Studies on gramadulla formation in the middle part of the Kuiseb River, South West Africa

by
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1. INTRODUCTION

When carrying out our research work on the Quaternary landform evolution of the Central Namib Desert (RUST/WIENEKE, 1973a) from January to April 1972 we visited among other regions the middle part of Kuiseb river between Hudaob and Gobabeb (Fig. 1). From Hudaob downstream to its delta at Walvis Bay the river separates the Dune Namib in the south from the Namib flats in the north. The Kuiseb river changes its course two times, at Hudaob from a NE/SW direction to a E/W direction, and at Natab upstream of Gobabeb from this direction to a SE/NW one. In this part the river flows in a canyon which has been incised more than 200 m into the flats of Namib Desert. On the northern side of the canyon the uncovered rock basement is dissected deeply and densely forming a marginal zone of some km width which is nearly lacking on the southern side. Those margins of dissection which are found also accompanying the Swakop und Khan rivers can easily be detected e.g. on the well known Gemini V satellite photograph (WIENEKE/RUST, 1972). In South West Africa they are called "Gramadullas". The stages of their morphogenesis and the correlation of these stages with the morphogenetic stages of the Central Namib Desert are not yet known.

Two different surfaces built up by sediments which are incrusted by calcrete formation and therefore are forming scarps can be observed upstream of Hudaob (Fig. 2). Partly they are mentioned in literature (SPREITZER, 1965). SPREITZER (1965), SCHOLZ (1968) and GOUDIE (1972) describe fluvial terraces at Gobabeb and at Natab about 10-20 m and 40 m above the actual river bed. Furthermore they mention "fossil high water sediments" at Natab and "lake deposits" at Ossewater/Homeb. From the relative altitude of these high water sediments (about 15 m above the actual river bed) and from the stratigraphical sequence (fossil high water sediments overlying dune sands) SCHOLZ (1968, p. 103) tries to deduce a former dammed up Kuiseb river due to a natural barring of its course by dune formation.

Our research work carried out in the coastal parts of the Central Namib Desert between the delta of the Kuiseb river in the south and Mile 30 in the north, and at the middle part of the Tumas river showed us (WIENEKE/RUST, 1973a) that the Quaternary landform evolution of these regions consists essentially of a repeated alternation of stages of arid-stable geomorphic environment with stages of humid-active geomorphic environment. Arid-stable geomorphic environments are characterized by autochthonic soil formation (crust formation) and allochthonic fluvial activity, humid-active geomorphic environments by autochthonic and allochthonic fluvial activity. In addition, stages of arid-active geomorphic environment, i.e. of predominantly eolian morphogenesis, can be deduced especially in the southern parts of our area of investigation.

We studied the evolution of landforms of that part

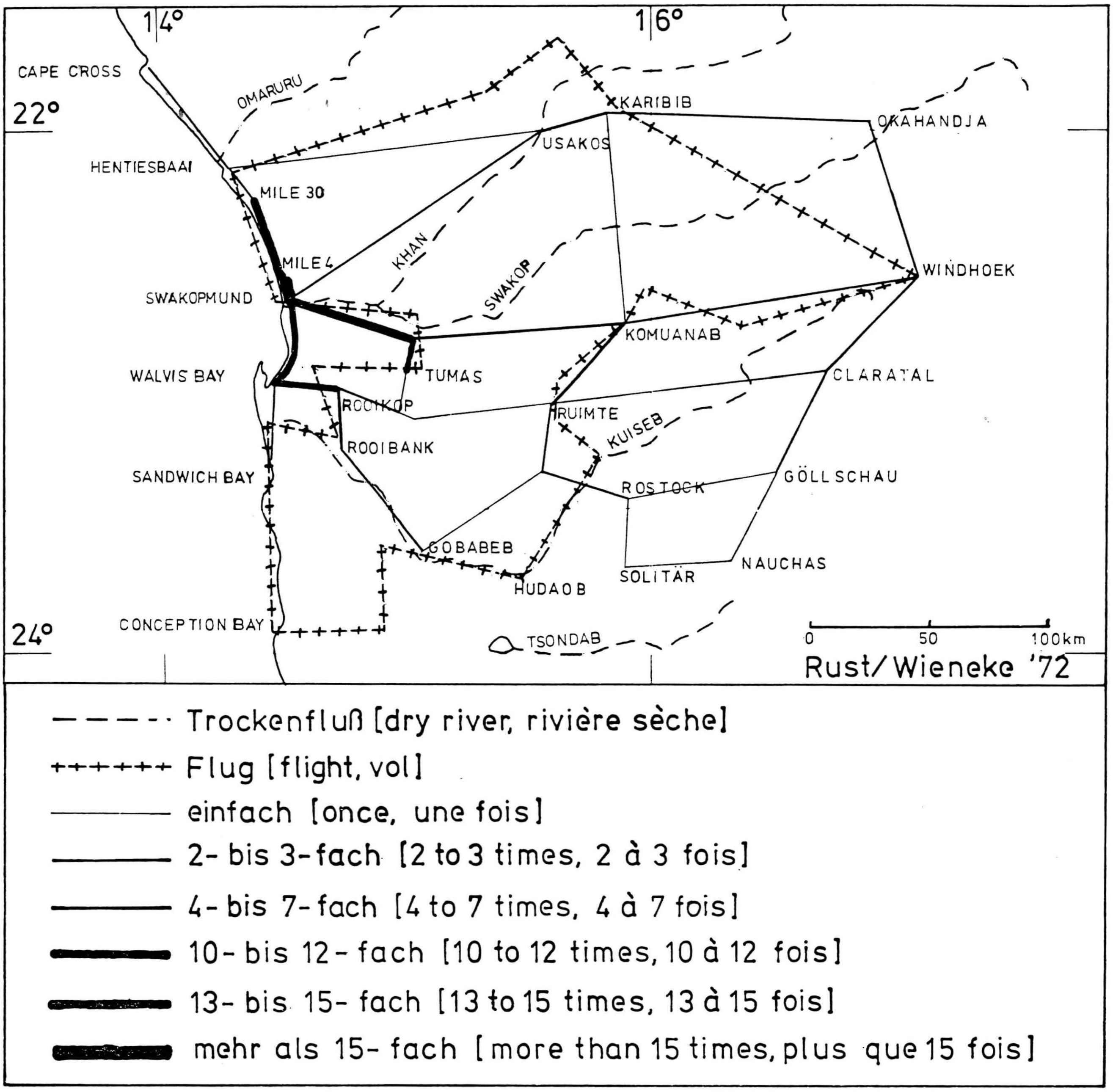

Figure 1. Sketchmap showing the routes travelled by the authors during their research work in South West Africa in January to April 1972 according to the frequency of use.

of the Kuiseb river situated between Hudaob and Gobabeb and tried to obtain at least a relative geochronology of the gramadulla incision. We aimed at a correlation of the morphogenetic stages of this area with the sequence of morphogenetic stages which we had found for the coastal parts of the Central Namib Desert. Based on this knowledge we hoped to be able to solve the problems of the changes of the course of the Kuiseb river at Hudaob and at Natab and of the stages of the northern extension of the Dune Namib. It proved to be impossible to solve all these problems definitely, because we had not enough time, the terrain is rough, and several points could not be visited due to the running of the river. But we think we are able to present a principle solution to the problem of gramadulla incision, based on the interaction of fluvial and eolian morphogenesis with arid pedogenesis, and have elaborated a basis of further investigations.

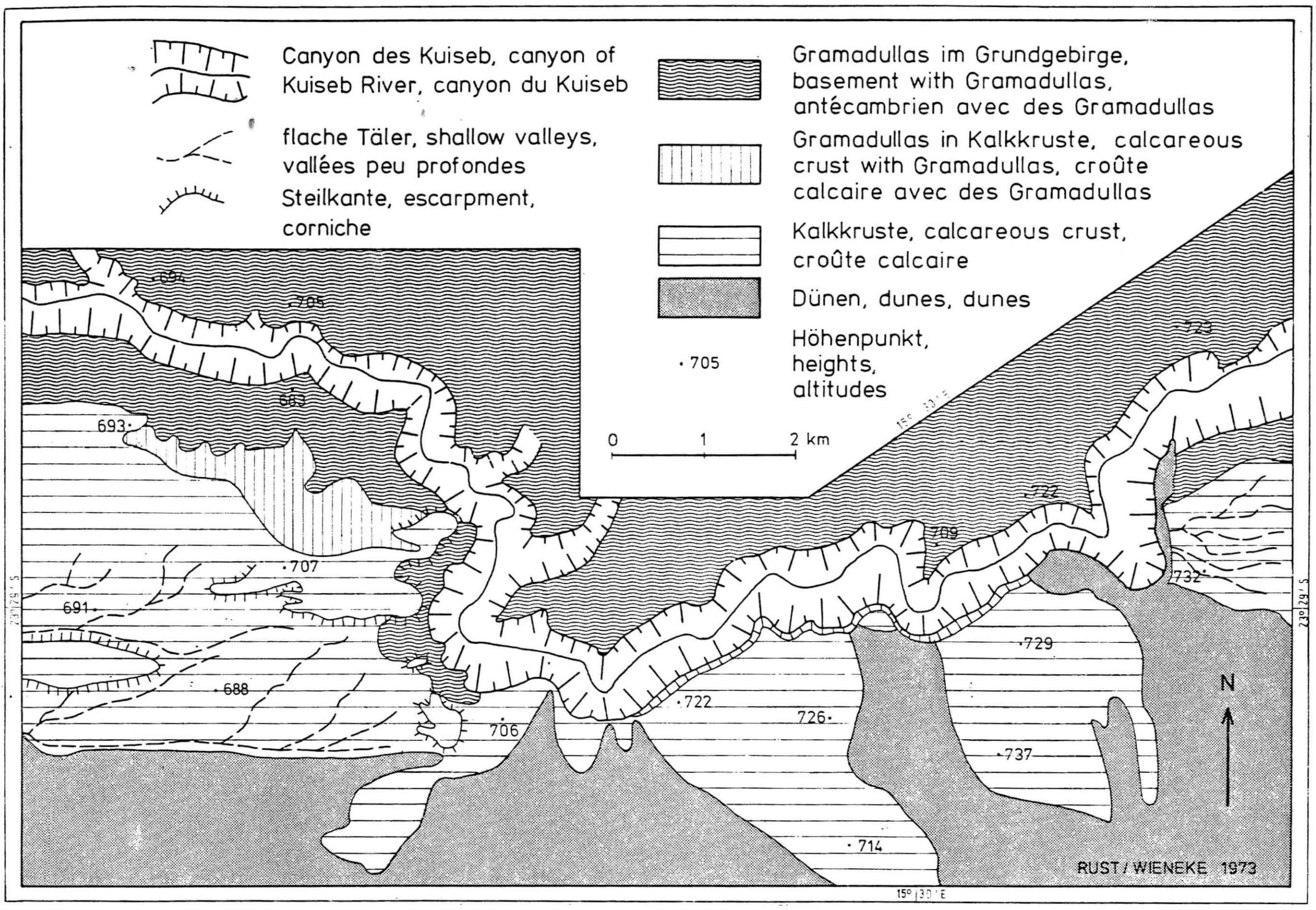

Figure 2. Geomorphological map of the region near Hudaob, S.W.A. (Interpretation of aerial photographs and of topographical maps).

2. INVESTIGATION OF LANDFORMS AND OF SEDIMENTS

2.1. Landforms

2.1.1. Interpretation of maps and of aerial photographs*)

The interpretation of the existing excellent topographic maps (1 : 25 000) and of the aerial photographs (1 : 36 000, 1961) enabled us to investigate the landforms in their spatial connection. We limited our study area upstream at the change of river course direction at Hudaob.

On the left, i.e. southern, side of the river, flats covered by dune walls of a more or less S/N direction limit the Kuiseb canyon which is incised more than 200 m. These flats end towards the river at a scarp and overlie the basement (Fig. 2), which is stripped at some localities near Hudaob. At Natab the river changes its direction to the NW, while the scarp of these uppermost flats continues to the WNW and therefore diverges from the river itself (Fig. 3). It is possible to follow this scarp westward for three more dune valleys, but then it can not be found anymore. The flats situated above this scarp are called the 42 m — terrace by GOUDIE (1972, Fig. 9). They can not be connected without doubt with the flats at Hudaob, because a dune wall about 5 km upstream from Natab covers a height difference from 510 m (survey level SWA) on its eastern side to 480 m on its western side.

The point of divergence between the so called 42 m — terrace and the actual river bed is the starting point of a terrace 10 to 20 m above the river level which continues undoubtedly several km downstream from Gobabeb. Further downstream it can only be found fragmentarily, and the interpretation is not definitive. On the right side of the river this terrace is not as prominent as on its left side. We were not able to find more terraces on either side of the river.

The dunes reach into the southern wall of the canyon which is dissected by short, steep hanging valleys down to about 40 m above the actual river bed (Fig. 4), according to the maps and to the aerial photographs. At about 40 m relative altitude the canyon wall shows some examples of denudational terraces. At Hudaob several dunes reach down into

*) We were given the opportunity to interprete the topographic maps and the aerial photographs in the office of the Trigonometric Survey, Windhoek. We want to thank Director Rousseau and his staff, especially Mrs. Holtzhausen, for their cooperation.

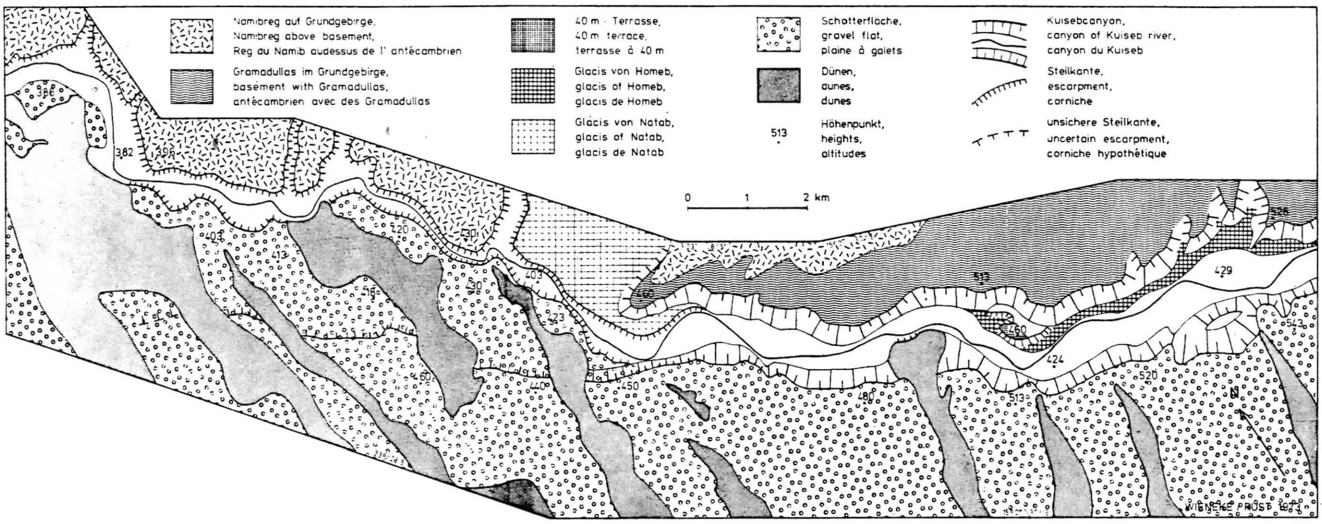

Figure 3. Geomorphological map of the region near Ossewater and Gobabeb, S.W.A. (Interpretation of aerial photographs and of topographical maps and field survey by the authors).

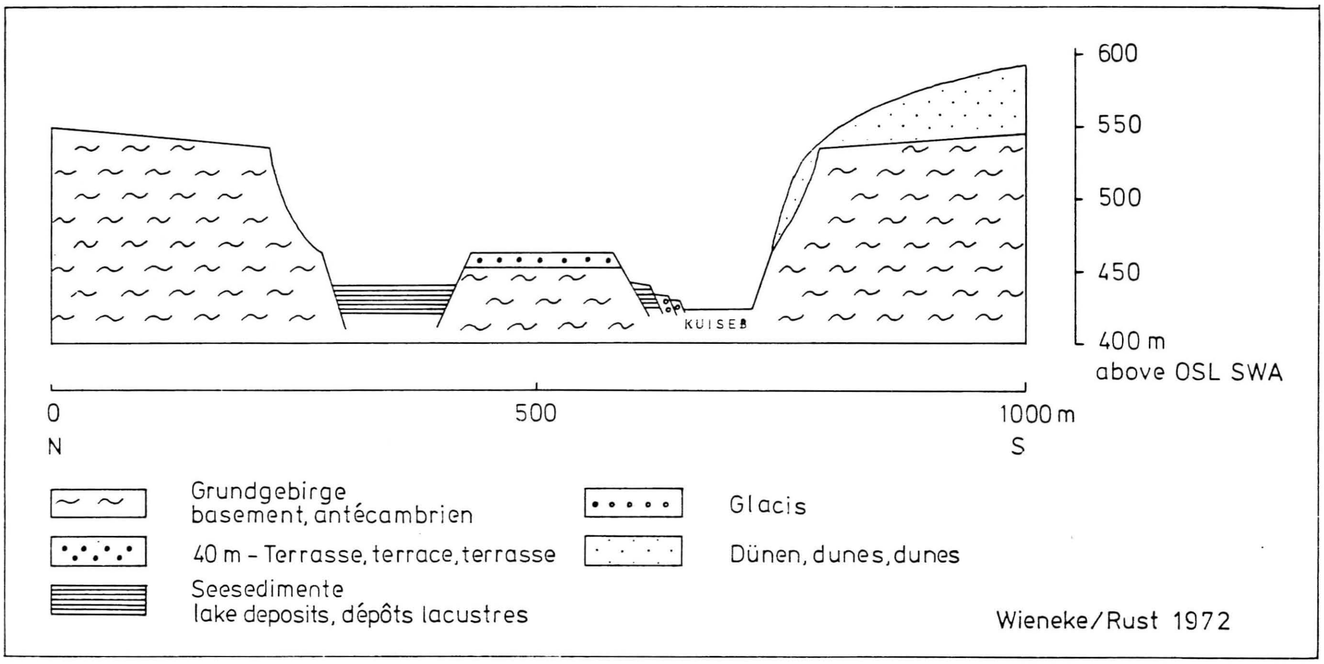

Figure 4. Schematic cross section of the Kuiseb canyon near Homeb, S.W.A. (Survey by the authors). (See WIENEKE//RUST 1972, Fig. 4).

the river bed itself and are eroded by the running river. At this locality too the hanging valleys reach back onto the flats and form a dendritic pattern on the basement and on the overlying incrusted sediments. At a point E of Hudaob this dissection is fossilized by blown sand and dune formation. A dune situated on top of the scarp above the Kuiseb canyon bars a system of tributary valleys. This dune separates the upper part of this valley system from the lower part incised into the wall of the canyon (Fig. 2).

On the right, i.e. northern, side of the river the basement is uncovered in a zone of several km width and is deeply and densely dissected down to the actual river level (zone of gramadullas). This type of gramadulla incision ends downstream at Natab. At this point glacis étagés (Fig. 7) have been formed between the Namib flats and the river bed. The tributaries possess only very shallow valleys on the flats, but are incised deeply into the Namib some km upstream of their inflow into the Kuiseb river. It is impossible to discern indubitably a terrace at 10 to 20 m above the river.

We found a remnant of a terrace about 40 m above the river (460 m) some 5 km upstream of Natab (Fig. 3). Two glacis, lying one over the other, and remnants of a terrace consisting of lake deposits (information resulting from our ground checks) form marginal flats between the northern side of the canyon and the river bed.

2.1.2. Field checks

Due to the running of the Kuiseb river we could not visit all the localities we wanted to check. As far as it was possible to do the ground check, our interpretations (see 2.1.1.) proved to be correct.

In the area of Homeb and Ossewater two glacis, reaching from the tributary valleys into the main canyon, are situated at a lower level than the remnants of a former terrace of lake deposits. The high-water bed of the river is undercutting the glacis. The lower one is actually forming the inactive bed of the dry gramadulla valleys (Fig. 8).

The remnant of a 40 m terrace at 460 m is surrounded by a scarp of 10 m relative height, formed in a conglomerate above the basement, and is higher than all the other accumulational forms in the valleys (Fig. 9). Therefore the Kuiseb canyon at Homeb consists of the landforms shown in Fig. 4.

2.2. Sediments

2.2.1. Sample collection, analysis and interpretation

GOUDIE (1972, Fig. 9) describes "grey silt" on a 6 m — terrace at Gobabeb and "lake deposits" near Homeb and Ossewater, while SCHOLZ (1968, p. 103, 104) describes "fossil flood silt" on both sides of the Kuiseb up to a position 15 m above the river bed. He shows e.g. profile Gobabeb XIV containing 20 cm of weathering debris of gypsum crusts and adjacent rocks on top of 40 cm of flood silt, which overlies lose dune sands on mica schists. We too found these sediments e.g. at Natab, but did not take samples.

SCHOLZ notes the existence of a grey, well stratified, calcified (17,1% $CaCO_3$) flood silt near Homeb and Ossewater. He says that it differs petrographically from the sediments at Natab.

The sediments described by GOUDIE and SCHOLZ have been conserved primarily in the tributary valleys of the canyon (Fig. 10). Flying over the area, we could see that their distribution starts several km downstream of Hudaob and continues until about 4 km upstream of Natab. They are to be found in positions protected from erosion in the gramadullas, but not so often in the main valley. The sediments are stratified nearly horizontally, they consist mainly of silt with layers of fine sand (compare further down).

We took three samples from these deposits at Ossewater (profile 70, samples 70/I, 70/II, 70/III). For comparisons we took samples from an active barkhan (55/B), from the recently flooded high-water bed of the Kuiseb river at Gobabeb (77/I) and from the bed of the running river (76/I). For further comparisons we analysed a vlei sediment (19/IIa, b). Sample 75/I was taken from a cemented lens of silt material in the conglomerate of the 40 m — terrace, some 5 km upstream of Natab.

Table 1 shows the contents of $CaCO_3$ and of $CaSO_4 . 2H_2O$. All the samples contain about 1 to 2% $CaCO_3$. The very elevated content of 75/I — taken from a remnant of a terrace which is disconnected from any soil water circulation — indicates a very long time of crust formation and therefore a very high age of the sediment (mainly fluvial gravels).

The samples have been boiled with HCl and then have been submitted to a granulometric analysis. Fig. 5 shows the cumulative frequency curves.

The samples 55/B and 70/II show similar cumulative frequency curves of grain sizes and similar colours. 70/II contains about 13,5% < 125 μ, and

Table 1. Contents of $CaCO_3$ and of $CaSO_4 . 2H_2O$ from selected sediment samples.

Sample no.	$CaCO_3$ (%)	$CaSO_4 . 2H_2O$ (%)
70/III	2,29	
70/II	0,84	
70/I	2,21	
76/I	1,75	
77/I	2,36	
75/I	53,49	0,14
	54,10	
19/IIa	0,76	39,11
19/IIb	5,58	2,27
55/B	1,98	

Note: The samples 70/I, II, III; 76/I; 77/I; 55/B have not been analysed regarding their content of $CaSO_4 . 2H_2O$. The sediments which they do represent are not cemented and do not contain nodules.

Table 2. Sediment samples.

No.	Position	Colour
55/B	active barkhan, S Swakopmund	7.5 YR 7/8—6/8
70/I	profile of lake sediments, Ossewater, bottom	2.5 Y 8/4
70/II	dto, 2,10 m above bottom	7.5 YR 5/8
70/III	dto, 2,40 m above bottom	5 Y 6/3
75/I	40 m — terrace, upstream Natab	
76/I	bottom of running Kuiseb river, Gobabeb	
77/I	actual high-water bed, Kuiseb river, Gobabeb	

shows a colour value comparable to that of sample 55/B. Therefore the sediment layers of the Ossewater profile which are represented by sample 70/II can be interpreted as layers of barkhan sands mixed with some material which is analogous to that lying underneath in the profile.

Sample 77/I collected from the recent high-water bed of the river contains about as much clay as sample 70/I from the bottom of the lake sediments. Both samples also show high contents of silt. The two samples 76/I from the bottom of the running river and 70/III have a very similar grain size distribution.

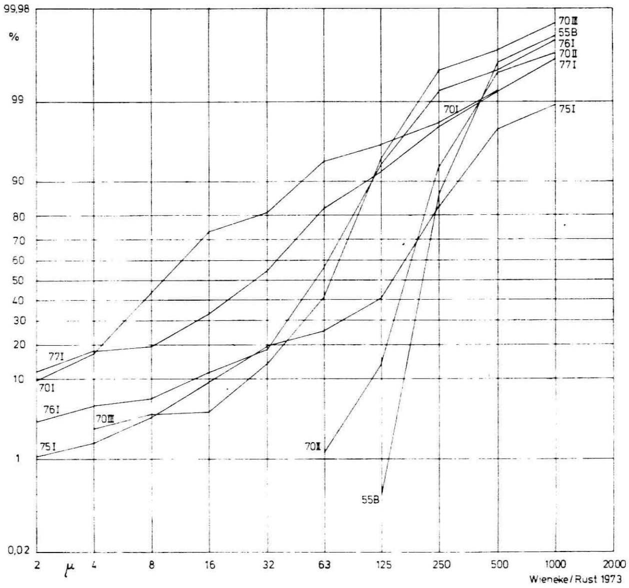

Figure 5. Cumulative frequency curves of grain size distributions of selected sediment samples, represented on probability paper with a logarithmic ordinate (compare table 2).

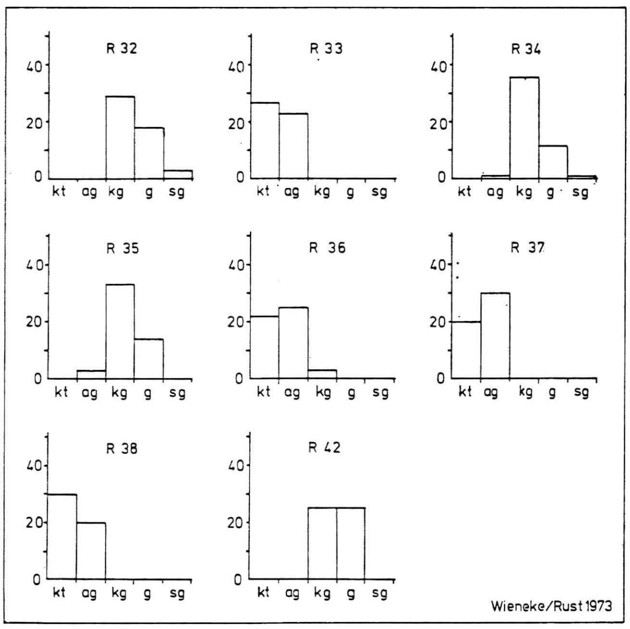

Figure 6. Histograms of the frequency distributions of the degree of roundness for selected samples of gravels (compare table 3).

Therefore the Ossewater deposits must be interpreted as a series of still water sediments with layers of barkhan sand which is covered by low water sediments. The sediments represented by profile 70 have been deposited by a Kuiseb river which was barred by dune formation ("tsondabized").**) SCHOLZ (1968, p. 103) postulated such a process already as an explanation for the existence of fossil flood silt at Natab. There can not be found any connection between the sediments of Homeb and Ossewater and the flood silt at Natab.

Sample 75/I, taken from a lense of finer material in the conglomeratic fluvial gravels of the 40 m — terrace, has a high content of fine sand (125-250 μ) and of clay and silt fractions after the dissolution of the $CaCO_3$. The cumulative frequency curve of its grain size distribution seems to be composed from respective parts of the curves of fluvial (76/I) and eolian (55/B) sediments.

2.2.2. The degree of roundness of gravels

The analysis of the degree of roundness of gravels enables statements about the modes of transport. We were able to extend REICHELT's (1961) method to gravels from arid regions (RUST/WIENEKE, 1973b). Table 3 lists the analysed gravel deposits and their geomorphic positions. The distributions of the degree of roundness are shown by Fig. 6.

The distributions of the degree of roundness of R 32 and R 42 are intermittent between the kg- and the g-type distributions ***). They reflect conditions of fluvial transport in a geomorphic environment which is not typical for arid regions. Some of the gravels were disintegrated after their deposition and have been submitted afterwards only to very limited transport (ag-type). The samples R 34 and R 35 belong to the kg-type, but they contain some gravels of deposits represented by samples R 32, 42. Gravels of this type of roundness can be found downstream until Rooibank. The samples R 36 and R 37 show a roundness distribution of the ag-type, according to their geomorphic position, i.e. they have not been submitted to effective fluvial transport. The sample R 33 shows the roundness distribution of rock debris which has not been transported (kt-type). Angular (kt) gravels dominate in the sample collected on the glacis at Ossewater (R 38), but it contains nevertheless much subangular (ag) material. This distribution indicates short, ineffective transport.

**) We define a river to be tsondabized, if its course is barred by dune formation as is exemplified by the Tsondab River (see WIENEKE/RUST 1973a).

***) kt = kantig = angular, ag = angerundet = subangular, kg = kantengerundet = subrounded, g = gerundet = rounded, sg = sehr gut gerundet = well rounded. For the definitions see RUST/WIENEKE, 1973b.

3. MORPHOGENETIC STAGES OF LANDFORM EVOLUTION BETWEEN HUDAOB AND GOBABEB

3.1. The sequence of morphoclimatic stages

In RUST/WIENEKE (1973a) and WIENEKE/RUST (1973b) we published a table containing all the criteria observable in the field which can be used for the recognition of the morphoclimatic stages of Quaternary landform evolution in the Central Namib Desert. These are the stages of arid-active, arid-stable, and humid-active geomorphic environments. By using these criteria in interpreting the above mentioned landforms and sediments we were able to deduce a sequence of morphoclimatic stages for the area of the middle Kuiseb river between Hudaob and Gobabeb.

The surface of the basement above the gramadullas is partly uncovered. The cemented fluvial sediments (arid stability following humid activity (?)) form a scarp over this surface. We interprete this scarp as the scarp of a denudational terrace due to different rock types. It is very well formed in the upper parts of the tributary valleys. We shall give further information about this phenomenon in another publication concerning the upper part of the Rutile river (compare Fig. 3 and compare Photo 3 in RUST/WIENEKE 1973a).

The first stage of incision of the Kuiseb river is represented by the 40 m — terrace upstream of Natab and by the hanging valleys of the southern canyon wall which are incised to this level (humid activity). Afterwards the dune walls reached at least the southern side of the Kuiseb valley (arid activity), where they are lying actually like glaciers in the hanging valleys, and where they impeded any further autochthonic dissection (Fig. 2, east of Hudaob). Hereafter the allochthonic river Kuiseb incised and deepened its valley to form a canyon (arid stability), followed by a consequent stage of strong incision of the gramadulla valleys (humid activity). Later the Kuiseb was tsondabized as documented by the sediments of profile 70 (arid activity), thereafter followed a new period of incision of both the main river and its tributaries (humid activity, upper glacis), at least a second period of humid activity (lower glacis), and the present stage of arid stability. These are the morphoclimatic stages which can be deduced directly from the study of landforms and of sediments. The sequence is incomplete, because the changes from an arid active geomorphic environment to a humid active one and vice versa are only understandable by means of an intermediate, perhaps short, stage of arid stable geomorphic environment. Therefore we have to except a sequence of at least 12 morphoclimatic stages, starting with the first main period of incision of the river Kuiseb (40 m — terrace). These stages are listed in the table 4. It is very probable that this list remains still incomplete.

Table 3. Analysed gravel deposits.

No.	Geomorphic position
R 32	So called 42 m — terrace of GOUDIE, dune valley S Gobabeb, gravel flats, polished gravels (corrasion)
R 33	Southern side of the valley of Kuiseb river near Natab, 50 m above the river, crest formed in mica schists
R 34	Southern side of Kuiseb valley near Natab, about 12 m above the river, lower edge of so called 20 m — terrace
R 35	Northern side of Kuiseb valley, upstream Natab at the limit of the gramadulla zone, upper edge of the glacis from the Namib flats to the river
R 36	Lower part of a small valley ending on this glacis (R 35), on both sides of the valley mica schists with veins of quartzite
R 37	Upper limit of the valley (R 36), still Namib flats reaching down on interfluves
R 38	Ossewater, upper glacis formed in front of profile 70, 2 m above the bottom of this tributary valley
R 42	Conglomerate of 40 m — terrace, 5 km upstream Natab, polished gravels, exclusively weathered quartz gravels

Table 4. Morphoclimatic stages of middle Kuiseb river.

Morphoclimatic stages		Main geomorphic or sediment criteria
No.	Geomorphic environment	
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.

This sequence shows once more that the sediments of the 40 m — terrace have been calcified during several different periods. The analysis of the degree of roundness showed that the gravels of the 40 m — terrace (R 42) and of the so called 42 m — terrace south of Gobabeb (R 32) most probably were transported under conditions of fluvial transport, which are not typical for geomorphic environments of arid regions. Therefore our statements about the oldest stages in table 4 need not to be correct, since we used our concept of morphoclimatic stages in an arid region.

It is difficult and not without the possibility of errors to correlate the landform evolution downstream of Natab with our sequence listed in Table 4, because it is impossible to follow both landforms and sediments found in the part of the valley between Hudaob and Natab further downstream. On the other hand we cannot prove that our sequence is complete. It was especially difficult to correlate the sequence of morphoclimatic stages found for the area of Homeb and Ossewater with the one which we had elaborated for the coastal Namib Desert.

3.2. An attempt at a geochronological correlation

In comparison to the morphoclimatic evolution of the coastal Namib Desert, stages of arid-active environment have been more numerous at the middle Kuiseb river. Without doubt we can correlate stage a observed in the coastal parts (RUST/WIENEKE, 1973a, Fig. 9) and stage 1 of table 4. The lower glacis (stage 2) may have formed during the humid-active stages b, c. The forming of the upper glacis (stage 4) may be correlated with the stage of humid activity posterior to the 17 m marine terrace. Then the tsondabizing of the river Kuiseb at Homeb and Ossewater (stage 6) took place during the forming of the 17 m marine terrace — or even earlier. Therefore it may be possible to correlate the main stage of gramadulla incision (8) with the humid-active environment prior to the 17 m terrace formation. This shows that the dunes had reached the southern side of the Kuiseb canyon upstream of Natab in the Middle Pleistocene (?). The 40 m — terrace is even older, which assumption is backed by the degree of roundness of the gravels. It is impossible to indicate the stages for the incrusted denudational terraces above the gramadullas and for the fossil red dunes at the inner margin of Namib Desert which are overlying them (e.g. farms Solitaire and Rostock).

Since it is impossible to continue a correlation of landforms and sediments downstream, every attempt at geochronological correlations of the sequence of morphoclimatic stages which we were able to elaborate remains doubtful. The fossil flood silts at Natab described by SCHOLZ as an example of the tsondabization of the river Kuiseb can not be ranged into the list of table 4, nor the so called 42 m — and 10 to 20 m — terraces of the Kuiseb river neither of which can be followed downstream to the coast.

3.3. Unsolved problems

We have arrived at the conclusion that the formation of the gramadullas in the middle part of the Kuiseb river was a multistadial process which started obviously a very long time ago. Over this time period we cannot exclude the influence of tectonic movements (positive crust deformations) on amount and effectiveness of incision. Some other problems still remain to be solved. It is uncertain if the glacis of Homeb and the glacis of Natab were formed contemporaneously, since there is a gap between them for more than 4 km. Since both groups of glacis are not far apart it might be possible to postulate that they were formed in the same stages. Further observations contradict this assumption. The formation of the glacis at Homeb indicates stages of gramadulla incision, but the gramadulla zone ends downstream at Natab. There the undissected Namib flats reach the valley of the Kuiseb river. We do not yet know why the gramadullas are limited to the area upstream of Natab. Furthermore the so called 42 m — terrace starts to diverge from the river itself at Natab, i.e. at this point the Kuiseb changes the direction of its course. Therefore most probably further investigations in the area of Natab may aid in connecting the morphogenesis of the middle part of the Kuiseb river, presented in this paper, which the morphogenesis of its lower part.

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RÉSUMÉ

La partie centrale de la rivière Kuiseb en amont de Natab montre une zone dissectée profondément et densément qui existe principalement dans la partie septentrionale de la vallée. La morphogenèse de cette zone à Gramadullas n'a pas encore été éclaircie. Nous avons ètudiè les formes du relief et les sédiments, analysé des échantillons des sédiments et des galets, et nous avons réussi à déduire douze phases morphoclimatiques dés la premiére phase d'activité fluviale du Kuiseb et de ses tributaires. Nous avons essayé de correler cette séquence des phases avec laquelle que les auteurs ont élaboré et publié pour les règions côtières du désert du Namib Central. Les problèmes qui restent pas solus et les possibilités d'investigations futures sont indiqués.

ZUSAMMENFASSUNG

Am mittleren Kuiseb, oberhalb von Natab, ist vor allem die nördliche Randzone des Tales auf einige km Breite tief und engständig zertalt. Die Morphogenese dieser Gramadullas ist bis heute ungeklärt. Wir untersuchten Reliefformen und Sedimente, analysierten Sedimentproben und Schottervorkommen und konnten hieraus eine Abfolge von zwölf klimamorphologischen Phasen ableiten, beginnend mit der ersten Eintiefungsphase des Kuiseb und seiner Nebenriviere. Es wird versucht, diese Abfolge mit der von den Autoren für die küstennahe Zentrale Namib erarbeiteten und veröffentlichten zu korrelieren. Noch ungelöste Probleme werden präzisiert und Ansätze zu weiteren Untersuchungen angedeutet.

SUMMARY

In the middle parts of the Kuiseb river upstream of Natab, mainly the northern side of the canyon is deeply and closely dissected, forming a marginal zone of some km width. This type of dissection is called gramadulla incision, and its morphogenesis is not yet understood. We checked landforms and sediments, analysed sediment samples and gravels, and were able to establish a sequence of twelve morphoclimatic stages starting with the first stage of incision of the river and its tributaries. An attempt is made to correlate these stages with the sequence of morphoclimatic stages which the authors elaborated and published for the coastal Namib Desert. Unsolved problems are stressed, and the trend of further investigations is indicated.

LITERATURE

Goudie, A., 1972. Climate, weathering, crust formation, dunes, and fluvial features of Central Namib Desert, near Gobabeb, South West Africa. Madoqua II, **1**: 15-32.

Reichelt, G., 1961. Über Schotterformen und Rundungsgradanalyse als Feldmethode. Petermanns Geogr. Mitt., **105**: 15-24.

Rust, U./Wieneke, F., 1973a. Grundzüge der quartären Reliefentwicklung der Zentralen Namib, Südwestafrika (erste ausgewählte Ergebnisse einer Forschungsreise 1972) J. S.W.A. Sci. Soc., **XXXVII**: 5-30.

Rust, U./Wieneke, F., 1973b. Die Rundungsgradanalyse nach Reichelt als Feldmethode in Trockengebieten. Petermanns Geogr. Mitt., **117**: 118-123.

Scholz, H., 1968. Die Böden der Wüste Namib/Südwestafrika. Zeitschrift für Pflanzenernährung und Bodenkunde, **119**: 91-107.

Spreitzer, H., 1965. Beobachtungen zur Geomorphologie der Zentralen Namib und ihrer Randgebiete. Sonderveröffentlichung S.W.A. Sci. Soc., Windhoek, **4**: 34.

Wieneke, F./Rust, U., 1972. Das Satellitenbild als Hilfsmittel zur Formulierung geomorphologischer Arbeitshypothesen (Beispiel: Zentrale Namib, Südwestafrika). Wiss. Forschung in Südwestafrika, 11. Folge, Windhoek, 16 S.

Wieneke, F./Rust, U., 1973a. Klimageomorphologische Phasen in der Zentralen Namib (Südwestafrika). Mitt. Geogr. Ges. München, **58**: 79-96.

Wieneke, F./Rust, U., 1973b. Variations du niveau marin et oscillations morphoclimatiques dans le désert du Namib Central, Afrique du Sud-Ouest. Finisterra, **VIII, 15**: 48-65.

Figure 7. View from the southern side of the running Kuiseb (foreground) at Natab, northeastward. In the background glacis étagés, on the right side gramadulla zone ending.

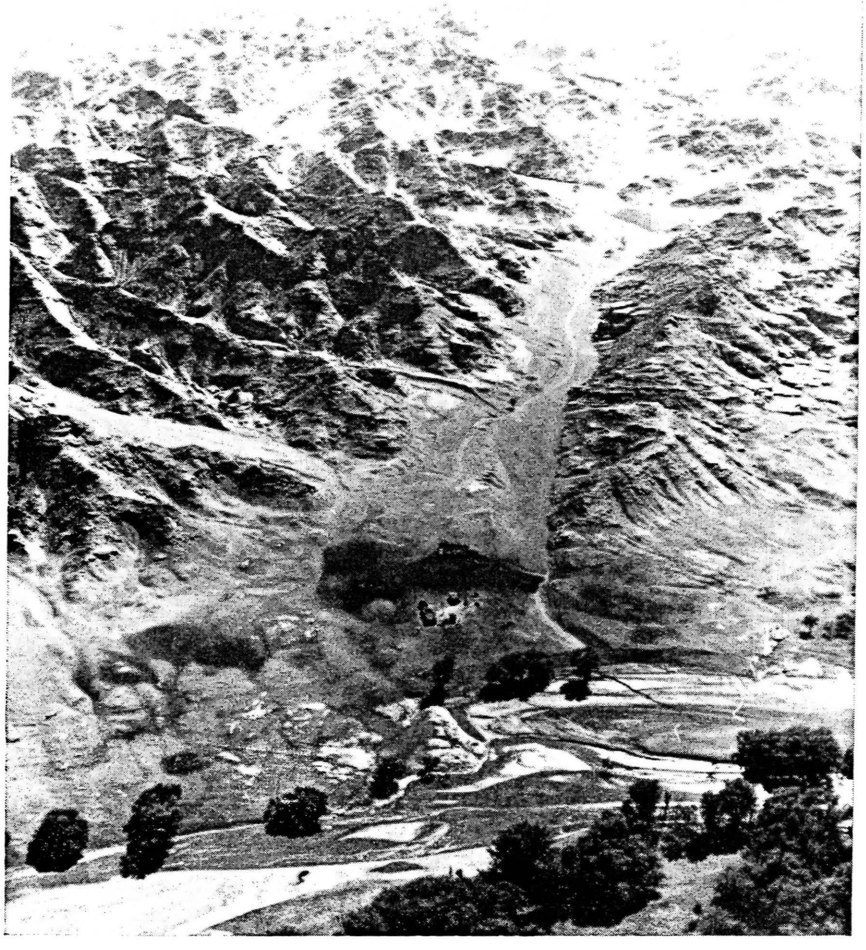

Figure 8. Gramadulla valley at Homeb. Foreground running Kuiseb undercutting the lower glacis, i.e. valley bottom. Settlement situated at the dissected upper glacis.

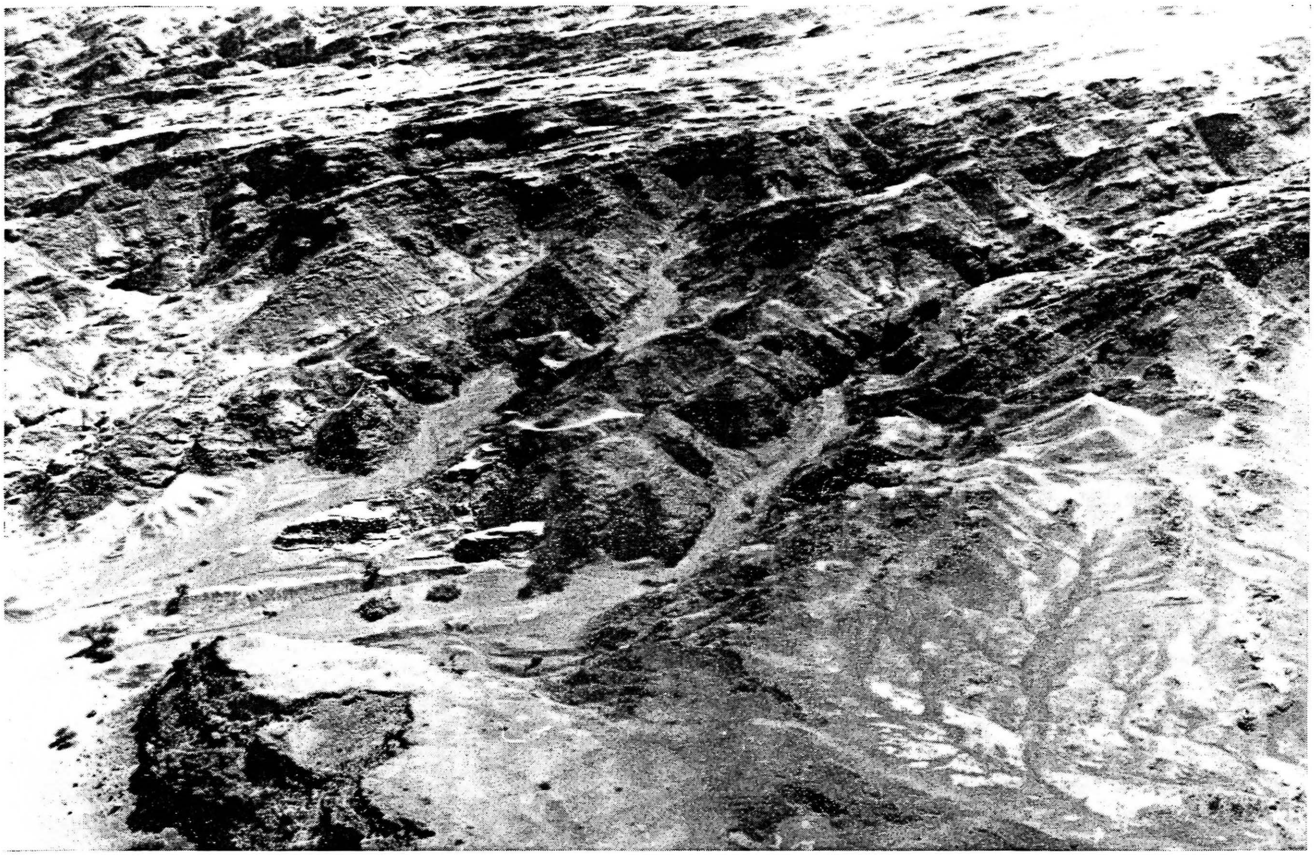

Figure 9. In the foreground 40 m — terrace remnant. Denudational scarp formed in calcified conglomerates. In the middleground the westernmost relicts of Ossewater sediments (light grey), compare Fig. 4.

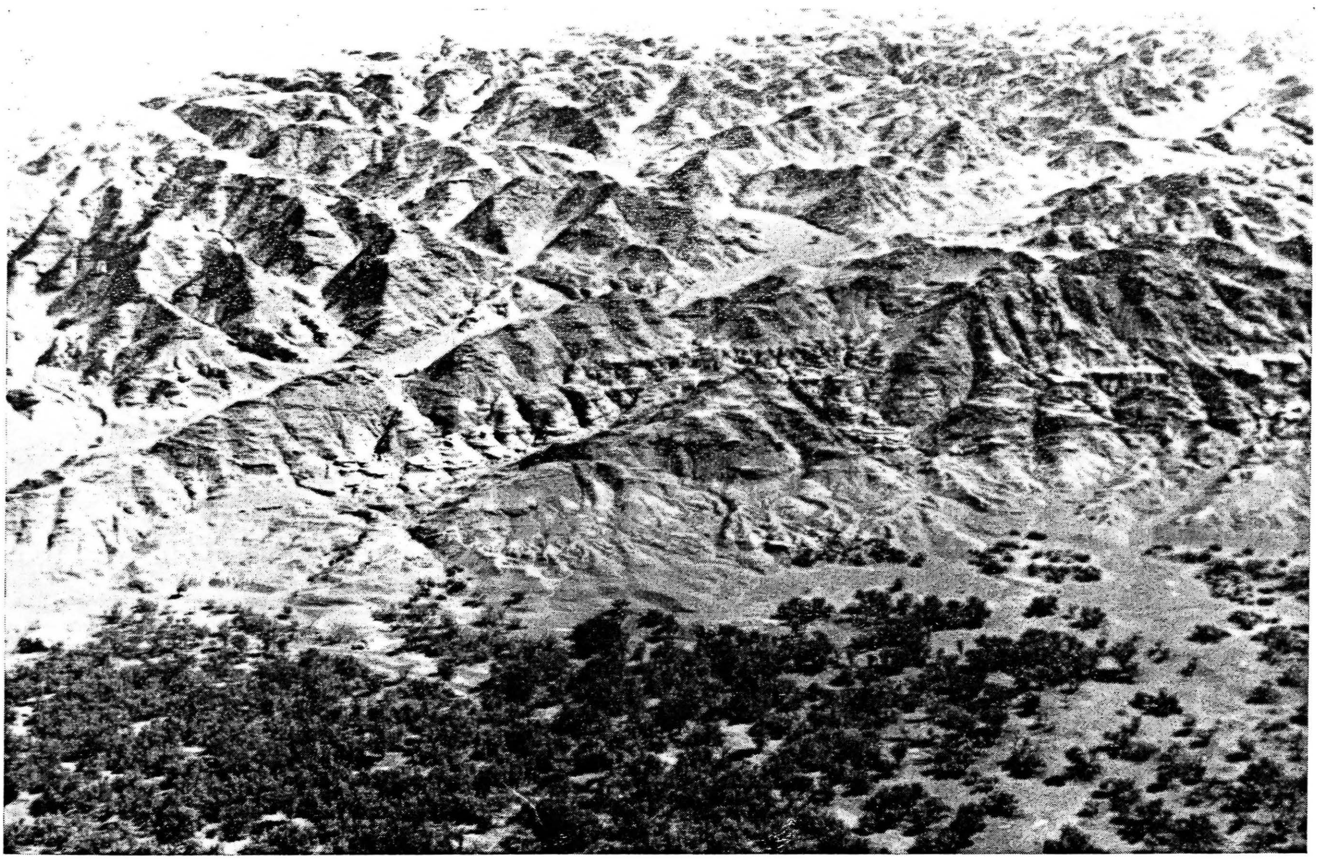

Figure 10. E Ossewater, typical position of Ossewater sediments in tributary valleys (protection against erosion).