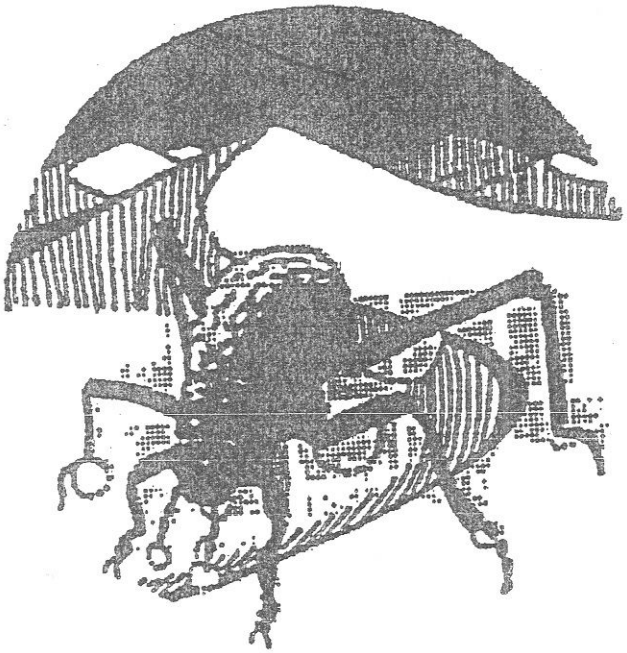
DUNES 2006 EXCURSION
Field Guide



Ecological Aspects of Dunes in the Central Namib Desert

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Illustrations by Christine Marais

Dear Colleagues

This collection of illustrations with its accompanying text dates back about 17 years to an international conference on sand dunes based at Gobabeb. Although the information is dated, the illustrations by local artist Christine Marais remain fresh as ever. We photocopied this material to guide you on your journey to Gobabeb.

Welcome and enjoy the journey.

Background Information

Namibia lies on the south-western coast of Africa between 17° and 19° S latitude. It is bordered on the north by Angola and Zambia, on the east by Zimbabwe and Botswana, on the south by South Africa and on the west by the Atlantic Ocean. Covering some 823 145 km^2, it is nearly four times the size of Great Britain with a total population of 1.8 million. The majority of the people live in rural areas. The largest town, Windhoek, has only 250 000 inhabitants.

In Namibia, four physiographic regions can be distinguished. The Namib Desert, between 80 and 140km wide, extends along the entire coastline. The escarpment, roughly parallel to the coast between 1000 and 2 000+ metres above sea level (*asl*) and the central highlands at 1 500 – 2 000+ metres *asl* constitute the mountainous terrain. The Brandberg is the highest mountain in Namibia, rising to 2 579m *asl*. The northern areas comprise the flat-lying plains of the Cuvelai Basin, including Etosha Pan, the Kavango and the Caprivi Strip. The fourth region is the lower-lying Kalahari Dorstland (Thirstland) to the north-east, east and south-east of the country. The only perennial rivers are found on the borders of the country: the Kunene in the north, the Kavango, Kwando and Zambezi Rivers in the extreme north-east and the Orange River in the south. The watercourses in the rest of the country are ephemeral.

Namibia has an arid to semi-arid climate except in the extreme north-east. Consequently the geological features are generally well exposed. Mean annual rainfall for the country is 270mm – ranging from less than 50mm in the Namib Desert to 350mm in the Windhoek area and to greater than 600mm in the Caprivi Strip (Fig. 2). Summer rainfall predominates except in the south-western corner, which is influenced by Cape winter rains. Fog water precipitation occurs along the coast. Potential average evaporation at Windhoek and Gobabeb is in the order of 3 000 – 3 500mm per annum.

In spite of the subtropical setting of Namibia, temperatures are lower than could be expected. In Windhoek, the average minimum temperature in July, the coldest month, is 6°C and the average maximum is 20°C. In December, the warmest month, the average minimum is 17°C and the average maximum is 31°C. At Gobabeb, the average minimum temperature in September, the coldest month, is 9°C and average maximum is 27°C. In March, the warmest month, the average minimum is 16.5°C and average maximum is 33°C.

The 15 major vegetation types distinguished by Giess (1961) for Namibia can be condensed into 6 groups (Fig.3):

- desert, notably the Namib and Etosha Pan
- dwarf shrub savannah in the south
- savannah, ranging from thornveld to mountain types
- mopane savannah in the north-west
- woodland in the north-east
- riparian woodland and forests along major water courses.

This excursion route traverses thornbush savannah in the Windhoek area, highland savannah across the Khomas Hochland, a transition from drier savannah on the top of the Escarpment to a semi-desert scrub at its base, and desert vegetation in the Namib.

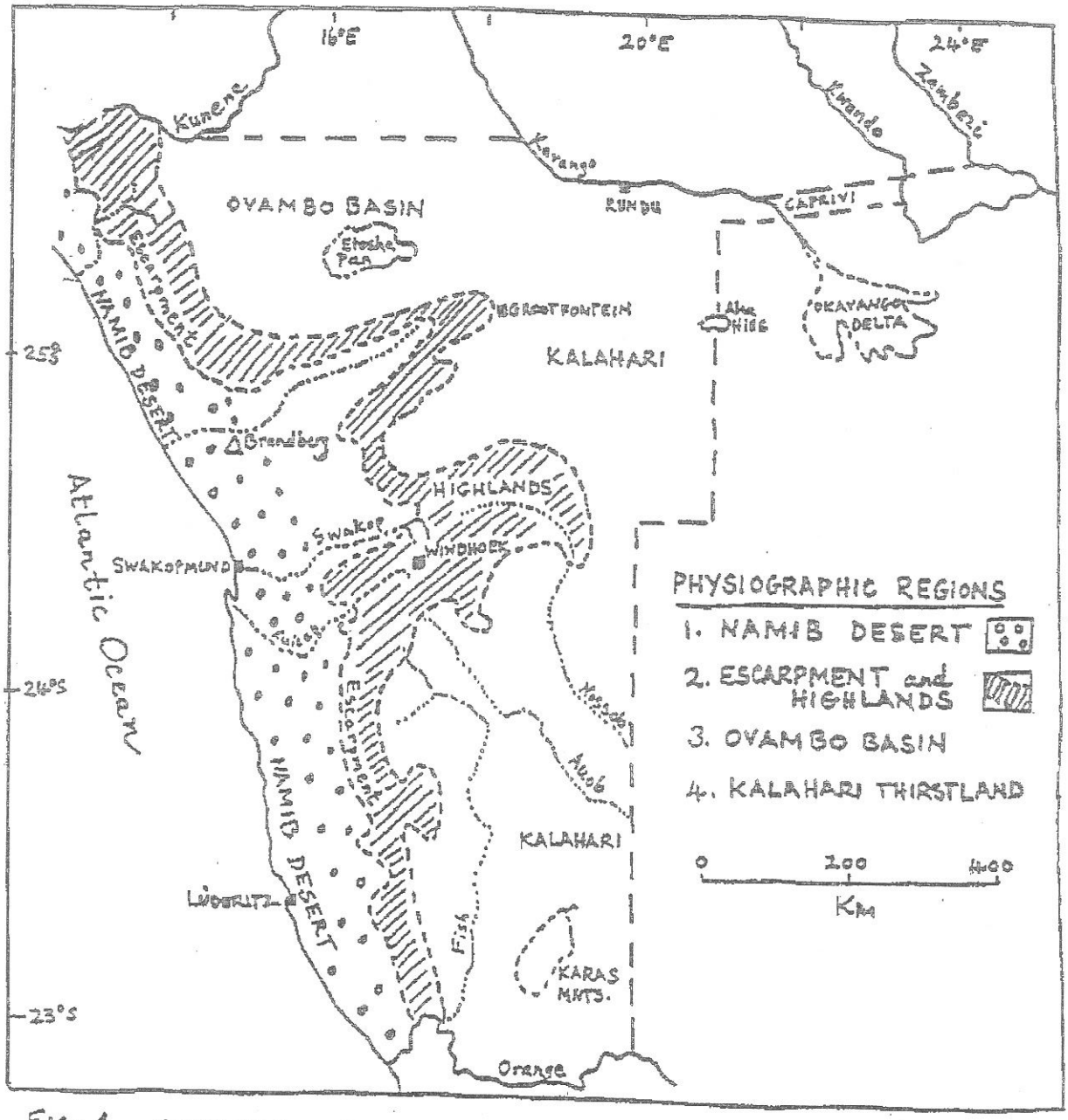


FIG. 1. SIMPLIFIED SKETCH OF MAJOR PHYSIOGRAPHIC REGIONS, NAMIBIA

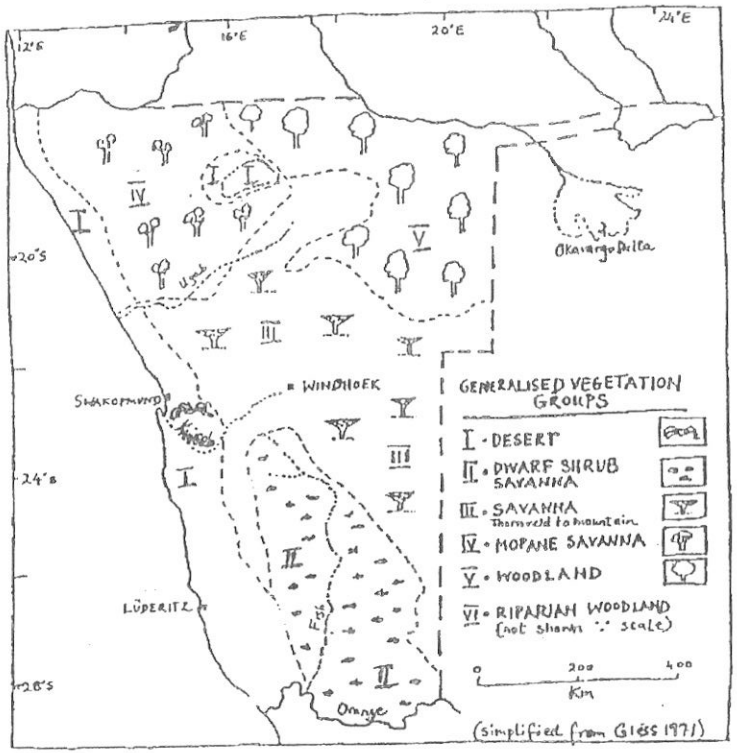


FIG. 3: Simplified Vegetation Map of Namibia

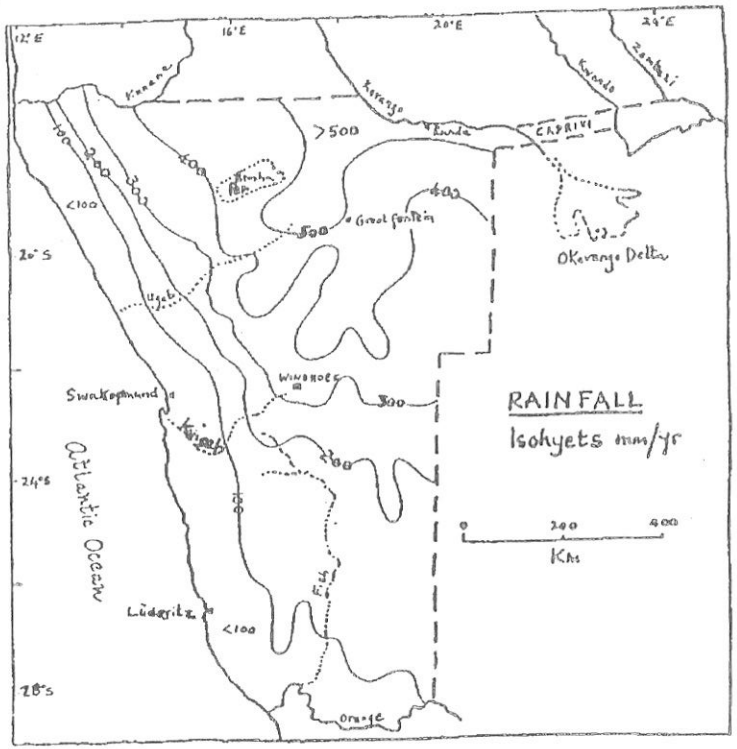
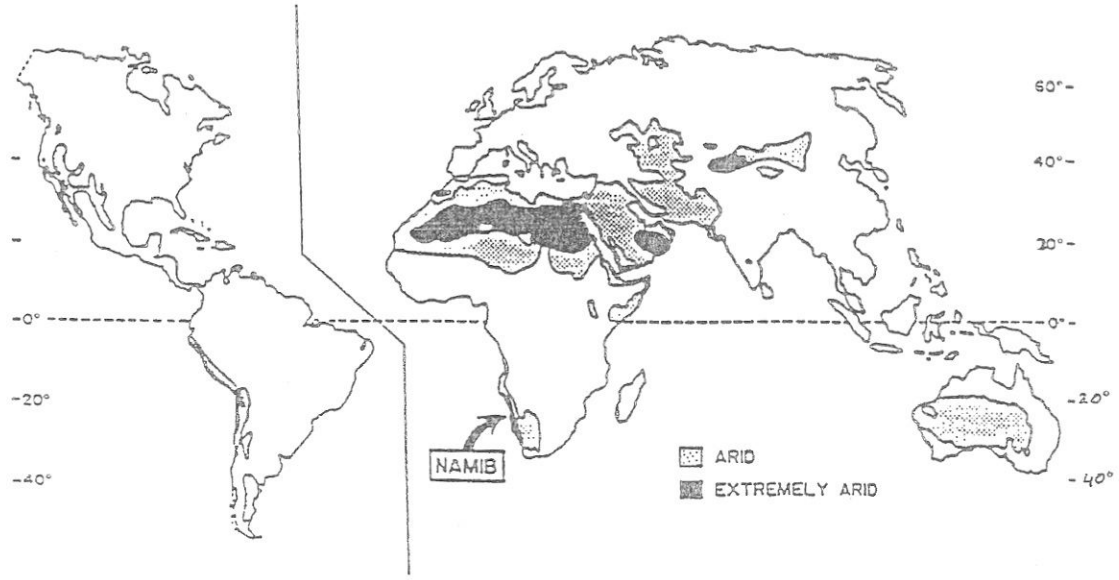


FIG. 2: Mean Annual Rainfall (Isohyets) for Namibia

Namib Desert Overview

The Namib is one of five west coast, low latitude desert regions of the world:



(After Mergs, 1966)

The Namib is a long: >2000km, narrow: <140km wide desert situated west of the Great Escarpment between the Olifants River, Northern Cape Province in South Africa and the Carunjamba River in south-western Angola. The climate of the central section, lying wholly within Namibia is extreme arid (hyperarid) whereas the area north of the Kunene River is classified as an arid summer rainfall desert and that south of Lüderitz and the Orange River an arid winter rainfall desert vegetatively represented by the Nama karoo.

The current desert conditions in the Namib are attributed to the interacting aridifying effects of:

- the subtropical South Atlantic anticyclone, which is usually situated offshore between Lüderitz and around the Orange River mouth
- the absence of convection with temperature inversion in the lower atmosphere
- the divergence of the South East Trades with their associated cold water Benguela upwelling system.

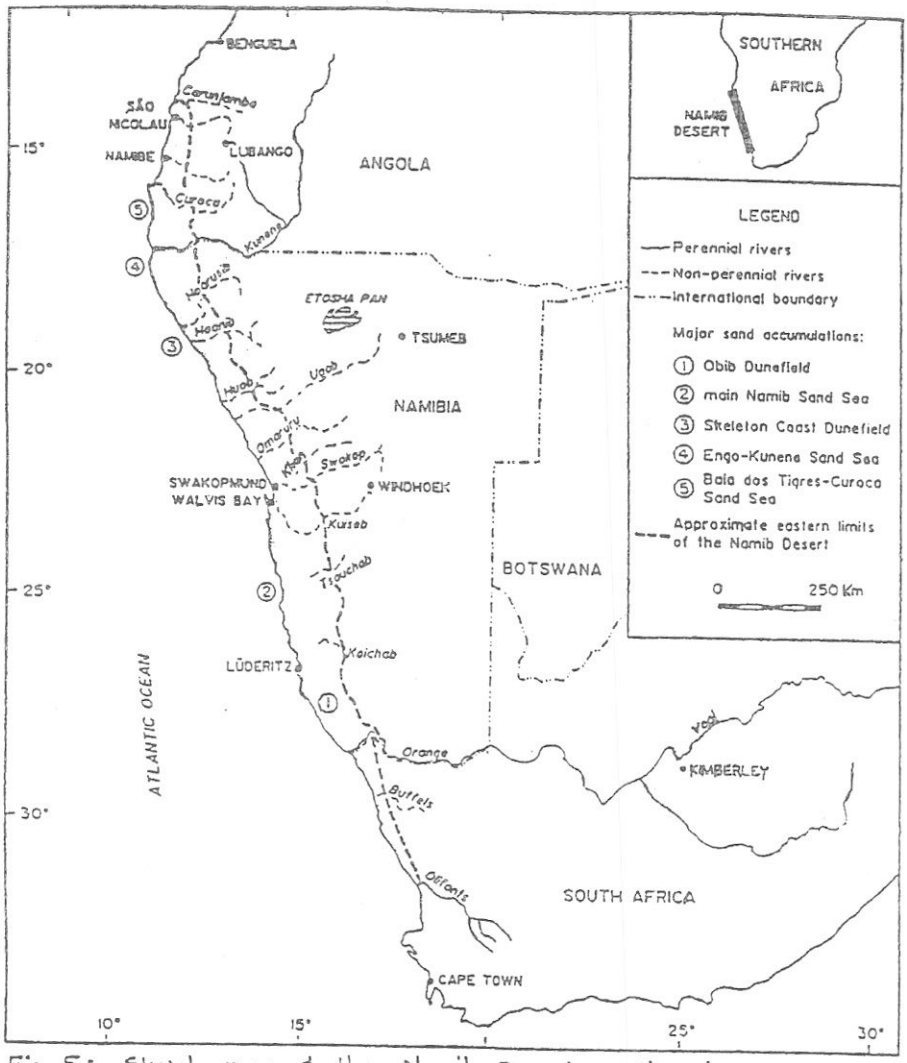
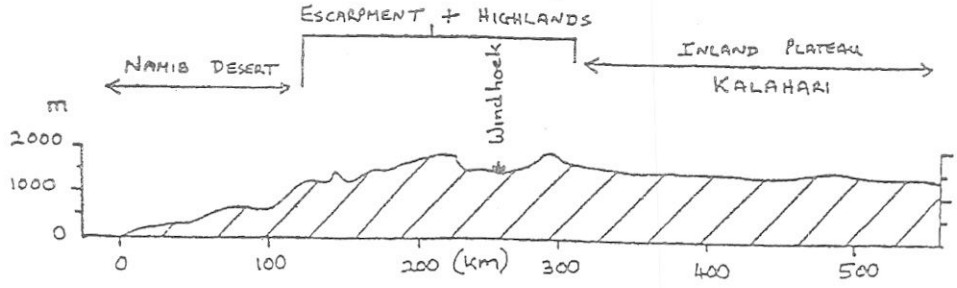


Fig 5: Sketch map of the Namib Desert, southwestern Africa and simplified cross-section of central Namibia



Towards an age for the Namib

(Ward and Corbett, 1989)

The age of the Namib Desert is a controversial issue. This topic has generated considerable debate, particularly since the Cretaceous Age – and thus implied antiquity – advocated by the late Dr Charles Koch (1961, 1962) for the Namib has been challenged by a number of subsequent workers. The alternate options, summarised in Ward et al (1983) cover a broad spectrum of the younger geological time scale, ranging from Oligocene c.35 million years (Ma) ago to Late Miocene c. 10-7 Ma, to Pliocene c.3 Ma ago, as well as into the Pleistocene, which covers the last 1.8 million years.

Thus two main views predominate with respect to the age of the Namib viz.

1. The Namib tract formed by the *Early Miocene* (18-16 Ma) and that the aridity dates back to a maximum age of Middle Miocene (15 Ma ago). For convenience this is called the Miocene model, proponents of which included Siesser (1978, 1980), Tankard and Rogers (1978), Tankard et al (1982), Dingle et al (1983), Partridge (1985), Humbleton-Jones et al (1986), Tyson (1986), Maud and Partridge (1987) and Partridge and Maud (1987).
2. The Namib tract formed by the *Late to End Cretaceous* (80-65 Ma) and that arid to semi-arid climates have since predominated. This is referred to as the Late Mesozoic-Cainozoic or LM-C model. Supporters of this view include Beetz (1926, 1933), Martin (1950, 1961), Stocken (1978), Ward (1984, 1987) and Ward et al (1983).

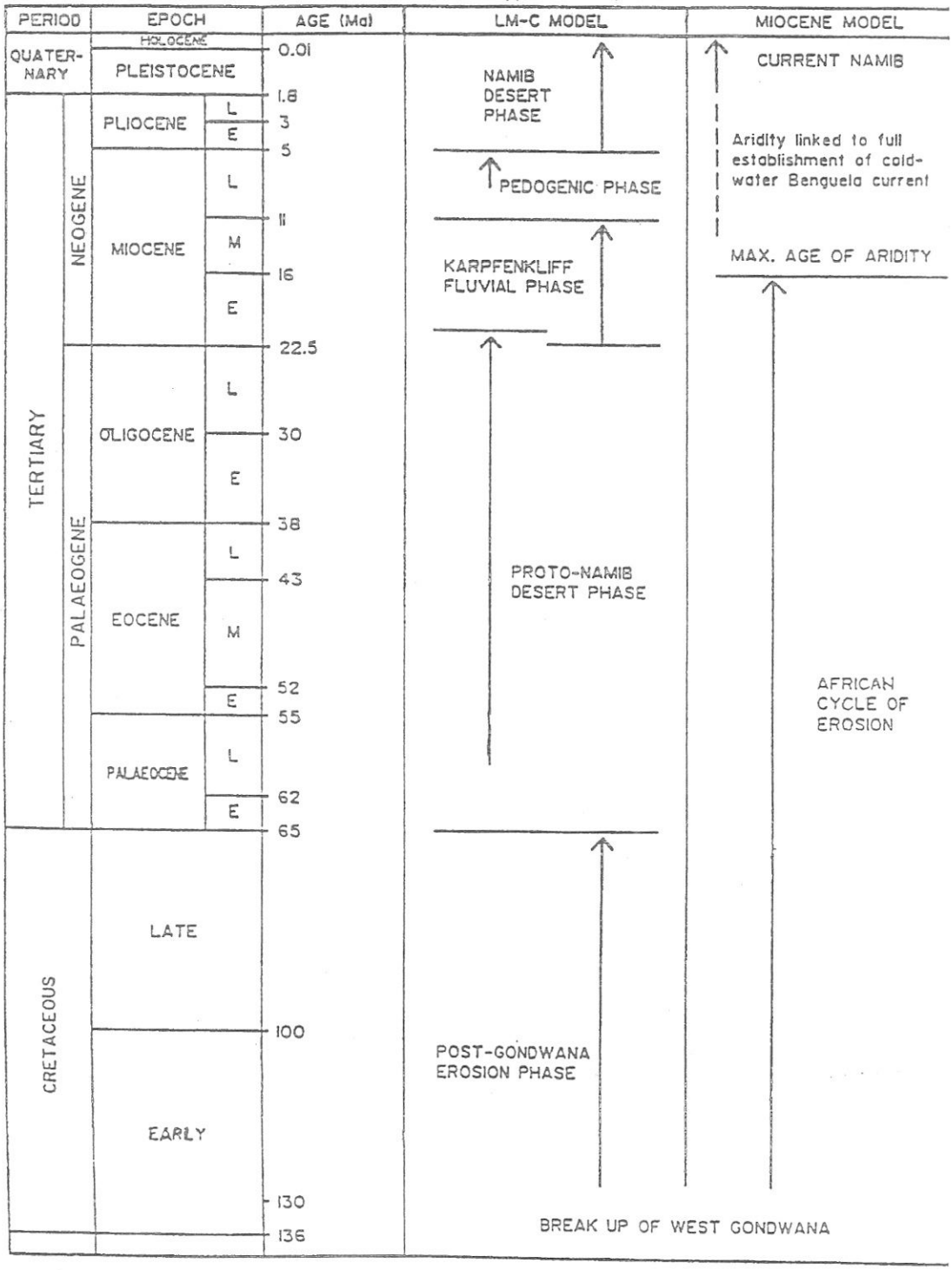
From a review of the post-Gondwana stratigraphic record in the Namib, the development of this desert tract is attributed to five major events of regional significance:

1. **Post-Gondwana Erosion Phase,** which spanned most of the Cretaceous (120-60 Ma). The eastern (Escarpment), western (South Atlantic Ocean) and basal (Namib Unconformity Surface) boundaries were formed
2. **Proto-Namib Desert Phase** that prevailed for much of the Palaeogene (55-22 Ma) and significantly southerly palaeo-wind regime dominated
3. **Pluvial Phase** in the Early to Middle Miocene (22-14 Ma) which reflected a change to mesic, semi-arid conditions
4. **Pedogenic Phase** that followed on in the Middle Miocene (14-11 Ma) heralding the onset of arid conditions attendant on the full establishment of the cold-water upwelling system of the Benguela Current in the Later Miocene (10-7 Ma)
5. **Namib Desert Phase** that has persisted from the Later Miocene to the present day (10-0 Ma). Late Cainzoic climate fluctuations have been superimposed on a generally progressively aridifying trend that is reinforced by the cold-water Benguela upwelling system. Deep incision of the major westward-directed drainages occurred early in the phase, possibly during the Early Pliocene.

The paucity of material suitable for absolute dating is still a handicap in the Namib Desert. Nevertheless, an understanding of the post-Gondwana stratigraphic record provides considerable insight into the age of, and the onset of aridity in, the Namib.

Table 1

Late Mesozoic-Cainozoic (LM-C) and Miocene Models for the development of the Namib
Time scale variable; E=Early, M=Middle, L=Late



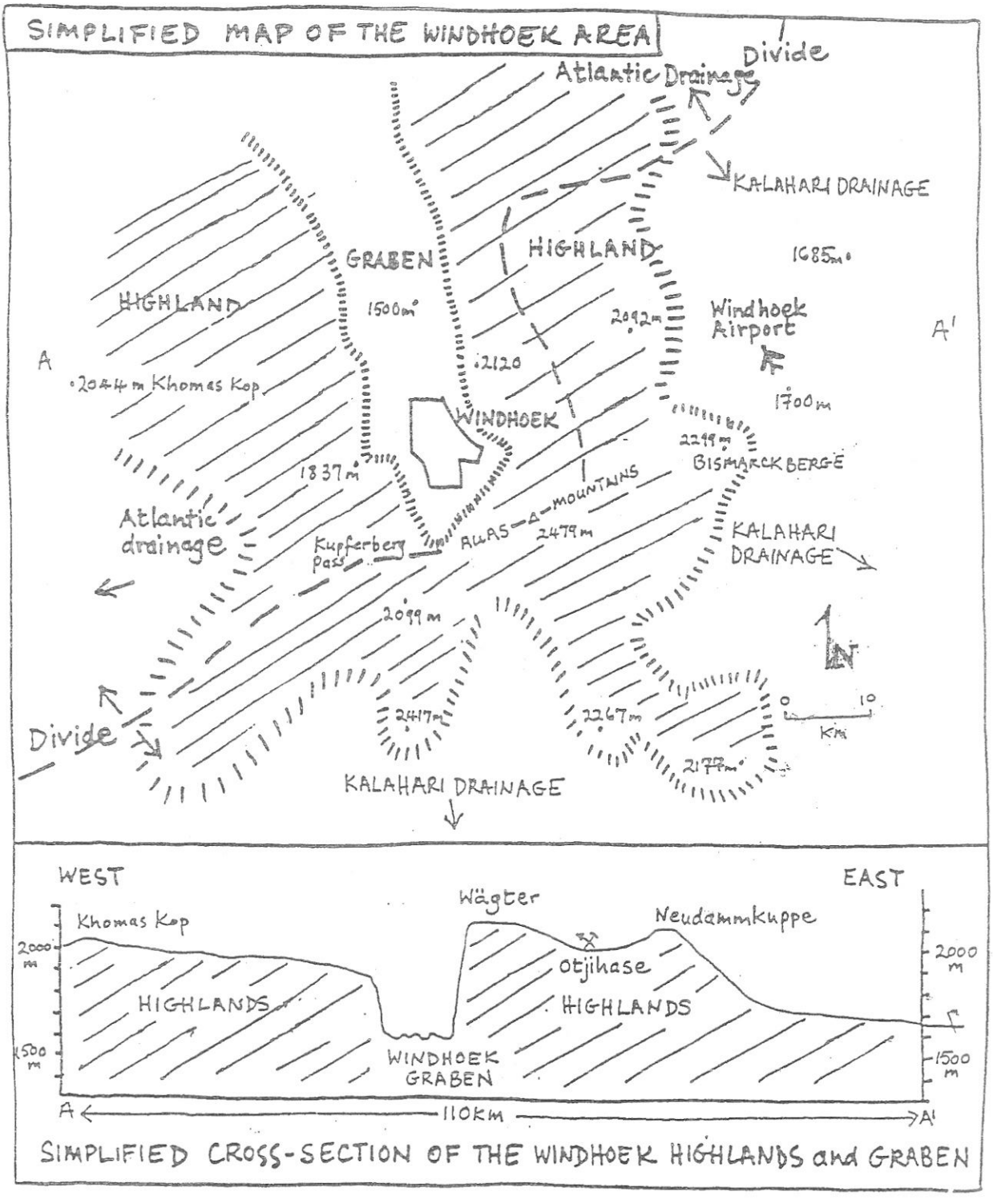
from Ward & Corbett (1989, in press)

Windhoek to the top of the Gamsberg Pass

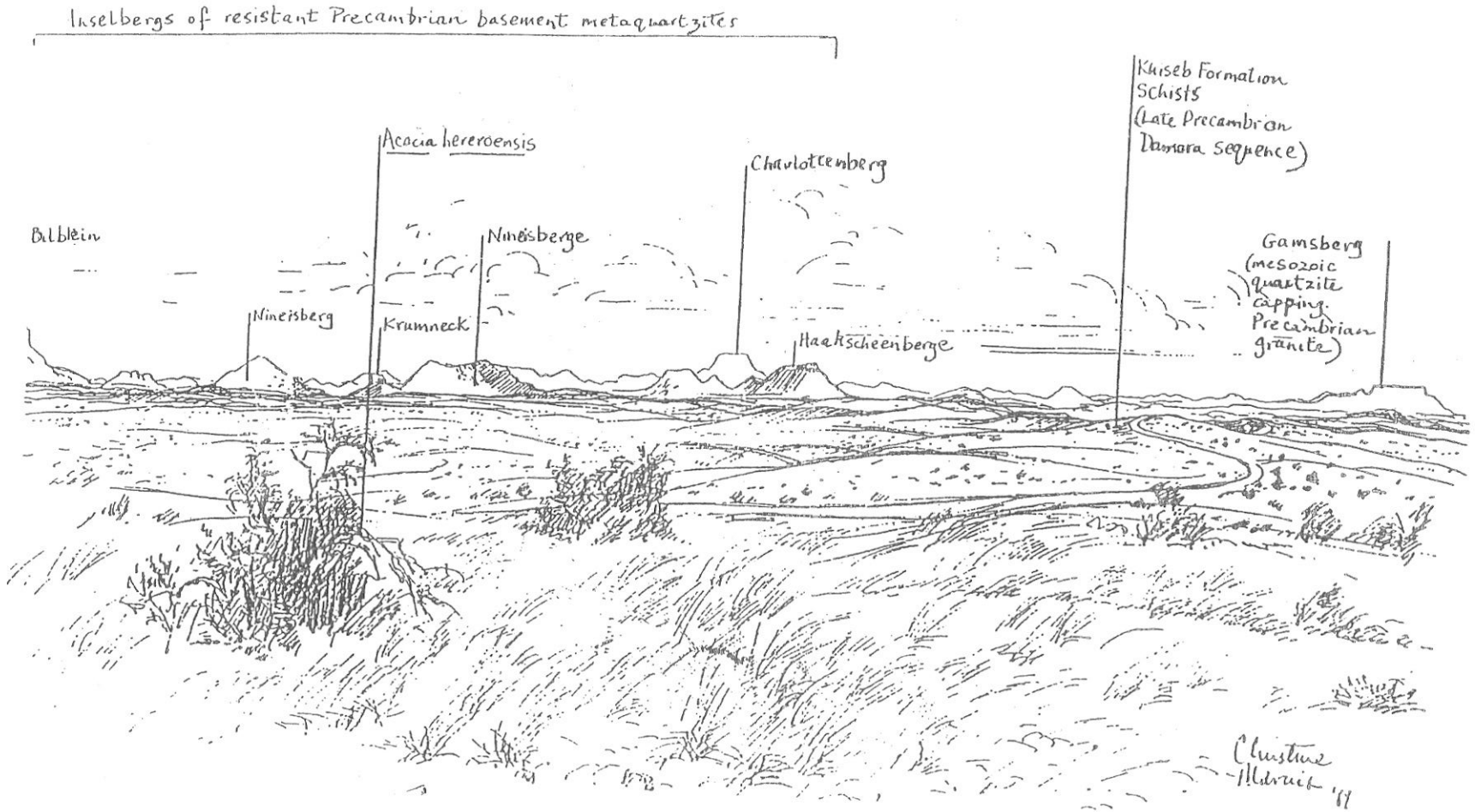
The route rises out of the Windhoek Valley via the Kupferberg Pass onto the upland plateau and highlands south of the Khomas Hochland. Drainage in the Windhoek Valley runs into the Swakop River that flows into the Atlantic Ocean. The watercourses on the upland plateau drain into the Kalahari basin. This region appears to have been a watershed and highland region from Permo-Carboniferous times, some 300 Ma ago. The undulating surface of this upland plateau is probably equivalent to a "lowered" African Surface (*sensu* Partridge and Maud, 1987).

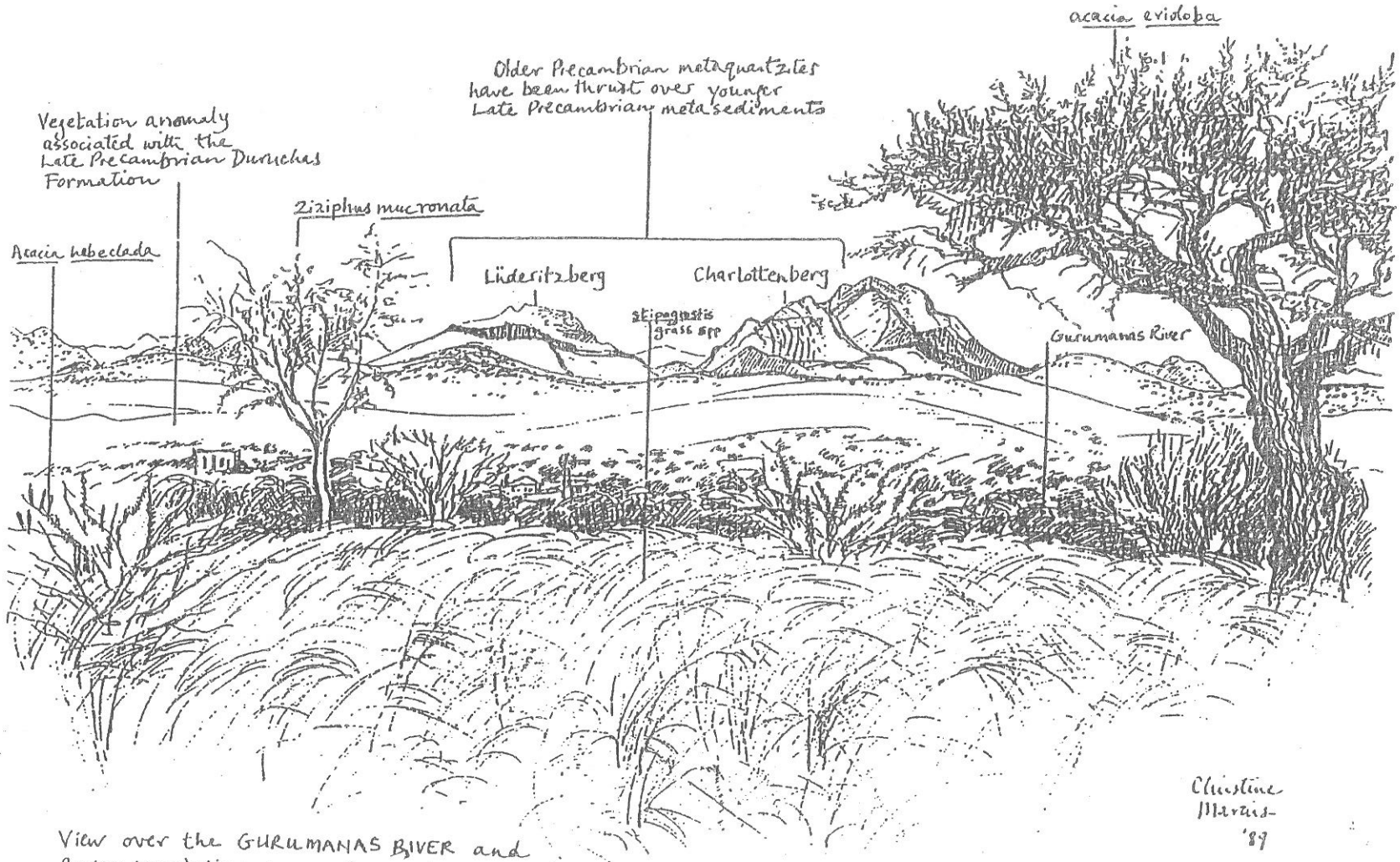
Rainfall decreases from about 350mm in the Windhoek area to about 200mm at the top of the Escarpment. This is reflected in the transition from highland savannah to a drier thornbush savannah on the Escarpment. Noticeably woody species along the rout include: *Boschia albitrunca, Ziziphus mucronata, Rhus lancea, Acacia erioloba, A. karoo, A. hereroensis, A. hebeclada (with upright pods), Euclea undulata, Combretum apiculatum, Dombeya rotundifolia, Tarchonanthus camphoratus* and *Elephantorrhiza suffruiticosa.*

The area is used for cattle and game ranching, with the average size of farms being about 6 000 hectares. The road passes through a part of the Rehoboth Area where smallstock, mainly goat, farming is practised.


SIMPLIFIED MAP OF THE WINDHOEK AREA
Divide
Atlantic Drainage
KALAHARI DRAINAGE
GRABEN
HIGHLAND
HIGHLAND
1685m
1500m
2092m
Windhoek Airport
A
A'
2044m Khomas Kop
2120
1700m
WINDHOEK
2299m
BISMARCKBERGE
1837m
Atlantic drainage
Kupferberg Pass
AUAS-A-MOUNTAINS
2479m
KALAHARI DRAINAGE
2099m
0
10
km
Divide
2417m
2267m
2177m
KALAHARI DRAINAGE
WEST
EAST
Wägter
Khomas Kop
Neudammkuppe
2000 m
Otjihase
HIGHLANDS
HIGHLANDS
1500 m
WINDHOEK GRABEN
2000 m
1500 m
A
110km
A'
SIMPLIFIED CROSS-SECTION OF THE WINDHOEK HIGHLANDS and GRABEN

View over Highlands Southwest of WINDHOEK from the top of the KUPFERBERG PASS





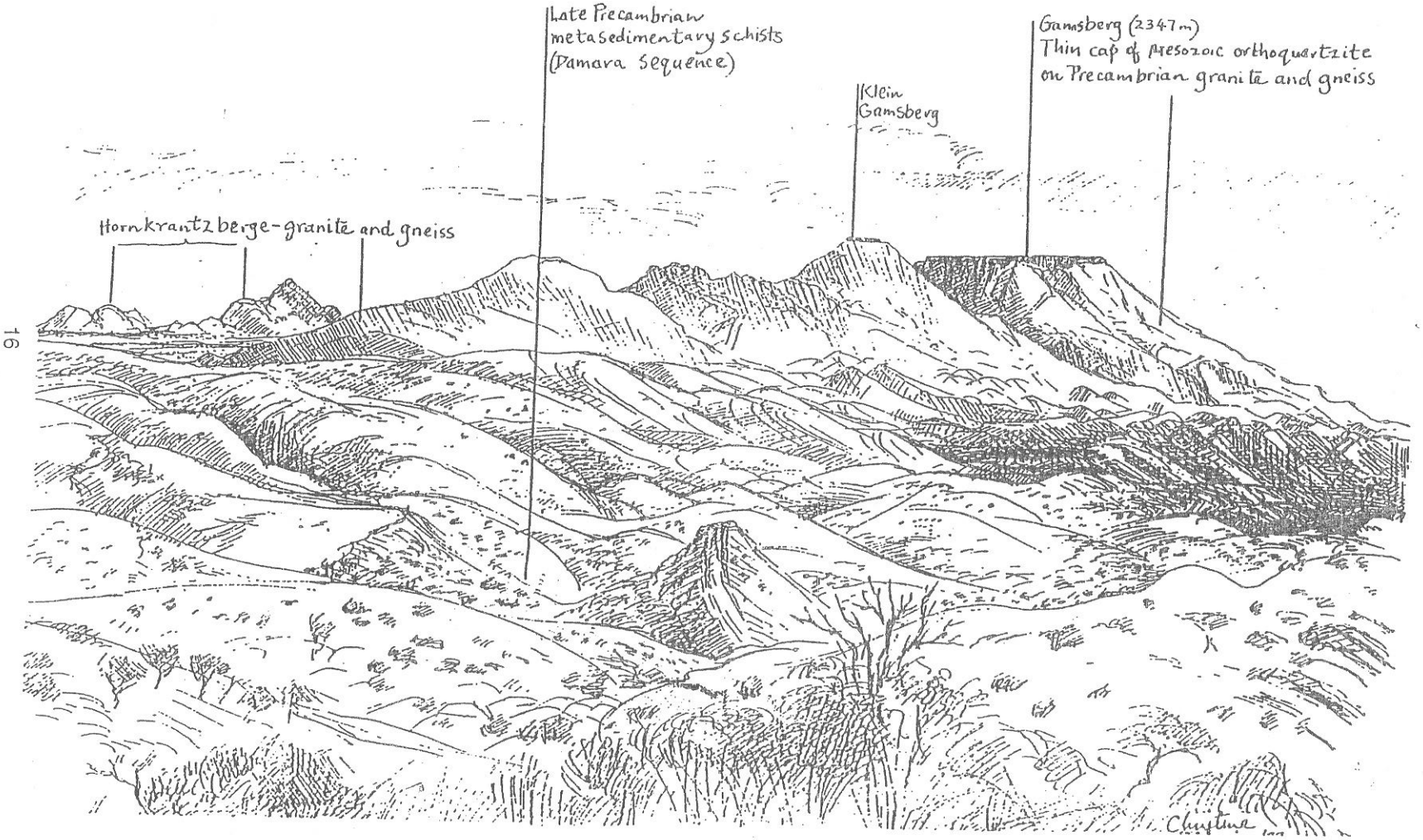
View over the GURUMANAS RIVER and grassy vegetation anomaly associated with the late Precambrian Duruchas Formation.

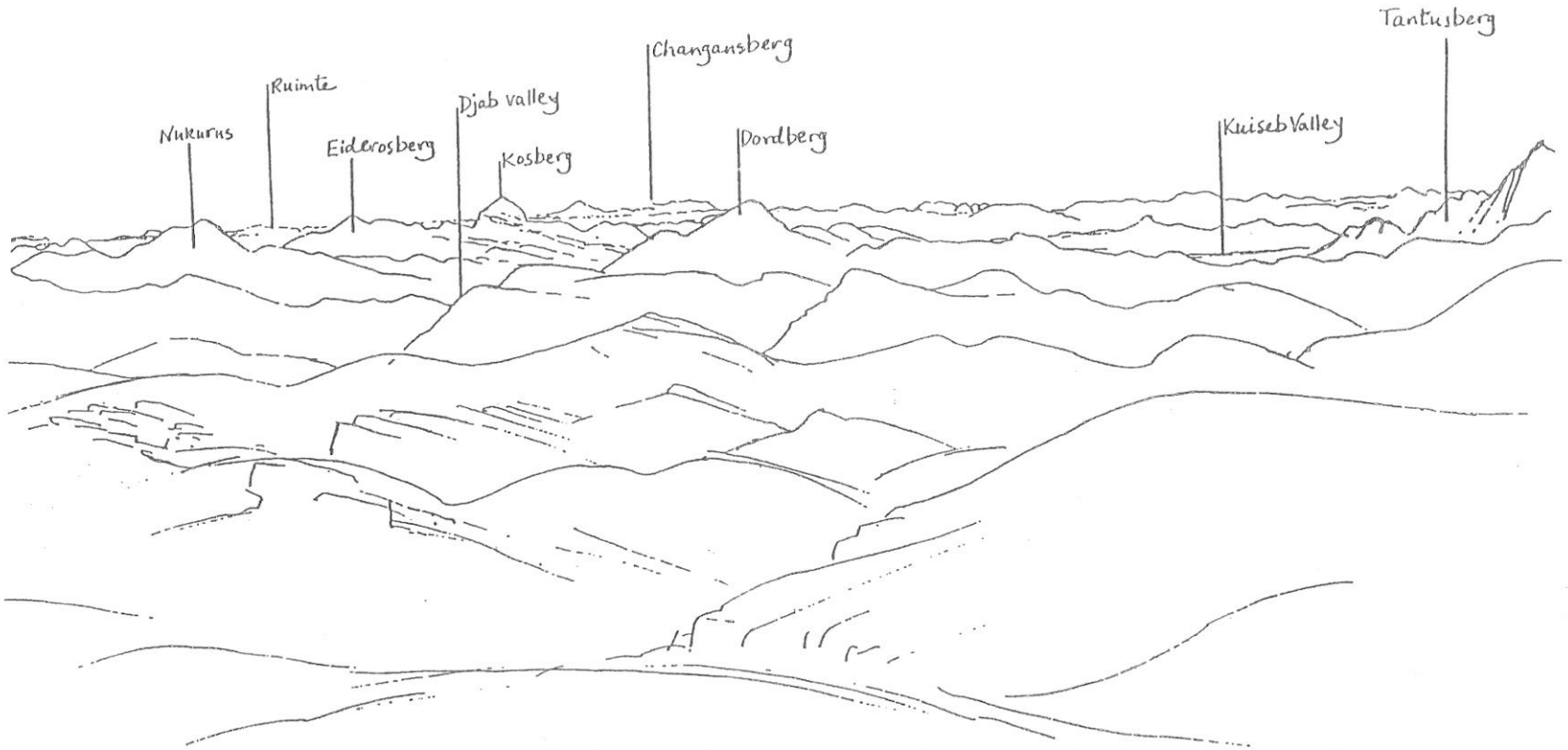
Sociable weaver nest in Acacia erioloba,
GÖLLSCHAU AREA

Christine Marais '89


Termite mounds in
Acacia Savanna,
ISABIS AREA.
Christine
Marais 89

View Southwestwards of the GREAT ESCARPMENT,
GAMSBERG AREA





Dissected Escarpment represents the deeply-eroded roots of the Nukurus and Hakos Mountain nappes and thrust sheets which consist of Precambrian metasedimentary and metavolcanic schists, quartzites and gneisses.

Gamsberg Pass

The Gamsberg, at 2 347m, is the highest point on the Escarpment in Namibia and the third highest in the country. The capping on the Gamsberg is 25m thick aeolian quartzite, part of the Etjo Formation of probable Triassic-Jurassic age. Rainfall decreases from about 200mm on the top of the Escarpment to about 100mm at the edge of the Namib. In this broken landscape, *Aloe dichotoma, Moringa ovalifolia*, several *Commiphora* species, and the resurrection plant, *Myrothamnus flabellifolius* are obvious.

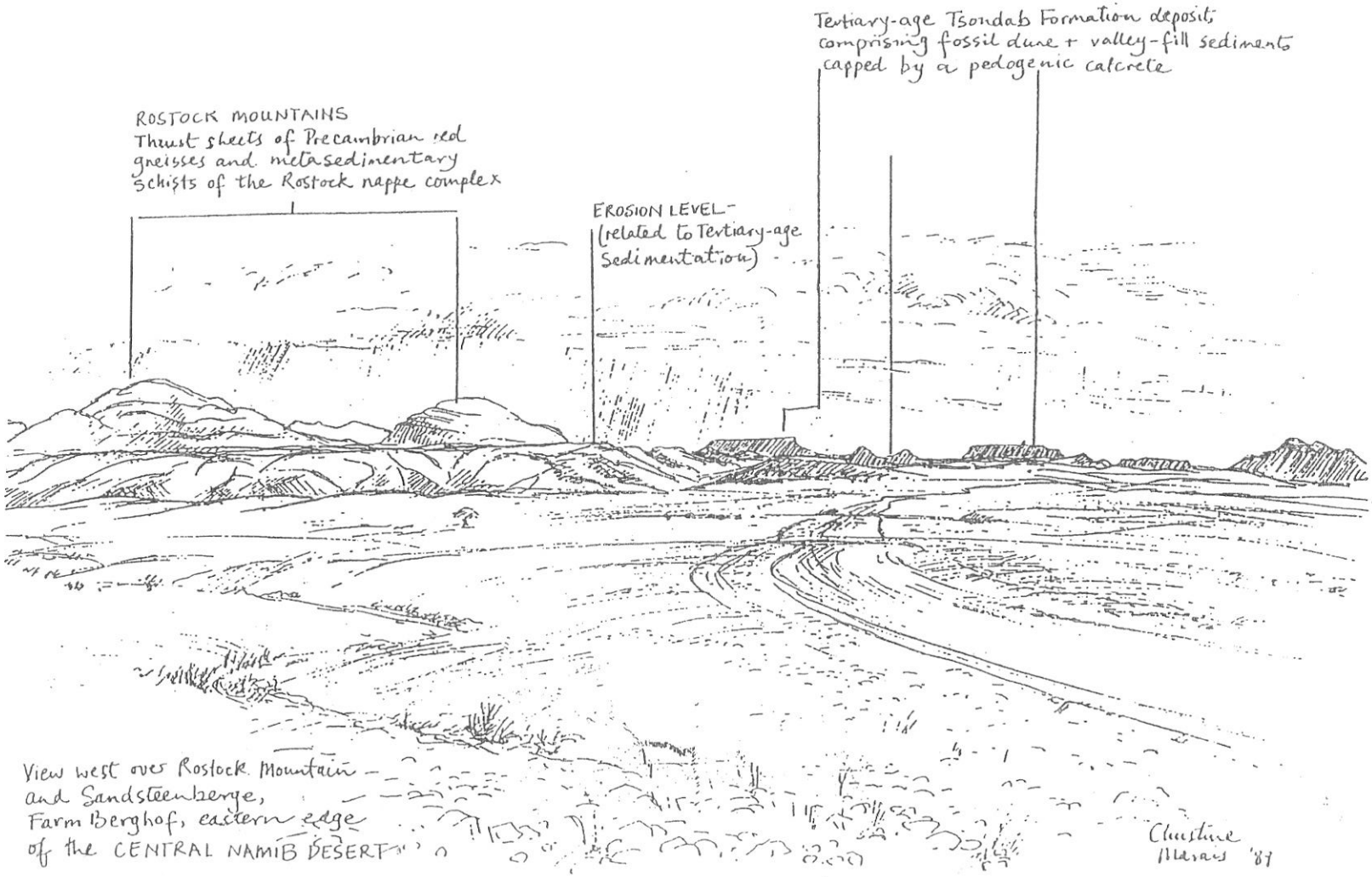
The vegetated red dune sand at the bottom of the Gamsberg Pass appears to be derived from older Tertiary dune deposits (Tsondab Sandstone Formation) farther west. The Tsondab Sandstone Formation represents an early arid phase in the central Namib between about 55 and 20 Ma and testifies to the antiquity of the Escarpment. This sand was probably blown into its present position by SW winds under a drier climate.

Namib-Naukluft Park

The total area of the Namib-Naukluft Park is 49 768km^2. In 1986 the park became an amalgamation of several large areas, namely:

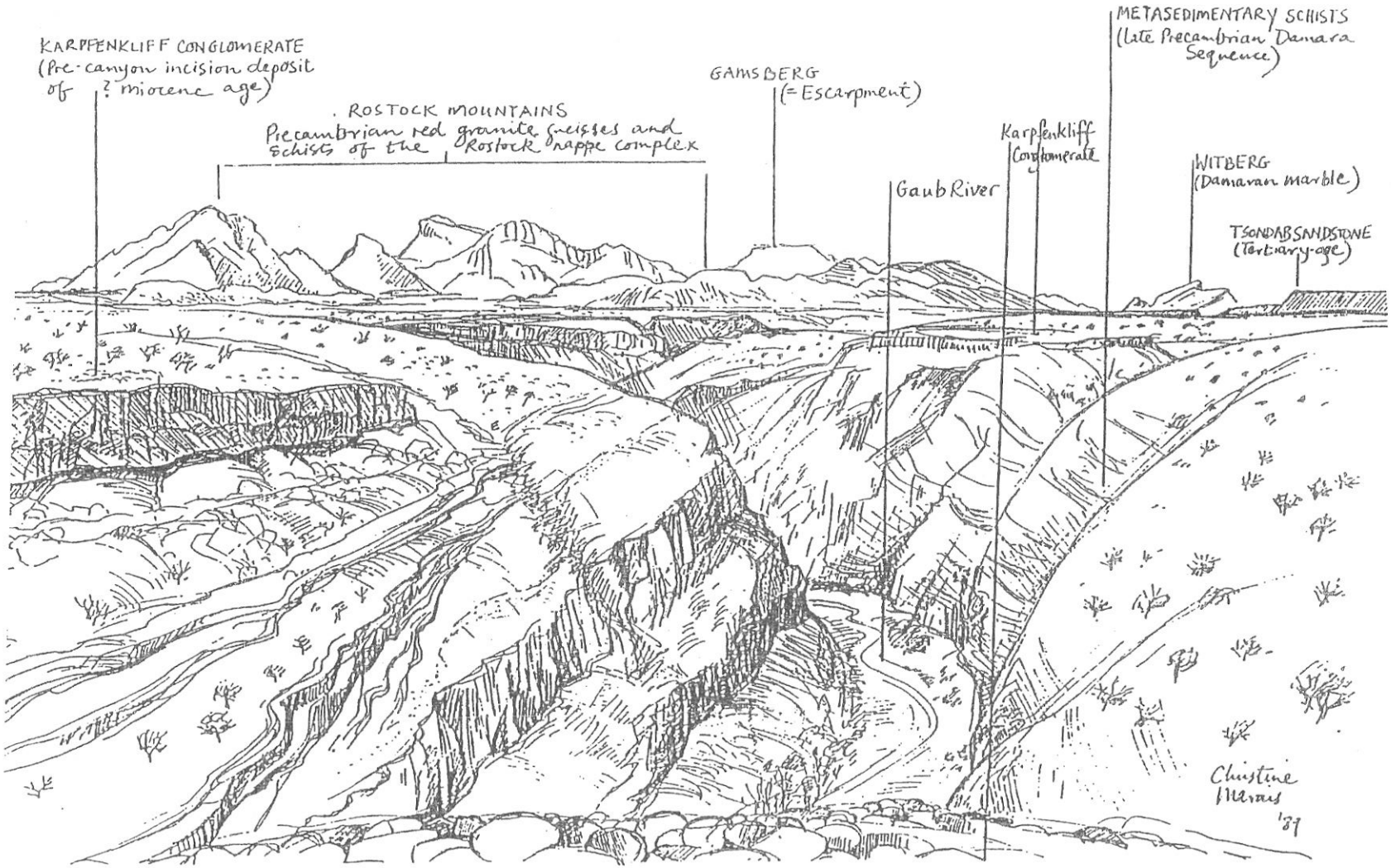
- the original Namib Desert Park, occupying mainly the central Namib between the Kuiseb and Swakop Rivers, first proclaimed in 1904 when South West Africa was a German colony and the British had occupied Walvis Bay,
- farms on and surrounding the Naukluft Plateau, including a corridor of farms connecting the mountainous terrain with the Namib that were purchased during the 1960s,
- all of what used to be known as Diamond Area No. 2. consisting predominantly of sand dunes south of the Kuiseb River,
- the part of Diamond Area No. 1 north of the Lüderitz/Aus road, also mainly sand dunes.

The Namib-Naukluft Park is fenced on its eastern and northern borders. Artificial water points and occasional food supplements are provided. Moderate populations of large animals, including oryx (gemsbok), springbok, Hartman's mountain zebra, ostrich and hyena are found mainly along the eastern borders and in the few linear oases (ephemeral watercourses with perennial underground water) that extend across the desert. A wide variety of smaller animals, however, may be found in all desert habitats. Of the unusual desert plants found in the Namib, *Welwitschia mirabilis* is probably the best known.



View west over Rostock Mountain and Sandsteenberge, Farm Berghof, eastern edge of the CENTRAL NAMIB DESERT

EAST UP THE GAUB CANYON, CENTRAL NAMIB DESERT



The Kuiseb River

The Kuiseb River demarcates the northern boundary of the main Namib Sandsea except near the coast where a narrow belt of dunes extends between Walvis Bay and the Swakop River. The subterranean water reserves of this large, ephemeral watercourse support well-developed riparian vegetation across the hyper-arid central Namib. The Kuiseb is thus an important linear oasis in the desert system. The Kuiseb Valley also contains extensive Cainozoic sediments, an understanding of which has helped elucidate the post-Gondwana history of the central Namib region.

The post-Gondwana stratigraphy in the Kuiseb Valley can be divided conveniently into two suites relative to canyon incision:

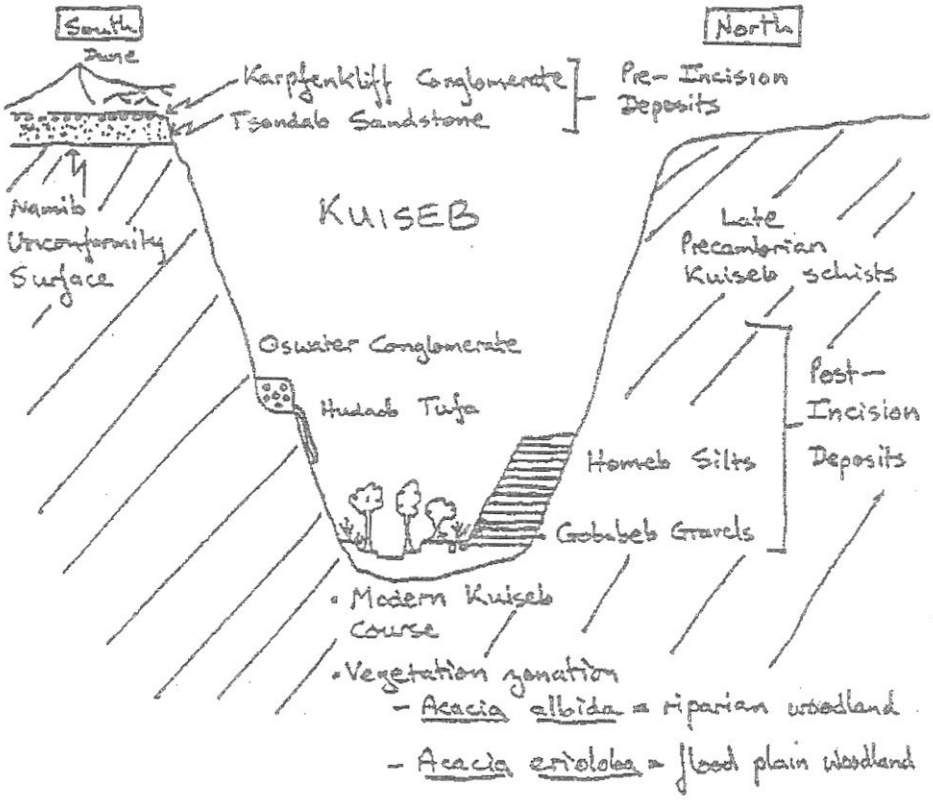
- a pre-incision suite of Early to Middle Tertiary age, which comprises the Tsondab Sandstone Formation, Karfenkliff Conglomerate Formation and Kamberg Calcrete Formation
- a post-incision suite of Later Tertiary to Qauternary age, which comprises terrace deposits of the Oswater Conglomerate Formation, the Homeb Silt Formation and the Gobabeb Gravel Formation, as well as the Hudoab Tufa Formation.

The linear oasis of the Kuiseb River supports a greater biomass and diversity of plants and animals than do the gravel plains to the north or the dunes to the south. The schematic profile depicts vegetation zonation on the contemporary flood plain of the Kuiseb River. In general, the riparian woodland is dominated by *Faidherbia albida*, whereas the flood plain is characterised by *Salvadora persica, Euclea pseudebenus* and *Acacia erioloba. Tamarix usneoides* is commonly found in the sandy, main courses. Alien vegetation includes *Nicotiana glauca, Ricinus communis, Datura stramonium, D. innoxia* and *Argemone ochruleuca*. This vegetation supports populations of baboons, genets, mongooses, tree rats, puff adders, black-necked spitting cobras and a rich variety of birds, species rarely encountered outside the linear oases of the central Namib.

The Kuiseb River Bridge

In this section of the river there is less underground water storage than further towards the coast and consequently there is less vegetation. This part of the river experiences floods most years as it is closer to the head-water area and the floods are of longer duration than further down the river. As a result of the lack of groundwater the *Faidherbia albida* lose all their leaves annually, while further downstream they have a partial cover of green leaves throughout the year. The bright, yellow-green shrub, *Salvadora persica* is also abundant here and a fine example of *Sterculia africana* can be seen about 1km west of the bridge. (Seely, 2004)

SCHEMATIC CROSS-SECTION OF THE KUISEB CANYON NEAR HOMEB, NAMIB-NAUKLUFT PARK

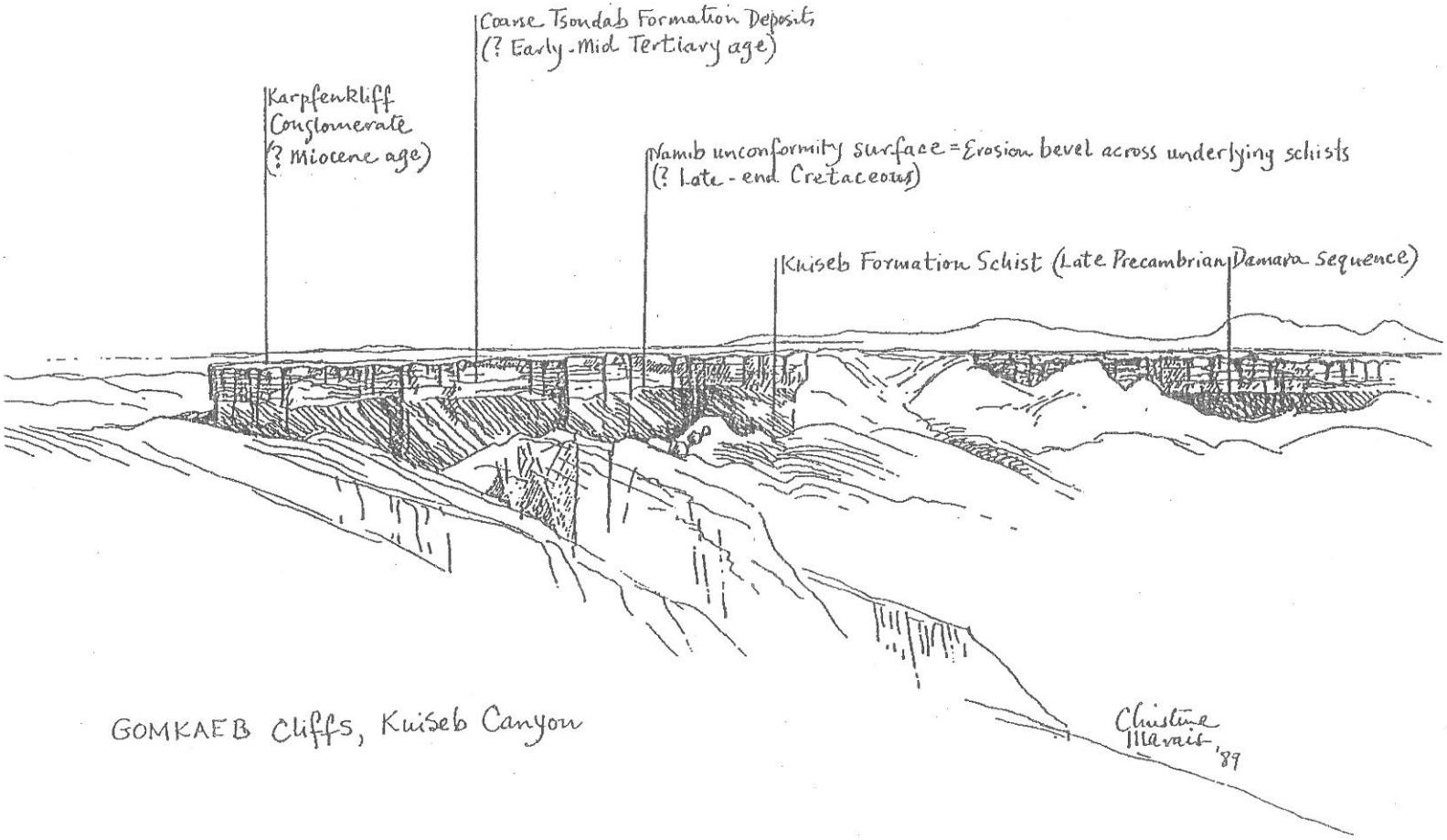


The post-Gondwana stratigraphy is clearly depicted:-

③ Post-Incision Deposits: 0 Ma ↓ 5 Ma
- Modern Kuiseb course
- Gobabeb Gravels
- Homeb Silts
- Hudaob Tufa
- Oswater Conglomerate

② Pre-Incision Deposits: 10 Ma ↓ 55 Ma
- Kamberg Calcrete (poorly developed)
- Karpfenkliff Conglomerate
- Tsondab Sandstone

① Namib Unconformity Surface: 60 — 100 Ma



GOMKAEB Cliffs, Kuiseb Canyon

The Kuiseb Canyon

The formation of the Kuiseb Canyon took place about 2 million years ago resulting from a wet phase within the semi-arid climate. This resulted in a change in the river course and intensified erosion. The Northern Hemisphere ice ages at that time caused a drop in ocean levels and a steeper gradient from land to sea which exacerbated the run-off and the erosion.(Grünert, 2000)

Here the Kuiseb River is very narrow with little vegetation and thus very little food for wildlife although there are more waterholes here than downstream. In the canyon, the river has exposed the Damara schist, grey jagged rocks underlying a lighter, tan coloured calcrete covering. Near the canyon lookout the proto-Kuiseb is clearly indicated in layers of cobbles in surrounding calcrete. Various levels of calcrete capping on the schist are visible on the horizon. The Canyon was also home to geologists Henno Martin and Hermann Korn during the Second World War when they tried to escape internment. (Seely, 2004)

The "Small Escarpment"

Turning south from the main C32 road, a decommissioned microwave tower looms on the horizon. Passing the tower one descends a small escarpment of schist. Here on the exposed schist layers grow a number of interesting plants including a group of *Aloe dichotoma*, *Euphorbia virosa* and *Commiphora glaucescens*. At the bottom of the small escarpment, the dry watercourse supports a variety of vegetation including an *Acacia erioloba* with a Lappet-faced Vulture nest dating back at least 40 years now used by Greater Kestrels and others.

Mirabib

A granite inselberg, rising out of the Namib Plain lies to the north of the road. Mirabib supports a rich collection of vegetation and in the several dry washes near the hill you can find examples of typical desert trees. These include *Boscia albitrunca, B. foetida, Commiphora saxicola, Moringa ovalifolia, Acacia erioloba, A. reficiens, Maerua schinzii* and *Parkinsonia africana*. Lappet-faced vultures, red-necked falcons and lesser falcons are among the birds that use the trees for nesting. Small mammals such as the elephant shrew can also be seen hunting in the vicinity while geckos, lizards, horned adders and sand snakes are commonly seen here.

Gobabeb

Gobabeb, or more properly /Nomabeb or /H^omabeb – meaning "fig tree" or "the place of the fig tree" is an old Topnaar village site on the north bank of the Kuiseb that has been the focus of research activities in the Namib for more than four decades.

The Homeb Silts

The Homeb Silts, of Late Quaternary age, form conspicuous, almost horizontally stratified yellowish deposits in the side tributaries (gramadoelas) of the Kuiseb Canyon. Various origins have been attributed to the Homeb Silts:

- deposits accumulated behind a series of dune dams
- river endpoint accumulations
- floodplain deposits of a aggrading Kuiseb River.

Sedimentary structures and other geological evidence point towards a flood plain origin. Moreover, it appears that the Kuiseb floods were of considerable magnitude during Homeb times, in contrast to the extremely arid conditions postulated by the first two hypotheses. The radiocarbon dates of 23 000 to 19 000 BP coincide approximately with the Last Glacial Maximum in the Southern Hemisphere.

Welwitschia Wash

Welwitschia mirabilis, first described in 1859, is endemic to the central and northern Namib and occurs from the Kuiseb River northwards into south-western Angola. Each plant has only two broad, perennial leaves arising from the meristematic tissue in the groove around the margin of the stem. The leaves grow continuously, while the distal ends are frayed and damaged by wind, animals and heat.

W. mirabilis is dioecious: male plants produce catkin-like cones resembling angiosperm reproductive structures, whereas females produce larger gymnosperm-like cones. Insects, and not wind as previously thought, are apparently responsible for pollination. Most of the mature seeds are infected with fungal spores (*Aspergillus niger*) which are introduced by the sap-sucking pyrrhocorid bug (*Probergrothius angolensis*). There is some evidence that fog water and dew can be absorbed directly through the stomata.

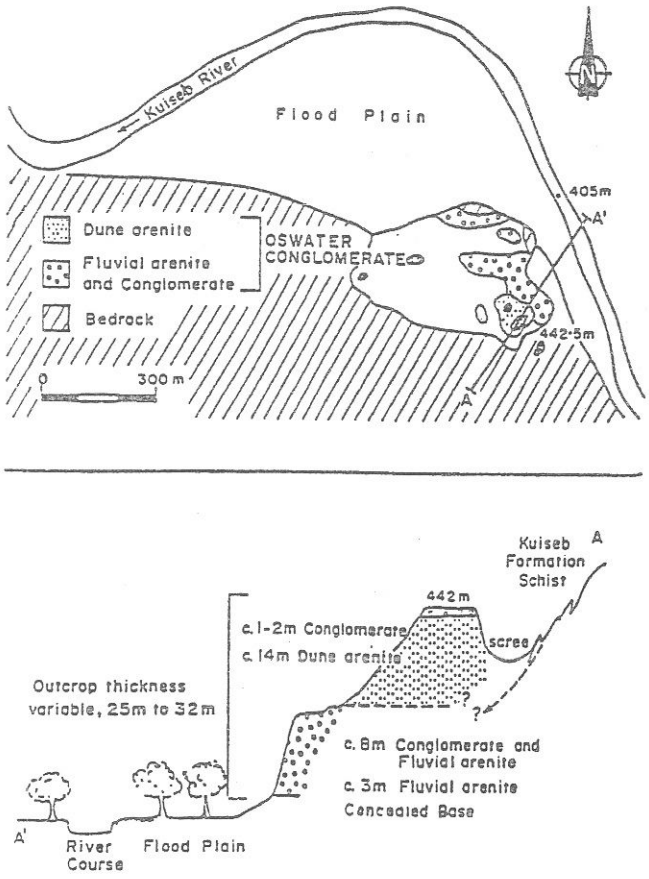
This plant presents a taxonomic paradox in that it is a gymnosperm with angiosperm traits. Moreover, it is a perennial that does not appear to be well suited for desert conditions. This is borne out by:

- only three relatively thin epidermal layers
- relatively short, fibrous taproot, despite a respiratory loss of about 1 litre of water per day

- no apparent reduction of leaf surface area
- many stomata on both the upper (250-144/m^2) and lower (250-87/m^2) leaf surfaces as well as on the stem (26/m^2). Most other Namib plants have between 0.2 and 1 stoma/m^2
- a C-3 type of photosynthesis, whereas many xeric adapted plants use a C-4 photosynthesis.

Aeolianite in the Oswater Conglomerate, Natab Area

The Oswater Conglomerate represents the first aggradational phase after initial incision of the Kuiseb Canyon. These conglomerates are dated provisionally to the Early Pleistocene. A number of Oswater outcrops along the left bank of the Kuiseb River in the lower canyon – open valley each contain interbedded large wedges, up to 14m thick of palaeo-dune arenite. The orientation of cross-stratification in these aeolianites indicates a southern source. Therefore, large, probably linear-type dunes were fronting onto the incised Kuiseb River by at least the Early Quaternary. It appears that the Kuiseb River has been a significant barrier to the northward encroachment of the main Namib Sandsea since this time – approximately the last 1.5 Ma.



PLAN AND TYPICAL SCHEMATIC SECTION OF AN OSWATER CONGLOMERATE OUTCROP NEAR NATAB

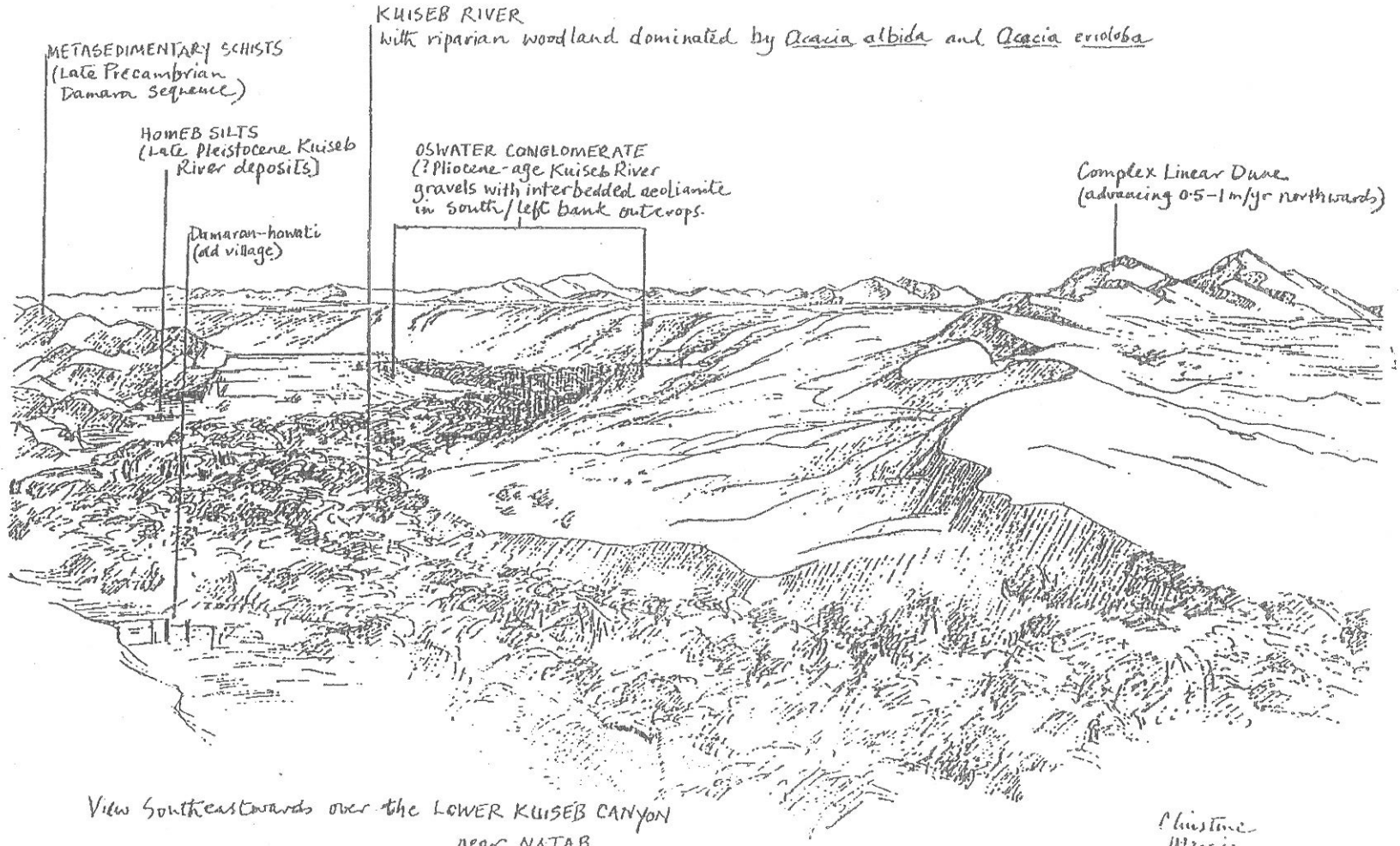
Mega-Ripples on the dunes south of the Kuiseb

Coarse-grained, golden coloured mega-ripples are prominent surface bedforms on the lower slope of the eastern side of linear dunes in this area. The coarse grains are derived from the breakdown of quartz pebbles and cobbles that form a lag in the interdune valleys. This gravel lag is the distal alluvial fan – braidplain facies of the Karpfenkliff Conglomerate Formation.

These coarse grains are moved onto the eastern flanks of the linear dunes by the strong, infrequent easterly berg winds that prevail during the winter months. In contrast, the bulk of the linear dune comprises medium to fine sand grains which are moved by the SW wind in a net northerly direction. This illustrates the threshold relationship between grain size and wind strength in dune sand movement.

Patterned Ground

The surface over which the present linear dunes are moving commonly displays a distinct patterning at several scales. The largest features, termed macro-fractures, are on a scale of several kilometres long and up to 100m wide. A hierarchy of patterned ground at a scale of 20-60m and at 3-5m occurs between these macro-fractures. The smallest scale patterning has been attributed to desiccation associated with gypsum in the host sediment whereas the macro-fractures have been interpreted as fluvial channels. An alternative view is that calcification of the underlying sandstone has resulted in expansion of that package to give a series of small to large pattern ground features.



View Southeastwards over the LOWER KUISEB CANYON
near NATAB

Christine Marais '87

Topnaar People

The Topnaar, or #Aonin, is a Khoekhoen tribe living in the lower Kuiseb Valley between Homeb and the Atlantic Ocean. In former times they ranged farther inland along the Kuiseb Canyon and north and south along the central Namib coast. Fish and mussels from the coast, *!nara* melons and perhaps smallstock maintained along the Kuiseb, were important factors in their economy until recently. Today about 300 Topnaars live along the lower Kuiseb in 12 settlements (Henschel et al, 2004) where they farm with goats, a few cattle and some sheep. Donkeys provide an important form of transport. Approximately 3 000 Topnaars reside in Walvis Bay and maintain close ties with relatives in the Kuiseb villages.

Villages are typically located on the north bank of the Kuiseb in full sun. The cooler, shady riverbed is avoided because of irregular floods. Traditional huts were constructed by sticking lengths of supple wood into the ground in a circle and bending the tops together in the centre. This framework was covered with long pieced of Acacia bark. Today, a variety of other building materials is combined and rectangular rather than circular dwellings are built.

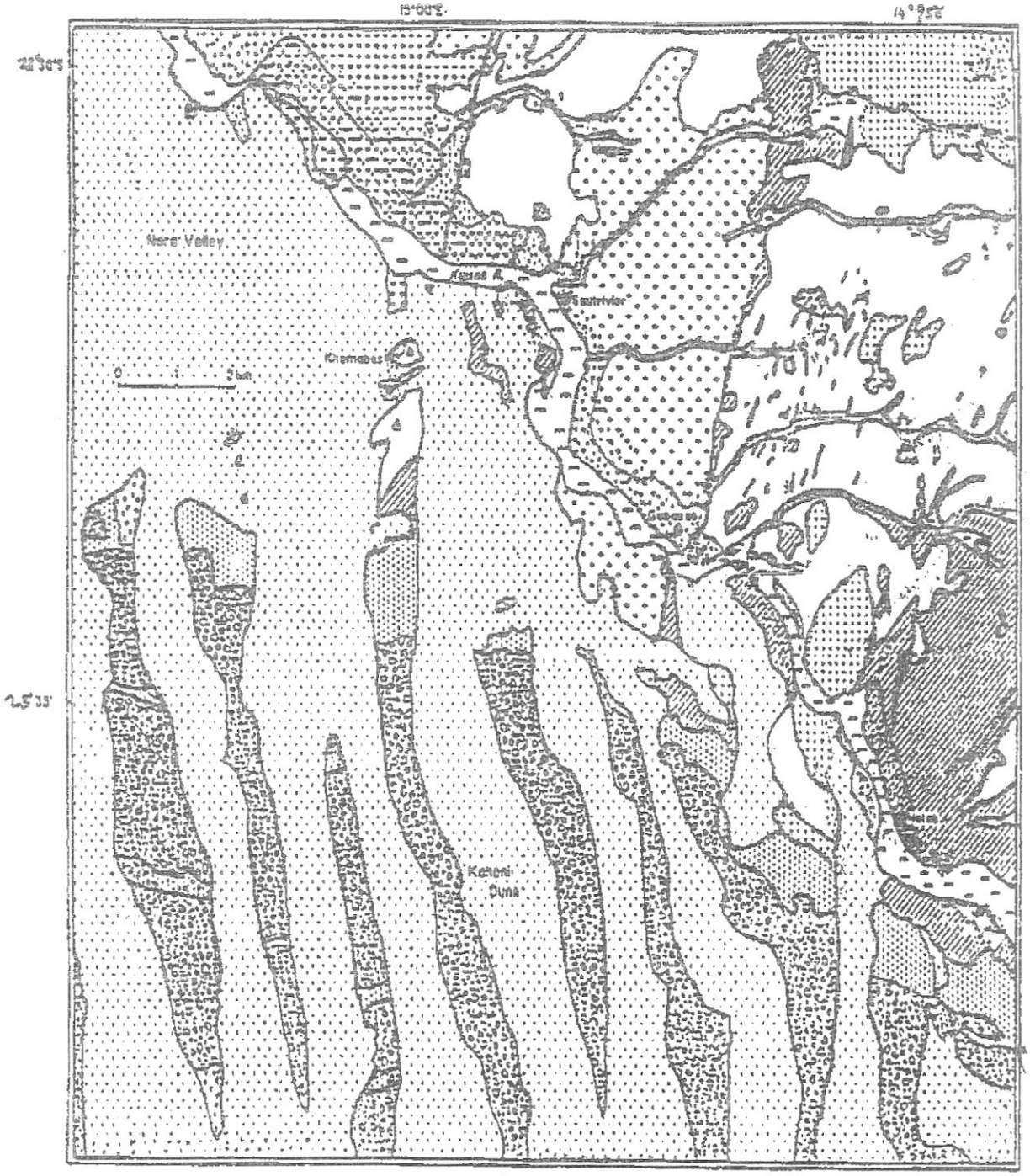
The Topnaar people make extensive use of the *!nara (Acanthosicyos horridus)* melon which is common along the lower Kuiseb Valley. The flesh is cooked and dried and the kernels are used as a food and for medicinal purposes. They have a very high cultural significance in the lives of the Topnaar people. The *!nara* plants often form hummock dunes up to 8m high. They occur in groups, or fields that are divided among the Topnaar families and are inherited from one generation to the next. Fifty one *!nara* fields, each with its local name, are recognised along the lower Kuiseb Valley (Henschel et al, 2004).

!Nara – Acanthosicyos horridus

!Nara is a large, perennial cucurbit endemic to the Namib. This species is dioecious, the male plant producing many flowers throughout most of the year, while the female has relatively few leaves. Leaves have become reduced to thorns and photosynthesis takes place through these and the stems.

This sprawling plant stabilises dune sand, providing shelter to a variety of desert animals. The flowers are eaten by a number of insects, ostriches eat the fresh stem tips and donkeys and jackals eat the melons. In the northern Namib *!nara* stems and thorns represent about 80% of the diet of the slipface-dwelling lizard, *Angolosaurus skoogi.*

Seeds have a high food value: kernels contain 20% water and dry matter consists of 25% protein, 29% fat and oil, 38% fibres, 4% sugar and 4% ash. Seeds (about 50 per melon) make up about 33% of the fruit volume.



SIMPLIFIED GEOLOGICAL MAP OF THE GOBABEB AREA, NAMIB DESERT

Legend for simplified geological map, Gobabeb area


Undifferentiated surficial cover, including loose sand, scree, calcrete and gypcrete — RECENT TO TERTIARY


Alluvium — QUATERNARY


SOSSUS SAND FORMATION (linear dunes, aeolian sands), including palaeo-pans (Δ) of Khommabes Carbonate Member


GOBABEB GRAVEL FORMATION, lag gravels on bedrock


Gravels derived from Tsondab River drainage, where overlying Tsondab Sandstone (:·:·:·:·)


HOMEB SILT FORMATION


OSWATER CONGLOMERATE FORMATION


KARPFENKLIFF CONGLOMERATE FORMATION, mainly lag gravels overlying Tsondab Sandstone — TERTIARY


TSONDAB SANDSTONE FORMATION


Fault


Major pegmatites or quartz veins — CAMBRIAN


DONKERHUK GRANITE


AUSSINANIS GRANITE


SALEM GRANITE


KUISEB FORMATION schist and metasediments (DAMARA SEQUENCE) — LATE PRECAMBRIAN

Source: E.W. Sawyer. (1974-1976) & J.D. Ward. (1979-1981) Geological Survey, Windhoek.

The route from Gobabeb to Swartbank

West of Natab, the Kuiseb Valley trends north-westwards and is no longer confined to a canyon course. This coincides with a fundamental change in bedrock lithology from the Kuiseb Formation schist (Late Precambrian Damara Sequence) to Cambrian-age granites (Salem and Donkerhuk Granites) associated with the Damara Sequence. Farther west in the Aussinanis River area, the granites abut onto the dark Tinkas Formation schists with intercalated thin marbles, which in turn give way to the pale grey quartzites of the Nosib Formation. Swartbank Mountain, a striking inselberg, comprises folded marbles of the Karibib Formation that have been cross-cut by Jurassic-age dolerite dykes. All the above rock types are part of or associated with the Later Precambrian Damara Sequence.

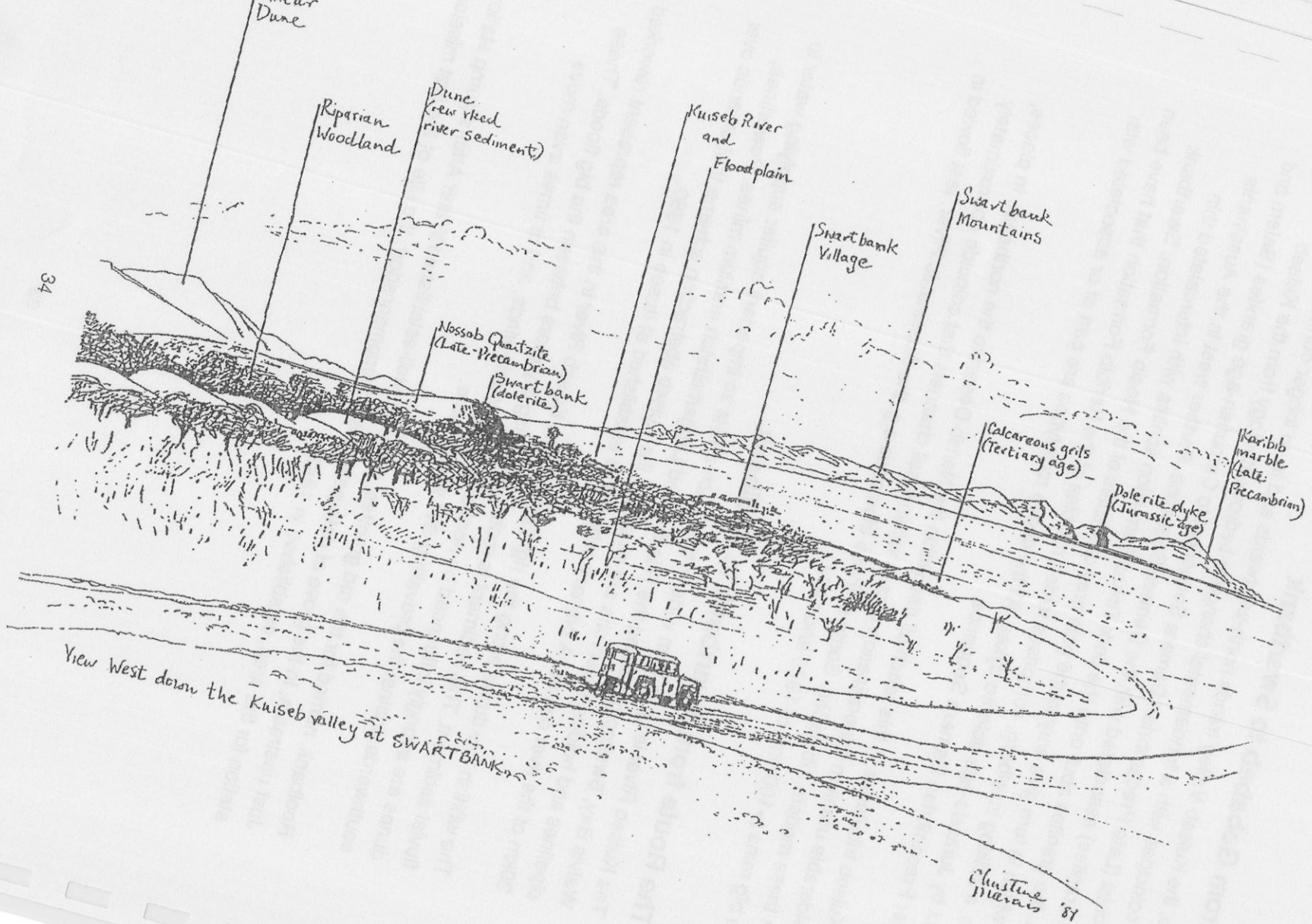
The Kuiseb tributaries in this reach all rise within the Namib Desert to the northeast. In places, considerable uranium mineralisation occurs within fossil channels that coincide approximately with these modern tributaries. Some of these tributaries e.g. the Aussinanis River, last flowed in the big rains (>100mm) of 1976 and 1978.

The Route from Swartbank to Rooibank

The Kuiseb River is up to 2km wide in this reach and is an important aquifer supplying water to Walvis Bay, Swakopmund and the Rössing and Langerheinrich uranium mines. Powerlines, pipelines and holding reservoirs are all part of the Kuiseb abstraction scheme that extends over 30km of the river course. A primary school was established at Ituseb in 1980.

The whitish low dunes along the right flank of the Kuiseb River in this area represent reworked fluvial sediment. This sediment is mobilised during dry years between the big floods. These dunes are strongly influenced by northerly and easterly winds, and at times even move southwards against the prevailing SW wind regime.

Rooibank, named for the red granites, is an old, well-established Water Affairs pump station. Just upstream, in the grove of date palms, is Scheppmannsdorf, the site of the first mission station for the area, established in 1843.



View West down the Kuiseb valley at SWARTBANK

Kuiseb "Delta"

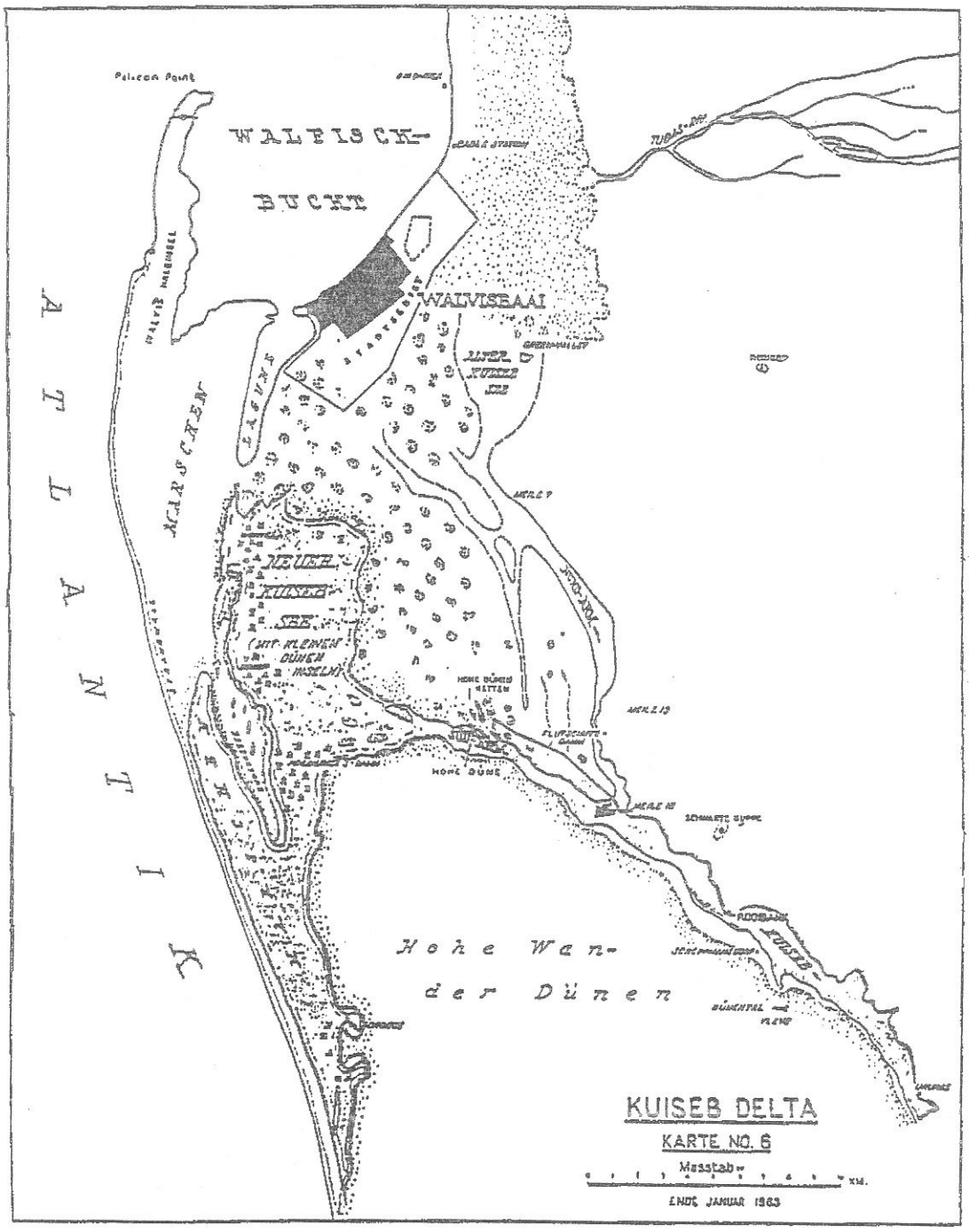
The delta is really an area where the Kuiseb debouches down a relatively steep gradient onto the coastal flats. A series of channels and palaeo-channels form an intricate network of fine-grained fluvial deposits associated with numerous small aeolian dunes. The Kuiseb last reached the sea through Walvis Bay in 1942. In 1962 a 7km long diversion dyke was constructed across the active channel, which flowed north-westwards, to protect the town from floods. This dyke has proved effective and all large floods since then have been diverted down the southern channel. In recent floods, since 1985, the Kuiseb flow has ended among the white transverse dunes on the western edge of the sandsea. The sands of these white dunes that contain some detrital shell fragments and striking garnet patches are derived from the beach area immediately north of Sandwich Harbour.

West of Rooibank, the dune types in the sandsea change from complex linear to mainly crescentic forms. This crescentic dune belt, mostly <20km wide, includes transverse, barchan, barchanoid ridge and some star dune types. This suite of dune types reflects the high energy, unidirectional SSW wind regime of the Namib coast.

In contrast to the large, complex linear dunes farther inland that encroach northwards at up to 2m/year, the coastal creascentic dunes move at rates of up to 10m/year in the same direction. This is considerably slower however, than the northward barchan movement of up to 100m/year measured near Lüderitz in the southern Namib and near Baia dos Tigres in the northern Namib.

Wind-blown mica is a common constituent of the coastal, crescentic dunes, readily visible on the slipfaces. The dunes south of the Kuiseb are characterised by white mica (muscovite) flakes that are derived from the granites in the Meob-Conception area some 120km farther south. In contrast, black mica (biotite) flakes, derived locally from the Kuiseb flood deposits, predominate on the dune slipfaces within the delta.

Below Rooibank, the riparian woodland is conspicuously reduced. *Tamarix usneoides* is common and the *Acacia* spp. are reduced to scattered, stunted trees. *!Nara* plants are also abundant and their fruits (melons) are harvested regularly here by the Topnaar people. The wide variety of herbaceous plants is the result of transport of seed from the highlands. Raptors e.g. pale chanting goshawks are particularly common, probably related to the abundance of rodents and reptiles in this dune hummock terrain. The endemic dune lark is usually seen in this area. The Kuiseb "Delta" area and low-lying coastal flats have been proposed as a nature reserve.



Extensive flooding of the Kuiseb Delta during the 1963 summer.

(From Stengel, 1964)

Coastal Flats

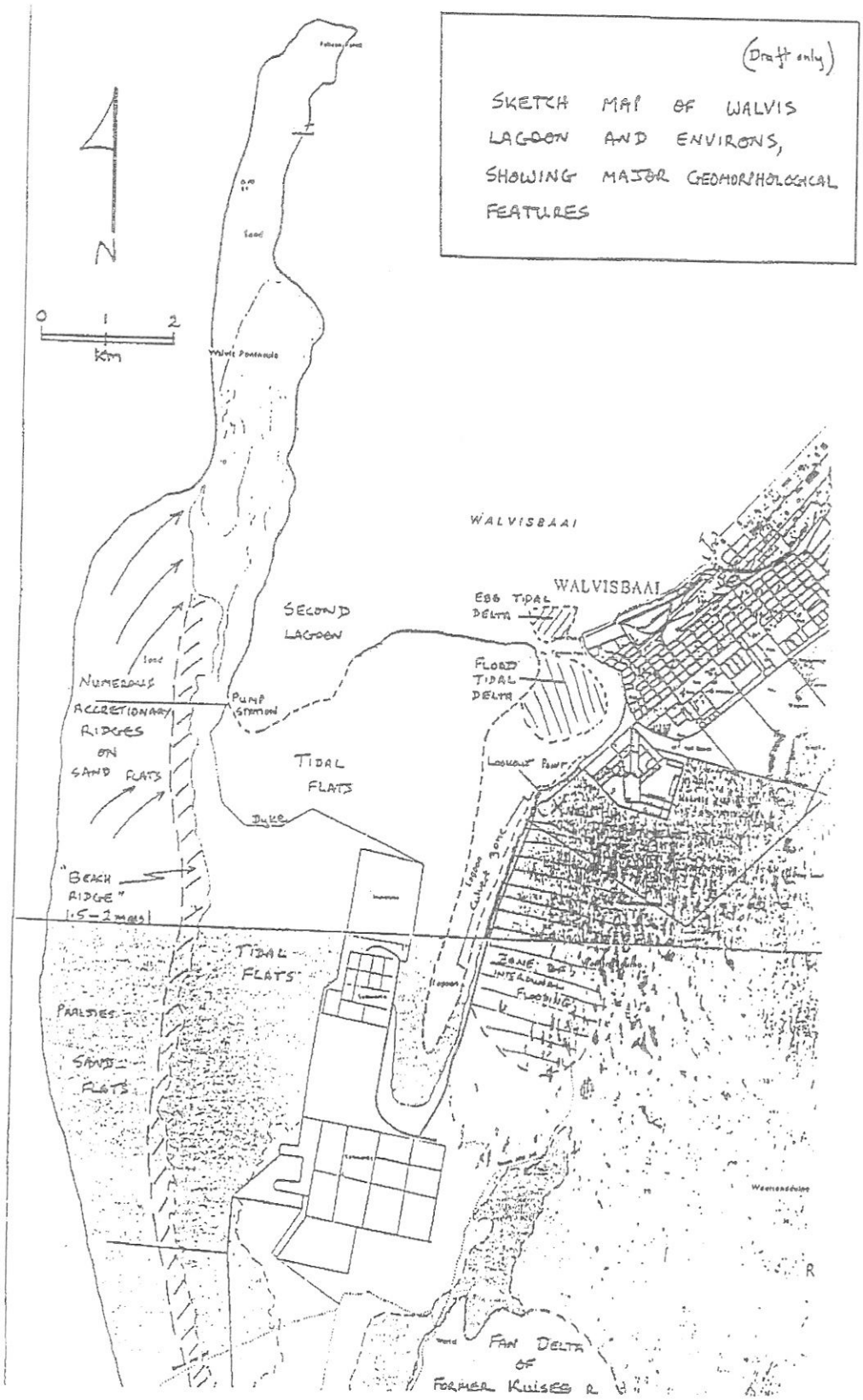
At the interface between the white transverse dunes and the coastal flats, a borehole revealed that the underlying sediment package was some 40m thick. This package included lagoonal deposits with mollusc shells. Several fan deltas of the Kuiseb are evident in this area. The reddish sand at the interface between the "Delta" and the coastal flats is one such deposit and the coarse sand in the Wortel area is another, much larger fan delta.

The low-lying coastal flats harbour extensive reed (*Phragmites australis*) beds and large sand hummocks are formed by *Salsola nollothensis, Lycium tetrandum* and *Tamarix usneoides*. The vegetation is supported by the high water table, which is only slightly brackish.

Shell middens, composed mainly of the white mussel, *Donax serra* – a sandy beach species, are common on the coastal flats. The Topnaar people exploited marine resources and are apparently responsible for these massive shell accumulations that are all <1000 years old.

Salt Pan and Salt Works

The extensive salt pans south of Walvis Bay have formed behind a beach ridge approximately 2m *asl*. This natural western barrier forms the southern part of the large sandspit known as Pelican Point. The eastern boundary is formed by parabolic and hummock dunes, the sand of which has been blown across the pan from the beach. Seawater is introduced into the pan during high spring and equinoctial tides as well as during storms. Some input from Kuiseb floods is also evident. The natural boundaries of the salt pan, the prevailing high energy SSW wind regime and the associated high natural evaporation rate, as well as the low rainfall (10mm/year) have facilitated exploitation of salt in the Walvis area.


(Draft only)
SKETCH MAP OF WALVIS LAGOON AND ENVIRONS, SHOWING MAJOR GEOMORPHOLOGICAL FEATURES
N
0 1 2
Km
WALVISBAAI
WALVISBAAI
EBB TIDAL DELTA
FLOOD TIDAL DELTA
SECOND LAGOON
NUMEROUS ACCRETIONARY RIDGES ON SAND FLATS
PUMP STATION
TIDAL FLATS
DUNE
"BEACH RIDGE" 1.5–2 metres
TIDAL FLATS
PEBBLES
SAND FLATS
FAN DELTA OF FORMER KUISEB R.