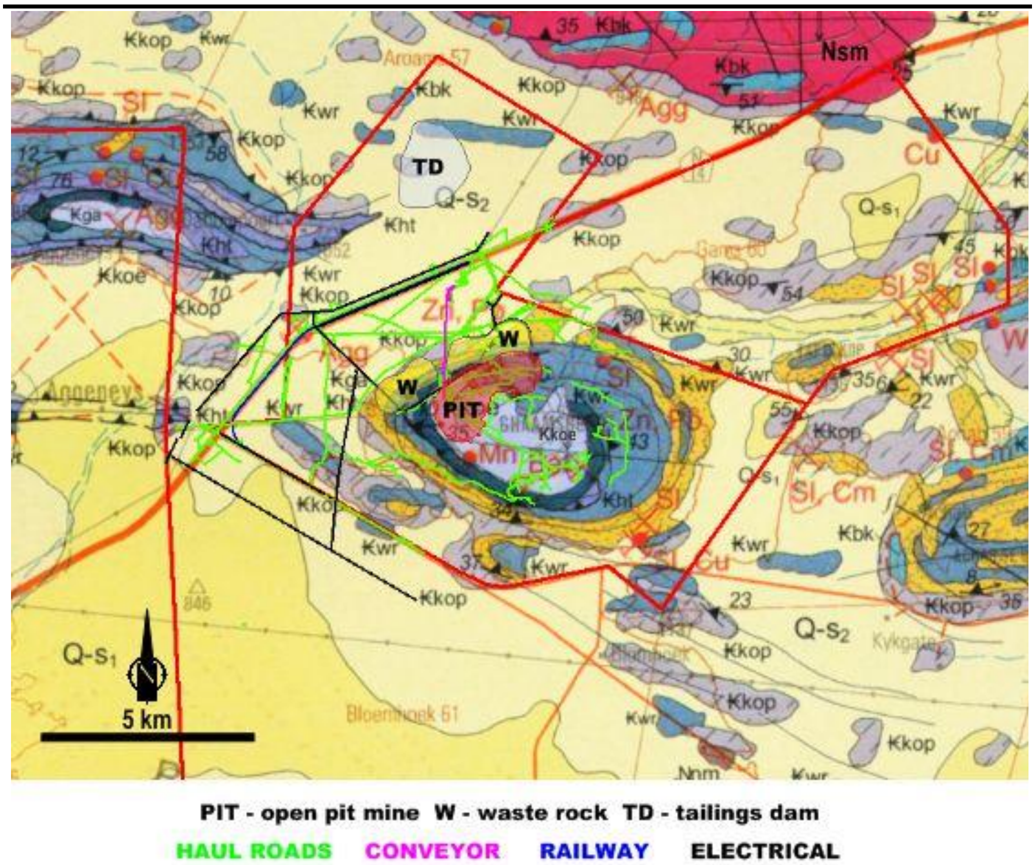


Between the inselbergs is a buried bedrock topography of ancient drainages that are now filled with a variety of deposits. These include fluvial gravels and sands, local lacustrine and pan deposits, alluvial fan deposits, colluvial deposits and aeolian sands. Within these deposits are palaeosols marking palaeosurfaces of longer duration when pedocretes such as calcrete formed in the soil profile. Boreholes in these palaeovalleys reveal thicknesses of sand and grit up to ~140 m (Rogers, 1915).

The most prominent palaeovalley is that of the Koa River, a broad fossil river course marked by red dunes and a series of pans, of which Bosluispan is prominent (*Figure 2*). The Koa Valley curves to the northwest where it passes south of the Gamsberg and is truncated by the rugged flank of the deeper Orange River valley near Henkries. The Koa River was either a major tributary of the Proto-Orange River or was the course of the actual Orange River when it took a southerly route to the Atlantic (De Wit et al, 2000). The basal fluvial deposits are fossiliferous.

The superficial deposits that form the surface of the plains are mapped as Quaternary to Recent Units Q-s2 and Q-s1 (Figure 3). Q-s2 is comprised of coversands and soils, ephemeral stream deposits and colluvial deposits. Unit Q-s1 is the red aeolian dunes and may be regarded as the western equivalent of the **Gordonia Formation** of the **Kalahari Group** deposits of the interior. Fluvial deposits occur along the larger watercourses.

Figure 3. Geology of the Study Area.



KALAHARI GROUP		
Q-s1	Gordonia Fm	Red aeolian coversands and dunes
Q-s2	Unnamed	Coversands and sandy soils, fluvial deposits and colluvium
NAMAQUA METAMORPHIC PROVINCE		
T'Oubep Suite		
Nsm	Swartmodder Gneiss	Biotite-hornblende augen gneiss
BUSHMANLAND GROUP - Aggeneys Subgroup		
Kkoe	Koeris Fm	Psammitic schist, conglomerate, amphibolite, quartzite
Kga	Gams Member	Sulphide-bearing magnetitegrunerite-garnet-pyroxene rocks,cordierite fels, sillimanite schist, quartzite
Kht	Hotson Fm	Rhythmically layered quartzite, quartz-feldspar-biotite gneiss ± sillimanite nodules, quartz-biotitesillimanite schist
Kwr	Wortel Fm	Sequence of medium- to thickbedded white quartzite with pelitic schist and interbedded sillimanite bodies
Kbk	Brulkolk Fm	Pegmatite-bearing quartz-feldspar gneiss, calc-silicate rocks with lenses of schist, marble, conglomerate and amphibolite
GLADKOP METAMORPHIC SUITE		
Kkop	Koeipoort Gneiss	Medium- to coarse-grained leucogneiss in places biotite- and augen-rich

Extract from Sheet 1: 250 000 Geological Series 2918 Pofadder (Council for Geoscience, 2007)

5 *PALAEONTOLOGY*

Western Bushmanland was intruded by numerous small volcanoes during the Late Cretaceous and Paleocene 77-54 Ma. Known as the 'Gamoep pipe swarm' or Gamoep Suite, these occur as volcanic pipes 50-500 m in diameter. Many of the volcanic pipes contain crater lake deposits which are highly fossiliferous. The crater lake mudstones from the Banke pipe near Platbakkies have provided a rich fossil pollen floral assemblage, fossil leaves and wood, some insects and several frogs. The fossil pollen indicates a dry subtropical forest of podocarps (yellowwoods) and araucarians (monkey puzzle trees now extinct in Africa), with an understorey of Restionaceae, Proteaceae and Ericaceae representing early Cape Floristic Region taxa (Scholtz, 1985).

The teeth and bones of a dinosaur *Kangnasuarus* were found in a well dug on the farm Kangnas 77 (Figure 2) (Rogers, 1915; Haughton, 1915). It was first thought that this find dated the initial infill of the Bushmanland palaeo-drainages to the Late Cretaceous (Rogers, 1915). Subsequent investigations of the spoil from the well and a magnetic survey of the site have revealed that the occurrence is in fact in the crater lake of a volcano and not related to a buried palaeodrainage (De Wit et al, 1992).

Interestingly, the preservation of Late Cretaceous volcano crater lake deposits shows that parts of the Bushmanland Plateau have undergone little erosion since ~70 Ma. This is the main subcontinental palaeosurface formed after the breakup of Gondwana and massive erosion since ~120 Ma, dubbed the 'African Surface' (Partridge & Maud, 1987).

The Koa Valley is incised into the African Surface. At Bosluispan the basal fluvial gravels and sands contain a faunal assemblage that indicates a mid-Miocene age of ~16 Ma for the sediments. The fossils include *Gomphotherium*, an extinct proboscidean, bovids, giraffids, a rhinocerotid, tortoises, rodents, crocodile teeth and catfish (Macey et al, 2011). The fauna indicates a warmer and more humid climate and the presence of both browsers and grazers suggests riverside woodlands with grassland in the wider area. To the east in the Geelvloer palaeovalley the basal gravels contain bones of Miocene anthracotheres, an extinct hippo-like amphibious herbivore. Fossil wood indicates a tropical/subtropical wet climate with low seasonality (Bamford, 2000). The ~16 Ma age of the Bosluispan fauna corresponds with the Mid Miocene Climatic Optimum recognized globally (Zachos et al, 2001). It is probable that the Geelvloer deposits are of similar age. At the coast the marine Kleinsee Formation, dated to ~16 Ma, contains a tropical molluscan fauna.

At Areb (Figure 2) the teeth of the extinct three-toed horse *Hipparion namaquense* were found in granitic grits underlying a 15 m thickness of multiple calcretes (Haughton, 1932; Pickford et al, 1999). In East Africa similar teeth occur in deposits dated to 6-4 Ma (latest Miocene/early Pliocene). Thus the maximum age of the calcreted deposits is early Pliocene. Pickford et al. (1999) suggest that the Pliocene was still relatively humid and characterized by fluvial erosion and that aggradation of sediments in the palaeovalleys commenced in the Quaternary and is associated with aridification. This accords with the global palaeoclimatic record of the commencement of Ice Age climates since ~2.6 Ma and the intensification of cold upwelling at the coast. Fluvial deposits in the Carnarvon Leegte contain teeth of *Hipparion* and *Equus* (zebra), the latter indicating that the deposits are younger than 2.6 Ma, ie of Quaternary age

The aeolianites of southern Namibia, which date from the mid-Miocene, incorporate fossil ostrich eggshells of extinct species. These differ from modern eggs by having the pores concentrated in clumps or pore complexes. Different pore arrangements occur in the eggshells in an evolutionary sequence through the units forming the aeolianite sequence. The units can be approximately dated by the co-occurrence of hares and rodents that are dated elsewhere in Africa. This biostratigraphic sequence of eggshells is already proving useful in correlations with eggshell finds in Africa and as far afield as Arabia. If found in Bushmanland, the fossil eggshell 'oospecies' present can differentiate deposits of Quaternary, Pliocene and Miocene ages.

6 FOSSIL CONTEXTS

6.1 FOSSILS IN AEOLIANITES

The fossils most commonly seen in aeolianites are land snails and tortoises. Closer inspection reveals the incisors, skulls and bones of moles. Other small bones occur sparsely such as bird and micromammal bones. This is the ambient fossil content of dunes and it includes the bones of rodents, lizards, snakes, birds, ostrich eggshell and small mammals (hares, mongooses, cats etc.). The bones of larger animals are generally very sparsely scattered. Notwithstanding, concentrations of bones are found in specific contexts.

During dune migration the sparse ambient fossil content is concentrated on the palaeosurface the dunes are traversing and leaving their fossil content behind in a deflation lag. The fossils may also be more dispersed in a basal interdune sandsheet deposit. The toes of the overlying dune crossbeds may include fossils, these low-angle sands having fringed the interdune areas.

Palaeosurfaces of very local extent occur in dune deposits, in the form of deflation "blowouts" between dunes, with scoop-shaped geometries. These are usually indicated by land snail concentrations. Deflation palaeosurfaces also encompass considerable areas, varying from regional in extent to areas confined to particular parts of the landscape. During large-scale deflation of a dunefield or coversands, downward erosion is limited by proximity to the local water table, as the damp sand is prevented from blowing away. If the water table subsequently rises, the deeper blowouts become pans or vleis and fossils may accumulate. Similarly, hollows between dunes (interdune areas) are the sites of ponding of water seeping from the dunes, leading to the deposits of springs and small vleis. These are usually muddy, with dark organic content and plant fossils, but being waterholes, are usually richly fossiliferous, with concentrations of large mammal bones due to predator activity, including Stone Age hunters.

In addition to fossils concentrated by the removal of sand by the wind, fossiliferous zones are also formed when the mobile sands become stabilized, when palaeoclimatic changes result in wetter or less windy periods, with reduced rates of sand accumulation, colonization by vegetation and soil formation showing the surface stability. Fossils accumulate on these palaeosurfaces and in the pedogenic profile due to their longevity. The lateral extent, thickness and maturity of the pedogenic profile indicate its longevity. The prime feature of the pedogenic palaeosurfaces is the formation of pedocretes – cemented soil profiles of various types such as calcretes and profiles cemented by iron-oxides, neoformed clays and incipient silicification. Land snails, tortoises and bones are usually noticeably more common within pedocretes.

Once pedocretes have formed in the soil profile of stabilized dunes, further contexts arise for fossil accumulation. They limit downward erosion so that palaeosurfaces form on them. A pedocrete impedes drainage and ponds groundwater, forming pans and vleis in low areas, with concomitant potential for fossil bones. Such deposits also contain fossil aquatic snails and the remains of other pan life such as frogs, fish, birds, crustaceans, vegetation etc.

The most spectacular bone concentrations found in aeolianites are due to the bone-collecting behaviour of hyaenas. These are stored in and around their lairs, such as the large burrows made by aardvarks that have been appropriated by the hyaenas. Porcupines are another bone collector in its burrows. Such bone accumulations are usually considerably younger than the aeolianite into which the burrow was made.

6.2 *TRACE FOSSILS*

Trace fossils are common in the aeolianites as well as in the alluvial and colluvial deposits. Rhizoliths or calcified root casts and termitaria are associated with palaeosol horizons. More pervasive is an overprint of termite bioturbation that has largely destroyed the primary sedimentary structures of sandy units. The termitaria and termite burrows constitute the *Termitichnus* ichnofacies which is comprised of a number of termitaria types that reflect different species of termites. The traces of burrows made by ants, beetles, wasps, spiders, scorpions, lizards, moles and other rodents are also expected.

6.3 *FOSSILS IN WATERCOURSES*

Watercourses are present at a variety of scales, from small, ephemeral, braiding-stream courses on alluvial fans to more entrenched, integrated drainages such as the T'Goop se Laagte system that drains the Gamsberg area northwards past Pella to the Orange River. The fossil potential of small-scale systems is very low. In larger drainages fossils such as abraded bone fragments and loose teeth occur sparsely in channel lags. These drainages must have been more active during periods of wetter climate such as occurred during the Quaternary. Finds such as the snail *Melanoides*, clam *Corbicula* and freshwater oyster *Etheria* attest to more perennial freshwater availability in the larger, now seldom-flowing drainages. The latter will also have hosted waterhole and pan deposits in places, with improved fossil potential.

7 *IMPACT ASSESSMENT*

7.1 *NATURE OF THE 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 wrt 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 depository that would not otherwise exist and thereby provide access to the hidden fossils. The impact is positive for palaeontology, provided that mitigation 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. 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. The loss of the opportunity to recover them and their contexts when exposed at a particular site is a direct negative impact that is irreversible.

7.2 *IMPACT ASSESSMENT*

The mining of the zinc ore in unfossiliferous Bushmanland Group bedrock strata does not have an impact on fossil heritage.

A direct impact is associated with bulk earth works that are excavated into the surficial Kalahari Group sediments that surround the Gamsberg amphitheatre, viz the red aeolian sands (Gordonia Fm/Q-s1), the Q-s2 coversands and colluvial deposits and the fluvial deposits in watercourses.

The bulk earth works with a potential palaeontological impact are those required for the installation of the mine infrastructure, ie the impact is during the **Construction Phase**.

No areas of particular palaeontological sensitivity are identified. The fossils are expected to occur sporadically in the subsurface of the sands.

Provided that no further bulk earth works in the surficial deposits take place there should not be an impact during the **Operational Phase**. However, it is possible that with time further infrastructure may be required.

The **Decommissioning Phase** likewise should not involve additional installations requiring earth works. However, it is possible that earthmoving involved with rehabilitation and landscaping might entail excavation into undisturbed deposits.

7.3 EXTENT

The physical extent (SITE) of subsurface disturbance during the construction of infrastructure is a direct impact on potential palaeontological resources.

Indirect impacts involve the consequences of a significant fossil find. The scientific impact is of regional to national extent, as is implicit in the NHRA 25 (1999) legislation. If important specimens or assemblages are uncovered these are of INTERNATIONAL interest. This is evident in the amount of foreign-funded research by palaeontologists of other nationalities that takes place in South Africa. Loss of opportunities that may arise from a significant fossil occurrence (tourism, employment) filters down to regional/local levels.

7.4 DURATION

The duration of the impact is not confined to the short-term construction period. The impact of both the finding or the loss of fossils is PERMANENT. The found fossils must be preserved for study 'for posterity'; the lost, overlooked or destroyed fossils are lost to posterity. This represents a long term cumulative impact of the ongoing bulk earth works for new developments that is both partly positive and partly negative.

7.5 *INTENSITY*

The assigning of an intensity rating for palaeontological impact is guided by the 'Sensitivity Rating' provided in *Appendix 3*. The deposits of the initial 1-3 metres subsurface are expected to be young (late Quaternary Q-s2) and very poorly fossiliferous, particularly since most of the material appears to be colluvial in origin. The preservation potential of bones on exposed surfaces is low. The botanical and faunal sensitivities of the watercourse environments will act to limit earthworks in the potentially more fossiliferous fluvial/stream deposits.

Accordingly the intensity is rated as LOW. Notwithstanding, when fossils are found in these formations, they are often very significant additions to the geologic understanding of the area (*Appendix 3*).

7.6 *LIKELIHOOD*

Due to the sparse, very patchy distribution of fossils in the subsurface, the probability of a significant fossil find is rated UNLIKELY. Nevertheless, although the late Cenozoic Bushmanland superficial deposits are not generally very fossiliferous, it is not impossible that fossiliferous material could occur. The very scarcity of fossils makes for the added importance of watching for them in excavations.

7.7 *DEGREE OF CONFIDENCE*

Due to the low fossil content predictability of the surficial deposits, the degree of confidence is rated as MEDIUM.

7.8 *SIGNIFICANCE RATING*

Nature: Construction Phase bulk earth works for infrastructure may result in a **negative direct** impact on the fossil content of the surficial deposits (Kalahari Group).

Impact Magnitude: Small

Extent: Direct – Construction Sites.
Duration: Permanent.
Intensity: LOW.
Likelihood: Unlikely.

IMPACT SIGNIFICANCE (PRE-MITIGATION): NEGLIGIBLE.
Degree of Confidence: Medium.

8 RECOMMENDATIONS

The possible presence of fossils in the subsurface does not have an *a priori* influence on the decision to proceed with the development. However, mitigation measures are essential. The potential impact has a moderate influence upon the proposed project, consisting of implemented mitigation measures recommended below, to be followed during the Construction Phase.

The monitoring of excavations by on-site personnel is recommended during construction of the infrastructure, under supervision of the Environmental Site Officer (ESO). Appendices 1 and 2 outline monitoring by construction personnel and provide general Fossil Find Procedures for incorporation into the Construction Phase EMP.

A professional palaeontologist must be appointed to respond to queries about possible or definite fossil finds (*see Appendix 2*). In the event of a significant fossil find, a palaeontologist must supervise the excavation of the fossils and record their contexts. Said palaeontologist/sedimentologist must also undertake the recording of the stratigraphy and sedimentary geometry of the exposures, must attempt sampling of the ambient small fossil content and must undertake the compilation of the detailed report.

8.1 MONITORING

Basic Measures for the Construction Phase EMP

OBJECTIVE: To see and rescue fossil material that may be exposed in the various excavations made in surficial deposits surrounding Gamsberg for installation of the mine infrastructure.		
Project components	Various excavations for foundations, cabling and pipes, run-off control, dams etc and spoil from excavations.	
Potential impact	Loss of fossils by their being unnoticed and/ or destroyed.	
Activity/ risk source	All bulk earthworks.	
Mitigation: target/ objective	To facilitate the likelihood of noticing fossils and ensure appropriate actions in terms of the relevant legislation.	
Mitigation: Action/ control	**Responsibility**	**Timeframe**
Inform staff of the need to watch for potential fossil occurrences.	Black Mountain, Environmental Site Officer (ESO), contractors.	Pre-construction.
Inform staff of the	ESO/palaeontology	Pre-construction.

procedures to be followed in the event of fossil occurrences.	specialist.	
Monitor for presence of fossils	Contractor personnel and ESO.	Construction.
Liaise on nature of potential finds and appropriate responses.	ESO and palaeontology specialist.	Construction.
Excavate main finds, record context, compile report.	Palaeontology specialist.	Construction.
Obtain permit from SAHRA for finds.	Palaeontology specialist.	Construction
Performance Indicator	Reporting of and liaison about possible fossil finds. Fossils noticed and rescued.	
Monitoring	Due effort to meet the requirements of the monitoring procedures.	

It is probable that sparse, valuable bone fossils will go undetected, even with the most diligent mitigation practicable. On the other hand, the finding and recovery of fossils will have a positive impact ranging from regional to international in extent, depending on the nature of the finds.

9 APPLICATION FOR A PALAEONTOLOGICAL PERMIT

A permit from SAHRA is required to excavate fossils. The applicant should be the qualified specialist responsible for assessment, collection and reporting (palaeontologist).

A permit has not been applied for prior to the making of excavations. Should fossils be found that require rapid collecting, application for a retrospective palaeontological permit will be made to SAHRA immediately.

The application requires details of the registered owners of the sites, their permission and a site-plan map.

All fossil finds must be recorded and the fossils and their contextual information (a report) must be deposited at a SAHRA-approved institution.

10 *REPORTING*

Should fossils be found a detailed report on the occurrence/s must be submitted. This report is in the public domain and copies of the report must be supplied to SAHRA, the Employer or Owner of the property and the applicable curatorial institution such as the McGregor Museum in Kimberley or the IZIKO S.A. Museum.

The report will be in standard scientific format, basically:

- A summary/abstract.
- Introduction.
- Previous work/context.
- Observations (incl. graphic sections, images).
- Palaeontology.
- Interpretation.
- Concluding summary.
- References.
- Appendices

11 REFERENCES

Almond, J.E. & Pether, J. 2008. *Palaeontological Heritage of the Northern Cape*. Interim SAHRA technical report, 124 pp. Natura Viva cc., Cape Town.

Bailie, R., Armstrong, R. & Reid, D. 2007. The Bushmanland Group supracrustal succession, Aggeneys, Bushmanland, South Africa: Provenance, age of deposition and metamorphism. *South African Journal of Geology* **110**: 59-86.

Bamford, M.K. 2000. Cenozoic Macro-Plants. In: Partridge, T.C. & Maud, R.R. (Eds.) *The Cenozoic of Southern Africa*, pp.351-356. Oxford University Press, Oxford.

Cornell, D.H., Thomas, R.J., Moen, H.F.G., Reid, D.L., Moore, J.M. & Gibson, R.L. 2006. The Namaqua-Natal Province. In: Johnson, M.R., Anhaeusser, C.R. & Thomas, R.J. (Eds.) The Geology of South Africa, pp. 461-499. Geological Society of South Africa, Marshalltown.

De Wit, M.C.J., Ward, J.D. & Spaggiari, R. 1992. A reappraisal of the Kangnas dinosaur site, Bushmanland, South Africa. *South African Journal of Science* **88**: 504-507.

De Wit, M.C.J., Marshall, T.R. & Partridge, T.C. 2000. Fluvial deposits and drainageevolution. In: Partridge, T.C. & Maud, R.R. (Eds.) *The Cenozoic of Southern Africa*, pp.55-72. Oxford University Press, Oxford.

Haughton, S.H. 1915. On some dinosaur remains from Bushmanland. *Transactions of the Royal Society of South Africa* **5**: 265-272.

Haughton, S.H. 1932. The fossil Equidae of South Africa. *Annals of the South African Museum* **28:** 407-427.

Macey, P.H., Siegfried, H.P., Minnaar, H., Almond, J. & Botha, P.M.W. 2011. The geology of the Loeriesfontein area. Explanation to 1: 250 000 geology sheet 3018, 139 pp. Council for Geoscience, Pretoria.

Partridge, T.C. and Maud, R.R. 1987. Geomorphic evolution of South Africa since the Mezozoic. *South African Journal of Geology* **90**: 179-208.

Pickford, M., Eisenmann, V. & Senut, B. 1999. Timing and landscape development and calcrete genesis in northern Namaqualand, South Africa. *South African Journal of Science* **95**: 357-359.

Rogers, A.W. 1915. The occurrence of dinosaurs in Bushmanland. *Transactions of the Royal Society of South Africa* **5**: 265-272.

Rogers, A.W. 1915. The geology of part of Namaqualand. *Transactions of the Geological Society of South Africa* **18**: 72-101.

Scholtz, A. 1985 The palynology of the upper lacustrine sediments of the Arnot Pipe, Banke, Namaqualand. *Annals of the South African Museum* **95**: 1–109.

Zachos, J., Pagani, M., Sloan, L., Thomas, E., Billups, K., 2001. Trends, rhythms, and aberrations in global climate 65 Ma to present. *Science* **292**: 686–693.

~ (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.

AIA: Archaeological Impact Assessment.

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

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

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, eg 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.

Coversands: Aeolian blanket deposits of sandsheets and 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.

ESA: Early Stone Age. The archaeology of the Stone Age between 2 000 000 and 250 000 years ago.

EIA: Environmental Impact Assessment.

EMP: Environmental Management Plan.

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 suspension and traction in water and laid down by a river or stream.

Fm: Formation.

Fossil: Mineralised bones of animals, shellfish, plants and marine animals. A trace fossil is the disturbance or structure produced in sediments by organisms, such as burrows and trackways.

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).

HIA: Heritage Impact Assessment.

LSA: Late Stone Age. The archaeology of the last 20 000 years associated with fully modern people.

LIG: Last Interglacial. Warm period 128-118 ka BP. Relative sea-levels higher than present by 4-6 m. Also referred to as Marine Isotope Stage 5e or "the Eemian".

Midden: A pile of debris, normally shellfish and bone that have accumulated as a result of human activity.

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

MSA: Middle Stone Age. The archaeology of the Stone Age between 20-300 000 years ago associated with early modern humans.

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 whose 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 (eg wind erosion/deflation) or by bulk earth works.

Peat: partially decomposed mass of semi-carbonized vegetation which has grown under waterlogged, anaerobic conditions, usually in bogs or swamps.

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.

SAHRA: South African Heritage Resources Agency – the compliance authority, which protects national heritage.

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

Type locality: The specific geographic locality where the stratotype of a layered stratigraphic unit is situated. The name also refers to the locality where the unit was originally described and/or named.

12.1 GEOLOGICAL TIME SCALE TERMS (YOUNGEST TO OLDEST).

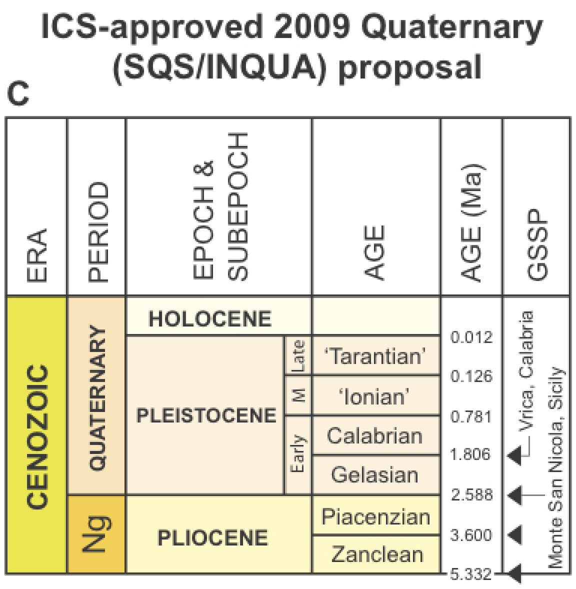
ka: Thousand years or kilo-annum (10^3 years). Implicitly means "ka ago" ie duration from the present, but "ago" is omitted. The "Present" refers to 1950 AD. Generally not used for durations not extending from the Present. Sometimes "kyr" is used instead.

Ma: Millions years, mega-annum (10^6 years). Implicitly means "Ma ago" ie duration from the present, but "ago" is omitted. The "Present" refers to 1950 AD. Generally not used for durations not extending from the Present.

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 (0.78-2.6.Ma).

Quaternary: The current Period, from 2.6 Ma to the present, in the Cenozoic Era. The Quaternary includes both the Pleistocene and Holocene epochs. The terms early, middle or late in reference to the Quaternary should only be used with lower case letters because these divisions are informal and have no status as divisions of the term Quaternary. The sub-divisions 'Early', 'Middle' or 'Late' apply only to the word Pleistocene. As used herein, early and middle Quaternary correspond with the Pleistocene divisions, but late Quaternary includes the Late Pleistocene and the Holocene.



Pliocene: Epoch from 5.3-2.6 Ma.

Miocene: Epoch from 23-5 Ma.

Oligocene: Epoch from 34-23 Ma.

Eocene: Epoch from 56-34 Ma.

Paleocene: Epoch from 65-56 Ma.

Cenozoic: Era from 65 Ma to the present. Includes Paleocene to Holocene epochs.

Cretaceous: Period in the Mesozoic Era, 145-65 Ma.

Jurassic: Period in the Mesozoic Era, 200-145 Ma.

Precambrian: Old crustal rocks older than 542 Ma (pre-dating the Cambrian).

See www.stratigraphy.org for more details on the geological time scale.

13 APPENDIX 1 – MONITORING FOR FOSSILS

A regular monitoring presence over the period during which excavations are made, by either an archaeologist or palaeontologist, is generally not practical.

The field supervisor/foreman and workers involved in digging excavations must be encouraged and informed of the need to watch for potential fossil and buried archaeological material. Workers seeing potential objects are to report to the field supervisor who, in turn, will report to the Environmental Site Officer (ESO). The ESO will inform the archaeologist and/or palaeontologist contracted to be on standby in the case of fossil finds.

To this end, responsible persons must be designated. This will include hierarchically:

- The field supervisor/foreman, who is going to be most often in the field.
- The Environmental Site Officer (ESO) for the project.
- The Project Manager.

Should the monitoring of the excavations be a stipulation in the Archaeological Report, the contracted Monitoring Archaeologist (MA) can also monitor for the presence of fossils and make a field assessment of any material brought to attention. The MA is usually sufficiently informed to identify fossil material and this avoids additional monitoring by a palaeontologist.

The MA then becomes the responsible field person and fulfils the role of liaison with the palaeontologist and coordinates with the developer and the Environmental Site Officer (ESO). If fossils are exposed in non-archaeological contexts, the palaeontologist should be summoned to document and sample/collect them.

Other alternatives could be considered, such as the employment of a dedicated monitor for the Construction Phase. For instance, a local person could be briefed/trained by personnel at the West Coast Fossil Park.

14 APPENDIX 2 - FOSSIL FIND PROCEDURES

In the context under consideration, it is improbable that fossil finds will require declarations of permanent "no go" zones. At most a temporary pause in activity at a limited locale may be required. The strategy is to rescue the 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, such as in the aeolian deposits. However, they may also serve as a guideline for other fossil material that may occur.

In contrast, fossil shell layers are usually fairly extensive and can be easily documented and sampled (See section 14.5).

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

14.1 ISOLATED BONE FINDS

In the process of digging the excavations, isolated bones may be spotted in the hole sides or bottom, or as they appear on the spoil heap. 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 (below).

Response by personnel in the event of isolated bone finds

- **Action 1:** An isolated bone exposed in an excavation or spoil heap must be retrieved before it is covered by further spoil from the excavation and set aside.
- **Action 2:** The site foreman and ESO must be informed.
- **Action 3:** The responsible field person (site foreman or ESO) must take custody of the fossil. The following information to be recorded:
    - Position (excavation position).
    - Depth of find in hole.
    - Digital image of hole showing vertical section (side).
    - Digital image of fossil.
- **Action 4:** The fossil should be placed in a bag (eg a Ziplock bag), along with any detached fragments. A label must be included with the date of the find, position info., depth.
- **Action 5:** ESO contacts the standby archaeologist and/or palaeontologist. ESO 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 ESO and a suitable response will be established.

14.2 *BONE CLUSTER FINDS*

A bone cluster is a major find of bones, ie 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 on the spoil heap.

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 spoil that may contain fossils.
- **Action 2:** Inform the site foreman and the ESO.
- **Action 3:** ESO contacts the standby archaeologist and/or palaeontologist. ESO 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 Black Mountain and the environmental consultant 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 developer/owner 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 to decide if Rescue Excavation is feasible, or if it is a Major Find.
- If the fossils are in an archaeological context, an archaeologist must be contacted to evaluate the site and decide if Rescue Excavation is feasible, or if it is a Major Find.
- If the fossils are in a palaeontological context, the palaeontologist must evaluate the site and decide if Rescue Excavation is feasible, or if it is a Major Find.

14.3 *RESCUE EXCAVATION*

Rescue Excavation refers to the removal of the material from the "design" 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 or undue delays, eg 1-3 days and definitely less than 1 week.

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 in sand.
- Fragile material in loose/crumbly sediment would be encased in blocks using Plaster-of Paris or reinforced mortar.

If the fossil occurrence is dense and is assessed to be a "Major Find", then carefully controlled excavation is required.

14.4 MAJOR FINDS

A Major Find is the occurrence of material that, by virtue of quantity, importance and time constraints, cannot be feasibly rescued without compromise of detailed material recovery and contextual observations.
A Major Find is not expected.

Management Options for Major Finds
In consultation with Black Mountain and the environmental consultant, the following options should be considered when deciding on how to proceed in the event of a Major Find.

Option 1: Avoidance

Avoidance of the major find through project redesign or relocation. This ensures minimal impact to the site and is the preferred option from a heritage resource management perspective. When feasible, it can also be the least expensive option from a construction perspective.

The find site will require site protection measures, such as erecting fencing or barricades. Alternatively, the exposed finds can be stabilized and the site refilled or capped. The latter is preferred if excavation of the find will be delayed substantially or indefinitely. Appropriate protection measures should be identified on a site-specific basis and in wider consultation with the heritage and scientific communities.

This option is preferred as it will allow the later excavation of the finds with due scientific care and diligence.

Option 2: Emergency Excavation

Emergency excavation refers to the "no option" situation wherein avoidance is not feasible due to design, financial and time constraints. It can delay construction and emergency excavation itself will take place under tight time constraints, with the potential for irrevocable compromise of scientific quality. It could involve the removal of a large, disturbed sample by excavator and conveying this by truck from the immediate site to a suitable place for "stockpiling". This material could then be processed later.

Consequently, emergency excavation is not a preferred option for a Major Find.

14.5 EXPOSURE OF FOSSIL SHELL BEDS

Response by personnel in the event of intersection of fossil shell beds

- **Action 1:** The site foreman and ESO must be informed.
- **Action 2:** The responsible field person (site foreman or ESO) must record the following information:
    - Position (excavation position).
    - Depth of find in hole.
    - Digital image of hole showing vertical section (side).
    - Digital images of the fossiliferous material.
- **Action 3:** A generous quantity of the excavated material containing the fossils should be stockpiled near the site, for later examination and sampling.
- **Action 4:** ESO contacts the standby archaeologist and/or palaeontologist. ESO to describe the occurrence and provide images asap. by email.

Response by Palaeontologist in the event of fossil shell bed finds

The palaeontologist will assess the information and liaise with Black Mountain and the environmental consultant and a suitable response will be established. This will most likely be a site visit to document and sample the exposure in detail, before it is covered up.

14.6 CONTACTS FOR REPORTING OF FOSSIL FINDS.

McGregor Museum, Kimberley
David Morris, Tel 082 2224777, mmkarchaeology@yahoo.co.uk
SAHRA
Tel 021 462 4502/Fax 021 462 4509
Email info@sahra.org.za
Web www.sahra.org.za
West Coast Fossil Park
Pippa Haarhoff: 083 289 6902, 022 766 1606, pjh@fossilpark.org.za
Iziko Museums of Cape Town: SA Museum, 021 481 3800.
Romala Govender. 021 481 3894, 083 756 5532, rgovender@iziko.org.za.
Heritage Western Cape
Troy Smuts. 021 483 9543
John Pether
021 783 3023, 083 744 6295, jpether@iafrica.com

15 APPENDIX 3 - PALAEONTOLOGICAL SENSITIVITY RATING

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

HIGH: Assigned to geological formations known to contain palaeontological resources that include rare, well-preserved fossil materials important to on-going paleoclimatic, paleobiological 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 paleontologists 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.