Environmental changes in the Kaokoland Namib Desert during the present millennium

(with 7 figures, 6 plates, and 2 tables)

by

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KEY WORDS

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ABSTRACT

Some fluvial forms and sediments in the valleys of the Hoanib and Hoarusib Rivers in the Kaokoveld Namib are described. Radiocarbon dates of plant remains from some of the younger deposits suggest a sequence of climatic fluctuations during the present millennium. Thus a relatively wet phase of autochthonous valley formation which occurred in both river systems came to an end in the 12/13th centuries AD in the Hoarusib valley. Arid conditions with low energy floods probably prevailed until after the 16th century AD in the Hoanib valley. Active incision set in after this, and still prevails, suggesting a recent increase of precipitation in the hinterland. The dated sediments are defined informally as the youngest members of two new lithostratigraphic units: the Hoanib Alluvium formation and the Hoarusib Alluvium formation. Palaeoenvironmental changes in terms of 'wetter' and 'drier' on a time-scale of centuries rather than millenia have now been recognized in the landforms of the region.

ZUSAMMENFASSUNG

Es werden einige fluviale Formen und Sedimente der Hoanib- und Hoarusibriviere (Rivier = Trockenfluß) in der Kaokoveld/Namib beschrieben. 'Feuchtere' und 'trocknere' Klimaschwankungen in der Zeitskala von Jahrhunderten statt Jahrtausenden lassen sich aufgrund geomorphologischer Beobachtungen und 14C-Daten an Pflanzenresten erschließen. Demnach endete eine relativ feuchte Phase autochthoner Talbildung, die in beiden Riviersystemen vorkam, im Falle des Hoarusibriviers im 12./13. Jh.n.C. Im Hoanibrivier scheinen hingegen bis nach dem 16.Jh. aride Verhältnisse mit energiearmen Fluten geherrscht zu haben. Danach begann wieder eine Phase aktiver Einschneidung, die bis heute fortdauert und auf eine neuerliche Zunahme der Niederschläge im Hinterland verweist. Die datierten Formen und Sedimente werden informell als jüngste Glieder zweier neuer lithographischer Formationen, die 'Hoanib Alluvium formation' und die 'Hoarusib Alluvium formation', definiert.

CONTENTS

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1 INTRODUCTION

In the Kuiseb River valley, upstream of the research station at Gobabeb, landforms and sediments bear evidence of climatic change during the Quaternary. The relative ages of these features were established in 1972 and correlated with the sequence previously derived mainly in the coastal area (Rust and Wieneke, 1974). Further work on, and discussions of, the geomorphology of this river valley have since been published by various authors (Ollier, 1977; Marker, 1977; Marker and Muller, 1978; Rust and Wieneke, 1980; Marker, 1983; Ward, 1984).

One of the prominent sedimentary features in the Kuiseb canyon is the 'Ossewater lake deposits' (Rust and Wieneke, 1974) or 'Homeb silts' (Marker, 1977; Ollier, 1977). These have been absolutely dated by radiocarbon to 23 000 to 19 000 BP (Vogel, 1982). The dating provides at least one useful fixed point in the chronological sequence of past climatic events in the region. The palaeoenvironmental interpretation of these and other geomorphic relics is not always uncontroversial, but there is no doubt that they do reflect palaeoclimatic conditions in one way or another. Eventually they may provide a reliable chronological framework of local environmental change during that geologic period which is still relevant to the present. This may then be used to predict the effects that future global climatic changes can be expected to have on the southern African subcontinent.

In order to investigate whether comparable landforms and sediments are represented in the dry valleys of the rivers to the north of the Kuiseb River and, if possible, to date them, the area between the Ugab and the Kunene Rivers was visited in July/August 1984 (Fig. 1, 2).

In the course of the fieldwork geomorphologic-stratigraphic evidence of climatic fluctuations was observed that obviously related to the more recent past. Radiocarbon dates indicate that these phenomena pertain to the present millennium and are relevant in that they reflect the variability of the present climate.

As is well known, radiocarbon dates, particularly for the past 500 years, are somewhat distorted (cf. de Vries, 1958; Stuiver and Suess, 1966; Lerman et al., 1970; Vogel, 1970, 1971), and it is necessary to convert such results to true historical dates in order to provide a realistic chronological sequence. This is done for the radiocarbon measurements presented here by using the most recent calibration curve for the southern hemisphere (see forthcoming issue of *Radiocarbon*, 1986, and Vogel et al., therein).

2 HOANIB RIVER

The Hoanib River derives from the Great Escarpment beyond the Namib desert and has a length of 238 km, and an average gradient of 0.48% (Topographical Map SWA 1 : 250 000). It normally ends in an extensive floodplain on the inland side of a ca. 10 km broad dune belt that runs parallel to the coast (Fig. 3). In exceptional rain years such as 1982 and 1984 the river breaks through the dunes and reaches the Atlantic Ocean. On the first of these occasions the floodwater built up in front of the dune barrier until it started to filter through on the other side. Once this happened the dune sand was rapidly eroded away on the downstream side until a passage through the dune was created (pers. comm. of the local rangers).

Within the dune belt remnants of sandy silts occur 7 m above the river bed, and driftwood was found at

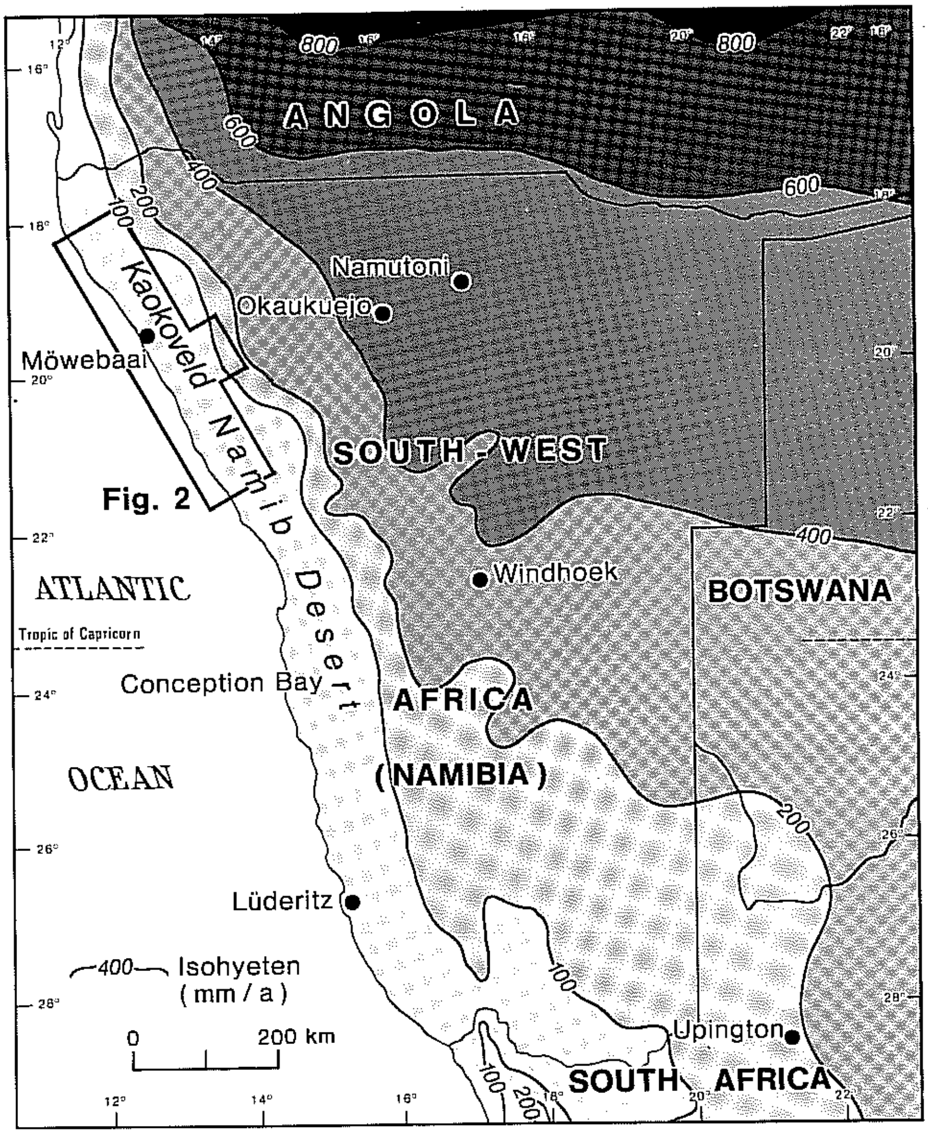


FIGURE 1: Locality of the investigated area in South West Africa/Namibia.

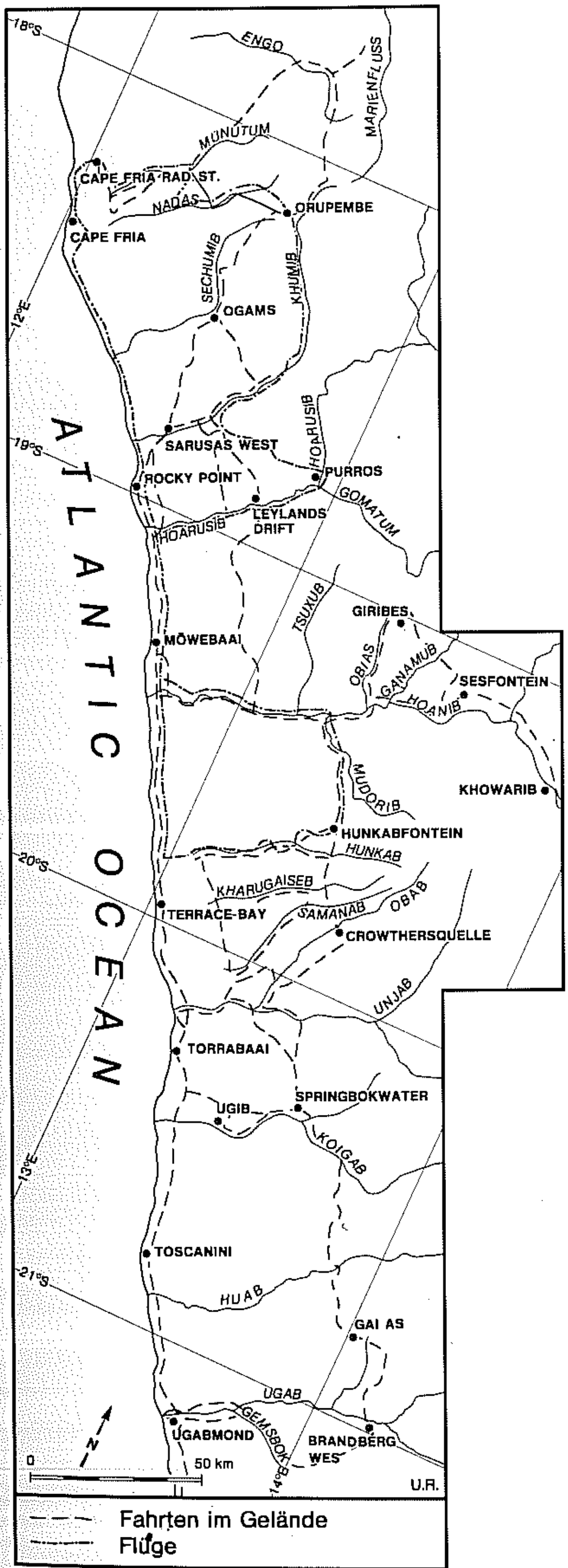


FIGURE 2: Enlargement of study area shown in Fig. 1 with the routes travelled.

various levels up to 13 m above the present river bed. Two of these logs (Fig. 3) were dated with the following results:

Pta-3882. Hoanib log + 7m 40 ± 30 BP
Outer annual rings of driftwood log 7 m above present river bed in Hoanib river course in dunefield ca. 10 km from coast. Most probable calibrated date: AD 1900.

Pta-3884. Hoanib log + 13 m 200 ± 70 BP
Outer annual rings of driftwood log 13 m above present river bed in Hoanib river course in dunefield ca. 10 km from coast. Most probable calibrated date: AD 1670 or AD 1770.

These datings confirm that considerable floods have passed through the dunefield during the last centuries to spill into the Atlantic.

As stated above, the river normally terminates in an extensive 'internal delta' or floodplain on the landward side of the dunes (Fig. 3). The floodplain extends for 16 km from 170 m above sea level to 200 m a.s.l., with a gradient of 1.9 o/oo. The sediment (HOM 3 in Fig. 6) consists of fine-grained river-end deposits which are in the process of accumulation.

From about 30 km inland to Amspoort (260 m a.s.l.) the meandering Hoanib is cutting into its own alluvial sediments (Plate 1). Geomorphologically the internal delta in this section forms a terrace of the Hoanib. We term the sediments that form this terrace as the 'Amspoort silt member' of the 'Hoanib Alluvium formation'. It consists predominantly of fine-grained fluvial silt (HOM 4, 10, 4211, II, IV in Fig. 6). The stratification is mainly horizontal, indicating low flow velocities (Picard and High jr, 1973).

In this tract of the river two buried trees have recently been exposed in the right-hand river bank, probably by the 1982 or 1984 floods. Radiocarbon analysis of samples from these trees gave the following results:

Pta-3880. Hoanib trunk 350 ± 40 BP
Outer annual rings of upright trunk of dead tree completely buried *in situ* by 9 m river silts and now exposed by lateral erosion of river bed (Plate 2) at site of profile 42 (Fig. 3) some 38 km from the coast. Most probable calibrated age: between AD 1490 and AD 1640.

Pta-3879. Hoanib tree (105.3 ± 0.6)%
Inner wood of dead branch of still living tree some 3 km downstream of Pta-3880, buried 2 m in silt and recently exposed in bank of river channel some 7 m above river bed. Most probable calibrated date: AD 1958.

The first of these dates, Pta-3880, shows that some 9 m of silt has accumulated to cover the still upright standing dead tree since the 16th century. The second date, Pta-3879, suggests that the incision of the present river channel must be a fairly recent event. Even if the 2 m of silt covering the trunk of the tree is overbank deposit, the adjacent river channel was probably not as deep at this point as it is today when the tree was partially buried. The evidence therefore indicates that active erosion of the Amspoort silts is taking place in the present century.

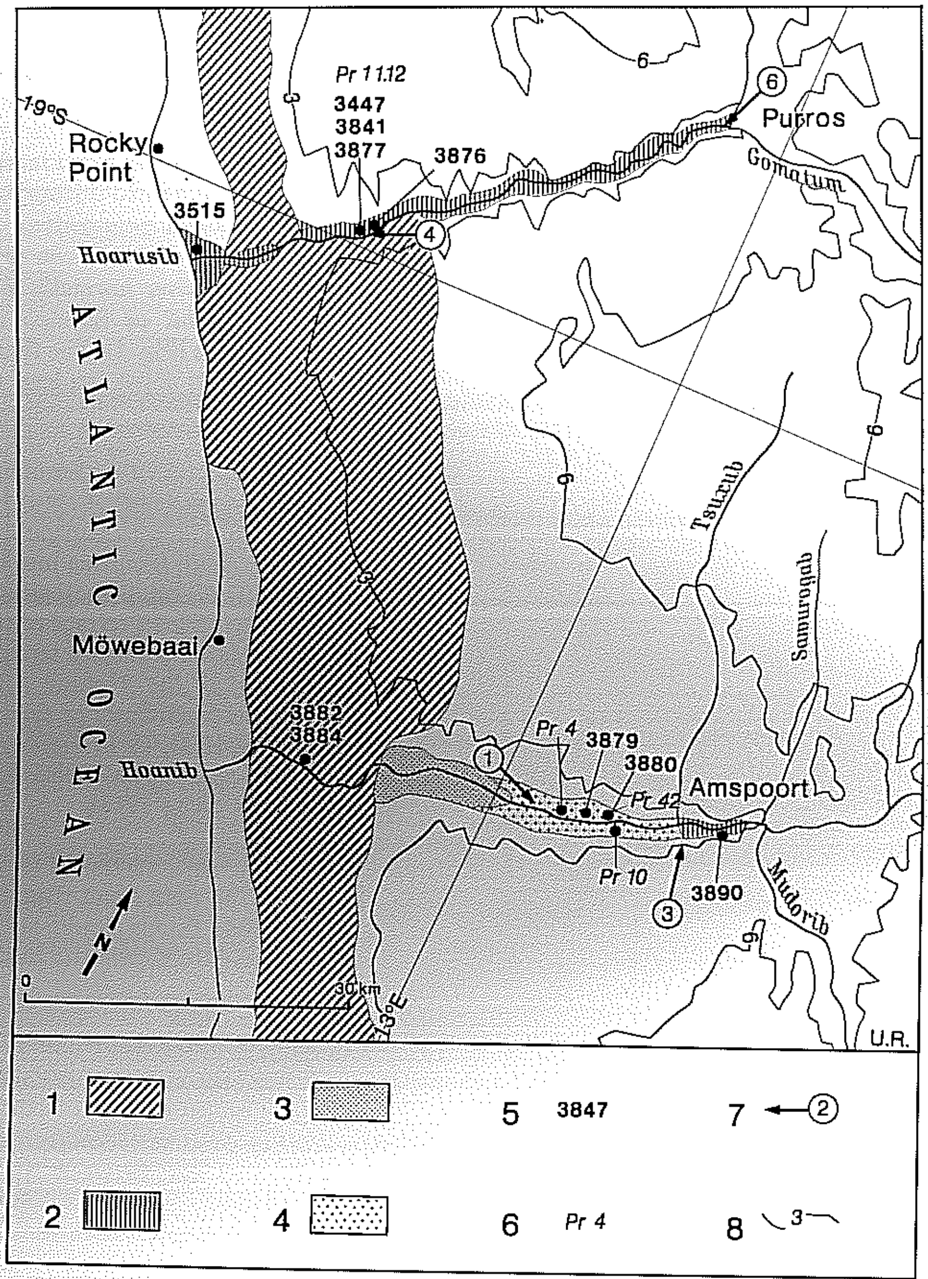


FIGURE 3: Late Holocene sediments and landforms along the Hoanib and Hoarusib Rivers.
1: Dune belt
2: Yount Terrace members (jT) of the Hoanib Alluvium formation and of the Hoarusib Alluvium formation
3: Floodplain of the Hoanib River
4: Amspoort Silts
5: Analysis number (Pta-) of the 14C dates
6: Number of field profile
7: Photo/Plate with direction of sight
8: Isohypse (x 100 m)

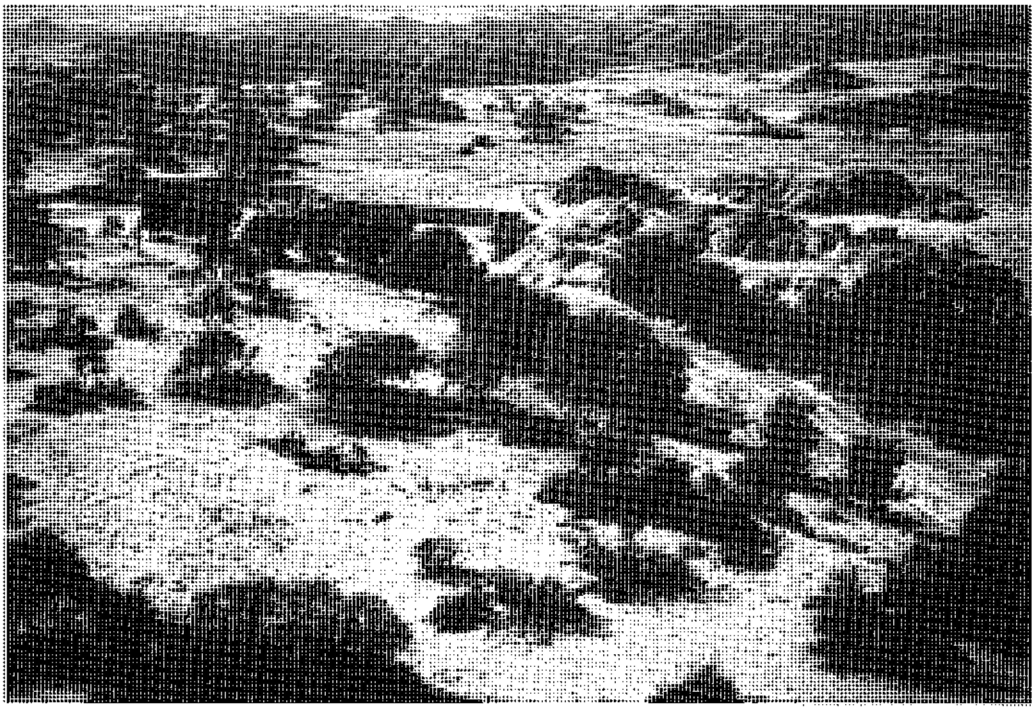
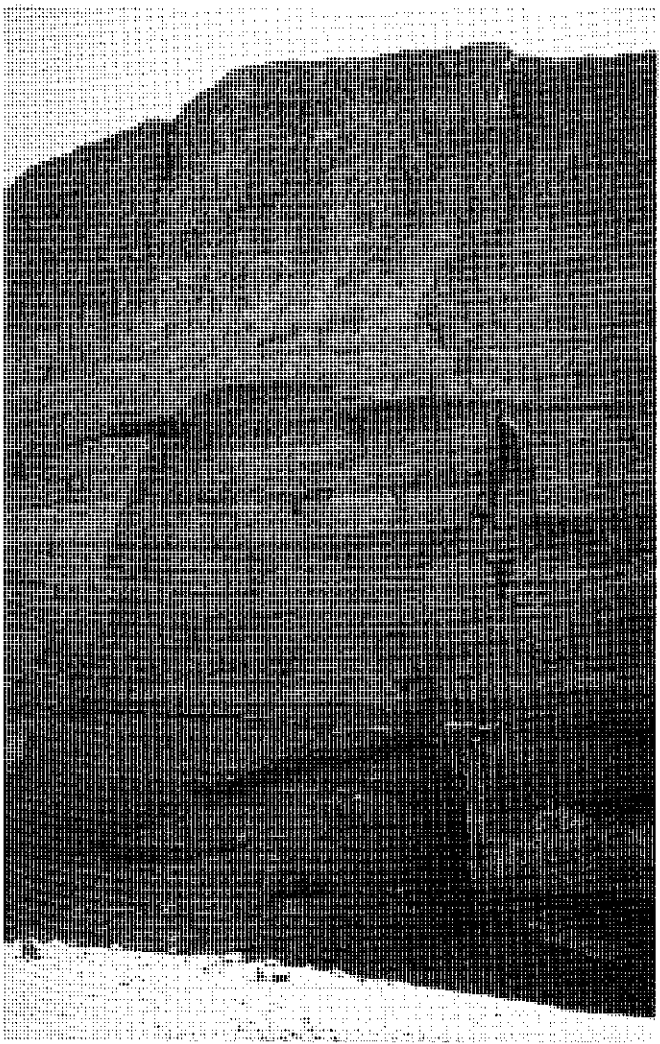


PLATE 1: 'Amspoort Silts' of the Hoanib River towards the SE. The Hoanib in the mid-distance is incised into its own former river-end deposits (the Amspoort silts member of the Hoanib Alluvium formation). These sediments bury a pre-existing relief which is visible in the background and on the right. (Air photo U. Rust 29.8.1984)



At Amspoort (poort = defile) the Hoanib cuts through bedrock to enter the previous floodplain area. At this point the Tsuxub tributary joins the Hoanib River from the north. The terrain is seen on Plate 3, and in Fig. 5 the sedimentary situation at the mouth of the Tsuxub is depicted schematically. The sequence of events here was as follows:

- accumulation and calcification of the basal conglomerate
- deposition of the gravels of the Lower Terrace (uT)+ from the Tsuxub valley up to level a

+ oT = obere Terrasse = Upper Terrace
  uT = untere Terrasse = Lower Terrace
  jT = junge Terrasse = Young Terrace

- incision of the Young Terrace (jT) to the base level b
- accumulation of the 'Amspoort silts' up to level c
- incision of the present Hoanib River course and formation of Tsuxub gully

PLATE 2: Profile 42 in the Hoanib River (cf. Fig. 3). *In situ* tree which grew from a level at or below the present river bed and was covered by 9 m of Amspoort silt while still upright. The tree ceased growing about AD 1565 ± 75 and was subsequently buried. When the silt build-up had reached a height of + 1.5 m, fire produced a charcoal level (below, left) but still left branches standing. (Photo U. Rust 22.8.1984).

The situation below, at and above Amspoort, must be considered together. The levels a and c in Fig. 5 cross each other downstream of Amspoort and the basal calcified gravel dips below the surface and is not exposed again. Above Amspoort the Hoanib is incised 1 to 2 m deep into fluvial sediment. This deposit is a typical channel-fill sequence consisting of fine and coarse fluvial sediment (Picard and High jr. 1973). An exposed log buried in this fill sequence (Fig. 3) gave the following date:

Pta-3890. Hoanib log 1120 ± 50 BP
Log protruding from Hoanib Young Terrace deposit above Amspoort in Hoanib river. Calibrated date: AD 920.

This fluvial deposit is designated the Hoanib Young Terrace (jT) of the Hoanib Alluvium formation. The

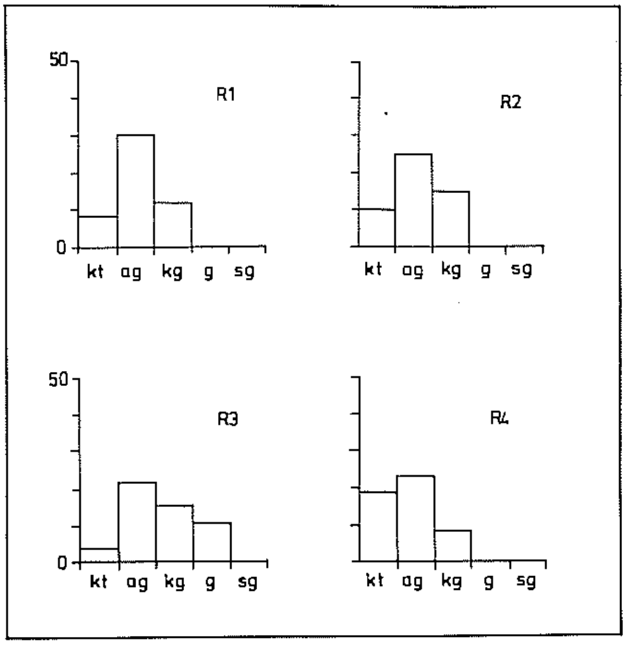


FIGURE 4: Histograms of the frequency distributions of the degree of roundness for selected samples of gravels (after RUST and WIENEKE, 1973).
R 1: Sawurogab Lower Terrace (uT)
R 2: Sawurogab river bed
R 3: Hoanib river bed
R 4: Hoarusib Young Terrace (jT)
kt = kantig/angular, ag = angerundet/subangular,
kg = kantengerundet/subrounded, g = gerundet/rounded,
sg = sehr gut gerundet/well-rounded

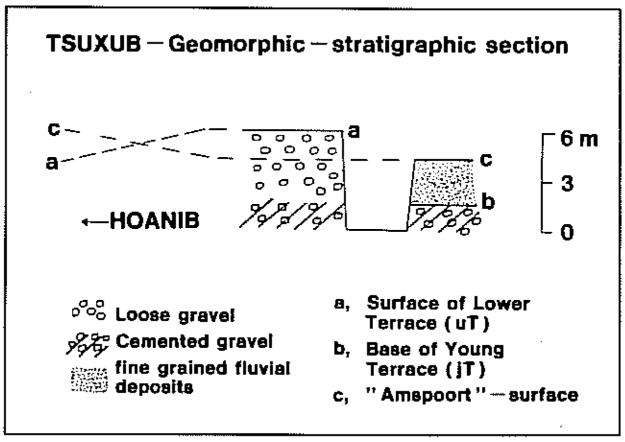


FIGURE 5: Schematic section through Tsuxub River at junction with the Hoanib River at Amspoort (see **Plate** 3).

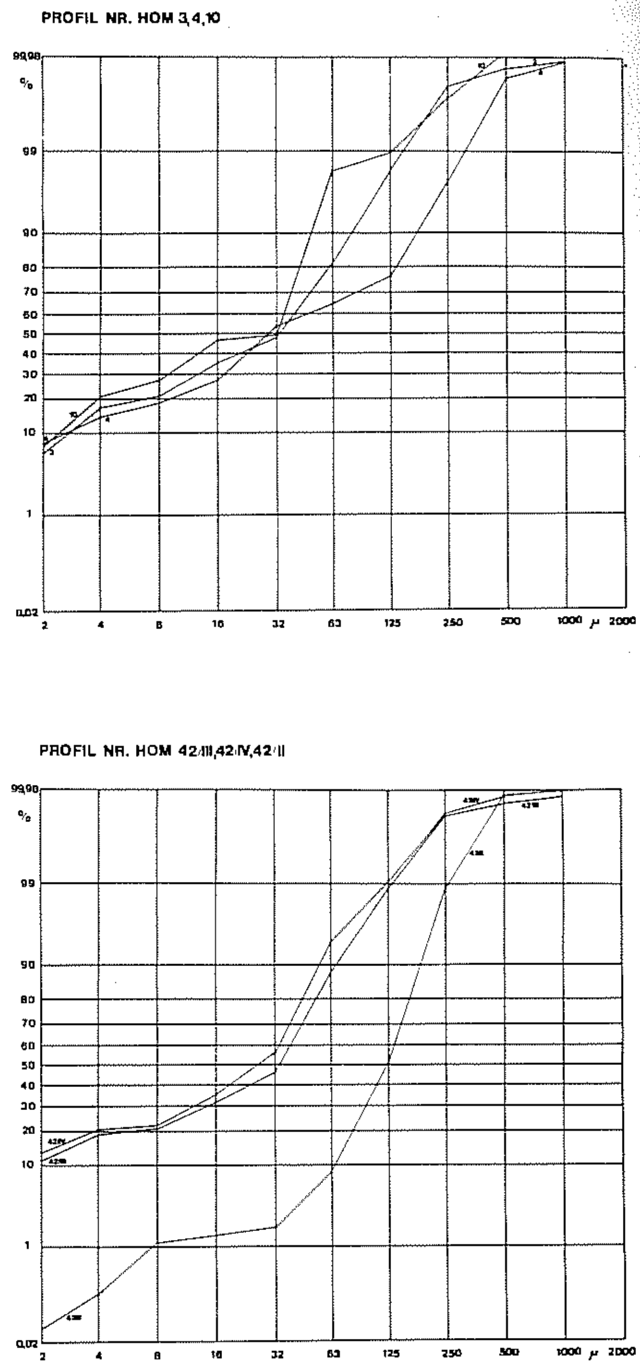


FIGURE 6: Cumulative frequency curves of grain size distributions of selected sediment samples from the Hoanib system, plotted on probability paper with a logarithmic ordinate.

basal part of the Hoanib Young Terrace was also accumulated from the Tsuxub side valley (Fig. 5) and thus documents autochthonous valley formation (RUST, 1980). The date Pta-3890 suggests that the Hoanib Young Terrace already started accumulating some thousand years ago and continued to do so at least until the 16th century (Pta-3880). In fact the dates indicate a gradual progression of the aggradation downstream during the present millennium.

At present deposition is still taking place on the floodplain (internal delta) east of the dunes, but incision has started upstream of this, thus eroding the 'Amspoort silts'. Lithostratigraphically the Hoanib Young Terrace upstream of Amspoort and the Amspoort silts downstream of Amspoort (Fig. 3) may be only one unit but geomorphologically they document two different palaeoenvironments (par. 4., Table 1.).

3 HOARUSIB RIVER

The Hoarusib River also originates in the more humid hinterland (Fig. 1, 2) along the Great Escarpment. It has a length of 240 km and an average gradient of 0.47‰ (Topographical Map of SWA 1: 250 000). Except in years of low rainfall it often reaches the Atlantic Ocean at least once during the season.

Between Purros at 300 m a.s.l. (Fig. 2, 3) and 'the Poort' at 80 m a.s.l. the river runs along a channel in bedrock with numerous, relatively short, ruggedly incised side-valleys or 'gramadullas' (in the sense used for the similar landscape in the Kuiseb River Canyon by Rust and Wieneke, 1974). From just above the final poort some 11 km from the sea, remnants of massive silt deposits occur, mainly in protected localities in the northern side-valleys. These silts rise to at least 70 m above the river bed and can be traced upstream to well beyond Leyland's Drift (200 ma.s.l.). They reflect extensive choking of the valley system by the river itself. The fine-grained (Hom 12 III, IV in Fig. 7) horizontally stratified sediments are similar to, but more extensive than, the 'Homeb silts' in the Kuiseb valley (Vogel, 1982) and may also document shortening of the river for an extended period during the Pleistocene. Radiocarbon dates (unpublished) show that these silts are considerably older than those at Homeb, but their chronostratigraphic position is still uncertain.

The type locality of the silts is in the Clay Castles Valley (Plate 4) ca. 17 km upstream from the river mouth. We therefore call these silts the 'Clay Castles Silts member' of the fluvial sedimentary sequence in the Hoarusib river, which we term the 'Hoarusib Alluvium formation'.

At its mouth the Hoarusib River has deposited an extensive fan some 7 km across which is at present being abraded by the sea. Radiocarbon dates (unpublished) suggest that these silts were laid down in mid-Holocene times. The present river has cut a bed some 8 m deep through the delta to spill directly into the Atlantic Ocean. This sedimentary body would constitute another member of the Hoarusib Alluvium forma-

TABLE 1: Environmental changes during the present millennium in the Kaokoveld Namib Desert

	Evidence		Interpretation		
	Time (AD)	Geomorphology	Morphodynamics	Climate	HELGREN's (1979) Model
HOARUSIB VALLEY	present	present river bed gullies in tributaries	river lengthening	as present	arid incision
	12/13th centuries	accumulation of jT Hoarusib Young Terrace)	autochthonous valley formation	more humid than present	arid aggradation
	before 12/13th centuries	base of jT			humid incision
HOANIB VALLEY	present	presen river bed present floodplain gullies in tributaries	river lengthening	as present	arid incision
	after 16th century	Amspoort silts	river shortening	more arid than present	arid aggradation
	before 10th century	accumulation of jT (Hoanib Young Terrace)	autochtonous valley formation	more humid than present	
		incision of jT (level 'b' in Fig. 5)			humid incision

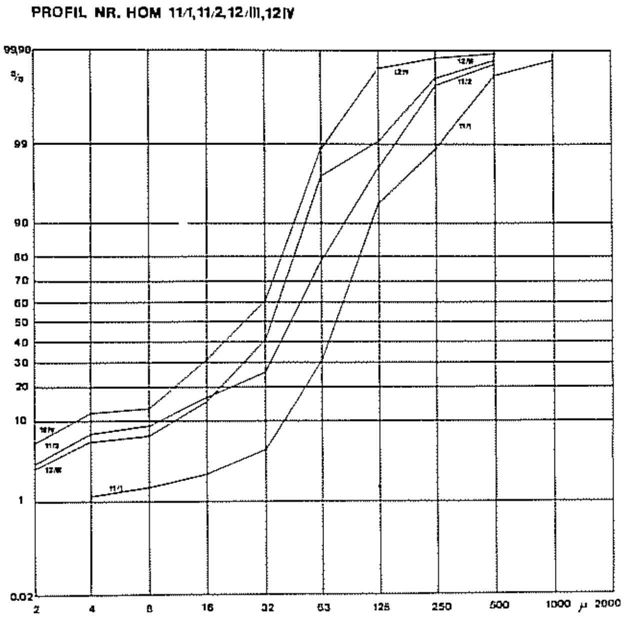


FIGURE 7: Cumulative frequency cures of grain size distributions of selected sediment samples from the Hoarusib system plotted on probability paper with a logarithmic ordinate.

tion. Along the river a lower terrace of silty material is visible at the mouth (see below).

In the Clay Castles Valley a Young Terrace is also prominently exposed (Plate 4). It consists of fluvial sediments (HOM 11/1, 11/2; Fig. 7) with only moderate rounding (R 4 in Fig. 4). The high proportion of angular gravels (kt-fraction) indicates the presence of slope rubble that has been transported for a short distance only (Rust and Wieneke, 1973). In addition the terrace incorporates reworked sediment and blocks of Clay Castles silt (Plate 5). Geomorphologically this Hoarusib Young Terrace (jT) can be intermittently traced all the way up to Purros (Plate 6) and downstream to the river mouth (Fig. 3). The Hoarusib River has removed most of this terrace deposit and often only a bench mark of silt remains clinging to bedrock on the river bank. In the gramadullas the terrace is, however, still mainly intact with relatively minor gullies extending up the side valleys (Plate 4). At Leyland's Drift (Fig. 2) there are also two older terraces (uT and oT) which will, however, not be discussed here.

Several samples of plant material were recovered from the Hoarusib jT-sediments at and near the Clay Castles Valley. Radiocarbon dates of these samples are as follows:

Pta-3447. Hoarusib jT plant 890 ± 20 BP
Scattered plant fragments stratified 2 m below surface of Hoarusib Young Terrace near entrance of Clay Castles Valley. Most probable calibrated date: AD 1170.

Pta-3841. Hoarusib jT reed root 860 ± 50 BP
Reed root in same level as above sample. Most probable calibrated date: AD 1200.

Pta-3877. Hoarusib jT log 1120 ± 50 BP
Outer wood of 20 cm log buried 0.4 m below surface of terrace at same locality. Calibrated date: AD 920.

Pta-3876. Hoarusib jT branch 720 ± 40 BP
Branch buried 1.5 m below top of 5 m terrace fragment clinging to bedrock in main river channel 2 km upstream from Clay Castles junction. Calibrated date: AD 1270.

Pta-3515. Hoarusib jT charcoal 900 ± 50 BP
Charcoal eroding from the Young Terrace 2 km upstream from the river mouth. Calibrated date: AD 1160.

Except for the log (Pta-3877) the calibrated ages of the samples all fall between ca. AD 1160 and 1270. That of the log is ca. AD 920, but this need not represent a discrepancy since it may already have had a considerable age when embedded. In this arid environment hard wood does not decay readily, and the possibility of finding redeposited old logs always exists. On the basis of these results we may conclude that the aggradation of the Hoarusib Young Terrace took place during the 12th and 13th centuries.

4 INTERPRETATION

As has been pointed out most recently by Mensching (1984), the palaeclimatic interpretation of terraces and deposits of ephemeral rivers poses specific problems. He came to the conclusion that palaeoenvironments can only be reconstructed by considering the interrelationship of the forms and sediments in both the main and side valleys. We agree with this view and, as has been shown for the Kuiseb River (Rust and Wieneke, 1980), the side valleys are in fact more important, because allochthonous influences need also to be taken into account in the main channel. Helgren (1979, pp 317-326) has developed a geo-ecological 'environmental scenario for alluvial fills' which can be applied to the features investigated here (Table 1).

The alluvial fills in the gramadullas or side valleys are locally controlled. The degrading of the slopes and material transport in the washes indicate that a period of active formation was terminated by a phase of accumulation. The Young Terrace (jT) of the Hoarusib River documents this situation: A period of active incision in the gramadullas, representing wetter conditions in the Namib itself, ended with 'arid aggradation' (Helgren, 1979), thus producing the sediment body of the Young Terrace. Subsequently the runoff

TABLE 2: Fundamental environmental tendencies during the present millennium in the Kaokoveld Namib Desert

Time (AD)	Geomorphology	Climate
present	river lengthening	as present
12/13th centuries to after 16th century	river shortening	drier than present
before 12/13th centuries	autochthonous valley formation	more humid than present

PLATE 3: Junction of the Tsuxub River with the Hoanib River at Amspoort from the S. In the middle and background the Lower Terrace (uT) of the Tsuxub is seen to grade into the talus on the hill slopes. In the mid-distance on the right an erosion gully of the Tsuxub cuts into the Amspoort silts while the Hoanib in the mid-foreground dissects the lower calcified gravels (compare Fig. 5) (Air photo U. Rust 29.8.1984)

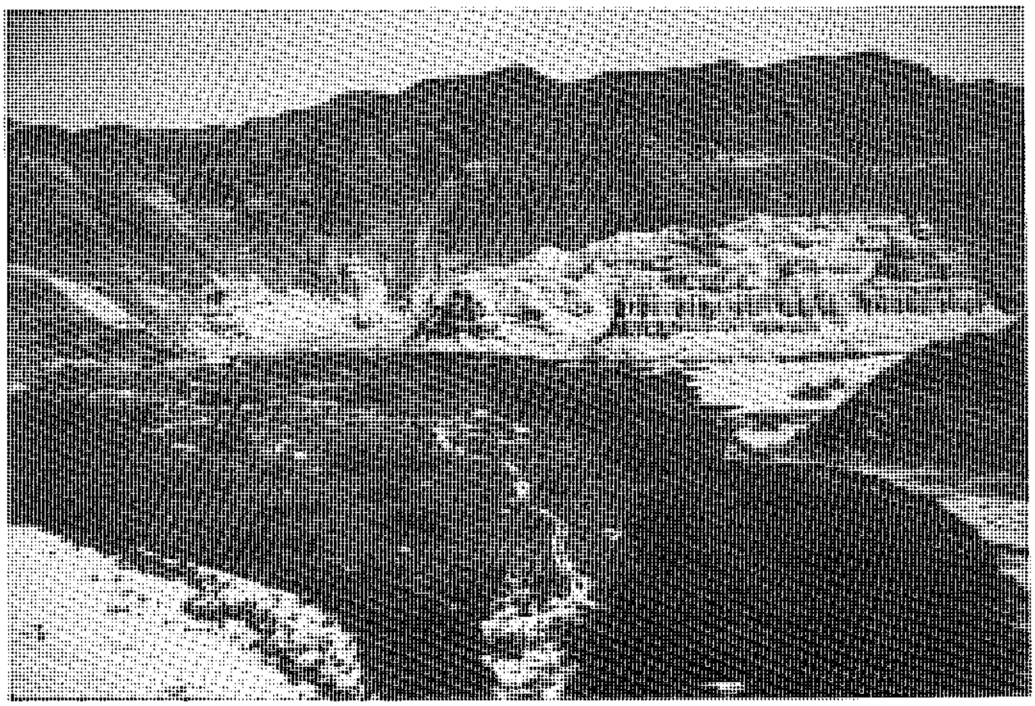


PLATE 4: Type locality of the 'Clay Castles Silts' in the Hoarusib grammadullas 130 m a.s.l. from the E (Fig. 3). In the left foreground is the Hoarusib river-bed with its overgrown high-water bed. In mid-distance the white erosion remnant, 25 m thick, of the 'Clay Castles Silts' which filled the preexisting valley relief. The Young Terrace (jT) of the Hoarusib in mid-distance and right foreground is present in the main channel and the local tributary (Clay Castles Valley), and is currently being eroded in both (Air photo U. Rust 28.8.1984).

from the hinterland resulted in the removal of the sediments from the main channel and the cutting of small gullies into some of the tributary valleys. This erosional phase that continues to the present can be classified in Helgren's (1979) terminology as a period of 'arid incision'.

The situation in the Hoanib River valley reflects a similar sequence of events: After a phase of active incision into older gravels (level 'b' in Fig. 5), also along the Tsuxub valley, showing local runoff and wetter conditions, the region became drier and flooding less intense and 'arid aggradation' set in, to produce the Hoanib Young Terrace (jT) sediments above Amspoort and later (?) the Amspoort silts below Amspoort. In the past few centuries downcutting has again set in, suggesting intensification of floods derived from the inland.

From a geomorphological point of view the manner in which the Hoanib River is dissecting the Amspoort silts is of interest: Upstream of Amspoort the river follows a straight course, while below Amspoort it is braided into shallow meanders, eroding both sideways and downwards, until it merges onto the present floodplain. This fluvial morphodynamic situation, inciden-

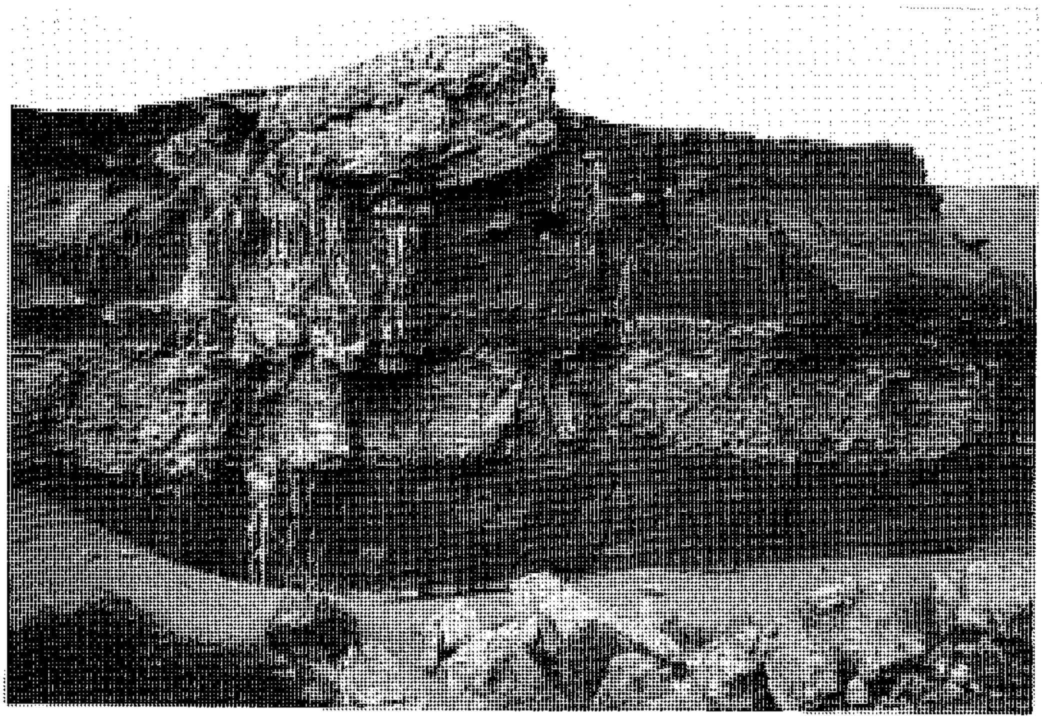


PLATE 5: Sediment body of the Young Terrace (jT) at the type locality in the Clay Castles Valley. The exposure of 2.5 m shows a block of re-deposited 'Clay Castles Silts' sediment in the top. Such blocks and stones document slope erosion in the side valley itself (Photo U. Rust 21.8.1984).

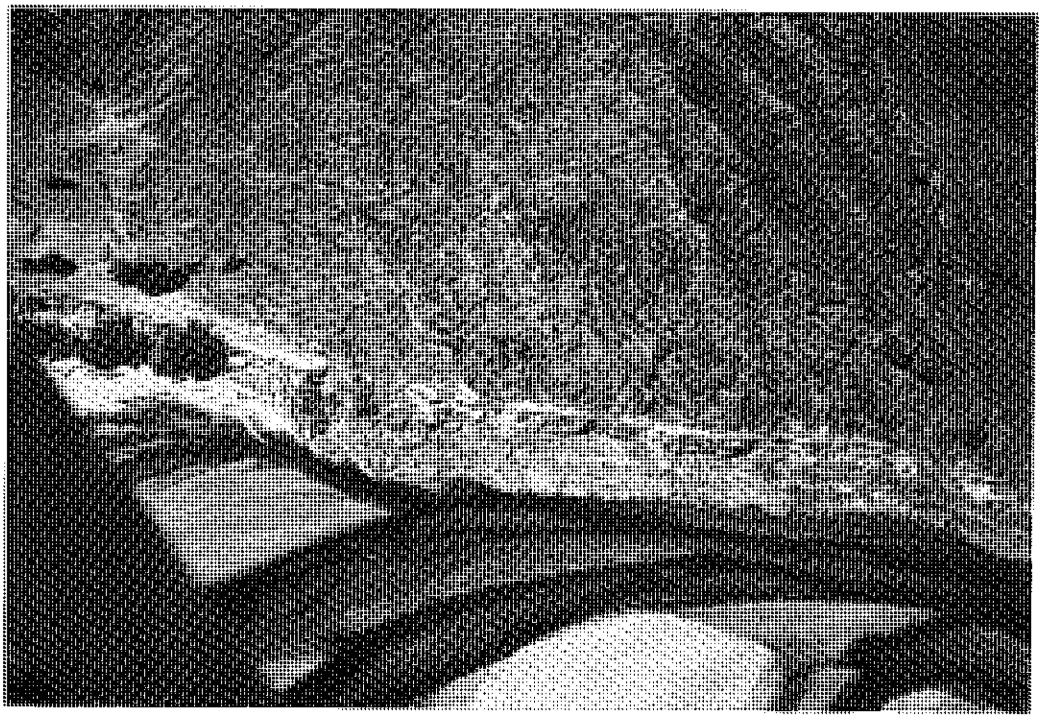


PLATE 6: At the entrance to the Hoarusib gramadullas near Purros (300 m a.s.l.). Looking S over the water-bearing river in foreground it can be seen that the Young Terrace (jT) fills the side valley (left background) and follows the main course down stream (to the right) as a bench mark (Air photo U. Rust 28.8.1984).

tally, is also observed in the periglacial transition from the Würm Glacial icemargin to the adjacent gravel plains in the Northern Alpine region ('Trompetentalbildung', Troll, 1954). This coincidence of forms and processes (Priesnitz, 1980) in two extremely different environments is remarkable.

In the Hoarusib valley we did not observe the equivalent of the Amspoort silts. It may be present on the alluvial fan at the river mouth, although the main body of this fan pre-dates the Hoarusib Young Terrace (unpublished radiocarbon dates).

It may be mentioned here that remnants of apparently young silt deposits (river-end deposits) were also found in other river systems to the south. In the Hunkab, Kharugaiseb and Samanab river beds (Fig. 2) these silts indicate shortening of the streams which could well be contemperaneous with the Amspoort silts of the Hoanib. They have, however, not been dated as yet. Another general observation that applied to virtually all the rivers along the Skeleton Coast is that they are at present all actively eroding their own sediments, suggesting that the increase in runoff deduced for the Hoanib and Hoarusib systems is the result of an increase in precipitation in the catchment area. Overgrazing on the upland plateau could, however, also be contributing to the increased runoff at present.

5 CONCLUSIONS

The findings described here document rather drastic geomorphologically active, environmental changes in the Kaokoveld Namib Desert and the adjacent hinterland during the present millennium (Tables 1, 2). That this part of the Namib Desert has been subject to changes of such magnitude in the recent past, has hitherto not been recognized (cf. Ward et al., 1983). We ourselves had not anticipated finding evidence of change on a time-scale of centuries rather than millennia. The realization of the geomorphic sensitivity of the region is a new result (cf. van Zinderen Bakker, 1975; Rust et al., 1984). It is of fundamental importance to Quarternary research for the ultimate reconstruction of the succession of changes in climate on the subcontinent in general.

The point of departure of this investigation was the recurring discussion of the features and sediments in the Kuiseb River system, and particularly of the Homeb silts (cf. par. 1). We undertook to search for corresponding silt bodies in the river courses to the north. What we found, was a profusion of silt deposits, but of obviously widely divergent ages. The mere existence of silts in different river systems therefore does not justify the assumption of synchronism and the independent dating of each such feature is essential before any valid conclusions can be drawn. Thus, for instance, the Clay Castles Silts in the Hoarusib River valley are phenotypically similar to the Homeb silts in the Kuiseb River valley, but we know already that they are actually much older and hence belong to a different climatological phase. It has furthermore become clear that the various sediment bodies encountered may reflect different palaeoenvironmental conditions, the main problem being whether the alluvial deposits are due to more or less runoff, and whether this was of a local or an allochtonous nature.

6 ACKNOWLEDGEMENTS

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