NAMIB SANDSTONE: A DISTINCT LITHOLOGICAL UNIT

by

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ABSTRACT

A report is presented of a red sandstone that underlies much of the Namib Desert west of the escarpment. It extends from the Kuiseb River in the north to Luderitz and in places outcrops along the coast. Dissection has resulted in characteristic tabular landforms along the eastern margin. Elsewhere the sandstone is overlain by blown sand and alluvial deposits. The massive, well-jointed strata are both horizontal and cross-bedded. Calcium carbonate inclusions are frequent. Unsorted quartz grains, subangular or rounded, pitted or clear, are the predominant constituent. Although the matrix is rarely solely calcium carbonate, the calcium content of all samples is high. Deposition under seasonally arid conditions is postulated. The Namib succession consists of sandstone resting on older basement rocks, overlain by a limestone conglomerate and then by dune sands derived by weathering from the sandstone. This succession has affinities with the Kalahari Formation of eastern Namibia, Botswana, Angola and the Congo but no firm analogy can as yet be drawn.

CONTENTS

I. INTRODUCTION

Conspicuous red sandstone cliffs interrupt the pediment slope between the Naukluft Mountains and the eastern margin of the Namib dune field, most notably on the farms Vreemdelingspoort, Dieprivier and Sukses. References to this deposit in the geological literature are scarce. On maps the area is shown merely as unconsolidated sediments. Attempts to ascertain the stratigraphical relationships and possible age of the sandstone met with no success. No local English or Afrikaans reports of its occurrence exist. Descriptions in German are few and not easily accessible. This note is presented to bring the deposit to the attention of southern African researchers and to stimulate further investigation and discussion.

The only detailed description prior to 1977 was published in German (Martin, 1950). Other publications merely mention the deposit in passing or fail to recognise it as sandstone, classifying it as calcrete (Goudie, 1972; Ollier, 1977). Selby (1976) recognised the significance of the sandstone for the understanding of Namib Cenozoic history and postulated a semi-arid depositional environment to explain its characteristics. Marker (1977) recognised the location of the Kuiseb River along the northern contact and temporarily termed the deposit "sandrock". Besler (1977) more recently has published considerable detail on the extent and stratigraphic relationships. However, her contributions are in German and not readily available. The name followed here, Namib Sandstone, differs from that suggested by Ollier (1977) and is preferred in view of the significance and extent of the deposit.

II. DISTRIBUTION AND LANDFORM CHARACTERISTICS

In the central Namib south of the Kuiseb River, sandstone gives rise to a tabular topography with near vertical cliffs, rectilinear 35° slopes, pediments and low angle foot slopes extending away from the main outcrops as plains overlain by sand, alluvium or calcareous river gravels. Although the sandstone was known to form high cliffs near Tsondab Vlei, conspicuous calcrete and gravel capped fluvial terraces within the Tsondab valley and to underlie the Tsondab Flats west of the vlei, its full extent was realised only following the 1976 expeditions and construction of a preliminary Namib morphological map from which dune types were excluded. The distinctive landforms are easily recognised even from small-scale air photography and level sandstone outcrops are tonally dissimilar from the mobile sand sheets that overlie their western extent. From a morphological map derived from stereoscopic air photo analysis on a scale of 1 : 100 000, later reduced to 1 : 250 000, the extent of the sandstone north of latitude 26°S has been established. Ground control was carried out by both authors, Besler being responsible for most of the survey (Figs. 1 and 3).

The sandstone extends from the foot of the escarpment, where many plains are floored by the deposit, to the coast and from the Kuiseb River in the north at least to Luderitz in the south. Field checking has shown it to underlie the dune-free area of the Tsondab Flats and the silts of Narabeb. By analogy, the level, tonally dark areas to the south of Sossus Vlei have also been mapped as sandstone. The markedly rectilinear alignment of the northern edge of the Tsauchab valley at Sossus Vlei and the anomalous height of the linear dunes there suggested that the 300 metre dunes rest on a sandstone plateau and spill over to conceal the cliff margin. This assumption has been confirmed by ground checking (Besler, 1977, p. 50). The disturbed nature of the dune pattern west of Sossus Vlei also suggests that the Tsauchab River, like the Tsondab River, once continued to the west (Seely and Sandelowsky, 1974), and that it too is contained in a fluvial valley incised into sandstone. The Sossus Vlei area seems to have been a critical point where the river cut a number of different channels after having been blocked by dunes. Evidence is provided by the more than 20 pan remnants separated from one another by sandstone ridges up to 40 metres high and now largely concealed by dune sands.

The sandstone is also known to outcrop south of Rooi-

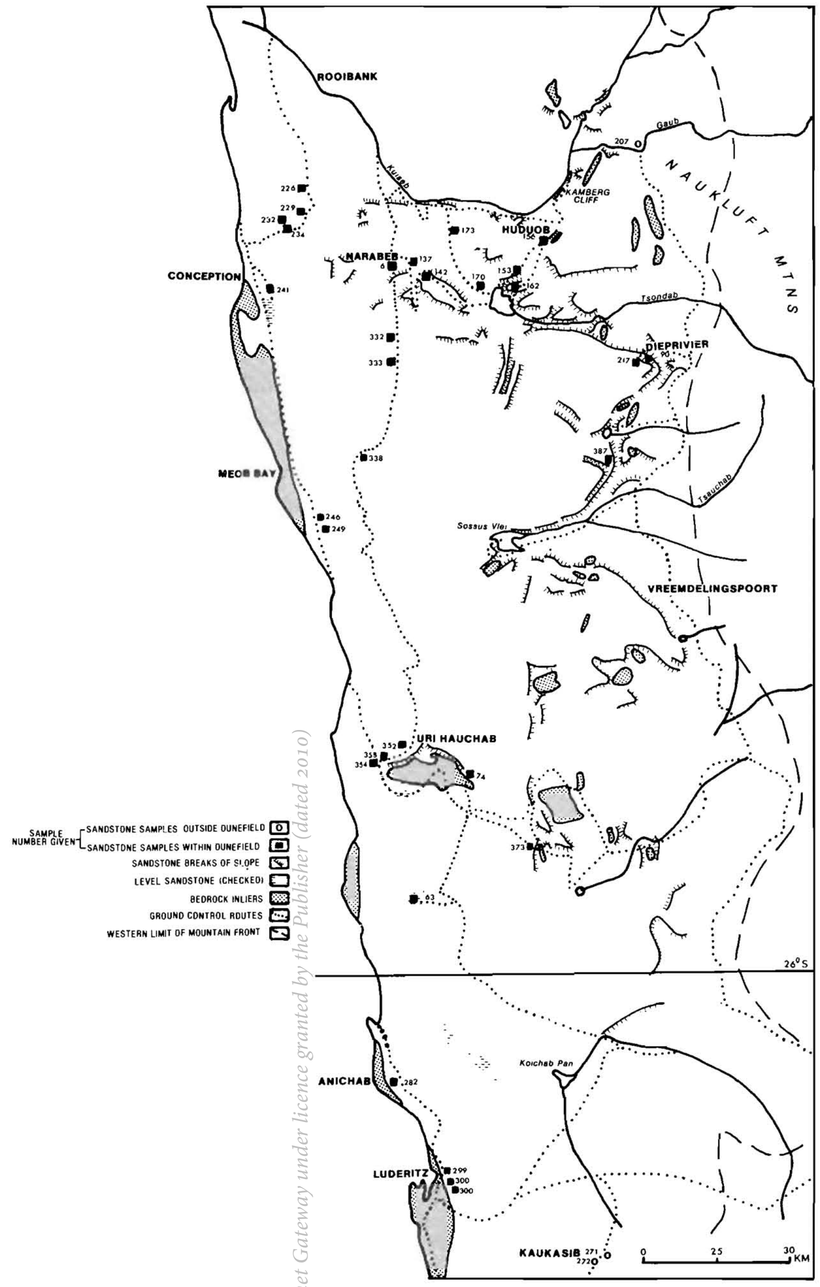

Figure 1
Namib Sandstone outcrops as determined from air photo analysis with ground control. Sample sites and numbers shown.

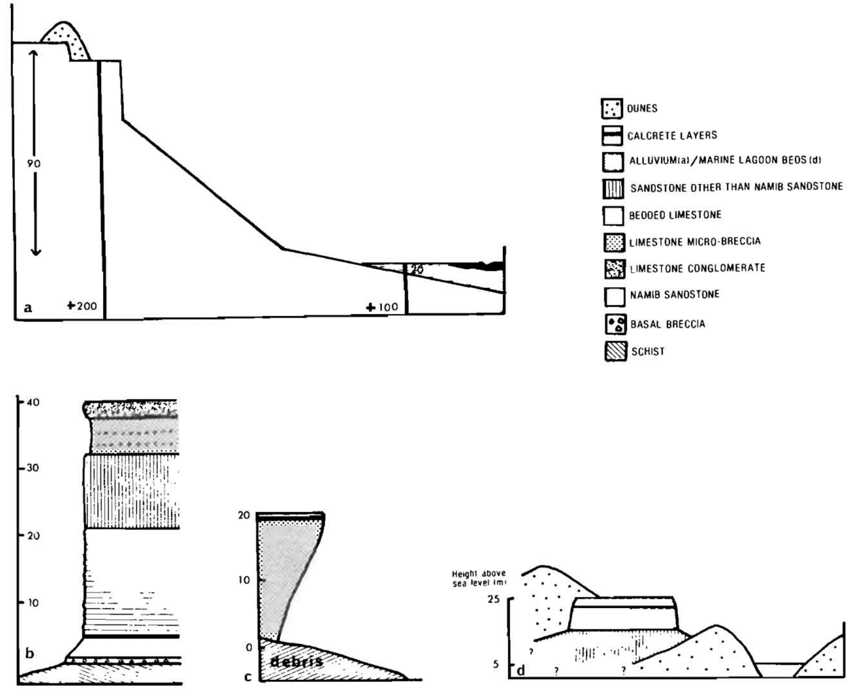

Figure 2
Cross-section to show Namib Sandstone relationships (all figures in metres).
(a) Dieprivier showing location of 2 boreholes (not to scale).
(b) Kamberg Cliff. (Upper sandstone is highly calcified reworked sandstone. Underlying limestone consists of alternating red and white impure limestones.)
(c) Kaukausib tributary section. (Calcrete surface materials consist of dark calcrete overlying white laminar material.)
(d) Raised beach near Meob Bay.

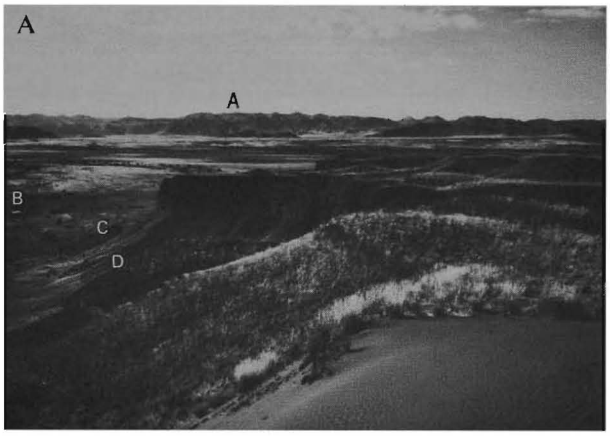

Figure 3
A. Namib sandstone topography at Dieprivier (Site 90) on the eastern margin of the outcrop. (View SSE; A = Naukluft escarpment; B = Dieprivier farm; C = "randfurche"; D = rectilinear slope cut in sandstone.)
B. Sandstone at 240 metres above sea level on the western margin of the outcrop 15 km inland in a dune hollow 60 km south of Rooibank. The sandstone dips north-west and is eroded into yardang-type features. Evidence for former fluvial activity is provided by rounded quartz, dolomite and calcrete pebbles in the foreground (view SW).
Photography: H. Besler, 1976.

bank and on the coast near Conception Bay, at Meob Bay, Anichab and Luderitz (Besler, 1977). Since outcrops have been found throughout the western dune field, it is assumed that sandstone underlies the coastal dunes which spill into the Atlantic Ocean. It also abuts on and surrounds the Uri Hauchab and other southern inselbergs where runoff from the older rock inliers has eroded encircling valleys (Randfurche). On the south-west side of the Uri Hauchab, the floor lies almost 200 metres below the dune-covered plateau. On the north-west of the same inselberg, sandstone terrace remnants veneered with rock débris are preserved against the older rocks 60 to 70 metres above floor level. Elsewhere in the southern Namib, however, dissection has been minimal as runoff is reduced by a lower altitude hinterland. The level surface exhibits truncated dune structures visible from the air even beneath a thin sand cover. In the central Koichab valley sandstone lies at altitudes considerably above the general Namib level and drops westwards towards Luderitz. As the northern limit is marked approximately by the Kuiseb River, the deposit covers a minimum latitudinal extent of 300 km and a longitudinal extent exceeding 100 km (Fig. 1).

The topography of the sandstone both within the northern section of the dune field and along its eastern margin shows that considerable dissection has occurred. Differences in mean altitudes derived from 1 : 100 000 topographic maps frequently reach at least 40 metres (Table I).

TABLE I
Cliff Heights

(a) mean heights according to topographic sheets		
	metres	
Uri Hauchab	64	
Nams	43	
Vreemdelingspoort	78	
Sossus Vlei	129	
Sukses	98, 60, 38	
Dieprivier	68	
Tsondab East	88, 61, 22	
Tsondab Vlei	122, 86, 27, 29	
Tsondab Flats	52, 19	
Sesriem West	130	
Kwessiegat	100	
Koichab	150	
(b) maximum heights found by ground control (aneroid)		
	metres	
Sossus Vlei	40	
Dieprivier	60	
Tsondab East	75	
Tsondab Vlei	90	
Tsondab West Cliff	65	
Koichab Pumping Stat.	200	(covered by dune sand)
Kanaän	45	(covered by dune sand)
South of Meob	25	(covered by dune sand)
SE of Conception Bay	50	

Ground control reveals cliff heights of 60 metres at Dieprivier and 90 metres at Tsondab Vlei. The tabular topography of these areas is a result of limited incision into the sandstone. Even north-east of Conception at sites 231 and 234, fluvial erosion has cut small channels aligned west to north-west. Thicknesses exceeding 90 metres are known from cliff measurements and Besler (1977) cites thicknesses of 60 metres and 130 metres. As few boreholes penetrate to the underlying rocks, total thicknesses remain undetermined although at Dieprivier a borehole sited on the cliffs has penetrated 200 metre sandstone without reaching the base (Fig. 2a). The sandstone appears to thin wherever it abuts on to the uneven older rock surface as shown by the many terrace remnants. In the main area of deposition, however, the sandstone attains considerable thickness.

The sandstone is capped by an impure limestone, prominent chiefly in the north and along major drainage lines. At Tsondab Vlei the higher cliffs are all capped by a limestone conglomerate containing river-worn cobbles. Similar conglomerates are found throughout the upper Kuiseb and Tsondab catchments. The Namib succession appears to include both pure sandstone and conglomerate. However, in the Kuiseb and other valleys, a younger impure limestone valley fill may also be present. At Hudaob, the limestone is a lime-cemented fine gritstone of angular quartz grains, with some pebble bands, which rests directly on schists of the Damara Sequence with no intervening sandstone (Besler, 1972 (Abb. 14); Marker, 1977). But only a few kilometres south, a limestone conglomerate overlies Namib Sandstone residuals at much the same altitude. North-east of Hudaob, the incision of the Kuiseb Canyon exposes a 40 metre cliff of red and white banded sandy limestone and reworked sandstone overlying Namib Sandstone resting on schists (Fig. 2b). Further upstream again, 30 metres of bedded sandy limestone with cobbles of sandstone rests directly on schist. There sandstone, similar to that farther south, appears to be absent. In the Kaukausib valley in the far south, no sandstone is exposed (Fig. 2c). The major valleys incised into either sandstone or into underlying older rocks thus contain depositional sequences that differ from the Namib Sandstone. These deposits must be considered as valley fills.

Subsequent to the deposition of these lime-rich fills, considerable further incision has occurred with the formation of true calcretes of varying ages and at altitudes below the main Namib surface. Investigations by Blümel (1976) and Hüser (1976) of an area between the Gaub and Tson-

TABLE II
Characteristics of Some Namib Sandstone Samples

Locality and No.	Munsell colour	$CaCO_3$	Other matrix	Friability	Main constituent	Grain Characteristics: Mean Grain size (mm)	Sorting	Patina* (% of grains)
Dieprivier 90	5 YR 5/4	†	†	medium	subang. pitted	0,117 2	moderate	90
Dieprivier 217	5 YR 5/4		†	low	subang. pitted	0,081 1	poor	90
Sesriem 387	5 YR 4/4		†	medium	subang. pitted	0,137 3	moderate	95
Sesriem 388	5 YR 6/3	†		medium	subang. pitted	0,069 0	poor	100
Awasib S 373	10 YR 5/3		†	medium	subang. pitted	0,210 1	moderate	85
Lost Valley 156	2,5 YR 4/4	†	†	medium	subang. pitted	0,172 7	poor	95
Tsondab Vlei N 153	2,5 YR 5/4	†		high	subang. pitted	0,143 7	poor	95
Tsondab E 162	2,5 YR 5/4		†	high	subang. pitted	0,081 3	poor	95
Tsondab W 170	7,5 YR 5/4	†		high	subang. pitted	0,231 2	moderate	75
Homeb S 173	5 YR 5/4	†		medium	subang. pitted	0,103 8	poor	95
Tsondab Flats W 142	5 YR 4/6		†	high	subang. pitted	0,174 0	poor	95
Narabeb E 137	7,7 YR 6/4	†		high	rounded pitted	0,244 6	good	10
Narabeb 6	5 YR 4/6		†	medium	subang. pitted	0,221 6	moderate	90
Narabeb S 332	5 YR 5/4	†		high	subang. pitted	0,200 5	moderate	90
Narabeb S 333	5 YR 5/4	†		low	subang. pitted	0,136 5	poor	85
Narabeb S 338	5 YR 4/8		†	low	subang. clear / rounded pitted	0,157 7	moderate	90
Hauchab E 74	10 YR 5/3		†	high	rounded pitted	0,339 6	moderate	5
Uri Hauchab W 352	5 YR 4/6	†		low	subang. clear / rounded pitted	0,111 3	poor	85
Uri Hauchab W 353	5 YR 5/4	†		high	mixed	0,243 6	poor	80
Uri Hauchab W 354	5 YR 5/4		†	high	mixed	0,155 8	moderate	45
Uri Hauchab S 63	7,5 YR 5/6	†	†	high	subang. clear / rounded pitted	0,210 5	moderate	75
Rooibank S 226	5 YR 5/4	†		low	subang. pitted	0,104 7	poor	5
Rooibank S 229	10 YR 5/4	†		high	subang. clear / rounded pitted	0,285 8	moderate	
Rooibank S 232	5 YR 5/6		†	medium	subang. clear	0,160 6	moderate	90
Rooibank S 234	5 YR 5/6		†	high	subang. clear	0,161 7	moderate	55
Conception E 241	10 YR 6/3		†	low	mixed	0,207 2	moderate	15
Meob E 246	5 YR 4/6		†	low	subang. pitted	0,227 7	poor	75
Meob E 249	10 YR 7/2	†		high	mixed	0,190 0	poor	5
Anichab 282	10 YR 6/3	†		high	subang. pitted	0,218 0	poor	5
Lüderitz 299	10 YR 6/3	†		low	subang. pitted	0,384 2	moderate	5
Lüderitz 300	10 YR 7/2	†		low	subang. pitted	0,144 9	poor	5
Lüderitz 300b	5 YR 5/4		†	low	subang. pitted	0,255 0	poor	80
Gaub 207	7,5 YR 6/4	†		low	angular clear	0,069 2	poor	0
Kaukausib 271	7,5 YR 6/4	†		low	angular clear and pitted	0,140 4	poor	0
Kaukausib 272	5 YR 5/6	†		low	angular clear and pitted	0,102 6	poor	0

*There seems to be no correlation between the percentage of grains coated and the Munsell colour because grains with stains or traces of patina only have been neglected.
†Present

dab valleys close to the escarpment, indicate the existence of three distinct generations of calcretes, the younger formations containing reworked calcrete pebbles derived from the older material. Erosion has released fluvial pebbles and calcium carbonate into the desert system so that relatively thin calcrete cappings are found throughout the dune field overlying sandstones at varying altitudes. These calcretes are younger than and distinct from the conglomerate and valley fills.

III. LITHOLOGICAL CHARACTERISTICS

Most of the sandstones are red-brown (5 YR) in colour, the tonal depth decreasing towards the coast where red and yellow beds interdigitate as at sites 232 and 234 south of Rooibank or where grey sandstones (10 YR) overlie red as east of Meob Bay and at Luderitz (Fig. 2d). The western outcrops all show 10 YR colours and are cemented by calcium carbonate. Deep red (2,5 YR) sandstone also with a high degree of calcification is characteristic of the eastern areas such as Lost Valley, Tsondab Vlei and Dieprivier. An exception is provided by the light sandstones in the Hauchab–Awasib area which, unlike the others, are not cemented by calcium carbonate. Colour and degree of calcification appear to be unrelated (Table II).

In cliffs and terraces, the sandstone is massive with prominent, widely spaced major joints. The polygonal surface patterns that are characteristic of some sandstone areas, may in fact have resulted from solutional enlargement of the joint system. Besler (1972) has attributed this polygon development to desiccation within gypseous sediments prior to calcium carbonate cementation. Within a single cliff exposure, both cross-bedded and horizontal beds may be present. Even in the east, where sections are frequent, no constancy in vertical succession could be shown. Lateral facies variation is common. Horizontally bedded strata often include rolled calcium carbonate pebbles concentrated along bedding planes, but nodules chiefly within joints also occur. Some lenses of calcium carbonate occur. A younger, cross-bedded sandstone, often containing calcium carbonate nodules, is found in the form of ridges but never as cliffs. It appears to be less compact and cohesive. The morphology and distribution of this variety of sandstone suggests that it may represent remnant Pleistocene dunes derived from weathering products of the massive deposit. Sample 137 east of Narabeb would seem to be typical of this type. The grains are rounded, well-sorted, pitted and have a mean size of 0,24 mm. Near the coast north-east of Conception at site 231, aeolian cross-bedding and even ripple marks can be seen in alternating red and yellow sandstone layers exposed in vertical channel walls only a few metres in height. At various horizons the coarser red grains form the ripple pattern within the dominant yellow finer-grained sands. Such sandstones contain no calcium carbonate.

In hand specimens the sandstone appears compact but fairly friable and only loosely cemented. However, preparation for grain size analysis demonstrated that only 12 widely distributed samples, out of 30 samples, had a high hand friability. Eleven others had low friability requiring crushing by jaw breaker, pin mill and mortar. The remaining samples with medium friability required crushing by jaw breaker and mortar and are all grouped along the eastern margin of the dune field and in the region north of Narabeb and Tsondab Vlei. The sandstone is, therefore, more compact in the east and hand specimens are deceptive.

All samples were treated with hydrochloric acid to determine the amount of calcium carbonate loss. Losses from surface calcified samples were high. Most samples reacted only slightly in acid and retained their structure. The matrix is, therefore, not solely calcium carbonate as postulated by Ollier (1977). Analysis by X-ray fluorescence spectroscopy, however, revealed a high calcium content in most surface samples of 1×10^4 to 8×10^4 ppm, giving a mean of 2×10^4 ppm which is almost twice as high as the world's average for surface materials (Evens, 1978). The calcium cement occurs in non-carbonate form.

Microscopic analyses (100 × magnification) were carried out (Table II). The main constituents of 17 out of 30 samples are subangular, frosted, quartz grains, in most cases coated with a clear orange-red patina. Under stereo 200 × magnification the frosting can be seen to be due not to chemical etching, but to aeolian pitting. In two samples from the highest marine bench, the main constituents are formed by clear subangular grains with patina. In two other samples from the middle marine bench grains are predominantly subangular and clear, rounded and frosted or subangular frosted all without patina. The marine bench samples are thus distinct from those of the inland Namib Sandstone. However, a very similar mixture of grains occurs in two samples from north-west of the Uri-Hauchab inlier although these show partial patina.

The sand grains are moderately to poorly sorted (calculations after Folk and Ward, 1957). The poorly sorted samples are located along the coast and within the northern dune field. Large, 0,20–0,35 mm, to medium, 0,11–0,20 mm mean grain sizes predominate. Small grains, 0,06–0,11 mm are abundant in samples from sites where water laid sediments have a higher clay content. All these sandstones are poorly sorted. Sorting is more effective in dune sands since smaller cementing particles will have been deflated. Comparison of sandstone and dune sand samples indicates that the sandstone is the source for the modern dune sands. The gradual change in grain size characteristics, during the breakdown of the sandstone, near Tsondab Vlei, provides evidence of this. Here the heavily cemented sandstone has a mean grain size of only 0,08 mm and is poorly sorted whereas the recently weathered sand on the foot slope has already increased to a mean size of 0,18 mm and is moderately sorted. The dune sand in the vicinity has a mean grain of 0,23 mm by comparison and is well sorted. Thus all the finer particles have been removed as aeolian dust.

Samples of the very hard sandstone from river-bed exposures in the Gaub River upstream of the Kuiseb confluence and in a tributary of the Kaukausib River differ in most respects from Namib Sandstone samples. The main constituents of these samples are clear and angular small quartz grains without patina but heavily cemented by calcium carbonate. The iron staining in the cementing calcium carbonate accounts for the colour similarity. These characteristics indicate that the reddish impure limestones were not deposited under arid conditions as blown sand, but during a period of valley infilling by fluvial action. The sediment was possibly coloured at a later stage during fluctuations of the groundwater. Whereas the matrix material of the valley fills may be reddened, that of the Namib Sandstone is always white or colourless.

IV. DISCUSSION

The Namib Sandstone has been shown to form a distinct lithological unit with considerable areal extent, reaching thicknesses exceeding 200 metres. The sandstone is a typical red desert formation that was deposited both as dunes and as sand sheets. The lack of constant stratigraphy, of included fossils or other dateable material makes geological correlation and age determination difficult. Five kilometres inland of Meob Bay, sandstone underlies raised beach deposits at an altitude of 25 metres above present sea level (Fig. 2d). The red Namib Sandstone is overlain by a sequence of grey sand and two distinct marine lagoonal deposits. The grey sandstone is not merely bleached Namib Sandstone since it differs in grain size and in other characteristics as well as in its structure. The overlying lagoonal deposits are of shallow marine origin and have since been dissected. Further remnants of the same deposit are found at lower altitudes near Conception and at Meob Bay. The same marine bench seems to form a cliff which is overlain by dunes 17 km south along the northern part of Grosse Lange Wand. The Namib Sandstone is, therefore, at least older than the 25 metre transgression. Along the Atlantic coast, however, elucidation of the raised beach sequence is complicated by difficulties of access, available information and localised warping (Tankard, 1977). However, in the Tumas catchment north of Walvis Bay, a tentative date of 30 000 to 35 000 years Before Present has been assigned to a younger 17 metre beach (Rust and Wienecke, 1976). The Namib Sandstone must be older than this deposit.

The suggestion has further been made that the Namib sequence of sandstone and conglomerate is a western equivalent of the Kalahari Formation (Martin, 1950). In this interpretation the Pomona Quartzite of the southern Namib is equated with the sporadic Botletle Beds. Martin also recognises the existence of valley fills along major drainage lines that differ from the Namib Sandstone. The Urinanib succession illustrated by Mabbutt (1955) has similarities with the Namib succession although gravel beds are absent. Cayen and Lepersonne (1952) describe the Congo Kalahari Formation as follows: a basal unconformable gravel, sand and sandstone series followed by compact sands, sandstones and silicified grès polymorphes. This solid succession is in turn overlain by dunes consisting of unconsolidated ochre-red sands. The Namib succession of sandstone overlain by limestone conglomerate is thus similar to the Kalahari Formation in eastern South West Africa (Namibia), Botswana, Angola and the Congo. However, no firm analogy can be drawn since lateral facies variation have resulted in little consensus as to the exact characteristics of the Kalahari Formation.

Recent work has attributed the source for the Kalahari Sandstones to the underlying Karoo strata; however, the Karoo succession is absent west of the Naukluft Escarpment. A tabular remnant caps the Gamsberg at an altitude of 2 300 metres. The conglomerate overlying the Namib Sandstone contains black limestone and dolomite pebbles derived from the Schwarzkalk Series of the Nama system found within the higher Naukluft Mountains. Thus, it might be postulated that the source material for the sandstone was derived from sandstones of a Karoo sequence which have since been totally removed. Sand grain characteristics indicate that the quartzitic Gamsberg sandstones have a mean grain size of 0,27 mm, most grains being subangular. In this respect they are, therefore, similar to those of the Namib Sandstone. Nama System quartzites and other older sandstones are all too metamorphosed and too fine-grained to have supplied sand to the Namib Sandstone.

The age of the Namib Sandstone and its derivation thus remains an open question. The Namib Sandstone would appear to have been deposited at some time between the Tertiary period and the present. If it was derived from the

Karoo sequence, then it must be relatively young since vigorous erosion only followed rejuvenation which, by analogy with Natal, occurred in the early Tertiary period. At present it can merely be stated that Namib Sandstone is temporally distinct from the Pleistocene and Recent dune sands that overlie it.

V. SUMMARY

The Namib Sandstone is a consolidated rock deposit with considerable surface extent. It underlies and extends beyond the present Namib dune field. It provides a source for the Namib sands and is of importance in any analysis of the Namib's geological history. An outline of its major characteristics has been presented in the hope that further research will be promoted and duplication of effort avoided.

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