Aspects of the geomorphology of the Kuiseb River, South West Africa

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ABSTRACT

Geomorphological aspects of the Kuiseb river catchment in central South West Africa are analysed. The characteristics of the Kuiseb drainage are compared with other Atlantic drainage systems in terms of pattern and discharge potential. The detailed morphology of Kuiseb longitudinal and cross profiles, derived from map analysis, are scrutinised and relevant terrace deposits are considered in an attempt to elucidate a sequential history for the catchment.

CONTENTS

1 INTRODUCTION

The Kuiseb-Gaub drainage system, a component of South West African Atlantic drainage, rises in the Khomas Highlands to cross the central Namib desert and reach the coast near Walvis Bay (Map 1). The siting of the Desert Ecological Research Unit at Gobabeb on the north bank of the middle Kuiseb river has resulted in considerable research effort being expended in the middle Kuiseb catchment, but no overall synopsis of the catchment geomorphology is, as yet, available. This paper outlines the characteristics of the Kuiseb drainage system as compared with other central Namib drainage components. Salient geomorphological features of the middle Kuiseb valley between Hudaob and Rooibank are emphasised.

2 THE KUISEB SYSTEM AS A COMPONENT OF ATLANTIC DRAINAGE

2.1 Drainage patterns

The watershed between Atlantic and Kalahari drainage lies east of the Escarpment, approximately along the longitude of Windhoek (17°E) in central South West Africa. Further south the watershed between the Namib endoreic drainage and the captured Fish-Orange system trends further west along latitude of 16°E (Map 1). Drainage has been presumed consequent on post Jurassic continental break up and to have undergone subsequent modification by capture (Mabbutt, 1955). Atlantic drainage has been affected by periodic uplift, maximised in the Escarpment zone, with the concomitant necessity to extend courses seawards.

North of the Kuiseb river, the prevailing alignment is west south west, whereas to the south, the trend becomes more generally due west (Map 1). By comparison, the orientation of the Kuiseb-Gaub system appears distinctly anomalous. From its source to Hudaob, the Kuiseb river is aligned southwest. The direction alters abruptly westward at Hudaob. From Homeb a northerly component is added and downstream of Gobabeb the alignment changes again to become northwest between Swartbank and Walvis Bay. Delta course alteration also to the northwest, downstream of Rooibank, has been documented for the historic period since 1885 (Stengel, 1970). It has also been suggested that a progressive northward shift of the entire lower Kuiseb downstream of Gobabeb has occurred over a longer time span, that the Kuiseb river originally flowed west to Conception Bay (van Zyl, unpub.). Advancing dunes, attendant on aridification in the late Cenozoic period have been cited as the controlling mechanism for these shifts (Wienecke & Rust, 1973).

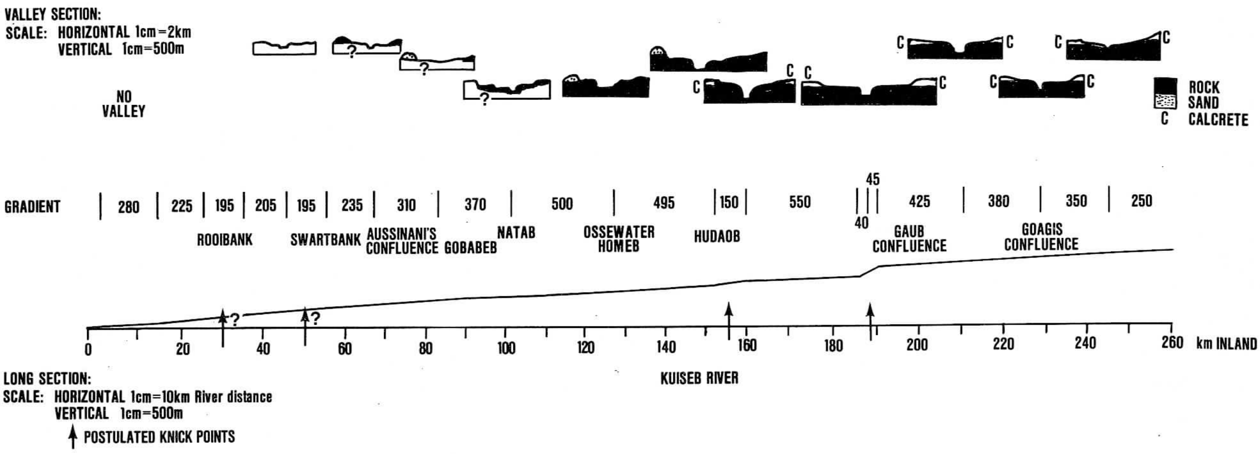
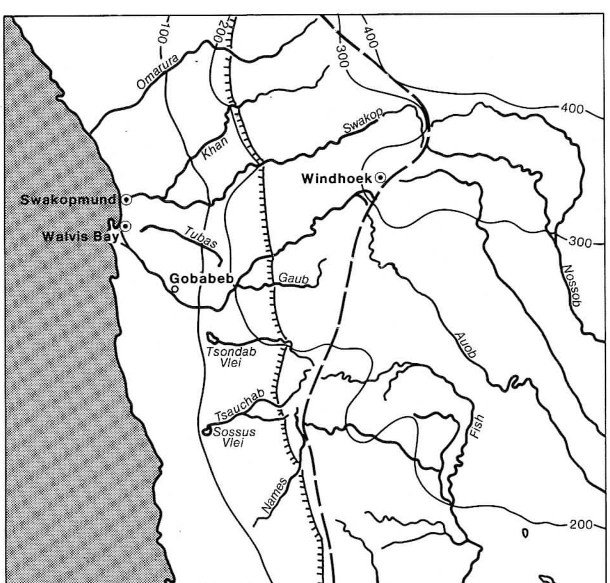


Fig. 1: Kuiseb cross-valley and longitudinal profiles constructed from 1:100 000 map sheets.

The course pattern of the Kuiseb river requires explanation. The Hudaob bend is now constrained by structural weaknesses in the basement rocks, as in detail is much of the bedrock upper course. Furthermore the seaward extension of all river systems following emergence might explain changes in direction coastwards. Although both factors have affected the Kuiseb system, they are not unique to it, yet the anomaly is confined to its catchment. Localised warping may have been significant and river capture has also been postulated on little evidence. Changes in discharge affect river pattern but climatically induced drainage changes are also unlikely to be restricted to a single catchment. The Kuiseb-Gaub drainage pattern is a legacy of its past evolution, for which a detailed explanation cannot be offered at present.



Map 1: Atlantic drainage components.

2.2 Discharge characteristics

Even in the highland zone few rivers flow perennially in South West Africa. Between 22° and 29°S only the Omaruru, Swakop-Khan and Orange rivers are able to maintain courses to the Atlantic. Other systems cease to flow where evaporation exceeds discharge and end in vleis, either on the gravel plain like the Tubas river, or among dunes, as is the case of the Tsondab, Tsauchab and Tsams rivers (Map 2). The Kuiseb-Gaub system is intermediate in character. Although normally flowing for a period annually in its middle course, discharge rarely enters the Atlantic Ocean. Since 1837 the Kuiseb river has discharged into the sea on only 14 occasions, an average of once in 10 years (Stengel, 1970). The construction of pumping works at Rooibank with direct loss by extraction now inhibits coastal discharge further. It occurs only exceptionally, as in 1963, but it is probable that given pre-1951 conditions, discharge to the sea would have occurred in 1974 and in 1976.

Discharge characteristics are a function of catchment size and precipitation patterns, on average over the catchment and in terms of seasonal distribution. Seasonal variation in totals and the incidence of high intensity storms are critical. Throughout South West Africa annual evaporation exceeds annual precipitation. Only high intensity storms, resulting in short-lived water surplus conditions, create sufficient discharge to promote channel flow. Comparative statistics for six Namib catchments have been derived from map analysis of 1:500 000 topographic and annual average rainfall map sheets (Table 1). Of these six catchments only the Swakop-Khan system maintains a course to the coast regularly. The Kuiseb-Gaub system flows through the dune barrier across its delta only periodically and the other four systems are endoreic (Map 1). Midgley and Pitman (1969), for the North West Cape Province, have calculated that, given the evaporation rates that obtain (which may be lower than in the central Namib), discharge is minimal where annual precipitation does not exceed 200 mm (Table 1.2.). Applying their expected discharge figures to the central Namib catchments, demonstrates that the two critical parameters are catchment size and area of catchment with precipitation exceeding 200 mm pa. (Table 1.1.). Mean annual precipitation does not exceed 300 mm in any portion of the catchments analysed.

Long-return, large-magnitude precipitation events (storms) cause significant discharge even in the endoreic systems and lead to geomorphological changes in bed and valley forms. However extension of regular fluvial discharge downstream to effect large-scale changes in valley geometry, such as

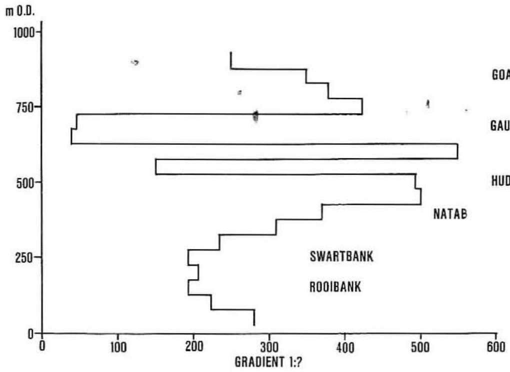


Fig. 2: River gradient variation with altitude.

evidenced by the terrace sequence west of Tsondab Vlei and as postulated by Seely and Sandelowsky (1974) requires long-term changes in either precipitation totals or in evaporation rates or in both simultaneously. Since the catchment area in receipt of over 200 mm annual precipitation appears to be critical, relatively small amplitude changes in climate could cause significant changes in discharge regimes and in the energy potential of the rivers. The Kuiseb system's intermediate position with respect to discharge characteristics, renders it particularly susceptible to such changes.

3 THE KUISEB CATCHMENT WEST OF THE ESCARPMENT

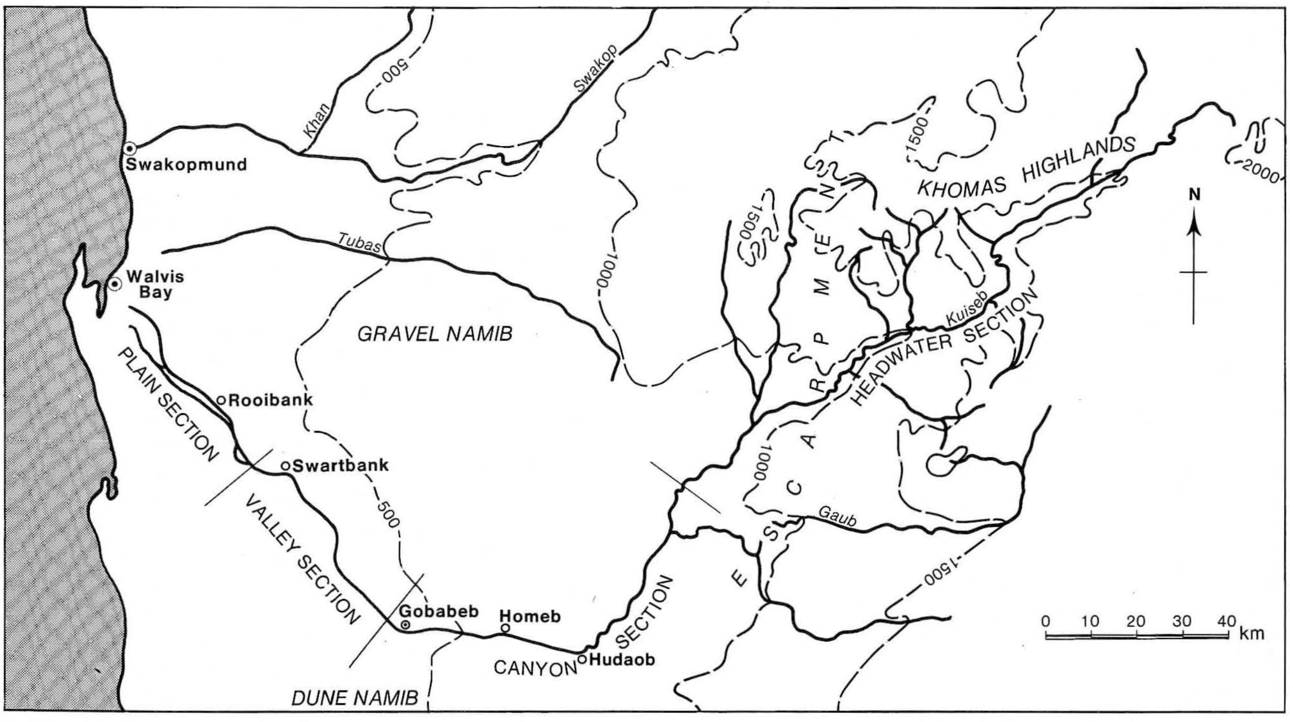
3.1 Catchment subdivisions

The Kuiseb-Gaub drainage system can be divided into four distinct sections on the basis of catchment characteristics and valley morphology (Map 2). East of the Escarpment in the Khomas Highlands headwater region, the highland zone, the river drains a planed bedrock plateau. The open valley is only shallowly incised into the former planation surface (Spreitzer, 1966). The margin of the highland zone is however more dissected and the valley becomes more entrenched immediately upstream of the canyon section. West of the Escarpment the Kuiseb river demarcates the dune and gravel-pediment Namib. Dunes conceal detail of the south bank in the three sections west of the highland zone. Between the highland front and Homeb, the Kuiseb river has incised through a calcrete fanglomerate into underlying bedrock. Incision, reaches its most spectacular proportions in the Kuiseb canyon, extending from the Kuiseb-Gaub confluence approximately to some 5 km upstream of Homeb. From this point downstream to Gobabeb in the lower canyon section, bedrock cliffs are visible but incision becomes progressively more open and less pronounced. From Gobabeb to Swartbank, although the river bed remains clearly defined, the valley is shallow, less than 10m depth within rock-defined banks. Seawards of the Swartbank ridges, the valley itself becomes indistinct for the sides are formed of less coherent deposits, while below Rooibank, no valley exists. River channels are braided and create the delta overlying a recently emerged marine plain. (Fig. 1) (Davies 1971).

The four sub-sections of the Kuiseb catchment comprise a bedrock highland zone, where incision has been minimal in the core region; the main and lower canyon downstream to Gobabeb superimposed from a calcrete veneered footslope; a shallow valley section between Gobabeb and some kilometres downstream of Swartbank where course shifts become apparent and the plain and delta section from Rooibank to the coast where bed changes result from every flood.

3.2 Geological components

Upstream the drainage system crosses Basement Complex rocks. Their geological variation is of significance as a control of local pattern and for the provision of load components. The



Map 2: The Kuiseb Catchment showing major subdivisions.

TABLE 1: Catchment and Drainage

1.1) Analysis of 6 Namib catchments
(0 indicates no portion of catchment fell in zone)

CATCHMENT	SWAKOP KAHN	KUISEB-GAUB	TUBAS	TSONDAB	TSAMS	TSAUCHAB
Catchment Area (Km^2)	30 636	16 896	2 748	5 780	2 040	5 572
% Catchment receiving over 200 mm pa.	68	55	6	35	0	0
% Catchment with up to 100 mm pa.	15	32	15	0	0	0
% Catchment in Namib (after Stengel 1970)	16	20.5	94	?	?	?
CALCULATED DISCHARGE (million m^2)						
From over 200 mm pa.	266.5	93.4	1.5	20.4	0	0
From 100 – 200 mm pa.	26.3	10.7	5.2	18.7	10.2	27.9
From less than 100 mm pa.	< 9.1	< 10.8	< 3.1	0	0	0
TOTAL	301.9	115.0	9.8	39.1	10.2	27.9

1.2) Expected Discharge (mm) (allowance made for evaporation) after Midgley & Pitman, 1969)

ANNUAL PRECIPITATION	DISCHARGE
105	2
160	5
220	10
295	20
445	50

Basement Complex Pre-Cambrian rocks are locally concealed by calcrete sheets and other Cenozoic components which have not yet been widely reported. The importance of these Cenozoic sediments was noted by Kaiser (1923) who discussed their relationship with the older rocks in the southern Namib and similar relationships appear to obtain in the Kuiseb catchment. The Pre-Cambrian Basement Complex consists chiefly of Damara System schists and marbles and Salem granite containing a high proportion of quartz and pegmatite. The older rocks have been intruded by presumed Karoo-age dolerite dykes (Clifford, 1967; Martin, 1965; Smith, 1963).

A red calcified sandrock impregnated with calcified nodules overlies the schists and granite between the Kuiseb and Tsondab drainage basins and outcrops along the Kuiseb valley. The sandrock appears to be of more than one age and to incorporate flat-bedded and cross-bedded sands. It is often capped and preserved by thick calcrete sheets but the full extent of the outcrop is concealed by calcrete and Namib dune sand.

Thick calcrete sheets rest on planed bedrock on both banks of the middle Kuiseb catchment immediately west of the Escarpment. Further downstream on the north bank the calcrete sheets rest on Basement Complex rocks and have been dissected by the close gramadulla valley network. Dissection is not restricted to the dune free north bank, however. On the south bank the calcrete capping, that at Hudaob has a thickness of over 10 m, also exhibits valley dissection. These valleys are now sand filled and interrupted by dunes (Goudie 1972; Smith, 1965). The Kuiseb river has apparently been superimposed from the calcrete caprock and has adjusted to flow approximately along the geological contact between sandrock and Basement Complex rocks for sandrock has been traced upstream of the Gaub confluence. Renewed incision has since stripped the sandrock to expose Basement schists underlying sandrock at Hudaob, Homeb, Ossewater and Gobabeb. The structure of the underlying Basement Complex now exerts constraints on river bed alignment in detail.

Components of the bed-load of the Kuiseb river derive from the rocks outcropping in the catchment. However at present the bed material in the middle and lower Kuiseb consists dominantly of re-worked dune sand from the dune field, encroaching from the south, and micaceous silts. Pebbles are rare downstream of Homeb. However the presence of well-rounded fluvial pebbles in the calcrete caprock, indicate that past discharge was more effective than that at present. These river pebbles, being largely of quartz and quartzite, remain in the system and are re-incorporated in a number of younger sediments. They may also be reworked as terrace deposits within the present valley having been let down from altitudinally higher calcrete sheets.

3.3 The morphology of the Kuiseb valley

The present morphology of the Kuiseb valley is the product of interaction between geomorphological process and past climatic events through discharge control, acting on bedrock geology. The whole of southern Africa, including South West Africa, has been affected by base-level impermanence throughout the Cenozoic period. Glacially controlled eustatic variations in sea-level have been superimposed on general but differentiated tectonic uplift. Regional warping has been presumed on the basis of the Fish River system incision and attendant capture of Kalahari drainage (Mabbutt, 1955). All western river courses are also progressively younger seawards since the coastal platform across which they flow is constituted by a series of emergent marine shelves. Progressive emergence implies progressive reduction in gradient and concomitant loss of fluvial energy. Associated with periodic dessication, some river systems have been unable to maintain their channels to the coast throughout their evolution. The degree of rejuvenation thus varies between catchments. Although a relict suite of terraces exists downstream of the present Tsondab river endpoint, the depth of rejuvenation in that catchment is considerably less than in the Kuiseb system.

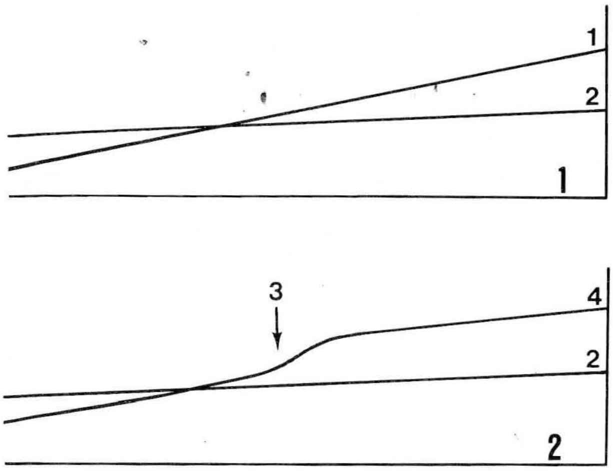


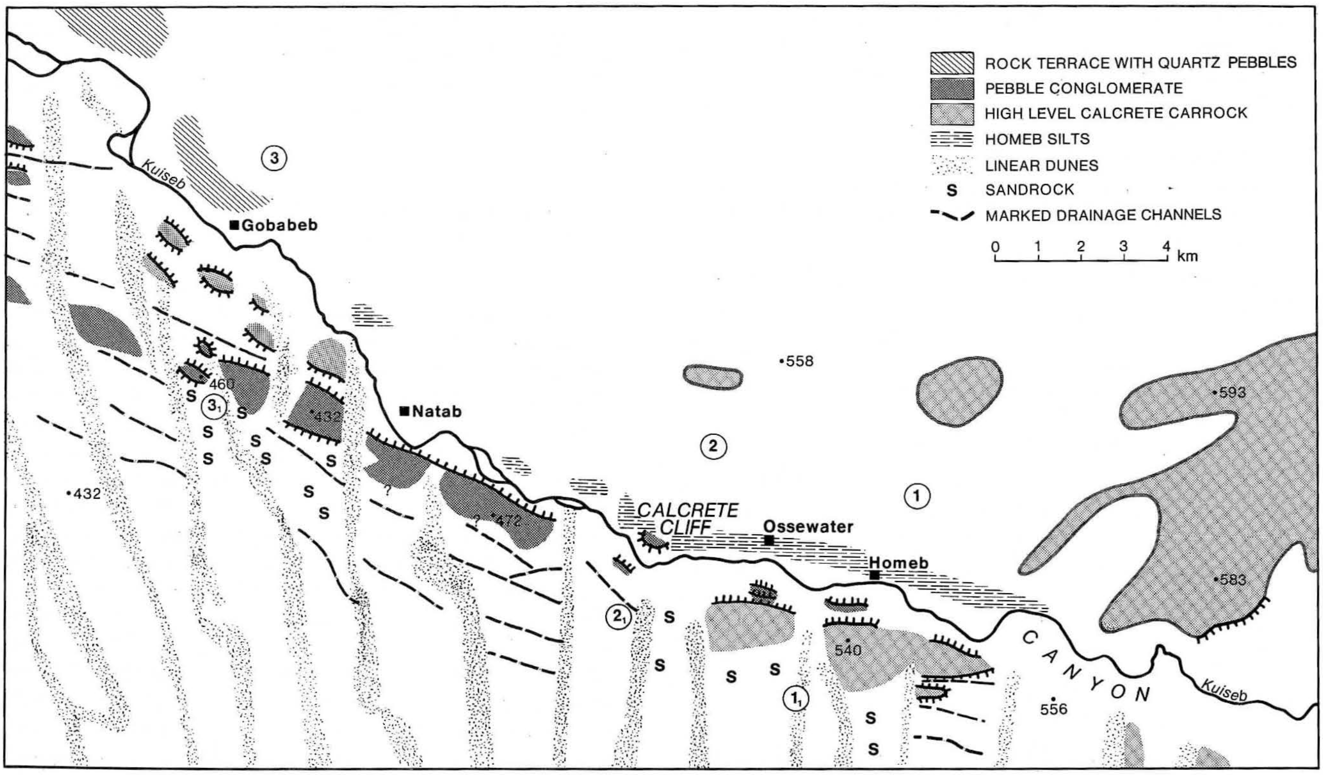
Fig. 3: Postulated gradient changes:
1 Hydrological effects
2 Tectonic effects
i) steep gradient associated with braided channels,
ii) lower gradient of channel flow
iii) zone of maximum uplift,
iv) warped surface.

A common base-level throughout geomorphological history cannot be assumed. The Kuiseb-Gaub system has apparently been able to sustain its course for the greater part of the Cenozoic period unlike the adjacent Tsondab system.

A geomorphological history of incision, equilibrium and deposition can be traced through an analysis of the cross and long profiles of the valley. A series of cross profiles were constructed using data from 1:100 000 preliminary map sheets (Table 2; Fig. 1). The effects of rejuvenation proceeding inland from changes in the marine base level can be identified. Valley-in-valley profiles are characteristic, only shallowly incised upstream of the Goagis confluence but becoming progressively more pronounced in the canyon section between the Gaub confluence and Homeb. At Hudaob the entire valley depth exceeds 200 m and within this valley, the 500 m wide canyon slot has a depth of 150 m. Downstream of Homeb, although the valley-in-valley form persists, the incised valley is wider and shallower. The markedly slot-like effects of rejuvenation manifest in the localised canyon section, may well have resulted from differential warping along the mountain front as suggested by Wienecke & Rust (1973) in another context.

Downstream of Gobabeb the valley form is far less pronounced and from Rooibank it is indistinct since the river flows across marine plains into which incision has not taken place. On such small-scale cross sections terrace details are masked. Field analysis of valley deposits between Homeb and Gobabeb, however, demonstrate that periodic incision was not sequential. Periodic changes of base level occasioned by eustatic sea level fluctuations were superimposed on tectonic uplift, resulting in phases of downcutting and an alternation of incision and aggradation.

The long profile of the Kuiseb river, similarly constructed from map data, confirms the evidence of the cross profiles (Fig. 1). Overall the long profile of the Kuiseb river, like that of many arid zone rivers, is convex. This convexity has been attributed to increasing desiccation seawards and loss of energy since an adjusted bed slope is essentially a transport slope in equilibrium with the load and energy available (Goudie, 1972; Rust & Wienecke, 1974; Stengel, 1970). Steepening may therefore, be a response to energy loss or to increased load. In detail the Kuiseb profile exhibits localised marked irregularities of gradient (Fig. 1). These variations in gradient become obvious when expressed as a histogram (Fig.



Map 3: Depositional materials of the middle Kuiseb valley as plotted, 1976 (from air photo analysis with ground control: Homeb silts after Rust & Wienecke, 1974).

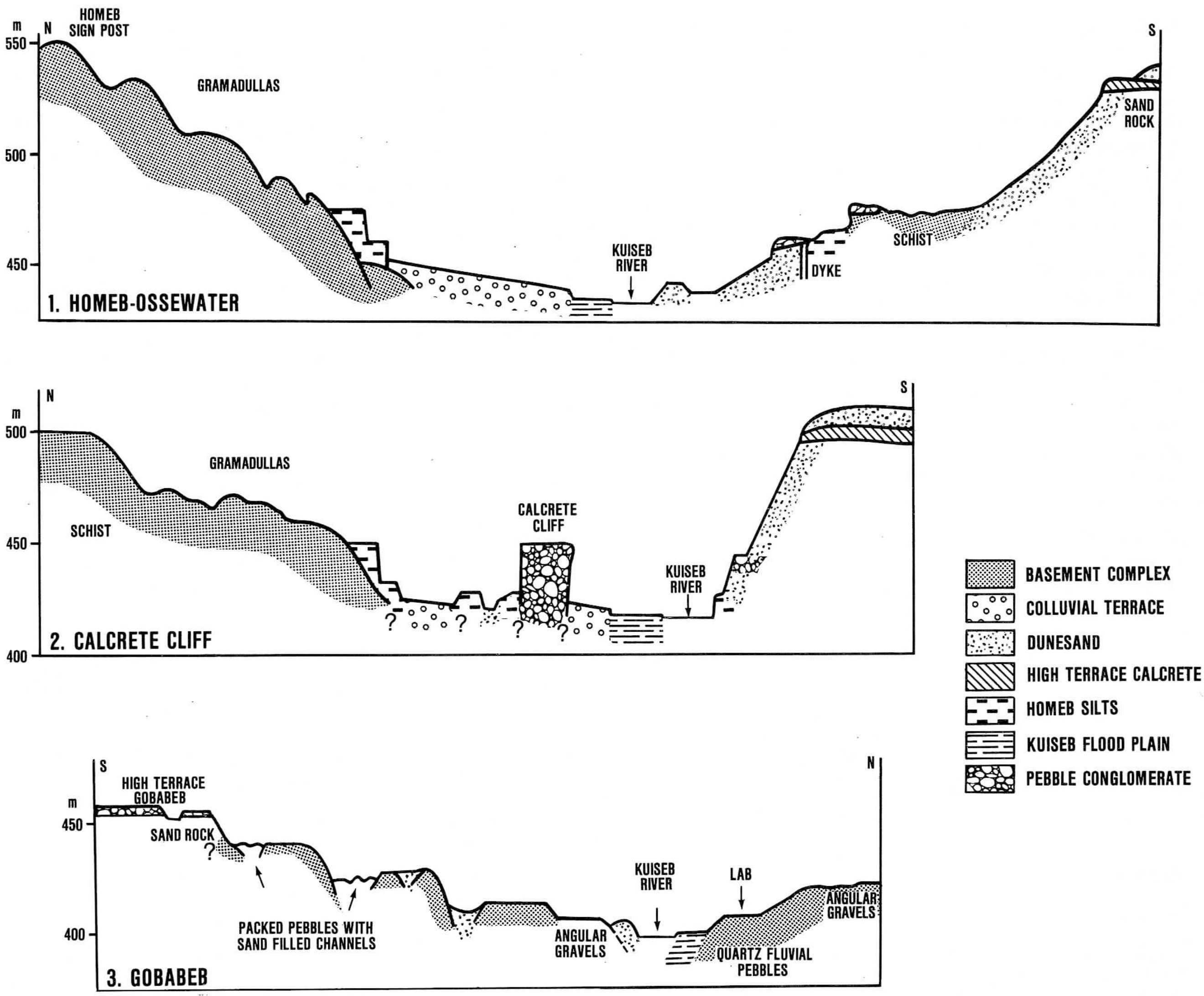


Fig. 4: Three depositional sequences in the middle Kuiseb Valley.
1. Homeb-Ossewater
2. Upstream of Natab
3. Gobabeb
(Altitudinal relationships determined by an ervid altimeter (accuracy ± 1 m.). Assistance rendered by Dr. M.K. Seely and staff of Desert Ecological Research Unit is acknowledged).

2). The presence of at least four knick points marking risers of about 40 m, 60 m, 100 m and 200 m respectively inland can be identified.

Localised steepening upstream of Hudaob and of the Gaub-Kuiseb confluence are interpreted as knick points associated with the canyon incision and the valley-in-valley profiles upstream of the canyon proper. Steeper gradients are also apparent at Swartbank and Rooibank respectively and these are also interpreted as knick points, superimposed on a regional convexity resultant from coastal emergence and possibly progressive desiccation (Fig. 2). The general convexity of the lower Kuiseb is therefore, a function of emergence rather than of desiccation.

Between the zones of knick point steepening, where gradients are less than 1:200, the bed gradient is extremely gentle. Upstream of the Gaub confluence, mean gradient is 1:385; between Hudaob and the Aussinanis confluence it is 1:420 and even seawards of the postulated Rooibank knick point where convexity is maximised, gradients exceed 1:200. The mean gradient of the Kuiseb channel is furthermore considerably less than that of the pedimented surfaces into which it is incised. Mean pediment gradients can be calculated for the gravel Namib north of the river with ease but to the south establishment of the interdune surface gradient is complicated by the presence of dune sand. A gradient of 1:100 appears to be average for the pediment surface wash slopes. Being also transport slopes, the steeper gradient may be a response to reduced efficiency. However it is likely that the surface has also been steepened by warping (Wienecke & Rust, 1973). Reactivation of the Kuiseb river in the steepened zone would inevitably result in incision upstream, with concomitant deposition downstream, a pattern that is apparent in the Kuiseb system (Fig. 3). Nevertheless it should be pointed out that a similar result can occur attendant on a change from braided to channel flow as a function of greater flow efficiency.

3.4 Terrace deposits and sequences

Periodic rejuvenation and changes in discharge cause depositional sequences which provide evidence of past events. West of Hudaob, the Kuiseb valley shows a number of minor valleyside bevels and within the incised valley, terrace deposits have been preserved. The earliest and most extensive surface is the high level calcrete caprock which is now in process of dissection (Besler, 1972). In many places it is no longer a single surface. Calcrete duplication occurs and even the highest, and presumably oldest calcrete sheets contain inclusions of rolled calcrete pebbles indicating a prior deposit. East of the Escarpment similar surface limestones resting on fluvial sands and gravels are considered to be part of the Kalahari System and to be early Tertiary in age (Mabbutt, 1955). In the Namib, the oldest, thick calcrete rests either on sandrock or directly on planed Basement Complex rocks. Similarity in geological relationships may thus indicate that the high level calcretes of the Kuiseb system may be a Kalahari System equivalent and also an Early Tertiary deposit.

The Kuiseb river has incised through these deposits to expose extensive areas of both Basement Complex schists and sandrock. Although the tributary gramadulla valleys are reputed to show some duplication of incision (Rust & Wienecke, 1974) the pronounced break of gradient in most channels is likely to be a function of more effective incision by the main Kuiseb channel. Sandfilled channels interrupted by longitudinal dunes dissect the high level calcretes to the south and are also totally unadjusted to the present Kuiseb channel.

Where the Kuiseb Canyon widens, some kilometres upstream of Homeb, a number of distinct deposits and associated terraces can be identified and traced downstream (Map 3). Remnants of a pebble-packed, calcrete-cemented conglomerate occur high on the valley sides but only one 30 m exposure is known; all other remnants have depths of 1 to 2 m only. This calcrete conglomerate differs from the high level calcrete caprock in the concentration of pebbles. It is likely to represent a recemented lag deposit derived from destruction of the higher calcrete caprock. The location of the cliff exposure in the Kuiseb valley indicates that aggradation was subsequent to the initial canyon incision (Fig. 4.2). Water-laid micaceous silts creating at least two distinct terrace levels have been preserved in side valleys from a few kilometres upstream of Homeb to Gobabeb (Map 3). At Homeb these silts can be seen to rest on cross-bedded dune sand and the upper terrace level is accordant with that of the pebble conglomerate surface

LOCALITY	POSITION (Alt. m)	DISTANCE UPSTREAM (km)	CHANNEL GRADIENT (ratio)	PEDIMENT GRADIENT (ratio)	TOTAL VALLEY WIDTH (m)	INCISION WIDTH (m)	OVERALL DEPTH (m)	INCISION DEPTH (± m)
	50	14	280	423	No valley	–	–	–
	100	25	225	100	No valley	–	–	–
Rooibank	150	35	195	100	No valley	–	?10	–
	200	42	205	100	2 500	–		
Swartbank	250	55	195	100	2 500	–	10 – 20	–
	300	67	235	100	2 500	–		
Aussinanis Confluence	350	82	310	90	2 700	–	60 – 100	–
Natab	400	101	370	110	2 800	200	60 – 100	30
	450	126	500	110	2 600	800	120 – 110	30
Hudaob	500	151	495	125	4 500	500	200	150
	550	158	150	125	2 625	500	200	150
	600	186	550	125	7 500	1 250	200	100 +
	650	188	40	91	5 125	500	160 – 190	80 – 100
Gaub Confluence	700	190	45	91	2 500	500	100 – 170	80
	750	211	425	91	3 000	400	130	60
Goagas Confluence	800	230	380	91	2 625	400	100	40
	850	248	350	–	2 625	400	150	50
	900	260	250	–				

TABLE 3: Postulated sequence of events for the Middle Kuiseb

GEOMORPHOLOGICAL EVIDENCE		HYDROLOGICAL REGIME
Erosional	Depositional	
	1 m Flood plain terrace	Channel
Incision		Channel
	Colluvial terrace	Sheetwash : braided
Incision		
	Lower silt terrace	?
Incision		Channel
	High silt terrace	?
Meander scarred river Channel		Channel
	Loose pebbles of low terrace	Braided
	Sand filled channels	Braided
	Pebble-packed channels	Braided
Braided channel Incision		
	Pebble conglomerate (calcification)	Channel
Canyon incision		
	High level calcrete (calcification)	Fan channels

(Fig. 4.1). A low colluvial fan with a steeper surface gradient abuts against the silts and occupies valleys excaved in them. It consists of waterlaid angular gravel derived from bedrock disintegration, interbedded with lenses of reworked dune sand. Below this level, lies the present flood plain terrace consistently at + 1 m above the dry river bed, built of micaceous silt and sand. Four distinct terrace deposits are thus present within the incised valley, pebble conglomerate, grey micaceous silts, colluvial gravel and sand and the present flood plain deposits.

An attempt to clarify the relationships between the deposits, all of which must post date canyon incision, will be based on three depositional sequences located between Ossewater and Gobabeb (Fig. 4). The pebble calcrete that caps the high terrace at Gobabeb is similar to that of the cliff exposure and to the outcrops along the south bank at Ossewater. The depth and location of the 30 m cliff deposit demonstrates that the phase of pebble deposition post-dates canyon incision. The pebble conglomerate calcrete must have filled the incised valley and overlapped onto both Basement rocks and sandrock on the upper valley slopes. The silts post-date the subsequent removal of the pebble conglomerate by renewed incision since they abut against the calcrete as well as against Basement Complex rocks. It is probably fortuitous that the upper silt level accords with the surface of the pebble calcrete. Nevertheless calcrete remnants may have acted as silt traps and caused the accordance. Incision to cut the initial canyon was followed by aggradation and calcification. This cycle was superseded by renewed incision and then by silt aggradation. The duplication of the silt terraces may in fact represent a third cycle of renewed incision and aggradation.

The gravel and sand fan deposit is younger than both the pebble calcrete and the silts. It occupies tributary valleys incised into the silts and is adjusted to a level lower than the lower silt terrace but above present flood plain level. The steeper surface gradient suggests that it was of colluvial sheet-flood origin rather than of fluvial or lake provenance. It thus records a further change in hydrology. The youngest member of the sedimentary suite is the 1 m silty-sand flood plain that abuts against all the other deposits and is aggraded whenever flooding occurs.

At Gobabeb, where the Kuiseb valley is much wider, the terrace evidence permits postulation of a sequence in the destruction of the pebble conglomerate (Fig. 4). A braided channel system, now sand-filled, dissects the pebble conglomerate. A series of lower channels have incised the pebble conglomerate, stripped sandrock and exposed Basement Complex bedrock. The bedrock channels appear to represent a gradual fluvial shift northwards to spread derived pebbles over weathered bedrock up to 2 km north of the present Kuiseb channel (Map 3). The bedrock valleys south of the present Kuiseb channel have since been aggraded with closepacked and uncemented pebbles. This fill has itself undergone some dissection. At a late stage the Kuiseb river shifted to its present position to cut a broad meander-scarred valley. In these meander scars are preserved silts similar in texture to those upstream but here not accordant with the pebble conglomerate level (Table 3).

It has been postulated that the northwesterly trend of the lower Kuiseb valley was caused by dune advance under conditions of increasing aridity (Wienecke & Rust, 1973). The channels dissecting the pebble conglomerate of the high terrace and those at lower altitudes in bedrock all prolong the westerly alignment of the Kuiseb course between Hudaob and Natab (Map 3). The northerly shift is therefore, subsequent to the phase of re-incision. If the silts are all of the same age, then the river had reached its present position prior to their emplacement. It is possible that the cause of the northward shift, which is repeated in the deltaic channels seawards of Rooibank in historic time (Stengel, 1970), is to be sought during a phase of marine regression which would have increased continentality making maintenance of the Kuiseb course to the sea more difficult. Preliminary analysis of the depositional sequence suggests cylic incision and aggradation (Table 3).

Cross-valley and long profile sections have demonstrated the effect of episodic rejuvenation on which are superimposed the effects of discharge variation. The cyclic nature of the Cenozoic events that have moulded the geomorphology of the Kuiseb River system is clearly apparent.

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