River-end deposits along the Hoanib River, northern Namib: archives of Late Holocene climatic variation on a subregional scale

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River-end deposits have formed along stretches of the Hoanib River (northern Namib). They include the older Anabeb Silts (c. 400 BC) and the very young Amspoort Silts (AD 1640–1720) and are indicative of rainfall variation on both a small temporal (hundreds of years) and also on a small spatial scale.

For decades, geoscientists have researched climatic changes affecting the Namib and its neighbouring oceanic and continental landscapes. A variety of scientific synopses have been published.[1–6] These reviews show that the inferred climatic changes were on different spatial scales (local to global) as well as on different temporal scales (from millions to tens of years) (because of the supposed antiquity of the Namib Desert). Authors do not, however, agree whether changes in rainfall affected the Namib Desert.

In this article I present observations and conclusions from the northern Namib Desert. They refer to research carried out in this area by J.C. Vogel and U. Rust during the 1980s.

The two great rivers of the northern Namib, the Hoarusib and Hoanib (Fig. 1), have the following geomorphological features in common: along their courses they connect basins filled by surface deposits[7,8] and they are accompanied by fluvial terrace deposits, which consist of loose sediments (Fig. 2). The deposits within the basins hitherto have not been studied systematically, but findings concerning the terrace deposits were published by Vogel and Rust.[3,5,8,9–13] Both authors infer palaeoclimatic conclusions from the geomorphological patterns of the fluvial deposits, and date palaeoclimatic events radiometrically. Along both the rivers, rainfall changes during the present millennium, that is, in historic times, could be proved. These climatic changes concern the Namib itself as well as its hinterland. The Young Terrace of the Hoarusib River is, for instance, indicative of a more humid climate than at present within the Namib Desert during the twelfth and thirteenth centuries AD and this result is confirmed by five ^{14}C-dates. The Amspoort Silts of the Hoanib River, on the other hand, are indicative of more arid conditions than at present in the hinterland during the Little Ice Age, and this result is confirmed by eight ^{14}C-dates.

Neither Vogel nor Rust stated explicitly that some of the inferred climatic changes could not be detected along both rivers. There are no deposits along the Hoarusib River corresponding to the Amspoort Silts of the Hoanib. Because of this, Vogel and Rust might have assumed spatially small-scale variations among the geomorphologically effective climatic changes in the northern Namib Desert and its hinterland, but they did not.

Here, I focus specifically on this problem, and concentrate on findings along only the Hoanib. I refer to only two ^{14}C-dates, which Vogel provided, derived from buried trees that I had collected during fieldwork undertaken with H. Leser (Basel) in 1996.

Amspoort

Starting at the Skeleton Coast, the following succession of landforms exists

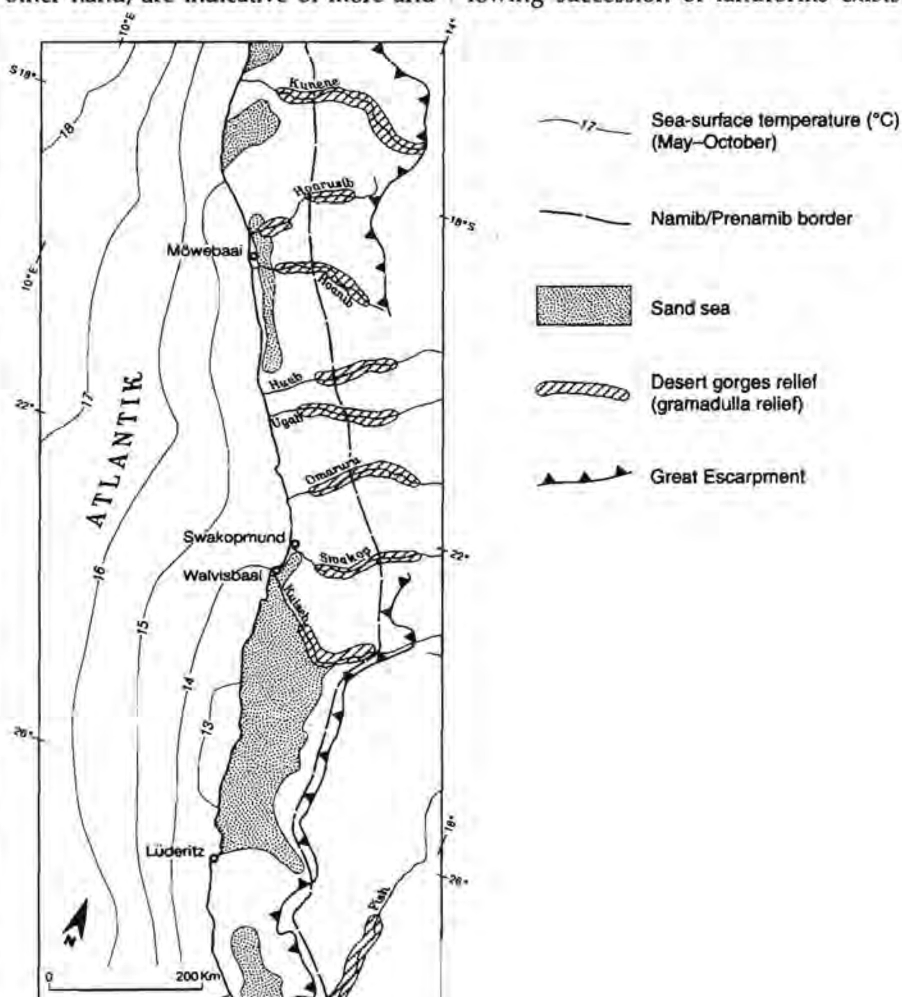

Fig. 1. Namib Desert: geomorphological and climatic features. Sea-surface temperatures after Van der Merwe.[14]

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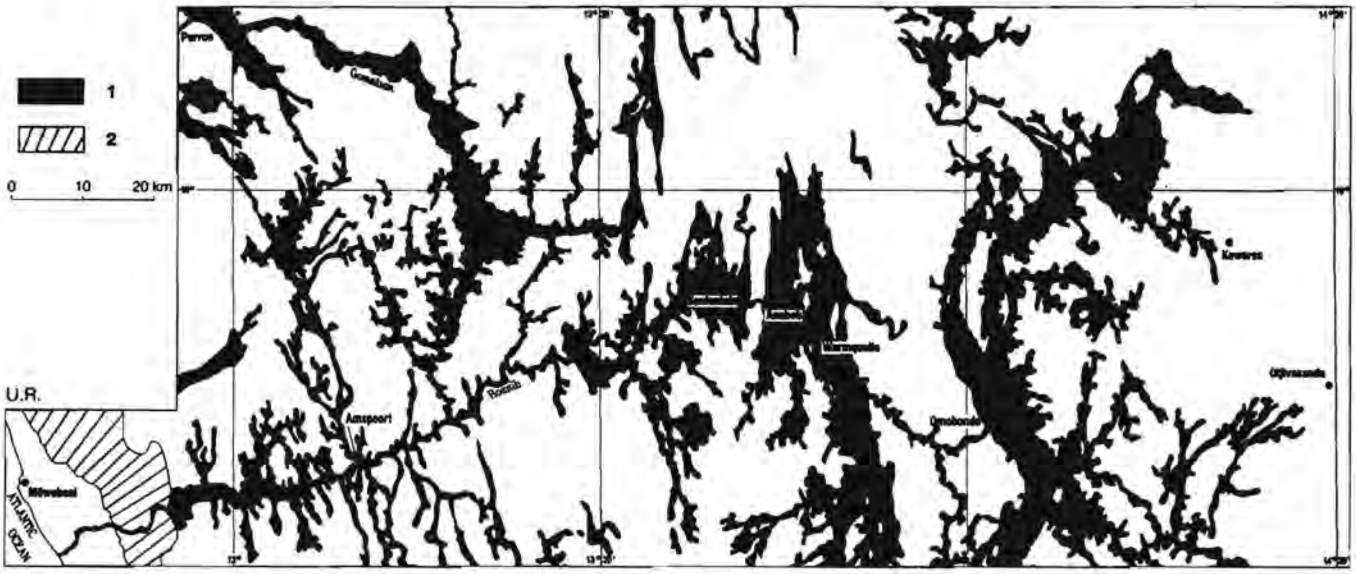

Fig. 2. Surface deposits along the Hoanib River (after Hedberg[7] and own observations). 1 = surface deposits; 2 = Skeleton Coast sand sea.

along the Hoanib River: the Skeleton Coast sand sea, including the epigenic river course — the present-day floodplain — Amspoort Silts (river-end deposits), including Hoanib River canyon (*cf.* Fig. 2 in ref. 10). At Amspoort (300 m a.s.l.), the Tsuxub River, a northern tributary, enters the Hoanib in the Namib Desert. At Amspoort a fanglomeratic Lower Terrace and calcified fanglomerates are found below the Amspoort silts (*cf.* Fig. 10 in ref. 8).

The dates obtained from a tree buried in the Amspoort silts just upstream of Amspoort are combined with those published by Vogel and Rust in Table 1. At this site the silts consist of stratified silty and sandy fluvial deposits, clayey deposits, layers including organic matter and aeolian deposits (Fig. 3).

The new ^{14}C-date of AD 1678–1814, compares closely with those from ref. 10.

Dates derived from *in situ* trees are the most consistent, from which we conclude that the Amspoort silts were deposited between AD 1640 and 1720. The deposition of the Amspoort silts can be linked to both landscape history as well as its climatic interpretation as shown in Table 2.

Table 1. ^{14}C-dates from *in situ* trees buried in the Amspoort Silts.

Sample	yr BP	Calibrated date (AD)
3880[a]	350 ± 40	1630, 1570, 1525
4548[a]	330 ± 40	1635, 1540
4546[a]	460 ± 40	1450
4547[a]	280 ± 45	1650
7356[b]	195 ± 20	1678, 1814

[a]Vogel and Rust.[10]
[b]This article.

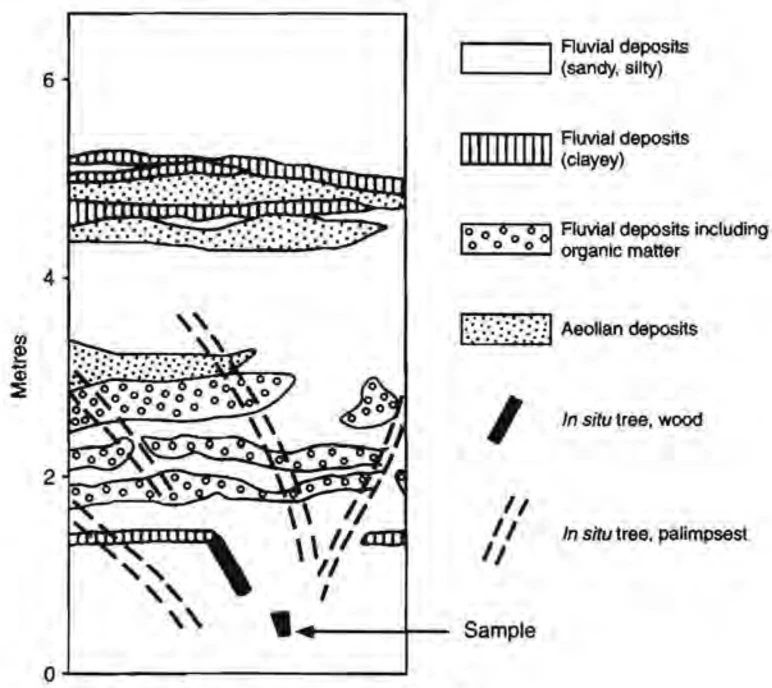

Fig. 3. *In situ* tree buried by Amspoort silts, at Amspoort.

Anabeb

The Hoanib River leaves the basin of Warmquelle through the poort of Anabeb and enters the basin of Sesfontein (Fig. 2). Anabeb is situated at 600 m a.s.l. in the Prenamib. Just upstream of Anabeb, the Hoanib and its local tributaries erode into calcified deposits of unknown age, which reflect different sedimentary environments.

River-end deposits form downstream, which I here define as 'Anabeb Silts', which can be traced through the poort onto the surface of Sesfontein. Either they are added laterally to the older calcified deposits or they bury erosional remnants of those deposits (Fig. 4). Within the poort the Anabeb silts are dissected. The surface of the deposits is transformed locally into coppice dunes.

The Anabeb silts consist of stratified loessian to sandy fluvial deposits and may contain ash horizons as well as reworked deposits of older, calcified deposits. A sample (Pta-7349) taken from charcoal of an *in situ* tree buried by the Anabeb silts provided the following dates: $\delta^{13}C$ –26.6 ‰; ^{14}C age 2400 ± 60 yr BP; calibrated date 417 (398) 382 BC. These are the first dates reported for the Anabeb silts.

A synopsis of the landscape history and associated climate is presented in Table 3.

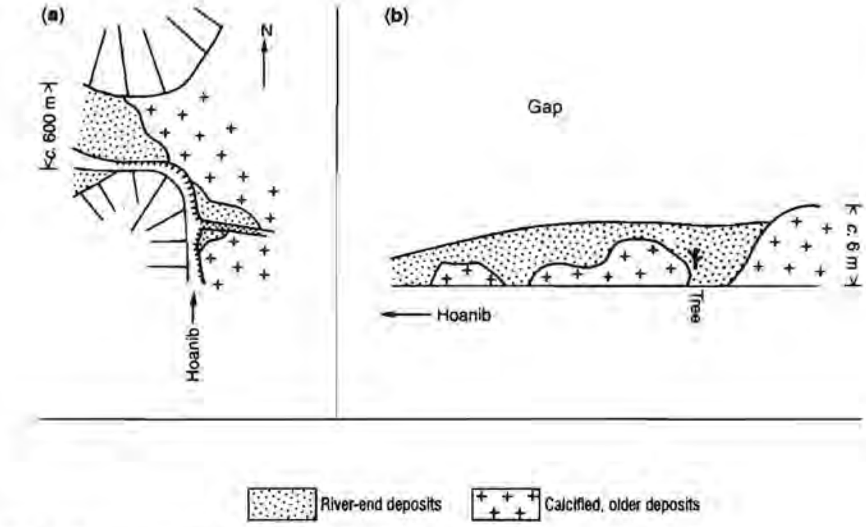

Fig. 4. Poort at Anabeb: sketch map, longitudinal profile.

Table 2. Association between landscape and climate at Amspoort.

Time (AD)	Landscape	Climate
Before 1640	Riverine forest	As now (Namib and hinterland)
1640–1720	Amspoort silts bury the riverine forest	Hinterland: more arid; Namib: as now
After 1720	Canyon, lengthening of river course into present-day flood plain; and present-day riverine forest returns	As now (Namib and hinterland)

Table 3. Association between landscape and climate at Anabeb.

Time	Landscape	Climate
Before 400 BC	Erosion of the older calcified deposits	?As now (Prenamib and hinterland)
c. 400 BC	Anabeb silts bury trees, fires	Hinterland: more arid Prenamib: as now
After 400 BC	Hoanib erodes into the silts	As now (Prenamib and hinterland)

I consider that these are the only conclusions to be drawn from the evidence since the Anabeb silts were deposited approximately 2500 years ago.

Conclusions

Thus far river-end deposits have been interpreted on a regional scale: within the Namib they are a geomorphological response to rainfall variation (more arid than at present) in the hinterland of the Namib.[8,10]

The evidence from the Hoanib River permits reflection on the geomorphological and palaeoclimatic bearing of the river-end deposits. For discussion purposes, I define 'Hinterland' as the catchment area of the Hoanib River upstream of a given site; 'Namib' as mean annual precipitation as at Amspoort (*c.* 50 mm/year); and 'Prenamib' as mean annual precipitation as at Anabeb (*c.* 120 mm/year). These precipitation values are arbitrary and for the sake of illustration. They are interpolated from isohyet maps (e.g. ref. 14), which present a rainfall gradient through the northern Namib Desert perpendicular to the coast of *c.* 120 mm per 100 km. The well-known temporal and spatial precipitation variability within desert and semidesert environments is disregarded.

Geomorphologically, hinterland is the source area whence the river-end deposits were eroded. The hinterland of Amspoort is much larger than that of Anabeb, which itself is only a part of the hinterland of Amspoort (Fig. 2). The source area of the Amspoort silts may or may not include the source of the Anabeb silts. I propose that the source area of the Amspoort silts is restricted to the basins downstream of Anabeb, for two reasons. First, by analogy, the deposits of the Anabeb silts were accumulated out of the relatively small source area upstream of Anabeb. Second, at Anabeb there are no traces of the much younger Amspoort silts. Thus, subareas of the hinterland may function as sources of the river-end deposits, such as basins.

From a palaeoclimatic point of view, hinterland is the area of precipitation upstream of Amspoort and Anabeb. Hinterland more arid than at present indicates a rainfall gradient upstream of these sites less steep than at present (Fig. 5). From Fig. 5 it can be concluded that: (1) 'Namib' extends landwards. 'Prenamib' is compressed or may disappear; 2) 'Namib' extends landwards. 'Prenamib' is compressed, but the rainfall gradient between 'Namib' and 'Prenamib' gets steeper; 3) 'Prenamib' upstream of Anabeb is situated as at present, but precipitation is less.

At Amspoort it is plausible that changes in precipitation affected only portions of its hinterland. Because of this (*cf.* Table 2), climatic changes in historical times were not only on a scale of centuries but may also have been on a small spatial scale (such as a basin).

Moreover, because river-end deposits always reflect the same tendency of less precipitation in the hinterland than at present, it is evident that different amounts of precipitation must have fallen in different parts of the hinterland (Fig. 5).

Discussion

The facts and conclusions presented here are strictly linked to the role played by river-end deposits in the Namib and Prenamib environments. Goudie[15] was the first to report on river-end deposits from the Kuiseb River (Fig. 1). Marker[16] was the first to name them and since Vogel[17] dated them they are called 'Homeb Silts'. Later river-end deposits were reported from the Hoarusib River (Clay Castles Silts[9]) and from the Hoanib River (Amspoort Silts[9,10]).

The sedimentary properties of these river-end deposits include: fine-grained, dominantly silty fluvial deposits, which are bedded subhorizontally downstream. They may contain aeolian sedimentary bodies, wind-imported silty components, organic matter, ash horizons, ichnofacies and desiccation polygons.[9,18–23]

The geomorphological properties of these river-end deposits are such that the river accumulated them into a pre-existing relief. A knick, therefore, exists between the surface of the deposits and adjacent pre-existing slopes. The surface of the deposits itself dips downstream.[10,13,19,24]

River-end deposits indicate a shorten-

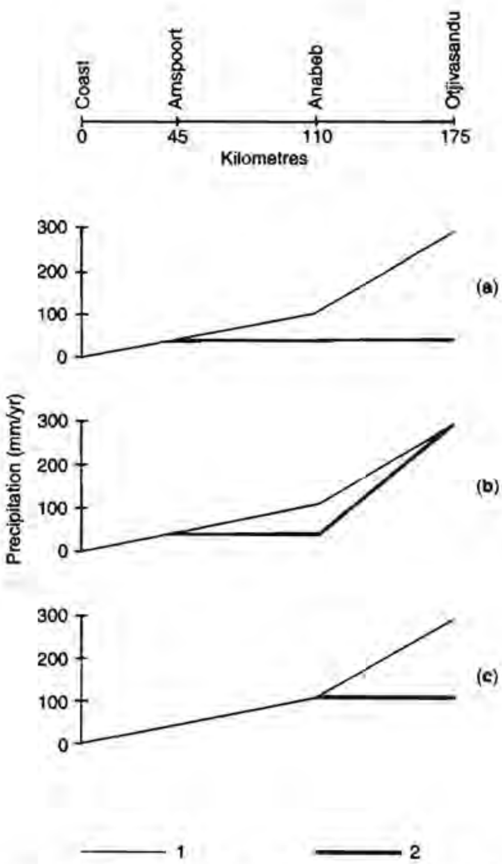

Fig. 5. Decrease in precipitation in the hinterland of the sites; **a**: entire hinterland of Amspoort; **b**: restricted hinterland of Amspoort between Amspoort and Anabeb; **c**: hinterland of Anabeb. 1 = present-day rainfall gradient; 2 = hinterland more arid than at present.

ing of the river course. Because of this, most authors interpret them to be the result of less precipitation in the hinterland.[2,13,16,18,21] Heine, however, believes they indicate more humid conditions within the Namib than at present.[22]

Eitel suggests that river-end deposits cannot be explained by actualistic models.[21] Contrary to this opinion, I assume that the floodplain of today's Hoanib River just upstream of the Skeleton Coast sand sea represents the geomorphological and sedimentary present-day model for the accumulation of river-end deposits.[12]

I conclude that such deposits in the Namib are the geomorphological response to reduced precipitation in the hinterland. It is necessary, however, to define the spatial dimensions of the hinterland more precisely.

I dedicate this article to my friend and field companion J.C. Vogel, who, I regret to note, is now entering his well-deserved retirement.

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Core education in the sciences is getting students to recognise that they are not supposed to respect authority. They are supposed to question and challenge and create good ideas. That comes to exactly the opposite of what most education is, which is mostly designed to instil obedience to authority and belief in power interests.
Noam Chomsky