The unique Namdeb trilogy—
Our past, present and future mining applications in this unique deposit

by S.H. Badenhorst*

Introduction

Zacharias Lewala discovered a diamond at Grasplatz, near Lüderitz in April 1908. While this stone may not have been the first diamond to be found in this barren, inhospitable area, it most certainly was the stone that set off a chain reaction ultimately leading to the creation of Namdeb as we know it today.

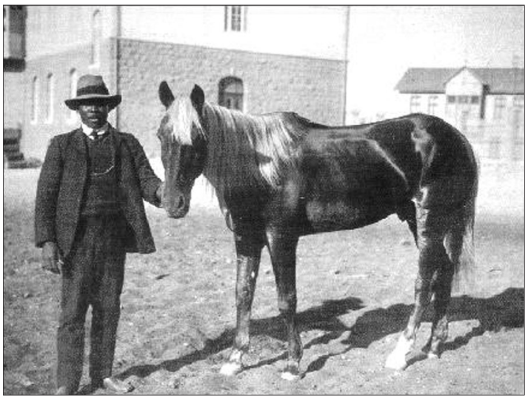

Figure 1—Zacharias Lewala

The stone was handed to August Stauch who was responsible for the removal of sand from the railway track linking Aus and Lüderitz. Within a year of the discovery the area was swarming with small mining syndicates, mostly holding a 50-year concession granted by the Deutsche Koloniale Gesselschaft (DKG). The German government, in agreement with DKG, decreed a desolate, under-populated coastal strip of land extending some 350 km north of the Orange River as a restricted area. Thus, the Sperrgebiet or Forbidden Territory was formed.

Consolidated Diamond Mines of South West Africa (CDM) developed following the First World War. The company was formed by Sir Ernest Oppenheimer to amalgamate and create synergy between the numerous smaller mining companies, which existed at the time. In 1923 the South West African Administration and CDM concluded the Halbscheid Agreement, which accorded CDM the mining rights in the Sperrgebiet.

Namdeb Diamond Corporation (Pty) Ltd was formed in 1994, following Namibia's independence, as a result of a shareholding agreement between De Beers Centenary AG and the Government of Namibia. Each shareholder had a 50% stake in the new company with an agreed profit split.

Diamond mining on the west coast of South Africa and Namibia is a huge logistical operation with activities spread over vast areas. Despite a relatively low grade compared to kimberlite operations, the good size and quality of the diamonds have dictated the mining methods employed. Large volume mining methods, followed by ore processing techniques, allow the economic extraction of some of the highest value diamonds in the world.

Geology—the making of diamond beaches

The Orange River system is the last of a vast, much larger geological environment that operated between 80–100 million years ago. The river cut through tectonic uplifts and periodic falls of the continental shelf in the past 3 million years (Pleistocene), when ice sheets expanded and contracted over large areas. Terraces have remained along the river and the ancient bends were in-filled by sequences of gravel, sand, clay and grit. Concentrations of diamonds, in various geological features carved by the ancient river, occur due to the difference in specific gravity between diamond and quartz pebbles. Other concentrations of diamond occurred where there was a rapid reduction in the velocity of the river. 'Push bars' occurred in these areas with high concentrations of cobble-like gravel.

Large volumes of diamonds have been able to complete the journey to the Atlantic Ocean. Some 70 million carats have been recovered from this area. A unique combination of environmental factors has contributed to the development of this, the world's greatest marine diamond mining placer. The tremendous energy of the Atlantic Ocean has been the real driving force behind the formation of the beach deposits. This energy, combined with the presence of a remarkable collection of fixed trap sites, characterized by gullies, and potholes on wave-cut platforms, has produced some of the highest grade deposits of its kind ever discovered.

Two types of coastal deposit can be identified. In the south, a coarse gravel barrier system about 4 km long and 0,5 km wide has developed a form of 'spit'. The deposit is characterized by the formation of thick, sheet-like seaward dipping sequences of coarse gravel. The high-energy surf conditions have allowed a continuous sorting process on the shore face that separates gravels on the basis of size and shape. More spherical clasts are drawn down the beach face and concentrate near the toe. Discoidal clasts are deposited higher up the beach. In major storm events it was possible for waves to either breach and/or over top the spit barrier complex.

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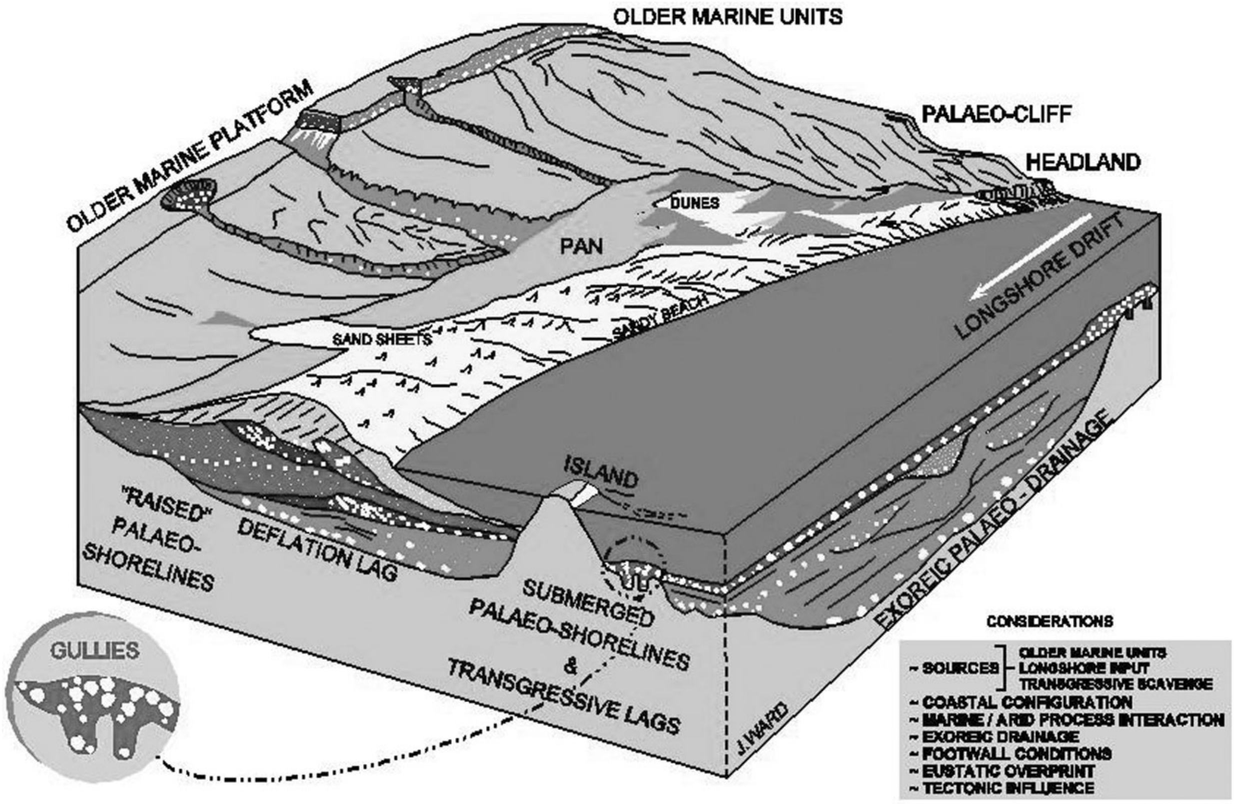


Figure 2— Geological model showing various environments

Diamond concentrations are also found within these large wash-over deltas. North of the gravel barrier complex the volume of gravel available from the Orange River has decreased. Late Proterozoic bedrock is progressively more exposed northwards. A very efficient northbound long shore sediment transport system, driven by the Atlantic surf and high southerly wind energy, allows for gravel movement to good trap sites. Late Proterozoic bedrock led to the formation of spectacular fixed trap sites during the extensive wave-cut platforms in the near shore area.

The linear beach deposits have been the primary targets for the large-scale mining operations within Mining Area 1. The area has therefore seen great innovative mining processes established. The most significant change came in the form of sea-wall technology to hold back the sea so as to allow diamond extraction to 20 metres below sea level. Considerable knowledge of coastal sediment dynamics was gained and early warning of prevailing storm conditions was essential.

North of Mining Area 1, the Namib Sand Sea regime operates within one of the world's highest energy aeolian systems. Very large barchan dunes have evolved from these windswept valleys known as the Namib Deflation Basin. Creep transport systems had the ability to denude and move high-density material. Old prospecting records of the Idatal and Hexenkessel mining areas south of Pomona show that one sample site 25 m long and 1 m wide produced 1 700 diamonds.

This extraordinary deposit continues beneath the waves on the continental shelf of Namibia. Again the Orange River has been the primary conduit through which diamonds have been delivered to the continental shelf for at least the last 40–50 million years. The Orange River system has incised and aggraded as the sea level has migrated up and down the shelf and coastal plain. Namdeb and De Beers marine geologists, using remote sensing techniques such as seismic and side-scan sonar, have delineated high potential trap sites along the coast.

Greater understanding of the undersea geology was gained using the Jago submersible from the MV Zealous in 1996. De Beers Marine have since, procured an Autonomous Underwater Vehicle (AUV), which is able to 'fly' over certain environments and scan using side-scan survey and sub-bottom profiling techniques. Once analysed, these images produce a complete 3-D view of the mining areas. Marine prospecting is ongoing within the Atlantic 1 mining license and the Exclusive Prospecting licenses held by Namdeb.

Past—'the pioneers'

CDM headquarters were established at Kolmanskop in the north of the Sperrgebiet following the formation of the company in February 1920. The decision was logical at the time due to mining activities, which were concentrated at Kolmanskop, Elizabeth Bay and Pomona. This was, however, destined to change. In 1928 Anglo American geologists were prospecting on the northern banks of the Orange River. Rich deposits were discovered in marine terraces under blankets of sand. Trenching, followed by basic trommel screening and jigging, produced 39 diamonds on the first washing.

Figure 3—Vehicles arriving in Oranjemund

Figure 5—Lubecker scoop

Excitement grew when diamonds as large as 246 carats where found, and the Orange River mouth was set for new beginnings. Word soon reached the operations at Kolmanskop and a road link was established through the harsh desert between Oranjemund and Lüderitz. Demand for basic supplies in the south led to a sophisticated supply chain from the north. It is reported that a truck purchased in 1932 had covered more than a million miles by 1948. Supplies were augmented by a pont that crossed the Orange River until finally a bridge was built in 1949.

In 1941 it was finally agreed that mining activities in the south of the Sperrgebiet were the mainstay of the operation and the mine office should be relocated to Oranjemund.

Overburden stripping

Efficient removal of the overburden or sand was a problem in the early years. In 1935, rotary scoops (early steam-driven bucket wheel excavators) and mechanical dredgers were introduced to excavate the overburden.

Mule-drawn trucks provided the haulage system. This was an extremely slow process in harsh working conditions. Two 'large' excavators, capable of moving up to 100 tons per hour, were introduced in 1936 and 1937. Despite shortages of equipment and supplies during the Second World War, the mine continued to develop.

Cat 631 and 641 scrapers were introduced in the '60s and '70s and were extremely successful when the sea-wall mining method was introduced. Their ability to continuously strip and maintain the sea wall made them perfectly suited to do the job.

An ingenious idea followed the Second World War, with the introduction of ex-military surplus Sherman tanks to be used as tractors. The Shermans eventually replaced the mules and soon after were converted into platforms for stackers, which were used in conjunction with small bucket excavators. Dumping into mined-out areas became a successful methodology following the use of this system.

In the early 1960s the first Lubecker Scoop capable of 180–200 cubic metres per hour was introduced. Manoeuvring problems were experienced and the scoops were eventually phased out in the mid '60s.

The first bucket wheel system was introduced in 1974 at a cost of approximately N$3 million—an enormous investment at the time! It was designed for a continuous operation and incorporated a 110m bridge. The machine was designed for a 1000 bcm per hour capacity giving a monthly call of 400 000 bcm's. The machine was operated by 3 men and was a major leap in mining productivity.

Small draglines were also used mainly for stripping in the western extremities of the prospecting trenches. The Sauerman tower scraper, comprised of two large towers, operated in the upper terraces in the 1950s.

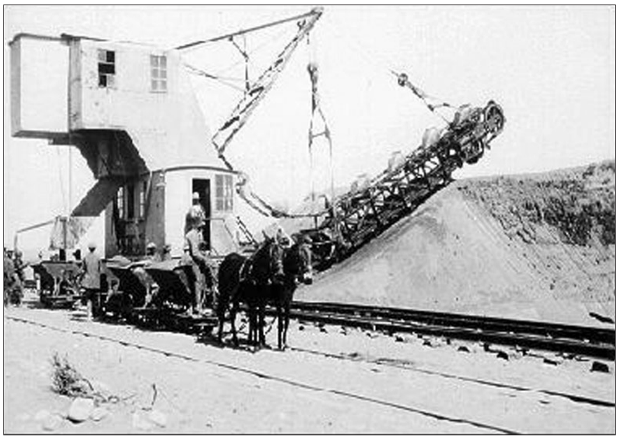


Figure 4—Early rotary scoops (note mule-drawn cocopans)

Figure 6—Open-bowl scraper

The first open-bowl diesel driven bowl scrapers with push dozers (le Tourneau 'D's) were introduced in 1952. They were fast, relatively inexpensive and suited to a variety of conditions. The Caterpillar DW21 scraper was introduced in the mid '50s with a stripping capacity of 100 bcm per hour. Large track dozers such as the Cat D9 were introduced in the late '50s to assist with the scraper operation.

Loading and hauling

The earliest method of hauling was by mule and horse-drawn cocopans. The cocopans were pulled along narrow gauge tracks to numerous screening plants. In the 1940s small, diesel driven locomotives and cocopans were introduced. One locomotive could haul six one cubic metre cocopans using a team of 3 people. The cocopans were loaded at the different faces, hauled to the plant and pulled up a ramp using an electrically operated winch. The material from the cocopans was tipped into a bin, and the cocopan reconnected to the locomotive for the return trip to the mining area. An obvious disadvantage of the system was the lack of flexibility offered by the tracks.

The loading tool used was 19 RB and later 24 RB excavators. These were very early rope shovels and were problematic in the harsh conditions. In 1950 a railway line was constructed from Oranjemund to Mittag in the northern portion of Mining Area 1, with diversions to the various screening plants. Logistical support to the mining areas and gravel transport to screening plants was ensured.

The inflexibility of the track-based system and advances in rubber tyred equipment led to the eventual phasing out of the system in 1972. In 1952, the first diesel powered dumper, a Le Tourneau rocker was purchased. The mid 60s saw the introduction of Michigan 210 dumpers with a capacity of 12 cubic metres. The excavators were later replaced by front-end loaders. Centralized screening and processing plants introduced in 1968 saw an increase in haul distance and new haulage units were required. Ralph and Kenworth trucks were purchased and special haul roads constructed. The 35 t off-high way rigid frame trucks eventually replaced the vehicles. These units provided the flexibility for the mining operation.

Bedrock cleaning

Bedrock cleaning was as much a challenge in the early pioneering days as today. Once the gravel has been removed, the bedrock must be 'swept' to collect the remaining high-grade material. This operation was initially carried out using large gangs of people armed with brooms and pick axes.

Figure 7—Labour intensive bedrock cleaning operations

Exposure to the elements and temptation to glean diamonds from the bedrock have been problems as long as bedrock has been exposed. A complex geological environment has made it very difficult to mechanize or automate the process.

An incentive scheme was introduced in the 1950s to reward individuals who picked up diamonds during this process. The diamonds were collected by security and after classification a reward was paid (up to 70% of the value).

In the '50s and early '60s mechanical assistance was introduced. Vacuveyors were tested for a short period. They were basically large, electrical vacuum extractors. Three employees, followed by a lashing gang to loosen material, operated each unit. The system was eventually scrapped as a result of a marked decrease in productivity.

Systems introduced and tested in the 1960s also included:

- air monitoring and jet lifting
- mini conveyors for material transport in the bedrock environment.

Both proved unsuccessful and were later scrapped.

A new incentive scheme was introduced in 1968 to reward productivity in terms of square metres swept per shift. During the same period LY2P hydraulic excavators were introduced to assist in cleaning areas with deep erosion gullies. The system allowed the bulk extraction of ore, followed by hand lashing of the remaining material, and finally sweeping. The cost of the system was about 30% cheaper than any other tested and extremely efficient.

Sea-wall mining

It was only a matter of time before the idea of mining the beaches below sea level came to mind. Various techniques were tried including the construction of 'skew prism walls' in the late '60s. In section the wall consisted of 3 large concrete blocks, each weighing around 7 tons, lifted into place with a large crane. The blocks were covered with a canvas layer to prevent the ingress of water. The technique was used until 1971. The introduction of bowl scrapers and dozers later showed that it was indeed possible to push back the high water mark.

Cofferdam areas where mining could take place were excavated in the sand-fill. The sea wall was maintained by a constant stream of sand being dumped on the wall to ensure erosion rates did not exceed dumping rates. By 1977 mining had advanced 200 m west of the original high water mark and by 1985, the wall had reached 360 m off the high water mark.

The problem of water inflow was solved using a vertical 'curtain' of perforated stainless steel tubes spaced approximately 1 m apart. These pipes were water jetted into the sand to the bedrock horizon and connected to a pumping system. It was not until the introduction of electrically powered vacuum pumps that the technique became successful and allowed sand (damp) to stand almost vertically. In deeper areas the sea wall was constructed in terraces with 3 sets of well-pointing systems. By 1974 some 33 million litres of water were being pumped back into the ocean every hour to maintain the sea walls.

Figure 8—Early sea-wall mining using bowl scrapers

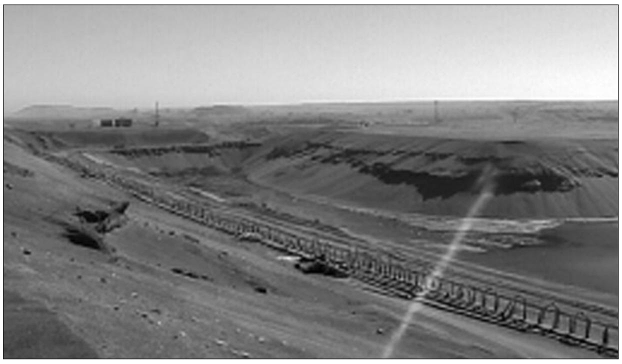


Figure 9—Sea-wall maintenance (note well-pointing system)

The vertical well-pointing technique was superceded by a horizontal drainage system in 2000. This became possible after the purchase of a large trenching machine, capable of trenching to 6 m for depths installing perforated plastic pipes. Installed on the beach, the system also has the ability to produce water for process reasons, an application which is being investigated as an alternative to sea water intake systems.

Early marine operations

In 1965 De Beers became the majority shareholder in the Marine Diamond Corporation (MDC) and many of the techniques used by the Texan, Sammy Collins, were improved, allowing operations at depths of 35 m. It soon became obvious that mining at this depth would not be economical and the vessels were stripped and sold.

Marine exploration and prospecting between 1971 and 1983 continued in deeper waters. Sampling at 200 m depths soon became possible, and it became evident that a considerable deposit existed on the continental shelf. De Beers Marine was formed in 1983 to allow efficient mining of material at the greater depths.

The MV Louis G. Murray was introduced in 1986 as a test platform for the development of tracked sea-floor mining systems. The MV Coral Sea, a converted petroleum exploration drill ship, was introduced in 1991 to continue exploration using a large diameter rotary drill bit. It soon became clear that the sea floor was extremely rugged and the variability of the orebody made mine planning extremely complex.

Figure 10—The trenching machine installed horizontal drainage systems (note white 'stocking' eliminating ingress of sand into pipe)

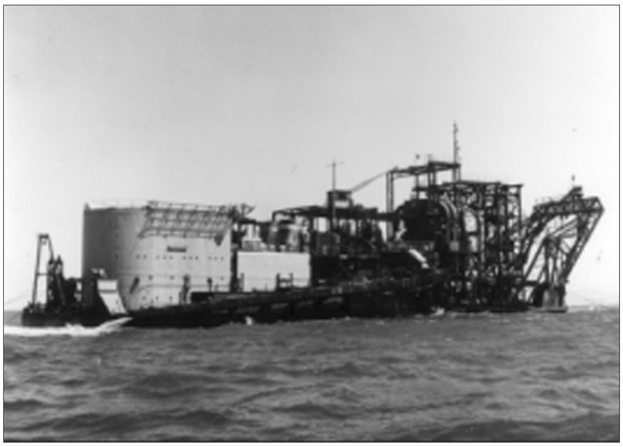


Figure 11—MV Pomona

Present

Namdeb's current mining operations take place over six mining licences in the southwestern corner of Namibia. Mining techniques have been influenced in those areas by the sheer extent, geographical diversity, extreme weather conditions, unique environment, biodiversity, and lack of infrastructure. Namdeb currently has tenure of the mining licences until 2020. In addition, Namdeb has the rights to conduct exploration and sampling activities in a series of Exclusive Prospecting Licences (EPLs) close or adjacent to existing licences.

Diamond production is sourced through two distinct areas:

- open-pit or strip mining techniques on land, also known as Diamond Area 1, and
- marine mining techniques for the Atlantic 1 and coastal area.

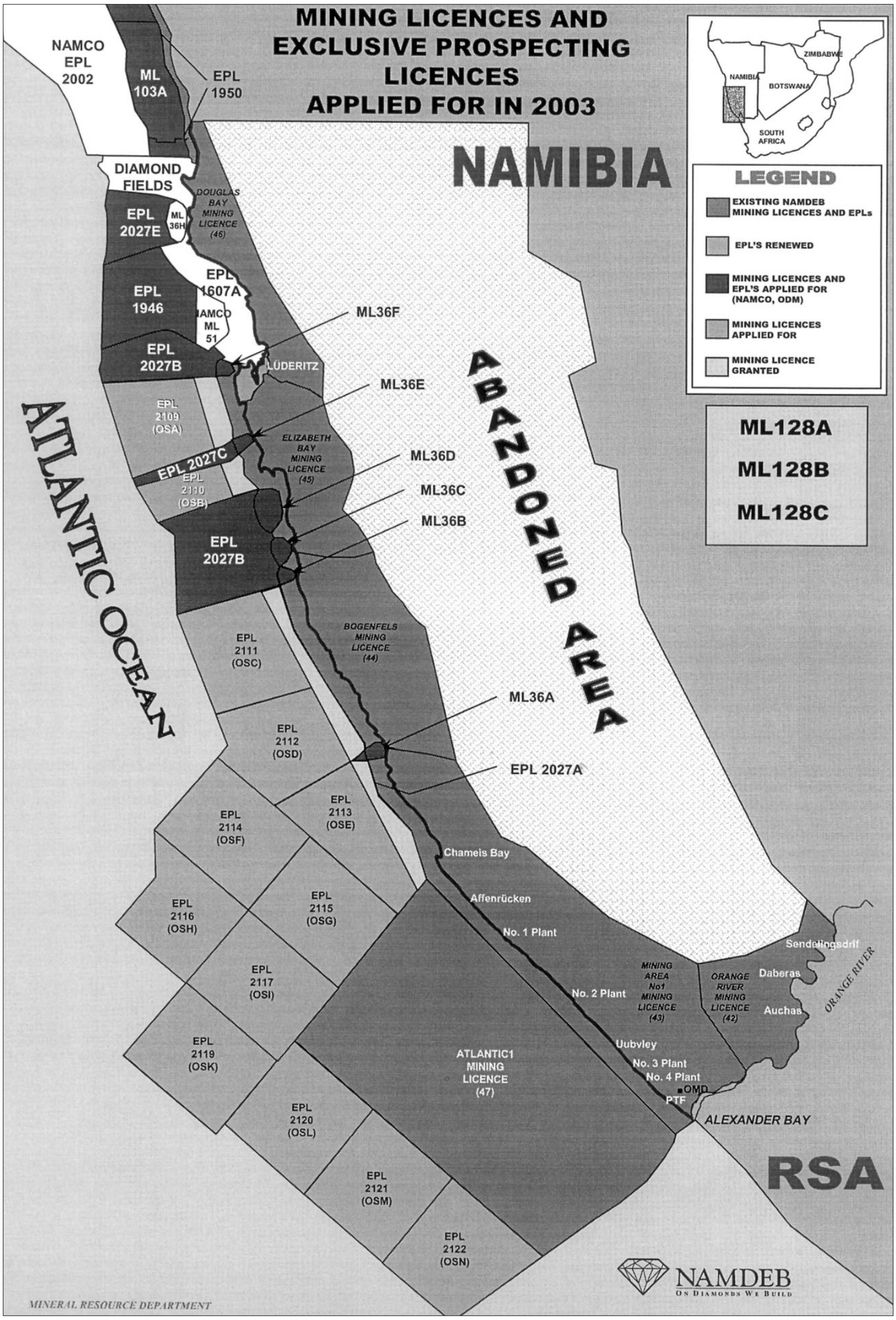
Mining is active in the following licence areas:

- Mining Area 1
- Orange River
- Elizabeth Bay
- Bogenfels
- Atlantic 1

Table I

Land-based production statistics

	Tonnage stripped		Tonnage treated		Carats produced	
	2002	2003 (Bud)	2002	2003 (Bud)	2002	2003 (Bud)
Mining area 1	26 272 738	23 397 000	21 659 055	25 910 000	549 398	534 400
Orange River Mines	5 218 274	5 200 000	2 709 329	5 643 000	58 548	69 000
Elizabeth Bay	–	140 000	2 024 415	2 050 000	88 968	97 000



The unique Namdeb trilogy

The Namdeb land-based deposits have been depleted since 1928 and are now nearing completion. Despite this, large volumes of low grade material remain. Innovative mining techniques and a reduction in operating cost over time have allowed previously uneconomical areas to be mined. The reduction in grade and the average stone size has also reduced over time and this trend will continue. These factors obviously have a detrimental effect on revenue and the consequent optimal utilization of the remaining resource.

Overburden stripping

The rapid increase in the fuel price and difficult underfoot conditions led to an investigation in the late ’70s into alternate techniques. The Holland loader was introduced in 1983. The vertical blade on the machine sheared strips of overburden, transported it via a cross conveyor, and discharged it to a continuous stream of bowl scrapers positioned alongside. The system was unfortunately phased out in the late ’80s due to a lack of mechanical efficiency, especially in harder ground. Development in pumping technology allowed the first jet-pump to be introduced in Mining Area 1 in 1983. The jet-pump was originally commissioned on a hydraulic excavator and later fitted to a small dredge commissioned in 1985. The dredge was constructed at Namdeb and, although it operated for a short period, the lessons learnt would become instrumental in the success of the large dredge introduced in 1997. Based on the success of the SH400 bucket wheel excavator introduced in the ’70s a second larger system, the O&K S800, capable of delivering 2500 tph was introduced in 1987. This system is ideally suited to the linear beach deposits in the southern corner of Mining Area 1 where overburden thickness is at least 10-15 m. The system becomes extremely expensive to operate if the designed throughput is not achieved in sub-optimal overburden environments.

Overburden is now removed by articulated dump trucks and excavators, bucket wheel excavators and a dredge. The need for versatile mining fleets operating in different conditions eventually led to the introduction of the hydraulic excavators and Articulated Dump Trucks (ADT) in the mid-’80s. The entire fleet of bowl scrapers was eventually replaced by this new technique in 1992. Stripping production has steadily increased over the past few years and can be ascribed to correct matching of the equipment and diligent adherence to mining standards.

The introduction of the dredge and floating treatment plant at Namdeb in 1997 heralded the start of a novel mining technology, which not only allowed the extraction of the overburden but also the economic extraction of diamonds within the overburden. These ‘low grade’ gravel lenses could not be economically mined using any other conventional mining technique. The dredge has allowed Namdeb to not only mine wet areas, but also accrete or build out the beach further west. Similar to the sea wall methodology, the accreted area is then available for further mining allowing *in situ* gravels ‘sterilized’ by the high-energy surf zone to be extracted from the gully environment using conventional dry mining techniques. The 2500 tph dredge was originally fitted with a double bucket wheel cutter head. This system was replaced with a cutter suction head fitted with a ‘rose-bud’ type cutter head to cope with the large oversize boulder layers encountered. The dredge is designed to operate to a maximum 15m dredging depth. The system currently operates at approximately one third of the unit operating cost of conventional stripping systems.

Figure 12—Cat5130 HEX loading a 773D RFT

Loading and hauling

320 kW front-end loaders load the gravels into rigid frame dump trucks (35 t) for transport to the treatment plants in Mining Area 1. In some areas such as Elizabeth Bay, the ADT fleet, loaded by hydraulic excavators, is used to transport ore to the treatment plants. ADTs have proven to be very successful in poor underfoot conditions found in this area. Their ‘flotation’ ability has also reduced the footwall preparation requirements in some areas. A GPS-based truck dispatch system is used to optimize the use of the haulage fleet. Haulage distances are excessive in some cases and the tkph rating for the tyres is a limitation.

Daberas mine (Orange River Licence) utilizes very large hydraulic excavators (180 t and 125 t) to load 50 t rigid frame haul trucks. The earthmoving equipment is used to remove overburden material and to produce run of mine ore to the treatment plants at Daberas Mine. The large unit, a Cat 5130 excavator, was purposely purchased as an oversize machine to ensure the surplus power was available for digging out of the solid using a smaller bucket.

Elizabeth Bay mine near Lüderitz has minimal stripping operations and therefore makes use of the same ADT / hydraulic excavator fleet for loading, hauling and stripping ore to the treatment plants. At Elizabeth Bay the wind plays an important role in overburden stripping. The wind denudes the sand on the deposit over time and this results in an additional challenge when it comes to mining scheduling.

Bedrock cleaning

Bedrock cleaning productivity has improved over the past few years using TransVac vacuum cleaning technology. The material, which has been ‘swept’ from the bedrock environment, is discharged into the collection bins. These bins containing high-grade material are sealed and hauled by tractor to the treatment plants to be discharged. Although successful, the technique is limited to dry areas, which also raises the security risk of exposed material. Investigations are underway to find alternative techniques to do bedrock cleaning in a wet environment.

Figure 13—Bedrock cleaning operation

Figure 14—Bedrock cleaning site (note Transvac units and trailers along the wall)

In-field screening plants

Daberas and Mining Area 1 have introduced in-field screening plants over the past few years to limit the volume hauled to the treatment plants. Dry in-field screening facilities have been supplemented with wet in-field facilities in Mining Area 1.

Figure 15—Mobile dense medium separation (DMS) plant on the Orange River

Figures 16 (a) and (b)—In-field screening plants (note plant above is a wet infield-unit)

The contractor-operated wet in-field facility on the Daberas deposit is used to produce a screened product for the Mobile DMS facility used in the 'hub/outlet' portion of the deposit on the Orange River.

Successful introduction of the mobile wet in-field system in Mining Area 1, in the 3 Plant area, has reduced the replacement requirements of the load and haul fleet. The non-grade bearing ore is removed close to the source and only screened product is transported to the plant.

Marine mining within the Atlantic 1 licence area

De Beers Marine Namibia was established in 2001 to replace the production responsibilities previously undertaken by De Beers Marine SA.. De Beers Marine SA is based in Cape Town to continue with the development of mining tools and techniques for the marine environment. In addition, De Beers Marine South Africa has the responsibility for marine exploration activities.

De Beers Marine Namibia has 5 drill ships and a 'crawler' vessel:

- ➤ MV Grand Banks
- ➤ MV Atlantic
- ➤ MV Pacific
- ➤ MV Douglas Bay
- ➤ MV !Gariep
- ➤ MV Ya Toivo

Table II

Contractor mining statistics

	Square metres mined		Carats produced	
	2002	2003 (Bud)	2002	2003 (Bud)
DBMN	2 507 634	2 518 965	506 804	500 000
Beach and Marine	–	–	72 181	99 500

Figure 17—MV Pacific leaving Cape Town

Figure 18—MV Ya Toivo

The MV !Gariep has recently been converted to a drill ship and will be returned to service in the last quarter of 2003. The MV Ya Toivo was purchased earlier this year. The vessel operates with a large sub-sea crawler weighing in at 238 tons. The crawler uses a horizontal attack methodology to mine areas of sea floor. The system allows for improved areal mining rates relative to the drill ships. Visualization systems allow accurate production monitoring and depletion of the resource

The mining system used on the drill ships consists of a large rotary drill bit suspended from a tower on the vessel, through a moon pool. The cutters on the disc are also assisted by water jetting to increase efficiency. Gravel is brought to the surface using an airlift system, with full recovery being affected on board the vessel in a high security, hands-free environment. A compensation system is used to exert constant pressure on the drill bit, allowing continuous operation in swells reaching 7–9 m. Production rates of around 150 m/hour of areal clean-up are currently possible for the large drill bits. Considerable productivity improvements have been achieved using water jetting techniques in the past few years. These improvements followed considerable development in the De Beers Marine testing facilities in Cape Town and Stellenbosch.

Future mining activities

The following factors have to be considered when contemplating the future of the Namdeb operation:

- declining grade of land-based resources
- declining stone size of land-based resources
- technology challenges
- large volume, but low grade overburden resources
- socio-economic influences
- remote mining operations
- lack of infrastructural development in certain areas of the Sperrgebiet
- environmental sensitivity of the Sperrgebiet
- provisions of the shareholders’ agreement
- macro-economic influences

Despite Mining Area 1 being the mainstay of Namdeb’s production over many years, plant closures have already occurred and will continue over the next few years as ‘virgin’ resources are depleted.

There are, however, very large volumes of low grade resources, namely overburden dumps and tailings dumps available for further mining in Mining Area 1. The Strategic Business Plan is, however, predicting an increasing portion of Namdeb’s carat production being generated from the Marine resource. Conceptual and feasibility studies are underway to consider mining the remaining Orange River deposits, the Elizabeth Bay deposits, and both the few remaining virgin and overburden resources in Mining Area 1.

Elizabeth Bay

Elizabeth Bay mine operates south of Luderitz in a south-facing embayment. The deposit has been mined for the past 11 years based on the aeolian deposit. Mining of large areas also took place on this deposit at the start of the 20th century. Recent exploration indicated that the geological factors responsible for the deposit were more complex and other geological facies existed which would extend the life of mine. Mining of the aeolian deposit is scheduled to be completed by mid-2004, after which the newly constructed Liberation plant would treat the full geological ‘package’ of:

- sand
- clay
- cementation
- wet or saturated material

The system will employ a wet gyratory crusher system (the first of its kind on this scale in the world) to treat the entire geological sequence. Extensive test work was undertaken in Japan using material from Elizabeth Bay. The project will extend the life of the operation by a further 10 years and exploration is still continuing to determine the full extent of the deposits. Detailed life of mine planning and short-term scheduling of activities have and continue to be undertaken on the deposit to ensure adequate blending of all the ore types to the plant.

Mining the resource would need a unique suite of equipment to handle a variety of factors such as:

- sandy gravel lenses
- clay
- water-logged gravel
- cementation (0.1 to 2 m thick intermittent lenses)
- bedrock
- moving dune fields

Pocket beaches

A pocket beach is defined as a sediment-filled embayment flanked by rocky headlands. Fourteen prospective pocket beach sites (Sites 1 to 10, 10A, 10B, 11 and 12) have been the subject of exploration and sampling activities over the past few years. Although fairly small relative to the linear beach deposits in the south, these deposits are of higher grade due to the concentration of gravel in the embayments from historic tidal activity. These sites are located 120 km north of Oranjemund along the coast, with limited infrastructural development in the area.

The first of the pocket beaches at Site 2 (north of Chameis Bay, 140 km north of Oranjemund) will be developed in early 2004 to start production in the second quarter of the year. The second phase of the project may involve a dredging or wet mining technique and is currently the subject of a full feasibility study.

Further work is continuing on the other pocket beaches to determine an optimum system. The area is within a harsh environment and pristine beauty and environmental sensitivity combined with a lack of basic infrastructure makes mining challenging.

Second dredge

A second dredge is being considered for the extreme south of Mining Area 1 in an area previously abandoned due to the volume of water inflow. If feasible, this project would allow the extraction of both basal gravels and the overburden spoils left from the bucket wheel system up to the –4 m amsl contour line. The gravels 'sterilized' by the sea walls would also be mined. Beach evolution modelling has shown that significant accretion can be expected immediately off the coast allowing up to 300 m of mining to take place in a westerly direction using the dredge. The estimated life of mine for this project is at least 10 years with upside potential if mining can take place in the accreted area. A challenge for this project is the establishment of a suitable resource in accordance with SAMREC guidelines.

Visualization techniques providing a degree of confidence for depletion efficiency remain elusive despite their use in the offshore environment. A parametric sonar sub-bottom profiling system has been installed on the existing dredge. The technique allows the operator to visualize gravel lenses in relation to the cutter head and react accordingly. The system was motivated to minimize the dilution or undermining by the dredge and to provide the operator with a tool to 'see' what was being mined or whether depletion had taken place.

Tailings dumps

Large volume, but low grade tailings dumps have been established at the major treatment plants within Mining Area 1 during their lives. Depending on the processing techniques available at the time, especially for conglomerate treatment, the dumps now have the potential for continued diamond extraction. A mobile liberation test plant has been introduced allowing the optimal crushing size to be determined. Once established, the grade of the resource may need to be modified and a suitable technique will be developed.

Mining techniques, which may be employed, are:

- front-end loaders (load and carry)
- pumping and water monitoring
- bucket wheel excavator loading
- remote mining techniques

Dry overburden mining

Conceptual studies have shown that it may be economical to mine the very large volumes of overburden in Mining Area 1. The resource was generated by the stripping operations which employed either scraper, excavators or bucket wheel excavators. Gravel lenses within the overburden were not considered economical at the time and stripping sometimes removed the top contact of gravel. Two distinct areas, North and South, are found within Mining Area 1 and a feasible mining system will provide an opportunity to treat the area and profile it to suit rehabilitation and closure requirements. A suitable dry screening system, which allows large volumes of sand to be treated, is required and investigations are continuing. A roller screen operating at a very fine aperture has been tested in Mining Area 1.

Inshore

A potentially large resource exists between the area mined onshore and the Atlantic 1 licence area. This is unfortunately the area with the highest energy levels (i.e. surf zone), and a suitable technique using the energy or withstanding the energy of the sea should be developed. A jet-pumping technique to clean gravel filled gullies has been developed. A simple concept of hydraulic excavator and jet-pump has been used and followed with the jet-rig, which has two operating arms.

Figure 19—The jet-rig in operation

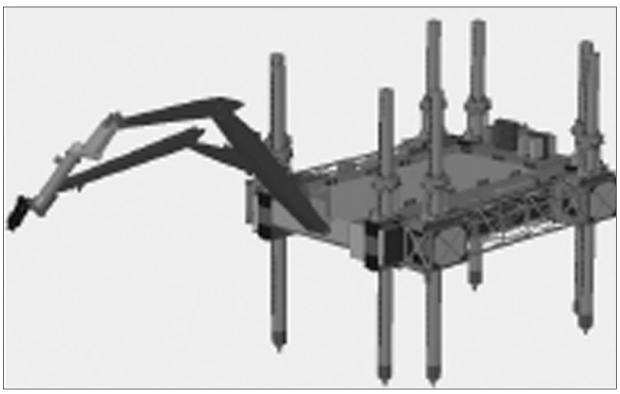


Figure 20—Computer image of the mobile jet-rig

Figure 21—A large hopper-suction dredger

The jet-rig is still in a research and development phase with design of a walking mechanism and 'visualization' system currently taking place. The system will sample the area between the western limit of conventional mining and the low water mark. Evolution to a full mining system is envisaged with screened gravel possibly being pumped to a shore-based DMS facility. A concept of multiple systems mining and discharging to a central processing plant is being considered.

A jack-up platform, the 'Sea-walker' is planned to operate within the near shore zone from early 2004. The system will firstly test the technique of walking in the surf zone. Secondly, it would be used for sampling the area off the coast using specially designed sampling/mining tools and finally testing the concept of a mining platform. The technique is exciting, offering many opportunities and the potential mining concept will be refined after testing.

Mud belt and low grade marine resources

A portion of the Atlantic 1 resource and the area between Atlantic 1 and Mining Area 1 is potentially 'sterilized' due to the occurrence of the 'mud belt'. This has taken place over a number of years of Orange River activity where fine silt, clay and organic material have covered gravel terraces. Large hopper suction dredgers may provide a technique to remove the 'overburden' and discharge it, and collect the gravel for discharge onto land. Vessels can now dredge effectively to depths in excess of 100 m. Conceptual work is being undertaken at this stage with DBMN.

Conclusions

The unique geology in this area and lower grade material remaining will require newer lower cost mining and processing methods. Underwater mining technology will also require 'visualization' systems to be developed. DBMSA and Namdeb are developing these techniques at the moment. The company has been able to persevere in the most trying conditions and a considerable challenge exists over the next few years to ensure the sustainability of operations.

The company's strength is in its people and the intellectual capital residing in them. The future of this great company will depend on the knowledge transfer from its human gems, the embracing of all aspects of diversity, stakeholder support and a sound value system. Namdeb's values are:

- ➤ *Teamwork*—harnessing the knowledge of the Namdeb team
- ➤ *Integrity*—eliminating theft of our valuable product and maintaining the highest ethical standards
- ➤ *Care*—the company is the sum of all its human gems which entails that care should come from within and healthy relationships be developed throughout the organization
- ➤ *Excellence*—intelligent utilization of the physical, intellectual, financial, production and material assets to maximize the use of the available geological resource.

Ingenuity and best business practice, tempered by lessons from the past and present activities, will ensure Namdeb's longevity. Our company slogan is 'On Diamonds we build'; we believe this is possible if all aspects of our business are aligned and focused on a common journey to ensure sustainability aligned with triple bottom line thinking—our environment, our society and a healthy contribution to our shareholders.

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