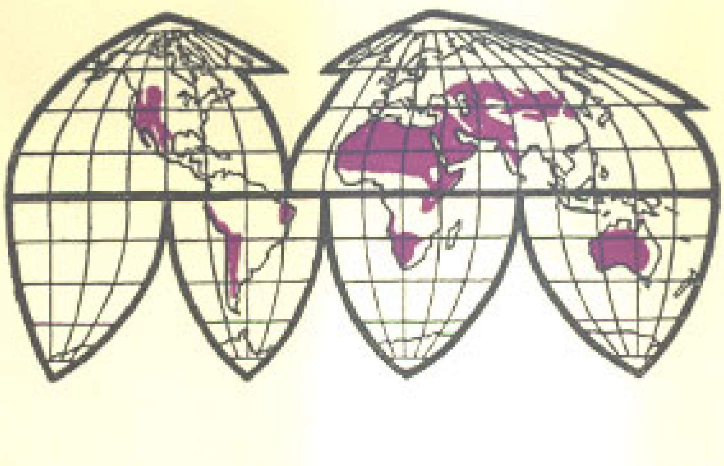
ARID ZONE RESEARCH

GEOGRAPHY OF COASTAL DESERTS

by Peveril Meigs



U N E S C O

ARID ZONE RESEARCH — XXVIII

GEOGRAPHY OF COASTAL DESERTS

Titles in this series:

- I. *Reviews of research on arid zone hydrology*
- II. *Proceedings of the Ankara Symposium on Arid Zone Hydrology*
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- XVII. *A history of land use in arid regions*
- XVIII. *The problems of the arid zone. Proceedings of the Paris symposium*
- XIX. *Nomades et nomadisme au Sahara*
- XX. *Changes of climate. Proceedings of the Rome symposium organized by Unesco and WMO*
- XXI. *Bioclimatic map of the Mediterranean zone. Explanatory notes*
- XXII. *Environmental physiology and psychology in arid conditions. Reviews of research*
- XXIII. *Agricultural planning and village community in Israel*
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- XXV. *Methodology of plant eco-physiology. Proceedings of the Montpellier symposium / Méthodologie de l'éco-physiologie végétale. Actes du colloque de Montpellier.*
- XXVI. *Land use in semi-arid Mediterranean climates / Utilisation des terres en climat semi-aride méditerranéen*
- XXVII. *Evaporation reduction*
- XXVIII. *Geography of coastal deserts*

The reviews of research are published with a yellow cover; the proceedings of the symposia with a grey cover.

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FOREWORD

The Arid Zone Programme first started by Unesco in 1949 was placed under the guidance of the Advisory Committee for Arid Zone Research when it was established in the spring of 1951 and, from 1957 to 1962, became one of the 'major projects' of the Organization. During that period it was possible to use additional funds and thereby to provide increased assistance to some research institutes and also to sponsor certain activities connected with the essential aims of the programme. Though that period is now over, the arid zone programme is nevertheless continuing as part of Unesco's scientific research activity concerning natural resources, and further works are being published in the Arid Zone Research series. This series comprises at present twenty-seven volumes dealing either with reviews of research on various special subjects such as hydrology, plant ecology, utilization of saline water, human and animal ecology, climatology, etc., or with the proceedings of symposia organized by Unesco on these same subjects as part of the arid zone programme.

The International Geographical Union and the Advisory Committee for Arid Zone Research have both expressed particular interest in the coastal deserts of the world. In view of the fact that a large amount of air moisture is brought to these regions from the sea and since it will probably be possible in the near future to use demineralized sea-water for domestic and industrial purposes, they offer special characteristics and potential economic interest which led the Advisory Committee to recommend that a study, as comprehensive as possible, be made. The task was entrusted to Dr. Peveril Meigs, chairman of the Arid Zone Commission of the International Geographical Union. His work is now completed and presented in the following pages.

In offering this volume to readers particularly interested in the problems of the arid zones, Unesco wishes to thank Dr. Peveril Meigs—whose well-known homoclimatic maps of the arid zones were published by Unesco in 1952—for adding this interesting survey of coastal deserts to the Arid Zone Research series. It should not need particular emphasis that the points of view, selection of material and opinions expressed in this volume are those of the author. References to geographical names or political frontiers do not imply any recognition on the part of the Organization.

CONTENTS

INTRODUCTION

Several years ago I was commissioned by Unesco to make a study of the geographic potentiality of the world's coastal deserts, as part of the programme sponsored by the Unesco Advisory Committee on Arid Zone Research. After many delays, some of them unavoidable and all attributable to me alone, the present report has emerged. This project, significant in itself as dealing with a distinctive segment of reality, is also related to other Unesco projects. The desalinification of sea water, for example, has been the subject of several studies by Unesco and various national agencies. Should cheap means be developed for extracting fresh water from sea water, the impact could be expected to be felt most strongly and immediately in coastal areas of deficient water supply. For domestic and industrial purposes, the large-scale distillation of sea water has already developed to the point where towns and industries with thousands of people depend entirely upon such supplies in coastal deserts, notably along the Persian Gulf and the Red Sea. Such a source of water greatly simplifies the exploitation of mineral, industrial, and commercial potentialities. The costs have not yet been reduced to the point where distilled sea water can be used economically for agriculture.

The magnitude of the present project can be appreciated when it is realized that the deserts of the world come down to the sea coast for a total distance of about 18,500 miles, with the greatest variety of physical and cultural conditions represented. For great stretches, little information is available and when available is not focused upon the strip with which we are concerned. Geographic potentiality is construed as meaning the total natural environment and the possible uses to which it can be put. As an indication of potentiality, a summary of present uses is required too. In attacking the problem, I have tried in Part Two to give at least a brief sketch of the main natural characteristics and types of land use for each sector of the coast. In addition, I have assembled detailed data on two simple aspects of the natural resource base: the climate and the terrain, in terms comparable from one desert to another. Climatic details are given in the text, in profile graphs, and in tables with detailed climatic statistics by months for about 200 weather stations. Terrain is discussed in the text, and one element pertinent to the present study is shown on the sector maps: the extent of lowland adjoining the coast. On most of the maps, the areas below 200 m. (656 ft.) are indicated. Under present engineering costs, it would be entirely uneconomical to raise water from sea level to 200 m., even if the water could first be made suitable for use. Yet the 200 m. contour was used because of its wide availability, and because it does provide at least some clue to the comparative extent of lowland near the sea. It can be said that roughly half as much land lies below 100 m. as below 200. The distribution of lowlands, the approximate limit of the continental shelf at sea, and the location of all climatic stations referred to in text and tables are represented on fourteen maps on a scale of about 1:8,000,000, drawn for this report.

Part One deals with general aspects of the coastal desert problems. Only the outlines of the problems have been sketched and mention has been made of some highlights of local situations that have a bearing on other areas.

This report does not try to present a complete, detailed picture of all or any coastal deserts. It does present a broad view of world distribution and types of coastal deserts, points out ways in which the potentialities of coastal deserts are being utilized in certain representative localities, calls attention to some of the areas of inadequately used potential, and lists some of the sources of further information. The references make no pretence at completeness. Any one of the thirty-seven coastal deserts is worthy of a large monograph itself.

In assembling data, I have depended chiefly upon the basic research monographs of the Unesco Arid Zone programme; the Harvard University libraries; the Thornthwaite Laboratory of Climatology, Elmer, New

Jersey; the library of the American Geographical Society in New York; my own files; and such current material as could be obtained through correspondence. I wish to thank the many individuals and government agencies who supplied materials from the four corners of the earth, sometimes involving large amounts of unpublished data. I express appreciation of the support and interest of Unesco and the International Geographical Union that made it possible to undertake and execute the project.

PEVERIL MEIGS
Chairman, Commission on the Arid Zone,
International Geographical Union

PART ONE

General aspects

THE DISTINCTIVENESS OF COASTAL DESERTS

Coastal deserts share many features common to all deserts. Rainfall is as low as anywhere on earth, and as a result fresh water is lacking most of the time except when brought from a more humid region through river or underground flow. Dry stream channels (wadis, arroyos) may be filled to flood levels at long intervals by run-off from the few rainstorms. Vegetation is sparse or lacking, except for ephemeral plants that spring up after a rain, phreatophytes with long roots where the ground water is near the surface, or woody shrubs in localities where run-off concentrates near the base of slopes. Lacking a protective cover of plants, the earth is exposed to the action of sun and wind. In some places the surface has been swept clear of loose sand and silt, leaving a pavement of bare rock (hammada) or loose stones (reg, or serir). In others, the sand has been piled by the wind into sand dunes. The soils, where they are not merely stones or sand dunes, often suffer from a concentration of salts. Poorly drained depressions (sebkhas, salt pans, playas) are common, where water may accumulate after rains to form temporary or even permanent lakes which never fill sufficiently to have an outlet, and consequently are highly saline.

Problems of land utilization also resemble those of other deserts. Agriculture can be carried on only by means of irrigation, and is confronted by problems of alkaline soil. Grazing, if possible at all, is meagre, depending chiefly upon erratic rainstorms for temporary forage (acheb), leaves of phreatophytic trees and shrubs, or slope-foot run-off brush. Lack of wells proscribes use of some areas, even where there might be enough forage to justify grazing. Mineral wealth, if sufficiently rich, may induce settlement despite the need for costly measures to provide fresh water.

The justification for dealing with the coastal deserts as a separate category, however, lies in the fact that they have certain distinctive qualities not shared by inland deserts. These unique qualities are related to the proximity of the sea. The climate over the land is modified by the adjacent sea. Places near the coast have smaller temperature differences between night and day, and between winter and summer, than those farther inland, because water heats and cools much more slowly than land. Along some of the west coast deserts the coast is so much cooler than the interior in summer that crop possibilities are affected: dates for example do not receive enough heat for proper growth near the west coast of the Sahara. Where there is strong on-shore wind, as on the west coast deserts outside of the tropics, the sea effect is naturally much greater than where winds blow from the land, though on nearly all coasts there is a tendency for a sea breeze to spring up during the day and give some relief from the heat for a few miles inland. Similarly, atmospheric humidity, fog, and dew are more common along the coast than inland. In some cases this non-pluvial moisture is sufficient to support some plants that could not grow in drier, hotter areas, and may permit better grazing near the coast.

One great category of resources of the coastal deserts is totally lacking in most interior deserts: the resources of the sea itself. In traversing the desert coasts one is impressed by the ubiquity of the small fisherman, and the fair abundance of large-scale fishing. The very earliest inhabitants of some of these areas were the clam-diggers and other gatherers of shellfish: an economic type requiring in its simplest form but little skill or capital. The gathering of pearls and mother-of-pearl represents a shellfish industry more dependent upon outside markets and fashions, and one still important for the Arab fishermen of the Persian Gulf and Red Sea, and the people of north-western Australia. The spongers of northern Libya represent still another group of desert fishermen. Seaweed, which has been used for centuries in some of the humid countries, appears to be an almost unused resource of the coastal deserts. Salt, obtained by evaporation of sea water, has been an important exploited resource of many coastal deserts from early times to the present. The sea water itself is a resource just beginning to be used as methods of desalting have been developed. The great reservoir of wave and tidal power has been tapped only in small, scattered establishments.

The accessibility of the coastal deserts to the ocean trade lanes of the world is not the least of their resource potentialities. Cross-roads locations on relatively sheltered coasts have been most affected by the sea trade factor. The Red Sea, between Egypt or Rome on the one hand and India and the Incense Coast on the other, has an ancient history of busy ports. The Persian Gulf mouth, the Makran coast, and the Mediterranean coast of Egypt and Libya, are other examples of great ancient trading areas. On the other hand, people of coasts on the open ocean not lying between natural trade centres find that the sea is a barrier rather than a highway. The Atlantic end of the Sahara has no history of flourishing mercantilism like that of the Red Sea end, nor have the Atacama, Namib, Baja California, and west Australian deserts. For bulk traffic, caravan routes cannot compete with sea routes. When the Portuguese first opened up sea contacts with the Sudan in the fifteenth century, the trans-Saharan caravan trade declined seriously.

In climate as in trade there are disadvantages as well as advantages in the coastal location. Counterbalancing the refreshing character of the sea breeze is the extremely enervating hot humidity that gives some of the ports of the Red Sea and the Persian Gulf their reputations as having the 'worst' climate on earth. Indeed, the highest absolute humidities or vapour pressures ever recorded in Nature are those of the hot desert coasts of the Middle East. Even the accessibility of the coasts has been a drawback in certain periods of history when pirates spread fear among the coastal dwellers. For better or for worse, the coastal deserts are quite distinct from the inland ones in character and in potentialities for development.

THE LIMITS OF COASTAL DESERTS

The problem of delimiting coastal deserts is twofold: where do these deserts end along the coast, and how wide are they transverse to the coast ?

Most coastal deserts are fringes of inland deserts. Their ends along the coast, therefore, are based upon their essential desertic qualities, and the same definitions used for deserts in general can be applied to the termini of the coastal phases. Because of the world-wide comparability of climatic data, climatic definitions will be here used as the primary basis for determining the coastwise ends of the desert. The definition of 'arid' used on world homoclimatic maps in an earlier Unesco study (Meigs, 1953)[1] based upon Thornthwaite's system, will be used here: that is, a moisture index of —40 will be considered to mark the end of the coastal deserts.

An additional subdivision of the arid climates will be introduced here, to be called 'semi-desert' (A), to include the area with moisture index between —40 and —50. The addition of the semi-desert type results from realization that there is a transition belt which is more desertic than the semi-arid steppes yet does have enough rainfall to support a fairly dense growth of desert shrubs, and is not considered to be desert by its inhabitants. Beyond the semi-desert along the coasts is the semi-arid climate (S), with moisture index above —40.

In the present study, moisture indexes for some stations have been derived through the use of a simpler evapotranspiration formula developed by Khosla (1949) instead of the complex one used by Thornthwaite. The resulting values are nearly or quite identical.[2]

It is proposed to modify the definition of extreme arid (or extreme desert) from the one used on the homoclimatic maps by dropping the requirement for absence of seasonality of precipitation. Along the Red Sea and in the coastal desert of Peru, for example, it was found that some of the extremely dry areas had their very limited rainfall concentrated in a definite season, when it rained at all.

As a rough guide it can be stated that the terminus (—40 moisture index) of the coldest type of coastal desert, that of Patagonia, is marked at the cold end by a precipitation of approximately 8 to 10 in.; the Mediterranean type of desert, with winter rain, by 12 to 14 in.; and the hot tropical deserts by about 16 to 20 in., or even more in the most equatorward of these deserts in southern Somaliland.

The mapping of deserts is complicated by the long distances between climatological observation stations. The Red Sea, south-western Africa, and Baja California all have stretches of coast 400 to 600 miles long without a single station. Furthermore, mapping of vegetation has usually been carried out with insufficient detail in such areas to permit precise distinctions to be made. Best coverage is ordinarily near the ends of the deserts, where rainfall is greater and population is denser.

The transverse dimension of the coastal deserts is more difficult to determine, in most parts of the world, than the lengthwise dimension. No moisture index can be used because the coastal and inland deserts may be

1. The bibliography starts on page 134. References in Part One are to be found in the 'General' section.
2. Khosla's formula for determining evapotranspiration is as follows:

$$L_m = \frac{T_m - 32}{9.5}$$

where L_m is the monthly water loss or evapotranspiration in inches and T_m is the mean monthly temperature in °F. This formula is to be used where T_m is greater than 40° F. Where T_m is less than 40° F., the loss (L_m) is as follows:

T_m	40° F.	30° F.	20° F.	10° F.	0° F.
L_m	0.84 in.	0.70 in.	0.60 in.	0.50 in.	0.40 in.

The value so obtained is then used as in Thornthwaite's system to determine the moisture index.

equally arid. Just how wide is the 'littoral'[1] or coastal strip ?

Some writers have limited it to the narrow strip of coast within reach of salt spray, a few hundred yards wide. Capot-Rey (1953, p. 376) considers the Atlantic Sahara, subject to significantly large amounts of dew and cloud from the sea, to extend inland about 185 miles. Specialized fields of research have come up with their own answers. One physical geographer defined the 'coastal region' as the area between the highest Quaternary marine forms and the outermost Quaternary action of the surf (Valentin, 1952). Such a definition is significant, as the Quaternary plains and terraces are vital sites for development of agriculture, but it makes no allowance for the older geological features that border some coasts, or for the Quaternary plains that extend inland far beyond present-day coastal influences.

From the over-all geographic viewpoint, the criterion for mapping the littoral must include the relationships to present-day coastal influences and some bearing upon actual and potential utilization by man. Sometimes a single factor, such as terrain or climate, can be used to mark off the littoral. Where a narrow lowland along the coast is shut off from the interior by a steep barrier of mountains, as along the Red Sea, the south-western African coast, or the west coast of the Gulf of California, there is no problem. Where a broad plain stretches inland from the coast, there may be no physiographic limit to the littoral, and we must depend upon climate or vegetation for clues. Vegetation mapped on a physiognomic basis, reflecting both climatic and edaphic factors, would provide perhaps the best single basis for delimiting the littorals. The distribution of certain lichens or other plants dependent upon moist air might be as good an indicator as anything. Unfortunately, mapping of vegetation has been too incomplete and generalized in most of the coastal deserts to serve the purpose. It is hoped that the publications of Unesco on the plant ecology of the arid zone will partially fill the gap by bringing together the scattered material available. In the meantime, general world maps of vegetation, such as those of Küchler (no date) give some guidance in certain parts of the earth.

Climatic data for littorals are sparse and poorly distributed. Best coverage is available for the immediate coast, where ports have attracted settlement. Back from the coast there are few stations, and a really adequate climatic cross-section does not exist for any desert littoral in the world. In a few areas, particularly where large rivers have brought together deltaic soil, abundant water supplies, and people, it has been possible to piece together three, or in the Nile delta, more stations at different distances from the coast, for temperature and certain climatic elements. For some of these rare localities, cross-sectional graphs have been drawn, following a technique suggested by Leighly (1947). These graphs have been inserted in Part Two with the corresponding texts for the different coastal sectors.

A careful study of the temperature graphs sheds much light on the character of marine influences. For all localities, the seaward ends of the curves are profoundly affected by the temperature of the adjacent sea. Daily maximum temperatures rise rapidly inland, especially during the hot season, when contrasts in heating are great. Minimum temperatures ordinarily drop slightly inland or show little change, in part because the local pressure differences result in a tendency for breezes to blow from the land towards the sea at night, thus minimizing the sea influence, and in part because normal night radiation cools the land until it is as cool as the sea. The coastal deserts bordered by cold ocean currents and having on-shore winds show the greatest contrasts between maximum temperatures of the coast and the interior during the hot season, as is strikingly shown by the January curve on the graph for south-western Africa. The effects of land breeze in flattening out the temperature curves is apparent in the winter curves for south-western Africa and Pakistan. In Pakistan the north-east monsoon heightens the effect.

As one goes inland from the sea, temperatures at first change rapidly, then gradually level off to approximate uniformity. The point where the curve becomes a straight line on the graphs might be regarded as the inner limit of coastal influence on temperature. From the few samples available, this point, for daily maximum temperature, lies about 50 to 100 miles from the coast. Half the change occurs within about 5 to 20 miles of the coast, and two-thirds of the change is within 15 to 30 miles of the coast. In winter the zone of coastal temperature influence is narrower than in summer. For an extremely rough generalization, one could say that the coastal zone of temperature, if we use the two-thirds change as the basis, is about 25 miles wide. It may be anywhere from twice to one-half that wide, depending upon local conditions. Each coastal sector must be analysed separately. Actually there is of course a gradual transition rather than a sharp line of demarcation.

In regard to other climatic elements, the situation is equally indefinite. The local distribution of rainfall, for example, has little relation to nearness to the sea. In the Nile delta rainfall is greatest near the coast because of broad air mass conditions rather than of distribution of land and sea. Where the coastal deserts are backed by mountains, as in south-western Africa and western North and South America, rainfall increases inland. On west-coast deserts, fogs and cloudiness are much greater

1. The term 'littoral' is here used, in accordance with common geographic practice, to denote the strip of land parallel to the coast and with pronounced coastal affinities. The term is used in a slightly different sense by individuals in other fields. Some oceanographers and biologists, for example, reserve the term either for the shallow waters of the continental shelf to depths of about 200 metres or for the narrow belt of seashore between high-tide and low-tide levels.

near the coast than inland. Humidity does decrease away from the source of water. Some measure of absolute humidity, such as vapour pressure or dew-point, gives much more useful results than relative humidity, because the latter is so closely dependent upon temperature conditions. This is well illustrated by the graphs of vapour pressure and relative humidity in the Nile delta (Fig. 5c). Dew measurements, if they were available, would be expected to show significant decreases inland. Sea fog is highly significant in some west-coast deserts, but few records of this element are available for inland stations.

Vegetational mapping in sufficient detail to distinguish the littoral is badly needed. The marine effects upon plants appear to be greatest on the west-coast deserts. On most of the hot east-coast deserts the differences appear to be too slight to have been noted. The preliminary generalized mapping that has been done (discussed in the individual sectors) suggests that there is a belt about 25 to 50 miles wide along the west-coast deserts of Africa and America where distinctive vegetation flourishes, related to the heavy fog, dew, and cloudiness.

CLASSIFICATION OF COASTAL DESERTS

Climate is the most suitable world-wide basis for a comparative classification of coastal deserts. Given the desert character of all the lands involved here, the most significant climatic differences, from the viewpoint of utilization, are those of temperature, since agriculture is dependent upon irrigation rather than rainfall. On the basis of temperature, the deserts fall into two broad categories: tropical and temperate. Except in South America, the Tropics of Cancer and Capricorn lie rather close to the divisions between these two categories. The temperate deserts have a cool season, while in the tropical deserts the mean temperature of even the coldest month is above 68° F.

The tropical deserts are of two chief types: the *extreme* or east-coast type, with temperatures of the warmest month averaging above 86° F., and the *modified* or west-coast type, with temperature of the warmest month averaging below 86° F. The extreme type is the more widely distributed, centring chiefly along the coasts of the east African horn, southern Red Sea, and south coast of Arabia. It exists also inland from the modified tropical type. The latter type occurs in small sections of the coast between the equator and the west-coast temperate deserts.

There are five principal types of temperate deserts: the *hot summer* type, with mean temperature of the warmest month above 86° F. as along the Persian Gulf, north Arabian Sea, northern Red Sea, and Gulf of California; the *monsoon type*, with summer rain and spring temperature maximum; the *Mediterranean type*, with warm sunny summers and mild winters, as developed along the desert shores of the Mediterranean, the western Sahara, and western Australia; the *fog type*, or extreme west coast desert, with no really warm season, and an abundance of fog or low overcast, characteristic of the west coasts of South America, south-western Africa, and Baja California; and the *Patagonian type*, with chilly winters and mild summers.

The tropical deserts are rendered still more uncomfortable by reason of the fact that most of the little rain that falls comes during the hottest season. In the temperate deserts, winter is usually the season of rain, though the monsoon subdivision of India and Pakistan is a notable exception to this rule. In the system of notation used in the Unesco arid homoclimatic maps (Meigs, 1953), the coastal portions of which apply to the present study, '*a*' denotes no distinct seasonal concentration of precipitation, 'b', summer precipitation, if any; 'c', winter precipitation. The summer precipitation is derived primarily from tropical storms or convectional thunderstorms, while the winter precipitation is of frontal origin, associated with middle latitude air masses.

Temperatures are indicated in this classification by the following numbers:

Symbol	*Mean temperature of month*
0	Below 0° C. (32° F.)
1	Between 0° and 10° C. (32°- 50° F.)
2	Between 10° and 20° C. (50°- 68° F.)
3	Between 20° and 30° C. (68°- 86° F.)
4	Between 30° and 40° C. (86°-104° F.)

The first of a pair of numbers denotes the temperature of the coldest month, the second the temperature of the warmest month.

Finally, to complete the system used in the Unesco homoclimatic maps, the degree of aridity is shown as follows:

Name	*Symbol*	*Moisture index* (Thornthwaite, Khosla)
Extreme arid	E	−57 to −60
Desert (arid)	A	−40 to −57

Thus, Ac24 denotes desert climate with rain, if any, in winter, the coldest month between 10° and 20° C. (50°-68° F.) mean temperature, and the warmest month between 20° and 30° C. (68-86° F.). The main types of coastal desert climate, with the symbols used to describe them, ignoring the matter of degree of dryness, are as follows:

Type	*Symbols*
Extreme tropical desert	a34, b34
Modified tropical	b33
Hot summer temperate	c24
Monsoon temperate	b24
Mediterranean temperate	c23
Fog temperate	c22, c23
Patagonian temperate	a12, a13

The most favourable climate is useless for agriculture in the deserts unless there are land configuration and soil suitable for crops and water to irrigate them. In studying the potentialities of the individual coastal sectors, the edaphic or land element must therefore be considered too. Most agriculture is practised on flat or gently sloping land. It is the width of the coastal lowlands, therefore, and the nature of their water resource, that will be used as the basis for a broad edaphic classification of the coastal deserts.

The coastal lowlands are of three main types: (1) narrow plain at foot of mountains or plateaux; (2) broad plain not restricted by highlands; (3) delta. Type 1, the commonest type of desert littoral, includes narrow marine terraces or plains, expanded here and there by alluvial fans and small deltas deposited by streams or wadis in time of flood. Where this type lies at the foot of mountains of heavy rainfall or snowfall, the streams may provide enough water to support intensive oasis culture, as in western Peru, and isolated spots elsewhere. Even where surface stream water does not reach the littoral, it may percolate through the sandy floor of the wadis and be available by means of wells. This type of littoral has potentialities for development through the action of individuals or small groups with a minimum of governmental assistance, through well-drilling or small stream diversion projects.

Type 2, represented by the broad plains along the western shore of the Persian Gulf, Somaliland, the Mediterranean shores of the Sahara, Mauritania, western Australia, and parts of the west coast of Mexico, has the vast expanses of unused lands that would be most benefited by the development of cheap methods of purifying sea water for irrigation. At present, development has occurred in these areas mostly where artesian water has been available, notably in southern Tunisia. Type 3, the deltas, contains the chief populations of the coastal deserts today. The deltas of the Nile, the Shatt-el-Arab, and the Indus have been developed to some extent since earliest historical times from the water brought from distant mountains by the giant rivers. Large-scale social action is necessary to control the annual floods of such rivers sufficiently for maximum safe development of agriculture. Such action has long been recognized as one of the main functions of the Government of Egypt, and has made of the Nile valley and delta a world example of river control. Even the Nile delta has large tracts of under-utilized land, in the form of marshes and lagoons, and there is a never-ending programme of reclamation. In Iraq, where the rivers sometimes go completely out of control, as in the spring of 1954, there are broad plans for reclamation. In Pakistan, which has the least-developed of the three big deltas, construction of the giant Kotri Barrage to develop the lower delta was begun in 1949, and will now have all but the outermost part of the delta under full control.

Our knowledge of the elementary physical facts about most coastal deserts is fragmentary. For many but not most of the coastal areas, large-scale topographic maps are available for detailed analysis and planning. There is great need for additional such maps, and for detailed soil surveys of type areas, both those successfully developed and those with potentialities of development. There is vital need, too, for estimates of the volume of water that would be available, through floods, springs, and ground water, at various sites. Almost nothing is known of the amount of water sent to the sea in the occasional wadi floods, for example. Such information ordinarily requires several years of field measurements for its determination, but it is possible to make intelligent estimates of the extent of floods through field observation of terrain indicators.

One aspect of the terrain that gives special attraction to limited localities on the coast consists of natural corridors to centres of importance in the interior. Jidda is important not because of any attraction of the coast itself, but because behind it there is a natural break in the mountains leading to Mecca, the goal of Moslem pilgrims the world over. Port Sudan has a similar position as the main economic outlet of the entire Sudan.

Then there are the water-route bottlenecks that have been responsible for the growth of Suez, Aden, and the Hormuz complex in forbidding desert areas. Indeed, any attempt at a 'complete' system of coastal desert classification would be so complicated that one might as well fall back on a sector-by-sector analysis.

POTENTIAL USES OF COASTAL DESERTS

The coastal deserts of the world are, as they always have been, uninhabited or sparsely inhabited stretches of land, punctuated by spots of intense settlement. The settlements have been limited to localities with access to reasonably fresh water. The amount of water requirements vary with the type of land use. For agriculture, relatively large amounts of water, well sited for use on suitable land, are needed. The raising of plants involves great losses of water through evaporation, transpiration, and percolation. For pastoral activity, only enough water is required for the consumption of the livestock and their tenders. For exploitation of the potentialities of the sea, a still lesser amount of water is required: just enough for human consumption, by the fishermen or shipping merchants and their families and supporting artisans. Any increase in the availability of water changes the economic potentialities of the coastal desert, but basic potentialities of land, climate, and resources of the sea remain relatively constant.

Under primitive technologies, water sources were limited to those locally available with a minimum of raising or diverting. With the development of water-storage and diversion by means of large engineering works, well-drilling and pumping equipment, and pipe-lines and tank ships to transport water from distant sources, there has been an increase in cultivated lands and in human footholds for non-agricultural pursuits. Yet water scarcity is still the major problem along the greater part of desert coasts.

Desalinization

To dwellers and observers of the arid littorals, the limitless supplies of sea water right at hand form a tantalizing picture. In order to use this limitless supply of water on the land, all that is necessary is to remove most of the 35,000 parts per million average of dissolved solids ('salt'). Among peoples accustomed to desert water, a reduction of the salt content to about 500 parts per million is satisfactory, and even 1,500 to 2,000 parts can be used if necessary. In more humid areas, a lower salt content is demanded.

To remove the undesired salt, a number of ingenious methods have been developed, all of which require sizable amounts of power or capital or both. Technically it has been possible for hundreds of years to obtain fresh water from salt, by the simple process of distillation: boiling sea water and cooling and condensing the steam. Hawkins distilled sea water for his ship as early as 1593 (Unesco, 1954, p. 73). Unfortunately the energy required for fuel has been too costly to justify distillation except for the highest forms of use. Where heat can be obtained as a by-product of power production, the engineering cost drops greatly. Thus for many decades the larger ocean-going vessels have obtained their fresh water through distillation as a by-product of heat used in propulsion. A more efficient type of distillation is widely used now, known as flash-effect distillation, involving distillation at low pressures. On a larger scale, the island of Aruba in the Dutch West Indies has long depended upon distillation of sea water in connexion with electric power generation for supplying its population with domestic fresh water. The method used, known as multiple-effect distillation, uses heat given off by successive evaporation chambers to additional chambers at lower pressures. Low-cost water by the evaporation processes necessitates low-cost fuel, such as the petroleum obtained at Aruba from nearby Venezuela. The largest distillation plant in the world takes advantage of the tremendous reservoir of oil at Kuwait, where more than 6 million gallons of fresh water are produced daily. At the present state of technology, modern distillation appears to be the cheapest way to obtain fresh water from the sea on a large scale.

Another promising method is the extraction of fresh water from sea water through the freezing process. Possibly cost is about the same as for the advanced distillation methods. A large pilot plant using this technique is being tried at Eilat, Israel. Still another method is distillation through solar power. Small solar stills have been developed that produce fresh water readily. Prime power cost is nothing; principal drawbacks are the relatively high original capital cost, the considerable expanse of land that is necessary for obtaining adequate solar energy for a large plant, and the large amount of hand labour involved (Unesco, 1954; U.S. Office of Saline Water, 1953-).

Where brackish water is available, with salt concentrations not above about 10,000 parts per million, from lagoons, marshes, or underground, a form of purification known as electrodialysis has proven highly practicable in recent years for providing moderate amounts of fresh water. The method involves removing salt by means of a battery of plastic membranes subjected to an electric field. Many scores of electrodialysis plants are in successful operation, supplying water to small towns, military installations, geological prospecting crews, and industrial, recreational, and hospital centres in dry areas. Northern Africa, Arabia, and the western United States have the greatest number of plants, most of which were installed by Ionics, Inc., of Cambridge (Mass.), U.S.A. This method is too expensive for processing sea water (Ionics, Inc. no date).

To date it has not been possible to reduce the cost of desalinification sufficiently to make irrigation economically feasible. The lowest cost yet obtained for desalinating sea water is about $1 per 1,000 gallons. This would mean a cost of about $271 per acre-foot of water (1,233 cu.m.), compared with usual costs of $3 to $20 per acre-foot for irrigation water (2 to 8 cents per 1,000 gallons). Most towns in the United States pay less than 30 cents per 1,000 gallons of water, though some hard-pressed ones pay several dollars. Thus present costs of desalinification begin to be within reach for municipal use. Recent reports suggest that with large-scale production, costs as low as 50 cents are attainable (Carr, 1963). Brackish water low in salts may be desalinified for as little as 30 cents per thousand gallons.

A much better knowledge of the costs of desalinifying sea water and brackish water should be available in the near future as the result of an ambitious programme of research and development initiated in 1952 by the Department of the Interior of the United States. After exhaustive study and experimentation, four pilot plants have been completed and put into operation in various parts of the United States, and others are in preparation, to ascertain and compare the costs of desalinifying water on a large scale (1 million gallons per day for some) by various processes: multiple-effect distillation, flash distillation (designed to use either conventional fuels or waste heat from a nuclear-reactor power station), the direct freezing process, solar stills, and, for brackish water, electrodialysis. The annual reports of progress of the Office of Saline Water are the major source of current information on sea water desalinification (U.S. Office of Saline Water, 1953- ; Carr, 1963).

To the cost of desalinization of sea water must be added the expense of pumping the purified water to the locality where it is to be used. As the source of supply is always at sea level, the energy required to lift the water to its ultimate destination may be large. There is little prospect that engineering costs will be low enough in the foreseeable future to justify lifting water for irrigation even as far as the inland limits of the coastal lowland shown on the sector maps in this study below elevations of 200 metres.

It can be said with assurance that the day is still distant when commercial irrigation will be possible with desalinified sea water, though hydroponic farming is economic. But the day is already here when sufficient fresh water can be produced from the sea by existing equipment to supply any part of the coastal deserts with adequate supplies of drinkable water. If a foothold is wanted for developing fishing, mineral, trade, or recreation resources, the needed fresh water can now be obtained from the sea. In scores of localities, it is already being obtained[1].

Agricultural potentialities

A climate warm enough for crop growth, a supply of fresh water, good land accessible to the water, are requisite for agriculture in the coastal deserts. The first requirement is met in all the coastal deserts except the southern half of Patagonia, where it is too cold for agriculture. The temperature conditions differ sufficiently among the various coasts to necessitate the use of different types of crops. The hot deserts, including the great deltas of the Middle East, are the site of date-palm forests, cotton, and millet-type grains. Dates flourish particularly in the deserts of very dry summers, as in Egypt and Mesopotamia. The mild west-coast deserts with Mediterranean rainfall regime do not have enough annual heat to ripen dates, but produce excellent citrus fruits and temperate climate crops. Where the climate is cool, with summer rains, as in northern coastal Patagonia, deciduous fruits and other temperate climate crops thrive. Throughout the whole gamut of agricultural climates, alfalfa or other leguminous fodder crops flourish and support local livestock industries or supplement forage for animals from the surrounding semi-arid land.

The second and third requirements are much more restrictive than climate. Both water and irrigable land of suitable quality are scarce. In the deltas of the Nile and the Tigris-Euphrates, and to a lesser extent the Indus and the Colorado, there are vast rivers bringing water from humid lands of the interior to vast expanses of flat land upon which they can be employed near the coast, and upon some of these deltas the greatest populations of the coastal deserts have developed. Despite the long occupation of the deltas of the Middle East, there still remain considerable potentialities of further reclamation, especially in those areas near the coast. The forces acting upon the outer parts of all large deltas, including alluviation and subsidence, as R. J. Russel has so ably and repeatedly demonstrated, have caused the development of marshy land, and it is this land that remains an especially large potential resource for development today.

In many other places smaller deltas have been built out along the desert coasts, especially where the littoral is backed by high mountains. The streams that built the deltas also provide water to irrigate them, either as surface water (usually seasonally intermittent) or as sub-surface water within the porous wadi beds. Some of these smaller deltas have long been under intensive irrigation, as along the coast of Peru, but modern storage and diversion works could greatly increase the productivity in many. There is also the possibility of using run-off water where it spreads naturally, either from a mountain-fed stream, as along the Sudan coast, or from more limited slope run-off, as was done in the past and is being revived in the present in parts of the Negev and the Mediterranean littoral of Egypt. The systematic use of local run-off is one of the coastal desert resources that is still underutilized.

Long stretches of the coastal deserts simply do not have much land suitable for agriculture even if water were available, owing to steep mountains bordering the coast or highly saline soil. There is very extensive development of marine terraces, mostly narrow, and of varying elevation, that might be intensively used if water were available. There are also vast stretches where interior plains, too low to generate precipitation and water sources, come down to the coast, as in Libya and Western Australia.

A water resource that is beginning to be studied for systematic exploitation is brackish water that might be used directly for irrigating salt-resistant crops. The experience and literature on this subject was summarized (see Unesco, 1954) and Unesco currently has a major programme of research and training in this field under way in Tunisia. Such a programme has considerable potentialities; much of the brackish ground water or lagoon water in the coastal deserts hitherto considered unusable with salt concentrations of 1,000 to 4,000 ppm produces crops.

The extraction of water from the atmosphere directly has intrigued mankind for generations. Systematic attempts to cause precipitation, or to increase it, have been seriously under way in many countries, using silver iodide, water spray, or ice particles to induce condensation. Though there is difference of opinion as to the success of these attempts, results have not been

1. While the present volume was being prepared, the United Nations published a book on *Water Desalination in Developing Countries* (New York, 1964) giving results of a survey on existing and planned desalination plants in forty-three countries. Sites were visited in most—though not all—of the coastal deserts, in addition to those in other areas of water deficiency. The study gives valuable summaries of sixty-one principal desalination plants that were in operation in developing countries at the end of 1962, together with a discussion of the related water problems of these countries, and summaries of costs of water desalination at various sites by various methods. This information complements the geographic backgrounds provided by the Unesco publication.

sufficiently conclusive to convince impartial analysts that any significant contribution to desert rainfall is in immediate prospect.

On a small scale, water can certainly be obtained in the form of dew in some coastal deserts. It is a common observation that near the sea at night dew often forms naturally on roofs or other sloping impervious surfaces in sufficient quantities to drip from eaves and flow in gutters. Fog also may condense when it strikes cool objects at night. Both dew and fog may drip enough from vegetation to maintain a local growth of green grass during a rainless season. Exploitation of these resources, by means of suitable structures, perhaps 'dew mounds', might at least provide a little drinking water, though probably never enough for significant agricultural production.

Grazing

Coastal deserts are likely to have better natural forage than the deserts farther inland. The atmospheric humidity is higher, often reading 100 per cent relative humidity and causing dew and fog that favour vegetative growth within a zone about 10 to 30 miles wide. Some of the scrubby brush in this zone even bears epiphytic lichens on its branches, especially in the mild or cool foggy deserts of west coasts. In addition, ground water in the wadis is often close enough to the surface in these areas near sea level to permit roots of shrubs or trees to reach moist ground, so that the wadis are bordered by a fringe of plants, including some grassy areas. Water is often close enough to the surface in the wadi beds for shallow wells to be dug for watering the livestock. The resources of the sea have been used to some extent for feeding camels: at places along the Makran coast and south-eastern Arabia the camels eat dried fish, and elsewhere special types of seaweed are consumed by camels. These products might justify further examination as livestock feed. But unless fresh water is sufficient for raising fodder, there does not seem too much potentiality for increasing the meagre livestock industry of the coastal deserts.

Minerals

Many forbidding stretches of coastal desert have been exploited at great expense, even when water has had to be imported, where rich mineral deposits existed. Gold, copper, and other minerals have been mined for thousands of years inland of the Red Sea coast and elsewhere. Today oil deposits have brought in small groups of explorers, sometimes followed by larger and larger settlements. The occurrence of mineral deposits is not one of the distinctive attributes of coastal deserts *per se*, and will not be dwelt upon here. It should be pointed out, however, that deposits near the coast are commonly much more accessible to the channels of world trade than those farther inland, and this propinquity to the sea sometimes justifies exploiting deposits that would remain unused if they were farther inland. Petroleum exploitation is often highly significant to the development of a coastal desert, whether or not the oilfields are on the coast, as in Peru, or farther inland. The economic development of the Kuwait, Saudi Arabia, or Libya littorals is closely tied with the oil production, processing, and movement.

Fish

Deserts and fish are not usually associated, but for coastal deserts the vast fish resources of the sea lie close at hand. Some form of sea food is available off all the desert coasts, but the size of this resource varies widely, and the exploitation is of varying degrees of intensity. The average desert dweller, whether oasis farmer or herdsman, lacks the specialization and experience necessary for carrying on significant fishing operations. His direct exploitation of the sea is likely to be limited to clams or other shellfish that can be gathered from the edges of the land. Real fishing in the sparsely settled desert margins is usually done by specialized fishermen living in small fishing villages, using seines hauled ashore by hand, or nets and hand lines employed within a few hours' sailing distance of home.

Commercial fishing usually centres on one or the other of two main habitat groups of fish: demersal fish, which spend most of their life near the bottom, or pelagic fish, which remain near the surface most of the time. Demersal fishing was the earliest developed type of commercial fishing. It has been based chiefly upon the use of hand and baited hooks, though deep, powerful trawlers are now being used more and more. Such varieties as cod, halibut, and, more common off coastal deserts, hake, belong to this group. The bottom dwellers of more shallow waters, such as lobsters, clams, and oysters, are gathered by other means. The pearl industry represents a highly specialized and localized type of shell fishing, now limited largely to the southern part of the Persian Gulf. A little pearl fishing is done off north-western Australia. At one time the Gulf of California had an active pearl industry, but this has disappeared completely. The sponge industry, active off the desert coasts of Libya and Tunisia, resembles pearl fishing in its use of divers.

Broad, shallow continental shelves like the North Sea or Grand Banks of Newfoundland are the most favourable sites for demersal fisheries. Such banks are poorly developed off most of the coastal deserts. The largest is the wide shelf off Patagonia, but the resources of this have not been intensively developed, perhaps partly because of the dominance of meat in the Argentine diet, partly because of the paucity of ports and sparcity of population along the Patagonian coast. The Gulf of Aden, too, has a relatively extensive continental shelf, but fishing has been little developed from the bordering desert coasts. There are more sheltered banks in the gulfs of Gabes and California, and the Persian Gulf.

The most spectacular large-scale fisheries are of the pelagic type. At one time whaling was a prime industry, with a highly specialized type of fishing, if it can be called such. This industry has declined in importance with the decline in price of whale products and a reduction in the number of whales. The sardine or pilchard, members of the herring family, have become the mass-produced harvest of the sea today. These fish flourish particularly in belts of cool water off the west coast deserts of North and South America, north and south Africa, and Australia. Here upwelling cold water brings a rich supply of food from the depths, in the form of plankton. The pilchards multiply in vast schools or shoals of fish, some of which have been reported off South West Africa as averaging 3 to 5 miles long, and in one instance 15 miles.[1] Such vast quantities of fish appear to be inexhaustible, even when scooped up by huge power-driven nets, but it must be remembered that large-scale exploitation of the pilchards off south-western Africa has only been under way since about 1947. In the fabulously rich pelagic zone off Peru and Chile, where exploitation has gone on much longer, the government has begun to find it necessary to require conservation measures because of signs of decrease in the numbers of fish.

Peru is the only one of the great west-coast desert areas where the pelagic fishing has been carried out chiefly from the ports of the desert itself. In the others, the fishing boats are based not upon the adjoining poverty-stricken desert, but upon neighbouring countries where denser population, more experienced fishermen, and sufficient capital for boats and equipment are available. Thus the fish of the Canaries Current are exploited chiefly from the Canaries, the Cape Verdes, and, more and more, from Morocco; fisheries off Baja California are fished by vessels from San Diego and San Pedro, often travelling several hundred miles from the home port; while the Benguela Current is frequented by ships from South Africa. The fish off western Australia have been exploited very little, partly for lack of large profitable markets. Some canning or other processing of the catch is done at installations on the nearby desert coasts, and some is done on the most modern large vessels designed as 'floating factories'. Not only small fish of the sardine type are caught in these areas, but also such fish as mackerel and large tunas. The fishing off Baja California has emphasized tuna rather than sardines because of the greater demand and higher prices in the United States for this type of fish.

All in all, fish constitute an under-utilized potentiality of most coastal deserts. Lack of nearby markets, lack of skills, lack of well-situated sheltered ports, and lack of the capital necessary for modern locating, catching, processing, and freezing facilities are among the problems that must be solved along different coastal deserts. (Morgan, 1956, and Walford, 1958, provide excellent world-wide background on the fishing industry, including that of the coastal deserts).

Seaweed

A vast potential resource off the desert coasts is seaweed, actually marine algae. It has been used a little in the deserts, but in more densely populated humid countries, especially Japan, China, and north-western Europe, it has been an important local food for centuries, in the form of salads, cooked or dried food, condiments, or jellies. Sustained research to determine the economic uses and ways of harvesting and processing seaweed has been carried out by the Seaweed Research Institute of Scotland (Seaweed Research Institute, 1947), though trial and error and sporadic research resulted in the discovery of many uses long previously.

In the Orient and to a less extent in north-western Europe and north-eastern North America several varieties of seaweed are used as human food. The most productive seaweeds, though they are rich in carbohydrates, are poorly digestible by man. They are, however, significant elements in the feed of sheep, cattle horses, pigs, and chickens in rural coastal areas of north-western Europe. In Norway a seaweed meal is prepared for domestic animals.[2] It is also used widely in these areas as a manure for fertilizing crop land within a distance of 10 miles of the coast, for it is rich in nitrogen, phosphorus, and potash. Commercially, the red and brown types of seaweed are the only ones widely used. In times of high prices, some varieties of red seaweed are used as a source of agar, an industrial element used in making firm food jellies and in chemical industries. Certain brown seaweeds, especially the giant kelp *(Macrocystis)*, are burned to make potash when prices are high, or are used for the extraction of iodine (Walford, 1958; Chapman, 1950).

Primitive exploitation has been reported along the arid coast of Tunisia, where camels, donkeys, and horses eat seaweeds cast up on the beach. The principal variety eaten there is *Cymodocea nodosa*, a red seaweed, which is described as forming great submarine prairies representing an immense food reservoir in time of need, off southern Tunisia where there is a broad expanse of water less than 5 m. deep (Pottier, 1929). Systematic field and laboratory study would doubtless show many other varieties edible at least by livestock.

The greatest development of potential seaweed crops is along the same cool west-coast desert coasts that favour the great schools of pelagic fish. Kelp of at least two varieties forms dense tangled masses along the outer desert coasts of north-western Mexico, Peru, and Chile, and south-western Africa, and other known usable varieties occur in these same zones. Western Australia has maintained from time to time an agar

1. *World Fishing* (London), February and March 1954.
2. *World Fisheries Abstracts* (FAO), Vol. 3, 1952.

industry based upon red seaweed along its west coast (Chapman, 1950; Tiffany, 1938).

The harvesting and processing of seaweed presents problems. For local agricultural use, seaweed is commonly gathered from the beach where it has been piled up by the waves, cleaned of sand, and hung up on walls or fences to dry. In this stage the desert littorals would have an advantage over the cool rainy coasts of northern Europe, in the greater rapidity of drying. The best quality and cleanest seaweed is harvested in the water while growing. The algae may be either cut or pulled, the latter being considered easier where the plant is short. For the long-stemmed heavy kelp of the southern California coast, underwater cutters on barges have been used successfully for large-scale harvesting.

Seaweed can hardly be considered a panacea for the economic problems of coastal deserts, but it is a resource that would justify serious study, particularly of the qualities, occurrences, and potential uses of the many varieties available.

Salt

The manufacture and gathering of salt in commercial quantities is characteristic of most if not all coastal deserts. Sea water is allowed to evaporate in natural or artificial shallow basins along the coast, and the salt can be scraped up into piles. The dryness of the atmosphere and paucity of rain gives this environment an advantage over the humid coastlands for salt production. The salt is available for local domestic use and for the fish industry which requires large amounts for dry salting and for canning. In some areas there is a surplus for outside sale or exchange.

Recreation

The combination of seashore attractions for swimming, skin-diving, sport fishing, or boating, clear weather mild even in winter, and the nearby wide open spaces of the desert, provide the coastal deserts with a basic potential resource for developing important recreation industries.

Already some recreational centres have developed in coastal deserts. Near large cities at the edge of hot plains, like Alexandria, Lima, and Karachi, nearby beach resorts are frequented by city dwellers seeking coolness and relaxation. Other recreational areas derive their income from tourists from afar. The Mediterranean coasts of Libya and southern Tunisia, for example, have the lure of ancient Phoenician and Roman history and traditions, as well as picturesque natural settings above and below water, and oasis development at such places as Northern Cyrenaica, Tripoli, Sfax, and Djerba, and visitors from Europe are welcomed. On the island of Djerba, for example, in the Gulf of Gabes, luxury tourist hotels offer shelter to visitors who wish to enjoy the island's long uncrowded sandy beaches, daily sea breezes, and abundant groves of palm, olive, citrus, and other trees. In the summer of 1963 two of these hotels were scheduled to install electrodialysis plants to reduce the salt content of their well water from 6,500 ppm of salt to less than 1,000 parts (Ionics Inc., no date). Desalinization equipment makes it possible to establish centres elsewhere in areas previously condemned to solitude, though availability of electric or other power is necessary for most desalinization equipment except solar stills.

The cool west-coast deserts, when not too far from areas of dense population, offer particularly refreshing locales for vacationists. In Baja California, Mexico, for example, visitors from the United States support a sizable tourist industry along the coast near the border. The aeroplane makes even La Paz, near the southern end of the Baja California peninsula, accessible to a limited number of tourists, and still farther south private luxury lodges have been built for people desiring solitude, sea views, and hunting or fishing. In short, an appreciation and utilization of the recreational possibilities of coastal deserts is only in its early stages, and is worthy of serious investigation by governments and private enterprisers.

Trade

Lacking dense populations for the most part that would support costly railway or road development, coastal deserts have taken advantage of their unique natural transport medium, the sea. In addition to large delta outlet cities like Karachi, Alexandria, and Basra, small ports have a vital role in the economies of their areas. Along the more protected seas, such as the Red Sea and Persian Gulf, trade routes have flourished since time immemorial. Here the sea lanes handle the bulk freight, while caravans and, today, motor traffic, provide feeder service to the ports. For bulk traffic, land routes cannot compete with sea routes. Thus, after the Portuguese opened up direct sea contacts with Africa south of the Sahara in the fifteenth century, the trans-Saharan caravan trade declined drastically (Thomas, 1957). Large ocean vessels pass by the more inhospitable desert coasts without stopping, unless there are special hinterland shipments to be made, such as the copper and nitrates of the Atacama. But most of the Namib, Atlantic Sahara, Baja California, and Western Australia receive only sporadic visits by small trading vessels.

Tidal power

A potential resource of some magnitude that may ultimately be developed is tidal power: a resource not available to interior deserts. Techniques exist for using tidal power to generate electricity, but substantial capital and sizable markets for the power are prerequisites. Areas most suitable for such development, from the physical viewpoint, are those with large tidal ranges, usually at the heads of broad funnel-shaped embayments in the coast. Notable among these are the gulfs along the Patagonian coast, with tidal ranges of 20 to 25 ft., the head of the Gulf of California, 40 ft., and the Gulfs of Cutch and Cambay in India. Small-scale utilization of this source of power lends itself to ingenious experimentation. Small tide mills, using directly the current of water that flows through a narrow channel connecting a lagoon or pond with the sea, have been used successfully in the past to grind grain. Could these not be used for local generation of electric power ? If continuous service is wanted, of course, some provision must be made for the short periods of slack water when the tide is turning. Wave movement, both vertical and horizontal, is another potential source of power. It has received even less attention than tidal power.

Sun and wind

There are other natural sources of power available to coastal deserts, notably solar radiation and wind. These are common to all types of desert, though wind speeds are greater on coasts than inland, and have been used for centuries to turn windmills. A systematic examination of the distribution and variability of wind speeds along the world's desert coasts would be useful. Major possibilities, problems, and recent developments in the field of wind and solar energy have been explored by Unesco in its Arid Zone research programme (Unesco, 1956).

PART TWO

Regional survey

From north-western India to the mouth of the Juba River in Somaliland the sea is bordered for 9,000 miles by an unbroken strip of desert; by far the longest desert coast in the world. The littoral is made up of landscapes of the greatest diversity, including stretches of precipitous slopes, narrow marine terraces, and broad plains. Common to all, however, is the intense summer heat, the deficiency of rainfall—and access to the food and trade of the sea. Here the hot deserts of Sahara, Arabia, Iran, and Thar come to the coast, where they acquire an oppressive humidity and a partly counterbalancing sea breeze. Lacking economical means of large-scale transformation of either sea water or the atmospheric moisture into usable form land utilization has had to depend largely upon the presence of water from outside sources. The barren coast is brightnened by widely spaced oases where mountain-fed wadis, springs, or wells support seasonal or permanent farming, and, in two cases, where vast rivers from the Himalayas and the mountains of Turkey have permitted the irrigation of broad fertile deltas.

In Sectors 1-16 which follow, an attempt will be made to sketch broadly the main characteristics and possibilities of use of the individual sectors of the littoral.

SECTOR 1: KATHIAWAR-KUTCH

The north Indian Ocean desert littoral starts on the east with the western part of the Kathiawar Peninsula and Kutch along the Arabian Sea. Physically, these peninsulas are outliers of the Deccan plateau of India, consisting as they do of low plates of hard crystalline rock surmounted by sheets of lava. Except for relatively small uplands, the general elevation is below 200 m., and along the southern edge there are narrow coastal plains below the general level of the plateaux. In the Kathiawar Peninsula the coastal plain, known as the Sorath Coast, is about 10 to 30 miles wide, consisting of 'miliolit' (a mixture of wind-blown sand with a matrix of lime) alternating with alluvium. Some of the wider alluvial stretches along rivers—notably the rich delta of the Bhadar River—are under crops, though there are considerable areas of coastal lagoon and marsh that cannot be used until comprehensive reclamation measures are taken. The miliolit surfaces are poor and support only the scanty pasture of the tropical thorn brush characteristic of the unused lands of most of this sector, but the material is of some value as an attractive creamy-white building stone, and is exported to some extent as 'Porbandar stone'. In Kutch, the coastal plain is very narrow and discontinuous.

Both Kathiawar and Kutch are almost cut off from the rest of India by surrounding gulfs and marshes: the Gulf of Cambay to the east, the Gulf of Kutch in the middle, the Rann of Kutch to the north and east of Kutch. The Gulf of Cambay, the great historic funnel for contacts of the outside world with India, is the focus of the principal trade of Kathiawar today through the port of Bhavnagar, but it is outside the arid area of this study. Several small ports lie within the arid area, mostly on the Gulf of Kutch. This gulf has the disadvantage of very high tides and wide mud flats along most of its shores. On the other hand, it provides more shelter against the south-west monsoon than the open seacoast. Okha has become the chief port of western Kathiawar, lying at the mouth of the gulf and beyond the mud flats, with reasonable tidal range of 7.5 ft. and sheltered by a projecting point. Mandvi and Kandla, farther up the gulf, serve Kutch, despite the larger tidal range of 11 to 16 ft. Okha and Kandla both have rail connexions with the Indian mainland.

Along the entire coast fishing has long been an important source of food. Despite the serious natural difficulties, small fishing ports have developed a core of hardy sailors for fishing and trading. The wide continental shelf of the Arabian Sea should provide a basis for enlargement of fishing activity. The Rann of Kutch is a vast expanse of salt mud flats, as large as the Kutch, forming perhaps the most distinctive part of this sector. The seaward portion of it is subjected to daily tidal floodings, the flooded area fluctuating sharply with the height of the tide and the direction and strength of the wind. An on-shore wind at the time of high tide greatly extends the submerged area. The vastness of the daily rise and fall of water, and the flatness of the land, inevitably suggest potentialities of tidal power generation along both the Rann and the Gulf of Kutch similar to those scheduled for development on the Norman coast of France. Above the high-tide mark, parts of the Rann are inundated annually during the rainy season by the large northern rivers that flow into it from more distant humid areas. Although a considerable mystery has been made of the origin of the Rann and its saltiness, the general situation suggests strongly that the Rann is a typical deltaic deposit subjected to the excessive evaporation of an arid climate.

South-western Kathiawar and Kutch are semi-desert in climate, according to the definition given on page 12. Thus Dwarka, Bhuj, and Jamnagar, with mean annual rainfall of 13 to 18.5 in., are semi-desert, while Veraval is only semi-arid (map 1).[1] The effective aridity is intensified by the fact that the rainfall comes from June to August during the hot season of the south-west monsoon, while the rest of the year is dry (Table 1).[1] Actually, the hottest time of year is in spring, when the sun is approaching zenith and before the rain and cloud of the summer monsoon have tempered the heat. At the immediate coast the daily maximum temperature of spring and summer is 85 to 90° F., and relative humidity remains between 75 and 90 per cent all day. Even at night the temperature remains above 80° F.

The daytime temperature rises rapidly inland, with mean daily maximum of 96° F. at Jamnagar, and 105° F. at Rajkot in May. Fortunately, however, the increasing continentality results in lower humidity and a greater drop in temperature at night too, with a mean daily minimum in May of 77° F. at Jamnagar, and 75° F. at Rajkot: still oppressive.

1. The maps and tables are grouped at the end of this volume (starting on page 116).

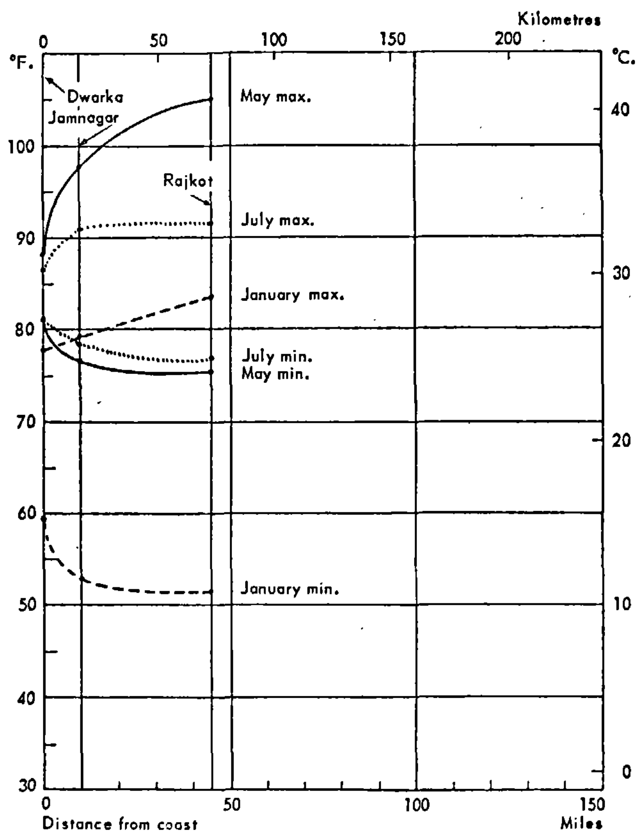


FIG. 1. Profiles of mean temperature, Kathiawar.

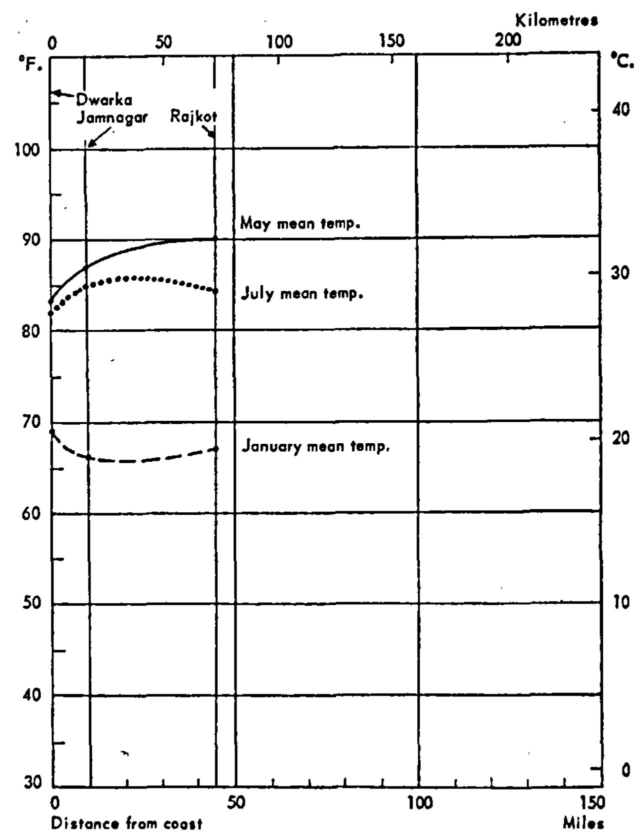


FIG. 2. Profiles of daily maximum and minimum temperatures, Kathiawar.

During the period of south-west monsoon rains, from June to August, the humidity and temperatures remain high even away from the coasts. In July, the only really wet month, the semi-desert stations get an average of 6 to 9 in. of rainfall, concentrated in one or two days per week. The sky is overcast most of the time in July, however. Variability is very great, in both the amount of rain in a given year and in the starting and ending dates of the rainy period. In Dwarka, for example, annual rainfall has varied from 1.03 in. to 37.01 in. during the forty-year period from 1901 to 1940.

By late August or September in most years the skies have cleared as the wind works around to the west and north-west, and daily maximum temperatures in October and November are higher than in summer. Nights are comfortable, however. By midwinter (or the middle of the dry season) the temperature falls to about 68° F. or slightly lower nearly every night.

Figures 1 and 2 are designed to convey graphically an idea of temperature conditions in relation to the sea coast in the hottest month (May), the wettest month (July), and the coldest month (January). The curves of mean temperature (Fig. 1) suggest that the marine influences are most pronounced within 10 or 12 miles of the coast. Although there is a tendency for mean temperatures to be higher inland than on the coast in summer, and lower in winter, the actual differences at a given moment are much greater than the means would indicate. In Figure 2, the actual temperatures at the hottest and coolest parts of the day are shown separately. The contrasts are more striking. In May, at Dwarka on the sea coast there is a difference of only 7° F. between the average highest and lowest temperatures of the day, while at Rajkot, 45 miles inland, there is a difference of 30° F. ! Rajkot is actually cooler than Dwarka at night, but much hotter than Dwarka during the day. The great range is accounted for by the fact that the prevailing wind in May is south-westerly and carries the stable ocean temperature conditions to the adjacent land. In January the contrasts between coast and interior are much less pronounced, for the prevailing northerly winds carry continental conditions to the coast: the effect of the sea is slight.

The western corner of Kathiawar and the whole of Kutch show the effects of the semi-desert climate in the natural vegetation and forms of land utilization. The tropical thorn bush here breaks down into low desert shrubs and scattered grass, and grazing is the dominant type of land use. Kutch has long been famous for its horses and camels. Where crops are raised, as in favoured coastal alluvial areas, irrigation is essential. The principal crop is millet, of the widely raised jowar and bajra types: staple cereal foods of this part of the world. The jowar is raised on the better lands, bajra on the poorer, lighter soils. For successful production of these crops without irrigation, an annual rainfall of about 25 in. is said to be required, or even more in the case of jowar. In the Dwarka area, nearly all the cultivated land is devoted to these crops. In favoured localities on the Sorath Coast cotton, rice, and oilseeds, especially rape, are also produced. Coconuts and casuarinas (the latter raised for wood) are raised here and there on the coast. At other places there is a natural fringe of mangrove. Most of the water for irrigation is obtained from wells. Some irrigation is carried on in the Halar Coast, a strip of marshy land along the south side of the Gulf of Kutch, but most of this land remains pastoral. Given sufficient water for irrigation, reclamation might bring about a sizable increase in cultivated land here.

The possibility of reclaiming the vast mud flats of the Rann of Kutch fires the imagination. Whether sufficient water can be guided onto the land, and kept in place with dikes long enough to leach out the salts, is a question. So far, emphasis has been placed upon putting into cultivation the better-drained alluvium farther upstream, nearer to the source of river water.

SECTOR 2: THE INDUS DELTA

Beyond the forbidding Rann of Kutch, in the Pakistan province of Sind, lies the desert delta of the Indus River, coastal outpost of the Moslem world. The first invasion of the Indian subcontinent by the crusading Arabs in the eighth century A.D., following the Makran gateway, was in this area. Further advance was easier northward than eastward.

A part of the obstacle to direct eastward penetration lay in the delta itself. The lower delta has been until recently an inhospitable wilderness, completely filling the 100-mile gap between the Rann of Kutch and Thar Desert on the east and the Kirthar Range on the west. Even today large tracts are virtually uninhabited deserts of mud and flood.

Climatically the delta is a true desert, with less than 8 in. of rainfall, nearly all of it falling in summer. Variability is profound: during the ninety-six year period 1856 to 1950 annual rainfall at Karachi varied from 0.47 in. to 28 in. Spring is very hot, particularly in the interior. Thus the mean daily maximum temperature 95 miles from the sea at Hyderabad in May is 107° F. compared with 89° F. at the coastal station (Manora Point) of Karachi (Fig. 3 ; Table 1). The relative humidity remains high throughout the day: between 70 and 80 per cent in the afternoon throughout spring and summer at Karachi. A fresh breeze from the sea reaches its highest velocity in mid-afternoon and makes the high humid temperatures bearable. It is common practice in the delta to orient houses towards the west or south-west so as to take fullest advantage of the afternoon sea breeze or summer monsoon wind. In Karachi some of the houses have special sails on the roof to deflect breezes down through the house. As the afternoon wind at the coast averages between 12 and 20 m.p.h. (5-9 m./sec.) in all months from February to October, the utilization of wind power is a possibility to consider. Even nights are warm in spring: mean minimum about 78° F. with almost no difference between coast and interior. The rapid cooling-off of the land at night results in a drop of about 30° F. in the course of the day at Hyderabad, while the coast drops only 10° F.

The very hot season is followed by two 'wet' hot months of July and August. Although rain falls on the average only two days per month during this season, the sky is cloudy most of the time and temperatures are lower in the daytime than during spring or fall. Winter is a mild, dry season, with very little difference between the coast and the interior, though the coast is a little

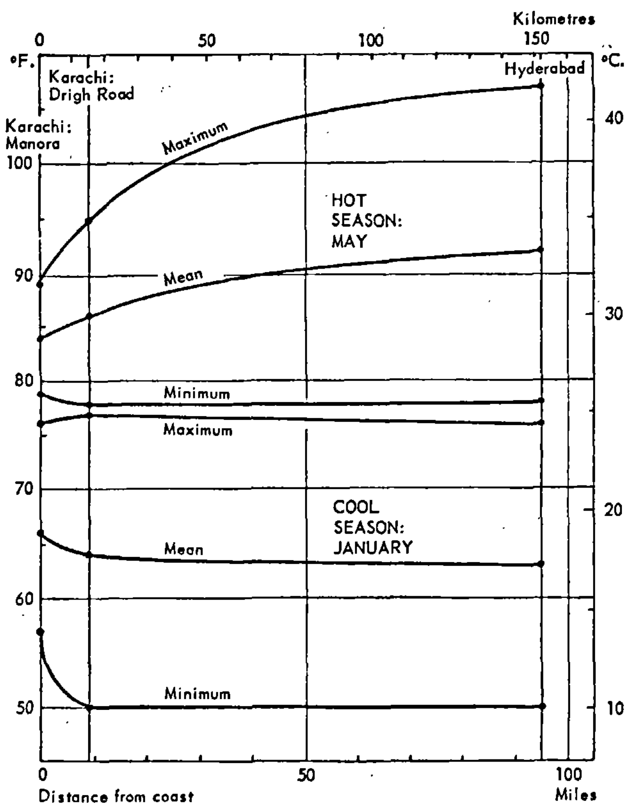


FIG. 3. Profiles of mean and mean daily maximum and minimum temperatures, Indus Delta.

warmer, especially at night (Fig. 3). The mean temperature of around 65° F. in January is just low enough to exclude this area from the strict tropical classification, but frosts are unknown in the delta. At night, temperatures commonly fall to about 50° F. while in the daytime they rise to about 77° F. Two or three times each winter a light shower from the west reaches the delta.

An inspection of Fig. 3 suggests that during the cool season and at night, marine influence upon temperature is not significant more than about 10 miles from the coast. In spring, for more than 50 miles inland there is considerable marine modification of temperature during the day, though a 25-mile zone would include the sharpest differences.

Though the effective rainfall is negligible, the delta is well provided with water from the Indus River and its distributaries. Every summer, with the coming of the monsoon rains and the melting of snow in headwaters areas, the Indus jumps its banks and floods great areas of its delta. Flooding in the southern portion of the delta is increased as a result of the high tides of the sea. When strong on-shore winds coincide with high stages of the river, the delta may be flooded as much as 20 miles inland. The water is so shallow and the flood so extensive that ships are sometimes unable to approach close enough to see land. The heavy load of silt carried by the Indus results in great variability from year to year in the courses of flood channels and the areas flooded.

Although some agriculture is carried on in the mud after the subsidence of the floods, and a certain amount of directed flooding is possible, most of the delta is still agriculturally unused. The completion of the Sukkur Barrage across the Indus in 1932 permitted the perennial irrigation of huge tracts of land in the upper delta, but the lower delta has had to depend upon floods and upon the lifting of water from the rivers and wells by pumps or water wheels. Animal power is provided by the water buffalo, which also ploughs the fields and furnishes milk. By far the outstanding crop of the delta is rice, well adapted to the heavy, muddy soils. Millet (bajra) is raised where less water is available. A great increase in irrigated rice land is anticipated from the Kotri Barrage a few miles upstream from Hyderabad. Ultimately the Kotri Barrage may serve nearly 3 million irrigated acres, compared with the one-third million acres now under irrigation in Tatta District (essentially the lower delta). There would still be more than 1.5 million acres of delta land unirrigated. At present native vegetation prevails in most of the delta: tamarisks and other trees along the water-courses, coarse marsh grasses in other areas, and thickets of mangroves along the coast. Chief utilization of the land at present is for grazing, especially by water buffaloes and hump-backed cattle. Great changes are in store for this region, with known resources of water to become available.

Not to be overlooked as a resource of the delta is fish. The hundreds of miles of delta creeks and rivers, and the numerous temporary or permanent flood-filled lakes, have long provided scope for a fisher population. The channel fishing could be considerably increased. More important is the sea fishing in the wide, shallow, silt-fed waters off the mouths of the Indus. Most of the 50,000 fishermen of Sind go to sea. The season covers about nine months; summer is unfavourable, owing to the strong, on-shore winds and storms and the flooded condition of the coastal sites. For harbours, the fishermen depend upon the little creeks and inlets of the delta: adequate year-round protected harbours are lacking in the entire 200 miles of coast between Mandvi and Karachi. The Government of Pakistan is already turning its attention towards development of its potentially much greater fishing industry. In fishing, as in agriculture, the problems of controlling and utilizing to the best advantage a powerful river and its appendages can be solved only through wise planning and execution by government.

As in many great deltas of the world, the Indus delta has its main seaport at its edge, where rocky spurs from the neighbouring mountains provide a firm site out of reach of the annual floods, and the harbour is less subject to siltation than the central coast of the delta. Karachi has a great natural site, lying as it does not only at the western edge of the delta but also at the point where the corridors of the Makran open out into the Indus valley from the west. The growth of the city has been phenomenal, especially since it became the capital of the world's largest Moslem nation, after the creation of the Dominion of Pakistan in 1947. By 1951 it had a population of 1,126,417. The harbour, consisting of estuaries of the Lyari River protected by a sand bar, provides shelter for fishermen and a medium-sized port for ocean-going vessels. On the flat lands to the east of the city has been developed the busiest airport of Asia, a convergence point for air routes between all parts of the Western and the Oriental world, in the wasp-waist between the Arabian Sea and the Soviet Union.

Apart from the great problems of any small town that grows overnight into a major city, Karachi has some characteristics related to its desert climate. Water supply has been a pressing problem. Water pumped from wells along the Malir River is no longer adequate in amount, and it has been necessary to bring water by aqueduct from the Indus River. A typical desert industry, the production of salt by the evaporation of brine in flats along the coast, continues to be important just west of the city. Attempts to utilize to the maximum the cooling effects of wind have already been mentioned. Temperature differences are pronounced within distances of a few miles from the coast, as is apparent from a comparison of statistics for Manora, on the sand-spit at the harbour entrance, and the airport at Drigh Road, about 9 miles inland (Fig. 4). The most desired areas for residence and outdoor recreation therefore are the coastal suburbs, including Manora and other sites south of the city.

West of Karachi the alluvial deltaic coastal deposits extend only a few miles before being pinched out by the thrust of the mountain outliers to the sea. The delta gives way to a narrow coastal piedmont only about 3 miles wide and less than 100 metres above Sea level. Small villages carry on precarious cultivation of patches of land irrigated by flood waters—spread with the aid of simple earth dams—across wadis leading down from the mountains.

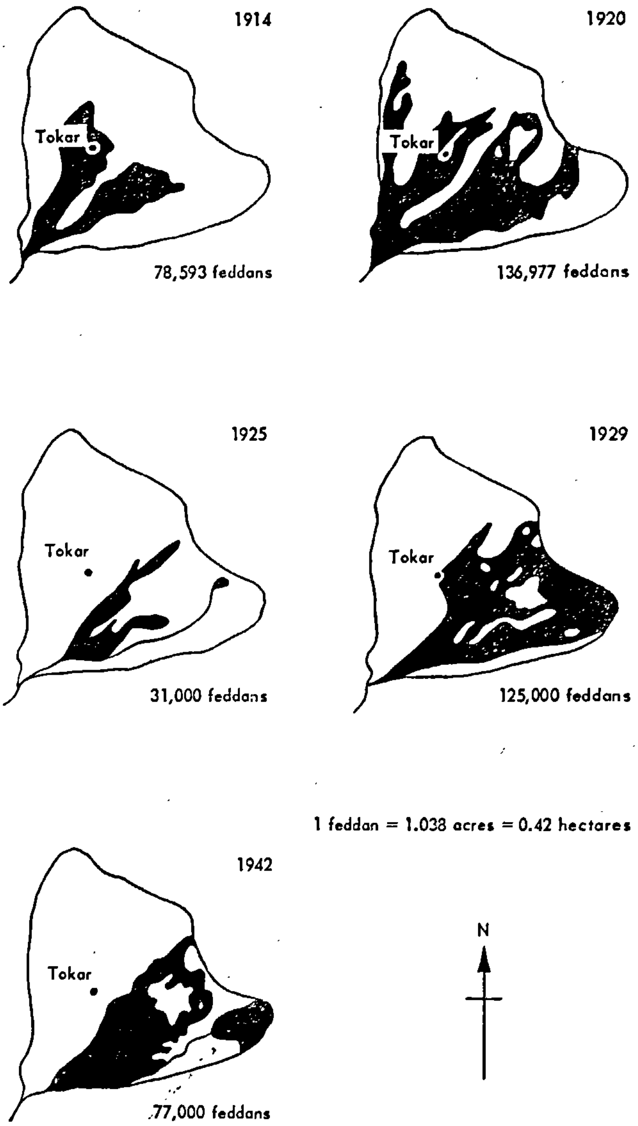


FIG. 4. The Tokar Delta, showing areas flooded in selected years. Adapted from *Agriculture in the Sudan*, by J. D. Tothill, London, 1948, p. 624.

SECTOR 3: LAS BELA AND MAKRAN

LAS BELA

West of the imposing wall of the Kirthar Range lies Baluchistan. The Kirthar is the easternmost of a series of parallel, folded mountains of limestone and other sedimentary rocks that fan southward for 350 miles from the Quetta knot. Continuous, steep, and barren, with narrow longitudinal gorges, these mountains form a barrier that has served to isolate the coastal area from contacts both to the north and east. The Hab River, easternmost of the straight, southward-flowing, intermittent streams, forms the boundary between Sind and the small state of Las Bela (Map 1).

The heart of Las Bela is the triangular alluvial valley of the Porali River, formed where the north-south ridges curve apart from one another as they approach the coast. Near the head of the valley, 55 miles from the coast and about 100 metres above sea level, is the small town of Bela that serves as capital of Las Bela. A desert climate rules the valley. At the coast, at Sonmiani, the rainfall amounts to only 4.80 in. per year, while Bela gets an average of 9.09 in. Summer rain is the rule, though even during the two rainiest months of July and August there are only two or three days with rain, on the average. However, the sky is overcast about two-thirds of the time during these months. Temperatures increase perceptibly inland. Bela, with a mean monthly temperature of 93° F. in the warmest month, June, is 6° F. warmer than the coastal station of Ormara, and the difference in daily maxima must be 10 or 12° F. Winters are mild, and where perennial irrigation is carried on two crops per year can be raised.

Agriculture, which occupies about half of the population of Las Bela, is conducted in the upper half of the Porali River alluvial fan. Cultivation is possible only with irrigation. The greatest concentration of population is near the head of the fan, where springs in the Porali River bed supply water for perennial irrigation. This spring area, known as Welpat, has been occupied by man since prehistoric times. Elsewhere, reliance for irrigation water is placed chiefly upon the annual summer floods of the river. The floods are spread onto the surrounding lands with the aid of crude diversion dams built across the branching river channels. Some slight use is made of wells. In all, only a small fraction of the land is cropped. With additional water, considerable extension would be possible.

Grazing, the occupation of about half the people of Las Bela, is carried on especially near the edges of the valley, where wadis concentrate some of the scanty run-off from the mountains and support some forage, in the form of thickets of tamarisk and other woody growth. The bordering mountains themselves are utterly barren of vegetation except in the bottoms of the canyons. At the mouth of the valley, which is about 50 miles wide along the coast, there is particularly abundant vegetation based upon water near the surface. Around the long Hor Lagoon (Miani Hor) there is a jungle of mangrove. Sonmiani, a village at the outlet of the Hor, was an important camel caravan centre and seaport before the rise of neighbouring Karachi.

MAKRAN

The Hingol River, west of the Porali, marks an important divide both in terrain and climate for the coastal deserts. To the west is the Makran, where the folded ridges and valleys from the north have swung westward and run parallel with the coast in Pakistanian and Iranian Baluchistan. Here no broad valleys open onto the coast. For 500 miles forbidding, barren mountain walls rise unbroken a few miles back from the shore-line, with only a narrow rim of coastal plain or marine terraces. Behind the coastal range lies a narrow valley, and beyond are other parallel ranges and valleys. Structurally the Makran resembles the Jura or Appalachian systems, with folded sedimentary strata which, through differential erosion, have remained with the harder rocks forming ridges, and softer rocks eroded into valleys. Like the Appalachians, too, the drainage pattern is trellised; connexions from valley to valley and from valley to coast are commonly in the form of narrow gorges, impassable even by the camels and donkeys that form the chief means of transport in the Makran. So isolated are the valley segments of a river that it may bear different names in different parts of its course. Thus the Dasht River is known as the 'Kech' (or Kej) in its central portion.

The Makran structure is expressed in yet another way at the immediate coast in the form of hammer-headed peninsulas consisting of the remnants of rocky ridges tied to the coast by necks of lowland. These peninsulas (Ormara, Gwadar, Chahbahar) provide the best shelter on the coast for trading or fishing vessels. In the case of Gwadar, symmetrical bays on each side of the peninsula are known as Gwadar West Bay and Gwadar East Bay.

Climatically, the Makran is the outpost of the Mediterranean regime of climate, with most of the meagre rainfall coming in winter, in contrast with the summer monsoon rain of all south-east Asia from Bela eastward. It is partly for this reason that the Makran marks the beginning of the vast realm of the date palm that extends from here to Mauritania. Wetting of the dates during the ripening period impairs the quality of the fruit, whereas winter rains cause no such damage. Rainfall in the first tiers of interior valleys differs but little from that of the coast: Turbat, in the Kej valley, and Ormara, Pasni, and Gwadar on the coast, all have a mean annual rainfall of about 6 in. Westward there is a slight drop, to a little under 5 in. at Chahbahar and Jask. In the far interior, which can hardly be considered as being in any way a part of the coastal desert, precipitation also decreases; the date palm oasis of Panjgur, 110 miles from the coast, has an annual mean of 4.8 in.

Nowhere in the Makran is rainfall sufficient to support crops directly. Agriculture has developed only in a few oases with favourable ground water or surface water conditions. Such conditions occur chiefly in the interior, where run-off from the mountain slopes concentrates in the narrow and disconnected alluvial ribbons of the valley floors. Back of the second range from the coast and about 50 miles inland, lies the greatest oasis of the Makran coastal desert, in the long, narrow valley of the Kech River. Here for centuries the valley has been green with groves of date palms under perennial irrigation. The highly prized dates are sent to the little coastal ports for export. With subtropical temperatures, a wide variety of other crops are raised too, including subtropical fruits, sugar-cane, and grain. The great valley occupied by the Kech River is prolonged, with some breaks intervening, by other valleys to the east and west, in which lie similar palm oases. Geh and Qasrqand, in the Iranian portion of Makran, are such oases; welcome spots of green and shade among the barren, naked hills. Geh, which had been a prosperous Moslem town until the late Middle Ages, was only a village of palm-mat huts at the time of Aurel Stein's visit in 1932 (see Stein, 1934).[1] Qasrqand is even smaller.

These and other oases of Iran are irrigated in part by kanats or karezes, ancient tunnels dug so as to conduct ground water by gravity from stream gravels lying farther upstream. The perennial kanat water is supplemented by surface water from the winter floods of the wadis. In many localities there are extensive remains of kanats that were used in the past but have not been maintained. Although this type of evidence has been adduced to support the theory of a decrease in rainfall within historic times, it is very likely that many of the kanats were allowed to deteriorate during periods of war or raids by nomads, and could be put back into operation if sufficient manpower and funds were available. In lands of cheap fuel oil, wells with motor-driven pumps are likely to be cheaper than kanats to develop, but adequate transportation and repair facilities are then essential. Kanats produce dependable if small flows of water with only hand labour to repair cave-ins and remove accumulated silt. The climate was already intensely arid during the period when the army of Alexander the Great suffered losses from thirst 2,278 years ago while retreating through Makran *en route* from the mouth of the Indus via Bela and the Kech Valley.

The interior valleys of the Makran have channelled traffic right down to the present. The Arab invasion of India in the eighth century took this route, and the only motor road to Quetta, capital of Baluchistan, follows it. Despite the barrenness of the hills, some grazing is carried on, taking advantage of slope run-off concentration and of vegetation stimulated by occasional winter rains. There is a tendency for the flocks and herds to move on to the higher, cooler land in summer.

The immediate littoral, widely known as the Makran Coast, is a world apart from the valley oases a short distance inland. Known to the Greeks of Alexander's day as the land of the *Ikthyophagoi* (fish-eaters), it continued through the centuries to look seaward. Everyone and his dog, cat, and camel eat fish, and fish are dried and salted to form an ever-present item of export from the tiny ports. The ports have good shelter and deep-water harbours for anchorage, but wharfage facilities are suitable only for small vessels of less than 10-ft. draught. The small sailing vessels are favoured by the tendency for winds to blow offshore in the early morning, switching to on-shore in the afternoon, as a result of the differential temperatures and atmospheric pressures building up over land and sea near the coast. The villages of fishermen and sailors at the ports had about 2,500 to 5,000 souls each in 1940, living mostly in huts of palm-leaf matting. With sea temperature above 80° F. from May to September, and between 70° and 80° F. the rest of the year, winter temperatures seldom drop below 50° F. even at night, and elaborate protection against the cold is unnecessary. The catching, drying, and selling of fish constitute the chief form of activity. In addition, dried dates, figs, grain, and oranges from the interior oases are exported. At Gwadar, a dependency of Oman, there is a salt manufacturing industry based upon evaporation from shallow, diked basins in addition to fishing and trading. The Kech Valley exports through Ormara, Pasni, and Gwadar; Chahbahar is the outlet for Geh. Many of the fishermen keep small herds of sheep or goats as a side line.

Agriculture is vestigial on the Makran Coast. Most of the coastal terraces are narrow and lacking in water. Alexander's fleet under Nearchus, which paralleled the march of the land army, found only a barren, inhospitable coast from the Indus to Hormuz, and even today there is not enough water for large-scale watering of ships. The fishing villages get their water from shallow wells in wadi floors. The largest tract of potentially agricultural coast land is the Dashtiari Plain, a level clay plain formed by alluvial delta-fan deposits of the Bahu (Dashtiari) River, just across the Iranian border from the delta of the Dasht River. Both rivers empty into Gwadar Bay. The Dashtiari Plain runs northward from the coast for about 45 miles, with a width of about 20 miles. Across it wanders the channel of the Bahu River, frequently shifting during the floods of winter. The river is perennial beyond 35 miles from the coast. At the time of the visit of Sir Aurel Stein in 1932, there were only a few small settlements on the plain, obtaining their water for irrigation by the use of low

1. References in Part Two are to be found in the 'Regional' section of the bibliography, except those marked with an asterisk which are listed under 'General'.

dams built across flood channels of the river. Numerous abandoned dams gave evidence of formerly much more extensive utilization of the land, and with careful planning no doubt much land could be reclaimed.

For this as in any other area, planned development must be preceded by field surveys of water-land-culture relationships in the area. Most difficult to obtain are likely to be records of stream flow, which should extend over several years because of the great fluctuations in rainfall and consequently in stream flow in individual years. Other small fans, deltas, and low marine terraces have modest possibilities if the water problem can be solved. Actually there is no significant present-day coastal oasis on the entire north side of the Gulf of Oman except at the extreme western end, at Minab.

SECTOR 4: IRANIAN LITTORAL OF THE PERSIAN GULF[1]

West of the Makran the coastal mountains of southern Iran are broken by the great arc of the Strait of Hormuz, outlet of the Persian Gulf. Through the strait for thousands of years has funnelled the seaborne trade of India and the Far East with the rich lands of Mesopotamia at the head of the gulf, the Arab coast along the southern side of the gulf, and the caravan centres of Iran inland from the north-east coast of the gulf. The north-east coast, skirted by trading vessels for about 600 miles from Mesopotamia to the Makran, is poor, barren, desert land for the most part.

THE CENTRAL LITTORAL

For the central 400 miles of this sector the coast is paralleled by a belt of steep, narrow mountains, of limestone, sandstone, and other sedimentary rocks folded and faulted sharply into narrow ridges and valleys aligned with the general trend. Along much of the coast the outliers of these ranges drop directly into the gulf, usually with a narrow rock-cut marine terrace at their seaward bases. Some outliers form islands, detached entirely from the mainland, including Qishm, the largest of all, a rough, rugged, complex mass of rock stretching for 70 miles along the Strait of Hormuz. At half a dozen places the rocky wall of the mainland coast is interrupted by small alluvial lowlands, where valleys between the echeloned ranges reach the coast or where rivers break through the barrier. Much of the surface of these little lowlands is occupied by marshes or swampy deltas. Such a coast is lacking in good harbours. Only at the ends of this ridge-and-valley area are there more extensive lowlands. At the south-eastern end, in Laristan, the Strait of Hormuz cuts across the grain of the land, and here the main ridges come down to the coast like the fingers of a hand, with long alluvial valleys between. Of the six ports large enough to be listed in the *World Port Index*, five are grouped at this south-eastern end, from Charak to Bandar Abbas, and one, Bushire, is at the Northern end.

Aside from the inner harbour of Bushire, all the ports are open roadsteads, even Bandar Abbas, the main port on the Strait of Hormuz. Dotted along the whole coast are small fishing villages, with a few boats in each, making a precarious living from the fish resources of the Persian Gulf. The fishing involves the catching of individual fish, for a warm, enclosed body of water like the Persian Gulf lacks the nutrients necessary for the development of great schools of pelagic fish, and only demersal or bottom-dwelling fish are important here. The violent and unpredictable winds of the winter storms, the occasional summer storms, and the abundance of coral reefs and sand bars, render the almost harbourless coast dangerous for boats at sea or anchored. The small-draught sailing boats of the fishermen are pulled up on to the beach when not in use.

The poor quality and scarcity of water is a further drawback. In years of relatively good winter rain crops may increase the people's income considerably, but after one or two years of subnormal rainfall, water problems become so great that temporary or permanent emigration results from some areas. At the time of his visit in 1932, Aurel Stein (1934) reported that the south-eastern part of this sector had been 'rainless' for the previous two years, camels and donkeys were thin and dying, and famine was widespread. Many of the people had gone to the Arab coast and Bahrein, across the Persian Gulf, to survive. Fish deteriorate rapidly in the moist heat of summer. In the absence of modern canning and freezing plants, fish are commonly dried when they are not eaten fresh.

The climate of the entire littoral of this sector can be classified as hot desert: a part of the extensive Sahara-Sindian desert as the bioclimatologists have called it. Climatic data are available for only three stations, near the northern and southern ends, with a stretch of 350 miles in the middle lacking data completely. The entire sector lies within the zone of Mediterranean rainfall regime, with winter rainstorms moving in from the west, and long dry summers. The average annual rainfall on the mainland ranges from 10.9 in. at Bushire to 5.8 in. at Bandar Abbas. The third weather station, on the tiny island of Henjam off the south coast of Qishm, gets only 5 in. of rainfall. Although

1. See Map 2 and Table 2.

small in amount, the rainfall is often concentrated into heavy downpours on the few rainy days of the year. Bushire records on the average only eighteen days with rain, and Bandar Abbas only eight, but there have been as many as 5½ in. of rainfall on a single day in January at Bushire. In all, 70 per cent of the rain at Bushire and 90 per cent at Bandar Abbas falls during the three winter months December to February. Even in these months, most days are sunny, with breezes from the interior. June, July, and August are completely rainless every year, and only in very rare years is there any rainfall from May to October in Bushire, or March to November in Bandar Abbas.

During a winter storm, most of the rain runs off the rocky slopes of the mountains and forms brief but turbulent floods. One of the major difficulties reported by travellers along the coastal road in winter is the occasionally flooded stream beds, which temporarily impede or prevent the animals from crossing. In some of the deltas they also create deep mud on the alluvial flats. Travel by automobile along the poor coastal road is feasible only during dry periods. The torrents flowing directly from the seaward slopes of the coastal mountains subside almost as soon as the storm stops, but those obtaining their water from a wider watershed may flow all winter or even all year, though with reduced volume in summer. The Mand River, draining a network of inter-range valleys, the longest 200 miles in length, is the most important of the rivers. It empties into the sea through a sizable delta 60 miles south of Bushire. To date only meagre use has been made of the flood waters for irrigation. Substantial storage or diversion structures would be necessary for any significant expansion of agriculture.

Marshes are an important factor in the geography of the sector. They are developed along the coastal end of nearly every sizable valley or plain, though the largest one, the great salt marsh of Mihrakan, 25 by 10 miles in dimensions, in the south, appears simply to occupy a poorly drained desert basin not especially associated with the coast or any river valley. The nature, use, and potentiality of the marshes is vague: some are reported as being salty, others as fresh. Certainly they affect transportation, for the coastal road has to bend inland to avoid the marshes of the Minab, of Daiyir, and others. Towns are usually built on firm land at the edges of the deltas rather than at the river outlet. Most of the marshes appear to be deltaic, and would be expected to have the usual potentialities and drawbacks of deltas. Opposite Qishm Island, the Mihran River has built a large muddy delta out into Clarence Strait, and a mangrove forest flourishes along this deltaic flat.

The natural vegetation of this sector consists of sparse growth of bunch grass and small woody plants, with large areas of bare ground: much like the Mediterranean desert vegetation of the northern coast of Africa from Egypt to Tunisia. Flat areas subject to soaking by winter rains or floods are covered in winter with grass and flowers, but relapse to bare, dusty plains during the long dry season. Somewhere between Bushire and Bandar Abbas there is a change from the drier, more barren-looking land in the south-east to the less arid land of the north-west. Travellers have been struck particularly by the 'utterly barren' hills of the south, as Aurel Stein (1934) put it. Another traveller, K. Lindberg (1955), working along the coast from the north, noted that the climate and landscape changed just south of Kangan, beyond the big bend in the coast 100 miles from Bushire. He did not specify the nature of the change, but it may be significant that to the north in February 1940 he reported numerous fields with growing wheat, apparently being raised without irrigation on the heavier, moisture-retentive soils.

The entire sector is suitable for hot desert crops such as dates so far as temperature is concerned. Bandar Abbas, 100 miles farther south and more protected than Bushire, is appreciably warmer. In winter it can be described as mild, with a mean daily range in January from 56° to 74° F. compared with the cooler 51° to 64° at Bushire. Winter nights can be uncomfortably chilly, especially during a rainy spell, and the sleeper appreciates two blankets. The temperature has been known to touch freezing at Bushire, while at Bandar Abbas 38° F. is the absolute minimum. Subtropical deciduous trees such as figs lose their leaves in winter.

The sector is notorious for its hot humid summers, especially in the south. The mean daily maximum in July at Bandar Abbas is 100° F., and even the coolest hour of the night is still 85°. An extreme of 119° has been recorded there. The relative humidity during July is 67 per cent. Bushire is even more humid and only two or three degrees less hot. Marco Polo, describing the Minab area (near Bandar Abbas) about 650 years ago, reported that 'the residents avoid being in the cities, for the heat in summer is so great it would kill them. Hence they go out (to sleep) at their gardens in the country, where there are streams and plenty of water' (Stein, 1934).

Apart from the two main centres near the ends of the region, the settlements consist of numerous small villages and towns, the largest, Kangan, having only about 1,000 souls in 1940, and most of them with about 20 to 500 people. The villages show a considerable variation in the economic activity of their inhabitants, most of whom are fishermen, traders, or farmers. On the rocky marine terraces there is little possibility of land use except for the limited quarrying of local minerals such as gypsum, and as a base for fishing or trade. Along the lower lands, fishing and trading may be supplemented by farming. Back from the immediate coasts, some villages concentrate entirely upon farming. The staple and most widespread crop is the date. Nearly every village has a date grove, large or small, and part of the Mand delta has 'veritable forests' of dates. The date palms flourish on sandy soil, and can take advantage of the usual ground water that is too brackish for most plants. On the heavier soils, the principal crop consists of small grains, which presumably are raised without irrigation during years of favourable precipitation in areas of favourable soil. It is likely that barley is more common than wheat in the drier areas, for it is more resistant to alkaline soils and requires less moisture. Many other crops are reported as growing in the sector, in small scattered areas of the more favourable soils and water conditions: vegetables such as egg-plants and fruits such as figs near the coast, and oranges and other subtropical fruits on the better-drained land near the base of mountains back from the coast. At Bardeh Khan-i-Nau, south of the Mand delta, Lindberg noted, besides abundant date groves and grainfields, cows and good milk, and chickens and eggs. Here the ground water obtainable from the wells was fresh in winter but salty in summer. At Daiyir, too, good cultivation was noted by Aurel Stein (1934) along the inner margin of the marsh.

From the available information, it is hard to estimate the extent of irrigated lands. Unquestionably most of the surface water run-off escapes to the sea after winter rains. Most of the ground water is brackish and unsuited to crops, besides being difficult to raise without mechanical devices too expensive for unaided local installation.

A characteristic feature of this sector is the large domed cistern, partly dug into the bedrock and partly a domed superstructure of cemented stone. Two such cisterns were reported by Lindberg between Bushire and Lavar, one of them recently constructed, with well-built arcades inside, and with a hole in the top for drawing out water by means of a bucket on a rope. Similar cisterns in the dry southern area were in use at Asalu, and Stein (*op. cit.*) was greatly impressed by a large number of cisterns, about seventy in all, now abandoned, at an old fort inland from Lingeh. One measured 188 ft. long, cut in the solid sandstone. The cisterns are used to store rain water for domestic use. Although details are lacking, it is likely that they obtain their water from surface run-off guided from nearby slopes into the reservoir. The cisterns are associated with settlements along bare mountain slopes, and in such areas they appear to have been the only source of fresh water for the people. There is no reason why they should not be as useful today as in the past. The vital importance of these supplies of water in the driest southern area is epitomized by the fact the Portuguese control of the Persian Gulf was brought to an end when the garrison on Hormuz Island was forced to surrender by exhaustion of the water supply in their cisterns, combined with the terrible humid heat, in April 1622 (Stein, 1937).

Of building materials there is no local shortage in the sector, provided construction does not require the use of steel or wood. Stone, lime, earth, and fibres are widely used. In the simpler villages the people live in huts of palm leaf ribs and leaves, available in abundance from the date groves. More permanent houses are made of rammed earth, the 'adobe' that is used in hot deserts all over the world. Beautifully woven mats of date leaves are sometimes used for roofing, or for siding. One would expect to find some conventional thatching of reeds in areas near some of the swampy areas. Near the largest town of the central littoral, Kangan, and its companion town, Daiyir, stone houses were in use by the well-to-do citizens at the time of Lindberg's visit. Kangan itself had walled gardens, five mosques, a large bazaar, and a port for small vessels.

Today the trade of the central coast is meagre and local. Bushire is about as far as the small sailing boats feel justified in going, with dried fish, dates, and plaster. There was a period, however, when a great commercial city existed at Siraf, about 20 miles south-east of Kangan, just west of the present fishing village of Tabiri. For a period of about one hundred years in the tenth century A.D. Siraf was the principal centre for the seaborne trade of Persia with India and the Far East. Its ruins now extend for a mile and a half along the terraced limestone ridge overlooking the gulf, running from the water's edge to the crest of the ridge 300 ft. higher. Huge cisterns were cut in the rock to collect the rainfall run-off from the usually dry, bare slope. The site of the city itself had no qualifications whatsoever for a seaport; it depended for its port facilities upon the Bay of Naband, 25 miles to the south, the best natural bay in the central coast, open only to winds from the west. As the bay is backed by the usual valley and marsh, the port town for Siraf was Asalu, at the northern edge of the harbour. This bay was visited by Nearchus in 325 B.C., who reported it as being sheltered and with palms and other fruit trees. Today, in contrast with the deserted Siraf, Asalu is a living town, with a good-sized fishing fleet, and a large rock-hewn water cistern, at the edge of a small fertile lowland.

The apparently unfavourable location of Siraf is to be explained primarily by the fact that it was at this point that the caravan route reached (and still reaches) the coast from the well-watered, fertile valley of Jamm and more distant interior points. Possibly the ridge site was considered more healthful than the marsh-edge site, too. At present roads do not penetrate to the interior except from the ends of the sector, near Bushire and Bandar Abbas. Animal traffic can give only poor competition to trucks. The decline of Siraf, however, occurred long before the coming of self-propelled vehicles. The city was shattered by a great earthquake towards the end of the tenth century, and by the thirteenth century it was almost deserted (Stein, 1934).

Evidence for any significant change of climate within historic times is lacking. The description of this sector by Nearchus in 325 B.C. would apply perfectly today: desert, dates, fish and poverty. The future development of the central littoral will probably depend more upon better use of water resources than upon any rejuvenation of the Naband Bay trade through improvement of routes to the interior. The largest single water concentration is the Mand River, draining an extensive area and emerging upon an expansive plain. In the absence of soil and terrain surveys it is impossible to estimate how much of the plain has suitable soils and elevations for irrigating if the Mand River were dammed or partially diverted by barrages. The northward portion of the plain, the valley of the Shur River, between Bushire and the Mand River, may well be suited to application of the river water. Surveys or estimates of the volume, quality, and seasonal distribution of water and of the type and distribution of soils, in relation to the arrangement of the terrain in the delta and in alluvial plains and fans, would be a prerequisite to even rough estimates of what might be done with that area.

Other areas of level land, with smaller and more local sources of water than the Mand, but equally unknown as to potentialities, are the lowland emerging at the coast between Daiyir and Kangan, the Asalu-Naband swampy lowland, the Mihran plain and delta opposite Qishm, and the next plain eastward, where four rivers coalesce. All these areas would probably need sizable hydraulic works for adequate utilization. These, and many smaller sites, could doubtless be partially improved by small local projects, such as well-drilling and pumping. Some of the countless intermittent wadis coming down from the mountains might have their flood waters systematically diverted or stored by means of local activity directed by experienced leadership, for irrigating excellent silty soils now unused on alluvial fans at the slope bases. Some of the old reservoirs might be reopened for use, though it must be remembered that many were not situated near lands suitable for irrigation even if the amount of water stored were adequate.

There remains the possibility that economic exploitation of minerals may be found possible, of limestone or other building materials, the salt domes that occur in the ranges and on the Island of Hormuz, iron oxides (already exploited for pigment on Hormuz and the mainland), or other minerals not yet found in commercial quantities. For such development the old cisterns might provide useful sources of domestic water supplies.

HARMOZIA

In contrast to the central coastal littoral, with its meagre resources and development, the centres at the southern and northern ends of the sector are *relatively* rich and well developed. For more than two thousand years the largest, most beautiful, and best-known oasis on the Persian Gulf has been that of Minab, sometimes called the 'Paradise of Persia', on the eastern side of the sizable coastal plain north of the Strait of Hormuz. The plain is made up of several coalescing alluvial fans and deltas with a total area of about 750 square miles. The water for irrigation that makes the oasis possible is provided by the Rudan River, a perennial stream which heads in the mountains in the interior and flows southward, uniting with the Minab River near the inner edge of the plain. The water is conducted from the river to water an area of almost continuous orchards and gardens stretching about 10 miles westward and 10 miles southward from the intake at the head of the delta, according to Stein (1937). In addition to the famous date groves, there are orchards of other fruits, such as oranges, peaches, apricots, bananas, and mangoes. The fields produce the staple grains of barley, wheat, and millet, market vegetables, and tobacco.

As long ago as the year 325 B.C. the fleet of Alexander the Great, headed by Admiral Nearchus, stopped at this fertile district, which he called Harmozia. The name was perpetuated by the port of Minab, Hormuz, where the river estuary provided shelter for Nearchus's shallow-draught vessels on their way westward from India. After the dry, hot cruise along the Makran Coast, Alexander's men found grateful shade and relaxation in the groves of Minab for two or three weeks. Even today those who can get away from Bandar Abbas or Qishm like to move to the Minab groves in summer, just as they did at the time of Marco Polo's visit in the thirteenth century, as quoted earlier in this chapter. Minab is an example of a desert area that has been cropped continuously for over 2,300 years.

Apart from the comparatively small area irrigated near Minab, most of the plain appears to be unused. With its true desert climate, its use for agriculture would depend upon development of water sources from the tributary streams, most of which fluctuate greatly during the year, or from the sea. We do not know how much of the land is suitable for crop production, even with water. Natural grazing can be of little permanence in the barren surrounding hills.

The sea provides another source of income for this area. Fishing, including at times pearling, has always attracted some activity along the coast from Lingeh to Minab, and Qishm Island. A limited amount of fish canning has been reported for Bandar Abbas. More important than fishing since the dawn of history has been the maritime trade of this area. Until the mid-eighteenth century, the principal seaport of the Persian Gulf lay at its outlet. The first great port was Hormuz, the port of Minab at the mouth of the Minab River. For about 1,500 years after the visit of Nearchus it seems to have had no serious rival as the meeting place of the caravan routes from the interior and the trading ships from the Orient. With the spread of the Mongols to this area, the shipping centre was shifted to the greater security provided by the Island of Hormuz, which held sway for about 200 years. After the capture of the Island from the Portuguese by the Persian-English allies in 1622, the port was shifted back to the mainland at a new location, named Bandar Abbas (Port of Abbas, the shah at the time). From that time to the present, Bandar Abbas has been the chief town of the delta region, and the chief outlet for those products of the Minab gardens that enter outside trade. Bandar Abbas controlled Persian Gulf trade until after the founding of Bushire in 1736.

Bandar Abbas was built west of the deltaic plain, at a point where the interior hills approach the coast and provide solid footing. The port lacks a natural harbour, but its open roadstead is of more use to modern vessels of large draught than the shallow estuaries of the old Hormuz of Minab. Cultivable lands are lacking in the vicinity of the town: trade is its life. Its dominant position in the economy of southern Iran has been strengthened by construction of a motor road northward to Kerman and the Iranian road network: the only such road south of Bushire. At the time of the 1940 census the town had a population of 14,278, and had developed some small-scale manufacturing, including cotton spinning and food canning.[1]

BUSHIRE

With the northward shifting of commerce in the Persian Gulf, Bushire became the chief port of Iran, only to be displaced after the First World War by the oil centres still farther north. It remains a key Iranian port, twice the size of Bandar Abbas and with better connexions to the interior, exporting such products as tobacco, rugs, wool, and nuts. A main road connects Bushire with Teheran by way of the fertile valleys of Shiraz and Isfahan, and it has developed a cotton textile industry in addition to its shipping and fishing. The town itself occupies the northern end of a long peninsula bordering a natural bay. The bay, surrounded by mud flats and swamps, is too shallow for large modern vessels, and facilities have been provided for them on the open coast just to the south. Facilities for vessels of still deeper draught have been constructed recently at the rocky island of Kharg, 20 miles north-west of Bushire, to handle giant oil tankers of 100,000 tons. The petroleum is transported to the island by pipe-line from the Gach Saran field in the east of the outer range foothills at the extreme northern limit of the sector. On the Island, a small garden has shown that dates, pomegranates, banyans, and even frost-sensitive limes can be grown successfully in limited spots of available water and soil (Skrine, 1958).

Bushire lies at the edge of a plain of about 1,000 square miles, made up of the delta of the Hilleh and lesser rivers. Agricultural possibilities of some significance would probably be revealed by a survey of the water sources and quality, character of swamps, soil, and terrain relationships. Chagadak, a village in the midst of the plain 10 miles east of Bushire, is surrounded by date groves, and near it there are areas of heavy soils where wheat or barley can be raised without irrigation in good years. Lindberg (1955) reports briefly on a farm established near Chagdak in 1924 by Wassmuss. Apparently the environment favoured his project, and for several years he produced varied crops, but social problems and a drought in 1929 led to disintegration. An examination into the details of such a sampling experience should prove instructive, along with a field study of present-day agricultural activities.

North-eastward from the Hilleh River plain, the lowland narrows somewhat but is still a significant expanse of flat terrain. Although there is a local area of greater rainfall than at Bushire, about 15 in. according to Overseas Consultants (1949), there are no streams that break through the bordering mountains with sizable potential supplies of irrigation water: only short, steep wadis flowing during and immediately after a rainstorm. Apart from ground water of unknown amount and quality, this is an area which should benefit if a cheap method of desalinification of sea water is found, assuming that some suitable soils exist.

This northernmost segment of Sector 4 is narrowed abruptly by a spur from the mountains that approaches the coast. Beyond the constriction lie the vast plains of Mesopotamia.

1. Since the above was written, it has been announced that the United States of America will give aid to build a major port at Bandar Abbas to serve all southern Iran and neighbouring Afghanistan (Belair, 1962).

SECTOR 5: MESOPOTAMIAN LITTORAL [1]

The head of the Persian Gulf is bordered for 125 miles by the vast composite delta of Mesopotamia. 'Mesopotamia' originally referred to the land between the Tigris and Euphrates Rivers, but the application of the term has been extended to the whole alluvial plain that stretches inland about 500 miles from the shores of the gulf and is today shared in its lower part by Iraq and Iran. Such natural unity as the region possesses lies primarily in its flatness and its climate—a true hot desert of the type suitable for growing date palms. The flatness does not mean uniformity of surface conditions. On the contrary, several basically different kinds of surface, with correspondingly different kinds of actual and potential development, have come into existence as a result of the delta-building activities of the central rivers on the plain and the fan-building activities of rivers emerging from the mountains along the eastern edge of the plain.

1. See Map 2 and Table 2.

THE RIVER SYSTEM

The great rivers of Mesopotamia are significant as creators of the terrain, as resources in themselves for water supply and transportation, and as constant threats to settlements in Mesopotamia. The main arteries of the plain are the Tigris and Euphrates, heading in the mountains of Turkey and flowing through Mesopotamia, uniting to form a single river, the Shatt-al-Arab, that flows the last 100 miles to the Persian Gulf. The rivers are subject to floods during winter rainstorms and particularly during the melting of mountain snow in the spring. The Tigris, on the mountain side of the valley with large tributaries, has more severe floods than the Euphrates, on the desert side of the valley. Thus the Tigris bore the chief responsibility for the terrible flood of March 1954, which inundated 1,400,000 acres of land, destroyed winter crops and young trees, drowned 50,000 head of livestock, drove 150,000 people from their homes, and was prevented from engulfing Baghdad only by strenuous activity in raising and strengthening the artificial levees on the river banks.

Floods of greater or lesser magnitude occur at least annually, and provisions are being steadily improved to allow the flood waters to pass harmlessly into natural basins of waste land. So much of the water of the Tigris and Euphrates is removed from the rivers through floods, irrigation withdrawals, and evaporation that only a small fraction of the total flow reaches the Shatt-al-Arab. Actually the biggest contributor to the flow of the Shatt-al-Arab is the Karun River, which loses little water before it joins the system from the Iranian side of the valley. In fact, Cressey (1960) estimates that of the 27 cubic kilometres of water discharged annually by the Shatt-al-Arab into the Persian Gulf, only 5 cubic kilometres come from the Tigris and Euphrates and 22 from the Karun. Most of the alluvium carried by the Tigris and Euphrates is dropped in the flooded land, so that the Shatt-al-Arab would be relatively clear of silt were it not for the contribution of muddy water from the Karun.

The Iranian portion of Mesopotamia includes all the lower course of the Karun River and of its tributary the Jarrahi. Much of the water of the Jarrahi is lost in the extensive coastal marshes through which it meanders. The principal stream in Iranian Mesopotamia not connected with the central system is the Hindian or Zuhreh River. It leaves the mountains near the south-eastern corner of the plain and winds through the alluvial lowland before emptying into the gulf at the eastern edge of the coastal marshes. At the time of Nearchus's survey in 325 B.C. the Hindian River (which he called the Arosis) was the boundary between Persia proper to the south-east and the land of Susa to the north-west (Bunbury, 1959).

CLIMATE

The climate of Mesopotamia (Climatol. Atlas for Iraq, 1945) has few significant local differences. There seems to be no sharply defined belt of coastal climate. The summers are everywhere hot, with a mean daily maximum of 112° F. at Abadan (35 miles from the open gulf), 103° at Khurramshur (40 miles from the Gulf), 104° at Basra (60 miles from the gulf; but 111° at Shuaibah just west of Basra), and 110° at Baghdad (350 miles from the gulf). Summer nights are consistently cooler far inland than nearer the coast. Thus, the mean daily minimum temperature in July for Baghdad is 76° F., compared with 81° at Basra and 82° at Abadan. In winter, areas near the coast are somewhat warmer than those farther inland. The mean daily minimum in January is 44° to 46° F. from Abadan to Basra, compared with 39° at Baghdad. On the average, the temperatures at Abadan and Basra do not drop to the freezing point in January, while at Baghdad 29° is the average lowest for the month. Still there is plenty of heat during the year for dates to mature anywhere in the lowland.

There is a perceptible decrease in humidity inland. At Basra on the average July afternoon the relative humidity does not drop below 35 per cent, while at Baghdad it drops to 12 per cent. Thus the lower part of the plain with higher humidities and hotter nights is definitely more uncomfortable in summer than the upper part. Even Fao, only six miles from the gulf, shows no maritime influence on its temperature most of the time during the one summer for which we have daily records (Sevian, private communication, 1954). In July 1954 the mean daily maximum temperature at Fao was 109.7° F., compared with 106° at Basra. However, on six of these days the wind was blowing off the gulf, and on these six days Fao was more than 10° cooler than Basra—the mean daily maximum for these days at Fao was 97.8° F., compared with 108.5° at Basra for the same days. Wind is prevailingly from the north-west or west at all times of day throughout the deltas, usually gentle, but several times every summer strong enough to stir up dust storms.

Rainfall, like temperature, varies too little along the axis of the valley to be a criterion for delimiting the coastal desert. Actually, the rainfall increases slightly seaward, from 5.5 in. annually at Bahgdad to 7.3 at Basra and 7.6 at Abadan. A short, five-year record at Fao showed an average of 8 in. In contrast with the insignificant rainfall contrasts from the coast inland along the Shatt-al-Arab, there are significant differences in both directions away from the river axis. To the south-west the rainfall decreases gradually into the deserts of Arabia, to about 4 in. per year 100 miles from the Shatt. North-eastward, on the contrary, rainfall rises fairly rapidly, attaining about 12 in. in the middle of the Karun plain, and 15 in. or more along the front of the bordering mountains. The inadequacy of rainfall and the requirement for irrigation of crops is apparent when it is considered that crops growing throughout the year could consume between 4 and 5 ft. of water per year under the hot, dry conditions prevailing —that is, potential evapotranspiration is about 55 in. (Thornthwaite, *1957).

For this entire sector the precipitation, such as it is, is concentrated in winter and early spring—summers are dry. It is brought mostly by westerly storms from the Mediterranean area—storms that bring a little rain to the plains and heavy snowfall to the mountains. Abadan is virtually rainless from May to October. From November to February it gets between 1 and 2 in. of rainfall per month on the average, with about one in four or five days rainy; in March and April between 0.5 and 1 in. per month. In a given year the amounts may be much larger or smaller than the means. On occasion, more than 2 in. of rain have fallen in a single day at Abadan. In good winters with well-distributed rainfall, it is likely that crops of grains, especially barley, can be raised on the heavier soils of the Karun plain without irrigation.

THE SHATT-AL-ARAB AND ITS LEVEES

In the absence of any sharp climatic or topographic limits, we may somewhat arbitrarily define the coastal desert of Mesopotamia as being that portion bordering the Shatt-al-Arab and extended laterally to the sides of the plain, including the seaward portion of Khuzistan or the Karun plain. This is the part of Mesopotamia that has received least attention by writers. The Shatt-al-Arab is, after all, the seaward element of the river system, and throughout the length of this aorta the tidal influence of the sea is felt by the sluggishly flowing water. For many centuries great seaports of Iraq and Iran have lain along the banks of the Shatt, and a distinctive landscape has developed.

The configuration and potentialities of this and other great deltaic regions can be understood only through a consideration of the processes of interaction between the rivers and their loads of alluvium. Rivers, especially when they and their tributaries traverse desert lands unprotected by a mantle of vegetation, become loaded with alluvium washed off the surface of the land in every rainstorm. Some alluvium is carried all the way to the sea and forms a deltaic deposit or is carried along the coast by currents. When the axial rivers flood their banks, some of the alluvium is deposited upon the flooded land as the velocity of the river is checked by friction at shallow depths. In the course of time, the recurrent floodings of the Shatt-al-Arab have built up great alluvial deposits on both sides of the river. The greatest accumulations are close to the river, where the flood waters are first checked. As one goes farther from the river, deposits are shallower, with the result that the land actually slopes very gently away from the river, forming a natural levee. Furthermore, the largest particles of alluvium, sand-sized, tend to be dropped first while the finest, mud-sized particles are carried farthest away from the river. With the development of natural levees along the tributary rivers, too, the result is a series of levee-lined basins, poorly drained and with heavy soil. Some of the basins are occupied by marshes, others by lakes of fluctuating size, including the 70-mile Lake Hammar inland of Basra.

The broad natural levees, with the best-drained soil and most favourable terrain, are best adapted for most crops. Along the Shatt-al-Arab since Babylonian times this land to a width of 1 to 10 miles has been planted with dates which now constitute by far the greatest date grove in the world. In some years these groves furnish as much as 80 per cent of the world's date crop, and provide the major export of Iran, apart from petroleum. These groves have certain unique natural advantages that have operated since time immemorial. They are watered by what is probably the most dependable and cheapest large-scale irrigation system in the world. Twice a day the tides from the Persian Gulf transmit their impulses to the Shatt-al-Arab, raising the surface of the water an average of 4 ft. at Abadan and 2 ft. even as far up as Basra. At high tide the water backs into the numerous creeks along the Shatt and into a network of irrigation canals among the date groves, without the necessity of pumps or diversion structures.

The date is the symbol and support of the hot deserts of the Old World. It requires high temperatures, dry air, and abundant water at its roots, but is tolerant of highly alkaline or saline water. It provides (along with barley or wheat) the staple food of the people—tasty, nutritious, durable, and light. In addition, the fruit can be made into syrup and sugar and can be fermented and used for manufacturing alcohol and alcoholic beverages. The stones are ground into a good feed for livestock. The trunks make clumsy but useful low-grade timber. The midribs of the leaves are used for light construction, and in some rural areas for the framework of huts. The fronds or leaves are used for many purposes, including roofing and material for matting. The fibres are used for making rope or string.

The same well-drained natural levees that provide land for date groves also provide the best sites for seaports through which to export the dates. The leading ports of both Iraq and Iran are situated on the levees of the Shatt-al-Arab, for the Shatt-al-Arab forms the boundary between these two countries. The uppermost and foremost seaport of Iraq, Basra, is at the head of navigation for seagoing vessels—depths at over 22 ft. are maintained in the channel by means of dredging. It lies at the crossing of the river where the best feasible road from central Iran swings around the southern edge of Lake Hammar on the way to the dry western route to Baghdad. Through Basra are exported the dates from the south, grain from the interior, and wool from the north. The city more than doubled in population since 1940, and now has over 200,000 inhabitants. Near the mouth of the Shatt-al-Arab is the small Iraqi port of Fao, which is the terminal for pipe-lines from the Zubair oilfield near Basra. It exports both petroleum and dates. The bar at the mouth of the river has been dredged to a depth of 30 ft.; formerly the depth here was only 11 ft.

On the Iranian side of the river the great ports of Abadan and Khorramshahr have developed. Khorramshahr, at the confluence of the Karun River and the Shatt-al-Arab, has long been the leading general commercial port. Through it are shipped dates, rice, cotton, skins, and other products from the nearby levees and basins, the Khuzistan lowland, and interior Iran. In 1943 it became a terminus for the trans-Iranian railway built to permit the shipment of lend-lease supplies to the Soviet Union. There is lively traffic of smaller vessels on the Karun River between Khorramshahr and Ahwaz, 70 miles upstream. Ahwaz lies at the head of continuous navigation, where rapids in the river constitute a barrier to traffic beyond the city. This site seems to have been already significant and well known in 325 B.C., for it marked the terminus of the navigational survey of Admiral Nearchus if we are correct in assuming that his Pasitigris was actually the Karun. Here he sailed for his rendezvous with the land forces of Alexander the Great (Bunbury, 1959). Alexander had built a pontoon bridge across the river here, for use in mounting his attack on Susa 65 miles to the north, and here he hastened to meet Nearchus and celebrate the reunion. This site is even today the major crossing of the Karun by rail and road routes. With its advantages for both land and sea travel, Ahwaz is the principal city serving the rich agricultural Khuzistan Plain.

Just across the Karun from Khorramshahr a distributary stream of that river, the Khor Bahmanshir, flows through the delta all the way to the Persian Gulf, keeping roughly parallel to the Shatt-al-Arab. The piece of land between the Shatt and the Khor forms Abadan Island, 40 miles long. In 1909 on the Shatt margin of the island, the city of Abadan was established and has since become the largest city of this coastal desert, the principal port of Iran in tonnage, and the site of one of the world's largest oil refineries. The economic life of the city revolves about the single product, petroleum, which is brought across the Khuzistan Plain to Abadan by pipe-lines from the oilfields at the foot of the Zagros Mountains on the eastern edge of the plain. Water for the industry is pumped from the Shatt-al-Arab. The refinery structures, tank farms, and homes of the population of over 225,000 have displaced large acreages of date groves around Abadan. The refined products are exported by way of the Shatt-al-Arab, though the river is not deep enough for large supertankers.

Several small river ports have developed for local traffic in an area where travel by water is easier than by land. Special mention might be made of Kabda, a small port on the east side of Abadan Island, using Khor Bahmanshir as its avenue of navigation.

THE KHUZISTAN PLAIN

Aside from the natural levees along the rivers, the best agricultural land with good drainage is that of the Khuzistan Plain of Iran. This is the plain of about 12,000 square miles (7,680,000 acres) that stretches from the Zagros Mountains to the Persian Gulf and the adjoining marshes. Although the lower part of the plain has its share of poorly drained marshy basins, the upper part consists of a continuous belt of alluvial fans built up by streams from the Zagros Mountains, which merge with the natural levees of the larger rivers: the Karun and its northern neighbour the Karkeh, the Jarrahi, and the Hindian. When Alexander the Great seized the Persian Empire, the Khuzistan Plain was flourishing, intensively irrigated, with the seat of the empire, Susa, established in the northern part of the plain (now Shush). The name Khuzistan means 'land of the sugar-cane', and the land was famous for this product, as well as for wheat, barley, alfalfa, fruits, vegetables, and cotton. Repeated invasions, the last by the Mongols in the thirteenth century A.D., destroyed the irrigation works, and recent travellers have described the plain as barren and desolate (West, 1958). Yet the land is about as good as ever, the flow of the rivers is still tremendous, and only capital, planning, and effort are needed to restore the former productivity. Actually, there are about 185,000 acres under irrigation in the plain at present—about 10 per cent of the land with soil and topography suitable for irrigation and about 2.5 per cent of the total area (West, 1958). Some land is irrigated by means of small diversion dams and diesel pumps on the Karun and Karkeh Rivers; and wheat, barley, maize, beans, melons, cucumbers, lettuce, and citrus fruits are among the crops reported. In winter some of the fruits and vegetables are sent by rail daily to Teheran (Skrine, 1958), which is too cold to grow winter crops in its vicinity.

Fortunately Iran, like Iraq, now has a vast annual revenue from its oilfields, and the government has committed itself to using a large proportion of this revenue to improve conditions throughout the country. A series of seven-year plans has been initiated, devised by the Development and Resources Corporation of New-York, headed by former Tennessee Valley Authority chairman David Lilienthal and Gordon Clapp. The first seven-year period ended in 1956; the second shows signs of greater accomplishments. While the plans include improvement of roads, irrigation tunnels (kanats), and other improvements throughout Iran, the keystone of the current plan is the development of Khuzistan. Soil and terrain are favourable and abundant water is at hand. The Karun River, the longest river of Iran and the largest of the Middle

East entirely within one country, is to be dammed for irrigation water and hydroelectric power generation. The ancient sugar-cane agriculture is to be revived, and sugar refining mills to be installed. Cotton production will be increased greatly. A common cause of failure of large land reclamation schemes in the arid zone has been the concentration of all planning upon the great dams and other engineering features without adequate advance consideration of possible and best ways of land use. A large dam on the Karkeh River built during the first Seven-Year Plan, for example, was found to be too low down on the river to reach the right lands with water; the soil within reach was too saline (West, 1958). It is hoped that current plans are making more realistic provision for use of the water after it is made available.

All in all, Khuzistan represents one of the best cases among the coastal deserts of rich undeveloped land and water resources for which a dependable and substantial source of capital is available and committed for large-scale development.

THE RIVER BASIN MARSHES

The marshes formed by river overflow into the poorly drained basins a few miles back from the rivers constitute a world of their own. The core of the basins consists of permanent marshland or shallow lakes, while the rest is subject to annual inundation at the time of the winter and spring floods. It has been estimated that about 80 per cent of the flow of the Tigris at Baghdad is dispersed in the marshes. The vast wet, muddy tracts form an impassable barrier to land traffic, and are avoided by the farmers and workers of the irrigated lands and towns.

The marshes, so inhospitable to the usual pursuits of the desert, are permanently occupied by people who have developed unique culture patterns adapted to their watery environment. The resources of these 'marshmen' consist of the network of creeks, channels, and ponds that enlace the area; an unlimited source of building material and stock feed in the form of 8-ft. bulrushes in the seasonally inundated land and 20-ft. giant reeds in the permanently wet area; plenty of heat and sunshine throughout the year; and rich mud. Hunting, grazing, and specialized farming are the mainstay of the people, as described for the big marshy tract east of the Tigris between Basra and Amara. Wild pigs abound and are hunted throughout the year, ducks and geese in winter. Fish are speared in the many water channels, from long-prowed slender canoes made of planks or reeds, well adapted to pushing through the reeds. Water buffaloes are widely kept, using the reeds as fodder, and are the basis of home dairying, supplying milk, butter, and cheese. Some of the buffalo-raisers are nomadic, but others are sedentary and have permanent villages, usually in connexion with rice fields. Rice is the staple cereal. The fertile, heavy, water-retentive mud of the seasonally inundated marshlands is well adapted to this crop. The rice is planted in May after the floods, grows rapidly in the sweltering heat of summer, and is harvested in November. The houses are made of the tall reeds, tied together in tight bundles (Thesiger, 1954).

The marshlands have considerable potentiality for future development as the floods become better controlled through the successive plans of Iraq and Iran, and as population pressure increases. Gradually the outer portions of the marshlands can be reclaimed and put into crops such as maize on the lighter soils, rice on the heavier soils. Here, as in the Khuzistan Plain, there is a superabundance of water, needing only better control. The six-year plans of Iraq are bringing the floods of the Tigris and Euphrates under better control, but the magnitude of the control problem in middle Mesopotamia is so great that a great many years are likely to elapse before the primitive culture of the marshmen is seriously disturbed.

COASTAL MUD FLATS

The margin of the delta bordering the head of the Persian Gulf east of Abadan Island consists of a broad waste of tidal mud flats. In his pioneering expedition, Nearchus kept well to seaward of the land along here, because the water was shallow and breakers were dangerous for a considerable distance from land. Partly covered with salt water by the daily tides, and all covered during periods of strong wind off the gulf, the mud flats are highly saline and virtually bare of any vegetation. This portion of Iran, extending along the gulf for about 50 miles and inland for an average of about 30 miles, is at present almost completely unused and is likely to remain so indefinitely. Large quantities of more tractable unused land are available for development in the rest of Mesopotamia.

Two important ports have been created towards the inner edge of the mud flats, on the sluggish tidal creek or estuary, the Khor Musa. The older of these ports, Bandar e Shahpur, is the principal deep-water outlet for general trade for Khuzistan, with which it is connected by a direct railway. The railway is the original southern terminus of the Trans-Iranian Railway, and for some years Bandar e Shahpur was the only outlet to the Persian Gulf for that line. With dredging in any direction possible almost at will, the harbour and the channel to it now have a depth of 30 ft. The high tides characteristic of the head of the Persian Gulf amount to 8 ft. at Bandar e Shahpur, and the ebb current helps keep the channel cleared of silt accumulations. The other port, Bandar Mashur, is farther upstream but still with a 30-ft. dredged channel. Its function is the export of crude petroleum, conveyed to it by pipe-line from the Zagros foothill fields.

It is widely believed that the delta of the Mesopotamian rivers has advanced notably during historic times. Monuments of early Mesopotamia, now more than 150 miles inland from the gulf, show boating scenes, for instance, and have led historians to assume that the gulf was that far inland at that time. However, the boats may have been on the river, and there seems to be no acceptable historical or geological evidence that the shoreline was ever north-west of its present position since the dawn of history (Stein, 1937).

SECTOR 6: ARABIAN LITTORAL OF THE PERSIAN GULF[1]

The south-western littoral of the Persian Gulf, from Kuwait to Cape Masandam, is strikingly different from the northern littoral in terrain. Instead of a narrow strip of lowland or terraces pressed against or even into the sea by mountains, the Arabian littoral consists of a broad plain, dipping gently into the sea from the far interior: the lowest part of the down-tilted slope of the great Arabian block. An elevation of 200 metres above sea level is not attained until 30 to 60 miles inland in most of the littoral; several hundred miles at the northern and southern ends. Across the plain no streams, even intermittent ones, reach the Persian Gulf, though there are some long, inconspicuous, sandy beds of wadis leading across the interior. Consequently large stretches of the coasts are uninhabited and desolate. In much of the sector the little water available is obtained from small wells of brackish water, though the central part has artesian water available for the tapping.

Lacking walls of mountains to delimit the coastal desert of Arabia along the Persian Gulf, we must rely upon the more subtle indications of climate and vegetation. Reasonably adequate climatic records are available for the coastal stations of Kuwait, Bahrein, and Sharjah; less complete records for Ras Tanura and Dhahran; and only short and scattered records for stations away from the coast. The coastal climate everywhere is marked by very hot, moist summer conditions: among the most oppressive in the world. At Kuwait and Sharjah the mean daily maximum temperature in July and August is over 100° F.; at Bahrein, barely below 100° (Table 2). Even during the coolest part of the night, temperatures remain well above 80° F. in summer. It is not surprising that the typical earth or stone dwelling in this sector is built with sleeping quarters on the roof to permit maximum radiation of heat to the sky at night. The side walls of the houses are extended some distance above the rooftop to provide privacy, and the visual impression from above is something like that of a war-damaged town, with roofs destroyed. The warm waters of the Persian Gulf, with temperatures above 85° to 90° F. in summer, keep the air of the nearby coast moist except when the wind is from the land. On the basis of more than 4,000 observations during two to three summers, it was found that wet-bulb temperature at Bahrein averaged above 78° F. 67 per cent of the time; at Dhahran, 18 per cent of the time. It may be noted that wet-bulb temperatures above 78° F. are considered too oppressive for continuous labour. In contrast, Abadan, on the Shatt-al-Arab in Iraq, exceeded this oppressive level only 2½ per cent of the time in summer (Dodd, 1955).

Winters are mild, with a daily range between 74° and 54° F. at Sharjah, in January, and between 61° and 49° F. at Kuwait. The thermometer has been known to drop to 37° in Sharjah. At water-surrounded Bahrein it has never fallen below 41° during the period of record. Kuwait is often uncomfortably chilly in winter when the 'shamal' (north-west wind) is blowing, especially during a rainy spell, and during one period of shamal the temperature is reported to have fallen to 24° F. (in January 1911).

Rainfall along this sector averages between 3 and 5 in. per year, with great deviations from these averages in specific years. The rain falls during the winter half of the year, under the influence of storms from the west. Even during the 'rainy' season, however, there are only two or three days with rain per winter month. Summer is completely rainless.

The fragmentary but carefully observed climatological data from stations back from the coast available from oil companies[2] shows a definite rise in summer temperature inland from the coast, a decrease in humidity, and a decrease in rainfall as the following tabulation shows:

Station	Distance from coast (miles)	Mean daily max. temp., July (°F.)	Wet-bulb temp. July (°F.)	Annual rainfall (in.)
Bahrein	0	97	81	3.1
Kuwait	0	103	—	5.1
Dhahran	0.01	106	73	—
Ras Tanura	0	—	—	4.78
Abqaiq	25	114	—	2.55
Nariyah	30	116	70	—
Quaisumah	130	113	68	—
AlKhraj	200	110	—	—

The rainfall figures for Ras Tanura and Abqaiq in the above tabulation are strictly comparable, for they cover the same three years. The gradient of high temperatures levels off apparently somewhere inland of

1. See Map 2.
2. Aramco. Unpublished weather observations.

30 miles from the coast; the increase of land elevation inland presumably accounts for the levelling-out of the temperature gradient.

A definite statement on the width of the coastal desert, on the basis of natural vegetation, is given by H. R. P. Dickson and his wife (1956), long-time residents of Kuwait. They consider that Ash Shaqq, a long, narrow valley running through the corner of Kuwait and the Kuwait Neutral Zone, lies at the inner limit of the coastal desert. The best grazing is eastward towards the gulf, where the vegetation includes *'arfaj (Rhanterium epapposum Oliv.)* a shrub on which camels graze; whereas to the west is a harsh desert grass, *nussi (Aristida plumosa L.)* On this basis, in the absence of any better criteria, we may thus consider the coastal desert to be about 40 miles wide, at least in the Kuwait portion.

On the basis of the sparse vegetation, most of the land of this entire sector was occupied sparsely and periodically by nomadic Bedouins, moving into the area in greatest numbers following seasons of particularly abundant rainfall and pasturage. Aside from an area of ancient oases using artesian wells, however, the most intensive development has long been based upon the resources of the sea. Fishing was always a possibility for Arabs who could find a land base with enough water for drinking. Pearling was for long a major specialized fishing industry, but has declined since 1930 in the face of cheaper Japanese cultured pearls, and, subsequently, the rise of oil income. Kuwait and Bahrein were especially noted as busy shipping centres, while much of the maritime energy of the poor tribes to the south went into highly organized and successful piracy, especially against the rich merchant vessels passing through the Strait of Hormuz. Since the discovery of petroleum in Bahrein in 1932, in Saudi Arabia in 1936, and in Kuwait in 1938, oil has come to dominate and transform the economy of the region, even more than in Iran and Iraq. Still, the Arab dhows along the coast and the great oases farther inland are far from defunct.

KUWAIT

On the basis of actualities and potentialities, three main subdivisions of the Arabian Littoral can be distinguished: Kuwait, the Hasa Littoral, and the Trucial Coast. Lesser divisions include Bahrein and Qatar.

The economic life of Kuwait revolved for many centuries about its one known great natural resource: Kuwait Bay, the largest and deepest natural harbour of the entire Persian Gulf. The north side of the bay is shallow and lined with muddy flats, behind which is a steep ridge 150 to 450 ft. high known as the Zor or Zaur. On the south side of the bay a sandy point projects into the bay close to a channel over 40 ft. deep. Good water found at shallow depths in the sand was a factor in placing the original encampment on the peninsula. The city of Kuwait developed on this natural site into one of the important maritime centres of the Persian Gulf. During the eighteenth and nineteenth centuries Kuwait was the principal intermediary for trade between north-eastern Arabia and the rest of the world and its fleet numbered over 800 seagoing vessels. For a few years after the capture of Basra by the Persians in 1776 it was even the chief outlet for Mesopotamia, thanks to its location just south of the Shatt-al-Arab delta. For a time the Kuwait island of Failaka, opposite the mouth of Kuwait Bay, constituted another power centre in this neighbourhood, when the British made it their Persian Gulf headquarters in 1821 (Sanger,* 1954).

The seagoing flavour of Kuwait has persisted down to the present, though its character has changed somewhat. Kuwait has always had to import most of its food and other commodities because of the poverty of its desert hinterland. Formerly most of its imports came from India (rice, tea, spices, teakwood, cloth, etc.) and the coast of East Africa (mangrove poles, coconuts, soap, and at times slaves), in exchange for dates loaded at the Shatt-al-Arab on the outgoing trip, plus wool, hides, skins, and animals from the Bedouin nomads. Today these exports pale into insignificance beside the export of oil in specialized tankers, in exchange for which the whole world can be tapped for any conceivable type of import desired. There are still perhaps a hundred ocean-going dhows of 75 to 300 tons burden profitably handling general cargo out of Kuwait, and the famous shipyards of Kuwait still make excellent large dhows of imported teakwood. Smaller boats are used for fishing and for the decreasing activity in pearling.

From the beginning of its activity as a fishing and trading centre Kuwait has been handicapped by inadequate local supplies of water. Scattered about the plains surrounding the bay there are some small wells with brackish water, and a little irrigation is possible from about 120,000 gallons of water supplied daily by the deep Suleibiya wells 11 miles south-west of the town of Kuwait (de Candolle, 1959). But until recently chief reliance has been upon water shipped by barge from the Shatt-al-Arab. Eventually a pipe-line may be built to bring water directly from the Shatt-al-Arab to irrigate some of the fertile land north of Kuwait Bay. In the meantime the largest sea water distillation plant in the world has been built along Kuwait Bay to convert sea water into fresh water for the city. The distillation plant consists of five units, four of which are completed, each producing 1 million gallons of fresh water daily. Natural gas, which otherwise would be wasted, is piped 25 miles from the oilfields for fuel. The distilled water is stored in large reservoirs from which it is then piped throughout the city to service stations, and distributed by tank trucks. It is planned to have a dual system, one system to supply untreated salt water for purposes not requiring fresh water. Even with extremely cheap fuel it is not yet possible to produce fresh water cheaply enough for the commercial irrigation of crops.

In the Sheikhdom of Kuwait outside the main city, most of the land is still devoted to the harvesting of natural vegetation by means of livestock. Small flocks of sheep, goats, and camels roam the desert, herded by Bedouins with their ubiquitous black-hair tents, trying to follow the areas with best vegetative growth from recent rainstorms. Ash Shaqq, the long, shallow valley in central Kuwait, has a special place in the economy of the region. In its 10-mile-wide floor, the valley supports a relatively abundant growth of woody vegetation, which is harvested for use as firewood in the city and surrounding villages. Al Batin, the long valley that forms the western border of Kuwait, is considerably drier and supports only low scrubby brush, the home of wild birds and animals. The wild game of the Kuwait desert includes gazelles, hares, and bustards. Kuwait also has its share of grasshoppers to plague its crops.

Enough ground water has been found at shallow depths to provide drinking water and some irrigation water for several villages near Kuwait Bay and on the sandy plain to the south. Dickson (1956) gives a good recent summary account of these villages. Originally the water was obtained by means of manual sweeps, or donkey-powered leather buckets on pulleys, but with the advent of cheap fuel more and more of the water is now pumped by petrol or diesel engines.

Agriculture has developed most in the vicinity of Jahra, a town of some 2,500 souls and 300 homes, about 40 ft. above sea level on a sandy plain two miles west of the head of Kuwait Bay. Here the date is the principal tree crop, but barley, wheat, and alfalfa are staple crops too, and a wide variety of vegetables are raised in small amounts, including beans, onions, radishes, leeks, water-melons, pumpkins, cress, clover egg-plant, and tomato. Most of the crops are irrigated from wells with brackish water at a depth of a dozen feet; some wells have water fresh enough for drinking. In years of good early winter rains, however, a little barley and even wheat is grown from rainfall alone, especially in spots where slope run-off water concentrates. These grains ordinarily are planted in September and harvested in March. Plenty of sheep, goats, donkeys, and camels are raised here too; some of them appear seasonally with Bedouins from the open desert. There are also some milk cattle and chickens. The excellent quality of the alfalfa is an attraction for the livestock raisers.

South of the city of Kuwait several suburban towns have developed. Thus Hawali, a town of about 500 houses, raises fresh vegetables for the Kuwait market by means of irrigation from wells. In one shallow natural depression near Kuwait wheat is planted if there is rain in the autumn, and matures successfully. An increasing number of suburban dwellers commute daily to Kuwait. South of the city of Kuwait there are five villages strung out along the coast for a distance of 15 miles and known collectively as Al Qusur. The villages, from Funaytis in the north to Ash Shu'aybah in the south, have a multiple role as local centres of gardens and livestock and as seaside resorts for the people from the city of Kuwait. The villages have about 100 to 400 houses each, some of which are occupied permanently, as by the farmers, and others only seasonally during the resort season. Farming is based upon irrigation from wells of fairly good water at depths of 12 to 20 ft. Dates are the universal crop, and the villages have from 150 to 1,000 date palms each. In addition, barley, wheat, vegetables, and melons are raised to some extent. Some of the soil is reported as excellent, and it is likely that the irrigated area could be increased greatly if more water were available. The towns of Fahayhil and Ash Shu'aybah have prospered greatly in recent years by reason of their proximity to the great petroleum port of Mina al Ahmadi.

Oil is now the keystone in Kuwait's economy: more so than in any other country except Qatar. The Burgan field 25 miles south of the city of Kuwait was the first one discovered, and its reserves have been estimated at 30,000 to 40,000 million barrels of petroleum, making it the richest-known oilfield in the world, with reserves that may be as large as those of the entire United States. Additional fields have been opened nearby, including that of Ahmadi 10 miles north-east of Burgan, and Maqwa 5 miles north-west of Ahmadi. The oil is developed and exported by the Kuwait Oil Co., jointly owned by Gulf Oil (U.S.A.) and Anglo-Iranian Oil (British). Royalties to the royal treasury of the Emir of Kuwait amounted to $415 million in 1958: enough to provide an average annual income of $2,000 to each man, woman, and child of the slightly more than 200,000 people in the sheikhdom. This State income, plus the wages paid by the oil companies, makes Kuwait easily the richest country in the world *per capita*.

The Emir takes the position that the huge annual oil revenue is a public trust of his, and part of it is being used to develop and modernize the country. In the city of Kuwait good roads, fine air-conditioned houses, eighty new schools, and public parks and gardens have been constructed. Utility services are partly subsidized, and welfare services are provided. Modern concrete is replacing the old stone and earth in house construction. There are free modern hospitals and colleges for boys and girls. Foreign contacts have not been neglected: good students are furnished full financial support for studying at foreign universities. A sizable sum is set aside from revenues each year for investment by British financial advisers in diversified enterprises, as an anchor against any disaster in the oil industry or the eventual but far-distant exhaustion of the oil pools.

The oil company itself has invested large amounts of capital in the course of its activities in Kuwait. Ahmadi, a town of 11,500 people, has sprung up on a desert ridge, 5 miles inland, with 2,500 homes and modern town facilities, all built by the Kuwait Oil

Company. Pipe-lines have been built to bring together the oil in southern Kuwait to the main tank farm at Ahmadi, and thence for export through the modern port of Mina al Ahmadi and Fahayhil, which constitute the world's largest oil loading terminal. In addition to deep-water piers, the terminal has off-shore submarine pipes for loading at sea. At these facilities eighteen large tankers can load simultaneously. Thus, even an open, harbourless site can develop into a great port if the economic incentive is great enough.

All in all, Kuwait is the outstanding example of what can be done to improve the economy and living conditions in a coastal desert where almost unlimited funds are available for development. The hot, humid climate can be air-conditioned indoors, and fresh water can be extracted from the saltiest sea of the world, to improve the comfort and health of these desert dwellers, through the intelligent application of income and cheap power derived from the virtually limitless treasury of oil and gas.

KUWAIT-SAUDI ARABIA NEUTRAL ZONE

Through the good offices of the United Kingdom, two desert areas of intermittent conflict between the wandering Bedouins of Saudi Arabia on the one hand and Iraq and Kuwait on the other were declared to be neutral zones. Any income derived from these zones is to be divided equally between the two countries involved. The Kuwait-Saudi Arabia Neutral Zone lies within the coastal desert just south of Kuwait. It is another segment of the great plain of eastern Arabia, with surface deposits of sand inland, but with a vast area of salt marsh land along the coast, especially in the southeast.

Unlike Kuwait, the Neutral Zone had virtually no economic value until the discovery of oil in 1953 at Wafra, about 40 miles inland and 25 miles south of the Kuwait border. This oil is being developed by two American groups, one licensed by Kuwait and one by Saudi Arabia. More recently a Japanese company obtained an oil concession in the belt of shallow water off-shore from the Neutral Zone, and succeeded in finding oil. This represents the first Japanese participation in the Persian Gulf oil riches. Their first shipments of oil were made in 1961 (Longrigg, 1961). Royalties from Neutral Zone oil go into the treasuries of the adjoining countries; to date nothing appears to have been done to develop other resources of the Zone.

THE HASA LITTORAL

From the neutral Zone to the Trucial States, Saudi Arabia borders on the Persian Gulf for 275 miles, in the province of Hasa. The Hasa littoral is a continuation of the gentle coastal plain, with its alternating stretches of sand, gravel, and salt flats, interspersed with silty tracts. The climate is as hot and dry as that of Kuwait, with an even higher humidity, and with brief irregular rain storms in winter. The north-westerly 'shamal' prevails, with frequent sand or dust storms that carry far out into the Persian Gulf and add to the hazards of navigation.

As in Kuwait, a sparse vegetation of brush and other herbage covers the parched ground, flourishing irregularly only in seasons and years with better rainfall. Most of the area supports wandering groups of Bedouins with herds of sheep, goats, donkeys, and camels subsisting upon the meagre forage.

Three natural characteristics in particular distinguish this region from Kuwait. First, it is more marginal to the great lines of river and sea trade, and has consequently figured less prominently in the past development of the Persian Gulf lands. Second, it borders the northern portion of the Great Pearl Bank, a vast area of shallow coral shoals and reefs, with tortuous channels, that stretches from about Ras abu Ali to beyond Sharja, and has provided special maritime resources to the Arabs from ancient times to the present. Third, the central part of Hasa, from Hofuf to beyond Bahrein in the Persian Gulf, and some distance northward, is underlain by a vast deposit of artesian water, the mainstay of large oases from pre-Biblical days to the present.

The core of the Hasa Arabian population has long been the oasis of al-Hasa, actually an area about 40 miles long with numerous individual oases tapping the artesian waters. Greatest centre of the oasis is Hofuf, capital of Hasa province, a compact city about 1½ miles square in an intensively cultivated oasis about 15 miles long with some 160,000 inhabitants. Hofuf lies 40 miles inland, near the inner edge of the coastal desert. The oases are predominantly groves of date palms, which produce the staple human food, and fields of alfalfa, the mainstay of food for livestock from the surrounding desert. Some of the date palms are hundreds of years old. Wheat, barley, rice, vegetables, and tree fruits are also important (Vidal, 1955). Of the great variety of minor crops of fruits and vegetables grown successfully at Hofuf, grapes and limes appear to be particularly successful and high in quality. Although Aramco has sponsored experimental gardens for trying out a variety of crops, and particularly for the raising of rice with modern machine methods, most of the cultivation is still carried out by hand among the closely spaced palm trees. Even draught animals are not used by most farmers: the soil is turned over deeply by hand, with the use of mattocks. While much can be learned about the use of machinery and the fertilization of crops from the Aramco specialists, it has been stated that practically everything that is known by Americans today about the basic principles of irrigation agriculture was known more than 2,000 years ago by Arab farmers (Crary, 1951).

Most of the water is obtained from natural springs several of which have flows as great as 20,000 gallons per minute. In addition, wells have been drilled to tap the artesian water, and at some places where water has ceased to flow naturally it is raised by means of animal or human power. The principal physical problems have been a gradual lowering of the water table and an increase in alkalinity of some of the land that has been unwisely irrigated. If enough water were available the cultivated acreage at Hofuf (27,000 acres in 1951) could probably be more than doubled.

A noteworthy feature in the midst of the Hofuf oasis is Jebel Qara, a flat-topped hill of pink sandstone, fantastically eroded into gorges and columns. The south face of the hill is penetrated by a huge branching cave, which provides a cool, natural haven. The Governor of Hasa is reported as using one of the chambers of this cave regularly as a retreat during the heat of the day.

On the basis of its surplus of dates, which have a reputation for very high quality, Hofuf has long been an important trading centre of Saudi Arabia and even of the Persian Gulf. Its ancient port of Oqair, at the entrance to the wide, shallow Salwa Bay, is a town of about 5,000, a base for small-scale trade, fishing, and pearling, as well as an oasis in its own right. With the development of oil and the great port of Dammam, however, Oqair has been left in obscurity. With a shoal less than one fathom deep across the entrance to its deeper channel, Oqair is suitable primarily for dhows of shallow draught.

Local industries have arisen in Hofuf to add to its significance as a commercial centre of the desert: manufacture of the swords and daggers so essential to the well-dressed man; copper and brass working; and weaving. With the development of oilfields to the north-east and south-west of the town, and with the Riyadh-Dammam railway running through, Hofuf finds itself with more and more customers to supply.

The next greatest old oasis town after Hofuf is Qatif, a seaport about 85 miles north-north-east of Hofuf. It shares in the vast basin of artesian water, on the basis of which it has long been a very rich agricultural centre, with date groves extending northward and southward for about 9 miles along the coast in a belt about 3 miles wide (U.S. Hydrog. Office,*Sailing Directions, no. 62), except where interrupted by salt marshes or other unfavourable terrain. Alfalfa, rice, and many types of fruits and vegetables are also raised here. In addition, fishing and pearling are still carried on from this base. Although Qatif has been notorious for its unhealthful, malarial site, particularly before the advent of modern public health controls, its population has grown to about 60,000 (Lippincotts*, 1961). It has been overshadowed by the modern rise of Dammam, but it has benefited commercially, too, by the development of a nearby oilfield.

The island of Tarut, off-shore from Qatif, also supports dense groves of date palms on its eastern side. It is worth noting that the artesian strata extend out under the Persian Gulf for a considerable distance. Springs below sea level in the coral floor seaward from Bahrein, Jubail, and other localities are a source of fresh water for dhows, whose crews have only to dive for water as they do for pearls.

Among the more permanent ways of fishing may be mentioned fish traps of rock debris, which are used at various suitable places along the coast to take advantage of the tidal fluctuations. The most important fishing device of the Hasa coast is the fish weir made of palm ribs set into the mud, closely spaced and lashed together rigidly, with funnel-shaped openings so placed that fish are trapped as the tide ebbs or as it flows in a current along the coast. At low tide the fishermen wade out to the end compartment of the weir and gather the fish in hand nets and carry them to shore in palm-leaf baskets. In providing food from the sea, the date palm is nearly as important as in providing the principal food from the oases. Most of the catch consists of small fish weighing perhaps a pound each, but occasionally a 6 ft. shark may be trapped. Jumbo shrimp are also caught in the weirs, especially in the fall. They are dried and keep indefinitely. Sometimes many hundred pounds of fish are obtained from a single weir at ebb tide. The catch is reported to be especially good during periods of strong northerly shamal winds. The weir owners get half of the profits, the workers the other half. Shallow Tarut Bay is especially suitable for weir fishing. Until the coming of the Ras Tanura refinery there were ten large weirs in the bay off Qatif, but Aramco has bought out the rights until only a few weirs were left (Bowen, 1951).

Although weirs are the principal traditional means of catching fish along the Hasa coast, there is also an appreciable amount of fishing from the shore through the use of hand lines or throw nets. Boats are also used for hand-line fishing and for setting and retrieving basketry and wire fish traps.

Pearling is carried out on a small scale during summer, with the use of relatively small dhows (up to 40-ft.) with crews of about ten men.

The sea provides other sources of income to the desert dwellers. Along the shore margins of the flats of Tarut Bay salt is obtained by the evaporation of sea water in diked pans. Salt production is favoured by the dry shamal, the high temperatures, and the fact that the Persian Gulf is one of the saltiest seas with about 38,000 parts of salt per million compared with a world ocean average of 35,000 ppm (Sverdrup,* 1946).

During the warm months the mining of 'sea rock' is important. Dead coral rock is pried up from the bottom, mostly by divers working from dhows. 'Faroush' (flat slabs of coral 3 to 6 in. thick) are the hardest to get and most valuable. 'Hasa' (irregular-shaped pieces of coral) is commoner and cheaper. These two forms of rock are the principal local building material. Each local port has a stockpile of the rock ready for use. Building lime is made by burning hasa (Bowen, 1951).

The major port of Hasa province in the years just before the development of the oil industry was Jubail, the caravan port for Riyadh. It lies 60 miles northwestward of Dhahran. With fairly good shelter for dhows provided by a sandy island near shore, Jubail was an important pearling centre, too.

With the discovery of petroleum in the Upper Jurassic strata of the Dammam field near Dhahran in 1936, rapid new development began in the littoral of Saudi Arabia: development related to the wealth below ground rather than to the desert environment, but certainly affected by the environment in many ways. One after another several new oilfields were discovered some of them much richer and more extensive than the Dammam field. While the latter covers about a dozen square miles, the Abqaiq field covers about 136, and the Ghawar field, farther inland, covers at least 1,200 square miles, in a lens about 150 miles long running northward from Haradh through Hofuf and Ain Dar. The Safaniya field, opened in 1957 off the north coast of Hasa, may be the world's richest off-shore field, and is expected to add about 125,000 barrels daily to Aramco production (Lipsky, 1959). From the production fields the oil is shipped by pipe-line to refineries and seaports for export. Longest of all is the Trans-Arabian Pipe-line (Tapline), that runs for more than 1,000 miles from the Abqaiq and Ohawar fields across the deserts to the port of Sidon on the Mediterranean Sea in Lebanon. As the cost of transport to the eastern end of the Mediterranean is about 50 cents per barrel, whether by pipe-line or tanker, there are definite economic advantages for western Europe in obtaining oil from the northern Sahara.

The drilling, refining, construction of pipe-lines, shipping, and administration of the oil resources of Saudi Arabia are in the hands of the Arabian-American Oil Company (Aramco), a joint subsidiary of four American companies. Aramco has developed a group of four specialized towns which may be called the Dhahran Complex, to manage, process, and ship the oil. Dhahran, on the original oilfield, is a company town, for oil company employees. It resembles an American town, thoroughly air-conditioned for comfort during the ten hottest months but without liquor stores or churches, which are restricted by the government. Nearby is the principal airfield of Saudi Arabia. American workers, with their families, are brought in by Aramco for two-year periods. The climate does not prevent them from leading healthy lives, and many renew their contracts at the end of their initial sojourn.

Greatest commercial port of the complex is Dammam, an ancient port just north of Dhahran that has been rejuvenated into a modern town of about 10,000 and is now the administrative headquarters of Aramco and the greatest general port of the Persian Gulf. Its trade is all one-directional: imports. Construction supplies, food, and goods of all sorts are shipped in and distributed to the oilfields and to the Arab towns inland by roads and by the railway which runs from Dammam through Dhahran and Hofuf to Riyadh. Some fishing is still carried on from this base, too. Seven miles of deep-water wharves with depths of 36 ft. serve the port, utilizing some of the channels that thread the coral shoals of this part of the coast. Just south of Dammam is the port of Khobar, a commercial town with channel depths suitable only for barges and other vessels with maximum draught of 12 ft. The great oil export port of Saudi Arabia is Ras Tanura, an Aramco facility at the end of a long, sandy peninsula across Tarut Bay from Dammam. Here refined products from its refinery and from the Dhahran refinery, as well as crude oil, are piped to large tankers through submarine pipes to anchorage in an open roadstead. The people of Ras Tanura, numbering about 6,000, supplement their somewhat brackish well water with water from a large distillation plant. The pearling fleet has come to depend upon visits to Ras Tanura for replenishing their water tanks.

Apart from the Dhahran complex, there are a few minor ports northward along the coast serving to import supplies for oil fields and Tapline, and as bases for local fishing and pearling. The Great Pearl Bank ends at Ras Abu Ali, about 50 miles north-westward of Ras Tanura. The whole of this coast and offshore islands is low, sandy, and reef-lined, with sizable areas of marsh extending inland. Some of the small islands are brush-covered, and are occupied by numerous birds. Guano has been obtained from them, and they are still visited by fishermen for turtles.

In the absence of maps of soil or geomorphology, it is hard to estimate how much of the Saudi Arabian littoral could be cultivated if water were available. Successful test gardens have been made here and there; but for the forseeable future Hasa is likely to continue getting most of its supplies, except dates, in exchange for oil, through world trade.

BAHREIN

The Bahrein Islands constitute a desert group about 25 miles off the coast from Dammam, at the northern end of the conspicuous coastal indentation of Salwa Bay. Most of the 250 squares miles of the group are in the main Bahrein Island, the largest island of the Persian Gulf after Qishm. It lies on the Great Pearl Bank of shallow limestone reef, and much of the coast, especially the southern half, is so closely surrounded by barrier reef that it is inaccessible except to small boats of shallow draught. In the north, deep channels permit the approach of large vessels.

Bahrein has been a flourishing centre of international trade with India and Mesopotamia since at least the third millennium B.C. The Romans knew it already as a great centre of pearl fishing, and it continued to be the focus of Persian Gulf pearl fishing and marketing until the sharp decline of the industry in the present century.

At the height of the pearl market Bahrein was considered to have the greatest *per capita* income of any State in the world, and its wealthy merchants were a potent factor in Middle Eastern trade.

Before the great depression following the First World War there were nearly 3,000 pearling dhows in the Persian Gulf. Even in the early 1940's there were still about 850: 300 from Bahrein, 200 each from Qatar and the Trucial Coast, 100 from Kuwait, and 50 from Hasa. By 1951 there were only about 600 pearling dhows in all. With greater prosperity and higher pearl prices, the industry has improved a little since then. The pearling season is the season of warm water, from the time when the temperature of the water reaches 85° F. in June to the time when it drops again to 85° in October (the water temperature sometimes reaches 100° F. in August). During the season when the water is too cool for diving, some pearls are obtained at low tide by wading.

Most of the pearling vessels, apart from the small ones of Hasa, are large sailing dhows 60 to 100 ft. long, with long oars for manœuvring on the oyster beds. The departure of the pearling fleets in June from Bahrein, the Trucial Coast, and Kuwait is the occasion for gala public ceremonies. The vessels sail to the oyster beds with crews of forty to sixty, somewhat over half of whom are Arab or Persian divers and most of the rest Negro assistants, descendants of former slaves, who do the heavy pulling of oars, the recovering of diving stones and of divers ready to surface. The divers sometimes go down as much as 90 ft., though the best oyster beds are usually at depths of 30 to 60 ft. The diver sinks rapidly on a 30-pound stone or iron, which is then hauled up by an attached line, and remains under water about one minute on the average. He is subject to many injuries and diseases, from abrasions from coral or spiny marine life and from effects of the changes of pressure during rapid ascent. Modern skin-living methods are not used. The oysters brought up are added to a common pile and opened the next day: no man knows whether the pearls come from the oysters he secured.

The pearls are sold to merchants of Bahrein at the end of the voyage, unless buyers in boats succeed in buying them while still at sea. From Bahrein (or Sharjah, Kuwait, or Dhahran) the pearls are flown to the Bombay market. In 1944 the average season's catch sold for about 20,000 rupees per boat: $4,200 to be divided, half to the dhow owner, half to the captain and crew. The average crew member gets about $10 to $100 for a season's work. Furthermore, he commonly obtains advance loans from his captain for food during the winter, and his season's earnings often are insufficient to pay off his debt. This results in a widespread system of peonage, under which a diver or assistant is forbidden by law to work for any other captain so long as his debt is unpaid. Even after the death of the worker, his debt was passed on to his son or brother, though this law has been revised in Bahrein so that the debt dies with the pearler. In view of the better wages and security in the oil industry and in lightering for the modern towns, it is not surprising that the pearl industry has declined and that it is increasingly difficult to find a pearling crew (Sanger,* 1954; Bowen, 1951).

Piracy, another popular source of income from the sea, was practically wiped out since the United Kingdom in the 1820's undertook to combat it, by treaty and by naval action. Somewhat later, smuggling of slaves and of guns was also greatly reduced.

Fishing, including shrimp fishing, is still another source of income from the sea for the people of these desert islands. The shallow bay in the north-east corner of Bahrein Island, just north of Sitra, lends itself especially well to the use of fish traps. A few years ago the Food and Agriculture Organization of the United Nations estimated the annual production of fish by Bahrein at 2,000 tons, compared with 1,000 for Kuwait, and 4,000 for all Saudi Arabia (Morgan,* 1956).

In the above ways, and through their substantial dhow trade with India and the east coast of Africa, the Arabs have demonstrated that they make as good seamen as they do camel- and date-raisers throughout the littorals of the Persian Gulf, Indian Ocean, and Red Sea.

Since long before the dominance of Hormuz in Persian Gulf affairs, Bahrein experienced strong Persian influences, with control contested between Persians and Arabs. Since 1783 the Arabs have controlled, and Bahrein has been an independent sheikhdom, with a predominance of Arabs but with sizable minorities of Iranians, Indians, and others among its present population of about 210,000. Iran maintains its claim to ownership. Moslem faith prevails, the Indian rupee is the chief coin used, the United Kingdom controls foreign relations and maintains its principal Persian Gulf naval base at Bahrein, and petroleum is extracted by American oil companies.

The physical setting of most of Bahrein consists of barren, unpromising desert land. The main island is an elongated geological dome in structure. Alternating strata of hard Eocene limestone and soft marl have been domed upward towards the centre of the island, and the middle portion has been reduced by erosion so as to leave an oval, flat-floored basin almost half the length of the island, surrounded by steep escarpments facing inward. In the very centre of the basin a sizable fragment of the dome has remained, in the form of a mesa or plateau, above which rises the highest point of the island, the steep-sided peak Jebel Dukhan, elevation 450 ft. The outer slopes of the dome slope gently seaward, except where cut into steep-sided rocky gorges by wadi torrents. In the north, the outer slope forms a rocky table-land 100 to 150 ft. in elevation. Around most of the periphery of the island the base of the dome has been covered by more recent flat-lying deposits, though on the middle part of the east coast the hard limestones of the dome plunge directly into the sea.

The principal surficial material on most of the island is reg, or desert pavement, consisting of angular small pieces of gravel from an inch to several inches in diameter, and so closely spaced as to almost completely cover the underlying sandy or silty ground. The reg covers most of the slopes of the dome and central plateau, and parts of the floor of the central basin and the peripheral lowlands. The many thousands of ancient tumuli which constitute a conspicuous feature of the Bahrein landscape were made by scraping up the reg gravel into mounds. Bare bed rock, or 'hammada', prevails on steep slopes and floors of some wadis and on some wind-swept parts of the central plateau. Sand is the common surface material of the peripheral zone, especially in the south where it has accumulated under the driving effect of the prevailing north-westerly shamal. At the extreme southern tip of the island the sand has been drawn out by combined wind and currents into a long, curving spit. Even in the central basin wind-blown sand has accumulated in the southern part. On the peripheral zone, the sand grades off into hard salt flats or salt marsh and, in the north, into mixtures of sand and silt that support great date groves (O'Good, 1954).

Water, like soil, is best in the northern part of the island. The great bed of artesian water from the mainland extends under much of Bahrein, but it is too saline for use in the south (about 4,000 ppm.). Consequently the principal population and agricultural development is found in the north, while most of the rest of the island supports only sparse grazing and small, widely spaced fishing villages.

Bahrein shares the general climatic characteristics of the Arabian mainland littoral, as shown in Table 2, except that it is even more humid and uncomfortable. From May to October the temperature usually rises above 90° F. during the day, and from June to September even the lowest temperature at night is usually above 80° F. Relative humidity in summer remains high even during the hottest time of day, averaging 69 per cent at 7.30 a.m. and 67 per cent at 3.30 p.m. The relative physiologic stress resulting from humidity can be better expressed by the wet-bulb temperature. At wetbulb temperatures above 78° F., conditions are considered to be too oppressive for continuous labour; above 85° F., the vapour pressure may be dangerous for people not accustomed to intensely hot climates. At Bahrein, hourly observations for two years showed that during the period June-July-August the wet bulb remained above 78° for 67 per cent of the time, compared with 18 per cent for Dhahran and 2.5 per cent for Abadan; and above 85° for 1.5 per cent of the time. Thus the statistics bear out the impressions of visitors, that Bahrein is one of the most disagreeably hot, humid localities of the world in summer (Dodd, 1955). In winter the weather is mild, even chilly at night. The mean daily maximum temperature in January is 68° F., and the daily minimum is 57°. Except in the winter months from December to February, the temperature has never been known to drop below 50° F. during sixteen years of systematic weather observations, and freezing is unknown.

The high temperatures and humidities of summer are accompanied by almost cloudless skies, and the total absence of rainfall. Such rainfall as there is (3.1 in. per year on the average) comes during the winter half of the year, from November to April. Rain usually falls on not more than one or two days per month during the 'rainy' season, and in some years most winter months may be rainless. At the same time there is considerable cloudiness during this season, even when rain does not fall.

The rainfall is not sufficient to support dense perennial vegetation.

The natural vegetation of the island is basically the same as that of the Arabian mainland: a part of the Saharo-Indic complex that prevails in the hot deserts of the Old World in the Northern Hemisphere. Woody shrubs, grasses, forbs, and succulents grow sparsely in diverse local combinations. In the bottoms of the arroyo beds, where roots can reach ground water, the shrubs sometimes grow in tall thickets. Along some stretches of muddy shore, especially in the north-east and north-west, mangrove swamps flourish.

Intensive agriculture is carried on only in the northern peripheral zone where the combination of artesian water and suitable terrain permits the maintenance of a continuous belt of date palms. The groves occupy the littoral west from Manama, the chief city of Bahrein, and much of the low sandy island of Muharraq, just offshore from Manama, and Sitra Island, just offshore to the south. The dates are ripe in August, when they are most delicious, but the bulk of the crop is allowed to dry on the trees and is picked in September for storage or shipment. Alfalfa is also a staple crop, and many other crops are raised on a smaller scale. Along the west coast there are occasional small date groves, some of them no more than clumps. Levels of the artesian water appear to be falling as the result of over-exploitation (Hay, 1954).

Like the Hasa coast, Bahrein today depends primarily for its income upon petroleum. Oil was discovered in 1932 and the field has been developed into a major producer, centring in the central basin south of the central plateau. The oil workers are housed in Awali, a newly created town in the northern part of the central basin. The oil is piped to a refinery in the peripheral zone north-east of the basin, and thence by pipe-line over a bridge to the island of Sitra for export from a pier and sea anchorage. The anchorage is open but is protected by Bahrein Island from the force of the shamal. Oil and its refined products are stored in a large tank farm in the middle of Sitra Island. Crude oil also is shipped to this refinery from Dhahran by way of a submarine pipe-line that enters Bahrein on the north-west. The town and associated oil complex of Sitra is an indispensable part of the Bahrein economy, but the principal urban centre is Manama and the nearby town of Muharraq which is linked to Manama by a causeway across the coral reefs. Manama has long been the principal general-cargo port of Bahrein. Although smaller boats find a sheltered inner harbour at Manama, the main harbour, Bahrein Harbour, is merely an open roadstead protected against the worst of the shamal by a reef off shore. The principal airport of Bahrein is in the middle of Murraq Island. With its international trade and its rich adjoining belt of date groves, Manama, has become a city of nearly 50,000. Oil income has led to the construction of important official buildings and some well-built residences of stone. Many of the houses are still built of adobe (earth), either left brown or covered with gleaming white plaster, with thick walls and few windows so as to keep out the heat of the day. Flat earth roofs, built over mangrove pole rafters, are used for dining and sleeping on hot nights (Sanger,* 1954).

Two other ports deserve special mention. Jufair Naval Base off the shallow bay, Khor Kaliya, between Sitra and Manama, is the principal British base in the Persian Gulf. Zallaq, in the middle of the west coast of Bahrein, has a local pearling and fishing fleet and is also a barge port for trade with Khobar on the mainland.

Three small islands of the Bahrein group lying a few miles off the north-west coast of the main island have been put to specialized uses adapted to their distinctive characteristics. The largest, Umm Nasan, with about 9 square miles, is used as a hunting preserve by the Sheikh, and is permanently inhabited only by a few of his retainers. The island is a flat, sandy plain overlying a limestone platform that is exposed here and there along the coast. Two low, rocky hills rise in the interior. The vegetation is similar to that of the main island. The island of Jedda, about a mile in circumference, is used as a prison. It is a flat, rocky plateau of limestone, surrounded by steep cliffs that drop somewhat less than 100 ft. to the sea. Raka, a tiny island of a few acres, is a private estate, intensively cultivated through the use of the artesian water (O'Good, 1954).

QATAR

Qatar, a big desolate peninsula of 4,000 square miles, projecting northward into the Persian Gulf, has the general outline of a moth-eaten mitten with the thumb on the west side. Most of its surface is unused, and even the coasts have large stretches without inhabitants. Since the discovery of oil in 1939 the population has nearly tripled, and since the start of oil production in 1949 the population has doubled, to about 35,000 or 40,000. Even now Qatar has only one-third as large a population as Bahrein though the area is sixteen times as great.

Except for oil, natural resources are extremely meagre. The peninsula consists essentially of an uneven limestone plateau, based upon two great north-south Eocene anticlinal upwarps, one about 35 miles long and 4 miles wide near the west coast, and one running the length of the centre of the peninsula. The western one, known as the Dukhan anticline, is responsible for the frayed thumb of the Qatar mitten and, more important for the lives of the people, it contains the vast pool of petroleum that is the present-day source of most of the revenue of Qatar. The middle fold is more gentle, and is known as the mid-peninsular rise. The whole plateau, especially the Dukhan anticline, is dissected by slope wash, and to some extent by karstic solution, into hills and depressions. The hills are varied, many of them in the form of mesas or long escarpments, in which softer limestone is capped by harder, the summits mostly below 200 ft. Most of the land surface is a gravelly desert. Some of the depressions contain pools of water during the 'rainy' winter season (though average yearly rainfall is only about 4 in. and highly variable from year to year); others have a nearly permanent growth of low grass; and still others are merely alkaline sebkhas. The southern part of the peninsula is covered by extensive deposits of sand, deposited in the form of varied types of dunes by the shamal from the north-west. In this sandy south, water is extremely rare. A sparse grazing activity is supported by the plateau, chiefly of camels, handicapped by meagreness of forage and scarcity of water. Qatar lacks great artesian reservoirs like those of Hasa and Bahrein.

The wrist of Qatar is connected with the mainland, or more properly speaking, separated from the mainland, by a series of salt marshes or sebkhas, ending on the two coasts in deeply indented sea lagoons. The local tradition that Qatar was once an island is easily believed; a slight subsidence of the land would again cut it off from Arabia (Johnstone and Wilkinson, 1960).

From the earliest times to the present most of the people of Qatar have lived along the coasts. Little income was to be obtained from the land, but the sea provided fish, pearls, legitimate trade, and, formerly, piratical and slave-trading opportunities. All the coasts are low, with alternating stretches of sand, gravel, and salt sebkhas, backed in places by low mesas of limestone.

The coast is broken by numerous shallow bays, flooded lagoons, and narrow inlets.

The east coast has been the most favoured by settlements, for it faces upon the widest portion of the Great Pearl Bank and at the same time is protected from onshore shamal winds from the north-west. Before the oil development, pearling was the main source of income. In winter, fishing became the leading occupation, with fishermen taking advantage of greater availability of water at that season to range widely along the coast. Even in recent years fish traps have been important, and stone fish traps are noted especially along the coast between Umm Said and Doha (U.S. Hydrog. Office,* *Sailing Directions, no. 62). As might be expected from the lack of water, agriculture is almost non-existent. Only two or three struggling date groves have been reported for all of Qatar (Melamid, 1953).

Two centres stand out on the east coast today: Doha, the capital and largest town of the Qatar sheikhdom, and Umm Said, the oil port. Doha (Ad Dahwah, al-Doha) is an ancient town on a broad bay in the middle of the Qatar east coast. It was the first place in Qatar ever to be visited by a European, so far as we know: in 1822, by Lieutenant Grubb of the Indian Navy. He landed at Bida, one of the quarters of Doha, and reported it as 'a most miserable place, not a blade of grass nor any vegation near it; the water good, procured they say at some distance' (Johnstone and Wilkinson, 1960). Doha remained a small political, pearling, and fishing centre until the flood of oil riches suddenly raised the income of the government to unimagined levels. An influx of non-Qataris has raised the population to 25,000: about two-thirds of the entire population of Qatar. A distillation plant now supplies the town with fresh water, another contribution made by the application of cheap oil, and a modern programme has improved the buildings and health conditions of the inhabitants. Doha has become a little Kuwait. The oil royalties ($57 millions in 1958) of the Sheikh, while much less than those of Kuwait, are several times as large as those of Bahrein, and give the present population a mean *per capita* income of about $1,500 in addition to the wages paid by the oil companies to its workers.

The petroleum from the Dukhan oilfield near the west coast has no suitable port nearby for export. It finds its outlet therefore at Umm Said, on the south-east coast, to which the oil is transported by means of a 12-in. pipe-line. At Umm Said pipe-lines run off shore to berths for direct loading of tankers. Other cargo, mostly imports, is handled at the main town about 4 miles north of the oil terminal. Large vessels must anchor well off-shore, and tranship their loads by lighterage. Still farther north is the town of Al Waqrah, with extensive ruins but now nearly deserted. It has a harbour which can be entered by small boats at high tide but dries at low tide.

The west coast of Qatar has poor approaches as the result of the coral reefs and shoals. Settlements consist largely of small, widely spaced fishing camps, sometimes on the ruined sites of former villages. The south half of the coast, along Salwa Bay, is especially inhospitable and unoccupied. Salwa, at the head of the bay, just across the border from Qatar, is an isolated village with small palm groves. During the development of the oilfield the necessary equipment and supplies were brought in, with difficulties, by shallow-draught barges to Zekrit, the nearest feasible approach to Dukhan. Historically, the most important part of the west coast has been in the extreme north-west. Following the Persian attacks upon Basra in 1776 many merchants fled from Basra and settled in al-Zubara. With this infusion of new enterprise, and lying as it does near the sea route from Bahreim and Hasa to the Strait of Hormuz, al-Zubara enjoyed great prosperity for a while. A few miles farther north the inlet of Khor Hassan became the base of a famous pirate, Rahma b. Jabir. As in Bahrein, the British put a stop to piracy in the early nineteenth century, though occasional piratical episodes have occurred as late as 1944. Some pearling, on a declining scale, has been based in the north-west, but today the old towns of this area are in ruin and are occupied by small fishing villages, whose little dhows can manœuvre in the narrow, winding channels among the coral reefs.

Qatar today is more utterly dependent upon oil than any other State, and no part of the sheikhdom is likely to be developed unless it is decided to direct some of the oil revenue in that direction.

THE TRUCIAL COAST

Eastward from Qatar the coast extends for 375 miles to the rugged limestone peninsula of Ruus al Jibal and its northern end, the Masandam Peninsula, at the entrance of the Strait of Hormuz. This southern littoral of the Persian Gulf is known as the Trucial Coast, for it is divided into a number of small sheikhdoms with which the British arranged a truce in 1820 and subsequently, in order to put an end to piracy. Although sometimes called Trucial Oman, this area has in fact no political connexion with Oman. Before the truce, this had been known as the Pirate Coast. In the year 1809 it was estimated to have 19,000 pirates: most of the adult males (Blanchard,* 1929).

Geographically this area was one of the most suitable in the world as a base for pirates. The coast is fronted by the Great Pearl Bank, extending 100 miles from the coast in places, made up of a coral limestone platform with numerous shoals, reefs, and small islands. Along the coast are tortuous channels, lagoons, creeks, and in places mangrove swamps, mostly not charted even today, through which fast craft manned by hardy Arab crews and piloted by men thoroughly familiar with local navigation could dart out to pounce upon merchant vessels and retreat without much chance of being overtaken by larger patrol vessels unversed in the intricacies of the navigational obstacles. The poverty of the barren desert land base had its part in encouraging desperate and ruthless adventures at sea. The desert also served as an area into which the Arab pirates could withdraw temporarily if forced to abandon ship.

Even the climate makes this a dangerous coast. For the navigator, this is a lee shore; the shamal here blows from the west-north-west, endangering the ships near shore, kicking up a choppy sea, and filling the air with enough dust to reduce visibility seriously. The shamal is strongest and most persistent in summer, though it is the prevailing wind at all seasons. In winter, storms of the Mediterranean type move down from the north-west, with variable and sometimes violent winds. Large vessels, which must anchor a mile or more off-shore because of the shallow water closer in, must weigh anchor and move out into the Persian Gulf during strong on-shore winds to avoid dragging anchor on the hard coral bottom and being driven aground. This was the situation on 8 April 1961, when the British liner *Dara* on its Basra-Bombay run, with about 550 passengers, had stopped at Dibai, the main port of the Trucial Coast. To avoid being blown against the shore by a violent thunderstorm, the *Dara* headed for open water and was about 50 miles out when a fire broke out, followed by an explosion. Although the majority of the passengers and crew were saved, there were some drownings.

To the land dwellers, both winds and rainfall may cause damage. The only weather station with a long record, at Sharja, shows an average rainfall of only 4.2 in. per year, all falling from November to April (Table 2). Amounts vary greatly from year to year and within a given year. Most of the season's rain may fall in a single violent downpour. Thus in the early morning of 23 November 1957 Sharja experienced a thunderstorm that brought 2.91 in. in 50 minutes. The village was flooded to a depth of 10 in. Gusts of wind from the north - north-east, with a maximum speed of 57 knots, did great damage to reed huts and sheet-iron roofs. The storm also struck Dibai, 9 miles south-west of Sharja, beaching a number of dhows, and sinking one with loss of life. Two children were killed by hailstones which were reported to be about 15 in. in circumference. A similar rainfall occurred in November 1954, but in the other five years between 1951 and 1957 there was no measurable rainfall in November (Murray and Coulthard, 1959).

Although pirates have been virtually eliminated through arduous military action by the British and the operation of the truce, the people of this area still depend upon the sea for most of their income. With the decline of piracy, pearling became the chief summer activity of able-bodied men. Though pearling has declined, it has retained a stronger hold on the Trucial Coast than elsewhere because there is as yet no large revenue from oil. Fishing is important most of the year. Dates and other crops form important oases in the eastern part of the littoral. And there is some nomadic grazing of camels, sheep, and goats on the sparse desert vegetation that grows irregularly during the winter rains.

Although statistical data of any sort are unreliable for the Trucial Coast, it is estimated that the total population numbers about 70,000, of whom about 10,000 are nomads at least part of the year. The nomads move about freely according to the best available grazing land resulting from the sporadic winter rains, with little attention to such nebulous international boundaries as may exist, and their political affiliations are loose and shifting. In summer many of them keep their herds near the alfalfa sources of the coastal oases. The little sheikhdoms are vague as to boundaries, especially where their territories fade off into the desert inland. Most of the people live near the coast, and each of the sheikhdoms has its own nucleus on the coast at some inlet, lagoon, or indentation where small boats of the local fleet can find shelter. The number of Trucial States has expanded and contracted in the course of time through mergers and splits. For some time there have been seven sheikhdoms, six of which are based on the Persian Gulf and one (Fujaira) is based on the Gulf of Oman, across the mountains from Sharja with which it was formerly affiliated.

All the States are under British influence, and conduct their foreign affairs through British representatives. For over a century the United Kingdom made no serious attempt to interpose in land quarrels among the Trucial States, contenting itself with keeping the seas free from piracy and smuggling. Starting in 1951, however, when boundaries between sheikhdoms began to acquire importance in connexion with oil contracts, the British have helped the Arabs to develop and maintain a small force of efficient mobile desert troops, known as the Oman Scouts. By their presence and mediatory activity, the scouts have been able to maintain reasonable security for workers and visitors and peace among the sheikhs (*New York Times*, 1961). Exploration for oil is being actively pursued, and already the sheikhs have received substantial payments for oil leases, and some oil has been discovered near Abu Dabi. The only discovery of oil in commercial quantities, however, was made recently on the Great Pearl Bank, near the island of Das (see below, p. 52).

Five of the six sheikhdoms and about 90 per cent of the population of the Trucial Coast live in the 75-mile stretch of littoral at the eastern end. This area is favoured by the only adequate supply of good water in the entire 375 miles of the Trucial Coast, furnished by percolation from the Ruus al Jibal, the rocky bare range that rises to elevations of over 8,000 ft. and concentrates enough run-off from the winter rains to develop substantial supplies of ground water in the sedimentary deposits at the base of the mountains. The water is used to irrigate extensive date groves and other crops near the coast, and to support a few scattered oases farther inland. Although data on the Trucial States are sparse and conflicting, an attempt will be made to characterize each of the sheikhdoms briefly.

The north-easternmost of the Trucial States is Ras al Khaima (Khaymah), which starts just south of Ash Shaam and follows the coast south-westwards for about 25 miles almost to Jazirat al Hamra. At the northern end of the sheikhdom the low sandy plain of Arabia tapers out between the sea and the Ruus al Jibal, but southward the plain steadily expands, and at the town of Ras al Khaima the mountains are already 6 miles back from the coast. A narrow extension of the sheikhdom extends across the base of the peninsula to include the village of Dibba on the Gulf of Oman.

Like many of the Trucial towns, the town of Ras al Khaima lies at the end of a long lagoon formed by a sand spit parallel to the coast. The lagoon is navigable by dhows, though the entrance is only two or three feet deep, and the town is the centre of local fishing and pearling fleets. Most of the buildings are of stone, and there are several high stone towers formerly used as look-outs and defences against attacks by sea or by land. The outstanding advantage of this sheikhdom is the availability of a good supply of fresh water. This permits it to maintain sizable date groves and other irrigated gardens. Date groves occupy land inland from the lagoons and coastal sand dunes as far north as Ar Rimth (Rimdh), a village on another lagoon about 1½ miles north of the Khaima lagoon and likewise used by dhows. Altogether Ras al Khaima supports about 15,000 people, and is second only to Dibai in population.

The sheikhdom of Umm al Qaiwain, with about 3,000 inhabitants, runs along the coast for about 15 miles south-westward from Jazirat al Hamra. The town of Umm al Qaiwain lies in the southern part of the country on a long and branching coastal lagoon uncharted and navigable only by small-draught dhows. Most of the people live in that town or on Hamra at the northern end. Fifteen miles from the coast lies the little oasis of Falq Al Ali, which recognizes the same sheikh.

The town and sheikhdom of Ajman is the next centre south-westward. It is a small fishing and pearling centre on the coast, surrounded on the land side by the sheikhdom of Sharja. It has only about 2,000 inhabitants, but is complete with pirate fort and date groves.

Seven miles south-west of Ajman is the town of Sharja (Sharjah, Ash Shariqah), with an importance greater than its 3,000 inhabitants would indicate. The sheikhdom extends about 20 miles along the coast and about 30 miles inland to include the oasis of Dhaid. The town lies on a creek and a wide shallow lagoon used for pearling and fishing, and larger vessels find anchorage about a mile off-shore in a rather exposed location. As it is near the eastern end of the Great Pearl Bank, Sharja was a principal pearling centre. The suburbs and the next village south are made up chiefly of mat huts, though a few are of earth. There are date groves to the north and south, some of them as much as a mile long. Some international importance attached to Sharja when the British political agent for the Trucial States resided there, but he has been shifted to Dibai. Scientifically it is noteworthy as having the only regular weather station that has operated for a number of years on this coast. The Sharja climatic data are given in Table 2. There appears to be a decided sea- and land-breeze effect here. Throughout the year, at the 07.30 reading, there is a south or south-east wind (land breeze), while at the 15.30 reading the wind is west or north-west (sea breeze), which helps make the very high summer temperature and humidity more bearable (U.S. Hydrog. Office, *Sailing Directions, no. 62).

Passing mention should be made of Fujaira, a sheikhdom of some 3,000 people, considered to be part of the Trucial States even though it lies on the Gulf of Oman. It was at one time a part of Sharja.

The sheikhdom of Dibai (Dubai, Dubayy) has about 40,000 people: more than half the population of the entire Trucial Coast. Although it stretches for about 50 miles along the coast from Abu Hail (on the Sharja border) to the Khor al Ghanadha (Abu Dabi), most of its inhabitants are concentrated in the north-eastern 10 miles, 25,000 in the town of Dibai alone. Dibai town is the chief port of the Trucial Coast. Considering the fact that Dibai is a busy international port, its natural advantages for shipping seem meagre in the extreme. It lies 8 miles south-west of Sharja town on the south shore of Khor Dibai, a shallow inlet that winds inland south-eastward for several miles. Traffic in the Khor is limited to fishing vessels and shallow-draught lighters, for the entrance depth has been only 1½ ft. though depths as much as 6 or 7ft. are found in parts of the inner channel. The situation has been improved recently by dredging operations. Large ocean-going vessels anchor about a mile off shore and discharge passengers or cargo by means of lighters to wharves along the Khor. Because of exposure to the shamal and other on-shore winds, ships often have to interrupt their activity, pull up anchor, and head for the safety of mid-gulf, as was described above for the liner *Dara*. Besides its activity as a cross-roads of sea trade, Dibai has an airport and sea-plane base. Dibai is also the base for considerable fishing and some pearling. The cosmopolitan population includes many Persians, Indians, and Baluchis as well as the Arab majority.

The core of the town is concentrated along the inlet. It consists of substantial square white-walled houses of coral blocks, with the usual open roofs for maximum coolness for the evening meal and sleeping. Many of the houses are surmounted by wind towers: square towers with open pillared tops to lead the cooling breezes down into the houses. In the 'suq', or shopping centre, shade is provided by awnings across the narrow streets. Fishermen's huts, of palm matting, lie along the outskirts (Hay, 1954; O'Shea, 1947). Dibai has two sizable suburbs, Shendagha, just north on the sandy spit that forms the west side of the entrance of the inlet, and Daira, on the east side of the inlet, across from the main town. The suburbs are made up mostly of palm mat huts, but with some substantial coral houses like those of the centre. The city and its suburbs are interconnected by ferries across the inlet.

Although the fresh-water supplies are of poor quality, they are good enough to support large groves of salt-tolerant date palms in the vicinity. The largest date grove extends about 2 miles south-west from the town.

On the outskirts of the Dibai date groves the relatively settled part of the Trucial Coast ends abruptly, and for 80 miles south-westward the littoral consists of low, barren-looking almost uninhabited sandy desert. The coast is interrupted by numerous lagoons inlets, and swamps, which in the last 30 miles are almost continuously interconnected by lagoons separated from the sea by narrow sand spits or islands, some of which are covered with mangroves. The inlets extend inland for miles. Some of them have deep water, but the entrances are all very shallow (U.S. Hydrog. Office,* Sailing Directions, no. 62). Owing to the lack of settlement, poor natural boundaries, and possibilities of oil discoveries, this no-man's-land has been the subject of bitter disputes between the two sheikhdoms that claim it. As recently as 1947 the United Kingdom intervened to prevent war between Dibai and Abu Dhabi (Sanger,* 1954).

The town of Abu Dhabi (Zaby) lies at the major angle of the Trucial Coast, the only significant inhabited centre in the entire western 280 miles of the Trucial Coast. The sheikhdom of Abu Dhabi, which covers this long segment of littoral and also extends its claims 70 miles inland to the oases of Buraimi, is by far the largest of the Trucial States in square miles. Its total population, however, numbers only about 5,000, most of whom live in the town of Abu Dhabi.

The town of Abu Dhabi lies on a low island separated from the mainland by an inlet so shallow that it can be forded at low tide. The inlet connects with a broad lagoon to the south, indented many miles into the land and studded with shoals, channels, and islands. The anchorage of the port is a channel about 15 ft. deep, just off the outer shore, protected against the most severe waves, but not against the shamal, by a shallow reef. Small vessels, of up to 12-ft. draught, can anchor here, but the harbour, poor at best, is usually too crowded with local dhows to afford comfortable additional berths. Lying where the Great Pearl Bank is nearly at its widest, Abu Dhabi continues to support a local fleet of pearling as well as fishing and trading dhows. It is the local commercial centre for the independent fishermen and pearlers who seasonally ply the waters of the long stretches of townless coasts and the islands scattered over the Great Pearl Bank. When pilots are needed for the Great Pearl Bank, Abu Dhabi is reputed able to supply the best ones; skill and experience are needed to navigate the uncharted channels, reefs, and shoals of this shallow expanse of water.

The town extends for about 2 miles along the coast. Most of it consists of palm mat huts, though there are some stone buildings on the coast in the centre of town, as well as stone forts and a mosque. The suq, with its Persian shopkeepers, has a fairly diversified supply of goods to tempt the visiting Bedouins, fishermen, oil workers, or travellers. Well water is brackish, but some small date groves and gardens are reported. Stock feed is so scarce that even mangrove foliage is used to feed donkeys.

For some years the Iraq Petroleum Company has been doing test drilling, under considerable difficulties of supply and at times of negotiation with conflicting claimants to territory. Although the limits between sheikhdoms are now fairly well defined along the coast, the inland boundaries with Saudi Arabia are vague: the boundaries between the British leases and the American Saudi Arabian lease. Oil explorations are intermittently under way at the Buraimi oases in the interior, which Abu Dhabi and Muscat administer but Saudi Arabia still claims. In the meantime, the oil exploration activity does bring additional outside contacts and some funds to the Trucial Coast.

Explorations on the Great Pearl Bank have been more successful than on the land. A British and French consortium, the Abu Dhabi Marine Areas, Ltd., finally has found oil about 75 miles off shore near the island of Das. When production begins, Abu Dhabi will be the latest of the tiny oil-rich states (Longrigg, 1961).

Westward from the port of Abu Dhabi the littoral for its entire 200 miles to Khor al Odaid, at the base of Qatar, is a poorly charted, almost uninhabited wilderness of inlets, marshes, and lagoons interspersed with sandy lowland or low mesas. It is fronted by the coral reefs and shoals of the Great Pearl Bank, through which underwater channels run to the coastal inlets. For the first 100 miles, much of the coast is skirted by long, low sandy islands forming a chain a few miles off-shore, providing a somewhat sheltered channel between them and the coast. Tidal currents are strong in some of the constrictions, and might be considered as sources of power if oil were not readily available. Immediately south-west of Abu Dhabi there is a rambling backwater, studded with islets, shoals, and channels. Starting about 20 miles west of Abu Dhabi, Khor Qantur begins and runs westward for about 20 miles further, winding as a narrow channel between the islands and the mainland. At its western end, Khor Qantur leads into Khor al Bazm, a wide shallow sound with a deep channel, 45 miles long and about 12 miles wide at its widest, western end. Protected on the north by an almost continuous line of islands and shoals, and with unmapped refuges along its south shore, this whole coast, but especially Khor al Bazm, was once a notorious refuge area for pirates, and more recently for smugglers. In recent years only one village has been reported for this entire stretch of coast, a small village on the island of Al Fihahi (Al Fuay), 8 miles off the mainland, on the north side of Khor al Bazm; and a few houses on small adjoining islands. These and some other islands are reported to have a growth of desert scrub, with mangroves along some parts of the coast.

The mainland along this coast is almost unmapped and unknown, as marine mappers have little concern with it. It consists of low sandy tracts, some of which are flooded at exceptionally high tide, and, back from the sandy coast, low hills or mesas capped by hard strata and strewn with stones. Probably it is visited at least seasonally by a few fishermen. About 100 miles west of Abu Dhabi town, a rugged rocky mass of hills rises to a height of 384 ft. at its peak, Jebel Dhanna, and forms a blunt promontory that marks an important angle in the coast. Directly north of the point and 4 miles off shore is the conspicuous volcanic island of Sir Bani Yas (Jazirat al Yas). Two villages have been reported for this island, one apparently permanent, of earth houses, and the other occupied only temporarily by fishermen in winter, with rush huts and tents. Direct information on sources of water is lacking, but it is known that on some of the islands of the Great Pearl Bank winter rainfall collects in rock pools, and doubtless some percolates into the sandy floors of small wadis.

West of Jebel Dhanna the coast bends inland to form the east side of a broad shallow, unnamed bay which for purposes of identification we may call Matti Bay. The head of the bay runs westward for 28 miles and merges by a poorly defined transition into Sabkha Matti. Sabkha Matti is a huge salt flat or marsh that extends inland perhaps 50 miles. After a winter rain, the Sabkha forms a barrier of deep mud which is avoided by coastal trucks. It is truly desertic in climate, and is reported to have the highest summer temperatures of the entire Persian Gulf littoral.

The west shore of Matti Bay runs north-south for about 16 miles, with numerous small rocky points. The land rises inland in a series of terraces to a light-coloured tableland about 100 ft. above sea level.

The remainder of the Trucial Coast westward consists of a series of four shallow embayments threaded by narrow channels, studded with reefs and shoals, and separated from one another by rocky points. Information about them is sketchy. The westernmost bay, Khor al Odaid (Udayd), is usually taken as separating Qatar from the Trucial Coast. In winter the bay is visited by fishermen for whom it provides good shelter. The narrow channel through the shoals of the bay is 12 to 24 ft. deep inside but the entrance is only 6 ft. deep, and good-sized vessels cannot enter but must anchor outside the bay.

Climatically, the islands scattered about the Great Pearl Bank far from shore are as desertic as the mainland. Vegetation, too, is the basic hot desert with scattered scrub and annuals. Most of these islands are in the western half of the Great Pearl Bank, though one, Sir Abu Nuair, is in the east. The islands tend to be tadpole-shaped, with the tail projecting from the south or south-east side. The tail is a sandbank, and owes its location to the prevailing north-westerly direction of the shamal, which drifts sand towards the south-east. The most sheltered anchorage is usually off the south-east coast of an island where the island and its sand spit give protection against the prevailing wind and waves, and the sandy bottom gives better holding for the anchor than the usual hard coral bottom. The islands are visited by fishermen from Abu Dhabi in winter and pearlers in summer, usually for shelter against storms, but sometimes, especially in winter, for water supplies.

Some of the more important islands deserve special mention. The largest (apart from the island of Sir Bani Yas, which is close to the mainland) is Jazirat Dalma (Dalmah). Its northern part consists of low flat-topped hills, the highest rising 305 ft. The southern part is low and sandy, terminating in the usual sand spit at the extreme southern end. Dalma is one of the few islands with a permanent settlement: a village of about sixty people in 1953, on the south-west coast. Jazirat Sir Abu Nuair (Nuayr), about 40 miles off-shore between Abu Dhabi and Dibai, is also hilly, with a mesa rising to 240 ft., smaller volcanic hills northward, and the usual sandy spit in the south-east. It is visited by many boats during the pearling season. In the winter of 1953 it had a transient population of about 250, devoted to the working of iron oxide mines.

Das is a small island that is used as a base for petroleum explorations in nearby parts of the Great Pearl Bank. A rich deposit has finally been struck, about 20 miles north-east of Das, the only commercial discovery in all south-eastern Arabia. The oil will flow in a submarine pipe-line to storage tanks on Das, where it will be picked up by tankers (Sectors 6-18). A small harbour in the south-east of the island is used for handling oil well supplies. It rises to 154 ft. in the north, but is low and sandy in the south, with the usual spit. An airfield utilizes a flat area on the west side of the island. Az Zarqa (Zirko) is the highest island of all, with a peak rising to 525 ft., despite the small size of the island. It has the usual low sandy spit on the south, with good landing on its east side (U.S. Hydrog. Office,* Sailing Directions, no. 62).

Beyond the Trucial Sheikhdoms in the north-east all the way to the Strait of Hormuz, the land is a part of the Sultanate of Muscat and Oman, separated from the main part of the sultanate by parts of Trucial sheikhdoms. For about 30 miles north-eastward of the Sheikhdom of Ras al Khaima as far as Ras Shaikh Masud, the littoral along the Persian Gulf is part of the steep mountain range of Ruus al Jibal, which rises in a short distance to heights more than 8,000 ft. above the sea. At places the mountains drop directly into the sea, with forbidding cliffs, vertical or even overhanging. One section of cliff near the northern end is over 900 ft. high. Here and there the coast is bordered by narrow strips of sandy lowland, but nowhere are there sheltered harbours. The coast, open to the direct force of the shamal, is quite unsuited for large vessels. There are fishing villages every few miles, however, each one with a small date grove. The canyons leading into the Jibal provide sources of good water. Ash Sham (Shuam), the chief settlement, is situated in a canyon back from the coast, where a large number of wells are used to irrigate dates, figs, pomegranates, melons, and vegetables. Its people also have fishing boats on the coast. Although the mountains are extremely barren looking, they do serve to concentrate the occasional rainfall by slope run-off.

North of the massive part of the peninsula, beyond the prominent headland of Ras Shaikh Masud, the Ruus al Jibal suddenly breaks down into the Masandam Peninsula which ends in the Strait of Hormuz. The Masandam Peninsula is a series of tortuous rocky peninsulas and deep inlets, some of the inlets winding inland 5 to 10 miles. The whole assemblage is connected to the mainland by a very narrow isthmus. The inlets provide shelter for sizable ocean-going vessels, but there is no hinterland. At the heads of the inlets and their branch bays there is usually a little valley ending in a sandy beach, with a small fishing village, with date palms and other cultivation. The north-eastern end of the peninsula, Cape Masandam, is a vertical limestone cliff 453 ft. high. This is the forbidding cliff sighted by Nearchos's men, and is the first part of the Arabian lands to come into view when entering Hormuz Straits. 'Masandam' (Mesandum) means 'the anvil', against which ships can be shattered readily (McCrindle,* 1879). Beyond Cape Masandam are islands, such as Jazirat Masandam, surrounded by steep cliffs, and inhabited by small groups of fishermen or State employees caring for light or radio bases (U.S. Hydrog. Office,* Sailing Directions, no. 62).

SECTOR 7: MUSCAT

The littoral facing the Gulf of Oman, from Cape Masandam to Cape al Hadd, an airline distance of about 350 miles, is known as Muscat (Masqat). Unlike the Trucial Coast, with its many tiny rival sheikhdoms, most of Muscat falls within a single political unit, the Sultanate of Muscat and Oman, an independent absolute monarchy dating from 1741. The mountains paralleling the coast inland, and the broken foothill area west of the mountains, make up Oman, ruled over by an Imam with his capital at Nizwa in the heart of the foothills, loosely subordinate to the Sultan. The coastal desert does not involve Oman, with the exception of water and goods reaching the Muscat strip. The entire population of Muscat and Oman, including the district of Dhufar south-west of Cape al Hadd, is estimated at about 550,000, the greater part of which lives in the Muscat littoral. A true desert climate prevails, with less than 4 in. rainfall, coming in winter, on the average, so that the people depend largely upon irrigation agriculture, fishing, and trade. Winds are prevailingly from the east, on shore, in summer, but from the north-west the rest of the year, parallel with the coast and favourable for sailing in and out.

The Muscat littoral has three broadly contrasting segments. In the northern and southern segments the mountains descend to the sea, resulting in a coast of rocky cliffs and promontories broken by steep-sided inlets. In the central segment the mountains recede from the shore, leaving a broad plain fringed by a low sandy coast.

The northern segment, about 90 miles long, from Cape Masandam to just north of Fujaira, is the roughest of all, especially in the Masandam Peninsula. The east side of the Masandam Peninsula, facing the Gulf of Oman, resembles the previously described west side facing the Persian Gulf. It has two deep bays penetrating the mountains, rimmed by cliffs broken here and there at the heads of coves by beaches at the ends of canyons. Small villages, combining fishing and date-raising, flourish on the alluvial accumulations at the ends of these canyons. Ghubbat al Ghazirah (Malcolm Inlet), the deep, branching inlet that separates the Masandam Peninsula from the rest of the Ruus al Jubal, is particularly striking. It extends for 9 miles west - north-westward, and has at least four villages at the heads of its branches. Fish are plentiful in the inlet, and are caught with long seines. Good anchorage, protected against the shamal, is available for ships of any draught, but the inlet is seldom visited by large ships owing to lack of a hinterland or other economic attraction.

Southward there are no bays approaching Ghubbat al Ghazirah in size. The base of the Ruus al Jibal here forms a rather straight, precipitous coast with small indentations and villages and two sheltered inlets. Still further south is the open Bay of Dibba, in the northern part of the eastern extension of the Trucial Kingdom of Ras al Khaima. At its head lies the fortified town of Dibba, surrounded by date groves. The remainder of the rocky coast south of Dibba Bay lies in a mountainous district known as Ash Shamailiyah, with the usual cliffed coast alternating with sandy bays backed by date groves and villages. A few miles north of the village of Fujaira, in the Trucial Sheikhdom of the same name, a narrow, continuous coastal plain begins, which widens rapidly southward into the main Batina plain of the Sultanate.

The heart of Muscat is the Batina Coast (Sahil al Batinah), the central lowland district stretching 175 miles from Fujaira almost to the town of Muscat. The district is terminated on the north and south by the mountain segments. Batina has most of the people and provides the economic mainstay of Muscat in the form of crops and fish.

The Batina plain, about 15 to 25 miles wide, slopes gently to the sea from the foothills of the Western Hajar mountains and hills. Although we lack geomorphological and soil surveys of the area, it probably consists in large measure of alluvial fans, bajadas, and possible marine terraces, intersected by wadis, with fertile sandy soils. It has been described as a single vast oasis, one of the world's great date groves. Although desert rainfall conditions prevail, with only 3.1 in. per annum recorded at the Muscat town weather station, mostly falling in winter, the rocky slopes of the Western Hajar concentrate enough run-off water in the wadis and fans to provide a substantial source of underground water. The water is obtained for irrigation both by wells and by falujes, the underground tunnels known to the Persians as qanats and apparently originally introduced to this region by the Persians. Some wells are dug inland of trickles observed on the beach at low tide (Merrylee, 1959).

Under the tropical temperature conditions, in which even the coldest month averages above 70° F., irrigation of diverse crops flourishes in the Batina district. The date is by far the most important crop. The quality is excellent, and the harvest is earlier than that of the Shatt al Arab in Iraq, so the crop brings top prices in the foreign market and constitutes the major agricultural export. During the date harvest season, late summer and fall, the anchorages off the Batina coast are crowded with dhows. Other crops range from true tropical to Mediterranean types: from bananas and mangoes to olives, almonds, and lemons. Among the staples are wheat, barley, and millet, sugar-cane, melons, and alfalfa. The alfalfa is the mainstay of an important livestock industry, including especially camels, goats, and cattle, linked to the nomadic grazing of the hinterlands. In the Western Hajar uplands the cooler climate favours vineyards and wine, walnuts, and figs (Lippincotts,* 1961).

Much of the outer fringe of the Batina Coast is lined with fishing huts and villages, the dwellings mostly constructed of palm matting. The sandy shore offers little shelter to large vessels, which must anchor some distance out, but it can be used by small fishing boats. In addition, much fishing is done with the use of huge communal seines rather than through fish fence traps as along the Bahrein and Hasa coasts (Bowen, 1951). Sardines and other fish are dried and salted, and add to the exports as well as to the local diet. India is a prime buyer of fish and fish fertilizer (Morgan,* 1956).

The two chief towns of the Batina district are seaports as well as local market centres for rich date groves. Sohar (Suhar), usually considered as the leading town, lies at the seaward terminus of the main caravan trail to the west. It is the market for hides, goatskins, and other products from the Western Hajar hill country and the Buraimi oases beyond. A pass about 2,000 ft. high leads across the mountains. On the other hand it supplies rice, textiles, and other imports and manufactures to the hill country. It exports dates, dried fruits, and animal products including hides, skins, and ghee. Local tradition says that Sohar was the birthplace of Sinbad the Sailor, in keeping with its long history of hardy seafarers. But Baghdad seems to have first claim to Sinbad. Sohar is a compact, substantially constructed walled town with a moat and an impressive fort with a 110-ft. tower. Many of its 7,500 people live outside the walls in mat huts. Some local manufacture of consumer goods, especially silk and cotton cloth for use in turbans and other clothing and for sails, is reported. The other important town, Khabura (Al Khabura), with about 8,000 people, lies about 40 miles south-east of Sohar. One section of the town has substantial stone and earth houses, while the rest has the usual palm matting huts. It has a considerable seaborne trade with Bahrein and Mesopotamia.

A large proportion of the land traffic is still by animal caravans. Trails across the plain in the dusty, sandy ground, winding among the closely spaced palm trees, gardens, and huts, are so difficult that travellers by motor vehicle can move most easily by driving along the hard sands of the beach at low tide, as was done by the Sultan's expedition in 1955 and reported by Morris (1957a). There are airports on the outskirts of Sohar and Muscat.

Sib, a small town of about 2,000 people, near the southern end of the Batina Coast, deserves mention. It lies at the mouth of Wadi Samail, which runs from the broad, deep valley that cleaves the Hailar mountains into their eastern and western segments. The valley also affords a good pass through the mountains, and caravans originating in Muscat or Matrah leave the coast at Sib en route for this pass. Sib is also a seaside resort for the people of Muscat during the hottest season.

A few miles south-east of Sib, a large cross-ridge of the Eastern Hajar comes down to the coast, terminating the southern end of the Batina plain and substituting a rocky shore for the sandy one of Batina. The northern end of the ridge forms a rocky point, the Ras al Hamar, at the main angle of the central coast of Muscat. From here on south-eastward the littoral consists of small valleys and plains at the heads of coves and bays wedged between precipitous cliffs and promontories.

Just 6 miles south-westward of Ras al Hamar is the most famous town and capital of the sultanate, Muscat. It lies in a small natural amphitheatre of steep black basalt rock, with a small defensible harbour and very restricted landing space. Though the palace of the Sultan and other buildings housing the Government and British representatives make it the political centre of the Sultanate, the cramped facilities have discouraged international trade. In addition, the climate is extremely hot and humid, and water supplies poor. Roof rain catchments are used to supplement the poor wells. Only about 5,000 people live here. The chief commercial town of the sultanate is Matrah, with about 8,500 people, in the next cove of Muscat. Functionally it can be considered a twin city with Muscat, or a western suburb of Muscat. Matrah, with a more commodious port and better accessibility, carries on an active trade with other ports of the Indian Ocean and Persian Gulf, shipping out dates, salt fish, and dried and fresh fruits. It also has facilities for building and repairing seagoing vessels.

South-eastward for over 100 miles, from Muscat to Ras al Hadd, the littoral supports a score or more of villages devoted to fishing, date-growing, or, usually, both. The size of the village depends in part upon the extent of cultivable land and, even more important, the amount of water available for irrigation. Some of the palm-surrounded settlements are on tiny tracts of alluvial land at the outlets of narrow gorges. A few have harbours consisting of narrow inlets suitable only for fishing boats, but most have only open anchorages with slight protection from headlands. Most of the dwellings are date mat huts. One of the largest villages, Quryat (Qaryat al Kabirah), with a number of stone houses as well as mat huts, and sizable date groves, lies at the coastal outlet of a large mountain valley.

Largest settlement of all this southern rocky coast is the town of Sur, with about 12,000 people, some 15 miles north-west of Ras al Hadd. Lying opposite a major embayment of the Eastern Hajar and not far from the southern end of the mountains, it serves as a port for all southern Muscat and Oman. In addition, it has large date groves and other cropland, intensively irrigated with water supplies accumulated from a considerable run-off area. The town itself has a core of stone and earth houses built on both sides of the entrance of a shallow inlet. From Sur to Ras al Hadd the coast is bordered by low hills and more extensive lowland areas, with several inlets. The deepest and most sheltered inlet is the Khor al Jarama, 10 miles south-east of Sur. It has a narrow, winding inlet about a mile long with depths sufficient for vessels of 15-ft. draught, leading to a broad, shallow lagoon suitable for smaller vessels.

Ras al Hadd, the major turning point in the Muscat and Oman coast, is a low, sandy cape. To the south, the area covered by Sector 8 begins.

SECTOR 8: ARABIAN SOUTH-EAST LITTORAL

The south-east littoral of the Arabian Peninsula is a long strip of true tropical desert. It runs in a north-easterly - south-westerly direction, bordering the Gulf of Aden and Arabian Sea for a distance of about 1,400 miles, from latitude 12½ to 22½° N. The eastern half of the littoral lies under the jurisdiction of the Sultanate of Muscat and Oman, while the western half consists of protectorates of Aden. Common to the entire coast are the hot desert climate, monsoon winds shifting from south-westerly in summer to north-easterly in winter, sparse Moslem population, and primary economic dependence upon irrigated crops, fishing, and trade. In other respects there are significant regional differences between different parts of the strip. Aside from a few climatic tables and conventional maritime navigational surveys, information for most of this littoral depends upon piecing together scraps from accounts of travellers and data from sketchy maps.

CLIMATE

Our quantitative knowledge of the climate of this sector is based upon four weather stations with adequate records, well spaced along the coast at distances of 300 to 400 miles apart, at Masira Island, Salala, Riyan (just east of Mukalla), and Aden (Table 2). There is also a short one-year record from Ras al Hadd. There are no records of localities back from the immediate coast. Sparse though they are, these records (U.K. Met. Office,* 1943, part 2), together with shipboard observations at sea off the coast (U.S. Hydrog. Office,* Sailing Directions, no. 61), do give a fair idea of the main climatic characteristics of the area.

The sea and the south-east coast of Arabia are dominated by pronounced monsoon winds, which affect all aspects of climate and human activity. These winds are strongest and most clearly apparent at sea, where they are not subject to local influences of terrain. The monsoons may be related to the tendency for low atmospheric pressures to prevail over southern Arabia in summer with winds from the south-westerly quarter, and high pressures to prevail in winter, with north-easterly winds resulting: in effect, an extension of the main Asiatic pressure systems. A further possible explanation lies in the fact that at the height of the summer monsoon the intertropical front commonly parallels the coast a short distance off shore and may impinge on the land at times, especially in the central part of the coast. There is a tendency for winds on the south side of the front to blow from a south-westerly direction, and on the north side of the front from the north-east. On either basis, the winds would tend roughly to parallel the coast. The south-west monsoon prevails for about seven months in the north-eastern part of the area (April to October), six months in the central portion (April to September), and four months in the south-western part in the Gulf of Aden (June to September). This is the season of strongest winds, which reach their greatest fury in July and August, with gales a frequent occurrence. Small vessels along the coast then seek refuge on the north-east side of promontories. The north-east monsoon is gentler and less persistent. It lasts on the average from about October to March or April.

Along the immediate coast the monsoon winds are modified by a strong sea breeze-land breeze tendency. At Riyan and Salala in the winter portion of the year, October to April, a distinct land breeze blows from the north in the early morning; by afternoon a sea breeze sets in from the south or south-east even though the north-east monsoon prevails out at sea. In summer, a south or south-west wind prevails at these stations in the afternoon, while in the early morning calm or light air predominates. The sea breeze tempers the hot afternoons. Small fishing or trading sailing vessels take advantage of the daily rhythms of the winds in entering or leaving port. Once a few miles out at sea, ships—from the earliest days—have taken advantage of the great monsoon winds to sail towards India in summer and to return to Arabia or Africa in winter.

The powerful winds of the summer monsoon have an interesting effect upon the temperature of the sea surface along the Arabian coast. As the drag of the wind sets up sea currents, cooler water from the depths wells up to the surface near the coast as the result of the removal of warmer surface water or of turbulence induced by obstructions on the sea floor. The upwelling of cooler water near shore develops in July and lasts through August and September. Although there is considerable variation in location and intensity of cold upwellings from year to year, the coldest belt of water in July and August is usually off the east central part of the coast, from about Ras Fartak to Ras Madraka. At this season the sea surface temperature near the coast averages at or below 74° F., compared with 80° far out at sea and 82° to 84° F. in most of the Gulf of Aden (U.K. Met. Office,* 1958, part 2). In September the focus of cool water shifts north-eastward, extending from about Salala to Masira Island. Individual temperature readings are sometimes much lower: 64° F. or lower has been recorded in August. As one result of the sea temperature contrasts, masses of moist tropical air become chilled and frequent fog and low cloud envelops the central littoral in July and August, strikingly at Salala and appreciably at Masira. As a side effect, the upwelling brings a rich supply of marine nutrients to the surface, resulting in an abundance of pelagic fish, which constitute one of the few important natural resources known for this sector.

The air temperatures over the land along the cool-water sector of the coast in summer are significantly lower than those of the rest of the coast. Whereas the July mean temperature at Aden is 90° F., and at Riyan 87°, at Masira Island it is only 80° and at Salala 78°. Along the entire sector the highest temperatures come before the onset of the intense south-west monsoon, in May in the east, June in the west. In the western part there is only a slight drop in temperature during the summer, but in the east-central part the drop is sharp, as the following tabulation indicates.

	Mean daily maximum, °F.					
	May	June	July	Aug.	Sept.	Oct.
Aden	93	98	97	96	96	91
Riyan	91	94	92	91	90	88
Salala	90	89	82	81	84	87
Masira Island.	96	94	88	86	86	88

At Salala the mean daily maximum temperature is 7° F. lower in July than in June. Furthermore, at both Salala and Masira the days are even hotter in May than in June. By September the 'cool belt' has begun to get warmer, and the warming trend reaches its peak in October.

Summers are unquestionably hot and oppressive along the entire sector. Highest wet bulb temperatures occur in May and June: 81° to 82° F. at Aden and Riyan, 78° to 81° F. at Salala, Masira Island, and Ras al Hadd, on the average. In contrast, the weather is relatively cool and pleasant during the season of the north-east monsoon, especially in December, January, and February, when night temperatures regularly drop below 70° F. except near the extreme south-western end, and wet-bulb temperature means range from about 66° to 71° F. (71° to 73° at Aden) (U.K. Met. Office,* 1943, part 2).

Nowhere along the littoral of south-east Arabia is there enough rainfall to support crops, or even to support significant amounts of pasturage. Judging by the four stations for which there are dependable data, there is considerably more rainfall in the central half of the coast than in the eastern and western quarters. Salala has the highest mean annual rainfall, with 3.2 in.; Riyan, 2.5 in.; Aden and Masira Island, less than 1 in. each. As in all deserts the amount fluctuates widely from year to year. When an unusually large amount of rain appears in a year's total, it may nearly all have fallen in a single exceptional storm lasting only a few hours. In the one year's record published for Ras al Hadd, for example, there were 2.5 in. but

1.9 in. of this fell during a violent line-squall thunderstorm one day in April 1943 (U.K. Met. Office,* part 2, p. 123). It is very likely that mountains a short distance from the coast receive considerably more rainfall, but measurements are lacking.

Although no season is truly wet, along most of the coast the greatest amount of rain falls during the winter half of the year, from November to April. In a given year rain may fall in any month, and in fact there is no month at any of the stations that has not received rainfall in one or more years. In December and January, all stations average about one day per month with precipitation of 0.04 in. or more, rising to two days in December at Aden, a locality which also averages one day in July. During the rest of the year the average is less than one day per month everywhere, with the notable exception of Salala.

Salala is the one station that has its maximum rainfall in summer rather than in winter: two-thirds of its annual total comes in July and August, and each of those months has eleven days with 0.04 in. or more of precipitation. The monthly rainfall averages about 1 in. July and August, making Salala the only station of the coast with any monthly means as high as 1 in. One inch of rainfall spread over eleven days means that the summer rain at Salala usually falls as a gentle drizzle, seldom enough to make the ground muddy. The appreciable rainfall of Salala in summer appears to be highly localized, and perhaps associated with lifting of maritime monsoonal air masses against the centre of the mountain arc of the Jebel Qara just behind Salala. It is reported that the Jebel Qara have heavy monsoonal rains, while the Jebel Samhan and Jebel Qamr immediately to the east and west are almost rainless (U.K. Met. Office,* 1943, part 2, p. 99-100). Except in the Salala area, most of the rain in the sector apparently falls as brief, intense storms. In contrast with the average of twenty-seven days per year with rainfall at Salala, Riyan has only seven, Aden six and Masira Island three. The gentleness of the rainfall at Salala may be the result of a temperature inversion resulting from the exceptionally low temperatures of the surface of the sea as previously noted.

Cloudiness fluctuates more or less as the days with rainfall. Hence for the eastern and western parts of the coast, cloudiness is greatest in winter, while in the central part it is heaviest in summer. According to the very limited published records of one to three years, cloudiness is greatest in the morning everywhere along the south-east Arabian coast. In January, for example, Aden had 63 per cent of the sky covered at the 10.00 observation, and only 31 per cent at the 15.00 observation; Riyan had 56 per cent at 09.00 against 25 per cent at 15.00; and Masira had 33 per cent at 10.00, reducing to 29 per cent at 16.00. Salala was the clearest of all in January, with 25 per cent cloudiness at 10.00 and 23 per cent at 16.00. In summer the story was quite different: Salala had 100 per cent of sky covered at 10.00 during July and August in 1943, its one year of record, and 90 per cent at 16.00, though the number of really rainy days was below normal—nine days in July and six days in August with more than 0.04 in. but twenty-two days in July and seventeen in August with more than 0.004 in. Such a persistent cloud cover helps accentuate the lower summer temperatures. Masira Island the same year had 41 per cent average cloudiness in July and 56 per cent in August at 10.00, 19 and 33 per cent at 16.00 (U.K. Met. Office,* 1943, part 2), though those months were rainless. Apparently the cloud either partly evaporates during the heat of the day or is blown inland from the coast by the strengthening sea breeze. So far as we can judge by the scanty available information, the cloud situation on the Salala-Masira coast has some resemblance to that of the west coast deserts of Baja California and the Namib, where a 'high fog' or low cloud develops daily inland from the cool coastal waters.

EASTERN SUBDIVISION

According to the character of the terrain, the sector breaks down into quite different major subdivisions. The eastern third, from Ras al Hadd to Kuria Muria Bay, consists of plains and low plateaux extending far inland. The western two-thirds is backed by mountains, in places coming down to the sea coast and in places receding a few miles and bordered by narrow coastal plains.

Economic activity in the eastern third is stringently restricted by the extremely limited amounts and poor quality of surface or underground water. Thesiger, an experienced desert traveller, after an extensive trip in the interior of Arabia, approached the coast at Khaur Wir, in this lowland, in search of water. He reported that probably nowhere is there fouler-tasting water still deemed drinkable. Near the western end of the subdivision, however, he again approached the coast, at Nahabub, and found deep pools of clear water in a shady narrow chasm between the limestone cliffs of the low plateau (Thesiger, 1948). Along the coast are widely spaced small villages, depending mostly upon fishing, but with a few date palms and goats.

The north-eastern portion of the littoral appears to have somewhat better ground-water resources than the central portion, owing to the presence of the Oman Mountains in the distant background. One of the larger villages in this area, Al Askhara, was reported as having about 200 houses, some of stone, but mostly huts. Another sizable village, Suweih, about 20 miles north-east of Al Askhara, with earth huts, was not occupied during summer. Presumably these villages have close contacts with oases of abundant water and extensive date groves reported to exist farther inland near the mountains. Most of the information on this portion of the littoral is of uncertain age, some of it going back as far as a survey made in 1917 (U.S. Hydrog. Office,* Sailing Directions, no. 61). The village of Hadd lies about a mile south-west of Ras Hadd, on a low, sandy coast. Its 700 people carry on fishing and trading, and some date-raising with the aid of fairly good ground water for irrigation. Huts made of woven mats from date palms, and several large, round defence towers, characterize the village.

South-west of the Al Askhara-Hadd segment of the littoral, only one sizable village was reported in 1917 all the way to the far side of Kuria Muria Bay. That was Sheiballa, with about 200 huts, near the northern end of Masira Channel. The one sheltered harbour, Ghubbet Hashish, is shallow, surrounded by sandy, desolate shores, and used principally by a small village on the mangrove-surrounded little island of Mahut. The coasts arcs in three broad bays: the Gulf of Masira, Sukra Bay, and Kuria Muria Bay, fringed in part by coral reefs and mangrove swamps, and very sparsely inhabited. Along Kuria Muria Bay a limestone plateau comes down to the coast in cliffs, alternating with sandy beaches. The few people of this portion of the coast live in natural or artificial caves worn into the cliffs.

The limestone-cliff lands merge at the western end of Kuria Muria Bay into the end of the Jebel Samhan of Dhafur, which terminates the flat north-eastern region. These mountains have several wooded ravines and valleys, with good springs of water that support small villages and date groves. One such village, with about twenty round huts of stone, lies on a little bay just north of Ras Nus, protected from the south-west monsoon. A little farther north is the small village of Hasik at the mouth of a valley densely wooded with short trees. A larger valley is reported still farther north. The nature, size, amount of water available, and potentiality of this relatively moist littoral is unknown in the absence of field observations.

Before attention is turned to the mountain-backed littoral of which the Jebel Samhan is the eastern precursor, note should be made of some islands off the low north-eastern coast. Masira is the only coastal island of any importance. It lies parallel with the coast and only about 10 miles distant. It is about 40 miles long and 2 to 5 miles wide. It is made up of northern and southern lobes of rocky volcanic hills averaging about 400 ft. high, connected by a narrow lowland in the middle. On the east coast of the island the hills plunge so abruptly into the sea and the coast is so rocky that only at the edge of the central lowland is there a village, Hakkan. On the west coast of the island, facing the mainland, there are six villages, two at the edge of the lowland and three grouped in a small area of gentle slopes on the north-west coast. In the latter group is Daua (Dawwah, Datta), the principal village of the island. Evidently the volcanic terrain is able to concentrate enough run-off from the slight rainfall to provide good quality ground water in some parts of the island, for Daua and Hakkan are both reported to have good well water and date palm groves.

Altogether, there were estimated to be a little less than 1,000 people on the island in 1939 (U.S. Hydrog. Office,* Sailing Directions, no. 61). Fishing and some trading with the mainland are carried on, though navigation is feasible only for small vessels because of coral reefs and shallow approaches. At one time Masira had a bad reputation for wrecking operations carried out at the north end of the island by tribesmen from the mainland during the north-east monsoon period. The most notorious case was the wrecking of the S.S. *Baron Inverdale* in 1904. The weather is usually pleasant during the north-east monsoon, from November to March, with cool nights with frequent heavy dewfall. During the south-west monsoon the high humidity combines with the heat to make conditions uncomfortable. In addition, the wind blows at gale force nearly half the time during July and August, putting a stop to most navigation.

The first account we have of Masira Island was written about A.D. 80 to 89 by a Greek living at Berenike in Egypt, on the Red Sea (McCrindle,* 1879). For the Red Sea and nearby coasts in Africa and Asia, his *Periplus Maris Erythraei* (Periplus of the Erythraean Sea) gives first-hand accounts, but Masira (which he called Sarapis Island) was the most distant area he described even by hearsay. Masira, he said, had three villages, of savage *ikthyophagoi* (fish eaters), who spoke Arabic and wore girdles of coco-palm leaves. They produced large amounts of tortoise shell of excellent quality, and merchants from the mainland farther west outfitted boats to trade for it.

The Kuria Muria (Khorya Morya) Islands (British possessions) form a group of three islands, two islets, and two high rocks. They consist mostly of bare granitic and limestone rock. The westernmost island, Hasik (Hasikiya, Haski), rises to a peak of 500 ft. and is white with guano deposited by sea fowl. Soda Island, the next east, has a 1,310-ft. peak. There are some tamarisks, and near the summit there is grass and moss. There are many little sheltered coves, but the only water reported is a brackish well in the south-east, with remains of primitive dwellings. Hallaniya is the largest island and the only one inhabited recently. It is about 9 miles long, and rises to granite peaks in the centre to 1,503 ft. A few people live in semicircular huts in the north-west part of the island, obtaining brackish water by digging in the floor of a wadi. The easternmost two islets are rocky and without water (U.S. Hydrog. Office,* Sailing Directions, no. 61). The Kuria Muria Islands were unmistakably mentioned in the *Periplus*, but were called 'Zenobios'. The only name used in the *Periplus* and still in use in south-east Arabia is Asikh, which was a port identifiable as the present village of Hasik previously mentioned.

From west of Kuria Muria Bay to the Strait of

Bab-el-Mandeb, the littoral everywhere is backed by mountains. This is the famed Incense Coast of antiquity. Its mountain slopes are still the chief source of the gums, frankincense and myrrh, exuded from trees, gathered by hand, collected at the ports, and shipped throughout the world, but mostly to India, to produce fragrant incense in temples and homes. The long littoral of about 900 miles falls naturally into three subdivisions, each of which is marked by distinctive natural landscapes and cultures and by definite economic geographic cores.

DHUFAR

From east to west, the first of these three subdivisions is Dhufar (Dhofar). Dhufar is the most distant province of the Sultanate of Muscat and Oman. Visited only rarely by the Sultan from Muscat, Dhufar leads a semi-independent existence. The core of the province is the green, crescent-shaped plain of Dhufar, bordering the coast for about 30 miles, hemmed in to landward by high mountains. The Dhufar or Jurbaib Plain, back of the main town, Salala, is one of the most beautiful and fertile parts of Arabia, with varied crops well watered from at least two streams that flow down from the central Jebel Qara and by numerous wells from which the water is pumped. Sugarcane, cotton, wheat, millet, indigo, tobacco, melons, limes, and bananas all flourish here (e.g., Ingrams, 1956). But none of the accounts of this favoured area mentions date palms in Dhufar except at the village of Thalfut, 10 miles inside the western border of the province, and a canyon near Ras Nus, 140 miles farther east. However, coconut palms flourish here.

Dhufar is the only part of the littoral of the Arabian Peninsula where the date palm is not grown and the coconut palm is. So far as this writer is aware, this unique situation has not heretofore attracted attention, and no attempt has been made to account for it. Though a study of the past might uncover some historical reason for the situation, there is no doubt that the distinctive climate of Dhufar gives a logical natural explanation. Date culture requires a hot, dry, ripening season. Salala is the one station along the entire coast where greatest rainfall comes during the summer monsoon rather than in winter, as has been pointed out earlier in this chapter. There are frequent drizzly rains during the height of the ripening season, July and August, and the persistent cloud cover and cool water off shore result in diminished solar radiation and relatively low temperatures: both conditions unfavourable to the ripening of dates. In the Sahara and presumably elsewhere, dates require a July temperature of 82.4° F. to ripen (Capot-Rey, 1953), and at Salala the mean July temperature is only 78.5° F. Thus Dhufar approaches the humid tropics in summer potentialities and disabilities, though the amount of rainfall is, of course, much less in Dhufar than in the humid tropics.

Most of the people of Dhufar, who number about 20,000 in all (Hay, 1954), live on the plain, where they form almost continuous coconut grove and fishing settlements near the coast for about 25 miles, centring on Salala, the capital of the province. In addition to a diversity of crops, livestock are raised and milk and eggs are produced. Sardines are netted in the teeming waters off shore and add to the resources of the plain for food and trading. Trade is carried on with the Qara tribesmen of the mountains just back of the plain and by boat with ports as far away as Muscat. Fishing and sea trade are hampered by numerous coral reefs, mangrove swamps along the central coast, and sea cliffs along the eastern coast.

The mountains behind the plain have extensive grassy meadows, watered by the monsoon rains, and herds of well-fed cattle. The Qara people who occupy the mountains are non-Arab tribesmen. Many of them live in caves (Morris, 1957a), evidently a long-standing practice, for the author of the *Periplus of the Erythraean Sea* described the people of these mountains as cave-dwellers in the first century A.D. (McCrindle,* 1879). In the limestone cliffs overlooking the sea in the eastern part of the plain, too, the people live in natural caves, and boats along the coast at night can see the lights in the caves (U.S. Hydrog. Office,* Sailing Directions, no. 61). Camels, goats, and other livestock from the mountains are traded with the plains for fish and grain. In addition, frankincense and myrrh are still extracted to some extent from small trees in the mountains and taken to Salala and other ports for export. Today, most of the gum is gathered by women from cuts made in the trunks of the trees. In his day, the author of the *Periplus* says that the gathering was done by the king's slaves and by criminals condemned to this service as punishment. He describes the climate of the mountain as unhealthful, with 'dense air loaded with vapours'. Certainly today during the south-west monsoon the mountains are covered with cloud, sometimes for weeks. For a month or two before the season of dense cloud, the mountain-dwellers come down to the markets of the coast (Morris, 1957b).

Conflicting statements are made about the merits of the lowland climate during the south-west monsoon season. On the other hand it is stated that the Sultan comes to Salala to enjoy the cool summer (Sanger,* 1954), and on the other it is said that 'most of the inhabitants of the plain retire to the mountains' during this season (U.S. Hydrog. Office,* Sailing Directions, no. 61). Maritime activity is virtually at a standstill during this season of thick coastal fogs and strong onshore winds and waves, and the airfield just north of Salala requires special low navigation when it can be used at all. Yet the Sultan has two beautiful palaces on the coast, a large one that dominates Salala, and a little white garden palace with a swimming-pool and a view of the sea a few miles away.

In 1923 Salala had about 160 stone houses and a small landing on the beach. It is a modest market town and port. The only other sizable town along the coast is Merbat, about 40 miles east of Salala. At present, Merbat has about 1,000 people, 100 to 130 stone houses and a number of huts, two forts, and a mosque. It has some local importance as a port (U.S. Hydrog. Office,* Sailing Directions, no. 61). In the first century A.D., however, it was one of the main ports for the great frankincense trade. There are many ruins of older buildings at Merbat. These and ruins elsewhere on the plain denote greater population during Sabean times. Towards the opposite end of the plain, west of Salala, there was an oil camp, called Risut, drilling for oil at the time of Morris' visit in 1955, where an American explorer had persuaded the Sultan to grant a lease to American oil interests (Morris, 1957a). To date, no petroleum in exploitable quantities has been found in Dhufar (Longrigg, 1961). There is a landing for small boats and an anchorage sheltered from the south-westerly gales near Risut Point: an alternative outlet in summer when Salala is unapproachable.

Of foreign trade, details are as scanty as of terrain and land use. It is known that dates are imported from the Muscat area by dhows and that frankincense is exported to India.

HADHRAMAUT

The Hadhramaut, or Eastern Aden Protectorate, is oriented about the Wadi Hadhramaut and its outlets to the sea, notably Mukalla. In the eastern part of the province, however, adjoining Dhufar, there is a large thinly settled area physically and culturally marginal and separate from the rest of the Hadhramaut. For lack of any existing regional term, this separate area may be called the Jiza Basin. It consists of a lowland and adjacent piedmonts, drained by the Wadi Jiza, between the Jebel Falik and Jebel Fartak. The Falik Range, a westward continuation of the Dhufar ranges, merges with the converging Fartak Range more than 100 miles west of the broad bight of Qamr Bay. The lowland between these ranges widens to about 40 miles of sandy coast along Qamr Bay. At both edges of the plain, the mountains come down to the sea in rocky, cliffed coasts. Ras Fartak, the terminus of the Fartak Range, is the greatest escarpment along the entire south-eastern coast of Arabia. With little doubt it is the promontory called Suagros in the *Periplus* 1,900 years ago and described as 'the greatest promontory in the world looking East'. At that time it had a fortress that protected a harbour and a storehouse to which frankincense was brought (McCrindle,* 1879). The promontory rises 1,900 ft. in almost vertical cliffs for 10 miles northward from the end of Ras Fartak (U.S. Hydrog. Office,* Sailing Directions, no. 61).

Today the littoral of Qamr Bay is deserted except for a few villages with small date groves, fishing, and a little trade. The two largest settlements are Damqut, a village of about 400 in 1917, with the only port of Qamr Bay; and Al-Gaidtha, where a trail from the interior joins the coastal trail near the outlet of Wadi Jiza at the middle edge of the plain. How often the Wadi Jiza has sufficient flow to reach the sea and to what extent the water, if any, is used at Al-Gaidtha we do not know. Presumably the wadi bed offers some opportunity for well water. We have not the haziest idea of the extent of level land in the basin, the amount of flood water, or the suitability of sites for water storage.

From the Falik Range some frankincense is still produced and is taken to the coast to be exchanged for sardines and grain (Thesiger, 1948). Probably some trade reaches Al-Gaidtha directly by trail from the heart of the Wadi Hadhramaut, too. There is a small inlet in the southern shore of the bay where dhows of up to 40 tons are sometimes hauled up during the south-west monsoon, and a straggling village of huts nearby for the crews.

Westward from Ras Fartak the littoral consists of rocky headlands and stretches of coast where the mountains come to the sea, interrupted at intervals by embayments backed by small valleys with date groves and fishing and trading villages, some of which, such as Qishn, carry on sea trade with places as distant as the Persian Gulf, India, and Zanzibar. A small valley immediately to the west of Ras Fartak in 1917 had a fishing and trading village (Khaisaib) of 150 people near the coast and small-scale manufacture of salt from two salt lagoons. About 1½ miles up this same valley there are water wells, date groves, and two more villages. A little farther up the valley is Waditown, with about 600 people, protected by several forts (U.S. Hydrog. Office,* Sailing Directions, no. 61). One wonders if these are 'descendants' of the fortifications reported by the *Periplus* 1,900 years ago.

Proceeding westward along a coastal trail, one emerges near Seihut upon the alluvial lowland of the Wadi Hadhramaut system, and enters upon the main complex of the Hadhramaut. Principal economic activities in the Hadhramaut are concentrated in two narrow strips, along the immediate coast and about 100 miles inland, where the Wadi Hadhramaut parallels the coast. Between these two strips and continuing northward of the Wadi Hadhramaut, lies the Jol. The Jol is a rolling upland of Eocene limestone averaging about 4,000 to 6,000 ft. high and extending east-west about 200 miles. Its western terminus is about half way between Mukalla and Aden. The highest part of the Jol is about 40 miles inland, so that most of the drainage is northward and only short, usually dry, wadis flow directly to the coast, apart from the Wadi Hadhramaut. The Wadi Hadhramaut and its extensions is the longest wadi of south-eastern Arabia, with a total length of about 350 miles. Its head, in the west, lies in the great Khudaif-Mulais Basin, at the east base of the mountains of Yemen. From there it flows eastward, cutting through the Jol in a broad canyon, before bending to the south-east as the Wadi Maseila and emptying into the sea (Bunker, 1953). The central, canyon portion of the Wadi Hadhramaut has long been famous as an area of tall, stone sky-scraper buildings and intensive irrigation agriculture. Its people, with their traditional date, dhurra (sorghum), sesame, alfalfa, and livestock production, and their more recently initiated crops of sugar-cane, are the main incentive for interior trade from the settlements of the coast.

The most direct routes from the central Hadhramaut canyon to the coast cut southward across the Jol. Although the weather of the upland Jol in winter has been described as 'perishingly cold' for the caravans traversing it (Stark, 1953), the route is not difficult, and it is only half as long as the route following the Wadi Hadhramaut-Maseila to the sea. Mukalla and Ash Shihr have developed as the two chief seaports of the Hadhramaut at the place where the two main trans-Jol routes reach the coast, and the coastal plain in their vicinity is the economic core of the Hadhramaut littoral. The coastal plain is about a dozen miles wide from the sea to the base of the mountains that parallel the coast. Its continuation extends 150 miles from Burum in the west to Seihut in the east, forming the next most fertile plain of south-eastern Arabia after Dhufar. Large villages, with sufficient water to irrigate large date groves and gardens, dot the plain. In addition to the Mukalla-Ash Shihr area, the lower valley of the Wadi Masseila is reported as being particularly well watered, with numerous wells and flourishing date groves and villages.

Mukalla, a town of 30,000 in 1956, is a port second in importance only to Aden along the entire south-east coast of Arabia. It is a city built on a rocky ridge near the sea, with tall substantial stone buildings in the crowded seaward portion (Eilts, 1957). Its inland portion has some stone buildings, including the mosques, and a large number of simple huts. The town itself has a bare desert appearance, but there are large date groves with watch towers a mile inland just west of the city. During most of the year the port affords safe anchorage, and large vessels call there regularly, though any trade must be lightered by smaller dhows. During the height of the south-west monsoon, however, the port is untenable and traffic is diverted to the sheltered bay of Burum, a small town 15 miles south-west. The life of Mukalla is bound up with the sea. Fishing is important. The fish, mostly sardines, are caught by means of long seines, as is characteristic of the whole Hadhramaut coast (Bowen, 1951). The drying and salting of fish and extraction of fish oil provide products for export as well as for trade with the interior. Significant to the life of the whole coast is the building of dhows, an industry that is carried on at Ash Shihr as well as at Mukalla. Tanned skins, burned lime, and sesame seed oil and cakes are additional products of local manufacture. Ash Shihr, 35 miles east of Mukalla, is a town of about 12,500 in 1947, at the end of a road across the Jol to the Hadhramaut middle valley, and with its own seaborne trade. An ancient defensive wall encloses the landward sides of the town. The water supply is brought by an open aqueduct from a point about 5 miles inland. Midway between Mukalla and Ash Shihr is the airport of Riyan, from which the official climatological data for this area are obtained.

At the far eastern end of the lowland, Seihut, an old walled town of about 10,000, lies near the mouth of the Wadi Hadhramaut-Maseila and serves as port and market for the fertile plain of the lower Maseila.

It is not known to what extent the land and water resources of the Hadhramaut coastal plain are being fully exploited. Judging by reports of ruins of ancient towns, populations may have been considerably denser in the past. Some ruins may represent simply changes of site; but others, like those of the large town of Musaina 40 miles west of Seihut, are found in areas with few people at present. The question arises whether these changes resulted from the decline of the incense trade or from other factors. There are other areas, notably an area of recent volcanic outpourings and lava cones, on the plain just west of Wadi Maseila, that are virtually devoid of soil and have no agricultural potential. Possibly some of the nearby hot springs might be a basis for small watering places (U.S. Hydrog. Office,* Sailing Directions, no. 61).

Westward from Makalia for about 100 miles the coast is irregular, with small harbours between rocky volcanic and limestone promontories. Beyond this stretch the coastal plain resumes as a sandy plain. Bal-Hof (Belhaf), at the eastern edge of this plain, is the principal port of the western Hadhramaut area. It is the outlet for the area drained by the Wadi Maifaa, which heads in the north-west in the gap between the Jol and the mountain mass of Yemen and runs to the coast about 40 miles west of Bal-Hof. According to some commentators (McCrindle,* 1879), the important ancient trading centre of Kane was situated about 12 miles east of Bal-Hof at Hisn Ghorab. Jebel Husn al Ghorab has ruins of an ancient city on its summit, but there is only a small village on the Bay of Husn al Ghorab today. Apparently, the area between Bal-Hof and Mukala, inclusive, has been commercially important right down to the present.

The goegraphy of the coastal plain to the west of Bal-Hof is poorly known, but it is reported that between Bal-Hof and the Wadi Maifaa there are some villages with good spring water, date groves, and maize fields. For 100 miles west of the Wadi Maifaa to Maqatin, the coastal plain varies in width from about 5 to 35 miles. It has a few villages scattered about on it, and some sizable ruins, including the ruins of Magatin. Few facts are known about the plain. Just off shore, scattered along the coast, are a number of rocky islets covered with guano, whether worked or in workable quantities we do not know. Across the middle of the dangerous plain the Wadi Sanam runs into the sea. It marks the boundary between Eastern Aden Protectorate (Hadhramaut) and Western Aden Protectorate.

ADEN

The Western Aden Protectorate, consisting of a number of sultanates, sheikhdoms, and emirates under the protection of the British Colony of Aden, extends for 250 miles along the coast to the strait of Bab-el-Mandeb. The littoral consists primarily of a desert coastal plain of varying width, backed by the granitic and lava mountains of the Yemen uplands. For thousands of years the focus of this area has been the harbour of Aden, the only major natural harbour between Alexandria and Karachi.

The economic function of the town of Aden today, as in the past, is to serve as an entrepôt for the exchange of goods between distant lands. At the time of the visit of the author of the *Periplus of the Erythraean Sea* in the first century A.D., Eudaimon ('rich and prosperous') as Aden was then known, was a maritime village at the entrance of a bay, with good water and good anchorage. The city was in ruins, having been destroyed by the Romans who captured it in A.D. 24. In pre-Roman days, according to the *Periplus,* Eudaimon had been a great port, because the merchants from India ventured no farther west, and those of Egypt no farther east; this was therefore the exchange place for their merchandise. It regained and maintained its importance through various changes of ownership, including Turkish and Yemeni. The discovery by the Portuguese of the Cape of Good Hope route to India dealt a severe blow to Aden, but the opening of the Suez Canal in 1868 revived it; and the port is now strongly dependent on Suez Canal traffic. It was finally occupied by the British in 1839 after it had become a notorious nest of pirates who preyed upon the commerce that was forced to use the great natural passage between east and west at Bab-el-Mandeb. It was administered from India until 1937, when it became a British colony.

Today, Aden carries on a lively exchange, with world-wide connexions. Thousands of ships pass through its harbour every year, from huge ocean tankers to small dhows. Aden is still the centre of the ancient incense trade. Every winter, during the favourable season of wind, dhows sail to Aden bearing loads of frankincense and myrrh gums from the many little ports of the Hadhramaut and Western Aden Protectorate for concentration and storage at Aden and later transhipment to India and elsewhere. It was only about the middle of the first century A.D. that the Romans learned of the monsoons and began to transport incense by sea instead of by land. The incense trails along Yemen declined accordingly (Ingrams, 1956). The highlands of Yemen send hides, skins, and coffee for processing and export. From oases of the coastal plains come grain and cotton. Aden itself produces salt in great quantities from the evaporation of sea water, for export to humid tropical areas such as India and east Africa. A lively local seine-fishing activity uses some of the salt for processing fish, too. In addition, there is local manufacture of consumer goods such as textiles. As one of the world's great bunkering ports, Aden supplies coal and petroleum products to fuel ships in this busy crossroads far from natural resources. Though it lacks local supplies of petroleum, it is able to tap the cheap seaborne petroleum from the Persian Gulf, and it operates a huge oil refinery at the edge of the Bay. Of the 3.5 million tons of petroleum products refined annually, more than half is used to fuel ships, and most of the rest is bought by users in east and south Africa and the Red Sea (Longrigg, 1961). In addition to crude oil and coal, most manufactured products must be imported for local use and for sale to the many thousands of ship passengers who take advantage of duty-free prices at the free port of Aden en route to other ports.

Climate is not one of the attractions of Aden. Very hot and humid in summer, though fairly pleasant in mid-winter, except during dust storms brought by northerly winds, Aden has the reputation of having one of the most unpleasant climates on earth. The erratic rainfall averages less than 1 in. per year (Table 2). The overwhelming natural advantage is the harbour, created by two hard rock masses thrust up near the coast 4½ miles apart and tied to the mainland by low sandy spits. The harbour lies between the two hammer-headed peninsulas, volcanic Aden Peninsula on the east and granitic Little Aden Peninsula on the west. The main bay is known as Bandar Tawayih. Three towns that make up the majority of the 140,000 population of the colony are clustered about the volcanic mass on Aden Peninsula. The main commercial town is the city of Tawahi ('The Crescent'), just inside the entrance of the bay along the north base of the hammer-head mountain cluster. Tawahi borders the inner harbour, dredged to admit ships up to 34-ft. draught. Even at Tawahi there are no wharves for ocean-going vessels; freight and passengers must be lightered. It is a modern, busy city lined with warehouses and coal stores. Just east of Tawahi is the town of Maala, the trading port for small dhows and terminus of routes inland. Its cosmopolitan population of Yemeni, Arabian, Indian, and others lives in small houses of stone or earth. The third element of the Aden agglomeration is Crater, a well-to-do residential town on the east side of the peninsula, nearly surrounded by steep rocky slopes of the old crater in which it was built.

To the north, an airport has been built on the sandy Khormaksar Isthmus that forms the base of Aden Peninsula. Khor Maksar, the shallow bay in the north-eastern part of Aden Harbour, merges on its north shore into 4,000 acres of diked evaporating basins (salt pans) capable of producing 100 tons of salt per acre per year (Cressey,* 1960). The low lift of the water from the bay to the pans is accomplished by means of windmills. Westward from the salt pans, the north shore of Aden Bay is lined by low sandy land, at the western end of which a shallow lagoon, Khor Bir Ahmad, opens out from Aden Harbour at the base of Little Aden Peninsula. On the previously unoccupied land along Little Aden Peninsula the oil refinery now operates, served by tankers using a 40-ft. channel dredged through the sediments of Khor Bir Ahmad (U.S. Hydrog. Office,* Sailing Directions, no. 63). Vessels of greatest draught find good anchorage in the outer harbour of Aden Harbour, where a channel has been dredged 48 ft. deep.

Highly uneven agricultural development occupies parts of the coastal plain. Irrigation water is obtained by small dams across wadis and by wells pumped by donkey- or camel-power or, increasingly, by petrol-engined pumps. Dates and grains are standard crops.

Twenty miles north-east of the colony lies Lahej, capital of the Sultanate of Abdali and chief town of a delta-like oasis plain watered by the Wadi Tiban. The plain is highly fertile, and produces fruit and vegetables for the Aden market, including grain, citrus, bananas, coconuts, mangoes, and sugar-cane. In addition, Lahej is the terminus of caravan routes to Yemen by a direct route to the north and by a coastal route to the west and is the main trade centre of the plain north of Aden.

Another rich cultivated area in the coastal plain is the Abyan Delta, 30 miles north-east of Aden. The Wadi Bana, heading in the mountains 100 miles inland, brings considerable quantities of water to the Abyan plain during its annual summer floods, and has long been the basis for scattered oasis culture in the area. Recently, agricultural production and consequently population have increased greatly in the Abyan Delta as a result of systematic development of water resources with the aid of British planning and funds. The area now has about 50,000 acres under irrigation, mostly devoted to raising high-quality long-staple cotton as a cash crop. It is now one of the few areas of south-eastern Arabia with a fairly adequate system of motor roads rather than mere camel trails.

Apart from the Lahej and Abyan districts the coastal plain has been little developed. Suqra, about 30 miles north-east of Wadi Bana, with which it is connected by a motorable road, is a small town of local importance as a port and fishing centre. It has a shallow harbour protected by a coral reef and suitable for small boats. As along most of the Arabian coast, the boats are commonly hauled on to the beach when not in use. Salt is produced by natural evaporation of sea water in diked pans east of the town. Inland there are small oasis villages scattered on the plain, and Suqra itself has a large date grove and maize culture on its outskirts.

The rest of the coastal plain, especially that from Aden to Bab-el-Mandeb, is very sparsely settled. Grazing, chiefly of goats, is confined largely to the better-vegetated wadi channels and the more humid uplands behind the plain. There are a few small villages with wells and date palms, and at least one fishing village at the west base of Little Aden Peninsula. Potential water resources do not compare with those of the wadis Bana and Tiban, but there are some smaller wadis, emptying on to alluvial fans of the coastal plain, that might supply seasonal water for flood irrigation or ground-water wells if properly managed. Only field surveys could determine the further agricultural potentialities of the littoral of the Western Aden Protectorate. For the entire Aden Protectorate it has been estimated that not more than 1 per cent is cultivable (Ingrams, 1956). There is little doubt that fishing, at least, could be greatly expanded with the proper application of capital for securing, handling, and processing the product of the rich offshore waters. To date, sporadic exploration has not found oilfields such as have enriched small Arab States of the Persian Gulf, and prospects are poor for finding petroleum anywhere in the south-east littoral of Arabia (Longrigg, 1961). Any capital development in this sector will have to rely upon other sources of funds.

SECTOR 9: THE RED SEA

The Red Sea, together with the hot desert climate, provides the physical basis for such unity of landscapes as exists for Sectors 9 to 13 of the desert littorals (Map 4). The sea stretches 1,400 miles from the head of the Gulf of Suez to the Strait of Bab-el-Mandeb. The deeps of the Red Sea are cut off from those of the Indian Ocean by a submarine sill at Bab-el-Mandeb, with the result that exchange circulation of water is impaired, and the Red Sea has acquired its own distinctive features. The water is warm, evaporation has resulted in a high salt content, and some unique species of fish have developed (Marshall, 1952). The sea is bordered almost continuously by jagged coral reefs and platforms, with numerous winding channels and islets: an ideal base for pirates. Sailors have learned to distinguish the deep blue water from the shoal jade-green waters of the coral. From about the Tropic of Cancer southward, much of the coast is lined with mangrove (*Avicennia marina*). The mangrove invades even the inlets, owing to the lack of deltaic deposits on the riverless coast.

The description of the Red Sea written in the first century A.D. by the Greek-Egyptian author of the *Periplus of the Erythraean Sea* records many of the physical features well known today, and also certain cultural traits that have changed little. The early author described a route crossing the Red Sea from the great Egyptian trading port of Myos-Hormos (about 200 miles north of Berenice, near present-day Safaga, to a Nabatean town, Leuke Kome, on the opposite coast (probably near present-day Umm Laj) (McCrindle,* 1879). Leuke Kome was a trade centre through which goods were imported into the Nabatean kingdom. Just to the south, Arabia extended for a great distance along the sea coast. The coast was occupied by *ikthyophagoi*, living in scattered huts; only farther inland, where there were pastures, did the people raise livestock and live in villages. They were said to be given to enslaving and plundering shipwrecked crews. To avoid these hostile people and the inaccessible coast, which lacked harbours and good road-steads, and was foul with breakers and girdled with rocks, the trading ships made it a practice to keep well out in the middle of the gulf (the Red Sea) so as to reach the civilized part of Arabia as soon as possible. This part began at the Zubair Islands, about 15° N., and continued from there on, with a regular government and herds of livestock. Near the end of this part was Mouza, a notable trade centre (probably at a site about 25 miles north of today's Mocha), full of Arabian vessels carrying on trade with places as far distant as India and southern Africa. Vessels bound for Africa and southern Arabia left Myos-Hornos about September and were quickly carried down the gulf by the prevailing north-west wind. Those headed for the Malabar Coast and Ceylon left in July, and if they cleared the Red Sea by September first they could take advantage of the favourable monsoons towards the east.

Today the people of most of the coast are still fish-eaters, and the best farm and pasture lands are still in the foothill belt away from the coast. The fishing is done from small boats which the skilful Arab sailors navigate from coves and inlets through the poorly mapped channels and along the coral fringes. Conventional large-scale fishing is impossible, as the nets would catch on the rough coral. Although motor boats are becoming more popular, large numbers of the small sailing dhows are still in use. Through the centuries the Arab dhow has evolved into its present efficient form, from the Phoenician vessels designed for sailing the Red Sea, in turn apparently derived basically from the lateen-rigged vessel of the Egyptians on the Nile (Crane, 1928). Even the trade of much of the coast is carried on by dhows, which can reach many of the settlements through coves and channels unusable by larger modern vessels.

The principal modern economic resource not available in the days of the author of the Erythaean *Periplus* is the 'hadj' (Haj): the annual Moslem pilgrimage to Mecca. Every year great numbers of the faithful converge towards Mecca, by land, sea, and air, Berbers from Morocco, Negroes from East Africa, Indonesians from Java, and Arabs from near and far. Jidda, easily the principal port of the Red Sea and, until the discovery of the Persian Gulf oil, the leading port of Arabia, owes its importance to its position as the nearest port to Mecca. A whole class of prosperous merchants has developed from the pilgrim trade. Along the land routes leading to Jidda and Mecca smaller towns and villages provide at least overnight accommodation for the pilgrims: a well, an enclosure for camels, a mosque, and barracks or huts for the travellers. Another recent development, the desalting of water by methods efficient enough to provide drinking water at reasonable cost, has helped several of the coastal towns to supply fresh water not only to pilgrims but to an increasing resident population of fishers and traders.

Climatically, the entire Red Sea and its margins are hot desert. The mean temperatures of the hottest months are from 85° to 96° F., with mean daily maximum between 92° and 108° F. (Table 2). The high humidity along the margins of the sea renders the summer heat especially oppressive, though a sea breeze often develops to alleviate the sensible heat during the afternoon. Even at night in summer the temperature ordinarily remains above 80° F. The northern gulfs of Aqaba and Suez are just cool enough in winter to fall outside the true tropical category, but even they have never experienced frost. Rainfall is deficient throughout. The northern third of the Red Sea, including its northern gulfs, is extreme desert, with mean annual rainfall ranging from 0.2 in. at Kosseir and 0.4 in. at Daedalus Island, to 1.1 in. at Eilat (Table 2 E). The least dry stations are along the south-west coast, where Suakin and Massaua average a little over 7 in. per year.

There is some difference in seasonality of rainfall and wind directions between the far south and the rest of the Red Sea. Over most of the Red Sea and its margins rainfall is of the Mediterranean type, falling in winter when the mid-latitude cyclonic storms reach farthest south. Summers are entirely rainless. Winds prevail from the north and north-west throughout the year. Over the southern third of the Red Sea there are two rainy periods, one in winter associated with south-east and east winds of the winter monsoon, a lesser one in summer associated with north-westerly and westerly monsoons. The summer rains are slight and ineffective on the coastal lowlands, but heavy enough in the bordering highlands of Ethiopia, Yemen, and Asir to send the floods of water into the lowlands in the wadis that make irrigation agriculture possible. One result of the prevailing north-westerly winds along most of the Red Sea is the formation of sand spits, which show a tendency to be attached at their northern ends to a point of land and open at the southern end.

The islands of the Red Sea do not fit into the coastal sectors as classified in this book, and deserve a brief treatment of their own. Most of them have slight potential development, though permanent settlement would be encouraged if suitable methods of water desalinization were applied.

The largest islands are in the south. There are smaller ones in the north, but the central part of the Red Sea is devoid of islands except for tiny islets and reefs associated with the coral fringe close to shore. Most of the islands are of coral origin, and covered with sand that has drifted in from the beaches. Near mid-channel in the far south the islands have a core of volcanic mountains and hills, bare and jagged, but even these islands are surrounded by coral reefs and platforms. The best harbours are usually on the south and east sides of the islands, protected from the north-westerly winds, but the approaches through the channels in the coral fringe are so narrow and tortuous that they are navigable only by dhows, and larger vessels must remain off shore and communicate by means of dhow lighters (U.S. Hydrog. Office,* Sailing Directions, no. 61).

Only five of the islands are known to have permanent settlements: Perim, Kamaran, Farsan and the adjacent little Segid, and Tiran. The others are visited for longer or shorter periods of time, mostly by fishermen from mainland bases. Perim Island, in the Strait of Bab-el-Mandeb, where the mainlands of Africa and Asia are only 17 miles apart, is a low, rocky, volcanic island, mostly bare, but with some patches of shrubs and grass despite its average annual rainfall of only 1.7 in. Its only settlement consists of a town of a few hundred people, sprinkled with abandoned and ruined houses, on a good harbour on the south side of the island. At one time it was an important coaling station for vessels passing through the Red Sea, and in 1921 had over 2,000 people, but in 1936 its declining coal business was transferred to Aden, and today it is largely a fishing base. To the north lie the Zubair and Hanish Islands, consisting of a number of small islands and two large ones, all of volcanic origin. The two large islands, Jebel Zugar and Great Hanish Island, are about 11 miles long in their major dimension, with rough, bare, rocky mountains and some flat sandy areas. Jebel Zugar is the highest peak in the Red Sea: 2,047 ft. There is little vegetation except sparse patches of grass and, around the coral margins, mangroves. Both islands have wild antelope. Although the islands are visited by fishermen, there are no permanent settlements.

Kamaran Island lies at the southern end of a long bank of coral, known as the Farsan Bank, fringing the coast for 350 miles, to the vicinity of Lith. The bank, at places as much as 60 miles wide, consists of a maze of coral reefs and channels, difficult to navigate, especially since there is frequent haze except during the period of January to May. Much of the way there are channels from ½ mile to 14 miles wide, paralleling the coast, protected from the open sea by the reefs and deep enough for any vessels that are able to run the barricade. Kamaran itself has the distinction of being the chief quarantine station for pilgrims coming from India and the rest of the Far East *en route* to Jidda. Normally the population is about 3,000, most of whom live in the town of Kamaran on the protected mid-east side of the island, but during the pilgrim season the population multiplies many-fold. Like Perim, Kamaran is administered from Aden.

The only island with a more or less balanced internal economy, based upon its agriculture and grazing as well as upon fishing and trade, is Farsan Kebir, the largest island of the Farsan group. It is 35 miles long, low, winding, and bordered by numerous little coves and channels in the fringing coral. Well water is adequate, and there are seven permanent villages, mostly with coral houses. Dates are the principal crop, though lesser amounts of other crops are raised primarily for local subsistence. Sheep and poultry are significant livestock elements. Fishing and some pearling are important occupations. The population fluctuates seasonally according to the date harvest and pearling seasons. Just to the north-east, adjoining the same coral platform, is the little island of Segid, which has two villages and flourishing date groves. Some of the other islets of the Farsan Bank are occasionally visited by fishermen, and one in the far north, Danak Islet, is used for turtle fishing.

From about Umm Laj northward, there are islets in the coral fringe. Hassam Island, off shore from Umm Laj, has at least seasonal sheep-grazing and fishing (U.S. Hydrog. Office,* Sailing Directions, no. 61). Daedalus, in mid-sea, is a barren desert coral reef with a lighthouse and weather station. Tiran Island, at the entrance to the Gulf of Aqaba, has been occupied intermittently down the ages by reason of its strategic location, controlling access to the gulf (Musil, 1926, p. 302-309). When first noted in a *Periplus* it was called Nessa, from the numerous ducks there. At this time the spur of land opposite the island was reported to be covered with thick forest which extended all the way to Palestine and Petra. Strabo reported the name as Phokon, from the large number of seals. Ptolemy called it Ainu. In A.D. 473 the island, then called Iotabe, was controlled by troops of a clan leader who had captured it by rafts and was using it to plunder neighbouring lands. In A.D. 490 the Romans captured it and set up a customs office to collect duties on goods from India. Later, members of an Arab tribe were reported as living on 'Taran', with no livestock or agriculture, living only on fish and on salvage from wrecked ships, and begging water and bread from passing ships. Tiran was fortified by the Egyptians during the Suez crisis, but United Nations have kept the strait neutral and open to ships of all nations since 1956.

YEMEN TIHAMA

To the east along its entire length the Red Sea is paralleled by a steep, dissected escarpment of bare, rugged mountains. They represent the eroded edge of the great Arabian plateau, upturned along a series of faults which separate the plateau from the trench in which the Red Sea lies. Along the Gulf of Aqaba the mountain slopes plunge directly into the water, but along the Red Sea proper a continuous coastal plain intervenes between the foothills and the shore. This coastal plain, known as the Tihama (Tehama, Tahamha, Theama), varies in width from a few miles to as much as 50 miles. Long before the rise of Mohammedanism, the northern and southern parts of the Tihama were the most developed, by the Nabatean kingdom in the north and the Sabean kingdom in the south. While the trade and agriculture of the north has dwindled to almost nothing, the south has retained a considerable measure of both.

The southern Tihama, the maritime border of Yemen, has a permanent advantage arising from its hinterland. The abundant summer rains and moderate winter rains, totalling 25 to 40 in. a year, on the slopes of the mountains and the high plateau to their east, support intensive agriculture in the uplands, and surplus water pours down the wadis on to the Tihama for irrigation in the dry plain that itself receives only 2-3 in. of rainfall. The Tihama has always been closely related to the mountainous area to the east, both hydrologically and economically. With its steep, easily defended slopes and its desert surroundings, the upland of Yemen became a rich independent State as early as about 1000 B.C., and has maintained its resistance to outside pressures up to the present. It was here that the powerful Sabean State developed, with its capital at Marib at the edge of the desert to the east, and from here that the Queen of Sheba came to Solomon, bearing gifts of gold, precious stones, and spices (I Kings, ii, 10) (the Bible). With gold and other valuable minerals from her own country, the queen also controlled the lucrative incense trail from the Hadhramaut, and the spice trade from India which used the overland route to avoid the pirates that infested the Red Sea. The rich trade, in addition to the cool, well-watered local agriculture and herding, led to the prosperous condition that led the ancients to call Yemen 'Arabia Felix'. Although the Romans broke the long monopoly of the Yemen by clearing out the pirates of the Red Sea and thus opening up direct shipping contact with the incense and spice lands, even they did not succeed in an attempt to conquer the country. In 24 B.C. they landed 10,000 troops just north of Yenbo and marched southward. Decimated by six months of struggle against the desert and mountains, lacking food and water, and under constant attack, they finally withdrew after almost reaching Marib. About A.D. 550 the great dam at Marib collapsed, internal strife and attacks by Abyssinians prevented reconstruction of the irrigation system of the east, and the capital was shifted to the humid uplands at Sana, and later Taiz (Sanger,* 1954).

To some extent the economy of the Yemen Tihama depends upon trade between the sea and the Sana-Taiz upland, but even more it depends upon the agriculture of the mountain valleys between Sana and the plain. It is here, at elevations above 4,000 ft., that the chief export crop, coffee, is raised, from the Taiz area all the way to Asir. The rainy seasons of both summer and winter, and the frequent mists that reduce the solar glare, favour coffee production. The coffee trees are grown under intensive agriculture, on carefully constructed terraces with stone walls, as much as a dozen, one above another, on the valley sides. The coffee is transported by camel—about 400 pounds per load—to coastal ports, principally Hodeida today. Another important commercial crop is khat (qat), the leaf stimulant that is chewed every afternoon by nearly all who can afford it (Fayein, 1957).

The Tihama plain itself has two principal lines of settlement, one consisting of fishing and trading ports along the coast, and the other of agricultural settlements in a piedmont location along the inner edge of the plain. Sea-borne trade is greatly hampered by the shallow, reef-filled approaches through the coral belt, and direct access is possible at most points only by dhows or lighters. The southernmost port is Mocha once famous as the great coffee port of Yemen, but, now insignificant. The coffee shipments from Taiz have been diverted to Aden, and the shallow lagoon running for 6 miles south of town has become badly silted. Large seagoing vessels must anchor about 1½ miles off shore and tranship their goods to dhows able to enter the port. South of town the edge of the lagoon is bordered for about 2 miles by extensive salt pans, where evaporation of sea water produces an important local item of trade. But Mocha is only a shadow of its former self, and houses occupied by its few hundred people are surrounded by the abandoned ruins of other houses. South of Mocha to Bab-el-Mandeb the Tihama is a low sandy plain with sparse scrub, almost uninhabited (U.S. Hydrog. Office*, Sailing Directions, no. 61).

From Mocha north to Hodeida there are several villages, with date groves and fishing activity. Hodeida is easily the most important city of the Tihama, and the chief port of Yemen. Although it was founded by the Turks only in 1849, it has grown to a population of about 30,000, and extends for a mile along the coast. Camel caravans with coffee from the interior converge at Hodeida, where the coffee is sorted and packed for shipment. Hides and skins from the Tihama and the interior are also exported. While a sand spit and Lagoon provide shelter for small boats at Hodeida, large vessels have to anchor 3 miles off shore, the coffee being transferred to dhow lighters. A port development programme is under way, involving dredging a deep channel and building a large wharf to deep water. Hodeida has a dhow-building works that supplies dhows for fishermen and traders up and down the coast. The city consists of a walled core, as is usual in Yemen towns, with date groves and gardens outside the walls. The houses are solidly constructed of stone or brick, sometimes with reed huts on their flat roofs. South of the city there is a suburb of grass or palm huts, occupied by Negroes.

Northward from Hodeida there are a few small villages, located on lagoons or inlets, carrying on fishing, a little agriculture, and even some grazing of sheep and hump-backed cattle. Near the coast, heavy dews encourage some forms of vegetation. Salif, opposite Kamaran Island, is a minor port near which is a deposit of rock salt.

The main portion of the Tihama plain is dry and unused, but within reach of water from the wadi channels there are extensive networks of irrigation canals and intensive agriculture. Durrah and other grains, vegetables, fruits, and livestock fodder are raised. In the hot, intense desert of the Tihama the native vegetation is insufficient to support much nomadic-type grazing: even the sheep-raisers depend upon feed from the irrigated lands. Very likely the Tihama, as much as 50 miles wide in places, could be used more efficiently if more were known of the amount and fluctuation of water available and the geomorphic relation of the land to the source of water.

The only agricultural towns of the Tihama of Yemen lie along the base of the piedmont, where the wadis from the mountains emerge upon the plain and provide a maximum of water for irrigation. There are three important towns here: from south to north Zabid, Bait al Faqih, and Bajil. Zabid, a mud-walled town of about 8,000, with brick houses three or four stories high, is the centre of rich cotton and indigo cultivation. Many varieties of fruit are raised here: bananas, papayas, and coconuts of the tropics along with figs, grapes, and lemons of the Mediterranean. The town manufactures textiles and leather products, but is better known as an important centre of the Sunni sect and as the seat of an ancient Moslem university. Bait al Faqih, a town of about 12,000, is a cotton-weaving and leather sandal-making centre, a market for local agricultural products and for trade with Hodeida. Bajil, a smaller town of about 3,000, lies on the main route from Hodeida to Sana. Between the towns, the piedmont is sprinkled with fertile irrigated valleys, in great contrast to most of the dry, barren plain to the west.

It would be of great interest to see in detail how the water resources of the Tihama are used and what possibilities there may be of still better use.

SECTOR 10: THE HEJAZ, ASIR AND TIHAMA

Sector 10 is the Red Sea coastal desert of Saudi Arabia. Most of it falls within the region known as the Hejaz, but the southern part is in Asir. The people of Asir, like those of Yemen, have maintained a spirit of independence, but they succumbed to the Arabs in the eighteenth century. Asir is now the best agricultural area of western Arabia.

Asir resembles neighbouring Yemen in many ways. It has the same sort of humid upland nucleus, not quite as high and not quite as humid as Yemen; the same mid-slope coffee cultivation, though less abundant; the same sort of coastal plain, though very narrow in places; the same lines of sea settlements and piedmont agriculture. Thesiger (1947) and Vesey-Fitzgerald (1955) have described the Asir Tihama in some detail, at least along the transects of their journeys. The inner edge of the Tihama is made up of coalescing alluvial fans, fairly smooth, and covered with stands of acacias and other woody plants which have long taproots that can reach ground water. Where wadis from the hills cut through the fans, there are thickets of tamarisks, acacias, and *Salvadora persica*. Farther west, the main portion of the plain consists of wind-blown sand, with tussock grass and a few scattered woody plants. The silt borne by the wadi flood spreads out in a broad sheet, and the water is usually dissipated before reaching the sea. The rare rains on the plain collect enough water in poorly drained flats or basins to favour growth of plants. The outer edge of the plain consists of coastal dunes and poorly drained salt flats, fringed at the water's edge by mangroves.

The principal wadi, the Baish, usually floods on to the plain twice a year, in the late summer or autumn and in winter, though the floods are highly variable and undependable. On the flooded silty land, dhurra (a sorghum) is the staple crop. Its grain is used for food, and the stalks are used as livestock fodder. At the edges of the flooded areas sesame, beans, and cotton are grown. Dukhn is grown on the sandy lands between the wadis when there is enough local rainfall. Garden vegetables are raised by irrigation. The flood water of the wadi is spread on to the desired fields by means of temporary earth diversion dikes. If one wadi fails to flow, the farmers move temporarily to another. The whole life of the plain dwellers centres upon the wadis. Although they are basically sedentary, they do raise livestock: cattle to plough and to build the irrigation dikes, sheep, goats, and poultry as the principal food animals, and donkeys as the chief transport animals. Camels are few. The usual shelter is a round grass hut. The principal source of fuel is the tamarisk and acacia, which have become scarce near the villages, and the stems and branches of smaller woody bushes are used to supplement the more substantial wood.

At the inner edge of the Tihama there is a piedmont zone of more settled villages, for the wadis where they emerge from the foothills are in permanent valleys. The houses are mostly flat-roofed stone structures. Here the natural forage is more abundant than out in the plain, and supports larger herds of goats and sheep. The fertile wadi valleys support irrigated land with date groves, dhurra, and sorghum.

Along the coral coast, sheltered by the Farsan Bank, are small fishing villages, but only one port of significance: Qizan (Gizan). Qizan, protected by the Farsan Islands from the waves and storms of the open Red Sea, is the principal port of Asir. Through it are shipped out grain, dates, skins, and a little coffee from inland, as well as dried fish from its local catch and from fishermen along the rest of the coast. It has its own dhow-building industry, supplying local fishing, pearling, and coastal trading needs. To the south of town are salt pans from which comes the salt needed in curing fish. The population, numbering about 3,000, lives mostly in straw huts, though there are some permanent stone buildings.

In ancient times the Hejaz, extending from Asir to the northern limit of the Red Sea, was better known to the outside world for its interior upland portion than for its Tihama. As cited above, the author of the *Periplus of the Erythraean Sea* considered this part of the Tihama as a wild, barbaric area to be avoided by merchantmen. Although the Hejaz was at one time controlled from Yemen by the Sabean kingdoms, its greatest early development occurred in the north under the Nabatean kingdom based at Petra. The incense trail from the Arabian Sea to Egypt through the cooler upland route, with relatively numerous wells of good water, was usually used in preference to the blistering hot, dry Tihama. In addition, the crystalline rock of the uplands abounds in deposits of various ores, some of which have been worked since at least biblical times. One of the ancient mines, at Maha Dahab (Mahad-al-Dhabad), 'The Cradle of Gold', was reworked as recently as the period 1945-51 by a joint American-British-Canadian syndicate. Though the mine had been considered to be exhausted, the syndicate was able, by modern methods, to extract an additional 12 million dollars' worth of gold and silver before closing down again. A solid contribution to the country was made by the miners in the form of a road from the mine to Jidda. This and other mines had been worked by the Turks, the Romans, and probably the Phoenicians and Solomon, especially in the northern part of the Hejaz known as Madian or Midian (O'Good, 1954). Potentialities undoubtedly exist for systematic exploration and development of precious as well as base metals.

However, the great attraction of the interior since the Hegira in A.D. 622, far overshadowing the gold mines, is the holy Moslem city of Mecca and its surrounding historic sites associated with the life of Mohammed. To the Kaaba of Mecca and its Black Stone, the Moslem faithful throughout the world turn in daily prayer, hoping that—at least once during their lifetimes—they will be able to visit the holy city. The tourist business resulting from pilgrimages to Mecca affects the entire economic life not only of the interior of Hejaz but also of the Hejaz Tihama through which most of the pilgrims pass.

The economy of the Tihama today is dominated by Jidda, where more than half of the people of the coastal plain live. Jidda is the pilgrim port of Mecca: the nearest port to Mecca and at the same time, by coincidence, opposite an easy pass in the lowest portion of the rugged escarpments that line the Red Sea trench. The city developed on the Bay of Jidda: not an outstanding natural harbour, but one that has been improved to meet the requirements of the pilgrim trade. The port, protected by three successive lines of coral reef, is always smooth and free from large waves despite any wind. The outer anchorage, between the second and the third line of reefs, can accommodate the largest ships, while dhows and other small vessels can come right in to shore. North and south of town, out of the way of the main port traffic, there are oil tanks and facilities for handling tankers.

Despite its mediocre natural environment, Jidda has become a rapidly growing city with a population now estimated at about 120,000, and even more during the height of the pilgrimages. Stores carry on a lively trade providing pilgrims with supplies and souvenirs. Building is going on rapidly. Most of the houses are of coral, four of five storeys high, stuccoed, and grouped along narrow, crooked streets. There are now some large modern buildings. Local supplies of well water had become completely inadequate when a British firm in 1947 built a pipe-line to bring water 30 miles from an oasis in Wadi Fatima in the piedmont zone. In addition, municipal water is obtained from the Red Sea through a multiple distillation desalinization plant. The increased availability of domestic water, and recently the installation of a refrigeration plant for freezing and storing fish, have helped Jidda to support its increasing population. There is little doubt that the fishing industry of the entire Red Sea would be greatly stimulated by widespread availability of refrigeration facilities, though the time-honoured method of preservation by drying will long continue to be the only way in which people in small settlements in the interior can obtain fish.

Jidda is notorious for its hot, humid climate, but a daily sea breeze alleviates the heat most afternoons. The winds from the Red Sea are strong enough to permit the use of windmills locally to pump water from shallow wells in parts of the nearby Tihama, though water from most local wells is still raised by camel- or donkey-power. During the heat of summer many of the well-to-do citizens move to Taif in the cooler uplands.

To support its population, and its visitors, Jidda carries on an active import trade, getting grain, dates, and other food from the Red Sea margins of Asir and Yemen, as well as from the nearby piedmont of the Tihama. This central portion of the Tihama is poor agriculturally, owing to the lower backing mountains and the consequent smaller amount of rainfall to flow down the wadis. The 2 in. average yearly local rainfall, mostly coming in November and December, is concentrated in an average of five days per year, and has little value except to improve the forage at places where the terrain favours accumulation of run-off water. The grass and brush do support some nomadic pasturage of sheep and goats, especially at the inner edge of the plain.

In addition to Jidda, there are small trading ports spaced about 100 miles apart up and down the coast, and many small fishing or agricultural villages at little coves or favourable locations on the wadis. Starting in the south, the first Arabian port is Al Qunfidha (Kunfida), with about 10,000 people, inside the Farsan Bank and at the terminus of a trail that runs from a pass in the eastern mountain wall. The Tihama is here wide, and has the benefit of the northernmost high, fairly well-watered mountains of Asir as a source of water for annual wadi floods. There is available in the plain considerable production of sorghum, millet, rice, dates and other fruits, and garden vegetables. Most of the people of Al Qunfidha, like those of the villages in the plain, live in simple grass huts. The town has several mosques, like all towns of more than a few hundred people in Moslem lands. Halfway between Al Qunfidha and Jidda is the smaller town of Lith. Lith lies about a mile inland from the coast, near a dense grove of date palms. It consists of small earth or straw dwellings. Its port, at the northern end of the coral Farsan Bank, is used by small trading or fishing vessels. The fishermen include many Negroes, probably the descendants either of slaves imported by the Arabs or of Moslem pilgrims from Africa, who sometimes cross Bab-el-Mandeb in large groups and work their way along the coastal trails towards Mecca. Some of these groups lack the wherewithal or perhaps inclination to return to Africa, and settle in communities along the Tihama (Fayein, 1957). On the plain inland from Lith there is intermittent grain-raising in years when water conditions are favourable.

Northward for about 200 miles, from Jidda to Yenbo, the coast is marshy and lined with mangroves which reach their northernmost limit, in stunted form, near Yenbo. About halfway between Jidda and Yenbo is Rabigh (Rabegh), a compact group of villages totalling some 7,000 people. Ground water near the surface supports extensive date palm groves, the principal local resource. During years of favourable rains and wadi flow, the plain to the east produces good crops of grain. Rabigh is favoured by a deep, well-sheltered inlet, Sherm Rabigh, 2 miles to the south, used by dhows for fishing and coast-wise trade. Like all the coastal towns, Rabigh derives substantial income by playing host to pilgrims *en route* to Mecca by land. In A.D. 1326 the great traveller, Ibn Battuta, mentions Rabigh as the point at which his trail from the north reached the coast. At Rabigh, he said, there were pools formed by rain that held water a long time (Gibb,* 1958, p. 186).

Yenbo (Yanbu), the next important town to the north, is the port of Medina, and ranks a distant second to Jidda among the ports of Hejaz. A trail from Medina descends through a pass in the mountains and then follows a wadi that crosses the Tihama in the direction of Yenbo. About 30 miles inland along the trail is Yenbo el Nakhl, a date palm oasis. Yenbo el Bahr is the seaport, the crossroads town where the route from the interior meets the north-south trail and the shipping terminus. Although entry to the harbour is made difficult by coral reefs, the strategic location has encouraged growth of the town to about 10,000 people, living in houses of local rock or coral. By the use of water from three types of source, supplies are adequate for the population. Besides wells sunk to the ground water and cisterns to collect rain run-off, there is a condenser with a capacity of about 5,000 gallons of distilled water daily (U.S. Hydrog. Office,* Sailing Directions, no. 61). In the absence of statistics or even descriptive reports it is impossible to estimate for Yenbo, or for any other small ports, the extent to which dates and livestock from the interior, or fish from the sea, are received in quantities sufficiently above local needs to allow of exports. It has been reported that one local product, charcoal, is exported from Yenbo and the next ports north, Umm Lej and Wejh, in the amount of about 500 tons per month.

As most of the charcoal is made from acacias from the Tihama, these trees have become scarce near the towns, and the wood has to be packed in from greater and greater distances (Vesey-Fitzgerald, 1957).

North of Yenbo the hard rock foothills project westward enough to crowd out the coastal plain and produce a broad bulge in the coast-line. The main coast-wise trail from Yenbo therefore cuts inland and rejoins the coast about 80 miles north, at Umm Lej (Umm Laj), a little port with groves in a nearby wadi.

About 70 miles north of Umm Lej the greatest of all the Arabian Tihama wadis, Wadi Hamdh, breaks through the mountains and flows north-westward, reaching the coast just south of Wejh. This wadi is formed by the union of two long tributaries that parallel the mountains on the plateau just to the east: the Wadi Aqiq which runs for nearly 400 miles from the south near Taif, and the Wadi Jizl which comes from the north. Owing to the irregular and often local character of the rainfall, the wadi system usually has flowing water only in disconnected segments at any one time, and there is seldom enough water to reach the sea. The autumn and winter rains of the seasons known to the people as Wasm (1 October to 20 November) and Shita (21 November to 21 February) bring annual floods to the Tihama via Wadi Hamdh. In some years these floods are substantial. These are also the only rains that fall upon the Tihama itself occasionally and permit some direct agriculture where terrain is favourable. The rains of the summer monsoon season, the Kharif, in August and September, are rare and uncertain in the mountains north of Jidda, and very seldom flood the wadis sufficiently to reach the Tihama.

Wejh (Wej, Wajh) is the only significant port of the northern Hejaz, an area known as Madian. As the principal outlet of the flood agriculture of the Wadi Hamdh, along with the usual pilgrim transit trade, its population has grown to about 15,000. Like Yenbo, its water supply is drawn from three sources to meet the growing domestic needs: rain-water cisterns, wells east of town, and a condenser to distil salt water. Grain and sheep for the pilgrims and the local population are raised on the basis of wadi floods and concentrated rain-water run-off in the Tihama. Sea trade and fishing are handled by dhows in a small but well-sheltered cove.

Northward from Wejh the hills of Madian approach the coast and reduce the coastal plain to a narrow strip. The pilgrim road skirts the sea, passing through Dhaba and other little fishing ports with date groves, and emerges upon a wider plain near the sharp angle of the north-east corner of the Red Sea. El Muhweilih (Mowila, Muweila), is a fortified village of stone houses and palm huts, with a small grain depot and sheep centre, in a date oasis in the plain north of Dhaba. Near here the Wadi Sarma, filled with acacia thickets, crosses the coastal plain to a wide marsh bordering the sea. Five miles from the sea up the Wadi Sarma, A. Musil in 1910 came to the oasis of Sarma, where a dense palm forest bordered the wadi for nearly half a mile. Scattered palms grew upstream from the oasis, and Musil believed the palm grove could be extended for 10 miles eastward. The hot, sheltered locality favours early ripening of dates, and Musil (1926, p.137-41) found some already brown at the time of his visit on 14 June.

Just around the Red Sea corner, where the coastline heads west towards the Strait of Tirana, there is a particularly fertile but undeveloped plain with good water, behind Aynuna (Ajnuna) Bay. Two miles from the coast, at the base of some red rock hills, where the Wadi Aynuna emerges from the hills, is the Aynuna Oasis and Valley, well known for its abundant supplies of good fresh water. At one time an aqueduct, the remains of which are visible, flowed from the oasis to El Khureiba (al-Hrajbe) on the coast. There are ruins of an old settlement on the side of the valley. The mile-wide wadi floor below the oasis might easily be transformed into one big date garden in the opinion of Musil. There are already small date gardens at Aynuna and El Khureiba (Musil, 1926, p.122-7). El Khureiba is a village of stone and earth huts, a trading centre from which the main trail for the north leaves the coast and cuts into the northern mountains *en route* to the head of the Gulf of Aqaba. The tantalizingly few hints of a once-flourishing settlement, and of presently under-utilized water and land resources for the Aynuna and Sarma areas, suggest that here may be a locality with potentiality for worth-while development. Possibly it was at one time related to the Nabatean or Byzantine culture that is known to have flourished in the mountains about 30 miles to the north.

Westward from Aynuna to the Strait of Tiran for 35 miles the Tihama is a low sandy plain, with shallow bays and marshes, bordered by coral reefs with narrow channels, and several coral islets. At the entrance of the Gulf of Aqaba the coast turns acutely northward. The long, straight coast of the Gulf of Aqaba is bordered by the steep slopes of the mountains plunging directly into the water with no intervening coastal plain. The Tihama has come to an end. Midway along the coast there is a good well, Bir Mersa, but the road from El Khureiba to Akaba cuts through the mountains of Madian, reaching the Gulf of Aqaba at a little palm oasis about 20 miles south of the head of the gulf.

SECTOR 11: SINAI AND THE NEGEV

Sinai is a massive wedge of mountains that splits the northern end of the Red Sea into two long narrow gulfs, the Gulf of Aqaba on the east and the Gulf of Suez on the west. The coasts of the two gulfs are quite different in character, but they agree in having the principal economic development and potentialities at the northern ends at the head of navigation.

On the Sinai coast of the Gulf of Aqaba the granitic upland plunges steeply to the water for the full 110 miles of the gulf, with only two significant breaks where wadis provide negotiable passes for trails leading from the coast to the interior plateaux and across the Sinai Peninsula. On the coast, opposite one of these breaks, about 70 miles north of the entrance of the gulf, is the sandy spit and small settlement of El Qarnus. Here there is a large grove of date palms, and 3 miles north is a smaller grove and a fort. The other break, with a trail, farther towards the mouth of the gulf, ends in the sandy Dahab Peninsula.

Only at the head of the gulf is there a broad route to the interior, by way of the Wadi Araba that prolongs the gulf trench north-eastward; and only here are there strong economic and political motives for development. Although the flat land between the mountains at the head of the gulf is only about four miles wide, it is the meeting place of four different nations: Egypt, Israel, Jordan, and Saudi Arabia. For Egypt and Saudi Arabia this locality is of little moment, but for Israel and Jordan it is vital. It has been vital intermittently for millenniums.

As early as the tenth century B.C. biblical Israel had a great seaport at the head of the Gulf of Aqaba. King David first appreciated the strategic value to Israel of the Wadi Araba and its outlet on the sea. His son, Solomon, consolidated and utilized the route. According to the Bible, 'King Solomon made a navy of ships in Ezion-geber, which is beside Eloth, on the shore of the Red Sea, in the land of Edom'. This navy sailed to the land of Ophir and brought back 420 talents of gold: over $ 23 millions' worth (I Kings, ix, 26). Later, the fleets brought in silver, ivory, apes, and peacocks, in addition to gold (I Kings, x, 22). An extensive but inconspicuous mound known locally as Tell el-Kheleifeh 500 yards from the head of the Gulf of Aqaba has been identified recently as the site of Ezion-Geber. Nelson Glueck (1959) has dated the site from pottery fragments as having been occupied from the tenth to the fourth century B.C. He found pieces of jars such as the Arabs and the Queen of Sheba people used to transport incense and spices by caravan; fragments of timbers, ropes, resin, and nails from old ships; and fish-hooks, net weights, and shells indicating an ancient fishing industry. Here Glueck found also the remains of a huge copper smelter, the largest known from antiquity. It was used in Solomon's time to smelt copper brought from rich mines a dozen miles to the north, along the sides of the Wadi Araba. These copper mines of King Solomon were rediscovered by Glueck while exploring the wadi. The great smelter was oriented so that its principal draught faced north-north-eastward, thus taking advantage of the prevailing natural wind blast that roars down the Wadi Araba from the north - north-east.

Not only the wind but other climatic elements appear to be essentially the same today as they were four thousand years ago. The Negev Desert, to the north, and Sinai to the west, were as forbidding during the period of Abrahamitic wanderings of the twenty-first to nineteenth centuries B.C. as they are today. Yet from time to time cultures of high level have developed in this area. The Nabatean culture that flourished at many points in the Negev and Madian from the second century B.C. to the third century A.D. was based in part upon the use of large cisterns cut into the ground and lined with cement against water loss, then filled by carefully constructed diversion systems to concentrate the rainfall run-off from an extensive surface. In some cases the run-off was focused upon low fields of good soil for cultivation. When the Romans conquered the area, the Nabatean culture continued, somewhat modified, as the Byzantine, until the sixth century A.D. Among other accomplishments, the Romans in this period built a road to Aila at the head of the Gulf of Aqaba.

The modern State of Israel is energetically developing all the resources that were used to good advantage by the earlier cultures. King Solomon's old copper mines have been reopened, and 700,000 tons of copper ore were mined from 1951 to 1961, all exported in a semi-refined state. Large enough ore reserves have been found to justify plans for a refinery (*New York Times*, 1961). Just west of old Ezion-Geber, at the western corner of the north end of the Gulf of Aqaba, was the town of Eloth, which by the time it was taken over by the new State of Israel in 1949 consisted of a few earth and stone huts. Even by 1954 it had only 100 people. Today the town of Eilat (Elath) has become the focus of effort, the vital outlet of Israel to the Red Sea and oriental seaways (Samuels, 1961). One aftermath of the Suez Canal crisis of 1956 was to open the Strait of Tiran for ships to pass freely, and now the ships of Eilat have regular sailing to the coasts of Africa and the Far East, previously inaccessible to Israel by reason of the closing of the Suez Canal by Egypt. Cargoes totalling 161,000 tons were handled at the port in 1960-61, compared with only 8,000 in 1956-57. Plans call for an ultimate capacity of 750,000 tons. A 16-in. pipe-line now transports petroleum from Eilat to the refinery at Haifa on the Mediterranean and good road and air links are in regular use. By 1961

Eilat had 7,000 people, and is still growing. Several modern hotels serve a rapidly growing winter tourist industry. The midwinter mean temperature of 60° F. is 12° above that of Jerusalem and 3° above that of Haifa. Serious efforts are being made to expand the fishing industry. The Gulf of Aqaba and the Red Sea abound in fish, and the annual catch is increasing steadily. The distance to the principal markets in the north is one of the principal drawbacks, but refrigeration and canning can overcome this problem (Cohen, 1957). Potash, phosphates, and salt from the Dead Sea and other desert sources are among the exports. A municipal supply of water has been a serious problem. With an average rainfall of only 1.1 in. per year (Table 2), Eilat has an extreme desert climate. The limited local ground water is saline, and water must be brought from a source several miles to the north. Primary reliance will have to be based either upon piping water from the well-watered north or upon a plant for desalinization of sea water. Progress has been made upon a desalinization installation at Eilat, based upon the Zarchin process of purification by freezing (Morris, 1961, p.240-52).

Little is to be expected from agriculture because of the scarcity of water. An experimental garden started at Eilat by Mrs. Hugo Boyko some years ago has shown that the climate would permit the raising of a great variety of plants if water resources were adequate. Work has been done particularly on plants that can grow with water of high alkalinity. The Eilat climate is one of mild, pleasant winters and intense summer heat: a mean daily maximum above 100° F. for three summer months; dry air: relative humidity in the hottest month 40 per cent at 8 a.m. and 22 per cent at 2 p.m.; evaporation of 0.83 in. per day in August; and the meagre and undependable rain falling on the average on one day per month in the six-month winter 'rainy' period from November to April (Ashbel, 1945; Israel, Met. Office, 1952).

Across from Eilat, at the opposite corner of the head of the Gulf of Aqaba, is the Arab town of Aqaba (Akaba). It is the only port of the Hashemite Kingdom of Jordan and, like Eilat in Israel, it is developing fast. Musil in 1910 reported that the settlement of 'al-Akaba' consisted of thirty huts of stone or earth and nineteen families. By 1958 it had about 8,000 people. Apart from its importance as the sea outlet for the separate State of Jordan, it has continuing importance as a strategic stopping place on the pilgrim route to Mecca. It has old extensive date groves, as well as Mediterranean fruits such as figs, lemons, and pomegranates, and assorted vegetables grown under the shade of the palms. Such agricultural development is possible only because of a much better source of water than Eilat. Musil reported plenty of water at depths of 0.5 to 2 metres, fresh water at a well at Aila (Ajla) just west of Aqaba; and many springs that gushed forth with great strength from the bare rock uncovered at the water's edge at low tide (Musil, 1926, p.85-8, 268). The extent to which these manifestations have changed today is not known, but they suggest an abundant supply of ground water. Presumably the mountain watershed to the east provides considerable run-off from the winter westerly storms, whereas Eilat is in the dry rain shadow of the Sinai highlands. Musil mentioned that wheat and barley are raised in the nearby Wadi al-Okfi, and give good yields in years when there has been enough rain to give the wadi a sufficient flow of water. At the time of planting and harvesting, the farmers lived in tents by the fields, returning to their homes in Aqaba the rest of the time. Sea trade is increasing for the port of Aqaba, and fishing is an important activity. Morris (1957) says that the Arab fishermen of Aqaba fish with dynamite exploded under water. After an explosion, they jump overboard and toss the stunned fish into the boat.

The west coast of Sinai, along the Gulf of Suez, has a coastal plain 12 to 15 miles wide in the south and in the north. In the middle the mountains approach the coast. From the vicinity of the village of Tor southward there is a rolling sandy plain. Tor averages only 0.5 in. of rainfall per year, and some years are entirely dry. Although summers are hot they are about 10° F. cooler than those at the head of the Gulf of Aqaba because of the better exposure to westerly breezes. Winters are slightly cooler than at any other station on the Red Sea littoral; the mean daily minimum in January is 48° F. (Table 2) The lack of local rainfall is somewhat compensated by wadi run-off from the mountains during the occasional winter rains, which permits limited irrigation agriculture on parts of the lowland.

Farther north there have been several discoveries of minerals. At Abu Zenima, the chief port of the western Sinai littoral, though still numbering only about 150 people, a light railway brings out manganese ore from the Um Bogma mine farther inland. Still farther north several small oilfields have been developed since 1945, at Ras Matarma, Asl, and Sudr, which make significant contributions to the petroleum supplies of Egypt. At Sudr there is a pipe-line to the coast (Platt and Hefny, 1958). The economic impact of the oil is felt most at the town of Suez, at the head of the gulf. So far as the Suez Canal is concerned Suez—at the south end—is little more than a transit channel, of minor importance compared with Port Said at the Mediterranean end of the canal. But Suez is the collecting place for all Egyptian oil produced along the Gulf of Suez and Red Sea. It has two large refineries, and sends the refined products and some of the crude oil inland by pipe-line, rail, and truck.

SECTOR 12: EASTERN DESERT LITTORAL OF EGYPT

Between the Nile Valley and the Red Sea lies the Eastern Desert of Egypt: a dry, inhospitable region. The core of this region is made up of the Red Sea Hills, a series of plateaux about 2,000 to 4,000 ft. high, with peaks rising to over 7,000 ft. These mountains constitute a formidable barrier between the Nile Valley and the Red Sea, yet they also provide a great assortment of valuable minerals in their highly varied rock types, and at the same time they extract enough additional moisture from the air to furnish what little water is available to the workers of the mines and the ports through which the minerals are shipped. The water divide of the Red Sea Hills is much closer to the Red Sea than to the Nile; the eastern slope is only about 30 to 40 miles wide. Consequently the coastal desert along the west coast of the Red Sea in Egypt has only a narrow ribbon of coastal flats and terraces, rising in a few miles to the rough, dissected mountain slopes.

The entire Red Sea littoral of Egypt has less than 1 in. of rainfall per year. Kosseir (Qoseir), with 0.2 in. or less on the average per year, is the driest climatological station with an adequate record along the entire coasts of the Red Sea (See Table 2). Temperatures are high, reaching their highest in August (mean August temperature at Kosseir, 87° F.). Furthermore, there is only slight relief from the heat at night: the daily range at Kosseir is 12° F. Furthermore, the humidity actually rises during the day, contrary to the expectation in 'normal' climates, because of a sea-breeze tendency. Thus Kosseir has a relative humidity of 47 per cent in the morning and 57 per cent in mid-afternoon on the average in August (U.K. Met. Office,* 1958). The almost complete absence of cloudiness in summer gives the sun full freedom to beat down upon the land. Winters are comfortable; in fact, nights may be rather chilly at this season. What little rainfall and cloudiness there is comes during the early winter. The inhospitability of the littoral is increased by the absence of fresh water except locally in a wadi during a rare winter flood that reaches as far as the coast. The ground water, when it is obtainable, is usually too brackish for human consumption.

In the face of these drawbacks, the Red Sea littoral has been largely an uninhabited waste within recent centuries, except for a very few small settlements connected with fishing or, intermittently, with mines in the mountains. In Greek and Roman times, and still earlier Phoenician times, this coast had centres of great activity. As was pointed out under Sector 10 above, the port of Myos-Hormos was an important centre of trade between Egypt, India, and intermediate points in the first century A.D. This port represented the last in a series of centres—founded by Ptomely Philadelphus, King of Egypt, in the third and fourth centuries B.C.—shifting as a result of trial and error to take advantage of the best combination of geographic factors. In order to divert to Alexandria the rich trade of Tyre with the Orient through the Phoenician monopoly of the Red Sea shipping, this Ptolemy first built a port at the head of the Gulf of Suez, near modern Suez, named Arsinoe after his wife. To avoid the dangers of navigation in the narrow, shoal-infested Gulf of Suez, Ptolemy founded Berenice, named after his mother, nearly 500 miles down the coast. For a while Berenice became the chief centre of Red Sea trade. It was necessary to tranship all goods by way of a 200-mile caravan route through the Red Sea Hills between Berenice and Coptos, a town on the Nile across from the ancient city of Thebes, near present-day Qus. Myos-Hormos, the third port established by Ptolemy along the northern half of the Red Sea, eventually displaced Berenice as the main Egyptian trading centre on the Red Sea, perhaps because the land haul to Coptos is very much shorter: less than 100 miles (Bunbury,* 1959). This last site has retained a permanent attraction, and is today occupied by the busy little town of Safaga, while Berenice is merely an archaeological remnant. An important local additional attraction of the Safaga site is the exitence of rich mines of gold and other minerals in the mountains nearby: mines that have been worked for at least 2,000 years and are still being worked.

The coral coast, with almost continuous reefs and shoals broken by occasional narrow, winding inlets, was reasonably satisfactory for small vessels, but impossible for large ships without extensive modern port alterations. Since the discovery of the direct route to India by way of the Cape of Good Hope at the end of the fifteenth century, and even more since the opening of the Suez Canal in 1869, the trade of this isolated littoral dwindled to almost nothing, and was regarded as an almost totally worthless desert until recent decades.

Even today most of this sector is unused, but several of the old centres have revived and new ones been established as a result of the development of the mineral resources of the Red Sea Hills and their seaward margin. Gold, silver, and emeralds, phosphates, natron (soda), talc, lead, zinc, and other minerals are being mined. But above all, oil has been found, and in view of the scarcity of power sources in Egypt, the development of oil has high priority no matter how forbidding the desert and difficult the work. The first discovery of commercial oil occurred in 1913 at Hurghada (Ghardaga), and small quantities of oil have continued to be produced there ever since that time. The biggest find was made in 1938, at Ras Gharib, farther north, and this has become the main port of the Eastern

Desert. The petroleum is shipped to Suez for transhipment to the centre of population at Cairo. An important by-product of the oil is a supply of asphalt that makes possible permanent roads of good quality.

The Red Sea ports fluctuate in size with the fortunes of the mines and oilfields, so that it is difficult to give reliable estimates of population. The big three—Hurghada, Safaga, and Kosseir—at which there is regular international trade, seem to have varied between 2,000 and 5,000 people each in recent decades (Ball, 1939).

To start in the north : Ras Gharib is purely an oil production and export town. Hurghada ships some oil, but also has a sizable fishing industry. Safaga is the best site of Egypt on the Red Sea, with fairly good natural shelter against the prevailing northerly winds and access to the Nile where that river makes its closest approach to the Red Sea. A good 100-mile road connects the port with Qena on the Nile, and provides access to mines in the mountains. The major export is phosphates, which are hauled by light railway from the mines to the coast, and thence shipped to India, Japan, and other distant countries. Kosseir, too, has a road to Qena, and ships out phosphates. There is also lead and zinc mining nearby.

Mersa Alam, farther south, is operated as a centre for minerals research. There are unquestionably more valuable finds to be made in the poorly known, difficult Red Sea Hills.

Finally, just north of the Sudan border, there is a little fishing village, Halaib. Halaib has adequate supplies of ground water near the surface, but it is so saline that to most people it is strongly purgative. The villagers are reported to have become accustomed to its use, however (Ball, 1912). At other localities there are small supplies of ground water, some of which is drinkable by camels, though not by humans, and some is too saline for animals.

Water is by all odds the chief environmental problem of this entire sector. Such water as reaches the littoral originates in the mountains. For nomads or caravans going through the mountains, an important source of water is provided by run-off that has collected in natural rock basins ('tanks' or 'tinajas', southwestern North America). This water is pure, but limited in quantity and non-existent in rainless years. There are a few good springs ('ain') in the mountains, too. Occasional floods of the longer wadis reach the coast, but wadi floods make their chief contribution in building up the ground water. In the sandy floors of the wadis water can be reached in many places at depths of around 30 ft., but each flood of the wadi fills in the wells with sand and gravel. Other wells, in the fringe of coastal flats, are brackish. Most of the littoral wadis are short, steep, and dry for years on end. A few cut through one or more lines of mountains and drain a many times larger area. One would expect the courses and vicinity of these larger wadis to have the most abundant supplies of ground water in the littoral.

For many years the three or four principal towns of the sector have depended upon distilled water for drinking: another contribution made possible by the availability of cheap fuel in the form of local petroleum supplies. The distillation process, like all others, is still far too expensive to be used to provide irrigation water, but it does make possible municipal supplies and hence the maintenance of settlements at strategic places for exploiting ports, mines, or other potentialities. Even if cheap water of good quality were available, it is unlikely that much agricultural development could take place on the Egyptian coast of the Red Sea because of the unsuitability of land. The coast is bordered by coral platforms, which in places extend inland as narrow plains, usually covered with wind-blown coarse sand, or with hard, alkaline flats. Behind this fringe, along large stretches, there is a series of marine terraces rising from heights of about 75 ft. to over 750 ft., as between Safaga and Kosseir (Ball, 1942). Even where the ground is not a desert pavement, alkali flat, or sand dune area, the terraces are so broken by transverse wadis as to be uneconomical to develop. The wadis, with their steep sides and shifting sandy floors, interpose serious handicaps to north-south travel, and the only roads in this direction, paralleling the coast, are poor, steep and sandy for long stretches. The main roads follow the grain of the wadis, east-west, connecting coastal points with the mountains and with the Nile valley.

The future of this region does not look promising but there are local possibilities. Already more and more systematic attempts are being made to discover and develop mineral deposits. Fishing is the most undeveloped industry with potentials: there is abundance of raw material in the sea, and a good market among the fast-rising population of Egypt. Means of preservation and transportation of the fish need great improvement before it will be worth while to develop better means of fishing. Whatever the local industry, at least water can now be distilled cheaply enough so that people need not be thirsty wherever there is profitable work for them to do.

SECTOR 13: SUDAN AND ERITREA

South of the southern border of Egypt in Sudan, certain changes in climate appear. Temperatures are truly tropical, with winters warm and summers hot, and the extreme aridity (E)[1] of the Egyptian littoral is replaced by 'normal' desert (A). Along the 325-mile stretch where the Sudan reaches the coast, the temperature from June to September surpasses 100° F. nearly every day (see Table 2), and in Tokar, 15 miles in from the coast, the mean daily maximum in June and July is 108° F. Even at night the temperature seldom falls below 80° F. in summer. There is a tendency for a gentle land breeze to blow at night, followed in the early morning by a dead calm in which the brazen sun beats down relentlessly. About 9 a.m. a sea breeze begins, increasing in strength into the afternoon. Though the sea breeze gives some relief from the oppressiveness of the heat, it increases the humidity, so that the normal tendency for relative humidities to drop as the temperature rises is actually reversed. At Port Sudan in July, wet bulb temperature at 2 p.m. averages 83° F., with a dry bulb temperature of 106°. Small wonder that as many coastal people as can do so move up into the nearby Red Sea Hills for the summer. Winters along the coast are bearable, with mean daily maximum just above 80° F. and minimum about 68°. The native inhabitants even complain of the cold at this season.

Winter rainfall continues to predominate throughout this sector, associated with northerly winds, but there are occasional tropical showers in summer, related to passage of the intertropical front that may move as far north as 20° N. latitude in July. The mean annual rainfall totals only 4-7 in. along the coast, slightly less inland at Tokar. In the Red Sea Hills, nearly all the rain comes in summer, sending occasional spates of water rushing down the dry wadis to the inner edge of the coastal plain.

North of latitude 18° N. the mountains are almost bare of vegetation except for sparse growths in the wadis. South, the hillsides have a little woody vegetation, including acacias, with a denser growth along the wadis in and near the hills where ground water is within reach of roots. Doum-palms in the wadis provide vegetable ivory for button manufacture, and constitute a limited natural resource. When the occasional rains are sufficient, acacias put forth leaves, and there is a brief growth of ephemeral plants, and sometimes a fairly abundant growth of grass in the wadis. Pastoral nomads take advantage of the irregular and sporadic growths of vegetation, especially in the mountains, but also venture down to the coastal plain in winter.

Lack of water is one of the chief obstacles to grazing as well as to permanent settlement. Some of the few wells available are salty. Suakin, the oldest town of the Sudan coast, is fortunate in having good wells. At Port Sudan and Massawa drinking water is obtained by distillation. The few small settlements of the sector are commonly situated either on the immediate coast or near the foot of the mountains. Tokar is one of the few towns out in the plain itself.

The coastal plain is only 5 to 10 miles wide throughout most of its length. It consists chiefly of desolate, gravelly alluvial fan deposits, fringed along the coast by a belt of uplifted coral about 10 or 20 ft. above sea level and about 1 mile wide at Suakin. A narrow line of old lagoons, now shallow mud-filled trenches, separate the coral belt from the main gravel plain in many places. Here and there the plains widen opposite the embayment of a large alluvial fan, and at two places there are substantial widenings. One of these is south of Massawa, where the main rift along the Red Sea turns inland and forms the great Dallol basin, partly below sea level, and occupied by salt flats in the centre: an area subject to reappraisal if irrigation water becomes obtainable from the sea. The other widening occurs where the Baraka River leaves the mountains and forms the flat known as the Tokar Delta: one of the most significant spots of the entire Red Sea littoral.

Like the rest of the Red Sea coast, coral reefs and islands line the shore, making an excellent haven for fish and small fishing craft, but rendering navigation near shore dangerous or impossible for large vessels except at limited, favoured spots. Until 1905 Suakin was the main settlement of this sector. It was an important debarkation point for Moslem pilgrims travelling to Jidda, just across the Red Sea. Its compact little harbour, two miles in from the coast, is reached by a natural channel through the coral plain. It is still used by small vessels for pilgrim traffic and fishing boats, and its town, confined to a peninsula in the harbour, is visited and admired for its numerous mosques and Arabic architecture. For the growing trade of the Sudan, however, stimulated by ever-increasing exports of cotton from the Nile, Suakin proved to be too cramped, and since 1936, when the railway from Atbara and Khartoum reached Port Sudan, the latter has been the chief port of the country and by far the greatest port on the Red Sea. Port Sudan, in its fifty years of existence, stands as an example of how an efficient modern town can be built and successfully occupied in the desert.

In the far south of Eritrea, where an extreme arid climate reappears, is the town of Assab. It now numbers only 8,000 people, but was an important outlet for Ethiopia before the building of the railway to Djibouti. Massawa, with about 25,000 people, is the chief port and town of Eritrea today. It is the main

1. See definition on page 14 et seq.

market of the Red Sea for pearls and mother-of-pearl. It derives support from the sea in the form of fishing, preparation of dried and salted fish, and production of salt by evaporation of the strongly saline water of the Red Sea. In addition, it ships out products of the pastoral and gathering economy of its hinterland: hides, doum nuts, oil seeds, gum arabic, and some coffee. Following many decades of Italian control, in 1952 Eritrea was assigned by the United Nations to Ethiopia as an autonomous unit in the federation of the two States.

From the viewpoint of land utilization in the coastal deserts of the world, the most interesting part of this entire sector is the Tokar Delta. Some of its agricultural practices may be adaptable to others of the numerous wadi-foot sites that border the coastal plains so frequently. It is true that Tokar has the advantage of the best water supply of any site on the western littoral of the Red Sea. The Baraka River, the source of the prosperity of the oasis, heads in the heart of the well-watered mountains of Eritrea 250 miles south of Tokar. Every summer, from July to September, the mountain rains result in a sharp rise in the river, which pours its floods, in several successive surges, over the fan-delta at its mouth. Owing to the great velocity of the river, the water is laden heavily with silt—46 times as heavily as the Nile. The silt spreads out along the overflow channels and builds up the delta irregularly, so that the river often shifts its flooded area. Since 1914, the floods have shifted quite distinctly to the eastern half of the delta (see Fig. 4, p. 27). The area flooded also varies profoundly. A good flood may water 125,000 acres, while a poor one may reach only 25,000. The silt provides excellent alluvium for crops, though it gives way to sand dunes along the edges of the delta and to salt flats near the sea. A certain amount of guidance is given to the flood waters to assure maximum coverage: cuts in the main channels, dams across channels, banks to prevent wastage to the sea.

The delta specializes in the raising of cotton. Each year, after a flood has subsided, the cotton is planted in the moist ground and the moisture retained is sufficient to carry the crop from September to May or June without further watering. In planting, a slab of newly deposited silt crust is pried up and the seeds are planted in the old soil thus uncovered, in holes punched with a planting-stick. Because of the impossibility of determining in advance which areas will be flooded, a system has been devised for giving some security to the farmers. Each year the government, which owns all the land, leases it to farmers in advance of the floods, keeping back from lease sizable reserves. After the floods come, farmers whose land was missed by the flood are given flooded land from the reserve. The total amount of water available each year and its utilization are illustrated by the following comparisons: In 1913, 205 million cubic metres discharged, 30,100 feddans flooded, 28,200 feddans planted to cotton.[1] In 1920, 968 million cubic metres of water, 136,000 feddans flooded, 116,500 planted.

After planting, there follows a long period of weeding, during which the crop is subject to various hazards. Sometimes a later flood washes out the crop and a new planting is necessary. In the late fall, a dry easterly or north-easterly wind of considerable persistence, the 'hababai', may desiccate the plants. Supplementary food crops of millet are sometimes planted as wind-breaks for the young cotton plants. In winter, the relatively cool north wind brings frequent cloud and heavy dew, and occasional light rains, which help the crops to recover from the hababai. In some years the rains moisten the ground sufficiently to permit the planting of additional millet. If the cloudy weather persists through March, it may delay the maturing of the cotton. The harvest season lasts from about February to May or June, and requires the use of seasonal workers who may come from some distance. Usually only about two-thirds of the planted area is harvested. The balance is lost from ill-timed floods, dry winds, weeds, alkaline soil, or insufficient labour at the time needed for harvest. Sometimes by the end of May—before all the harvest is in—the delta and the rest of the coastal plain is visited by the season of wind and dust storms (haboob) from the south or south-west. The haboob, which reaches its peak in July and August, fills the air with dust for days at a time, forcing the suspension of virtually all labour. At the beginning of the haboob season, the exodus to the hills begins.

The cotton crop is sold by the farmers in the market at Tokar. The share of the government is 25 per cent of the sales, and one-fifth of that amount is placed in a revolving fund to help finance the growers in their sowing and harvesting. The crop is hauled by rail to the little port of Trinkitat for export. In addition to the staple cash crop of cotton, important amounts of food crops for local use are raised. Most important of these is millet, both the Great Millet (*Sorghum vulgare*), known as 'dura' and Spiked Millet (*Pennisetum typhoideum*), known as 'dukhn'. The dukhn is the standard crop of dry sandy areas. Sudanese lentil (*Cajanus cajan*) and various vegetables are also raised. But all crops are subordinate to cotton.

1. A feddan equals 1.038 acres or 0.42 hectares.

SECTOR 14: SOMALI LITTORAL, GULF OF ADEN[1]

The Horn of Africa, ending in Cape Guardafui, is occupied by the Somali Republic, commonly known as Somalia. Adjoining Somalia and extending north to the Strait of Bab-el-Mandeb, is French Somaliland. The entire littoral is classed as a hot desert, with high temperatures throughout the year, and with a scanty rainfall regime related to the alternating north-easterly (winter) and south-westerly (summer) monsoonal winds. The native people are Somali of several different tribes, dependent upon sparse herding and simple agriculture (Murdock, 1959), with a sprinkling of Europeans, mostly French, British, and Italian, at the principal ports. There are enough differences between the north coast, along the Gulf of Aden, and the east coast, south of Cape Guardafui, to justify breaking the littoral into two sectors.

The south coast of the Gulf of Aden, from Bab-el-Mandeb to Cape Guardafui, is occupied successively by French Somaliland and former British Somaliland and independent Somalia. The mountains press close to the sea, and ribbons of coastal lowland are lacking or are narrow and sandy except in a few small patches Rainfall is scanty, ranging from 5.2 in. at Djibouti, through 2.4 in. at Berbera, to 0.4 in. per year at Bender Cassim near Guardafui (Table 2), and is rapidly evaporated in the high temperatures that prevail during the day.

The aridity is so great that most of the coast, except for the vicinity of Djibouti, could be classed as extreme desert, with annual precipitation of less than 2 in. though Pichi-Sermolli, in an excellent analysis of the region, feels that the vegetation is abundant enough, partly as the result of heavy dewfall, to remove the extreme desert characterization. He maps maritime or sub-maritime vegetation in a narrow belt 6 to 12 miles wide along the coast (Pichi-Sermolli, 1955). At any rate, the land has only a sparse cover of vegetation, and the less arid hilly interior is devoted to pastoral nomadism of goats, sheep, camels, and cattle within range of the few meagre water holes in wadi floors.

The two largest patches of lowland littoral, about 12 miles wide at the widest, are in the northern half of French Somaliland. The northern one of these, the Doumeira Plain, at the Eritrean border, is so lacking in water resources as to be unusable. It is a windswept uninhabited flat of gravelly reg. At the international border the Weima, largest wadi of the country, reaches the Red Sea. It is dry most of the time, though there is water at shallow depths in its sandy bed. In the next plain south, at the entrance of the Gulf of Tadjura, the village of Obock uses water pumped from a wadi bed. Once it was an important fort guarding the gulf, but most of it has fallen into ruins (Aubert de la Rue, 1939).

The most important city of French Somaliland is Djibouti, on the south side of the mouth of the Gulf of Tadjura across from Obock. It owes its development simply to the fact that it is the terminus and port for the railway that connects Ethiopia with the outside world. It is a busy little Moslem city of about 20,000. Apart from an abundant supply of salt, sea-food, including lobsters, and livestock from the neighbouring upland nomads, nearly everything consumed in the city must be imported. Even water is shipped by barge from Obock, as the local ground water is too brackish. A few vegetables and dates are grown in a small nearby alluvial oasis, Ambouli, but not enough to supply the people. Even in Ambouli the ground water has been lowered by pumping in the wadi floor so much that salty sea water has seeped in and become a problem. With its oppressive temperatures, ranging in July from a daily maximum of 103° F. to a nightly low of 87°, Djibouti would not attract residents who did not have to be there to make a living. But this is true of the whole sector.

The Gulf of Tadjura, the largest indentation in the east African coast, is used very little except in the deep water near its mouth. At its head is a salt plain, and farther inland are other small plains, either salty, sandy, or covered with the polished stones of desert pavement. Salt is in fact the principal locally produced export of Djibouti. Most of it is produced in salt pans along the sea near the city, and is exported by rail to Ethiopia. Hides and skins are the other chief export (Aubert de la Rue, 1939).

To the east of Djibouti the rainfall decreases steadily most of the way along the coast. Former British Somaliland, which was freed in 1960 to unite with the independent republic of Somalia, consists of mountains and plateaux, coming down to the coast with a fringe of varying width of level coastal littoral. Grazing in the arid and semi-arid interior, particularly of camels, sheep and goats, is the principal type of land use, though there are pockets of irrigation of dates, durra (a sorghum), millet, and maize. Meat, milk, and durra are the main foods. Gums of myrrh and frankincense are harvested from wild shrubs, as on the Incense Coast of Arabia across the gulf, and also from cultivated plantations. Indeed, northern Somalia is reported to be the world's chief source of incense (Reyner, 1960). Near the French Somaliland border at Zeilah, and at Bender Cassim, salt evaporation flats provide salt for the local fishing industry. Fishing, an occupation not seriously limited by aridity, has possibilities of expansion. Some canning and curing facilities have already been established with foreign aid to encourage the industry. Bender Cassim and Alula are centres for fishing (Pankhurst, 1951; U.N. Techn. Assist. 1952).

1. See Map 5.

Grazing probably has reached its limit, considering the erratic rainfall that produces good forage one year and almost none another year. Loss of livestock, with resulting famine conditions, occurs when a season's rains fail.

This is an area of seasonal monsoons. At Berbera most of the rainfall is spread out during the north-east monsoons, from November to April, when the winds are blowing onshore. But the monthly amounts are insignificant. At Bender Cassim only one month, December, averages as much as 0.1 in. The south-west monsoon of summer (the kharif) is a land wind and brings drought, heat, and dust to the coast (Roquero de Laburu, 1962). It is possible that some of the wadi floods could be used during the rainy season to irrigate more land in the coastal belt, but agriculture is not an outstanding potentiality. The United Nations once estimated that of 68,000 square miles only 54 were arable (Roquero de Laburu, 1962).

Although the coast is hotter and more humid than the interior, the need for trade with the outside world has led to the development of Berbera as the chief port, through which sheep, skins, and gums from the interior and dates from coastal oases are exported, and manufactures and other commodities are imported. The population of Berbera fluctuates from about 15,000 in the hot season to 30,000 in the cool. The interior, with elevations of 2,000 to 7,000 ft. including the former capital city, Hargeisa, is climatically more pleasant.

SECTOR 15: SOMALIA, EAST COAST

Most of Somalia faces south-eastward towards the Indian Ocean. The terrain of the desert littoral is here quite different from that of Sector 14, facing northward along the Gulf of Aden. It has been called 'a featureless expanse of nothing in particular' (Pankhurst, 1951). A broad plain, 50 to 100 miles wide, borders the coast. At its inner edge, the plain rises gently through low gradations towards the distant mountains in the interior. The whole coastal desert is flat, with principal distinctions based upon the usual desert variations of sandy, gravelly, or salty silt surfaces. No rivers reach the littoral north of the Scebeli, and even the Scebeli bends southward and flows just inside the coastal dunes for 250 miles without breaking through to the sea (Map 5). The Scebeli, furthermore, is dry from November to April (Reyes Prósper, 1915). Rainfall is greater than along the Gulf of Aden, ranging between 4 and 7 in. from Guardafui to Obbia, to 19 in. at Mogadiscio, just beyond the southern edge of the desert (Table 2).

The desert extends southward to $2\frac{1}{2}^{\circ}$ N. latitude, a position about 60 miles north-east of Mogadiscio, according to the character of vegetation. (Pichi-Sermolli, 1955, p. 317). This limit agrees well with the annual rainfall values associated with the aridity index of de Martonne. Under the high temperatures of this area, annual rainfall of about 14.6 in. would denote an index of 10, the limit of aridity. Thornthwaite's system, which appears to extend the deserts unduly in tropical situations, carries the desert beyond Mogadiscio and across the equator (Carter, 1954), to include an area that most classifications would call semi-arid. Bulo Burti, on the middle Scebeli River, lies just within the limits of the desert, though too far inland to be considered a part of the coastal desert.

Evidence on the width of the coastal desert is scanty. Weather stations are too widely scattered to reconstruct a climatic profile across the littoral, and vegetation studies have not dealt specifically with this region. The best estimate is contained in the vegetation map of Pichi-Sermolli (1955, p. 315), which shows a maritime and sub-maritime belt 9 to 37 miles wide along the entire coast. The rainfall seems to be about the same near the coast and farther inland, with an amount sufficient to support a growth of forage herbs and shrubs. Socotra, the large island off Guardafui, is similar to the Somali littoral. It has a desert climate, and desert vegetation on a poor, sandy surface (Pichi-Sermolli, 1955, p. 319).

The north-eastern half of the littoral has a slight predominance of rainfall during the winter monsoon, though with occasional convectional storms at other seasons. The southern half is definitely within the tropical regime, with maximum rainfall in summer. Owing in part to a zone of upwelling cooler water off shore, temperatures of the warm season are less extreme than those along the Gulf of Aden. The mean daily maximum of the hottest month (which occurs just after the spring equinox in this area so near the equator) at Obbia, for example, is 93° F. (April), compared with 107° at Berbera in July. However, away from the coast temperatures rise, and Lugh Ferrandi, in the Scebelli Valley, 225 miles inland, has the highest mean annual temperature (88° F.) of any weather station in the world (Table 2).

Most of the area is devoted to nomadic raising of livestock. Cattle of the zebu type are the most important form of wealth, though outnumbered by sheep and goats. Camels also occupy a significant place in the economy, especially in the drier areas, as means of transportation—for roads are commonly poor or non-existent—as well as for their meat and milk. Meat, milk, hides, skins, and butter are the chief products of the livestock. Some of the western tribes, in addition, make a practice of regularly tapping the cattle for fresh blood to drink (Murdock,* 1959, p.321). There is a pronounced tendency to over-stock the range with more livestock than can be supported by the natural vegetation or than are needed by the owners ordinarily. It has been stated that the Somalis look upon cattle as indicators of prestige, and that large numbers, however scrawny, are the main objective. However, a recent economic study has reached the conclusion that cattle-hoarding is motivated primarily by a desire for security: that the rainfall and forage fluctuate so drastically from year to year that the herdsmen try to keep surplus cattle on hand so that there will be some left even if large numbers starve during dry years (Karp, 1960). In a land so dependent upon livestock, one of the best possibilities for amelioration of economic conditions is the improvement of breeds and reduction of numbers. Improvement of water resources, for watering livestock, is another possibility. Tribal animosities are one obstacle to rational land use. It is reported that one tribe destroyed a well in a desert area rather than leave it unguarded so another tribe might use it (Reyner, 1960, 6, p.255).

In the better-watered southern part of the littoral, at the southern edge of the desert, there are areas of intensive tropical agriculture, especially along the main river, the Scebeli, which brings water through the plain from the Ethiopian highlands almost to the coast before bending southward. Here sugar-cane, bananas, cotton, maize, durra and a great variety of other irrigated crops flourish, some introduced during Italian occupation. Bananas have been a major export to Italian markets. Dates are notably conspicuous by their absence: summer rain is adverse to date production. Cape Guardafui may be taken as the approximate dividing line between date-raising to the north and humid tropical types of crops to the south. There is additional good alluvial land and river water in southern Somalia for an increase in irrigation, though most of it is beyond the limits of this study, in the semi-arid areas rather than in the desert. The administrative centre of Somalia, Mogadiscio, is also outside the truly arid portion of the country.

Fishing probably could be developed much further than it has been to date. Sources of fish in the cool waters off shore are large, and some fishing has been carried on with intermittent fluctuations in emphasis. Obstacles to success are serious. Most of the coast is straight, without natural harbours. Coral reefs form a barrier for long stretches. The only real port north of Mogadiscio is Dante, an open roadstead on the tombolo peninsula of Ras Hafun, near the northern end of the coast. The peninsula consists of a mass of hard rock linked to the mainland by a sandy spit. By shifting from one side of the peninsula to the other, vessels can obtain shelter during either the north-east or south-west monsoon. There is very little fishing done during the period of south-west monsoon, because of the roughness of the sea. The area of Ras Hafun was already an important trading centre nearly 2,000 years ago, when it was regularly visited by trading ships from Egypt for frankincense and other fragrant gums, cinnamon, tortoise shell of high quality, and slaves (McCrindle, 1879, chap. 12 and 13). In modern times Dante has been noted as a fishing centre from which dried, salted, fresh, and canned fish were shipped to Italy. Before World War II it had a large salt-evaporating industry, and produced 200,000 tons annually. The salt basins occupy most of the bay on the north side of Ras Hafun (U.N. Techn. Assist. Prog., 1952). How much the industry will recover without the Italian presence in Somalia remains to be seen. For Dante and other tiny settlements on the coast, such as the fishing town of Obbia, labour supplies are scarce in the desert, all drinking water must be hauled long distances from the interior, and nearly all supplies must be imported and lightered on the open coast. Preservation of the product, and shipment to market, present additional problems. Still, development has been carried out in the past with outside financial support, and there is no reason to suppose that further aid will not be forthcoming. Probably the main water centres in the south, the Scebeli and Juba rivers, have better prospects for producing maximum economic benefits from a given application of capital than the livestock or fishing industries of the desert. For the people who live in the desert, however, it is the livestock industry that must be helped.

SECTOR 16: NILE-SINAI MEDITERRANEAN LITTORAL

The north-eastern littoral of Egypt is a broad plain sloping gently to the Mediterranean Sea, with long, shallow lagoons along the coast. Much of it consists of the northern part of the Nile Delta; the balance, to the east, is a coastal plain descending from the uplands of Sinai and the Negev. The entire littoral shares a moderate desert climate of mild winters with occasional light rains, and warm, dry summers: a climate where most sub-tropical and tropical crops can be raised with irrigation. The soils and water supplies, and hence the potentialities, of the delta, however, differ greatly from those of the Sinai plain.

The delta soils, unlike the light-coloured coarse, sandy soil of the desert to the east and west, consist of dark, fine-grained silt and clay, among the richest of the world when they are properly drained. They have been accumulated to a great depth from mud carried down by the Nile, mostly from the Blue Nile and Atbara, and deposited in time of flood. The history of Egyptian agriculture and strength have been bound closely to the annual floods, which originally provided the natural watering for the Nile Valley and the delta. The waters of the two great Ethiopian tributaries begin to rise about April and May, with the onset of the summer rainy season. As the rains increase to their peaks in July and August, the river waters rise steadily. But it takes about two months for the water to reach the delta from the head of the Blue Nile, and the peak of the flood does not reach the delta until September or October. The great White Nile, stabilized by its head-water basin in Lake Victoria and by the vast Sudd swamps of the Sudan, keeps the lower Nile flowing throughout the year. No tributaries add water to the Nile in its lower 1,700 miles.

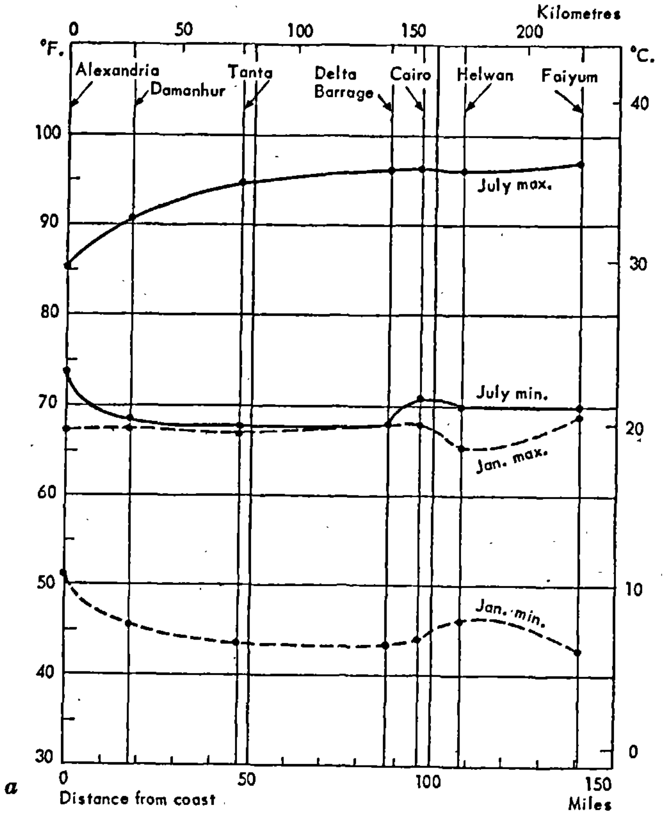
The ancient system of agriculture in the Nile Valley and Delta depended upon the annual rise of the river to flood the land. The flood water was retained in diked basins to soak deeply into the ground. Seeds were planted in the mud left by the receding flood. This system of natural basin irrigation was supplemented during the dry season by water lifted from the river by primitive mechanical devices such as the 'shadoof', or sweep, using manpower or animal power, to irrigate a smaller area. The only season of relative relaxation for the peasants ('felaheen') was during September and October, when the land was under water. The basin system is no longer used in the delta, and shadoofs are used very little except to lift water for domestic use, for the water of the Nile has been brought under control by vast engineering works. A portion of the flood water is stored behind the Aswan Dam, and barrages have been constructed at intervals along the Nile to raise and spread the water so that it can be used perennially at levels high enough to reach all parts of the rich soil. In the delta an intricate system of State-managed canals brings the water to its final destination with techniques that have been developed and improved during about 7,000 years. There is still a surplus of water that flows to the sea unused at time of flood, and there is still considerable annual fluctuation in the amount and height of water available, with a resulting fluctuation in the extent and intensity of irrigation, and in the total crops. During a season of surplus water, marginal lands are flooded, and plantings of rice expand.

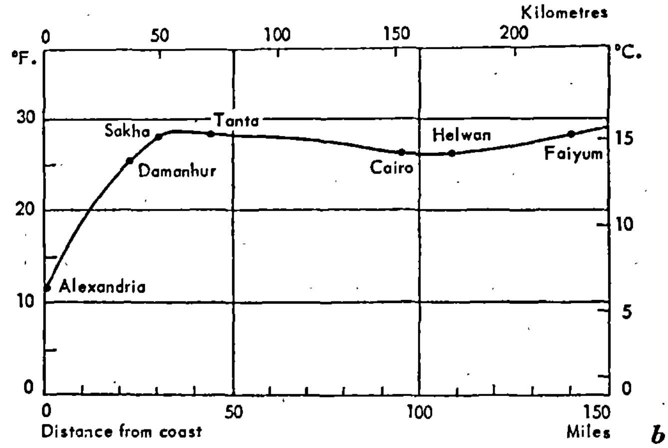
In the early historic period, the Nile divided in the delta into as many as six or seven distributaries or 'branches' as they are called. In the course of time, all have silted up but two: the Damietta and the Rosetta branches. The branches diverge near the head of the delta, where the narrow Nile Valley enters a natural embayment of the original limestone plateau of northern Egypt which has been filled in by alluvial mud deposits to form the almost level surface of the Delta. Here at the exit of the Nile Valley there has always been a great city: from Memphis, west of the river, the original capital of Lower Egypt (the delta) about 3,400 B.C. during the First Dynasty, when Menes first succeeded in uniting the two kingdoms of Egypt, and near which the great pyramids were later built, to Cairo, east of the river, the greatest city of Africa and of the Moslem world today.

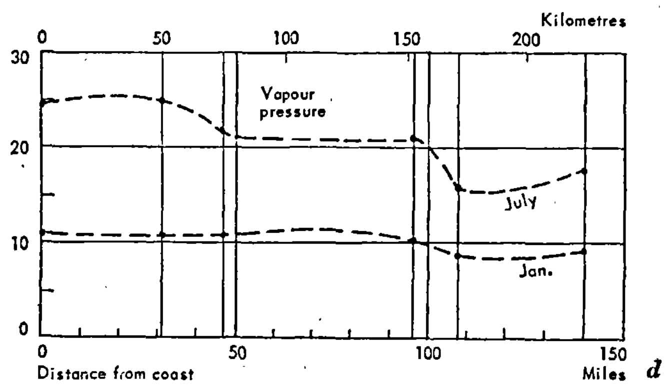
Just how much of the delta can be considered a coastal desert? Culturally, much of the delta has faced inward during its long history, with little dependence upon outside, coastal contacts. The central part of the delta, and Cairo, 100 miles from the coast, have traditionally been Egypt-oriented, devoted to intensive development of the rich agricultural potentialities of the land and water, and working up the farm products into textiles, leather goods, and food, just as in the Nile Valley for 700 miles southward. At times the delta has been drained of its produce for distant lands, as during the Roman period when Egypt was considered to be the Roman granary for wheat. During the past hundred years cotton has been the great export crop, for consumption in the mills of England, Czechoslovakia, and elsewhere. Still, direct foreign contacts are restricted mostly to a few coastal ports.

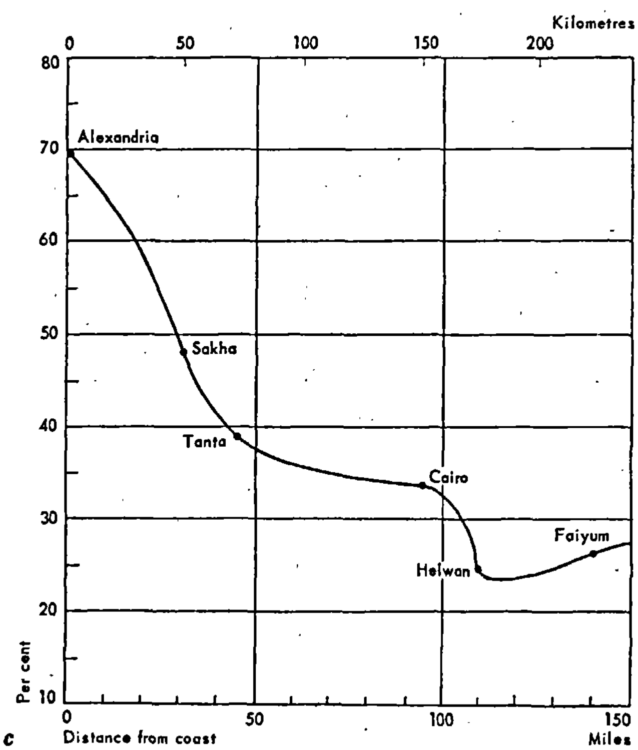
Physically, a distinctive littoral zone can be distinguished from the rest of the delta, on the basis both of climate and terrain, with resulting cultural differences. This zone, averaging about 25 miles in width along the whole 175 miles of the Delta coast, is known by the Egyptians as the Barari (Arabic 'barren'). Although it is to some extent a transition zone between the marine environment of the sea coast and the harsh desert of central Egypt, the Barari does have enough individuality to set it apart as a distinctive region, with some recognizable natural limits.

The climate of the immediate coast differs greatly from that at the head of the delta and beyond. In the Nile Delta, the relative abundance of climatic observations makes this the best place in the world for analysing climatic contrasts in a coastal desert on the basis of existing records. Climatically the Barari might be defined as that portion of the delta in which pronounced maritime elements prevail. A prevailing northerly breeze, especially persistent in summer, helps reduce the oppressiveness of the summer heat and carries the coastal influences in from the coast. As in other coastal deserts, one of the best indicators of marinity is the temperature during the hottest time of day in summer. The coast is cooler during the day and warmer at night than the interior. As shown in Figure 5*a*, the daily maximum temperature in July at Alexandria on the coast is 85° F., compared with 96° at Cairo 97 miles inland. Half the rise occurs in the first 15 miles. By the time Sakha is reached, 30 miles from the coast, the temperature is already 94° F. and









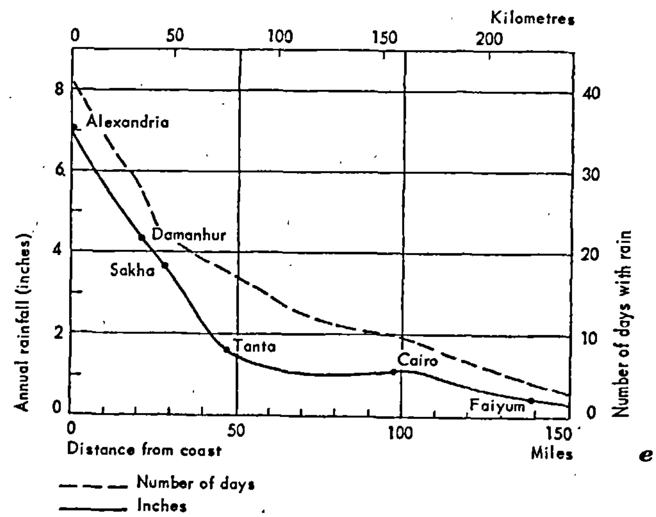


Fig. 5. Climatic profiles, Nile Delta.

a Profiles of mean daily maximum and minimum temperatures, Nile Delta.
b Daily temperature range, July.
c Relative humidity, 2 p.m., July.
d Profiles of atmospheric humidity, Nile Delta.
e Rainfall.

the gradient profile has pretty well levelled off. Probably a sea breeze plays a part in producing these contrasts. The July nightly minimum exhibits smaller differences; between Alexandria and a point 50 miles inland the drop is only 6° F, 5° of which occur in the first 15 miles. The difference between the minimum and maximum temperatures, or the mean daily temperature range, shows the sharpest break of any single climatic parameter as we go inland. In July, the mean daily temperature range is only 12° F. at Alexandria; it rises sharply and steadily inland to Sakha, 30 miles from the coast, then levels off abruptly at about 28° (Fig. 5*b*). In winter, temperature contrasts are slight. The daily maximum profile shows almost no change; the daily minimum shows about a 7° F. drop in the first 50 miles inland.

The profile of annual rainfall shows a steady drop inland. Alexandria, 7.0 in., Damanhur 4.25, Sakha 3.62, Tanta 1.65. Then the curve bends sharply and levels out, so that the next 50 miles show only a slight drop, to 1.1 in. at Cairo (Fig. 5*e*). The statistician who attaches great significance to break points might choose 50 miles as the limit of the coastal desert on the basis of rainfall. Probably 25 miles, the position of the 4-in. level, would have more significance in the landscape, though all the delta, including even Alexandria, would be classified as desert according to most definitions. From another viewpoint, too, rainfall constitutes a poor basis for delimiting the coastal desert Barari here; for rainfall diminishes in both directions along the coast as well as inland. Alexandria and Rosetta have 7 in., Damietta 4, Port Said 3 towards the east; while Mersa Matruh has about 6½ and Sidi Barrani 6, at slightly higher latitudes, towards the west.

One would expect atmospheric moisture to provide a meaningful index to marinity, and this proves to be the case, especially for certain parameters. The most stable indicator of humidity is vapour pressure (readily convertible into dew point). In July, the vapour pressure profile for about 30 miles inland from Alexandria is level, at about 25 millibars; it drops to about 21 millibars and levels off for the next 50 miles; then drops sharply again towards the interior (Fig. 5*d*). January vapour pressure shows only a slight drop inland, from about 11 millibars at the coast to 10 millibars 100 miles inland. Relative humidity, unlike vapour pressure, is closely related to temperature changes. This results in confusing and often meaningless profiles, though the relative humidity profile for the 2 p.m. mean in July is consistent and significant (Fig. 5*c*). Starting at 70 per cent at Alexandria, it drops steadily to 39 per cent at Tanta 47 miles inland, then bends to show a more gradual decrease towards Cairo and beyond.

Cloudiness is somewhat greater on the coast than in the interior, but the contrasts are not great nor is there a consistent diminution inland. Greatest cloudiness is of course characteristic of winter, the rainy season. Thus Alexandria in January averages 51 per cent of sky covered by cloud, Cairo averages 40 per cent, while Sakha, in between, has only 27 per cent. In summer the skies are usually clear. In July, average cloudiness at Alexandria is 16 per cent, compared with 11 per cent at Cairo and only 4 per cent at Sakha. Estimations and comparisons of this element are notoriously difficult for observers to make.

In summary, on the basis of summer daytime temperatures, temperature range, vapour pressure, and to a less extent rainfall, the inner limit of the coastal desert would be placed about 25 to 30 miles inland.

The distinctive physical features of the terrain, soil, and hydrography of the Barari agree well with this limit. They occupy a zone extending inland on the average about 25 miles. The landscapes consist of marshy and poorly drained salty land and a series of huge, shallow lagoons, with islands and long barrier beaches of sand. This sort of landscape is characteristic of many of the great deltas of the world, where the land is gradually subsiding under the ever-growing load of sediment brought down by the river. A large area south of Alexandria is actually below sea level, and has gradually been reclaimed by a system of dikes and pumps not unlike that of The Netherlands, but in most of the Barari the surface has been built up by sedimentation about as fast as the underlying basement has sunk. Ancient settlements, many with their foundations now below sea level, have been partly buried by the river deposits. Yet the coast has not moved seaward within historic times, for the coastal currents of the Mediterranean have been strong enough to carry the alluvium away to the east. The best sites for human settlement are the natural levees of the Nile branches: the gently sloping ribbons of land adjoining the rivers where the flood waters make their first and most frequent deposits of alluvium, and which therefore stand above the height of the surrounding plain. Towns have grown up on the levees of present and past branches of the Nile, and on some of the better-drained sandy islets scattered here and there in the Barari. Most of the Barari is wild, thinly settled land, capable of improvement only through expensive, long-continued flooding and draining to reduce the salinity and lower the level of the ground water.

The coastal lagoons form a special resource for fish and wildfowl, a resource that has been used from earliest times. From west to east the lagoons are Lake Maryut, 76 square miles, south of Alexandria; Lake Idku, 55 square miles, west of the Rosetta Branch; Lake Burullus, 215 square miles, between the Rosetta and Damietta Branches; and Lake Manzala, 560 square miles, largest of all the lakes, from the Damietta Branch to the Isthmus of Suez. The abundance of fish and water birds has impressed all observers of these lakes. Ibn Battuta in 1326 reported that the markets of Damietta abounded in fat sea fowl and mullet from

Lake Manzala (Gibb,* 1958). A later writer wrote of Lake Manzala, 'The various outlets of the lake to the Nile and Mediterranean being full of islands, rushes, insects and herbs, the river and sea-fish swarm and multiply here infinitely; supplying two thousand fishermen and clouds of birds, without apparent diminution.... The waters of the lake are covered with wild geese, ducks, teal, divers, and the ibis. Far as the eye can reach they cover its surface' (Savary, 1787). Fishing villages have grown up on the shores of the lakes especially El Matariya on Lake Manzala, Baltim on Lake Burullus, and Idku on Lake Idku. The latter towns are built on sandy barrier beaches north of the lakes, while El Matariya is on the south, land side of its lake, and has some importance as an outlet for the delta farms. On Lake Manzala vessels bring grain from the farms on its margins to Port Said on the Suez Canal and Damietta at the opposite end of the lake.

Damietta and Rosetta developed as ports on the two main branches of the Nile. Both were important early centres for overseas trade. Damietta (ancient Coptic Tamiatis) in particular was once a great port for trade with the East, exchanging dates, fish, and textiles for spices and raw silk. It lost much of its prominence after 1820, when Alexandria took an overwhelming lead with the completion of a ship canal connecting it with the Rosetta Branch of the Nile. Yet Damietta has kept some of its traditional industries, especially silk weaving, leather working, wood working, and candy manufacture. In addition, it has close trade contacts with Port Said by land and lake. Rosetta, the other main sea gate of the ancients, also declined with the rise of Alexandria. Today it is chiefly a centre for salting fish and milling rice.

All Egyptian ports are insignificant compared with Alexandria. Although it lies on the narrow limestone barrier between Lake Maryut and the sea, and carries on some lake fishing at its 'back door', Alexandria has always been international in its economy and outlook. It was founded by Alexander the Great in 332 B.C. on the site of a small fishing village, for the purpose of giving him a naval base for operations against the Persians, and a port for better access to trade between Greece and the agricultural riches on the Nile Valley and Delta. It soon became the major trade link between the Mediterranean lands and the East, and a centre of intellectual activity. Ibn Battuta outdid his usual flowery language in describing Alexandria in 1326. His comparisons were based upon his extraordinarily wide range of personal observations gained from travel. Of the city he wrote: 'She is a unique pearl of glowing opalescence, and a secluded maiden arrayed in her bridal adornments, glorious in her surpassing beauty, uniting in herself the excellences that are shared out through her mediating situation between the East and the West'. Of all the ports of the world that he had seen, none equalled Alexandria except Quilon and Calicut in India, Sudaq in Turkey, and Zaitum in China (Gibb,* 1958). He gave a detailed description of the city.

With the drying-up of the Canobic Branch of the Nile upon which it depended for water and interior transport, and the rule of the Turks who discouraged its trade aspirations, Alexandria declined to an insignificant town of about 4,000 from the sixteenth to eighteenth centuries. But since the opening of the new canal by Mohammed Ali in 1820 it has surpassed all its former predominance, and is now a city of 1,600,000. In 1951, 91.2 per cent of the value of Egypt's exports went through Alexandria, including most of the cotton which is the major product and export.

The favourable cross-roads location of Alexandria, at the outlet of the Nile Valley and the transit point between East and West, is well supported by local advantages of the site. Alexandria has the most commodious natural harbour of the entire Mediterranean, surrounded by hard limestone deposits. A famous lighthouse, believed to have been at least 400 ft. high—the prototype of all lighthouses—was built by the Ptolemies on Pharos Island to guide ships through the rocky entrance of the harbour; the word for lighthouse in the modern Latin languages today is derived from this. It no longer exists, and the Eastern Harbour that it served has been silted to the point where it is now only a fishing centre. The Western Harbour is now the main centre for large vessels. A further advantage of Alexandria over its former Nile-mouth rivals is its position west of the edge of the delta. It is less subject to siltation by alluvium brought down by Nile floods.

Lake Maryut, at the south edge of Alexandria, supports a local fishing industry. In addition, the basin of the lake is steadily being diked and pumped so as to enlarge the agricultural area. The surface of the lake is below sea level, but the natural limestone barrier keeps out the sea.

Agriculturally the Barari is quite different from the rest of the delta. Much of the soil is so poorly drained that salt concentrations have rendered it unfit for use unless reclaimed. Large stretches are still unused and almost uninhabited, resulting in a low average population density compared with the rest of the delta. It is one of the few areas of undeveloped agricultural potentiality in Egypt. The favourite lands for farming are the relatively well-drained natural levees along the present and past branches of the Nile. Here, and along the sandy strips near the coast, are the date groves that contribute to making Egypt second only to Iraq as a date producer. Here too are many small orchards of citrus fruits, mangoes, guavas, pomegranates, figs, and bananas, and scattered growths of more temperate orchard trees such as peaches and apricots. Grapes are raised especially in the province just south of Alexandria, and wine is manufactured for sale to non-Moslems.

The main staples of the delta, and on the best reclaimed lands of the Barari, are field crops. Temperatures are high enough to permit cropping throughout the year, but climatic conditions favour quite different crops in winter, summer, and fall. A larger percentage of the cropland is planted in winter than in any other season. The chief winter crops are clover and wheat, which can take advantage of the lower temperatures and the occasional winter rains. It is reported that on favourable sites a wheat crop has been obtained on the basis of as little as 4 in. of well-distributed winter rainfall (Hassan Awad, personal communication). The Egyptian clover, 'berseem', is the most important crop of Egypt in total acreage, and is the main food of the cattle and water buffalo used for tilling and milking. In reclamation of salty soil, berseem is usually the first crop planted, because of its high salt resistance and its tendency to remove some of the salt. Wheat is still an important food in Egypt, though less so proportionately than in ancient times. In summer, cotton is by far the most important crop throughout Egypt where land is suitable, second only to berseem in acreage. Rice is the second summer crop in importance, and is particularly significant in the Barari, where it thrives in the poorly drained basins and helps counteract the salinity of the soil. Sorghum is the third summer crop, growing in areas where least water is available. In the autumn, maize (Indian corn) occupies 90 per cent of the cropland cultivated. It is the leading food grain of the rural population, its stalks are fed to livestock, and its cobs serve as fuel in a fuel-scarce economy. The corn is usually planted as soon as water becomes available for perennial irrigation, usually towards the end of summer, and is harvested about November. Despite the production of about 2.5 million tons of maize and wheat per year, Egypt still has to import about 0.5 million tons to meet the food requirements of the people.

Egypt has in the course of millenniums developed a highly efficient system for planning the use of the restricted land and water resources. Competent irrigation engineers of the central government assess the annual water yield and plan the diversion and use of the water all the way from larger and smaller canals down to the individual consuming farm. Reclamation is steadily progressing, in some cases in connexion with the establishment of modern farm colonies in the Barari.

But reclamation is a slow and costly process, requiring 10 to 15 years for a given piece of poorly drained saline land in the Barari. It is not surprising that Egypt looks forward eagerly to the high dam at Aswan so that large acreages of the desert land to the west can be brought into food production. Already a pilot project is under way in the Western Desert in Tahrir (Liberation) province to show that the sandy desert soil beyond the delta can produce good crops under irrigation (Little, 1958).

A special resource of the Barari is the attractiveness of the coast for escape from the summer heat of the interior. Sizable summer resorts have developed on the beach near Alexandria, and at Ras el Barr on the beach near Damietta. This development represents one practical advantage taken of the summer temperature gradient, as well as of the sand and water juncture.

The terrain does not encourage political cohesion within the Barari. The natural waterways lead towards Cairo. Even the main canals are part of the fan-like pattern that provides 865 miles of navigable waterways in the delta. The roads tend to parallel the waterways: none go all the way across the grain from east to west. Railways are the most adequate form of modern transportation, but even these do not connect Alexandria and Port Said.

East of the Nile Delta the muddy black sediments give way to a coarser desert soil. Through this marginal area the Suez Canal has been dredged to form one of the most-used waterways of the world for international traffic, as a link between the Mediterranean and the Red Sea. The canal ends in the Mediterranean at Port Said, the third largest city of Egypt. Port Said is a creation of the canal, its harbour artificially dredged, its town built upon canal and harbour dredgings, and its population depending almost entirely upon activities related to the canal traffic. Here all ships pause, and here cotton from the north-eastern part of the delta is shipped. The city has little industry of its own, apart from fishing. In Roman days the Pelusiac Branch of the Nile ended here, and Pelusium, about 22 miles south-east of the present Port Said, was an important Roman seaport for a time. Its natural advantages were greatly inferior to those of Alexandria, and it could not long compete.

The upper portion of the Pelusiac Branch once played an important role as part of the first canal connecting the Red Sea and the Mediterranean. This pioneer canal, apparently constructed in the nineteenth century B.C., joined the Pelusiac Nile by way of the Wadi Tumilat and the Bitter Lakes to the Gulf of Suez. The canal was used for about 600 years before it fell into disuse, probably because of silting. From time to time since then it has been revived in whole or in part, resulting each time in stimulation of delta trade, the last time under Sultan Hakim, about A.D. 1000. Large ships, however, could not negotiate a passage until the opening of the Suez Canal in 1869 (Roberts, 1943).

The Suez Canal follows a series of natural lakes and swamps in its northern and southern ends, but in its central portion it had to be cut through the high, dry desert sands. Apart from the two ends, only one site along the canal has seen the development of an important town: the west bank of Lake Timsah, near the lower end of Wadi Tumilat. Isma'iliya was founded at this site in 1863 as the centre of operations for De Lesseps during the construction of the canal. To it a fresh-water canal brought water from the old ship canal, down the Wadi Tumilat, to supply the workers. Isma'iliya has remained as a residential town of pleasant homes and luxuriant gardens, and much of the good soil along Wadi Tumilat is devoted to irrigation agriculture (Platt and Hefny, 1958).

Eastward from Port Said the littoral of Sinai and Gaza spreads as a wide sandy plain, much of it in prominent dunes, for 100 miles along the coast. Much of the drainage from the limestone Sinai plateau in the south is gathered by a series of tributaries into the great Wadi el-Arish which is the only sizable stream reaching the Mediterranean coast, though it is dry except during spells of heavy winter rainfall. El-Arish, the capital of Sinai, lies on the coast near the mouth of the wadi. Along the wadi are alluvial terraces that might be used for agriculture if the water of the wadi were stored or pumped from the subsurface deposits. Near the town an experiment station uses small reservoirs to store the light and irregular winter rainfall, averaging less than 4 in. per year, for irrigating crop land (Unesco, 1960; Issawi, 1954). Gaza, farther along the coast, is beyond the true desert area. With winter rainfall averaging 15.3 in. it falls into the semi-arid category. Despite the high temperatures and high relative humidity in summer, these coastal localities have just enough breeze to keep them from being unbearable in the heat of the day in summer.

SECTOR 17: QATTARA LITTORAL[1]

The Mediterranean littoral of Egypt west of Alexandria was once extensively used for irrigation and settlement, but in recent centuries it has been given over mostly to nomadic grazing. The climate is of the pleasant Mediterranean coastal type, with mean daily maximum temperatures in summer only 86° F. or less (Table 3)[2]. Winters are cool, but freezing temperatures have never been recorded along much of the coast. The light rainfall of 3 to 7 in. per year comes with winter storms.

The littoral consists of a belt a few miles wide below the level of the interior desert, with parallel lines of dunes interspersed with flat limestone-floored surfaces (Egypt. Public Works, 1938). In some places the general water table is accessible to drilled wells, lying at sea level to 50 metres below sea level (Issawi, 1954). Remains have been found of about 3,000 cisterns cut into bedrock, some of them very large, up to 2,000 tons water capacity. Surface run-off from rainstorms was led into the cisterns by diversion dikes. Since their construction in Roman or pre-Roman times, most of the cisterns have filled with sand and silt carried by surface run-off of wadi floods. Recently some of the cisterns were cleaned out and put back into operation to store water, and it is found that the rainfall of today is just as able to fill them as in the past (Murray, 1955).

The restored cisterns provide a valuable source of water for livestock, and in some instances for irrigating small plots of soil. Successful experiments have been made, too, in diverting run-off from extensive rocky slopes directly on to fields for cultivation. Crops requiring a minimum of water, or tolerant of somewhat alkaline water, like figs, grapes, olives, barley, and almonds, have been found to flourish under the conditions in this littoral area. A research centre at Burg el Arab, and individual Arab farms, suggest the possibility of eventually establishing a series of gardens all the way to the western border (Platt and Hefny, 1958).

About 30 miles south of the coast, beyond a low height of land, the surface of the Western Desert of Egypt declines into the Qattara Depression. Much of this vast basin of salty earth is below sea level, more than 400 ft. below at the lowest point, and recurrent proposals have been made to dig a channel to allow Mediterranean Sea water to flow into the depression by gravity, generating large amounts of hydroelectric power *en route*. The Qattara Depression was part of the natural barrier that helped the British, under Montgomery, stop the advance of the Germans under Rommel at El Alamein, only 80 miles from Alexandria, in the Second World War.

1. See Map 6.
2. The figures for monthly and annual rainfall for Mersa Matruh given in Table 3, Part 1, were obtained from the Meteorological Department of Egypt (Egypt.Public Works, 1938).The values given in the tables of the Meteorological Office (U.K. Met. Office, 1958) are more than double the true amount for the months, and about half the true amount for the yearly total: one of the few serious errors noted in this valuable compendium.

SECTOR 18: LIBYAN LITTORAL

The present kingdom of Libya, an independent State since 1951, is made up of three provinces which during much of the past and in certain respects even now have been largely independent of one another. All three have their own nuclei, widely separated from one another and based upon local advantages of water supply. The Fezzan centres about an area of accessible ground water, in the south-western interior of Libya about 350 miles from the coast. Tripolitania, in the north-west, centres along the coast from Misurata west to Tunisia, where ground water and surface supplies from Jebel Nefusa and higher rainfall support agriculture. Cyrenaica, occupying the entire eastern half of Libya, centres along another stretch of coast fed by run-off from Jebel el-Akdar and by higher rainfall (Map 6). The boundary between Cyrenaica and Tripolitania on the coast is essentially that of the ancient division between Greece and Carthage.

Most of Libya consists of vast expanses of the Sahara, completely unused except along caravan tracks. Farther north, where there is enough moisture and vegetation to support livestock raising, internal political boundaries have little meaning to the nomadic herdsmen with their sheep, camels, and goats. The main axis of Libya since the dawn of history has been the narrow strip of coastal desert and semi-arid land. It is here that the main centres of power reside today, connected by the coastal highway that forms the principal artery of traffic.

The entire 1,000-mile length of Libyan littoral has no extreme desert climate, and only relatively small sections have enough moisture deficiency to be called desert at all. The two cultural cores should be classed as semi-arid, and there is even a small section of northern Cyrenaica that has a genuine Mediterranean climate with more rainfall than Athens. Between the two semi-arid cores is the bleak coastal section of the Desert of Sirte. Another strip of desert extends from east of Derna to the Egyptian border. The entire coast of Libya, however, shares the Mediterranean trait of winter maximum of rainfall and long, dry summers. Temperatures are mild, with means ranging from about 55° F. in winter to about 80° F. in summer, along the immediate coast. This range is intermediate between the extreme marine climates of the west-coast deserts and the hot deserts of the Persian Gulf and Red Sea. The daily maximum temperatures increase rapidly back from the coast. Thus Jedabya, about 30 miles from the sea, has a mean daily maximum temperature 10° F. higher than that of Benghazi in summer (Table 3, Part 2).

Grazing, farming, and fishing, in that order, have been the principal economic activities of the Libyan littoral. Livestock, especially sheep, have been the principal export until the discovery of petroleum. During the period of Italian occupation, between the First World War and the Second World War, intensive agricultural colonization was begun, based upon development of the underground water resources for some distance back from the coast, and the cultivation of small grains by dry farming in the Cyrenaica uplands. By 1940 more than 120,000 Italians had immigrated as farm colonists. They devoted themselves particularly to developing intensive irrigation projects, mostly based upon wells, and raising vegetables, citrus fruits, grapes, and other products. After Libyan independence, a majority of the colonists returned to Italy, and their farm projects fell into disuse (Meckelein, 1956-57). It has been estimated that a million trees planted by the colonists were cut down by the Arabs to satisfy their demand for fuel (Calder, 1951). At present a rebuilding of agriculture is under way, involving retraining of Libyan Arabs in farming methods. There is need for production both of food for local consumption and feed to help livestock weather the uncertainties of fluctuating rainfall. Barley is the principal crop and the staple food of Libya (UN, Techn. Assist. Prog., 1953).

Fishing is a relatively undeveloped activity for Libyans, despite the existence of abundant potentialities. There is some catching of tunny and sardines, and a few canneries are operating. Most of the fishing in Libyan waters, however, is done by Greek, Italian, and Maltese fishermen, based in their home countries and taking their catches back home with them. Sponge fishing on rocky bottoms off Cyrenaica is a speciality of Greek divers. The furthering of fishing is part of the economic plans of the Libyan Government. It will involve substantial applications of capital for the large boats, nets, other equipment, and port handling facilities required.

Tripolitania has about two-thirds of the population of Libya, and their chief economic basis is the western half of the Tripolitanian littoral. This is the most intensively developed part of Libya agriculturally, though its potentialities are by no means exhausted. The largest stretch of cultivable plain is known as the Gefara, occupying the triangle next to the Tunisian border. Irrigation, made possible by the ground water from the Jebel Nefusa, is concentrated particularly along the immediate coast near Tripoli and in alluvial valleys surrounding the Jebel. There are the remains of hundreds of rock-cut cisterns built by the Romans to collect run-off, and these could doubtless be restored and used today if required (Calder, 1951). Besides irrigated crops of Mediterranean type, there are extensive groves of olive trees, some ancient and others still being planted, most of them being raised without irrigation. Some dates are raised, but they are less highly esteemed than those produced in the very hot desert oases of the Fezzan. Much of the Gefara will be left for grazing, as there is not enough water to irrigate it all.

The relatively abundant supplies of water are used to provide municipal water as well as irrigation water. Tripoli, the largest city of Libya, with 191,000 inhabitants in 1962, is supplied with water from the Jebel by an aqueduct more than 70 miles long (Calder, 1951). With a 50 per cent growth in the eight years to 1962, Tripoli has need for an assured and abundant supply of water. A secondary source of income is provided by the staff of the Wheelus air base maintained by the

United States outside Tripoli. There is also some tourist trade based upon the attraction of archaeologic restoration of Roman ruins at Leptis Magna (Homs). Tripoli is the leading general port of Libya, and one of the two cities between which the seat of government oscillated, the other being Benghazi: an arrangement designed to prevent the charge of favouritism by the two coastal provinces, Tripolitania and Cyrenaica.

Cyrenaica has some natural advantages over Tripolitania, chiefly in having even more rainfall. The Barce Plateau, of hard limestone, rises northward from the Sahara with gentle gradients, culminating in the Jebel el-Akdar, a summit plateau about 2,000 ft. above sea level. The Jebel drops rapidly to the sea, forming a rocky coast and leaving no room for coastal flats at its foot. The eastern and western ends of the Jebel, near Derna and Benghazi, abut a coastal plain, especially wide south of Benghazi, and having the advantage of abundant supplies of ground water and springs from the Jebel limestone. Even the north central coast, with picturesque rocky cliffs and crags, and only narrow, flat terraces, has the site of an important Phoenician and later Greek colony and trading base. Cirene, on the north edge of the plateau, is the principal present-day inheritor of the Greek colony. With rainfall of 23.6 in. per year, and an elevation over 2,000 ft., the Cirene area has the natural endowment of vegetation and climate that, combined with the classical traditions and remains in the vicinity, could form the basis for a significant tourist industry. Of greater immediate effect, however, is the fact that a site near Cirene has been selected for the building of a new, unified administrative capital for Libya, the city of Beida. Though not exactly cheered by the business men of Tripoli, there is no denying the natural advantages of the new capital (Clarke, 1963, p.49).

On the higher portions of the plateau, the rainfall is adequate for the production of wheat and barley without irrigation. Although good crops of grain have been raised some years, and grapes and other fruits grow well, the full potentialities of the plateau have not yet been realized. Southward is a broad expanse of semi-arid terrain, with the largest natural grazing area of Libya, and one that has been devoted especially to sheep-raising. The best irrigated land around the plateau is the coastal plain south of Benghazi, where there are extensive areas of suitable soil. Here irrigation can be considerably expanded beyond its present state of development, by tapping ground water and utilizing the floods from wadis. To the south the irrigated farmland gives way to olive groves. Southward from the vicinity of Jedabya the desert replaces the olives and the semi-arid landscape. Some irrigation is possible in the desert wadis, but the ground water supplies are not as rich as they are nearer to the Jebel el-Akdar.

Benghazi, the metropolis of Cyrenaica, is the second of the two cities of Libya, with a rapidly growing population of 120,000 in 1962. It received a severe setback during the Second World War when its port facilities were virtually destroyed, but since 1961 a vigorous programme of reconstruction has been under way, and the port is once more playing an important part in Libyan trade.

At the eastern base of the Jebel two large springs form the basis for the flourishing oasis of Derna. Here date and lemon groves flourish. East of Derna the semi-arid climate is replaced by desert to the Egyptian border. Tobruk and El Adem are representative stations, with rainfall of only 4 to 6 in. Water supplies are inadequate for any significant agricultural development. Even Tobruk, a military post primarily, has difficulty getting enough water of good quality.

The Desert of Sirte, occupying the margins of the deep indentation of the Gulf of Sirte, is poorly endowed with geographic potentialities of its own. It consists of salty flats, lagoons, and sand dunes, with only a few spots of land suitable for farming even if adequate water were available. The longest lagoon stretches southward from near Misurata for about 60 miles. Owing to developments in the desert to the south, however, this desert coast now handles enormous quantities of overseas trade. The new factor is oil.

In 1958 the first oil was found in Cyrenaica at Zelten, about 100 miles south of the Gulf of Sirte, by the Standard Oil Company. This field was exploited rapidly. A new port was built at Port Brega, designed for rapid loading of tankers, and a pipe-line was built from Zelten to the sea. In 1961 the first oil was shipped from Port Brega. A parallel development took place across the border in Tripolitania, where a consortium known as Oasis Oil Company (Amerada, Marathon, and Continental Oil Companies) discovered another big field. Oasis has built a pipe-line to its new port, Ras el Sidra, near Sirte. Production is increasing rapidly, with one field after another being discovered, put into production, and tied into the pipe-line system. At the present time the Oasis production alone amounts to more than 230,000 barrels (about 11,500 tons) of crude oil per day, and the Standard Oil fields must be producing even more. At first the oil was all shipped abroad, to England and elsewhere, for refining. Gradually refineries will come into production at the two oil ports, the first at Port Brega. Another development in progress is the construction of pipe-lines to carry water from the Mediterranean to the oil fields to permit forcing water under pressure into the wells. It is believed this will double the amount of ultimate recovery. Other fields have been found elsewhere, the first in Fessan near the Edjele field of Algeria. These fields are smaller and less accessible than those found in the vast Sirte Basin (Clarke, 1963).

The sudden development of a major oil field has catapulted Libya into the same sorts of problems and potentialities as those of Saudi Arabia and Kuwait. The government, formerly one of the most poverty-stricken in the world, dependent upon loans and gifts from the United States, the United Kingdom, the United Nations, and elsewhere, now finds itself with the internally generated means to develop its resources in a major planned fashion. The immediate effects, as usual in such situations, were the enrichment of individual land owners, contractors, and merchants. A small number of people became wealthy overnight, and suburbs of expensive houses developed around Tripoli and Benghazi. The crowded slum quarters remained as before. The petroleum industry does not require a large number of employees, and the few required are primarily specialized technologists. While a limited number of Libyan workers were trained and recruited for excellent jobs, the majority were at first affected adversely. Because of the greater effective demand for goods of all sorts, commodity prices rose, and the cost of living became even more oppressive for those with low incomes. The government soon became conscious of the inflationary trend, and measures are being taken to combat it. Imports have increased greatly. Much food must be imported. Many of the high-priced imported foods, including even fish, can be produced from local sources if such production is stimulated and supported.

A five-year plan has been developed with the aid of outside experts to use the oil revenues to the best and most permanent advantage. Chief emphasis in the plan is placed upon agricultural developments. Next is utilities, such as roads, ports, and power, necessary for any sort of development. Building projects such as the new capital at Beida can be undertaken now when they would have been considered utter extravagances before the flow of oil revenues began.

Education is next highest on the list (Clarke, 1963) Ultimately, there seems little doubt that the general standard of living of the Libyans, and their ability to appreciate and satisfy wider cultural enjoyments will rise. It seems likely, too, that the centres of the new culture will remain in the same coastal strip now being enjoyed by the old, with its permanent geographic and climatic advantages.

SECTOR 19: TUNISIA[1]

The coastal desert and steppe of Tunisia might be called the land of the olive, for the olive dominates the economy and the landscape of the littoral. Olive oil is the only fat eaten by the Moslem majority as well as by the Jewish population. It has been estimated that half the population depends upon the olive industry for a living. Gathering and processing require much hand labour. Most of the littoral consists of a broad plain of good soil suitable for olive orchards. Mountains do not approach the coast anywhere, though there are hills and plateaux fairly near, in the Matmata-Medenine area south of Gabés. Annual rainfall along the coast ranges from 7 in. at the Libyan border through Gabés, to 13 in. beyond Sousse. As nearly 8 in. is required to raise olives without irrigation, the principal unirrigated groves are north of a line about half-way between Gabés and Sfax. Even almonds and apricots are raised here without irrigation (Despois, 1961). This is also roughly the northern limit of commercial date culture, and was essentially the limit chosen by Despois for the northern edge of the desert, though he declared: 'It is almost impossible to trace a limit, even approximate, between the steppes and the Tunisian Sahara' (Despois, 1942, p.118). To the south, irrigation is required for most lowland plantings of olives, though unirrigated trees flourish in some of the better-watered uplands at elevations between 1,000 and 2,000 ft. Dates, which are normally irrigated anyhow, are most important towards the hotter, drier western and southern parts of Tunisia, though they occur in places near the coast, as in the vicinity of Gabés.

One of the great olive districts of the world is in the Sousse-Sfax area. This is the region originally known as the Sahel (an Arab word meaning 'shore'): a term that has since been applied widely to semi-arid areas bordering the Sahara. Plantings are most intensive near these two cities. According to standard climatic classifications, the northern limit of ordinary desert lies midway between the two cities. The groves at Sousse, an old city of about 50,000 inhabitants, are older than those near Sfax. They have been subdivided in the course of time into tiny holdings. The great groves near Sfax, a more modern city of about 75,000, were planted by French settlers, more recently, in an area that was previously assumed to be too dry for unirrigated olives. The trees are in large estates, cultivated by European mechanized methods. Because of better varieties and more scientific care, the Sfax groves yield several-fold more per tree than those of Sousse. Any fluctuation in the annual olive crop, or in the price of olive oil abroad, has immediate repercussions in the economy of Tunisia (Laitman, 1954).

Besides its production and processing of olives and olive oil, Sfax is an export centre for olive oil and for another major export, phosphates from the interior. Salt is also produced, from basins north and south of the city. Water for Sfax and for Sousse is piped from the mountains of the west. In most of the littoral, water is obtained from wells.

1. See Map 6 and Table 3, Part 2.

According to the evidence of old olive presses, olives were raised in the southern littoral of Tunisia in Roman days. Their disappearance has been popularly attributed to a desiccation of climate, but olives are today raised successfully at the old Roman sites, and there is no evidence that the climate has changed appreciably (Bovill, 1933, p. 3-6).

A special culture has grown up in the littoral along the coast of the Gulf of Gabés and eastward: an oasis culture, specializing in irrigated groves of dates. Gabés has been called 'the Oasis of a Million Palms' (Calder, 1951). Gabés, an old, moderate-sized town of about 20,000 people, is the historic terminus of a trans-Saharan caravan route from Gao by way of In Salah and Ouargla. It is a minor port today, and also shares in fishing in the Gulf of Gabés. The gulf is shallow, inclining seaward only very gradually, and spotted with sandbanks. Furthermore it has a tidal range of about 5 ft., far more than any other part of the Mediterranean (U.S. Hydrog. Office,* Sailing Directions, vol. 52-1), which further complicates navigation by small boats. Still, fishermen of Gabés, Zarzis, and other towns of the south dive for sponges in the shallow water and fish for tunny and sardines farther out from shore (Despois, 1955). Salt is produced from evaporating basins south of Zarzis.

The island of Jerba (Djerba), at the southern entrance of the Bay of Gabés, is a condensed version of the mainland oases. It is densely covered with groves, both of olives and of dates, plus many other varieties of Mediterranean fruits and nuts. It is the ancient Greek Island of the Lotus Eaters: a veritable garden of delight. The smaller Kerkenes Islands, at the northern entrance of the bay, are likewise planted to orchards. The people of all the islands also devote effort to sponging and fishing. Jerba is so densely populated that there is a continual emigration to the mainland, supplying a highly esteemed labour element (Despois, 1955).

In addition to the two fixed major crops of olives and dates, there is substantial production in the coastal zone of the principal food and feed grain of the country, barley. The barley is raised especially in wadi valleys, planted in the muddy earth when the floods recede. There is usually a surplus of barley for export, and wheat is raised in the least arid areas for export, too. Grazing, primarily of sheep, secondarily of goats, is still carried on in extensive areas of semi-arid land inlands, on forage that grows with the winter rains, but more and more of the herdsmen are planting olives or other trees and becoming more settled. It is common for herdsmen to own some trees, and return at harvest time to gather their crops.

Tunisia has been studying and developing her water resources systematically. There is still room for expansion of the agricultural areas, as water resources are put to more complete use.

SECTOR 20: THE NÍJAR DESERT

On the north shore of the Mediterranean Sea there are numerous areas with semi-arid climates: in south-eastern Greece, south-eastern Italy, spots in Sicily and Sardinia, the Rhone Delta, and most extensively in coastal and interior Spain. There is only one true desert area north of the Mediterranean, however, and that is along the south-eastern coast of Spain. Although this area was noted as early as 1924 as being the driest part of Spain, it was not until 1933 that Gonzalez de Reparaz pointed out that the driest spot in all Europe was not the Caspian depression, but Cabo de Gata, on the Spanish coast 20 miles north-east of the port of Almeria (de Reparaz, 1933).

The amount of rainfall at Cabo de Gata varies strikingly from year to year. In 1921 there were 7.32 in., and in 1922 only 2.95 in., for example (Reparaz, 1933). Consequently the figure for mean annual rainfall differs somewhat depending upon the particular period of time used. The figure used in Table 3, Part 2, of 5.04 in. (Lautensach, 1951) is towards the upper estimate. A 17-year record (Espana, Min. Obras Públicas, 1942) gives the mean as 4.57 in. In any event, the climate is highly arid, with a de Martonne index of less than 5. Several other stations north, south, and inland from Cabo de Gata fall within the desert category, with de Martonne indexes of less than 10 and Thornthwaite indexes below —40. The situation, then, is that of a coastal desert, which, in the absence of an existing comprehensive regional term, may be called the Desert of Níjar from the village of Níjar at the inner edge of the desert, 11 miles north of the coast of the Gulf of Almería. Locally, the area between Cabo de Gato and Níjar is known as the Campo de Níjar (Reyes Prósper, 1915).

There is some disagreement concerning the coastal limits of the Desert of Níjar, and because this desert is so poorly known a discussion is justified. A map by C. Tome of Spanish climates according to the Thornthwaite system, published in 1949, has been widely used (del Cañizo, 1960, p. 32; Roquero de Laburu, 1962, p. 58). It shows a region of 'arid' climate stretching for about 145 miles north-eastward and for 57 miles westward of Cabo de Gata, or a total distance of 220 miles from Motril to Alicante: the longest distance of any of the maps. Emberger, Gaussen, *et al.** (1962) show their 'sub-desertic' category (which falls within the desert category of standard climatic classifications) as extending only about 44 miles north-eastward and westward from Cabo de Gata, or a total length of 85 miles, though their 'Xerothermomed' is about as extensive as the Thornthwaite strip. If we accept 11 in. of mean annual rainfall as the approximate limit of the desert, which here corresponds to the de Martonne index of 10, then the northern limit as given above is about right: the desert ends just south of Alicante. Towards the west, the limit should lie only about 44 miles west of Cabo de Gato, thus agreeing with the Xerothermomed limit rather than with the Thornthwaite limit. The latter was presumably drawn on the basis of insufficient stations: certainly Motril, with 14.9 in. of rainfall (España, Min. Obras Públicas, 1942), is far beyond the desert limit, and several stations east of Motril have more than 13.8 in.

As thus defined, the Níjar Desert includes the eastern end of the south-facing Costa del Sol and a longer strip of the northward-trending coast from Cabo de Gata almost to Alicante (Map 6, inset), a total length of about 190 miles. Cabo de Gata, the elbow of the desert and its dry nucleus, is a cape of volcanic rock that has been able to withstand the attack of the waves. The width of the desert is determined as much by the terrain as by the climate. Along the coast west of Almería the mountains form a wall with the base only about 2 to 10 miles from the coast, and eroded terraces between. From near Almería to Cabo de Palos (the prominent cape between Cabo de Gata and Alicante) the narrow coastal lowlands are backed by a general plateau surface of about 200 to 600 metres elevation and 20 to 30 miles wide. The plateau, which occupies the central driest part of the desert, is sharply dissected into steep slopes, thinly covered by widely spaced woody spiny desert brush, of which *Zizyphus lotus* is a common species, succulent *Mesembryanthemum nodiflorum*, and other desert plants (Reyes Prósper, 1915). The rain, which falls predominantly in the winter half of the year, runs off the bare ground by way of temporary wadis, here known as 'ramblas', too rapidly to be of use for irrigation even if there were suitably level land.

Most of the land surface is useless for agriculture, and supports meagre herds of goats. There are some plantings of the *Opuntia* cactus, or prickly pear, for use as fodder for livestock. Occasional situations permit flood farming of small acreages from slope run-off. The only substantial tract of fertile irrigable land is the lower valley and delta of the Almería River. The river water is used for irrigating varied crops, including Egyptian berseem for fodder, potatoes, maize, and best known to the rest of the world, high-quality table grapes which are exported through the port of Almería (del Cañizo, 1960, p. 291-7). The Almanazora River, 35 miles north-east of Cabo de Gata, is the only other river in the central part of the desert with irrigated valley floor and delta. Most of the desert has neither the terrain nor the water supply suitable for agriculture.

The only wide coastal plain of the desert lies between Alicante and Cabo de Palos. Although the plain is 10 to 20 miles wide, much of it is too saline to have agricultural value. The southern portion is occupied by a large coastal lagoon, the Mar Menor, 10 miles long. The largest tract of irrigated land in the entire desert is in the valley of the Segura River between Murcía and the coast, and in the coastal plain thence northward to the outskirts of Alicante (Roquero de Laburu, 1962). Murcía, 25 miles from the coast, and with annual rainfall of 11.2 in., is just about on the inner border of the coastal desert. It is sufficiently continental to be several degrees warmer than Alicante during the day in summer, and slightly cooler at night in winter. The whole northern segment of the desert has a mean temperature in January of about 50° F., which is about 4° F. cooler than Almería on the protected south-facing coast. Winds from the west sweep strongly across the northern plain, too, and early vegetables in some of the oases are protected by wind-breaks of woven reed (Lautensach, 1951, p. 158). The climate is still of the mild Mediterranean subtropical type, suitable for most Mediterranean crops. The chief limitation is water. Most of the available river supplies have already been intensively developed. The olive, with low water requirements, has extensive groves in the lowlands between Murcía and Alicante, mostly on slopes just above the irrigated alluvial floors of the valleys.

Income from the sea along the coastal desert is limited. Most of the coast is too deficient in water and in harbours to support a fishing industry. However, at the three main ports, Almería, Alicante, and Cartagena (at the southern base of Cabo de Palos) there are artificial harbours formed by breakwaters, and there is some fishing based there, as well as trade.

The desert climate of the south-east coast of Spain extends to the Island of Formentera, with mean annual rainfall of 8.2 in. and the tiny islet of Alboran, south of Costa del Sol. Formentera, the driest of the Balearic Islands, has a moderate desert landscape like that of the Desert of Níjar, with angular terrain and sparse brushy vegetation.

THE ATLANTIC LITTORAL OF THE SAHARA

The desert extends along the Atlantic coast of the Sahara for about 1,200 miles. The coastal strip is much cooler in summer than the interior of the Sahara, with moister air and frequent fog and cloud. On the basis of climate alone, this is one of the most pleasant of the coastal deserts of the world. Despite the abundant moisture in the air, there is little rainfall, chiefly because of the stability of the atmosphere induced by the existence of the cool Canaries Current off the coast and a persistent high-pressure area over the adjacent part of the Atlantic in winter. The central part of the desert littoral, in Spanish Sahara and northern Mauritania, is extremely dry, with irregular rainfall, but rainfall increases towards the northern and southern extremities. In the north the desert rainfall has the normal Mediterranean regime, with maximum in winter. In the south the tropical storms result in a summer maximum of precipitation. These three rainfall types are the principal basis for the three natural subdivisions of the Atlantic coastal deserts.

SECTOR 21: SOUS-IFNI DESERT

The south-westernmost 175 miles of coast in Morocco, from a little north of Agadir to Wadi Draa, is desertic. For lack of any usage to the contrary this stretch of littoral may be called the Sous-Ifni Desert, from the Wadi Sous and its valley that dominates the northern part, and Ifni, the tiny Spanish enclave towards the south (Map 7). This desert differs from the rest of the Saharan Atlantic littoral in being closely backed by mountains and in having regular winter rainfall of the Mediterranean type. There is no room for vast plains or low plateaux such as stretch in from the coast in the Spanish Sahara and Mauritania. Instead, between Wadis Sous and Draa the Anti-Atlas ends in a narrow ribbon of marine terraces, and north of the Sous the High Atlas terminate in an even narrower strip. Only along the Sous, between the two mountain masses, is there a sizable expansion of the coastal lowland, merging into the alluvial valley of the wadi. The Draa has a smaller piece of valley floor at its lower end.

Aridity increases steadily southward along the coast. From north to south, average annual rainfall for the three stations listed in Table 4 include 8.6 in. for Agadir, 6.1 in. for Sidi-Ifni, and 5.3 in. for Goulimine. Still farther south, in the Draa valley, Aium-du-Dra, 35 miles from the coast, has only 3.5 in. (Debrach, 1953).

Limited though the rainfall is, its effectiveness is increased by the fact that it falls during the cool season. January is on the average the wettest month at Agadir, and December farther south. In fact Emberger, Gaussen, *et al.**(1962) show this area and its continuation southward to Cape Bojador as semi-desert rather than desert. Their criterion, however, is the number of wet days, and high humidity and fog are considered in the tally in addition to days with rain. Consequently their system has more physiologic than agricultural pertinence. Certainly fog and mist are frequent in this desert. Fog occurs on about sixty days per year, and is especially common in summer. It is usually a phenomenon of early morning. It commonly develops over the cool sea water and is blown over the land by the sea breeze. The alternating sea-breeze and land-breeze tendencies result in prevailing winds with westerly and easterly components. The sea-breeze plays a large part in keeping the atmosphere of the coastal desert more cool and moist than would otherwise be the case. The refreshing breeze is felt inland for about 25 to 30 miles, and thus reaches virtually all of the area below 200 metres in elevation. Apparently the sea breeze does not reach areas at higher elevations than 500 metres (Bidault and Debrach, 1948, p. 22-4).

The winds of more than local significance are mostly either westerly winds known in Morocco as 'gharbi' or easterly winds known as 'chergui'. The gharbi is the cool, moist wind, most common in winter and at times associated with the rainstorms that move southward to this desert at times in winter. The chergui is a dry, hot wind from the east, warmed and dried in the Saharan interior and further desiccated by the mechanical foehn effect as it descends the mountains towards the coast. It raises temperatures along the coast to about 95° F., and very rarely to 113°. Heavily laden with dust, and at times blowing violently, the chergui is one of the unpleasant events of the region.

On the whole the temperatures are mild. The mean temperature is only about 59° F. in midwinter, and 70° in summer: a very small annual range, such as is typical of marine locations in middle latitudes. Even the daily maximum temperature is moderate close to the coast, but gets 20° F. hotter on the average during the day than Sidi-Ifni in July (Table 4). There is little difference between the outer and inner margins of the coastal desert in night temperatures. The mean daily minimum of the coldest month, January, is just above 50° F.

The outer part of the littoral is undoubtedly too cool for the standard desert irrigated crop, the date. Even at Tiznit, 7 miles from the coast, date palms are cultivated mostly for their leaves (Chevalier, 1952). Tiznit is one of several small oases between the Sous and the Draa based upon exploitation of water from short wadis from the Anti-Atlas. The irrigation water is either raised from wells from the ground water, or is diverted by dams across the wadis during the winter season of occasional storms and floods. The alluvial plain of the Sous is by far the most extensive irrigated land in this coastal desert. In 1952-53 there were 37,200 acres under irrigation, and it was planned to increase the acreage by 30 per cent. Some of the land was irrigated in the original primitive manner, by guiding natural flood waters to the fields by simple diversions, to water wheat or barley. Many wells and some foggaras (tunnels dug at slight gradients to intercept ground water) were also used. Considerable increase in irrigation is possible through more systematic use of the water resources (Houston, 1954). A wide variety of crops is possible, ranging from heat-loving plants farthest inland to temperate ones nearest the coast. The Draa is used to some extent by diversion of winter floods, but most of the Draa agriculture is carried out in the east of the coastal desert. The upper Draa lies in the full Sahara, south of the Anti-Atlas. Most of the foggara experts who build these tunnels in central and western Morocco learned their trade along the Draa (Despois, 1961, p. 230).

Outside of the wadis and other oases, where water is available for irrigation, agriculture is impossible because of the scarcity of rainfall. In this climate dry farming, even of hardy native barley, requires 9 to 12 in. of precipitation (Houston, 1954, p. 316). There is limited grazing, especially of goats, but the best possibilities for livestock would be based upon production of irrigated alfalfa or other stock feed in the alluvial valleys.

The only port of the Sous-Ifni desert is Agadir, a small harbour formed by a breakwater. It lies at one side of the mouth of the Sous valley, and is connected by roads to the interior and along the coast.

SECTOR 22: SPANISH SAHARA

The Spanish Sahara (Map 7) is the driest part of the Saharan coast. Until A.D. 1434 the Atlantic fringe of the Sahara was considered impassable and leading only to dangerous regions of fire farther south. In that year Captain Eannes, sent by Prince Henry of Portugal, succeeded in the historic feat of sailing beyond Cape Bojador and in landing unscathed on the coast of central Spanish Sahara. His successor landed at the inlet of Villa Cisneros, and named it 'Rio de Oro' because he mistook it for a river, up which he expected to find rich goldfields (Bovill, 1933, p. 141-2). Further exploration resulted in disappointment.

The Spanish Sahara, the southern half of which has been known since early times as Rio de Oro, is a very dry desert area. Not only is rainfall low, from 3.8 in. at Tantan in the north to 1.5 in. at Smara (U.K. Met. Office,* 1958, part 4), but there is no backing of mountains to multiply wadi run-off. Wadi Draa, the largest wadi, reaches the coast along the northern border but is dry most of the time. The largest wadi within the country is Saguia El Hamra, which reaches the coast at El Aiun south of Cape Juby. This wadi flows only during local rains.

The 'alisio', a northerly wind, prevails throughout the year, and is especially strong and persistent in summer (Font Tullot, 1949). It helps maintain cool, equable temperatures in the littoral, where, at Cape Juby, the mean monthly temperature ranges from only 62° F. in winter to 70° in August and September, the warmest months (Table 4). Occasionally the 'irifi', a dreaded easterly wind, arises suddenly and brings stifling heat and dust from the Sahara to the coast and at times even to the Canaries. In March 1941, the irifi raised the temperature at Smara from 64.9° F. at noon to 109° F. at 4 p.m., and kept the thermometer above 103° F. for about thisty-six hours, until the alisio brought back the usual 60.8° F. (Diaz Villegas, 1949).

The coast is bordered by low marine terraces, with a width of about 28 to 44 miles of dissected quaternary and tertiary deposits (Flores Morales, 1946), broken here and there by salty depressions known as 'sebjas' (sebkhas), with steep, cliffed sides (Hernandez-Pacheco, 1942). Farther inland the land is equally barren but rougher, with large stretches of stony hamada. There are a few wells, but these are highly saline. Only at El Aiun are there springs.

Permanent vegetation consists of euphorbias and stunted woody shrubs, with tamarisk and acacias characteristic of wadi beds where the long, penetrating roots can reach moist sand. After the occasional winter rain an ephemeral growth of grasses and herbs arises, and is the chief basis for the meagre nomadic grazing, chiefly of camels, that constitutes the chief economic activity (Hernandez-Pacheco, 1942).

Another activity is fishing. Small groups along the coast from Villa Cisneras southward, mostly of Imraguen tribes, fish in shallow water. They are hampered, except after an unpredictable rainstorm, by lack of drinking water; this has to be brought from the interior in goatskins carried on camels' backs.

The Saharan conditions extend to the Canary Islands. It is a base for the local shore fishermen, and also serves fishermen from the Canary Islands, who come with large base ships and small satellite boats. The continental shelf from 24° N. to 19° N., bathed by the cool Canaries Current, is among the richest areas of the world in fish. While the local shore fishermen wade out into the water, with spear and seine, to make their catches, the Canary islanders fish from their boats. By tacit agreement the demarcation between the two groups is the depth of 1.5 metres at low tide. The shore fishers dry their fish and sell them in the interior, by exchange with the camel-raising Moors. The Canary islanders take their catches back to their home ports.

Villa Cisneros, the only port of Spanish Sahara, is the principal trading outlet of the desert. Its water is now supplied by distillation of sea water, as is true also of Cape Juby. These towns serve as bases for oil explorations in the interior of the country, which, it is hoped, may eventually provide a substantial economic foundation that is lacking in any of the present meagre resources. The administrative centre is Aiun, at the mouth of the Saguia el Hamra.

The Canary Islands share in the desert climate of the adjacent mainland, though parts of the islands are more humid. Las Palmas, on Gran Canaria, for example, has a yearly rainfall of 8.6 in., concentrated in the winter half of the year (Table 4). Other stations are even drier: 6.2 in. for Punta Orchilla, on Hierro Island, and 4.4 in. for Tefia on Fuerteventura Island (U.K. Met. Office,* 1958).

SECTOR 23: MAURITANIA

The southern sector of the Atlantic littoral of the Sahara lies in Mauritania, an area in which French and Arab-Berber influences have mingled. The littoral has no well-defined physiographic limit to the interior. It is the lower end of the gently sloping plain that extends the 200-metre contour line 94 to 220 miles into the continental Sahara. The surface is marked by coastal dunes and playas (sebkhas), inland from which long lines of high, reddish sand dunes, oriented north-east - southwest, extend for hundreds of miles inland over barren surfaces of sand and rock. Except at Port Etienne, in the far north, the rainfall has a true tropical regime, with maximum in summer: a projection from the adjoining tropical lands to the south. In Port Etienne most of the rain comes in the autumn, but the amount is insignificant, averaging only 1.4 in. in the whole year. The modifying effect of the ocean is felt on temperatures, though the heat in summer is greater than at the Moroccan end of the littoral. There is the usual large rise in temperature as one goes inland. Port Etienne and Nouakchott, on the immediate coast, show the marine tendency for delayed maximum temperatures: September is the warmest month at both (Table 4).

The inner part of the littoral is a sparse grazing area, plagued by limited water and scanty vegetation. The stony regs between the dunes are almost bare of vegetation. The dunes themselves, with the ability to retain moist ground at moderate depths, have a development of woody shrubs. Certain species of acacias have been a long-time source of income based upon gum arabic exuded from their stems. This material, once a major attraction of the area, is used in pharmacy, cooking, and textile manufacture. Although its importance has declined, some is still gathered, especially in the southern part of the sector, north of the Senegal River, where aridity is least. The acacias grow better near the coast than inland, owing to the moisture of the sea breezes, and the almost daily occurrence of dew during the dry season (Church, 1961; Hubert, 1926).

Lacking significant water resources for agriculture, the chief-known economic resource of the Mauritanian littoral is fish. North of the latitude of 19° N. there is a rich fishing area, which has been used for centuries and is being more and more developed. Fishing activity is greatest from the Bay of Levrier, upon which Port Etienne is situated, to the Arguin Bank, a shallow area extending to about 80 miles south of Port Etienne. The fishing is carried on by three principal groups. The Imraguen, a simple Berber tribe, fish for mullet and other species in shallow water by seine and spear, and dry the fish for sale inland, or for drying, concentrating in Port Etienne, and shipping to tropical African countries. Sailors from the Canary Islands, with large mother ships putting in fleets of smaller boats, make regular visits to these waters. They fish during spring and summer, usually returning to the Canaries by September. In recent years a third group, consisting of former nomads from the interior, has begun to acquire boats and operate from Port Etienne (Robin, 1955; Valentin,* 1952, p. 447-8).

Port Etienne, with its good harbour, has become more and more the predominant centre of the area. Deficient in water supplies, it imported its domestic water from France until 1955. Now it distils sea water and is thus able to provide domestic supplies for all comers (Church, 1961). St. Louis, the next seaport to the south, in Senegal, is beyond the limit of the desert in the semi-arid tropical savannah fringe. It was formerly the capital of Mauritania even though outside its borders, but the new State of Mauritania has selected Nouakchott as its capital.

The centre of gravity of Mauritania is shifting northward with increasing rapidity. Mineral deposits far in the interior are at last being developed on a large scale, and in a few years the republic expects to obtain most of its income from royalties. Though there are important copper deposits, the outstanding development is at a great iron ore deposit in the Kedia d'Idjil Range, near Fort Gouraud, 250 miles from the sea. With the aid of a loan from the International Bank, a mining town has been built, water discovered at a depth of 130 ft., and a railway is under construction to Port Etienne, a distance of 400 miles, for exporting the ore. The port of Villa Cisneros, much closer than Port Etienne, is too shallow to be satisfactory. Incidentally, the municipal water of Port Etienne will be hauled by tank cars from large underground supplies recently discovered at Boulanouar, 75 miles north-east of the port. Crossing the dunes was a major problem, but they are being stabilized with deep spraying. With an estimated export of 4 million tons annually, Port Etienne will be a major general port instead of a small fishing port as formerly. For the people working in northern Mauritania, Port Etienne has ideal natural conditions for a seaside resort: splendid sandy beaches and mild climate (Church, 1961, p. 189-92).

SECTORS 24 AND 25: ANGOLA LITTORAL AND NAMIB DESERT

LIMITS

Along the south-western coast of Africa the Atlantic Ocean is bordered by the Namib Desert, a cool coastal desert, second in length only to the cool coastal desert of Peru and Chile among the west-coast deserts. On a climatic basis the Namib extends 1,750 miles from Luanda (8° 45′ S.) in Angola to St. Helena Bay (32° 45′ S.) in the Republic of South Africa (Carter,* 1954; Schulze, 1947). The core of the Namib, classified as extreme desert, extends from about 18° to 29° S. latitude, or less than half the total length of the desert. (Meigs, 1953b). The mean annual rainfall is only 0.9 in. at Walvis Bay, near the middle of the desert. Northward and southward it increases slightly to 2.1 in. at Moçamedes and 2.3 in. at Port Nolloth. Thence the increase is more rapid, to about 13 to 14 in. at Lobito and Luanda in the north, and 9 in. at Cape Columbine by St. Helena Bay in the south (See Table 5 and Blanchard,* 1929).

Like the rainfall, the vegetation is most sparse in the central part of the Namib. Long stretches of ground are bare of vegetation, and the few plants are predominantly succulents. Only on the floors of the wadis and intermittent streams that flow across the desert from the rainier east is there relatively abundant woody vegetation, where roots can reach the sand moistened by ground water. Toward the northern and southern ends of the desert, vegetation becomes more abundant as rainfall increases, and the phytogeographers consider the portions north of Lobito and south of the Olifants River, where grass begins to appear, with woody shrub among the succulents, as being semi-desert rather than desert (Adamson, 1938; Gossweiler and Mendonca, 1939). Though the usage of the term 'Namib' varies in precise location from author to author, the present writer proposes to use it in the broadest sense as covering the entire desert strip, as outlined in the preceding paragraph. In this he follows on the whole J. H. Wellington, who wrote the most comprehensive book on the entire Namib. Wellington refers to the area north of Lobito as 'transitional Namib' (Wellington, 1955, vol. 1, p. 123).

The Namib coastal desert averages about 25 to 30 miles in width; that is, the strip closely and directly affected by the presence of the ocean. East of this coastal strip there is enough additional rainfall to support a semi-arid vegetation that is the basis for great herds of antelope, zebras, ostriches, and other wild herbivores, and that gives meagre support to a present-day pastoral economy. The marine influence upon temperature is hard to measure because of the dearth of weather stations in lines transverse to the coast, and because the land back from the coast is so high that most of the stations inland are too elevated to yield comparable data. Toward the southern end of the Namib, however, it was possible to select

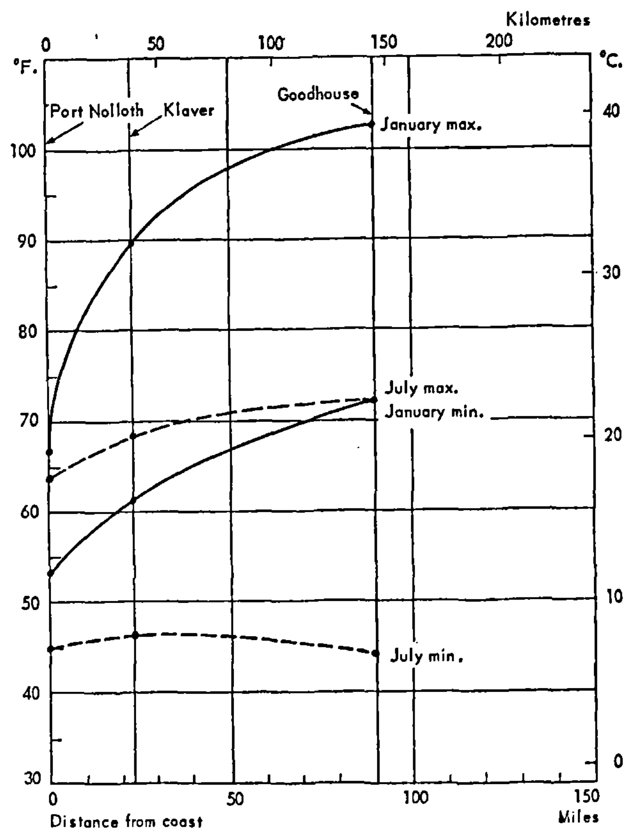


FIG. 6. Profiles of mean daily maximum and minimum temperatures, south-western Africa.

three stations which, though not in direct alignment, are near enough to sea level to be comparable: Port Nolloth, on the coast; Klaver, 23 miles inland, and Goodhouse, 90 miles inland. The data are listed in Table 5, and the mean daily maxima and minima for summer (January) and for winter (July) are plotted on Figure 6. The usual relationships are apparent. In summer, there is a steep rise of daily maximum temperature away from the coast for the first few miles, and an increasingly gradual rate farther inland. Two-thirds of the total 36° temperature rise in this profile occurred in the first quarter of the distance, between the coast and Klaver. Hence 25 or 30 miles seems a reasonable width for pronounced marine effects. In winter the contrasts are much less, as the coolness of the coastal waters tends to be balanced by the radiation cooling of the land. At night in winter, temperatures along the profile are virtually uniform. Incidentally, mean annual precipitation varies from 6.85 in. at Klaver to 2.24 in. at Goodhouse (South Africa Dept. Transport, 1954).

In the Central Namib, the Namib Desert Research Station, about 70 miles south-east of Walvis Bay, is making regular climatic observations which will furnish another valuable profile. In the meantime, field observations by Logan (1960) in the Walvis area show differences of 4° or 5° F. in the daily range of stations on the coast and a few miles inland.

THE FOGGY DESERT

Aside from scanty rainfall, which is a common trait of all deserts, the Namib is distinguished by coolness, moist air, and fog. Like the west-coast deserts of South America, the Namib is climatically dominated by a belt of cold water along the coast. The Benguela Current, a part of the counter-clockwise drift of South Atlantic waters, brings cool water northward against the west African coast. In addition, there is an upwelling of cold water from the ocean depths off shore. The current is essentially the result of the winds, which are the result of the South Atlantic high pressure area which is centred in about 30° S. latitude in summer, and shifts somewhat north in winter. The water near shore averages about 60° F. in the south and all the way to the great bend in the coast by Porto Alexandre. Thence to about Mossamedes it rises to about 67° F. and to about 73° by Benguela (Isaac, 1937). Farther out at sea, 150 miles from the coast, the water temperatures average several degrees higher (Currie, 1953). The air cooled by the passage of the prevailingly south - south-west winds over the belt of cold water stabilizes the temperature of the coastal desert even more than the normally conservative effects of any large body of water. Summers, in particular, are very cool for the latitude (Table 5).

Fog is another result of the cool belt of off-shore water. As the wind blows from the warmer part of the ocean across the cool belt near shore, thick fog or low stratus cloud forms and is blown over the land. Logan (1960, p. 48-9) gives a graphic description of the daily course of the weather from his observations in the central Namib. The early morning is calm, with a thick fog that gradually 'lifts' as its lower surface is warmed by indirect heating from the warming ground. Before noon, the stratus has evaporated completely from upper and lower surfaces, and the sun shines. A sea breeze springs up in the morning and develops enough intensity by mid-afternoon to raise clouds of dust. Before sunset the solar energy weakens sufficiently so that the sea fog again passes on to the land. The night remains calm, moist, and foggy: so wet, indeed, that travellers sleeping in the open have their blankets drenched with fog or dew, plants are dripping, and the surface of the ground is dampened. This condition of night condensation extends as much as 30 miles inland, and would be one way of delimiting the coastal desert if there were systematic observations (Cannon, 1924, p. 10). Boss was cited (Eriksson, 1958, p. 171) as estimating an annual deposit of 1.4 to 1.6 in. of fog near the coast, and 0.8 to 1.2 in. 25 miles inland, on horizontal plates on the ground. Vertical objects would doubtless result in still greater condensation.

Even when there is no fog on the ground, the relative humidity is high for much of the day. On the basis of thermograph charts for short periods of observation it was found that the relative humidity stayed at 100 per cent for 18 hours per day in summer, and for 15 hours per day in winter in the Walvis Bay area (Logan, 1960, p. 22). Only during the sunny part of the day does the humidity remain below 100 per cent. Observations during a sample year on the coast 18½ miles north of Luderitz Bay showed 285 days with dew or fog. The plants of the drier parts of the desert, particularly succulents and lichens, apparently rely chiefly upon surface condensation for their water supply. On the basis of fog-fed vegetation Walter placed the limit between 'inner' and 'outer' Namib at 34 to 37 miles from the coast (Walter, 1936).

Occasionally the high over the south African plateaux becomes strong enough to send a hot, dry wind from the east. This east wind, or Berg Wind as it is known locally, appears to be a typical foehn, descending the Great Western Escarpment on to the coastal desert and becoming adiabatically heated and dry as it descends. Clouds of dry, choking dust are raised, and discomfort is profound.

The scantiness of precipitation in the Namib, despite the high humidity of the air, is the result of two basic factors. In the first place, the cool water results in great stability of the air: an 'inversion' that sometimes extends upward for several thousand feet. This is the reverse of the unstable conditions that would cause the rising and cooling of large enough masses of air to make rain. The second factor is the existence of the semi-permanent high in the South Atlantic that acts as a barrier to the passage of the usual extra-tropical storms from the south-west. In winter, when the high shifts northward, occasional storms move in from the south. The rainfall regime of the southern Namib is therefore of the winter or Mediterranean type, and it is in the far south that sclerophyll-leafed brush, typical of Mediterranean regimes, begins to appear. At the northern end of the Namib, on the other hand, the cool off-shore current and upwelling loses its strength in summer, and this area is therefore a transition to the normal tropical regime of summer rainfall.

In short, the Namib Desert can be divided climatically into three areas: an extreme desert in the middle, a tropical desert in the north, and a Mediterranean desert in the south. The distinctive features can be summarized as follows: a long, central area of extreme desert from about Mossamedes to Port Nolloth with less than 2½ in. of rainfall per year and cool temperatures; a northern area of moderate desert in Angola as far north as Luanda with summer rainfall and barely tropical temperatures; and a southern area extending to St. Helena Bay with winter rainfall and chilly temperatures.

TERRAIN

The Namib Desert lies on a bedrock platform between the ocean and the high plateau of southern Africa. The plateau drops to the Namib platform in a series of steep slopes, in a zone a few miles to 20 miles wide, known as the Great Western Escarpment. From the sea coast to the base of the escarpment the Namib platform is about 50 to 90 miles wide. The inner edge of the platform is everywhere above 2,000 ft. in elevation. That portion of the platform less than 200 metres above sea level, of greatest concern in a study of coastal deserts, as shown on Map 8, varies in width from about 5 to 50 miles, averaging about 20 miles.

The geomorphological subdivisions of the Namib owe their distinctive characters principally to differences in the nature of surficial deposits and the hardness of the bedrock. There are great local differences within short distances, sandy flats alternating with rocky outcrops, but in a broad way the terrain can be grouped into three subdivisions of unequal length (Wellington, 1955, vol. 1, p. 119-23). The northern terrain subdivision comprising about 60 per cent of the entire length of the Namib, from Luanda to Walvis Bay, consists principally of exposed bedrock surfaces, with a sandy strip along the coast. The only extensive area of sand dunes in this subdivision lies in the area north of the Cunene River. Here the Cunene River has brought large amounts of sand to the coast, and the south-westerly winds have transported the sand in the form of dunes inland for as much as 30 miles and northward to 10 miles beyond Porto Alexandre. South of the Cunene River and Walvis Bay the platform is particularly bare, and is sometimes called the 'Skeleton Coast'.

The central terrain subdivision is from Walvis Bay to Luderitz, and is a vast expanse of tremendous sand dunes. The dunes, with a few crests up to 800 ft. above the troughs, are made up of sand spread out on the platform by short intermittent wadis from the front of the Great Western Escarpment. The south-westerly winds have built the sand into great windrows, with major alignments north-west - south-east perpendicular to the wind direction. Locally the easterly Berg Winds have produced disorderly modifications of the main pattern. At the inner edge of the dune belt, 20 to 80 miles from the coast, the dunes are of an almost brick-red colour, while those near the coast are yellow-white: probably a reflection of the greater age and oxidation of the interior dunes. The dunes near the coast are almost devoid of vegetation, while those farther inland, with greater rainfall and more fixed position, support widely scattered bushes and bunch grasses (Logan, 1960, p. 133-8). The Kuiseb River, whose dry bed reaches the southern end of Walvis Bay, marks the northern end of the sea of dunes, except near the mouth of the river where the dunes spill across to the Swakop River.

The southern terrain subdivision, known in South Africa as a 'Sandveldt', consists of a belt about 20 to 50 miles wide, from south of Luderitz to St. Helena Bay. In the northern 80 miles of this subdivision the hard rock outcrops in prominent ridges with shallow sand and gravel troughs between, but in the rest of the subdivision the platform is rather flat, with low, hard rock ridges rising only a short distance above the general surface of shallow deposits of sand and gravel. It is in the gravel and sand deposits in the swales of this subdivision that one of the world's great deposits of diamonds exists. The diamond fields, the first of which was discovered in 1908, have been extended by new discoveries until now they are known to occupy a stretch about 250 miles long, centred approximately at the mouth of the Orange River. The diamonds are all found from the coast to 15 miles inland, from sea level to 330 ft. above sea level.

Throughout the entire Namib, the terrain of the main platform has virtually no potentiality for agriculture, because of roughness and lack of soil, even if water were available. The only suitable land is that of the floors of the valleys that cross the platform in deep troughs. Most of these 'rivers' are actually dry wadis, heading in the Great Western Escarpment and carrying water only rarely after storms and seldom to the sea. The Cunene River at the northern edge of South West Africa, and the Orange River at the southern edge, are the only two rivers in the extreme desert with a permanent flow all the way to the sea, and even these are cut off from the sea by sand-bars part of the year. In the far north, the Cuanza is the largest of several permanent rivers, and in the far south, the Olifants River brings together the water from several sizable tributaries from the more humid interior and south. Only the Cuanza, Cunene, and Orange bring water from extensive drainage basins east of the Great Western Escarpment. The Swakop and Kuiseb by Walvis Bay have considerable permanent flows of water in their upper portions, but at the coast the only available water is somewhat brackish supplies from wells in the sandy floors of the wadis or (potentially) from better water piped from eastern portions of the rivers.

The sea coast of the Namib is notably uniform and deficient in natural harbours, owing to the lack of mountain ridges extending to the coast and to the lack of coastal subsidence. The few harbours are the result of the deposition of sand into bars and spits as a result of the northward-moving coastal waters and the south-westerly winds. Lobito, the best natural harbour of the entire Namib, Luanda, Mossamedes, and Walvis Bay are all situated on spit-formed bays. Only at Luderitz do old crystalline basement rocks form a point that provides some shelter; and at Cape Columbine, at the southern end of the Namib, resistant crystalline rocks form the point that created St. Helena Bay (Kaiser, 1926, vol. 1, p. 154). Cliffs border most of the coast, except where rivers or dry wadis provide sea-level access to the interior. The same factors that produced the straight, harbourless coast also prevented the formation of islands off shore. Only in the vicinity of Luderitz have fragments of the hard rock basement been available for the creation of several tiny rocky islands, from Hollam's Bird Island to Possession Island (Map 8).

ECONOMIC GEOGRAPHY AND POTENTIALITY

Aside from the diamondiferous gravel deposits of the southern Namib, which form the basis for long-term local exploitation, the land resources of the Namib are poor. Most of the terrain is entirely unsuited for any conceivable use. It is true that game reserves have been created in the northern part of South West Africa and in an area near Walvis Bay, and the herds of interesting wild animals may attract a limited number of sightseers or hunters. For the rest, the chief potentialities of the Namib are irrigation in the river valleys of northern and southern sections, fishing along the entire coast, processing of marine products, and trade with the interior and overseas.

Only limited farming is possible for most of the desert. Irrigation with water pumped from wells in the sandy floors of wadis can support some farming, though floods sometimes wash out the developments in a wadi. In the northern tropical climate, near Luanda and Lobito, a wide variety of crops is being produced in the broad valleys near the coast. The Cuanza, just south of Luanda, is a major potential source of irrigation water. Already sugar-cane is an important commercial crop in the vicinity of the Luanda and Lobito, and oil palms (*Elaeis guineensis*) grow naturally in the river valleys. Sugar-cane and fruits are particularly important on one of the rare coastal flats between Benguala and Lobito, where water from the Catumbela River is used for irrigation (Van Dongen, 1960; Hance and Van Dongen, 1956; Wellington, 1955, vol. 1, p. 459). In the central Namib only small gardens occur, and only in limited areas where water can be pumped from wadi-bed wells to irrigate the valley floor. At least small plots have demonstrated the climatic feasibility of raising crops, if suitable water and land can be found and combined. At Rooibank, 10 miles from the coast in the valley of the Kuiseb River south-east of Walvis Bay, date palms grow readily. They could be expanded, though probably not towards the coast which is too cold for maturing that fruit. Logan feels that many other fruits and crops could be produced in the valleys of the Swakop and Kuiseb rivers (Logan, 1960).

In the Mediterranean-type arid and semi-arid lands of the far south, where good and abundant river water begins to be available, expansion of Mediterranean crops is possible. The biggest irrigation project of the Namib is in operation in the valley of the Olifants River, where a dam was constructed near Klaver, north of Fort William, and 21,000 acres were brought into an irrigation scheme (Wellington, 1955, vol. 2, p. 48, 112).

Pastoral activities are impossible in most of the Namib because of complete lack of pasturage and difficulty of procuring water. In the Inner Namib, beyond the true coastal desert, pasturage improves, and there has been a nomadic type of herding from time to time, subject to long-distance travel of the livestock (sheep in the south, cattle farther north) in accordance with the spotty distribution of the scanty rainfall.

The aridity of the Namib favours the development of at least one agricultural asset: fertilizer. The small islands in the vicinity of Luderitz are occupied by marine birds which feed on the vast supplies of fish and which in the course of time built up tremendous deposits of guano. As a result of the lack of rainfall the guano does not wash away, but accumulates in deposits as much as 60 ft. thick. The guano deposits were discovered first on Ichabo Island in 1843, only eight years after the first shipments of guano from the bird islands of Peru reached England. A tremendous boom in guano-mining resulted. In 1844 there were as many as 300 ships at one time harvesting the guano, and the original Ichabo deposits, estimated at 700,000 to 800,000 tons were nearly used up that year. The activity spread to the other islands, as far south as Possession Island, before the supply of guano was entirely exhausted. The Government of the Republic of South Africa now controls guano production, and permits harvesting only during the season from April to September, when the birds are away. Gradually the guano deposits are rebuilding, and the annual harvest is dependable though small (Watson, 1930).

Fishing has long been the major basis of support for most of the Namib. The cold upwelling water along the coast is high in plankton concentration, and supports an abundance of marine life: one of the world's major fisheries. Pilchards (sardines) eat plankton, and larger fish eat pilchards. The richest resources of fish are concentrated 10 to 45 miles off shore, from Luderitz northward (Hart, 1953). Here vast shoals of pilchards have been exploited only in the past fifteen years, and trawlers are yielding tremendous hauls. Hake (stockfish) are caught in quantity even farther out than the pilchards. Another major catch is the snoek, a larger fish caught near shore by hand-lines. Crawfish, known as rock lobster in South Africa, are a major product. They are caught from Walvis Bay southward, from small boats near shore, in baited bag nets on rocky bottoms at depths from low tide to 150 ft. (Isaac 1943; Speight, 1952; Wellington, 1955). All the ports of the Namib participate in the fishing industry, and most of them were first settled as fishing bases. Originally most of the fish were dried in the sun for export, but most of the vast hauls of pilchards and hake are used today for making fish meal for livestock feed or for fish oil. Some of the fish is canned for human consumption. There are canneries at the larger ports, as well as bases for the fishing fleets. In addition, many small ports have their own fleets, using small beaches at the mouths of wadis or wharves extending out from the coast and served by lighters to larger vessels.

The fishing industry appears to be exploiting its resources almost to capacity, though there is always the possibility of further rich discoveries of fish at unexplored localities and depths. The Republic of South Africa has deemed it necessary to introduce conservation measures to prevent depletion, especially of pilchards and crawfish. There are possibilities of upgrading the use of marine products. Consumption of fish per capita is still far below that of the countries of northern Europe, and fish would help assure an adequate protein element in the diet (Van Dongen, 1962; Wellington, 1955). Shortage of fresh water has always been a problem to fishing groups along the Namib coast, but modern methods of finding and delivering ground water, and for desalting sea water, should make adequate supplies possible at least for domestic and limited industrial use. The lack of low-priced power or fuel is a handicap for desalting.

Salt has always been essential for drying, canning, and other types of fish processing. The natural conditions of a coastal desert are favourable to salt deposits, and salt pans based upon evaporation of sea water near the coast occur in the vicinity of Walvis Bay and the ports of Angola.

Finally, foreign trade offers opportunities quite apart from those of the local environment. Substantial exchange of commodities from the interior with those of overseas countries is most important for the northern ports of Angola. Lobito is the outlet for a major railway connecting with central Africa. Luanda has a water- and rail route part way to the interior: the lower 150 miles of the Cuanza are the only navigable inland waterway in the Namib. Mossamedes, Walvis Bay, and Luderitz also have rail connexions through breaks in the Great Western Escarpment (Hance and Van Dongen, 1956; Van Dongen, 1960; Wellington, 1955). Local manufacturing has developed especially at Lobito and Luanda. The other ports are still handicapped by water of inadequate quality and quantity —not necessarily a permanent condition—as well as very limited hinterlands, an obstacle that will be harder to surmount.

SECTOR 26: SOUTHERN MADAGASCAR

Along the south-west coast of Madagascar there is a definite strip of coastal desert. Two stations along this coast, Tuléar and Androka (Map 8, inset) conform to the criteria of desert climate as given by Köppen, Thornthwaite, and de Martonne. Tuléar, the wetter of the two stations, with 13.5 in. of rainfall per year (see Table 5 and U.K. Met. Office,* 1958) has an aridity index of —47 in the Thornthwaite classification. Androka has a mean annual rainfall of 12 in. (Goldflam and Jones, 1949). As the rain falls mostly during the hot season, when temperatures average about 81° F., it evaporates rapidly and is not sufficient to remove the climate from the arid category.

Owing to the wide spacing of weather stations and the fragmentary nature of information about southern Madagascar, it is difficult to draw precise limits for the coastal desert strip. At a minimum, the desert must be longer than the 125 miles separating Tuléar and Androka. At a maximum, it must be a little shorter than the 260 miles between Morombe and Tsihombe, since both of those stations have barely enough rainfall to be classed as semi-arid. According to the distribution of *Didiera*, a twisted xerophytic bush used as an indicator of the driest parts of Madagascar, the desert strip extends almost the whole way from Morombe to Tsihombe (Goldflam and Jones, 1949, p. 14;

Aubreville,* 1949, p. 175, 307). A reasonable approximation of length would be 250 miles. The width of the desert according to the vegetation maps, confirmed by the rapid rise in rainfall inland, is only about 30 miles, which agrees well with the width of coastal deserts elsewhere. Beyond the inner margin of the desert, a savannah-type semi-arid climate prevails.

The Madagascar type of desert, with tropical conditions, modified by proximity to the sea or by elevation, and with distinct summer maximum of rainfall, is of rather limited occurrence in the world. Nearest analogues are in north central Australia, the southern part of the Chihuahua Desert of Mexico, and the southeastern part of the Nubian Desert in Sudan, all of which, like the Madagascar desert, lie on the Tropic of Capricorn or Cancer (Meigs,* 1953).

The landscape is of the typical desert type. Plains, especially broad in the north, rising in a series of gradual steps towards the interior; traversed by several large rivers bringing water from the rainy uplands; and further dissected in detail by local wadis and gullies. Floods occur even in the dry wadis during heavy storms. Scattered vegetation, including *Didieraceae*, Euphorbias, prickly pears (*Opuntia*) originally imported but now a widespread nuisance, and other succulents and low woody bushes, predominates, leaving much bare ground between plants. A rather rare rubber plant, *Euphorbia intisy*, has been virtually destroyed by gatherers (Platt, 1937; Aubreville,* 1949). Despite the considerable literature on Madagascar, the coastal desert remains poorly known in detail (Platt, 1937).

The core of the coastal desert, between Tuléar and Androka, is occupied by one of the more primitive tribes of Madagascar, the Mahafaly. They are predominantly nomads and fishermen, raising cattle for milk and, more recently, goats. The best grazing is in the semi-arid lands inland from the desert. In the desert goats have proven the most adaptable to the harsh environment (Duvergé, 1949, p. 5). A primitive agriculture is also carried on, and sorghum is the chief crop and main vegetable food. It survives with minimum water and care. Sweet potatoes and manioc are important root crops. The standard subsistence corps of most of Madagascar, rice and corn, are humid climate products, and are of little importance in the desert strip (Murdock,* 1959; 1960). Of cash crops, sisal is well suited to the environment and is raised to some extent. At times, castor oil beans also contribute to local income.

Owing to the irregularity of the rainfall from year to year and the primitive character of agriculture, serious famines are frequent. Natural resources are available to avert famines, in the form of good alluvial soil within reach of the large rivers that bring down ample supplies of water from the interior. It is the technology and capital that are lacking to develop intensive irrigation agriculture (Platt, 1937).

Transportation is another serious problem of the Mahafaly and their neighbours along the desert littoral. There are no railways, and no roads connecting the different parts of the desert except for short projections extending north and south from Tuléar 50 and 25 miles. The desert segment of coast is more poorly provided with roads than any other Madagascar coast of equal size. River- and wadi-crossings are a problem. Flood-proof bridges are expensive to build. The permanent rivers are crossed by means of primitive ferries, and the wadis are just not crossed when they are in flood. Coastwise traffic at sea is faced with poor and exposed ports, except at Tuléar. Tuléar also has the only airport on the coast between Morombe and Fort Dauphin (Hance, 1958).

Tuléar is the main town of the desert. It is both the centre of a local road network, and the terminus of the only important road to the interior of the island. In tonnage, it has become the fifth port of all Madagascar, as an importer and, to a less extent, exporter. It is the only international port in the desert, and is well ahead of Fort Dauphin as the leading port of southern Madagascar. Tuléar is favoured by a coral reef off-shore that effectively breaks the force of the waves and gives sheltered harbour. Although it is on the lee side of Madagascar from the prevailing easterly trade winds, Tuléar does have on-shore local winds a majority of the time (Ravet, 1948). Fort Dauphin, on the humid south-east coast, is subject to the full on-shore force of the trade winds (Hance, 1958).

In short, the Madagascar Desert is a marginal area, both geographically and economically. Yet the natural potentialities are sufficient for an improved irrigation agriculture, and a good port is ready to serve the area. It is doubtful that the local resources are enough to finance the irrigation projects, roads, and facilities necessary to change the economic scene into a more productive one.

SECTORS 27 AND 28: WESTERN AND SOUTHERN AUSTRALIA

The extensive deserts that make up the interior of Australia break out to the sea coast in the west and the south. Both of the coastal deserts are barely dry enough to be considered arid, and are in fact treated as semi-arid by some writers. In other respects they are quite different from each other.

WESTERN AUSTRALIA LITTORAL

Australia has one of the five west-coast deserts of the world. Like the other west-coast deserts, the Australian one has three subdivisions based upon the seasonal distribution of rainfall. The northern subdivision, bordering the tropical savannah, has a summer maximum of rainfall (Anna Plains, Port Hedland, and Roebourne, see Map 9 and Table 6); the southern subdivision, bordering a region of Mediterranean climate, has winter rains (Carnarvon and Hamelin Pool); and the central section, though less clearly defined, has rainfall about equally divided between winter and summer (Onslow).

Lacking a pronounced cold off-shore current such as is found in the other four west-coast deserts, the west Australian coast is considerably warmer and less arid than the others. The stations average 8 to 15 in. of rainfall per year, compared with 2.50 in. or less in some stations in all the other deserts. The mean temperature of the warmest month at Onslow, 86° F., for example, is 4° higher than at San José del Cabo, 7° higher than at St. Etienne, 18° higher than at Antofagasta, and 19° higher than at Walvis Bay, all at comparable latitudes about 22° from the Equator. Winter differences are less marked.

With the climatic stations averaging about 150 miles apart, it is difficult to draw the precise limits of the coastal desert and of its climatic subdivisions. The valuable large-scale fold-in maps of vegetation and soils included in the Unesco contribution by Dr. Davies (1955) give useful supplementary indications, though it is uncertain to what extent they too have an entirely adequate observational base. For the over-all climatic limits, the Thornthwaite, de Martonne, and one of the Köppen formulas place the northern limit of the coastal desert just north of Anna Plains, with mean annual rainfall of 14.9 in. and the southern limit just south of Hamelin Pool, with 7.9 in. (Gentilli, n.d., Marshall, 1948). With its mean temperature 16° F. higher than at Hamelin Pool, and with its rainfall coming during the hot season instead of the cool season, Anna Plains clearly must lose much more rainfall by evaporation, and a given amount of rainfall is less effective there than at Hamelin Pool.

Data upon which to base an estimate of the width of the coastal desert are scarce. Climatological stations are not situated so as to permit meaningful profiles in from the coast. The few inland stations, such as Marble Bar and Nullagine, are at a much higher elevation than the coastal ones (Table 6). One good indicator of marine influence that shows distinct regional zonation on the map is the average length of the frost-free season. Along the entire coast to a point south of Carnarvon there is a strip about 30 miles wide shown as being frost-free for the entire year, considering a frost-free day to be one where the temperature does not drop below 36° F. There is also a compression of the isotherms of the normal daily maximum temperature in summer along this coast, of a width of about 30 to 50 miles (Australia, Met. Bureau, 1952, 1957). Vegetation also gives a clue. Although along most of the coast the vegetation is mapped as an extension of the inland types, along the north-east part of the desert littoral a strip 20 to 40 miles wide is shown as differing from the interior spinifex desert by having woody shrubs scattered through the plant association (Davies, 1955, Fig. 7). In the central section of the coast the width of the coastal desert is limited by the terrain, the mountains coming to within 10 to 25 miles of the sea except at embayments in river valleys. A rough figure of 30 miles seems reasonable for the average width of the entire coastal desert, varying locally in accordance with terrain.

The entire desert littoral is characterized by marine climate. In addition to freedom from frost, the reduction of annual temperature range, and the limited rainfall, the coast experiences greater seasonal and daily shifts in wind than inland stations. Sea breezes are particularly strong in summer and in the afternoon. Land breezes predominate in winter and in the early morning (Australia, Met. Bureau, 1957). Terrain is far from uniform. The nearest universal trait, apart from the usual desert features such as steep slopes, sand, and limited water, is the existence of coral reefs along most of the coast except the sandy coast at the north of the sector (McGill,* 1958). Differences in terrain are at least as important as differences in climate among the principal subdivisions of the sector.

The north-east subdivision has the widest lowlands of Sector 27. Here the Great Sandy Desert of Australia comes down to the coast, forming a flat, sandy plain; one of the most desolate coasts of the world. The 100-metre contour bends inland 100 miles, and the 200-metre contour at least twice that far (Map 9). The sand forms great parallel dune ridges, transverse to the coast, and best developed on the plateau inland. The littoral itself, known in its principal portion as the Eighty-Mile Beach, or Ninety-Mile Beach, consists of a coastal plain or low sandy marine terrace rising at places as much as 50 ft. above sea level. The vegetation association is known locally as 'pindan'. It includes a general cover of spinifex (*Triodia* of various species), the sharp, pointed spiny bunch grass, sometimes called Porcupine Grass, that covers so much of the Australian deserts. Unlike the interior vegetation, however, the pindan contains also woody shrubs or small trees of acacias and other varieties. Davies, following Wood, calls this vegetation an 'arid formation: grass scrub' (Davies, 1955, p. 122).

The desert littoral has been little used. There are no streams, and the very few widely scattered cattle stations, all within 5 miles of the coast, depend upon wells dug to depths of 30 to 100 ft. to water their livestock (Clapp, 1926). The soils are too poor even to support healthy sheep, according to one authority (Salisbury, 1951). The principal market town, Broome, lies just east of the desert. With a good port, Broome was once the centre of several hundred vessels engaged in gathering pearls and mother-of-pearl shells, but today the pearl industry has declined until only about a dozen boats are left, mostly collecting the shells. Broome, with less than 1,000 inhabitants in 1952, is a regional centre for collection and shipment of wool, hides, and livestock from the surrounding area (Villiers, 1963, p. 322; Cressey,* 1960).

Westward, the pindan formation continues as far as Port Hedland, but here it occupies coastal terraces that are backed by the hard-rock uplands of the Hamersley Plateau and Mountains, rising several thousand feet above sea level. This Port Hedland portion of the coastal desert is dependent upon mining resources in the interior for its economic base. Important gold-fields use the small ports for their supplies and for shipping out their products. Other minerals, too, such as silver, copper, lead, and tin are mined in this region. Currently there is great activity preliminary to developing a rich deposit of iron ore near the coast at Mt. Goldsworthy, 65 miles eastward of Port Hedland (Villiers, 1963). Port Hedland has a small but well-sheltered natural harbour of moderate depth and considerable potentiality (U.S. Hydrog. Office,* 1958).

The gold-fields inland from this subdivision have the highest air temperatures of any part of Australia. At Marble Bar in the summer of 1923-24 the temperature rose above 100° F. on 160 successive days (Australia, Met. Bureau, 1952, p. 34). Nights are bearable, however, and winters are cooler than on the coast. Although precipitation is only slightly greater than on the coast, there is enough run-off on the impermeable rock surfaces to generate several sizable streams, which reach the coast at least intermittently and whose gravels bear water accessible to coastal localities. To date, agriculture has not developed in this portion of the littoral for lack of good land, water, and incentive. None of the towns, even Port Hedland, has more than a few hundred people normally.

South-west of Port Hedland the climate and vegetation gradually lose their tropical character. Although Roebourne is still within the temperature limits defined as tropical, Onslow falls into the sub-tropics, as its coldest month is below 64.4° F. The vegetation too shows a change, and the prominent point just west of Roebourne may be selected as the beginning of the central subdivision of the coastal desert. This subdivision extends south-west across the Tropic of Capricorn almost to Carnarvon. The littoral of this western 'shoulder' consists of a broad plain called by Prescott 'desert sand plain' (Davies, 1955, Fig. 5), with an extensive salty lagoon in the southern part. The vegetation is classified by Davies, following Wood, as 'Arid formation: sclerophyll grass steppe'. The area is thinly settled, with very meagre grazing activity. Onslow, the chief town, with a shallow open roadstead, had only 180 people in 1952 (*Columbia Lippincott*,* 1961). With a series of coral reefs and shoals off shore, the coast does not encourage a fishing industry. Any study of potential development might well examine whether fishing could be developed, or whether water from the Ashburton River might be applied to irrigation.

The third and last major subdivision of Sector 27 extends from just north of Carnarvon to a point on the coast about 40 miles south of Hamelin Pool. Carnarvon lies opposite the mouth and Hamelin Pool at the head of the shallow, coral-bordered Shark Bay. The land consists of desert loams overlying a sedimentary platform in continuation of the coastal plains just north. The vegetation is classified as 'Arid formation: mulga scrub'. This formation extends far inland, stretching continuously eastward across the Australian deserts in the southern, winter-rain part of the continent. Mulga is a low, shrubby type of acacia (*Acacia aneura*) with which is associated other woody brush, including a bushy, low variety of eucalyptus and other sclerophyllous shrubs such as are usual in deserts bordering Mediterranean-type winter-rain areas. Carnarvon reports a little more rainfall than Hamelin Pool. The climate, well represented by the two weather stations, falls at the margin of desert and semi-desert in the classification of Emberger, *et al.** (1962), just within the arid according to the best-known strictly climatic classifications.

Although most of this subdivision is an area of sparse grazing of sheep, it includes also the one locality in the entire Sector 27 in which agriculture is significant. Carnarvon uses water from the Gascogne River to irrigate a variety of crops, including bananas and pineapples (Bagley, 1949). Markets and accessibility are among the limiting factors of this activity. In addition, Carnarvon, with a population of about 1,000 in 1952, is a centre for the sheep industry of the back country. It has a shallow harbour formed by breakwater, suitable for small coastal vessels (U.S. Hydrog. Office,* 1958). For large vessels, it is necessary to resort to Geraldton, just south of the desert coastal region. Geraldton, with a population around 6,000, is by far the largest city within reasonable reach of the coastal desert.

All in all, the potentialities of Sector 27 are limited agriculturally, by terrain as much as by climate, though there may be possibililities of expansion in the south-western subdivision. Possibly marine industries can be stimulated. For the rest, the region seems likely to remain primarily a service area for its hinterland.

SOUTHERN AUSTRALIA LITTORAL[1]

The Great Australian Bight bends just far enough northward to cut into the Australian deserts. About

1. See Map 10.

150 miles of the coast, from Eucla eastward, is barely desert in the climatic sense. Emberger *et al** (1962) call it semi-desert. This is a cool desert, with a slight tendency towards winter maximum of rainfall. Temperatures average about 10° F. lower than those of the southern part of the west-coast desert (Table 6) and approximate those of Agadir, Morocco.

Eucla is merely a tiny village on an open roadstead through which limited trade from the sparse grazing of the interior is carried on. It lies at the edge of the vast Nullarbor (i.e., treeless) Plain, an expanse of flat-lying limestone, with even less rainfall than the coast. The plain lacks rivers, as the rainfall disappears into the ground in sinks and channels. The plain is covered with vegetation classified by Davies as 'Arid formation: shrub steppe', consisting of small woody shrubs and ephemeral vegetation (Davies, 1955). As there is no significant terrace at the foot of the 250-ft. cliffs that terminate the Nullarbor Plain (Cannon, 1921), and mineral potentialities are non-existent, the future of the coastal desert of Sector 28 holds no great promise. Possibly fishing in the broad shelf of the Great Australian Bight might be developed systematically, despite the adverse natural conditions of the coast, but even here it would probably be more economical to base such development upon the better natural ports in the better environments of such ports as Port Lincoln, Adelaide, or Port Augusta.

In passing, it is worthy of note that the belt of semi-arid and sub-humid climates extending eastward from Sector 28 for 500 miles is breached again to the edge of the interior desert by the sharp northern point of Spencer Gulf. Here Port Augusta has developed a true coastal desert port, with rainfall of less than 10 in. (Table 6), though its desert strip includes only a few miles of coast. Typical mulga scrub just reaches the coast at Port Augusta (Davies, 1955). Port Augusta owes its importance to its strategic transportation location rather than to any attractions of the local desert. It is the hub for railways and roads from all directions, and from here the transcontinental railway heads west across the desert to Perth, and another heads northward into the heart of the desert at Alice Springs.

SECTORS 29 TO 33: NORTH-WESTERN MEXICO

The desert coasts of North America are confined to the Mexican peninsula of Baja California and the shores of the Gulf of California: a total of about 2,000 miles of coastline.

There is a certain resemblance between the littorals of the Gulf of California and of the northern half of the Red Sea in similar latitudes. Both are marked by hot summers of high humidity and near-tropical winters. Rainfall is considerably greater in the Mexican area, however, and in addition there is a much larger supply of surface and ground water as a result of rainfall in the mountain ranges of Sonora and Sinaloa east of the gulf. There are larger tracts of good alluvial soil at the head and east side of the gulf than along the Red Sea. West of the gulf, however, there are only small patches of level land, with little water available for irrigation.

The Gulf of California has not been a great international thoroughfare like the Red Sea since the dawn of history, but rather an isolated cul-de-sac. On the other hand the Red Sea has no areas of mild summer climate comparable to those of the west coast of Baja California. Unfortunately, the west coast has very little water available for irrigating its only two large tracts of level land.

The greatest temperature contrasts within the coastal deserts of north-western Mexico are between the west coast, and especially the north-west coast, of Baja California, facing the Pacific Ocean, and the sheltered shores of the Gulf of California. The relatively cool water of the open ocean, combined with prevailing on-shore winds, keep the summer daily maximum temperatures at least 9° F. cooler on the west coast than on the gulf coasts (Table 7). In winter, the west coast is warmer than the east. Tropical climate, with mean January temperature above 64.4° F. (18° C.), starts near Bahía Magdalena, Loreto, and Guaymas.

Rainfall is greatest in the north and south, least in the centre. There are sharp regional contrasts in the season of occurrence of rainfall, too. In the north the rainfall is of winter Mediterranean type, while in the south the rain is chiefly of tropical or convectional origin, concentrated in summer, often in connexion with violent hurricanes. Occasional light winter rains extend even to the southern edges of the desert, and more rarely a tropical storm intrudes into the far north in summer. Stations of intermediate location, such as San Ignacio, receive some rain in both seasons but little in either.

In Baja California the concentration of water in the north and south has led to the historic political division of the peninsula into northern and southern administrative areas separated by a seldom-traversed desert wilderness. The dividing line lies in the midst of this wilderness, at 28° N. latitude. Until recently neither the northern nor the southern district had the 80,000 population necessary for the creation of a state in the Republic of Mexico. A recent surge of immigration in the north, however, resulted in the creation of the State of Baja California Norte in 1952. Baja California Sur, with a population of only 60,495 in 1950, is one of the two remaining *distritos* of Mexico.

On much of Baja California there is a fairly abundant growth of desert vegetation, especially on arroyo floors where the water table is near the surface and in a belt along the west coast within reach of fog and moist sea air. Cactus and other succulent and woody plants predominate, though the occasional rains bring forth a brief growth of herbaceous plants.

Before the occupation of the peninsula by the Spaniards, starting in 1697, the wild vegetation and associated animal life supported a sparse population of Indians. The Indians were entirely non-agricultural. Their food included the fruit of several species of cactus, the roasted heart of the agave, and numerous types of seed and root. Small rodents were numerous and rabbits were particularly important sources of meat. Larger grazing mammals, including deer, antelope, and mountain sheep, were also caught. Quail were caught throughout the year, and geese and ducks were available on some of the western lagoons in winter. Greatest resources of wild food were provided by the sea, and the Indian population was especially dense along the coasts. Extensive large mounds of shells attest the importance of clams, mussels, abalones and other shellfish in the native diet. Surplus shellfish were dried and stored for later use. Fish were caught by various means. Large turtles were numerous along the southern coasts, and occasionally whales cast up on the shore provided a supply of meat for hundreds of Indians. The bays of the southwest, including Magdalena Bay, are favoured breeding grounds for whales.

Most of the original types of wild food are still available in Baja California, though they are much less used today than formerly. The native Indians have disappeared without descendants except in the semi-arid lands of the far north, and have been replaced by agriculturists and pastoralists from the mainland of Mexico, whose culture places little dependence upon direct consumption of products of the natural landscape. Natural deposits of salt are worked on Carmen Island, San Quintín, and elsewhere. The bark of certain native trees is used in tanning. Some years ago there was a flourishing industry along the west coast, particularly at Magdalena Bay, in the gathering of *orchilla* (*Rocella*), a long grey lichen epiphyte that flourishes within reach of the moist ocean air. This lichen, gathered for making dyes, has long since been replaced by aniline dyes.

The strikingly abundant sea life has been exploited chiefly from sources outside Mexico, though turtles and clams continue to be gathered from the land base. The number of whales has been greatly reduced by the activity of whalers. Large-scale fishing is carried out on the west coast by vessels based upon the United States ports of San Diego and Los Angeles, but fishing in the Gulf of California has been little developed to date.

Today the raising of livestock is the most widespread occupation of Baja California, and agriculture supports the greatest number of people. An important limiting factor for grazing is the lack of drinking water over much of the peninsula, especially in the centre. Even in the better-watered north and south the water holes are often too far apart for sheep, and cattle are the principal type of livestock.

Agricultural possibilities are limited by the scarcity of surface and ground water. The best supplies in Baja California are in the north and south, where high mountain ranges with considerable amounts of rainfall result in seasonal floods in the 'arroyos' (wadis) that lead down to the coast. Though much of this flood water runs wasted to the sea, some of it replenishes the ground water *en route* and results in a few valuable springs or in ground-water levels high enough to permit the successful drilling of wells.

At the rare localities where water is available, highly fertile oases have developed. Crop possibilities at these oases vary considerably in accordance with climatic differences. In north-western Baja California (Sector 29), the cool Mediterranean temperature regime favours wheat, barley, and beans near the coast where summer temperatures are reduced by cool winds and morning fog, and such fruits as grapes, figs, olives, oranges, and pears in the warmer areas a few miles inland. Nearly all the cultivated land in this sector lies north of 30° north latitude, the approximate southern limit of well-watered mountains that provide ground water and seasonal floods. The irrigation is confined largely to the floors of arroyos, chiefly at sites of missions established by the Dominican Fathers in the late eighteenth and early nineteenth centuries. There could be considerable increase in cultivated acreage if some of the surplus winter run-off were stored by means of dams in canyons of the arroyos. The largest lowland in the north-west is the Llano de San Quintín, where a plain of about 100 square miles borders the sea, with a few small spots of successful agriculture based upon wells. South of 30° N. for 150 miles the littoral has such rough eroded land and so little water that there is no agriculture. For this wild desert there are no climatic records; from Ensenada to San Ignacio, a distance of 400 miles, there is not a single weather station. With its mild marine climate, the littoral north of 30° N. has possibilities as a resort area, though this aspect has been little exploited south of Ensenada.

In south-western Baja California (Sector 30) the hotter summers, especially away from the immediate coast (Fig. 7), permit the growth of hot desert and tropical crops. San Ignacio, in a spring-fed valley, is famous for its great groves of date palms, and represents the northernmost commercial stand of this fruit on the western slope. In California of the United States east of the coastal mountains, dates are raised even beyond 36° north latitude. In the Cape area, south of about 24° 30′ N., sugar-cane is the major commercial crop. The cane is processed by crude methods and retailed in the form of hard brown pieces known as 'panoche'. Sugar-cane is the main crop at the flourishing stream oases of Todos Santos and San José del Cabo. At San José del Cabo, where there is a permanent river and where the mean temperature of the coldest month is 68° F., even coconuts and bananas are raised. A wide variety of subtropical fruits are grown locally. Comondú, for example, is particularly well known for its fig groves, and to a lesser extent for its raisins, dates, and sugar.

The south-western sector contains the two largest plains of the Pacific slope of Baja California, the Vizcaino Desert and the Magdalena Plain (Nelson, 1921). These lowlands, each of five or six thousand square miles, include sizable areas of excellent soil, but are deficient in water and consequently are almost entirely unused except at a few points on the eastern and southern edges. A few good springs or wells are used near the foot of mountains at the inner edge of these plains, especially the Magdalena plain, and it is possible that further exploration would reveal additional water

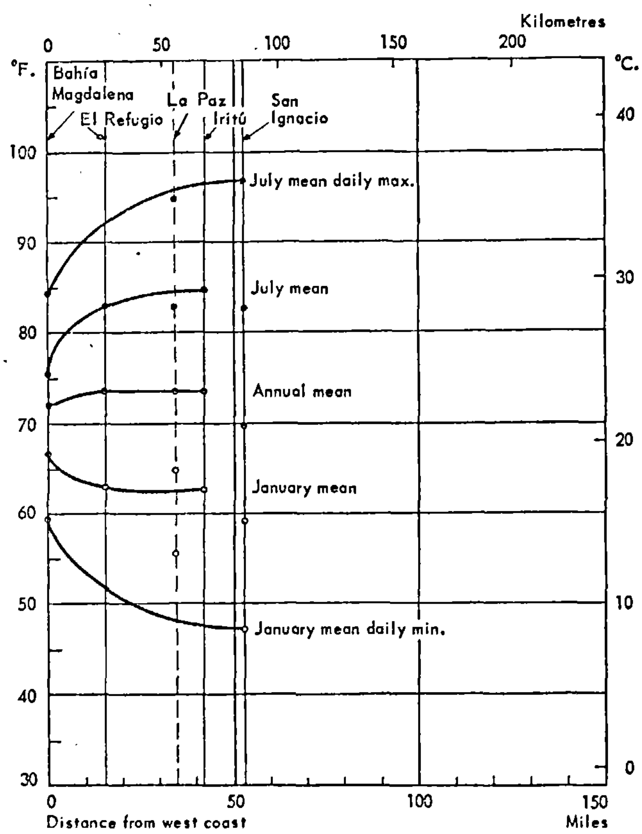


FIG. 7. Profiles of temperature, Baja California.

resources, but there is little chance that most of the surface can ever be used, unless the desalinization of sea water becomes economically feasible, or unless some means is found of impounding the water from the annual hurricanes. Magdalena Bay, one of the most magnificent natural harbours of the entire Pacific, remains largely unused.

Special mention should be made of the hurricanes, locally known as 'chubascos', that visit southern Baja California once a year on the average.[1] These violent rotating storms usually originate off the west coast of Central America or Mexico, between 10° and 20° N., and move north-westward, following the Mexican coast at varying distances off shore, and commonly recurving to the north-east near the Tropic of Cancer, crossing the southern portion of Baja California and dying out finally in the mountains of Sonora. September is the usual month of occurrence of chubascos, though they occur occasionally in August or October.

Violent winds of hurricane speed and tremendous bursts of rainfall are associated with the chubascos. Normal maritime contacts of the peninsula with the Mexican mainland are disrupted by the storms, which are so much dreaded that many navigators avoid activity in the exposed areas in the autumn. Many shipwrecks have resulted from these storms, particularly in the days before the development of radio broadcasting of storm warnings. Early records mention more than one expedition from the mainland to the peninsula as being lost *en route* by shipwreck in the autumn.

From the viewpoint of land utilization, the heavy rainfall is more important than the strong winds. More than half the mean annual rainfall in southern Baja California comes with hurricanes, a single storm often bringing several times as much rain as the annual mean. 'Mean rainfall' has but slight significance, especially when based upon short periods of record. At Bahía Magdalena, for example, the published mean annual rainfall (Contreras Arias, 1942) of 10.4 in. is based upon the four-year period 1937-40, which included the year 1939 when two chubascos brought 27.6 in. of rainfall in September: more than the combined rainfall of the other fourteen Septembers on record! The fifteen-year period 1936-50 shows a mean annual rainfall of 4.8 in. for this station (op. cit.). If the year 1939 had not been included, the annual rainfall would have been only 1.3 in. for the other fourteen years.

Heaviest rainfall is in the southern mountains, extending from near La Paz to Cabo de San Lucas and known collectively as the Serranía del Cabo. In the Sierra de la Victoria, the core of the Serranía, rising to heights of over 6,000 ft. rainfall is particularly heavy. In September 1939, for example, San Felipe received 24.8 in. of rain, and Santa Gertrudis

1. During the period 1931-43 at least 13 chubascos were reported for Baja California, occurring in 9 of the 13 years (Mexico, *Bol. Serv. Meteorologico*, 1953).

nearby had 40 in. in September 1949. Downpours such as these result in destructive floods. The arroyos, dry or nearly dry most of the time, are converted into huge rivers roaring down from the mountains for a few hours or days, and destroying everything in their paths. Floods from a chubasco in September 1941 washed out the villages of San Bartolo and San Lucas, with the loss of seventeen lives, and slashed a new highway at La Paz into ribbons, in addition to other unrecorded damage (Gardner, 1948, p. 152-65; Miller, 1943, p. 35; see also: *Boletín Anual del Servicio Meteorológico de México*, 1941, p. 2, 44, 49).

Most of the water from such floods pours into the sea, but a certain amount of it sinks into the floors of arroyos and adjacent lowlands and is added to the ground water. If a means could be devised to retain a portion of the flood water, to be used either for surface irrigation or for groundwater storage, a substantial increase in irrigated land would be possible. Already several valley floors near the coast surrounding the Serranía del Cabo have flourishing oases irrigated directly from the streams or from pumped wells.

The most extensive lowlands in this area consist of a pair of flat-floored valleys, separated by a low portion of the Serranía del Cabo: the Valle de La Paz and the Valle de los Planes. The former represents the low, southern end of the Magdalena Plain. It forms a long, narrow triangle, with the apex near the Pacific coast and the base 45 miles farther north along the Bay of La Paz. Its surface, of roughly 250 square miles, consists of slightly dissected alluvium, ending on the north in an almost flat area of about 20 square miles of alluvial plain near La Paz. The valley is crossed by several arroyos from the Serranía that borders it on the east. The Valle de los Planes, of similar area but less elongated, lies at the east base of the Serranía, north of San Bartolo. Some agriculture is carried on in parts of these valleys, but it is likely that sizable crop increases would be possible with systematic exploitation of the water resources. Surveys are needed of the extent of cultivable land, the distribution and rate of replenishment of ground water, and the possibility of retaining part of the occasional surface run-off. Although a useful but highly generalized description of the terrain of these valleys has been given (Hammond, 1954), details are lacking for all phases of land character and use.

Sector 31, the eastern littoral of Baja California, has little cultivable land apart from the valleys of La Paz and Los Planes previously described. Along most of this sector the mountains come down very close to the coast, with precipitous fronts, leaving little flat land. There are occasional small flats, especially between Santa Rosalía and Mulegé, at the mouths of short arroyos that descend steeply from the mountains. Some of those arroyos supply springs or ground water that permit the development of small oases, where tropical and subtropical crops respond luxuriantly to the high temperatures and intense radiation. Though rainfall is slight, humidity is said to be high and oppressive in summer. Where there are lagoons, small mangroves provide a natural growth nearly as far north as Santa Rosalía.

The two chief centres of population of this coast are La Paz and Santa Rosalía. La Paz, the administrative centre of Baja California Sur, was formerly the centre of an important pearl fishing industry in the Gulf of California. Since the decline of that industry, reportedly the result of a malady among the pearl oysters, La Paz has remained a small pastoral, agricultural, and tourist centre. In addition, the cattle resources of the surrounding area have led to the development of leather, shoe, and cheese manufacturing. Sport fishing in the Gulf of California has increasingly attracted sportsmen. Commercial fishing has developed very little, though at one time there was considerable activity in the procuring of shark livers at La Paz and elsewhere along the coast. Santa Rosalía is the outlet of one of the world's great copper mines, El Boleo, operated by a French firm and supporting a population of several thousand. Other mines, especially of gold, have risen and fallen from time to time, particularly in the Serranía del Cabo, inland of La Paz.

At the head of the Gulf of California the rocky, barren coast gives way to the vast alluvial lowland of the Colorado River, stretching northward into the United States. This delta area, Sector 32 of the present study, is even hotter in summer than the gulf coasts to the south, with mean daily maximum temperatures in July and August rising to 104° F. as illustrated by the border stations of Mexicali and Yuma (Table 7). Climatically it belongs to the category of extreme desert. The fertile soil, high temperature and abundant water from the Colorado River for irrigation have made possible important agricultural development, specializing in cotton growing but including also the production of diversified crops such as alfalfa, wheat, maize, tomatoes, and melons. A burst of development led to an increase in cotton acreage from 115,000 acres in 1940 to 400,000 acres in 1950, while cotton production rose from 60,000 to 265,000 bales. The influx of population, largely associated with the increased agricultural exploitation of the Colorado delta, made Baja California Norte the fastest-growing state of Mexico, with a rise of population from 78,907 in 1940 to 226,871 in 1950 (*Encycl. Brit.*, 1955). Mexicali, the capital of Baja California Norte, is a processing centre for cotton-seed and vegetables. All the irrigation water of the delta comes from the Colorado River, which heads in the United States and originally flowed into the Gulf of California. The United States is now able to control virtually the entire flow of the river by means of Hoover Dam and other works, but by international agreement a minimum of 1.5 million acre-feet (1,825,000,000 cubic metres) will be released annually for use of Mexico in Baja California.

The head of the Gulf of California is noted for the great height of its tides. At Puerto Peñasco (Sonora) the mean tidal range is 23 ft., and from earliest times explorers have been impressed by a spectacular bore in the lower Colorado River as the rising tide was translated into a great wave. It is not inconceivable that technology may some day be able to harness this vast potential source of power, though the lack of an established electric power network in the surrounding area is today one of the strongest deterrents from considering such development. It is interesting to note that the Indians of Baja California took advantage of the high tidal range to catch fish. Low stone walls were built almost across the entrances of lagoons, and at high tide these walls were completed, so that when the tide fell the water would trickle out between the stones while the fish were left stranded on the ground (Kniffen, 1931, p. 58; Meigs, 1939, p. 27; Nelson, 1921, p. 18). The abundant fish are exploited today to a slight extent by way of small fishing ports on both sides of the gulf.

In Sector 33 the hot desert extends along the east side of the Gulf of California through Sonora and into Sinaloa to about 25° N. This sector is the most highly developed agriculturally of any part of the northwest Mexican littoral, though there is still great scope for expansion of agriculture. The wide, flat coastal plain is rough and forbidding in much of the northern half, where it is extremely arid, but in places, especially in the southern half, the plain is made up of highly fertile alluvium 40 miles wide, needing only water to produce high yields of crops.

Water is available chiefly in the form of rivers that head in the Sierra Madre Occidental where the heavy rains of summer are concentrated by numerous tributaries into a few great streams. The principal rivers, from north to south, with the average annual flow of each, are as follows (Tamayo, 1949):

	Million cu.m.
Río Concepcíon	400
Río Sonora	600
Río Yaqui	3415
Río Mayo	1065
Río Fuerte	5420

Since pre-Spanish days, the Indians of this region have carried on agriculture in the river valleys, raising such staple crops as corn, beans, and cotton. They depended upon natural flooding by the rivers to moisten the soil. The use of natural flood water continues to be important, aided by the construction of large canals to conduct some of the flood water to the lands away from the river. Increasingly, however, the Federal Government of Mexico has been conducting a vigorous programme of water resource development, including the building of large storage dams on the principal rivers which make it possible to irrigate throughout the year instead of only following the summer floods. Water storage and irrigation have been developed most on the Yaqui River, which has two major dams; the 285,000 acres that were irrigated about 1948 have been expanded since. Hermosillo, the capital of Sonora, on the Río Sonora, and Navojoa, on the Río Mayo, are also important centres of irrigation. The Río Fuerte, though lacking large storage projects, has several prosperous agricultural centres, including San Blas, which obtain water through diversion of floods or through wells. Wells with powerful pumps have made it possible to develop the use of ground water rapidly and flexibly in many of the river valleys without waiting for the slow and expensive process of dam-building.

Among present-day crops cotton predominates, but there is a great diversity of other crops as well: early vegetables raised for sale in the United States, oranges and other fruits, and staple subsistence crops of corn and beans. South of Guaymas tropical conditions prevail, with mean temperature of the coldest month 64.4° F. or higher, and sugar-cane, bananas, and other tropical plants are important, especially in the Fuerte valley.

Tenure systems in use include individual land holdings as well as 'ejidos' or government co-operatives. An interesting episode in the development of agriculture was the attempt of 2,000 citizens of the United States to establish a co-operative colony near the southern edge of the region, at Topolobampo, starting in 1886. Under the leadership of the civil engineer Albert K. Owen the group, known as the Crédit Foncier of Sinaloa, carried on an energetic programme of development for a number of years in the tropical desert between Topolobampo Bay and San Blas, using water from the Río Fuerte (Robertson, 1947). Gradually the movement disintegrated owing to disunity and rivalry with private interests, but some of its members remained as individual farmers. One plan drawn up by Owen and supported by the Mexican and American Governments involved the construction of a railway from Kansas through Texas across Mexico to the port of Topolobampo: a short cut to the Pacific coast. Although much of this railway has actually been constructed from both ends of the line, the connecting portion through the Sierra Madre Occidental has not been completed to date.

Principal artery of transportation through the area is a railway paralleling the coast as far north as Guaymas and thence turning inland on a northern course to the United States. This railway has made possible the development of markets and hence of specialized agriculture. Vegetables and minerals are transported to the United States, cotton and sugar to the interior of Mexico, for example. Seaports, of which Guaymas is the principal one, are of less importance than the railway for the trade of the region.

Fishing of local importance has developed at several small ports, and has potentialities of great expansion, with establishment of modern processing plants. The Indians formerly caught fish by hook and line, by nets, and by spearing. In addition, at least in the Topolobampo area, fish were caught by means of brush fences across the outlets of lagoons, completed at high tide so that fish would be stranded as the tide fell. Turtles were also an important source of food for the Indians. A vestige of the aboriginal type of life remains on the island of Tiburon, where the Seri Indians continue to subsist by catching fish and turtles, hunting, and gathering wild plants.

On the mainland, the problems of production appear to have been solved, and continued expansion of crop production depends chiefly upon the economic development of the water conservation programme.

SECTORS 34 AND 35: THE NORTH-WEST PERUVIAN LOWLANDS AND THE PERUVIAN LOMAS [1]

Bordering the Pacific Ocean for 2,300 miles at the base of the Andes stretches the longest west-coast desert in the world. The southern part of the desert, in Chile, is known as the Atacama. The northern part, in Peru, has no accepted inclusive name, unless it be simply 'La Costa' (the coast).

The Peruvian desert littoral itself is strikingly lacking in unity. The economy of the sectors is based largely upon more than forty transverse valleys with streams large enough to be called rivers, heading in the Andes and obtaining enough water from mountain rainstorms and melting snow to flow all or part-way to the coast. The rivers differ greatly from one another in amount of water, seasonality of flow, fluctuation from year to year, and character of accessible irrigable lands. Maximum flow is during the southern summer (October to April), and many of the streams dry up completely during the winter. The water provided by these rivers, directly or through the intermediary of ground water, supports irrigation agriculture along the valley floors, the deltas by the coast, or the alluvial fans where the streams emerge from the mountains. Any comprehensive study of the potentialities of this region must study each of the valleys, for each has its own peculiarities of terrain, water regime, coastal relationships, and economic history (de Reparaz, 1958).

Though the land offers little unity, the sea and its associated climatic and biologic influences are strikingly uniform along the entire coast. Directly off shore is a belt of water abnormally cool for the latitude. Although associated with the northward-flowing Peru Current or Humboldt Current, the cold water belt consists actually of upwelling water from the deep layer of the ocean. Lowest temperatures of about 60° F. are found within a mile of the coast, and westward they rise steadily for at least 100 miles, to a level about 16° F higher. The temperature is remarkably uniform along the whole coast to Punta Pariñas, where the continent reaches its westernmost extent within less than 5° latitude of the equator.

As a result of the cool water off shore, and the prevalence of south-westerly winds, the littoral has a strikingly mild and uniform climate. The coolest month, usually August, averages above 59° F., while the warmest month, January or February, is from 68 to 81° F. (Table 8). At such temperatures, practically all temperate and subtropical crops are possible, provided water is available. As in other west-coast deserts, the cool water off shore gives such stability to the air that rainfall is slight or, in some years, nonexistent. Along most of the coast the mean rainfall averages from 0.5 to 2.0 in. But in winter, from June to October, there is a strong development of low cloud, of a type locally famous under the name 'garua'. The garua, a fine mist, forms a layer about 1,000 ft. thick, with its base between about 1,000 and 3,000 ft. above sea level. It furnishes enough water to support a growth of vegetation on any hills or mountains within its reach near the coast. In addition, the garua shuts out the sunlight for most of the time, resulting in chilly, gloomy conditions, and retarding evaporation in the land below it.

The cool water off shore has other profound consequences for human activity. The upwelling water supports a prolific growth of plankton, which in turn feed fish of many species and tremendous numbers. From the earliest times the fish have been an important source of food for the Peruvians. In addition, they support many millions of sea birds that crowd the desert islands up and down the coast. These birds, of which a type of cormorant, the guanay, is by far the most numerous, nest on the islands, where their droppings form the guano accumulations that constitute one of the most valuable resources of Peru. Such accumulations are possible only in deserts, where there is virtually no rainfall to erode the deposits. Although the guano deposits were used by the ancient Indian civilizations to maintain the fertility of the irrigated lands of the coastal desert in Peru, their great value was only 'rediscovered' in the mid-nineteenth century, at which time the guano had accumulated to depths of as much as 150 ft. on some islands. In the ensuing feverish 'guano rush', millions of tons were shipped to Europe, and the deposits were mined out in

1. See Map 12.

a few years, with no thought given to conservation of the sea fowl that made these riches possible.

During the last fifty years, however, the Peruvian Government, through the Companía Administradora del Guano, has sponsored the necessary conservation measures to encourage the multiplication of the guanayes, and the guano, now treated as a perpetual annual crop, yields more than 300,000 tons per year. Not only are the fifty or more guano islands set aside as bird sanctuaries, with guano harvesting permitted only at certain seasons, but positive measures are taken to encourage multiplication of the birds. Thus at some localities low walls are built to prevent the young birds from falling over the cliffs into the sea. To expand the overcrowded nesting areas, starting in 1946 the Government has walled off peninsulas of the mainland so that birds can breed without molestation by animal predators. In effect, this has already created ten or more new guano 'islands', most of them on the southern coast where true islands are lacking.

In recent years a new threat to the guano industry has appeared. The vast schools of anchovies that make up the chief food of the birds are now being harvested directly by fishermen through mass methods, to be dried, ground up, and sold as fresh meal for poultry and cattle feed. One of the big questions is the extent to which direct harvesting of the anchovies can be made without upsetting the ecologic balance that makes possible the production of guano. Already the Government has placed restrictions on this type of fishing (Murphy, 1925, 1959; de Reparaz, 1958).

A complicating factor in the ecologic balance enters the scene at irregular intervals: a warm countercurrent from the north, known as the Niño (Christ Child) because it appears about Christmas, when the solar heating system, along with its intertropical air masses, has moved south of the equator. The Niño annually flows southward 5° to 8° from the equator, over-riding the northern part of the Peru Current near the coast. Occasionally, usually at intervals of seven or more years, the Niño thrusts much farther south, sometimes even reaching Pisco, 14° S., where it is finally deflected seaward at the Paracas Peninsula. The abnormally warm water causes the plankton to remain far below the surface, in cooler water, or to die at the surface where they form great masses sometimes known locally as the 'Callao Painter'. The fish, in turn, die by the millions, and the birds, weakened by undernourishment and the effort of flying much farther than accustomed in search of live fish, sicken and die in such numbers that the guano crops drop disastrously, building back to normal only after a period of some years. The presence of the warm water off shore also gives the air an instability that sometimes results in torrential rain and floods in areas that may have had no rain for a year. In 1925, one of the worst Niño years, Lima had a rainfall of 60 in., as compared with an average annual rainfall of 1.8 in. Along the whole northern half of the coast there was more rainfall in March than during the preceding ten-year period (Marmer, 1951; Murphy, 1923; de Reparaz, 1958).

The attractions of mild climate, abundant water from the Andes, abundant fish everywhere off shore, vast deposits of guano to maintain soil productivity and nearby mineral deposits were taken advantage of to develop ancient centres of advanced civilization in the coastal desert 2,000 years before the Spanish conquest. Primitive agriculture may have started in this area as early as 3,000 B.C., with cotton and later maize among the chief crops, though sea food was the chief source of nutriment. From 1225 to 700 B.C., ceramics, textiles, architecture, irrigation and goldworking were developed. From 600 to 350 B.C., beans, llamas as beasts of burden, stone-walled terraces for irrigation, and copper-working entered the picture. Then arose one of the greatest American civilizations, which lasted from the fourth century B.C. to the tenth century A.D. Unlike the Egyptian, Mediterranean, and ancient Greek civilizations, the ancient Peruvian cultures were not ancestral to modern European-type culture and consequently have received little attention from Western writers, apart from the specialized academic circles. Furthermore they had no written language. However, they do provide valuable clues to the potentialities of coastal deserts, and they passed on certain economic institutions that still prevail in coastal Peru.

Many details of the material culture and chronology of the great coastal civilization of Peru were obtained from artefacts uncovered by the guano-quarrying between A.D. 1840 and 1880. The early Indians, in the course of their guano-gathering, left behind articles of gold, copper, textiles, and other materials that soon became buried and preserved under the constant accumulation of guano. We know that arts and crafts reached peaks of excellence, especially in pottery, textiles, and metallurgy in gold, silver, copper and alloys (bronze was never hit upon). Agriculture reached a level never subsequently regained in this region, through the use of thoroughly planned irrigation systems and intensive use of guano.

Although the great civilization extended throughout most of the Peruvian coastal desert, it involved numerous variants in the different irrigated valleys, most of which were separated from one another by sterile stretches of desert. Three distinct subculture areas have been recognized: the Mochica culture in the north, the Lima culture in the centre, and the Nazca culture in the south. The northern culture was the most extensive, reaching from about Rio Jequetepeque to Rio Casma, and centring in the great city of Chanchan, adjacent to the present-day city of Trujillo. Chanchan, a city of 200,000 people, has probably made more intensive use of sun-dried 'adobe' bricks than any other locality in the world. Adobe is, of course, well adapted to use in areas of slight rainfall. Great engineering works, including one canal 73 miles long, brought water from the Moche and Chicama rivers to irrigate the alluvial plain of Chanchan. Some of these canals have been rebuilt and are in use today, though large areas of formerly farmed land have not yet been brought back into irrigation. In the Nepeña valley, near the southern limit of Mochica culture, remains of a huge dam have been found. Guano was systematically used to extract maximum production from the intensively cultivated land. It was transported as much as 435 miles, from the Chincha Islands near Pisco, to the Chanchan farms.

Nazca culture in the south, in the basins of the Rio Grande and Rio Ica, lacked the advanced metallurgy of Mochica, but attained unsurpassed levels of excellence in weaving. It had its own distinctive pottery. The Lima culture, in the valleys of the Rios Chancay, Chillón, Rimac, and Lurín, was the most primitive of the three main culture areas of the period.

In the eleventh and twelfth centuries A.D., the great coastal cultures were overwhelmed by the Tiahuanacan group from the interior. In the thirteenth to fifteenth centuries there was another blossoming of coastal civilization, known as the Chimú culture. Chanchan was a major centre, but other small kingdoms flourished too. Then in 1470 the Inca conquest extended to the coastal desert, and in 1533 Pizarro conquered all Peru and brought to an end the whole highly organized civilization that he found (de Reparaz, 1958).

The modern cultures, like those of the distant past, still depend upon irrigation agriculture, fishing, guano, and llama travel off the main roads. Cotton and maize remain major crops, but two other chief crops, sugar cane and rice, are post-Columbian in this region. Iron ore and petroleum, unknown by the Mochicas, have been added to the exploited resources of the region. Hydro-electric power from the bordering mountains is another new source of energy. Yet the present-day population of Peru, about 11 million, remains less than that of the ancient Mochica and Inca periods. As in those times, the coastal desert has many nuclei of dense population.

THE NORTH-WEST PERUVIAN LOWLANDS

Although the landscapes differ from valley to valley, a broad subdivision of the coastal desert of Peru can be made on the basis of terrain, climate, resources, and land use, into a sector from Trujillo north-westward and a sector southward from Trujillo. The north-westward sector, with a combination of level land and abundant though poorly distributed river water, is the most under-utilized part of Peru agriculturally.

Trujillo is near the southern end of a continuous coastal lowland that extends northward to the frontier of Ecuador. The southern part of the plain, made up of deltas of the short transverse rivers, averages only about 10 to 15 miles wide. Near Chiclayo the coast makes a sharp bend towards the west - north-west, and the coastal plain expands rapidly to a width of about 100 miles. The wide northern plain consists mostly of a waste of shifting sands, part of which, within the great bend of the Piura River, is known as the Sechura Desert. The town of Piura and the Rio Piura are 120 miles north-west of Chiclayo. An irrigated oasis has existed along the Rio Piura since pre-Spanish times, but the erratic fluctuations in volume of flow from year to year are a serious handicap to agriculture. In 1950 and 1951, for example, the Rio Piura was dry and no water at all reached the cultivated lands, and 1952 was little better. In 1953 water was brought by a new canal from the nearby Quiroz in sufficient quantities to save the crops. In addition, the Rio Piura had an unusually good flow that year. It has been estimated that the cost of diverting water from the Rio Quiroz to the Piura Valley was repaid in a single year by the value of the additional cotton produced. A plan to divert Quiroz river water had been proposed sixty years earlier (Eguiguren, 1895a, vol. 13, p. 4). Lacking glaciers and snowfields in the mountains where it rises, the Piura is without the stabilizing factor of melting snow and ice. Even in normal years the volume of flow is not usually sufficient to reach the coast.

Despite its undependable water supply, the Piura Valley produces substantial amounts of a variety of crops: cotton and rice in the lower portions, and subsistence crops such as maize nearer the mountains. Long-staple cotton is the major crop along the Piura, as it is also along the next main river north, the Rio Chira. The Chira has the greatest average annual flow of any stream of the coastal desert of Peru: 4.5 million acre-feet (5,500 million cubic metres), about nine times as much as the Piura. With a longer course in the mountains than the Piura, the Chira has the further advantage of lying within the southern margins of tropical rains. The Tumbes, northernmost river of the Peruvian coast, rises in Ecuador and, despite its short course, has about seven times as much run-off as the Piura. The use of the large volume of water of these two northern rivers is limited by the small amount of land in the valley floors. Considerable expansion of cultivated acreage would be possible if the water could be raised to the height of the surrounding plain. The northern part of the plain, between the Piura and the Tumbes rivers, is elevated, and the rivers flow in deep valleys.

Agriculturally, the north-western lowlands sector has certain climatic advantages over the rest of the coastal desert. The climate is truly tropical, and such tropical plants as coconut palms and tamarinds can be raised (Weberhauer, 1945) (see Table 8, Lambayeque and Chiclayo). Rainfall, related to the annual appearance of the Niño off shore and concentrated in the summer period, especially January to April, is enough to support sparse desert vegetation, grading into woody steppe brush from Piura northward. Algarroba (*Prosopis dulcis*), a mesquite with edible pods, and faique (*Acacia punctata*) attain the size of small trees, and are important sources of fuel (Eguiguren, 1895b). A semi-arid climate north of Piura extends into Ecuador along the outer coast, at least as far as Ancon. The sun shines about twice as many hours per year as in the foggy deserts of the central and southern sector. It is not surprising, then, that the principal Peruvian production of sugar cane, cotton, and rice comes from this sector.

Besides irrigated cotton, some cotton in the Piura area is raised upon natural rainfall and high-level ground water. The rainfall agriculture varies greatly from year to year, in accordance with the widely fluctuating rainfall. A qualitative examination of 100 years (A.D. 1791-1890) showed 68 dry years (11 in succession once), and 28 years classed as 'regular', 'good', or 'extraordinary'. In the ten extraordinary years, only two of which were in succession, damage from downpours and floods was extensive (Eguiguren, 1895b).

In addition to the Piura-Chira complex in the far north, and small oases at the foot of the mountains east of the main lowland, there are two other major oasis complexes in the northwestern sector: at Chiclayo and at Trujillo, in the southern, narrow part of the plain on coalescing alluvial fans. The Chiclayo district consists of an intensively irrigated coastal plain, using water diverted from the Sana, Chancay, and de la Leche rivers, supplemented by supplies brought through Andean ridges by tunnels from headwater streams of the Amazon system. Sugar cane is produced on the upper parts of the river alluvial fans, rice on the lower parts where the soil is heavier and more retentive of water. This is the principal rice-producing district of Peru. The average and yield of rice fluctuate in accordance with the yearly volume of water. The Trujillo district, the southernmost part of this sector, uses the water from the Moche and Chicama rivers to irrigate their alluvial fans. This district, where the great Mochica culture reached its apex, is now the leading producer of sugar cane in Peru. The sugar is produced on large corporate-owned estates, among which are situated the crushing mills (James, 1959, p. 195-6).

Another factor that distinguishes the northwestern sector from the rest of Peru is the production of petroleum north of Paita. The oil is refined at Talara, the port of the oil field. Thus a measure of industrialization is introduced, creating a market for varied local agricultural products, while at the same time making available additional actual and potential natural resources for northwestern Peru.

The ports are vital to the development of the land, for they are the chief trade contacts with the rest of Peru and with foreign countries. Three commercial ports stand out, in addition to numerous smaller ones: Talara, the oil port; Paita, the outlet for the Piura and Chira oases; and Salaverry, serving Trujillo. These three are also among the seventeen fishing ports of northwestern Peru. The two major fishing ports, however, are Sechura and Pimentel. Sechura is near the mouth of the Piura River. The continental shelf, outlined approximately by the depth contour of 200 metres on Map 12, is fairly wide in Sechura Bay and Paita Bay, and food fish such as mackerel are abundant. Sechura also produces salt by evaporation, important for the fishing industry, where salting and drying are the traditional means of fish preservation. Canning is increasing, and freezing offers great potentiality for the future when electric power and refrigeration are more fully developed and used. South of the Sechura fisheries, the continental shelf widens into the main fishing banks of Peru, the northern part of which is exploited by little fishing ports from Trujillo northward. Pimentel, a port of Chiclayo, is the main fishing centre of this part of the coast (Fiedler, 1943).

SECTOR 36: ATACAMA DESERT[1]

DEFINITIONS AND LIMITS

The Atacama Desert of northern Chile is the driest coastal desert in the world. At several weather stations many years go by without any rainfall, and the mean annual rainfall at Arica and Iquique is less than .04 in., or practically none (Table 8). Strictly speaking, only a small portion of this region is a coastal desert. Coast Ranges run the whole length of the desert, rising steeply almost from the water's edge to summits of 3,000 to 3,500 ft. on the average. In one place, 110 miles north of Antofagasta, a summit above 7,500 ft. lies only three miles from the ocean (Rich, 1941). Only the sea-facing slope of the Coast Ranges experiences temperature and wind conditions of a truly maritime character. There are very narrow wavecut platforms or terraces along much of the coast, seldom more than a few hundred yards wide, and the zone below 200 metres in elevation appears on Map 13 as a narrow ribbon. Plant geographers have esti-

1. See Map 13.

mated the width of the 'coast region' as being about 30 miles: approximately the average width of the Coast Ranges (Reiche, 1907).

Like the Peruvian desert, the Chilean desert is the result of atmospheric stability associated with the cool Peru current off shore and the semi-permanent south Pacific high. Although heavy fogs and high humidity are the rule, conditions do not favour rainfall.

The extreme desert extends inland an average distance of about 75 miles, ranging from 50 to 100 miles. Even up to about 8,000 ft. on the slopes of the Andes there is virtually no vegetation (Bowman, 1924). It includes three parallel zones: the Coast Ranges, a Longitudinal Depression, and the lower slopes of the Andes. Strictly speaking, only the Coast Ranges are a true coastal desert.

The best-known desert area of Chile is the series of flat-floored basins that forms a longitudinal depression just east of the Coast Ranges. This trough-like feature contains the 'salares' with nitrate deposits. In a broad sense this might be considered part of the coastal desert, but by most objective standards it does not qualify, though there is no difference in amount of rainfall. The floor of the depression lies about 2,000 to 3,500 ft. above sea level, and the climate is continental in contrast with the marine climate of the outer coast ranges. Annual ranges between maximum and minimum temperatures are more than twice as great as along the coast. Thus Canchones, 45 miles from the coast, in the Longitudinal Depression, at an elevation of 3,150 ft., has a mean daily maximum temperature in January of 90° F. compared with 77° F. at Iquique, and a mean daily minimum temperature in July of 32° F. compared with 55° F. at Iquique (Table 8).

Much more solar radiation is received in the interior than on the coasts, as the following tabulation (Of Mét. Chile, 1954) suggests:

	Number of days							
	Clear			Cloudy			Rainy	Frosty
	Jan.	July	Year	Jan.	July	Year	(year)	(year)
Iquique	8	1	66	4	17	113	1.6	0
Canchones	12	25	264	2	0	8	1.1	72

The contrasts are particularly strong in winter.

Northward, the desert of Chile merges into the Peruvian coastal desert. Southward there is disagreement as to where the desert ends, partly because of lack of agreement on terms such as arid, desert, and semi-arid. Rainfall increases southward, but so gradually that even Caldera, 600 miles south of Arica, receives only about 1 in. per year. The traditional southern boundary of the Atacama is Río Copiapó, which flows to the ocean just south of Caldera (Murphy, 1923). Vallenar, on Río Huasco, 90 miles southward of the town of Copiapó, with annual precipitation of 2.52 in. is a better southward limit of extreme desert in several ways. For one thing, from Vallenar southward there is some rain every year, as Bowman (1924) pointed out, though he called the area south of Vallenar 'semi-arid'. Lauer (1960), on the basis of twelve arid months, extends the 'vollarid' or extreme arid to Vallenar. Emberger *et al.* use the same limit for their driest desert inland. Owing to the weight they give to humidity, however, they do not show any extreme deserts along the immediate coast of Chile or other west-coast deserts such as the Namib, or Baja California, even though they have virtually no rainfall (Emberger *et al.*, 1962). Finally, Rich (1942) noted from the air that from just south of Vallenar northward the desert basins of the Longitudinal Depression are undergoing alluvial aggrading, while southward erosion is reducing the floor of the depression.

Southward of Río Huasco, then, a normal arid area prevails. This area is known as 'Monte Chico' (Amiran, 1960). Lauer (1960) calls it 'Kleinen Nordens', and cites La Serena as a typical station in this 'semi-desert' area. On the basis of nine or more dry months, Lauer maps arid climate as extending to within 45 miles of Valparaiso on the coast, and almost to the outskirts of the city of Santiago in the interior. With 14.1 in. of precipitation (U.K. Met. Office,* 1958), and winter rainfall, Santiago is far outside the desert limit of most classifications, as is Zapallar on the coast 40 miles north of Valparaiso. On the basis of rainfall and of vegetation, the mouth of Rio Limarí, 60 miles southward of La Serena, might be taken as the approximate southern limit of the 'regular' desert. Emberger *et al.** (1962) use about the same limit, based upon fewer stations. It is about here, at 30° 30′ S., that mesophytes replace xerophytes in the vegetation (Reiche, 1907). This would outline a normal desert area for about 260 miles southward of the extreme desert of the Atacama. Still farther to the southward the area could be called semi-desert or semi-arid, according to the classification used, until the true Mediterranean climate of central Chile is reached. At present dogmatism must be avoided in defining all the southern limits.

REGIONS

The greater part of the population of the extreme desert of Chile lives in the narrow strip along the immediate coast at the foot of the Coast Ranges. The climate is salubrious enough, with fresh, moist breezes from the ocean, and mild temperatures winter and summer (Table 8), though somewhat dreary from cloud and fog in winter. However, the almost rainless coast of 18° 30′ to 29° S. has little intrinsic potentiality for development. It has neither the land nor the water for agriculture. Mineral resources are lacking, except for the iron ores mined at El Tofo, near the southern end of the desert, 30 miles north of La Serena. The continental shelf is narrow and fisheries are not as prolific as those off Peru. Besides, there are no good natural harbours to give anchorage and protection against the south-westerly winds to fishing or other vessels. Arica has the best fishing grounds and fishing activity. Despite these handicaps, a number of important seaports have developed, perched on small widenings of the narrow marine terraces. These towns exist solely to export mineral products from the interior and to carry on other needed trade for inland communities. Their geographic asset is their location relative to their hinterland.

Two ports of the desert coast are outlets for countries beyond the borders of Chile. Arica is the rail terminus for La Paz, and by international agreement Bolivia, which has no outlet of its own on the sea, is entitled to the continuous use of the railway and port. It is also the port for Tacna, Peru. It is an exporter of minerals, llama wool, and hides from the mountains. It also has a local area of irrigation producing such crops as alfalfa, cotton, and oranges. Antofagasta, the largest city of the Atacama, with over 60,000 people, has direct rail connexions with Salta, in Argentina, via a trans-Andean railway completed only in 1948, as well as an older rail connexion to Bolivia by way of Calama. It is one of the chief outlets for nitrates from the Longitudinal Depression, and the port for the great Chuquicamata copper mines in the lower Andean slopes near Calama. Municipal water supplies are piped to Antofagasta 120 miles from Río Loa near Calama: the only river that is able to flow across the Longitudinal Depression and the Coast Ranges to the ocean. Antofagasta is connected with the widest flat of the entire coastal fringe, created in the form of low pediment rocky surfaces and plain behind the shelter of an isolated fault-block mountain 20 miles north of the City, Morro Moreno, that rises 4,163 ft. above the sea and has saved the flats from being destroyed by the waves as they have along the rest of the coast. The flat is adequate for an airfield. Incidentally, the terraces of Morro Moreno at one time had important deposits of guano, probably accumulated when the mountain was still an island (Reiche, 1907).

At nine other places railways cross the Coast Ranges to the sea, mostly to serve the nitrate fields. The railways represent engineering feats, zig-zagging up the steep seaward side of the mountains, for the few canyons that traverse the Coast Ranges are too narrow, steep, and rugged to be used as transportation routes. The largest of these other rail termini are Iquique and La Serena, with about 40,000 inhabitants. Iquique is primarily an outlet for the nitrates and other products of the Longitudinal Depression. It is also the centre of a local fishing industry, and does some fish canning. It gets its domestic and industrial water supplies from the lower Andes at Pica, by means of a 55-mile pipe-line (*Columbia Lippincott,** 1961). La Serena, in contrast, is an outlet for the irrigated Lands of Chico Norte, south of the extremely arid basins of the Atacama nitrate fields.

All the deserts ports, even the largest, have to depend upon lighters to transport freight to and from ocean-going ships lying off shore. At times stormy weather forces a suspension of activity for two or three days.

The Coast Ranges themselves consist of faulted masses of rock, completely devoid of vegetation, sometimes with local basin fills between ranges, in a typical basin-and-range geomorphological pattern, and in other cases in massive undulating surfaces. In some areas the rock is worn into smooth, flowing curves, with little evidence of erosion caused by running water. In others, the pattern of water-worn gullies and channels might well come from a more humid region. Evidently there have been enough rainstorms, usually separated by many years, to have developed erosion patterns that have subsequently been preserved in the dry air. Possibly the differences in pattern are related to the type of rock material. In places, sand from the coast has blown into the Coast Ranges in the extreme desert. In the most extreme example, for many miles north and south of Río Copiapó, the south-westerly winds have blown the sand inland for as much as 17 miles from coastal beaches, filling shallow valleys and climbing the peaks 3,000 ft. above sea-level. The Coast Ranges drop abruptly into the ocean, rising, in the extreme case of a 90-mile stretch between Antofagasta and Taltal, in an unbroken front 6,000 feet high. On their east side, however, the Coast Ranges dip gently under the flat floor of the Longitudinal Depression (Rich, 1942, see photos).

The Longitudinal Depression in the Atacama Desert consists of a series of 'bolsones', or undrained basins, 25 to 50 miles wide. The floor of the bolsones is made up largely of vast alluvial fans that slope down from canyons in the Andes from which the gravels, sands, and clays have been eroded. It follows that the lowest part of the plain is at the edge of the fan on the western side of the bolsones, pressed closely against the base of the Coast Ranges. From the floor of the plain, which is 2,000 to 3,500 ft. above sea level, the Coast Ranges look like a low, hard-rock rim. The principal nitrate and other salt deposits, known as 'salares', have accumulated in the lower parts of the bolsones. Some of the best deposits of sodium nitrate, in fact, are now very near the hard-rock western rim, above the general level of the salar. Whatever the origin of the deposits, they have been the sole economic basis for occupation of the bolsones by man, and have for many generations supplied much of the fertilizer badly needed by the rest of the world for obtaining maximum yields from their agricultural efforts.

The Chilean fertilizer industry has suffered wide fluctuations owing to factors quite apart from the local resources base. In 1831, 110 tons were shipped to England; by 1860, 50,000 tons a year were exported; by 1895, 1 million tons. After a brief, drastic set-back caused by over-speculation in 1914, the First World War brought renewed demand for manufacture of nitroglycerin explosives as well as for fertilizer; shipments rose above 3 million tons per year, and there were about 65,000 workers in the salares. During the war, however, a method for extracting nitrogen from the atmosphere had been developed, and under the stimulus for national self-sufficiency the production of such nitrogen struck a severe blow at the Chilean industry. By 1931 Chile exported only 617,000 tons, and in 1932, at the bottom of the depression, only 60,000. Since then, through the aid of international agreements, Chilean production of sodium nitrate has climbed back above 1 million tons per year (Rich, 1942). More than half the world's iodine is produced in the Atacama as a by-product of nitrate processing.

Life is harsh in the nitrate fields. Hot days, cold nights, and dust are the common lot. All food and water must be brought in from outside, and only an organized exploitation of the resources is possible: the individual is helpless. A railway runs the length of the Longitudinal Depression, with links to the coast and connexions with the Andes foothills for water and food. The Río Loa, which transports water from the Andes to the coast, crosses the salares in such a deep canyon that its water is not accessible to the dessiccated plains above. Near the northern end of the depression, south of Arica, streams have cut across the plains, dividing it up into separate plateaux. Southward the first real river is the Copiapó, which has a valley floor wide enough to support a beautiful belt of irrigation below the general surface of the longitudinal plain.

Although the lower slopes of the Andes are as dry as the rest of the Atacama, there are running streams in the upper parts of many of the canyons. Most of these streams disappear before reaching the foot of the mountains, but they support a number of small oases, set deep in the mountains. The people of these oases, mostly Indians, live in isolation, irrigating enough crops for their own use. In the days of the Incas the oases served as stopping points along a north-south route from Bolivia to Copiapó. Even though the water does not reach the mouth of most canyons it continues to move slowly westward through the fan gravels, where it can be reached with wells in those few places where it is not too far below the surface. At one oasis, Pica, it is reported that ground water in the upper part of an alluvial fan has been tapped by a 'kanat', an underground tunnel dug at slight inclination so that the water can flow out by gravity (Kobori, 1960).

The only large oasis is that of Calama, at an elevation of over 7,500 ft., on Río Loa above the point where that river enters its gorge in the Longitudinal Depression. Here the temperatures are too low for subtropical crops, but wheat, corn, alfalfa and other crops of the temperate clime are produced under irrigation from the Loa. Its limited record shows no rainfall at all at Calama (Table 8).

The large-scale exploitation of copper at the Chuquicamata mines near Calama has given new business to that town and to the railway and port of Antofagasta. Chuquicamata, the world's largest known copper deposit, has developed a town of 25,000, with pipelines going far up the canyon into the mountains for water, originally brought by ox cart, later by railway, and now the pipe-lines. An earlier large copper mine, at Potrerillos, 300 miles south of Chuquicamata, is nearing exhaustion, but is being replaced by another about 15 miles away. Copper is now the chief commercial product of Chile. Revenue from the mines is a major source of income for the Government of Chile (Marcosson, 1957, chap. 9). The Río Copiapó, only transverse oasis of the Atacama Desert, forms an intensively irrigated green ribbon 90 miles long, with alfalfa, corn, grapes and other fruits. Copiapó, a city of about 20,000, is the centre of a mining district, too. South of it the extreme arid climate gradually gives way to the more normal desert, which starts at about Vallenar, with a rainfall of 2.52 in. Vallenar lies at the bottom of the broad Huasco valley, and forms another fruitful oasis. From there southward, in the Norte Chico area, there are small transverse streams with limited irrigated fields, set into a landscape of volcanic and agglomerate mountains. The mountains are aligned roughly in a north-south direction as is true throughout most of northern Chile. The Longitudinal Depression is here compressed into a relatively narrow trough.

A short distance south of Río Limarí the desert is replaced by a semi-arid zone with precipitation above 7.5 in., which in turn gives way to the verdant populous core of Chile, the Valley of Santiago, and the great port of Valparaiso, with a full Mediterranean climate. The desert region of northern Chile is, in a sense, an economic appendage to the centre of Chilean power, and its development will continue to be influenced by the power centre outside the desert.

SECTOR 37: EASTERN PATAGONIA

The arid zone extends along the entire length of Argentina, bordering the eastern base of the Andes and stretching eastward an average distance of about 350 miles into the plains. As the continent narrows southward, the southern half of the arid zone reaches all the way to the sea, forming a coastal desert and steppe along the Atlantic Ocean for 1,000 miles from approximately 39° to 53° south latitude (see Map 14). The Patagonian Desert has no counterpart among the world's deserts. It is the only east-coast desert in high latitudes, corresponding in position to the humid continental regions of New York, New England, and Canada's Maritime Provinces in North America, and northern Japan in Asia.

The unique aridity of Patagonia is the result of several contributing factors. Of primary significance is the presence of the Andes, a formidable barrier to the rain-bearing air masses that come prevailingly from the west. The tapering of the continent in these latitudes, the presence of the cold Falkland Current off the east coast, and the lack of a developed monsoonal system, contribute to the aridity of the region.

Though there is great diversity of opinion as to the classification and delimitation of the interior arid lands of northern Argentina, there is substantial agreement on the limits along the coast. Burgos and Vidal (1951, p. 30) have mapped the climates of Argentina according to the systems of Köppen, de Martonne (hydrologic regions), and both classifications of Thornthwaite. In all of them, the semi-arid climates start near Bahía Blanca (mean annual precipitation 20.6 in.), and extend southward to northern Tierra del Fuego. The desert climate is shown as starting between Viedma and San Antonio, and extending southward nearly to Puerto Gallegos, a distance of about 750 miles. The desert extends inland almost to the base of the Andes, a width of about 500 miles in the north and 150 miles in the south.

The inland margin of the coastal desert is not clear climatically. Patagonia consists of extensive plateaux, more than 3,000 ft. high in many places, sloping toward the sea. The increasing height inland closely balances the cooling effect of the immediate coast, so that pronounced temperature contrasts are lacking. Along much of the coast the plateaux end in cliffs, with a coastal plain narrow or lacking. Only in the far north is there an extensive coastal plain, with the 200-metre contour line 200 miles from the coast. The two great rivers of the north, the Colorado, which forms the traditional boundary between Patagonia and the Pampas, and the Rio Negro, have the broadest stretches of alluvial farmland. All the large rivers, including these, originate in the Andes or their adjacent lakes and flow across the plateaux in deeply incised valleys. It is in these valley floors, mostly quite narrow, that nearly all the agriculture and present-day settlements of Patagonia are found. The valleys provide accessible water for irrigation and shelter from the strong persistent winds that sweep across the plateaux (James, 1959). The plateaux are too high above the valley floors (100 to 300 ft.) for water to be lifted, even if the climate permitted.

Annual precipitation in the Patagonian Desert averages about 5 to 8 in., dropping to less than 4 in. at Arroyo Verde on the coast north of Puerto Madryn (Turnbull, 1961, fig. 8). This precipitation, fairly evenly distributed throughout the year, is insufficient to support agriculture, and in most of Patagonia grazing is the principal means of exploiting the climate and vegetation. In most of the desert, forage is poor and brushy, especially in midsummer, but along the moist western margins and in the cooler southern plains and valleys, there is good natural grassy steppe. Sheep do well on these lands, almost to the exclusion of other livestock, and wool is the export of most of Patagonia. The bearing capacity of the pastures is low. Even in the grassy plains of the south and west it requires 1 to 2½ acres to support a sheep, while the drier central and northern area takes about 5 to 15 acres per sheep (Cabrera, 1955, p. 100). Individual ranches have tremendous acreages, and a very sparse population. The headquarters of a ranch is usually in a sheltered canyon.

Larger settlements are either in the sheltered valleys or at points on the coast suitable for ocean shipping. The irrigation oases are largely confined to the valleys of the three northern rivers: the Chubut, the Negro, and the Colorado. South of the Chubut the mean temperature of the warmest month is below 68° F. and crop production is not feasible along the Rio Santa Cruz or Gallegos, though the mean of the coldest month remains above the freezing level. Frosts are fairly frequent along the whole coast in winter, and occur almost daily south of Comodoro Rivadavia in July. The principal irrigated crop of Patagonia is alfalfa, which has made possible some localized cattle-raising. Small diversion works for the rivers, or wells from the valley floors, are the source of water for most of the farms. In the valley of the Rio Negro modern irrigation works have been constructed with government and private funds, including storage dams and canals, and cultivation is more intensive. Though alfalfa is still the principal crop, the Rio Negro has become an important producer of fruit and wine. It is the principal pear district of Argentina, and its vineyards are of high quality. Expansion is largely contingent upon an increase of markets (James, 1959, p. 323-5).

The coast of Patagonia, smooth in outline, open to sea, and commonly backed by cliffs, has few good natural harbours. Puerto Madryn is the best-protected, aside from Punta Arenas on the Strait of Magellan, in Chile. High tidal range in the south, amounting to as much as 48 ft. at the Santa Cruz estuary, adds further complications to sea trade. Local shipment of wool and other products are lightered out to larger vessels at many points along the coast. Development of petroleum, originally and most importantly to date at Comodoro Rivadavia, has provided an additional source of revenue for Patagonia and a further need for coastwise shipping.

Finally, there is the potentiality of fishery developments on the broad, gently sloping continental shelf. The general slope of the plateaux continues even more gently eastward under the Atlantic Ocean. The 200-metre depth averages about 250 miles distant from the shore along the entire coast of Patagonia (Amer. Geogr. Soc., 1944). The utilization of the fish resources can hardly evolve from the pastoral, farming, or oil industries of the area. It will depend upon fleets from more distant ports to the north, or upon establishing and encouraging local fishing centres along the difficult Patagonian coast.

CLIMATOLOGICAL TABLES

TABLE 1. India, Pakistan, Makran

A. MEAN TEMPERATURE (°F.)

Station	Elev. (ft.)	Miles to sea	No. years rec.	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Veraval, India	26	0	30	71	71	75	79	82	84	82	80	80	81	78	73	78
Dwarka, India	37	0	20	69	70	75	79	83	84	82	80	81	80	77	70	78
Jamnagar, India	60	10	40	66	69	77	83	87	88	85	82	82	82	76	68	79
Rajkot, India	432	45	60	67	70	79	86	90	89	84	82	81	82	76	65	80
Bhuj, India	343	30	60	66	70	79	86	89	86	85	83	83	84	76	68	80
Karachi (Manora), Pakistan	13	0	65	66	69	76	81	85	87	85	83	82	81	76	69	78
Karachi (Drigh Road), Pakistan		9		64	67	76	83	87	88	86	84	83	82	75	68	79
Hyderabad, Pakistan		95	30	63	68	78	86	93	93	91	88	87	83	75	65	82
Bela, Pakistan		55		62	67	73	81	90	93	91	88	86	82	73	66	79
Ormara Pakistan	16	0	10	65	68	75	82	86	87	86	83	82	80	74	68	78
Gwadar, Pakistan	22	0	10	65	69	75	81	86	87	85	82	81	80	74	69	78
Chahbahar, Iran	26	0	10	66	69	74	79	85	87	87	84	83	81	75	70	78
Jask, Iran	13	0	38	67	69	74	80	85	90	91	89	87	83	76	71	80

B. MEAN DAILY MAXIMUM TEMPERATURE (°F.)

Station	No. years rec.	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Veraval, India	30	82	82	86	86	86	86	84	82	84	89	89	85	85
Dwarka, India	20	78	78	82	85	88	89	87	85	85	87	87	81	84
Jamnagar, India	40	79	83	90	96	98	96	91	88	89	94	89	81	89
Rajkot, India	60	83	86	95	102	105	99	91	89	92	96	91	85	93
Bhuj, India	60	79	84	93	100	101	97	91	88	92	96	90	82	91
Karachi (Manora), Pakistan	65	76	78	82	85	89	91	88	85	86	88	85	78	84
Karachi (Drigh Road), Pakistan		77	80	89	94	95	94	91	88	90	95	90	81	89
Hyderabad, Pakistan	30	76	81	92	101	107	105	100	96	97	98	89	78	93
Ormara Pakistan	10	73	73	83	90	93	93	90	87	87	90	85	77	85
Gwadar, Pakistan	10	73	77	83	89	94	93	90	87	88	89	84	77	85
Chahbahar, Iran	10	74	76	81	87	91	93	91	88	88	88	84	78	85
Jask, Iran	38	74	75	81	87	93	97	97	95	93	91	84	78	87

C. MEAN DAILY MINIMUM TEMPERATURE (°F.)

Station	No. years rec.	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Veraval, India	30	60	61	66	72	79	82	80	78	77	73	68	63	72
Dwarka, India	20	60	63	71	76	81	82	81	79	78	76	69	62	73
Jamnagar, India	40	52	56	63	70	77	80	78	77	74	71	62	55	68
Rajkot, India	60	51	54	62	70	75	78	76	75	73	69	61	54	66
Bhuj, India	60	52	56	64	71	77	80	78	76	75	70	62	54	68
Karachi (Manora), Pakistan	65	58	61	68	74	79	83	81	78	77	73	67	59	71
Karachi (Drigh Road), Pakistan		50	53	62	71	78	82	81	79	76	68	60	54	68
Hyderabad, Pakistan	30	50	54	64	72	78	82	82	80	76	71	60	52	69
Ormara Pakistan	10	56	60	66	74	80	82	81	79	76	71	64	59	71
Gwadar, Pakistan	10	57	61	66	73	78	81	81	77	75	71	65	61	71
Chahbahar, Iran	10	58	61	66	72	78	82	83	80	77	73	66	62	71
Jask, Iran	38	60	62	67	73	78	83	85	84	81	75	68	63	73

D. MEAN CLOUDINESS (tenths of sky covered)

Station	No. years rec.	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Veraval, India	50	1	1	1	2	3	6	8	8	6	2	1	1	4
Dwarka, India	40	2	2	2	2	3	5	8	8	5	2	2	2	4
Jamnagar, India	40	1	2	1	2	2	5	6	6	4	2	1	1	3
Rajkot, India	50	2	2	2	2	3	6	8	8	5	2	1	2	4
Bhuj, India	50	2	2	2	1	1	5	8	8	5	1	1	1	3
Karachi (Manora), Pakistan	32	3	2	2	3	3	5	7	8	5	2	1	2	4
Karachi (Drigh Road), Pakistan		3	4	3	3	3	6	8	9	7	2	3	3	4
Ormara Pakistan	10	3	3	2	2	2	4	7	8	5	2	2	3	4
Gwadar, Pakistan	10	4	4	3	3	3	4	7	8	6	3	3	4	4
Chahbahar, Iran	10	3	2	2	1	1	2	4	4	2	1	1	2	2
Jask, Iran	17	3	3	2	2	1	1	2	3	2	1	2	3	2

E. MEAN PRECIPITATION (in.)

Station	No. years rec.	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Veraval, India	50	*[1]	0.1	*	0	0.3	4.7	7.8	3.6	2.5	0.6	0.2	0.1	19.8
Dwarka, India	40	0.1	0.2	0.1	*	*	2.0	7.0	2.6	1.5	0.2	0.1	0.1	13.9
Jamnagar, India	40	*	0.1	0.1	*	0.3	2.6	8.9	3.8	2.2	0.3	0.1	0.1	18.6
Rajkot, India	60	*	0.1	0.1	*	0.5	4.1	10.7	5.1	3.3	0.6	0.2	0.1	24.8
Bhuj, India	60	0.1	0.2	0.1	0.1	0.3	1.4	6.3	2.9	1.8	0.3	0.1	0.1	13.6
Karachi (Manora), Pakistan	84	0.5	0.4	0.2	0.1	0.1	0.6	3.1	1.7	0.6	*	0.1	0.2	7.6
Karachi (Drigh Road), Pakistan		0.2	0.2	*	0.3	0.2	0.7	6.2	0.8	0.4	0	0.1	0.1	9.2
Hyderabad, Pakistan		0.1	0.3	0.3	0.1	0.2	0.4	3.4	2.1	0.9	*	*	0.1	7.9
Bela, Pakistan	29	0.4	1.0	0.6	0.6	0.7	0.5	2.8	1.4	0.6	0.1	0.1	0.4	9.1
Sonmiani, Pakistan	29	0.3	0.6	0.3	0.1	*	0.4	1.7	0.8	0.3	*	*	0.3	4.8
Ormara, Pakistan	29	1.4	1.6	0.3	0.5	*	0.4	0.6	0.4	*	0	0	0.7	6.0
Gwadar, Pakistan	10	1.5	1.2	0.6	0.3	0	*	0.3	0	0	0	0.2	2.3	6.4
Turbat, Pakistan	30	1.6	1.4	0.5	0.7	0.2	0.2	0.5	0.1	0.1	0.1	0.1	0.7	6.2
Chahbahar, Iran	10	2.2	0.6	0.3	0.1	0	*	0.2	0	0	0	0.1	1.2	4.8
Jask, Iran	38	1.2	0.9	0.6	0.2	0	*	*	0	0	0.2	0.3	1.2	4.7

1. * = 0.05 in. or less.

TABLE 2. Persian Gulf, West Arabian Sea, Red Sea littorals

A. MEAN TEMPERATURE (°F.)

Station	Elev. (ft.)	Miles to sea	No. years rec.	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Bandar Abbas, Iran	29	0	7	65	67	72	80	86	91	92	92	90	85	76	68	80
Henjam, Iran	100	0	9	65	67	72	78	84	88	91	91	89	85	77	69	80
Bushire, Iran	14	0	53	57	59	66	74	83	87	89	91	87	80	71	61	75
Abadan, Iran	7	35	10	54	58	66	76	88	93	97	97	90	81	69	58	77
Basra (Shaibah), Iraq	63	60	16	52	57	66	75	87	92	96	96	90	80	67	55	76
Kuwait		0	7	55	57	65	75	85	89	93	94	90	81	69	58	76
Bahrein	18	0	12	62	64	69	77	85	89	92	94	88	82	76	64	78
Sharja, Trucial Coast	18	0	11	64	66	70	76	82	89	91	92	88	82	76	68	78
Muscat	20	0	38	71	71	77	84	91	93	91	87	87	85	79	73	82
Masirah Island, Oman	53	0	11	72	73	78	83	87	86	81	80	79	80	77	72	80
Salalah, Oman	55	0	12	72	74	78	80	84	84	78	78	79	78	77	75	78
Riyan, Hadhramaut	82	0	13	74	76	78	81	84	87	84	84	84	80	78	76	80
Aden	94	0	40	76	77	80	83	87	89	88	86	88	84	80	77	83
Kamaran Island	20	0	26	78	78	82	84	88	90	92	91	90	88	82	79	86
Jidda, Saudi Arabia	20	0	5	75	75	77	81	85	86	89	89	87	84	81	77	82
Eilat, Israel	7	0	7	60	62	68	76	79	88	91	92	88	81	72	64	77
Tor, Egypt	6	0	39	59	60	65	71	78	83	85	85	81	75	69	61	73
Suez, Egypt	33	0	23	58	60	65	71	78	82	85	85	81	77	70	61	73
Daedalus, Egypt	13	0	12	72	71	73	76	81	83	86	86	84	82	79	74	79
Kosseir, Egypt	23	0	18	65	66	69	75	81	85	85	87	84	81	75	79	77
Dongonab, Sudan	16	0	12	71	71	73	77	82	87	89	90	87	82	78	73	80
Suakin, Sudan	15	0	25	74	73	75	79	85	90	95	96	90	84	81	76	83
Tokar, Sudan	66	15	28	76	76	79	82	88	92	95	95	92	87	82	78	85
Massawa, Eritrea	63	0	18	79	79	81	85	88	93	95	94	91	87	84	80	86
Assab	18	0	5	78	80	82	86	98	93	94	94	92	86	82	76	82
Djibouti, French Somaliland	12	0	51	78	79	81	84	88	93	95	94	91	85	81	79	86
Berbera, Somalia	45	0	25	77	77	79	83	88	96	97	96	92	84	80	77	86
Bender Cassim, Somalia	23	0	5	77	77	80	84	88	96	96	97	92	82	78	78	86
Cape Guardafui, Somalia	262	0	3-5	74	77	78	81	82	81	81	80	77	78	77	74	78
Socotra, Socotra	141	0	3	76	76	78	82	87	86	83	84	84	79	78	78	80
Obbia, Somalia	50	0	7	78	80	83	86	83	80	78	78	79	80	82	80	80
Mogadiscio, Somalia	39	0	27	81	83	82	84	82	80	79	79	80	81	82	81	81
Lamu	30	2	15	81	82	82	82	80	80	78	78	80	80	81	81	80
Lugh Ferrandi, Somalia	535	225		89	92	93	91	88	87	85	85	87	88	88	88	88

B. MEAN DAILY MAXIMUM TEMPERATURE (°F.)

Station	No. years rec.	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Bandar Abbas, Iran	7	74	75	81	89	97	101	100	100	98	95	87	77	89
Henjam, Iran	9	71	73	78	85	92	95	97	97	95	91	83	75	86
Bushire, Iran	53	64	65	73	81	89	92	95	97	94	88	78	68	82
Abadan, Iran	10	63	68	76	88	101	108	112	113	107	97	81	68	90
Basra (Shaibah), Iraq	16	62	67	79	89	101	107	111	112	107	96	80	66	90
Kuwait	14	61	65	72	83	94	98	103	104	100	91	77	65	85
Bahrein	16	68	70	75	84	92	96	99	100	96	90	82	67	85
Sharja, Trucial Coast	11	74	75	80	86	93	97	100	103	99	92	87	78	89
Muscat	38	75	76	81	89	96	98	95	91	91	91	84	78	87
Masirah Island, Oman	11	78	79	85	92	96	94	88	86	86	88	84	80	86
Salalah, Oman	12	81	82	86	88	90	89	82	81	84	87	86	83	85
Riyan, Hadhramaut	13	82	83	85	88	91	94	92	91	90	88	86	83	88
Aden	3	85	86	88	93	95	97	94	93	95	92	91	86	91
Kamaran Island	26	82	83	86	89	95	97	98	97	97	93	87	83	91

Station	No. years rec.	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Jidda, Saudi Arabia	5	84	84	87	91	95	97	98	99	96	95	91	86	92
Eilat, Israel	7	70	73	79	87	96	101	103	104	99	92	82	74	88
Tor, Egypt	30	69	71	76	82	88	92	93	94	89	84	79	72	82
Suez, Egypt	19	68	70	75	83	90	95	97	97	92	88	80	71	84
Daedalus, Egypt	12	75	75	77	81	85	87	90	92	88	86	83	78	83
Kosseir, Egypt	18	73	74	77	82	88	91	92	93	90	87	82	76	84
Dongonab, Sudan	12	79	80	83	88	94	100	102	102	99	92	87	81	91
Suakin, Sudan	25	80	80	82	87	94	102	108	107	100	92	87	82	92
Tokar, Sudan	28	84	84	88	93	101	108	108	107	106	97	91	86	96
Massawa, Eritrea	4	84	83	85	89	93	100	99	98	98	95	89	85	91
Assab	6	85	86	89	94	98	99	102	100	98	94	88	86	92
Djibouti, French Somaliland	51	82	83	85	88	93	100	103	101	96	90	86	84	91
Berbera, Somalia	25	85	84	86	90	96	107	107	106	102	92	89	86	94
Bender Cassim, Somalia	5	85	85	88	93	98	104	103	104	101	90	87	86	94
Cape Guardafui, Somalia	3-5	80	82	83	87	89	88	88	87	84	85	83	81	85
Socotra, Socotra	3	83	83	86	89	94	92	89	90	90	86	84	83	87
Obbia, Somalia	7	85	87	90	93	89	85	83	84	85	86	89	87	87
Mogadiscio, Somalia	27	89	89	89	91	88	86	84	85	87	87	88	88	87
Lamu	15	86	87	87	87	86	86	85	84	85	85	86	86	86
Lugh Ferrandi, Somalia		102	105	106	103	97	96	94	94	98	99	100	101	100

C. MEAN DAILY MINIMUM TEMPERATURE (°F.)

Station	No. years rec.	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Bandar Abbas, Iran	7	56	59	64	70	76	81	85	84	81	75	66	58	71
Henjam, Iran	9	60	61	66	71	77	81	85	85	83	78	70	63	73
Bushire, Iran	53	51	53	59	67	76	81	84	84	79	72	63	55	69
Abadan, Iran	10	44	49	55	64	74	78	82	81	73	65	57	48	64
Basra (Shaibah), Iraq	16	42	46	53	61	72	77	81	80	72	64	55	45	62
Kuwait	15	49	51	59	68	79	82	86	86	81	73	62	53	69
Bahrein	16	57	59	63	70	78	82	85	85	81	75	69	60	72
Sharja, Trucial Coast	11	54	57	60	65	72	77	82	82	77	71	64	58	68
Muscat	23	66	67	72	79	85	88	87	84	83	80	74	69	78
Masirah Island, Oman	12	65	66	70	74	78	78	74	73	72	72	70	68	73
Salalah, Oman	12	64	66	69	73	77	79	75	74	74	69	68	67	71
Riyan, Hadhramaut	13	67	68	70	74	77	80	77	76	78	72	69	68	73
Aden	3	73	75	76	79	83	86	82	82	83	78	75	74	79
Kamaran Island	26	74	74	77	79	82	84	85	85	84	82	78	75	80
Jidda, Saudi Arabia	5	65	65	67	70	75	75	79	80	77	73	71	67	72
Eilat, Israel	7	50	52	57	64	62	75	79	79	77	70	61	53	66
Tor, Egypt	30	48	49	55	61	68	74	76	76	73	65	58	51	63
Suez, Egypt	19	49	50	54	59	65	70	73	74	71	67	60	52	62
Daedalus, Egypt	12	68	68	70	73	77	79	81	82	81	79	75	71	75
Kosseir, Egypt	18	57	58	62	67	74	78	79	81	78	74	68	61	70
Dongonab, Sudan	12	63	63	64	66	71	73	77	79	76	72	70	66	70
Suakin, Sudan	25	68	67	68	71	75	78	83	84	80	77	75	70	75
Tokar, Sudan	28	68	67	70	72	74	76	81	83	79	77	73	70	74
Massawa, Eritrea	4	71	72	74	76	80	85	87	86	84	80	74	70	78
Assab	5	72	73	75	78	80	84	86	87	85	79	75	71	79
Djibouti, French Somaliland	51	73	75	76	80	83	86	87	86	85	80	77	74	80
Berbera, Somalia	25	68	70	73	77	80	86	88	87	83	76	71	68	77
Bender Cassim, Somalia	5	69	69	71	76	79	87	89	86	83	73	68	70	77
Cape Guardafui, Somalia	3-5	69	71	74	75	76	75	73	73	71	71	71	68	72
Socotra, Socotra	3	70	70	71	74	80	80	77	78	77	72	72	72	74
Obbia, Somalia	7	72	74	76	78	77	75	72	72	73	74	74	73	74
Mogadiscio, Somalia	27	74	78	76	77	76	75	74	73	73	75	76	74	75
Lamu	15	76	76	78	78	75	74	72	73	74	75	76	76	75
Lugh Ferrandi, Somalia		75	79	80	79	79	77	76	75	76	76	76	74	77

D. CLOUDINESS (tenths of sky covered)

Station		No. years rec.	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Henjam, Iran	08.00	9	4	3	3	3	1	1	2	2	1	1	2	3	2.2
Bushire, Iran	07.30	15-25	4	4	4	3	2	*[1]	1	1	1	1	3	5	2.4
Basra (Shaibah), Iraq	05.00	10	4	3	3	3	3	*	1	1	*	1	3	3	2.0
	16.00	10	5	4	4	4	3	1	1	1	*	2	4	4	2.7
Kuwait	08.00	7	4	4	3	3	2	*	*	*	*	2	3	4	2.1
Bahrein	08.00	14	4	4	4	3	2	*	1	1	*	1	3	4	2.3
Muscat	08.00	28	3	3	2	2	1	2	4	3	1	1	2	3	2.1
Aden	09.00	4	6	7	6	5	4	3	4	4	4	3	3	6	4.5
	15.00	4	3	3	3	3	3	2	2	2	2	2	2	3	2.5
Jidda, Saudi Arabia	09.00	5	3	2	2	2	2	1	2	2	1	1	1	2	1.7
	15.00	5	3	2	2	2	2	1	2	1	1	2	2	2	1.8
Tor, Egypt	Mean	41	2	2	2	1	1	*	*	*	*	1	1	2	1.1
Suez, Egypt	08.00	16	3	3	3	2	2	1	1	1	1	2	3	3	2.1
Daedalus, Egypt	Mean	16	2	2	2	2	2	1	1	1	1	2	2	2	1.6
Kosseir, Egypt	Mean	15	1	1	1	1	1	*	0	*	0	1	1	1	0.6
Dongonab, Sudan	08.00	10	3	2	2	1	1	1	2	2	2	1	2	3	1.8
Port Sudan	08.00	16	4	3	3	2	2	2	2	2	2	2	3	4	2.6
Suakin, Sudan	08.00	15	5	4	4	2	2	1	2	2	2	3	4	5	3.1
Djibouti, French Somaliland	08.00	5	3	3	3	2	1	1	2	1	1	1	1	2	1.7
Berbera, Somalia	08.00	17	4	4	3	2	2	1	2	2	1	1	2	2	2.2
Cape Guardafui, Somalia	07.00	3	8	6	5	4	2	3	5	4	2	3	5	6	4.3
Mogadiscio, Somalia	Mean(?)	3	4	4	4	4	4	5	4	4	3	3	4	4	3.9

1. * = 0.5 or less.

E. MEAN PRECIPITATION (in.)

Station	No. years rec.	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Bandar Abbas, Iran	8	2.4	1.2	0.3	0.2	0.1	0	0	0	*[1]	*	*	1.6	5.8
Henjam, Iran	9	0.9	1.5	0.7	0.6	0	0	0	0	0	*	0.1	1.2	5.0
Bushire, Iran	53	2.9	1.8	0.8	0.4	*	0	0	0	0	0.1	1.6	3.1	10.9
Abadan, Iran	10	1.5	1.7	0.6	0.8	0.1	0	0	0	0	0.1	1.0	1.0	7.6
Basra (Shaibah), Iraq	15	1.3	1.2	0.4	0.5	0.1	0	0	*	0	0.1	1.1	1.0	5.6
Kuwait	10	0.9	0.9	1.1	0.2	0.1	0	0	0	0	0.1	0.6	1.1	5.1
Bahrein	22	0.4	0.6	0.5	0.2	0.1	0	0	0	0	*	0.4	0.9	3.1
Sharja, Trucial Coast	12	0.9	0.9	0.4	0.2	0	0	0	0	0	0	0.4	1.4	4.2
Muscat	38	1.1	0.7	0.4	0.4	0	0.1	*	*	0	0.1	0.4	0.7	3.1
Masirah Island, Oman	12	*	*	0.2	0	*	*	*	*	*	*	*	0.4	0.6
Salalah, Oman	12	*	*	*	*	*	0.2	1.1	1.0	0.1	0.5	*	0.3	3.2
Riyan, Hadhramaut	13	0.3	0.1	0.6	0.2	*	0.1	0.1	0.1	*	*	0.7	0.3	2.5
Aden	40	0.3	0.2	0.5	0.2	0.1	0.1	*	0.1	0.2	0.1	0.1	0.1	1.8
Kamaran Island	21	0.2	0.2	0.1	0.1	0.1	<0.1	0.5	0.7	0.1	0.1	0.4	0.9	3.4
Jidda, Saudi Arabia	5	0.1	*	0	0.1	*	0	0	0	0	0.1	0.4	1.3	2.0
Eilat, Israel	10	*	0.3	0.3	0.2	*	0	0	0	0	*	*	0.3	1.1
Tor, Egypt	27	0.1	0.1	0.1	*	0	0	0	0	0	*	0.1	0.1	0.5
Suez, Egypt	25	0.1	0.1	0.1	*	*	*	0	0	0	0.1	0.2	0.1	0.8
Daedalus, Egypt	16	*	*	*	*	*	0	0	0	0	*	0.2	0.1	0.4
Kosseir, Egypt	19	0	0	0	0	0	0	0	0	0	*	0.1	*	0.2
Dongonab, Sudan	12	*	0.1	0	0	0.1	0	*	*	*	0.3	0.5	0.4	1.5
Port Sudan	29	0.3	0.2	*	*	*	*	0.2	0.2	0	0.6	1.8	1.0	4.3
Suakin, Sudan	45	0.7	0.3	*	*	*	0	0.3	0.3	0	1.0	2.8	1.7	7.1
Tokar, Sudan	15	0.8	0.2	*	0.1	0.1	0.1	0.2	0.1	0	0.3	0.7	0.8	3.4
Massawa, Eritrea	18	1.7	0.7	0.6	0.2	0.3	0	0.1	0.4	0.2	0.4	1.0	1.7	7.3
Assab	5	<0.1	<0.1	<0.1	<0.1	<0.1	0	0.2	<0.1	<0.1	<0.1	0.2	0.6	1.0
Djibouti, French Somalia	51	0.4	0.5	0.9	0.5	0.2	*	0.2	0.3	0.3	0.4	1.0	0.5	5.2
Berbera, Somalia	33	0.2	0.2	0.5	0.5	0.3	*	0.1	0.1	0.1	0.1	0.2	0.1	2.4
Bender Cassim, Somalia	5	*	0	*	*	0	*	0	0	*	*	*	0.2	0.4
Socotra, Socotra	3	0.1	0.1	0.4	0	0.1	1.2	0	0	0.1	0.4	2.0	3.2	7.6
Obbia, Somalia	7	0.5	0	0.3	0.8	1.3	0	*	*	0.1	1.5	1.0	1.0	6.5
Mogadiscio, Somalia	15	*	*	*	2.6	2.8	3.7	2.8	2.1	1.4	1.2	1.7	0.7	19.0
Bulo Burti	9	0.1	0.1	0.2	3.1	2.1	0.3	0.2	0.1	0.4	4.2	3.2	*	14.1
Bardera	9	0.1	0.5	0.8	4.1	2.8	1.2	2.0	3.0	0.6	3.3	2.3	1.3	21.0
Giumbo	9	*	*	0.1	1.9	1.8	3.1	2.6	0.8	0.6	2.0	1.2	0.2	14.2
Lamu	40	0.2	0.1	0.8	4.9	14.2	6.7	2.7	1.6	1.2	1.6	1.3	1.1	36.4
Lugh Ferrandi, Somalia	15	0.1	0.2	1.0	4.2	2.2	*	0.1	*	0.1	2.8	2.7	0.6	14.0

1. * = 0.05 in. or less.

TABLE 3. Part 1: Eastern Mediterranean

A. MEAN TEMPERATURE (°F.)

Station	Elev. (ft.)	Miles to sea	No. years rec.	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Gaza, Egypt	157	1	26	56	59	66	75	83	88	89	88	83	78	69	59	74
Beersheba, Israel	938	28	14	54	54	61	66	73	77	79	79	77	73	66	57	68
El Arish, Egypt	33	0	18	54	55	59	64	70	73	77	79	77	73	64	57	66
Port Said, Egypt	13	0	45	57	57	61	66	72	77	79	81	79	75	68	61	70
Rosetta, Egypt	7	43	17	59	59	63	66	72	75	79	81	79	77	79	63	70
Alexandria, Egypt	105	0	45	58	59	63	62	71	76	79	80	80	76	69	62	70
Damanhur, Egypt	20	19	17	57	57	63	66	73	77	79	81	77	73	68	61	70
Tanta, Egypt	46	50	19	54	54	59	66	73	77	79	79	75	72	64	57	68
Zagazig, Egypt	43	78	27	54	55	59	66	63	79	81	81	75	72	64	59	68
Delta Barrage, Egypt	66	93	22	56	57	61	68	75	79	82	81	77	73	66	59	70
Cairo (Ezbekiya), Egypt	66	106	42	56	59	64	70	77	82	83	83	79	75	68	59	72
Helwan, Egypt	381	124	42	54	55	61	68	75	81	81	81	77	73	66	57	70
Faiyum, Egypt	98	143	18	54	55	61	68	77	82	82	79	79	73	66	55	70
Shakshuk, Egypt	−141	130	18	54	55	63	70	77	81	84	84	81	75	68	57	70
Mersa Matruh, Egypt	23	0	24	56	57	60	64	68	74	77	78	77	73	67	60	68
Siwa, Egypt	−49	233	30	53	56	62	69	70	83	85	84	80	74	65	56	71
Sollum, Egypt	13	0	9	54	56	60	64	69	74	77	76	74	72	62	58	67

B. MEAN DAILY MAXIMUM TEMPERATURE (°F.)

Station	Elev. (ft.)	Miles to sea	No. years rec.	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Gaza, Egypt	157	1	21	65	66	70	76	81	85	87	89	87	84	77	69	78
Beersheba, Israel	938	28	14	64	66	75	82	90	93	95	95	91	88	81	70	82
El Aris, Egypt	33	0	18	64	68	70	75	81	84	86	88	86	82	73	70	77
Port Said, Egypt	13	0	45	66	68	70	74	80	85	88	89	87	84	77	69	78
Rosetta, Egypt	7	43	17	64	64	68	72	77	81	82	84	84	81	75	68	75
Alexandria, Egypt	105	0	45	65	66	70	74	79	83	85	87	86	83	77	69	77
Damanhur, Egypt	20	19	17	68	68	73	81	86	90	91	91	88	86	79	70	81
Tanta, Egypt	46	50	19	68	70	75	82	90	93	95	95	91	86	79	70	82
Zagazig, Egypt	43	78	26	68	70	75	82	90	93	95	93	90	86	79	72	82
Delta Barrage, Egypt	66	93	22	68	70	75	82	90	95	97	95	90	86	79	70	82
Cairo (Ezbekiya), Egypt	66	106	42	65	69	75	83	91	95	96	95	90	86	78	68	83
Helwan, Egypt	381	124	42	66	68	75	84	90	95	97	95	90	86	77	68	82
Faiyum, Egypt	98	143	18	70	72	77	86	93	97	99	97	91	88	81	72	86
Shakshuk, Egypt	−141	130	18	66	70	75	82	91	95	99	99	93	88	79	70	84
Mersa Matruh, Egypt	23	0	24	64	65	68	72	75	80	82	83	83	80	75	68	75
Siwa, Egypt	−49	233	30	67	71	77	86	94	100	101	100	95	90	80	70	86
Sollum, Egypt	13	0	9	63	65	69	74	77	83	86	85	83	81	74	67	76

C. MEAN DAILY MINIMUM TEMPERATURE (°F.)

Station	Elev. (ft.)	Miles to sea	No. years rec.	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Gaza, Egypt	157	1	24	46	47	50	54	60	65	68	69	67	63	57	50	58
Beersheba, Israel	938	28	14	41	43	46	50	58	61	64	64	61	57	52	46	54
El Arish, Egypt	33	0	18	45	46	50	55	59	64	68	70	68	63	55	48	57
Port Said, Egypt	13	0	45	51	52	56	60	66	71	74	75	73	70	64	55	64
Rosetta, Egypt	7	43	17	54	54	57	61	66	72	75	77	75	72	64	57	64
Alexandria, Egypt	105	0	45	51	52	55	59	64	69	73	74	73	68	62	55	63
Damanhur, Egypt	20	19	17	45	46	50	54	63	64	68	68	66	63	57	50	57
Tanta, Egypt	46	50	19	43	45	46	52	59	63	66	68	64	61	55	46	55
Zagazig, Egypt	43	78	26	43	43	48	52	59	64	68	68	64	61	55	46	55
Delta Barrage, Egypt,	66	93	22	43	45	46	52	59	64	68	68	64	61	55	46	55
Cairo (Ezbekiya), Egypt	66	106	42	47	48	52	57	63	68	70	71	68	65	58	50	60
Helwan, Egypt	381	124	42	46	48	52	57	63	68	70	70	68	64	59	50	59
Faiyum, Egypt	98	143	18	43	45	48	55	63	68	70	70	66	63	55	46	57
Shakshuk, Egypt	−141	130	18	43	45	52	57	66	70	73	73	70	66	57	48	61
Mersa Matruh, Egypt	23	0	24	47	48	51	56	61	67	71	72	70	65	58	51	60
Siwa, Egypt	−49	233	30	39	41	46	53	61	66	69	68	64	58	50	41	55
Sollum, Egypt	13	0	9	45	47	50	54	60	64	68	68	66	62	57	49	58

D. MEAN CLOUDINESS (tenths of sky covered)

Station	No. years rec.	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
El Arish, Egypt	18	3	3	3	2	2	1	1	1	1	2	3	3	2.2
Port Said, Egypt	45	4	4	3	3	2	1	1	2	2	2	3	4	2.8
Alexandria, Egypt	45	5	5	4	3	3	2	2	2	2	3	4	5	3.4
Tanta, Egypt	19	4	4	3	3	2	1	1	1	2	2	3	4	2.6
Zagazig, Egypt	27	3	3	2	2	1	1	1	1	1	1	2	3	1.8
Cairo (Ezbekiya), Egypt	23	4	4	3	2	2	1	1	1	1	2	3	4	2.4
Helwan, Egypt	42	4	4	3	3	2	1	1	1	1	2	3	4	2.2
Faiyum, Egypt	18	3	3	3	2	2	0	0	1	1	2	3	4	2.0
Mersa Matruh, Egypt	22	5	4	4	2	3	1	1	2	2	3	4	4	2.9
Siwa, Egypt	18	2	2	1	1	1	0	0	0	0	1	2	2	1.0

E. MEAN PRECIPITATION (in.)

Station	No. years rec.	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Gaza, Egypt	34	4.1	3.0	1.2	0.5	0.1	<0.1	0	<0.1	0.1	0.7	2.5	3.2	15.3
Beersheba, Israel	14	1.9	2.2	0.71	0.39	0.12	0	0	0	0	0.08	0.83	1.6	7.8
El Arish, Egypt	35	0.71	0.71	0.55	0.24	0.04	0	0	0	0	0.20	0.59	0.75	3.8
Port Said, Egypt	60	0.7	0.5	0.4	0.2	0.1	<0.1	0	0	<0.1	0.1	0.4	0.6	3.0
Rosetta, Egypt	27	1.8	1.3	0.47	0.12	0.04	0	0	0	0	0.28	0.86	1.9	6.8
Alexandria, Egypt	61	1.9	0.9	0.4	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.2	1.3	2.2	7.0
Damanhur, Egypt	43	0.95	0.83	0.39	0.15	0.12	0	0	0.04	0	0.15	0.43	0.83	3.9
Tanta, Egypt	24	0.35	0.35	0.16	0.16	0.16	0	0	0	0	0.24	0.20	0.32	1.9
Zagazig, Egypt	26	0.20	0.24	0.16	0.08	0.04	0	0	0	0	0.08	0.16	0.16	1.1
Cairo (Ezbekiya), Egypt	42	0.2	0.2	0.2	0.1	0.1	<0.1	0	0	<0.1	0.1	0.1	0.2	1.1
Helwan, Egypt	42	0.24	0.20	0.20	0.12	0.12	tr[1]	0	0	tr	0.04	0.12	0.20	1.2
Faiyum, Egypt	18	0.04	0.08	0.08	0.04	0.08	0	0	0	0	0.04	0.04	0.27	0.67
Shakshuk, Egypt	18	0.04	0.08	0.04	0.04	0	0	0	0	0	0	0.04	0.12	0.35
Mersa Matruh, Egypt	37	1.6	1.0	0.5	0.1	0.1	0	0	0	*[2]	0.6	1.0	1.3	6.2
Siwa, Egypt	30	<0.1	<0.1	<0.1	<0.1	0.1	<0.1	0	0	0	<0.1	<0.1	0.1	0.4
Sollum, Egypt	10	0.8	0.6	0.3	<0.1	0.2	<0.1	<0.1	0	<0.1	<0.1	1.0	0.7	3.6

1. tr = trace
2. * = 0.05 in. or less.

TABLE 3. Part. 2: Western Mediterranean

A. MEAN TEMPERATURE (°F.)

Station	Elev. (ft.)	Miles to sea	No. years rec.	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Tobruk, Libya	151	0	17	55	57	60	65	69	74	77	78	76	73	67	60	68
El Adem, Libya	525	35	10	53	55	58	64	71	76	78	78	76	70	63	55	67
Derna, Libya	22	2	24	56	56	60	64	68	73	77	78	76	72	66	59	67
Cirene, Libya	2 037	15	20	47	48	52	58	65	71	72	73	69	66	64	53	61
Benghazi, Libya	82	0	46	57	58	62	66	71	76	78	79	76	73	67	60	68
Jedabya, Libya	197	30	16	55	67	63	69	76	78	79	80	78	73	68	59	70
el-Agheila, Libya	39	0	13	55	57	61	66	72	77	78	80	78	74	66	58	78
Sirte, Libya	59	0	14	56	57	62	67	71	75	78	80	79	75	68	59	69
Misurata, Libya	33	0	18	54	56	62	65	69	76	79	81	79	74	66	57	68
Tripoli, Libya	72	0	47	54	56	60	65	69	74	78	79	78	73	60	57	67
Castel Benito, Libya	59	15	19	54	55	61	66	73	79	82	82	79	73	64	55	68
Idris, Libya	263	14	19	53	56	60	67	73	79	82	83	79	74	65	56	69
el-Azizia, Libya	367	26	30	53	56	60	67	74	81	84	84	82	75	65	55	70
Zarzia, Tunisia	0	0	10	54	57	61	66	73	79	82	84	82	75	64	57	70
Medenine, Tunisia	361	15	50	53	56	61	67	73	80	85	85	81	73	63	55	69
Matmata, Tunisia	131	25	11	46	50	55	63	70	77	82	82	79	70	59	50	64

Station	Elev. (ft.)	Miles to sea	No. years rec.	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Gabes, Tunisia	7	0	50	52	54	59	64	70	75	80	82	78	72	62	54	67
Kebili, Tunisia	361	68	11	46	52	57	66	73	82	90	90	92	73	59	50	68
Metlaoui, Tunisia	525	100	14	50	54	59	64	73	81	88	86	81	72	61	52	68
Tozeur, Tunisia	591	112	. . .	52	55	61	68	77	84	90	88	82	72	59	52	70
Sfax, Tunisia	69	0	50	53	55	58	62	68	74	78	79	77	72	63	56	66
Kairouan, Tunisia	223	30	50	51	54	57	63	69	78	84	84	79	70	61	53	67
Sousse, Tunisia	20	0	50	52	54	57	61	66	73	79	80	78	71	62	54	66
Tunis, Tunisia	217	5	50	51	53	56	61	66	74	79	80	77	68	60	52	65
Almeria, Spain	220	0	21	54	55	58	62	66	73	77	79	75	68	60	56	65
Alicante, Spain	115	0	22	51	53	56	60	65	71	76	77	74	67	56	53	64
Murcia, Spain	197	20	25	50	53	56	61	67	73	79	79	74	66	58	51	64

B. MEAN DAILY MAXIMUM TEMPERATURE (°F.)

Station	Elev. (ft.)	Miles to sea	No. years rec.	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Tobruk, Libya	151	0	17	62	64	67	73	76	80	82	82	81	79	73	67	74
El Adem, Libya	525	35	10	63	65	69	75	83	87	88	88	86	80	73	65	77
Derna, Libya	22	2	24	65	65	69	74	78	82	84	85	84	82	75	68	76
Cirene, Libya	2 037	15	20	54	56	61	69	76	83	82	81	79	76	67	59	71
Benghazi, Libya	82	0	46	63	64	69	74	79	83	84	85	83	80	74	66	75
Jedabya, Libya	197	30	16	66	69	76	73	90	94	93	95	93	87	80	69	83
el-Agheila, Libya	39	0	13	63	66	71	76	81	84	83	86	86	83	75	67	77
Sirte, Libya	59	0	14	64	66	71	78	81	85	87	88	87	84	77	68	78
Misurata, Libya	33	0	18	63	66	71	75	79	86	89	90	88	84	75	66	78
Tripoli, Libya	72	0	47	61	63	67	72	76	81	85	86	85	80	73	64	74
Castel Benito, Libya	59	15	19	64	66	73	82	88	93	99	99	93	88	75	66	82
Idris, Libya	263	14	19	64	67	73	82	87	94	98	98	93	87	76	66	82
el-Azizia, Libya	367	26	30	63	68	73	81	88	97	100	100	97	88	76	66	83
Zarzia, Tunisia	0	0	10	64	68	73	79	84	90	95	97	93	88	77	68	82
Medenine, Tunisia	361	15	50	62	66	72	79	85	92	98	98	93	84	73	64	81
Matmata, Tunisia	131	25	11	52	57	64	73	82	90	97	95	90	79	66	55	75
Gabes, Tunisia	7	0	50	61	64	69	74	79	83	89	91	87	81	72	63	76
Kebili, Tunisia	361	68	11	57	63	72	82	91	100	108	108	99	88	72	61	84
Metlaoui	525	100	14	57	63	68	75	86	93	100	100	91	82	70	61	79
Tozeur, Tunisia	591	112	10	62	66	73	82	91	108	108	104	95	84	70	63	82
Sfax, Tunisia	69	0	50	61	63	66	71	75	82	86	87	85	79	71	64	74
Kairouan, Tunisia	223	30	50	61	65	69	76	83	93	100	99	92	82	72	63	80
Sousse, Tunisia	20	0	50	60	62	65	69	74	81	87	89	87	79	70	62	74
Tunis, Tunisia	217	5	50	58	61	65	70	76	84	90	91	87	77	68	60	74
Almeria, Spain	220	0	21	60	61	65	69	74	80	84	86	82	75	65	62	72
Alicante, Spain	115	0	22	60	62	66	70	75	81	86	87	83	77	67	62	73
Murcia, Spain	197	20	25	60	63	67	72	79	85	91	91	85	77	68	61	75

C. MEAN DAILY MINIMUM TEMPERATURE (°F.)

Station	Elev. (ft.)	Miles to sea	No. years rec.	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Tobruk, Libya	151	0	17	48	49	52	57	62	67	72	73	71	66	60	52	61
El Adem, Libya	525	35	10	43	44	47	53	59	65	68	68	65	59	52	45	56
Derna, Libya	22	2	24	47	47	50	54	58	64	69	70	67	62	56	50	58
Cirene, Libya	2 037	15	20	40	40	43	47	53	59	62	62	59	56	50	44	51
Benghazi, Libya	82	0	46	50	51	54	58	63	68	71	72	69	66	60	53	61
Jedabya, Libya	197	30	16	44	45	49	55	61	63	65	65	62	59	55	48	56
el-Agheila, Libya	39	0	13	46	47	51	56	72	67	72	73	70	64	57	48	59
Sirte, Libya	59	0	14	47	47	52	56	61	65	69	72	71	65	58	49	59
Misurata, Libya	33	0	18	45	46	50	54	59	65	69	71	69	64	57	48	58
Tripoli, Libya	72	0	47	47	49	52	57	61	67	71	72	71	65	57	49	60
Castel Benito, Libya	59	15	19	43	45	46	52	57	64	66	66	64	61	54	45	55
Idris, Libya	263	14	19	42	44	46	52	58	64	66	67	65	61	53	45	55
el-Azizia, Libya	367	26	30	42	44	47	52	59	65	68	68	67	61	53	44	56

Station	Elev. (ft.)	Miles to sea	No. years rec.	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Zarzia, Tunisia	0	0	10	43	45	50	55	61	66	70	72	70	63	52	45	57
Medenine, Tunisia	361	15	50	43	45	49	54	60	67	71	71	69	62	53	45	57
Matmata, Tunisia	131	25	11	39	43	46	52	57	64	70	72	66	61	50	43	55
Gabes, Tunisia	7	0	50	43	44	49	54	61	66	71	72	69	62	52	45	57
Kebili, Tunisia	361	68	11	36	39	45	50	57	64	70	70	68	57	48	37	54
Metlaoui, Libya	525	100	14	43	45	50	55	63	68	73	75	70	63	52	43	57
Tozeur, Libya	591	112	10	41	45	48	54	63	70	73	72	68	57	48	41	57
Sfax, Tunisia	69	0	50	44	46	50	53	60	66	70	71	69	64	54	47	58
Kairouan, Tunisia	223	30	50	40	42	45	49	55	62	67	68	65	58	49	42	53
Sousse, Tunisia	20	0	50	44	45	49	53	58	65	70	70	68	62	53	46	57
Tunis, Tunisia	217	5	50	43	44	47	51	56	63	68	69	66	59	51	44	55
Almeria, Spain	220	0	21	47	48	51	54	59	65	69	71	68	61	54	49	58
Alicante, Spain	115	0	22	41	43	46	50	55	61	66	67	64	57	45	44	54
Murcia, Spain	197	20	25	40	42	45	49	55	61	66	67	62	55	47	41	52

D. MEAN CLOUDINESS (tenths of sky covered)

Station	No. years rec.	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Derna, Libya	7-9	6	5	4	3	3	2	1	1	2	3	4	5	3
Benghazi, Libya	5	6	6	5	5	4	2	1	1	2	4	5	5	4
Tripoli, Libya	5	5	5	5	4	4	3	1	*[1]	3	4	5	5	4
el-Azizia, Libya	8-10	5	4	4	3	3	3	1	1	2	3	4	4	3
Castel Benito, Libya	14	5	6	5	5	4	3	1	1	3	5	6	6	4

1. * = 0.5 or less.

E. MEAN PRECIPITATION (in.)

Station	No. years rec.	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Tobruk, Libya	22	1.6	1.0	0.4	0.2	0.1	0	0	0	<0.1	0.3	0.8	1.5	5.9
El Adem, Libya	10	0.8	0.4	0.6	<0.1	0.2	<0.1	<0.1	<0.1	<0.1	0.4	1.1	0.5	4.0
Derna, Libya	25	2.5	1.8	1.0	0.4	0.3	<0.1	<0.1	<0.1	0.1	0.8	1.7	2.6	11.2
Cirene, Libya	22	6.1	3.0	2.3	0.7	0.6	<0.1	<0.1	<0.1	0.3	1.7	2.9	6.0	23.6
Benghazi, Libya	46	2.6	1.6	0.8	0.2	0.1	0.1	0.1	0.1	0.1	0.7	1.8	2.6	10.5
Jedabya, Libya	14	1.6	1.1	0.1	<0.1	0.1	<0.1	0	<0.1	<0.1	0.3	0.9	1.1	5.2
el-Agheila, Libya	10	1.3	0.6	0.1	0.1	<0.1	<0.1	0	<0.1	0.1	0.2	0.6	1.1	4.1
Sirte, Libya	12	1.9	1.1	0.5	<0.1	0.1	<0.1	0	0	0.3	0.7	1.2	1.5	7.3
Misurata, Libya	12	2.6	1.4	0.8	0.2	0.1	0.1	0	<0.1	0.5	1.0	1.0	2.0	10.6
Tripoli, Libya	56	3.2	1.8	1.1	0.4	0.2	0.1	<0.1	<0.1	0.4	1.6	2.6	3.7	15.1
Castel Benito, Libya	23	2.5	2.0	1.0	0.51	0.20	0.12	tr	tr	0.39	0.98	1.42	3.0	12.09
Idris, Libya	23	2.5	2.0	1.1	0.5	0.2	0.1	<0.1	<0.1	0.4	1.0	1.4	3.0	12.2
el-Azizia, Libya	21	1.9	1.2	0.9	0.3	0.3	<0.1	<0.1	<0.1	0.2	0.6	1.0	2.4	8.8
Medenine, Tunisia	50	0.8	0.7	1.0	0.4	0.3	<0.1	<0.1	<0.1	0.3	0.6	0.8	0.6	5.5
Matmata, Tunisia	23	1.7	0.95	1.3	0.79	0.67	0.16	0.04	0.20	0.59	1.2	0.91	0.83	9.09
Gabes, Tunisia	50	0.9	0.7	0.8	0.4	0.3	<0.1	<0.1	0.1	0.5	1.2	1.2	0.6	6.7
Kebili, Tunisia	50	0.5	0.3	0.6	0.3	0.2	<0.1	<0.1	<0.1	0.2	0.3	0.6	0.4	3.4
Tozeur, Tunisia	10	0.47	0.79	0.75	0.24	0.24	0.55	0	0.08	0.20	0.16	0.98	0.20	4.25
Mefta, Tunisia	11	0.59	0.32	0.59	0.55	0.28	0.04	0.08	0.04	0.16	0.39	0.16	0.51	3.7
Sfax, Tunisia	50	1.0	0.7	1.0	0.5	0.4	0.2	<0.1	0.1	0.9	1.1	1.2	0.6	7.7
Kairouan, Tunisia	50	1.1	1.0	1.4	1.0	0.9	0.5	0.2	0.3	1.5	1.2	1.2	1.0	11.3
Sousse, Tunisia	50	1.7	1.3	1.2	0.9	0.7	0.2	<0.1	0.2	2.0	1.7	1.5	1.5	12.9
Tunis, Tunisia	50	2.5	2.0	1.6	1.4	0.7	0.3	0.1	0.3	1.3	2.0	1.9	2.4	16.5
Almeria, Spain	20	0.9	1.0	0.7	0.9	0.7	0.2	<0.1	0.1	0.6	0.9	1.5	1.1	8.6
Cabo de Gata, Spain	. . .	0.59	0.39	0.47	0.55	0.28	0.08	*[1]	*	0.20	0.71	0.91	0.95	5.04
Alicante, Spain	21	1.0	1.0	0.9	1.1	0.9	0.5	0.2	0.4	1.8	1.2	2.0	1.3	12.3
Murcia, Spain	27	0.5	0.9	0.9	1.4	1.1	0.5	0.1	0.3	1.3	1.3	2.0	1.0	11.2

1. * = 0.05 or less.
2. tr = trace.

TABLE 4. North Atlantic Sahara Littoral

A. MEAN TEMPERATURE (°F.)

Station	Elev. (ft.)	Miles to sea	No. years rec.	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Sidi-Ifni	148	0	14	59	61	63	65	66	67	70	70	70	69	67	63	65
Goulimime	984	13	8	61	61	66	68	70	69	76	81	76	74	70	63	70
Agadir	460	0	8	59	60	61	62	65	68	72	71	71	69	64	60	65
Cape Juby	20	0	14	62	62	63	65	66	68	69	70	70	69	67	63	66
Smara	1 509	110	6	60	64	68	73	73	76	83	85	80	75	69	62	73
Villa Cisneros	35	0	12	64	65	67	67	68	70	72	73	74	73	70	65	69
Port Etienne	13	0	7	67	68	69	70	71	73	72	75	79	75	73	67	71
Atar	761	208	7	69	71	77	82	87	94	94	93	91	85	78	80	83
Nouakchott	69	6	5	71	73	76	77	81	83	82	83	84	81	77	70	78
Moudjeria	—	248	9	73	79	84	90	95	95	91	88	90	90	84	77	86
Saint-Louis	23	0	10	72	71	72	70	72	78	82	82	83	82	76	74	76
Rosso	16	25	24	69	71	75	81	84	86	86	86	84	86	84	81	73
Las Palmas	23	0	10	64	64	64	65	68	70	72	74	74	73	69	66	69

B. MEAN DAILY MAXIMUM TEMPERATURE (°F.)

Station	Elev. (ft.)	Miles to sea	No. years rec.	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Sidi-Ifni	148	0	14	66	67	69	71	71	72	75	75	75	75	74	69	71
Goulimime	984	13	8	71	72	78	81	83	85	95	96	92	89	82	73	83
Agadir	460	0	8	66	68	68	71	75	76	80	80	79	77	71	68	73
Cape Juby	20	0	14	67	67	68	70	70	72	73	74	74	74	73	69	71
Smara	1 509	110	6	73	79	83	88	87	90	99	102	95	98	81	74	87
Villa Cisneros	35	0	12	71	73	74	74	75	77	78	80	80	80	77	72	76
Port Etienne	13	0	7	81	83	81	82	83	85	81	85	90	87	85	77	83
Atar	761	208	7	84	86	92	97	101	107	106	105	103	98	91	84	96
Nouakchott	69	6	5	85	87	89	90	93	92	89	90	93	91	89	83	89
Moudjeria		248	10	88	95	102	108	113	111	108	102	106	108	100	90	102
Saint-Louis	23	0	10	83	81	81	76	77	83	87	88	89	88	84	84	83
Rosso	16	25	8	88	91	99	102	104	102	99	93	97	97	95	88	97
Las Palmas	23	0	10	71	70	71	72	74	76	77	80	81	80	76	74	75

C. MEAN DAILY MINIMUM TEMPERATURE (°F.)

Station	Elev. (ft.)	Miles to sea	No. years rec.	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Sidi-Ifni	148	0	14	52	54	57	59	60	62	64	64	64	62	60	56	59
Goulimime	984	13	7	51	50	53	55	56	62	66	65	60	58	58	52	57
Agadir	460	0	8	51	52	54	54	54	60	63	63	63	61	56	53	57
Cape Juby	20	0	14	56	57	58	60	62	64	65	65	65	64	61	57	61
Smara	1 509	110	6	47	49	53	58	59	62	66	67	65	61	57	49	58
Villa Cisneros	35	0	12	56	57	59	60	61	63	65	66	67	65	63	58	62
Port Etienne	13	0	7	53	53	56	57	59	60	63	65	67	63	60	56	59
Atar	761	208	7	54	56	61	67	73	81	81	80	79	72	65	55	69
Nouakchott	69	6	5	57	59	63	64	69	73	74	75	75	71	65	56	67
Moudjeria		248	9	59	63	68	73	77	77	75	73	73	73	68	63	70
Saint-Louis	23	0	10	60	61	62	63	66	73	76	75	76	76	68	63	68
Rosso	16	25	8	57	61	64	66	68	70	73	73	73	71	64	59	66
Las Palmas	23	0	10	57	57	58	59	62	65	67	69	68	66	62	59	62

D. MEAN CLOUDINESS (tenths of sky covered)

Station	Elev. (ft.)	Miles to sea	No. years rec.	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Cape Juby	20	0	10	4	4	4	5	5	6	6	6	4	4	4	4	4.6
Port Etienne	13	0	6	3	2	2	1	2	1	2	2	3	3	4	3	2.5
Atar	761	208	6	2	3	2	2	3	1	2	2	2	2	2	3	2.2
Saint-Louis	23	0	6	3	3	2	3	3	3	4	4	4	4	2	3	3
Las Palmas	23	0	5	6	5	6	5	6	5	6	6	4	5	6	5	5.4

E. MEAN PRECIPITATION (in.)

Station	No. years rec	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Sidi-Ifni	14	1.0	0.6	0.5	0.6	0.1	0.1	<0.1	0.1	0.4	0.1	0.9	1.8	6.1
Goulimime	9	0.7	0.6	0.4	0.3	0.1	<0.1	<0.1	0.1	0.4	0.2	0.8	1.7	5.3
Agadir	6	2.8	1.0	0.9	0.3	0.2	0	0	0	0	0.2	1.3	1.8	8.6
Cape Juby	14	0.3	0.2	0.2	<0.1	<0.1	<0.1	<0.1	<0.1	0.3	<0.1	0.6	0.3	1.9
Smara	6	0.1	<0.1	0	<0.1	<0.1	0	0	<0.1	1.0	<0.1	0.4	0	1.5
Villa Cisneros	14	<0.1	<0.1	<0.1	<0.1	0.1	0	<0.1	0.2	1.4	0.1	0.2	0.1	3.0
Port Etienne	10	0.1	<0.1	<0.1	0	<0.1	<0.1	<0.1	<0.1	0.3	0.5	0.1	0.4	1.4
Atar	10	<0.1	0	<0.1	<0.1	<0.1	0.1	0.3	1.2	1.1	0.1	<0.1	<0.1	2.8
Nouakchott	10	<0.1	0.1	<0.1	<0.1	<0.1	0.1	0.5	4.1	0.9	0.4	0.1	<0.1	6.2
Moudjeria	10	•	0	0	0	0.11	0.55	0.94	2.8	1.5	0.35	0.20	0.27	6.7
Saint-Louis	10	<0.1	<0.1	<0.1	0	0.1	0.3	2.2	7.7	4.0	1.0	0.1	<0.1	15.4
Rosso	16	•	0.04	•	•	0.08	0.27	1.4	5.6	2.9	0.67	0.08	0.08	11.4
Las Palmas	48	1.4	0.9	0.9	0.5	0.2	<0.1	<0.1	<0.1	0.2	1.1	2.1	1.6	8.6

1. • — 0.05 or less.

TABLE 5. South-western Africa and Madagascar

A. MEAN TEMPERATURE (°F.)

Station	Elev. (ft.)	Miles to sea	No. years rec.	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Luanda, Angola	194	0	27	79	80	81	80	78	73	70	69	72	75	73	79	76
Lobito, Angola	4	0	13	76	80	81	81	77	72	69	68	70	74	78	78	76
Moçamedes, Angola	10	0	15	72	76	77	74	68	65	62	64	66	68	76	72	70
Walvis Bay, S. W. Africa	24	0	20	66	67	66	65	63	61	59	57	57	59	63	65	63
Port Nolloth, Rep. of S. A.	23	0	20	60	61	60	58	57	56	54	54	60	57	59	60	57
Klaver, Rep. of S. A.	137	23	23	76	76	74	69	64	60	57	60	62	66	70	73	67
Goodhouse, Rep. of S. A.	648	90	90	87	86	83	76	67	59	58	64	69	76	80	85	74
Morombe, Madagascar	16	0	17-18	82	82	81	78	74	71	69	71	73	76	79	80	76
Tulear, Madagascar	20	0	27	82	80	79	77	73	71	70	69	72	76	78	81	76
Androka, Madagascar	33	0		81	81	79	77	72	68	68	68	72	73	77	81	75
Tsihombe, Madagascar	210	20	18-19	82	82	80	77	71	68	66	69	72	77	80	81	76
Luanda, Angola	194	0	27	83	85	86	85	82	77	74	74	76	79	82	83	81
Lobito, Angola	4	0	13	83	85	87	86	83	78	74	74	76	79	83	83	81
Moçamedes, Angola	10	0	15	79	83	84	82	77	72	68	70	72	74	78	79	77

B. MEAN DAILY MAXIMUM TEMPERATURE (°F.)

Station	Elev. (ft.)	Miles to sea	No. years rec.	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Walvis Bay, S. W. Africa	24	0	20	73	74	74	75	74	74	70	68	66	67	71	72	72
Port Nolloth, Rep. of S. A.	23	0	20	67	67	67	66	66	65	62	63	63	64	66	66	65
Klaver, Rep. of S. A.	137	23	23	90	90	88	82	77	71	68	72	74	79	84	87	80
Goodhouse, Rep. of S. A.	648	90	90	103	101	97	91	81	74	72	78	84	91	95	100	89
Morombe, Madagascar	16	0	17	91	91	90	89	85	83	81	83	85	87	89	90	87
Tulear, Madagascar	20	0	27	92	89	89	89	84	81	81	80	83	86	87	91	86
Tsihombe, Madagascar	210	20	10	92	91	90	88	82	79	80	82	85	89	91	92	87

C. MEAN DAILY MINIMUM TEMPERATURE (°F.)

Station	Elev. (ft.)	Miles to sea	No. years rec.	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Luanda, Angola	194	0	27	74	75	75	75	73	68	65	64	67	71	73	74	71
Lobito, Angola	4	0	13	72	74	75	75	71	66	63	62	65	69	72	72	70
Moçamedes, Angola	10	0	15	65	68	69	66	59	57	56	57	59	61	63	64	62
Walvis Bay, S. W. Africa	24	0	20	59	60	59	55	52	48	47	46	48	51	54	57	53
Port Nolloth, Rep. of S. A.	23	0	20	53	54	53	50	48	46	45	45	47	49	51	53	49
Klaver, Rep. of S. A.	137	23	15	61	62	61	56	52	48	46	48	50	53	57	59	54
Goodhouse, Rep. of S. A.	648	90	15	72	71	69	62	53	45	43	47	53	60	65	70	59
Morombe, Madagascar	16	0	18	73	73	71	67	62	58	56	58	60	65	69	70	65
Tulear, Madagascar	20	0	27	72	71	69	64	61	61	58	58	61	65	69	71	65
Tsihombe, Madagascar	210	20	19	72	72	70	66	59	56	53	56	59	63	68	70	64

D. MEAN CLOUDINESS (tenths of sky covered)

Station	Hour	No. years rec.	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Luanda, Angola	09.00	14	9	8	8	8	7	8	9	9	9	9	9	8	8
	15.00	14	7	6	7	7	5	1	4	4	5	6	6	6	5
Moçamedes	09.00	2	5	5	5	5	5	5	7	9	7	7	7	6	6
	15.00	2	3	3	4	3	4	5	4	6	5	4	4	4	4
Walvis Bay, S. W. Africa	08.30	10	8	8	8	6	5	4	4	5	8	8	8	8	7
	12.00	6	3	3	3	1	1	1	2	2	2	2	3	3	2
Port Nolloth, Rep. of S. A.	08.30	13	5	5	5	5	4	4	4	4	5	5	5	5	5
	15.00	7-8	3	4	4	4	4	4	4	3	4	4	3	3	4

E. MEAN MONTHLY PRECIPITATION (in.)

Station	No. years rec.	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Luanda, Angola	59	1.0	1.4	3.0	4.6	0.5	<0.1	<0.1	<0.1	0.1	0.2	1.1	0.8	12.7
Lobito, Angola	19	0.8	1.5	4.7	2.1	0	0	0	<0.1	0.1	1.2	1.0	2.4	13.9
Moçamedes, Angola	21	0.3	0.4	0.7	0.5	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.1	0.1	2.1
Walvis Bay, S. W. Africa	20	<0.1	0.2	0.3	0.1	0.1	<0.1	<0.1	0.1	<0.1	<0.1	<0.1	<0.1	0.9
Port Nolloth, Rep. of S.A.	64	0.1	0.1	0.2	0.2	0.3	0.3	0.3	0.3	0.2	0.1	0.1	0.1	2.3
Morombe, Madagascar	15	4.7	7.3	2.2	0.2	0.2	0.4	0.2	<0.1	0.1	0.3	0.8	2.9	19.3
Tulear, Madagascar	15	3.1	3.2	1.4	0.3	0.7	0.4	0.1	0.2	0.3	0.7	1.4	1.7	13.5
Androka, Madagascar		1.8	2.0	1.8	0.67	0.95	0.98	0.59	0.39	0.39	0.83	0.39	1.2	12.0
Tsihombe, Madagascar	20	3.2	4.0	1.9	0.8	0.9	1.3	0.6	0.4	0.5	0.7	1.1	3.9	19.3

A. MEAN TEMPERATURE (°F.)

Station	Elev. (ft.)	Miles to sea	No. years rec.	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Broome	63	2+	41	81	81	85	83	77	71	70	73	77	82	85	86	80
Anna Plains	10	6	x^1	87	86	—	85	75	69	67	71	76	76	81	84	87
Roebourne	40	3	x	90	90	88	82	75	68	67	71	76	80	87	88	80
Marble Bar	595	83	27	93	92	90	84	74	68	67	71	78	84	90	92	82
Nullagine	1 266	130	32	89	88	85	77	68	62	60	64	71	79	86	87	76
Onslow	14	2	44	86	86	85	80	72	66	64	67	71	75	80	83	76
Carnarvon	15	0	43	80	80	79	75	73	64	61	63	66	70	73	77	71
Hamelin Pool	14	*[2]	x	83	83	81	75	66	61	59	60	65	69	75	79	71
Geraldton	13	2+	x	75	76	74	70	65	62	60	60	62	64	68	72	66
Rawlinna	607	83	9	74	75	70	65	59	54	52	54	60	65	71	73	65
Eyre	15	0	29	70	70	68	64	60	60	54	55	58	61	65	66	67
Eucla	15	0	60	70	71	70	66	61	56	55	56	59	63	66	69	64
Cook	404	65	6	71	74	70	64	58	52	50	54	59	63	71	73	63
Streaky Bay	45	0	50	72	73	70	64	60	55	53	55	58	63	67	70	63
Port Augusta	18	**[3]	52	78	78	74	67	60	55	54	56	61	67	72	76	66
Adelaide	140	5	86	74	74	70	64	58	54	52	54	57	62	67	71	63

1. x = official Australian Bureau of Meteorology normal.
2. * = at head of narrow bay 20 miles from open sea.
3. ** = at head of narrow bay 190 miles from open sea.

B. MEAN DAILY MAXIMUM TEMPERATURE (°F.)

Station	Elev. (ft.)	Miles to sea	No. years rec.	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Broome	63	2+	41	92	92	93	93	88	82	82	85	89	91	93	93	89
Anna Plains	10	6	x^1	95	95	—	96	90	83	82	87	92	94	97	98	92
Roebourne	40	3	x	101	101	98	94	86	79	79	83	90	94	101	102	92
Nullagine	1 266	130	32	103	101	98	91	82	75	74	80	88	95	101	103	91
Onslow	14	2	44	97	96	96	92	84	78	77	80	85	89	94	96	89
Carnarvon	15	0	43	88	88	88	84	78	73	71	73	75	78	81	85	80
Geraldton	13	2+	x	84	85	84	80	74	70	68	69	71	73	78	82	77
Rawlinna	607	83	9	89	91	83	79	71	65	64	68	75	80	86	89	79
Eyre	15	0	29	79	79	78	74	70	65	64	66	69	72	75	77	72
Eucla	15	0	60	78	78	78	75	71	66	65	67	70	73	75	77	73
Cook	404	65	6	88	89	85	79	71	65	63	68	75	80	89	90	78
Streaky Bay	45	0	50	84	85	81	74	68	62	60	63	67	73	79	82	73
Port Augusta	18	**[2]	52	90	90	85	78	70	64	63	66	72	79	84	88	77
Adelaide	140	5	86	86	86	81	73	66	61	59	62	66	73	79	83	86

1. x = official Australian Bureau of Meteorology normal.
2. ** = at head of narrow bay 190 miles from open sea.

C. MEAN DAILY MINIMUM TEMPERATURE (°F.)

Station	Elev. (ft.)	Miles to sea	No. years rec.	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Broome	63	2+	41	79	79	77	72	65	60	58	60	65	72	76	79	70
Anna Plains	10	6	x^1	78	77	75	74	60	55	52	55	60	67	72	76	65
Roebourne	40	3	x	79	79	77	71	64	58	55	58	62	67	73	77	79
Nullagine	1 266	130	32	75	75	71	63	54	48	45	48	54	62	70	74	61
Onslow	14	2	44	74	75	73	67	60	54	52	53	57	61	66	70	63
Carnarvon	15	0	43	72	72	71	66	58	54	51	53	57	61	65	69	62
Geraldton	13	2+	x	65	66	64	60	56	54	51	52	53	55	59	63	58
Rawlinna	607	83	9	59	59	57	53	47	42	39	40	45	50	55	57	50
Eyre	15	0	29	60	61	58	54	49	45	43	44	46	50	54	57	52
Eucla	15	0	60	62	63	61	56	51	46	44	45	48	52	56	60	54
Cook	404	65	6	54	58	55	49	44	39	37	40	42	46	52	55	47
Streaky Bay	45	0	50	59	60	58	54	51	48	46	47	49	52	55	58	53
Port Augusta	18	**[2]	52	66	66	62	56	50	46	44	46	50	55	60	64	55
Adelaide	140	5	86	61	62	59	55	50	47	45	46	48	51	55	59	53

1. x = official Australian Bureau of Meteorology normal.
2. ** = at head of narrow bay 190 miles from open sea.

D. MEAN CLOUDINESS (tenths of sky covered)

Station	No. years rec.	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Broome	25	5	5	4	2	2	2	1	1	1	1	2	4	2
Onslow	3	2	4	3	3	4	3	3	1	1	1	1	2	2
Carnarvon	25	2	2	2	2	3	3	3	2	2	2	2	2	2
Eyre	28	4	5	5	5	5	5	4	4	4	4	4	4	4.3
Eucla	30	5	5	5	5	5	5	4	4	4	4	5	5	4.8
Port Augusta	21	3	3	3	4	4	5	4	4	4	4	4	3	3.6
Adelaide	76	4	4	4	6	6	7	7	6	6	6	5	4	5.4

E. MEAN PRECIPITATION (in.)

Station	No. years rec.	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Broome	50	6.3	5.8	3.9	1.2	0.6	0.9	0.2	0.1	0.1	0.1	0.6	3.3	22.9
Anna Plains	x[1]	3.8	2.4	3.4	1.0	0.8	0.7	0.3	0.1	x	*	0.2	1.7	14.9
Port Hedland		1.1	3.7	1.7	1.0	0.8	0.5	0.3	0.2	*	0.1	0.2	1.2	10.8
Roebourne	x	1.7	1.8	3.4	1.0	1.1	0.9	0.2	0.2	0.1	0.1	0.1	0.6	11.0
Marble Bar	34	2.6	3.2	1.9	0.9	0.7	1.1	0.6	0.2	0	0.2	0.4	1.3	13.0
Nullagine	33	3.0	2.4	2.2	0.8	0.7	0.9	0.5	0.3	0.1	0.2	0.5	1.7	13.2
Onslow	54	0.9	1.1	1.8	1.0	1.5	1.6	0.8	0.4	0.1	0.1	0.1	0.2	9.3
Carnarvon	57	0.4	0.7	0.7	0.6	1.5	2.4	1.6	0.7	0.2	0.1	0.1	0.2	9.1
Hamelin Pool	x	0.3	0.4	0.7	0.5	1.2	1.9	1.4	0.7	0.3	0.2	0.2	0.1	7.9
Geraldton	x	0.2	0.3	0.3	1.1	2.5	4.4	3.8	2.6	1.1	0.5	0.3	0.2	17.4
Rawlinna	14	0.2	0.6	0.7	0.4	0.8	0.7	0.5	0.6	0.3	0.5	0.6	0.6	6.5
Eyre	42	0.6	0.5	0.9	0.9	1.6	1.6	1.2	1.3	0.9	0.8	0.7	0.6	11.6
Eucla	64	0.6	0.7	0.9	1.0	1.2	1.1	0.9	0.9	0.7	0.7	0.7	0.5	9.9
Cook	34	0.4	0.5	0.7	0.5	0.5	0.6	0.4	0.5	0.3	0.5	0.6	0.5	6.0
Streaky Bay	30	0.4	0.5	0.6	0.9	1.9	2.8	2.4	2.0	1.3	1.0	0.7	0.4	14.9
Port Augusta	83	0.6	0.5	0.7	0.7	1.1	1.1	0.7	0.9	0.9	0.9	0.7	0.6	9.4
Adelaide	104	0.8	0.7	1.0	1.8	2.7	3.0	2.6	2.6	2.1	1.7	1.1	1.0	21.1

1. x = official Australian Bureau of Meteorology normal.

TABLE 7. North-western Mexico

A. MEAN TEMPERATURE (°F.)

Station	Elev. (ft.)	Miles to sea	No. years rec.	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Baja California, Pacific Littoral																
Tijuana	95	5	—	55	55	57	59	63	64	70	70	68	64	61	55	61
Ensenade	10	0	—	55	55	57	59	63	64	68	70	66	64	61	57	63
San Ignacio		53	8-10	59	63	64	66	72	75	82	82	81	72	66	63	70
Comondu	206	22	15	63	63	66	68	72	77	84	86	82	77	72	66	73
Buenavista		0	12-14	61	63	63	63	68	72	81	82	81	75	68	63	70
Bahia Magdalena	6	0	15-16	66	64	66	66	68	70	75	79	79	77	73	70	72
El Refugio		15	12-14	63	63	66	72	72	75	82	84	86	77	72	64	73
Iritú		43	12-13	63	66	64	72	73	79	84	86	82	77	70	66	73
Todos Santos		2	10-13	64	64	64	68	64	70	77	81	75	75	72	68	70
Santa Gertrudis		12	12-14	64	64	66	70	73	77	81	81	81	75	70	64	72
San Felipe		12	7-9	64	64	66	72	77	82	84	82	82	75	70	64	73
San Jose del Cabo	95	0	15-19	68	68	68	72	79	79	82	82	82	79	75	70	75

Station	Elev. (ft.)	Miles to sea	No. years rec.	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Baja California, Gulf Littoral																
Mexicali	3	71	—	54	59	64	70	77	86	91	91	86	73	63	54	72
Santa Rosalia	16	0	14-17	61	63	68	72	79	82	88	88	86	79	70	64	75
Mulege	111	2	13-16	57	59	64	70	73	81	86	86	84	77	68	61	72
Loreto		1	13-14	64	64	70	73	79	84	90	90	88	82	73	68	77
La Paz	62	0	—	64	64	68	70	75	79	82	84	82	79	73	66	73
San Bartolo		7	13-14	61	63	64	70	73	84	82	82	79	73	68	64	72
Sonora-Sinaloa Littoral																
Yuma, U.S.	200	68	71	55	59	64	70	77	84	91	90	84	73	63	55	72
Puerto Penasco, Sonora		0	4-5	55	55	57	64	72	82	86	88	82	77	64	59	70
Hermosillo	692	57	—	61	63	68	73	79	88	90	88	86	79	70	61	75
Guaymas	10	0	—	64	66	70	73	79	84	88	86	86	81	73	66	75
Navojoa	259	27	—	64	66	70	75	81	88	93	90	90	84	73	66	79
Topolobampo, Sinaloa	10	6	—	66	68	68	72	77	84	86	86	86	82	75	68	77
San Blas, Sinaloa	230	43	10	64	68	72	77	82	90	90	90	84	86	77	68	79

B. MEAN DAILY MAXIMUM TEMPERATURE (°F.)

Station	Elev. (ft.)	Miles to sea	No. years rec.	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Baja California, Pacific Littoral																
Tijuana	95	5	—	66	68	68	68	70	73	79	79	77	73	73	70	72
Ensenade	10	0	—	64	64	66	66	70	72	75	77	75	73	73	68	70
San Ignacio		53	8-10	73	75	79	84	88	91	97	95	95	86	79	75	85
Bahia Madgalena	6	0	4	77	77	77	77	77	79	84	86	88	86	84	81	81
Baja California, Gulf Littoral																
Mexicali	3	71	—	66	73	77	86	95	104	104	104	100	90	79	68	87
Santa Rosalia	16	0	14-17	68	72	77	82	86	91	93	95	93	88	79	72	83
Mulege	111	2	6-9	70	73	77	82	86	91	97	95	93	88	79	75	84
La Paz	62	0	71	71	72	75	79	82	88	91	95	93	93	90	81	73
Sonora-Sinaloa Littoral																
Yuma, U.S.	200	68	71	66	72	79	86	93	102	106	104	100	88	75	68	87
Hermosillo	692	57	—	77	79	82	88	95	102	100	99	97	91	86	72	89
Guaymas	10	0	—	75	75	79	82	86	91	93	95	93	90	82	75	85
Navojoa	259	27	—	75	77	81	86	95	97	97	95	95	91	82	75	87
Topolobampo, Sinaloa	10	6	—	75	79	77	82	86	93	93	93	95	91	84	75	85
San Blas, Sinaloa	230	43	10	81	84	91	97	104	108	108	108	106	104	95	84	98

C. MEAN DAILY MINIMUM TEMPERATURE (°F.)

Station	Elev. (ft.)	Miles to sea	No. years rec.	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Baja California, Pacific Littoral																
Tijuana	95	5	—	43	45	46	48	54	57	61	63	57	54	46	45	52
Ensenade	10	0	—	46	46	50	50	54	54	61	63	59	55	52	46	53
San Ignacio		53	8-10	46	48	48	50	54	59	66	68	66	59	54	50	56
Bahia Magdalena	6	0	4	61	59	61	61	63	64	70	73	75	72	69	64	66
Baja California, Gulf Littoral																
Mexicali	3	71	—	39	45	48	55	61	70	77	75	70	57	46	41	57
Santa Rosalia	16	0	14-17	54	54	59	63	68	73	81	81	77	72	63	57	65
Mulege	111	2	6-9	45	46	52	59	63	72	81	79	77	66	55	50	62
La Paz	62	0	—	55	54	54	57	61	68	77	75	75	70	64	57	64
Sonora-Sinaloa Littoral																
Yuma, U.S.	200	68	71	43	46	50	54	61	68	77	77	70	57	48	43	58
Hermosillo	692	57	—	48	50	54	59	64	73	79	77	75	66	57	50	63
Guaymas	10	0	—	55	57	59	64	70	77	81	81	79	72	64	57	68
Navojoa	259	27	—	48	50	50	54	63	73	79	77	75	66	59	50	62
Topolobampo, Sinaloa	10	6	—	55	57	59	63	69	77	77	77	77	72	64	57	67
San Blas, Sinaloa	230	43	10	48	50	52	55	64	72	75	75	73	68	59	52	62

D. MEAN PRECIPITATION (in.)

Station	No. years rec.	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Baja California, Pacific Littoral														
Tijuana	—	2.12	2.24	1.69	1.14	0.75	0.12	0	0.08	0.16	0.79	0.67	2.60	12.4
Ensenade	18-22	2.32	2.05	1.34	0.98	0.31	0.12	0.08	0.04	0.35	0.59	0.67	2.64	11.5
San Ignacio	14-16	0.32	0.43	0.59	0	0	0	0.32	0.63	0.94	0.31	0.08	0.43	4.02
Comondu	15	0.47	0.16	0.08	0.04	0	0	0.12	1.14	1.22	0.39	0.12	0.79	4.57
Buenavista	12-14	1.02	0.20	0.24	0.04	0.04	0	0.12	0.87	1.65	0.31	[1] *	0.43	4.92
Bahia Magdalena	14-16	0.20	0.28	0.24	*	*	*	0.16	0.28	2.32	0.12	0.67	0.51	4.80
El Refugio	12-14	0.31	0.12	0.04	*	*	0	0.08	0.51	0.55	0.35	*	0.55	2.52
Iritú	12-14	0.47	0.16	0.08	0.04	0.08	*	0.63	1.38	2.52	0.79	0.08	0.39	6.65
Todos Santos	12-15	0.20	0.08	0	0	0	0.04	0.63	0.39	4.49	0.39	0.39	1.02	7.68
Santa Gertrudis	9-11	1.81	0.04	0.12	0	0	*	1.73	3.98	9.80	1.22	0.47	1.30	20.47
San Felipe	7-9	1.10	0.04	0.08	0.20	0	1.65	3.19	2.20	7.08	1.57	0.35	0.91	18.35
San Jose del Cabo	15-19	0.35	0.16	*	0.08	0	0.04	1.22	1.34	5.43	0.55	0.28	0.70	10.12
Baja California, Gulf Littoral														
Mexicali	22-25	0.35	0.35	0.16	0.16	0.04	0.08	0.08	0.24	0.28	0.31	0.28	0.51	2.79
Santa Rosalia	19-21	0.47	0.31	0.16	*	0	*	0.31	1.22	2.0	0.47	0.16	0.43	5.63
Mulege	30-32	0.12	0.24	0.08	*	0	*	0.31	0.87	1.46	0.08	0.16	0.47	3.82
Loreto	13-14	0.28	0.28	0.04	0	0.04	0	0.04	0.98	2.17	0.47	0.12	0.39	4.92
La Paz	25-30	0.27	0.28	0.04	0.04	0.04	0.02	0.31	1.61	2.91	0.47	0.55	1.02	7.48
San Bartolo	12-14	0.47	*	0	0.08	0	0.08	1.18	3.27	5.04	1.30	0.12	0.55	12.13
Sonora-Sinaloa Littoral														
Yuma, U.S.	79	0.39	0.39	0.31	0.08	0.04	*	0.20	0.55	0.39	0.28	0.24	0.47	3.39
Puerto Penasco, Sonora	4-5	1.65	0.08	0.28	0.31	0	0	0.63	0.35	0.08	0.08	0.35	1.06	4.92
Hermosillo	—	0.08	0.63	0.20	0.08	0.08	0.12	2.79	3.31	2.48	1.61	0.24	1.02	12.64
Guaymas		0.31	0.26	0.20	0.12	0.12	0.02	1.85	2.99	2.13	0.39	0.43	1.14	9.96
Navojoa	—	0.12	0.04	0.12	0	0.39	0.24	2.87	3.93	2.20	2.24	0.55	2.87	15.59
Topolobampo, Sinaloa	—	0.20	0.28	0.24	0	0.08	0.20	1.57	7.52	2.20	2.91	0.28	2.16	14.13
San Blas, Sinaloa	10	0.28	0.35	0	0	0	0.12	3.42	3.98	3.62	0.43	0.16	0.28	12.64

1. * = 0.05 in. or less.

Table 8. South America

A. MEAN TEMPERATURE (°F.)

Station	Elev. (ft.)	Miles to sea	No. years rec.	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Ancon, Ecuador	46	0	14	79	81	81	77	77	75	72	70	72	72	73	75	75
Lambayeque, Peru	16	0	10	77	79	79	77	72	70	68	66	68	68	70	72	72
Trujillo, Peru	60	0	20	77	77	75	72	68	63	64	64	64	68	68	72	70
Callao, Peru	—	—	4	68	70	72	70	66	66	63	63	63	64	64	68	66
Lima, Peru	158	7	14	73	75	73	70	66	63	61	61	61	63	66	70	66
Mollendo, Peru	24	0	7	70	72	70	68	64	61	59	59	61	63	66	68	64
Arica, Chile	29	0	30	72	72	72	68	64	63	61	61	63	64	66	70	66
Iquique, Chile	6	0	30	70	70	68	64	63	61	59	59	61	63	64	68	64
Canchones, Chile	960	—	5	70	70	66	63	57	55	55	55	61	61	64	66	63
Pintados, Chile	977	—	4	68	68	66	64	59	57	57	55	59	61	64	66	63
Calama, Chile	2 260	81	2	63	59	57	55	52	48	46	55	54	59	61	63	55

Station	Elev. (ft.)	Miles to sea	No. years rec.	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Antofagasta, Chile	94	0	30	68	68	66	63	59	57	55	57	57	61	63	66	63
Taltal, Chile	5	0	20	72	72	68	64	63	59	55	59	61	63	64	68	64
Caldera, Chile	14	0	31	68	68	64	63	59	55	55	55	57	59	63	64	61
La Serena, Chile	32	—	10	64	64	61	59	55	54	52	54	55	57	59	61	57
Vallenar, Chile	47	25	4	66	66	66	61	57	52	52	54	55	57	61	64	59
Vicuna, Chile	620	—	8	68	70	64	59	55	54	54	54	57	61	59	66	61
Puerto Madryn, Argentina	40	—	12	68	68	64	58	50	45	44	47	50	55	60	66	56
San Antonio, Argentina	—	0	10	72	70	64	57	52	46	45	46	54	59	66	70	59
Puerto Deseado, Argentina	—	0	8	61	59	55	50	45	39	39	43	46	52	54	55	50
Puerto Gallegos, Argentina	—	0	13	55	54	50	45	39	32	32	36	41	45	50	52	45
Santa Cruz, Argentina	39	—	12	59	59	54	48	42	35	34	39	44	48	51	55	48

B. MEAN DAILY MAXIMUM TEMPERATURE (°F.)

Station	Elev. (ft.)	Miles to sea	No. years rec.	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Lima, Peru	158	7	13	81	82	84	81	75	70	66	66	68	70	73	79	75
Mollendo, Peru	24	0	10	72	73	72	70	66	64	62	61	62	64	68	70	67
Arica, Chile	29	0	86	79	79	79	75	72	68	66	66	68	70	72	75	72
Iquique, Chile	6	0	30	77	77	75	72	68	66	64	64	66	69	72	77	70
Canchones, Chile	960	—	5	90	90	90	88	86	82	84	86	88	88	90	90	89
Pintados, Chile	977	—	4	86	88	86	86	82	81	82	84	86	84	86	86	84
Calama, Chile	2 260	81	2	81	81	79	79	77	73	73	77	77	77	81	82	79
Antofagasta, Chile	94	0	30	75	77	73	70	66	64	63	63	64	66	68	72	68
Taltal, Chile	5	0	20	81	81	79	72	68	64	61	64	66	70	75	79	72
Caldera, Chile	14	0	31	73	75	72	68	64	63	61	63	64	66	68	72	68
Vallenar, Chile	47	25	4	82	84	79	75	73	68	66	68	73	75	79	81	75
Vicuna, Chile	620	—	8	82	84	82	77	72	68	68	70	75	77	81	82	77
Los Andes, Chile	—	—	36	90	88	84	79	68	63	63	66	70	77	82	86	77
Puerto Madryn, Argentina	40	—	12	81	81	76	70	61	54	54	58	62	66	74	79	68
San Antonio, Argentina	—	0	10	86	82	79	70	61	54	55	59	64	70	79	82	70
Puerto Deseado, Argentina	—	0	8	72	66	68	61	52	45	46	48	55	63	66	66	59
Puerto Gallegos, Argentina	—	0	13	66	66	63	54	46	39	39	43	50	57	61	64	54
Santa Cruz, Argentina	39	—	12	70	70	65	57	51	42	41	47	53	58	62	65	57

C. MEAN DAILY MINIMUM TEMPERATURE (°F.)

Station	Elev. (ft.)	Miles to sea	No. years rec.	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Lima, Peru	158	7	13	64	66	64	63	59	57	55	55	55	57	61	63	61
Mollendo, Peru	24	0	10	66	67	65	63	61	59	57	57	57	59	62	64	61
Arica, Chile	29	0	30	64	64	63	61	57	57	55	55	55	57	59	61	59
Iquique, Chile	6	0	30	63	61	61	57	57	55	55	55	55	57	59	61	57
Canchones, Chile	960	—	5	54	52	46	41	36	32	32	34	36	37	41	45	39
Pintados, Chile	977	—	4	52	54	48	45	39	36	34	34	39	39	41	46	43
Calama, Chile	2 260	81	2	41	41	39	37	36	34	34	37	37	39	39	41	37
Antofagasta, Chile	94	0	30	63	63	61	57	55	52	52	52	54	55	57	61	57
Taltal, Chile	5	0	20	64	64	63	59	55	54	52	54	54	57	59	63	59
Caldera, Chile	14	0	31	61	61	59	57	54	50	50	50	52	54	55	59	55
Vallenar, Chile	47	25	4	55	54	52	48	46	43	43	43	45	48	48	52	48
Vicuna, Chile	620	—	8	54	54	50	46	45	43	43	41	45	46	48	50	46
Los Andes, Chile	—	—	36	54	54	50	45	41	47	47	49	41	45	48	52	45
Puerto Madryn, Argentina	40	—	12	55	56	52	46	40	36	34	36	39	44	46	53	45
San Antonio, Chile	—	0	10	57	54	50	45	41	36	36	36	39	43	50	54	45
Puerto Deseado, Argentina	—	0	8	50	48	46	41	36	34	32	34	36	39	45	46	41
Puerto Gallegos, Argentina	—	0	13	43	41	39	34	28	25	25	28	32	36	37	41	34
Santa Cruz, Argentina	39	—	12	48	48	44	39	33	29	28	31	34	39	42	46	39

D. MEAN CLOUDINESS (tenths of sky covered)

Station	No. years rec.	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Lima, Peru	8	5	4	4	4	7	9	9	9	9	8	6	6	7
Mollendo, Peru	10	6	6	5	6	7	8	8	9	9	8	7	7	7
Tacna, Peru	6	6	6	5	5	6	6	6	6	6	6	6	6	6
Arica, Chile	11	5	4	3	4	6	7	7	7	7	6	5	4	5
Iquique Chile	14	5	4	4	4	6	8	8	8	8	7	6	4	6
Canchones, Chile	5	4	3	1	1	2	2	1	1	1	1	1	2	2
Pintados, Chile	4	4	6	4	4	5	5	3	4	3	3	2	5	4
Calama, Chile	2	2	2	1	2	2	1	0	1	0	1	2	1	1
Antofagasta, Chile	14	3	2	3	4	4	4	4	5	5	5	5	4	4
Taltal	12	4	3	3	4	5	5	5	6	6	6	5	4	5
Los Andes, Chile	14	1	1	2	3	5	5	5	5	5	4	3	2	4
Valparaiso, Chile	14	4	3	4	5	5	5	5	5	5	5	4	3	4
Bahia Blanca, Argentina	29	3	3	4	4	4	5	5	4	4	3	4	4	4
Puerto Gallegos, Argentina		8	7	7	6	6	6	6	7	6	7	7	8	7

E. MEAN MONTHLY PRECIPITATION (in.)

Station	No. years rec.	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Ancon, Ecuador	14	1.6	3.4	4.2	1.7	0.07	0.12	*[1]	*	0.04	0.04	*	*	10.7
Lambayegue, Peru	8	0.04	0.12	0.4	0.07	0.07	0.04	0	*	*	*	*	0.07	0.9
Chiclayo, Peru	3-4	0	0.07	0 4	0	0	—	0	0	0.07	0.04	0	—	0.6
Trujillo, Peru	2-4	0.1	0.4	0.3	0.03	0	0.03	0.07	0	0	—	0.07	0.03	1.1
Lima, Peru	26	*	*	0.04	0.04	0.07	0.20	0.3	0.4	0.3	0.16	0.08	0.04	1.8
Mollendo, Peru	13	0.04	0.08	0	0.04	0.08	0.04	0.04	0.20	0.20	0.08	0.08	*	0.87
Tacna, Peru	6	0.28	0	0	0.08	0	0	0.16	0.20	0.24	0.12	0.04	0.04	1.18
Arica, Chile	10	0	0	—	—	—	*	*	*	*	0	—	—	0.04
Iquique, Chile	30	0	0	0	0	0	0	*	0	0.04	0	0	0	0.04
Canchones, Chile	6	*	*	—	—	—	—	*	—	—	—	—	—	0.04
Pintados, Chile	8	—	*	*	—	—	*	—	—	—	—	—	—	*
Calama, Chile	2	0	0	0	0	0	0	0	0	0	0	0	0	0
Antofagasta, Chile	30	—	—	—	*	*	0.08	0.08	0.04	0.04	0.04	*	0	0.32
Taltal, Chile	21	*	0	0	*	0.08	0.24	0.24	0.24	0.08	0.08	0.04	*	0.98
La Serena, Chile	10	*	0.24	*	0.12	0.83	0.83	0.87	0.83	0.16	0.08	0.08	*	4.0
Caldera, Chile	10	*	0	*	0.04	0.24	0.43	0.08	0.08	0.04	0.04	*	*	1.1
Vallenar, Chile	39	—	0	0	0.08	0.43	0.98	0.43	0.47	0.08	0.08	*	0	2.52
Vicuna, Chile	30	*	0.04	0.04	0.12	0.75	1.77	1.18	1.02	0.28	0.20	0.04	*	5.82
Valparaiso, Chile	57	0	0	0.35	0.55	3.8	5.7	3.9	2.6	1.3	0.43	0.28	0.08	19.2
Puerto Madryn, Argentina	20	0.6	0.5	0.5	0.6	0.7	0.6	0.5	0.2	0.3	0.5	0.5	0.5	6.1
San Antonio, Argentina	10	0.59	0.27	0.66	1.14	1.10	0.66	0.74	0.23	0.70	0.43	0.20	0.20	6.9
Trelew, Argentina	10	0.12	0.23	1.06	0.63	0.94	0.27	0.98	0.47	0.74	0.20	0.78	0.94	7.40
Sarmiento, Argentina	10	0.47	0.43	0.74	0.59	1.10	0.55	0.94	0.55	0.55	0.20	0.70	0.35	7.2
Puerto Deseado, Argentina	8	0.59	0.51	0.31	0.70	1.61	0.59	1.30	0.51	0.08	0.31	0.2	0.51	7.2
Puerto Gallegos, Argentina	13	1.06	0.67	1.18	0.83	1.3	1.4	0.79	0.63	0.39	0.75	0.83	1.77	11.65
Santa Cruz, Argentina	20	0.6	0.3	0.3	0.6	0.4	0.5	0.4	0.5	0.3	0.3	0.4	0.7	5.3

1. * = 0.05 in. or less.

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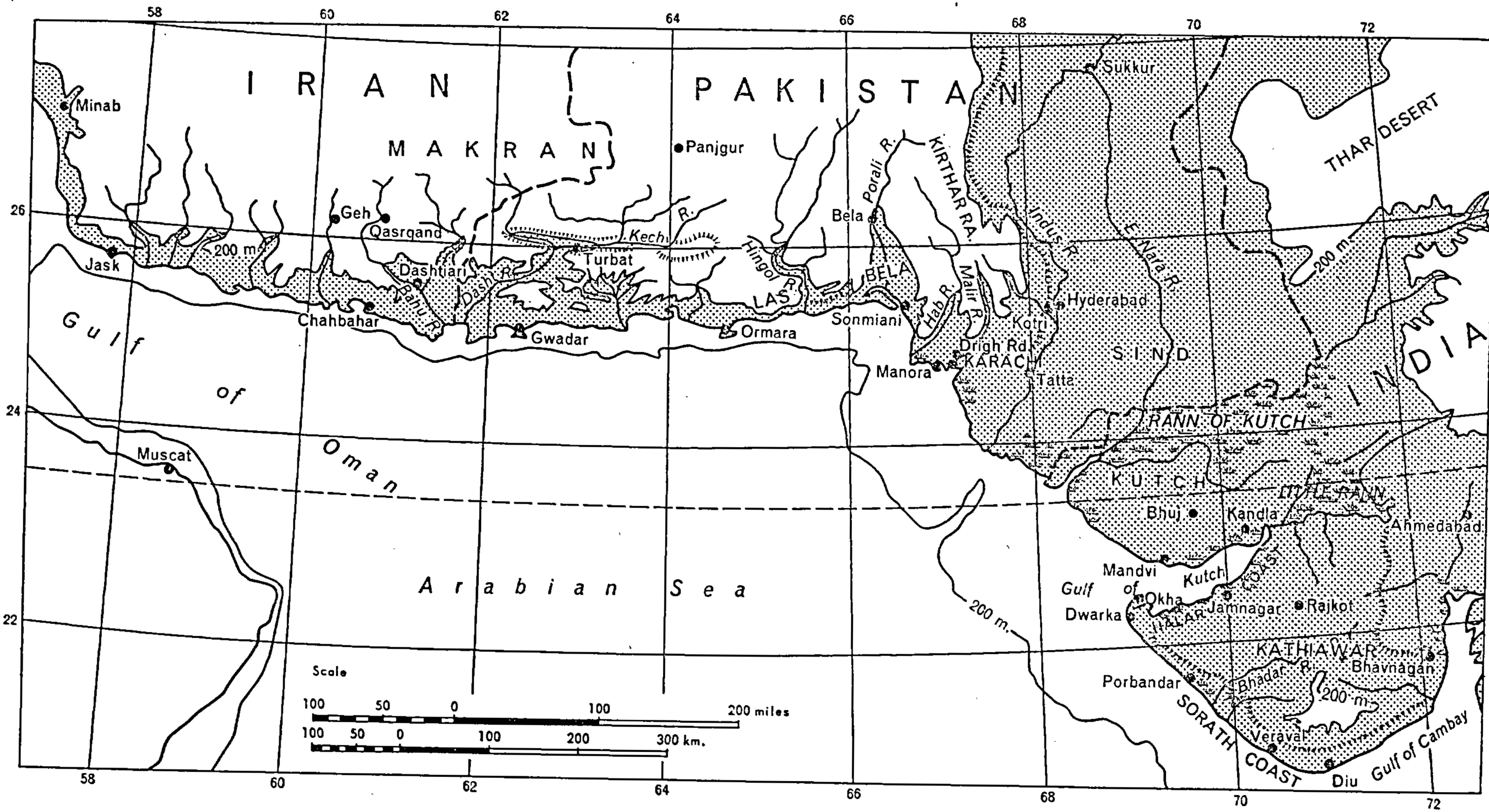
Map 1. Kathiawar-Makran.



IRAN
FARS
LARISTAN
MAKRAN
IRAQ
KUWAIT
Kuwait
NEUTRAL ZONE
SAUDI ARABIA
QATAR
JAFURA DESERT
TRUCIAL COAST
MUSCAT AND OMAN
BATINA COAST
Persian Gulf
Gulf of Oman
Great Pearl Bank
Scale
100 0 100 200 miles
100 0 100 200 km.
Andimeshk
Karun R.
Tigris R.
Euphrates R.
Shatt al Arab
Hor al Hammar
Basra
Abadan
Bandar Shahpur
Shiraz
Bushire
Shur R.
Mand R.
Lavar
Kangan
Daiyir
Siraf
Asalu
Naband
Mehran R.
Charak
Mihrakan
Lingeh
Qishm I.
Henjam
Hormuz
Bandar Abbas
Minab
Cape Masandam
Jask
Ras as Safaniya
Nafiya
Ras Abu Ali
Ras Tanura
Qatif
Dammam
Dhahran
Bahrein I.
Abqaiq
Oqair
Hofuf
Salwa Bay
Doha
Umm Said
Haradh
Das I.
Zirko I.
Sir Abu Nuair
Dalmah I.
Yas I.
Matti Bay
Sabkhat Matti
Abu Dhabi
Buraimi
Sharja
Dibai
Ras Shaikh Masud
Dibba
Fujaira
Sohar
Khabura
Sib
Ras al Hammar
Muscat
Quryat
Ras al Hadd
Sur
200 m.
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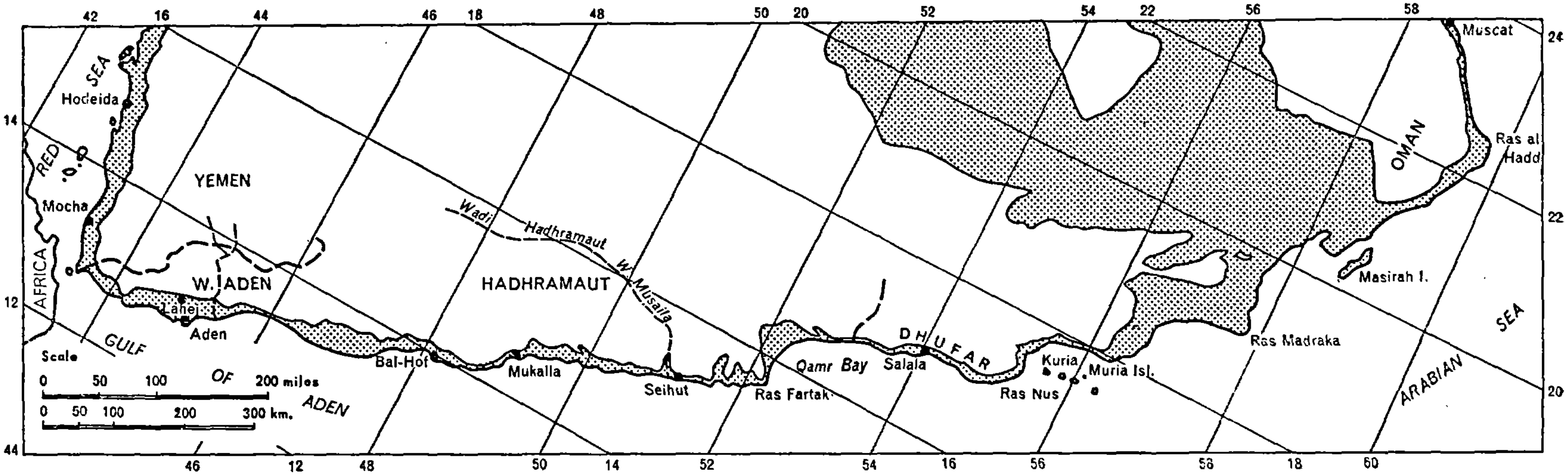
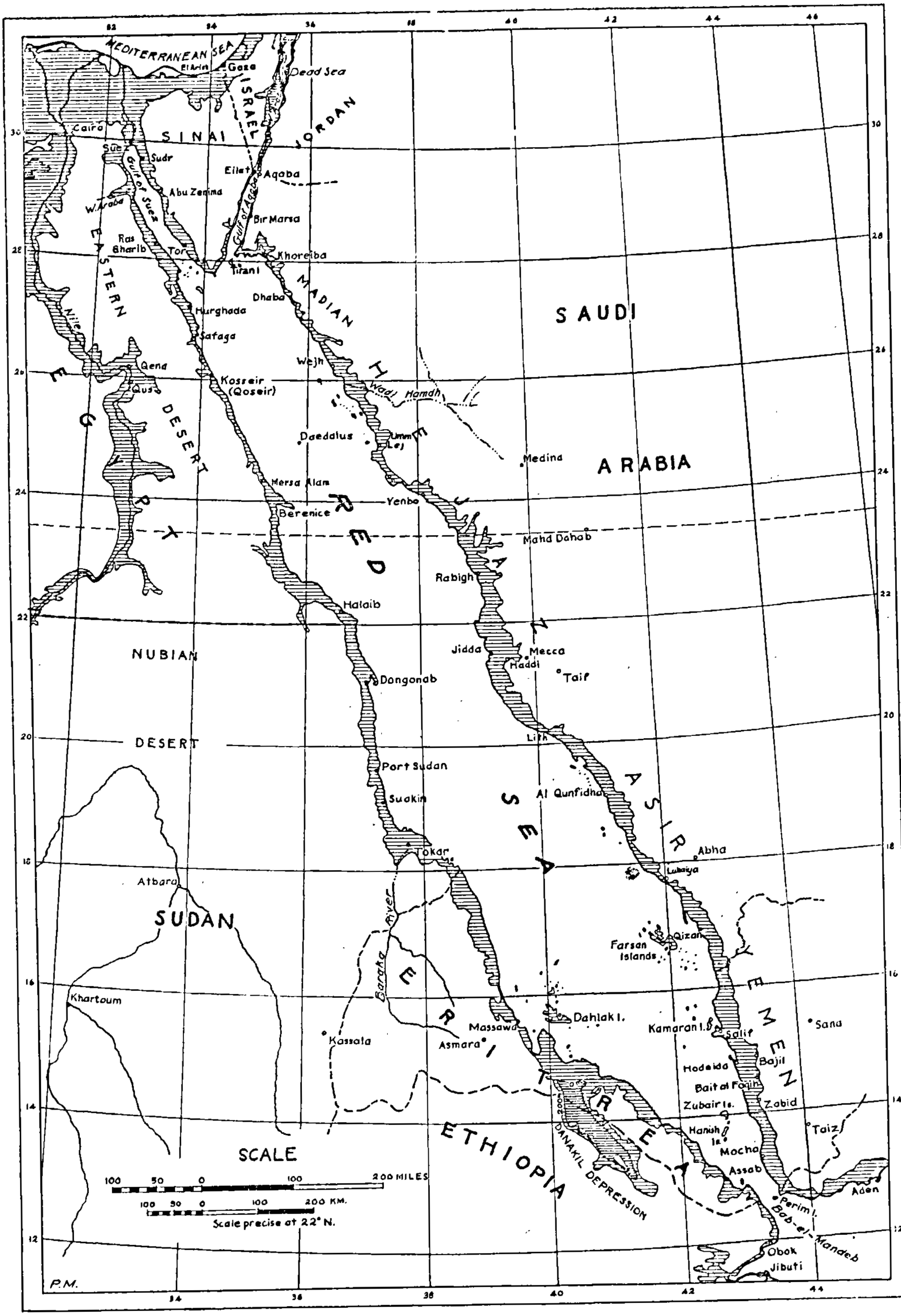
P.M.

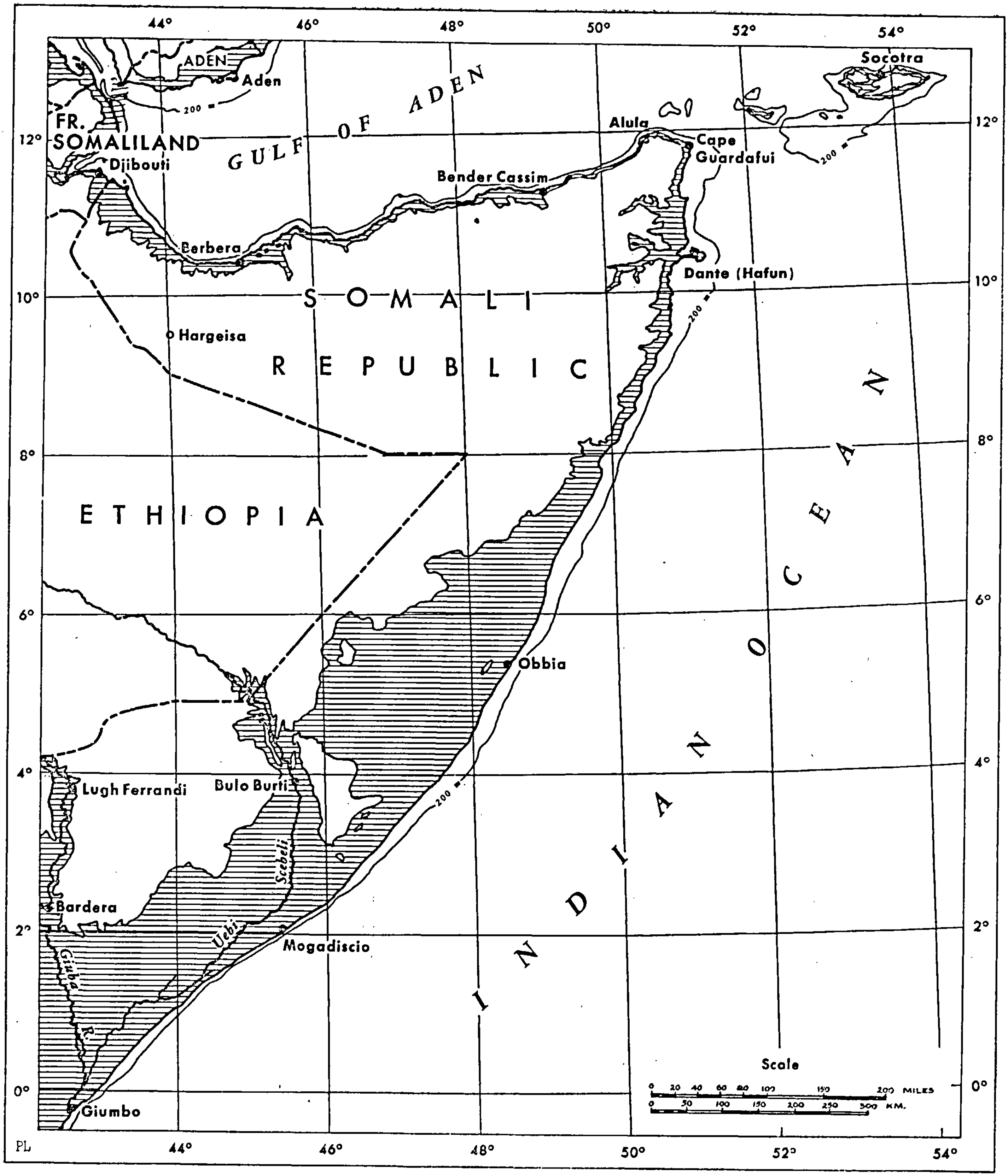
Map 2. Persian Gulf.



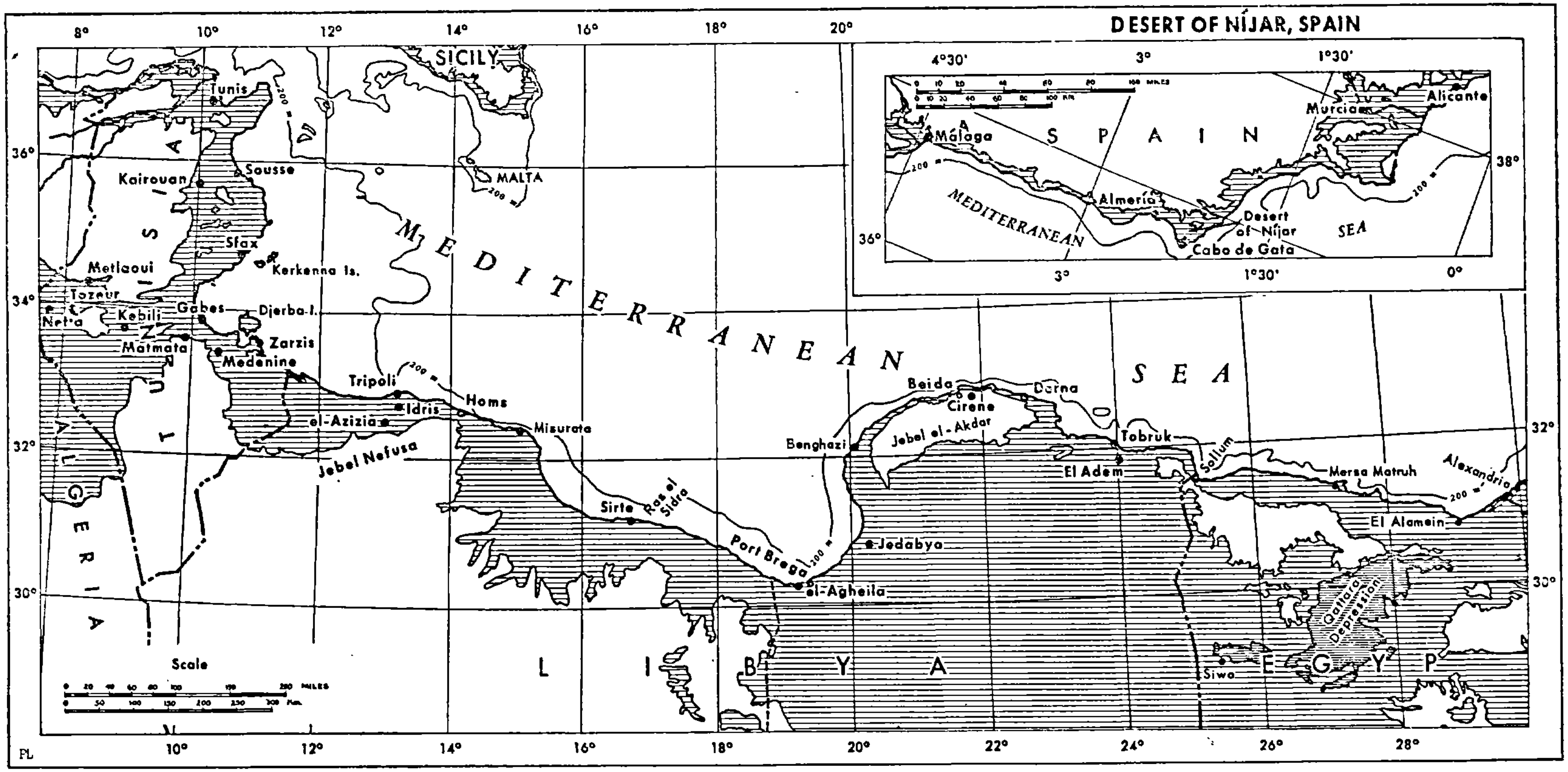
Map 3. South-East Arabia.


MEDITERRANEAN SEA
El Arish
Gaza
Dead Sea
ISRAEL
JORDAN
SINAI
Cairo
Suez
Sudr
Gulf of Suez
Eilat
Aqaba
Abu Zenima
W. Araba
Gulf of Aqaba
Bir Marsa
Ras Gharib
Tor
Khoreiba
Tiran I.
EASTERN
Dhaba
MADIAN
Hurghada
Nile
Safaga
SAUDI
Wejh
Qena
Qus
Kosseir
(Qoseir)
Wadi Hamdh
EGYPT
DESERT
Daedalus
Umm Lej
Medina
HEJAZ
ARABIA
Mersa Alam
Yenbo
RED
Berenice
Mahd Dahab
Rabigh
Halaib
NUBIAN
Jidda
Mecca
Haddi
Taif
Dongonab
DESERT
Lith
Port Sudan
Suakin
SEA
Al Qunfidha
ASIR
Abha
Tokar
Luhaiya
Atbara
SUDAN
River
Baraka
Farsan Islands
Qizan
YEMEN
ERITREA
Khartoum
Dahlak I.
Kamaran I.
Sana
Massawa
Salif
Kassala
Asmara
Hodeida
Bajil
Bait al Faqih
Zubair Is.
Zabid
ETHIOPIA
Hanish Is.
Taiz
DANAKIL DEPRESSION
SCALE
Mocha
Assab
Aden
100 50 0 100 200 MILES
100 50 0 100 200 KM.
Scale precise at 22° N.
Perim I.
Bab-el-Mandeb
Obok
Jibuti
P.M.

Map 4. Red Sea.

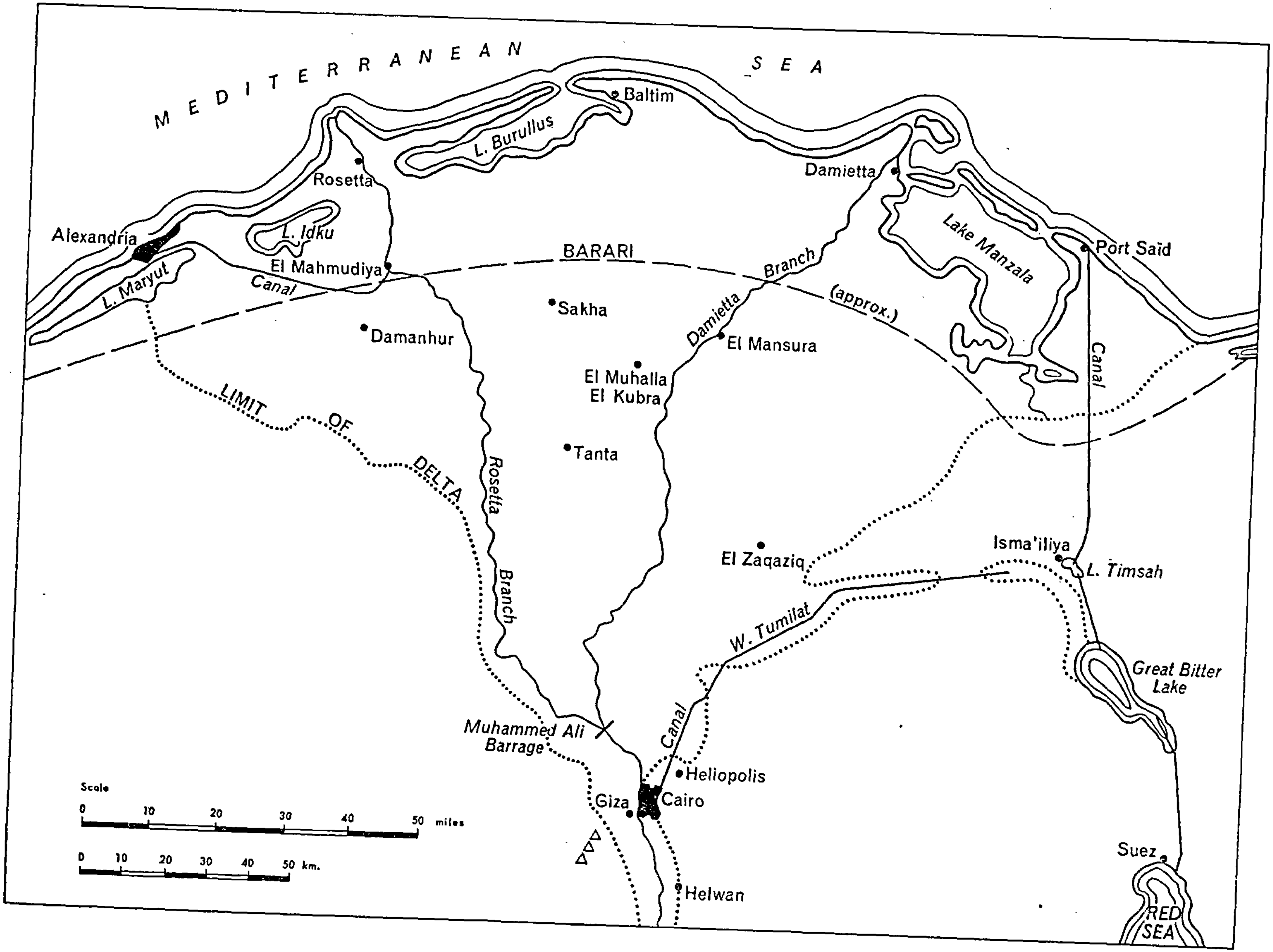


Map 5. Somalia.

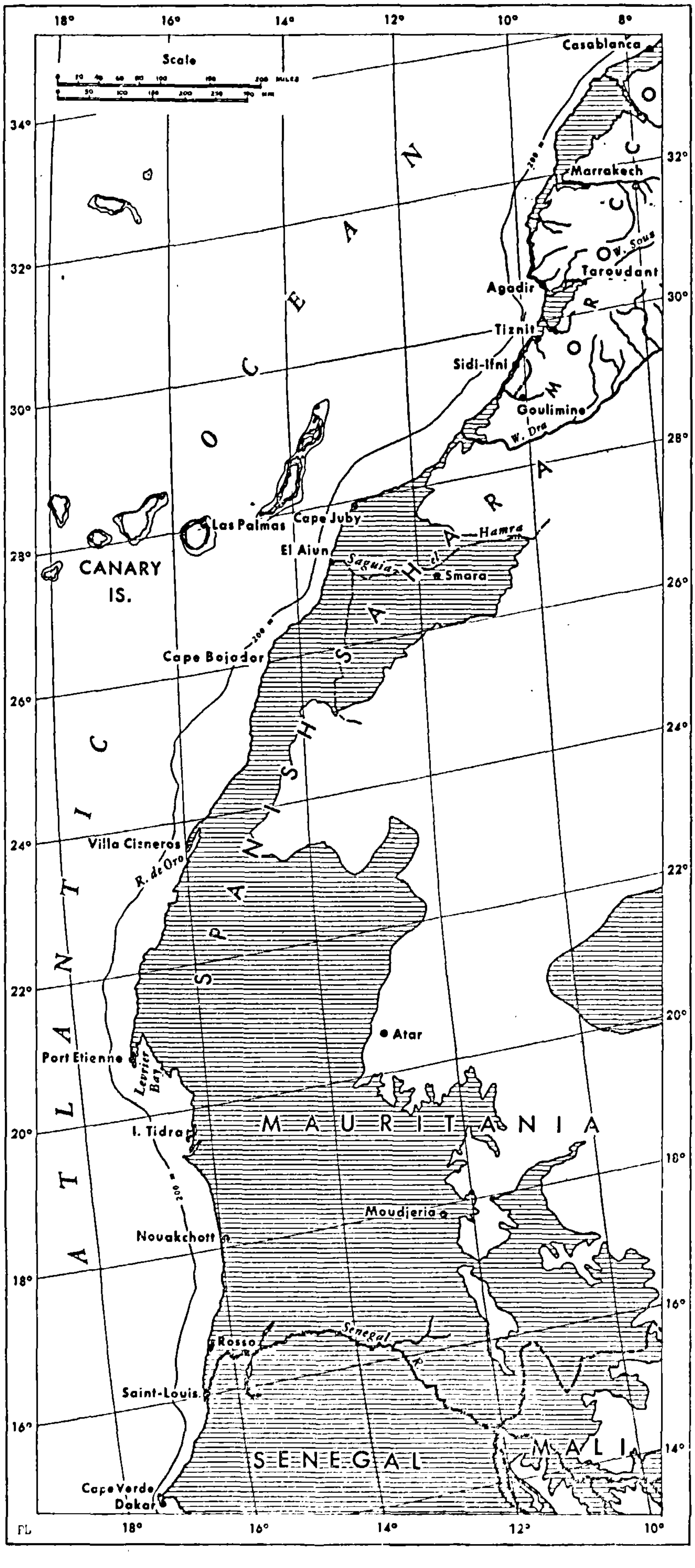


Map 6. Mediterranean.

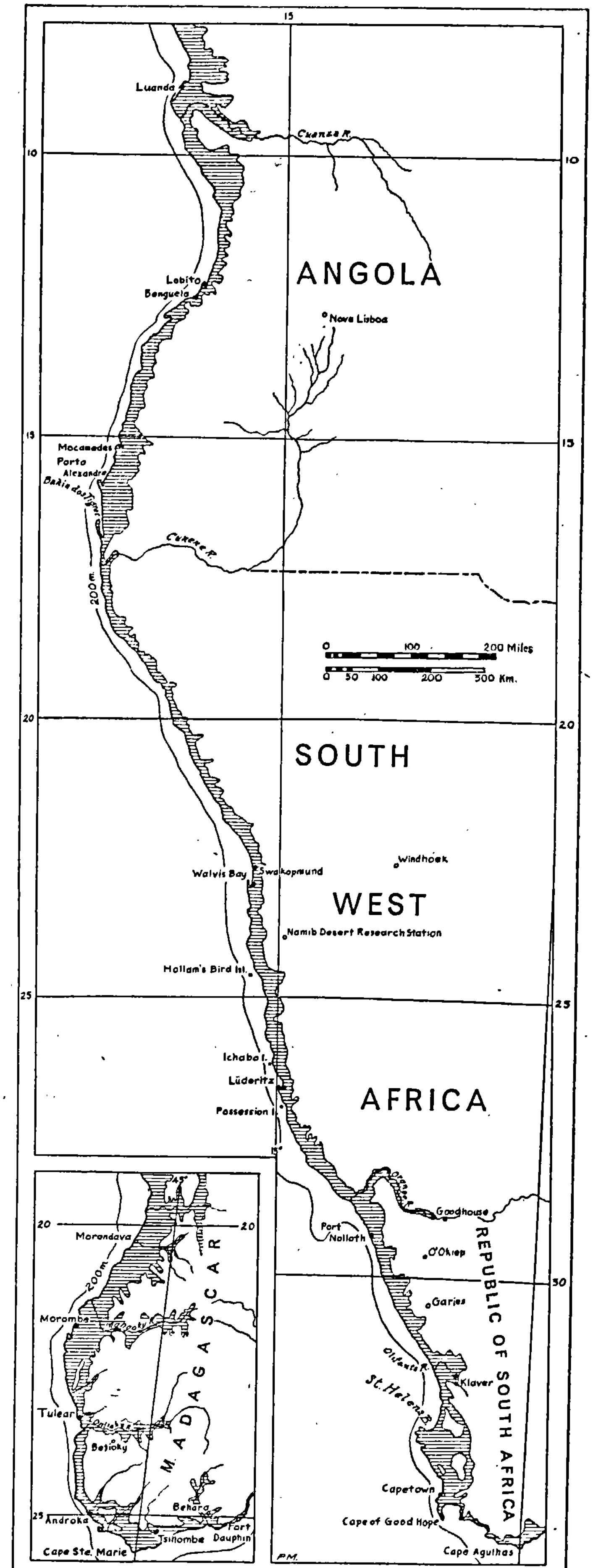
Map 6ª. Nile delta.



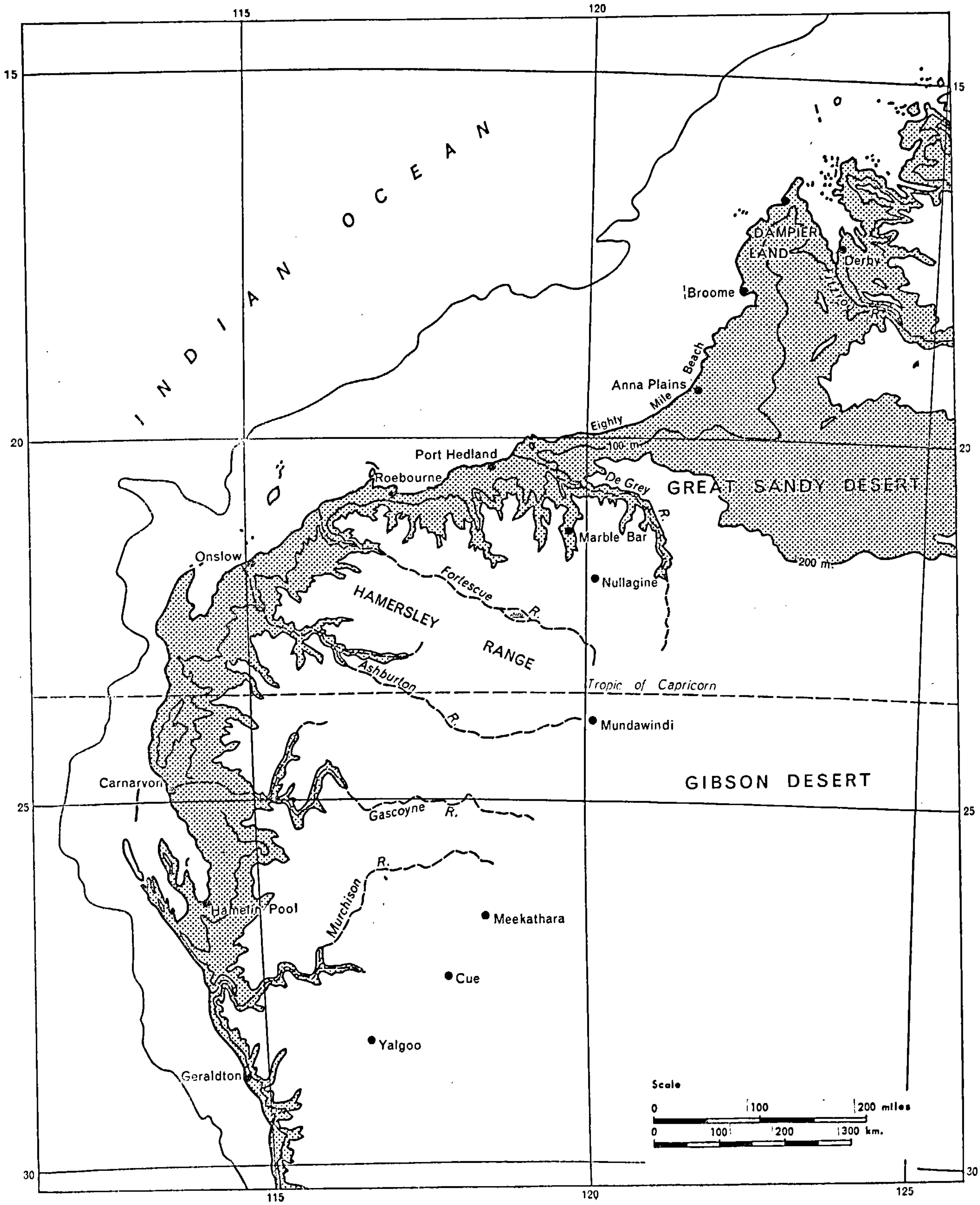
MEDITERRANEAN
SEA
Baltim
L. Burullus
Rosetta
Damietta
Alexandria
L. Idku
Lake Manzala
Port Saïd
BARARI
El Mahmudiya
L. Maryut
Canal
Branch
(approx.)
Sakha
Damanhur
Damietta
El Mansura
Canal
El Muhalla
El Kubra
LIMIT
OF
DELTA
Tanta
Rosetta
Branch
El Zaqaziq
Isma'iliya
L. Timsah
W. Tumilat
Great Bitter
Lake
Muhammed Ali
Barrage
Canal
Heliopolis
Giza
Cairo
Scale
0 10 20 30 40 50 miles
0 10 20 30 40 50 km.
Suez
Helwan
RED
SEA



Map 7. Atlantic Sahara.

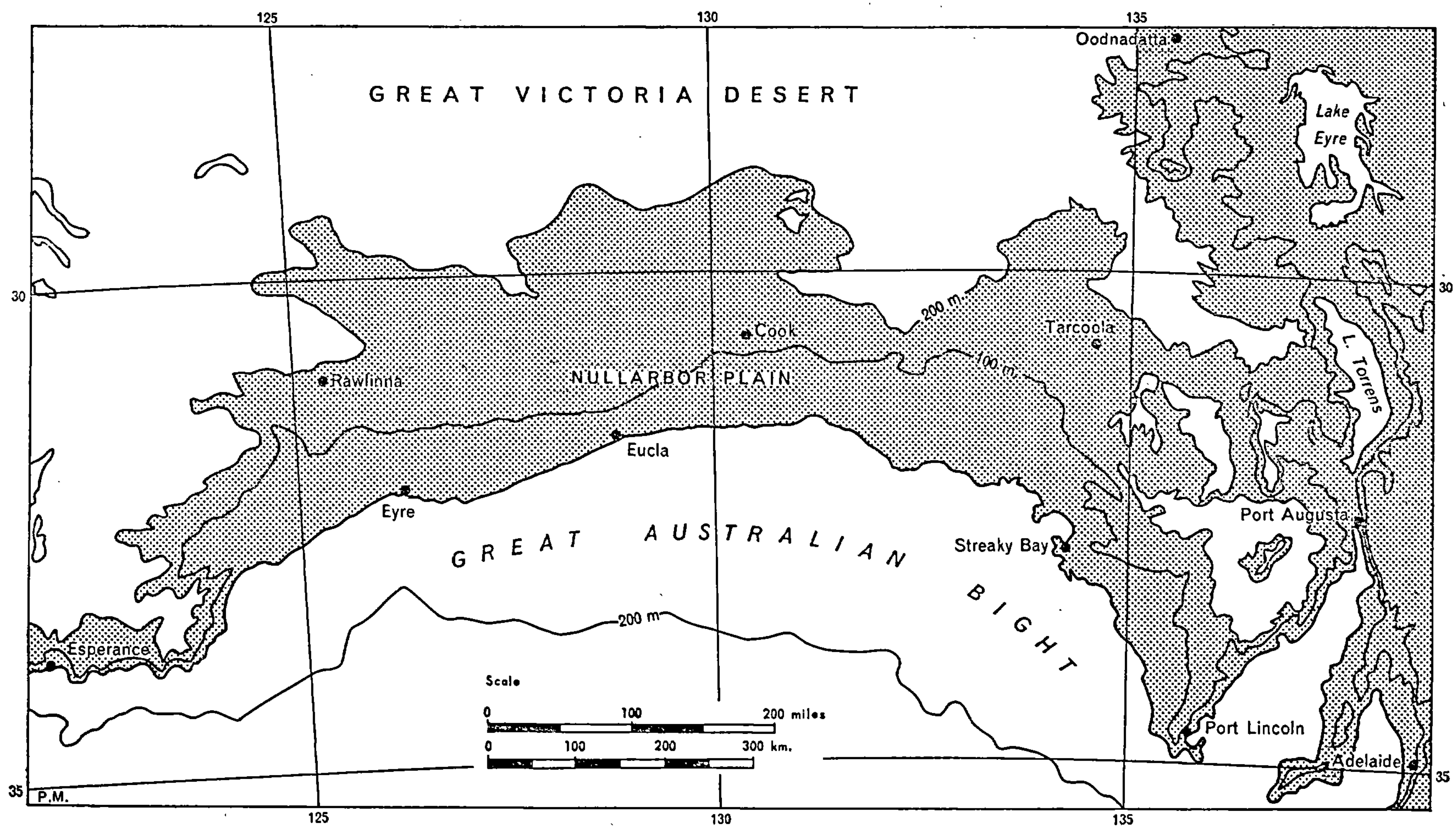


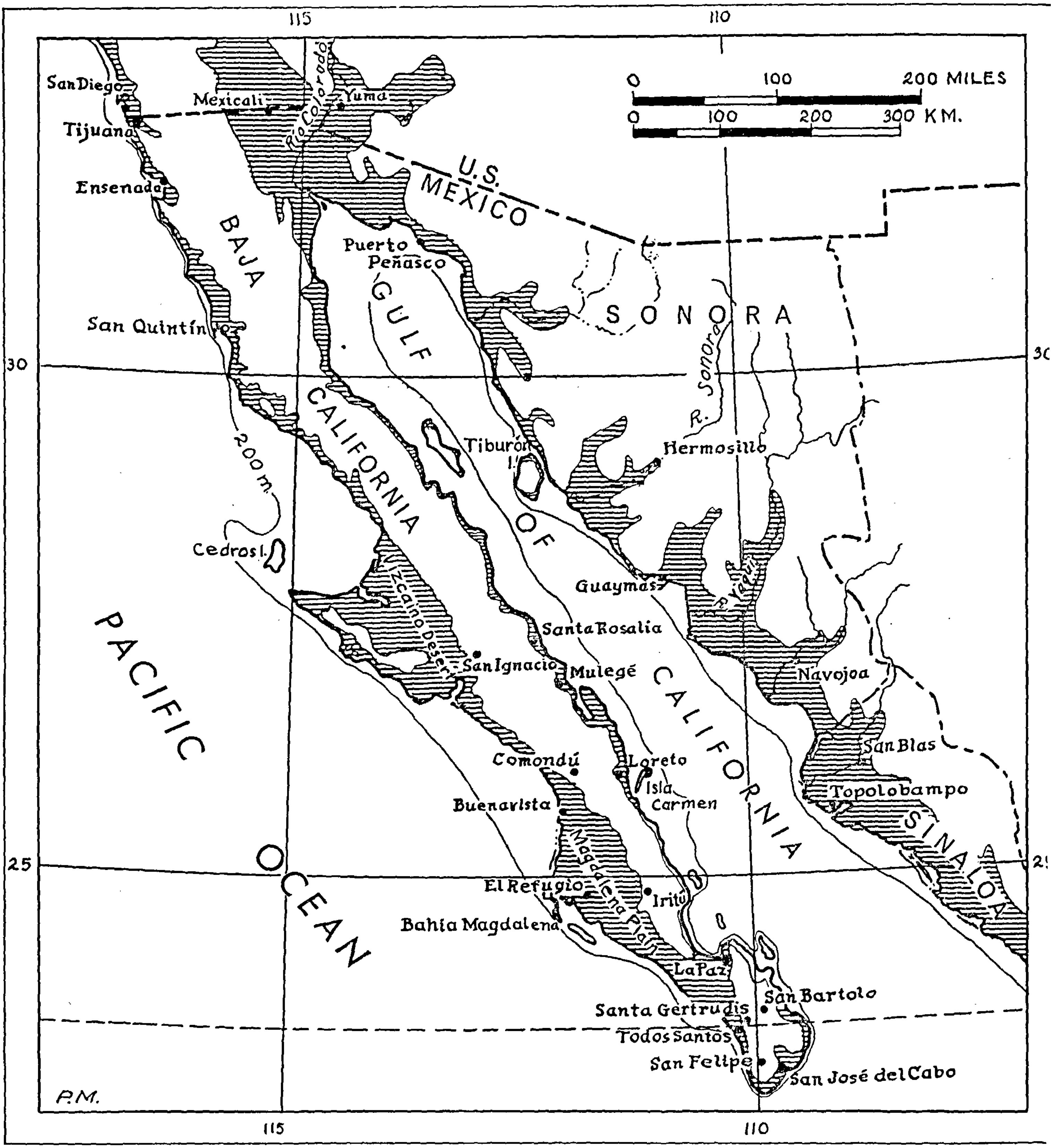
Map 8. Southern Africa.



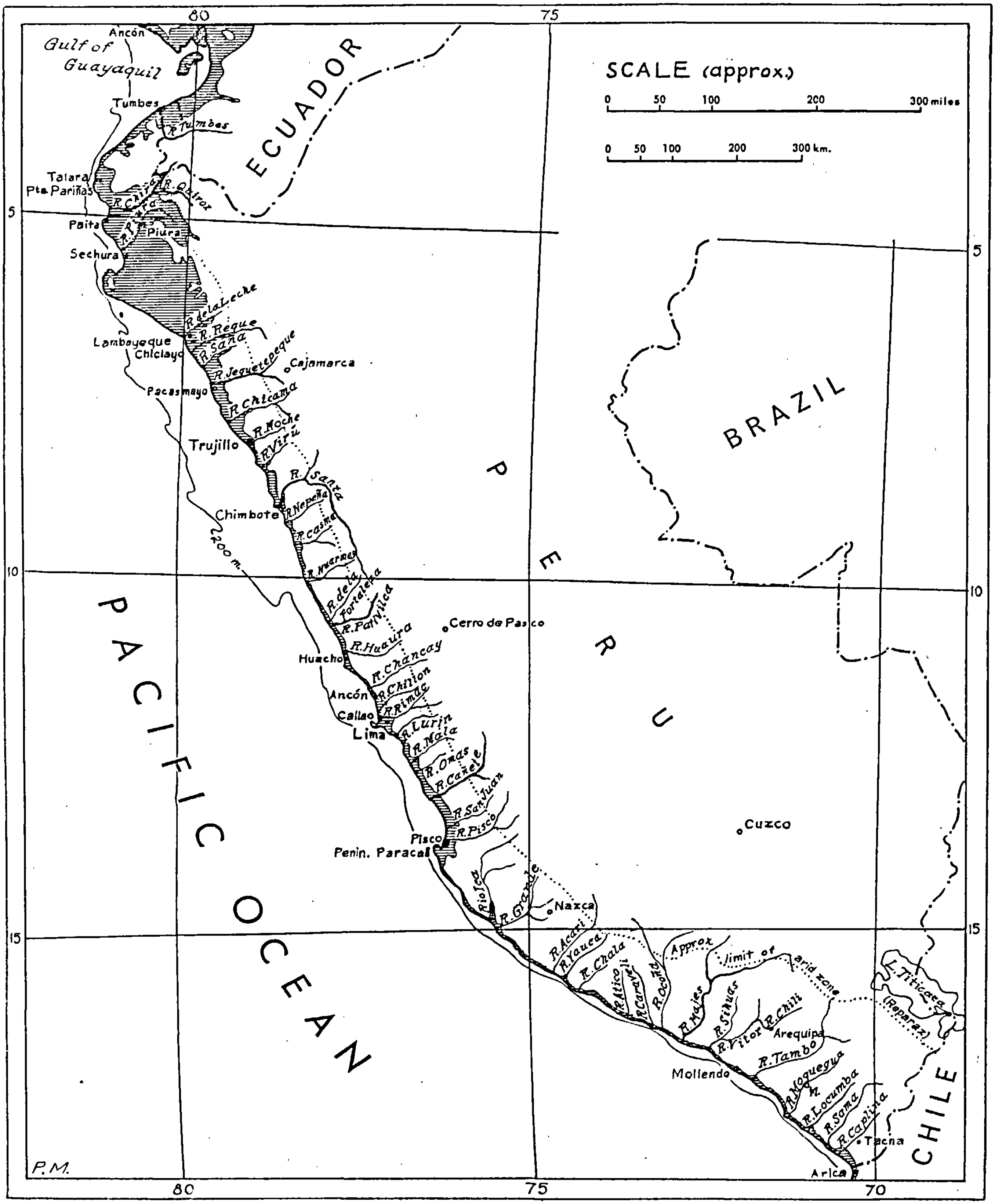
Map 9. Western Australia.

Map 10. Southern Australia.

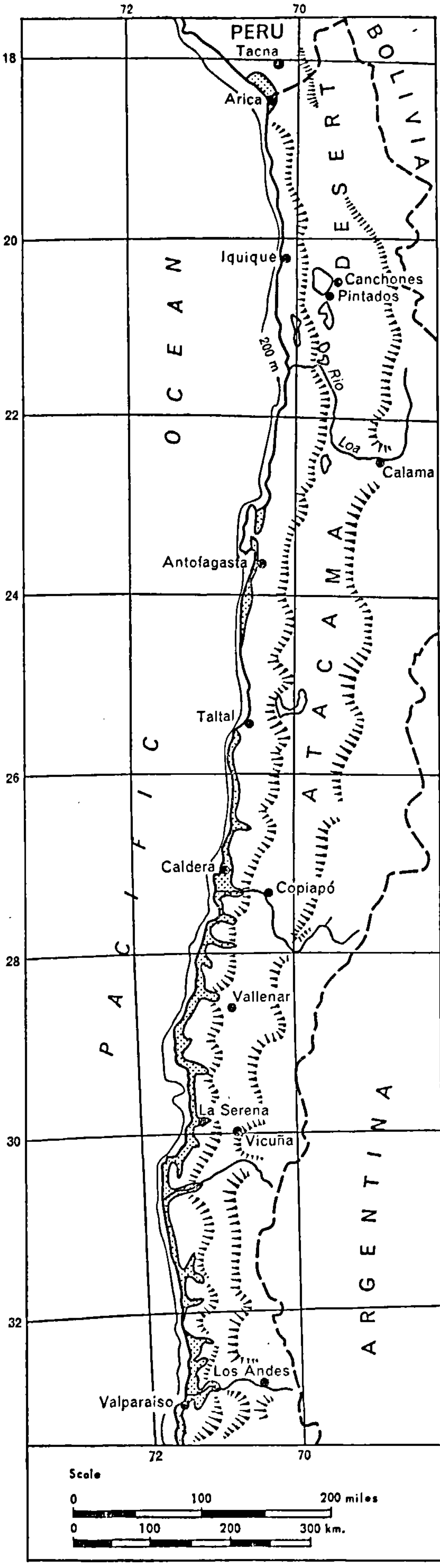




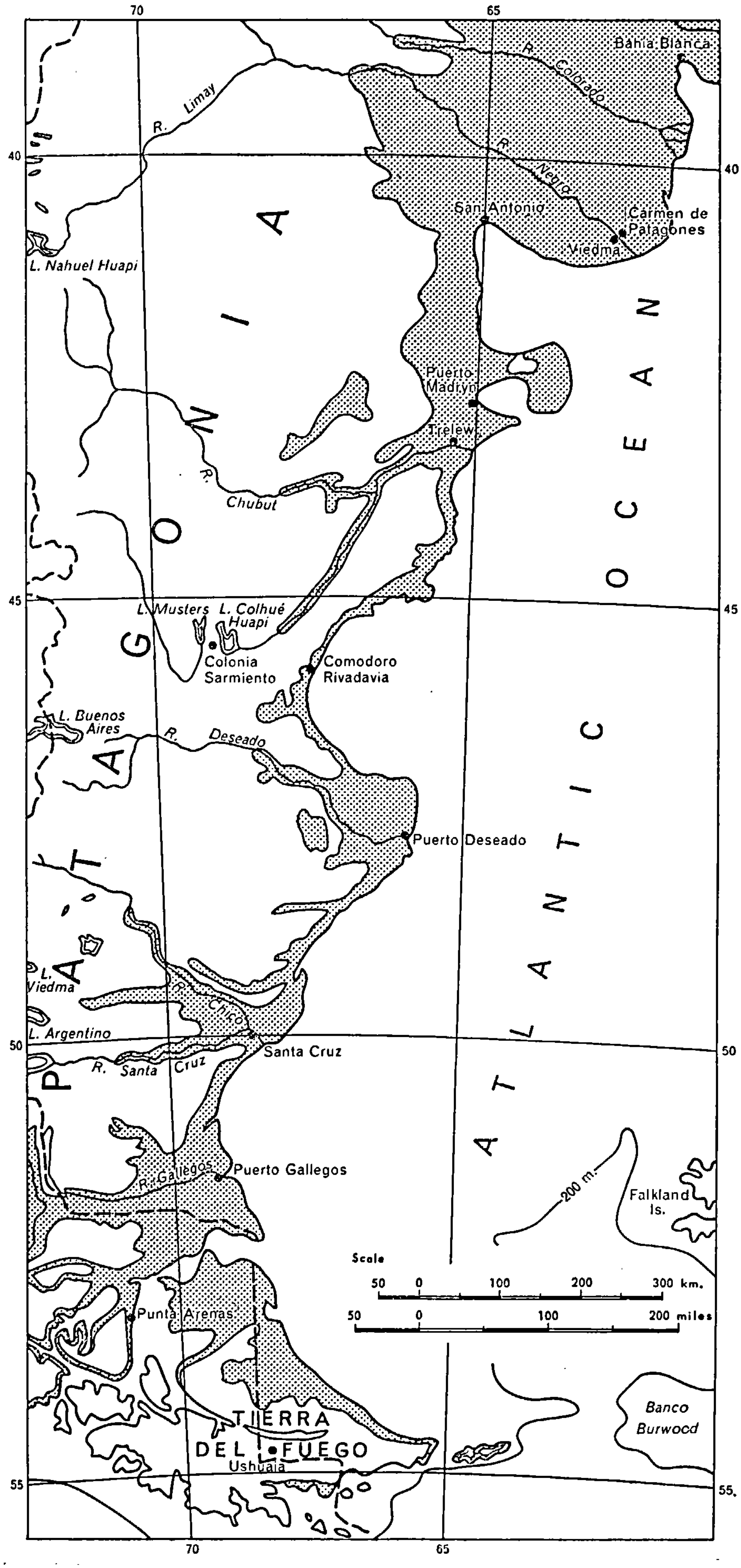
Map 11. North-West Mexico.



Map 12. Peruvian coast.

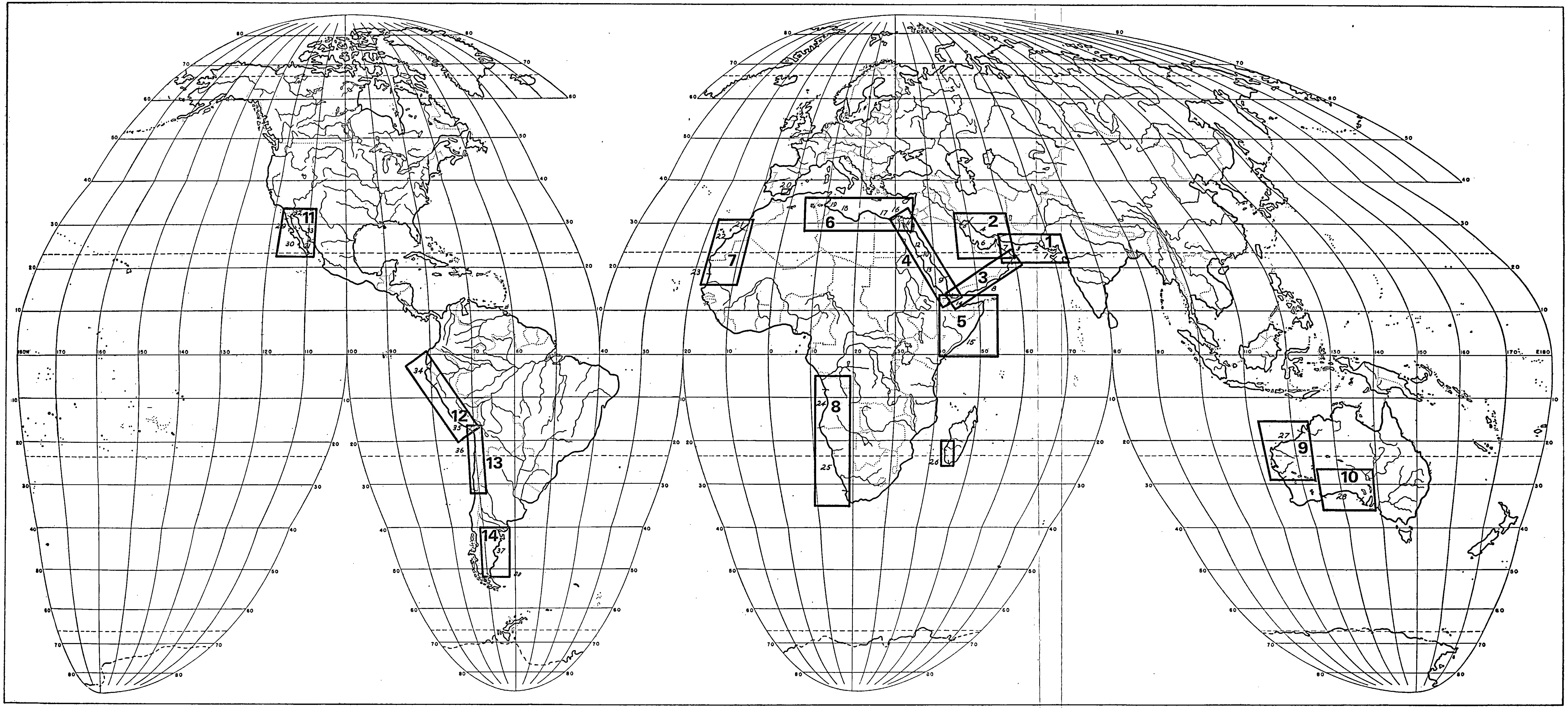


Map 13. Atacama.



Map 14. Patagonia.

Location chart



Goode's Homolosine Equal-area Projection

Key: Map **3**
Coastal sector 8

0 500 1000 1500 2000 2500 3000 Miles
0 1000 2000 3000 4000 Kilometres

(True distances on Mid-Meridians and Parallels 0° to 40°)