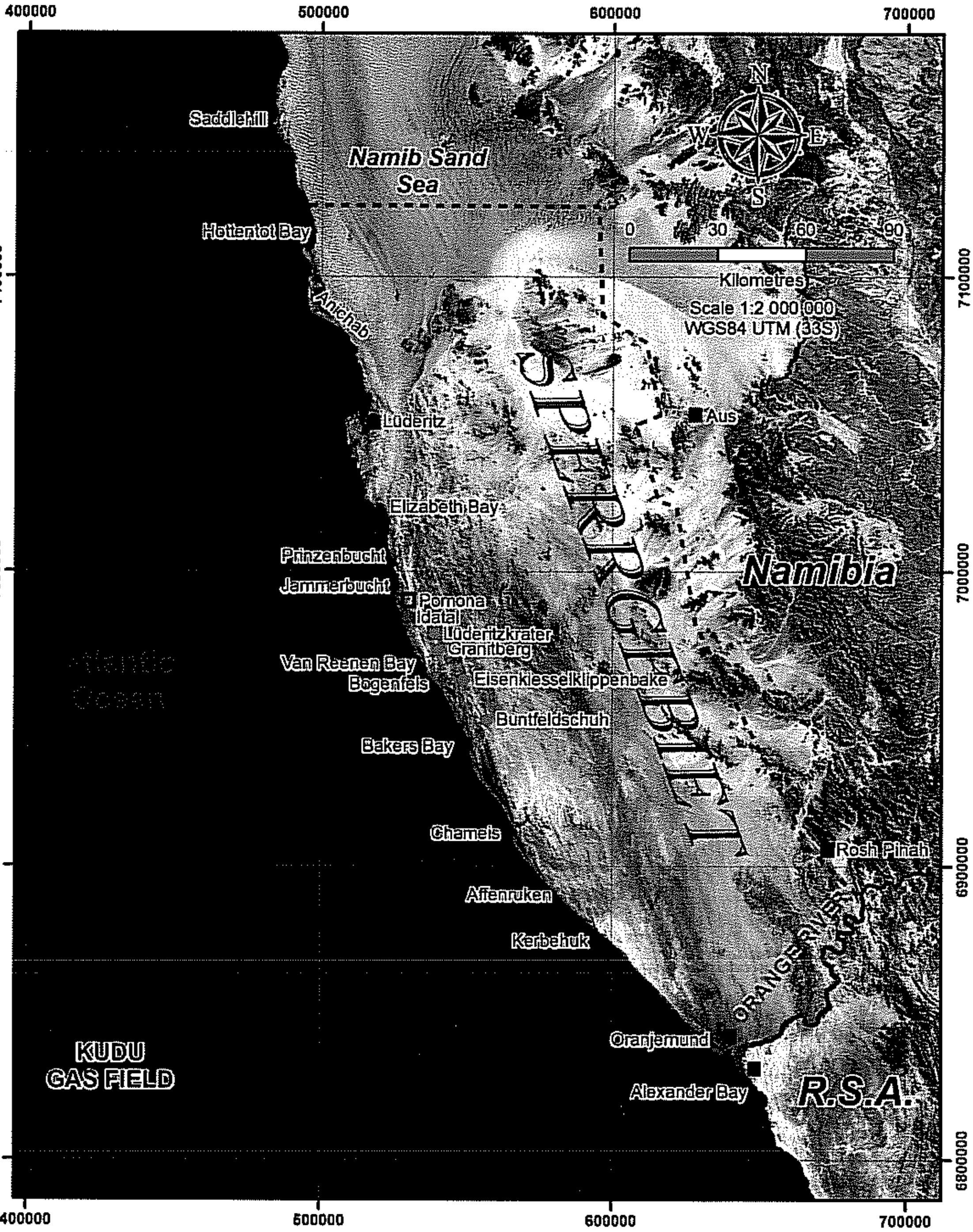
NAMDEB

ON DIAMONDS WE BUILD

Field Guide to the Northern Sperrgebiet

Geological Society of Namibia visit – 24 to 27 July 2008



Compiled by: Andre Oelofsen & Urban Burger

1. INTRODUCTION

With the break-up of West Gondwana approximately 120 million years ago, the southern Atlantic Ocean opened up between the continental masses of South America and Africa. Erosional processes transported sediments from the interior where they were deposited along the coast on the continental shelf (Bremner *et al.*, 1990; Dingle & Hendey, 1984; Dingle & Scrutton, 1974). As a result of sediment accumulation, the shelf is relatively wide at the Orange River Mouth where the -200 m isobath is situated approximately 120 km west of Oranjemund. Moving away from the point source of sediment supply, the continental shelf narrows so that 250 km northwards the -200 m isobath is situated approximately 45 km west of Lüderitz.

Since the late Cretaceous/early Tertiary the west coast of southern Africa has largely been a passive margin (De Wit, 1999; Van der Wateren & Dunai, 2001). Events of continental uplift occurred during the Early Tertiary, the Miocene and the late Pliocene/early Pleistocene (Partridge & Maud, 1987; Jacob *et al.*, 1999; Wigley & Compton, 2006; Bluck *et al.*, 2007). The uplift resulted in increased amounts of erosion and fluvial transport of sediments to the western margin. Global changes in sea-level (*eustatic change*) resulted in the shoreline slowly retreating from the land (*regression*) during cold periods of glaciation when water from the world's oceans were accumulated and locked-up in ice caps. When warmer periods ensued, the ice caps melted and released water into the oceans resulting in relatively rapidly rising sea levels with shorelines encroaching on the land (*transgression*). Large volumes of sediment transported by the Orange River would be deposited seaward from where the river enters the sea (Bremner *et al.*, 1990; Dingle & Hendey, 1984; Dingle & Scrutton, 1974). During a regression this would be further out on the shelf and during a transgression it would be closer to the landmass (Pickford & Senut, 2002). Several cycles of glaciation and melting have resulted in the coastal shelf, and the sediments deposited on it, either being submerged or exposed to wind driven (*aeolian*) and coastal fluvial processes.

Diamonds occur along the western coast of Southern Africa, starting in the south from the mouth of the Olifants River to Angola in the north. It is generally accepted that the diamonds found along the southern Namibian coast originated predominantly from Cretaceous aged diamondiferous kimberlites in the interior of Southern Africa. These diamonds were released from the kimberlites through weathering processes and a significant proportion of them were carried towards the western margin of the continent by streams and rivers entering the Atlantic through the Orange River (Bluck *et al.*, 2005 & 2001; Pether *et al.* 2000; Jacob *et al.* 1999; Corbett, 1996; De Wit, 1999 & 1996; Apollus, 1995; Khuns, 1995). There is also a school of thought that suggests that a substantial portion of the West Coast diamonds originated from pre-Karoo kimberlites which were then transported from the interior of Southern Africa via Dwyka glaciation and then redistributed into the fluvial system after weathering of tillite deposits (Moore & Moore, 2003). After exiting the Orange River mouth the winds, currents and wave action distributed the sediments containing the diamonds largely northward along the coast (Bluck *et al.*, 2005; Bremner *et al.* 1990; De Decker, 1988, Rogers, 1977) (Figure 1). During prolonged sea-level stand-stills at various elevations, diamonds were concentrated in gravels and other trapsites to form placer deposits. If not protected by being covered by other sediments or a cemented horizon, these placers were often re-worked during subsequent transgressions and other erosional processes. Subsequently, the southern coast of Namibia hosts one of the world's two known diamond megaplacers i.e. ≥ 50 million carats at ≥ 95% gem quality (Bluck *et al.*, 2005; Hallam, 1964).

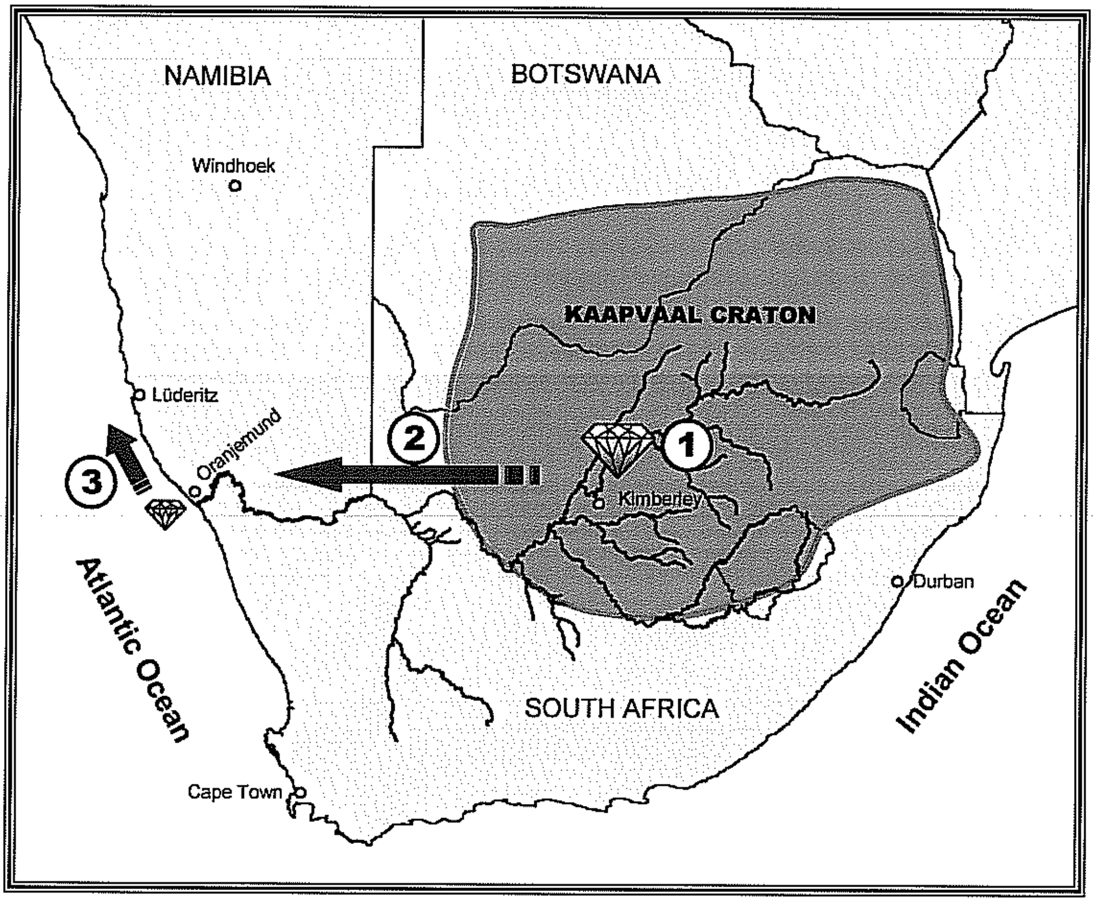


Figure 1: Transport of diamonds from source to sink simplified (1). Diamondiferous kimberlites emplaced on the Kaapvaal craton predominantly during the Cretaceous. Post-emplacement denudation and accumulation of diamonds occur. (2) Uplift of the interior of southern Africa results that a significant proportion of accumulated diamondiferous sediments are flushed to the coast through the Orange River drainage system in 2 major pulses. The first during the Miocene, which gave rise to the Proto-Orange Gravels, and the second during the late Pliocene/early Pleistocene forming the Meso-Orange River Gravels. (3). Transport of diamonds northward through wave action, longshore drift and wind action. Transport result in a well sorted, 95% gem quality, diamond population at West Coast.

The discovery of diamonds in Namibia has been accredited to a railway worker Zacharias Lewala, who in 1908 found the diamond while shovelling sand at Kolmanskop (Figure 2). Not knowing the significance of his discovery, Lewala handed over the "pretty stone" to the Railway Supervisor, August Stauch (Levinson, 1983). Unnoticed, Stauch proceeded to peg off large claims. It was only after the news of the discovery of diamonds at Kolmanskop was confirmed two months later by Dr. Range, the Government Geologist, that the news was spread by the media and Lüderitz was engulfed in a wave of prospectors and fortune seekers (Oppenheimer & Williams, 1914).

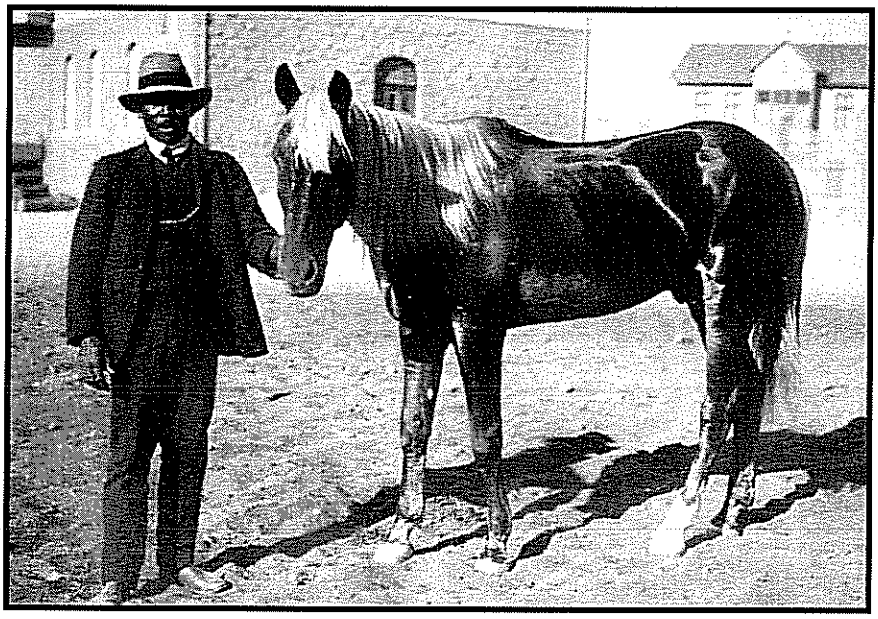


Figure 2: Zacharias Lewala who reportedly found the first diamond at Kolmanskop in 1908 while employed as a railway worker (Photo: Namdeb Archives).

Shortly after, in 1909, the German colonial government declared a 120 km wide strip along the coast as "*Sperrgebiet*" (*Forbidden Territory)*, to keep illegal miners and prospectors at bay. To this day entrance into this area remains controlled and can only be entered with a permit issued by the Ministry of Mines & Energy. Mining commenced in earnest in 1909 when the *Koloniale Bergbau-Gesellschaft*, in which August Stauch was the majority shareholder, commenced operations at Elizabeth Bay in what turned out to be the world's largest aeolian diamond placer (Oppenheimer & Williams, 1914). Between 1909 and 1921 approximately 6.7 million carats were mined from the thin superficial deposits in the wind swept coastal valleys between Kolmanskop and Bogenfels.

After the termination of World War One in 1918, South Africa took over the mandate of South West Africa from the German colonial government. In 1921 the Anglo American Corporation amalgamated 9 independent diamond companies to form the *Consolidated Diamond Mines of South West Africa* which later became *Consolidated Diamond Mines* (CDM). By 1941 the bulk of the deflation deposits mined in the northern portion of the Sperrgebiet were depleted and the *Consolidated Diamond Mines of South West Africa* headquarters, and mining focus, were moved from Lüderitz to Oranjemund (Corbett, 2002).

2: COASTAL DIAMOND PLACER DEPOSITS

Marine, fluvial and aeolian processes shaped the diamond placers along the coast of the Sperrgebiet into 4 broadly classified types namely linear beaches, pocket beaches, deflation deposits and aeolian deposits (Figure 3).

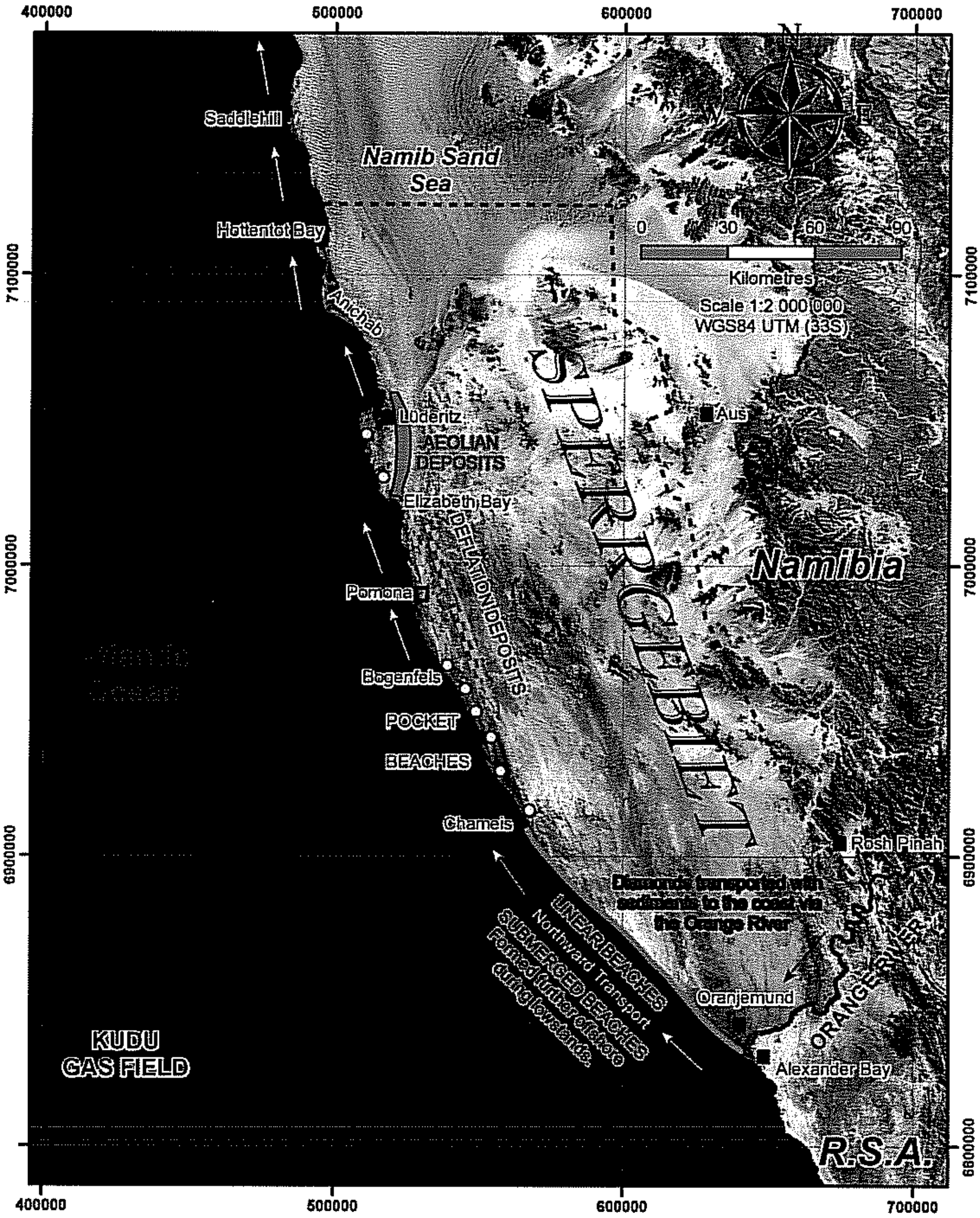


Figure 3: The 4 major diamond placer types found along the coast of the Sperrgebiet are linear beaches (on land and submerged), pocket beaches, deflation deposits and aeolian deposits (Source: Namdeb Archives).

- **Linear beaches**: The Plio-Holocene raised gravel beach complex (Hallam, 1964) is comprised of 6 shingle and basal conglomerate beaches and is partly covered by marine and aeolian sands which resulted in their preservation. Between the Orange River Mouth and Affenrucken, 100 km to the north, the beaches have been deposited on a narrow marine abrasion platform. The width of the shelf varies from 3000 m in the south to less than 200 m in the north and it has been cut by various river channels which have now been filled with silty clays and quartz rubble (Stocken, 1978; Rogers *et al.*, 1990). The 6 beaches have been assigned letters A (youngest and lowest) to F (oldest and highest) for ease of identification (Figure 4). The "Upper Terrace" beaches D, E & F, are characterized by warm-water fossil fauna such as *Donax rogersi* and *Crassostrea margaritacea* (Hallam, 1964; Stocken, 1978). The aggradational fluvial terraces, the Meso-Orange III River Gravels found in the lower Orange valley, are compositionally linked to the D, E & F beaches and the Namaqualand equivalent is the *30 m Package* (Pether, 2008; Pether *et al.*, 2000). It now seems increasingly likely that the 30 m Package was deposited during the mid-Pliocene i.e. older than 3 Ma (Pether, 2008). The "Lower Terrace" beaches A, B & C respectively occur at elevations of 2, 4 & 8 metres above mean sea level (mamsl) in the Sperrgebiet and were deposited from the mid Pleistocene to Holocene. These younger beaches are characterized by modern cold-water fauna and the absence of a red-sand or calcrete capping (Stocken,1978). The Namaqualand equivalent of the A, B & C beaches of the Sperrgebiet is the *Recent Emergent Terraces* comprised of the 2-3 m Package, the 4-6 m Package and the 8-12 m Package (Rogers *et al.* 1990; Pether, 2008).

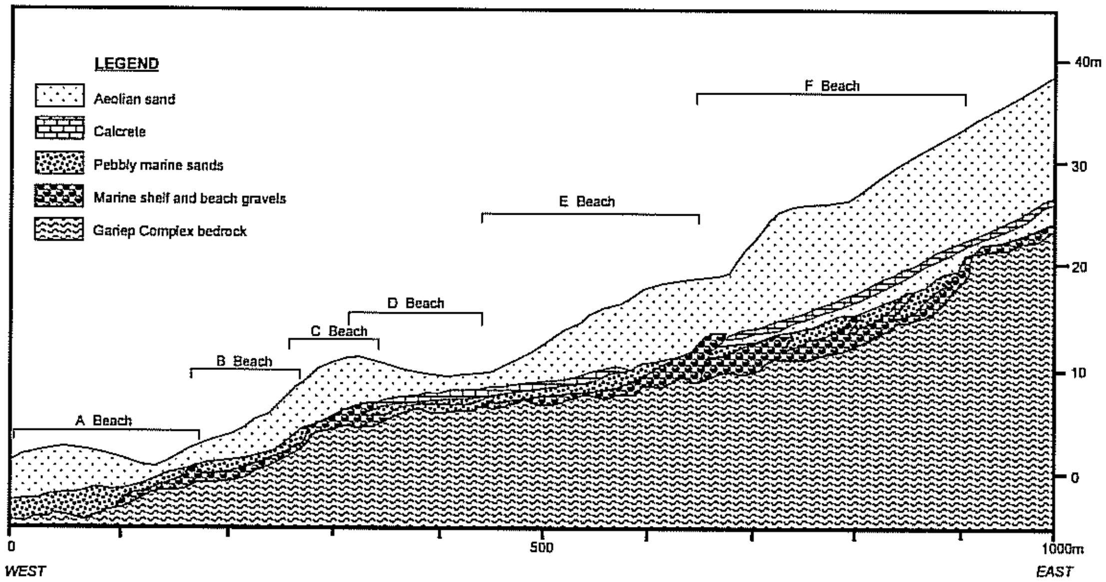


Figure 4: Schematic cross-section of beach terraces identified in Mining Area 1 (Stocken, 1978).

- **Pocket beaches**: Apollus (1995), has shown that the greatest diamond concentration occurred in the northern part of the + 4m beach facies (Eemian age) in the southwest facing pocket beach in Chameis Bay in the Sperrgebiet (Figure 5). It was also shown that diamonds in these intertidal deposits do not necessarily gravitate to the base of the marine gravel sequence, so much so that the beaches themselves contained considerable concentrations of diamonds – not necessitating the presence of shore platform trapsites to concentrate diamonds. However, these raised gravel beaches were most likely to be destroyed during subsequent sea-level fluctuations. In the Chameis pocket beach specifically, the most important factors in diamond concentration in intertidal beach facies are the processes of beach accretion and wave energy levels. Gravel clast size appeared to have played a lesser role in the concentration of diamonds. Several pocket beach deposits of varying grade occur between Chameis in the south and Bogenfels in the north.

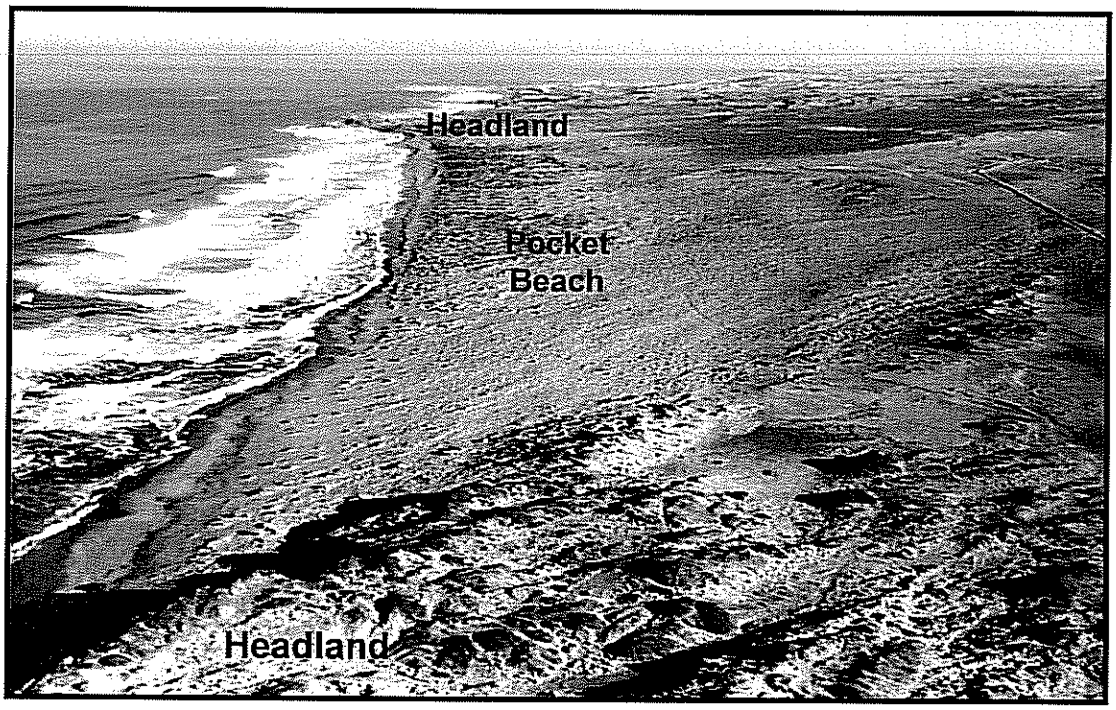


Figure 5: Facing north, the Chameis Bay pocket beach situated between two rocky headlands (Photo: Namdeb Archives).

- **Deflation deposits**: The deflation deposits occur mostly in the "talle" (valleys) of the Trough Namib north of Chameis Bay. Through transgression and regression cycles, shoreline beach sequences were deposited at various levels through time in the current terrestrial setting. Remnants of the "Eocene shoreline" can still be seen at elevations of approximately 170 mamsl at Buntfeldschuh, Eisenkiesselklippenbake, Granitberg and Lüderitzkrater north of Chameis. These Eocene marine beds contain exotic stones such as jaspers, agates, and characteristically common yellow chalcedony and are thought to be the major source of diamonds of the "Northern Areas" part of the Sperrgebiet deflation deposits (Hallam, 1964). During emergent periods, this area was subjected to wind erosion, which combined with favourable basement structures formed north-south bedrock ridges (yardangs) and valleys (yardang troughs), (Rogers *et al.*, 1990; Corbett, 1993). Ephemeral stream action, salt weathering and the aggressive southerly wind regime, transformed the high-volume, low-grade Eocene shoreline through deflation into the legendary deposits encountered by August Stauch in Idatal in 1908 when diamonds were picked up by hand in the moonlight (Levinson, 1983). Remnants of these deflation deposits are still being mined on a small scale by Namdeb contractors in the general Pomona area. To date, no Eocene marine deposits have been found in Namaqualand. Very little evidence remains along the Namibian coast of the *90 m Package* and the *50 m Package* as they have been largely eroded. However, these Packages left their diamond content to be flushed down to lower levels (John Pether, pers. com.).

- **Aeolian deposits**: At present times there are four major coastal point sources supplying sediment to the Namib Sand Sea through transport of dominantly southerly winds, from the south these points are situated at 1.) the Chameis area, 2.) Bakers Bay area, 3.) Van Reenen Bay area and 4.) Prinzenbucht-Elizabeth Bay area (Corbett *et al.*, 1993). These are the current principal feeders of sediment to the main Namib Sand Sea. The worlds largest economical aeolian diamond placer is situated at Elizabeth Bay (Figure 6).

  This area of high sediment flow is particularly important to this study because it is situated at the southern end of the study area. The south-facing re-entrant embayment effectively acts as a headland bypass system whereby sediment is moved from a coastal setting into a terrestrial setting by the wind, and then re-introduced back into the marine coastal environment to the north of Lüderitz.

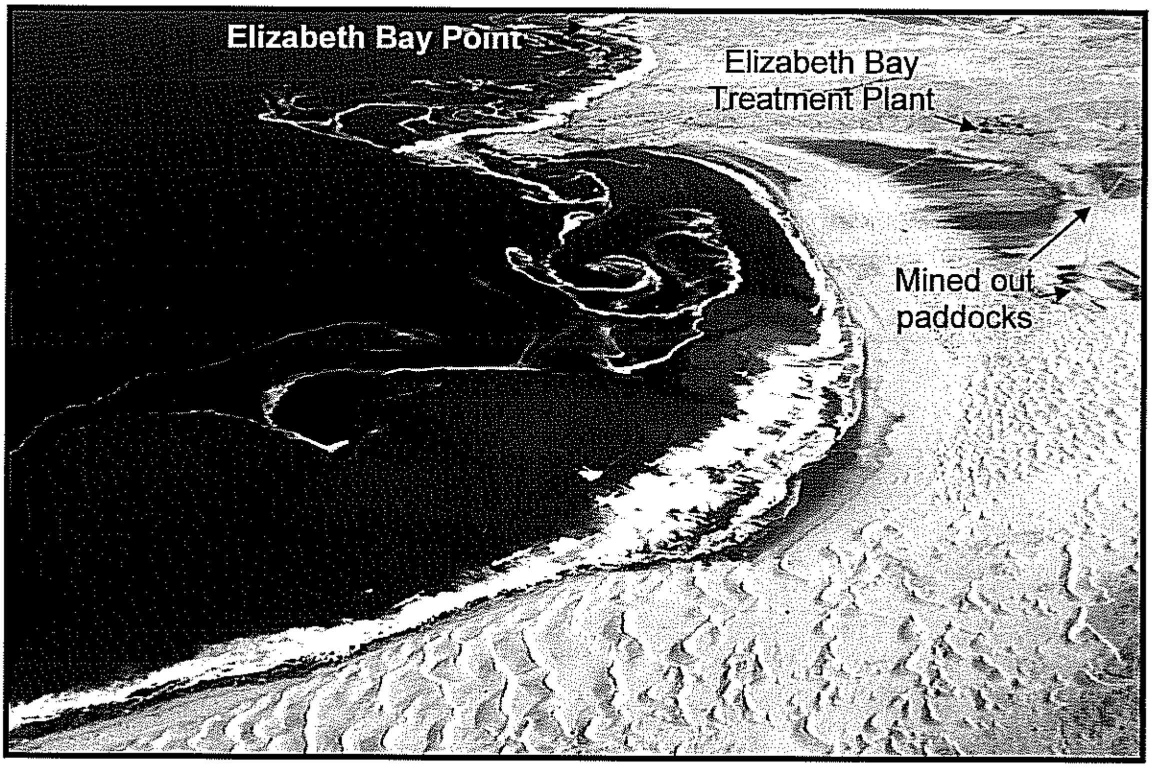


Figure 6: Facing west, an oblique aerial photograph of Elizabeth Bay which is the largest south facing embayment found along the Namibian coast and the location where the world's largest economical aeolian diamond placer is situated (Photo: Namdeb Archives).

3: ELIZABETH BAY MINE

Namdeb's northern satellite mine, Elizabeth Bay, is an opencast operation that has seen three main phases of mining; the last of which continues today (Figure 7). The first phase, undertaken by the Deutsche Kolonialgesellshaft für Südwesafrika (DKG) saw the start of surficial mining in 1911 which abruptly ended in 1915. After World War I, a second phase of mining by Consolidated Diamond Mines of S.W.A., later known as CDM began in the early 1920s and with interruptions in mining operations during the Great Depression and World War II, the mine was finally closed in 1948. The official opening of the Elizabeth Bay Mine in 1991 saw the implementation of the third phase of mining that today continues to produce diamonds 100 years after the first diamond was found.

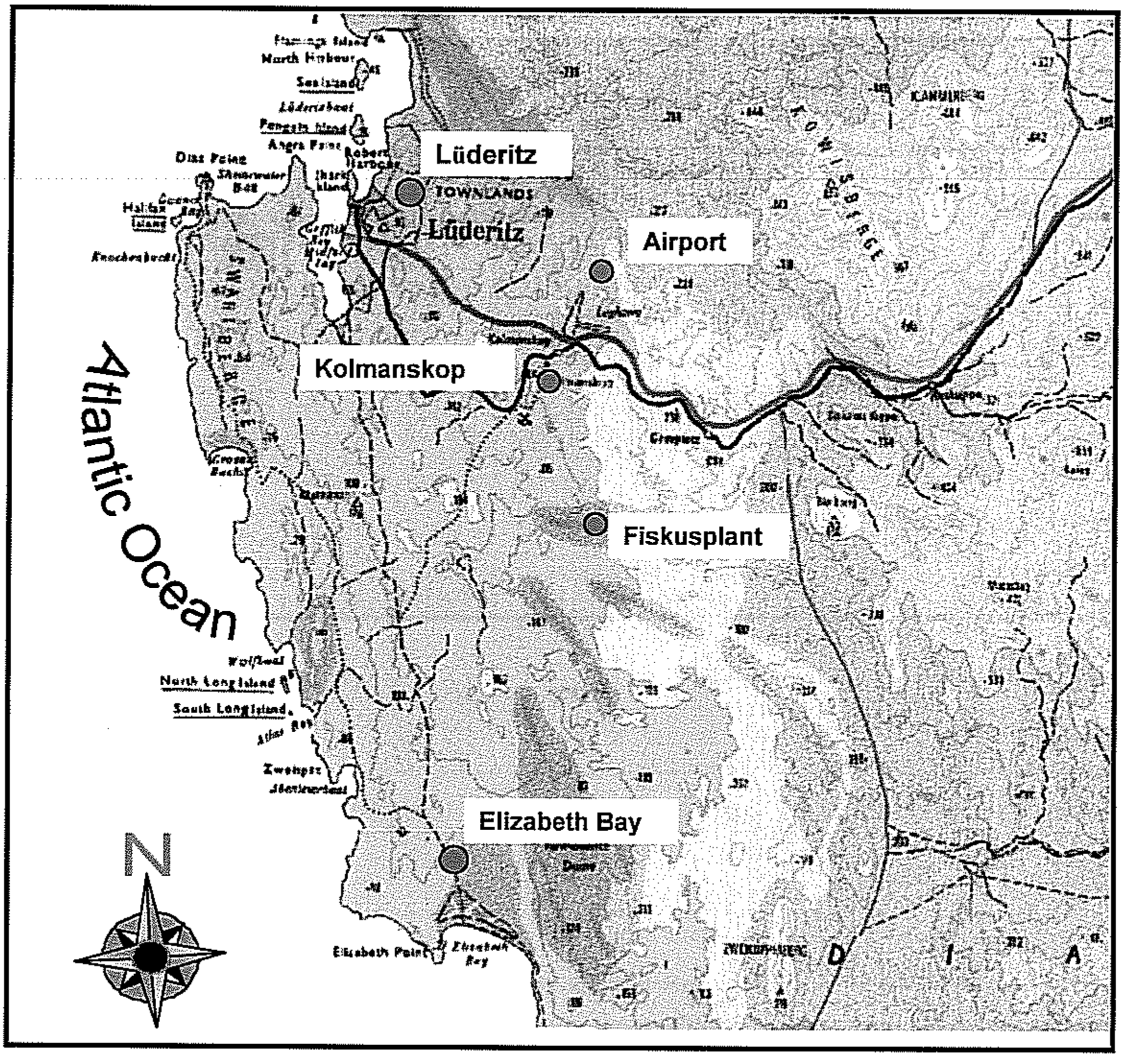


Figure 7: General locality map of the Lüderitz – Elizabeth Bay area.

Geology of Elizabeth Bay

The main part of the Elizabeth Bay sedimentary deposit is surrounded on three parts by rocks (mostly gneiss) of the Precambrian Namakwa Metamorphic Complex and to the south by the Atlantic Ocean (Figure 8).

A prominent valley has been scoured into the basement from the north and extends into the Atlantic Ocean in the south. The Grillental clay beds are defined as green, white and yellow Miocene (Pickford, 1994) dolomite clay deposited under estuarine conditions (Figure 8). The Grillental clay beds overly the gneiss basement rock with an occasional thin (less than 10 cm thick) basal conglomerate of angular, locally derived clasts. The clay has been drilled to a maximum thickness of 40 m. The clay has been found at elevations up to 100 m above sea-level in the eastern part of the mine, indicating high sea-stands at that time. The topmost surface of the clay beds has been scoured with numerous channels draining into a valley that drains into the Atlantic Ocean at the southeastern end of the mine, indicating fluvial erosion during a subsequent drop in sea level.

The Red Beds (or Fiskus Beds) comprise the basal part of the diamondiferous resource at Elizabeth Bay Mine (Figure 8). The red beds are defined as brick red grits and gravel greater than 2mm in average clast size. The red beds consist of fluvial sheetwash gavel and grit that have washed down local valley slopes during flash flood events, as well as aeolian grit. The red beds are well oxidised, hence the red colour.

The Brown Beds lie unconformably over the Red Beds and have a large spatial extent across the whole deposit (Figure 8). The Brown Beds are defined as brown grits and gravel greater than 2mm in average clast size and contain varying degrees of dolomite cementation. The degree of cementation is determined by the permeability of the sediment, with the more permeable sand waste preferentially cemented. The highest degree of cementation occurs in the southeastern part of the mine and in the centre basal parts of valleys, due to groundwater control.

The Grey Beds comprise the youngest topmost sediments of the deposit at Elizabeth Bay Mine (Figure 8). The Grey Beds were extensively mined by the Germans in the early 1900's. Mining and sampling information indicates that the surface deflation units carry the highest diamond grades. The Grey Beds are unconsolidated and spatially extensive, but most of this deposit has been mined out in the last century. The Grey Beds are defined as the grey, topmost, unconsolidated grits and gravel with an average size of greater than 2 mm. Some overburden (<2 mm average size clasts) and internal waste can be found as well).

- **Grey Beds**
  - **Recent, unconsolidated**
- **Brown Beds**
  - **Pleistocene, Predominant aeolian, post depositional CaCO3 cementation**
- **Red Beds**
  - **Pliocene, sheetwash grits, oxidised**
- **Grillental Clay**
  - **Miocene**
- **NMC Gneiss**
  - **Mid-Proterozoic**

Figure 8: General stratigraphy encountered at Elizabeth Bay Mine

4: AEOLIAN TRANSPORT CORRIDORS

Log-spiral embayments like Chameis, Bakers Bay, Van Reenen Bay and Prinzenbucht act as sediment take-off points for the modern day aeolian system (Rogers *et al.*, 1990). Strong, consistent southerly wind regime deflates the beaches and the sediments are transported northward in the form of Barchan dunes and surface sediment creep. These dunes are up to 33 m high and move 60-100 m per year. An Aeolian Transport Corridor (ATC) is defined as a narrow, wind-parrallel zone, about 1-2 km wide, in which sediment is transported by aeolian action. There are 4 major ATCs in the Sperrgebiet (Figure 9). The generation of ATCs are controlled by sediment supply to the aeolian system, which is governed by coastal morphology (log-spiral embayments), which in turn is a function of deflation basin geomorphology and sealevel. ATCs move in conjunction with eustatic fluctuations – parallel to coast (Rogers *et al.*, 1990).

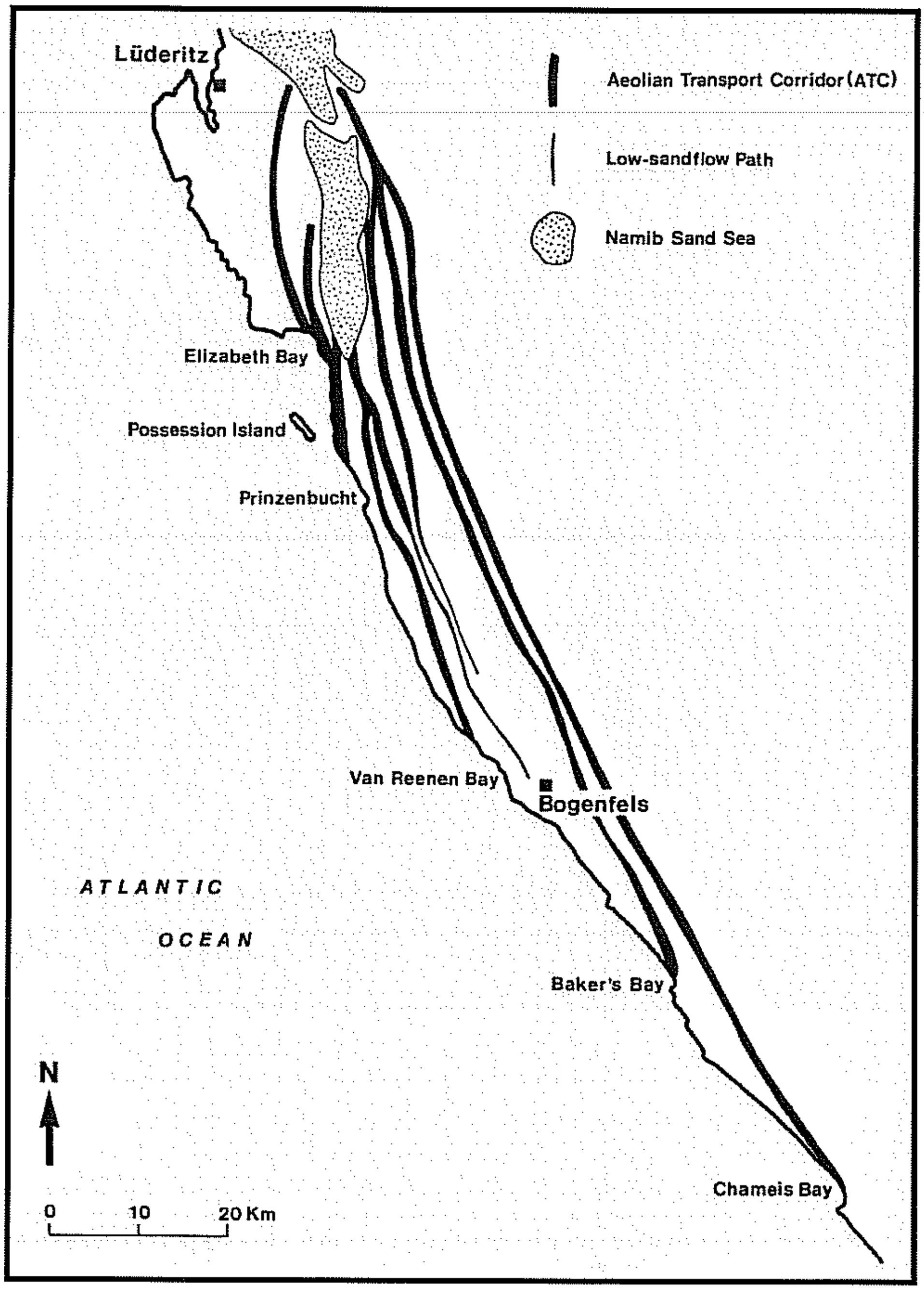


Figure 9: Present-day distribution of the aeolian transport corridors that maintain the Namib Sand Sea (Corbett, 1989).

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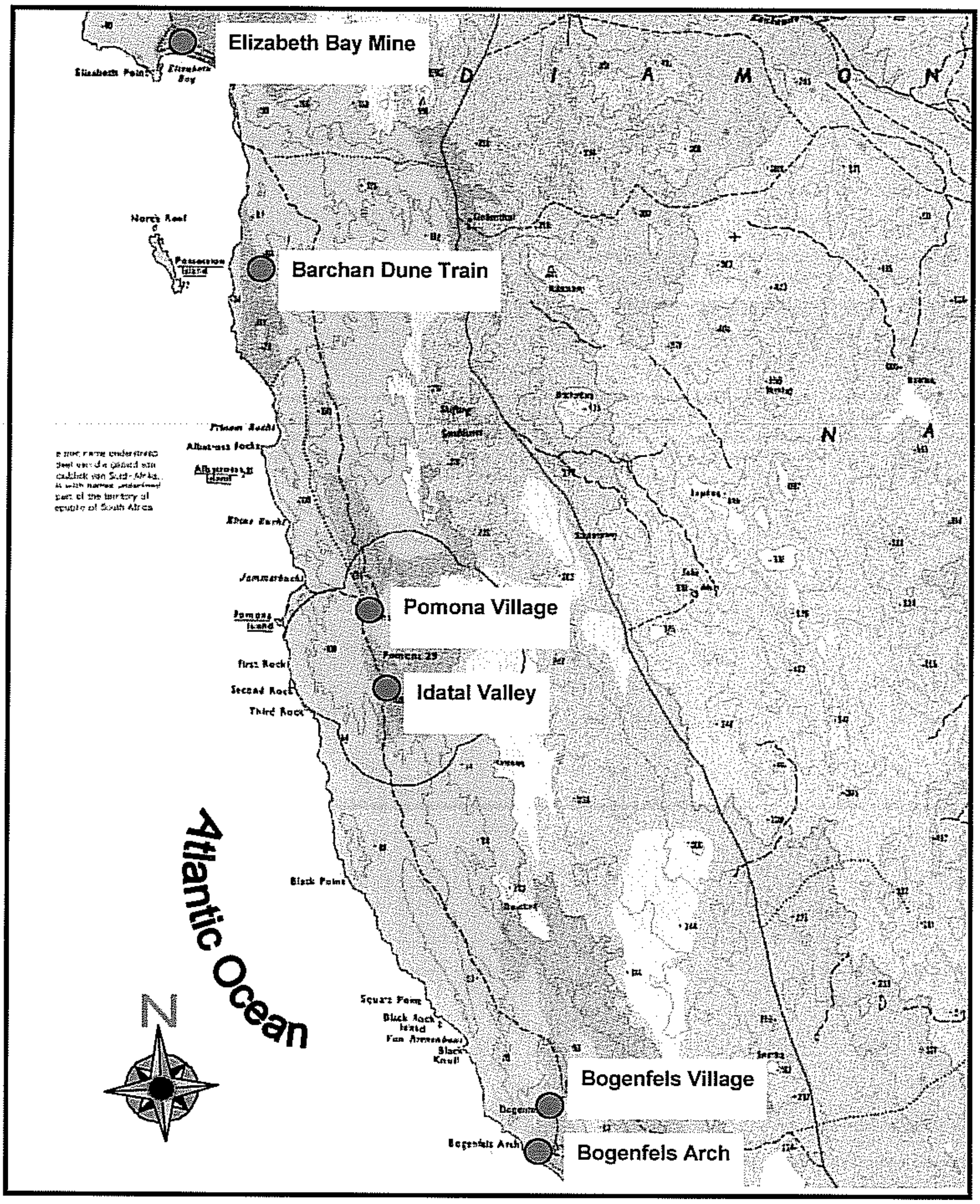
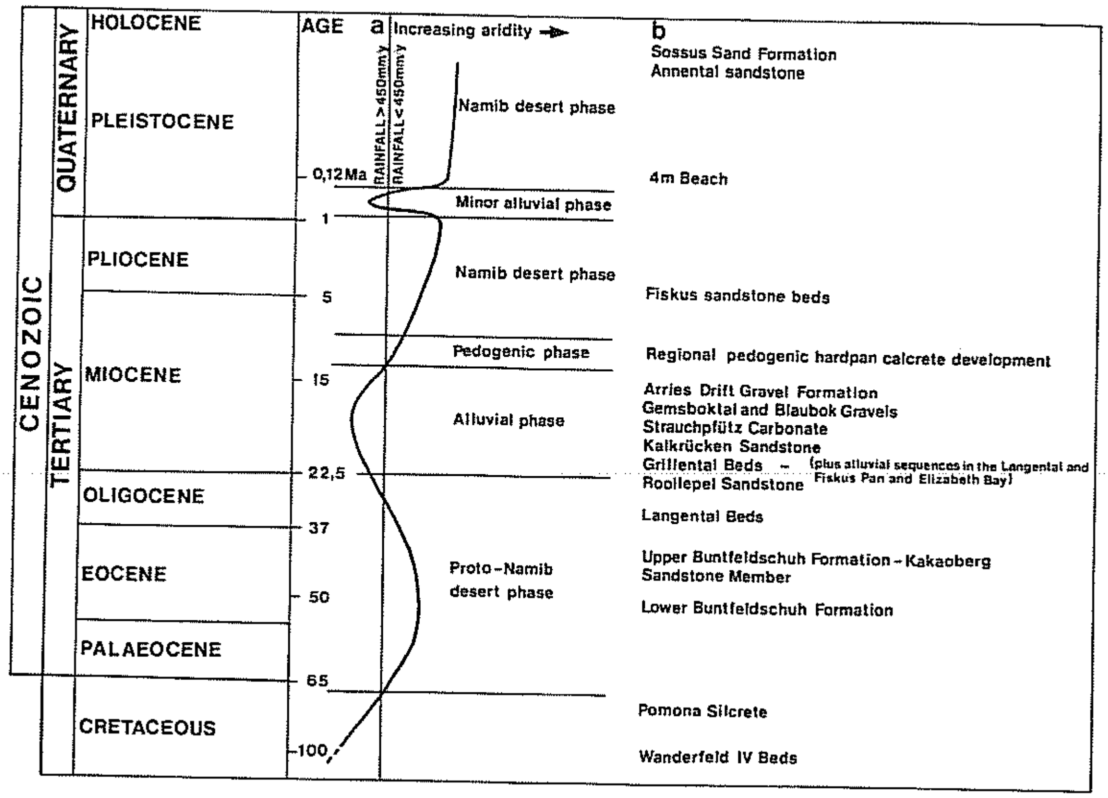
APPENDIX A



General location map (topo).

APPENDIX B



(a) Palaeoclimatic variation in the southern Namib; (b) Cenozoic stratigraphy of the southern Namib (Corbett, 1989).