

https://dspace.org/

# Models in geomorphology- Quaternary evolution of the actual relief pattern of coastal central and northern Namib desert

**Rust, U.**

**1980**
Bernard Price Institute for Palaeontological Research
http://hdl.handle.net/10539/16330
None

Downloaded from a DSpace repository. https://dspace.org/

*Palaeont. afr.*, **23**, 173–184 (1980)

# MODELS IN GEOMORPHOLOGY — QUATERNARY EVOLUTION OF THE ACTUAL RELIEF PATTERN OF COASTAL CENTRAL AND NORTHERN NAMIB DESERT

by

**U. Rust**

*Institut für Geographie, Ludwig-Maximilians-Universität, München, Federal Republic of Germany*

**ABSTRACT**

Field and laboratory results gained at various SWA/Namibian sites between the Kuiseb river in the south and the Unjab river in the north are presented. At the Namib coast under study two low stands of sea level and two high stands, one of them of Intra-Würmian age, can be proved. From Toscanini northward a third (? Holocene) high stand exists besides the other two. The former shore lines can be linked spatially and temporally to the terrestrial relief sequences by means of fluvial and eolian land forms and sediments. Thus the changing patterns of more arid or more humid environments at different morphoclimatic stages up to the present one can be described. Furthermore, it is evident that the geomorphic processes themselves change regionally, and it is seen that the Central Namib desert is a geomorphologically unique area in comparison with the Skeleton Coast and the southern dune area. Finally, the tendencies of Quaternary landscape evolution even enable us to deduce some geoecological consequences concerning man's activities in this desert.

**CONTENTS**

*Page*

INTRODUCTION ..... 173
SIX MODELS — THE FRAMEWORK OF THE GEOMORPHOLOGICAL ARGUMENT ..... 173
Model 1 ..... 173
Model 2 ..... 173
Model 3 ..... 175
Model 4 ..... 175
Model 5 ..... 175
Model 6 ..... 176
RESULTS ..... 177
Models 1, 2 ..... 177
Models 4, 5, 6 ..... 179
Models 1, 3, 4, 6 ..... 180
Models 4, 6 ..... 180
Models 3, 5, 6 ..... 180
Models 3, 4 ..... 180
SOME GEOECOLOGICAL CONSEQUENCES ..... 183
ACKNOWLEDGEMENTS ..... 183
REFERENCES ..... 183

## INTRODUCTION

The subject of the geomorphological field work which I carried out together with my friend and colleague Doz. Dr. F. Wieneke, München, has been the study of the interrelationships of fluvial, eolian, and marine-littoral morphogenesis along the Central and Northern Namib desert coast. Spatially and chronologically, the actual relief pattern is the result of these three morphogenetic sequences. Results for the central Namib have been published elsewhere (Wieneke and Rust 1975, Rust and Wieneke 1976).This paper presents some of the syntheses of that work and a number of results concerning the Skeleton Coast area are documented for the first time. The major evidence regarding purely marine-littoral and purely terrestrial results, as well as mixed results, is emphasized.

## SIX MODELS — THE FRAMEWORK OF THE GEOMORPHOLOGICAL ARGUMENT

Six major conceptual models exist concerning landscape evolution of the Namib desert coast. Some of the models are contradictory, and the theoretical consequences are, of course, evident. No single model can explain exclusively all land forms. Consequently, it is important to recognise that any interpretation will be limited.

### Model 1 — Eustatic changes of sea level

This model has been generally accepted. At least the younger changes of sea level were induced by northern hemispheric glaciations and deglaciations (Flohn 1970, Schwarzbach 1974).

### Model 2 — Littoral zonation by extremes and means of tidal water stands (fig. 1)

Wieneke (in Rust and Wieneke 1976) has pro-

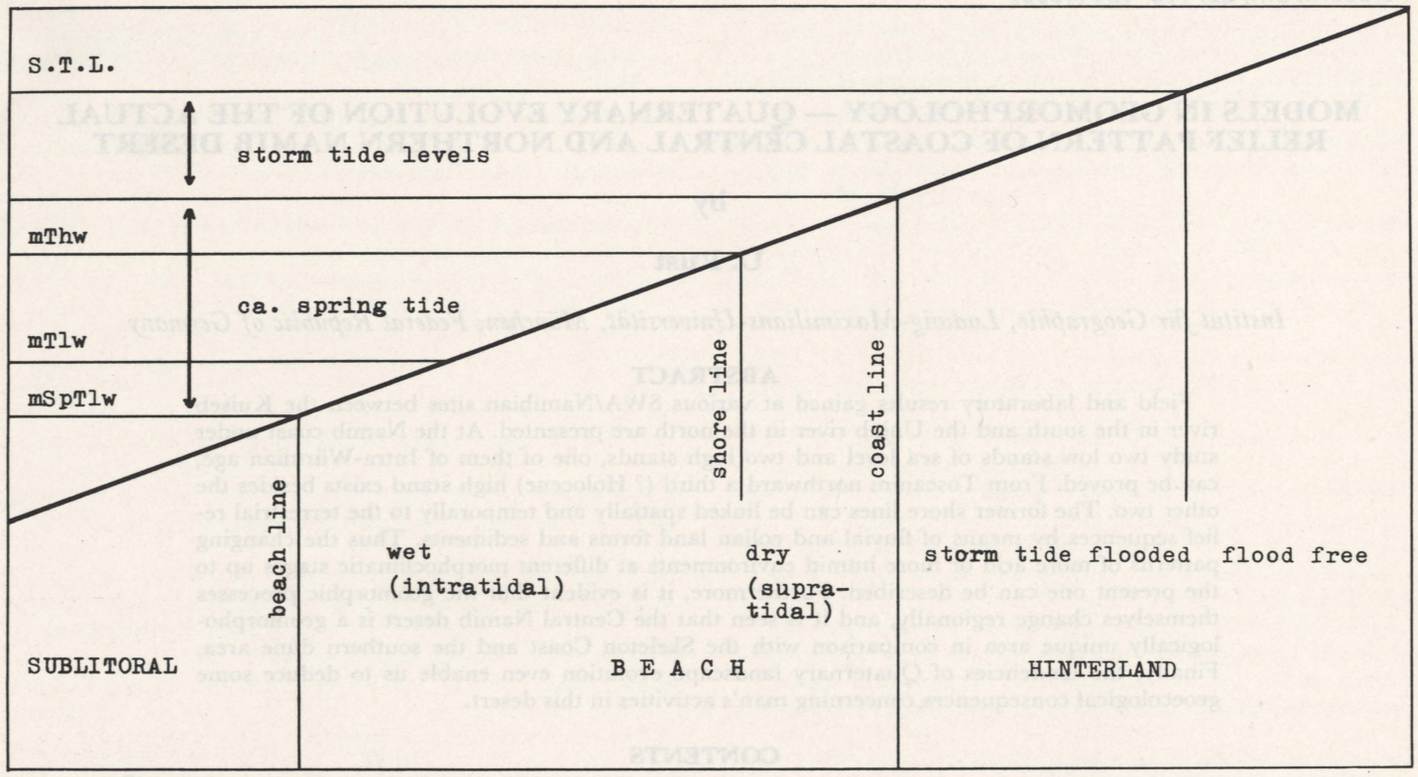


Figure 1. Model 2. Littoral zonation by extremes and means of tidal water stands. After Wieneke (in Rust and Wieneke 1976).

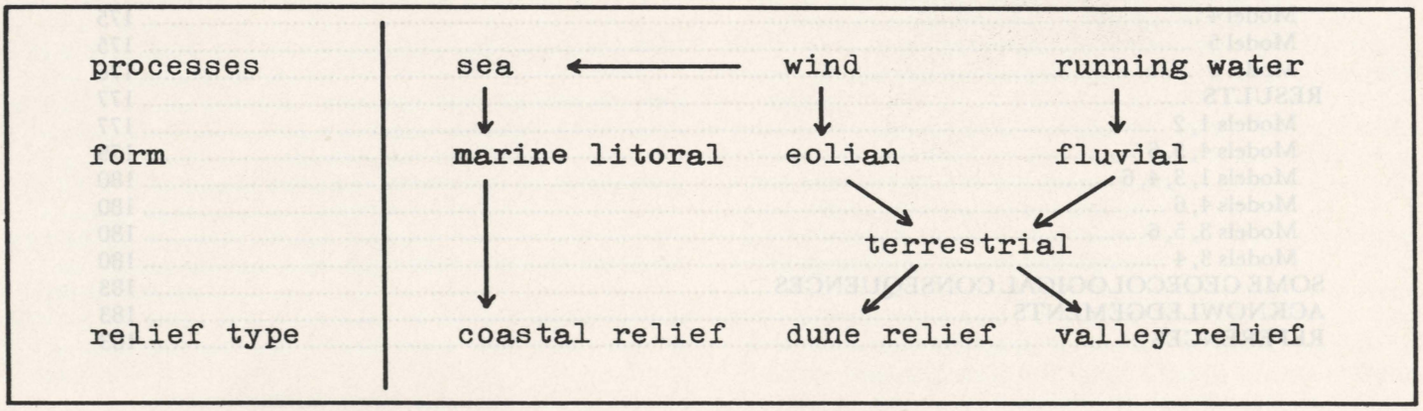


Figure 2. Model 3. Azonality of geomorphic processes.

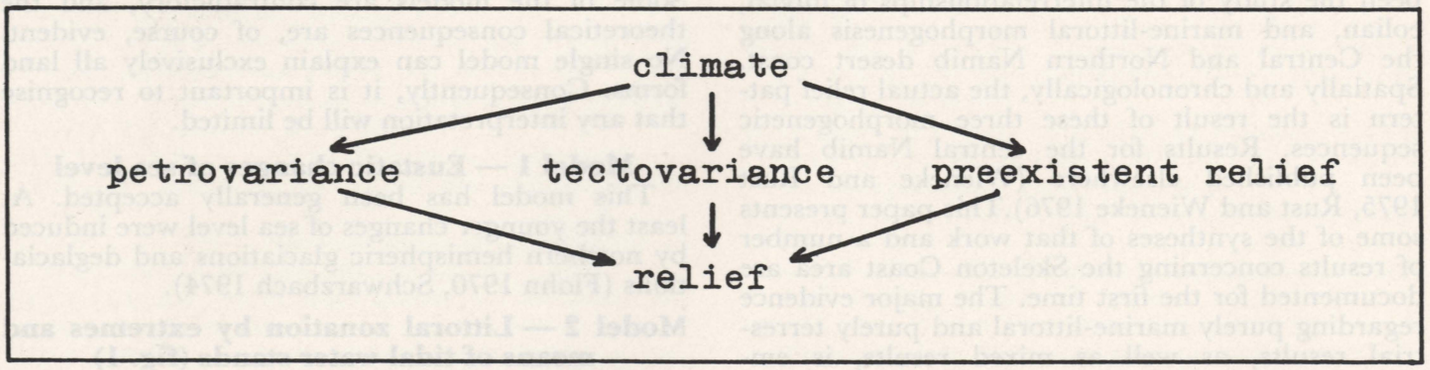


Figure 3. Model 4. Climatic geomorphology.

posed this model and some geomorphic consequences ought to be emphasized. Forms, sediments, and faunas of the same littoral can be found at different heights in respect to any arbitrary level of reference. For example, beach rock is considered to be indurated in the intratidal zone (Guilcher 1961, Russell 1962). It is obviously necessary to connect remnants of former low or high stands of sea level to their littoral geomorphological position. If this is not possible, no exact heights of former shore lines can be given.

### Model 3 — Azonality of geomorphic processes (fig. 2)

This model has been stressed by Tricart and Cailleux (1955). Beyond the nival or gelid areas three azonal processes (fig. 2) may act at coastal areas contemporaneously all over the world.

### Model 4 — Climatic geomorphology (fig. 3)

This model has been elaborated especially by Büdel (1961, 1969) and other German authors (e.g. Bremer 1965). In terms of systems theory this is a model of dominance, since climate is regarded as dominating the other variables. On the other hand, this is also a model of zonality because climate changes zonally.

### Model 5 — Morphodynamic stability and activity (figs. 4 and 5)

Rohdenburg (1970) has pointed out that at any spot on earth periods of morphodynamic activity or stability exclude each other synchronously because of their quite different geoecological environments. In the humid extratropical and tropical regions morphodynamic stability may be linked to soil formation, and morphodynamic activity to

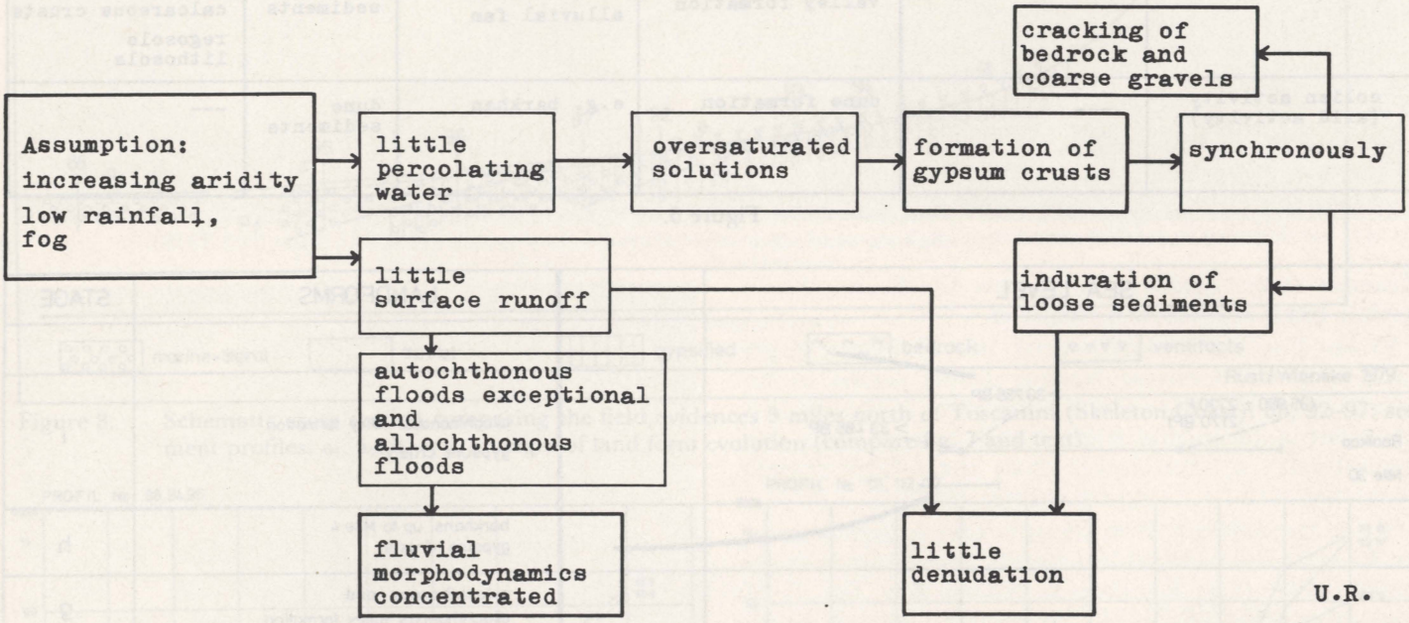


Figure 4. Period of morphodynamic stability.
(Example: Zone of gypsum crusts in coastal Namib desert)

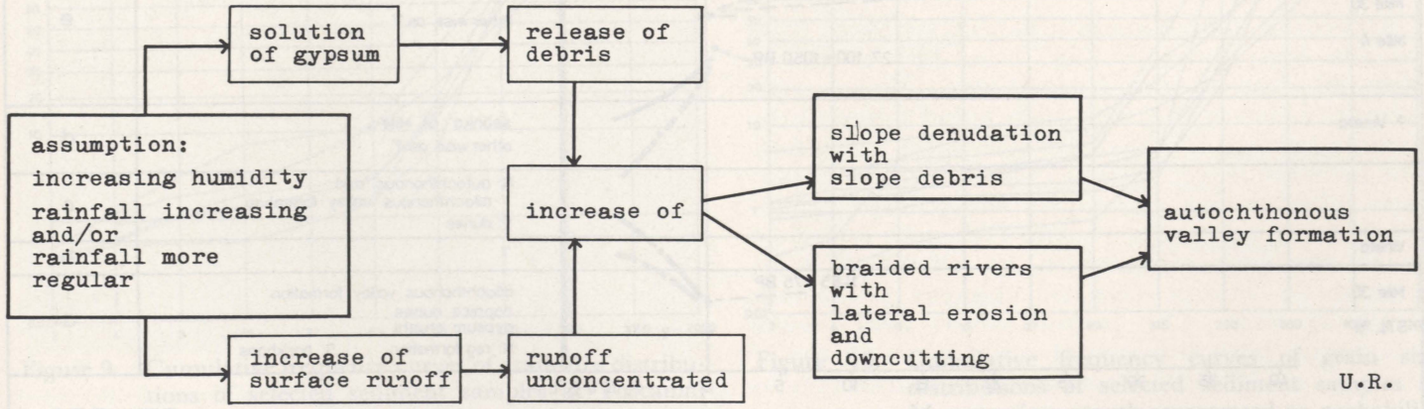


Figure 5. Period of morphodynamic activity.
(Example: Zone of gypsum crusts in coastal Namib desert)

land forming processes, such as denudation and accumulation. According to our own results, those two alternative possibilities may be categorized for the environment of the Namib desert (figs. 4, 5). Taking into consideration the results of gypsum karst geomorphology (Jakucs 1977, Priesnitz 1969), it becomes obvious that these two environmental conditions may exist diachronously, but never synchronously in fluvial morphodynamics.

## Model 6 — Geomorphic environments (fig. 6)

Our own Central Namib field evidence (Rust and Wieneke 1976) has led us to elaborate the model of three different geomorphic environments:

Morphoclimatic stages in Central Namib desert

| Geomorphic environment | | Parametres | | | |
|---|---|---|---|---|---|
| relief formation alternatively | soil formation | 'processes' | relief | sediments | soils |
| fluvial activity (humid activity) | --- | autochthonous valley formation<br>solution of gypsum crusts | main valley and tributary valleys<br>alluvial fan | fluvial sediments | --- |
| --- | arid stability | allochthonous valley formation | canyon<br>alluvial fan | fluvial sediments | gypsum crusts<br>calcareous crusts<br>regosols<br>lithosols |
| eolian activity (arid activity) | --- | dune formation | e.g. barkhan | dune sediments | --- |

Figure 6.

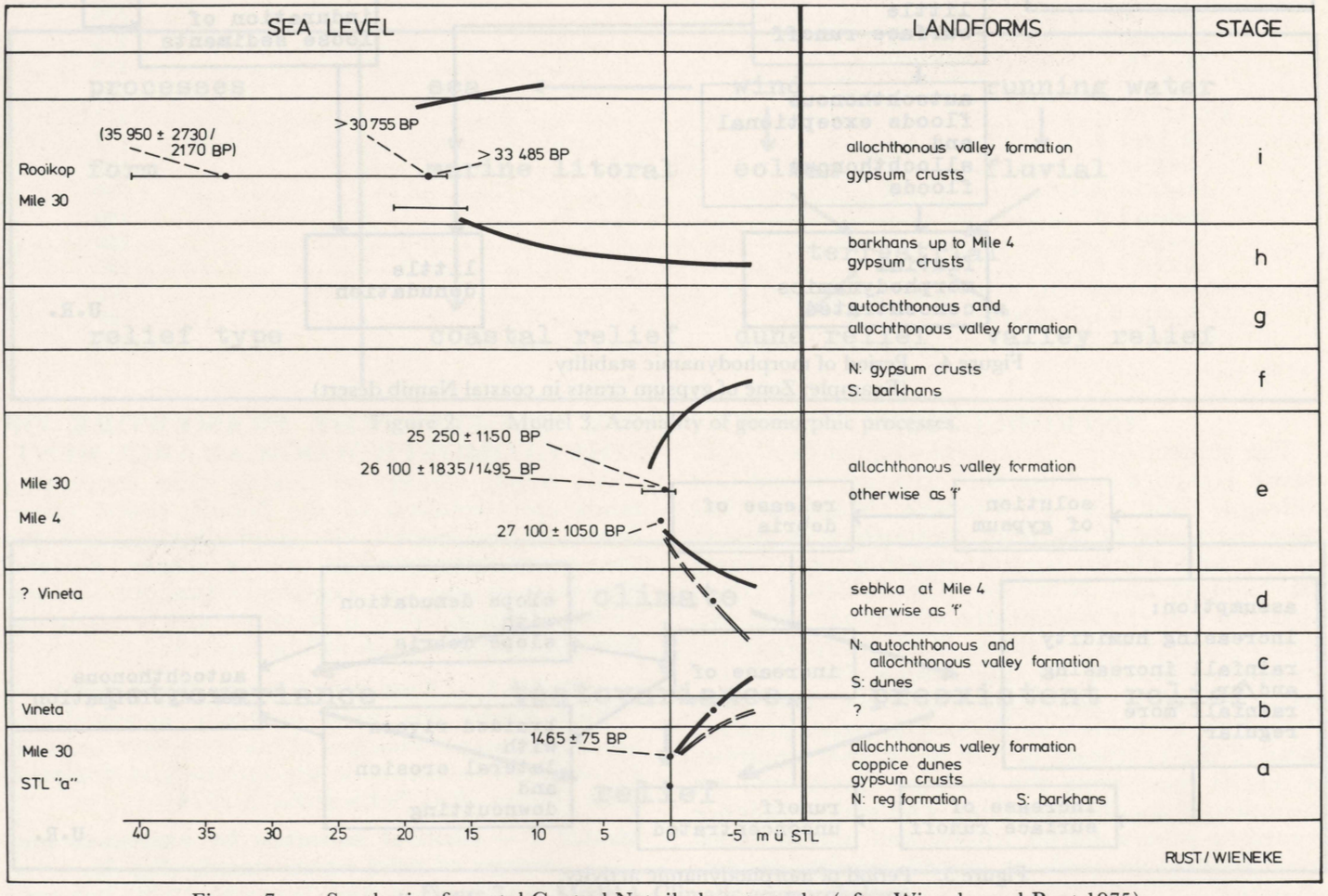


Figure 7. Synthesis of coastal Central Namib desert results (after Wieneke and Rust 1975).

humid activity, arid stability and arid activity. Thus, this model enables us to describe the relief pattern at different morphoclimatic stages by means of different parameters. This model stresses the environment at different sites. By introducing the morphodynamic effects of allochthonous rivers like Swakop or Kuiseb in this model, the influences of higher and eventually more humid hinterlands are included.

## RESULTS
### Models 1, 2

On the central Namib desert coast marine-littoral field evidence is found for four morphoclimatic stages: i-e-b-a (fig. 7). They are documented by land forms, such as terrace remnants, former littorals and breaker zone bars, and marine-littoral sediments, beach rocks, and faunas. Two high stands (i, e) of sea level topographically higher than the present one (a) and one low stand (b) are directly proved by field evidence. A further low stand (g) may be deduced indirectly.

Comparable marine-littoral features also exist on the Skeleton Coast. At Torrabaai beach rock (stage b) is found analogous to the beach rock of Vineta (fig. 13). The shore lines of stages a, e, and i are found ubiquitously in the form of sediments (figs. 9 and 10) and faunas at Toscanini or the

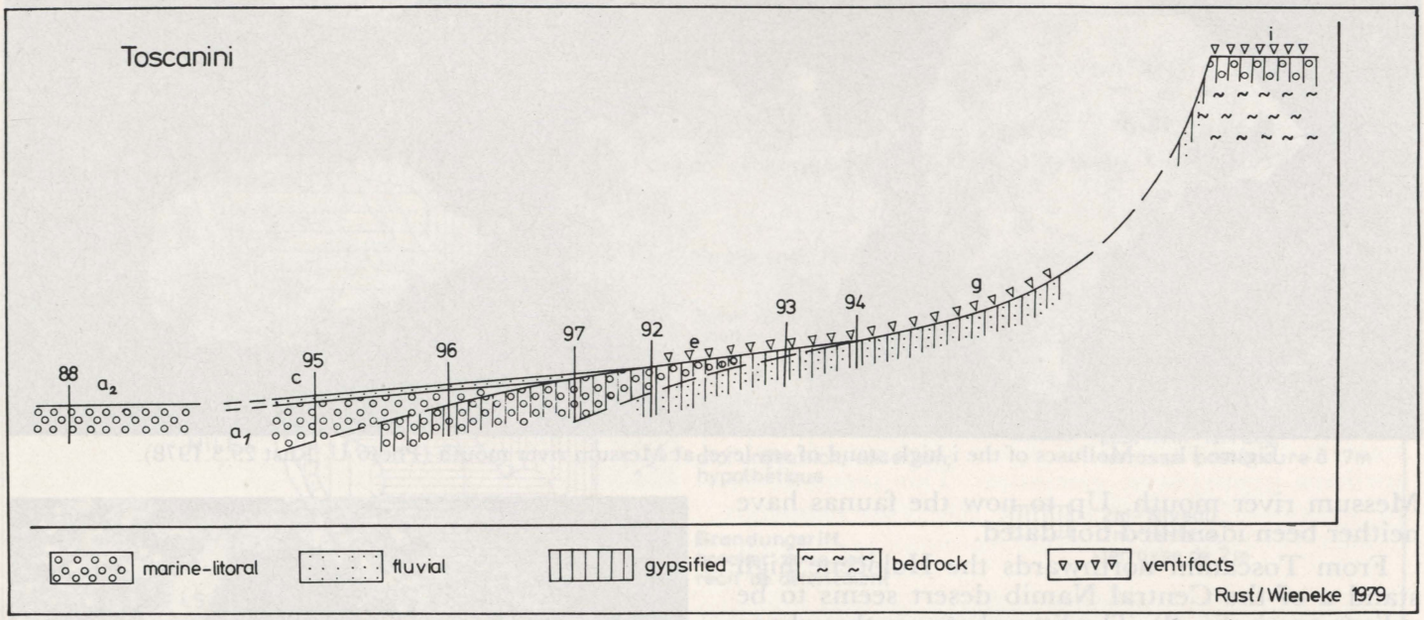


Figure 8. Schematic cross section composing the field evidences 3 miles north of Toscanini (Skeleton Coast). 88, 92–97: sediment profiles. $a_1$, $a_2$, c, e, g, i: stages of land form evolution (compare fig. 7 and text).

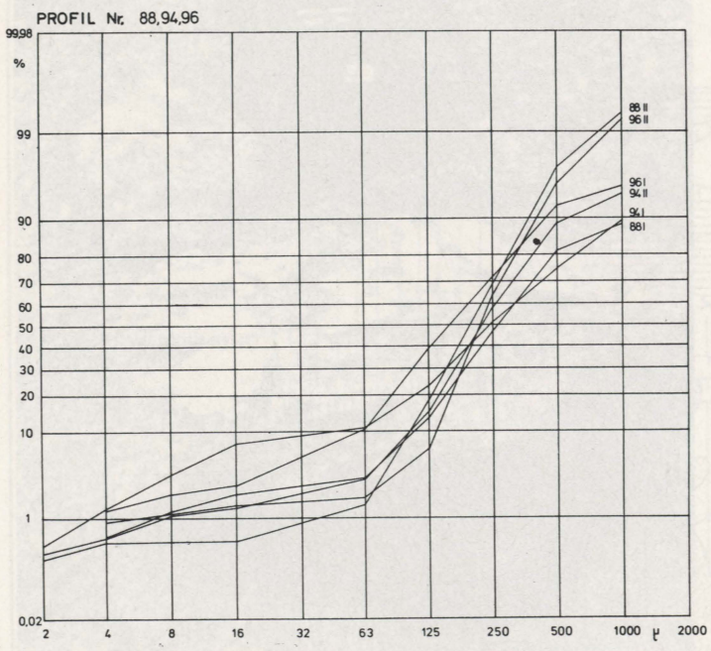


Figure 9. Cumulative frequency curves of grain size distributions of selected sediment samples at Toscanini (compare fig. 8) represented on probability paper with a logarithmic ordinate.

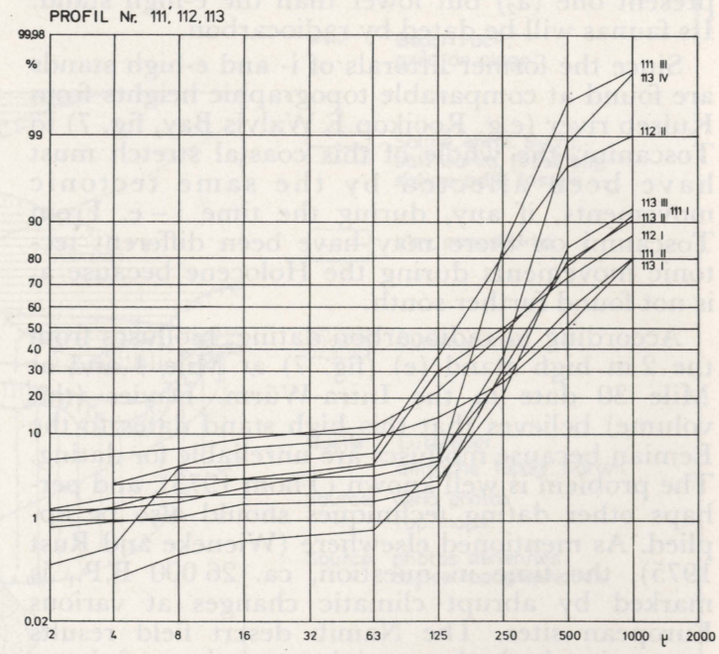


Figure 10. Cumulative frequency curves of grain size distributions of selected sediment samples at Messum river mouth represented on probability paper with a logarithmic ordinate.



Figure 11. Molluscs of the i-high stand of sea level at Messum river mouth (Photo U. Rust 29.3.1978).

Messum river mouth. Up to now the faunas have neither been identified nor dated.

From Toscanini northwards the Holocene high stand a of the Central Namib desert seems to be split ($a_1$, $a_2$ in fig. 8). The littoral of $a_1$ is thought to represent a Holocene high stand higher than the present one ($a_2$) but lower than the e-high stand. Its faunas will be dated by radiocarbon.

Since the former littorals of i- and e-high stands are found at comparable topographic heights from Kuiseb river (e.g. Rooikop E Walvis Bay, fig. 7) to Toscanini, the whole of this coastal stretch must have been affected by the same tectonic movements, if any, during the time i – e. From Toscanini on there may have been different tectonic movements during the Holocene because $a_1$ is not found further south.

According to radiocarbon dating, molluscs from the 2 m high stand (e) (fig. 7) at Mile 4 and at Mile 30 date to the Intra-Würm. Davies (this volume) believes that this high stand dates to the Eemian because molluscs are unreliable for dating. The problem is well known (Thom 1973), and perhaps other dating techniques should also be applied. As mentioned elsewhere (Wieneke and Rust 1975), the time in question, ca. 26 000 B.P., is marked by abrupt climatic changes at various European sites. The Namib desert field results concerning both the spatial connections of the e-littorals at different sites and their connections with the corresponding geomorphic environments (fig. 7) are nevertheless not invalid.



Figure 12. Sediments of e-high stand of sea level at Toscanini. Compare profile 92 in Figure 8. Rounded pebbles and gypsified sands with molluscs (Photo U. Rust 21.3.1978).

The beach rock of Vineta and Torrabaai is a littoral remnant either of the sinking Late Würmian sea level or of the rising Post-Würmian sea level.

The faunas of the i-sea level high stand are not datable by radiocarbon techniques. After the i-high stand complex land forms (e.g. fig. 16) evolved, and this marine-littoral event is assumed to be quite old.

### Models 4, 5, 6

On the Namib desert coast between Swakop and Ugab terrestrial land forms of merely autochthonous fluvial origin exist. They are gypsified ubiquitously. To explain these land forms, major climatic changes must be assumed. Here in the desert an arid-stable geomorphic environment (fig. 4) can only change into a humid-active one (fig. 5) if the actual arid climate, that is a climate of arid-stable geomorphic environment, becomes more humid. This must have happened, for example at stages g and c (fig. 7). From the point of view of climatic karst geomorphology (Priesnitz 1969, Jakucs 1977) an enormous amount of water is required to dissolve the gypsum. A climate inducing such solution processes could be imagined to have at least three elements: higher and/or more regular precip-

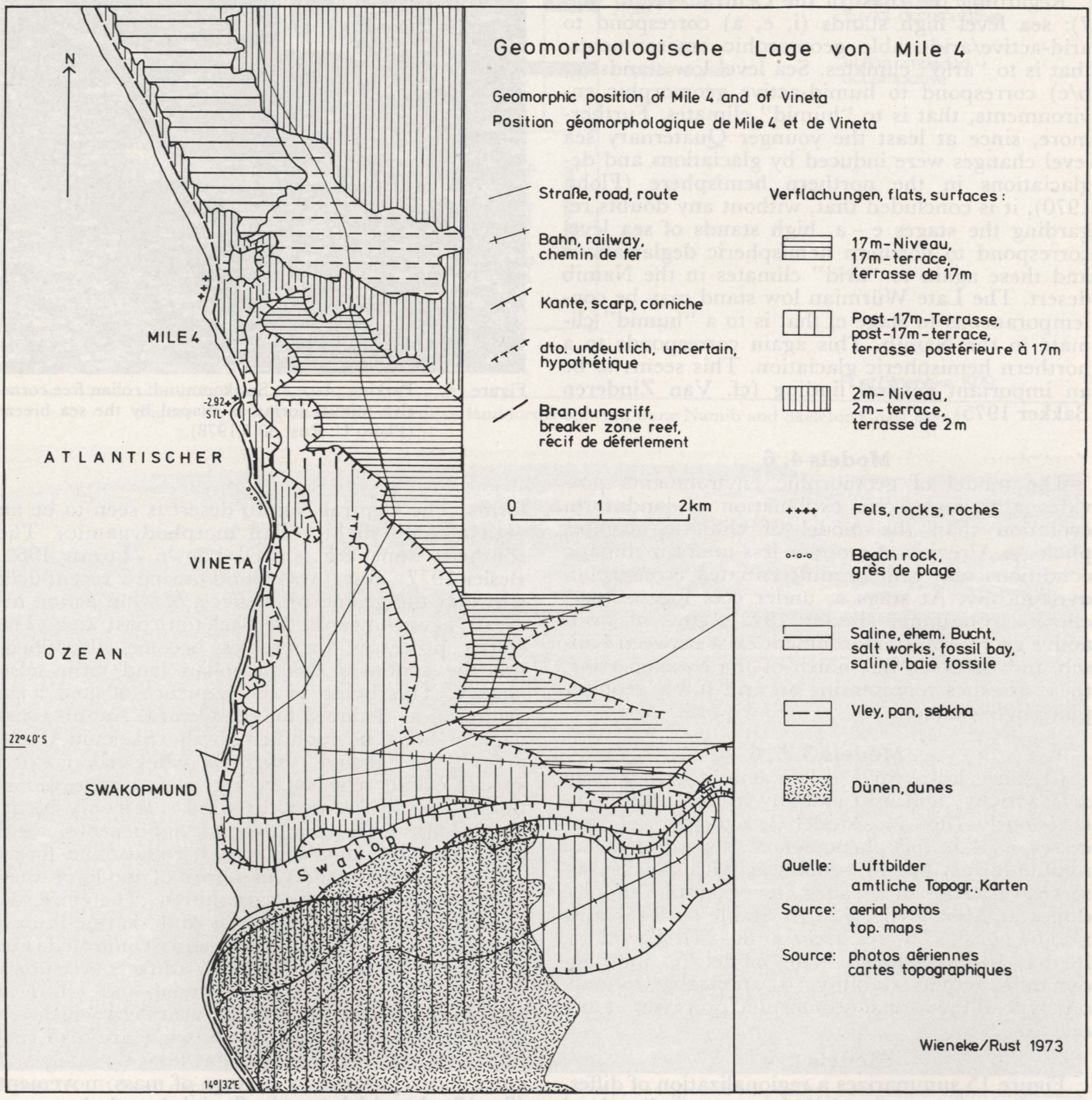


Figure 13. Geomorphology of Swakop river mouth area (after Rust and Wieneke 1976).

itation; lower temperatures and therefore less evaporation; and cyclonic rains.

### Models 1, 3, 4, 6

By means of quite different arguments (geomorphological, sedimentological and topographical) terrestrial and marine-littoral landscape evolution may be linked. For example, at lower Swakop river (fig. 13) the terraces "17 m terrace" and "2 m terrace" have been formed by the Swakop river under arid-stable geomorphic environmental conditions. They can be connected sedimentologically and topographically to the littorals of the i- and e-high stands of sea level.

Regarding the coast of the Central Namib (fig. 7): sea level high stands (i, e, a) correspond to arid-active/arid-stable geomorphic environments, that is to "arid" climates. Sea level low stands (g, b/c) correspond to humid-active geomorphic environments, that is to "humid" climates. Furthermore, since at least the younger Quaternary sea level changes were induced by glaciations and deglaciations in the northern hemisphere (Flohn 1970), it is concluded that, without any doubts regarding the stages e – a, high stands of sea level correspond to northern hemispheric deglaciations and these again to "arid" climates in the Namib desert. The Late Würmian low stand may be contemporaneous to stage c, that is to a "humid" climate in the Namib. This again corresponds to a northern hemispheric glaciation. This seems to be an important general finding (cf. Van Zinderen Bakker 1975).

### Models 4, 6

The model of geomorphic environments provides a more precise explanation of land form evolution than the model of climatic geomorphology. A region of more or less uniform climatic conditions may still be differentiated ecomorphodynamically. At stage a, under cool foggy desert climate conditions (Besler 1972), sites of arid-active geomorphic environment exist between Kuiseb and Swakop, but north of the Swakop river, there are sites representing an arid-stable geomorphic environment.

### Models 3, 5, 6

At stages k-i-h, f-e-d, eolian activity, which is an arid activity, and arid stability are observed synchronously (fig. 7). Model 3, azonality of processes, explain this phenomenon. Regarding eolian minute forms (fig. 15), eolian activity may be observed at arid-stable sites: for example coppice dunes at Mile 4 (fig. 7, 15). Stable surfaces may also be polished by sea breezes (fig. 14). Therefore, it may be concluded that model 5, morphodynamic activity/stability, is applicable to only one type of the azonal geomorphic processes at any one time.

### Models 3, 4

Figure 15 summarizes a regionalization of different eolian processes and their corresponding land



Figure 14. Parking place at Swakopmund: eolian free corrasive minute forms as shaped by the sea breeze (Photo U. Rust 30.3.1978).

forms. The Central Namib desert is seen to be an area of only slight eolian morphodynamics. The southern dune erg is well known (Logan 1960, Besler 1977). But it was found during a recent field trip that the geomorphic effects of wind action increase again towards the Skeleton coast area. The eolian processes themselves become diversified, but the spatial scales of eolian land forms also change. This being so the sequence of land form evolution as deduced for the Central Namib coast (fig. 7) must be modified in the Skeleton Coast area. The "azonal" medium wind has created special eolian relief types (e.g. closed depressions, fig. 16), partly because the wind is the only agent, and partly because of alternate influence of wind and running water. Since such eolian land forms are pre-existent reliefs in terms of model 4 they also influence land form evolution. Therefore, on the Skeleton coast terrestrial and marine-littoral land form evolution are not readily connected. For example, at Toscanini (fig. 8) ventifacts are superimposed on remnants of g-fluvial and e-littoral land forms. Those parts of the ventifacts which are at present not exposed to the wind are also corraded. Therefore, they prove at least two stages of corrasion separated by a stage of mass movement (fig. 17a, b) which may be fluvial-denudative.

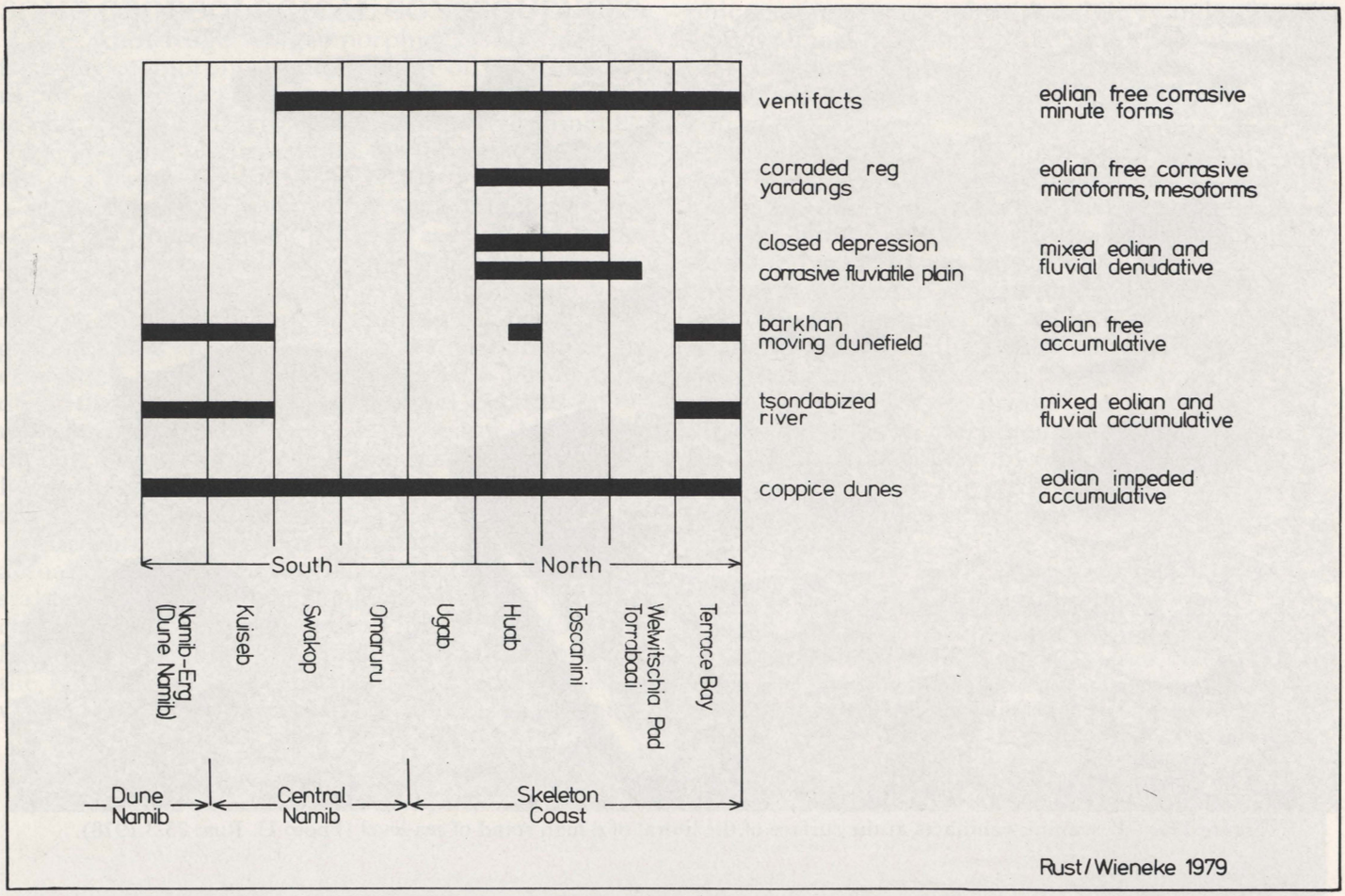


Figure 15. Regionalization of eolian land forms between dune Namib and Skeleton Coast area.



Figure 16. Closed depression at Toscanini area: foreground, salt swamp, background left, valley; background right, small cuestas and eolian sands; background above, terrace remnant of the i-high stand of sea level (Photo U. Rust 22.3.1978).



Figure 17a. Toscanini: ventifacts at the surface of the litoral of e-high stand of sea level (Photo U. Rust 23.3.1978).



Figure 17b. Toscanini: several stones turned upside down. Their bases are seen also to be corraded by wind. (Photo U. Rust 23.3.1978)

## SOME GEOECOLOGICAL CONSEQUENCES

The knowledge of geomorphic history gained from an ecomorphodynamic point of view enables me to give some statements about man's activities in the Namib desert geomorphic environments. Two of these environments are observable today (stage a in fig. 7).

The arid-stable geomorphic environment is very sensitive to pollution. There are no morphodynamic processes other than small-scale eolian processes; there is almost no weathering, no vegetation and soil formation and almost no disintegration. This environment may be described as an ecosystem unable to digest man-made inputs. Indeed, the area between Swakop and Ugab is enormously polluted by rubbish of many kinds, although usually only a few tourists visit this area. From the geomorphologist's point of view the tourists should be prohibited.

The pattern of relief evolution is known for the actual boundary between arid-active and arid-stable geomorphic environments (fig. 7). Three consequences result from it. First on the Central Namib desert coast, the eolian land forms between the Kuiseb and Swakop rivers tend to shift northwards. Secondly, as explained above, the geomorphic environments of arid-stability and of arid-activity may have been contemporaneous at several former stages. Thirdly, these two environments are adjacent now at the allochthonous Swakop river.

With these three facts in mind it becomes evident that a very sensible frontier exists along the lower Swakop river (fig. 18). Barkhans are shifting into the Swakop valley from the south. Attempts to stop the barkhans are unsuccessful. If the Swakop river was unable to remove the eolian sand masses when discharging into the Atlantic Ocean, the barkhans would cross the valley and reach its northern bank, that is the town of Swakopmund. Geographically, therefore, it must be emphasized that the Swakop river catchment area should not be strained immoderately by dam constructions or water withdrawals, for in this case the river would no longer be able to stop the barkhans.

### ACKNOWLEDGEMENTS

I am indebted to the Deutsche Forschungsgemeinschaft (DFG) for financial support and the Director, Nature Conservation and Tourism, SWA Administration, Windhoek, for the opportunity to work in the Namib desert area.



Figure 18. Lower Swakop river area viewed from NE: foreground right, post — 17 m — terrace (see fig. 13); middleground, barkhans stretching down to Swakop high water bed (with scrubs). Swakop river itself (from left to right): restricted water channel superimposed the braided river low water bed (Photo U. Rust 11.4.1972)

### REFERENCES

BESLER, H. (1972). Klimaverhältnisse und klimageomorphologische Zonierung der zentralen Namib (Südwestafrika). *Stuttgarter Geogr. Stud.*, **83**, 1–209.

— — — — (1977). Untersuchungen in der Dünen-Namib (Südwestafrica) — Vorläufige Ergebnisse des Forschungsaufenthaltes 1976. *J. S.W.Afr. Wiss. Ges.*, **31**, 33–64.

BREMER, H. (1965). Der Einfluss von Vorzeitformen auf die rezente Formung in einem Trockengebiet — Zentralaustralien. *Tagungsber. u. wiss. Abh., 34. Deutscher Geographentag Heidelberg 1963*, 184–196.

BÜDEL, J. (1961). Morphogenese des Festlandes in Abhängigkeit von den Klimazonen. *Die Naturwiss.*, **48**, 313–318.

— — — — (1969). Das System der klima-genetischen Geomorphologie. *Erdkunde*, **23**, 165–183.

FLOHN, H. (1970). Ein geophysikalisches Eiszeit-Modell. *Eiszeitalter u. Gegenwart*, **14**, 204–231.

GUILCHER, A. (1961). Le "Beach Rock" ou grès de plage. *Ann. Géogr.*, **70**, 113–125.

JAKUCS, L. (1977). *Morphogenetics of Karst Regions*. London, Hilger.

LOGAN, R.F. (1960). The Central Namib Desert, South West Africa. *Nat. Acad. Sci. — Nat. Res. Council*, no. 758, Washington D.C.

PRIESNITZ, K. (1969). Über die Vergleichbarkeit von Lösungsformen auf Chlorid-, Sulfat- und Karbonatgesteinen. *Geol. Rdsch.*, **58**, 427–438.

ROHDENBURG, H. (1970). Morphodynamische Aktivitäts- und Stabilitätszeiten statt Pluvial- und Interpluvialzeiten. *Eiszeitalter u. Gegenwart*, **21**, 81–96.

RUSSELL, R.J. (1962). Origin of beach rock. *Ann. Geomorph. N.F.*, **6**, 1–17.

RUST, U. and WIENEKE, F. (1976). Geomorphologie der küstennahen Zentralen Namib (Südwestafrika). *Münchener Geogr. Abh.*, **19**, 1–74.

SCHWARZBACH, M. (1974). *Das Klima der Vorzeit*. (3rd Ed.). Stuttgart, Enke.

THOM, B.G. (1973). The dilemma of high interstadial sea levels during the last glaciation. *Progr. in Geogr.*, **5**, 167–246.

TRICART, J. and CAILLEUX, A. (1955). *Introduction à la géomorphologie climatique*. Paris, S.E.D.E.S.

VAN ZINDEREN BAKKER, E.M. (1975). The origin and palaeoenvironment of the Namib Desert biome. *J. Biogeogr.*, **2**, 65–73.

WIENEKE, F. and RUST, U. (1975). Zur relativen und absoluten Geochronologie der Reliefentwicklung an der Küste des mittleren Südwestafrika. *Eiszeitalter u. Gegenwart*, **26**, 241–251.