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THE LIBRARY 53 NAMIB DESERT RESEARCH STATION

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Variations in Sea Level and Morphoclimatic periods in the desert of the Central Namib, South West Africa.

Friedrich Wieneke and Uwe Rust (1973).

Introduction

From December 1971 to April 1972 we have carried out researches into the quaternary morphogenesis of the coastal areas and their hinterland in West Africa, (Senegal and Mauretania) and in South West Africa (Central Namib), (fig. 1). In these regions the landforms result from the interaction of coastal, fluviatile and eolian processes. Important works have been carried out in West Africa by geomorphologists and French geologists (Tricart 1961, Michel 1967, 1968, Elouard 1967). They have clarified the fundamental aspects of the stratigraphy and of regional morphogenesis. Certain problems remain however unresolved. In South West Africa no such study exists of the series of problems which we have attempted. The literature offers only certain indications on raised beaches (Jaeger 1965, Davies 1959, Spreitzer 1965), and on fluvial terraces (Jaeger 1965). Soares de Carvalho (1961) has described the stratigraphy and the geomorphology of the high marine beaches of the Mocamedes desert (central Angola). The levels show shell deposits and are perhaps comparable with those which we have studied.

These two regions have the same geographic position (latitude, climate, marine currents, aspect of the coast). Researches which have been carried out in West Africa and above all the detailed study of type-sections and the interpretation which has been given, have suggested to us a hypothesis for work in South West Africa. However important differences between the two regions studied (altitude of the hinterland, extension of the deserts, different centres of glaciation in the two hemispheres), added to the great distance which separates them obliges us to be very careful in comparison.

Figure 2 of our article (Rust and Wieneke 1973a) shows the relationships existing between different researches which have been carried out in the Namib Central desert and the correlations which it has been possible to establish between the local results obtained. One cannot take up here the problems resulting which will be the subject of further publications, but only of the overall results which are submitted in this discussion.

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1) THE VARIATIONS OF MARINE LEVELS AND CLIMATIC OSCILLATIONS

(a) Variations in sea level.

We can show differences between two marine levels , now above sea level the highest being the most ancient. This assumption that the highest is the oldest gives us a chronology founded on a geomorphologixcal fact which appears to be valid in this region, because no tectonic movements have been recognised for the period that interests us (recent Quaternary) [2].

In several places we have observed two definite marine levels higher than present sea level. We have called them provisionally the 17m level (the oldest) and the 2 m level (the most recent) [3]. The section 67, at Rooikop (fig.2), contains sedimants witnessing to a transgression and a regression of the marine level of 17m and, in the two cases, the presence of a wave-cut platform on this area,(shown by the degree of rounding and the size of sediments). The transgressionary deposits cantain above all whole shells, whereas those which mark the regression show only broken shells. This demonstrates quite clearly a modification of the ecological conditions. Whole shells indicate an advance of the wave zone, which has changed the ecological environment (sand fine to average, at 26 to 66 cm of depth in the section); then a zone of marine regression cutting across the same place for the second time during the retreat of the sea. This ancient marine floor is actually a topographic terrace.

The 2m marine level is represented by a notch and wave-cut platform about 12 miles south of Swakopmund at Henties Bay. The beach corresponds to that recognised at Mile 30 where it is found at 2,5 m above sea level (Wieneke and Rust 1972). Figure 3 describes the marine level from the geomorphological point of view (notch and wave-cut platform and cliff) as well as the sedimentology and paleontology.

At Vineta one can prove the existence of a marine level below present sea level. At low tide a beach rock outcrops on the beach at - 3,38 m on one side and -2,94m on the other. This beach rock is not included in the present notch being cut by the sea as at this place it is more recent. The fact that one finds beach rock pebbles among the present beach pebbles shows that it is now inactive and not the present notch. Russell(1962) has shown that cementation of beach rock cannot take place except in the open air, above the level of the lowest sea level. The marine level corresponds therefore to a sea level lower than the present.

We have not found any other marine level, subaerial or submerged, over and above those which we are about to describe. Section 68, at Rooikop (fig,2) shows a marine sediment resting on fluvial gravels. The absolute altitude od the section (+33,22m) poses problems of interpretation. The corresponding beach is preserved in the form of beach cobbles at 40,47m. The application of our own hypothesis indicates therefore a higher and older sea level than that at 17m. But one cannot exclude the view that section 68 and the beach corresponding to it is the maximum extension of a transgression responsible for the marine formation in section 67 at +17m. Indeed a transgression is a phenomenon which occurs progressively in time and on the other hand/one has not only two sections with no distinction between them but also shells outcropping over the whole surface slope between the two sections. One cannot therefore exclude the view that these are relics of the same marine level. We are well aware that this view is very different from the general attitude to a flight of marine levels. It is necessary to await C14 dating to be conclusive.

(b) Climatic oscillations.

Table 1 contains the land criteria that enable one to decipher arid and humid periods. Laboratory analyses (not yet concluded) will provide other criteria. A correlation of the proven sequence of climatic periods for the coastal region of the Central Namib desert with eustatic stillstands can be attempted.

The topographic section at Mile 30 (fig.4) shows a succession of climatic periods: the 17m sea advanced over an eolian cemented sand (aridity), then marine deposits were crusted with gypsum (aridity) after the marine regression. A very intense phase of dissection later cut the deposits into slopes (humidity). The cutting of marine sediments into slopes indicates previous lithification (aridity). The slopes formed during the "humid" period were encrusted by gypsum (aridity) before the 2m sea advanced to a maximum of 2,15m.

The later climatic oscillations can be taken up in the topographic section at Mile 4 (fig.3). The 2m sea advanced to cut a cliff in fluvial sediments laid down during the preceding humid period which implies a cementation crusting of gypsum in between (aridity). The regression sea deposited marine sediments between the wave-cut platform and the shore. These were covered by sebka sediments (aridity), then by fluvial gravels (humidity) correlating with the dissection of the cliff. The crusting by gypsum of these fluvial sediments, the formation of a reg by deflation and sand encroachment on the cliff correlate with nebka regosols and are witness to the present arid period.

TABLE 1

Criteria of aridity and humidity observable on the ground

Criteria of "aridity"	
Processes	Reg formation (deflation) Sand accretion
Relief forms	Nebka Barkhan (seif?)
Sediments	Sebka sediments Barkhan sands Eolianite
Soils	Gypsum crusts Regosols (on the nebka) "Takyres"
Criteria of "humidity"	
Processes	Slope formation Dissection
Relief forms	Alluvial cones (fans ?) Valleys
Sediments	Fluviatile sediments Stream pebbles (see Rust and Wieneke 1973b)

(c) Correlation of sea level and climatic oscillations.

Michel (1967) represented periods of climatic morphogenesis and eustatic morphogenesis in the region of lower Senegal by curves with an axis on a vector representing time. Following Michel's method, we constructed curves of variation of sea level and climatic oscillation for the same period of the Quaternary (fig.5). Provisionally we indicate time without a scale. We have distinguished definite periods and hypothetical periods separately. The curve of variations of sea level is constructed on a metric abscissa and is not absolute for the periods which can be taken up without error on the cross points. One can thus read their amplitude. The intervals between the curve cuts are not certain; one can only indicate the transgressive or regressive tendency of the variations.

The curves of the diagram are founded on the succession of eustatic and climatic phases. This diagram of Michel's, which we have been the first to adapt for the coastal region of the Central Namib desert shows a correlation of arid phases with the last high sea levels (phases k to h, e and a) and humid phases with the last low sea levels (g and b).

It is scarcely probable that this parallelism has happened by chance; it indicates instead an interaction of world glacio-eustatic evolution and regional climatic development.

If one compares a diagram constructed for the Central Namib desert with that established by Michel one sees that the parallelism between arid phases and high sea levels is not applicable in the Senegal-Mauretania region, despite the comparable geographic positions of the two regions.

2. THE MORPHOGENETIC CLIMATIC PERIODS: A MODIFIED CONCEPT

(a) Introduction to the problems.

The curve of climatic evolution in Michel's diagram results from the organisation of a time series of grouped criteria in Table 1 as a result of the nature (relief forms, processes, sediments, soils). This fact establishes a direct relation between ground observable criteria and two climatic expressions which are themselves complex - "aridity" and "humidity" (which indeed express only certain aspects of real climate). This with the end in mind of attempting a reconstitution of climatic evolution is neither a logical nor an exact form of deduction.

The problems shows a functional illogicality in climatic geomorphology and indeed in all attempts to establish correlations between relief forms and climatic types. Many publications in climatic geomorphology, above all those on arid regions, bse their reasoning on a direct relationship between relief forms and climate although the relationship is merely one factor among many. One can make the same criticism of Michel's diagram.

Weischet (1969) criticised the direct application of the climatic term "arid" to geomorphological problems. He suggests that one should try to establish a geomorphological definition for the idea of aridity which is applicable to relief forms, at the same time taking into consideration, if possible, climatic results. These naturally also concern terms such as "humid," "Cold" and "warm."

Tricart and Cailleux (1965) developed the idea of a dependence of morphogenesis not only with regard to elementary azonal processes, but also with complex processes resulting from a network in a zonal morphogenetic system where different ecological factors combine, such as climate, vegetation and soils. They distinguish these morphological systems on the one hand predominantly physical, for example in arid regions, and systems of predominant biological and pedological systems, for example in tropical forest. They neglect thus, the importance of arid pedogenesis(gypsum crusts and calcareous crusts) as an expression of reduced morphological activity.

Rust (1970) studied the problem of inselbergs in South West Africa and tried to conceive a fluviatile morphogenesis in the Central Namib related to morphoclimatology. He introduced the ideas of "surface pluvial," "runoff of the pluvial surface," and "allogenic runoff of the pluvial surface," to interpret the arid morphogenesis in terms of the forms of relief and the morphogenetic process.

From the global point of view of a geomorphologist-pedologist, Rohdenburg (1970) has shown the importance in morphogenesis of ecological factors where climate is not the only element. He has elaborated a basic system, based on the alternation of periods of morpho-dynamic activity, during which the morphogenetic processes are active, and periods of morphodynamic stability, during which morphogenetic processes give way to active pedogenesis. These periods are determined by ecological conditions. This conception of Rohdenburg's gives climate its right place among many morphogenetic factors.

(b) Morphoclimatic periods in an arid region.

Having distinguished morphogenetic periods in the Central Namib desert and represented them on Michel's diagram, we studied the terraces of the Swakop. We placed the active incision of the Swakop (which indicates a humid phase in terms of morphogenetic process) after phase e, typically arid following sedimentological and pedological criteria.

This apparent contradiction showed us the illogical manner by which the diagram was constructed. In trying to resolve this problem we arrived at the idea of combining , enlarging and extending the concept of Rust (1970) and those of Rohdenburg (1970). We elaborated a new concept, described below, in Table II. We have tried to apply this new terminology to our filed study and we have found it acceptable as it allows us to clarify existing relations between the climatic geomorphology and the fluvial morphogenesis, and that of eolian and marine(eustatic)morphogenesis.

We deduced and verified, on the ground, the existence of three morphoclimatic phases responsible for the quaternary morphogenesis in the Namib desert : periods of humid activity, of arid stability and of arid activity. One can easily imagine the existence of a period of humid stability witnessed by the inselberg landscape of the inner margin of the Namib desert. This would be responsible for the genesis of certain other relief forms (Scholz 1963, Rust 1970). But our research was not extended to the period of humid stability.

Sedimentological analysis has not been decisive(Table II). Fluvial sediments deposited during humid activity phases or arid stability are analogous. Except that the geomorphological analysis, by itself, allows one to distinguish these two phases: humid activity will not be confirmed unless one can prove

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that fluvial sediments are the correlative deposits of an autochthonous river - a river rising locally.

One can deduce from Table II different types of morphogenesis evoked by the succession of different periods of morphoclimatology. This problem will be taken up in Wieneke and Rust (1973).

(c) Application of this new concept to the morphogenesis of the Central Namib desert.

This new concept of morphoclimatic phases in an arid region allows one to explain the morphogenesis of the lower Swakop terraces, (Rust and Wieneke 1973a). They were formed during an alternation of periods of fluvial activity caused by allogenic rivers (Swakop and Khan) and periods of fluvial activity simultaneously allogenic and local.

Having thus facilitated the comparison between the results obtained in different localities, we constructed a Michel-tupe diagram modified to show phases of coastal eustatic evolution and morphoclimatic periods in the arid region for the coastal desert of the Central Namib, (fig. 6). We constructed, from south to north, morphogenetic curves at three localities: lower Swakop, Mile 4 and Mile 30. In this modified diagram, the ideas of aridity and humidity have a more precise geomorphological sense than those shown by Michel.

The diagram shows that the evolution of Central Namib relief forms is well founded on an alternation of periods of humid activity and arid stability, that is to say on an alternation of periods of fluvial activity, at the same time autochthonous and allogenic, and of allogenic fluvial activity combined with the pedogenesis described in Table II. There were also rare phases of arid activity where eolian processes dominated. Further south, at the northern limit of the dune Namib, one could better recognise the arid activity phases in the quaternary morphogenesis.

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Translation by M.E. Marker

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Morphoclimatic periods		Criteria observable in the field			
Climatic periods	Morpho-/ pedogenesis	Process	Relief form	Sediments	Soils
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Aridity	Stability	Runoff non-local	Incision of allogen~~x~~ic rivers; alluvial cones on allogenic river	Fluvial	Gypsum calcrete regosol "takyres"
Aridity	Activity	Moving dunes inland	Dunes	–	–
		Wind erosion	Yardangs+	Eolian	–

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	Processes	Reg formation (deflation)
		Sand accretion
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	Sediments	Nebka sediments
		Barkhan sands
		Eolianite
	Soils	Gypsum crusts
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