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Relict fluvial terraces on the Tsondab Flats, Namibia

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Within the hyper-arid central dune Namib, the dune-free Tsondab Flats, extending 40 km west from Tsondab Vlei, are characterized by terraced topography incised into a conglomerate-capped red sandstone. The hypothesis is posed that the terraces are fluvial in origin and that they preserve a record of fluvial incision and arid interruption. It is shown that although the first part of the hypothesis may be accepted, subsequent modification by deflation requires caution in the acceptance of the second.

Introduction

Although the Namib is a hyper-arid desert, former fluvial processes, considerably pre-dating the present dune system, contribute significantly to the landscape assemblage. The advent of satellite photographs (such as that of Gemini V, 27 August 1965) confirmed the hypothesis that the dune Namib rivers, such as the Tsauchab and Tsondab, formerly continued to the coast. The disturbance to the dune pattern seawards and the sand-free Tsondab Flats extending 40 km west from Tsondab Vlei are clearly visible. On the Tsondab Flats, between Tsondab Vlei and Narabeb (a stone age site associated with alluvial silts interpreted as a former river end-point (Seely & Sandelowsky, 1974)), the Tsondab Flats are largely free of dunes enabling identification of the terraced topography (Fig. 1). The hypothesis is posed

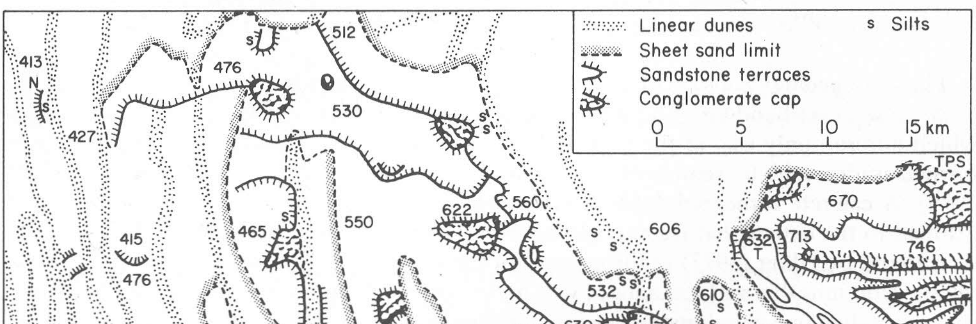

Figure 1. The terraces of the Tsondab Flats (selected altitudes in metres; TPS, Tsondab Planation surface; T, Tsondab Vlei; N, Narabeb).

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that the terraces on the Tsondab Flats are fluvial in origin and that they record a sequence of fluvial incision with arid interruption. It will be shown that although the first part of the hypothesis may be accepted, subsequent modification of the topography by deflation requires rejection of the second and restricts application of the data. The terrace analysis was initially expected to permit the location of the former Tsondab river channel, its point of debouchment at the coast, its relationship to earlier shorelines and its former flow characteristics as derived from gradient analysis.

The terraces

The terraces were first distinguished during compilation of a morphological map of the central Namib using 1969 stereoscopic air photo interpretation.* From the air photos on an approximate scale of 1 : 625,000 data were plotted onto 1 : 100,000 provisional topographic map sheets with 50 m contour intervals and spot heights. Additional relative height data were obtained using a parallax bar. Some ground control was added during journeys to and from other localities in 1975, 1976 and 1977. From this information a terrace map was compiled from which sections were derived (Figs 1 and 2).

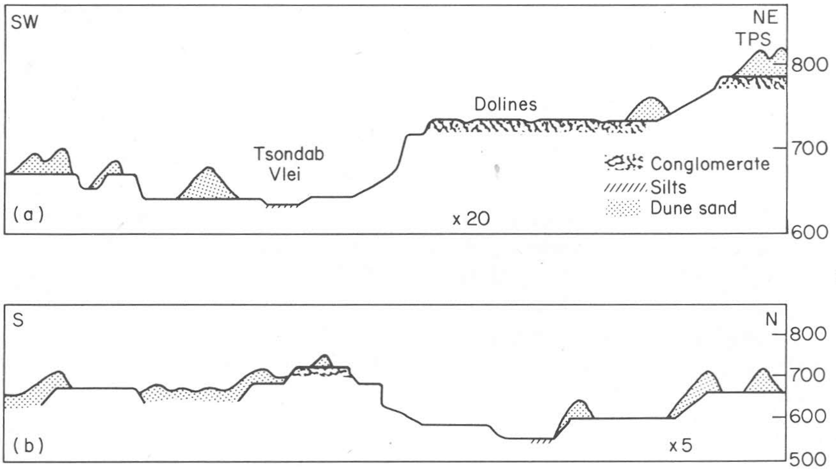

Figure 2. Terrace cross-sections: (a) through Tsondab Vlei (TPS, Tsondab Planation surface); (b) 8 km west of Tsondab Vlei.

The solid geology consists of a massive well-jointed red sandstone in thick horizontal beds with some cross-bedding. The sandstone overlies basement schists of the Damara System which outcrop only east of the area under consideration. The sandstone is believed to have formed under arid to semi-arid conditions (Selby, 1976; Ollier, 1977; Besler & Marker, 1979). A calcrete cemented cobble and pebble conglomerate overlies the sandstone and is lithified to the extent that fractures break across the river-rounded cobbles. This material is considered by Ollier (1977) as the caprock of the former Tsondab Planation surface. Following incision into this surface, subsequent periods of carbonate mobilization have occurred, so that more than one conglomerate capped surface may occur. Destruction of the conglomerate releases rounded stones and calcium carbonate into the desert system. Derived lag gravels, also acting as surface caps, show varying degrees of wind abrasion implying a considerable time span in their present position. The presence of rounded stones is therefore not necessarily indicative of specific flow régimes. The sandstone weathers to provide sand for the sandsheets and linear dunes (Fig. 1).

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Attention will be focused on three terrace sequences, immediately east of Tsondab Vlei where attitude relationships are most clear, at approximately 10 km west and some 25 km west of the Vlei. At Tsondab Vlei itself there are two conglomerate capped surfaces at 787 and 949 m respectively, the higher being a residual of the Tsondab Planation surface. A subsidiary sandstone surface, the summit of the Tsondab cliffs at 727 m, may carry a pebble lag and appears to result from stripping of the conglomerate. A similar double surface obtains at Huduob where the conglomerate overlies an impure limestone. An intermediate surface at approximately 670 m creates significant landscape components upstream of Tsondab Vlei and there is also a low Tsondab Vlei surface at about 10 m above vlei level. There are thus five surfaces, two capped by the conglomerate, of which three are believed to have originated as fluvial terraces incised below the original Tsondab Planation surface (Fig. 2(a)).

Ten kilometres farther west, the conglomerate capped terrace occurs between 720 and 708 m altitude. Lower surfaces at 641 m, at 618 m and at 574 m, above a plain at 560–540 m preserving alluvial silts, can be distinguished (Fig. 2(b)). Twenty-five kilometres west, the conglomerate surface lies at about 600 m and other sandstone terraces occur at 555 and 524 m with silts at 510 m. Only the lowest terrace retains an approximately consistent elevation above the alluvial silts (Table 1). Farther west again, approximately 35 km from

Table 1. *Mean terrace elevation on the Tsondab Flats*

	Tsondab Vlei		8–15 km		15–30 km		30–38 km	
	A	B	A	B	A	B	A	B
Tsondab planation surface	787	155						
Conglomerate terrace	749	117	720–708	146	600–592	82		
Stripped sandstone	727	95	641	79				
Intermediate surface	670	38	618	56	555	45		
Tsondab Vlei surface	640	8	574	12	524	14	492	19
Tsondab Vlei west	607							
Alluvial silts (datum)	632		562		510		473	

A, Actual mean elevation (m); B, height above datum (m).

Tsondab Vlei, the plain surface lies at 473 m and the only plateau here capped with gravel lies at 492 m. No other terraces are obvious but the increased volume of sand cover complicates recognition. At Narabeb, west of two linear dunes beyond Tsondab Flats (Fig. 1) the base of the interdune valley cut in sandstone, veneered with sand and stone tools, lies below the level of the remnant silts. Deflation has occurred and the calcified silts have themselves acted as a protective capping.

Discussion

Analysis of the Tsondab Flats terrace sequence demonstrates no consistency in elevation, in attitude relationships nor in gradient (Table 1; Fig. 3). Nevertheless, desert processes in a region of less than 100 mm annual average precipitation are unlikely to have produced the markedly stepped topography. The presence of alluvial silts on the lowest plain throughout the Tsondab Flats on a gradient comparable with that of the present Tsondab River substantiates a fluvial origin for the incision.

Some tentative dates for the silt deposits are available. Selby (1977) quotes a uranium/thorium date of 210,000 ± 1000 years B.P.* for the Narabeb silts and some silts 6 km west of Tsondab Vlei have yielded a ^{14}C date of 10,000 ± 2000 years B.P. (Seely & Sandelowsky, 1974).

* B.P., Before the present.

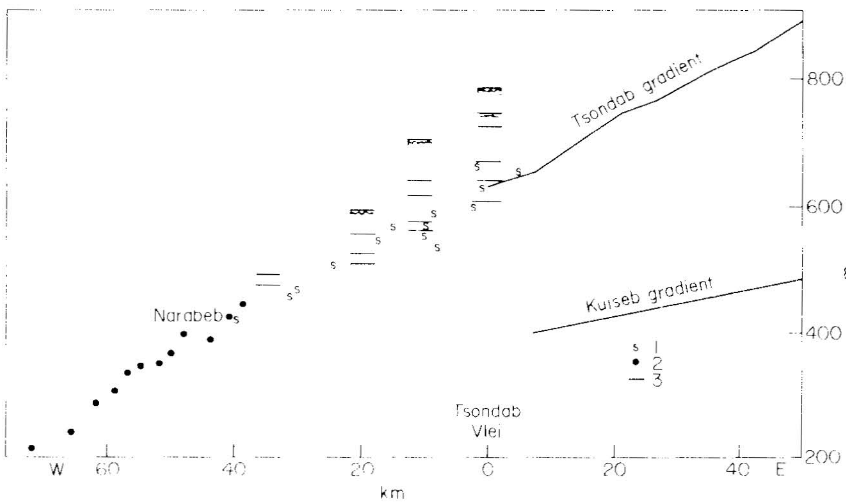

Figure 3. Altitude relationships of terraces and alluvial silts including gradients of the Tsondab and Kuiseb rivers and mean altitudes of interdune streets west of Narabeb (1, alluvial silts; 2, mean dune street altitude; 3, terrace positions, conglomerate shaded).

These dates indicate a progressive recession of silt deposition at the river end-point, presumably with increasing aridity: they also indicate the extreme age of the terraces, since active fluvial incision preceded silt deposition and higher terraces must pre-date the planation of the lowest surface on which the silts are located.

The altitude relationships of the terraces cannot be explained solely in terms of gradient. Braided silt-depositing low energy channels such as the Tsondab itself have a gradient approximating 1 : 200. Channelled, higher energy systems, capable of incision, such as the Kuiseb river upstream of Gobabeb, have a gradient between 1 : 400 and 1 : 500 (Marker, 1977). The pedimented sheet-wash, gravel plain Namib, north of the Kuiseb river, has a gradient of 1 : 100 and that of the interdune flats seawards of Narabeb is 1 : 146. The decline in altitude of the terrace remnants seems to project inland the gradient of the interdune flats suggesting that the fluvial terraces, cut by a higher energy system, have been modified subsequently by arid processes.

It is suggested that arid denudation of the sandstone has caused modification to the fluvial topography. The frequency of pebble lag gravels capping minor breaks of slope lends credence to this view. The pebbles, let down from disintegration of the conglomerate, act to maintain breaks of slope. Furthermore, they promote nocturnal condensation and thus maximize chemical disintegration of the underlying weakly cemented sandstone. Loose sand is then deflated and the surface is lowered. Multiplication of such pebble-capped surfaces is inevitable and the presence of pebbles is not indicative of a former fluvial level. This type of situation can be demonstrated conclusively near Gobabeb in the Kuiseb drainage basin.

Conclusion

The presence of terraced breaks of slope incised into sandstone and carrying conglomerate or pebble lag gravels is accepted as evidence for former fluvial activity on the Tsondab Flats. The terraces have, however, been in existence so long that their surface attitudes can no longer be used to derive a history of periodic fluvial incision. The geomorphic significance of the Tsondab terraces is therefore limited. The hypothesis that the terraces are fluvial in origin and that their sequence records alternating incision and arid interruption can be accepted but the corollary that their interpretation can be applied to establish former fluvial régimes or by inference to climatic phases, or even to relate them to marine benches, has to be rejected.

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