resources.

1) Development of land as a result of a structure plan
2) Development of land as a result of a rezoning application
3) Development of land as a result of a subdivision
4) Establishment of housing developments not subject to conditions of 1, 2, 3 above.
5) Establishment of townships
6) Establishment of resorts
7) Any development on undeveloped land
8) Mining and quarrying activities
10) Construction of airports
11) Construction of dams
12) Construction of ports harbours and marinas and seabed work.
13) Laying of pipelines
14) Construction of major sporting facilities
15) Flood control schemes, canals, aqueducts, river diversions
16) Any major landscaping, excavation or land remodelling projects
17) Construction of roads
18) Construction of railway lines
19) Illegal demolition of structures over 50 years old
20) Agricultural activity

8.1.2 Secondary Sources of Impact on Heritage Material

These impacts can be as serious as those caused by large developments but are usually of more limited nature and occur on an *ad hoc* basis. They are generally associated with increase in human activity resulting from proximity of residential areas and recreational facilities. Primary impacts which lead to the increase in human use of an area will usually be accompanied by secondary impacts. In a mining situation these impacts can occur on short term prospecting sites which can cause disturbance of surface archaeology, as well as driving off-road and creation of dirt tracks. Impact assessments must also consider these additional factors resulting from development activity. *The ad hoc* nature of the impact makes it difficult to control beyond educating the public as to the sensitivity of archaeological resources. We have identified some of the secondary impacts on archaeological sites below, many of which have the potential to occur in the project area.

1) Illegal collection of artefactual material
2) Indiscriminate use of off-road vehicles
3) *Ad-hoc* creation of dirt tracks or tracks for off-road vehicles
4) Establishment of informal parking areas
5) Establishment of Informal camp sites and picnic areas
6) Dumping
7) Unplanned footpaths
8) Erosion resulting from any of the above or any other source.

5.1.1 Impacts of mining on palaeontology

Palaeontology sensitivity is a risk at the land-based mining areas unless the management plan supplied by Pether (2008) is implemented. In the past mining operations have open a number of deep excavations which have contributed significantly to understanding the palaeontology of Namaqualand and developing the regional sequence. Much of this work was done by De Beers geologists themselves, however they also allowed opportunities for research to take place through allowing access to pit profiles before remediation takes place. Hence, there is considerable benefit to be had by using mining operations as an opportunity to examine deep sequences that would not normally be available to researchers. The gaining of this knowledge is a positive impact provided that pit profiles are examined before backfilling or remediation takes place.

The mining of beach sequences has the potential to provide new knowledge with respect to marine regressions and transgressions in the project area. The presence of fossil shell beds exposed in beach mining must described/sampled and provenance by a suitably qualified person.

5.1.2 Mining Impacts on shallow archaeological sites

The spatial distribution of the components of archaeological sites are very important as it is the relationships between objects in time and space that that archaeologists use to deduct the events of the past. Artefacts for which there is no contextual knowledge have little more than curiosity value. Hence the breaking of the physical relationships between the components of archaeological sites destroys 90 percent of its scientific and heritage value. Such destruction will occur if a site is raided by illegal collectors or even driven over with a 4x4. Mining operations are the extreme of this spectrum of disturbance due to the scale of earthmoving and the size of the equipment used. Typically the destruction tends to be complete, permanent and non-reversible. While exact figures are not available diamond mining has destroyed at least half of the west coast heritage resources, while outside of mining areas uncontrolled 4x4 use, property development and farming has caused extensive damage. The impacts are of very high significance, irreversible and permanent.

5.1.3 Impacts on deeply buried archaeological sites

Considering that humans have inhabited Namaqualand for more than a million years, and through multiple sea level regressions and transgressions, erosion and depositional phases in the earth's history, archaeological sites can be deeply buried. Diamond mining operations clear all sediment down to bed rock which means that any archaeological site buried by sediment has the potential to be negatively impacted by mining. No archaeologists have ever had the opportunity to audit the extent of buried sites in Namaqualand, so it is very difficult to understand the extent to which impacts have taken place in the past. There are at least two recorded incidents of ancient archaeological sites destroyed by mining.

Case study – Brandsebaai. The first of these was recorded by ACO at Brandsebaai. Ancient archaeological materials with fossilized organic remains were found lying on the edge of an old prospecting trench immediately on the coastal dunes. Indications were that a Middle Stone Age site with very rare organic remains had been cut through by excavators. Trial excavations to a depth of about 3 m deep along the edge of the trench showed that none of the material had survived *in-situ*.

Case study – Boegoeberg. Mining by Alexcor along the coastline close to the Boegoeberge targeted old wave cut shorelines and inlets. Two shallow caves were exposed in a sea-cliff some 7 m below today's surface. Diamond diamondiferous gravels were mined out of a cave (Boegoeberg II) and in the process destroyed a 120000 year old archaeological site to the extent that only 10 percent of the site survived. The remaining 10 percent was sampled and studied and resulted in several scientific papers being written. It was one of a few archaeological sites of its kind in the world dating to early modern humans who lived on the coast of Namaqualand during the interglacial when sea levels were little higher than they are today. Fortunately at the adjacent cave (Boegoeberg I) mining was halted by the mine geologist before complete damage was done. The site was not anthropomorphic but an ancient hyena lair the provided a wealth of information about ancient environments.

The above cases show that archaeological sites can occur deep underground, especially in caves in ancient sea washed gullies. Finding one intact would make a huge contribution to science. This is of particular importance where mining of gullies and ancient sea cliffs are envisaged. The total loss of such archaeological sites due to impacts of mining is scientifically disastrous so measure must be put in place to stop this from happening.

5.1.4 Impacts of mining on historical and proto-historical sites.

Historical sites that are over 100 years of age are very rare in the study area. Only one historical site is known from the study area at Samsonsbak which included numerous glass bottles of the 19th century, fragments of metal and foundations of a simple dwelling. Also evident were several simple graves. Like other forms of surface archaeological material, they will be destroyed by earthmoving.

5.1.5 Impacts of mining on shipwrecks

There are a number of known wrecks on the Namaqualand coast and those that are greater than 60 years of age are protected. Off-shore and coastal operations can impact wrecks. Boshoff (pers com) has conducted a number of beach surveys on the south coast using proton-magnetometry and has encountered a number of early wrecks completely covered by sand with no surface evidence whatsoever. The discovery of the oldest known wreck in the southern hemisphere took place when a geologist found copper ingots in a beach mining operation. In the sediments behind the see dam were the remains and cargo of a Portuguese East Indiaman that had foundered north of Oranjemund. It was laden with ivory, copper, bronze cannons and gold bullion. The Namdeb resident archaeologist, Dieter Noli was put under some pressure to shift the material as quickly as possible which was a near disaster, as Namibia (like RSA) did not have a dedicated conservation laboratory which resulted in very valuable artefacts being exposed to oxygen and resulting rapid deterioration. It has taken an international effort to salvage what could be done, however irreparable damage has been done to some material (Noli pers com). The bullion (worth a considerable fortune) is housed in the Bank of Namibia as the country's heritage legislation deems all material to be the property of the state (as in RSA). Ideally the wreck should have been left undisturbed behind the sea wall and mining deferred until international effort could be mustered to have the necessary conservation facilities put in place before any aspect of the ship was removed.

There is a real but generally low possibility that shipwreck material may be impacted by mining in the near shore areas. Should a wreck of significance be destroyed, this would be a severe impact without mitigation being in place, but a positive contribution to knowledge and history with mitigation.

5.1.6 Impacts of mining on human remains

Human remains are strongly protected by several bodies of legislation including the National Heritage Resources Act. Do date a number of human skeletons have been found in west coast mining areas, a number of which have been either excavated or collected by ACO. Graves are hard to recognise more often than not being unmarked, or marked with a pile of stone. Even historic graves marked with earth mounds and wooden crosses disappear over time. In the face of mining, a grave or human skeleton is unlikely to be noticed and will end up in the processing plant or mine dump. The impacts of mining are therefore high, and the presence of human remains very difficult to mitigate unless they are identified in pre-disturbance surveys and exhumed.

5.1.7 Impacts of mining of landscape and setting

Landscapes and places of scenic value to a given community are protected under the NHRA. Mining on the West Coast has been taking place for 70 years or more, and as such has become a heritage layer and a characteristic of this part of the world. From this perspective it is hard to argue that continued mining has a major negative impact under circumstances that are so well established, and which under the NHRA are in some instances functionally generally protected. There are scenic areas and enclaves that will be impacted and the character of such places will change as infrastructure is established. Mine rehabilitation can be very successful to the extent that intimately some scenic impacts can be fully reversed.

Table 2 Assessment of Impacts

Activities	Impacts	Aspects affected	ase	Significance rating			Typical mitigation measures
Impact of beach mining on palaeontology	The process of creating a berm, followed by pumping out of the sea followed by excavation to bedrock has the potential to expose prehistoric marine regression events, shell beds and extinct invertebrate species. There is also a low possibility of fossil bone and shark teeth.				Without mitigation	With mitigation	Mine geologist to be mindful of palaeontological potential. Mine to foster a relationship with a palaeontologist and facilitate opportunities to make research observations and collect samples (see management plan by Pether 2008).
				Severity	Low	Low	
				Duration	High	Low	
				Extent	Local	Local	
				Consequence	Medium	Low	
				Probability	Medium	Low	
				Significance	Low	Low	
				Status	Negative	Positive	
				Confidence	High	High	
				Reversibility	Low	High	
				Loss of resource	High	Low	
				Degree to which the impact can be mitigated		High	
Impact of beach mining on maritime heritage	The process of creating a berm, followed by pumping out of the sea followed by excavation to bedrock has the potential to expose maritime archaeological debris including shipwrecks. Shipwrecks have varying importance which has a bearing on the severity of the impact; however destruction of a previously undescribed wreck with significant cargo and great age is a possibility. Destruction of such a wreck through uncontrolled excavation, looting of cargo and non-implementation of artefact conservation measures would be a significant loss of historical				Without mitigation	With mitigation	Pro-active measures involve conducting remote sensing scans for evidence of shipwrecks with are best avoided, or if need be removed under a SAHRA issued permit. Staff on site to be mindful of artefacts that may appear in excavated material from seabed. Such material can include lumps of iron, ballast stones or ingots, pieces of rope, wood, leather as well as ceramics and porcelain. Iron and bronze cannons are also
				Severity	High	Low	
				Duration	High	Low	
				Extent	Regional	Local	
				Consequence	Medium	Low	
				Probability	Medium	Low	
				Significance	High	High-Low	
				Status	Negative	Positive	
				Confidence	High	High	
				Reversibility	Low	Medium	

	information as well as a breaking of the law of the land if destruction takes place without a permit.			**Loss of resource**	High	Low	possible. In the event of a find, an archaeologist must be consulted. Shipwrecks that need to be destroyed or moved that are more than 60 years old require a permit for this to be issued by SAHRA.
				Degree to which the impact can be mitigated	Low	High	

Impact	Description				Without mitigation	With mitigation	Mitigation
Impact of beach mining on maritime heritage	Any earthmoving activities, establishment of roads and areas for setting up processing plants in areas immediately behind beaches and bays hold the possibility of impacting some of the many shell middens and other archaeological sites that exist close to the shoreline, in particular estuaries, rocky headlands and sheltered bays tend to be very archaeologically rich.			**Severity**	High	Low	Pro-active measures involve contracting an archaeologist to survey and mitigate the coastal zone adjacent to beach mining operations, as well as any proposed roads and infrastructure. This work can happen on a periodic basis to coincide with mining schedule.
				Duration	High	Low	
				Extent	local	Local	
				Consequence	Medium	Low	
				Probability	High	Low	
				Significance	High	Low	
				Status	Negative	Positive	
				Confidence	High	High	
				Reversibility	Low	Medium	
				Loss of resource	High	Low	
				Degree to which the impact can be mitigated	Low	High	

6.5 Heritage Management and mitigation

The numerous surveys that have been done to date have established that there is a wealth of archaeological material within the West Coast Resources controlled areas. This is a heritage that can be considered significant at both local and international levels. Some of this has been seriously impacted by mining activities. On the other hand, due to the high security nature of the mining operation, large tracts of land have been conserved and the preservation of archaeological material in these areas is excellent. Township and resort development, industry, as well as establishment of nature reserves will follow when the mining ceases. This means that management of heritage resources will have to operate within a wider range of circumstances. The long term aim of any management goals should be to:

i) Conserve the archaeology of those areas that have been protected or excluded from the public.

ii) Ensure that good heritage impact assessments are made in any areas that may be developed or mined in the future.

iii) Mitigate the archaeology of those areas to be impacted by mining during the remaining life of the mine (Figure 3).

Figure 3 Mitigation of archaeological sites at Rooiwalbaai

6 Current Heritage Management Mechanisms

While mechanisms for impact assessment are prescribed by the Environmental legislation (IEM procedures), the National Heritage Resources Act 25 of 1999 indicates what kinds of heritage are protected and how they should be assessed in the context of an impact assessment. The system that is presently in operation and described below, is one that has evolved over time.

6.1 Reactive management

Many heritage assessments or rescue excavations take place reactively because the archaeological potential of development is seldom taken into account at the initial planning stage. In many cases management can be characterised as knee-jerk responses, with mitigation procedures carried out as a result of the intervention of an authority or lobbying by interest groups and members of the public, or if a find of significance is exposed during the course of construction.

Whilst the reactive approach will always be a component of heritage resource management, it should not be seen as an acceptable mechanism for dealing with heritage issues. In some instances there will be no indication that important finds will be uncovered and the reactive approach therefore becomes unavoidable. This way of carrying out mitigation has many disadvantages for both the archaeologist and developer/mine alike. One of the major disadvantages is in terms of delays to the development/mining which can be extremely costly. In addition money will not have been budgeted for the purpose of mitigation and may mean that the archaeologist is forced to complete the task unsatisfactorily. Secondly, should any conservation worthy features be found, it may not be possible to preserve these for posterity. Despite its disadvantages reactive management will be necessary at West Coast Resources. As described in the in the impact section of this report, there are deeply buried heritage sites that will only become visible during mining. These must be reported to SAHRA and/or an archaeologist for evaluation and mitigation of need be.

8.2.2 Pro-active Management

Pro-active management is through the identification of heritage sites as described in sections 34-38 of the National Heritage Resources Act and more or less marries with the IEA process. The process is by no means perfect but a good deal of successful mitigation has been accomplished using these procedures over the last 10 years. The process consists of two phases of work, which we believe greatly lessens the need for the reactive approach to be adopted. These procedures are described below:

Heritage impact assessment

The heritage resource professional (archaeologist, architect, historian, and palaeontologist) needs to be approached as early as possible in the planning phase of a development/mining project. The project is initially assessed as to whether it is likely to impact heritage resources and the details are uploaded up-loaded onto the SAHRIS web-based application system. Normally a more detailed study is required which can form the specialist component of an EIA process or take the form of a stand-alone HIA which will usually involve fieldwork and/or interrogation of archival material and other documentary sources, depending on the age and nature of the remains. Typically with previous mining operations in the area, as well as further south in the Western Cape at the Tronox operations the over-arching study formed part of an EMP after which stand-alone HIA's were conducted on an annual or bi-annual basis in response to planned mining blocks.

The stand-alone HIA's will identify any heritage that needs to be mitigated. This is reported on, then the necessary permits applied for and obtained. With archaeological sites and palaeontological exposures mitigation involves systematic sampling and in some cases the complete removal of archaeological material. This is normally taken out of the mine and transported to a laboratory for curation, after which it is re-patriated to a regional museum where it is kept indefinitely (the law requires all archaeological material to be housed in a registered museum). Previous experience has shown it is advantageous to "batch" mitigation operations to cut down on paperwork and logistics. Typically, in previous De Beers operations a month of mitigation operations were carried out on proposed mining blocks every two years or so in keeping with the mines planned phasing of operations and scale of works. SAHRA, who managed Northern Cape heritage by agency, require the issuing of permits for material to be moved, sampled or documented. Provided that the mitigation is carried out satisfactorily, the mine will be given permission to proceed.

The company will have to allocate an annual (or as fit) budget to heritage resources management. This size of this would depend on the amount of new mining areas opened up during any one financial year. The budget would have to be enough to bring in a heritage management team to Heritage Impact Assessments as well as cover the costs of any mitigation if this is required.

Table 3

ACTIVITIES	PHASE	SIZE AND SCALE of disturbance	MITIGATION MEASURES	COMPLIANCE WITH STANDARDS	TIME PERIOD FOR IMPLEMENTATION
Prospecting Beach mining operations. Establishment of roads and infra-structure (	Most impacts will take place during the operational and construction phases of mining. Archaeological sites can be affected by earthmoving during which destroys the context and content. Earthmoving during rehabilitation can obscure un-recorded paleontological evidence.	N/a	An archaeologist must be appointed to survey and assess archaeological material in mining areas before mining commences. If necessary the archaeologist will need to apply for permits to excavate archaeological material prior to mining. For beach mining, location of shipwrecks is Best established before mining and wrecks mitigated or avoided. During mining	Sections 34 and 38 of the National Heritage Resources Act 25 of 1999 mandate the EIA process to take cognisance of heritage. All heritage as defined in the NHRA is also generally protected by the NHRA. Following due process allows for legal protection mitigation and destruction of	Archaeological assessment of mining areas should take place well in advance of mining. A year – 6 moths is ideal as this allows for time to mitigate if need be. Maritime heritage studies should be done well in advance of mining, ideally during mine planning. Palaeontological assessments must take place before mine pits are rehabilitated.

			any human made finds must be reported to an archaeologist. Pits should be checked by a palaeontologist before rehabilitation.	heritage,	

7 Mitigation

7.1 Pro-active assessment

While some sites are extremely important and merit careful study and need to be mitigated or even conserved where mining is envisaged, work done to date demonstrates that the majority of surface archaeological sites have limited information potential on an individual basis but on a broader scale, each site and its location is part of a pre-colonial system of human habitation on the landscape and is therefore worthy of some measure of recording.

Provided that a range of archaeological sites are preserved in areas which are not going to be mined, this will to some extent mitigate the damage that mining does to heritage sites elsewhere. However, there are will always be the possibility that unique archaeological sites exist in proposed mining areas and these should nevertheless be identified. In order to execute effective conservation and mitigation procedures, mining should be treated like any other development activity. New mining areas should be subjected to a heritage impact assessment well in advance of the start of any earthmoving. During the course of the HIA all archaeological and other heritage sites will have to be identified and their surface characteristics recorded and certain kinds of archaeological material collected. Sites which are important will have to be sampled/excavated as part of a mitigation programme.

7.2 Heritage sites and fossils found during mining operations – the reactive approach

There are some types of heritage sites that are not going to be detected during the course of a heritage impact assessment, although the possibility of their presence may be anticipated. Of particular concern are deeply buried ancient archaeological sites dating to the Middle or Early Stone Age. Experience has shown that these can be located in areas associated with previous Pleistocene marine transgressions. Especially sensitive are buried caves and gullies that would have acted as *foci* for ancient camp sites. Well preserved ESA and MSA sites are extremely rare in international terms which mean that the loss of such material is very serious. If such finds are located, earthmoving will need to be diverted and an archaeologist be immediately appointed to sample the material. Short of the mining operation employing a full-time archaeologist to monitor earthmoving in all active mining areas, it is suggested that suitable personnel (such as an environmental officer or geologists) be designated the task of checking deep excavations for any archaeological deposits. It may be necessary for such a person to undertake some practical archaeological training so that he/she has enough knowledge to recognise such deposits and the materials associated with them. In addition, consideration should be given to the distribution of a handbook which would describe typical sites and their content. These could be made available to the mine geologists, environmental officers, foremen, machine operators and other field personnel who may come across sites in the course of their duties.

7.1 Impacts of rehabilitation

Rehabilitation of mined areas, although positive for the environment, can pose a threat to otherwise undisturbed sites through earthmoving and related activity, particularly where the edges of deep excavations are collapsed and contoured. Archaeological sites that have survived on the edges of pits have been destroyed during rehabilitation. Similarly sites on prospective roads, mine dumps and infrastructure should be included in the HIA programmes.

7.1.1 Palaeontology

Almost every deep excavation contains some form of palaeontology that is exposed in the stratigraphy. Positive outcomes for knowledge and science can be gained by ensuring that a palaeontologist inspects pits and profiles before they are rehabilitated.

7.2 Conservation of sites on undeveloped Land

One of the most striking features of the project area is the excellent surface preservation of many archaeological sites; in particular those in un-mined areas under secure control. This preservation is as a result of these areas having been restricted to the public for many years. In other parts of South Africa sites which are as well preserved are scarce because they have been negatively affected by the actions of people. Even on parts of the coast where property development has not taken place, many sites have been damaged by illegal collection of artefactual material such as pottery and stone artefacts. Furthermore, recreational use of off-road vehicles has caused irreparable damage to sensitive dune areas and the sites that they contain. To minimise the destructive effects of human action in the future it is suggested that the following measures be applied:

- Archaeological sites are an irreplaceable aspect of the environment and should be protected as vigilantly as any endangered animal or plant species. It should become part of the company environmental policy that people are actively discouraged from collecting artefactual material or conducting excavations without a SAHRA permit, or removing material from shipwrecks.

- Off-road vehicles should be restricted to existing roads and tracks which will minimise damage to archaeological material. This is particularly so in areas within 1km of the shoreline which contain large concentrations of sites.

7.3 Maritime heritage

The identification of shipwrecks and other seabed risks will be necessary for the shore mining operations. There are a number of technologies available that can be used for the detection of shipwrecks; however it suggested that a proton-magnetometer survey of sea mining areas would be of benefit. This can potentially be done from the air as a single survey.

The SAHRA maritime unit has indicated that they would like to have a working relationship with any operation that is involved with seabed work. Their requirements are indicated below. Overall, the best form of mitigation is avoidance and micro- adjustment of mining areas. Salvage of historic shipwrecks as a mitigation measure is slow, complex and expensive, therefore if the wreck is highly significant, the costs of its removal would need to be considered. Minor wrecks can be recorded and described the removed under permit.

SAHRA has recommended that to to manage any potential impacts on maritime heritage sites that a geophysical (side scan sonar, multi-beam bathymetry and/or magnetometer), be used to survey the seafloor. There is advantage in knowing where shipwrecks are located ahead of mining to avoid impacts during excavation which could result in down time, instead of waiting for a find on site then implementing reactive measure which may result in costly delays (which is what the law demands).

- If any shipwreck material or unexplained seabed anomalies are discovered during the seabed survey or mining activities, the findings should then be assessed by a maritime archaeologist at SAHRA to identify the need for further action / mitigation.

- It is recommended that should any shipwrecks be discovered, any relevant observations and position of the find be reported to SAHRA for inclusion on the National Shipwreck Database.

- SAHRA's permission in the form of a permit would be required to disturb a maritime archaeological site or material (this includes any sites within the inter-tidal zone below the high water mark), should it not be possible for the project to avoid such sites. It is important to bear in mind that such permission is likely to be premised on suitable archaeological mitigation of any such site having been conducted, to ensure preservation of the site by record.

7.4 Surveys and mitigation completed to date within the projects area.

Appendix A contains a schedule of mining blocks and assesses the work done up to 2008 when De Beers began to wind down its west coast operations. A considerable amount has been accomplished which will lessen the need for renewed heritage impacts assessments and mitigation, however there are some 45 mining blocks that have not been surveyed and 36 (including some large areas) which have been surveyed and mitigated, all of which are presented and mapped in appendix A (Figures 4-8). Most of the beach mining areas have not been considered as in the past these were not De Beers priority areas, furthermore the ACO survey team was excluded from undertaking beach checks in the high security areas.

8 Acceptability of the proposed activity

Provided that mitigation is applied where necessary, all mining work can proceed in accordance with the law. This report finds that the proposed activities are acceptable and that most heritage impacts can be successfully mitigated.

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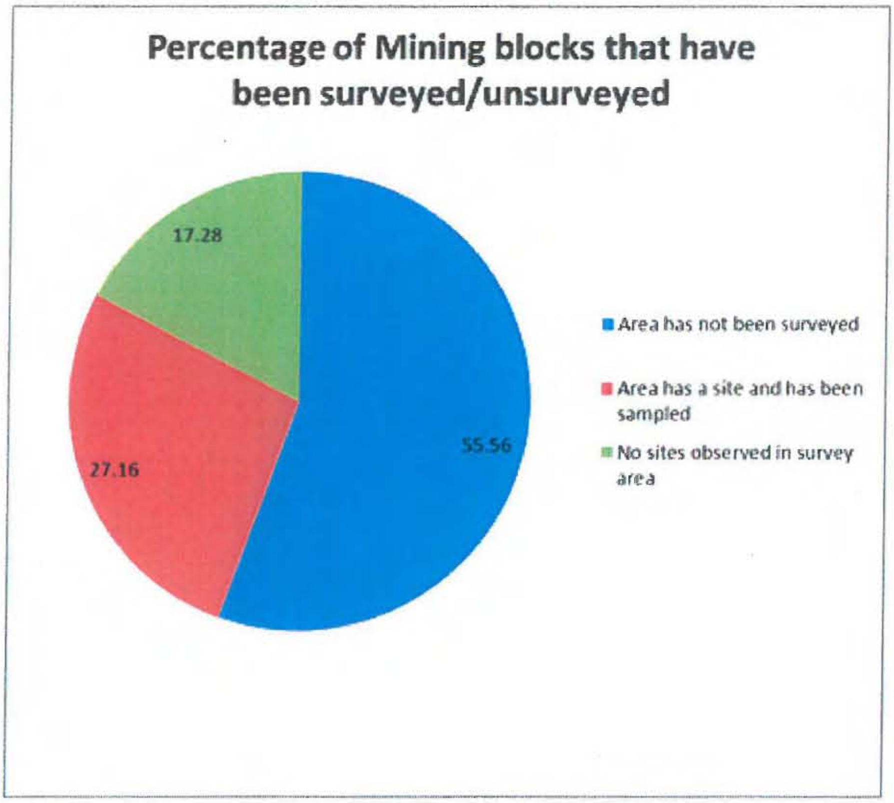
APPENDIX A

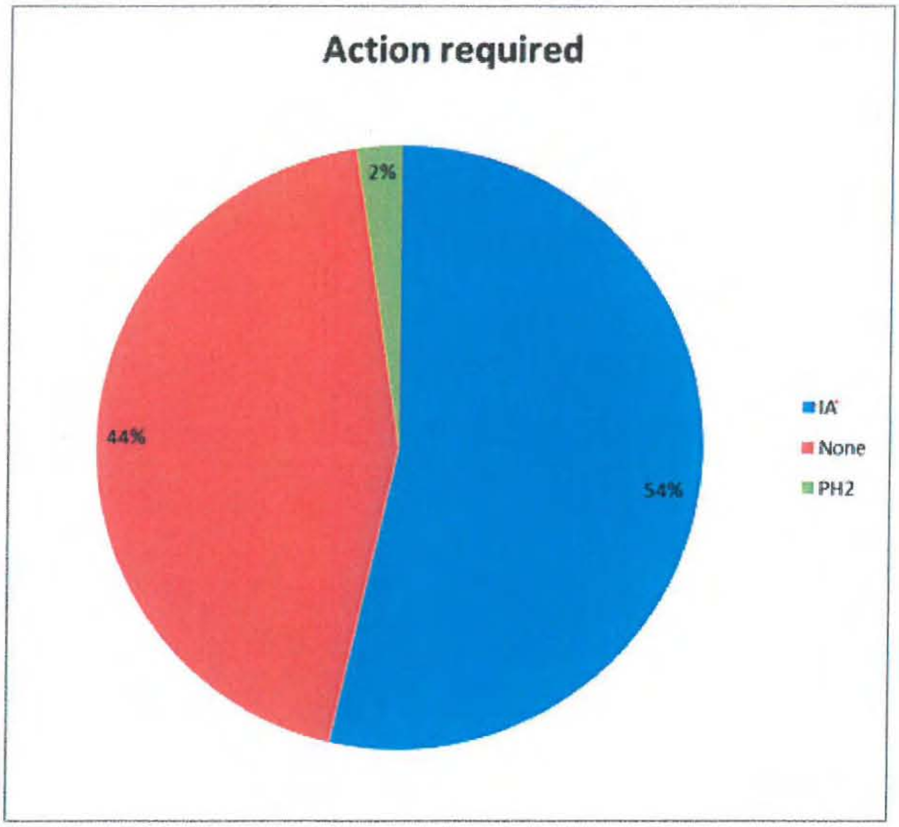
Mining blocks that have been subject to survey (HIA) and mitigation vs those for which no action has been taken.

Mining Block	Associated Sites	Subj. to HIA	Mitigation	Action Required	Comment
SN16	-	YES	NO	NONE	NO SITES OBSERVED IN HIA
SN17	-	YES	NO	NONE	NO SITES OBSERVED IN HIA
SN_SN_17	-	YES	NO	NONE	NO SITES OBSERVED IN HIA
KN_KLNA_02	-	NO	NO	HIA	AREA HAS NOT BEEN SURVEYED
KN_3R	KN2005/09	YES	PH1	NONE	SURFACE COLLECTION
KN_KLNA_06	-	YES	NO	NONE	NO SITES OBSERVED IN HIA
KN41A	-	YES	NO	NONE	NO SITES OBSERVED IN HIA
KN41B	-	YES	NO	NONE	NO SITES OBSERVED IN HIA
KN114OR	KN2004/021	YES	PH1	NONE	LSA SAMPLED
KN114OR	KN2005/096	YES	PH1/2	NONE	LSA SAMPLED SURFACE COLLECTION
KN114OR	KN2004/022	NO	NO	NONE	SITE DEEMED INSIGNIFICANT
KN15A	KN2005/099	YES	PH1	NONE	LSA SAMPLED SURFACE COLLECTION
KN15A	KN2005/101	YES	PH1	NONE	LSA SAMPLED SURFACE COLLECTION
KN15A	KN2005/100	YES	PH1	NONE	LSA SAMPLED SURFACE COLLECTION
KN9882_29	-	NO	NO	HIA	AREA HAS NOT BEEN SURVEYED
KN9882_24	-	NO	NO	HIA	AREA HAS NOT BEEN SURVEYED
KN9882_21	-	NO	NO	HIA	AREA HAS NOT BEEN SURVEYED
KN9882_20	-	NO	NO	HIA	AREA HAS NOT BEEN SURVEYED
KN51	-	NO	NO	HIA	AREA HAS NOT BEEN SURVEYED
KN7-1	-	NO	NO	HIA	AREA HAS NOT BEEN SURVEYED
KN114OR	-	NO	NO	HIA	AREA HAS NOT BEEN SURVEYED
KN7-2	-	NO	NO	HIA	AREA HAS NOT BEEN SURVEYED
KN_R7	-	NO	NO	HIA	AREA HAS NOT BEEN SURVEYED
KN_R8	KN2004/023	YES	PH1	NONE	LSA COASTAL SHELL SCATTER WITH ARTEFACTS
KN14	-	YES	NO	NONE	NO SITES OBSERVED IN HIA
KN15A	-	YES	NO	NONE	NO SITES OBSERVED IN HIA
KN17-1	KN2004/032	YES	PH1	NONE	LSA SHELL MIDDEN COASTAL
KN17-2	KN2004/033	YES	PH1	NONE	LSA SHELL MIDDEN COASTAL
KN17-3	KN2005/110	YES	NO	NONE	NO MITIGHIATION REQUIRED
KN17-2	-	YES	NO	NONE	NO SITES OBSERVED IN HIA
KN18-1	-	YES	NO	NONE	NO SITES OBSERVED IN HIA
KN16-1	-	NO	NO	HIA	AREA HAS NOT BEEN SURVEYED
KN19-1	-	NO	NO	HIA	AREA HAS NOT BEEN SURVEYED
KN20-1	-	NO	NO	HIA	AREA HAS NOT BEEN SURVEYED
KN27_C	KN2004/001	YES	PH1	NONE	NOT SAMPLED
KN27_C	KN2004/002	YES	PH1	NONE	NOT SAMPLED
KN27_C	KN2004/005	YES	PH1	NONE	NOT SAMPLED
KN27_C	KN2004/007	YES	PH1	NONE	NOT SAMPLED
KN27_C	KN2004/008	YES	PH1	NONE	NOT SAMPLED
KN27_C	KN2004/009	YES	PH1	NONE	NOT SAMPLED
KN27_C	KN2005/052	YES	NO	NONE	SHORELINE LSA NO MIT REQ
KN27_C	KN2005/074	YES	NO	NONE	SHORELINE LSA NO MIT REQ
KN27	-	NO	NO	HIA	AREA HAS NOT BEEN SURVEYED

KN26	KN2005/108	YES	PH1	NONE	LSA
KN26	KN2005/109	YES	PH1	NONE	LSA
KN25_B	KN2004/029	YES	PH1	PH2 mitigation	
KN25_B	KN2004/028	YES	PH1	PH2 mitigation	
KN25_B	KN2004/027	YES	NO	NONE	
KN25_B	KN2004/026	YES	PH1	NONE	RANDOM SAMPLE
KN_6869_17 -1	-	NO	NO	HIA	AREA HAS NOT BEEN SURVEYED
KN_6869_17	-	NO	NO	HIA	AREA HAS NOT BEEN SURVEYED
SLS_15	-	NO	NO	HIA	AREA HAS NOT BEEN SURVEYED
SLS_19A	-	NO	NO	HIA	AREA HAS NOT BEEN SURVEYED
SL__20_05	-	NO	NO	HIA	AREA HAS NOT BEEN SURVEYED
SL_4-1	-	NO	NO	HIA	AREA HAS NOT BEEN SURVEYED
SL__20_09	-	NO	NO	HIA	AREA HAS NOT BEEN SURVEYED
SL__20_10_ A	-	YES	NO	NONE	NO SITES OBSERVED IN HIA
SLS_14	-	NO	NO	HIA	AREA HAS NOT BEEN SURVEYED
LK_N15	-	NO	NO	HIA	AREA HAS NOT BEEN SURVEYED
LK_N10-3A	-	NO	NO	HIA	AREA HAS NOT BEEN SURVEYED
LK_N10-2	-	NO	NO	HIA	AREA HAS NOT BEEN SURVEYED
LK_R1A	-	NO	NO	HIA	AREA HAS NOT BEEN SURVEYED
LK_R1C	-	NO	NO	HIA	AREA HAS NOT BEEN SURVEYED
LK_L1D	-	NO	NO	HIA	AREA HAS NOT BEEN SURVEYED
LKC1-8	-	NO	NO	HIA	AREA HAS NOT BEEN SURVEYED
LKC1-3	-	NO	NO	HIA	AREA HAS NOT BEEN SURVEYED
LKC1-2B	-	NO	NO	HIA	AREA HAS NOT BEEN SURVEYED
LKC1-2E	-	NO	NO	HIA	AREA HAS NOT BEEN SURVEYED
LKC-15	-	YES	NO	NONE	NO SITES OBSERVED IN HIA
LKC5-3	-	YES	NO	NONE	NO SITES OBSERVED IN HIA
LKC-16	-	YES	NO	NONE	NO SITES OBSERVED IN HIA
LKC6-1	-	NO	NO	HIA	AREA HAS NOT BEEN SURVEYED
LKC6-3	-	NO	NO	HIA	AREA HAS NOT BEEN SURVEYED
LKC10-1	-	NO	NO	HIA	AREA HAS NOT BEEN SURVEYED
LK_LK_02	-	NO	NO	HIA	AREA HAS NOT BEEN SURVEYED
LK_LK_05	-	NO	NO	HIA	AREA HAS NOT BEEN SURVEYED
LK_LK_09	-	NO	NO	HIA	AREA HAS NOT BEEN SURVEYED
LK_LK_10	-	NO	NO	HIA	AREA HAS NOT BEEN SURVEYED
LK_LK_13	-	NO	NO	HIA	AREA HAS NOT BEEN SURVEYED
LK_LK_12	-	NO	NO	HIA	AREA HAS NOT BEEN SURVEYED
LK_LK_11	-	NO	NO	HIA	AREA HAS NOT BEEN SURVEYED
LK_LK_14	-	NO	NO	HIA	AREA HAS NOT BEEN SURVEYED
LK_LK_08	-	NO	NO	HIA	AREA HAS NOT BEEN SURVEYED
LK_LK_18	-	NO	NO	HIA	AREA HAS NOT BEEN SURVEYED

HIA: Impact Assessment, LSA: Late Stone Age, PH1: Phase 1, PH2: Phase 2, MIT: Mitigation.


Percentage of Mining blocks that have been surveyed/unsurveyed
17.28
27.16
55.56
Area has not been surveyed
Area has a site and has been sampled
No sites observed in survey area


Action required
2%
44%
54%
IA
None
PH2

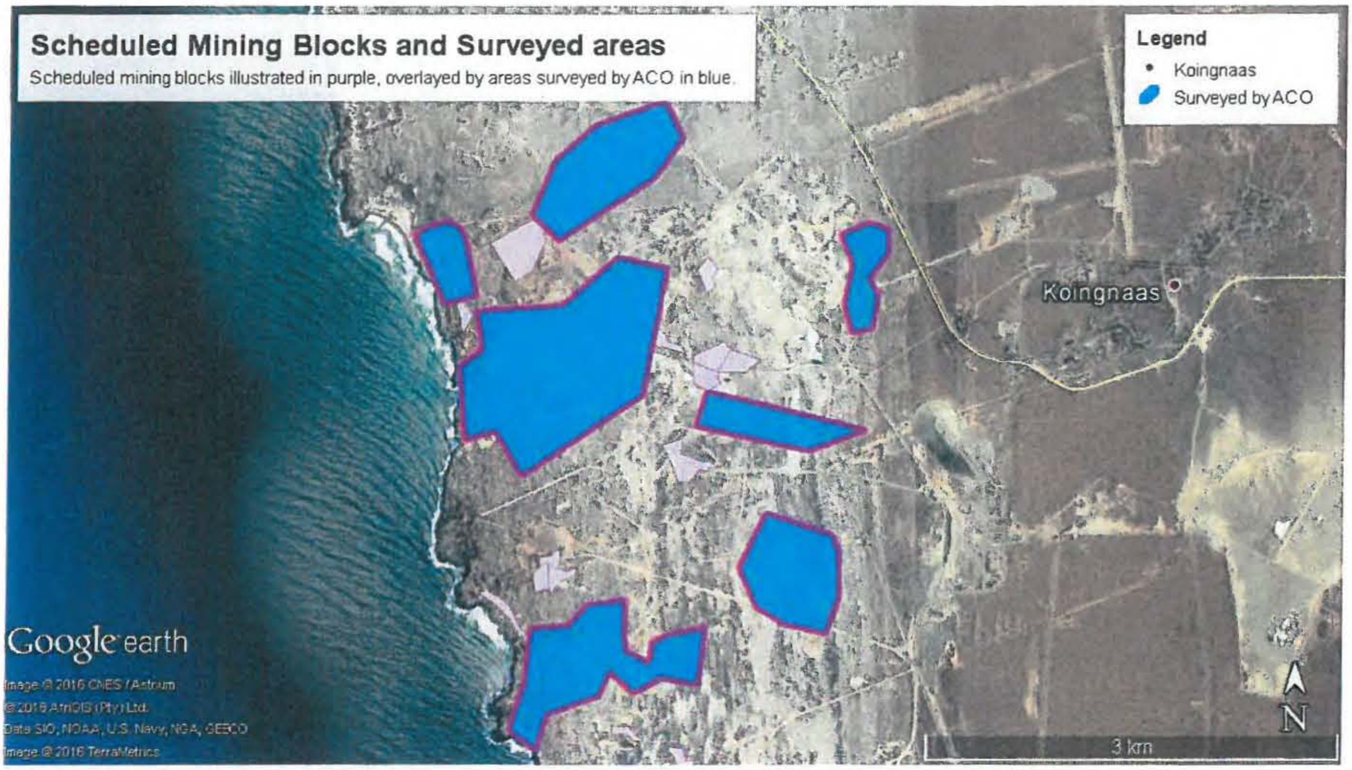


Figure 4 Koingnaas areas - old De Beers blocks already assessed vs new mining areas

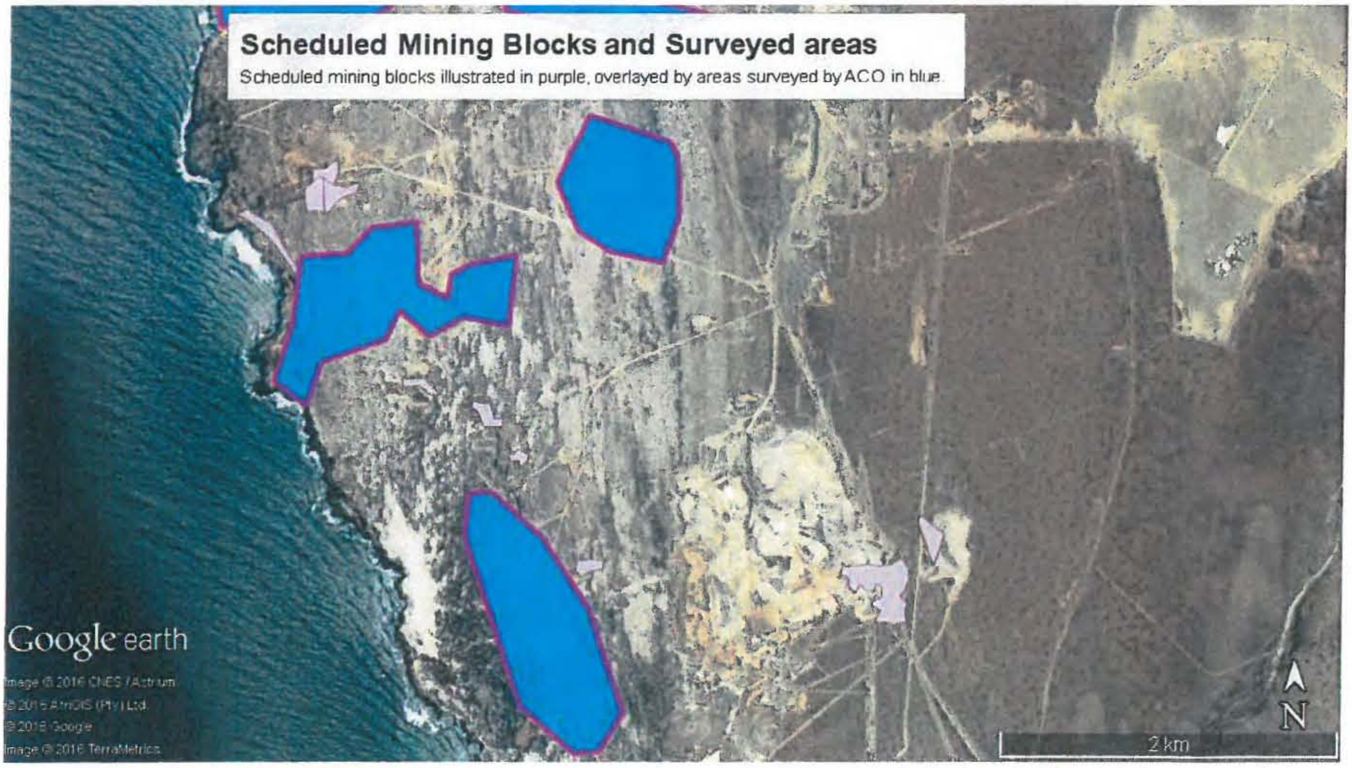


Figure 5 Southern Koingnaas areas - old De Beers blocks already assessed vs new mining areas

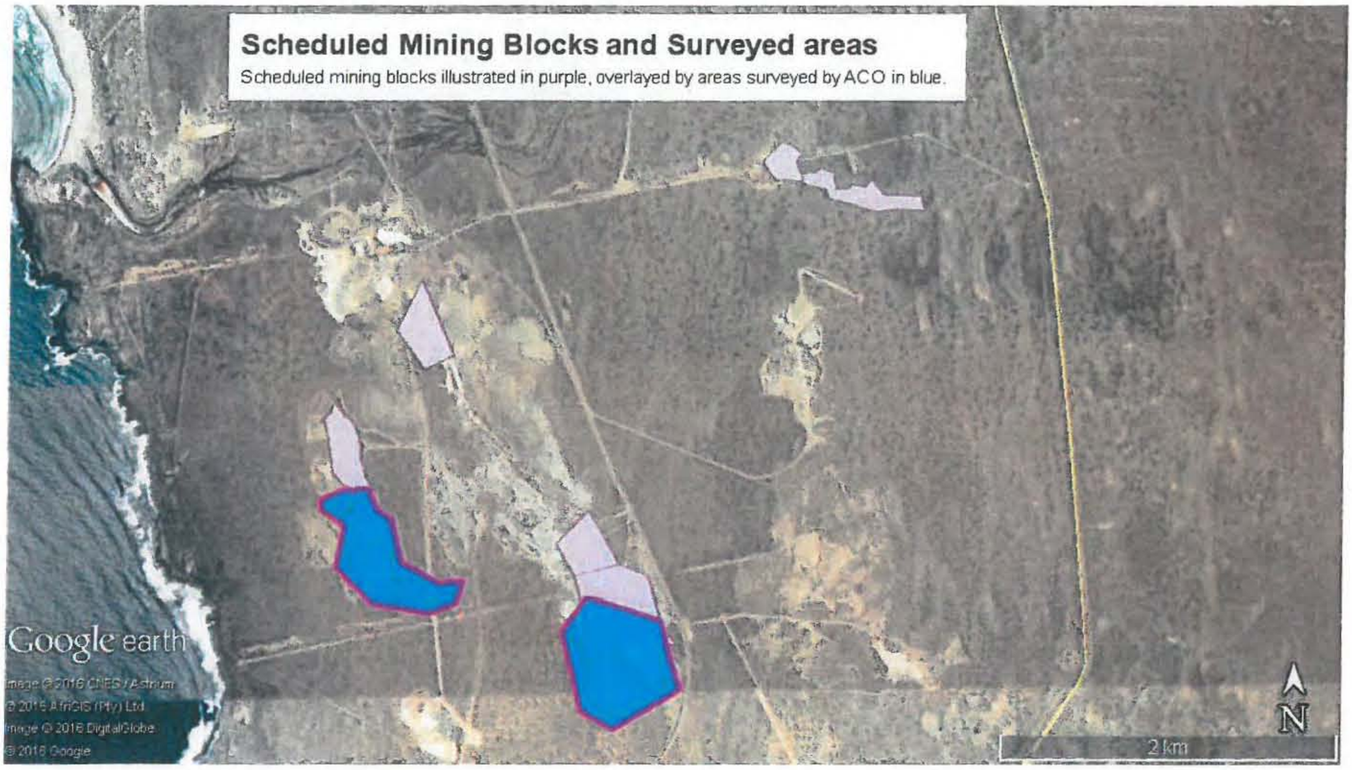


Figure 6 Swartlintjies – Doctor se Baai areas - old De Beers blocks already assessed vs new mining areas

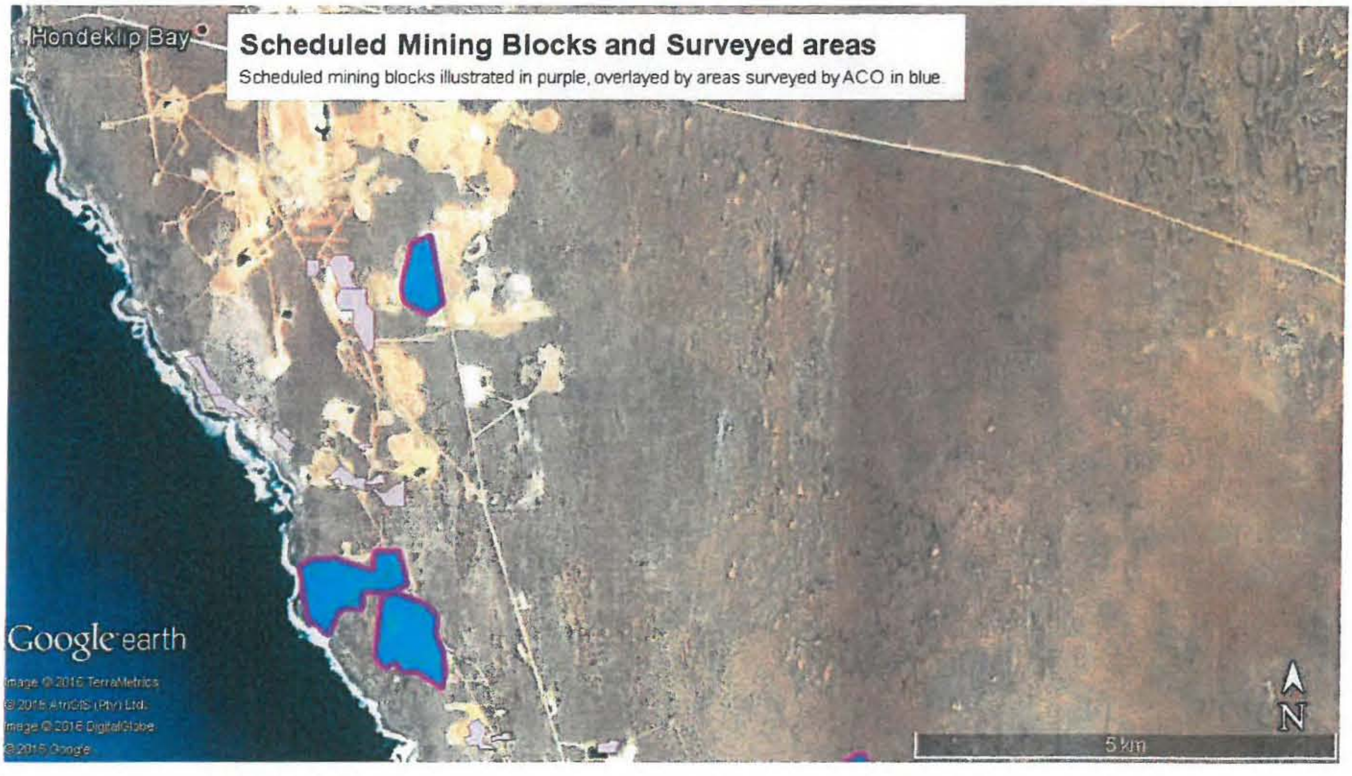


Figure 7 Hondeklipbaai south - old De Beers blocks already assessed vs new mining areas

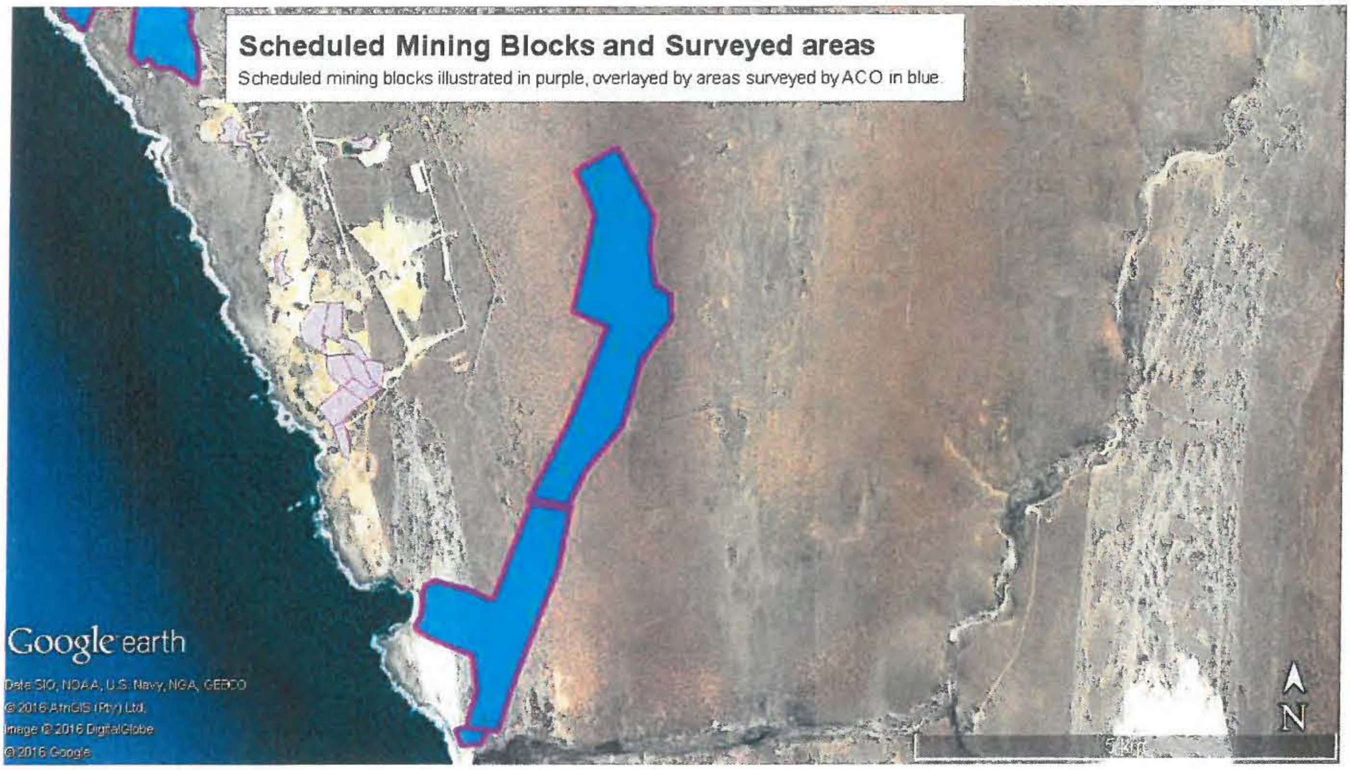


Figure 8 Mitchells Bay - old De Beers blocks already assessed vs new mining areas

APPENDIX B

Palaeontological Management.

- Heritage Conservation Management

- PALAEONTOLOGICAL MITIGATION AND GEOHERITAGE

- DE BEERS NAMAQUALAND MINES

- INITIAL DRAFT REPORT

- MAY 2008

Version 2

John Pether, M.Sc., Pr. Sci. Nat. (Earth Science)
Consultant: Sedimentology, Palaeontology, Stratigraphy

P. O. Box 48318

Kommetjie, 7976

Tel. /Fax (021) 7833023

Cell phone 083 744 6295

jpether@iafrica.com

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ACCOMPANYING SEPARATE DOCUMENTS

Maps 1-4

Images 1 - 8: 8 Document files with selected digital images nos. 1-49.

ICS Stratigraphic Chart

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• ACKNOWLEDGEMENTS

De Beers Namaqualand Mines
Paul Kruger
Graham Avery
David Halkett

SUMMARY

This report provides an assessment of the status of palaeontological scientific research along the Namaqualand coast, with particular reference to the De Beers Namaqualand Mines (DBNM) exposures. It is undertaken at the request of DBNM Environmental/Conservation Management, under the auspices of the Iziko S. A. Museum (Dr G. Avery) and is allied to the existing archaeological heritage mitigation programme carried out by the Archaeology Contracts Office of UCT (Dr D. Halkett).

The purpose is to provide the initial inputs to the palaeontological aspects of the Heritage Management part of the overall Environmental Management Plan (EMP) for the terminal phases of the mine. In essence, this is about the "last chance" opportunities to collect fossils from the remaining mine exposures, before they are finally backfilled. Conversely, that a number of selected mine pits be rehabilitated as "open" GeoHeritage sites for the intersecting purposes of science and GeoTourism. Thirdly, that a palaeontological mitigation programme is established for future mining activities.

The report includes a Desktop Study (Sections 2-6) summarising:

- The current understanding of the stratigraphy of Namaqualand coastal deposits.
- The ages of the formations, on the basis of the fossil evidence from Namaqualand, viewed in the context of palaeoceanographic records based on microfossil geochemistry.
- A brief account of the historical development of Namaqualand coastal stratigraphy.
- Outstanding concerns w.r.t. gaps in the fossil record hitherto obtained.

Section 7 presents brief observations made at a number of selected exposures during the "flying" pilot field study, with discussions and recommendations.

Recommendations for Mitigation

Primary Palaeontological Mitigation - Current Exposures

It is advocated that all available pit faces be inspected for fossil content.

This process is to be prioritized in terms of the schedules for the filling the pits, including:

- Current pits that are being backfilled in the continued course of mining.
- Old pits that are being filled or due to be filled soon in terms of the rehabilitation program.

Requires liaison with a suitably-placed persons regarding backfilling and excavation schedules.

Sections must be described where fossil material is sampled. Additional observations of sedimentary features should be made where these inform about the origin of the deposits.

A prescribed data requirement is adequate 3D spatial referencing. For this the specialist would require the assistance of the surveyor w.r.t. co-ordinates and base maps.

Priority Fossil Exposures

These exposures should not backfilled and the exposed fossils should be collected as soon as possible.

- The apparent silicified bone and macrofossil plant material exposed in the "Megalodon" palaeochannel at KVS_E16 (Waypoint 137).
- The fossil wood pieces and plant debris from the "Langklip Channel Clays" in the LK_LK_22 exposures (Waypoint 51).
- The unique 90 m Package fossil shells occurrence in the Koingnaas KN_KLNA_15 exposure (Waypoint 56).

Contingent Archaeological Mitigation

In the process of scanning palaeosurfaces in the terrestrial sequences for fossil bones, buried occurrences of ESA and MSA implements are certain to be found. Significant finds are to be referred to the contracting archaeologist. For example:

- The Early Stone Age site at Waypoint 139 should be examined by the UCT Archaeological Contracts Office.

Dumps and Discarded Oversize Gravel

Overburden dumps, particularly after deflation, have provided valuable fossils. Discarded oversize gravel dumps have been the source of extremely valuable vertebrate teeth sourced from the basal petrified assemblage. In the process of backfilling from these dumps or regrading them it is possible that fossil material will be exposed.

Legacy Material

Compilation of a detailed inventory of existing fossil samples and their state of diagnosis, together with where they currently are stored/displayed, at company sample archives, local museums and various research institutions.

Existing descriptive documentation/projects should be reviewed where appropriate, in order that the fossil search and contexts of finds are informed by the prior observations of the deposits.

In the case of the Quaternary RETs and the BIC, any photographic records and sketches made when existing exposures were less covered would be useful.

Proprietary information concerns should be addressed, such as non-disclosure agreements and limitations/permissions for access to reports.

- **Geohistorical Heritage Sites**

There is considerable interest in the preservation of selected mine-pit exposures, both as:

- Type Sections for the formations of the Namaqualand coastal plain and the Buffels River.
- GeoHeritage sites that will form the basis of GeoTourism routes on the Namaqualand coast.

It is predicted that there will be agreement and support from the geological community that Type Section sites be preserved among the DBNM exposures. The geological community is also increasingly engaging in GeoHeritage and GeoTourism e.g. the Vredefort Dome World Heritage Site

Visit www.unesco.org/science/earth/geoparks.html).

The West Coast Fossil Park at Langebaanweg is the GeoTourism precedent on the West Coast.

The Namaqualand community has an interest in GeoHeritage and GeoTourism, as a potential sustainable, albeit minor, economic opportunity while the diamond-mining continues to decline into the future.

In the process of the comprehensive pit inspection, particular exposures can be earmarked and rated w.r.t. their value as a type section/Geohistorical site that should be maintained in an accessible and meaningful condition.

Although the preservation of selected mine-pit exposures may reduce the costs of rehabilitation, there will obviously be costs incurred in keeping pits open and accessible, in stabilization of the faces and in safety concerns.

The following are initial proposals for potential Type Sections and GeoHeritage sites:

- The unique exposure of the highly plant-fossiliferous "Channel Clays" on Langklip (LK_LK_22 exposures, Waypoint 51).
- The "Megalodon" palaeochannel at KVS_E16 (Waypoint 137), including the contact between the edge of the "Megalodon" palaeochannel sediments and the 90 m Package.
- The 90 m Package remnant occurrence with unique shell fossils in the Koingnaas KN_KLNA_15 (Waypoint 56). Overlain by the 30 m Package.
- An exposure (unspecified, if one still exists?) of the BMC Upper Terrace and overlying 90 m Package where it is of typical aspect. Aspects could include the 95 m cliff, silcrete boulder conglomerates and the black, heavy-mineral beach zones.
- An exposure (unspecified, if one still exists?) of the BMC Middle Terrace where it is of typical aspect. Important aspects are the 65 m Cliff, the sedimentary architecture in relation to the 65 m Cliff and the transgressive maximum of the 50 mm Package overlying the lower Middle Terrace.
- An entire section (unspecified) through the Quaternary RETs.
- A suitable exposure (unspecified) of the Buffels deposits at Nuttabooi.

1. INTRODUCTION

1.1 Context of this Palaeontological Assessment

De Beers Namaqualand Mines (DBNM) is now in the "sunset" phase of diamond mining along the Namaqualand coast, after 80 years of activity. The intention of this report is to provide an assessment of the status of palaeontological scientific research along the Namaqualand coast, with particular reference to the DBNM exposures. The purpose is to provide the initial inputs to the palaeontological aspects of the Heritage Management Plan. The latter is part of the overall Environmental Management Plan (EMP) for the mine, of which the main focus now is the rehabilitation of the mine open-cast pits and overburden dumps. In essence, this is about the "last chance" opportunities to collect fossils from the remaining mine exposures, before they are finally backfilled.

Hitherto, heritage management has mainly involved the sampling and recording of archaeological occurrences on the land surface, prior to mining in an area. Fossils however, are exposed once overburden is being stripped. The opportunities in the past for fossil collection have not been fully exploited, for a variety of reasons. The mining environment is not favourable for spotting sparse fossils and there are the exigencies of production schedules that do not lightly brook interruptions. Valuable fossils such as bones are difficult to spot and if seen, are difficult to recover intact without specialized techniques. Necessary product security measures limit access to material, particularly basal units. There have been and still are few locally-based palaeontologists with funding to carry out long-term monitoring for fossil occurrences.

Notwithstanding, a considerable legacy of "in-house" scientific knowledge has accumulated over this period, much of it hinging on the finding and diagnosis of fossils. A portion of this knowledge resides in the public domain via the support of research projects such as DBNM-funded thesis projects, by the facilitation of research by external scientists and by the hosting of conferences and workshops. The current knowledge of the geological history of Namaqualand owes much to this support.

Although this report is primarily about fossils, there is overlap with archaeological interests. Buried, older archaeological material occurs within the upper parts of the terrestrial deposits, usually in association with fossil bones. The search for fossils will also include such finds.

Now that the value of fossils has been recognized legislatively, the process of compliance with the heritage legislation provides the opportunity to address outstanding concerns regarding the scope of fossils from coastal Namaqualand represented in existing scientific collections and the contingent scientific questions. There will be "spin-off" as inputs for the still-evolving geological model of the Namaqualand deposits, at the least as a confirmatory/auditing process for the interpretations of the stratigraphy of the exposures. Indeed, as the scale and intensity of exploitation is decreased into the future, in the process of eking out the remaining resource, it may now be opportune to undertake a field-based review process of the "anatomy" of the mine.

1.2 Significance of the Palaeontological Heritage Resource

In terms of the National Heritage Resources Act No. 25 of 1999, Sections 35 & 38, palaeontological materials (fossils) are regarded as a heritage resource and appropriate actions are required to mitigate impacts from mining, construction and development on palaeontological heritage. If fossils are turned up in excavations, they must be rescued from destruction and loss.

The significance of fossils as natural heritage is primarily their scientific value. They contribute to the understanding of South Africa's geohistory, the progression through "deep time" of changing climates, oceanography and of the biota, both plant and animal, that lived on the land and in the sea. This history ultimately resulted in the landscapes and coasts and the resources that sustain us today. Generally-speaking they are scarce, non-renewable and irreplaceable when destroyed. Their value is also severely compromised when they are collected without proper recording of their geological context. Geological (sedimentological/palaeoecological) observations are indispensable for the interpretation of fossil finds.

The value of fossils extends far beyond the curiosity of palaeontological study in museums, for they provide the basis for biostratigraphy, the division of the sedimentary record into units of distinct ages that can be correlated both regionally and globally. The fossil content of strata is thus very important for understanding the genesis of exploitable mineral resources and for the geological models that furnish the basis for ongoing mineral exploration.

Moreover, there are the intersecting broader concerns of **GeoHeritage**, scientifically w.r.t. the preservation of Type Sections of the deposits and **GeoTourism** as a sustainable endeavour for the future.

1.3 Palaeontological Impact Assessment and Mitigation

Impact Assessment Criteria

The following criteria are a standard part of HIAs, herein briefly adapted to the DBNM context.

- *Extent*

The physical extent of impacts on potential palaeontological resources relates directly to the extents of subsurface disturbance. This will mainly be in the areas of quarrying, but also includes excavations for infrastructure.

- *Duration*

The duration of the impact has been long-term (80 years) and will continue to the end of the mine (10 years?).

- *Intensity*

The impact of mining on fossil resources is potentially high. This is because fossils are rare objects, often preserved due to unusual circumstances. This is particularly applicable to vertebrate fossils (bones), which tend to be very sporadically preserved.

While it is clear that fossils in the subsurface would remain there were it not for the mining activity, the failure to attempt to maximize the opportunities provided by the mining represents loss of such resources.

- *Probability of occurrence*

The probability of impact is definite. The area is known to have considerable fossil potential. Given the scale of machinery involved in mining, it is certain that fossils have been and will be destroyed, regardless of efforts in mitigation.

- *Significance (unmanaged)*

There is certainty of fossils being lost in the absence of management actions to mitigate such loss. Such loss would be of national and international significance. The area has already produced fossils of international scientific importance.

- *Significance (managed)*

There remains a medium to high risk of valuable fossils being lost in spite of management actions to mitigate such loss. Mitigation is the key concept and is all that can realistically be achieved.

- *Status of the impact*

The status of the impact for palaeontology is not neutral, but has duality from the fact that the "windows" into the coastal plain depository, that provide access to fossils, would not exist without the mining, the impact is positive for palaeontology. From the point of view that fossils are going to be destroyed, in spite of efforts at mitigation, the impact is negative.

- *Degree of confidence in predictions*

Certain.

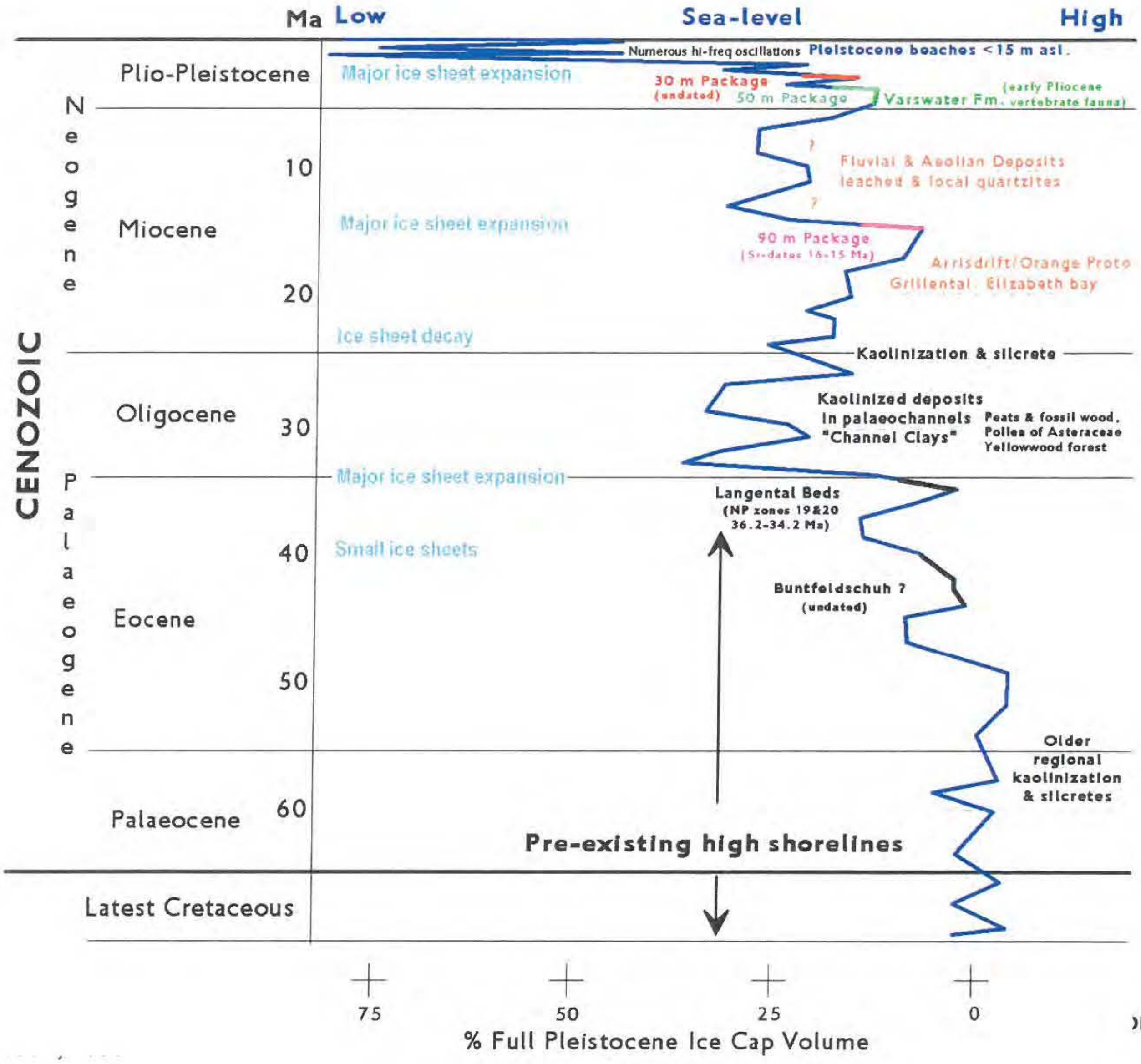
- **Typical Mitigation Process**

The essentials of the palaeontological mitigation process, in "typical" circumstances such as coastal housing developments or industrial sites, involves:

- Compilation of the PIA outlining the potential fossils occurrences in the vicinity, with recommendations for the mitigatory actions to be taken.
- Terms of Reference of project drawn up. A site-specific permit is obtained from the relevant Provincial Heritage Resources Authority or SAHRA.
- Any exposed fossil occurrences threatened by activities are sampled and described.
- The digging of excavations is monitored. A reporting/action protocol for monitors is in place for finds uncovered.
- A primary fieldwork phase follows. The faces of excavations are closely inspected for fossils and recorded.
- A Final Report is compiled and rescued fossil material is deposited in the scientific institution.

2. SUMMARY OF COASTAL-PLAIN STRATIGRAPHY

Shown below (Fig. 1) is a proxy sea level/ice-volume record for the Cenozoic Era, annotated with the main elements of the stratigraphy of Namaqualand. The current geological time scale will accompany this report, for nomenclature reference purposes.



›m Lear

2.1 EARLY POST-GONDWANA EVENTS

During the early Cretaceous separation of Africa and South America, fault-bound grabens formed parallel to the approximately N-S basement structural grain during basement extension and collapse along the early coastline. Dolerite dykes intruded the faults and lineaments in the basement, with volcanic activity in places.

Vigorous erosion during the later Cretaceous exposed the coastal bedrock of metasediments and gneisses from beneath a cover of Nama and Dwyka rocks. Notwithstanding, large-scale topographic aspects of the coastal plain, its backing escarpment and major drainage lines still reflect persistence of the basal Dwyka topography, formed beneath huge glaciers ~300 Ma. In more detail, faulting during continental breakup affected coastal topography. Deposits from these times are only preserved in rare instances, One example, a graben preserved some distance to the north of Kleinzee, contains lacustrine deposits that have yielded Lower Cretaceous pollen (Molyneux, in Rogers *et al.*, 1990), indicating deposition 145-130 Ma.

The coastal plain would have been transgressed during Cretaceous high sea-levels. Transgressive Eocene events also affected the coastal plain and deposits of this epoch are found in southern Namibia *viz.* at Buntfeldschuh and Langental (Fig. 1), but little evidence of this earlier marine history remains along Namaqualand. Rather, much of the further evolution of the coastal drainages took place during these times, with flushing of pre-existing deposits to the offshore depositories. The coastal plain bedrock became deeply weathered and kaolinized under the influence of the humid tropical climates of the later Cretaceous and early Tertiary, with silcrete duricrusts developing.

Remnants of the late Cretaceous African Surface have been preserved on the escarpment and coastal hinterland (Partridge and Maud, 1987) as silcrete-capped mesas underlain by deeply kaolinized bedrock. However, not all the weathering-profile silcretes are necessarily latest Cretaceous; those on valley flanks of current drainages are probably early Tertiary. Along the present coast these older weathering profiles have been truncated by marine transgressions.

• 2.2 Earlier Tertiary Fluvial Deposits

Incised into this ancient, weathered land surface are remnants of fluvial palaeochannels, whose infills have also been kaolinized, disguising their presence (informally called the "Channel Clays"). These channel sediments consist of oligomictic, subangular quartz paraconglomerates, locally rich in diamonds, overlain by beds of clayey sand, clay and carbonaceous material containing plant fossils (Molyneux, in Rogers *et al.*, 1990). Silcrete has also formed within the channels. Pether (1994b) has concluded that the conglomeratic and sandy beds were originally arkoses derived from the surrounding gneisses.

The deeply weathered nature of these channel infills suggests a considerable age, but their age has been controversial. Fossil pollen from the organic-rich beds fills has variously been interpreted as dating to the Palaeogene and the Neogene (de Villiers, 1997). In contrast, a mid-Cretaceous (Albian to Turonian) age was suggested by marginal-marine microfossils (I.K. McMillan, pers. comm.). Subsequently, he concluded that the maximum age must be late Cretaceous (late Campanian/early Maastrichtian (I.K. McMillan, in press).

Due to the economic importance of the "Channel Clays", additional samples were sent to analysts. The presence of Proteaceae indicates an age not older than Maastrichtian (end-Cretaceous), whilst Oleaceae (ironwoods) and Asteraceae (daisies) indicate an age not older than Oligocene (Muller, 1981). This suggests that the bulk of the infill is Oligocene/earliest Miocene, with humid weathering (kaolinization) continuing to ensue during the earliest Miocene. Sue de Villiers argues for a possible Palaeocene/Eocene age, but this would imply that the daisies and ironwoods evolved in South Africa quite early on, well before their radiation to larger Africa (and beyond). The possibility remains open that the stratigraphy of these deposits is more complex than thought and that the channels were active over a considerable time span.

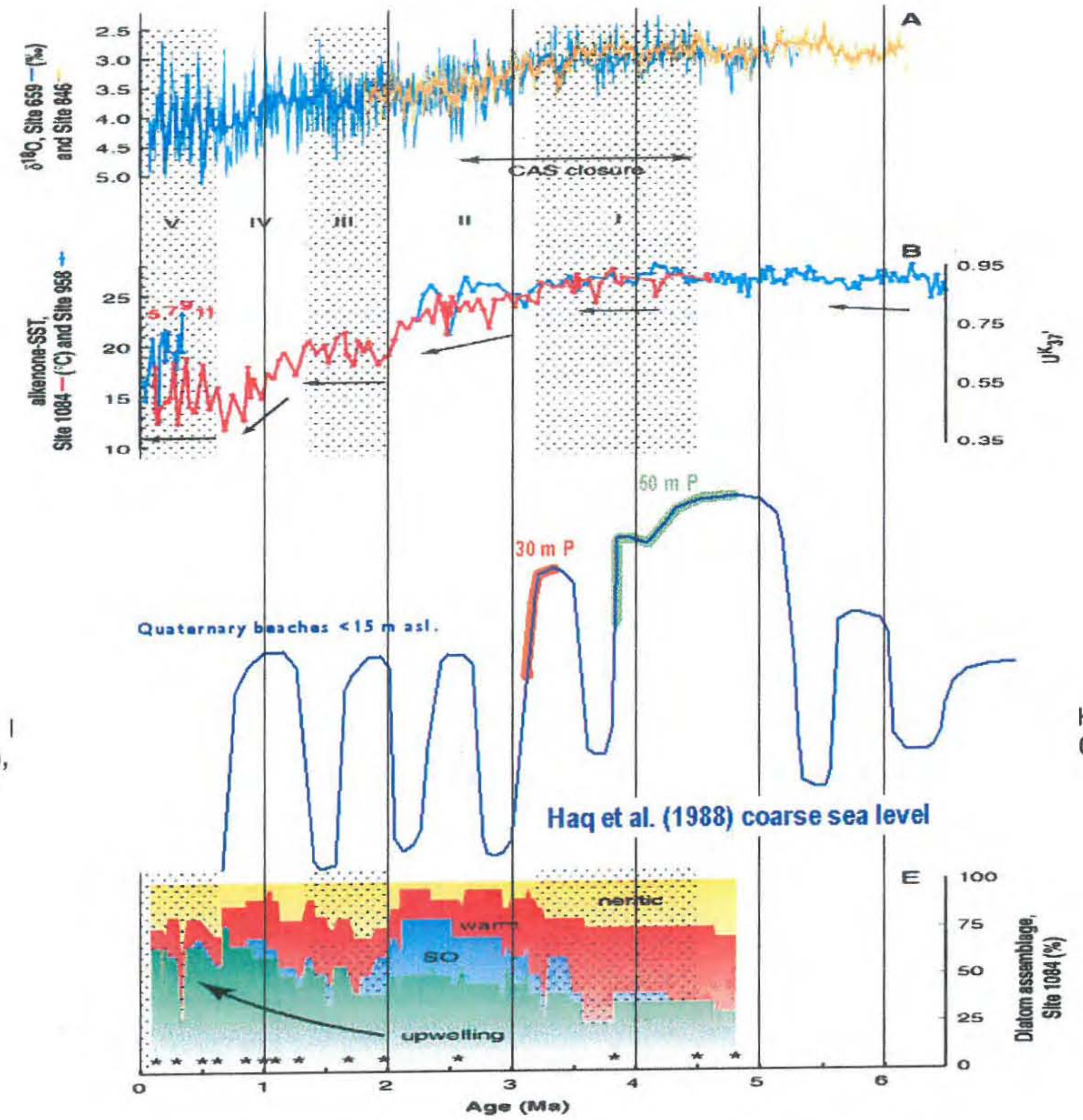
• 2.3 Neogene Marine Deposits

Consistently represented along the length of the coast are three extensive marine formations containing warm water mollusc assemblages. This older, Neogene, warm-water group includes the 90 m Package, the 50 m Package and the 30 m Package. The latter is transgressed by younger, Quaternary littoral deposits up to about 10 m asl. that include cold water shell assemblages similar to those inhabiting the coast today. This Quaternary, cold-water group comprises the 8 - 12 m Package (~400 ka BP?), the 4 - 6 m Package (Last Interglacial (LIG) ~125 ka BP) and the 2 - 3 m Package (mid-Holocene 6-4 ka BP).

These packages are alloformations that are defined genetically, each being related to a cycle of marine transgression and regression. Each comprises the package of marine sediments deposited during regressive progradation seawards from the maximum elevation reached by the transgression. The packages are arranged *en echelon* down the coastal bedrock gradient, from oldest and highest to youngest and lowest at the coast, each package truncating the preceding one at a lower elevation. Each package is named after the elevation of its transgressive maximum, as represented in the Hondeklip area. In terms of sequence stratigraphy they are highstand tracts, each comprising only one parasequence. They are not marine terraces, which are geomorphological entities that may have developed over more than one sea-level cycle. In each case, their basal gravels locally contain exploitable reserves of diamonds.

From the biostratigraphic viewpoint, the 90, 50 and 30 m packages each contain their own unique suite of extinct fossil mollusc shells. Most well-known among these is *Donax haughtoni* (50 m Package) and *Donax rogersi* (30 m Package), whilst recent findings suggest that *Isognomon gariesensis* is a good zone-fossil candidate for the 90 m Package, previous finds from the basal 50 m Package having been reworked. The barnacles (Pether, 1990) and brachiopods (Brunton and Hiller, 1990) are also biostratigraphically useful. The microfossils from the packages have been investigated by Dr Ian McMillan and also exhibit distinct assemblages.

The extant warm water taxa present in the 50 and 30 m packages include species that today inhabit the east coast of southern Africa only and West African species. Chief among the warmer water indicators is the oyster *Crassostrea margaritacea*, which is abundant in both packages. Despite the intensification of upwelling along this coast from late Miocene times (Siesser, 1978), its influence was clearly not as great during late Neogene interglacials as at the present interglacial (Fig. 2). The explanation may be sought in latitudinal shifts and reduced intensity of the trade winds, which would have been associated with shifts in upwelling loci and reduced upwelling, as well as with an enhanced tendency for Agulhas water to round the southern tip of Africa and influence the Benguela system. (E.g. Pether, 1994a). Clearly too, tropical taxa from the West African province were not cut-off from the southern African coast by an upwelling barrier. The onset of bipolar glaciation and the Quaternary climatic mode impacted locally as considerable extinction and speciation in the shallow marine molluscan fauna, such that the post 30 m Package faunas are essentially modern.



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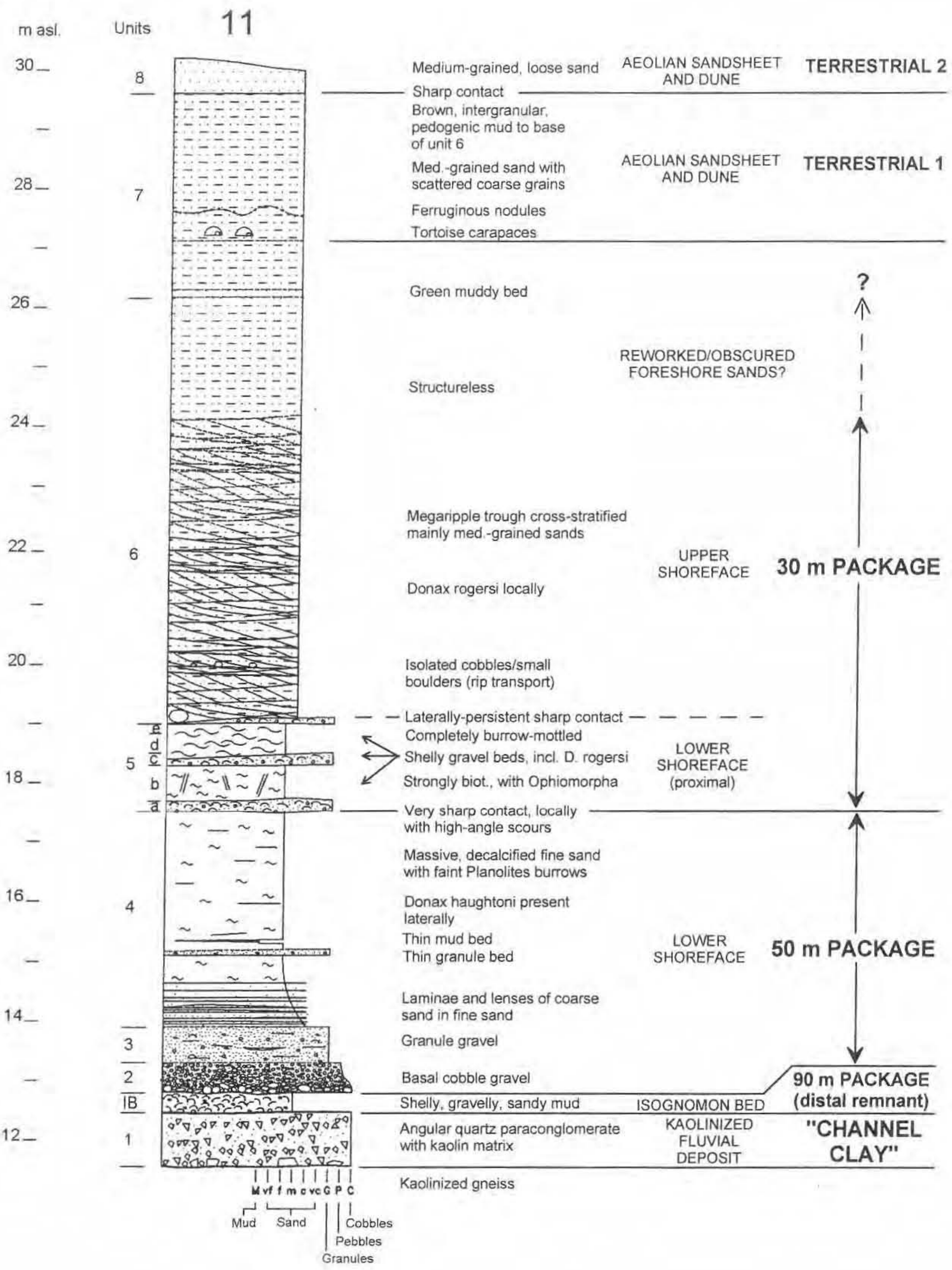
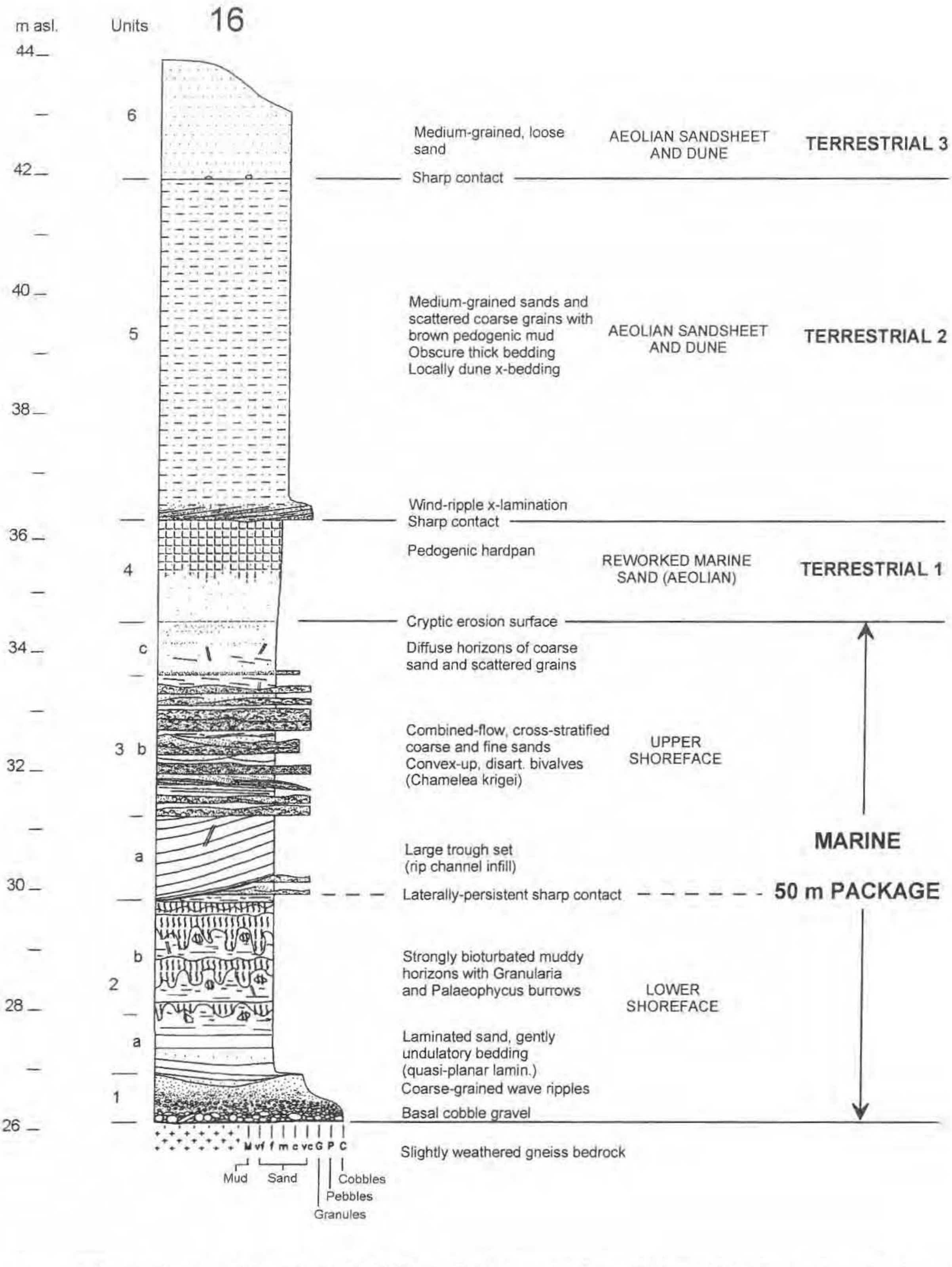


Figure 3: Graphic section of 50 m Package, Avontuur Section 16.

Lower shoreface tempestites with fairweather bioturbation in upper part. The upper-shoreface facies (breaker and surf zone deposits) is preserved here, but the foreshore (beach) has been eroded away. A subtle, cryptic contact separates in situ green marine sand from very similar, but reworked (aeolian sand sheet) green sand in which is developed a pedogenic hardpan. The latter has also been eroded and overlain by sandsheet and dune sands, locally with sheetwash lenses and mud lenses, the latter deposited in ephemeral pans.



- **Figure 4: Graphic section of 30 m Package and eroded, underlying 50 m Package. Hondeklip Section 11.**

A thin remnant of the basal kaolinized deposits (Eocene-earliest Miocene) is also present at this site. The mid-Miocene Isognomon bed (distal 90 m Package remnant) has been inserted at the appropriate stratigraphic position, whereas it is actually preserved ~50 m away from the section site. The 50 m Package section has been eroded down to the lower-shoreface (storm deposits) facies and a sharp contact, locally with pots and gutters, is overlain by the 30 m Package. The section is not far seaward from the 30 m Package transgressive maximum, so that there was accommodation for only the "beginning" of a lower-shoreface facies. The megaripple bedforms of the 30 m Package upper-shoreface attest to high sediment supply.

- **2.4 The 90 m Package**

In the vicinity of Kleinzee a cliff line at 95 m is cut into the silcrete-capped bedrock and forms the landward edge of a wave cut platform down to ~75 m. Sediments comprize a basal gravel with abundant silcrete clasts and overlying, reddened sands with heavy mineral laminae (Rogers *et al.*, 1990). Farther north the Grobler Terrace in the Alexander Bay area is at equivalent elevation. In the Hondeklip area, landwards above ~40 m ASL, coarse sands and gravels of the truncated edge of the 90 m Package appear in bedrock lows beneath the over-riding 50 m Package.

These high-elevation 90 m Package deposits are decalcified and generally lack all but the most robust macrofossils. However, a shelly, more distal marine (shelf) facies of pebbly muddy sands and clays is very locally preserved at even lower elevations, beneath the 50 and 30 m packages (*Isognomon* bed, Fig. 4). Strontium isotope ages of 16-15 Ma have been obtained from foraminifera sealed in clay at one such occurrence in the Hondeklip area (Langklip), consistent with high sea levels during the warm mid-Miocene climatic optimum *ca.* 17 to 15 Ma (Fig.1).

- **2.5 The 50 m Package**

This package was laid down in the course of shoreline progradation as the sea regressed from a maximum of ~50 m ASL. It consists typically of fine green sands overlying basal gravels. The sands may exceed 8 m in thickness and were deposited at lower shoreface palaeodepths; they are not beach deposits. The basal gravels generally are not transgressive lags, but are tempestites swept from the foreshore and upper shoreface during extreme storm events to be deposited, at the foot of the prograding wedge and extending onto the inner shelf. The distal (inner-shelf) tempestites were lithified by impregnation of phosphorite and subsequent reworking and additional deposition during storms generated multiphase beds and phosphoritic intraclasts. As the regression advanced, deeper water facies were destroyed except for a few remnants preserved in depressions, which were overridden by the proximal gravel tempestites.

The proximal, shallower gravels were also repeatedly reworked by storms until they were finally buried by the advancing fine sands of the lower shoreface. These fine sands exhibit hummocky and swaley stratification, quasi-planar lamination and interbedded coarse-grained wave ripples (CGR) that attest to storm deposition, whilst fair weather conditions are reflected by rippled sand, mud drapes and bioturbation. A cross-bedded, coarse-sandy upper shoreface facies sometimes overlies the fine sands of the lower shoreface (Fig. 3), but has mostly been lost by erosion. A unit of wind-reworked marine sand and calcrete overlies the marine section and this is sharply overlain by several meters of pedogenically-reddened aeolian and sheetwash sands.

- **2.6 The 30 m Package**

The 50 m Package was truncated by the next major transgression, which reached ~30 m ASL. and another progradational wedge then built out seawards from the ~30 m transgressive maximum, forming the regressional 30 m Package. The package extends to near the present day shoreline, where it is overlain by deposits relating to a ~10 m high sea level. An important contrast between the 50 m and 30 m packages is that usually only the foreshore facies of the latter has been variously subjected to terrestrial reworking and its upper shoreface facies is extensively preserved (Fig. 4). However, this facies has over large areas been affected by decalcification and pedogenic reddening, superficially causing it to resemble terrestrial deposits.

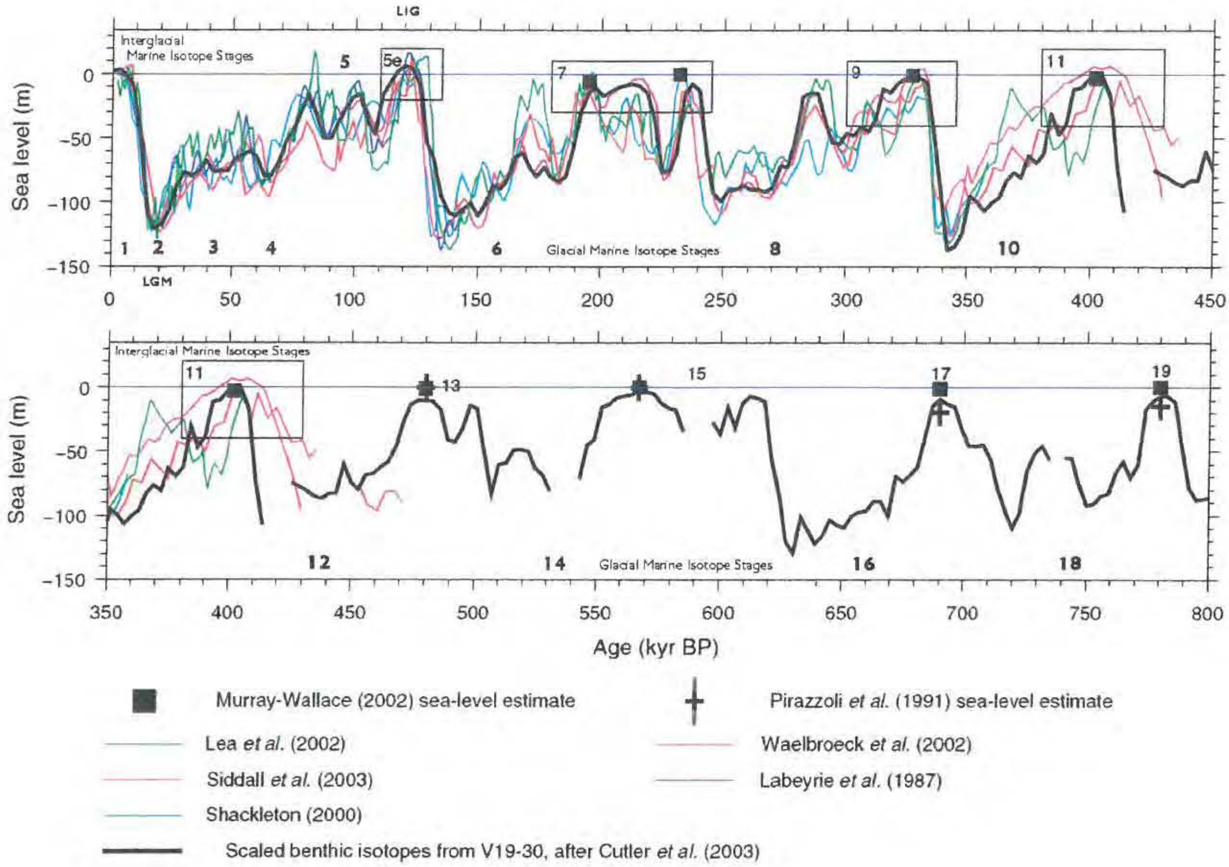
The 30 m Package upper shoreface is typically dominated by thick megaripple troughsets, whereas trough-lag amalgamation typifies the 50 m Package upper shoreface. There are more coarse-grained beds in the proximal lower shoreface of the 30 m Package, as thin gravelly units entirely reworked after deposition as coarse-grained ripple (CGR) fields and thicker, poorly-bedded units debouched from rip channels which have only their upper portions reworked as CGR. These aspects support a greater sediment supply to the littoral and faster progradation during 30 m Package times relative to 50 m Package times.

- **2.7 The Quaternary Packages**

Very little descriptive information is available for the Quaternary "Recent Emergence Terraces", the 8-12 m Package, the 4-6 m Package and the 2-3 m Package, along the Namaqualand coast.

As in the southwestern Cape, the most prominent of these deposits are the younger, LIG and mid-Holocene deposits. The older, 8-12 m Package could relate to a prominent middle Pleistocene interglacial called Marine Isotope Stage 11 (MIS 11) ~400 ka ago (Fig. 5). Alternatively, it is been argued on the basis of vertebrate evidence that this old shoreline is early Pleistocene, about 1.2 Ma (Hendey & Cooke, 1985).

Given that all of the pre-LIG Pleistocene highstand evidence is "subsumed" in the "8-12 m Package" deposits, at this stage, it quite feasible that the poorly-known "8-12 m Package" deposits could include units of differing age at various localities. It is clear that the record of Pleistocene high sea levels is very condensed along the west coast, with each highstand largely destroying deposits of the previous highstand. Low sediment supply for progradation and slow or negligible uplift contributed to this situation. However, it also seems that few later Quaternary highstands exceeded present sea level (Siddall *et al.*, 2007). Other complications are evidence of brief high spikes in sea-level during interglacials 5e and 11 (Siddall. *et al.*, 2007).



- **Figure 5. Approximations of sea-level history during the last ~0.8 Ma, from Siddall. *et al.*, 2007.**

3. THE VERTEBRATE RECORD AND AGE CONSTRAINTS

The vertebrate fossils found in the coastal plain deposits are absolutely critical for the provision of age constraints. Sparse vertebrate fossils indicative of Neogene ages have been retrieved from various sites on the Namaqualand coast. From fluvial deposits at ~35 m ASL. near Kleinzee, Stromer (1931) described a small vertebrate assemblage that included extinct hyaena, otter and mongoose bones. Thereafter, no major assemblages were recovered, but a trickle of finds was presented for identification through the many years of mining (Hendey, 1984). During research at Hondeklip mine, a special effort was made to improve the situation, involving painstaking scrutiny of the exposures. Some of this well-provenanced material, and new finds from the Hondeklip area, have now been examined systematically (Pickford and Senut, 1997), shedding new light on coastal plain history.

Fossilized teeth of suids and a hominoid tooth, recovered from 90 m Package gravels at ~50 m asl., are adjudged to be of latest early Miocene age (ca. 18 - 17.5 Ma) (Pickford & Senut, 1997). This range of age's places the 90 m Package sea-level high contemporaneous with the higher, or *proto* gravels of the lower Orange River valley. The latter deposits at Arrisdrift have evidence of an encroaching sea and were apparently aggraded in the vanguard of the mid-Miocene transgression (Fig. 1).

The 50 m Package contains a basal concentration of petrified and abraded vertebrate remains inherited from earlier periods. This "Basal, petrified, mixed assemblage" or remanié fauna includes shark teeth and the bones and teeth of extinct whales, proboscideans, rhinocerotids, bovids and equids (Pether, 1994b; Pickford and Senut, 1997). The oldest fossils present are the bear-dog *Agnotherium* sp. (13 - 12 Ma) and the gomphothere *Tetralophodon* (12 - 9 Ma), but the age indicated by most of the material is terminal Miocene (7.5 - 5 Ma) (Pickford and Senut, ibid.). These youngest taxa in the reworked basal assemblage constrain the maximum age of the 50 m Package. The important, unpetrified finds from within the package are the Langebaanian (Varswater) phocid (seal) *Homiphoca capensis* and the suid (bushpig) *Nyanzachoerus kanamensis*, the latter reported by Pickford & Senut (1997) to have an age of 5 - 7 Ma. Stromer's (1931) assemblage includes Langebaanian carnivores (Hendey, 1984).

Linking of the 50m Package to the Varswater Formation and the early Pliocene (~5 Ma) high sea level of Haq *et al.* (1988) is therefore considered appropriate, but as the package is a regressive, prograded deposit it is correlated with the fall in sea level from the ~5 Ma highstand, *i.e.* only part of the Varswater Formation as currently defined.

The top of the 50 m Package in the Hondeklip area is eroded away and a cryptic contact separates pristine marine sediments and reworked marine sediments. On the cryptic surface are sparsely scattered bones (tortoise, zebra, ostrich, jackal, various antelopes, rhino). This erosion surface and the overlying terrestrial sediments must be younger than the ~2.6 Ma *Equus* (horses) dispersal in Africa because of the zebra (*Equus capensis*) bones.

4. OTHER AGE CONSTRAINTS

Many attempts at strontium-isotope dating of fossil shells have been done, but almost all age estimates from strontium isotopes have been bedevilled by the alteration of the original marine signatures that is typical of carbonate sequestered in arenaceous deposits. Notwithstanding, the strontium dates of 15-16 Ma for foraminifera from the 90 m Package (samples sealed in clay), are broadly consistent with local vertebrate evidence and global ice-volume proxies (Figure 1). Improvements in analytical equipment encourage continued efforts with this technique, using improved sample-volume selections in sectioned fossils.

Broad age constraints issue from palaeoceanographic/climatic reconstructions based on proxy data of global significance such as the oxygen-isotope records of deep-sea microfossils. The highest elevation marine deposits of the 90 m package have previously been considered early Pliocene. The evidence now that the 50 m Package is early Pliocene better fits the oxygen-isotope record, which negates major Pliocene deglaciation and very high sea levels (Hodell & Venz, 1992).

An age-diagnostic vertebrate assemblage associated with the 30 m Package has not yet been recovered and so its age is not constrained by vertebrate datums. Notwithstanding, it is the last, major formation of the coastal plain, deposited during a high sea-level never since exceeded. With its warm-water molluscan fauna, it is unlikely to postdate the inception of major cooling in the Benguela System. A core from off Lüderitz (ODP Site 1084) has provided alkenone-based SST (from fossil organic matter) and diatom microfossil-assemblage records extending from 4.5 Ma. This shows a decline in temperature since 3.2 Ma, from previous mid-Pliocene warmth (~26°C) (Marlow *et al.*, 2000).

Seismic reflection data from the margins of Antarctica show a major change in sedimentary geometry and processes since ~3 Ma, explained by the transition of the Antarctic ice sheet regime from polythermal to the present (Quaternary) polar cold, dry-based conditions during late Pliocene global cooling (Rebesco *et al.*, 2006; Rebesco & Camerlenghi, 2008). Northern hemisphere glaciation intensified during 3.1-2.5 Ma, with onset of bipolar glaciation and the Quaternary climatic mode since ~2.6 Ma. Accordingly, the 30 m Package is not likely to predate 2.6 Ma or ~3.0 Ma. Speculatively, with reference to the coarse sea-level history inferred from sequence-stratigraphic interpretations of margin seismic profiles (Haq *et al.*, 1988), the 30 m Package may correspond with the major sea level highstand in the mid Pliocene at ~3.0 to 3.4 Ma.

5. HISTORICAL GEOLOGY AND PALAEONTOLOGY

5.1 INTRODUCTION

The first recorded references to the raised beaches of Namaqualand are in the journals of the explorers R.J. Gordon (Raper & Boucher, 1988) and W. Paterson (Forbes & Rourke, 1980). En route to the "Great River" (Orange/Gariep) in 1779, they headed towards the Holgat River (Fig. 2) in search of water. There they noted the presence of fossil marine shells in marine deposits on top of the cliffed shoreline (Forbes & Rourke, 1980; Raper & Boucher, 1988). They also made the distinction between raised beach deposits and shell middens of anthropogenic origin. One and a quarter centuries after Gordon and Paterson's explorations, Rogers (1904, 1905) made observations on marine gravels and sands on the cliffs at ~25 m asl. between the Olifants River and Doring Bay (Fig. 2). He noted their apparent geomorphological association with the occurrence of siliceous and ferruginous duricrusts in the area.

Krige, during his survey of raised beaches around South Africa, published in 1927, made observations on the occurrence of low-elevation (<20 m asl.) marine terraces and deposits along the Namaqualand coast, his "Major Emergence" (15-18 m asl.) and "Minor Emergence" (5-8 m ASL.) (Krige, 1927). He provided Haughton with fossil shells from the cliffs at Doring Bay, which resulted in the first descriptions of Tertiary fossil molluscs from Namaqualand (e.g. *Donax rogersi* Haughton, 1926; *Chamelea krigei*, Haughton, 1926).