A reinvestigation of some aspects of the evolution of the Kuiseb River valley up-stream of Gobabeb, South West Africa

by

Uwe Rust and Friedrich Wieneke

Institut für Geographie der LM Universität,
Luisenstraße 37,
D-8000 München 2,
F.R. Germany

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ABSTRACT

In 1974 the authors elaborated an initial geomorphological outline of the Kuiseb River valley up-stream of Gobabeb. Subsequently other authors contributed to the geomorphology of this region and published differing results. Consequently we re-checked the area in 1978 and obtained the following conclusions: The beginning of gramadulla formation can hardly be pinpointed (? Post-Stormberg), the depth of incision has to be explained tectonically to a large extent. The morphoclimatic stages are best deduced by studying the terraces of the tributary valleys (gramadullas). Some sedimentary layers and some levels can be explained lithogenetically, e.g. the 40 m terrace remnant east of Natab. The Ossewater lake deposits represent a temporally and locally singular event. The last 12 stages of landscape evolution may still be best explained by our concept of geomorphic environments.

1 INTRODUCTION

In 1972 we studied the land-forms of the middle section of the Kuiseb valley between Hudaob and Natab. We elaborated a sequence of morphogenetic stages (Table 1) and the results were published in Madoqua (Rust/Wieneke 1974).

Subsequently, several other studies have been carried out on the same subject and have also been published in Madoqua (Marker 1977, Ollier 1977, Müller/Marker 1978). These authors presented a number of different conclusions and interpretations. This led us to re-check the key areas, i.e. the valley section at Ossewater/Homeb, when we revisited the area in 1978. Since Madoqua is a forum for scientific discussion we are now presenting our 1978 findings and current views.

2 TERMINOLOGY

In our 1974 paper we presented information on the landforms of the middle section of the Kuiseb valley. Two of these features, i.e. a high terrace on the southern side of the river near Gobabeb (42 m terrace) and fine-grained, light-grey lake deposits near Homeb/Ossewater were described by Goudie (1972). Other features, namely a newly detected conglomerate with a flat upper surface at 35–40 m above the present high water level of the Kuiseb River 5 km up-stream of Natab and two flat surfaces at Homeb/Ossewater accompanying the main river course and reaching into the tributary valleys were described for the first time in our paper. We named these features the "40 m terrace", "Upper glacis of Homeb" and "Lower glacis of Homeb" respectively (Table 2).

Subsequent workers have described the same land-form inventory – as shown in Table 2 – so that we can still refer to our previous paper. Nevertheless, Marker and Ollier introduced new terms for these features, which may lead to confusion and misinterpretation.* Consequently we shall use the terms which were introduced by Goudie (1971) and by Rust/Wieneke (1974), with one exception, viz. the use of "terrace" instead of "glacis" (upper and lower Homeb terraces in Table 2). In this case we prefer to speak of terraces, because this connotation, with reference to morphogenesis, is a more neutral one. The term "terrace" does not imply any concept in the hydrological regime, while there is quite an extensive discussion in geomorphological research on the correct usage and interpretation of "glacis" (Mensching 1968).

* As long as land-forms and sediments denominated merely by descriptive terms are still found, and as long as scientific findings do not necessitate changing genetic terms for land-forms and sediments, we think it good scientific tradition to respect seniority and to use the existing terms, as we did by using Goudie's terms (1972).

3 OSSEWATER LAKE DEPOSITS, UPPER AND LOWER HOMEB TERRACES

We shall treat the sedimentology and the geomorphology of these features successively.

In Rust/Wieneke (1974) we published some laboratory and field results on the Ossewater lake deposits. Müller/Marker (1978) published a very thorough and definitive description of the "relict silts" of the Kuiseb River valley. Although they correctly describe the relict silts as terraced (p. 1 "... There they occur as a double terrace, the lower partially concealed by bedded sands and residual gravels ..."), they do not present a geomorphological evaluation. To the contrary, they interpret these sediments as one unit since they argue from a sedimentological viewpoint (p. 2 "... There appears little justification for maintaining a distinction between the better exposed, terraced silts and the partially concealed deposits ...").

TABLE 1: Morphoclimatic stages of the middle Kuiseb River.

Morphoclimatic stages		
No.	Geomorphic environment	Main geomorphic or sediment criteria
12	humid activity	40 m – terrace, hanging valleys
11	(arid stability)	
10	arid activity	dunes on the southern side of the canyon
9	arid stability	canyon
8	humid activity	gramadulla valleys
7	(arid stability)	
6	arid activity	Ossewater sediments
5	(arid stability)	
4	humid activity	upper glacis of Homeb
3	(arid stability)	
2	humid activity	lower glacis of Homeb
1	arid stability	actual river-bed

Note: The stages written in brackets are deduced indirectly. From Rust/Wieneke (1974).

Marker's (1977) "upper silt terrace" and "lower silt terrace" correspond with our (1974) morphogenetic stages 6 (Ossewater lake deposits) and 4 (upper glacis of Homeb) (Tables 1 and 2). The upper silt terrace is built up by remnants of those still water sediments which the Kuiseb River accumulated when it was blocked by dunes during stage 6. The lower silt terrace consists of reworked lake sediments and of debris sediments (see sediment profile 117, Plate 1), i.e. "concealed sediments" (Müller/Marker 1978). As far as we observed there is no real basal conglomerate, but lenses and strata of gravels and stones as well as single gravels intercalated with lake sediments are found.

TABLE 2: Comparison of the connotations for sediments and land-forms at Ossewater/Homeb according to the different authors.

Goudie (1972)	Rust/Wieneke (1974)	Marker (1977)	Ollier (1977)	Rust/Wieneke (1978)
42 m terrace	gravel flats, 42 m terrace	pebble conglomerate, calcrete caprock	basement conglomerate, thin veneer of gravels/ Kuiseb terraces	Namib gravels/42 m terrace
	40 m terrace	calcrete conglomerate, pebble conglomerate, 30 m cliff deposit/ calcrete cliff	Ossewater conglomerate	40 m conglomerate/40 m terrace
lake deposits at Ossewater/Homeb	Ossewater lake deposits	Homeb silts/upper silt terrace	Homeb silts	Ossewater lake deposits
	upper glacis of Homeb lower glacis of Homeb	Homeb silts/lower silt terrace colluvial terrace	young terrace gravel/ lower terraces of Kuiseb, minor terraces	upper Homeb terrace lower Homeb terrace

The upper and lower silt terraces differ sedimentologically because of their different geomorphic history. The sediments of the upper silt terrace were accumulated successively by the Kuiseb River in a still water environment. Those of the lower silt terrace were transported and deposited by tributary streamlets eroding the gramadulla valleys towards the Kuiseb River which constituted their base level of erosion. This process was accompanied by a hill wash of bed-rock debris.

The Ossewater lake deposits may have been reworked repeatedly, since they also partly constitute the lower Homeb terrace sediments (Fig. 1). Concave debris slopes from the basement walls down to both Homeb terraces show that during these stages gramadulla erosion was linked to slope forming processes, which prove once more that both Homeb terraces represent stages of autochthonic valley formation post-dating the blocking by dunes of the Kuiseb in stage 6.

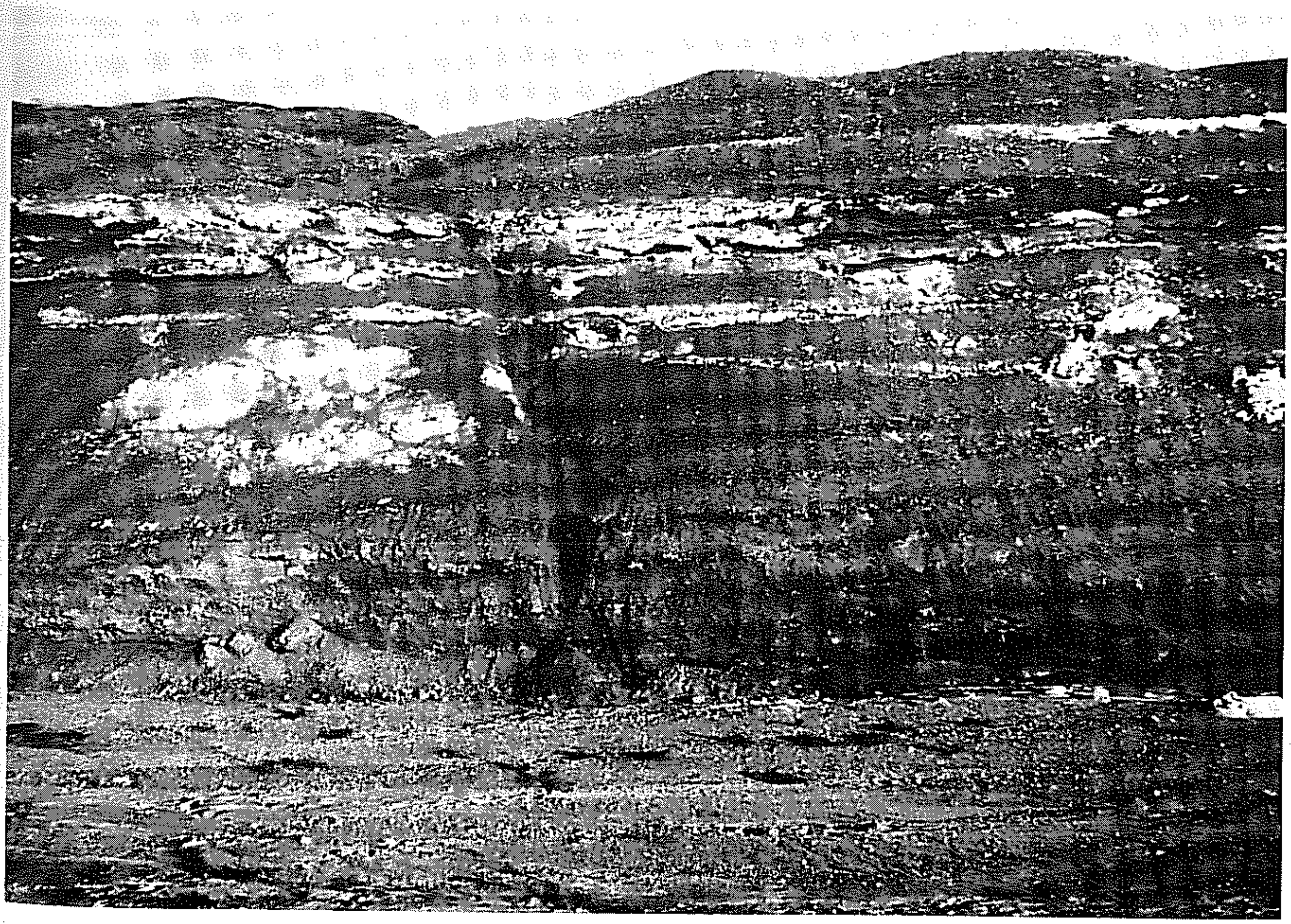

PLATE 1: Upper Homeb terrace at Homeb. About 4 m of concealed sediments (see light tones), i.e. reworked Ossewater lake deposits intercalated with debris sediment (see e.g. bottom left) and covered by debris.

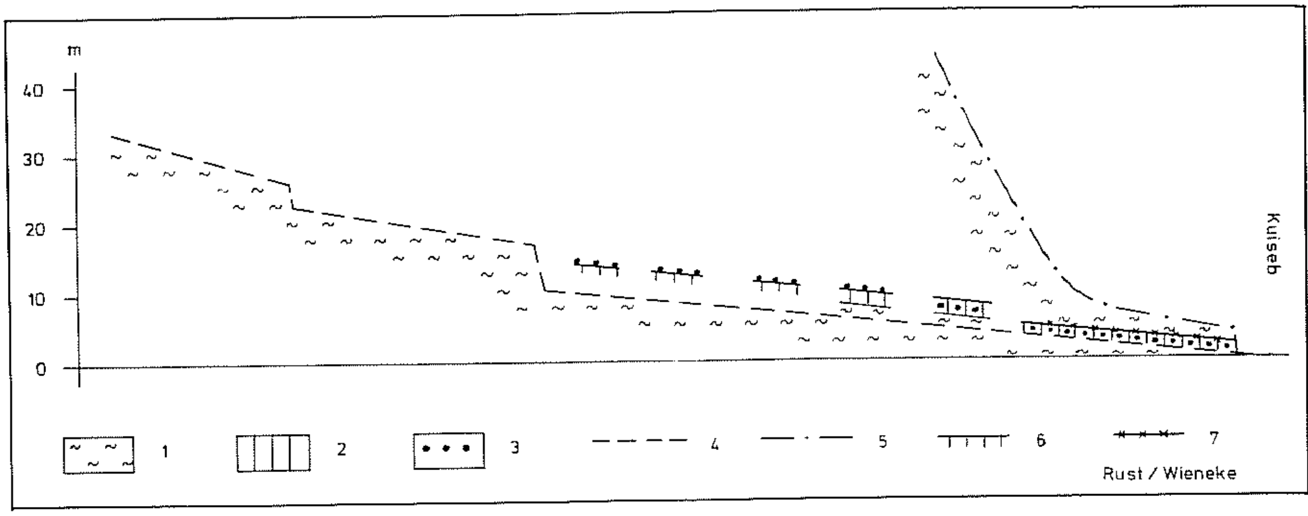

FIGURE 1: Gramadulla valley longitudinal profile up-stream of the 40 m terrace remnant:
1 = bed-rock, schists, 2 = Ossewater lake deposits, 3 = gravels, slope debris, 4 = actual valley bottom, 5 = actual Kuiseb

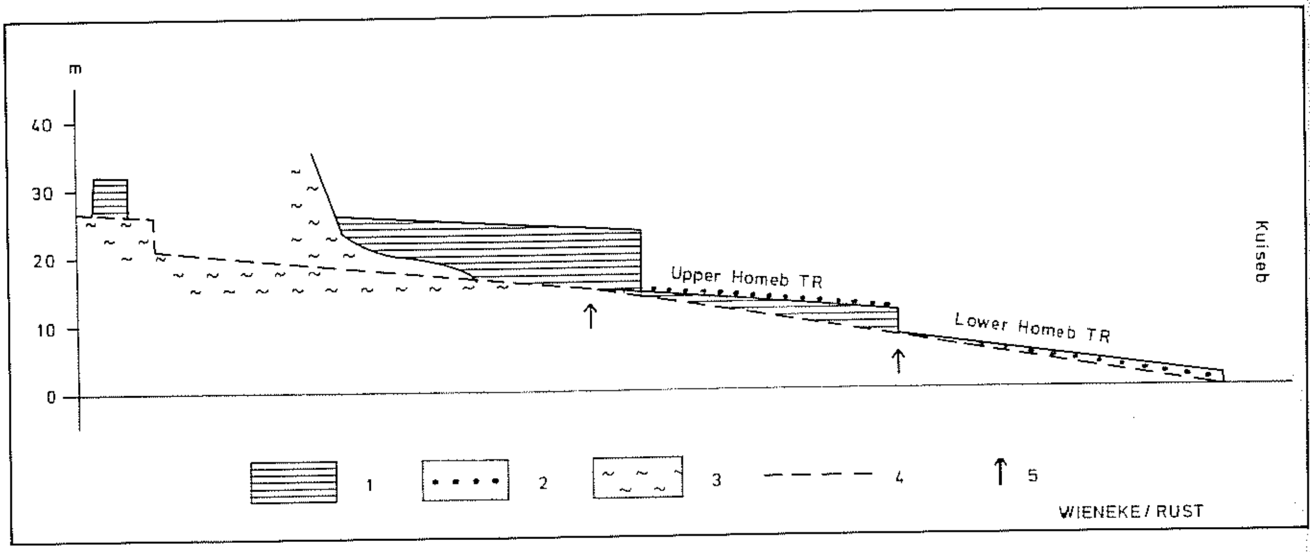

FIGURE 2: Gramadulla valley longitudinal profile down-stream of the 40 m terrace remnant:
1 = Ossewater lake deposits, 2 = gravels, slope debris, 3 = bed-rock, schists, 4 = actual valley bottom, 5 = points of terrace convergence (metres above Kuiseb high-water bed).

The longitudinal profile in Fig. 2 gives some other interesting hints concerning the landscape evolution of this region: The surfaces of the Homeb terraces diverge down-stream of the gramadulla valleys. Following the valleys up-stream from the Kuiseb high-water bed to their ends the actual valley bottom and the lower Homeb terrace level converge. This new level converges with the level of the upper Homeb terrace. Further up-stream a step is formed in the bed-rock schists. Above this step there are no traces of terraces, but remnants of Ossewater lake deposits are still to be found.

Such steps within the longitudinal profiles of gramadulla valley bottoms are ubiquitious. They are steps of convergence (Sammelstufen; Rohdenburg 1971), focussing on the point up to which the base level effects of the Kuiseb River reach. Because of these steps, the stages of gramadulla formation post-dating the Ossewater lake deposits may only be deduced by studying the terraces of the lower parts of gramadulla valleys. Ossewater lake deposits situated above the top of these steps of convergence indicate pre-lake deposit valleys there.

From the relative height differences of the terrace deposits in Fig. 2 the respective height positions of the Kuiseb as base level of erosion may be estimated (Fig. 3). This level must have been about 2 m higher than the actual Kuiseb high-water bed at the time of the formation of the lower Homeb terrace, and about 7 m higher when the upper Homeb terrace was formed. These values are valid for the final steps of the two valley forming stages, when the streamlets have accumulated in the river-bed, as indicated by the thickness of the sediments (e.g. 4 m in Pr 117). Hövermann (1978) mentioned a similar trend of slight accumula-

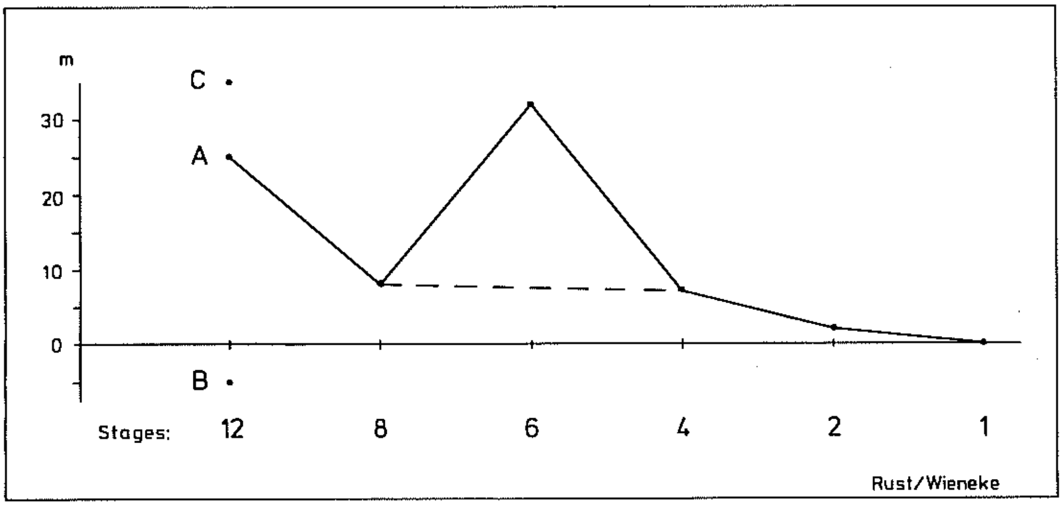

FIGURE 3: Levels of the Kuiseb River at different stages of land-form evolution. Stages from Rust/Wieneke (1974) (compare Table 1):
A = base of 40 m terrace conglomerate according to Rust/Wieneke (1974) at stage 12
B = this base according to Marker (1977)
C = Surface of 40 m terrace at stage 12
Metres above Kuiseb high-water bed. Dashed line between stages 8 and 4 indicating general trend of Kuiseb incision (compare text).

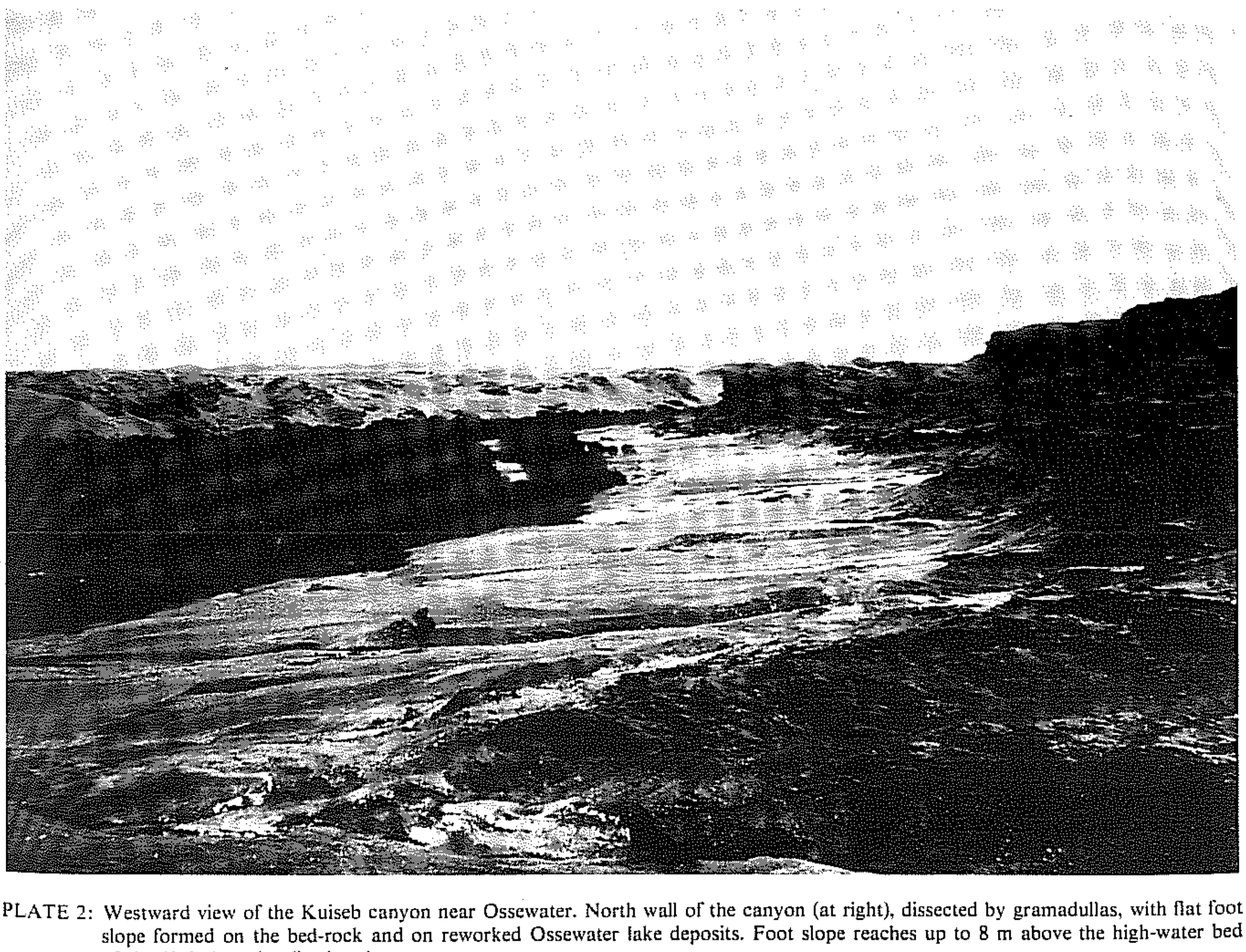

PLATE 2: Westward view of the Kuiseb canyon near Ossewater. North wall of the canyon (at right), dissected by gramadullas, with flat foot slope formed on the bed-rock and on reworked Ossewater lake deposits. Foot slope reaches up to 8 m above the high-water bed of the Kuiseb at its distal end.

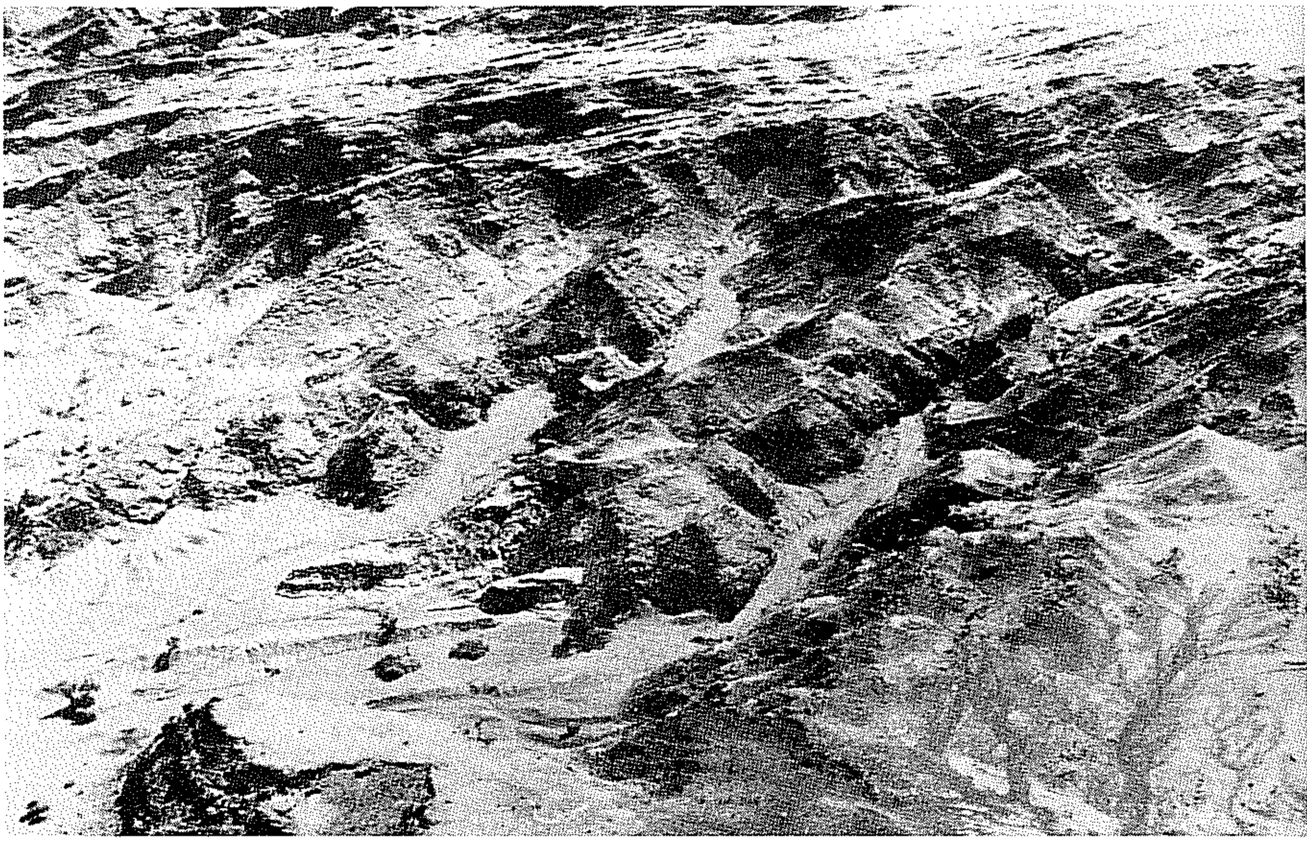

PLATE 3: 40 m terrace remnant in the foreground at left, flat surface of conglomerate cap, slope mantled by precipitated blocks. Tributary valleys with terraces in their lower parts, remnants of Ossewater lake deposits in protected positions at different heights (light tones). To the north-west dipping Damara schists, forming a cuesta-like landscape with denudational steps on the valley slopes.

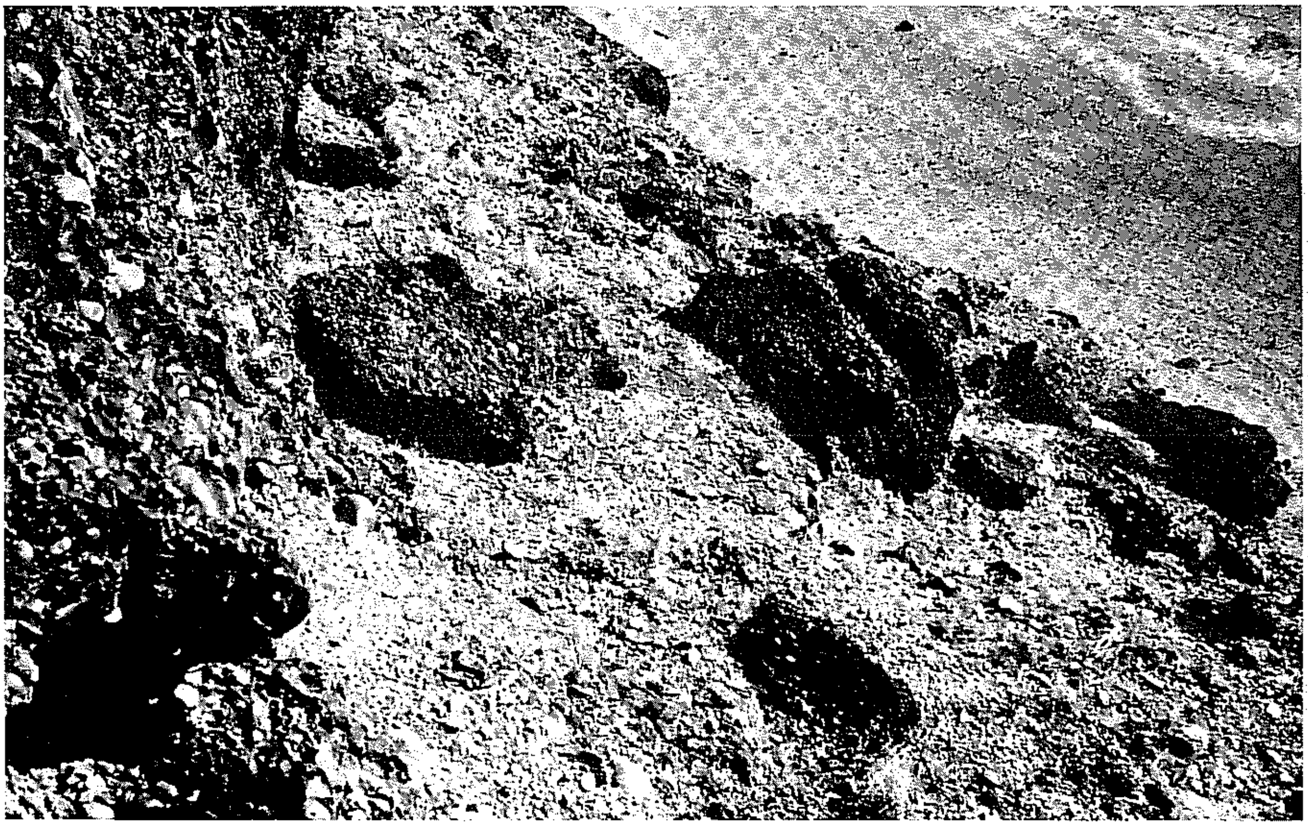

PLATE 4: View from the upper part of the westward slope of the 40 m terrace remnant down-slopes towards the Kuiseb River. Precipitated blocks of the conglomerate mantle the whole slope, the boundary bed-rock/conglomerate cannot be detected.

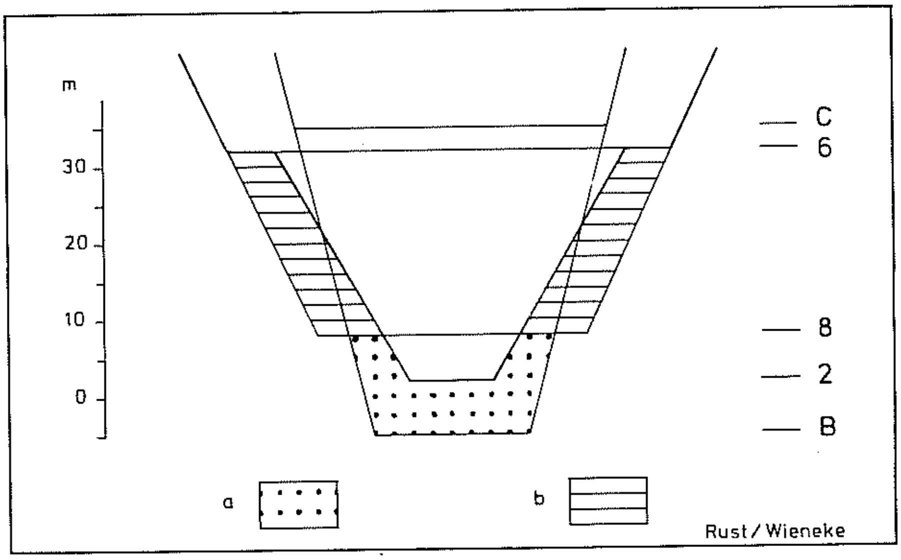

FIGURE 4: A simplified model of land-form evolution according to Marker's (1977) concept. Schematic cross-sections of the Kuiseb valley at different stages:
2, 6, 8 = stages, compare table 1
B = base of 40 m terrace conglomerate according to Marker
C = top of 40 m terrace
a = 40 m terrace conglomerate
b = Ossewater lake deposits
(metres above Kuiseb high-water bed)

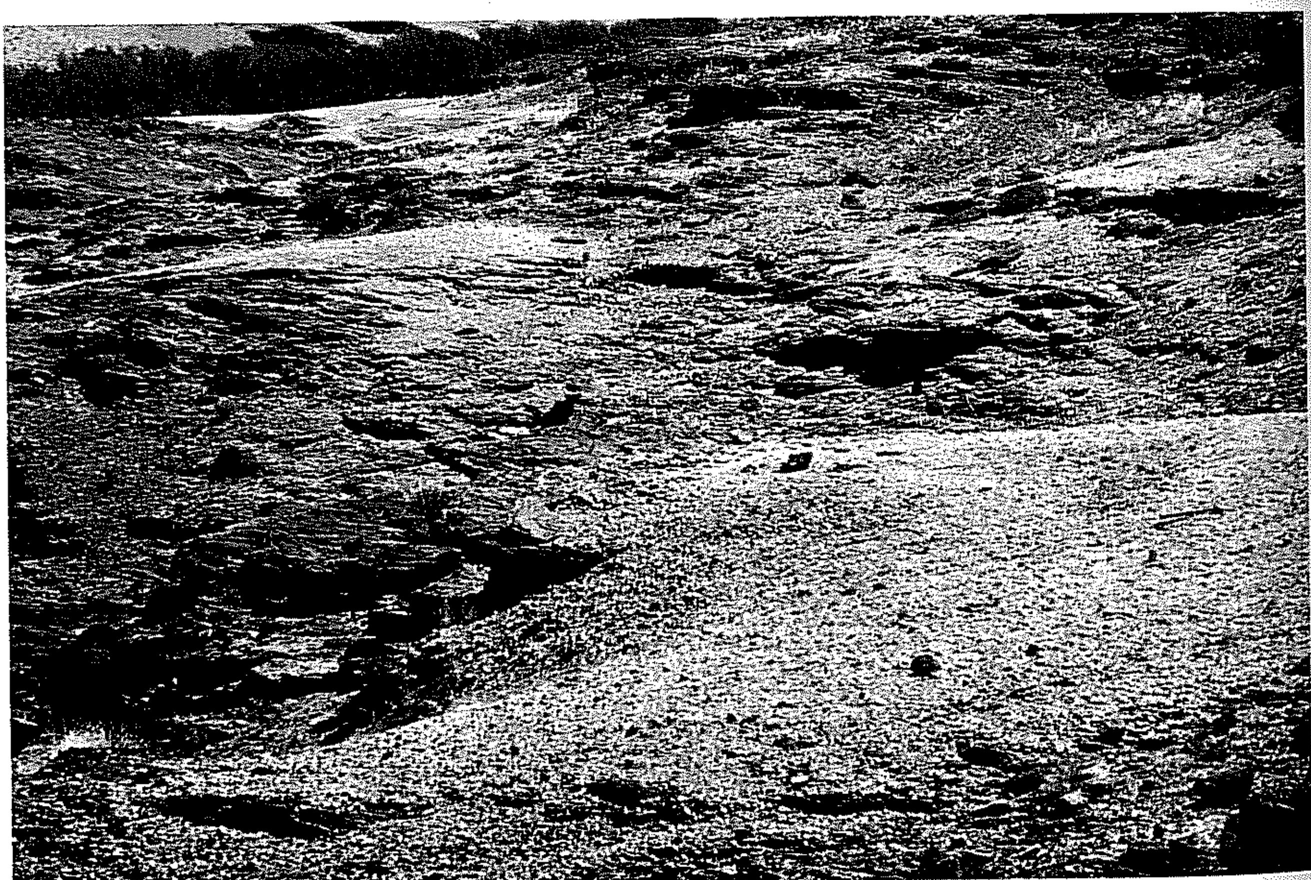

PLATE 5: Down-stream of Homeb, westward view. Damara schists dipping to the north-west (i.e. back right). Foreground, middleground, and background: Traps of loose Namib gravels situated on denudational slope benches (yellow colour because of the predominance of well-rounded quartz gravels with iron oxide coatings).

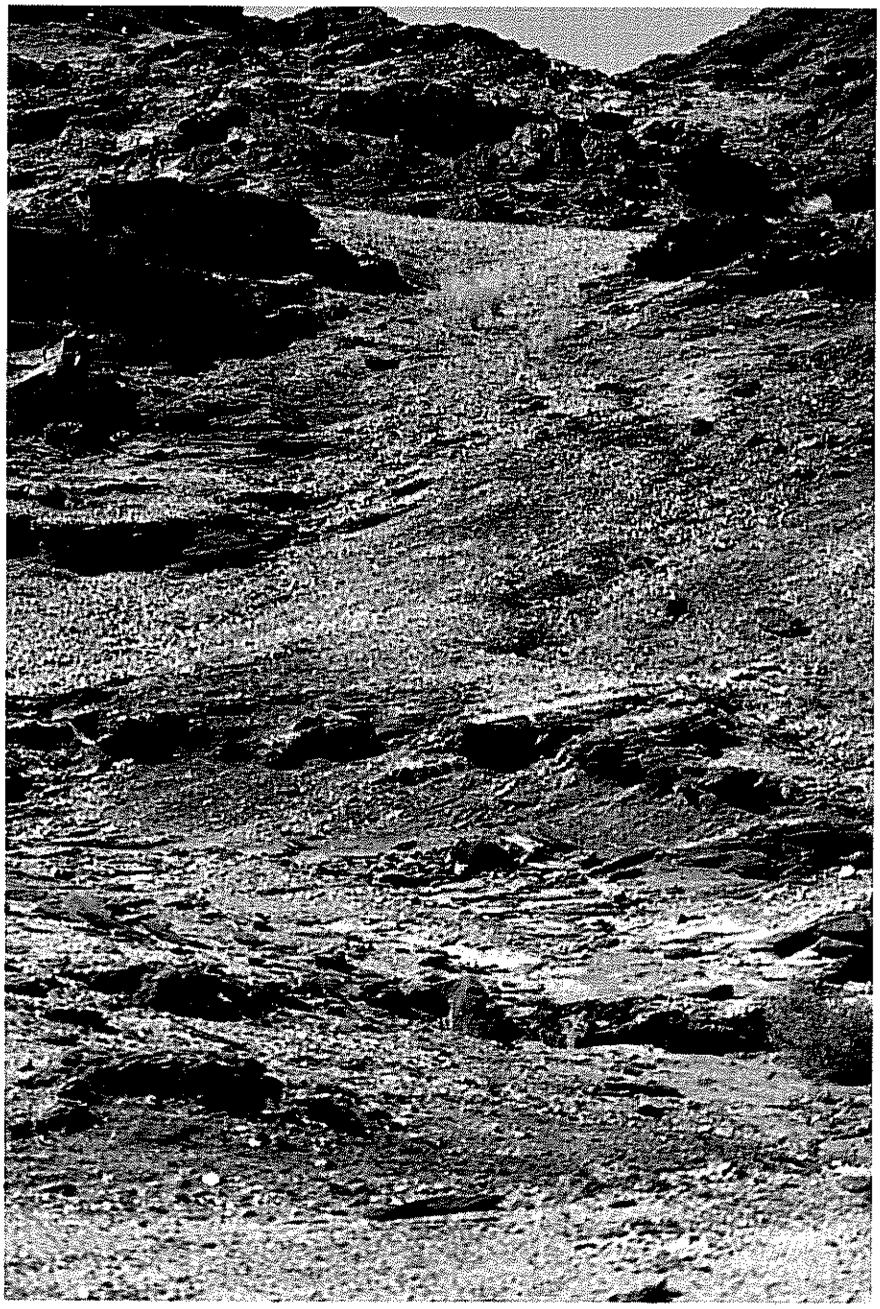

PLATE 6: Down-stream of Homeb. Sedimentary trap of Namib gravels in the upper middle ground. Loosened Namib gravels showing the downslope process of sedimentation, transport and resedimentation steered by the lithological inhomogeneities of Damara schists.

graphically higher than the base of the Ossewater lake deposits, i.e. nearer to point A in Fig. 3.

4.2 The uniqueness of the 40 m terrace remnant

The 40 m conglomerate was deposited laterally at a steep slope in the bed-rock. The Damara schists dip to the north-west (Plate 3). Differences in erosional resistance of the bed-rock lead to denudational terraces at the gramadulla valley slopes. We observed that characteristic Namib gravels are ubiquitiously accumulated on top of and behind such ledges of higher resistance (Plate 5). The Namib gravels are loosened from their original matrix, e.g. the high level calcrete bed-rock (Marker 1977). During the formation of valley slopes they are transported down-slope and are left on denudational terraces as re-deposited residual gravels (Plate 6). By analogy the sediment body of the 40 m terrace may be interpreted as a deposit of residual gravels in a sediment trap on a denudational terrace. This view would consider the lithological influences on the landscape evolution. Thus the 40 m terrace remnant appears to be a local sediment remnant on a slope which was structured by denudational terraces.

All of us working on the Kuiseb gramadullas have possibly over-emphasised the significance of the 40 m terrace in the landscape evolution of the whole Kuiseb gramadulla section. Since such a stepped denudational valley slope must have been formed before or synchronously with the sedimentation of the conglomerate, the above (4.1) reasoning on the base level of the conglomerates is not invalid.

5 GENERAL REMARKS

Up to now the authors working on the landscape evolution of this region have stressed the geomorphology of the Kuiseb valley. This is a legitimate but somewhat one-sided viewpoint. We would like to point out that further results might be achieved by studying the terraces, the sediments and the longitudinal profiles of the tributary valleys. Furthermore, the landform evolution was obviously influenced by local lithology (Petrovarianz; Büdel 1961). Because of the northwest dip of the Damara schists land-form elements such as cuesta-like stepped valley slopes, local sediment traps on the backside of denudational steps, steps of convergence or local steps of erosion have been formed. Consequently there are levels at different heights which do not all indicate stages of a morphoclimatic succession. They are determined by lithology. Hence the problem of land-form analysis is to check whether forms and sediments were formed by fluvial processes or by denudational slope processes, and how these processes interacted.

Fig. 3 shows a general trend of incision of the Kuiseb River during the stages of landscape evolution. Before the sedimentation of the 40 m conglomerate must have taken place, a rather strong incision of more than 100 m occurred which cannot be divided into sub-stages at the present stage of research. On the contrary, since stage 8 (pre-Ossewater) the incision does not exceed more than a few metres. This shows that the Kuiseb River incised continuously, but only slightly over a period of eight morphoclimatic stages. We obtained analogous results e.g. for the lower part of the Swakop River (Rust/Wieneke 1976) as well as for the autochthonous rivers of the coastal Namib Desert.

Thus Fig. 3 also demonstrates that the sedimentation of the Ossewater lake deposits (= elevation of the Kuiseb level up to 32 m above the actual high-water bed) represents only a local and singular phenomenon superimposed upon the trend of general weak incision. To assume that tectonic influence causes more than 20 m oscillation of the Kuiseb level, is highly improbable. Consequently this general reasoning admits only a morphoclimatic locally effective influence, namely the barring by dunes of the course of the Kuiseb River, the occurrence of which has already been postulated by the stratigraphical-sedimentological analysis of the Ossewater lake deposits (Rust/Wieneke 1974, Müller/Marker 1978). Therefore a very arid stage of landscape evolution has to be assumed for this period.

It is probable that the dammed up Kuiseb River broke through this barrier in a rather short time. This opinion is backed by the "juvenility" of the tributary valleys. Nevertheless, in the time following the Ossewater lake sedimentation two stages of humid-activity (autochthonous valley formation) must have occurred, since there are tributary valleys with two terraces and evidence of two stages of slope processes.

The Ossewater lake deposits (stage 6) indicate the damming up by dunes of the Kuiseb, and not the totality of the "relict silts" as Müller/Marker (1978) seem to believe. The lake deposits are limited to the canyon up-stream of Natab (Rust/Wieneke 1974, Müller/Marker 1978 "exposed silts" in Fig. 1?). Remarkably enough Müller/Marker mapped and described only "partially buried silts" and concealed sediments in the area of Natab/Gobabeb. This coincides with our observations. We, however, believe by analogy to the upper and lower terraces of Homeb that the relict silts of that area have been re-deposited, i.e. during the humid-active stages 2 and 4. They were eroded up-stream by the Kuiseb River during the incision of the lake deposits and were re-deposited down-stream. As shown in cap. 3 the geomorphological approach seems to lead further than the strictly sedimentological one. Additionally, according to our interpretation, we are not forced to postulate a hypothetical west-east migration of the obstructing dunes (Müller/Marker 1978, p. 11).

Before stage 8 (pre-Ossewater) and particularly before the deposition of the 40 m conglomerate (stage 12) there must have been a very strong incision of the Kuiseb River (canyon) as well as of the tributary streamlets (gramadullas), which differs considerably from the weak incision during the last morphoclimatic stages. Since it is impossible to find indications for basically different geomorphic environments during those periods of strong incision, it is necessary to introduce tectonic movements for the explanation of such great amounts of valley incision. Therefore we must allow for strong vertical movements before the stage of Ossewater sedimentation, at least before the 40 m terrace sedimentation. These movements must have been simultaneous with a strong river flow and with autochthonous valley formation (humid-activity). The Kuiseb canyon and Kuiseb gramadullas are situated inland of a great tectonic line which is traced by the course of the Kuiseb down-stream of Natab and which in fact, may be seen in the field e.g. on the farm Hebron (personal communication by Dr. Hugo, Geological Survey, Windhoek).

The 40 m conglomerate contains Stormberg dolerites, which indicates at least a post-Stormberg age of this accumulation. At present it is impossible to give a more precise dating of this sediment body. Therefore a very long time span is available for the formation of both the canyon and the gramadullas.

All these facts bear out a basically simple and nondramatic explanation of the landscape evolution of the middle part of the Kuiseb valley. A very long time span is available, tectonic influences are highly probable and the morphoclimatic trends which we have already proved for the central Namib Desert are also valid for this part (geomorphic environments of arid morphogenesis, Wieneke/Rust 1973). The 40 m conglomerate is a spatial singularity; the Ossewater lake deposits a temporal one**).

6 RESUME

Après avoir été étudiée géomorphologiquement par nous en 1974 la vallée du Kuiseb a été visitée par plusieurs géomorphologues qui publiaient des résultats différents. En réétudiant cette région nous avons alors obtenu les résultats suivants: ce n'est guère possible de fixer la date de la première dissection des gramadullas (? postérieur à Stormberg), la profondeur de la dissection a été influencée partiellement par la tectonique. Il faut déduire les phases morphoclimatiques par l' étude des terrasses des vallées tributaires (gramadullas). Il y a des dépôts et des aplanissements qu' il faut expliquer lithogénétiquement, par exemple la terrasse de 40 m en amont de Natab. Les sédiments lacustres d' Ossewater sont une singularité régionale et temporelle. La conception des milieus morphoclimatiques reste d' être apte à décrire les 12 phases dernières de la morphogenèse.

7 ZUSAMMENFASSUNG

Das Kuisebtal oberhalb Gobabeb ist seit einer ersten geomorphologischen Bearbeitung durch die Autoren 1974 inzwischen mehrfach untersucht worden, mit teils abweichenden Ergebnissen. Eine Neubearbeitung 1978 führte zu folgenden Ergebnissen: Die Anlage der Gramadullas ist zeitlich kaum präzise zu fassen (? Post-Stormberg), die Zertalungstiefe zum großen Teil tektogenetisch zu erklären. Morphoklimatische Phasen sind aus dem Studium von Nebentalterrassen abzuleiten. Verschiedene Sedimentkörper und Verflachungen sind lithogenetisch zu deuten, so auch die 40 m Terrasse oberhalb Natab. Die Ossewater lake deposits sind eine lokale und zeitliche Singularität. Für die letzten 12 Phasen der Reliefentwicklung ist das Konzept der geomorphologischen Milieus weiterhin anwendbar.

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** In connection with our lecture at the SWA Scientific Society, Windhoek on the 28/2/1978 Mr W. Rusch, Windhoek, drew our attention to the fact that there are similar sediment remnants in the valleys of the Omaruru and the Ugab.

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