	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	

pact of each mining on aritime eritage	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.				Without mitigation	With mitigation	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.
				Severity	High	Low	
				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 I999 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.

11. REFERENCES

Deacon, J. (1992) Archaeology for developers, planners and local authorities. National Monuments Council: Cape Town.

Deacon, J. ed. (1996) Monuments and Sites in South Africa. ICOMOS Central Cultural Fund Publication No. 206. National Committee of ICOMOS: Sri Lanka.

Deacon, J. & Pistorius, P. 1996. in: Deacon, J. ed. (1996) Monuments and Sites in South Africa. ICOMOS Central Cultural Fund Publication No. 206 pp 1 - 8. National Committee of ICOMOS: Sri Lanka.

Dewar, G Halket, D. Hart, T and Orton J and Sealy J. 2006 Implications of a mass Springbok kill site (Antidorcas marsupialis), South Africa. Journal of Archaeological Science.

Elphick, R.H. 1977. Kraal and castle. Khoikhoi and the founding of white South Africa. New Haven: Yale University Press.

Raper, P.E. & Boucher, M. eds. 1988. Robert Jacob Gordon-Cape Travels, 1777 to 1786. Vol2. Brenthurst Press: Houghton.

Halkett, D. & Hart, T. 1993. Excavations at six archaeological sites in the near shore diamond mining area, Brand se Baai, Namaqualand. Unpublished CRM report prepared for De Beers Namaqualand Mines Division.

Halkett, D. & Hart, T. 1994. Report on phase 2 archaeological excavations at the Namakwa Sands project, Vredendal district, Namaqualand. Unpublished CRM report prepared for Namakwa Sands Ltd.

Huffman, T.N and Sievers, C. 1996. Cultural resource management on South African Mines. Unpublished report prepared for the Department of Environment Affairs and Tourism

Jerardino, A.M., Yates, R., Morris, A.G. and Sealy, J. 1992. A dated human burial from the Namaqualand coast: observation on culture, biology and diet. *South African Archaeological Bulletin* 47: 75-82.

Kaplan, J. 1993. The state of archaeological information in the coastal zone from the Orange River to Punta Do Oura. Unpublished report prepared for the Department of Environment Affairs and Tourism

Klein, R.G. 1989. The human career. University of Chicago Press: Chicago & London.

Orton, J. Hart, T. Halkett, D. 2005. Shell middens in Namaqualand: two later Stone Age sites at Rooiwalbaai, Northern Cape Province, South Africa. South African Archaeological Bulletin. Volume 60 No 181

Klein RG, Cruz-Uribe K, Halkett D, Hart T, Parkington JE. Palaeoenvironmental and human behavioural implications of the Boegoeberg 1 late Pleistocene hyena den, Northern Cape Province, South Africa. Quat Res. 1999; 52(3):393–403.

Manhire, A.H. 1987. Sandveld deflation hollows: a study of open site assemblages in the south-western Cape. In: Parkington, J.E. & Hall, M. (eds) Papers in the Prehistory of the of the western Cape, South Africa: British Archaeological Reports International Series 332: 326-349.

Morris, A.G. 1995. The Einiqua: an analysis of the Kakamas skeletons. *In* Einiqualand: Studies of the Orange River frontier. UCT Press Rondebosch.

Klein RG, Cruz-Uribe K, Halkett D, Hart T, Parkington JE. Palaeoenvironmental and human behavioural implications of the Boegoeberg 1 late Pleistocene hyena den, Northern Cape Province, South Africa. Quat Res. 1999; 52(3):393–403.

Manhire, A.H. 1987. Sandveld deflation hollows: a study of open site assemblages in the south-western Cape. In: Parkington, J.E. & Hall, M. (Eds) Papers in the Prehistory of the of the western Cape, South Africa: British Archaeological Reports International Series 332: 326-349.

Morris, A.G. 1995. The Einiqua: an analysis of the Kakamas skeletons. *In* Einiqualand: Studies of the Orange River frontier. UCT Press Rondebosch

Parkington and Hart 1991. An assessment of the archaeological sensitivity of Tweepad, Brazil and Skulpfontein, Kleinzee. Report prepared for The Environmental Evaluation Unit, UCT.

Parkington, J.E., Jerardino, C., Yates, R., Halkett, D., Hart, T. & Kaplan, J. in prep. Mid -Holocene deposits at Doorspring 16.

Parkington, J.E., Yates, R., Manhire, A. & Halkett, D. 1986. The social impact of pastoralism in the south Western Cape. *Journal of Anthropological Archaeology* 5: 313-329

Pistorius, P. 1996. In: Deacon, J. ed. (1996) Monuments and Sites in South Africa. ICOMOS Central Cultural Fund Publication No. 206:1-8. National Committee of ICOMOS: Sri Lanka.

Raven-Hart, R. 1967. Before Van Riebeeck. Cape Town: Struik.

Rudner, J. 1968. Strandloper pottery from South and South West Africa. Annals of the South African Museum 49: 441-663

Sampson, C.G. 1974. Stone age archaeology of southern Africa. New York Academic Press

Sealy, J. & Yates, R. 1994. The chronology of the introduction of pastoralism to the Cape, South Africa. Antiquity 68: 58-67

Smith, A.B. 1985. Excavations at Plettenberg Bay, South Africa of the campsite of the survivors of the wreck of the *Sao Gancalo* 1630. *International Journal of Nautical Archaeology and Underwater Exploration* 15.1: 53-63

Smith, A.B. 1987. Seasonal exploitation of resources on the Vredenberg Peninsula after 2000BP. in Parkington, J.E. and Hall, M.J. (Eds) Oxford: BAR International series 332 (ii).

Smith, A.B., Sadr, K., Gribble, J., & Yates, R. 1991. Excavations in the south-western Cape, South Africa, and the archaeological identity of prehistoric hunter-gatherers in the last 2000 years. South African Archaeological Bulletin 46: 71-91

Webley, L. 1992. Early evidence for sheep from Spoeg River Cave, Namaqualand. *Southern African Field Archaeology* 1: 3-13
Yates, R. in prep. Ostrich eggshell beads and the appearance of pastoralism: a study of size changes in the southern and south-western Cape, and Namibia. M.A. thesis: University of Cape Town.

Parkington and Hart 1991. An assessment of the archaeological sensitivity of Tweepad, Brazil and Skulpfontein, Kleinzee. Report prepared for The Environmental Evaluation Unit, UCT.

Parkington, J.E., Jerardino, C., Yates, R., Halkett, D., Hart, T. & Kaplan, J. in prep. Mid -Holocene deposits at Doorspring 16.

Parkington, J.E., Yates, R., Manhire, A. & Halkett, D. 1986. The social impact of pastoralism in the south Western Cape. *Journal of Anthropological Archaeology* 5: 313-329

Pistorius, P. 1996. in: Deacon, J. ed. (1996) Monuments and Sites in South Africa. ICOMOS Central Cultural Fund Publication No. 206:1-8. National Committee of ICOMOS: Sri Lanka.

Raven-Hart, R. 1967. Before Van Riebeeck. Cape Town: Struik.

Rudner, J. 1968. Strandloper pottery from South and South West Africa. Annals of the South African Museum 49: 441-663

Sampson, C.G. 1974. Stone age archaeology of southern Africa. New York Academic Press

Sealy, J. & Yates, R. 1994. The chronology of the introduction of pastoralism to the Cape, South Africa. Antiquity 68: 58-67

Smith, A.B. 1985. Excavations at Plettenberg Bay, South Africa of the campsite of the survivors of the wreck of the *Sao Gancalo* 1630. *International Journal of Nautical Archaeology and Underwater Exploration* 15.1: 53-63

Smith, A.B. 1987. Seasonal exploitation of resources on the Vredenberg Peninsula after 2000BP. in Parkington, J.E. and Hall, M.J. (Eds) Oxford: BAR International series 332 (ii).

Smith, A.B., Sadr, K., Gribble, J., & Yates, R. 1991. Excavations in the south-western Cape, South Africa, and the archaeological identity of prehistoric hunter-gatherers in the last 2000 years. South African Archaeological Bulletin 46: 71-91

Webley, L. 1992. Early evidence for sheep from Spoeg River Cave, Namaqualand. *Southern African Field Archaeology* 1: 3-13

Yates, R. in prep. Ostrich eggshell beads and the appearance of pastoralism: a study of size changes in the southern and south-western Cape, and Namibia. M.A. thesis: University of Cape Town.

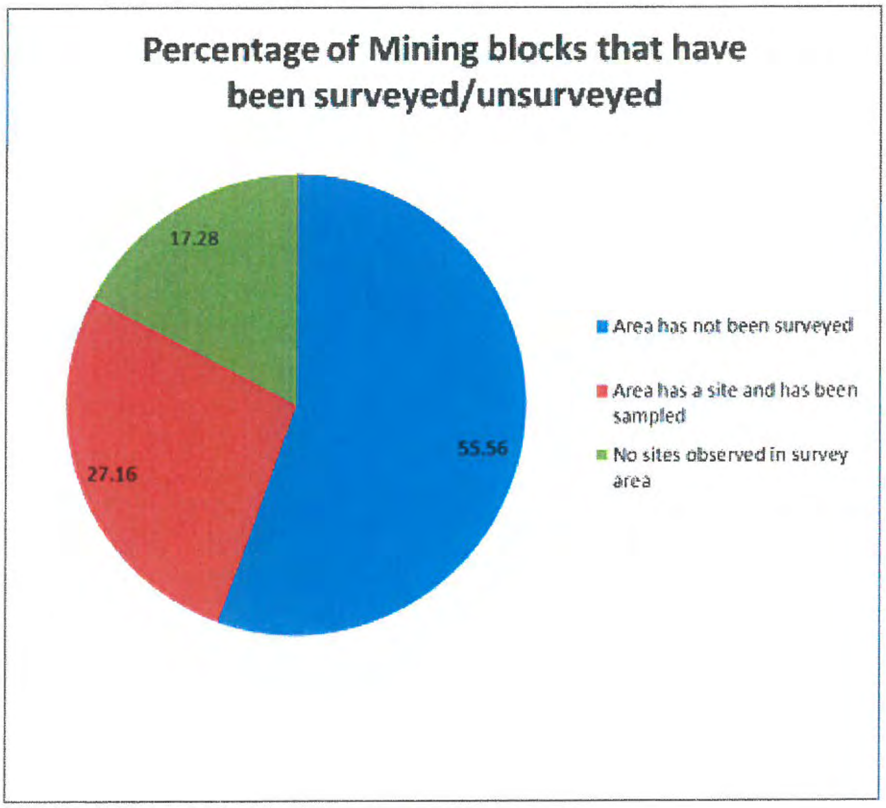
APPENDIX A

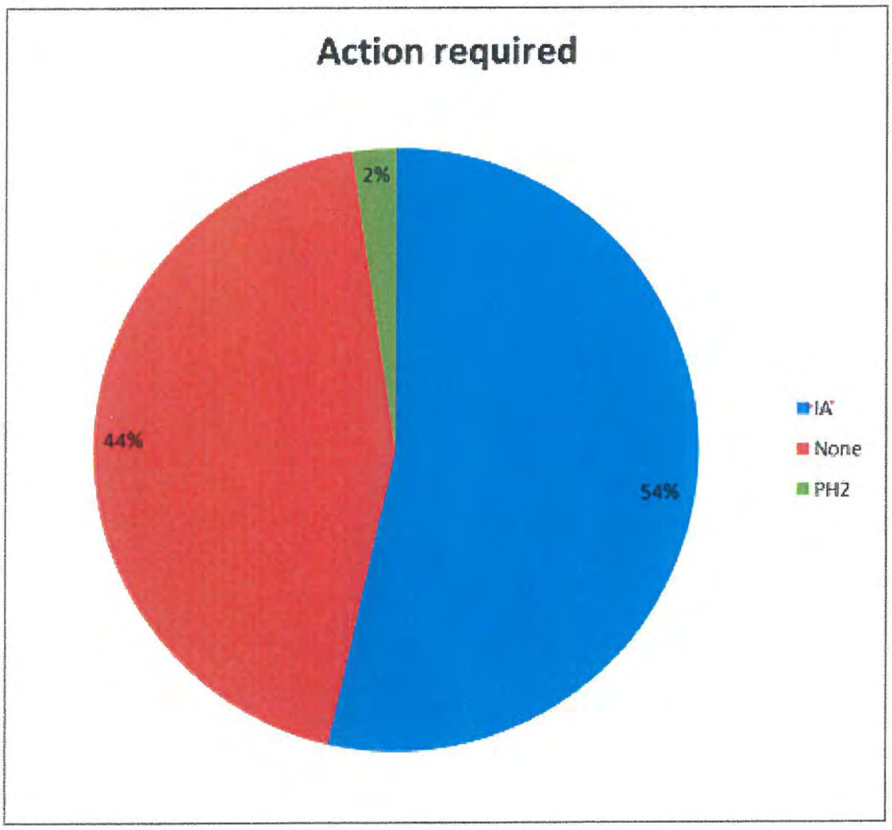
Mining blocks that have been subject to survey (HIA) and mitigation vs those for which no action has been taken.

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

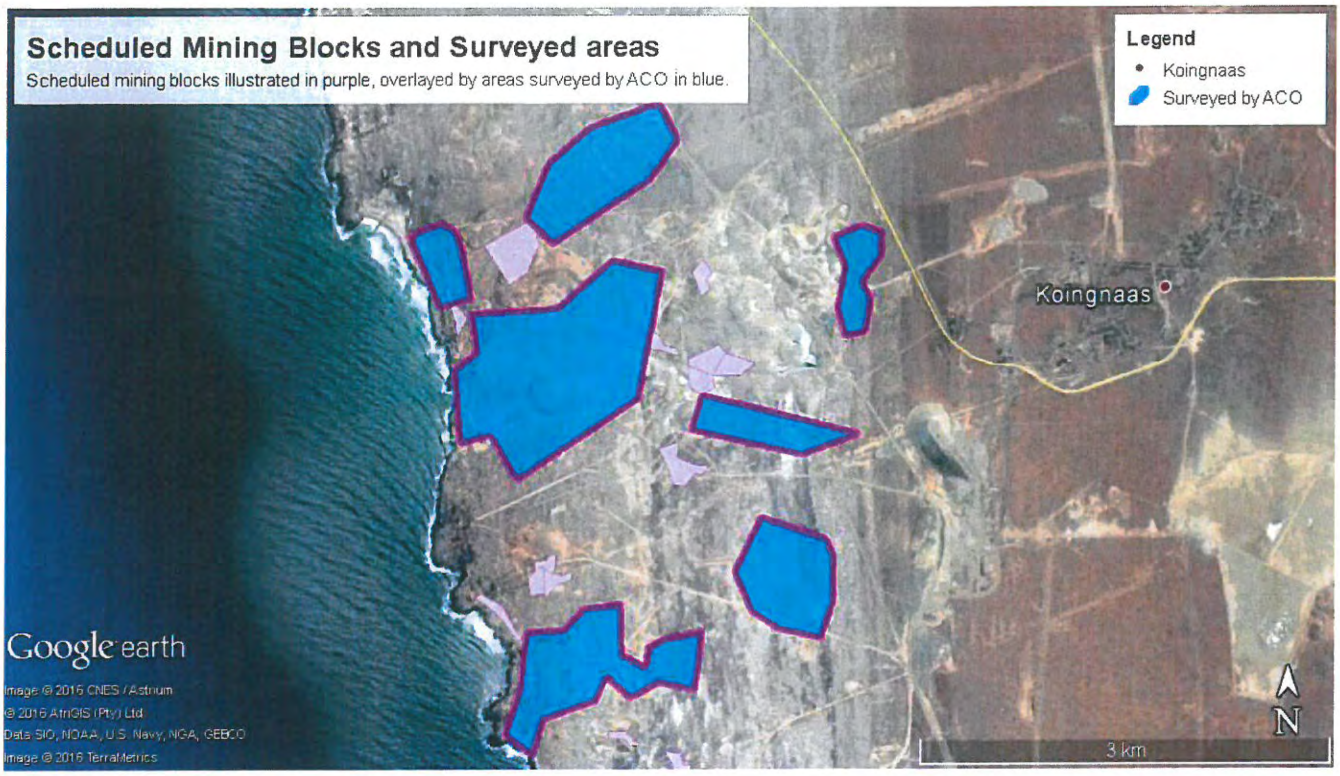


Figure 4 Koingnaas areas - old De Beers blocks already assessed vs new mining areas

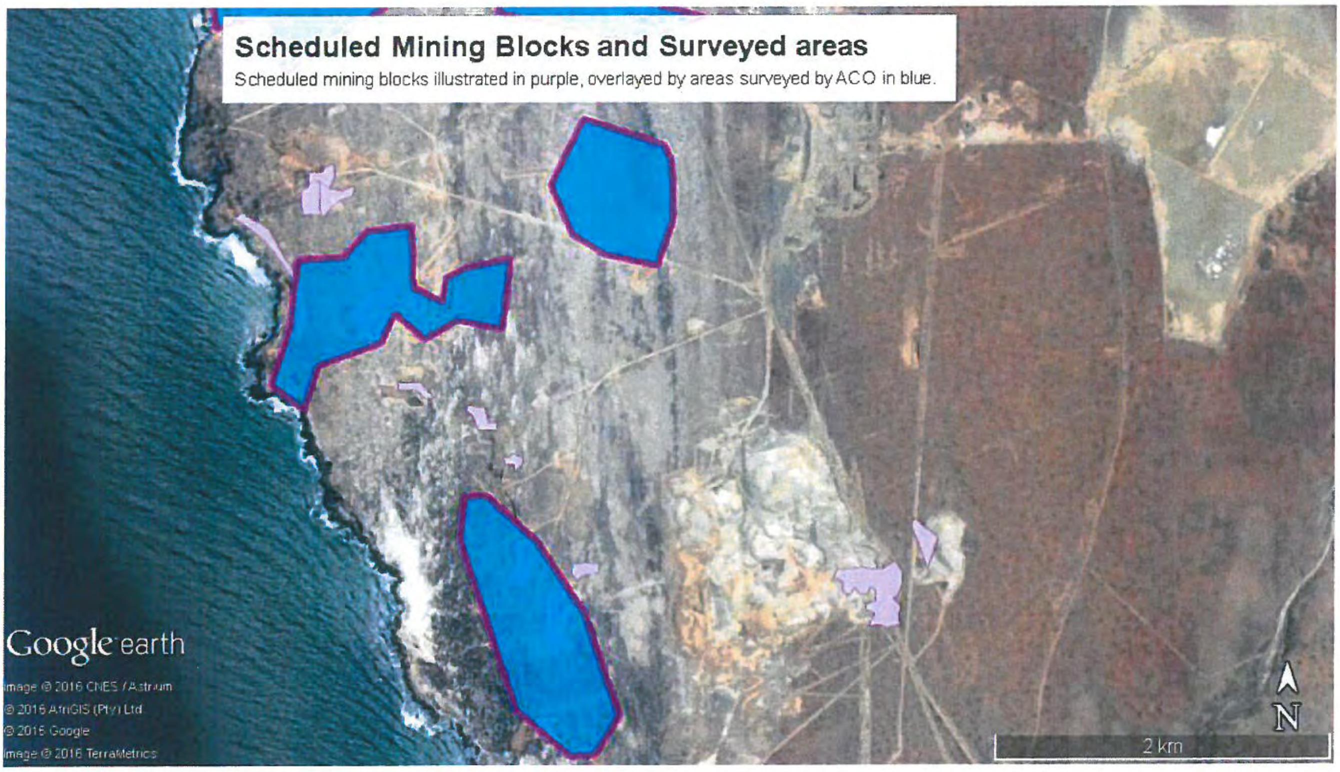


Figure 5 Southern Koingnaas areas - old De Beers blocks already assessed vs new mining areas

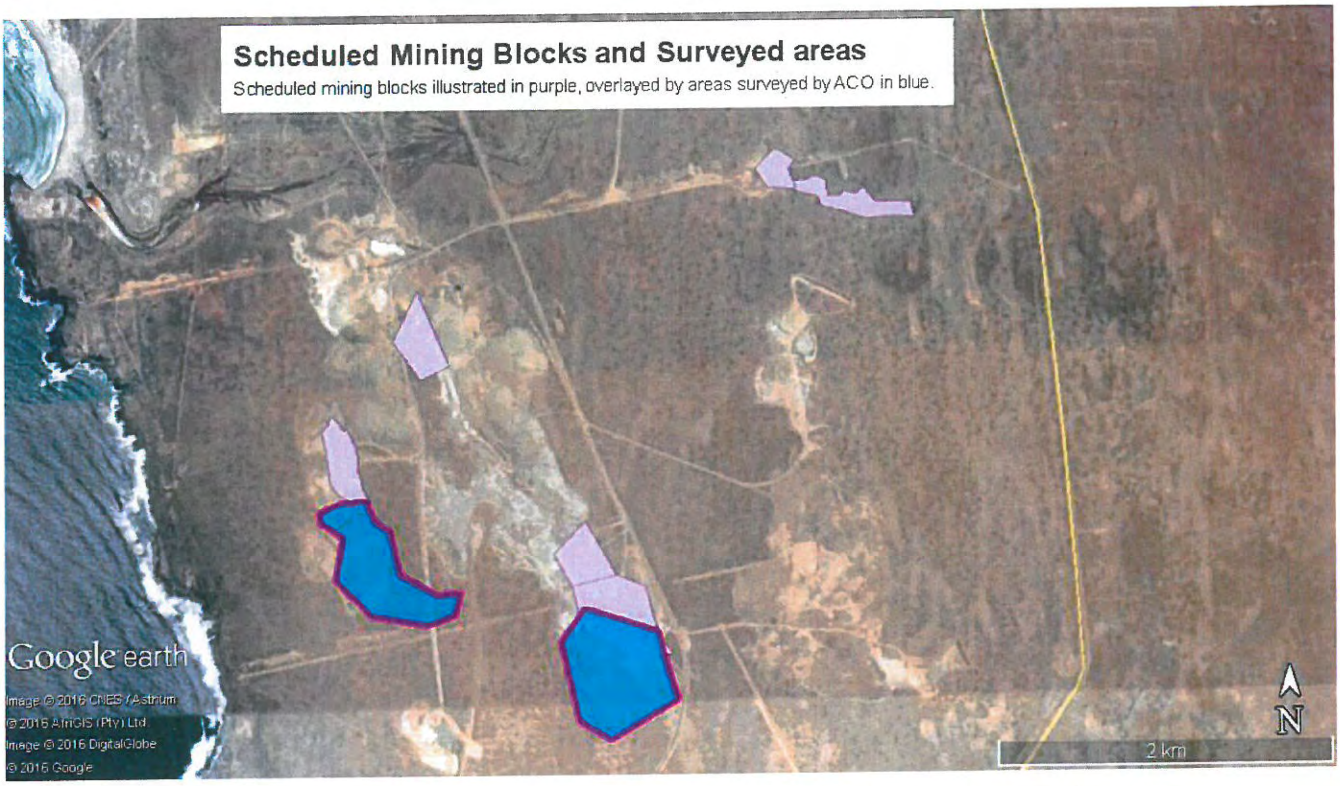


Figure 6 Swartlintjies – Doctor se Baai areas - old De Beers blocks already assessed vs new mining areas

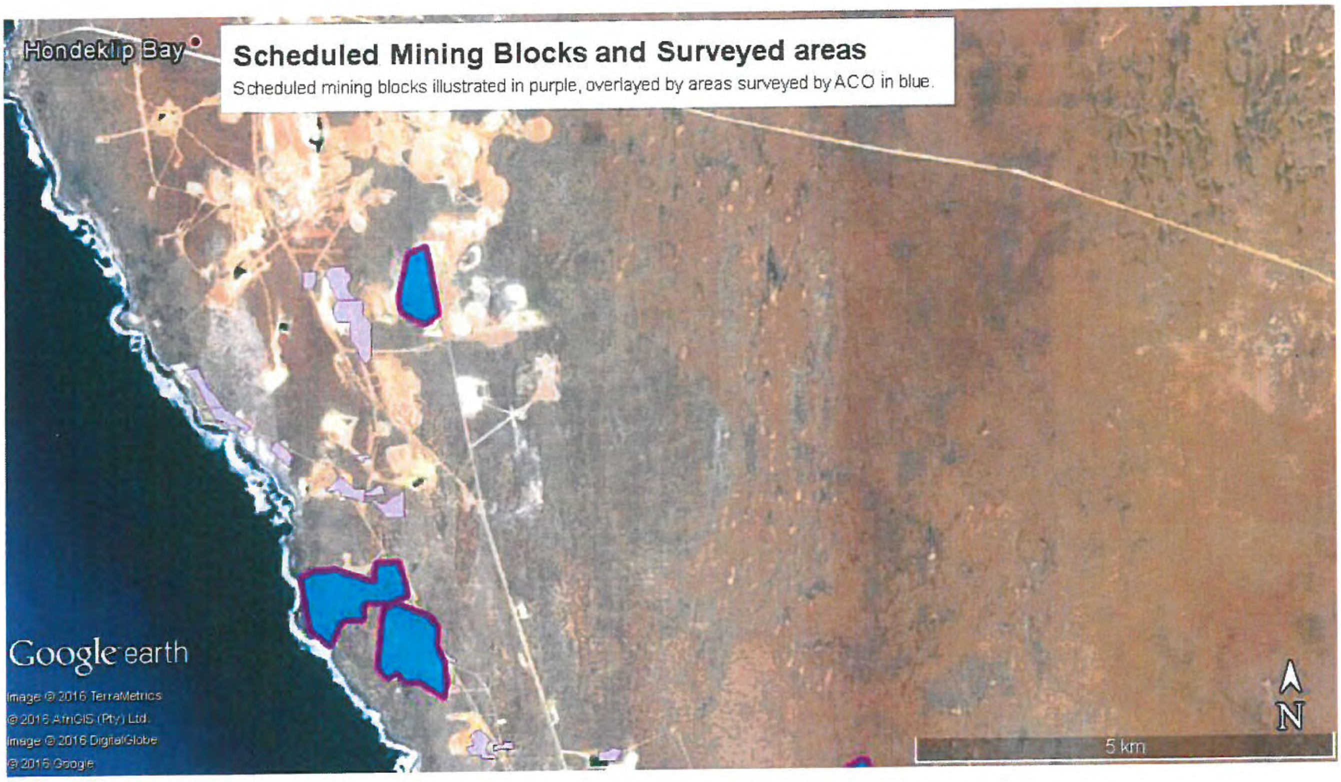


Figure 7 Hondeklipbaai south - old De Beers blocks already assessed vs new mining areas

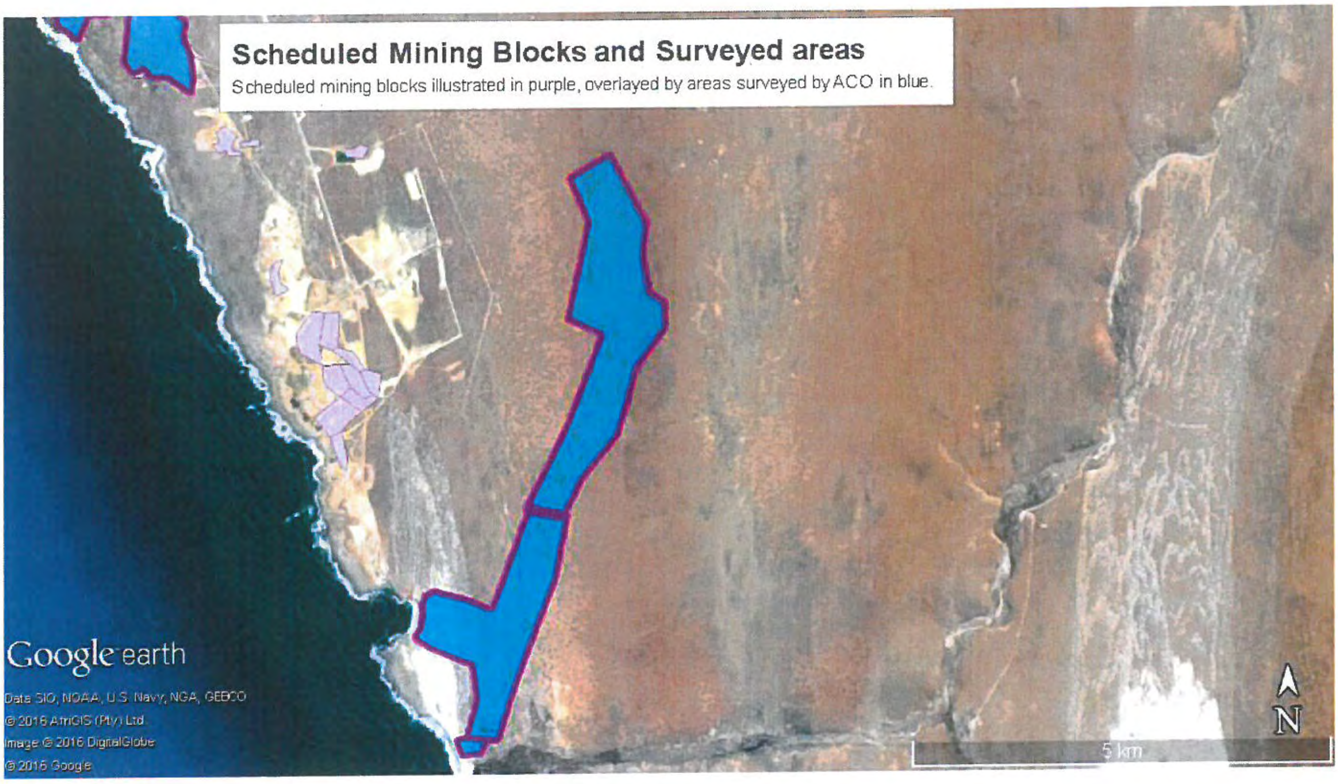


Figure 8 Mitchells Bay - old De Beers blocks already assessed vs new mining areas

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

CONTENTS

ACCOMPANYING SEPARATE DOCUMENTS

Maps 1-4

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

ICS Stratigraphic Chart

****

- ## 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

<u>Primary Palaeontological Mitigation - Current Exposures</u>

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.

<u>Priority Fossil Exposures</u>

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).

<u>Contingent Archaeological Mitigation</u>

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.

Additional Type Sections/GeoHeritage sites should be designated amongst the exposures at Alexcor, but Alexcor is yet to begin compliance with the National Heritage Resources Act. The exposures at Buffelsbank also require evaluation.

- **Additional Aspects of Geohistorical Note**

Evidence of Neotectonic Activity

An exposure showing faulting of the bedrock extending into the overlying Pliocene marine deposits has been seen previously (Langklip, Waypoint 50) and several exposures exhibit soft-sediment deformation features caused by earthquakes. This evidence of neotectonics or geologically-recent (Quaternary) faulting is very rare on the coastal plain. It is of considerable interest, for instance, in the site selection of nuclear power stations. The writer has been requested to propose such exposures for preservation (CGS).

Places of interest for the History of Mining

A good example is the early workings just to the south of Kleinzee. Additional sites could include "The Crater" and other areas of early workings. Kleinzee/DBNM historians should be consulted here. Similarly, sites should be designated amongst the exposures at Alexcor (Oyster Line?).

Natural Exposures

Here the issue is not preservation of pit exposures, but eventual facilitation of access for inclusion in a GeoTourism itinerary. For instance, occasional outcrops of poorly-represented formations occur, such as aeolian and fluvial quartzite sandstones on the flanks of drainages (e.g. Swartlintjies River at Waypoint 53). Such occurrences represent a largely-unknown period of geological history post-dating the 90 m Package. Other examples may be known of as a result of DBNM exploration of the area.

In this category may also be features of the Precambrian bedrock stratigraphy that could be included in a Geohistorical route itinerary. Suggestions to be sought from relevant "hard-rock" researchers.

- **Palaeontological Monitoring**

It is suggested that a degree of monitoring be carried out during the making of excavations in the future.

At this stage it is perhaps premature to propose monitoring strategies in any detail. It is proposed that feasible and cost-effective strategies be discussed in the near future.

Next Steps

Discussion of this report, clarifications where required.

Drafting of the Terms of Reference for the palaeontological mitigation project.

Very Important Point

It is vital that it is understood by the depts. of Minerals and Energy, Environmental Affairs & Tourism, Arts & Culture and environmental lobbies that the process of full consultation with all the I&APs w.r.t. the filling or preservation of exposures still has to be carried out.

The backfilling of each exposure should be carefully considered first in terms of scientific and heritage value.

Some Interested and Affected Parties

- South African Heritage Resources Authority.
- Iziko South African Museum.
- Council for Geoscience.
- Geological Society of South Africa.
- South African Commission for Stratigraphy.
- Namaqualand communities and local government.
- Sustainable development NGOs.
- Namaqualand tourism I&APs.

****

• ABBREVIATIONS

ASL. above (mean) sea level.

BMC Buffels Marine Complex. Marine deposits on wave-cut terraces north of Kleinzee, extending towards Port Nolloth. Terraces are formed on somewhat schistoze quartz arenites of the Stinkfontein Subgroup and extend to ~100 m ASL. Older palaeochannels occur.

BIC Buffels Inland Complex. Fluvial deposits of various ages preserved locally along the flanks of the Buffels Rivier.

BP Before Present. (Before AD 1950).

bsl. Below (mean) sea level.

DBNM De Beers Namaqualand Mines.

EIA Environmental Impact Assessment.

EMP Environmental Management Plan.

ESA Early Stone Age.

Fm. Formation.

HIA Heritage Impact Assessment.

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

KC Koingnaas Complex. Marine deposits between the Hondeklipbaai area and Kleinzee, locally underlain by palaeochannels incised into the basement gneisses, with "Channel Clay" and quartz conglomerates.

k.y. Thousand years. Used for duration only *e.g.* the duration of the LIG was 10 k.y.

LGM Last Glacial Maximum. Interval of maximum "Ice Age" ice volumes ~30 to 19 ka.

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

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

MIS Marine Isotope Stage. Numbered stages of the marine oxygen-isotope record ($\delta^{18}O$) - see Figure 5.

MSA Middle Stone Age.

ODP Ocean Drilling Project.

PIA Palaeontological Impact Assessment.

RET Recent Emergence Terraces (Quaternary raised beaches).

SAHRA South African Heritage Resources Authority.

SST Sea-surface temperature.

m.y. Million years. Used for duration only *e.g.* the duration of the Eocene Epoch was ~22 m.y.

w.r.t. with respect to.

****

• 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.

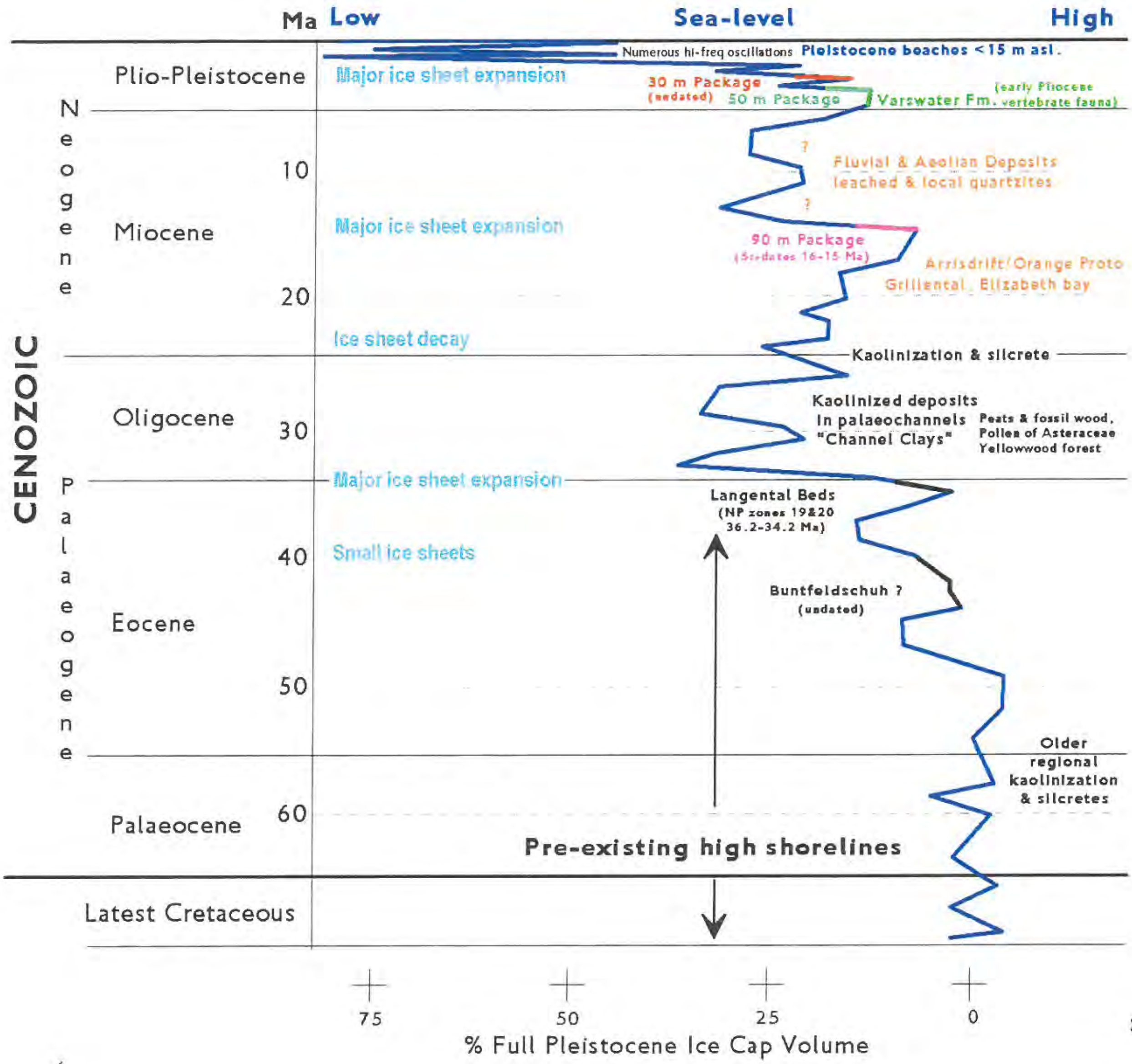
- **Typical Mitigation Process**

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.

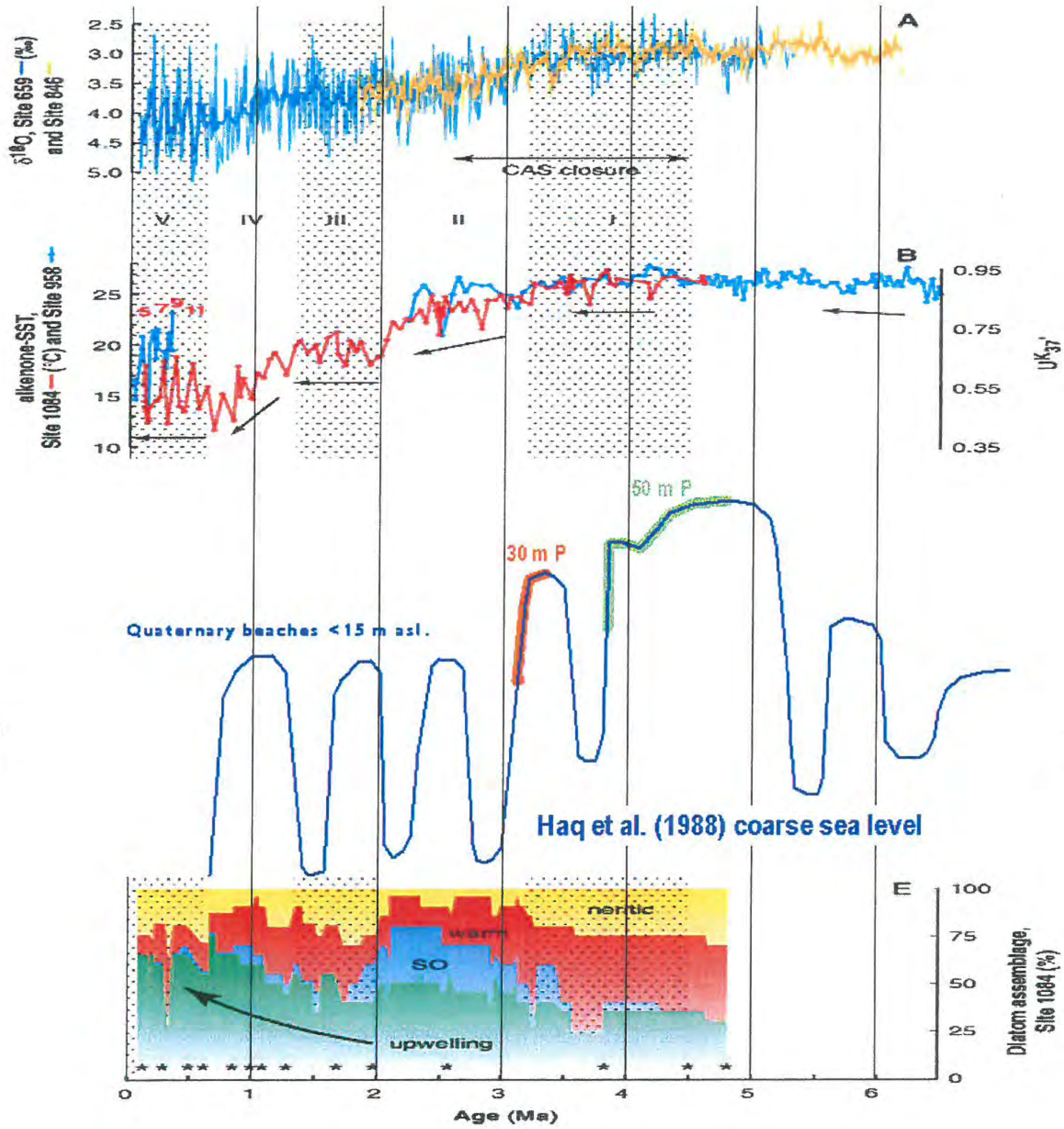
• 2.3 Neogene Marine Deposits

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.



• I 1988), Haq *et al.*, 000).

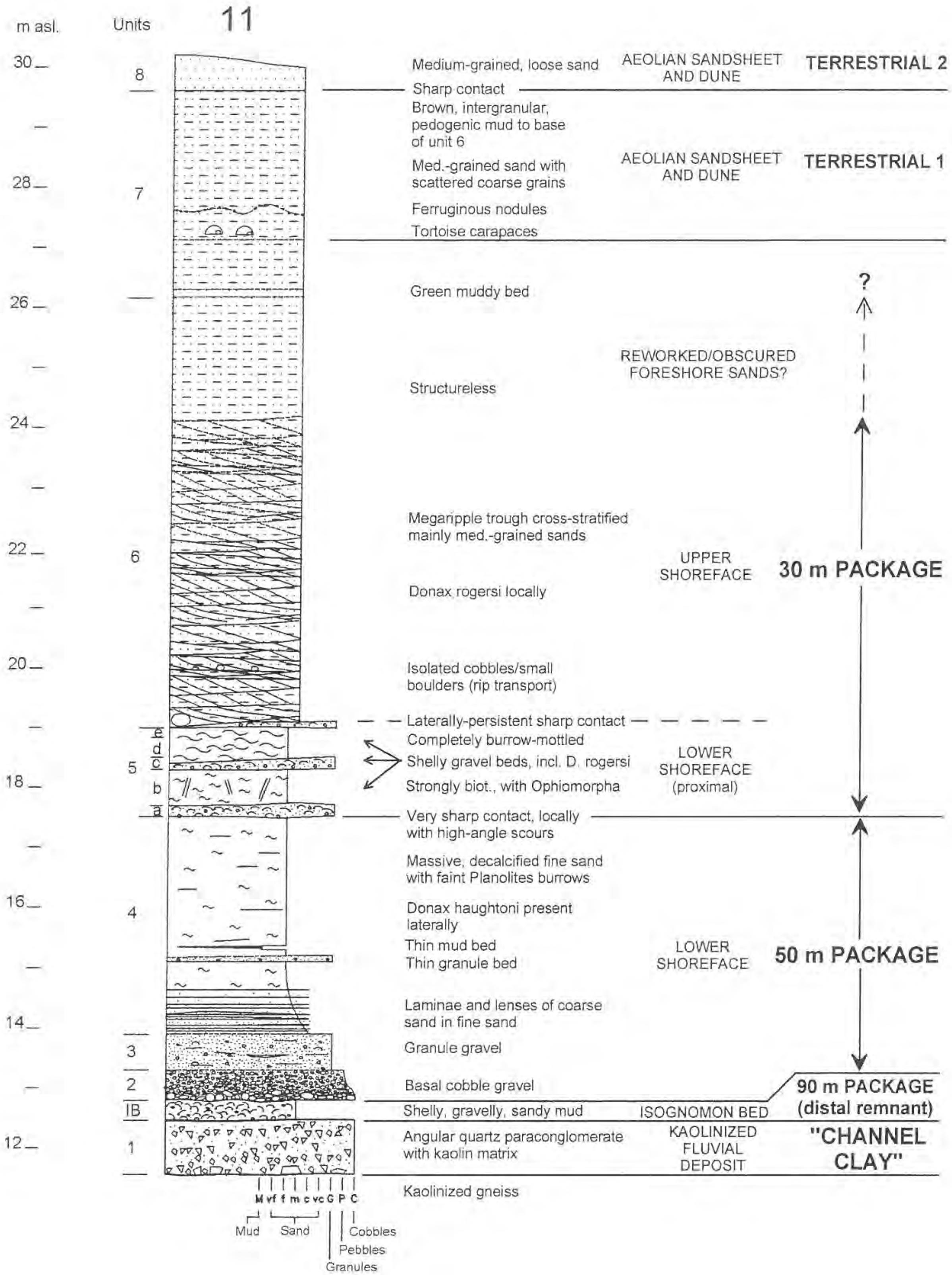
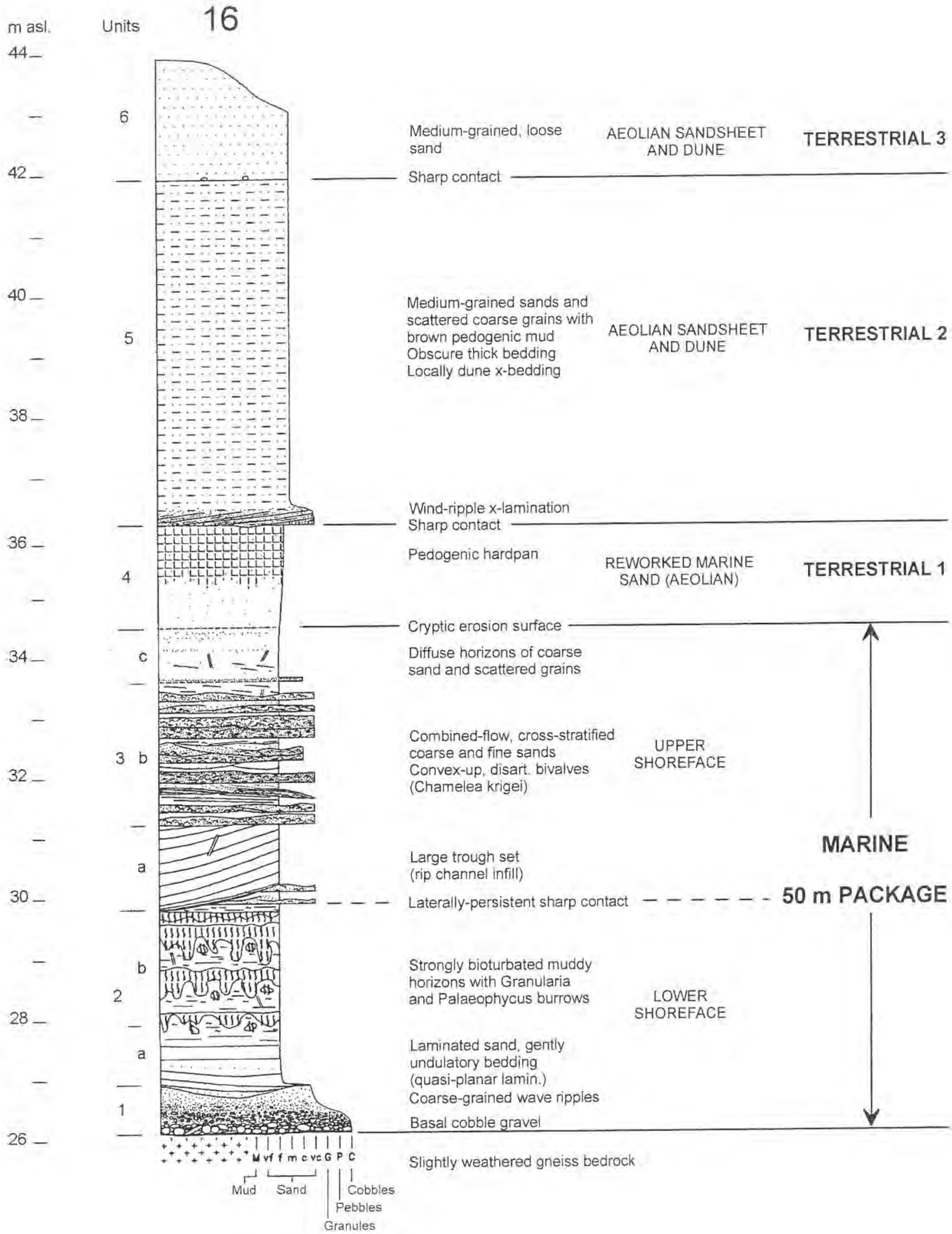


Figure 3: Graphic section of 50 m Package, Avontuur Section 16.

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.

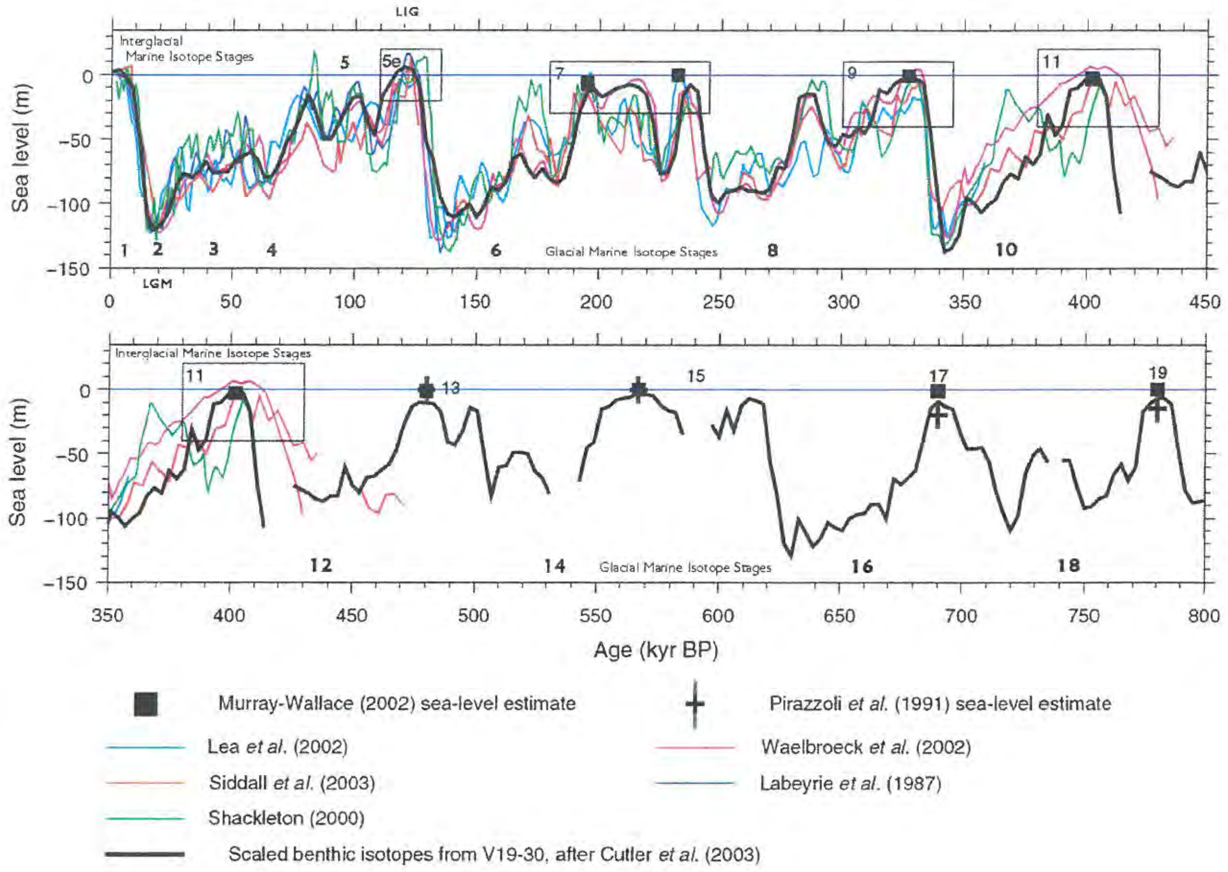
The 30 m Package upper shoreface is typically dominated by thick megaripple troughsets, whereas trough-lag amalgamation typifies the 50 m Package upper shoreface. There are more coarse-grained beds in the proximal lower shoreface of the 30 m Package, as thin gravelly units entirely reworked after deposition 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).

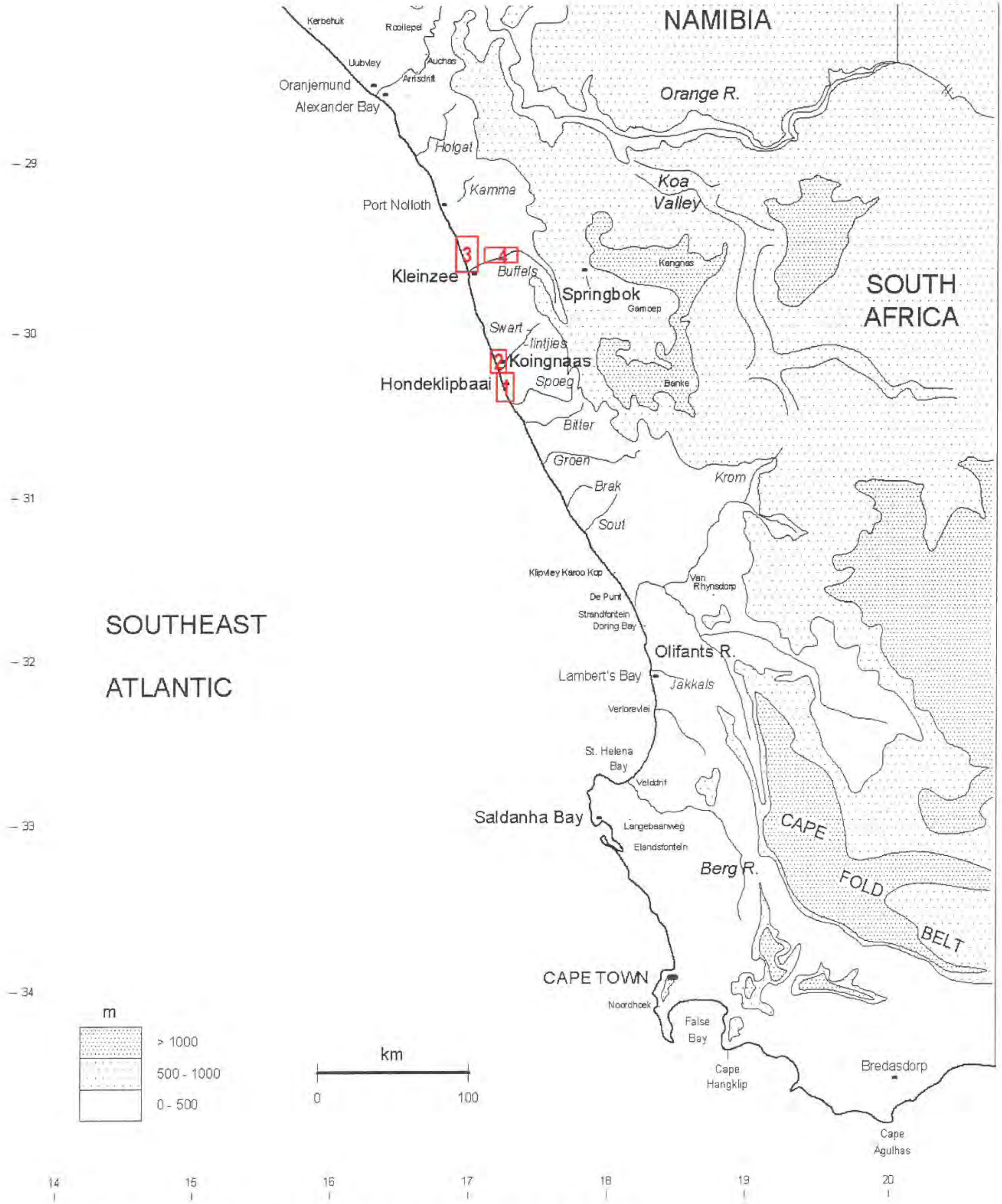
Seismic reflection data from the margins of Antarctica show a major change in sedimentary geometry and processes since ~3 Ma, explained by the transition of the Antarctic ice sheet regime from polythermal to the present (Quaternary) polar cold, dry-based conditions during late Pliocene global cooling (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).



- **Figure 6. West Coast localities and positions of Maps 1-4.**

Significant diamond reserves in the marine gravels south of the Orange River became apparent by 1927 and these early prospects were examined by Wagner & Merensky (1928), Reuning (1931) and Haughton (1932). The profusion of fossil oysters in the deposits led to the popular perception of an "Oyster Line" associated with diamonds and the realization that sea temperatures along the west coast were once significantly warmer than at present.

In an appendix to Wagner & Merensky (1928), Haughton described the fossils they collected (Haughton, 1928). Wagner & Merensky (1928) recognized that "surface quartzites" or silcretes are the oldest stratigraphic unit on the Namaqualand coastal plain. On the basis of the molluscan fossils, Haughton (1928) recognized that the raised beaches are late Tertiary (Mio-Pliocene) to Pleistocene in age and identified three biostratigraphic units: the "Ostrea Bed" or "Oyster Line," the "Operculum Bed" and the "Lowest terrace".

The oysters in the "Ostrea Bed," now identified as the living east coast species (*Crassostrea margaritacea*), but then called *Ostrea prismatica*, indicated sea temperatures higher than those now occurring on the west coast. Extinct species (e.g. *Donax rogersi*, *Chamelea krigei*) implied a Mio-Pliocene age (Haughton, 1928). In hindsight, the "Ostrea Bed" or "Oyster Line" probably involved exposures of both 50 and 30 m Package basal gravels. The "Operculum Bed" was regarded as an intermediate unit between the "Ostrea Bed" and "Lowest terrace". This abundance of operculae is usually found in 30 m Package deposits. The "Lowest terrace" (= Quaternary Packages) enclosed an extant fauna and a younger, Pleistocene age with sea temperatures similar to the present was implied.

Haughton (1932) made observations from Bogenfels, Namibia, to Saldanha Bay. From his further collecting of fossils, he refined his initial biostratigraphy for west-coast deposits, erecting five faunal zones, from "Zone E" (oldest) to "Zone A" (youngest with extant fauna) (Haughton, 1932). Instead of being entirely superseded, Haughton's early biostratigraphic zonations (1928, 1932) are explained and enlarged upon from observations at Hondeklipbaai (Pether, 1994b).

Hallam (1964) wrote an account, wide-ranging in areal coverage (from northern Namibia to Kleinzee) and subject matter, of the west coast, its raised beach deposits and its diamonds. As a synthesis of west coast economic geology of the 1950s, after a period during which little published information was forthcoming, this remains a useful resource.

The growth of data during the 1970s prompted a number of syntheses emphasizing Cenozoic palaeoclimates, biogeography and sea-level history (Tankard & Rogers, 1978; Siesser & Dingle, 1981; Hendey, 1983a, 1983b, 1983c; Dingle *et al.*, 1983), wherein which the coastal-plain history of Namaqualand, as then understood, was discussed.

In a recent summary (Coastal Cenozoic Deposits, Roberts *et al.*, 2006), alternative names conventionally based on "type areas" were proposed for the 90, 50 and 30 m Packages and the combined Quaternary raised beaches (Table 1), but at the rank of members of an overarching Alexander Bay Formation. It is the writer's opinion (Sect. 2.3) that these packages, of disparate ages and faunal contents, are of formation rank.

• 5.2 State Alluvial Diggings (Alexkor)

De Villiers & Söhnge (1959) provided a valuable description of the marine terraces and deposits of the State Alluvial Diggings (Alexander Bay to Port Nolloth, Fig. 2), as seen in 1944. The significance of their observations on sedimentary geometry in relation to cliffed bedrock is contextualized by observations from Hondeklipbaai.

Keyser (1972) provided the most detailed, extant description of the terraces in the State Alluvial Diggings (SAD) area (Alexander Bay to Port Nolloth). Marine deposits are present to high elevations and four terraces were recognized. In order of descending elevation, these are the Grobler Terrace (64-84 m asl.), SAD Upper (34-47 m asl.), SAD Middle (17-26 m asl.) and SAD Lower (0-9 m asl.). The three higher terraces rise gently in elevation to the south. These marine deposits have been named the Alexander Bay Formation (Kent and Davies, 1980).

Gresse (1988) has described sections and listed fauna from the terrace deposits, suggesting correlations with the Hondeklip sequence. Subsequently, (Hill, in Rogers *et al.*, 1990), the altimetric definitions of the terrace elevations have been altered: 75-90 m ASL. (Grobler), 30-60 m ASL. (SAD Upper), 15-30 m ASL. (SAD Middle) and 0-15 m ASL. (SAD Lower) (Table 1). Extinct taxa occur in the older, higher terraces, whereas the SAD Lower Terrace deposits enclose extant molluscan fauna.

Importantly, De Villiers & Söhnge (1959) showed that the bedrock topography, with its terraces and cliffs, predates the marine deposits that overlie these geomorphic, erosional features. The 50 m Package overlies the Upper Terrace (30-60 m asl.), but it extends seawards over the cliff onto the Middle Terrace, where it is truncated and overlain by the 30 m Package. This emphasizes that the record of bedrock terraces is separate from the depositional record of covering marine sands and gravels.

• 5.3 Kleinzee (Buffels Marine Complex)

Elevations of platforms, stormbeach ridges and cliffs in the Kleinzee area were provided by Hallam (1964) and Davies (1973). The sequence of terraces currently recognized is provided by Molyneux (in Rogers *et al.*, 1990). Notably, although the terrace nomenclature at Kleinzee also employs Upper, Middle and Lower appellations, the terraces to which these apply are at elevations different from those at the State Alluvial Diggings (Table 1).

The Kleinzee Upper Terrace at 75-95 m ASL. (corresponding altimetrically with the SAD Grobler Terrace) terminates landward in a marked cliff cut into silcrete-capped hills. The Kleinzee Middle Terrace (≈SAD Upper) is at 30-65 m ASL. and is subdivided into upper and lower parts. The Kleinzee Upper Middle Terrace (K-UMT) terminates landward in another well-developed cliff at 65 m asl., whilst a break in bedrock gradient at ~45 m asl. generally marks the boundary between the K-UMT and Kleinzee Lower Middle Terrace (K-LMT). The 65 m ASL. cliff is considered to have been produced at a transgressive maximum, whilst the K-LMT represents a stillstand at

~45 m asl. during the subsequent regression. This stillstand was succeeded by renewed transgression that overlapped the seaward edge of the K-UMT sediments (Molyneux, in Rogers *et al.*, 1990).

The separation of the K-LMT and the Kleinzee Lower Terrace (≈SAD Middle) is not clearly defined by bedrock topography, but an extent between 10-30 m ASL. is indicated and is supported by inflexions of bedrock gradient at ~30 m asl. in some profiles (Molyneux, in Rogers *et al.*, 1990). Late Quaternary beach deposits occur below ~10 m ASL. and three units at ~8, ~5 and ~2 m asl. are recognized (≈SAD Lower) and enclose an extant, cold-water fauna.

As mentioned, an interesting development was the discovery by drilling of a deep depression north of Kleinzee (on Karreedoornvlei) that is infilled with carbonaceous, fluvial sediments, dated palynologically as Lower Cretaceous (Molyneux, in Rogers *et al.*, 1990).

- TABLE 1

Depositional Record - Coastal progradation during sea-level falls.			
Koingnaas/Hondeklipbaai		Alexander Bay Group[3]	Age
C & K, 1969[1]	Current[2]		
~2 m T.C. ~5 m T.C. 7-8 m T.C.	2-3 m Package. 4-6 m Package. 8-12 m Package.	Curlew Strand Fm. (Strandfontein), equiv. to Velddrif Fm.	Quaternary <2.6 Ma.
17-21 m T.C. 29-34 m Beach.	30 m Package.	Hondeklip Fm.	Middle Pliocene >3 Ma.
45-50 m T.C. Phosphatic siltstones.	50 m Package. (includes shelf phosphorite)	Avontuur Fm.	Early Pliocene 4-5 Ma.
75-90 m T.C.	90 m Package.	Kleinzee Fm.	Middle Miocene 15-16 Ma.

Terrace Record - Erosion mainly during sea-level rises.		
Alexkor (SAD)[4]	Kleinzee[5]	Overlying Deposits
SAD Lower 0-15 m asl.	Recent Emergence Terraces (RETs) <10 m asl.	
SAD Middle 15-30 m asl.	Lower Terrace Local slopebreaks at ~30 m asl.	Trangressed by 30 m P Overlain by 50 m P Patches of 90 m P
SAD Upper 30-60 m asl.	L. Middle Terrace 30-45 m asl. U. Middle Terrace 45-65 masl.	Trangressed by 50 m P. Partly overlain by 90 m P.
Grobler Terrace 75-90 m asl.	Upper Terrace 75-95 m asl.	90 m Package.

1. Carrington and Kensley, 1969. T.C. - "Transgression Complex".
2. Pether, current. Approximate highstand maxima, with regressive, prograded deposits extending seawards.
3. Roberts *et al.*, 2006 (modified to formation rank).
4. Hill, in Rogers *et al.*, 1990.
5. Molyneux, in Rogers *et al.*, 1990.

5.4 HONDEKLIPBAAI AREA (KOINGNAAS COMPLEX)

Little information was forthcoming from the Hondeklip area of central coastal Namaqualand until Tankard (1966) described aspects of the succession revealed by prospecting. At that stage, the sequence was seen in terms of the preliminary biostratigraphy erected by Haughton (1932) (Zones E to A). Significantly, Tankard (1966) reported the presence of channel-infilling, kaolinitic, non-marine sediments overlying kaolinized gneiss (the "Channel Clays"). The occurrence of abundant phosphatic nodules was observed. Tankard encountered difficulties in the application of Haughton's (1932) biostratigraphic zones to the more extensive prospecting exposures he saw (*i.e.* the "megatrenches").

An important advance for the stratigraphy of Namaqualand coastal deposits was Carrington & Kensley's (1969) article describing new molluscan fossils from the central Namaqualand area in which a summary stratigraphic column was presented. Channel-infilling, unfossiliferous, fluviatile clays and clayey sands, considered Mio-Pliocene in age, were recognized as the oldest unit, which was succeeded by remnants of phosphatic beds with abundant shell moulds, considered Pliocene in age.

In contrast to the earlier suggestions of a Mio-Pliocene age for the higher elevation coastal-plain deposits (Wagner & Merensky, 1928; Haughton, 1932), Carrington & Kensley (1969) considered the bulk of the succession to be of

Pleistocene age. They identified "transgression complexes" at 75-90, 45-50, 17-21, 7-8, ~5 and ~2 m ASL. and a 29-34 m Beach. Importantly, they found that the bivalve *Donax rogersi* Haughton, 1926, actually subsumed two species; the thick-shelled, robust *D. rogersi* "proper" and a thin-shelled, generally smaller species (thought by Haughton to be juveniles), which they named *Donax haughtoni*. The latter species occurred only in the fine-grained, usually laminated, sands of the "45-50 m complex," whilst *D. rogersi* occurred only in the coarse, usually cross-bedded, sediments of the younger "17-21 m complex". This finding constituted a major advance in the biostratigraphic subdivision of the older coastal-plain marine deposits. Additionally, species obtained from the "45-50 m complex" suggested a fauna of warm-water affinity.

Further notes on the deposits of central Namaqualand were provided by Davies (1973) and by Tankard (1975a, 1975b). Tankard (1975a) differed from Carrington & Kensley (1969) in regarding the phosphatic beds in the Hondeklip area as older than the "channel clays". However, Carrington & Kensley (1969) were correct and the "channel clays" are older than the phosphatic beds. Tankard provided some information on the phosphatic beds that infill hollows in the bedrock and which had come to be known as "E stage," from Haughton's oldest biostratigraphic unit, "E Zone". Tankard (1975a, 1975b) proposed correlations of lower, middle and upper "E stage" sub-units with the succession in the Varswater Quarry near Langebaanweg. Kent & Davies (1980) informally named the coastal-plain deposits between the Olifants River and Kleinzee the "Hondeklipbaai sandy gravels".

Pether (1986) provided a summary of the main findings of his research on the succession at Hondeklipbaai, including suggested correlations farther afield. More intensive faunal sampling carried out during this study led to considerable additions to the marine molluscan fauna of Namaqualand coastal deposits (Kensley & Pether, 1986). The first extinct Tertiary barnacle recorded from South Africa was described from Hondeklip by Pether (1990). Brunton & Hiller (1990) have described the fossil brachiopods collected by the writer in the Hondeklip study area. Pether (1994b) provided detail on the exposures and palaeontology at Hondeklipbaai.

• 5.5 BUFFELS RIVIER DEPOSITS (BUFFELS INLAND COMPLEX)

Published information on the exploited Buffels river terraces and deposits, and other prospects on Namaqualand river terraces (e.g. Spoeg, Groen), is minimal.

Keyser (1976) reported that the diamondiferous terrace gravels of Namaqualand river valleys are lithologically distinct and appear to occupy a single terrace within the terrace sequence preserved. The basal layer is the main diamondiferous horizon, is best developed in channels incised into the main level of the terrace, and is a poorly-sorted, massive gravel with clasts of decomposed bedrock (Keyser, 1976). These "white quartz" gravels are patchily preserved in the rivers south of the Buffels River. Overlying sediments are "clean-washed to clayey (kaolinitic), reasonably sorted, and sometimes cross-bedded sands incorporating thin, disjunct, lensiform, very well-rounded ("golfball") and well-sorted quartz and quartzitic pebble gravels".

Molyneux (in Rogers et al., 1990) similarly describes the deposits as consisting of a basal, indurated, oligomictic gravel of sub-angular to sub-rounded vein-quartz clasts. This is only preserved in deeper bedrock depressions; in most instances only remnants are preserved due to reworking.

The basal, poorly sorted, vein-quartz gravels in the terrace depressions may be equivalent to the coastal kaolinized fluvial deposits, or may represent their reworking. Evidence of *in situ* kaolinization or the presence of silcrete clasts might resolve these alternatives. The overlying fluvial terrace deposits with "clean-washed" sands and lenses of very well-rounded, "golfball" gravels are difficult to reconcile with the kaolinitized, angular, basal fluvial conglomerates at the coast and are probably younger. The interpretation of Keyser (1976) is that the "white quartz" terrace gravels have been derived from the kaolinized terrain *i.e.* post-date the regional kaolinization.

Considerable thicknesses of sands and silts overlie the lower gravels, with features such as buried pedogenic profiles, erosion surfaces and channels. Variations in these aspects of this overburden at different localities along the Buffels Rivier suggests deposits of varying ages occur. As is apparently the case with the lower Orange River, the local Namaqualand rivers can be expected to have undergone aggradation within their valleys during transgressions in the mid-Miocene and Pliocene. However, more localized, West Coast palaeoclimates very likely overprinted or partly modified deposits relating to the broader-scale base-level controls, such as the later Miocene and Pliocene record of progressive aridification, likely interspersed with wet or pluvial phases. This makes direct analogies between the lower Orange River record and the Buffels River incautious, especially if detailed fieldwork and some age control is lacking.

The local occurrence of kaolinitic, oligomictic, quartz gravels and kaolinitic weathering profiles on the flanks of the present-day, "oversize" rivers in Namaqualand suggests that later Miocene to Recent fluvial history of the Namaqualand coastal plain involved only modification of the preceding, early to middle Tertiary drainage patterns on the African surface. The progressive aridification since the middle Miocene concentrated drainage modification along fewer channels, resulting in the preservation of ancient palaeochannels in the intervening areas. Many of these evidently still retain Oligocene/early Miocene kaolinized deposits. Some other channels continued as active drainages for longer, with upper fills of later Miocene sands and clays, before finally being covered. In the remaining, present-day drainages, patches of silicified sandstones occur that are evidently remnants of these deposits, both fluvial and aeolian in origin.

6.0 PALAEONTOLOGICAL STATUS AND CONCERNS

Palaeontological endeavours in the De Beers Namaqualand exposures will contribute to addressing the following concerns regarding the scope of sampling of fossil shells and bones in existing scientific collections and the contingent scientific questions. The status w.r.t. botanical fossils are covered under the "Earlier Tertiary Fluvial Deposits" sections.

6.1 INVERTEBRATES

Despite there being a considerable sample of fossil molluscs, brachiopods and barnacles from Namaqualand in the South African Museum collections, it is by no means a thorough collection. The bulk of the collecting has been quite localized, *viz.* from the excavations made at the Transhex mine on the properties Hondeklip and Avontuur (*e.g.* Image 1). The collection is also restricted palaeoenvironmentally *viz.* mainly from shallow-water shoreface facies. These shortcomings are illustrated by the fact that several taxa found by Carrington & Kensley (1969) have not been found again. These are of uncertain location and stratigraphic provenance. By further example, while briefly "passing through" an exposure of lower-shoreface facies of the 50 m Package on Swartlintjies (Feb., 2006), previously unrecorded taxa were readily seen by the writer.

Previous fossil shell sampling undertaken under the auspices of the SA Museum in De Beers excavations has been limited to the occurrences of the more rare facies very locally preserved in bedrock depressions, *viz.* the "E Stage" or "E Zone" deposits. The "E Stage" appellation stems from the perceived correlation with the oldest of Haughton's (1931) biostratigraphic units, "E-Zone", now shown to be problematic (Pether, 1994b). These "E Stage" facies were not well-developed in the Hondeklip mine.

It is now appreciated that the "E-Stage" involved different stratigraphic entities, but broadly similar deeper-water facies (inner shelf), of the 90 and 50 m packages, and possibly also the 30 m Package. The faunas are different because they are from the deeper-water environment. They are also confusing because of the large extent of reworking. These deeper facies are preferentially preserved in the bedrock depressions and this was repeated during each sea-level cycle, with mixing of shelf faunas of differing ages. The shells are poorly preserved due to persistent residence in groundwater pooled in the bedrock depressions.

In the Koingnaas Complex, thin remnants of 90 m Package deposits bearing fossil shells have been preserved in bedrock depressions associated with exhumed palaeochannels at a number of localities. The main area where encountered in the past is within the area of exhumed, confluent palaeochannels that occurs north and south of the boundary between Hondeklip and Langklip (Map 1, general area of Waypoint 50). Here the deeper-water shelf deposits are interbedded, yellow, sandy muds and green clays in patches beneath lower shoreface sands of the 50 m Package. The very fragile shell content has not yet been studied in detail, due to the requirement of painstaking preparation.

Existing scientific samples in the S.A. Museum are "lumps" from the "Isognomon Bed" on Hondeklip (Figure 4) and one small bulk sample of shelf-facies fauna from De Beers exposures, *viz.* from KN_1. Some specimens were collected on Swartlintjies SL 20 and "blocks" of this facies, collected by the writer from LKN_10-02, are in the De Beers Marine sample collections and intended for transfer to the S.A. Museum.

More samples are highly desirable to facilitate the unravelling of these interesting faunas (and stratigraphy).

Due to the poor preservation of shell in most of the decalcified 30 m Package, the total faunal sample from this formation is relatively small. Certainly efforts to increase the overall fossil sample size from wider afield in the 30 m Package are worthwhile.

In the Quaternary beaches, one extinct slipper limpet is known from LIG deposits, but its range further back in the Quaternary is not established. Although the fossil shells in these youngest deposits are mainly modern species living today (extant species), unexpected taxa sometimes occur. Mostly these are warm-water, subtropical West African taxa that lived in LIG embayments. These are recorded from deposits of the western and southern Cape, from St. Helena Bay around to the Port Elizabeth area. However, the Quaternary beaches north of St. Helena Bay are very poorly sampled.

Further collection of samples for microfossils is desirable. The microfossil record has been sampled at few localities and the results w.r.t. age diagnosis are controversial, at least partly due to the fact that most taxa are benthic and conservative and not well correlated with the oceanic (planktonic) biochronostratigraphy. This again emphasizes a need to focus on the deeper-water facies, wherein planktonics are most likely to occur.

6.2 VERTEBRATES

The sample of identifiable fossil bones and teeth from coastal Namaqualand is small (see tables in Pickford & Senut, 1997) and currently is just sufficient to provide age constraints that support correlations with gross sea-level/ice-volume history (Section 2, Figures 1 & 2). Nevertheless, study of the Hondeklip exposures have demonstrated that there are more bone/teeth fossils in the deposits than is generally perceived, as has been revealed by dedicated searching. These occur in the following contexts:

- **Basal, petrified, mixed assemblage:** petrified (phosphatized), variously abraded, reworked fossils found the basal gravels and that predate the enclosing marine deposits. Includes both terrestrial and marine vertebrates. See Images 2 & 3.
- **The marine assemblage:** cetacean, seabird and seal fossils contemporaneous with the enclosing marine deposits. Input of terrestrial bones is associated with local back-barrier environments (lagoons, tidal channel lags). See Images 4 & 5.
- **The capping, terrestrial assemblage:** Bones of land animals on the extensive palaeosurface erosively formed on the marine deposits and within the overlying terrestrial deposits. See Images 6 to 8.
- **Overlying aeolianites and sheetwash:** Rare bones occur on palaeosurfaces within these sequences.

Currently, vertebrate fossils have not been found within or closely associated with the following formations and therefore age constraints of the desired accuracy are lacking for:

- The Earlier Tertiary Fluvial Deposits. This includes both the lower, kaolinized deposits and the younger fluvial deposits locally in "reoccupied" palaeochannel complexes such as the "Megalodon".
- The Buffels River Deposits (BIC).
- The 30 m Package.
- The 8-12 m Package.

7. FIELD VISIT OBSERVATIONS

7.1 Earlier Tertiary Fluvial Deposits

KC, Map 1, Mitchell's Bay, Waypoint 51, LK_LK_22 exposures

This formation, the "Channel Clay", is classically preserved in a narrow, coast-parallel, bedrock palaeochannel debouching into Rooiwalbaai. It has been mined away, remaining outcrop being the "seawall" at the south end of the pit (Image 9).

These deposits, as seen elsewhere along the coast, are known for their organic content of carbonaceous sediments and lignitic/peaty beds with both plant microfossils (pollen) and "charcoal" macrofossils and plant impressions. More specifically, this exposure is the most pervasively organic-rich and fossiliferous w.r.t. macroscopic plant material that the writer has seen. The preservation is likely due to oxygen-poor groundwater ponding at this location. In less favourable locations the organic matter is largely lost.

Very disturbed material is accessible along the western side of the palaeochannel exposure. Large pieces of fossil wood are readily found (Image10). Friable, carbonized, smaller plant fragments occur abundantly as local masses or more distributed in the clayey sands.

BMC, Map 3. Kareedoornvlei, Waypoint 137, KVS_E16 area

An exposure of this formation in the context of the "Megalodon Palaeochannel Complex". Here the formation has been eroded into and overlain in the west by the mid-Miocene 90 m Package. In contrast to the Mitchell's Bay exposure, here this formation is dry and oxidized. Considerably complexity is seen in sedimentary structures and local deformations.

Patches and stringers of black organic matter are readily seen (Image 11). Closer examination shows the occurrence of plant material with enigmatic vermicular structure (Image 12).

Most importantly, silicified nodules were readily noticed and these appear to be petrified fossil bone (Images 13 & 14). To the writer's knowledge, no bone fossils have ever been recovered from this formation before.

Discussion

- The formation remains poorly described and understood, in spite of its supreme economic importance as the local palaeoplacer source of diamonds in younger deposits. Any detailed work that has been done is not in the scientific literature, but presumably exists in DBNM archives.
- The age of the deposits has been controversial (Section 2.2). Traditionally, the deposits were long regarded as late Cretaceous, but several microfossil pollen studies have rendered this untenable. Nevertheless, the fossil pollen work is not unproblematic. The deposits are of international scientific importance w.r.t. the evolution/biostratigraphy of plants in Africa.
- There are few natural exposures of this formation available. Known natural exposures are at Rooiwalbaai where it is cliffed (*i.e.* the other side of the "seawall") and in the seacliffs at Geelwal Karoo just north of the Olifants River. These weathered/oxidized exposures are unfossiliferous. Some other exposures occur in Namaqualand drainages, but are surficial outcrops, lacking vertical section.
- No Type Sections have been erected in Namaqualand.
- Importantly, the Mitchell's Bay exposure is incomparably fossiliferous w.r.t. plant macrofossils. This provides an opportunity for comparison of these different, separate fossil records of micro and macrofossils from the same deposit. The preservation of the fossil wood is remarkable for deposits of this age! A chunk of wood from the "Channel Clay" 6869 exposures remained unstudied until a drive to obtain more data on these deposits prompted its despatch to a fossil wood anatomist for study. It has been identified as mahogany (Meliaceae) and not yellowwood as would have been expected from the pollen data. The wood is similar to the extant tropical African mahogany that grows in dense, wet, tropical forest, but it is an extinct new species. A comprehensive collection of the fossil wood would be scientifically invaluable.
- The finding of probable petrified bone material *in situ* in the KVS_E16 area is <u>unprecedented</u>. The Palaeogene land-vertebrate record is poorly preserved in southern Africa. The writer has previously seen extremely rare pebbles of grey, silicified bone in marine gravels and wondered if these were perhaps derived from this formation. The recovery of fossil bone from this formation holds the promise of age constraints independent of the pollen chronology.

Recommendations

- A large sample of wood and other macro plant debris from the LK_LK_22 exposure must be collected. The more friable plant-fragment material is degrading and oxidizing with exposure. Sampling should take place in the near future.

- All exposures of the "Channel Clays" and "Megalodon" palaeochannel fills must be scanned for bone and plant fossils, as well as sedimentary features of palaeoenvironmental utility.
- Sections must be described where material is sampled. Additional observations of sedimentary features should be made where these inform about the origin of the deposits.
- The LK_LK_22 exposures should be considered as a geohistorical heritage site and type-section locality.
- An exposure like that in the KVS_E16 area should be considered as a geohistorical heritage site and type-section locality.
- As mentioned in Section 2.2, these ancient palaeochannels may sequester deposits of differing ages. The previous palynological and wood-anatomy work and sampling status of the "Channel Clays" and "Megalodon" palaeochannel fills needs compilation and review (unpub. reports to DBNM).

7.2 THE 90 M PACKAGE

BMC, Map 3, Dreyers Pan, Waypoint 134, DL92F area

Upper Middle Terrace, 65 m Cliff area. Residual basal marine gravel overlying weathered bedrock with microrelief. The thick overburden section is decalcified and pedogenically reddened (Image 15). Most of overlying section is of terrestrial origin, with features such as isolated, angular clasts and "stone lines" marking the more obvious palaeosurfaces. Smoothed, "re-absorbed", pedogenetically-cemented burrows prominent in lowermost section. It is possible that marine deposits are preserved in the lowermost section, but recognition of such and its upper contact requires careful scrutiny.

BMC, Map 3, Dreyers Pan, Waypoint 135, DP_114 area

Upper Terrace at foot of Wolfberg, 80-90 m ASL. Section evidently as previous (Image 16).

BMC, Map 3, Dreyers Pan, Waypoint 136, DP_133Q area

A limited exposure of terrestrial deposits with two distinct units (Image 17). In a bedrock gully feature incised in the 95 m cliff, edge of Upper Terrace.

BMC, Map 3, Kareedoornvlei, Waypoint 137, KVS_D16 area

Upper Terrace. Of note is the contact between the edge of the "Megalodon" palaeochannel sediments and the oldest marine formation, the 90 m Package.

BMC, Map 3, Kleinzee, Waypoint 140, AK_52T area

Upper Terrace ~90 m ASL. Thin deposits overlying kaolinized bedrock (Image 18). Much exhumed silcrete in evidence. Likely only residual marine gravels under reworked marine sands. Possibly also residual "Channel Clay" basal conglomerates present here and at AK_34V ~2 km farther south.

KC, Map 2, Koingnaas N boundary, Waypoint 56, KN_KLNA_15 area

In contrast to the preceding, high-elevation exposures, this instance of the 90 m Package occurs close to the sea near Visbeenbaai. The deposits are shelly and pebbly marine calcarenites preserved beneath the 30 m Package in a bedrock depression (Image 19). They are recognized as older, Miocene deposits solely on the basis of the enclosed shells that are quite distinct from the Pliocene faunas.

Discussion

- Deposits of the mid-Miocene 90 m Package, where they "classically" occur on the higher bedrock terraces of the BMC, are extensively decalcified and thus largely unfossiliferous. However, fossil shells have occasionally been found, usually those of thick-shelled species such as *Isognomon* and oysters. The writer's impression is that these fossils are sporadically preserved in the basal gravels, in crevices and small gullies, and seldom occur in the main bulk of the overlying reddened sands.
- Vertebrate fossils also occur mainly in the basal gravels and these are mainly undiagnostic petrified bone pebbles, but fossil teeth occur. The latter are mostly fish teeth, but occasionally the teeth of terrestrial animals are found by diligent searching of gravel concentrates and "small" oversize, such as by Wessels, Pickford and Senut (1997) at Ryskop, where a small assemblage now supports the Miocene age of the 90 m Package. In the BMC, the occurrence of fossils mainly in the gravel ore has meant that very few have ever been saved, as a result of diamond security concerns w.r.t. access to gravels and concentrates. Perhaps some 90 m Package fossil material resides in the Kleinzee geological collection?
- The "new" exposure of 90 m Package shelly sands on Koingnaas (Waypoint 56) is different from these previous occurrences. It is a shallower facies, of shoreface palaeodepth, and thus samples littoral taxa that

are rare or absent in the shelf facies. Furthermore, its fossil content has stratigraphic "integrity" in that it was apparently cemented prior to the Pliocene transgressions.

- In 1985, the late Brian Kensley and the writer sampled some "anomalous" species from 30 m Package lower shoreface sands exposed in an excavation then known as "KL, south face". These were described and listed as from the 30 m Package (Kensley & Pether, 1986), but hitherto have remained unique finds not found again. It is now apparent that these taxa were reworked from these Miocene deposits nearby.
- There are reported stratigraphic aspects of the deposits overlying the Kleinzee Middle Terrace (Section 5.3, Table 1) that have not been independently verified and for which biostratigraphic evidence is lacking. The implication of De Beers observations is that there is a "65 m Package" on the Kleinzee Upper Middle Terrace that is not recognized in the south in the "Koingnaas Complex". Notwithstanding, the writer's observations at ~65 m ASL. on Sandkop, just to the south of Kleinzee, indicate a deeper-water shoreface deposit of 15-20 m palaeodepth (Image 20). This would be consistent with the older deposits on the Kleinzee Upper Middle Terrace actually being the 90 m Package.

- **Recommendations**
  - It is proposed that the existing exposures of the 90 m Package in the BMC must be scanned for rare fossils.
  - This task should include the overlying terrestrial sequence, wherein scattered vertebrate material on major contacts (palaeosurfaces) is more common than generally held.
  - Consideration should be given to the preservation of type section localities/geohistorical sites where the BMC 90 m Package is of typical aspect. Aspects could include the 95 m cliff, the contact between the edge of the "Megalodon" palaeochannel sediments and the 90 m Package, silcrete boulder conglomerates and the black, heavy-mineral beach zones (e.g. Image 21).
  - The unique shell fossils occurrence in the Koingnaas KN_KLNA_15 area must be thoroughly sampled.
  - An exposure like that in the KN_KLNA_15 area should be considered as a geohistorical heritage site and type-section locality.
  - Additional observations of sedimentary features should be made where these inform about the origin of the deposits (*e.g.* Image 20). Important observations include the sedimentary architecture in relation to the 65 m Cliff.

7.3 THE 50 M PACKAGE

BMC, Map 3, Kleinzee/Dreyers Pan boundary, Waypoints 131 &132, AK75_LM area

The eastern part of the trench exposes the 50 m Package (Image 22). It is decalcified, but pervasive crossbedding indicates upper shoreface palaeodepths (Image 23). A pedogenic profile/duripan is developed in the upper part of the section. The 30 m Package also occurs in this exposure - see below.

BMC, Map 3, Kleinzee, Waypoint 133, AK70_MN area

The surface here is ~57 m ASL. and a much thicker section is present. The faces could not be inspected in detail, but it is likely that only the lowermost portion is *in situ* 50 m Package, the remainder above the more pale unit being terrestrial in origin (Image 24).

BMC, Map 3, Kareedoornvlei, Waypoint 139, KV_174_KL area

At ~40 m asl., this site was visited to view the large midden deposit present there. A small exposure nearby shows only terrestrial deposits (Image 25) and evidently only residual 50 m Package deposits remain at depth. A prominent, white, cemented unit occurs and is in a state of "retrograde" dissolution. It is possibly a pan carbonate. Overlying this are deposits wherein ESA tools and bone material occurs on palaeosurfaces.

&KC, Map 1, Langklip, Waypoint 52, LKC_2B area

&KC, Map 1, Zwartlintjies Rivier, Waypoint 54, SL_20_09 area

At both these localities, deeper-water deposits were observed in February, 2006 (*e.g.* Image 26). Shells are more common in the exposure at Waypoint 54 and included species not previously sampled. Also at this locality the 50 m Package section appears to be more complete, as opposed to the usual situation where several metres are missing due to erosion, and unusually it is overlain by pale aeolianite (Image 27) rather than reddened sheetwash and sandsheets. These and other "additional" sites, not seen during the Feb. 2008 field visit, are flagged by an ampersand (&).

- **KC, Map 2, NW Koingnaas and SW Somnaas**

As above, with extended sections of the deeper-water 50 m Package in the area.

- **Discussion**
  - As it happened, not many 50 m Package exposures were inspected during the field visit. However, this formation, known also as the FGS or Fine Green Sands, has been extensively exposed during mining of its basal gravels in the past. It has mainly been described from exposures in the Hondeklipbaai Transhex mine where most palaeontological sampling has taken place.
  - Notwithstanding, other aspects of this formation and its fossils have been seen in past years during fleeting visits to De Beers exposures of the "Koingnaas Complex". Particularly important has been the occurrence of more extensive, deeper-water facies, both as extended/distal lower shoreface facies and as shelf deposits, that were deposited in the areas of accommodation provided by exhumed palaeochannels. As mentioned (Section 6.1), a main complication is the reworking of the Miocene fauna into the similar muddy shelf deposits of the 50 m Package that are also just locally preserved in the same locales.
  - In the BMC it appears that 50 m Package deposits are largely decalcified, but fossil shells or shell moulds probably occur sporadically. As mentioned above, there are stratigraphic aspects of the deposits overlying the Kleinzee Middle Terrace (Section 5.3, Table 1) that require further investigation. For instance, the Lower Middle Terrace must be overlain by the 50 m Package, but the contact zone with the deposits on the Upper Middle Terrace is not described in the available literature.
  - The reported transgression overlapping the seaward edge of the Lower Kleinzee Middle Terrace is evidently the 30 m Package, but this also needs verification. This transgressive maximum is largely eroded away by deflation in the KC, but its geometry is presumably preserved in the BMC.

- **Recommendations**
  - It is proposed that the existing exposures of the 50 m Package in the BMC must be scanned for rare fossils.
  - Additional observations of sedimentary features and geometry should be made where these inform about the origin of the deposits.
  - Consideration should be given to the preservation of type section localities/geohistorical sites where the 50 m Package is of typical aspect. Important exposures include the transgressive maximum of the 50 mm Package, overlapping older deposits on the Upper Middle Terrace.
  - Sampling of the fossil content of deeper 50 m Package lower-shoreface facies, that were deposited after underlying 90 m P shelf facies were "sealed", is important for the unravelling of the basal, condensed and mixed shelf faunas.
  - The fossil search should include the overlying terrestrial sequence, wherein scattered vertebrate material occurs on major contacts (palaeosurfaces), e.g. Waypoint 139.

- ## 7.4 THE 30 M PACKAGE

- **BMC, Map 3, Kleinzee/Dreyers Pan boundary, Waypoints 131 &132, AK75_LM area**

The 50 m Package deposits mentioned above are eroded to the immediate west and overlying the gently seaward-dipping contact are pebbly deposits of the 30 m Package (Image 28). Notably, the pedogenic profile developed in the upper part of the 50 m Package is truncated by the 30 m Package lower contact. The elevation of the surface here is estimated from the 1:50000 map at ~35 m ASL.

- **BMC, Map 3, Kleinzee, Waypoint 127, AK_45H area**

- **BMC, Map 3, Kleinzee, Waypoint 128, AK_45B area**

- **BMC, Map 3, Kleinzee, Waypoint 130, AK_61H area**

These are three shallow trench exposures of cobbly material, at quite low elevations (10-15 m asl.?), decalcified and with a well-developed pedogenic (calcrete?) capping (*e.g.* Image 29). Would appear to be 30 m Package deposits. The original thickness has evidently been reduced by substantial deflation.

- **&KC, Map 2, Somnaas, Waypoint 55, SN_SN_23 area**

An interesting exposure of the 30 m Package where unusually it overlies a terrestrial, colluvial deposit instead of the marine 50 m Package (Image 30).

- **KC, Map 2, Koingnaas, Waypoint 124, KN_7 area**

- **KC, Map 2, Koingnaas, Waypoint 125, KN_R8 area**

Exposures of decalcified 30 m Package (Image 31), with upper shoreface at section top and thin calcrete capping.

- **KC, Map 2, area at seaward end of Koingnaas 6869 orebody**

Extensive exposures of decalcified 30 m Package, effectively a cliff *cf.* at Rooiwalbaai. However, no clear exposures of onlapping Quaternary beaches were seen.

- **&KC, Map 1, Hondeklip/Langklip boundary, LK_N6 area**

Lower shoreface with transgressive contact and overlying 30 m P deposits. See Figure 4 for the graphic section of these exposures. A similar exposure is at Waypoint 50 (Image 32). Further seawards, the thickness of 50 m Package lower-shoreface sands diminishes and the 30 m Package lower-shoreface facies is increasingly developed (*e.g.* Image 33).

- **KC, Map 1, Langklip, Waypoint 141, north from LK_LK_08 area**

North of Waypoint 141 is partial exposures of decalcified 30 m Package shoreface sediments. Clear examples of onlapping Quaternary "raised beaches" were not seen in the vicinity of 141.

- **Discussion**
  - Exposures at Waypoints 131 and 132 show the transgressive maximum of the 30 m Package. This important stratigraphic feature is not often seen. It is consistent with the feature called the "29-34 m Beach" by Carrington & Kensley (1969). Likewise to the 50 m P in the Hondeklip area, the actual transgression maximum (or thinnest inland edge) of the 30 m Package was eroded away. Instead, the transgression maximum had to be estimated at about 33 m ASL. by projecting the transgressive contact farther inland and assuming a thickness for the missing foreshore deposits.
  - In the past, admittedly in the earlier stages of the work at Hondeklip, a criticism had been levelled that "an exposure showing a pedogenic profile developed in the 50 m P and subsequently eroded by the 30 m P is not present", this casting doubt on these formations being related to discrete, separate sea-level cycles. This exposure confirms that this relationship exists.
  - On the same topic, the exposure of the 30 m P at Waypoint 55 might well be rare evidence for considerable erosion of the 50 m P during the intervening regression. However, the possibility that the colluvium predates the 50 m P cannot be excluded.
  - Exposures at Waypoints 127, 128 and 130 need a more thorough inspection to look for fossil content (oysters, *D. rogersi*), diagnostic sedimentary structures and confirmatory evidence of deflation on top (wind polishing, etching of clasts).

- **Recommendations**
  - Although the 30 m Package is largely decalcified, occasional lenses with shells are found. It is proposed that the existing exposures of the 30 m Package in the BMC and KC must be scanned for rare fossils. Thicker 30 m P sections with lower-shoreface facies, developed in areas of relatively lower bedrock, should especially be targeted.
  - The fossil search should include the overlying terrestrial sequence, wherein scattered vertebrate material occurs on major contacts (palaeosurfaces) *e.g.* Figure 4.
  - Additional observations of sedimentary features and geometry should be made where these inform about the origin of the deposits, for example the waypoints 131/132 exposure where preservation of a type section locality/geohistorical site is recommended.

- **7.5 THE QUATERNARY PACKAGES**

- **KC, Map 1, Langklip, Waypoint 142, LKC5-2 area**

In the east, relatively thin upper-shoreface exposures of the decalcified 30 m Package are seen. These appear to be overlain seaward by pale, boulder-bearing deposits of the Quaternary beaches (Images 34 and 35). The south faces are obscured, limiting scope for laterally-continuous observations.

Potentially a very informative exposure, but requires "clean-up" to provide some clearer vertical sections.