GEOGRAPHY OF THE CENTRAL NAMIB DESERT

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ABSTRACT

The Namib Desert of the South West African coast is representative of the cool coastal desert type. Little affected by seasonality, its climate is cool and extremely damp all year at the coast, but markedly warmer and drier inland. The very scanty vegetation is strongly succulent near the coast, with grasses and nonsucculent bushes dominating the interior. Large areas are totally barren.

Three regional units are recognized: the Coastal Namib, the area of strongly marine climate; the Namib Platform, an erosional surface (pediment) of extreme flatness cut by a few stream valleys and interrupted by widely scattered *inselberge;* and the Dune Namib, a vast sand-sea.

Aside from primitive herders of goats in riparian situations and very marginal commercial grazing in the interior, economic development is based entirely on fisheries and port activities and a rapidly expanding seaside resort activity.

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LOCATION AND GENERAL NATURE

The Namib Desert of South West Africa is a part of one of the two great belts of desert that encircle the world in the vicinity of the tropics. The northern hemisphere belt is composed of the Sahara and the deserts of Arabia, Iran, Afghanistan, and Pakistan in the Old World, and of Mexico and the southwestern United States in the New World. In the southern hemisphere, the arid belt includes much of Australia and the desert areas of Chile and southern Africa. While the land areas in the southern-hemisphere arid belt are much smaller than those of the northern-hemisphere arid zone, it must be realized that tremendous expanses of ocean within tropical latitudes actually have arid climates, and despite the presence of water everywhere, are as climatically dry as the Sahara.

The landward portions of the tropical deserts suffer from extreme aridity, great summer heat, and very low humidities, except in certain extraordinary, anomalous areas: the cool coastal deserts.

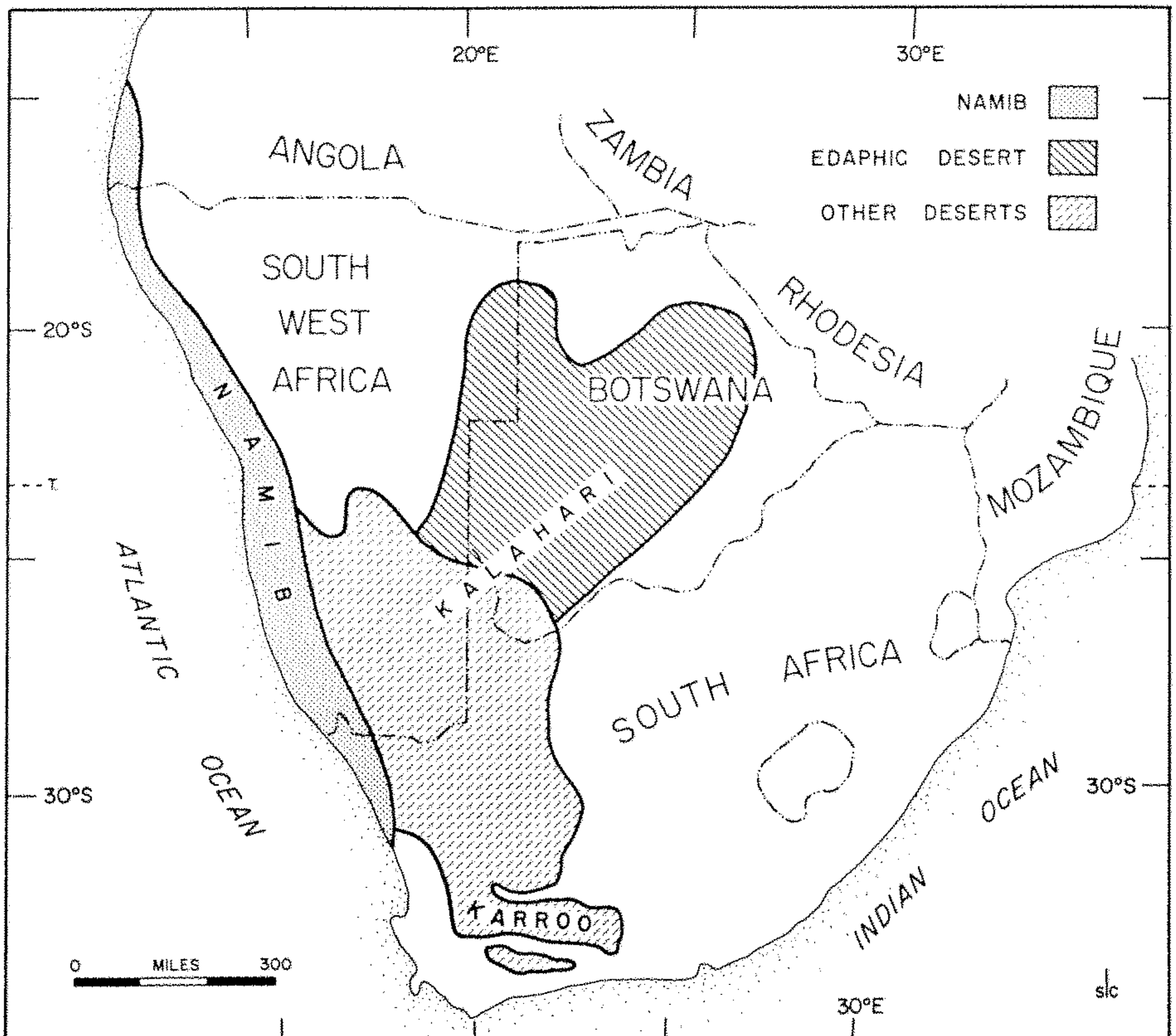

Fig. 1. The deserts of southern Africa.

Three such deserts exist: the western coastal desert of Baja California in Mexico, the Atacama desert of Chile, and the Namib of South West Africa. All occur in about the same latitudes on the western coasts of continents, where the water alongshore is abnormally cold for the latitude. All have the same climatic characteristics, quite far removed from the popular concept of deserts. While virtually rainless, they have very high humidities and are frequently swathed in fog; their summers are cool, their winters mild, and their rare hot spells come only in winter. The Namib is in every way representative of this cool coastal desert type.

The Namib is actually the western coastal phase of the much larger desert area of southern Africa, with which it merges almost imperceptibly (Fig. 1). But the desert of southern Africa is by no means simple or uniform, and so the transitions are multiple and varied in natures. Southern Botswana, the southeastern part of South West Africa, and

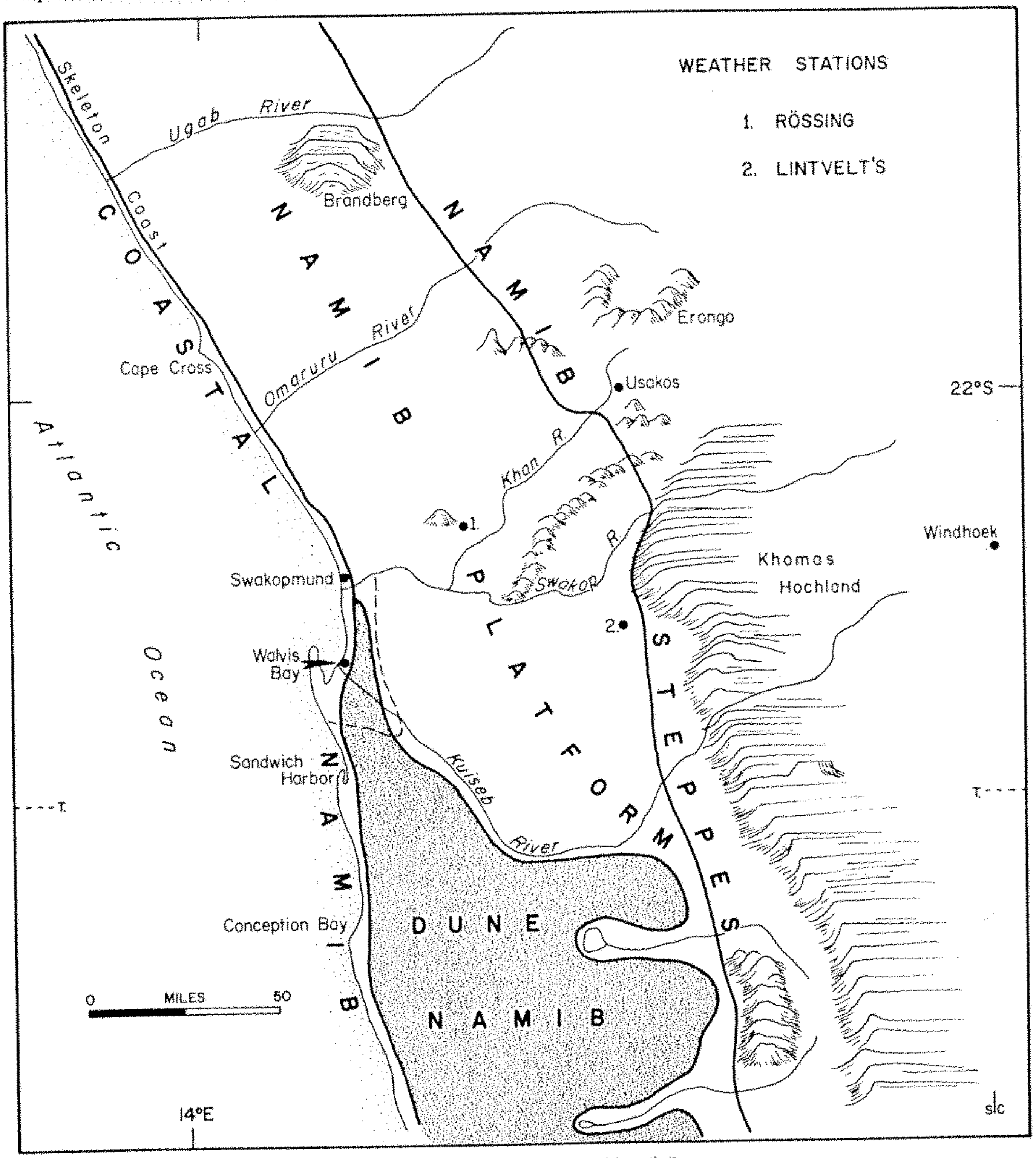

Fig. 2. Regional divisions of the central Namib Desert.

part of the Cape Province of South Africa lie within the Kalahari Desert—an area of very little rain and quite devoid of vegetation. The Kalahari is generally considered to extend much farther northward, to include most of northern Botswana and much of eastern South West Africa. Climatically, however, this area does not qualify as a desert, for its annual average rainfall is relatively high. It is considered desert because its rainfall is absorbed directly by the thick layers of sand that cover its surface, making surface water unavailable. On the other hand, deep-rooted trees and shrubs tap this water, and an open woodland and/or a brush cover exists over much of the so-called desert. This then is a desert of edaphic, rather than climatic, origin.

Within both parts of the Kalahari, such rain as does fall comes in the form of summer convectional showers, and the winters are dry, clear, and cool. Farther south, within the Cape Province, lies the Karroo, wherein desert conditions also prevail but where the precipitation occurs in winter, sometimes in the form of snow. The southernmost part of the Namib exhibits tendencies in this direction and represents a transition between the Namib proper and the Karroo.

Southern Africa thus has four desert types—the Namib: mild, rainless, but with high humidity; the Kalahari proper: with hot summers, cool, dry winters, and summer precipitation; the *edaphic* Kalahari: with summer precipitation of non-desert proportions, hot in summer and cool in winter, and desertic because of the porosity of its surface materials; and the Karroo: with cold winters, warm summers and winter precipitation.

The Namib occupies an elongated tract on the western (Atlantic) coast of southern Africa. It extends from the vicinity of Mossamedes in Angola across the breadth of South West Africa to the mouth of the Olifants River in the Cape Province of South Africa—a distance of about 1,300 miles. From the coastline, it reaches inland to the foot of the Great Western Escarpment of southern Africa—a distance of 50 to 90 miles. From the purely climatic viewpoint, the same desertic condition also extends over the neighboring ocean—northward almost to the equator and northwestward almost to the bulge of Brazil.

This paper will concern itself with the core area of the Namib, from the sea to the foot of the Escarpment between the parallels of 22°30′S and 23°30′S (the Tropic of Capricorn). Within that area (Fig. 2) it is possible to study representative samples of most aspects of the Namib and to observe contrasts between its coastal and interior parts.

CLIMATE

Throughout the year, the semi-permanent high-pressure cell occupying the center of the South Atlantic exerts a great influence on the weather of the Namib. Within the cell, cool, dry air subsides from aloft. With descent, this air is warmed adiabatically and comes to the surface as warm dry air. A similar cell is normally developed over the high plateau of southern Africa. During the winter its descending air usually reaches the surface, producing warm, dry, clear air over all of the interior. During the summer, however, surface heating is strong, and the resultant convectionality not only prevents the descending air from reaching the surface but develops a fairly strong, low-pressure circulation pattern on the surface, although the high-pressure zone still exists in the upper air.

In response to the South Atlantic pressure cell, the air movement off the South West African coast is from the south-south-east throughout the year. Since at any season, the temperatures of the interior Namib are warmer than the sea, a thermal pressure gradient develops which deflects some of the moving air across the coast and inland, creating a sea breeze; this is strictly a diurnal phenomenon, from late morning until sunset. The direction of air movement is usually from the south-south-west, and it blows with moderate vigor (force 3 to 4 Beaufort). Blowing across the whole width of the Namib, it rises in irregular streams up the face of the Escarpment before dispersing.

The Benguela Current flows northward in the eastern Atlantic, bringing water from the Southern Ocean far equatorward. This already cold water is made even colder by the admixture of water upwelled from the depths. As a result, water temperatures along the Namib coast are far below the normal for the latitude, being in the middle fifties (Fahrenheit) at all seasons. The air in contact with this water is chilled thereby and is normally at or near the saturation point. It is the daily movement of this air into the desert that makes the Namib so different from the usual concept of a desert.

This regular importation of air from the cool sea produces a strong temperature inversion over a wide zone back of the coast. At the coast, the layer of cool air is normally some two-thousand feet thick (*1*). Within it, the surface temperature is that of the sea offshore, and humidities approach the saturation point. Fog is common; and when fog is not present, a stratus layer often exists, with its base less than a thousand feet above the coastal surface. In its passage across the desert, this air warms considerably, evaporating the fog and cloud and lowering the relative humidity. But as far inland as the top of the Escarpment, the air is distinctively different from the interior and the superior air.

Throughout the year, the air above the inversion is devoid of moisture, having descended from high aloft in one of the high-pressure cells; hence it cannot be looked upon as a source for precipitation. During the summer, however, the surface low-pressure draws in moisture-bearing air from the Indian Ocean to the interior, and sometimes as far west as the Namib. This air is the source of the summer rains of the interior of the continent, where strong surface-heating produces strong convectional currents, which in turn produce thunderstorms. Over the Namib, however, this chain of events is stopped before it starts by the interposition of the temperature inversion between the ground and the moist air aloft; the cool sea air precludes any convectional activity in the moist upper air. The lower layer is moist also, of course, but too cool and too shallow to contain a great volume of moisture, and too cool for convectionality. Thus we have the anomaly of a virtually rainless area whose air is almost permanently saturated with moisture. Were this layer of moist air thicker, or were the ocean off shore warmer, conditions potentially productive of precipitation would prevail and the desert would disappear.

No area is totally without rainfall, however, and the Namib does receive some. On the rare occasions when moist air is present aloft and not sealed off from terrestrial heating by the inversion, rain may occur. Such conditions develop usually only at the beginning and the end of the summer. Two conditions are necessary: absence of the inversion and the sea breeze, and presence of moist Indian Ocean air aloft. The chances of the coincidence of these conditions are very slight, and hence rains occur very infrequently.

Rain is least plentiful in the coastal sector. Swakopmund, situated on the coast, has an annual average of 0.65 inches (2). In one year (1934), however, 6.13 inches were received—2 inches of it in a single day. If this very abnormal year is omitted from the record, the average annual rainfall is only 0.52 inches. Many years are completely rainless.

Rainfall increases with the distance inland. At Goanikontes (787 feet, 20 miles from the coast), the average is 1.35 inches. At Khan Mine (925 feet, 32 miles inland), it is 1.71. At Donkerhuk, in a valley between massive outliers of the Escarpment (4,200 feet, 90 miles from the sea), it is 6.8 inches, or 5.8 if the exceptional year of 1934 (when 29.67 inches fell) is omitted.

The nature of weather conditions can be best described by a detailed study of representative stations on representative days. For this purpose, three stations at which the writer maintained weather instruments have been selected: Swakopmund, at the coast; Rossing, 26 miles inland and 1,394 feet above sea level; and Lintvelt's, a gap in the first outliers of the Escarpment 76 miles from the coast and 3,750 feet in elevation. Hygrothermograph traces for these stations on representative midsummer and midwinter days are presented here.

Meteorologically, conditions at Swakopmund in summer are monotonously regular. The trace for Christmas Day, 1956, is representative (Fig. 3). During the first half of the day, from midnight until noon, the humidity remained consistently at 100 per cent, and the temperature fluctuated only between 58° and 56°F. The temperature curve crossed 60°F about 1 p.m., at which time the humidity first dropped below the saturation point. During most of this period, however, there was no fog; but a very low stratus cover persisted, at times shrouding the top of the lighthouse. Through the remainder of the afternoon the sun occasionally broke through, and the temperature rose to a maximum of 63°F at 5 p.m., while the humidity dropped as low as 92 per cent. At 6 p.m., the humidity went once more to 100 per cent and the stratus cover was resumed; these conditions prevailed the rest of the day.

During the summer, the humidity is normally at 100 per cent for 19 hours per day, and the mean minimum is 90 per cent. Summer days have a range of 8.6°F, from a minimum of 58.5° to a maximum of 67.1°. In all respects, the climate of Swakopmund is the epitome of oceanity.

Along all of the Namib coast, most days dawn slowly, with gray fog shrouding the area. There is no sunrise—only a gradual graying, an enlightening of the darkness of the night. The air is calm, or wafting lightly from the north, and feels very damp. The few objects that can be seen seem all out of proportion. One is conscious of his whereabouts chiefly from the sounds about him—the dull boom of the surf or the crying of the sea birds on the invisible banks.

By 9:00 a.m. or so, the fog lifts. Actually there is no *lifting;* the air stays still while droplets in the lower levels are evaporated. Short wavelengths of insolational energy have penetrated the fog blanket and warmed the soil of the marsh and the sand of the dunes. Long wavelengths radiated by these now-warmer bodies heat the air above, and the fog particles go rapidly from the liquid into the gaseous state. And so, suddenly, one can look for miles up and down the coast under the fog; but the ceiling is at 100, or 50, or even 25 feet.

About this same time, the sea breeze begins to blow gently. About 10:00 or 11:00 a.m., the sun becomes visible intermittently as a pale gray disc, and soon thereafter, following several premature bursts, it comes out to stay. The fog has now succumbed to evaporative attacks from both above and below and has gone for the day. But banks of it will persist just offshore, and wisps will scud by all day, just overhead.

The sea breeze gradually increases its vigor until by noon it is blowing at force 4 or 5 Beaufort. At first soil and sand are held in place by the dampness of the preceding night, but eventually they dry out and the finer particles are released, filling the air

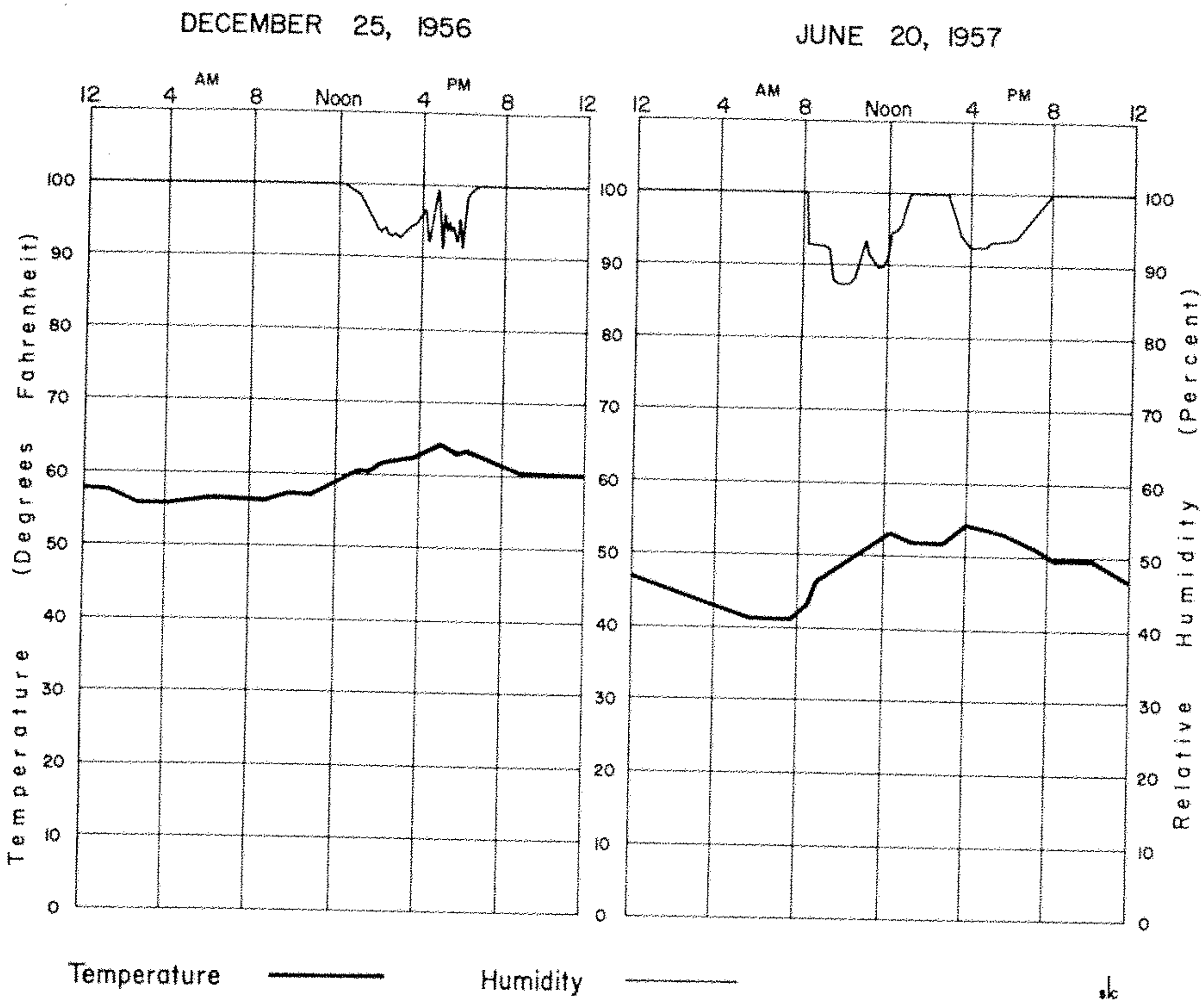

Fig. 3. Typical temperature and humidity patterns at Swakopmund.

with dust. Small ripples of sand blow across the ground and collect behind every obstacle.

With late afternoon, the insolational heating gradually decreases, the evaporative attack on the offshore fogbank lessens, and the wall of fog begins to creep shoreward, cutting off the sun from the shore. And so, just as there was no sunrise, so there will be no sunset: the sun merely disappears into the fogbanks, and much later, darkness comes on imperceptibly.

But the fog does not come in at sea level: the radiating warmth of lagoon, marsh, and sand keeps the air warm, and therefore clear, for a few feet above the surface. Once again one can look for miles up and down the coast under a gray roof of fog. Above the lagoons, the air chills rapidly. The shallow water, warm from the day's sun, gives off moisture more rapidly than the chilled air can absorb it, and so the lagoon *steams*, forming little waftings of fog that float off eastward on the declining sea breeze. Eventually, stored heat of pool and land is exhausted; with nothing left to keep the fog aloft, it settles down and blankets everything.

The Christmas Day trace for Rössing (Fig. 4) shows strikingly greater variation in both temperature and humidity than was recorded for Swakopmund. The air was saturated for fourteen hours but was markedly drier (to 37 per cent) in midday. The cause of the saturated condition is different from that at Swakopmund. The fog at the coast is advectional sea fog, blown in from the neighboring ocean. That at Rössing appears to be radiational fog resulting from pronounced nocturnal cooling. It will be noticed that the night temperatures at Rössing are well below those of the coast. Sea air drawn inland is warmed greatly during the daytime; but as night comes on, radiational cooling is strong, temperatures drop below the dewpoint, and condensation occurs, forming fog.

The rise in temperature at Rössing starts a little before the fog clears away, due to the penetration of shorter wavelengths of insolation through the fog and their absorption and re-radiation by the ground. Temperatures rise rapidly through the morning and cease abruptly at noon, when the advent of the sea breeze imports fresh, cool, sea air. The humidity curve drops spectacularly during the morning and rises with equal steepness in the early evening.

The sea air blowing inland across the Namib warms considerably by the time it reaches the Lintvelt station. There the mean maximum temperatures normally reach the mid-eighties, and even the strong nocturnal cooling does not depress them much below the minima of Swakopmund. The relative humidities are much lower than in the coastal area, moisture having been condensed in the form of dew in the radiation fog belt. Hence, when the temperature dropped to 58°F (Fig. 5), the humidity barely reached 60 per cent, whereas with the same temperature at Swakopmund (Fig. 3), 100 per cent humidity was reached. The inland area has a much higher diurnal temperature and humidity range than the coast, as well as lower humidity; the summer days are free of both clouds and fog.

The normal conditions of winter weather in the coastal area are little different from those of summer. The June 20 trace for Swakopmund (Fig. 3) indicates a daily range of 13°F contrasted with 9°F on Christmas. The period of unsaturated air was longer, occuring earlier and lasting later, and was slightly drier; but the differences are more academic than apparent.

An exception to these general conditions occurs, however, on the rare days when the Berg (mountain) Wind blows from the east. While the cause of this wind is in dispute, there is no doubt as to its existence, for it is notorious throughout the desert. It brings extremely high temperatures (with the result that the highest temperature of the year is usually recorded in winter) and very low humidity (Fig. 6). It also brings great clouds of dust and sand and makes life almost unbearable along the coast while it is blowing.

June 23, 1957, was a typical day at Rössing (Fig. 4). From midnight until morning the humidity was 100 per cent and the temperature descended ir-

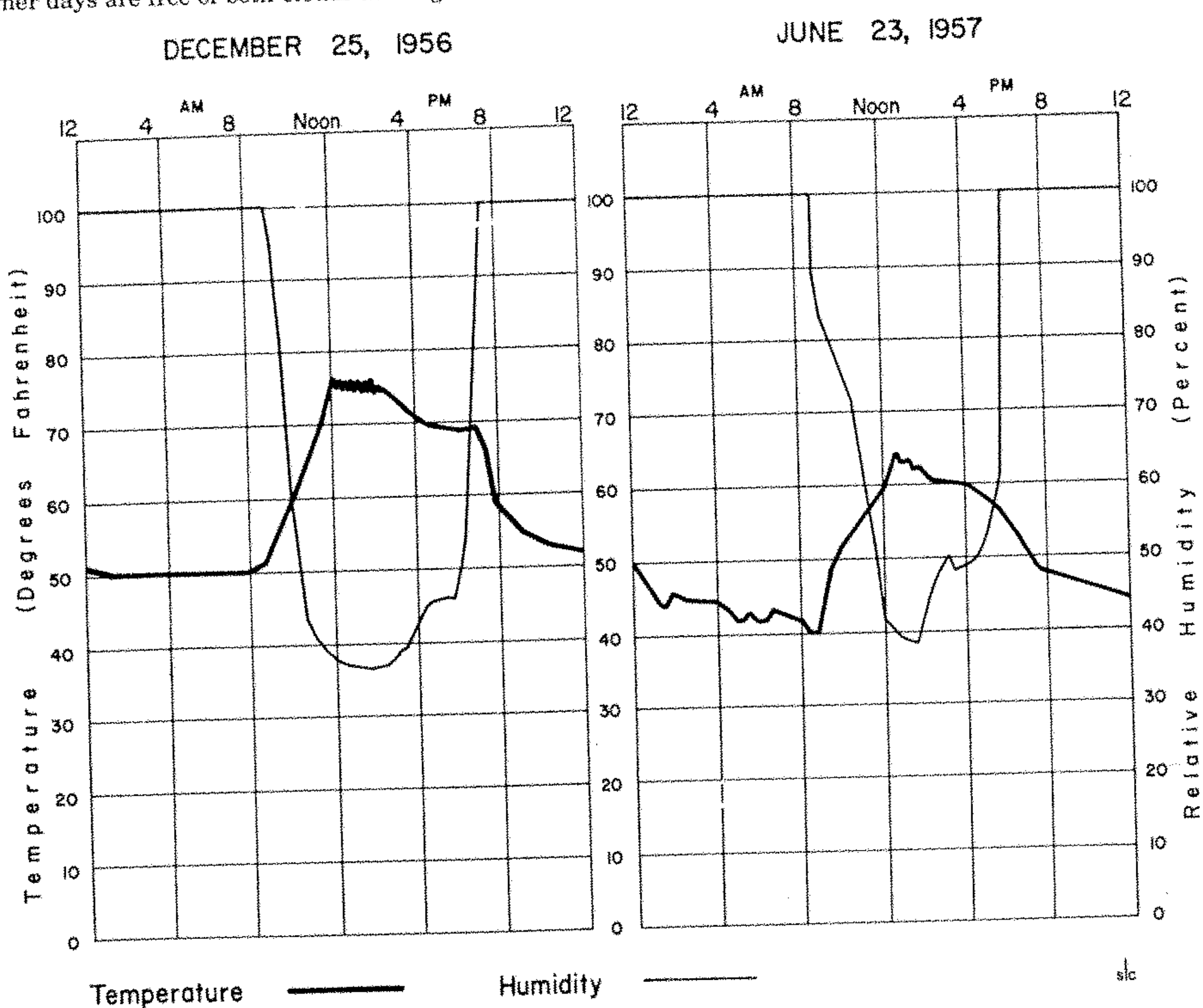

Fig. 4. Typical temperature and humidity patterns at Rössing.

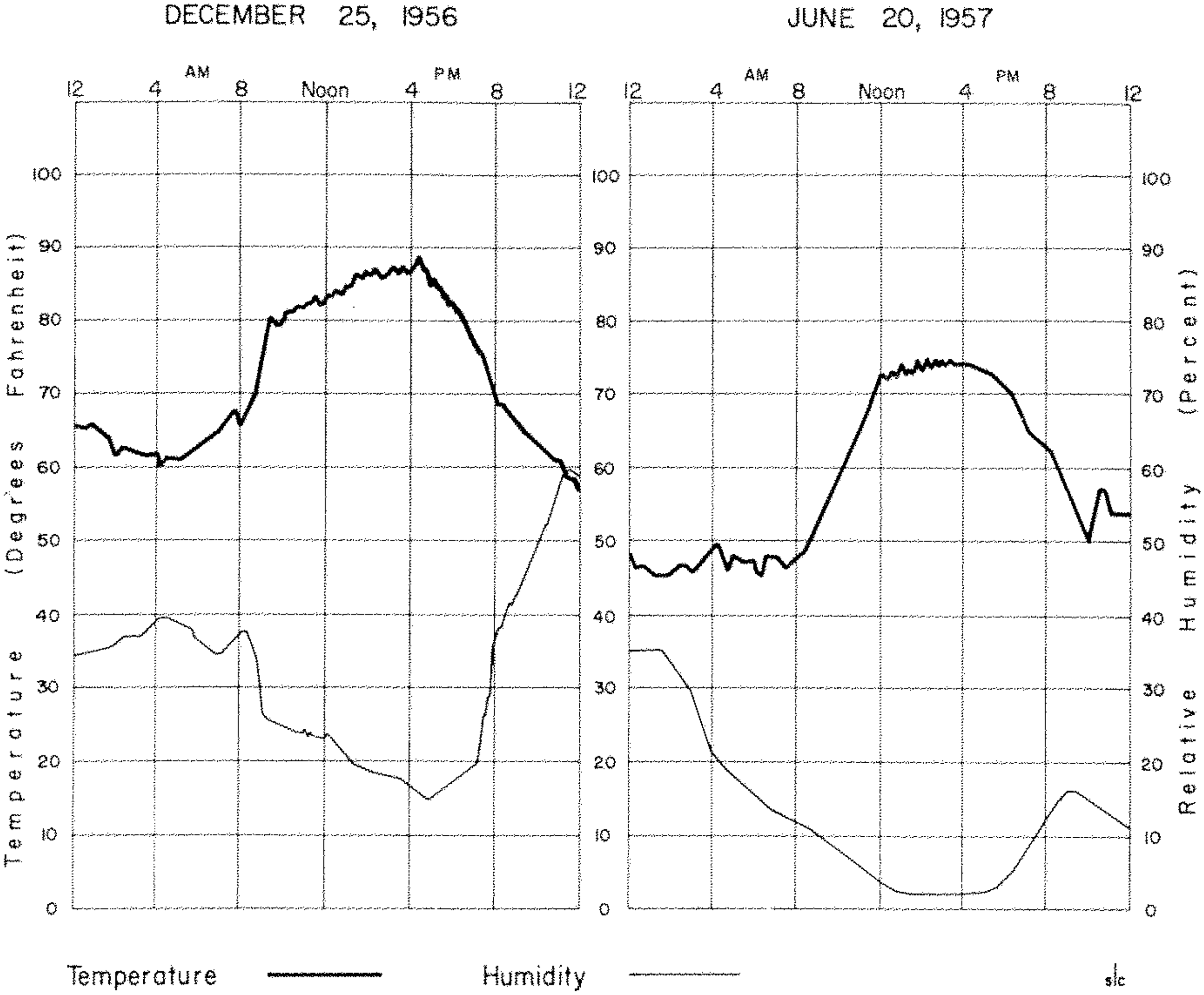

Fig. 5. Typical temperature and humidity patterns at Lintvelt.

regularly from 50° to 40°F. At 8:30 a.m., the humidity dropped spectacularly, reaching a minimum of 38 per cent at 1 p.m., and the temperature soared to 62°F. With sundown, the temperature dropped rapidly and the humidity rushed back to the saturation point. The fog here is, as in summer, radiation fog. But in contrast to the summer situation, there is no midday effect from the sea breeze, which does not penetrate strongly into the interior in the winter months.

June 20, 1957, provided a typical midwinter trace (Fig. 5) for the Lintvelt station. Thermometrically, the night hours showed a serrate trace, the result of local winds upsetting an inversion developed from terrestrial radiational cooling. Temperatures averaged in the middle forties. Temperatures rose strongly from 8 a.m. until noon, cresting in the middle seventies. Humidity was low throughout the period, ranging from a high of 35 per cent to a minimum of 2 per cent. Fog is almost unknown in the Inner Namib, where the winter is characterized by cool, brilliantly clear nights and sunny, very dry, warm, clear days.

GEOMORPHOLOGY

In the area under consideration here, the Namib is underlain by rocks of highly metamorphosed nature and of very great age, probably largely pre-Cambrian (*3*). The most widespread and the most characteristic, although not the most conspicuous, formation is a great mass of mica schist. Grading from almost pure biotite-muscovite schist to micaceous quartzite, these beds are found from sea level to the top of the Great Western Escarpment at an altitude of well over a mile. Although silvery-gray on close inspection when fresh, they commonly appear darker on weathering and make a dark and foreboding landscape. Over much of the Namib, they strike in a northeast-southwest direction. Certain more arenaceous members resist weathering and stand as ridges above troughs eroded in their weaker

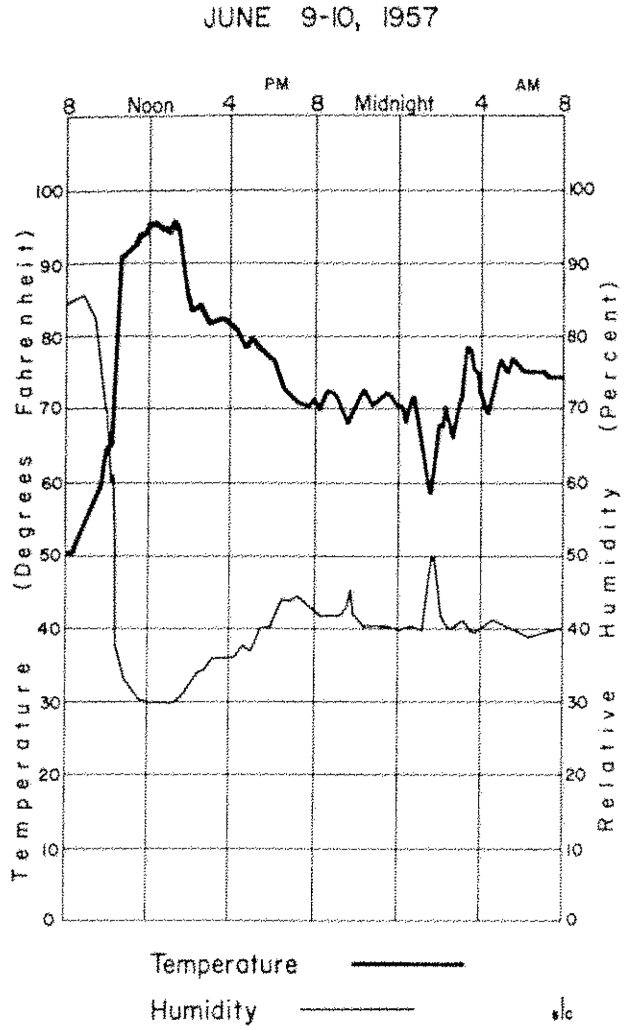

Fig. 6. Atypical temperature and humidity pattern at Swakopmund.

neighbors—giving the country a corrugated aspect of low relief. Other formations include bands of marbles, pristinely white and standing as conspicuous ridges, and quartzites, including pre-Cambrian tillites (*4*). Intruded into all of these are granites of indefinite age (*5*).

All of these formations have been beveled by an erosional surface whose origin has not been definitely determined. Earlier writers (*6*) pronounced it a surface of marine planation; later authorities have leaned toward sub-aerial agencies as the major causative factors. The present writer believes it to be a peneplain or a pediplain, basing that opinion on the presence of scattered unreduced remnants (monadnocks or inselberge) which rise above the general level, are more frequent toward the Escarpment, and bear no sign of marine erosion; the face of the Escarpment, which is a product of normal stream erosion, with the re-entrant valleys graded accordantly with the peneplain; and the fact that where marine erosion has occurred, in the last few miles seaward, its evidence is clear and unmistakable.

This surface, termed by the writer *the Namib Platform*, rises smoothly and gradually from the highest marine terrace to a 3,000-foot elevation at the foot of the Escarpment 80 miles inland, or at the rate of about 40 feet per mile. Marine terraces are well-developed along the coastal portion of the Platform in many places. Commonly the treads are well preserved and the intervening risers are but partly eroded. In many areas, the smoothness of the Platform has been reinforced by the deposition atop it of a gravel veneer, ranging in depth from a few inches to at least a few score feet. In such areas, the surface is extraordinarily monotonous. South of the Kuiseb River, the Platform is buried under a thick cover of sand. Carved into the surface of the Platform are the canyons of the three streams that make their way from the Escarpment across the Namib to the sea: the Kuiseb, the Swakop, and its tributary, the Khan.

REGIONAL SUBDIVISIONS OF THE CENTRAL NAMIB

The central Namib Desert can be easily divided into three segments: the Coastal Namib, the Dune Namib, and the Namib Platform (Fig. 2). The first is set apart on the basis of its distinctive climate, the other two on the nature of their landforms. Actually, the Coastal Namib is the seaward extension of the other two, but its climate is so strikingly different that it warrants separate treatment.

The Coastal Namib

The coast of South West Africa is one of the cruelest shorelines imaginable. It is devoid of drinkable water, uninhabited, bleak and barren, and endlessly pounded by a wild surf. It is a land of paradox. Rain almost never falls, yet the area is drenched in moisture. There is nothing to eat, yet the surface reveals myriads of tracks: of beetles, mice and lizards, jackals and antelopes, flamingoes and penguins. Here the hottest days come in winter, rain seldom falls but floods are violent, fog shrouds a parched land, and sterile sands conceal gravels rich in diamonds.

Within the area under study here, the coast consists of two major indentations closed or partly closed by sand spits, and a series of long beach ridges and barrier beaches separating elongated lagoons from the sea. The oblique breaking of the rollers from the southwest, combined with the steady southwest wind, tends to move water and sand northward along the coast. The effect has been to construct spits across the indentations, including a large one that has closed Sandwich Harbor almost completely since 1889, and another (Pelican Point) that forms the present (1968) harbor of Walvis Bay and is steadily building forward (northward).

While the foreshore is totally devoid of vegetation (aside from seaweed cast up by the surf), it is particularly rich in avifauna, a reflection of the abundance of fish in the adjacent sea. Flamingoes line the shore, fishing standing on spindly legs at the surf-edge. With them are snowy-white pelicans, with their great yellow beaks. Small strandlopers run in and out of the surf, stopping nervously to probe in the sand with their long, thin bills. Overhead fly flocks of cormorants, duikers, gannets, mews, gulls, and a variety of small sea birds. Small groups of penguins walk along the beaches in great solemnity. Jackals live in the dunes back of the beach and prey on the flamingoes, pulling them down at night as they sleep standing on one leg at the water's edge. Hyenas scavenge the beach at night, and seals bask on it in the sunny hours of the afternoon.

Back of the beach, a sand ridge has been accumulated by the waves and built higher by the wind into irregular dunes. Behind small mat-like bushes (notably *Arthraerua leubnitziae* and *Mesembryanthemum salicornioides*), elephant-head dunes up to 6 feet in height are seen. Where the orientation of the coast is favorable, larger dunes (to 40 feet) have developed. On them, four additional plants occur: two shrubby perennial grasses (*Aristida sabulicola* and *Eragrostis spinescens*) and two halophytic shrubs (*Salsola aphylla* and *S. nollothensis*). Amidst the dunes live the jackals, a little mouse (*Gerbillus swakopensis*), some lizards and scorpions.

The lagoon at Sandwich Harbor consists of a large expanse of open water with a level rising and falling with the tide, broad expanses of sand flats and bars, small areas of mud flats, and a large development of salt marsh. The latter results from deposition of fine silts by the tidal currents, sand blown from the adjacent beaches and dunes, decay of plants, and shells of mollusks, crustaceans, and other shellfish. Thus the marsh ranges from slick black organic mud to beds of sand and banks of shell. It is cut by a maze of channels that alternately flood and drain the marsh. Very low natural levees border the channels, preventing the interior areas between channels from draining, and thus creating stagnant pools with slimy mud bottoms. The vegetation is that of the typical coastal salt marsh the world over: thick-leaved, thick-stemmed, recumbent and sprawling succulents. The marsh swarms with birds and crustaceans, but mammalian fauna is virtually absent.

The mud flats of Sandwich and Walvis Bay are usually inundated during the higher high tides. While they have very low relief and are cut by only very shallow channels, they are pock-marked by low, ring-shaped mounds, from 1 to 10 feet in diameter and up to a foot in height. These are explosion craters from which hydrogen sulphide gas has erupted. Such eruptions occur along the central Namib coast at irregular intervals during the summer. They apparently result from the generation of gas through biochemical action in the thick mud deposits underlying the area, although the exact mechanism is not thoroughly understood (7). During such eruptions, great numbers of fish are killed, paint and silverware is discolored, and the odor is smelled for miles inland. The mud flats are totally devoid of vegetation but are extremely popular with many forms of bird life.

Between Sandwich Harbor and Walvis Bay, discontinuous chains of basins lie inland from the beach ridge, separated from each other by older, abandoned beach ridges. These basins are occupied by pans, which may take the forms of shallow semi-permanent salt lakes, or basins flooded at high tide, or salt flats dry at all seasons. Some can be traversed by a car at any time, while others are always morasses of slimy mud. Most are completely barren and have no regular animal inhabitants. Salt is commercially extracted on a fairly large scale from certain pans north of Swakopmund.

In the stretch of coast between Walvis Bay and Swakopmund, the waves beat against the feet of sand dunes that rise to heights of more than a hundred feet. The dunes (like those to be described in a later section) are vigorously active and pose a serious and endless problem to the railway line and highway that parallel the coast in this section. The position of the coastline here is apparently determined by the presence of bedrock that outcrops in a number of places and sometimes creates a rock-defended bench between the dunes and the sea.

The Kuiseb River, which rises in the plateau east of the Escarpment and flows across the Namib to the sea at Walvis Bay, has constructed an estuarine delta completely filling a former embayment of the coast. The stream flows on the surface only once in several years, but when it does, it flows with surprising volume and violence. Since its source and most of its course are in areas of mica-schist, it carries a great load of mud, and its delta consists chiefly of a clay plain. Across it the daily sea breeze blows an endless succession of small dunes, some of them barchans. These obstruct the flow of surface waters and create temporary stagnant ponds in flood years. Normally, the delta has a scanty cover of *Salsola* species, a few *Tamarix austroafricana*, and the import from South America, *Nicotiana glauca*.

The city of Walvis Bay is situated on the seaward edge of these deltal flats. Few places in the world have a more dismal and unprepossessing location than it: on a mud-flat in danger of inundation, plagued by drifting sand and sulphur eruptions, in a windy, foggy, rainless environment. Yet it is today a relatively attractive, prosperous, fast-growing, and forward-looking community.

Being vulnerable to flooding, the early homes were built on stilts. Today, an earth dike prevents inundation by deflecting the waters. A wind-obstruction fence has been built, creating a *municipal sand dune*, which halts the dunes that formerly migrated right through the town. The soils are heavily impregnated with salts, but homeowners grow attractive lawns and gardens in soil brought from the uplands over a hundred miles to the east. Water of excellent quality is brought by pipeline from the underflow of the Kuiseb. Some of the streets are tarred. Others are surfaced with a mixture of clay and salt from the nearby pans; at night the deliquescent salts absorb mositure from the fog, which binds the clay through the ensuing day.

Walvis Bay is the only harbor in South West Africa where full-sized freighters can come alongside a wharf. Before improvement, the bottom shoaled so gradually that the 18-foot depth curve was a mile from shore. The port handles most of the export-import trade of the Territory and is a major base for fisheries in the plankton-rich Benguela Current. Canneries line the shore-front; large tanks store fish oil; and acres of fish-meal stand out-of-doors, awaiting shipment.

Swakopmund, the only other town of the Central Namib, is situated on the coast just north of the mouth of the Swakop River. It is an old German town, the former port for the former German colony; and today it is the chief shore resort and summer capital of the Territory. From early December through February its hotels flourish, and a tent colony springs up on the beach as great numbers of people flock from the hot interior down to the cool coast. While formerly provided with highly saline water from the Swakop River, the city is now connected by pipeline to Walvis Bay and the Kuiseb River supply.

The town exhibits remarkable examples of German architecture: towers and turrets, half-timbering, balconies, and steep roofs. In its language, culture, architecture and ethnic composition, it is still thoroughly German.

The coast north of Swakopmund has undergone remarkable changes in the past decade. Long completely isolated and uninhabited, famed only for its shipwrecks (which earned it the name *Skeleton Coast*), it is today much in use. A road up the coast is graded and surfaced with salt and clay well beyond the limits of this study, and another road runs directly from Usakos west to the coast. Three communities have developed: Vineta, Wlotzka's Bakken, and Henty's Bay. The latter, near the mouth of the Omaruru River, has a good water supply from wells, and a store and a motel. All three communities have scattered buildings ranging from shacks to quite pretentious houses, much used in summer and on weekends by residents of the interior who come here to escape the heat, to rest, and to fish.

While there is no road along it, the coast south of Walvis Bay is much used by sports fishermen, many of them going all the way to Sandwich Harbor for their angling. The area is accessible with difficulty by Land Rover and other four-wheel-drive vehicles as far as Sandwich, but there are no habitations or occupants, other than one Coloured family living at Sandwich Harbor. Travel south of Sandwich is completely impossible both by edict (it is closed to entry because of possible diamond-bearing formations) and by trafficability (dunes that are practically impassable).

The main line of the South African Railways from Windhoek passes through Usakos to Swakopmund and on to its terminus at Walvis Bay. It uses diesel-electric engines and operates on a 3.5-foot gauge. A paved highway parallels the rail line, and graded roads run inland from Walvis Bay directly east to Windhoek, and southeast to the southern part of the Territory. A large airfield a few miles inland serves Walvis Bay, and there is regular air traffic to Windhoek.

The Dune Namib

Stretching as an unbroken sea from the Kuiseb River to Luderitz (250 miles) and from the surf of the Atlantic nearly to the Great Western Escarpment (50 to 80 miles) are the Great Sand Dunes. They rank among the great sand dune accumulations of the world, both in area and in height (in excess of 800 feet in some places). The dunes lie atop the Namib Platform, which shows through in a few places amidst the dunes.

The sand has been derived from the erosion of the plateau east of the Escarpment. It has been carried westward by streams that emerge from the Escarpment only to dwindle away and be lost by evaporation on the Namib Platform. The sand, left behind as the water disappears, becomes the plaything of the winds. The daily sea breeze carries it obliquely inland in a northeasterly direction; the rare but violent Berg Wind blows it directly seaward. The dunes lie in great irregular waves, aligned chiefly at right angles to the sea breeze, but the regularity of their crests is much interrupted, chiefly by breakthroughs caused by the Berg Winds.

The Dune Namib is bounded abruptly on the north by the Kuiseb River, which flows across the Namib Platform in a sharply incised gorge. Over a period of years, sand cascades down the steep south wall and encroaches on the channel. Then, in one of its violent floods, the river sweeps the sand away, and the process begins again. Only at its mouth, where the stream spreads out across the flats and loses its carrying power, are the dunes able to cross the Kuiseb and extend themselves northward to the Swakop River.

The dunes near the coast are yellow-white; inland they are deeply red. This would seem to indicate a greater degree of oxidation inland, and hence a greater age.

Near the coast the dunes are almost totally barren, with only an occasional narra bush *(Acanthosicyos horrida)* growing on small hummocks in hollows amidst the larger dunes. The narra is a leafless, thorny bush growing in a scraggly manner, looking more like a tangle of green barbed wire than a plant. Its melons bear an edible, almond-like seed, formerly an important food of the local Nama tribesmen, and today much used in the confectionery industry of the Cape. The red dunes of the interior have a scattered vegetation of bushes such as *Galenia* and a couple of shrub-like grasses: *Aristida sabulicola* and *Aristida namaquensis*.

The Dune Namib is totally uninhabited and totally unused.

The Namib Platform

The Namib Platform can be subdivided into a number of typical areas; inasmuch as there is a marked variation in climate between the Outer (more coastal) and Inner Namib, two variations for the same landscape type may sometimes be described.

Gravel Flats, Outer Namib

Great expanses of the Outer Namib are unbelievably flat, totally barren, and surfaced entirely with gravels. While the extent of individual units may be measured in tens of miles, their relief is measurable in inches per acre. While apparently flat, their surfaces actually slope up inland at the rate of about 40 feet per mile.

Normally, the surfaces have a slight to moderate development of desert pavement, with pebbles covering up to 50 per cent of the surface. The color of the landscape varies from gray-white to yellow. The surface is never cemented, but layers of lime or gypsum cementation occur at varying depths, and all areas investigated had some cementation in the upper two feet of soil, although it was universally weak. Gypsum is most frequent in the seaward portion. Its presence, in place of the more common calcium carbonate, is unusual. It has been proposed by Martin (*8*) that the carbonate radical has been replaced by the sulphate radical derived from the hydrogen sulphide of the submarine explosions, borne landward by the sea breeze and condensed out with the dew.

Vegetation consists of very widely scattered bushes of *Arthraerua leubnitziae* and *Zygophyllum stapffii*, none over two feet in height and each with a small elongated dune on its southwest side—product of the Berg Winds. The larger stones have coatings of lichens on their seaward faces but are bare on the eastern side.

It has often been stated that the curious plant, *Welwitschia mirabilis*, grows only on the gravel flats of the Outer Namib. Field work by the writer indicates that while the plant does grow in such areas, it is also to be found on rocky benches in the Swakop gorge, on very stony relict fans west of the Brandberg, and in the mopane *(Copaifera mopane)* steppes of the Petrified Forest area near Franzfontein. Often termed a *living fossil*, the *Welwitschia* is a gymnosperm. It has only two leaves, often over six feet in length, split longitudinally into numerous strips, and exhibiting in their leathery texture their extreme xeromorphism. The leaves grow out of the top of a huge woody trunk that protrudes only a few inches above the ground and has a depth of only two or three feet, yet has a diameter of at least two feet. Each plant is host to a number of brilliantly red-orange beetles that seem peculiar to only one plant species.

Gravel Flats, Inner Namib

The increased precipitation of the more inland portions of the Namib alters both the vegetation and the morphology of the flats. The flats apparently represent vast amounts of alluvium fluvially deposited in the past and since partially dissected. Over great areas the gravels have been strongly cemented by calcium carbonate. This cementation may represent the present situation in which occasional heavy rains saturate the gravels, dissolving the calcareous material, which is redeposited as a cementing agent upon the evaporation of the ground-water. But the writer feels that the present climate is not sufficiently moist for this; he believes that the present cementation reflects a former period of greater moisture.

In many areas the cementation occurs at the surface. Such areas are virtually devoid of vegetation except for widely scattered grasses on exceptionally rainy years. Lichens are totally absent, due to the absence of dew. Areas underlain by uncemented gravels support noticeably heavier growths of grass, especially *Aristida ciliata* and *Aristida obtusa*, which become heavier still in areas of sandy soils. But even the *heaviest* grass covers are very thin by humid land standards, shading less than 20 per cent of the total area in the best years and seldom exceeding two feet in height.

Lines of heavier vegetation, chiefly bushes such as *Lycium* sp. and *Acacia hebeclada*, growing to 10 feet in height, and widely scattered camelthorn trees, *Acacia giraffae*, reaching heights of 30 feet, mark the position of *omurambas*, or stream courses incised a few feet below the level of the gravel flats and carrying water from the face of the Escarpment or the plateaus at its top. Such streams run only a few hours a decade, but they apparently carry a moderate underflow at all seasons.

Granite Pediments

Over broad tracts, mass downwastage of granite has produced an almost featureless landscape with bedrock at the surface everywhere. Low mounds of bedrock, covered with exfoliating scales, protrude from beneath a thin mantle of *grus* (disintegrated granite), which masks the presence of bedrock in the intervening pockets. Unreduced remnants of various sizes rise a few feet above the common surface; most of them seem to be lithologic in origin: aplite or pegmatite dikes and quartz veins.

Most of the surface is undergoing continuous granular disintegration. On all exposed surfaces, individual grains and exfoliation sheets are only lightly attached and fall off at the touch of a finger, joining the adjacent accumulation of grus. Endless attack of the more exposed surfaces by granular disintegration and protection of other surfaces by a layer of grus results in the eventual attainment of a common level of surface – the pediment. Considering the immensity of such surfaces, the lack of precipitation and run-off, and the omnipresent evidence of the role of weathering and disintegration, it is quite apparent that lateral corrasion by streams, once theorized as the cause of pediments, could never produce such features, and that mass wastage through weathering is obviously the chief agent involved.

In the Outer Namib, vegetation is very sparse on the pediments – yet actually more plentiful than on the adjacent gravel surfaces. This is probably due to the facts that dew is more important than rain as a source of water, that dew condenses more readily on rock than on gravel, and that this water is stored in crevices in the rocks and remains available to shallow-rooted plants, but is lost through percolation in the gravels. Common shrubs are *Arthraerua leubnitziae, Zygophyllum stapffii,* and *Salsola aphylla.* Grass is completely lacking. In the Inner Namib, similar pediments support a thin phase of bush steppe, with *Barleria* spp., *Petalidium* sp., and *Boscia foetida* as the chief components, together with a thin growth of grass. The bushes are dwarfed (under one foot in height). In other areas, erect, 6-foot *Euphorbia gregaria* and recumbent *Aloe asperifolia* are major components.

Granite Inselberge

A few isolated knobs rise conspicuously above the pediments. Those of the Outer Namib have an abrupt angular contact with the pediment and are exfoliating, dome-shaped, granite masses. On their seaward faces, they are pitted with large cavernous recesses and myriads of small pits. The inland faces are not pitted; hence the pits are not sand-blast phenomena, since the chief abrasive aeolian action would be associated with the Berg Wind. It would appear that the pitting results from chemical action involving, perhaps, dew, sea-fog, salt and/or hydrogen sulphide from the eruptions. These inselberge are devoid of vegetation, except for the lichens that grow plentifully on the seaward faces.

Mica-schist Pediments

Over large areas of the Central Namib, steeply dipping beds of mica-schist have been truncated by erosion, producing what appears to be a pediment surface. The method of formation of such a surface is not easily explained. Granular disintegration is not possible, for the schist is not granular; hence mass wastage is unlikely. The writer has no ready explanation for these developments.

In some areas the schist is apparently homogeneous, and the surface is monotonously flat and featureless. Elsewhere, beds of ordinary mica schist alternate with a more arenaceous and hence more resistant variety. The latter forms low ridges, aligned in a northeast-southwest direction, making a corrugated country. The relief is small (in the neighborhood of 20 to 50 feet), but the ridges culminate in jagged crests and are steep enough to make travel even by jeep or Land Rover difficult and uncomfortable. In the coastwise portions, lichens grow on the seaward sides of rock outcrops. In the central portion, they are joined by a yellow matlike succulent, but together they cover less than one per cent of the surface. The lower areas between the ridges are veneered with materials washed and blown from the higher parts, especially quartz from inclusions in the schist. Such areas are totally devoid of vegetation. Some cementation by calcium carbonate occurs.

Rocky Ridges of the Outer and Central Namib

Occasional elongated rocky ridges rise conspicuously above the monotony of the Namid Platform. They break sharply with the surrounding flats, with very little slope wash or talus accumulation at their bases. Sandblasting is common on their lower northeastern sides, the result of Berg Winds, but sand accumulations are negligible.

The ridges of the more coastal section have a cover of lichens plastered over most of their southwestern faces. The ridges, composed of white limestone, usually have a number of species of plants growing on them. While actually sparse, this vegetation is relatively rich compared to the surrounding gravel flats. Included are such surprising plants as certain *Lithops* species, which look almost exactly like the pebbles amidst which they grow. Other succulents include *Trichocaulon dinteri, Aloe asperifolia, Hoodia curori,* and *Senecio longiflorum.* As mentioned before, the rocky areas are better suited to water accumulation and retention than are the surrounding areas; the white limestone ridges are perhaps especially so, since the light color makes for less heat absorption, a cooler condition, and hence a longer period of temperature below the condensation point of the surrounding air.

Rocky Ridges of the Inner Namib

The greater precipitation of the Inner Namib permits the development there of a much richer vegetation, both in number and sizes of individuals and in numbers of species. Most conspicuous are the sentinel-like *Aloe dichotoma*, standing erect and tall (to 8 or 10 feet), large cactiform *Euphorbia dinteri* (to 6 feet), *Croton* sp. (6 feet), and *Boscia albitrunca* (3 feet), together with two species of *Commiphora*, which while only 3 feet in height, have trunks 2 feet in diameter. Succulence is not as common a feature here as in the Outer Namib. Curiously interesting is *Myrothamnus flabellifolia*, known as Resurrection Plant because its seemingly dead foliage becomes green with reactivated chlorophyll soon after being moistened.

Exotic Stream Courses

Incised well below the level of the Namib Platform are the canyons of three streams (the Kuiseb, the Swakop, and the Khan) which rise in the rainier plateaus above the Escarpment and hence occasionally carry flood waters all the way to the sea. While the streams flow through an essentially rainless area, their sides are nonetheless dissected by streams of purely local origin—the result of once-in-a-decade downpours. In areas of softer and impervious sediments, the valley sides are eroded into an intense dissected belt with an intricate stream pattern, extremely rugged relief, and strikingly rugged landforms. Were the precipitation greater locally, the rejuvenation of these tributaries would have reduced the whole country to a dissected hill land. As it is, the degree of dissection that does exist is remarkable, considering the extreme aridity of the region. These dissected belts are totally devoid of vegetation.

On the other hand, the underflow of the major streams supports a relatively rich riparian growth, characterized by several trees and a number of bushes. The most common trees are *Acacia giraffae*, (camelthorn) growing to a height of 30 feet, and *Acacia albida* (anaboom), which grows even taller. *Euclea pseudebenis* and *Ficus damarensis* grow to heights of 20 feet. Bushes include *Lycium* sp. and *Tamarix austroafricana* and a brushlike grass, *Eragrostis spinescens*. This vegetation is totally different from that of the surrounding desert; it is composed of nonsucculent trees and bushes, growing far taller, larger, and more densely than anywhere in the surroundings—a response to the relatively humid edaphic environment.

VEGETATIVE SUMMARY

The Outer Namib is almost totally devoid of vegetation (*9*), particularly on the gravel flats, mica schist, and granite pediment areas. Rocky ridges condense and store some water from the fog, and thus support a slightly richer vegetation. Nearly all vegetation of the Outer Namib is succulent, whereas very few succulents grow in the Inner Namib. Lichens are common in the Outer Namib but not in the Inner, whereas grass is restricted to the Inner Namib. Arborescent riparian developments are common along the through-flowing streams.

ANIMAL LIFE

Both the Dune Namib and the Outer Namib Platform are quite devoid of higher forms of animal life. Certain lower forms are common, however: several types of beetles live in the dunes, lizards are surprisingly plentiful, a dune-dwelling snake (*Bitis peringueyi*) has developed a locomotion similar to that of the American sidewinder, and several types of smaller rodents are to be found (*10*).

The grassy plains of the Inner Namib are the home of great herds of herbivorous grazers—especially several species of antelope: gemsbok, springbok, steenbok, duiker and klipspringer. The first two normally travel in herds—up to a score for the first, and hundreds for the second. The others are more solitary. Zebras occur in large troops. Ostriches roam in flocks numbering in the scores. Several burrowing herbivores are found. Carnivores include several members of the cat family (including cheetah, leopard, and until recently, the lion), jackals, hyenas, the termite-eating aardvark, the mongoose, and a small fox.

The ease of accessibility of the area, especially since the development of the Land Rover and jeep, plus the role of hunting in the philosophy of the white South African, has resulted in a sharp reduction in the number of the larger animals through both unrestricted and illegal hunting. In an effort to stem this trend and to preserve the animals, most of the Central Namib has been proclaimed a game reserve, but there remains the major problem of effectively controlling so large an area.

HUMAN OCCUPANCE

Until a few decades ago, small wandering bands of Bushmen known as *Saan* hunted and gathered food over the wide expanses of the Namib. None remain today, they having been either exterminated by other groups (*11*) or merged into the almost unidentifiable mass of natives on certain reserves or within urban communities.

Along the banks of the Swakop and Kuiseb Rivers, small groups of Topnaar Hottentots (Namas) graze their flocks of goats on the riparian vegetation and gather narra seeds to sell to dealers in Walvis Bay. No attempt is made to irrigate, and no crops are raised, even though water is just below the surface and is lifted by hand to water the goats, and even though plenty of good land is available. Unfortunately, cultivation of the soil is not inherent in the philosophy of these people. The Namas have always been graziers and gatherers, and it would be difficult to change their way of life. Date palms, planted on the Kuiseb by an early German missionary, grow unattended; the Topnaars have made no effort to care for them or to plant them elsewhere, although it is quite likely that they would grow well along the Kuiseb and the Swakop across the full width of the Namib.

Several farms have been developed by Europeans along the lower Swakop River, with irrigation by pump from shallow wells. They are chiefly engaged in a small-scale garden type of production.

Despite the restricted size of their areas, it would seem that the stream valleys of the Namib afford greater potentialities than are now realized. Much more agriculture could be carried on, producing fresh vegetables and milk for the coastal towns and for ships calling at Walvis Bay, as well as dates, citrus, and other subtropical fruits. An overall plan for allocation of the rather limited water supply between the urban and port uses and the agricultural requirements would be necessary. Should agriculture be developed, the problem of providing for the Topnaars would also have to be solved.

The surfaces of the Outer Namib Platform, whether gravel, pediment or other, and of the Dune Namib, defy the imagination in regard to future developmental potentialities. Even if water from some inexpensive source (such as desalinization of sea water by solar or atomic power) were available, almost none of these would be useful agriculturally, due to their extreme porosity (sand dunes), gypsum or salt content (gravel flats), or lack of soil (pediments).

The Inner Namib alternates between being a sea of highly nutritious grasses and a vast barren waste, depending on the rainfall in the preceding several months. Until recently, the area was totally unoccupied, and only the game animals suffered from droughts. In the past two decades, however, the land in the more-humid interior of South West Africa has largely been settled by European graziers and their native herdsmen, and many would-be ranchers have looked with interest at the Namib borderlands. Seeing the lands in good years, covered with grass and game, the outsider fails to understand the total picture: that the game, being mobile, can range far afield in search of food in drought years, whereas his own domestic stock, confined by arbitrary property boundaries, will starve on his own farm. As a consequence, graziers during the late 1940s and early '50s settled too far westward into the desert borderlands and were badly hit by the droughts of the early '60s. Today, the last row or two of farms (*12*) should be, by administrative edict, taken back by the government and their areas added to the Game Reserve. No ranching activity should be permitted west of the foot of the Escarpment.

FUTURE OF THE NAMIB

Within the portion of the Namib under consideration here, extensive future mining developments seem relatively unlikely. Copper, tin, and other ores are produced sporadically at several places, but their production is not likely on a large and continuing scale. Diamonds are found both north and south of the area and conceivably might be found in the local gravels. Marble may be exploited for cement in the future. A search for petroleum goes on offshore, but there is little likelihood of its discovery on the mainland.

Grazing should be prohibited entirely, and agriculture will be restricted by nature to small-scale operations along the major stream valleys.

On the other hand, the coastal area will continue to develop in the same ways as at present. Assuming continuation of existing conditions, Walvis Bay will flourish and expand as the port for the Territory, as a fisheries and canning center, and as a growing industrial community. Its water supply is adequate for considerable growth and can be augmented by desalinized sea water if necessary.

Swakopmund will continue its role as summer capital and seaside resort of the Territory. Further development of recreation along the coast is to be expected. Touristic developments are not to be anticipated on any large scale; the area simply does not have anything that will attract visitors from afar.

While other desert areas of the world will no doubt develop industry based on the harnessing of solar energy, the fogginess of the coastal Namib will preclude or sharply limit such developments.

In summary, the Namib, in the foreseeable future and with the assumption that political situations remain relatively stable, will probably remain much as it is today, with a modest development based more on its position relative to the interior of the Territory than on any inherent basic resource (*13*).

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    Most aspects covered in the present paper have been discussed previously in greater detail in this monograph by the same writer.

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