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# PALEOENVIRONMENTS IN THE TSONDAB VALLEY, CENTRAL NAMIB DESERT

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## ABSTRACT

Fluvial deposits, which include calcreted conglomerates, gravels, sands and silts can be found for up to 50 km west of the present end point of the Tsondab river in the central Namib desert. They provide evidence for at least eight periods of variably increased fluvial activity in the area during the late Cenozoic. Paleoclimatic interpretations of the deposits suggest that all periods of fluvial deposition took place in arid or semi-arid environments and indicate that, although fluctuations in rainfall and runoff have occurred in the central Namib during the Quaternary, they have mostly been of limited extent. Trends in the character of the deposits suggest that the fluctuations that have occurred have been superimposed upon an overall increase in the aridity of the region.

## 1 INTRODUCTION

Today the Tsondab river is an ephemeral stream draining from the highlands along the western escarpment of Namibia towards Tsondab vlei, its present end point, 30 km into the Namib sand sea and 90 km from the Atlantic (Fig.1).

Fluvial and lacustrine deposits and traces of former channelways, together with a disturbed pattern of the north-south trending linear dunes occur to within 20 km of the coast. They provide evidence for increased fluvial activity and more westerly penetration of the Tsondab river at intervals during the late Cenozoic.

Some aspects of the geomorphology and deposits of the Tsondab valley have been discussed by Seely & Sandelowsky (1974), Ollier (1977), Marker (1979) and Selby et al. (1979). This paper reports the initial results of an investigation of landforms and deposits in the Tsondab valley and discusses their paleoclimatic significance.



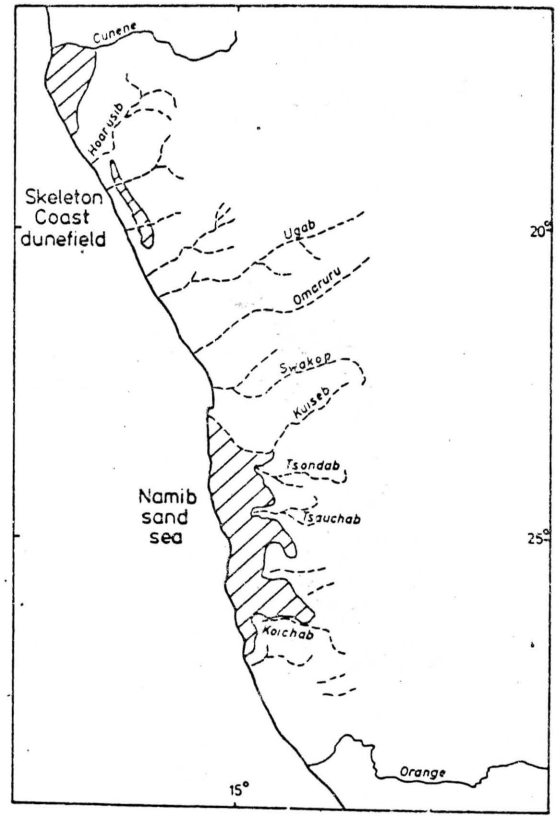


Figure 1. The Tsondab in relation to the rivers of the Namib.

## 2 CHARACTER AND DISTRIBUTION OF FLUVIAL DEPOSITS

### 2.1 *The capping conglomerate*

The oldest fluvial deposit recognised in the Tsondab valley is a 2-5 m thick calcreted angular to sub-angular conglomerate which caps the Tsondab sandstone formation east of Tsondab vlei and occurs in a number of outliers to the west. The flat to gently undulating surface of the conglomerate was termed the Tsondab Planation surface by Ollier (1977) and the deposits themselves the Namib limestone (which manifestly they are not) by Marker (in press).

The conglomerate has a variable clast lithology and size, from sub-angular cobbles of andesitic volcanics to sub-rounded coarse quartz sands. There is an overall decrease in clast size from cobble to gravel grade westwards. The character of the capping conglomerate suggests that it was deposited by

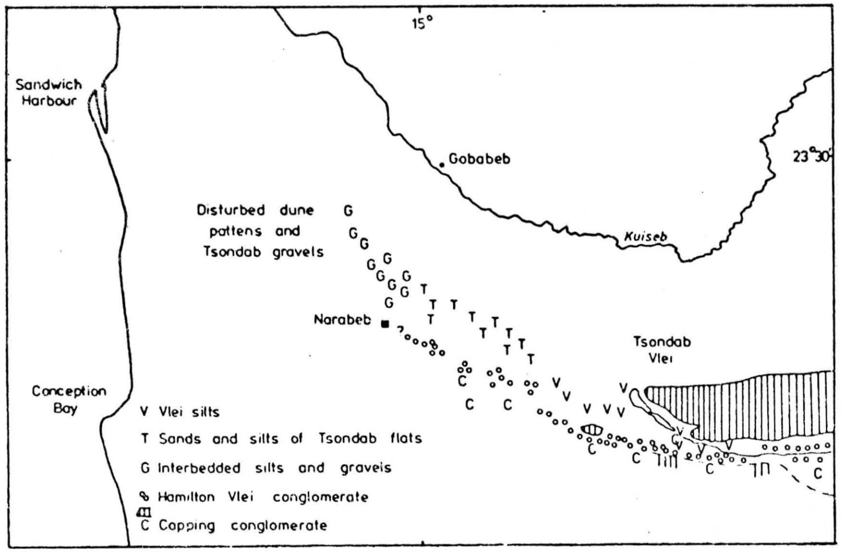


Figure 2. Extent and distribution of fluvial deposits in the lower Tsondab valley and areas to the west.

braided streams in the distal parts of a wide alluvial fan system extending from the escarpment into shallow valleys cut into the Tsondab sandstone formation of Eocene to lower Miocene age.

The capping conglomerate may be equated with similar but thicker deposits in the Kuiseb valley which predate the incision of the river. Ward et al. (in press) regard this conglomerate as being of mid-Miocene age, with subsequent calcreting by pedogenic processes which also affect neighbouring sandstone interfluves, in a period of late Miocene geomorphic stability.

## 2.2 *The Hamilton Vlei conglomerate*

Following at least partial cementation of the capping conglomerate, there occurred a period of valley formation and incision to a maximum depth of 30 m.

Deposition of a suite of clast supported conglomerates, subsequently cemented by calcium carbonate, then took place in a shallow valley 1-2 km wide, situated to the south of the present Tsondab course and its westerly continuation (Fig.2). These deposits can be traced to a point east of Narabeb (40 km west of Tsondab vlei). Their thickness declines from 5-8 m in eastern areas to 1-2 m in the west.

Clasts of the Hamilton vlei conglomerate are distinctive, with a characteristic rounded oblate or bladed shape and pale blue or black colour. They are derived from Pre-Cambrian Nama System dolomites and limestones which



outcrop in the Naukluft and adjacent mountains. Clast size declines from large cobble with occasional boulder size in eastern areas to coarse gravel size in the west. Imbricated structures and lenses of fine gravel or sand are common and indicate deposition in a braided stream environment. The good to excellent sorting of the conglomerates suggests that they were laid down by a stream with moderately high energy, at least seasonally.

## 2.3 *Narabeb deposits*

The westward limits of the Hamilton vlei conglomerates are uncertain, but they appear to die out 4-5 km east of Narabeb, where there occurs an extensive series of horizontally bedded clays, sandy clays, silts and sands up to 12 m thick and often strongly indurated by calcium carbonate. They were first described by Seely & Sandelowsky (1974). Dates of 240 000-210 000 BP, obtained by uranium disequilibrium methods, were reported by Selby et al. (1979) for a lower member of the sequence.

The fine grained nature and horizontal bedding of the Narabeb deposits suggests that they were laid down in a fluctuating lacustrine environment with a strong fluvial input, especially in later periods. They appear to represent a sequence of deposits laid down in or near the terminal playa of a major stream. This may have been the one which deposited the Hamilton vlei conglomerate.

Abundant stone artifacts occur in the vicinity of Narabeb and rest on the surface of the lacustrine deposits (Seely & Sandelowsky 1974). They are of ESA affinities at Narabeb itself, but MSA in areas to the west (Shackley personal communication) and give a minimum age for the deposits of 60 000-100 000 years.

## 2.4 *Interbedded gravels and silts of western areas*

Following induration of the Hamilton vlei conglomerates, the Tsondab valley experienced a major period of erosion and incision, during which a valley up to 80 m deep was carved in the Tsondab sandstone and the extensive sandstone relief of the Tsondab flats formed. Much of the eroded material was of sand size and was either carried to the Atlantic or incorporated into the dunes north of the Tsondab. Rolled clasts of conglomerates can be traced to within 20 km of the coast and were carried westwards during this period of erosion. Unrolled artifacts of MSA affinities are common away from the major valleyway, but only scattered rolled examples are found within it, suggesting a Middle Stone Age date for the major erosion phase, perhaps coeval with the MSA 'pluvial' in the Naukluft mountains recognised by Korn & Martin (1957).

All Upper Pleistocene deposits in the Tsondab are confined to this major valleyway. The earliest deposits are patchily exposed amongst dunes in the western areas of the Tsondab flats and consist of up to 2-3 m of interbedded silts and gravels, which often include clasts of earlier conglomerates. In one area 60 km northwest of Tsondab vlei, they intercalate with quartz gravels of the Kuiseb catchment and are associated with calcified reed beds and organic muds. The character of this suite of deposits suggests deposition in a low energy environment by streams reworking gravels upstream. Deposition of silts dominated in the distal reaches of a seasonal or ephemeral stream, with occasional floods depositing gravels. Modern parallels are to be found in the Tsondab upstream of the terminal vlei, and in the lower parts of the Tsauchab river (Sossus Vlei).

### 2.5 *Sands and silts of the Tsondab flats*

The lower areas of the Tsondab flats are floored by pale, often calcareous, sands with areas of intercalated thinly laminated silts with abundant dessication cracks. To the west, they overlie the interbedded gravels and silts. Inferred depositional environments are a low energy flood plain with seasonally shifting channels and probable blocking of the channels by sand dunes.

Calcified root casts from Narabeb, with ages of 28 500 ± 500 BP (Vogel & Visser 1981), indicate that sufficient moisture was available for plant growth and probably reached Narabeb in the distal reaches of this stream.

### 2.6 *Vlei silts*

Tsondab vlei is underlain by up to 12 m of grey calcareous muds and silts (Wilson 1979), implying long continued deposition at this point. Similar, but thinner (maximum thickness 4-5 m) horizontally bedded silts, often overlying and draped around the basal parts of small sand dunes, continue for 15-20 km west of the vlei. An exposure 10 km west of the vlei was described by Seely & Sandelowsky (1974) as containing shells of the freshwater molluscs *Lymnea natalensis* and *Biomphalaria pfeifferei,* which require at least seasonally continuous water. Radiocarbon dates of 13 300 ± 90 and 14 300 ± 130 BP were obtained from these shells and adjacent carbonate layers (Vogel & Visser 1981). It is inferred that the vlei silts represent the position of the terminal playa of the Tsondab river which was situated on the Tsondab flats prior to 14 000 BP. The valley has subsequently been blocked by five to six dunes up to 100 m high and the terminal playa has retreated to its present location during the Holocene.

## 3 CHRONOLOGY OF LATE CENOZOIC PALEOENVIRONMENTS

A tentative chronology of paleoenvironments for the Tsondab may be constructed, based upon geomorphic and stratigraphic relationships, supplemented by absolute dates where available. These are summarised below, from oldest to youngest.



1. Proto Tsondab erodes wide shallow valley in sandstone. Deposition of gravels in distal reaches of fan extending west from escarpment. Mid-Miocene.
2. Calcrete cementing of these gravels to form Capping conglomerate, with pedogenic calcretes on sandstone interfluves. Upper to end-Miocene.
3. Erosion of Capping conglomerates and sandstone to maximum depth of 30 m.
4. Deposition of Hamilton vlei conglomerates and possibly Narabeb silts. ±250-200 000 BP.
5. Calcreting of Hamilton vlei conglomerates with localised pedogenic calcretes on higher surfaces.
6. Extensive erosion of conglomerates and sandstone to depth of 80 m or more. Later Mid- to early Upper Pleistocene.
7. Localised reworking of conglomerates and gravels to form interbedded silts and gravels in western areas. Pedogenic calcretes on higher Tsondab flats surfaces.
8. Deposition of Tsondab flats sands and silts. Water and vegetation at Narabeb. 25 000-30 000 BP.
9. Deposition of vlei silts in eastern Tsondab flats. Retreat of terminal playa from flats following dune invasion after 12 000 BP.
10. Localised fan development in middle and lower parts of Tsondab valley. Incision of Tsondab river to depth of 2-3 m. Holocene.

## 4 DISCUSSION

### 4.1 *Paleoclimatic implications*

Fluvial and lacustrine deposits in the Tsondab valley preserve a record of irregularly fluctuating fluvial activity in the area throughout the late Cenozoic.

Limited aggradation of cobble and gravel size material is marked by the capping and Hamilton vlei conglomerates. Sands, silts and occasional gravels in the Tsondab flats and areas to the west provide evidence for periods of deposition of fine grained sediments. These were separated by periods of erosion and incision, only one of which was of major proportions.

Generally, the thin nature of the Tsondab fluvial deposits is a reflection of the small size of the Tsondab catchment (3 640 km$^2$ above the vlei) and the wide shallow nature of the valley. It may also be partly explained by the lithology of the upper catchment, for much of the Naukfluft mountains are composed of Pre-Cambrian limestones and dolomites in which karst features are widely developed. One implication of this is that much of the sediment load of the Tsondab has been carried in solution rather than in the form of clastic debris.

Interpretation of the Tsondab deposits in paleoclimatic terms is difficult, notwithstanding the conceptual problems inherent in deducing paleoenvironments from fluvial deposits. It is tempting to view the sequence of deposits as representing periods of arid aggradation interrupted by humid incision. However, as Helgren (1979) has pointed out, such models are an oversimplification of the situation in sub-tropical arid and semi-arid areas. Further, in modern times, floods in the Tsondab river occur only after periods of exceptional rainfall, and rarely reach the terminal vlei (Stengel 1970). Thus all fluvial deposits lying to the west of this point were deposited in conditions of increased stream flow, implying increased rainfall and runoff in the upper parts of the catchment. The presence of cobble and gravel grade deposits 40 km west of Tsondab vlei and silts and sands to 60 km west of this point are clear evidence for the existence of streams with much higher competence and capacity than the present Tsondab. Thus all fluvial deposits in the Tsondab, with the possible exception of the vlei silts, were deposited when runoff was considerably greater than it is today.

The character of all deposits in the Tsondab valley indicates that they were deposited under semi-arid to arid conditions. In this context, aggradation is the result of increased sediment concentrations downstream as discharge decreases by evaporation and percolation into permeable substrates. It may be accompanied by erosion and incision upstream. The locus of deposition is thus a function of the magnitude of flood discharges in relation to sediment supply, much of which may be derived from reworking of deposits upstream. Overall incision and valley development only occurs, as it did in the early Upper Pleistocene in the Tsondab, when discharge is sufficient to remove sediment from the middle and lower parts of the valley.

Essentially the Tsondab has behaved throughout most of the Late Cenozoic as the distal end of a large alluvial fan extending west from the escarpment. In periods of low rainfall, as at present, fluvial activity is confined to upper and middle reaches of the valley. These deposits are eroded and deposited further west in periods of higher rainfall and runoff.

With the exception of the mid to late Pleistocene erosion period, increases in rainfall were confined to the highland parts of the catchment and there is no evidence for substantially increased rainfall in the Namib desert at any other period.

The nature of the Tsondab deposits changes from gravels and cobbles in earlier deposits through sands to silts in later times. This fining trend implies an overall decrease in discharge and stream energy, a trend which is consistent with the suggestions of a progressive late Cenozoic increase in aridity by Tankard & Rogers (1978).

### 4.2 *Correlations*

Correlation of events between the Tsondab and the nearby Kuiseb river is facilitated by the overall similarities between their fluvial histories. Thus the capping conglomerate in the Tsondab is equivalent to that called the calcrete caprock by Marker (1977). In both rivers, there followed a period of incision and valley formation. In the mid-Pleistocene further aggradation occurred when the Oswater type conglomerates were laid down (Ward in press). Tsondab equivalents of these deposits are apparently the Hamilton vlei conglomerates. In both catchments, the conglomerates were cemented by calcium carbonate prior to a major erosion and incision phase. There is no equivalent to the Homeb silts in the Tsondab catchment, but a tentative correlation with the sands and silts of the Tsondab flats may be made. Differences in the scale and nature of fluvial deposits between the two rivers result from catchment and lithological variations. The larger catchment of the Kuiseb (16 200 km$^2$) results in a greater discharge, which has enabled it to maintain a course to the Atlantic. With the probable exception of the major mid to upper Pleistocene erosion period, there is no evidence to suggest that the Tsondab has reached the Atlantic at any time during the Pleistocene. Apart from the greater sediment supply consequent upon its larger catchment, deposits in the Kuiseb valley are thicker because they are confined in a narrow valley cut in Damara schists rather than the semi-consolidated Tsondab sandstones.

The present paucity of absolute dates for Tsondab deposits unfortunately precludes reliable correlations with events elsewhere in the Namib and southern Africa.

## 5 CONCLUSIONS

Evidence derived from a study of fluvial and lacustrine deposits in the Tsondab valley suggests that, in the context of the present hyper-arid climate, all periods of fluvial activity imply greater discharge and hence higher rainfall and runoff in the highland parts of the catchment. These fluctuations have generally been of low magnitude and intensity and are superimposed upon an overall trend to increasing aridity in the region.

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