Outline geological and geomorphic history of the Central Namib Desert

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CONTENTS

ABSTRACT

The history of the Central Namib includes the following: deposition, metamorphism and granitization of the Precambrian; planation of the Precambrian to form the Namib Unconformity Surface, an unweathered pediplain with a few inselbergs thought to be of Jurassic age; deposition of the Tsondab Sandstone, a terrestrial sandstone thought to be equivalent to the Kalahari System, and of Upper Cretaceous and Tertiaty age; planation to form the Tsondab Planation Surface, a vast pediment crossed by east-west drainage; incision of the Tsondab and Kuiseb Rivers with formation of minor terraces; formation of the modern sand dunes.

Numerous workers have made contributions to the geomorphology of the Namib and some have constructed partial geological histories, or placed events of landform history in an order of succession (e.g. Rust and Wieneke, 1973, 1974; Selby, 1976; Wieneke and Rust, 1973a, 1973b; Marker, in press). No one seems to have tried to construct a full geological and geomorphic history of the region, possibly because they feel available data is inadequate. Such a history should be constructed as a fundamental basis for geological work, to provide a scheme which can be tested, modified, improved or even refuted. The existance of such a geological outline constrains workers to either fit data into the scheme, or to challenge the data or the proposed relationships. In an area of limited knowledge a formal geological history, with all its imperfections, has its uses. It is to provide such a starting point that the following outline is offered.

1 PRECAMBRIAN

Varied sedimentary rocks, shales, sandstones and limestones, were laid down and later metamorphosed to schist, gneiss, quartzite and marble. These rocks were injected by veins of quartz, aplite and pegmatite, sills of dolerite (Swartbank), and in places converted to or intruded by granite. There has evidently been uplift since these metamorphic rocks were created, followed by erosion to form the ground surface that truncates the rock structures.

2 NAMIB UNCONFORMITY SURFACE

Long continued erosion across the Precambrian rocks formed a plain. This plain is a fundamental datum in the area, separating the metamorphic bedrock from all younger deposits. I shall call this plain the Namib Unconformity Surface. Although generally flat, the Namib Unconformity Surface has some irregularities which rise as hills, strike-ridges, cuestas or inselbergs above the general surface of the plain. The age of the planation will be discussed later.

Upon the Namib Unconformity Surface were deposited a basal conglomerate, here simply termed the Basal Conglomerate, and a red sandstone, here called the Tsondab Sandstone.

3 THE BASAL CONGLOMERATE

The Basal Conglomerate on the south side of the Kuiseb Canyon near Hudaob contains very angular quartz fragments and a basal concentration of garnets which can be matched in the immediately underlying bedrock. The detritus that is incorporated in this conglomerate is not marine and, if fluvial, it has suffered very little wear and is not far travelled. At this locality the rock could be termed a breccia, but elsewhere equivalents are conglomeratic. There are some places north of the Kuiseb (as on the road to Mirabib) where limestone capping mesas of Precambrian rock has no pebble content, but this limestone is probably equivalent to the Basement Conglomerate.

Carbonate has thoroughly permeated the Basal Conglomerate either contemporaneously with deposition of the conglomerate or as a later introduction. In some places there appear to be two similar conglomeratic hard bands with softer material between, the upper one making a distinct mesa. Airphoto Strip 14 No. 56 provides an example (Fig. 00)

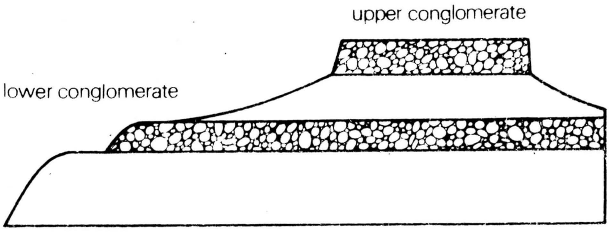

Figure 1: Diagrammatic sketch of conglomeratic hard banks with softer material between.

4 TSONDAB SANDSTONE

South of Gobabeb, at Tsondab, and at many other localities, there is a red sandstone as bedrock. I shall call this the Tsondab Sandstone. This may be a lateral equivalent of the Basement Conglomerate in part, but most of it overlies the conglomerate and is younger. At Gobabeb the sandstone appears to overlie Precambrian metamorphic rock and granite directly, so the Basal Conglomerate is locally absent.

The Tsondab Sandstone is a quartz sandstone cemented by carbonate. In places it has cross bedding, consistent with it being originally deposited as dune sand, but also possible foreset beds of a delta deposit. There are also plane bedded sandstones. There are no pebble bands as might be expected in a water-deposited sediment, and most authors have assumed that this sandstone is consolidated dune sand. This sandstone is considerably older than the dunes of the present day and should not be confused with them. An analogy may be found in Britain where the Old Red Sandstone (Devonian) and the New Red Sandstone (Triassic) mark two periods of aridity in the same area separated by millions of years, a whole geological Period. The two episodes of dune formation in the Namib may be separated by a similar time span.

The Tsondab Sandstone has been referred to as "sandrock" (Marker, in press), a term that adds nothing to the concept of "sandstone", and as "consolidated red desert sands" by Selby (1976). This sort of terminology tends to link the Tsondab Sandstone with the modern sand dunes and I suggest that the simple term "sandstone" be stressed to emphasize that this is not merely the consolidated ("calcreted") base of the present dunes but a stratigraphically quite distinct unit.

There is no direct evidence of the age of either the Basal Conglomerate or the Tsondab Sandstone, and they could be anything from Precambrian to Tertiary. They are unfossiliferous and have no materials suitable for radiometric dating. A good possibility for dating would be a palaeomagnetic study of the Tsondab Sandstone. It is well oxidised and, if it has sufficiently intense and stable magnetisation, its magnetic direction and dip could be fitted onto the palaeomagnetic wander curve for Africa and so give the age of magnetisation and a minimum age for the rock itself.

The age of the Tsondab Sandstone can only be estimated by comparison with similar deposits elsewhere. They may be equivalent to the Kalahari System of Botswana and the Republic of South Africa. The similarity may be guaged from the following description of the Kalahari deposits (Truswell, 1970): "Rivers draining into this region, ... deposited clay, more calcareous marls, sands, and occasional gravel bands in the basin to form the primary Kalahari beds. Covered by the ubiquitous later sands as they are, information on these beds comes largely from boreholes. Their age is uncertain, but generally believed to be early Tertiary. They are capped by one or more sheets of calcrete and silcrete ... The age of these deposits is again uncertain, and made more so since they appear to have formed at several different times ... Subsequently the underlying material was reworked to produce the widespread blanket of Kalahari sands."

According to Haughton (1969, p. 427) the lowest horizons of the Kalahari System may be of Lower Cretaceous age, and this could also apply to the Tsondab Sandstone.

5 THE TSONDAB PLANATION SURFACE

After deposition of the Tsondab Sandstone a new erosion surface was cut across the sandstones. This was probably in the form of a vast pediment stretching from the Naukluft Mountains to the sea, and was traversed by drainage flowing from east to west. The terraces and vleis preserved in interdune corridors bear gravels derived from the east. Those of the Tsondab area have dolomite from the Naukluft Mountains which is absent from the Kuiseb area. There was presumably a period of sheet-flood activity when these gravels were deposited over a huge pediplain cut across sandstone and Precambrian basement rock. This activity, which pre-dates dune formation, would presumably also affect the gravel plains to the north of the Kuiseb. Thick deposits of gravels were laid down which have since been cemented into conglomerates (calcretes).

This planation surface is another fundamental surface in the history of the area, separating the period of accumulation of the Tsondab Sandstone from the later history of fluvial erosion and wind deposition.

Again we can find a comparison with the Kalahari, where the geomorphic history, according to Grove (1969) appears to be similar to that of the Namib. The deposition of the lacustrine and terrestrial Kalahari Beds with numerous calcretes was

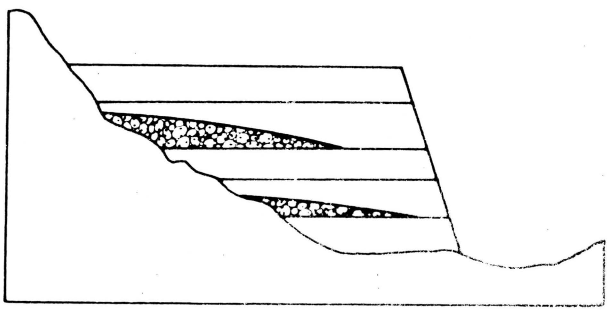

Figure 2: Diagrammatic section of the Homeb Silts.

succeeded by a period of river incision, and renewed wind dominance created the present dunes.

The Tsondab Planation Surface is best preserved as the upper terrace at Tsondab Vlei, where it is about 100 m above the vlei surface. The age of the planation surface is not known but will be considered further later in this paper.

6 FLUVIAL INCISION PERIOD

The broad plain that existed after the formation of the Tsondab Planation Surface was later cut into by the major rivers crossing it from east to west to form major valleys. At times downcutting was replaced by lateral erosion and terraces were carved across the sandstone.

South of Gobabeb an old course of the Kuiseb is preserved within the dunes. The terraces have carbonate cemented terrace gravels and are essentially rock cut terraces eroded across the Tsondab Sandstone and Precambrian bedrock with a thin veneer of gravels. The terraces and river course are older than the present Kuiseb course, and the gravels can be distinguished from those of younger Kuiseb terraces by the abundant desert varnish on quartz pebbles.

At Tsondab Vlei the Tsondab Sandstone has been eroded to form a terrace about 50 m above the present valley bottom and 50 m below the Tsondab Planation Surface. The terrace has a cover of terrace gravels, now carbonate cemented. The size of the valley and the size and roundness of the pebbles in the terrace deposits indicate that the Tsondab River had a high flow, at least intermittently, at the time of downcutting and terrace gravel deposition. At the time when the Tsondab Valley was occupied by an active river the present dune field did not exist. In a few places the Tsondab Sandstone has been stripped away exposing inliers of gneiss, usually in the form of hills or strike ridges. From this point on the geomorphic history of the area is best considered by areas: the Kuiseb River Valley, the dune area to the south and the gravel plains to the north.

6.1 The Kuiseb River Valley

The Kuiseb River flows in a canyon cut through the Precambrian bedrock, with badland topography extensively developed on the northern side. Downstream from Homeb there are remains of a river terrace preserved in cemented gravels, a deposit here called the Ossewater Conglomerate. The top of this terrace is about 30 m above the present valley floor, and the base of the conglomerate is a few metres above the present valley floor. Therefore the Kuiseb cut down almost to its present level and then built up its bed (aggraded) with river gravels to the level of the terrace. The gravels became cemented with carbonate either penecontemporaneously or subsequently. The river then cut down again, carving a valley through the Ossewater Conglomerate and eroding to the present river level.

Then came a new period of aggradation when the river built up its bed by deposition of the Homeb Silts, now preserved in the side-valleys around Homeb (Rust and Wieneke, 1974), overlying both Precambrian bedrock and the Ossewater Conglomerate. The silts themselves are fine sediments, near horizontal, and are fine material brought down by the Kuiseb in flood and deposited away from the actual river course. Interdigitating with the silts are wedges and lenses of angular gravels, hillwash derived from the local valley sides. The silts represent far-travelled debris brought down by the Kuiseb after rain in its upper catchment: the gravels represent hillwash brought down by local storms, washed onto a dry terrace top. If the hillwash had gone into a lake it would be watersorted, which it is not. When the hillwash was deposited the Kuiseb was either not flowing, or slightly flowing leaving the terrace top dry.

Some minor river terraces a few metres above present river level post-date the Homeb Silts. Further details of the geomorphology of the Kuiseb Valley and its terraces are provided by Marker (in press).

Table 1: The geomorphic history of the Kuiseb may be summarised as follows: (oldest events at the bottom): –

8. Formation of minor terraces and the present flood plain
7. Formation of the lower terraces of the Kuiseb
6. Re-excavation to bedrock, leaving remnants of Homeb Silts
5. Deposit Homeb Silts
4. Erode to bedrock at present river level
3. Deposit gravels of Ossewater Conglomerate to form a terrace. Cement.
2. Cut canyon, almost to present level; tributaries form badlands.
1. Initiate Kuiseb course on the Namib Unconformity surface or on the Tsondab Planation Surface.

What sort of time periods can be associated with these events?

The erosion of the canyon and its tributaries would take hundreds of thousands of years, perhaps millions. It could occupy much of the Lower Pleistocene, or be of Tertiary origin.

The ossewater Conglomerate would require at the very least some tens of thousands of years, to accumulate, cement, and erode again. There is no need to invoke any special mechanism such as damming of the river by dunes to cause the accumulation of these river sediments.

The Homeb Silts could have been deposited in a few hundred but more probably a few thousand or tens of thousands of years. They are river sediments (deposited in tributary backwaters) rather than lake sediments, and could have accumulated during a period of general aggradation. If a lake were ever present it must have periodically dried up. The remnants of the Ossewater Conglomerate Terrace downstream could have acted as a partial barrier to the river, causing it to spread out and deposit its silt upstream of the barrier, where the silt is now found. As with the Ossewater Conglomerate, if the dune-dammed lake hypothesis is rejected it becomes impossible to tie to the Kuiseb fluvial history into the history of the dunes.

6.2 The dune area south of the Kuiseb River

This area has been covered by sand dunes at some time in the past and these dunes are still active to some extent. The date of the commencement of dune activity is not known.

The main mass of the sand is in essentially fixed north-south linear dunes. Only the crests and minor dunes are active and it is thus invalid to use (as some authors have) movement rates of minor dunes as a general figure for migration of the dune field as a whole.

As water courses flow east-west and the dunes are north-south it should be possible to study the interplay of the two to

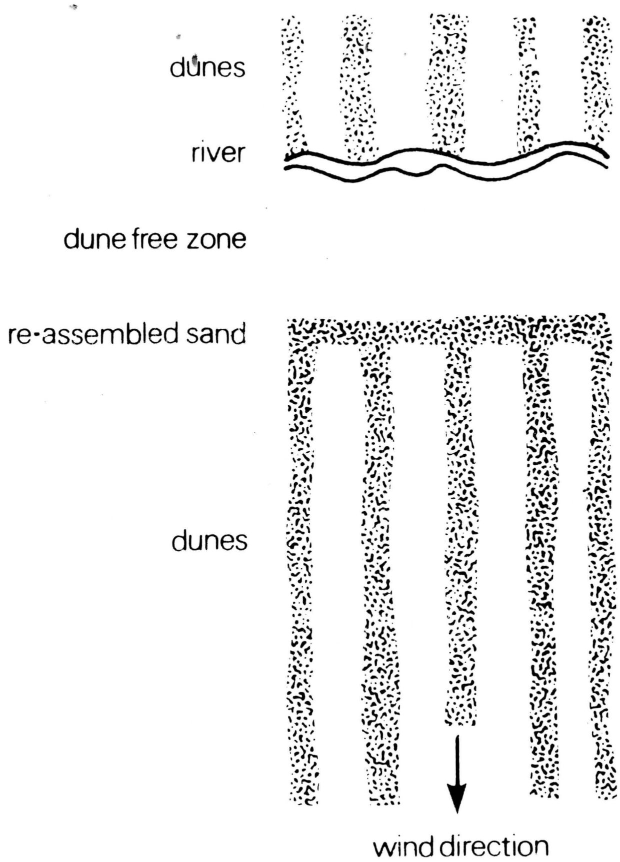

Figure 3: Kalahari type river with dunes.

some extent, and some estimates of the age of termination of the rivers in the dunes can be attained (Seely and Sandelowsky, 1974). The amount of interplay is probably quite small and the dunes simply post-date the valleys.

One of the most spectacular features of the Namib is the abrupt termination of the dunes at the Kuiseb River. It would seem that the Kuiseb carries away any sand deposited in its bed and prevents the dunes from crossing its valley. It is possible towards the coast that dunes may have deflected the Kuiseb to the north, but in the central part of its course the river is dominant and dunes do not cross it. If dunes ever crossed the river there should be evidence of them on the north side, and there is none. Dunes blocking the Kuiseb have been invoked to account for the deposition of the Homeb Silts. The lack of necessity for a dune-dammed lake has already been explained; if such a lake did exist there should be remnants of the damming dune to the north of the Kuiseb. Alternatively one may postulate that any dune sand that did cross the Kuiseb was carried across the gravel plains and dispersed to the north. It cannot be demonstrated that this process did or did not happen in the past, but there is no evidence that it is going on now. Sand dunes do cross intermittent rivers. In the Kalahari, as in the Namib, longitudinal dunss approached a river course at near right angles, and the dunes stop abruptly at the river. When the river flows it carries away sand. But some sand does cross the river. There is a dune-free strip parallel to the river on the downwind side, then a strip of sand parallel to the river where the sand re-assembles. This is then blown out into further parallel dunes.

What is the explanation for the difference between this situation and that of the Kuiseb? The Kuiseb flows sufficiently frequently and with sufficient velocity to remove the sand blown into its bed, whereas the Kalahari type of stream described above is inadequate for removing all the sand.

This further suggests that the Kuiseb River valley was in existence, and the river was flowing before the sand dunes came into existence. If the sand dune field pre-dated the river, old dunes should be found to the north.

The Tsondab valley to the south is similar. The river had to be large (at least in flood time) to carve the deep valley and terraces; and it could not be simultaneously eroding its bed and being blocked by sand. The sand dunes post-date the terraces and the lower course of the Tsondab. The present dunefield is therefore relatively young, and is separated from the Tsondab Sandstone by (a) the planation of the Tsondab Planation Surface and the spread of gravels on the resulting pediplain, and (b) the incision of the Tsondab and Kuiseb valleys, with the complications of terrace formation, river course change from the prior-Kuiseb to the present course, and probably the various depositional terraces of the Kuiseb. The time gap between the formation of the Tsondab Sandstone and the modern dune is therefore great, probably millions or tens of millions of years.

6.3 The gravel plains

The gravel plains north of the Kuiseb bear little evidence to reveal their history. Present day weathering processes are tending to make the plain ever flatter, and the slopes of inselbergs are retreating (Selby, 1976).

However, there are considerable remnants of an indurated cover of surficial materials, calcrete up to 30 m thick, which is apparently equivalent to the Basement Conglomerate of the south side of the Kuiseb. No remnants of the Tsondab Sandstone are known north of the Kuiseb.

The present day processes are doing little more than bevel a pre-existing plain (the Namib Unconformity Surface) which is being exhumed from a calcretised cover of younger rocks.

Table 2: The history in brief appears to be: –

5. Modern pedimentation and minor river and wind action
4. Erosional stripping of younger rock to re-expose the Namib Unconformity Surface
3. (possibly deposit equivalent of Tsondab Sandstone)
2. Deposit "calcrete" equivalent of the Basement Conglomerate
1. Erosion of the Namib Unconformity Surface.

The Kuiseb River runs along the geological contact between the Precambrian rocks of the gravel plains and the Tsondab Sandstone of the dune area to the south. It is possible that the middle course of the river has moved south by uniclinal shifting down the slope of the Namib Unconformity Surface as it stripped the cover rocks. Now, however, it is incised in Precambrian rock and such movement, if it ever occurred, has stopped.

7 AGE OF THE EROSION SURFACES

King (1969, fig. 119) shows the gravel plain of the Namib as part of the Post African Late Cainozoic land surface. It is possible, however, that it is a downwarped part of the African (early Cainozoic) or even Gondwana (Jurassic) land surface preserved on the Khomas Highlands.

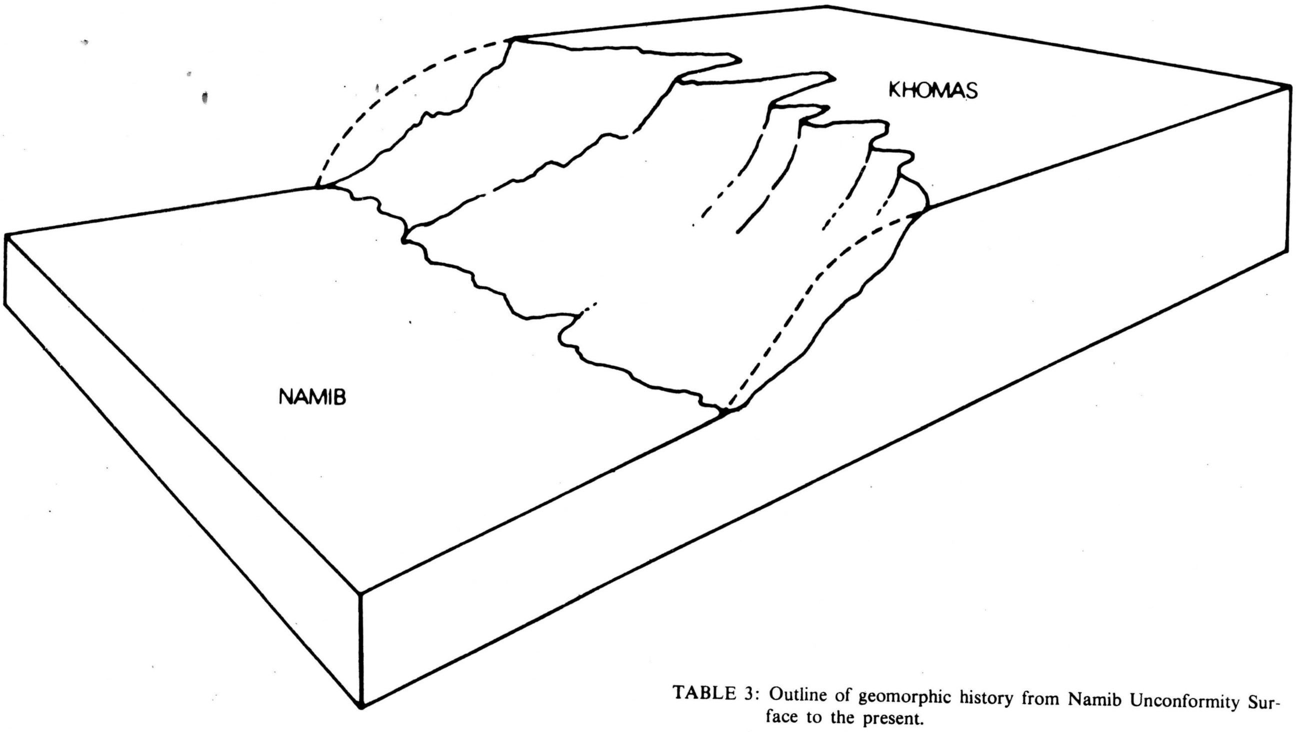

Figure 4: Namib and Khomas Highland land surfaces.

On his latest terminology (King, 1976) the planation surfaces are called the Gondwana (Jurassic), Kretacic (early-mid Cretaceous) and Moorland (late Cretaceous to mid Cainozoic). According to King the Moorland surface is characterised by calcrete and silcrete, and on this basis is the most likely to be equated with the Tsondab Planation Surface. Its postulated age is greater than that of the previously postulated Post-African surface and would not conflict with any information currently available. Another approach to the age of the erosion surfaces (Selby, 1976) is to equate the gravel plain of the Central Namib with a similar plain in the South Namib where there is a silcrete – the Pomona sandstone – which is thought to be pre-middle Eocene. However, according to Haughton (1969, p. 436) the Pomona sandstone is not dated by fossil evidence, so this approach is also speculative.

The situation is complex, for there are two erosion surfaces in the area, the Namib Unconformity Surface cut across the Precambrian rocks, and the Tsondab Planation Surface cut across the Tsondab Sandstone and possibly continuous with the bevelled surface where the calcretes are being stripped from the gravel plains. The concepts and terminology involved in this situation of closely coincident surface and exhumed surfaces are beyond the scope of this brief paper. The namib Unconformity Surface is probably pre-Upper Cretaceous and or Jurassic, and the Tsondab Planation Surface is probably middle to late Tertiary. The cross section shown in Figure 00 shows diagrammatically the main features which have to be fitted into a geological and geomorphic history.

Table 3 is a suggested outline geomorphic history from the Namib Unconformity Surface to the present.

It must be remembered that, as with all geomorphic histories, this one is a minimal history. Whole episodes may be missing, and all the events that are included could be elaborated.

TABLE 3: Outline of geomorphic history from Namib Unconformity Surface to the present.

Kuiseb

10. Deposit young terrace gravel and floodplain
9. Erode to river level
8. Deposit Homeb Silts
7. Erode to present river level
6. Deposit Ossewater Conglomerate
5. Erode almost to canyon bottom

Tsondab

8. Deposition of modern dune field
7. Erode to Vlei level, leaving the 50 m terrace
6. Erode to 50 m level
5. Deposit gravels from the east
4. Erosion of Tsondab Planation Surface
3. Deposition of the Tsondab Sandstone
2. Deposition of the Basal Conglomerate
1. Formation of the Namib Unconformity Surface

8 GEOMORPHIC HISTORY AND CLIMATIC CHANGE

It is very superficial to attribute climatic changes to every change in geomorphic history. With present knowledge this cannot be done in a satisfactory way. The various possible combinations of rainfall, vegetation growth, runoff, soil formation, and erosion are too complex to allow conclusions to be drawn from a single geomorphic event. Much more abundant, varied and accurately dated data are required for more than the most general speculation.

For example, in South-eastern Australia where abundant dated stratigraphic material has been studied in detail, it has been found that periods of world glaciation were represented in south-eastern Australia by arid conditions, in the sense that vegetation was reduced, strong winds blew and dunes were active. But the rivers at that time were bigger than those of the present day and lakes were generally full. If only part of the data had been found who would have thought that full rivers were correlated with arid periods?

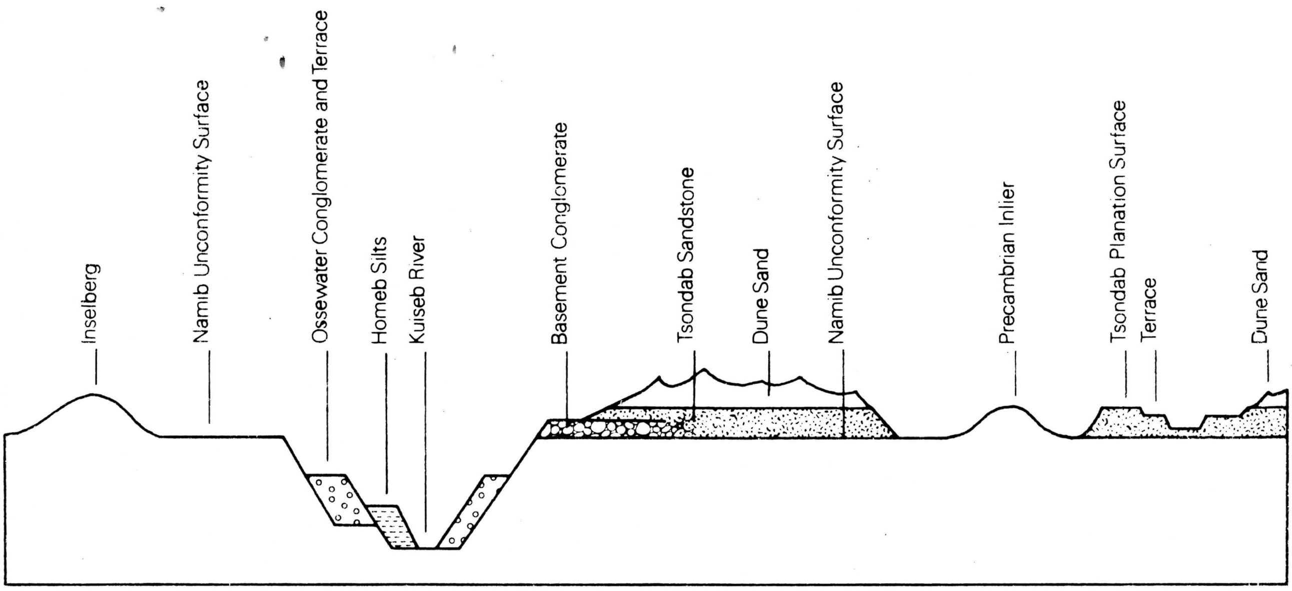

Figure 5: Diagrammatic cross section of the main features which have to be fitted into a geological and geomorphic history.

In the Namib, until the geomorphic-stratigraphic evidence is much more detailed, climatic inferences are highly speculative. The area has been arid to some degree for a very long time, perhaps back to Mesozoic. Periods of river downcutting indicate the flow of rivers, but they may have been (like the present Kuiseb) rivers that collect their water outside the desert. The modern period of dune building may indicate greater aridity than before, or it may, for example, result from greater flow of the Orange River bringing more sand to the area.

At the present state-of-the-art of geomorphology more direct conclusions are likely to come from study of lakes or sedimentary basins in or around the Namib than from study of the relatively barren dunes and gravel plains. However, to establish the correlations necessary for a sound history, the stratigraphy, sedimentology and geomorphic history of the Namib needs to be known in greater detail than it is at present.

9 A NOTE ON CALCRETES

Various different materials in the Namib area have been referred to as calcrete, to the point where the term has little meaning or value. According to Netterberg, an authority on the calcretes of Southern Africa, "A calcrete may be defined as almost any terrestrial material which has been cemented and/or replaced by dominantly calcium carbonate . . . calcretes may be of pedogenic or non pedogenic origin". (quoted in Goudie, 1973).

In the Namib area it is clear that carbonate cementation of sands and gravels has taken place many times, and deposits of very different age have been termed "calcrete." It must be stressed that "calcrete" has no value whatever for correlation of deposits from different areas. It has no time significance, and if used as in Netterberg's definition it has little lithological value. I have avoided it as much as possible in this paper, and recommend that it should be used as little as possible.

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