1963

Physical Geography of the Las Bela Coastal Plain, West Pakistan.

Rodman Eldredge Snead
Louisiana State University and Agricultural & Mechanical College

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A Dissertation

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Louisiana State University and
Agricultural and Mechanical College
in partial fulfillment of the
requirements for the degree of
Doctor of Philosophy

in

The Department of Geography

by
Rodman Eldredge Snead
B.A., University of Virginia, 1953
M.S., Syracuse University, 1955
June, 1963
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ABSTRACT

This study is a description of a little known segment of the West Pakistan coast and an interpretation of the physical changes it has undergone during the Quaternary Period. Field work was carried on for six months in 1959 and for three months in 1960.

The Las Bela Valley and coastal plain are at the extreme south-eastern part of Baluchistan. They form a triangle, the coastal base of which is approximately 100 miles long and is situated between 65° and 67° East Longitude; the apex of the triangle extends 70 miles inland (24°50' to 26°30' North Latitude). The total area of approximately 3500 square miles includes the low coastal zone, the alluvial plain and the foothills of the mountain ranges.

Climatically, the region is a transitional zone between the winter rainfall from western depressions and summer rainfall from monsoon storms. A few Arabian Sea cyclones cause considerable damage. The dominating climatic factor is the dry continental air mass which is broken only occasionally by the above mentioned storm patterns.
Vegetation on the coastal plain is predominately xerophytic shrubs with low, widely-spaced species of *Suaeda*, *Haloxylon*, and *Salsola*. *Tamarix* trees and *Sacchrum* grasses are the most important riverine vegetation. Gravel fans and foothills are dotted with high, cactus-like *Euphorbia neriifolia*. This plant helps to indicate older surfaces for it is seldom found on Recent alluvium.

The area is a segment of the Alpine-Himalayan geosynclinal belt, with compressive stages of mountain building in continuing process. The largest Pleistocene sand accumulation is on the east side of the central plain where over seven cubic miles of material have been deposited by southwest winds. There is no sand accumulation on the west side of the valley but Pleistocene gravel fans exist from 4 to 5 feet thick.

Although broad belts of raised beaches characterize much of the coast west of the Las Bela area, they are not found in the section under study. Recent local movements consist of three terrace levels to a height of ten feet in the alluvium of the central plain; by the tilting of the main Pleistocene sand accumulation toward the depression of Siranda Lake, and by crustal movements across the beach ridges.

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The sand accumulation around the north end of Miāni Lagoon, the wave cut arcs in the Pliocene-Pleistocene deposits on both sides of the valley, and the beds of oysters and barnacles, which are uplifted in places from 10 to 15 feet above sea level, constitute evidence that the sea once occupied the lower portion of the coastal plain.

At the present time two large spits extend across Sonmiāni Bay. Ādi Spit has developed eastward from the south tip of the Hāro Mountain Range to a distance of 35 miles. Sonmiāni Spit has grown west from the Pleistocene sand accumulation as a result of delta building by the Windar River. Changes in the beds of mangroves and bottom profiles indicate Miāni Lagoon is being filled in.

At present retreat of the coast appears to be taking place. No new beach ridges are being formed and sand is migrating inland in the form of large crescentic dunes.
CHAPTER I

INTRODUCTION

This study has two aims. One is to describe a little known segment of the Pakistan coast—the Las Bela Coastal Plain; the other to depict and interpret the physical changes that have taken place in this region during the Quaternary Period. It is hoped that the data presented in this study may contribute to a better understanding of a tectonically and geomorphically active area.

The study is based upon field work carried out in the Las Bela Region of Baluchistan, West Pakistan during the years 1959 to 1961. A preliminary acquaintance with the area was gained during 1957 and 1958 when the writer was engaged in another project in Pakistan.

Difficulties in accomplishing field work in the Las Bela area are many. Roads are poor and bridges nonexistent. Many hours were spent in extricating the jeep from sand or mud. Long delays were incurred when floods filled the river valleys and gullies. Sections of coastline, notably the
large spit, called Ādi, and areas along the western side of
the plain, were difficult to reach.

Archival and library work was undertaken in Karāchi,
Pakistan; New Delhi, India; and London, England. Field in­
vestigations included first a study of the over-all land forms,
climate, and vegetation of the region. Later a series of
selected representative locations were examined in detail.
During the second trip field work concentrated on those areas
which presented particular geomorphological problems. Daily
weather information was obtained from observations by the
writer in the field and from the records of the meteorologi­
cal stations at Sonmiāni, Bela, and Ormāra. Long term
climatic data was procured from the meteorological office at
Karāchi.

The Las Bela Coastal Plain, which is the extreme east­
ern part of the Makrān coastal strip of Baluchistan, lies
within an area bounded by parallels 24° 47' and 26° 30'
North Latitude and meridians 65° and 67° East Longitude
(Fig. 1). Part of the Makrān coastal strip which is the
subject of this study extends from Ras Muāri (Cape Monze)
westward approximately 65 miles to Ras Malān, and inland to
include the triangular Las Bela Plain and the foothill
regions of the Mor and Hāro mountain ranges (Fig. 2 and Fig.
10). These two ranges, approximately 60 miles apart at the
FIGURE 1. Location Map
FIGURE 2. Coastal Types
coast, merge 70 miles to the north to enclose the plain.

The Las Bela Plain can be divided physiographically into three portions: the low, sandy, coastal plain (Fig. 3), which includes beach ridges, shifting sand dunes, and lagoonal flats; the central plain covered with alluvial deposits derived mainly from the waters of the Porāli, Kharrari, and Windar rivers, and their tributaries (Fig. 19); and older and higher sand and gravel foothills that flank the central plain. The region under consideration has an area of approximately 3,500 square miles. Except for the Hāro and Hala mountain sections, which are within Kalāt Administrative District, the area lies within the former Las Bela State and is under the present Karāchi Administrative District.

The Baluchistan hills form the rugged eastern escarpment of the Iranian Plateau (Fig. 3). Evidence exists that these hills have been inhabited for at least 5,000 years and man may have lived as both herdsman and farmer in the Las Bela area for approximately that length of time and possibly much longer. The absence of monuments or buildings of former civilizations does not exclude the possibility that man has derived subsistence from the land for a very long period of time. Recent investigations by archaeologists indicate that the Indus Civilization may have had outposts
FIGURE 3. Recorded earthquakes and active mud vents in southern Baluchistan (1919-1948). (Data from the Geophysical Institute, Geological Survey of Pakistan, Quetta, 1959.)
along the Makrān coast to facilitate trading with the Babylonian and Egyptian peoples between 2,500 and 1,500 B.C. Dales, found pottery of Harappan age north of Jīwani, and pottery discovered at Windar Kot, a site on the eastern side of the Las Bela Valley, also may belong to this age (Fig. 2).

One of the earliest accounts of the Makrān coast (Fig. 1) is found in Arrian's report on the voyage of Nearchus. While Nearchus sailed along the coast, Alexander the Great, in the year 327 B.C., crossed the Las Bela area by land. His exact return route from India is not known. Early Arab geographers explored Baluchistan and left valuable accounts, but not until the coming of the British were research expeditions sent out. The British, mainly interested in trade, made a few exploratory trips into the area.

Although the number of coastal studies has increased enormously during and since World War II the number of papers on coastal deserts is not large. Papers dealing with coastal deserts in the vicinity of Las Bela are few in number.

Utilization of the Coastal Plain by Humans and Animals

Although the main concern of this study is the physical geography of the Las Bela Coastal Plain, the inhabitants,
animals and their environment deserve mention.

Today, if the area has any cultural unity it is to
be found in a common way of life based mainly on subsistence-
agriculture and fishing. Economically, the Las Bela region
is beginning to stand out from adjacent areas as a result of
its position in the immediate hinterland of the port of
Karāchī, which is connected to the Las Bela Plain by a single
very poor road that is metalled for only 30 miles (Fig. 19).
With the improvement of communications, cultural changes
will probably accelerate.

Linguistically and racially, there is no unity in the
area. Four main indigenous groups are generally recognized.
Lāsi, who farm the central plain and speak a dialect of the
Sindhi language, introduced from Sind and Rajputana;
Brahui-speaking people from the mountain border country;
Baluchi-speaking people who live mainly along the coast and
the Pathans who have moved into the area from the north. The
Baluchi and Pathan languages are Iranian, but Brahui is
Dravidian in origin and is believed to be a remnant of the
once much larger Dravidian group whose principal body is now
some 1,700 miles away. The ancient Med fishermen along the
coast speak a dialect of Baluchi called Makrāni. Racially
there is a large admixture of people. A few Negro
descendants of African slaves are found along the coast and in some of the larger villages.

The low economic status of the Las Bela region is expressed by a dependence of the population upon local materials (Plate I-A). Farsh (*Nannorphos ritchieana*) grows abundantly on the rocky slopes of nearby hills and in the river beds and is widely used by the inhabitants in making mats, for baskets, sandals, walls and floors of huts and many other things (Plate I-B). Very little (*Typha elephantina*) pan elephant grass grows on the coastal plain and the inhabitants import mats made of this material from the Indus delta in exchange for fish.

Other local resources include barnacles and mussels which grow on the roots of mangroves in Miāni Lagoon. Barnacles and mussels are ground and used as bait for fish. Desert brush is gathered to feed the herds of camels which are used to carry commercial goods and to transport fish to Karāchi. Mangroves are used as fodder for these animals during the dry season. Approximately 20 per cent of the people living in the coastal villages are both agriculturists and herders. Sheep and goats ravage the countryside, stripping the surface of desert plant cover. A main export crop grown near the coast is castor bean (*Ricinus communis*).
The principal food crops, *jowar* (*Sorghum vulgare*) and millet *bajara* (*Pennisetum typhoides*), are grown on less sandy soils.

Potable water is one of the serious problems of the coastal villages. Most water is obtained from the base of sand dunes where it must be drawn off soon after it accumulates; otherwise, it becomes brackish because of seepage from ocean water. At Gadāni fishing village (Plate I-C), four wells have been dug at the base of a sand bluff to tap underground channels. Three of these wells are five or six feet deep and the water is slightly brackish (Plate I-D). A fourth well, only 40 feet from the coast, furnishes water too brackish for drinking.

**Fishing Settlements.**—At the time of Alexander the Great, the Makrān coast was known as *Gedrosia* (Fig. 1) and its inhabitants were called *Ichthyophagi*, or "fish eaters" by the Greeks. These people lived on a basic diet of fish and used local trees and brush for ordinary building materials. They traded fish and salt for wood suitable for boat building and for cotton which they used in making fish nets (Plate I-E). The population of the coast probably was quite small and early inhabitants' effect upon the physical landscape was insignificant.
The fishermen did not begin to change culturally until the eighth century A.D., when the Arabs conquered the territory and developed overland trade routes to neighboring districts. The most important change came with the introduction of the camel. This pack animal made possible transportation of products far into the interior of Baluchistan and Afghanistan, and the ports of Sonmiāni, Ormāra and Pasni became important trade centers. Gwādar, property of the Sultan of Oman, became a free port (Fig. 1). Imported items, such as silk, china, and cotton from as far away as Japan, were transported from Gwādar to other coastal ports and inland to Quetta and Kandahar. During the height of this trading period the fishing village of Sonmiāni acquired a population of 3,000 to 4,000 people. Active trading resulted in cultural changes. Hunting of wild animals for food and clothing practically ceased and clothes were made from imported cloth stitched in Arabic style. Fishing boats were built in Karāchi or imported from the Malabar coast (Plate I-F).

Settlements were located where they were protected from strong winds and high waves. Although the villages, Sonmiāni and Dāmb, were close to the large lagoon called Miāni, no improvement or change was made in the entrance of
the lagoon. With the development of Karāchi as a leading port around 1860, commerce moved mainly along the Indus Valley, and the Las Bela coastal ports lost their importance and reverted to small local fishing settlements. Today, not a single channel marker exists in Sonmīāni Harbor and because of the shifting shallow sand bars only small fishing craft are able to enter. Southern Baluchistan, on the fringe of British development of transportation along the Indus River and only 30 miles from the large seaport of Karāchi, was neither explored nor surveyed in detail until the first triangulation network was established in 1915.

Fishing.--The Arabian Sea and coastal lagoons abound in fish. The main deep sea fish caught include tuna (Thunnus thunnina), swordfish (Xiphias gladius), and several species of sharks, the largest of which is the "whale shark" (Rhineodon typicus). "White sharks" over 40 feet in length have been caught off the Makrān coast. In winter when the sea is calm and the surface water close to shore is warmer than offshore, fish move close to the beach for food and spawning. Plankton meadows on continental shelf attract not only small fish, but also the larger ones that feed on them. The number of species of fish may be more than 200, but the actual number is difficult to verify because fishermen throw
back the species that are valueless. The most important inshore fish include shark, drums or croakers, profets, catfish, skates, and rays. Perch, herring, yellow-tail, mackerel, butterfish, and silver bar fish are caught near shore during winter. In the monsoon months Miāni Lagoon is a protected fishing ground for the villages of Dāmb and Bearo. The lagoon, separated from Sonmiāni Bay by two large spits, seldom becomes too choppy for the small lateen sailing craft. Lugar (sardines) and prawn are the main catch here.

From June 1st to mid-August, fishing craft seldom venture out into Sonmiāni Bay because of rough seas created by the monsoons. Sudden storms at sea throughout the year take a high toll of life.

Animal Life.--The rural population of the Las Bela Plain is so dense that most of the wild game animals have retreated to the hills and mountains. Some animals, however, are rarely killed by man and thrive close to man's habitations. Numerous gray and white foxes inhabit dens which commonly consist of intricate systems of passageways through the sand dunes. The foxes feed on rabbits, rats, and mice. Lizards abound on the desert plain. Several genera are found, but the species Phrynocephalus is the most numerous. The desert iguana (Dipsosaurus sp.) and the chuckwalls
(Sauromalus sp.) attain lengths of 18 inches. Ground utas (Uta stansburiana), desert spiny swifts (Sceloporus sp.) and night lizards (Xantusia sp.) are found. Several species of ground lizards or skinks (Eumeces sp.) and gila-monsters (Heloderma suspectum) live in rocky crevasses and burrows.

The region is well populated with poisonous snakes. Several species of true vipers (Viperidae), pit vipers (Crotalidae), kraits and cobras (Elapidae) are found. One of the most poisonous snakes is the small sand krait. Cobras are most active during the summer months. A poisonous sea snake (Hyridae) lives in the quiet backwaters of Miāni Lagoon.

Few aquatic animals are found. Crocodiles (Crocodilus patustris) live along the larger stream beds where pools of water remain most of the year. Water turtles, frogs and salamanders inhabit the moist river channels and tidal mud flats. It is surprising how quickly ponds and marshes become infested with small animals when rain falls and fresh water stands for a few weeks or months.

Of interest is the large number of blue and yellow sand crabs (Ocypoda quadrata) that build mounds of sand from six to 12 inches high on the beach. Numerous shells (Appendix C), many types of jellyfish, and large sea turtles are
found along the foreshore. Sea turtles, weighing as much as 400 to 500 pounds, crawl along the beach to lay their eggs in the soft sand. Clams, oysters, crawfish, turtles and turtle eggs are rarely eaten by local people.

Larger animals including small herds of gazelles (Gazella fusitorma) and ravine deer (Cervulus sp.) graze on the plains west of Liāri (Fig. 2). Here the desert country is flat and open. The gazelles, scarcely more than three feet high, travel in herds of from three to ten animals.13 An animal which the writer saw several times on the eastern side of the valley, but which has never been reported by naturalists, is the cheetah (Cynaelurus jubatus). A cheetah was seen near Khurkera, and near the slopes of the Pab Range, only 17 miles from Karāchi, one crossed in front of the jeep. Hyenas (Hyaena sp.) are found mostly in the Hala hills; wolves (Canis pallipes) and wild pigs or boars (Sus scropha) exist in the forests of the central plain and around Siranda Lake. At times, wolves form packs and do considerable damage to flocks of sheep and goats. A few Sind ibex (Capra aeqagrus) and black bear (Ursus torquatus) live in the highlands surrounding the plain.14
NOTES TO CHAPTER I


Camel caravans carry more dwarf palm leaves than any other single item.


Government of Pakistan, Marine Fishes of Karāchi and the Coasts of Sind and Makrān, Ministry of Food and Agriculture (Central Fisheries Department), Government of Pakistan Press, 1955, pp. 4-5.
Sharks found in the vicinity of the Makrân coast belong to many genera and average in length from six to 18 feet. During the monsoons a large number of them are caught about 40 miles south of Ormâra. According to local fishermen the sharks gather here for protection against the high temperatures and heavy waves of summer. Shark meat is not eaten by the natives but the fins have many uses and the oil is exported, used for smearing boats and burned in lamps. (Siddiqi, op. cit., p. 53).

These small snakes, the size of the North American coral snake, hide in the brush-covered roofs of the native huts to escape the cold of winter nights and occasionally bite the fingers or toes of sleeping people.

One small village reported that, on the average, one person, four or five goats, and as many as two or three camels were killed each year by snakes, mainly the cobra.

During the middle of the day gazelles are seldom seen, but at dusk and in the early morning they can be seen moving across the horizon.

The local inhabitants of Las Bella seldom hunt the wild animals, but hunting expeditions are still popular among wealthy families who use a tract of forest near Khurkera that was set aside as a game preserve by the former ruler of Las Bela State. Today, members of the military stationed in the area do most of the hunting.
CHAPTER II

WEATHER AND CLIMATE

The weather and climate of the Las Bela area of Pakistan have the same broad characteristics as the surrounding hot desert regions in the western part of the Indian subcontinent. Insolation is intense, particularly during the long hours of sunshine in the hot season of April and May. The coastal plain can be divided into two major climatic regions on the basis of rainfall. The central coastal plain and eastern hills are a summer rain area. This region receives about 62 per cent of its total rainfall from the monsoon. The western part of the coastal strip and hill ranges are winter rain areas and receive 77 per cent of their total rainfall from western depressions. The weather and climate in both areas are characterized by scanty and extremely variable rainfall.

The coastal region from the Iran border to Karachi has only five weather stations with records of more than 30 years. Therefore, it is difficult to present an accurate
quantitative description of the climate (Fig. 4). Two stations in the Las Bela area, Bela and Sonmiani, became rainfall recording stations in 1912. Karachi, 30 miles to the east of the Las Bela Valley, has maintained records for more than 100 years. Weather stations in southern Baluchistan have been operated with inadequate equipment and untrained personnel. Published figures from these stations are fragmentary and unreliable.

Reasons for the Desert

Existence of an arid region near a warm body of water such as the Arabian Sea deserves an explanation. The reasons are complex, but there appears to be one main factor. The dominating factor seems to be the presence of a high, dry, continental air mass that extends over Baluchistan during all seasons of the year but is most pronounced in winter. The marked dryness of the weather is dependent upon the position and intensity of this central Asian anti-cyclone which forms an inversion layer close to the surface. Precipitation occurs only when continental air is forced to rise or is pushed back, allowing a condensation of more humid air near the surface (Fig. 5). Associated with the dry continental air are high temperatures which result from the absence of clouds and rain.
FIGURE 4. Average annual rainfall
FIGURE 5. Intertropical convergence zone between Jīwani and Karāchi. (Adapted from J. S. Sawyer, "Intertropical Front over N.W. India," Quarterly Journal of the Royal Meteorological Society, 73, Nos. 317-18 (July-October, 1947), p. 351.)
There are three storm patterns common to the area which act as triggers and which break the high pressure system allowing precipitation to occur. These include:

1. Summer eastern depressions associated with the monsoon.

2. Winter western depressions originating in the Mediterranean area or over the Arabian Peninsula.

3. Arabian Sea cyclones which occur during the transitional periods of May and June and September and October.

The Las Bela Coastal Plain is on the southeastern side of the high pressure system and is affected by all three types of storms, but the heaviest rainfall accompanies the monsoon.

Absolute humidity up to 6,000 feet is often high. In the hot season, April to June, relative humidity averages from 70 and 80 per cent at the coastal town of Sonmiāni. At nearly all seasons of the year air close to the surface is moist enough to produce precipitation, but the continental layer prevents it from rising and condensing moisture that might fall as rain. Mountains on both sides of the plain reach elevations of 3,000 feet within 50 miles of the coast. Still farther inland the Kalāt plateau attains an elevation
of 6,000 feet. Although the mountains and prevailing on-shore wind from the warm sea would seemingly favor precipitation heat from the hot ground over which the air passes soon dissipates the clouds. When the air rises over the mountains the adiabatic cooling which usually accompanies an orographic rise is offset by radiational heat from the ground. When the wind blows down from the mountains, adiabatic heating makes it a drying wind. Thus the Las Bela Valley is a desert, for there is little rainfall except during short periods when the dominance of continental air is mitigated.

**Temperature**

In the summer temperatures rise rapidly in the central and northern parts of the Las Bela Plain. The mean maximum temperature for Sonmiāni in May and June, the hottest months, reaches 85°F. while at Bela, 64 miles inland, the mean maximum exceeds 100°F. In contrast, winter temperatures decrease from the coast inland. The mean for Sonmiāni in January averages 63°F. and for Bela 62.1°F. (Fig. 6). A low temperature of 23°F. has been recorded for Bela. As a result of the maritime influence, the daily minimum temperature at Sonmiāni rarely falls below 41°F. No measurements are available for the surrounding 2,000 to 3,000 foot mountain ranges,
but temperatures there probably average a few degrees cooler than on the central plain.

During the seven hot months over a period of 30 years (1931 to 1961) maximum daily temperatures of over 100°F. were often reached at Bela between 2 P.M. and 3 P.M. in the afternoon. For the cooler months during this same period the corresponding maximum temperatures were around 78°F. Minimum temperatures which occur around 5 A.M. in the morning can be unpleasant for one sleeping without a light blanket. Over a 10 year period (1931 to 1941) the mean low temperature at 7:30 A.M. in January at Bela was 46°F.²

Average maximum and minimum temperatures do not present a very informative picture. For example, Bela had extreme daily temperatures of over 100°F. on 933 days during a five year period. During the same period temperatures of 115°F. or over were recorded on a total of 44 days, and an absolute maximum of 120°F. was reached on May 10, 1938 (Table I). From the point of view of temperature and humidity, Bela, from April to November, is one of the most uncomfortable towns in Pakistan.

From September to June the daily monotony of cloudless skies is only occasionally broken. During June, July, and August stratocumulus clouds, which move inland about 10 A.M.
<table>
<thead>
<tr>
<th>Station</th>
<th>Location</th>
<th>Absolute Maximum</th>
<th>Absolute Minimum</th>
</tr>
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<tr>
<td>Karāchi</td>
<td>Coastal</td>
<td>109 (May)</td>
<td>43 (January)</td>
</tr>
<tr>
<td>(1953-1959)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sonmiāni</td>
<td>Coastal</td>
<td>112 (May)</td>
<td>43 (February)</td>
</tr>
<tr>
<td>(1955-1959)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ormāra</td>
<td>Coastal</td>
<td>117 (May)</td>
<td>41 (January)</td>
</tr>
<tr>
<td>(1953-1959)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pasni</td>
<td>Coastal</td>
<td>115 (June)</td>
<td>31 (February)</td>
</tr>
<tr>
<td>(1953-1959)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bela</td>
<td>Interior</td>
<td>120 (May)</td>
<td>23 (February)</td>
</tr>
<tr>
<td>(1953-1959)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
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<td>Interior</td>
<td>122 (June)</td>
<td>30 (January)</td>
</tr>
<tr>
<td>(1953-1959)</td>
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<td></td>
<td></td>
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<tr>
<td>Kalāt</td>
<td>Interior</td>
<td>106 (July)</td>
<td>-7 (February)</td>
</tr>
<tr>
<td>(1953-1959)</td>
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</tr>
<tr>
<td>Panjgur</td>
<td>Interior</td>
<td>114 (July)</td>
<td>20 (January)</td>
</tr>
<tr>
<td>(1953-1959)</td>
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<td></td>
<td></td>
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</tbody>
</table>
hold down excessively high temperatures along the narrow coastal plain.

A dominant control over precipitation in the Las Bela area is the previously mentioned temperature inversion layer. To the east over central and eastern India the ceiling of this layer, especially in summer, is considerably higher, and rain is produced by convection which is induced by terrestrial heating of the lower atmosphere. Over southern Baluchistan a dry, hot layer of air, approximately 3,000 feet in elevation, caps a humid, slightly cooler air mass near the surface (Fig. 11). Both of these air masses are conductive to stability. Inversion occurs perhaps because of small differences in temperature between continental and monsoon air. Its sharp character is maintained by radiation from the ground and moist air below the inversion layer. During the heat of April and May, and at the time of the southwest monsoon season (April to September), a wedge of moist air moves inland under the cell of dry continental air (Fig. 5). Krishna Rao established the lower limit of the continental air mass over Karāchi at 3,000 to 4,000 feet. Later it was found that the elevation of the inversion boundary at Jīwani to the west decreases to less than 1,500 feet; the elevation northwest of Karāchi increases to
6,000 feet.\textsuperscript{5} The air is very dry above the inversion layer with a relative humidity of 30 per cent or less. The lapse rate approaches the dry adiabatic rate at a height of from 12,000 to 15,000 feet, where a second decrease in the lapse rate takes place. Above this second decrease air has the same temperature as the monsoon air near the surface, but is much drier.\textsuperscript{6} Inversions during winter are feeble and rare and generally are of the frontal type associated with western depressions. A reverse situation occurs in summer because the moist layer of air lies aloft and dry air is near the surface.

\textbf{Relative Humidity}

Relative humidity along the coast is high throughout the year. Records for Sonmiāni over a five year period indicate a range of between 75 and 87 per cent. Inland, relative humidity decreases rapidly and ranges from 42 to 63 per cent at Bela. The five year records for Sonmiāni and Bela are unreliable because untrained personnel gathered the data, but they tend to show that the highest monthly mean occurs during the southwest monsoon, between May and September. Lowest humidity is experienced in January, but annual variation from the two extremes is irregular.
Table II presents a more reliable record for a 19 year period at Karāchi.

**Precipitation**

Rainfall that reaches the Las Bela Coastal Plain is uncertain and scanty. Average annual rainfall for most of West Pakistan is shown on Figure 4. This map shows that average annual total rainfall is less than 12 inches for all of southern Baluchistan and is from four and eight inches for the coastal plain. At the coastal village of Sonmiāni (elevation 18 feet) average annual rainfall, based on years for which a complete record exists, is 4.83 inches (Fig. 6). This rainfall is extremely irregular in nature as shown on Table III. For example, in 1950 for Sonmiāni there was only 0.10 inches of rain, but 24.79 inches fell in 1944. During the summer of 1959 12.12 inches of rain fell in five days with 5.22 inches in a single day. If the three abnormal years of 1933, 1944, and 1959 are omitted from the column for Sonmiāni (Table III), the average annual rainfall is reduced to 3.97 inches. Figure 6 shows extreme variability at the four stations of Sonmiāni, Bela, Karāchi (Drigh Road), and Ormāra. The eastern side of the coastal plain receives its maximum rainfall from eastern depressions during the southwest monsoon. The average at Sonmiāni is 1.54 inches.
TABLE II

DIURNAL VARIATION OF MEAN RELATIVE HUMIDITY FOR KARACHI
(Period: 1928-1947)

<table>
<thead>
<tr>
<th>Month</th>
<th>Maximum</th>
<th>Minimum</th>
<th>Range in Per Cent</th>
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<tr>
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<td>60</td>
<td>1300</td>
</tr>
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<td>Place</td>
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<td>Karachi</td>
</tr>
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<tr>
<td>1959</td>
<td></td>
<td>17.90</td>
<td>22.91</td>
</tr>
</tbody>
</table>
in July, which is the month of most rain. West of Sonmiāni, the coastal plain receives predominantly winter rainfall, which occurs as light rain and drizzle, called vando by the local people. Ormāra receives its maximum rainfall in January (Table IV). Generally, winter precipitation for the Las Bela area is more reliable than the summer.

Table V presents the mean number of rainy days over a five year period for eight stations. The Makrān coast may be rainless during any month and rarely receives rain from April to June, or in September and October. Two serious droughts are recorded for the area; one occurred around 1845 and a second lasted from 1897 to 1901.9

Thunderstorms are occasionally related to tropical depressions and cyclones. On the Makrān coast they occur chiefly in the transition months before and after the monsoon. In winter, thunderous weather sometimes accompanies the cold fronts of western depressions. The northern part of the plain receives a number of local convectional showers as a result of extreme diurnal heating of the interior plain. Bela, over a five year period, has an annual total of 19 thunderstorms per year; for the same period, Karāchi has six and Ormāra three. Snow has never been recorded and hail is very rare.
<table>
<thead>
<tr>
<th>Station</th>
<th>Minimum Recorded (Inches)</th>
<th>Maximum Recorded (Inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sonmiani, Las Bela Division</strong></td>
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</tr>
<tr>
<td>Rainiest month (July)</td>
<td>0</td>
<td>13.89 (1959)</td>
</tr>
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(Directions Indicate East, West, or North of the Las Bela Valley)
(1955-1959)

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</table>
Winds

At Sonmiani, 51 per cent of the wind comes from the southwest, at average speeds of seven to 16 miles per hour on from 13 to 18 days of the month. Highest wind speeds occur between 1:00 P.M. and 5:00 P.M. Along the coast during winter months, 24 per cent of the wind comes from the west and one per cent from the north (Fig. 19). Northwest winds occur during the western depressions while eastern winds often bring hot, dry dust storms.\(^\text{12}\) Winds, other than from the southwest ordinarily blow with sufficient force to move quantities of sand, but they seldom last more than a few days.

The linear shape of the Las Bela Valley influences the southwest wind as it moves inland. The central part, especially in the vicinity of Liāri, and the east side of the coastal plain receive full force of the southwest wind. The western part of the valley lies in the lee of the Hāro and Hala mountain ranges. When the wind reaches Bela it becomes more southerly. About 40 per cent of the wind comes from the south and only 15 per cent from the southwest. The strongest and most important winds are the 13 per cent from the northwest that accompany winter storms. These cold winds, called uttar by the native people, almost always
abate before reaching the coast. They are greatly feared because of epidemics of pneumonia following the cold. The most pleasant location in the valley is Uthal. Here wind is usually not strong enough to cause severe dust storms, as at Liārī, and is not cold enough to cause discomfort. Uthal also receives a stronger sea breeze during the hot season than Bela.

**Storms**

Three main types of storms reach the Las Bela area.

- **Western Depressions.**—Western depressions may develop any time between November and April. They are associated with westerly lows of the middle-latitude type. As frequently as four or five times a month (December to April), these cyclones cross Afghanistan, West Pakistan, Kashmir, and India, generally north of latitude 30°N. Their paths are commonly traced from the Mediterranean Sea or the Black Sea across southwest Asia.$^{13}$ Storms that reach the Las Bela area are usually secondary depressions that are associated with main depressions over the Arabian peninsula or southern Iran. These secondary storms at times increase in intensity and move along the Makrān coast toward India.$^{14}$ The passage of a western depression may give rise to local gales and squally weather. Many of the disturbances do not
have the well-marked cold and warm fronts associated with mid-latitude cyclonic disturbances. Most of them are extremely weak, lacking both moisture and temperature contrasts. From 1945 to 1955, only six storms induced heavy orographic rainfall against the hills of the Punjab and only seven storms caused noticeable temperature changes. This is a low percentage of the 30 or 40 storms which cross West Pakistan during the usual winter period. The paths of the depressions vary considerably from year to year with (1) shifting of the intertropical convergence zone; (2) position of the central Asian anti-cyclone; (3) size and strength of the storms themselves; and (4) upper air conditions which are affected by position and intensity of the jet stream. 

**Eastern Depressions.**—The monsoon season along the Makrān coast is an extreme modification of the true monsoon season over Bombay and Calcutta. High temperatures in June, the first month of the monsoon, are not often different from those of May. The change begins when stratus clouds develop during the afternoon. From the middle of June into September these low clouds cross over the coast and dissipate themselves either against the Pab or Mor Mountain Ranges, or in the interior of the Las Bela plain. Their height is closely associated with the inversion layer which lies between 2,000
and 3,000 feet along the coast. The low clouds have a
diurnal variation, being more frequent in the forenoon than
in the afternoon. The opposite is true in the northern part
of the plain where cumulus clouds are more likely to build
up in the afternoon and evening as a result of convectional
heating. Rainfall from both the low stratiform clouds and
the higher interior cumulus is negligible.

The main monsoon rainfall is associated with eastern
depressions that originate in the Bay of Bengal, Arabian
Sea, or occasionally, in central India. Depressions which
form at the head of the Bay of Bengal travel westward over
the land. Sometimes they seem to be almost on the verge of
dissipating over central India, but intensify over the Thar
desert where they meet fresh monsoon air from the Arabian
Sea. Then, if such a storm moves directly west into the
Sind and eastern Baluchistan area instead of turning north
to the Punjab, clouds, winds, and rainfall may occur. If
the storm passes through Sind and enters the north Arabian
Sea, still heavier rain and higher winds occur along the
Makrān coast from Karāchi to Ormāra. Rainfall, dependent
upon such specialized eastern depressions, is erratic and
unpredictable. Records for 1933, 1944, and 1959 show very
heavy rainfall which was directly related to the eastern
depressions passing into the north Arabian Sea in those years.

Eastern depressions usually have the following characteristics. Before the storm there may be strong wind shifts which cause dust storms if the wind is off the land; or very choppy, rough seas if the wind is from the southwest. The storm center of dark, stratonimbus clouds is often accompanied by thunder and lightening and hard intermittent showers. If the storm has lost intensity before reaching the Las Bela area, there may be only drizzle or no rain at all. On the average, four to six eastern depressions affect the area during a monsoon season.

*Arabian Sea Cyclones.*—Weather conditions during the transition months of April to May and October to November are more settled than at any other time of the year. During these months the main disturbances arise from Arabian Sea cyclones which occasionally move westward or northwestward toward the Makrān coast. Since these are transitional periods, the cyclones may be connected either to the first or last manifestation of a monsoon season. Storm tracks for the period 1847-1956 are indicated on Figure 7. They have the characteristics of small hurricanes but generally lose much of their intensity as they move to more northerly
FIGURE 7. Tracks of major recorded Arabian Sea cyclones (1847 to 1955); Adapted from C. W. Normand, The Weather of India (Calcutta: Indian Science Congress Association, I, Park Street, November, 1937, p. 9), and Records of the Pakistan Meteorological Department, Karachi.)
latitudes and reach the coast. However, there have been severe storms which have wrought destruction as a result of rough seas and high tides inundating the low coastal areas. An intense storm experienced by the writer at the end of June 1959 was a combination of a small Arabian Sea cyclone and eastern depression (Plate II-A and B).

**Theory of Dessication**

Historical and archaeological evidence have been advanced in support of the theory that the Las Bela area at one time received more rainfall. According to certain archaeologists the shape and form of houses and streets in the large cities of Mohenjo-Daro and Harappa indicate a period of increased rainfall in the Sind-Baluchistan region between 2500 and 1500 B.C. Archaeologists also believe that the increased use of wood would be indicative of larger forest areas.

The writer believes that the above evidence is not valid. The more prosperous cultures they seem to represent could have been supported by the effective use of existing forest and ground water resources. The large number of earthen dams throughout Baluchistan, some of which were built at the time of Mohenjo-Daro, point to a need to store water rather than indicating an increase in rainfall.
Geomorphologically, an extended and extreme degree of aridity would be necessary to account for the large eolian deposits of the Thar and Baluchistan deserts. It appears that over seven cubic miles of sand have blown inland across the valley and foothills of Las Bela since the late Pleistocene. The fixed dunes in the area today may have resulted from a greater sand supply when the sea was lower without a significant climatic change. Available records can not reveal what extreme climatic conditions might have existed in the past.
NOTES TO CHAPTER II


5J. S. Sawyer, "Intertropical Front over N. W. India," Quarterly Journal of the Royal Meteorological Society, 73, Nos. 317-318 (July-October, 1957), 360.

6Rao and Bhatia, op. cit., p. 123.

7India Meteorological Department, Poona, "Monthly Statistical Data" (unpublished), 1928-1947.

8Pakistan Meteorological Department, Karāchi, "Climatological Tables" (unpublished), 1960.

9Great Britain, Meteorological Office, Air Ministry, The Makrān Coast from Gwadar to Karāchi and the West Coast of India to Latitude 20°N., pp. 58-59.

10"Climatological Tables," op. cit.

11"Climatological Tables," op. cit.

12Local fishermen dislike the dry east wind because it brings an upwelling near the coast which results in cooler water injurious to tropical fish, creates choppy seas, and prevents much needed rain.


CHAPTER III

VEGETATION AND SOILS

The desert and semi-desert climate of Baluchistan mainly supports a xerophytic type of scrub vegetation which grows sparsely in most areas. However, in years with more than eight inches of rainfall, a thick layer of grasses, herbs and shrubs covers the ground. Climate is the major determinant of vegetation types, and rainfall is much more significant than temperature.¹ The flora of the plains and lower highlands resembles, in general, vegetation of the Punjab, western India, and adjoining parts of Sind. Many plants have spines and thorns of diverse appearance.² Many of the shrubs are woody and stunted, being about 12 inches high with round cushion-like outlines. With bleached stems and few leaves, many look like skeletons of plants. Few annuals begin sprouting even in March when warmer days occur. Although the number of families is large, the number of species is small.

During April and May all plants suffer from hot, dry winds which sweep across the central plain. The shrub
Capparis aphylla (Plate II-C) is one of the more adaptable plants under these conditions for it lacks true leaves and can withstand the dry wind better than other plants. With the beginning of the monsoon rains, usually in June, the desert may appear to be lush savanna within a few weeks. The rapidity of vegetation change is directly related to the amount of precipitation. When there are more than five inches of rainfall in the three-month monsoon season, thick stands of grasses, two to three feet in height, and shrubs cover the landscape. The most important grasses include Panicum antidotate, Eleusince, and Eragrostic species. Two weeks after 11.2 inches of rain fell in the summer of 1959, vegetation became rank, especially in areas where flood water remained behind beach ridges and sand dunes or in low areas on the coastal plain. The western side of the Las Bela Plain receives less rain and has less vegetation than the eastern part. When 10 to 12 inches of rain falls in the eastern foothills, the region west of Liāri receives only four to five inches. Vegetation on the western side seldom becomes dense enough to hinder vehicle movement.

Main Divisions of Natural Vegetation

Natural vegetation of the Las Bela Region can be divided into six main divisions. Table VI summarizes the
succession of vegetation which appears to take place in each of these categories.

Central Plain.—The central plain is covered with alluvium deposited by the Porāli, Khāntra and Windar rivers. In the southern part of the plain the top soil has a high concentration of wind blown sand and salt. The pioneer vegetation of this section consists of the halophytic species (low growing, widely spaced shrubs) represented by Suaeda fruticosa, Salsota foetida, Haloxylon recurvum, Convolvulus pluricaulis and Sporobolus pallidus (Plate II-D).³ These are perennial plants with well developed tap-root systems. During dry periods the aerial portions wither, but root stumps survive to grow again in the rainy season. Farther north, near the village of Lākhra, blown silt rather than sand is deposited around plants during dust storms. Where silt hillocks occur Capparis aphylla (Plate II-C) makes its appearance. Still farther to the north this spiny, leafless, four to five foot shrub provides protection for the growth of young seedlings of Salvadorá oleoides and Prosopis spicigera. In the vicinity of Bela, large Salvadorá and Prosopis plants, from six to eight feet high, are the dominant vegetation. Here the soils are better developed and
rich alluvium is deposited by rivers issuing from the surrounding mountains.

Riverine Vegetation.--In the river beds freshly deposited, moist alluvium is colonized predominantly by large, lush Tamarix and Saccharum (Plate II-E) species. Tamarix troupii (Plate II-F), a tree and Tamarix articulata, a shrub, are hardy plants. They withstand saline conditions well and grow more rapidly than most other plants on arid tracts. They endure extremes of temperature, excessive drought, and considerable frost. The natives use Tamarix as a building material. Herbaceous vegetation growing to a height of about four feet, is represented by Cynodon dactylon, Alhagi camelorum, Ranunculus sceleratus, and Lippa nodiflora. When water is scarce, the long roots of trees such as kikar (Acacia arabica) and Populus euphratica tap underground moisture. When a river changes its course, the dry bed reverts to desert conditions. Prosopis and Salvadora in the northern part and halophytic species near the coast replace the riverine vegetation.

Mountains and Foothills.--Mor and Häro Mountain Ranges, averaging from one to three thousand feet, bound the central valley on the east and west. Fans covered with gravel
occur at the base of these mountains. Near the coast these gravels are mantled with 200 to 300 feet of sand deposits. Cactus-like *Euphorbia neriifolia* (Plate III-A) a thick, spiny shrub, similar in appearance to the North American Organ Pipe cactus, has an excellent taproot system and is commonly found on the older surfaces. Although it is occasionally found on the alluvial plain, it is much more abundant on the foothill and mountain slopes. Near Uthal this plant reaches a height of 14 feet. Lower species of *Abutilon fruticosum*, *Viola stocksii*, *Frangonia cretica*, and *Inula grantiodes* grow between the larger *Euphorbia* shrubs. Vines also appear in the clumps of *Euphorbia*; of which two are *Ephedra foliata* and *Cocculus pendulus*. Bands of vegetation consisting of *Acacia* shrubs, *Tamarix* trees, and *Saccharum* grasses follow the small braided channels that cross gravel fans. Where the gravels are particularly coarse, small grasses and shrubs from one to three feet high occur. Several of the species found include *Daemia*, *Chloris*, *Cyopogon*, and *Cocculus*. Daytime heating of the gravel surfaces is often intense. *Capparis spinosa* is effectively protected against the heat and resulting transpiration by a coating of wax. A dwarf palm, *Nannorrhops ritchieana*, called *rsh* by the local people, grows to a height of six feet in the narrow river
beds of the hills up to an elevation of 3,000 feet. This stemless plant has many uses. Its leaves are woven into mats, fans, baskets, and sandals, and rope is made from the leafstalks. The heart of the plant is eaten uncooked as a vegetable in times of food scarcity, and the seeds are strung as muslim prayer beads.  

Swamp Vegetation.—Mangrove vegetation, called timmar by the Lasi people, consists of Avicennia officinalis (Plate III-B), Rhizophora conjugata (Plate III-C), and Ceriops candolleana. Mangroves are limited to Miāni Hor, the largest tidal lagoon in the Las Bela Coastal Plain. Mangroves flourish on the eastern side of the lagoon where the tidal range is sufficiently high and regular to moisten the estuarine flats, where a necessary fresh water supply can reach the plants and in the areas where the salt content of the soil does not restrict plant growth. Individual mangrove trees, mainly Avicennia, when uncut by man, grow to heights of 20 to 30 feet. The largest band of trees grows in an area of 20 square miles along the north and south shores between the fishing settlements of Bearo and Gāgu (Fig. 19). Small tidal channels pass freely through the narrow bands of mangrove and provide access to the mud flats. In only a few
places thickets of low, young mangrove, or the propped roots of *Rhizophora conjugata*, present a barrier difficult for man or animals to penetrate. Around the edges of the tidal mud flats salt-tolerant species of *Haloxylon*, *Tamarix*, and *Suaeda* attain heights of from one to three feet.

After heavy showers, residual waters in small ponds, ditches and depressions between beach ridges and dunes support short-term successions of plant life lasting from a few days to several weeks. Submerged plants include species of *Zannichilla palustris*, *Hyrilla verticillata*, and *Potamogeton pectinatus*. Other amphibious plants include *Juncellus alopecuroides*, *Typha augustata*, and *Phragmites karta*. The latter two species live in fresh water. When the ponds dry, larger *Tamarix* and *Saccharum* species appear.

**Dune and Beach Ridge Vegetation.**—The first dunes behind the backshore differ in vegetation from the inland dunes. The difference is due mainly to high salinity and a high water table, which is only 0.5 to 4.0 feet below the surface. One of the best plants for confining the sand is the vine *Ipomaea eriocarpa* shown in Plate III-D. Another common plant is *Calotropis procera*, locally called *awk*. This plant, which is similar to milk weed, grows to a height of seven feet and is used for building huts. A fibre is
also made from its milky bark. Several species of Suaeda are found near the coast and Salsola foetida grows particularly well in the saline soil. This low, widely spaced, perennial plant has a well developed tap root system. Calligonum polygonoides and Haloxylon salicornicum deserve special mention because of their ability to stabilize the coastal dunes landward of the highwater line.

Inland dunes and ridges have a much higher percentage of the following species: Crotalaria burhia, Sericostum pauciflorum, a vine Citrullus colocynthis, and several species of Suaeda (Plate II-D). Three plants, with average heights of from two to three feet, are found on the more stable dunes: pnoq (Calligonum polygonoides), bhui (Aerua javanica) and mart (Aristida nutabilis). The latter is a low grass growing in tufts and is one of the principal forage plants. Where dunes are stable Suaeda is the dominant species. When a soil profile begins to develop Capparis aphylla appears, followed by Salvador a oleoides and Prosopis spicigera. A proposed succession of vegetation for the Las Bela region is presented on Table VI. This represents a revision of the classification proposed by I. I. Chaudhri at a symposium in Karāchi in 1957.
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<th>HILL LANDS AND OLDER SANDS</th>
<th>SALT WATER-LOGGED AREAS</th>
<th>FRESH WATER-LOGGED AREAS</th>
<th>SHIFTING SAND DUNES AND BEACH</th>
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<td><strong>Salvadora oleoides</strong> and <strong>Prosopis spicigera</strong></td>
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<tr>
<td><strong>Capparis aphylla</strong></td>
<td><strong>Acacia senegal</strong></td>
<td><strong>Capparis aphylla</strong></td>
<td><strong>Capparis aphylla</strong></td>
<td><strong>Capparis aphylla</strong></td>
<td><strong>Capparis aphylla</strong></td>
</tr>
<tr>
<td><strong>Acacia arabica</strong> and <strong>Populus euphatica</strong></td>
<td><strong>Acacia arabica</strong> and <strong>Populus euphatica</strong></td>
<td><strong>Acacia arabica</strong> and <strong>Populus euphatica</strong></td>
<td><strong>Acacia arabica</strong> and <strong>Populus euphatica</strong></td>
<td><strong>Acacia arabica</strong> and <strong>Populus euphatica</strong></td>
<td><strong>Acacia arabica</strong> and <strong>Populus euphatica</strong></td>
</tr>
<tr>
<td><strong>Suaeda fruitocosa</strong></td>
<td><strong>Euphorbia neriifolia</strong></td>
<td><strong>Tamarix troupiai</strong> and <strong>Suaeda spp.</strong></td>
<td>**Saccharum spontaneum and <strong>Tamarix spp.</strong></td>
<td><strong>Arthrocnemum indicum</strong></td>
<td><strong>Phragmites polygonoides</strong></td>
</tr>
<tr>
<td><strong>Tamarix spp.</strong> and <strong>Saccharum spp.</strong></td>
<td><strong>Commiphora mukul</strong> and <strong>Grewia spp.</strong></td>
<td><strong>Arthrocnemum indicum</strong></td>
<td><strong>Phragmites polygonoides</strong></td>
<td><strong>Avicennia officinalis</strong> and <strong>Typha spp.</strong></td>
<td><strong>Calligonum Karka,</strong> and <strong>Aerua spp.</strong></td>
</tr>
</tbody>
</table>
Disturbed Vegetation

Natural and human factors disturb the desert vegetation and lead to temporary changes in plant cover. Disturbed areas result from such natural causes as varying moisture, wind, and soil conditions, and destruction by sudden floods. Activities of man which disturb plant successions include the clearing or destruction of the original vegetation for purposes of cultivation, fuel, fodder, and building material. Animal grazing is the most destructive factor.

Vegetation Disturbed by Man and Animals.--In and around the villages, man has altered the pattern of natural vegetation to his own use. Trees, which can provide shade such as the widely scattered kikar (Acacia arabica) and jandi (Prosopis spicigera), become the predominant flora on the village scene. Herbs and shrubs serve as brush fences. Other plants and trees are cultivated for their nutritional or medicinal value. Varieties common to the villages in the area are trees such as dates (Phoenix dactylifera), mangoes (Mangifera indica), guavas (Psidium guavava), and the medicinal plant, Ehretia aspera. Nearly every tree, shrub and herb has some use, for buildings, food, fuel, medicine, or dye. Even the mangrove provides animal fodder and its
roots are used for baiting fish. A variety of domestic grains and vegetables is grown on the central plain. The four most important commercial crops are: mung beans *(Phaseolus radiatus)*, a millet called *juari* or *jowar* *(Sorghum vulgare)*, the seeds of the fibre plant *patsān* *(Hibiscus cannabinus)*, and the castor-oil plant *arind* *(Ricinum communis)* (Plate III-E). *Patsān* is fed to cattle and poultry and oil from its seeds is useful as a lubricant and as lamp oil. *Arind* grows well on sandy soils near the coast.

Except in areas which can be irrigated by the Porāli, Kharrari, and Windar rivers, the Las Bela Valley is a thinly populated desert with a population density of less than 20 people per square mile. Outside of the agricultural settlements, people engage mainly in pastoral and nomadic pursuits, keeping herds of camels, sheep, and goats. Of these, goats are the most destructive to vegetation. The amount and distribution of arable land varies from year to year and from region to region. Before the rains of 1959, the principal plain was extremely dry for ten years and large numbers of people were compelled to leave the valley. However, the rapid growth of vegetation even from a limited amount of rainfall can in a few weeks draw a large influx of tribal people
from neighboring areas. Regular and seasonal movements of nomads also account for fluctuations in population. Much of the nomadism involves trans-humance. The Brahui tribes move onto the plains from the northern hills during the winter to escape the cold. Being half farmers and half shepherds, they move on a restricted route between flocks and fields, often reaching the northern Las Bela plain in time for the date harvest.

**Soils**

The sand, silt, clay mantle of the Las Bela Region is divided into six soil types. It is hardly appropriate to call the soils of this region true soils, for when horizons are present they are only slightly differentiated and lack definite profiles with well developed A and B horizons. The top to bottom width of the immature profile seldom measures more than a few inches. Grayish and only slightly altered parent material is closely underlaid by a zone of calcium nodules. The soils are young and constantly subjected to the influence of wind and water. No true fossil soils were found in the area. Table VII is a tabular representation of the six soil types found in the region. Names used are local Sindhi words.
<table>
<thead>
<tr>
<th>Soil Type</th>
<th>Local Name</th>
<th>Characteristics</th>
<th>Vegetation</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light sandy-silt loam</td>
<td>milk</td>
<td>Tan to brown in color. Fine textures soil. In places, a soft white friable clay. Best crops of the Las Bela Plain are grown on this soil. Juari, Bajara and mung are three of the main crops.</td>
<td>Confined to the middle portions of the plain where Porāli, Kharrari, and Windar rivers flood.</td>
<td></td>
</tr>
<tr>
<td>Clay-sand soil</td>
<td>obawari</td>
<td>Light gray to tan in color. Forms on newly exposed materials under arid conditions. Found where aeolian sands are carried furtherest inland and flood water deposit clay materials. A horizon clay—substrata sand. Sierozem zonal and intrazonal soils.</td>
<td>Good soil for millet and the grains juari and sarih.</td>
<td>Found on the south central portion of the plain. Best represented between Lākhra and Liāri.</td>
</tr>
<tr>
<td>Soil</td>
<td>Local Name</td>
<td>Characteristics</td>
<td>Vegetation</td>
<td>Location</td>
</tr>
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<td>-----------------------------------------------------------------------------------------------</td>
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</tr>
<tr>
<td>Dark-clay loams</td>
<td>phaslanr</td>
<td>Dark brown in color. Forms where a thick covering of grasses and shrubs grow for about half the year. More organic material and a thicker soil profile. Often has indurated layers of clay throughout the profile. Soloth intrusive soil.</td>
<td>One of the best soils in the area for juari. Where the soil is difficult to plow, grasses are used for grazing.</td>
<td>Extent limited to grass areas between the beach ridges and on the east side of the plain between Liāri and Uthal.</td>
</tr>
<tr>
<td>Salt-pan soil</td>
<td>kalrasi and chiki</td>
<td>Light gray in color. Clay strongly impregnated with salt and mixed with silt. Soil develops under imperfect drainage conditions and is characterized by abnormal salt concentrations in the upper horizons as a result of capillary action. Solonchak intrusive soil.</td>
<td>Soil is particularly well suited for oil-seed (arind the castor plant).</td>
<td>Found on lake beds south of Liāri in a wide arc around Miāni Lagoon and Sirianda Lake. Sirianda Lake has a white alkali surface</td>
</tr>
<tr>
<td>Soil Name</td>
<td>Characteristics</td>
<td>Vegetation</td>
<td>Location</td>
<td></td>
</tr>
<tr>
<td>---------------------------</td>
<td>---------------------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------------</td>
<td>------------------------</td>
<td></td>
</tr>
<tr>
<td>Older stony-sandy soil</td>
<td>Gray to brown in color. Oldest soils in the area. Thin stony soils mixed with light silt loam called mutkenwari. Where a larger admixture of sand occurs called kangar. Thin crusts composed of ferruginous and calcareous materials scattered throughout the soil profile. Soils formed under conditions unfavorable to further development. Thin stony surface, little or no illuviation, stony parent materials. Lithosols-azonal.</td>
<td>A poor soil for agriculture. Juari grows well in the deeper pockets of light, silty loam. Castor plant on sandier parts.</td>
<td>Found on lag gravels and aeolian sands which border the central plain.</td>
<td></td>
</tr>
<tr>
<td>Soil</td>
<td>Local Name</td>
<td>Characteristics</td>
<td>Vegetation</td>
<td>Location</td>
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<td>-----------------------------------------------</td>
</tr>
</tbody>
</table>
NOTES TO CHAPTER III

1 Spate, op. cit., p. 66.


3 S. Z. Hasanain and Obaidur Rahman, Plants of Karāchi and Sind, Department of Botany Monograph, No. 1, University of Karāchi (Karāchi: by the author, 1957), pp. 1-100.


7 Adapted from Chaudhri, ibid.

CHAPTER IV

GEOLOGIC FRAMEWORK

Conditions arising from aridity, proximity to the Arabian Sea, and an integrated exterior drainage pattern have worked upon the bold structure and diverse rock types of the Las Bela Region to produce a variety of spectacular landforms. Studies of the geology of the area are few and mostly of limited scope and value. The majority are descriptive geological reconnaissance reports on the area, with some detailed investigations of small sections, or of special phases of the geology and morphology. Among the most useful are Vredenburg's\(^1\) early reconnaissance and the accounts by Blanford,\(^2\) Krishnan,\(^3\) and Wadia.\(^4\)

Until 1953, the only comprehensive geologic map of the Las Bela area was that published by the Geological Survey of India at the scale of one inch to 32 miles.\(^5\) This map showed only generalized stratigraphy and no structure except the planimetric pattern of the orographic belt. In 1953 the Government of Canada agreed to provide through the
Colombo Plan an aerial photographic survey of West Pakistan to be followed by geological, soils, and land-use surveys. The geologic report and the excellent 1:243,440 geologic maps compiled from aerial photography by Canadian geologists are the principal references used by the writer in summarizing the geologic features of the area.6

Geological History

The Las Bela area forms a segment of the Alpine-Himalayan geosynclinal belt which accumulated thick marine sediments during Paleozoic to Tertiary times and then underwent a great orogeny late in the Cenozoic Era. Two clearly defined geanticlinal ridges appeared in the medial portion of the Baluchistan geosyncline in late Jurassic and early Cretaceous times. These ridges center along two tectonic axes. Figure 8 shows the Las Bela Axis, which leads northward from the Arabian Sea through the Las Bela Valley to a point near Khuzdār where it closely approaches the Central Axis. To the southwest, the Las Bela axis presumably continues through the Arabian Sea to the Oman Peninsula.

At the beginning of the main Himalayan orogeny in late Cenozoic time, deformation of the axial belt took place creating great wave-like, compressional folds and a succession of faults. The nature of the folding is
FIGURE 9. Stratigraphic division of Baluchistan. (Adapted from Colombo Plan, Reconnaissance Geology Map, West Pakistan, Sheet No. 6, Area Key to Stratigraphic Legend. Toronto: Hunting Survey Corporation, Ltd., 1952-1954.)
comparable to that of the Appalachian mountains, with alpine nappes being absent and low-angle thrust faults rare.

Mountains bordering the Las Bela Coastal Plain are part of the western extension of the Himalayas and are linked with the Iranian Plateau. The Kirthar, Pab, and Mor Mountain ranges are the folds on the east side of the plain and the Haro and Hala Mountain ranges are two folds on the west side (Fig. 10). Three elements are common to the structure of these mountains: (1) regular open folds which have vertical or slightly inclined axial planes; (2) high angle reverse faults whose strike generally parallels the fold axes; and (3) strike-slips or tear faults which intersect the direction of fold axes at approximately 45 degrees. Tear faults, whenever found, are the youngest structures, displacing both folds and reverse faults. The majority of these faults have a northeast to southwest or northwest to southeast alignment (Fig. 10). It appears that the compressive stages of mountain building are still in the process of formation.

Near the end of the Tertiary epoch there appears to have been extensive subsidence and faulting along the west coast of India and Pakistan. One such fault appears to exist along the Makrān Coast from a little west of Ras Muāri towards the entrance of the Persian Gulf (Fig. 9), and
a second, even more extensive fault occurs along the west coast of India. A study of the submarine contours of the region to the west of India reveals a continuation of the Hala Mountains as a submarine ridge extending to the west.  

The Baluchistan geosyncline, the subsidiary axial belt, and the main Himalayan orogeny are merely phases in a single tectonic process which continues and will likely continue into another geologic epoch. Seismic records give evidence of the continuation. They show that the greatest number of recent earthquake epicenters lie along or close to the tectonic axes at shallow depth. Figure 3 indicates the main earthquake epicenters recorded in southern Baluchistan in the past 30 years.  

It appears that with orogeny, the sea began its retreat from the area but lagged in the structural troughs, one of which was the Las Bela Valley. The eventual retreat of the sea into its present position was caused by both deposition of alluvium and epirogenic uplift associated with the process of isostatic adjustment. When this took place is difficult to ascertain, but it may have been within the last 5,000 years. Epirogenic forces have resulted in local uplift, plus tilting and subsidence of materials within the Las Bela area. These processes are continuing
at the present time.

Vast quantities of gravel and sediment from the newly risen terrain were deposited into the retreating margins of the sea and structural troughs. In some areas these coarse clastic deposits underwent considerable folding and faulting during the tectonic period, as for example on the west side of the Las Bela Valley. In other places, as on the east side of the valley, the deposits continue laterally into upfolded layers of Pleistocene and Recent ages.

The Highlands

The main Las Bela Valley and its coastal plain and the bordering mountains are parts of the same general structural belt. The rocks are mainly sedimentary, consisting of limestones, sandstones, and shales ranging in age from Mesozoic to Recent. The valley separates two principal rock formations shown on Figure 9. To the east is a calcareous Jurassic and Cretaceous sequence of rocks which forms the eastern highlands. To the west is a highly fossiliferous arenaceous Tertiary and Pleistocene sequence which forms the Makrān Ranges.

Eastern Mountains.--The eastern highlands have a relatively simple stratigraphy. The north to south trending
Kirthar, Pab, and Mor Ranges are denuded anticlines of Jurassic and Cretaceous limestones, shales, and slates. Jurassic volcanics similar to the Dekkan lavas of the Indian Peninsula occur in places (Fig. 10). Except in a few areas where the ridges have been cut through by deep and narrow river gorges, the structural highs are also topographic highs. Plate III-F shows the low mountains with elevations of from 2,000 to 4,000 feet. The highest point in the Las Bela district is in the northeast and exceeds 4,500 feet above sea level. The mountains decrease in elevation near the coast. The Kirthar Range reaches the coast at Ras Muāri (Cape Monze), and an outlier of the Pab Range reaches the coast at Gadānī (Fig. 2). The lower Mor Range is buried under Pleistocene sand near the coast.

**Western Mountains.**--West of the Las Bela Valley is an arenaceous zone of Pliocene and Pleistocene rocks consisting of weak, poorly cemented sandstones with interbedded conglomerates, siltstones, mudstones, shales, and shelly limestones. The Hāro and Hala ranges are anticlines separated by a syncline through which the Phor River flows (Fig. 10). The elevation of the Hala Range averages 2,000 to 3,000 feet in the section northwest of the valley. This range is the eastern part of the wide arc of northeast to southwest
trending mountains which curve near the coast and become the parallel east to west striking Makrān Ranges. Ras Malān and Sarpai are the coastal headlands of the Hala mountains, and are the western limit of the area under study (Fig. 2).

The Hāro Range is a small northeast to southwest striking anticline 32 miles long, with maximum width of six miles (Plate IV-A). The average elevation is about 1,500 feet above sea level with a maximum of 2,400 feet. In places, high angle step faulting has tilted the strata to a nearly vertical position. The underlying clay beds have been eroded to a degree that leaves indurated sandstones in fantastic shapes and forms. Figure 10 depicts the major faults along the crest of the ranges. At several locations along these faults there are gas seepages accompanied by mud derived from an underlying Miocene mudstone. On the crest of the Hala Range a continuous belt of extruded mud extends for 22 miles. Numerous mud volcanoes are positioned along the major fissures of the region. The largest mud volcano is over 1,600 feet above sea level on the crest of the Hāro Range. A group of four mud volcanoes occurs along a seismic zone near the coast (Plate IV-B). One of these, Chandragup, two miles from the coast and 340 feet high (Fig. 3), is the only active mud volcano of this group. One of the volcanoes
has a collapsed cone, the cone of another contains a caldera, and a third is a remnant mud volcano with radial dikes.

**Marine Invasion of the Las Bela Area**

When the sea level rose at the end of the last major glaciation, a marine invasion occurred which extended in a wide arc into the lower portion of the Las Bela Valley. The invasion is believed by archaeologists to have extended as far inland as Liāri, or even farther north for a short time. The inland limit is difficult to establish because alluvial and eolian depositions have buried the evidence. The first distinguishable feature of an inner coastline is the arc of dunes around the northern end of Miāni Lagoon. This large sand accumulation formed behind a shoreline that may have existed from 1,000 to 5,000 years ago.

During the marine inundation, the southern part of the Hāro Mountain Range was under active wave attack. South of Kandewāri erosion was intense enough to remove gravel fans and the southeast portion of the mountain range. More material was removed from the extreme southeastern side of the Hāro Mountain Range than from the southwestern side. The western side may have been protected by sediment brought down by the Phor river or it may be that the section of coastline from the Phor River to Ras Malān headland extended
farther into the sea during the period of active cutting (Fig. 2).

A few miles farther north, in the area of the Bitko River (Fig. 11), the gravels and Hinglaj rocks remained but were truncated on the seaward side. Small arcs cut into the fans were sharply preserved by subsequent uplift. Pockets of wave-cut cliffs (Fig. 23) extend over a distance of four miles with less cutting to the north. The northern limit of pockets occurs where the beach ridges disappear beneath the alluvium of the Las Bela Plain. An interesting narrow band of barnacles attached to gravels and Hinglaj rocks 70 to 80 feet above present sea level is believed by the writer to belong to a younger Pleistocene or Recent age because they are less oxidized, less weathered, and less indurated than the shall material found in the Hāro Pleistocene and Pliocene deposits. The barnacles were found only on the seaward side of the rocks and were very uniform in elevation and distribution.

Through the more recent formation of accretion ridges, spits and bars, the present coastline has advanced from five to eight miles seaward of the inner arc of dunes. It appears that epirogenic uplift may have played an important role in promoting the retreat of the sea from the central
FIGURE 11. Physiography of the west side of the Las Bela Valley
portion of the Las Bela Valley.

**Uplift Along the Makrān Coast**

Significant structural movements have occurred along the Makrān coast within historic time. A broad upwarping of the coast from the Iran border to the Rann of Cutch continues to take place. The amount of uplift and tilting varies. The greatest activity is found between Jīwani and Pasni (Fig. 1) where flat-topped rocky headlands rise to a height of 400 to 600 feet. Some of the beds are composed of Pleistocene gravels and shelly conglomerates. Raised beaches and archaeological sites were investigated by George F. Dales, Jr., and identified as ports dating back to approximately 2,000 years B.C. Several of these sites are now 100 to 200 feet above sea level.

Uplift lessens toward the east and may be measured in tens of feet in the Las Bela area. As evidence of the uplift are the Pleistocene and Recent oysters and barnacles found at four main locations in the vicinity of Karāchi: (1) at Hawks Bay, west of Karāchi, oyster shells were found exposed at an elevation of five to eight feet above present sea level; (2) on Sonmiāni Hills, two miles east of Sonmiāni fishing village, beds of oyster shells were found at elevations of 50 to 70 feet above present sea level.
(Plate IV-C); (3) on the gravels and Hinglaj Pliocene rocks on the west side of the Las Bela Plain barnacles were found at an elevation of 70 to 80 feet above present sea level; (4) at the southern tip of the Hariro Range oyster shells and barnacles were found at elevations of 50 to 60 feet above present sea level. Uplift is further supported by terraces and wave cut benches around Ras Muari and the poorly consolidated and indurated group of rocks called "Oyster Rocks" in Karachi harbor. The highest point on the Oyster Rocks is 92 feet above sea level. 11
NOTES TO CHAPTER IV


2Blanford, op. cit.


4Wadia, op. cit., p. 531.

5Geological Survey of India, Geological Map of India and Adjacent Countries, 1931.


8Personal interviews with Robert Raikes, archaeologist and consultant to the Water and Power Development Authority, Karachi, West Pakistan, November, 1961, and George F. Dales, Jr., Assistant Curator, Royal Ontario Museum, Toronto, Canada.


10Personal interview with Dales, op. cit.
Considerable movement has taken place to the east of Karāchi in the region of the Rann of Cutch. Allah Bund, a barrier 50 miles long, 20 miles wide and 10 to 26 feet high, formed in Cutch as a result of an earthquake in 1819 and obstructed the Indus River flooding an area of 2,600 square miles for a period of two years. This example shows the intensity and amount of movement that can occur from a single earthquake. The earthquake is mentioned by M. R. Sahni, "Bio-Geological evidence bearing on the decline of the Indus Civilization," Journal of Paleontological Society of India, I, No. 1 (1956), p. 101.
CHAPTER V

PLEISTOCENE TERRAIN

The distribution of Pleistocene in the Las Bela area is shown on Figure 10. The two main areas of older sands and gravels, which flank the valley, and the smaller outliers stand topographically above the active flood plain. Pleistocene surfaces can be differentiated from the Recent on aerial photographs. The Pleistocene sands stand higher and are drained by smaller streams that have developed distinctive, entrenched courses and local relief is much greater. However, the type of contact between the Pleistocene and Recent varies. Where scarps occur, as along the west flank of Siranda Lake and along the wave cut cliff, there is a sharp differential in elevation between the two. Where Recent sand has drifted over older Pleistocene deposits, there is little or no break and Pleistocene slopes gradually beneath overlapping Recent sediments.

Areas mapped as Pleistocene were differentiated on the basis of sedimentary and topographic characteristics, but there are similarities between the Recent and Pleistocene sands. As far as grain size and mineral content are
concerned, the materials are virtually identical. Cumulative curves plotted on Figure 12 were made from 12 Pleistocene sand samples and 30 Recent sand samples. There is little difference between the maximum grain size of the two sets of samples. The Pleistocene sands are well sorted with a coefficient of 1.06. Well inland the grain size decreases until in some areas along the mountain front the sand grades to loess-like silt.

Dune topography is obscure over most of the Pleistocene area and the few remnant dunes that do exist are degrading rather than growing. Reduction of relief and stabilization of the dunes has resulted in subdued topography with only faintly undulating surfaces. Along the seaward edge, however, there is less vegetal cover resulting in the reworking of Pleistocene sand and at times the addition of Recent sand.

In places water percolation through the Pleistocene sands has reoriented the sediments. Generally near bands of shells cementation has occurred and the sands are more indurated.

Distribution of certain types of vegetation is another indication of Pleistocene or older material. *Euphorbia neriifolia* (Plate III-A), a cactus-like plant, is found only
FIGURE 12

RECENT SEDIMENTS

COMPOSITE OF 30 GRAIN—SIZE
ANALYSES OF RECENT SANDS

PLEISTOCENE SEDIMENTS

COMPOSITE OF 12 GRAIN—SIZE
ANALYSES OF PLEISTOCENE SANDS
FIGURE 13. Profile along 25° 15' N. Latitude. (For location of profile see Figure 14.)
on more indurated, stabilized materials. It grows on the cones along the base of the Pleistocene cliffs, but does not occur on the present coastal or central alluvial plains.

**Alluvial Gravels**

Alluvial cones which are now surfaced by gravels extend away from the base of the mountains. These gravels form a wide band around the mountain flanks of the Las Bela Plain (Fig. 10). On the east side of the valley, coarser deposits are buried under thick layers of sand. To the north, they blend into the gravels presently being carried by the main rivers that enter the plain (Plate IV-D), while on the west side of the valley, gravels overlie the steeply dipping Pliocene-Pleistocene Hinglaj and Hāro rock formations.

The gravels are best exposed on the eastern, lee-sides of the hills and mountains and on the western flanks of the Mor Range between Uthal and Bela, where less sand has been deposited. In places, the gravels stand out as caps of, or as whole sections of, isolated erosional remnants. In addition to gravel caps platforms occur along the eastern flanks of the Pab Mountains and around the coastal headland of Ras Muāri (Plate IV-E). Correlations of elevations and identification of individual platforms are difficult because so
much local down faulting and differential uplift has taken place. Some of the platforms extend for miles and are then cut into small remnants by intermittent streams. These remnants are only small patches but nevertheless useful in indicating surfaces that are now difficult to correlate.

**Dating.**—Because the unconsolidated gravel surfaces truncate and overlie the steeply dipping Pliocene-Pleistocene Hinglaj rock formation, they probably have a maximum age of middle or late Pleistocene and a minimum age of Recent. The gravels predate large eolian accumulations of sand on the side of the hills and mountains.

Eolian accumulation is active today, but may have been even more intense in the past when the nearby sand-covered continental shelf was exposed during the last glacial low stand of the sea. Figure 14 indicates the size of the continental shelf to the south of the main sand accumulation. Present dimensions of the total sand deposit appear to exceed seven cubic miles. Original dimensions must have been appreciably larger. The removed material probably makes up the bulk of the Recent sands.

**Pleistocene on the East Side of the Coastal Plain**

The Pleistocene sand accumulation on the east side of
FIGURE 14. Pleistocene sand on the east side of the Las Bela Valley. Profile A - A' is on Figure 13.
the Las Bela Valley is a thick, elongate, north to south trending body of well-sorted, cross-stratified eolian sand (Fig. 14). The sandy area is 50 miles long and averages 10 miles wide and 70 to 80 feet thick. Near the coast, sand up to 150 feet thick is present but it gradually thins up-valley toward the northeast. The upper limit of sand, overlying hard rock, averages 600 to 700 feet above sea level (Plate IV-F).

Figure 13 is a southwest to northeast profile extending from the Arabian Sea across the Recent coastal plain, Pleistocene sand accumulation, and mountain ranges, to the Hab River Plain. The bulk of the sand was moved by the strong southwest monsoon winds. Different levels of sand deposition were not found, but erosional terraces occur in several localities and may be the result of successive stages of uplift and river cutting. The surface of the sand is deeply dissected by rivers. This suggests accumulation when sand was more abundant in supply, before sea level attained its present stand. Field and air photo investigations suggest that the entire sand body is tilted downward toward the northwest.

A vertical exposure of the Pleistocene sand near the Chabechi River, two miles east of Nāka Khārari, reveals
detailed depositional features. The upper 25 feet of sand is fine grained, poorly indurated, tan to buff in color, and weathers gray when exposed to the air. Cross-bedding is indistinct near the top of the section but becomes more distinct at depth, where a slight variation in the texture of the individual laminae can be observed. In places, the laminae stand in relief because they are cemented. With the removal of the less indurated lenses, the cemented layers protrude as much as 10 inches. Cross-stratification is almost exclusively planar in type and dips of the bedding are east-northeast at 25 to 30 degrees, as might be expected of deposits from southwest winds (Plate V-A). Shell and clay lenses are nearly horizontal. These are one to five inches thick, but are seldom more than several hundred feet in length. The shells consist of fresh water species of *Melanoides tuberculata* and *Indoplanorbis exustus*.² Both of the above species are found living today in ponds of water trapped between sand dunes. The writer believes that these shell and clay lenses mark locations of ponds of water that existed when the sand was being deposited.

The lower 45 feet of the section consists of cross-stratified sand lenses and coarse gravels. As depth increases, bands of thin pebble stringers become more abundant and grade
into thick gravels. The size of the pebbles increases from one to two inches in the middle of the section to as much as eight-inch boulders near the base of the section. The lower gravels are well cemented and they have a great range in size and extent. One gravel lens can be traced for several miles with an average dip of from one to two degrees toward the south and southwest along the bed of the Chabechi River. The gravels, if projected across the coastal plain, would probably extend to a point about two to five miles seaward of the present shoreline if differential uplift had not taken place. With a lower sea level, the gravels might have extended even farther. The size and quantity of the gravels in the Pleistocene sands resemble those found in the present river beds. The source of the gravel in the sand body is the mountain range three miles to the northeast. The gravels in the present river bed probably have been derived from eroded gravel lenses. The gravels are not uniform throughout the sands and do not appear to be related to the coarser gravels that underlie them.

**Seaward Cliff of the Main Sand Accumulation.**—The seaward edge of the Pleistocene sand body is a steep cliff that stands out sharply on aerial photographs. The cliff is a
wide arc paralleling the present shoreline of Sonmiāni Bay for a distance of 15 miles. It was formed by wave attack against the base of older sands. There is no evidence of faulting.

The greatest erosion has taken place in the vicinity of Lak Bidok (Fig. 14). At this location an almost vertical scarp stands 370 feet high and the highest point of the cliff is 393 feet above present sea level. According to local reports, exceptionally high waves still reach the base of the cliff. This occurred in 1945 when 40-foot waves, as a result of the Makrān earthquake, pounded the coast near Pasni.3

Between Lak Bidok and Ras Muārī the amount of sand decreases and rocky headlands occur at several locations. Wave cut arcs indent the coast between the promontories. The arcs are cut back in less resistant Pleistocene sand. North of Lak Bidok, as a result of tilting, Pleistocene sand decreases in elevation toward the central plain.4 Further northwest the sands continue as isolated hillocks with a maximum relief of 58 feet (Fig. 13). The isolated hillocks are surrounded by the Recent flood plain of the Mobār and Windar rivers.

The oldest, most inland portion of the face of the
Lak Bidok Cliff is located west of Nāka Khārari (Fig. 14). At this location sand cones have developed at the base of the cliff. On top of the cliff, reworked Pleistocene sand blown up from the face, has formed large parabolic dunes that are now stabilized by vegetation. At present, similar parabolic dunes are also being formed above the cliff face at Lak Bidok.

**Minor Pleistocene Sand Accumulations.**--A sand body north of Sonmiāni fishing village and west of Sīranda Lake has been given the name Sonmiāni Hills (Fig. 15). These hills, with an area of about 36 square miles and a maximum elevation of 107 feet above sea level, are outliers of the main Pleistocene sand accumulation. They are separated from the main sand body on the east by an escarpment that drops to the depression of Sīranda Lake. This escarpment, which appears to be of fault origin, has a steep slip face and a nearly straight northwest to southeast alignment which can be followed for a distance of nine miles. Small sand hills are present at a much lower elevation on the down-dropped side in the bed of Sīranda Lake.

Sonmiāni Hills are similar to the main Pleistocene sand accumulation for the following reasons: (1) most of the sand is indurated; (2) topographically the area stands
FIGURE 15. Physiography of the Siranda Lake area. Profile A-A' on Figure 16.
FIGURE 16. Cross sections of Sîranda Lake depression. (For location of areas A - A' and B - B' see Figure 15.)
as a high fixed sand body; (3) the hills are undergoing erosion rather than buildup except where active dunes are migrating inland; and (4) there is a vegetation cover over most of the area with species of plants similar to those on the main sand body. These species of plants include *Euphorbia neriifolia*, found growing on the higher, more stable materials that flank the valley.

In the southeast, the Sonmiani Hill area is breached by a former course of the Windar River (Fig. 15). The southern section of hills has less width and length than the northern and are lower in elevation and local relief. At the southern edge, a small exposure of bed rock is believed by the writer to be Tertiary in age (Hinglaj Group on Fig. 15). This exposed rock area is only one-quarter of a mile long and several hundred feet wide. No other outcrops of rock were found in the Sonmiani Hill Region. The outcrop is of interest for several reasons. Its shelly arenaceous rocks appear to be more similar in age and composition to the marine Hinglaj and Hāro series on the west side of the coastal plain than to the calcareous Cretaceous and Jurassic series on the east side. They indicate that, near the surface, the separation between the two rock series is close to the east side of the valley. Small local reverse faults bring the Tertiary to
the surface (Plate V-B). On Figure 15 this fault line has been projected north along the eastern escarpment of Sonmiāni Hills. This suggestion of the geologic structure confirms the topographic suggestions that the eastern face of the hills is a fault scarp.

Two bands of isolated Pleistocene sand remnants suggest a connection between Sonmiāni Hills and the main Pleistocene sand accumulation. A line of hills once joined the southeastern tip of Sonmiāni Hills with the western part of the main sand body (Fig. 13). These hills are wave cut on the seaward side and are a continuation of the wave cut cliffs that extend northwest from Nāka Khārari toward Sonmiāni. The isolated hills decrease in elevation toward the northwest and appear to be tilted. They decrease from over 200 feet near Nāka Khārari to 50 feet near Ambāgh where branches of the Mōbar River flood plain have breached them. Northwest of Ambāgh the hills have been eroded by the Windar River. They appear next as a sharp 107 foot escarpment which is part of the southern Sonmiāni Hills. A second hill area extends around the southern end of Sīranda Lake and connects with the main Pleistocene sand accumulation near the town of Khurkera. This hill, depicted on Figures 30 and 33, is breached by former courses of the Windar River which may have flowed through the Sīranda
depression and around the northern part of Sonmiāni Hills to reach Miāni Lagoon.

**Pleistocene on the West Side of the Coastal Plain**

Because the west side of the valley is in the lee of the Hāro and Hala Mountain ranges and does not receive strong southwest winds, large sand accumulations have not formed. The localized sand veneer that covers the western part of the plain is derived mainly from the present river beds. Extensive gravel fans occur along the immediate mountain front of the Hāro Range (Fig. 11). The gravels can be traced from the alluvial plain toward the front of the mountain. Generally the dip of the gravels varies between two and four degrees while the dip of the underlying Hinglaj series of rocks varies from five to six degrees eastward. In most places coarse, unconsolidated materials have thicknesses of only four to five feet. As a result of their dip these gravels commonly rise to 1,000 or more feet above the central plain. The gravels have been complicated by differential erosion and varying degrees of faulting and tilting that results in benches as on the east side of the valley. The faults are steep, normal, and dip in the same direction as the strata. The rapidly rising Hāro and Hala Mountains resulted in the deposition of the
gravels. Sections of the mountains today are eroded to mere remnants and there are clearly visible faults cutting the tilted beds.

A new cycle of erosion was initiated by uplift of the mountain front. Near the southern tip of the Hāro Range the gravels reach a height of 70 to 80 feet above sea level and 40 to 50 feet above the existing alluvial surface (Plate V-C). The gravel fans stand out sharply on aerial photographs for several reasons. The light colored, fine grain material was removed by eolian and fluvial erosion, leaving a residue of darker colored gravels. The gravels have been darkened through the development of desert varnish. The alluvial fans presently show traces of many small channels that once flowed across their surface.

After uplift, the larger streams issuing from the mountains cut gorges through the gravel fans and formed large secondary alluvial fans in front of them. These new coalescing fans extend east to the edge of Mīāni Lagoon and are finer and lighter colored than the older, uplifted gravels.
NOTES TO CHAPTER V

1Ullah, op. cit., p. 5. Asrar Ullah identified 10-, 20-, 35-, and 50-foot intervals between terrace-like gravel platforms to the west of Las Bela.

2Shells were identified by Mrs. W. S. S. van Der Feen-van Bentem Jutting, Zoological Museum, Amsterdam, Netherlands and Dr. Fritz Haas, Chicago Natural History Museum.

3C. G. Pendse, "The Mekran Earthquake of the 28th November 1945," Scientific Notes (India Meteorological Department), X, No. 125 (1948), 144.

4At Nāka Khārai the cliff is 325 feet above sea level.

5Conversation and correspondence with H. S. Scott, Consulting Geologist, 111 Gordon Road, Willowdale, Ontario, Canada.
CHAPTER VI

CENTRAL PLAIN

The central Las Bela Valley is a triangular level plain approximately 48 miles long. From a width of 34 miles, at Liāri, it narrows northward to a width of 11 miles at Bela. It is made up largely of alluvium deposited from the mountains on the northern, western, and eastern sides of the plain, by the major rivers and their tributaries. The principal alluvial formations are older and younger gravels, fine, loose, brown silt, and eolian sands. The silts overlie boulder fans at depths between five and 100 feet and there is evidence that the silts thicken towards the west.

North of the town of Bela, Pleistocene and Recent gravel and boulder fans are exposed and form continuous coarse outwash debris around the northern edges of the plain. The fans grade into the uplifted Pleistocene alluvial gravels which flank the sides of the valley all the way to the coast. In the northern part of the plain the water table is at least 200 feet below the surface as the mountain front is
approached. In the central part of the plain the water
table ranges between depths of from 20 to 40 feet and in the
southern sections of the plain the depth is from 10 to 30
feet.

Figure 17 is a north to south profile across the
central part of the Las Bela Plain. At the northern end of
the valley the mountains rise abruptly from a gravel surface
of 700 feet to ridges of 2,000 feet. From the edge of the
mountains the coalescing alluvial fans extend south for a
distance of five to eight miles with an average slope of 35
feet per mile. The fans are crossed by numerous small
intermittent streams. The beds of the larger rivers, the
Porāli, Kūd, and Kharrari, are half a mile wide (Fig. 18).
In places, the beds of these rivers are entrenched 35 feet
below the surface of the fans, but the average depth is 13
feet. It is the belief of the writer that the gravels
around the northern part of the plain have been under the
influence of tilting and uplift. Present rivers are under­
going a new cycle of cutting and interfluve gravels are
being eroded rather than aggraded. The present progressing
rejuvenation may be partly the result of the activities of
man and animals.

A few miles north of Bela the remnant gravels and
FIGURE 17. North to South profile of the Las Bela Valley. (For profile location see Figure 18.)
FIGURE 18. Irrigation and drainage of the Las Bela Plain (Profile A - A' on Figure 17.)
river bed gravels disappear beneath the finer Recent alluvium of the plain. From this point, south to the inner line of coastal dunes, the plain is comparatively flat, with a gentle slope of 6.3 feet per mile. An investigation of the material covering the plain reveals that the silts are nearly horizontal, although some infrequent layers of cross-bedded, fine sand can be found. Three former terrace levels, each 10 feet high, can be traced in the silts and show that some uplift has taken place.¹

Rivers

All streams and rivers crossing the central plain are intermittent. Three main types occur:

1. Small, shallow streams which flow across the plain for only a short distance. These streams issue from the mountains after heavy rains and carry alluvium six to eight miles out onto the plain and deposit their load. They seldom join the main rivers and their waters quickly sink into the fine alluvium. Deposition by these rivers fills low depressions on the plain and in places has raised the level of the surface.

2. Larger channels cross the plain and reach Mīāni Lagoon or Siranda Lake. These channels have cut gorges from 12 to 20 feet deep into the Recent alluvium. Under present natural conditions floods would experience difficulty in overflowing these deep cuts. The larger rivers appear to be continuing to deepen and widen their channels as they cut toward a new base level.

3. Small tributary streams, which have cut
numerous small gullies from 10 to 15 feet deep, are found near Lākhra. These streams are cutting headward very rapidly. In 1939, the northernmost gullies were terminated in the vicinity of Lākhra; in 1960, they had reached points two to three miles farther north. This section of the plain is now in process of developing a badland topography that is very apparent on aerial photographs.

The entrenched larger rivers and small headward cutting gullies are difficult to cross because they have nearly vertical channel walls. On early maps main trade routes ran west from Lākhra but today western travel must detour well to the north or to the south, to avoid these deep gorges. This is especially true for motor vehicles.

Three of the major rivers are the Porāli-Titiān (Plate V-D), with its large tributary the Kud, the Kharrari which flows past Uthal to the Titiaān or into Siranda Lake, and the Windar, which enters Miāni Lagoon west of Sonmiāni village. The Porāli, the main river of the plain, is 175 miles long, with headwaters in the mountains south of Khuzdār (Fig. 1). Water flow is perennial in northern reaches where the river flows in deep ravines. The lower 60 miles of the river cross the Las Bela Plain. Its course is poorly defined in the northern part of the valley where it is joined by a large number of tributaries. The river is 200 yards wide where it crosses the gravels and, in places, is entrenched in a gorge 40 feet deep. After the river
leaves the gravel fans, it cuts into the readily erodible silts and clays to an average depth of 20 to 30 feet. On the alluvial plain the bed of the river narrows but, except during flood, the depth of the river remains shallow. At Bela the width is only 35 yards. South of Bela the Porāli receives flood water from several large tributaries, the largest of which is the Kud River which drains part of the Hala Mountain Range.

Formerly a branch of the Porāli is reported to have diverged from the main channel at Māngiā and to have flowed along the west side of the valley past the archaeological site of Kāiāra Kot to Miāni Lagoon. The present day Chank River may be relict of this branch of the Porāli.

The second largest river of the plain is the 80 mile long Kharrari. It drains the foothills of the Mor and Pab ranges on the east side of the valley. This river, like the Porāli, has a perennial flow of water only in headward stretches. Where the Kharrari enters the Las Bela Plain, it develops several channels that are diverted to irrigate fields around the town of Uthal. South of Uthal the Titiān and Kharrari rivers follow an anastomatic pattern of channels. Eastern channels join the bed of the Watto River which flows into Siranda Lake. Western channels join the main course of
Titiān and flow to Miāni Lagoon. Since 1907 an increasing proportion of flood water joins the Watto.\(^5\)

The third major river is the 63-mile-long Windar. In the hills this stream has a perennial flow of from 20 to 25 cusecs. On the plain the river is intermittent with standing pools of water during the dry season. In flood, the river has a width of several hundred yards and a depth of as much as six feet (Plate V-E). During the summer floods of 1959 it could not be crossed for several weeks. Although such severe flooding is exceptional, sudden showers in the mountains create floods that now and then disrupt communications between Karāchi and Bela. The Winder follows various courses to Miāni Lagoon and Siranda Lake. Three of these routes are shown on Figure 15. The course that the river follows depends upon a man-made dam built east of Khurkera. In 1907 too much water was taken off to irrigate the fields and the excess filled Siranda Lake to overflowing. At present the Windar River has cut a gap around the southern part of Sonmiāni Hills and is building a large delta south of Sonmiāni fishing village.

The Effect of Man.—Man has affected the erosion and deposition of the rivers. For centuries the Lāsi farmers have been building earthen dams to trap the flood waters of
the major rivers. In the process, they have over the years increased moisture content and added a new deposit of alluvium to the central portion of the Las Bela Plain. The main area of flooding is a 10 miles wide 38 mile long zone from Liāri north to Bela and this is the main section that rises above the surrounding plain.

The dams built by the Lāsi farmers are of two types:

1. **Band**—a large composite dam of earth covered with branches of trees and brush which floods completely wash away. There are usually three bands in operation on the Porāli and at least one on the other major rivers.

2. **Kirar**—a smaller earthen dam is constructed in the shape of an L across only part of a river channel. Flood waters trapped behind the L rise and briefly flood the fields. Kirar are washed out easily and need to be repaired after each flood. There are about 13 dams of this type on the Porāli River. Effectiveness of irrigation is limited by the height to which a river can be raised and by the length of time flood waters can be detained before such an earthen dam is broken.

The largest band is five miles north of Lākhra. This dam is 260 feet long, 40 feet high, and 15 feet wide. It diverts the Porāli River into three main canals. One, called Lākhrāwāla, carries drinking water to storage tanks within the village of Lākhra. The other two carry water to nearby fields. Excess water from the fields and underground seepage finds its way to two rivers. The smaller river, called Lasra, is growing in size and cutting headward. The second,
called Titiān, is receiving progressively larger proportions of Porāli flood water as well as flood waters of the Kharrari River. The Titiān has reached base level by cutting a gap through the dunes to Miāni Lagoon near Gāgu. The bed of this river at Liāri is entrenched 22 feet below the surface of the plain (Fig. 17). The Lasra and Khāntra rivers, unable to breach the dunes, turn east and join the Titiān at the point where it is presently cutting through a gap to the lagoon (Fig. 18). Earthen dams have diverted almost all water from the original natural channel of the Porāli River. The resulting almost dry river bed is now called the Khāntra by the local people and presently is 18 feet below the surface of the plain.

Silt Dunes

Sand and silt particles are carried by wind inland from the coastal zone. The sand is deposited as a thin veneer behind the inner line of dunes. Lighter silt is carried much farther inland (Fig. 19). On the west side of the Las Bela Plain silts have been deposited inland from the tidal flats of Miāni Lagoon. A second area lies north and west of Sonmiāni Hills where silts have been carried from the same lagoon through a wide gap.
FIGURE 19. Physiography of the Recent coastal plain. Numbers represent sequential development of beach ridges. Block Diagrams A-A', B-B', and C-C' are on Figure 22.
In places, sand and silt dunes have formed around obstacles. One such obstacle is the plant *awk* (*Calatropis procera*), which is able to tap moisture in the accretion deposit as its deep roots penetrate successive layers of material to greater and greater depths. When a dune becomes too high for *awk* root penetration, *Tamarix*, with still longer roots, flourishes. At this stage *awk* is found around the edges of the dune and *Tamarix* on top. When a dune reaches a height of 10 to 15 feet, even the *Tamarix* dies and the dune form begins to dissipate leaving a projecting welter of dead roots and branches (Plate V-F).

**Sīranda Lake**

Sīranda Lake is a large desert depression with no normal outlet to the sea. It separates the Sonmiāni Hills from the main Pleistocene sand area, trends northwest to southeast, and is approximately nine miles long and two miles wide. During winter drought the lake is dry except for a few small pockets of brackish water from three to five feet deep. The dried surface is covered with mud cracks and salt incrustations (Plate VI-A). During the monsoon, flood waters drain into the lake from the north by way of branches of the Porāli and Kharrari rivers which join the Watto River.
Surplus flood water from the Windar River enters the lake from the southeast. When flooded, the lake has an average depth of from 10 to 12 feet. The water is potable during larger floods. As the waters evaporate dead fish and shells of *Melanoides tuberculata* leave a series of high water marks around the edges of the lake.

During most years Siranda Lake has no outlet to the sea, but it has been known to flood to levels permitting outflow around the north and south ends of Sonmiani Hills. This drainage was aggravated when an earthen dam was built east of Khurkera to divert the flood water of the Windar River into the fields. A large amount of excess irrigation water was diverted into the lake and the level rose until it overflowed around the north end of the sand hills into Miāni Lagoon (Fig. 15).

**Origin of the Lake.**—Siranda Lake was formed by uplift of the coastal plain and by tilting of the main Pleistocene sand area toward the central plain. The present surface of the playa is one and one-half feet above sea level while low pockets in the depression reach a depth of from three to five feet below present sea level (Fig. 16). Why large amounts of alluvium brought into the closed basin have not raised the floor of the playa deserved investigation. A series of
bore holes were drilled along a straight line traverse from the center of the lake for three miles east across the playa floor and lake terraces on the eastern side. Nine holes were made, the deepest 24 feet. The depth of the water table in the holes was uniform and close to sea level. However, very thick bedded clays with scattered gypsum crystals were found two feet below the water table in the lake bed and 10 feet above the water table near the Bela road, three miles to the east. It was impossible to bore through this layer of thick clay. Tilting of the bedded clays gives an indication that movement may have taken place, involving uplift of the eastern side of the valley and down tilting of the Siranda depression. Local subsidence and continued tilting appears to be the reason why the lake does not fill (Fig. 16).

Faulting has also influenced Siranda Lake. On the eastern side of the lake a sharp escarpment occurs where the high portion of Sonmiāni Hills (102 feet) rise abruptly from the lowest portion of the playa flat (three to five feet). This almost straight escarpment, discussed under the Sonmiāni Hill unit, appears to be an important fault zone. The uplifted hills, four miles in width, separate the Siranda depression from Miāni Lagoon.
Marine Invasion of Siranda Lake.—There is evidence that Siranda Lake was lower and functioned as a tidal lagoon in the not-too-distant past. Marine shells were found in the lake bed and around the shores of the lake. The species include: *Telescopium telescopium*, *Terebralia palustria*, *Tibia fusus*, and *Turbo*. Raised beaches on the east side of the lake are mentioned by Vredenburg, and Pithawalla. These beach surfaces have been altered by wind deflation and lake wave action. Historical accounts indicate that the lake may have once joined Miāni Lagoon. A group of Arab tombs on the eastern side of Siranda Lake was pointed out to the writer and the guide indicated that these heavy stones were brought by boats from Miāni Lagoon in the 14th century. However, historical accounts also indicate the existence of a lake in the time of Alexander the Great. Siranda is cited by Aurel Stein as the lake which furnished water for the animals of Alexander's army on his return from the Indus plains.
NOTES TO CHAPTER VI


3 Figure 18 traces the courses of the major rivers across the central plain. Solid lines indicate where flood waters presently flow. Dashed lines suggest former courses of rivers. The earthen and masonry dams plotted were the main ones found in the area in 1961.


5 T. H. Holdrich in "Notes on ancient and medieval Makrān," Journal of the Geographical Society, 7, No. 4 (1896), 394, reports on his visit to the area that at that time the Porāli River (the ancient Arabius) was gradually shifting westward and finding its way into the sea through a large tract of low lying country which according to him was a shallow sea at no very distant date.

6 A similar sequence in dune development and decay was described by Dr. Richard Joel Russell in "Land Forms of San Gogonio Pass, Southern California," University of California Publications in Geography, 6, No. 2, (1944), 107-16.

7 Shells were identified by W. S. S. van der Benthe Jutting, op. cit.

8 Baluchistan District Gazetteer Series, op. cit., p. 9.
Shells were identified by Jutting and Haas, op. cit., and A. R. Ranjha, Zoology Department, D. J. Science College, Karachi, Pakistan.


CHAPTER VII

COASTAL ZONE

The coastal zone of Las Bela is characterized by two distinct land form areas: (1) the rocky headlands that project to the coast at several locations from Ras Muāri to Gadāni on the eastern side of the valley and the Sarpai-Ras Malān headland complex on the western side; (2) the low alluvial coast fringed by sandy beaches and backed by beach ridges, sand dunes, and the large Miāni Lagoon. The two areas of coastal land forms, so different topographically and geomorphically, present diverse problems for human occupancy. They share, however, certain common phenomena: a large tidal range characteristic of the north Arabian Sea (high tide rises to six to eight feet on the average and reaches nine to 11 feet during the monsoon season), and a true desert climate, which limits vegetation.

Coastal development has been determined by the action of wind and current on the eroded materials. These are carried along the beaches and spits by littoral drift, the
direction of which is toward the center of Sonmiāni Bay where currents converge. The predominant direction of the drift is that of the prevailing southwest winds, particularly during the monsoon (Fig. 2). Evidence of this converging littoral drift is found in the mechanical analysis of the beach sand, which indicates coarser sand near the headlands.2 The bulk of the material moved by longshore currents in Sonmiāni Bay is derived from the silts, clays, and sands brought down by the Porāli and Windar rivers. Large amounts of these materials are deposited in Miāni Lagoon and then resorted and carried into Sonmiāni Bay by tidal currents in the lagoon. A second major source consists of material brought into Sonmiāni Bay by the Hingol and Phor rivers on the west and the Hab River on the east. The Hingol and the Hab are two of the longest rivers in Baluchistan. A third source of material is the coastal headlands which are composed of sandstones, shelly limestones, and conglomerates.

Mountainous Coast

Although most of the Las Bela coast is a broad plain composed of sand dunes and alluvial deposits (Fig. 19), rocky outcrops occur at several locations (Fig. 2) on the extreme eastern and western sides of the valley.
The Offshore Area.--Near the headland of Ras Muāri the continental shelf is narrow with several shoal platforms covered with reef coral. Beyond these reefs the shelf drops off abruptly, but Churma Island, a small rocky outlier of Ras Muāri, four miles to the west, rises 609 feet above sea level. In the vicinity of Churma Island the ocean floor is rugged and irregular with deep holes where conspicuous faulting has taken place and shallow shoals and reefs make navigation dangerous. Between the headlands of Ras Muāri and Ras Malān the floor of Sonmiāni Bay is bottomed by a wide shelf. The gradient is very gentle to the 100-fathom contour at which point the shelf drops off sharply. In the vicinity of 60 degrees east longitude a submarine canyon was discovered by Pakistan Navy surveyors. This canyon may be the former course of the Hab or Porāli rivers (or both) when sea level was lower.

The Headlands.--The longest stretch of cliffed, rocky coast east of the Las Bela Valley extends from Hawks Bay around Ras Muāri to the mouth of the Hab River. Ras Muāri, the seaward end of the Kirthar Mountain Range, juts 10 miles southwest into the Arabian Sea (Fig. 2-B). The ridge is composed of Miocene sandstones, limestones, and shales that have been eroded by wave action to form headlands. Sheer
sea-cliffs range in height from about five feet at Hawks Bay to as much as 100 feet near the tip of the promontory. Around Cape Muāri are old raised terraces (Fig. 2-B), the highest of which is about 250 feet above present sea level and two lower ones exist at approximately from 50 to 100 feet above sea level. Although these terraces are not easily recognized on the ground, they can be detected from the air and on aerial photographs. Successive stages of uplift has taken place along much of the Makrān Coast and Ras Muāri can be tied in with the evidence found to the west. Near Hawks Bay Recent oyster beds may have been raised from five to six feet above present sea level, but no oysters, barnacles, algae, or coral were detected on higher terraces.

Several small headlands occur between Ras Muāri and Ras Malān. One of the most prominent is the small Cretaceous limestone block of Gadāni which reaches a height of 286 feet above sea level. Wave erosion at the base of this headland has cut deep caves, blow holes, and picturesque rocky promontories (Plate VI-B). Two spectacular headlands rise on the west side of the Las Bela Coastal Plain. At Sarpai (Fig. 2) the seaward facing side of the anticline has been deeply eroded under wave attack. In some places, the limbs of the anticline have been truncated leaving stacks, caves, and
arches. This isolated mountain block, devoid of vegetation and composed of upturned indurated limestones interbedded with weak mudstones, has a striking appearance from the air.

Ras Malān is the western limit of the area under study. It is an immense sandstone-shelly-limestone tableland cut into irregular sections by thousand-foot gorges. The highest point on the tableland is 2,003 feet above sea level and is close to the coast where a sheer cliff from 1,500 to 2,000 feet high drops directly into the sea. This cliff extends for a distance of three miles. The uniformly white sandstone of this headland is the most conspicuous feature of the entire Makrān Coast.

Uplift of the headlands appears to be very recent and both fluvial and marine agents of erosion are now destroying the cliffs. Orthogonals converge on the rocky promontories of Ras Muāri and Ras Malān.

Pocket Beaches.--The mouth of the Hab River is situated north of Ras Muāri. This intermittent river is confined by the cliffed coast on the south and Pleistocene sand on the north. At its mouth small compound bars have formed with wide, sandy beaches. Shallow lagoons are found behind
the bars. Although the Hab is one of the longest rivers in eastern Baluchistan, with a considerable discharge of turbid water during floods, it formed no delta between Ras Muāri and Churma Island.

From the mouth of the Hab River to Lak Bidok, a distance of 23 miles, several small stretches of cliffed headlands alternate with short, sandy beaches. Four pocket beaches fill the arcs cut into Pleistocene sands. The beaches average from 50 to 100 feet in width at low tide but are covered at high tide. The smaller pocket beaches contain a high percentage of coarse material that was eroded from the headlands (Plate VI-C). The largest pocket beach is found between the headland of Gadāni and an outcrop of rocks at Lak Bidok (Fig. 2-C). A series of small beach ridges were formed as sand filled this pocket and today the beach is three-fourths of a mile wide and three miles long at low tide. During severe storms, the entire beach ridge series is covered.

On the west side of the valley two pocket beaches have formed to the east of Ras Malān. Small intermittent rivers have deposited material between the headlands.

The larger pocket beaches on each side of the coastal plain are used as sites for fishing villages and the coves
afford protection for boats during the monsoon season. The villages of Gadāni, Ḥīsā, Goth Kechu, Khori Kod, and Malān Bandar are examples (Fig. 2).

**Inner Dunes**

Around the north shore of Miānī Lagoon, a large 20-mile long sand accumulation, with an average width of from two to four miles, has developed (Fig. 19). When the coastline of Sonmiānī Bay was from five to six miles farther inland, dunes formed as sand was blown inshore from the beaches. It is difficult to estimate the amount of time needed for the accumulation of the dunes, but if an ample supply of source material was present the entire sand mass could have formed within several hundred years.

The sand appears to be of Recent origin. Topographically, the area does not stand as high in relief as Sonmiānī Hills or the sand areas flanking the sides of the valley. The body of sand is less eroded and subdued. Its dunes are more apparent in the field and more stable sands are less indurated than in nearby Pleistocene materials. A further indication of age is furnished by the vegetation. The distribution of plants is not dense and the majority are salt-tolerant species. No *Euphorbia neriifolia* shrubs were found.
The seaward side of the dunes is attacked by the strongest winds reaching the Las Bela Coastal Plain. Almost every afternoon during the monsoon season southwest winds, averaging 16 miles per hour blow against the windward face of the sand. Elongated U-shaped troughs have been cut by wind action. These troughs resemble the yardangs described by Hedin, Stein, and Blackwelder. In places, the wind has smoothed the corners of ridges, shortened the ends, and reduced them to conical mounds (Plate VI-D). The yardangs, protected from north winds by high dunes, are cut by predominantly one wind from one direction.

Material removed from yardangs and blowouts is deposited as chains of large coalescing dunes with well developed slip faces in orientation normal to the trend of the whole dune field. The size and extent of the moving sand is plotted on Figure 19. Some dunes reach an elevation of 118 feet above sea level and are the highest active ones in the region. The continually shifting sands and migrating dunes fill river beds and force streams to change their courses. When floods occur, water unable to cross the sand barrier, spreads out in a series of ponds and pools behind the dunes (Plate VI-E). The trapped water remains for weeks or months, until it evaporates or seeps through the
the sand to a lower level.

Deep indentations suggest places where rivers formerly cut through the sands to the lagoon. Two miles west of the present course of the Titiān River, the Khāntra River once flowed through a gap.

On the lagoonal side of the sands, mud flats are found in the blowouts and at maximum tide these are completely covered by lagoonal waters. Small waves break against the base of the sand and set the stage for wind erosion. Heaviest wave action occurs east of the Chānk River.

Clay, blown from the lagoon, is plastered in layers against the seaward side of the yardangs. West of the Chānk River, where the largest mud flats occur, the layers of clay are from two to three inches thick. Clay accumulates to an elevation of only eight feet because the particles are too moist or too cohesive to be carried far by wind.

On the seaward, gently sloping, western side of Son-miāni Hills large Recent crescent-shaped dunes are migrating inland over the older sands. The active sand takes two forms. One form appears as a very large single crescentic mass, containing a jumble of irregular dunes, that is as much as one mile long and one-half mile wide. Some of the slip faces on the lee side of individual dunes attain a local
relief of 75 feet. The second form is small dunes on top of large sand masses. The movement of these large sand colonies is accomplished by the migration of the smaller dunes across their top. There are at present three such large sand colonies north of Dāmb fishing village.

It is conjectured that such large dune fields result from sand being trapped between the lagoon and the higher Sonmīānī Hills. Sand is transported inshore from the tidal mud flats of Miānī Lagoon and up the windward face of the large crescent dunes. The height to which this sand is lifted is related to the movement of air currents up and over Sonmīānī Hills. Both the hill area and the active dunes average 56 feet above sea level.

Although the bulk of the sand is from the tidal flats, some sand is derived from the Pleistocene sands that are presently undergoing degradation. Stable, partially indurated layers of sand are found near the base of the active dunes, or stand as small isolated blocks from two to three feet high in locations formerly occupied by dunes. Organic remains aid in distinguishing the active from the stable dunes. The older sands are filled with terrestrial gastropods (Zootecus chion), and the Recent dunes contain concentrations of marine foraminifera at the base of the leeward slopes.
Mini Lagoon

Mini Lagoon is 28 miles long and has a maximum width of four miles. It was formed by the growth of a series of recurved spits across Sonmiāni Bay. The largest spit, called Ādi, extends 35 miles west from the beach ridges at the south end of the Hāro Mountain Range. A second, shorter series, called Sonmiāni Spit, extends about four miles westward from the beach ridges near Ambāgh. The lagoon is connected to Sonmiāni Bay by a two and one-half mile wide tidal channel which separates the two main series of recurved spits. The tidal range within the lagoon averages from 4.2 to 6.4 feet and the velocity of the tide is irregular. The highest speed, according to A. W. Hughes, is reported to be two knots. At times the incoming tide has a small tidal bore.

Bottom profiles for Mini Lagoon are plotted on Figure 20. The depths of the water of these profiles are based on mean high water for October, 1959. The course of the generally distinguishable main central channel has shifted in places. Sediment, deposited by rivers emptying into the northern part of the lagoon, has forced the main channel toward the south shore. This is plainly indicated in Profile E-E', where the Titiān River is presently building a large delta. On the east side of the lagoon (Profile F-F') sand
FIGURE 20. Bottom profiles of Miāni Lagoon
from Ādi Spit has forced the main channel closer to the northeast shore.

Miāni Lagoon is filling. Not only is this reported by local fishermen, but early maps reveal changes in the size and width of the channels. Figure 21, with accompanying letters and numerals, depicts the changes that have taken place:

Figure 21—A (1890). During this period the Chānk River was filling in a large area around former beach ridges on the west side of Miāni Lagoon (1). Farther to the east flood waters, from the Porāli and Khāntra Rivers, with poorly defined channels, spread over a wide area. Deltas were formed at (2) and (3), and in the eastern portion of the lagoon the Winder River was beginning to build its delta at (4). This delta eventually closed off the port of Sonmiāni. At this time a deep narrow channel led to the port of Gāgu (5) and sailing craft could reach this point.

Figure 21—B (1939). During this period more material was deposited in the lagoon and more mud was exposed at low water. The rivers on the west side of the plain continued to fill in the low tidal flats. The Chānk River shifted its course more to the east, cutting a gap through the dunes (7). By 1939, the Porāli, Khāntra and Kharrari rivers were using the channel of the Titiān River (8) as their outlet into the lagoon. Sediment from these rivers began to build islands in the central part of the lagoon (9) which were exposed at low water. The northeast shore of the lagoon was being undercut by the shifting main channel (10). The Windar River increased the size of its delta (4) to the point where the fishing village of Sonmiāni was forced to move west to Dāmb.

Figure 21—C (1954). By 1954 the main channel leading through the lagoon had become narrower and shallower. Mud and clay deposits filled in the entire western
portion of the lagoon (11). Sailing craft no longer could reach the port of Gāgu (5) at the mouth of the Titian River. The northeast shore of the lagoon (10) continued to be under attack by the central channel.

North of the fishing village of Dāmb, in 1959 and 1960, tidal channels were in the process of being extended between the stable and active dune colonies at the base of Sonmiāni Hills. Layers of marine clays, shells, and thin bands of gypsum were found in borings to a depth of 13 feet. The darker sands were covered with glauconite.

**Mangroves.**—Narrow bands of mangroves grow in the tidal zone of Miāni Lagoon (Fig. 21). These bands grow under physical conditions which barely meet their minimum requirements. The rivers entering the lagoon along the north shore provide moisture and soft, fine-grained alluvium which the seedlings require. Some of this alluvium finds its way to the south shore where a thin band of mangroves struggles to survive against the migrating sands of Ādi Spit (Plate VI-F). In areas where the fresh silts and clays are no longer being deposited, the trees die very quickly.

There are several other adverse factors for the growth of the mangroves in Miāni Lagoon. The average temperature of the coldest month is between 63 and 67 degrees
Fahrenheit which is about five degrees too cold for optimum growth. The 25-degree seasonal temperature range is also excessive for mangroves. The trees require fresh water, and this is received in sufficient quantity only during monsoon floods. During the rest of the year a meager supply of fresh blister water in sand helps to support their growth. The plants are often being disturbed by shifting river courses and by being buried under sand. A particular location is seldom adapted to their survival for more than 15 or 20 years. Mangroves around Mīāni Lagoon are further subjected to destruction by men and animals. Herds of camel are driven onto the tidal flats to eat the trees during the winter dry season in spite of efforts by local officials to protect the area.

Figure 21 shows the distribution of mangroves in Mīāni Lagoon in 1890, 1938, and 1953. During these 63 years, mangroves have disappeared from the central and eastern parts of the lagoon. By 1959, the trees were reduced to zones on the north and south shores of the lagoon from Dāmb fishing village west to the delta of the Titiān River.

Most of the mangroves growing today consist of *Avicennia officinalis* (black mangrove). These have a system of surface roots that send up sharp pointed pneumatophores
from five to six inches above the ground. Along the main channel of Miāni Lagoon individual trees grow to heights of from 30 to 40 feet (Plate III-B). A second dominant genus is red mangrove, *Rhizophoria conjugata*. This genus has large arched stilt roots which raise the trunk above the ground, and long drop-roots that develop from the branches. Most of these trees grow no taller than 10 to 15 feet. Young mangroves may grow in thick clumps in a few places, but generally they are not dense enough to block man's movement. Small boats can pass through the mangrove forests by using the tidal channels during high tide (Plate VII-A). The mangroves quickly thin to scattered individual shrubs away from main tidal channels. On the north side of the mud flats, widely spaced *Avicennia* shrubs, surrounded by pointed pneumatophores, are found dispersed across the tidal flats. The maximum width of tidal flooding around the shores of Miāni Lagoon is three miles. All of the tidal channels are small and few streams are large enough to display winding patterns.

Mangroves west of the Las Bela area are limited to a few delta areas where intermittent rivers bring just enough fresh water to supply a few small scattered shrubs. Small mangrove shrubs are found in the Kalmat tidal region between
Ormāra and Pasni and in the delta of the Dasht River near Jīwani on the Iran border (Fig. 1). These locations, along with scattered small delta areas in Iran and the Red Sea coast of Saudi Arabia, are examples of areas where mangroves grow near a completely barren, sandy, desert environment.14

Beach Ridges and Spits

The internal structure of the beach ridges of the coastal zone conforms to the internal structure of present-day beaches. Both are composed of thin layers of sand and shell that dip seaward at angles of from five to 15 degrees. The landward dip of the sand layers ordinarily varies from two to four degrees. Loose sand on the wind-blown summits of the ridges is structureless. In most of the beach ridges land gastropods (Zootecus chion) are found to a depth of about three feet, along with worm burrows and old shrub roots. Below three feet, marine shells were encountered in irregular patches throughout the sands. Thin beds of coarser sand appeared in several holes dug below a depth of four feet. On the seaward side of several of the beach ridges narrow bands of heavy minerals, mainly ilmenite and magnetite, dipped seaward at an inclination of five degrees.

The beach ridges stand out prominently in the field and on aerial photographs. Silts and clays were deposited
in the swales by flood waters from the Mobār and Chabechi rivers on the east side of the coastal plain and the Phor River on the west. Vegetation consisting of grasses and a few aquatic plants on the swales appears darker on aerial photographs and forms a contrast with the more widely spaced desert shrubs on the ridges. During a rainy season grasses blanket not only the swales, but also fill in the open spaces between the individual xerophytic shrubs on the beach ridges.

Beach Ridges on the West Side of the Coastal Plain.—Old accretion ridges begin as a narrow band a few miles to the west of the southern tip of the Hāro Range and widen to the east into a large fan (Fig. 2). West of the Phor River the ridges are truncated by the Arabian Sea. Projection of the alignment of beach ridges to the west indicates that their removal results from coastal retreat. The area of greatest coastal retreat extends from the southern tip of the Hāro Range 35 miles west to the headland of Ras Malān. The total retreat since the formation of the accretion ridges appears to be from one to two miles.

East of the Phor River, beach ridges extend for a distance of 14 miles to the northeast. Some of the ridges have been buried by active dunes migrating inland across
Adi Spit; others have been buried by the inner line of dunes around the north end of Miāni Lagoon and others have been truncated by wave action at the western end of the lagoon.

The evolution of the accretion ridges may be explained most readily if several stages of development are recognized (Fig. 19). During Stage 1 an elongated, comparatively narrow beach extended along the extreme western side of the plain. A narrow remnant of this beach now forms a strip of sand, possibly a beach ridge, that appears above the plain at several locations. The beach begins near the south end of the Hāro Range, approximately two and one-half miles north of the present shoreline. It continues northeastward parallel to the front of the mountain about 12 miles. Recognition of the beach ridge is difficult on the ground for it is similar to the longitudinal dunes that have formed leeward of small river beds. In places, the beach ridge is completely buried by alluvial fans which have formed east of the mountain front.

In Stage 2 (Fig. 19), the next seaward ridge can be followed in a nearly straight line from the south tip of the Hāro Range to a point west of the Chānk River, a distance of 14 miles. This is one of the most pronounced accretion ridges. Five remnants of this ridge rise above the tidal
mud flats of Miāni Lagoon, the highest of which is 33 feet above sea level with a maximum width of about 100 yards. Borings made by the writer with a soil auger on the east side of the accretion ridge to a depth of seven feet reach beach material. Bedded sand with thin bands of heavy minerals dip away from the seaward face at a gradient of 12 degrees. On the landward side of the ridge lagoonal clays rather than beach deposits were encountered. The south-western end of the ridge abuts abruptly against the extreme southern tip of the Hāro Mountain Range.

Between Stage 2 and Stage 3 (Fig. 19), a series of 15 to 20 accretion ridges were formed. These, which probably were much longer, are now truncated on the northeast at the edge of Miāni Lagoon and on the southwest bend around the southern tip of the Hāro Range. They extend across a major fault zone (Fig. 10), and in turn are crossed by the Phor River and terminate suddenly at the coastline. When these beach ridges were formed the Phor River followed a course either to the west or flowed along the swales between the individual beach ridges.

In Stage 3 a beach ridge began to extend itself eastward across Sonmiāni Bay. From the end of the hooks, spits recurved toward the land and remnants of these can be
identified as small islands in the lagoon.

In Stages 4 through 7 (Fig. 19), compound and complex growth of Ādi Spit toward the east is depicted. In Stage 5 the spit may have curved northward, to a small group of sand remnants at Gāgu. With continued growth of the spit toward the east, a general retreat of the coastline occurred near the Phor River.

Stage 8 includes the most recent formation of Ādi Spit. The extension of this spit toward the east may be related to the growth of Sonmiāni Spit. A balance exists between the seaward extension of these two spits and the width of the entrance of Sonmiāni Harbor. From Stage 4 through Stage 8 no well-defined beach ridges were formed. A succession of hooks became covered with large crescentic dunes. However, the general pattern of the dune colonies and the low troughs between the dunes are suggestive of the curved hooks that formed the spits. With migration of the dune chains toward the northeast, the original pattern of hook growth has changed but the outline can be detected on aerial photographs.

Beach Ridges on the East Side of the Coastal Plain.-- Eight stages of coastal progression are shown for the east
side of the Las Bela Valley (Fig. 19). These do not conform to the eight stages of growth for the accretion ridges on the west side of the plain.

In Stages 1 and 2, beach ridges formed at the base of the wave-eroded cliff near the village of Nāka Khārari and continued westward for a distance of 16 miles to Miāni Lagoon. The western extent cannot be established because shifting channels of the lagoon, along with wind and wave erosion, have destroyed the original spits and hooks.¹⁵

In Stages 3 to 5 the largest beach ridges were formed. In the vicinity of Ambāgh a single accretion ridge rises 42 feet above sea level and is several hundred yards wide (Fig. 19). To the west, a channel leading into Miāni Lagoon has truncated the ends of the ridges but to the east they converge at a point of origin in the vicinity of Lak Bidok.

Stages 6 through 8 (Fig. 19), include the most recent changes along Sonmiāni Beach. A succession of compound and complex hooks and spits, similar to those of Ādi Spit, formed in conjunction with seaward growth of the Windar delta.¹⁶ Beach ridges and spits grew westward and seaward, but at the extreme southeastern portion of Sonmiāni Coastal Plain, in the vicinity of Lak Bidok, a general retreat of the shoreline has occurred. The retreat is similar to that near the Phor River on the west side of the valley.
Block Diagram of the Coastal Plain.—Figure 22 shows block diagrams of the three principal types of coastal plain found in the Las Bela area. The numbers on the diagrams refer to the following features:

Block Diagram A - A' is a sketch of Sonmiani Coastal Plain.

(1) A wide beach continues uninterruptedly from Lak Bidok to Sonmiani Harbor entrance.

(2) There is an irregular frontal dune ridge located immediately landward of the backshore. Ridge sand is held in place by low mats of salt-tolerant creepers (Plate III-D) and scattered clumps of grass, mainly *Aristida mutabilis*. The growing dunes unite to form an irregular crest bordering the shore.

(3) Behind the frontal dunes, there is a series of beach ridges parallel to the coast. Each band or level of these can be distinguished by a slight change in relief, by denser vegetation, and by a larger amount of fixed sand. The beach ridges are in the process of being eroded and deformed. Small linear furrows, perpendicular to the wind, have cut across them forming a series of blowouts.

(4) Landward from the beach ridges, more deflation has taken place and deep blowouts occur. Sand remnants within these blowouts are more indurated. The process of cementation is in progress. In places the older sands include large numbers of *foraminifera*.

(5) At several locations beach ridges run parallel to one another. In other locations they have been buried by active dune complexes or destroyed by blowouts.

(6) Material from blowouts reform into large crescentic shaped sand bodies that are aligned in
FIGURE 22. Block diagrams of the Las Bela Coastal Plain
parallel ridges perpendicular to the prevailing wind. Dunes reach heights of 81 feet above sea level with as much as 72 feet of local relief on their slip face. The dunes migrating across the sand ridges give the impression of great thickness which is not always the case.

(7) Belts between the dune fields may be former swales that have increased in size through wind deflation.

(8) In places, deep blowouts reach the water table and contain pools of standing water and lush vegetation consisting mainly of Tamarix.

(9) At the landward end of the large active dunes, linear accretion ridges again appear. Sand migrating across the ridges, fills swales and levels the topography locally. However, the beach ridges can be identified because darker vegetation grows in the swales.

(10) Close to the Pleistocene bluff, sand has not completely filled the swales and the beach ridges have more distinct form. Near Ambāgh the accretion ridges are several hundred yards wide and swales between are very narrow. In several places the hollows are only from four to eight feet wide and are lined with a single row of Tamarix shrubs.

(11) Beach ridges are not distinct near the Pleistocene bluff because materials eroded from the slopes have formed a covering.

Block Diagram B - B' is a sketch of Ādi Spit.

(1) A wide beach is found with an average gradient of 12 per cent.

(2) Immediately inland from the high water line, crescentic dunes form and migrate across the spit. Closely spaced low dunes near the shore become larger, 30 to 35 feet high with slip faces of 25 feet local relief, farther inland. The shape of the dune fields coincides in general outline with the underlying stages of spit growth.
(3) Between the dunes long troughs consist of blowouts with flat salt incrusted pans.

(4) The dunes on the north side of the spit migrate directly into the lagoon and the lagoon is slowly being filled in because sand from the dunes is blown into it from the south and alluvium is being deposited from the north.

Block Diagram C-C' shows the coastal plain on the west side of the Las Bela Valley.

(1) There is a wide beach with fine sediments largely derived from the mouth of the Phor River.

(2) A complex series of accretion ridges grade from one into another (Plate VII-B). The ridges criss-cross and merge with each other instead of remaining as long parallel linear beach ridges. Drifting sand and wind deflation along with flood waters from the Phor River and high tides within the lagoon that occasionally inundate the swales have aided in destroying their linear form.

(3) Two active sand fields composed of complex dunes and blowouts are migrating across the sand ridges. Material for these sand fields is derived from the mouth of the Phor River.

(4) At one location the beach ridges have been displaced resulting in a three-foot-deep depression which is a graben (Figs. 10 and 22 C-4). The beach ridges and swales within this small depression are several feet lower than those on either side. The straight sides of the depression are aligned with a major fault at the south end of the Hāro Range.

(5) Evaporation of rain water trapped in the swales has left a series of pink and white salt pans. Very high tides from the Arabian Sea and Miāni Lagoon are a probable source of salt water in these depressions.

(6) The disappearance of the beach ridges at the western end of Miāni Lagoon probably results from
several factors: mud that has been deposited in the lagoon may have buried them, or, with the formation of Adi Spit (Fig. 19), lagoonal water, trapped behind a series of hooks, may have helped create waves which truncated their ends. Local subsidence and faulting in the vicinity also could account for this truncation.

The Beach Zone

An almost continuous beach extends in a wide arc for 75 miles from the small rocky point at Lak Bidok (Plate VII-C) to the headlands of Sarpai (Fig. 2). The beach is broken at the large tidal inlet of Miāni Lagoon and at the small inlet of the Phor River. When large floods occur other rivers, such as the Chabechi (Plate VII-D), cross the coastal plain and reach the beach. Soft, slippery sand, left on the beach after a flood, delays or hinders animal and vehicular movement along the foreshore.

The beaches and spits are composed of fine, yellow to white sand containing quartz grains, considerable amounts of finely broken shells, and some micaceous mud. The sand is derived mainly from streams but is sorted effectively by wave action. The sand composing Sonmiāni and Ādi beaches was sampled in 1959 and again in 1960. Samples were taken at selected locations along the beach, from mean high to mean low water. Mechanical analysis of all samples reveals very little coarse sand. Although the size of the particles in
the samples ranged from 1.00 millimeter to 0.07 millimeter in diameter, very little exceeded 0.60 millimeter. The samples taken in 1959 showed on analysis that largest grain sizes occurred near the headlands and at the entrance to Miāni Lagoon. Size decreased progressively toward the center of the beach. Samples varied only slightly in size of particles over the entire length of Sonmiāni Beach. Those tested during the summer monsoon were coarser than those tested in the winter.

Above low water mark Ādi and Sonmiāni beaches have a gradient ranging from two to three degrees with an average of about five degrees. The beach profile varies from the calm winter season to the stormy monsoon season. Individual storms steepen beach profiles at any time of the year.

Figure 23 shows three profiles of Sonmiāni Beach and one of Ādi Beach from data collected from June to October, 1959. These locations were selected to demonstrate characteristic gradients. A measurement of Ādi Beach could be made only when moderate waves permitted crossing to the point of Ādi Spit. A measurement of Ādi during July, Profile A (Fig. 23), shows a beach with a small storm berm. By September and the end of the high seas caused by the monsoon this storm berm was much larger.
ELEVATION MEASURED FROM MEAN LOW WATER
In June, 1959, before the start of the monsoon season, the height of ocean breakers is small and the slope of all the beaches is gradual. By August, 1959, heavy seas had removed part of the foreshore on the eastern and western ends of Sonmiani Beach and built a storm berm at the backshore. In the middle of Sonmiani Beach, Profile C (Fig. 23) shows a slight build-up. With the return of calm seas in October, the foreshore of the beach is again built up with berms seaward of the August storm berm.

At low tide the foreshores of beaches around Sonmiani Bay are smooth and firm. The sands are able to support heavy motor vehicle traffic, and camel caravans frequently use them. After heavy storms these beaches are too steep and the sand too soft for vehicles to reach the firm foreshore surface. Large amounts of driftwood and debris accumulate on them during the storm season (Plate VII-E).

**Sonmiani Harbor**

Figure 24 depicts the changes in the entrance to Miāni Lagoon between 1842 and 1956. The following changes have taken place:

A. In 1842 a deep channel existed close to Sonmiani fishing village. The channels were not easy to navigate because they contained shifting sand bars within the harbor and only shallow passages crossed the outer bar. The shape and location of the spits may be inexact because land areas were only roughly sketched by Montrion.
DRYLAND

DRY AT LOW WATER - Bars occur to depths of 6 ft.

DEEPER CHANNELS 18-36 feet deep

MANGROVE

FIGURE 24. Sonmiāni Harbor
B. About 1890 the Windar River was beginning to build a delta near Sonmiāni Village. The sand bar which existed in 1842 was no longer present in 1890. Instead, two large bars had formed on either side of the single main channel.

C. By 1926 Sonmiāni Spit had prograded toward the west. Its shape was related to the growth of the Windar delta. Sonmiāni and Ādi spits reached their greatest seaward extent during the 110-year period of record. A large sand bar again existed in the main channel of Sonmiāni Harbor.

D. The 1956-sketch shows a general retreat of the coast. A series of shallow small sand bars are found in the main channel of Sonmiāni Harbor. The Windar delta continued to grow toward the west completely closing off the port of Sonmiāni.

The appearance and disappearance of large sand bars in Sonmiāni Harbor raises the question of why and how these features form. From accounts of local fishermen, who know the channel well, the bars form during the calm winter season when sediments are carried from the lagoon and deposited at the entrance of the bay. During the monsoon season heavy surf destroys or partially removes the bars and redistributes their sediment. Large floods in the lagoon result in strong currents which change the shape of the bars.

Perhaps distribution of material along the beaches and spits and even the growth of beach ridges and offshore bars are possibly related to the destruction of the sand bars that form at the mouth of Sonmiāni Harbor. Destruction
of the bars and distribution of their materials may not take
place each year, but may follow cycles depending upon their
rate of growth, the number of storms which reach the coast,
and the strength and movement of the longshore and lagoonal
currents.

Formation of the beach ridges and spits seems to have
been rapid. Growth of the Windar River delta serves as a
guide to indicate the time required for the last stages of
beach ridge growth, and for the development of spits. The
entire advance of the Las Bela Coastal Plain from the inner
dunes to its present location probably took place during
the past 500 to 1,000 years.

There is evidence to indicate that in the past few
years a decided change is taking place along the shoreline.
Sand is migrating inland across accretion ridges that were
stable for a long time. No new beach ridges are forming
along the coast at the present time. Within the past five
years dune accumulations have migrated several thousand feet
inland in the vicinity of Nāka Khārari (Plate VII-F). The
people living in this area report that the dunes have been
migrating at a steady rate and 1930 is approximately the
time at which they first began their movement from the beach.
At the present rate of movement they will soon reach the
Pleistocene cliff on the east side of the coastal plain.

Material is not being carried from the mouth of the Phor River along the length of Ādi Beach. On the other hand, sand is being deposited at the mouth of the river and carried inland by the wind to form crescentic dunes (Fig. 22, C - C'). These dune complexes are not large and may have originated during the past 10 to 15 years.
NOTES TO CHAPTER VII


2Mechanical analysis of the sand is given on page 121.

3Revisions to British Admiralty Chart Nos. 38 and 145 were made by the Pakistan Navy during the years 1959-1961.

4Muhammad Ismail Siddiqi, The Geology and Physiography of Karachi Coast (West Pakistan), Department of Geography, University of Karachi (Karachi: by the author, 1959), p. 3.


6Stein, op. cit., p. 201.


8Shells were identified by Dr. Fritz Haas, op. cit.


11The numerals in parentheses refer to corresponding locations on Figure 46.
12 When the writer visited Miāni Lagoon in 1959 and 1960, mangrove trees, being undercut by the waves of the lagoon, were falling into the central channel (Plate-III C).


15 The writer believes that the beach ridges may have extended several miles northwest of Dāmb fishing village and material comprising the original hooks and spits may have nourished the large crescentic dune fields presently found at the base of Sonmiāni Hills. Remnants of the first line of beach ridges can be identified east of the village of Sonmiāni near the southern end of Sonmiāni Hills.

16 The changes in the delta are shown on Figure 24.

17 C. M. Montrion, A Sketch of Sonmiyani Harbour (Great Britain, Admiralty Chart, East India Company, June 14, 1843).
CONCLUSION

The Las Bela Valley is a structural trough in the Alpine-Himalayan geosynclinal belt where thick marine sediments have accumulated from Paleozoic to Tertiary times. Late in the Cenozoic Era the entire region underwent violent orogeny resulting in folded and faulted mountains forming on the east and west sides of the valley. These structures are correlated with the compressive stages of mountain building and apparently the process is continuing. The effects of numerous earthquakes with local structural movements are evident in the area.

During the past million years alternate filling and erosion in the valley accompanied the four major glacial stages. At each stage of deglaciation there occurred alluvial filling. During glacial stages, the low stand of the Arabian Sea exposed a broad continental shelf in Sonmiani Bay which became a voluminous source of fine material that was carried inland by southwest winds to form the more than seven cubic miles of unconsolidated sand and silts on the east side of the coastal plain.
From about 18,000 to 5,000 years ago, sea level rose and covered the lower portion of the Las Bela Coastal Plain. A sand dune accumulation around the north end of Miāni Lagoon was formed at the time of this inner shoreline. There is no valid evidence that the marine encroachment reached as far north as Lākhra, in the central part of the plain, but a tidal lagoon may have existed in this vicinity for several thousand years. The marine encroachment affected the east and west sides of the valley where wave cut arcs were formed at the base of the alluvial fans on the west and steep cliffs were cut as Pleistocene sands were removed by water on the east.

In the past 5,000 years, with no significant change of sea level, a progradation of the coastal plain has taken place. A series of beach ridges and spits were formed from five to eight miles seaward of the inner shoreline. During the last 30 years coastal growth appears to have slowed down in places with erosion of the beach ridges and migration of eolian material inland by steady southwest winds.

Local tectonic movements have occurred during the last 5,000 years. There is considerable evidence of Recent major faulting parallel to the Arabian Sea coast, including the effects of earthquakes and the sudden appearance of
temporary islands. Belts of raised beaches which characterize much of the coast to the west of the area under study and as far as the Iranian border, do not occur along the entire coast and in the Las Bela region are confined to a few localities.

Three areas where local uplift has taken place include sections of the coast near Karāchi, raised from six to eight feet above present sea level, a hill unit in the Sonmiāni area, uplifted on the order of 50 feet, and the Hāro Mountain Range with alluvial fans at its base, where approximately from 70 to 80 feet of uplift has taken place. West of the Las Bela area, coastal uplift increases to a maximum of from 200 to 400 feet above present sea level. In the northern part of the Las Bela Valley, man-made caves at the base of vertical walls of a valley of the Hala Mountain Range, have been uplifted beyond human reach. The Pleistocene sand accumulations and coarse fan materials on the east side of the plain have been tilted downward toward the northwest. Siranda Lake represents one of the depressions formed as a result of tilting.
PLATE I

A On the west side of the Las Bela Coastal Plain rugs and mats are made on the sand. The rug shown in the picture was made by nomads of wool and camel hair.

B A hut being constructed at the village of Dāmb. It will be covered with mats made from the dwarf palm (*Nannorphos ritchieana*). Almost the entire hut is constructed of local materials.

C Gadāni fishing village as seen from the rocky headland of Gadāni. The village is located on the southern end of a small pocket beach.

D One of the three wells which contained potable water at the fishing village of Gadāni. Local drinking cup is a tin can.

E Cotton nets being repaired at the fishing village of Dāmb. Stakes and mats in the background are used for drying the nets.

F "Datti Hora" fishing craft being beached at the village of Bearo. Most of the fish caught by this boat were sharks and sting rays.
PLATE II

A Sudden flooding of the Chabechi River occurred soon after a cyclone from the Arabian Sea moved across the Las Bela Coastal Plain at the end of June, 1959. The writer crossed the dry river bed two hours before this picture was taken.

B After heavy rains the main road from Karachi to Bela became extremely soft. Trucks and busses attempting to maintain communications made deep ruts in the mud which became impossible for a motor vehicle to follow.

C Capparis aphylla is one of the largest shrubs on the central Las Bela Plain. It is more adaptable to drought conditions than many of the plants found in the area because it lacks true leaves and can withstand dry winds.

D Along the coastal section of the plain low salt-tolerant plants grow to heights of from three to five feet. The main species in this picture are Suaeda fruticosa and Haloxylon salicornicum.

E One of the tallest grasses found growing in the Chabechi River bed is Saccharum spontaneum. Often clumps of this grass will trap sand which forms high mounds around the roots.

F Tamarix troupii thrives best in the moist river beds where individual trees reach heights of 20 feet. This picture is a southwest view from Sonmiāni Hills to the Windar River.
The cactus-like shrub *Euphorbia neriifolia* is similar in appearance to the North American organ-pipe cactus. This plant has an excellent taproot system and is commonly found on the older surfaces surrounding the recent alluvial plain.

The largest mangrove trees (*Avicennia officinalis*) found in the Las Bela area occur a few miles west of the fishing village of Bearo on the north shore of Miāni Lagoon.

Along the northeast shore of Miāni Lagoon mangroves are being undercut by tidal currents and waves from the main channel. Two of the main species of mangroves found in this locality are *Avicennia officinalis* and *Rhizophora conjugata*. Outrigger of local lateen sailing craft in the foreground.

One of the plants which help to hold the sand in place is *Ipomoea eriocarpa*. It is found growing on the backshore immediately landward of the high water line. This long, salt-tolerant, creeping vine has large purple flowers and yellow fruit.

Near the coast the castor-oil plant arind (*Ricinus communis*) is the principal cultivated crop. This plant can withstand both saline and drought conditions.

The eastern dip slope of the Pab Mountain Range. These mountains are from 1,000 to 3,000 feet high. Light colored areas are sand dunes on the lee slope of the mountain front.
PLATE IV

A Air view of the southern part of the steeply dipping faulted and folded Hāro Mountain Range. In places, the Tertiary beds are nearly vertical. In this location gravel fans are missing from the seaward face of the mountains.

B View south from the cone of Chandragup mud vent toward an extinct mud volcano. The dry crater of this cone is 180 feet in diameter. The Arabian Sea is in the distance.

C Beds of oyster shells were found at elevations of 50 to 70 feet above present sea level two miles east of Sonmiāni fishing village.

D Gravels form a wide band around the northern flanks of the Las Bela Plain. Cutting across these coalescing fans are wide river beds. The bed of the Porāli is shown in the background.

E East coast of Ras Muāri. Several platform levels can be identified. Cliffs at this location are 75 feet high. Numerous sea caves, stacks, and blow holes occur at the base of the cliffs. Ras Muāri is 10 miles west of Karāchi.

F Strong southwest winds have moved sand inland against the Pab Mountains 600 to 700 feet above sea level. High up on the sides of the hills sand grades into loess-like silt. View northeast toward the western flank of the Pab Range.
A Cross-bedded Pleistocene sand exposed along the sides of the Chabechi River. Cross-stratification is almost exclusively planar in type and dips of the individual lenses are east-northeast at 25 to 30 degrees from the horizontal.

B Small reverse fault with slickensides on the southern edge of Sonmiāni Hills (Fig. 15 and Plate V-B). This very small Tertiary rock outcrop is more similar to the Hinglaj arenaceous series on the west side of the valley than to the Jurassic and Cretaceous rocks that are closer to this area.

C Looking northeast toward the Las Bela Plain from the uplifted Hāro conglomerates on the flanks of Hāro Mountain Range, the dip of the bedrock averages between five and six degrees eastward. The dip of the four to five feet thick unconsolidated gravels varies between two and four degrees eastward.

D The Titiān River at Liāri. Small pools of water and channels with soft mud make vehicle crossing difficult. Five large river beds obstruct movement across the Las Bela Plain in an east to west direction.

E Windar River in flood after heavy monsoon rains in 1959. The river is receding after flooding an area of one-fourth of a mile wide. At this location the main road to Bela crosses the river. All land transport was disrupted for a month during the very heavy flooding.

F Cross section of an eroded silt-clay accretion dune on the lee side of the tidal mud flat of Miāni Lagoon. Successive layers of growth can be seen in the bedding. The interior is composed of loose, dry, silt-size aggregate particles and usually one or more surfaces which appear as consolidated, hardened layers.
A First stages in the formation of mud cracks on the bed of Siranda Lake. At the time this picture was taken the ground was still damp and the surface "rubbery." Light area in the background is salt incrustations.

B In places, on the east side of the Las Bela Coastal Plain, coves with small marine benches occur. Algal rims, covered at high tide, are found growing on the terraces. No older beds of algae were found at higher elevations.

C Small pocket beaches have a large percentage of coarse material. The material is derived principally from the Cretaceous limestone headlands.

D Yardangs occur around the north shore of Miāni Lagoon. Low sand platforms are dissected into small trenches and terraces that tend regularly from approximately southwest to northeast.

E Water is tapped behind the dunes after heavy monsoon rains and floods. This photograph was made northwest of Sonmiāni fishing village on the east side of the coastal plain. The water remained in pockets for several months.

F Sand dunes migrating across Ādi Spit advance over the low young mangrove shrubs growing on the northeast shore. The main species of mangrove, growing along this section of coast, is Avicennia officinalis.
PLATE VII

A A photograph of one of the largest tidal channels around the edges of Miāni Lagoon, taken at ebbing tide when the bed of the channel was being exposed. At low water these short channels are completely drained.

B Aerial view of the sand ridges on the west side of the Las Bela Coastal Plain. Picture was taken at a height of about 1,000 feet. Ridges average 25 feet in width and six to eight feet in height.

C At the extreme southeastern end of Sonmiāni Beach a small outcrop of bed rock is found. Large accumulations of eolian sand cover most of the bed rock except where it is exposed at the coast. (Small marks on the beach are the tracks of sand crabs.)

D The Chabechi River bed crossing Sonmiāni Coastal Plain to the Arabian Sea. The bed of the river weaves around accretion ridges. Although the river is completely dry during most of the year it can become a raging torrent during sudden rains.

E The eastern part of Sonmiāni Beach after a heavy storm. Debris consists mainly of sea plants from the bottom of Sonmiāni Bay and brush carried in by flooding rivers. Castle-like mounds are made by sand crabs.

F Crescentic dunes advancing inland across Sonmiāni Coastal Plain. Dune form changes during the winter season when wind shifts to northwest.
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APPENDIX
APPENDIX A

The following is a systematic list of the plant species that were observed and collected in the Las Bela area. Families are arranged according to Dr. Carl Wilhelm von Dalla Torre et Dr. H. Harms, *Genera Siphonogamarum ad Systema Englerianum Conscripta ab Auctorisbus* (Lipsiae: Sumtibus Guilelmi Engelmann, 1900-1907). English names for families are from M. L. Fernald, *Gray's Manual of Botany* (New York: American Book Company, 1950). The general location and use of the plants, where known, is included. Underlined letters indicate local names used by the Lāsi people of the central Las Bela Plain and the Makrāni speaking people of the Las Bela Coastal Plain. The writer is indebted to the following persons for their assistance in the identification of the plants:

Dr. S. Z. Hasnain, Department of Botany, University of Karachi; Dr. Jason R. Swallen, Head Curator, Department of Botany, Smithsonian Institution, Washington 25, D. C.; Mohammad Tasnif, botanist, Pakistan Council of Scientific and Industrial Research, Karachi.

SPERMATOPHYTA (Seed plants)

Sub-division I. Gymnospermae (Gymnosperms)

GNETACEAE (Woody plants)


Sub-division II. Angiospermae (Angiosperms)

Class I. Monocotyledoneae, Monocoty-ledons

TYPHACEAE (Cat-tail family)

2. *Typha angustata* Chaub. (ser)
3. *Typha elephantina* Roxb. (pan elephant grass) has many uses such as for mats and sandals.
4. **Typha latifolia** Linn. Found on the beach ridges on the western side.

NAJADACEAE (Naiad family)

5. **Potamogeton pectinatus** Linn.
6. **Zannichellia palustris** Linn.

HYDROCHARITACEAE (Frog's-bit family)

7. **Hydrilla verticillata** casp.
8. **Vellisneria spiralis** Linn.

GRAMINACEAE (grass family)

10. **Aristida funiculata** Trin. Found in areas of shifting sand dunes. Also, found in river beds north of the town of Las Bela.
11. **Aristida nutabilis** Trin. (mart). Found on shifting sand dunes.
12. **Arundo donax** Linn. (castor, oil seed). One of the main crops of the area.
13. **Cenchrus biflorus** Roxb. (sandbur)
   Syn. **Cenchrus catharticus** Del. Grown best where there is some rainfall. Not abundant on sand dunes and sand flats.
14. **Cenchrus catharticus**. Found on shifting sand dunes.
15. **Cenchrus pennisetiformis** Hoschst.
16. **Chloris barbata** Sw. Often found growing in rock crevices.
17. **Chloris quinquesetica** Bhide. (chabbar)
18. **Cymbopogon iwarancusa** Schult.
   Syn. **Andropogon iwarancus** Jones. Found growing in rocky areas.
20. **Digitaria pinnata** Chiov. Found growing in rocky crevices.
21. **Eleusine flagellifera** Nees. Helps to hold desert sands in place.
22. **Eleusine indica** Gaertn. (gandil)
23. **Elionurus hirsutus** Monro. Found on shifting sand dunes.
24. **Eragrostis amabilis** W & A.  
   Syn. **Eragrostis plumosa** Link.
25. **Eragrostis tremula**. Found on shifting sand dunes.
26. **Halopyrum mucronatum** Stapf. Found predominately on the west side of the valley.
27. **Panicum antidotale** Retz. (garam)
28. **Panicum turgidum** Forsk. Found on shifting sand dunes.
29. **Paspalum distichum** Linn.
31. **Pennisetum glaucum** R. Br.  
32. **Pennisetum prieurii** Schum. Found on shifting sand dunes.
33. **Phragmites karka** trin.
34. **Saccharum munja** Roxb.  
   Syn. **Saccharum arundinaceum** Retz. Found mainly in the river beds.
35. **Saccharum spontaneum** Linn. Found mainly in the river beds. Moisture required.
37. **Sporobolus diander** Beauv.
38. **Sporobolus pallidus** Boiss.  
   Syn. **Sporobolus arabicus** Boiss. (gemol, banich, budhan)
39. **Cyperus arenarius** Retz. Grows predominately on sand dunes inland from the coast.
40. **Cyperus bulbosus** Vahl.
41. **Cyperus rotundus** Linn. (nut grass, bhadra muste). Widely distributed in India and Pakistan. Used as a dye and insect repellent.
42. **Juncellus alopecuroides** C. B. Clarke.  
   Syn. **Cyperus alopecuroides** Rottb.
43. **Scirpus maritimus** Linn.

**PALMAE** (palm family)

44. **Nannorhops ritchieana** H. (dwarf palm, farah, rsh). Found on rocky ground up to 3,000 feet. A cultivated species.
45. *Phoenix dactylifera* Linn. (date palm)

**LEMNAEAE** (duckweed family)

47. *Lemna minor* Linn.

**LILIACEAE** (lily family)

49. *Asparagus gharoensis* Blatter.

**MUSACEAE**


Class II. **DICOTYLEDONEAE**, Dicotyledons

**CASUARINACEAE** (beefwood family)

51. *Casuarina equisetifolia* Forst.

**SALICACEAE** (willow family)

52. *Populus euphratica* Oliv. (*bhan*)

**POLYGONACEAE** (buckwheat family)

53. *Calligonum polygonoides* Linn. (*phog.*) One of the main plants which stabilize sand.
54. *Polygonum barbatum* Linn.
55. *Polygonum glabrum* Willd.
57. *Polygonum plebejum* R. Br.
58. *Polygonum polygonoides* Linn.

**CHENOPODIACEAE** (goosefoot family)

59. *Arthrocnemum indicum* Moq. Species grows in swamps having high salinity and high water table.
60. *Atriplex stocksii* Boiss. Found growing on sand dunes near the coast.
61. Chenopodium murale Linn.
63. *Haloxylon recurvum* Bunge ex Boiss. Found growing on sandy soils.
64. *Haloxylon salicornicum* Bunge. (lana). One of the main plants found on the sand dunes and saline soils north of Miāni Lagoon. Used for fuel in the villages.
66. *Salsola loetida* Del. Found growing on saline soils and in low clay areas between the beach ridges.
67. *Suaeda fruticosa* Forsk (lani). One of the main salt tolerant plants of the sand dunes.
68. *Suaeda mudiflora* Moq. Found on sand dunes near the coast.
69. *Suaeda monoica* Forsk. Found on sand dunes near the coast.
70. *Suaeda maritima* Dumort.
71. *Suaeda vermiculata* Linn. One of the principal plants found on the higher parts of the beach ridges.

**AMARANTHACEAE (amaranth family)**

Syn. *Aerua tomentosa* Forsk.; *Aerua javanica* Juss. (bhui). One of the most common desert plants. Found on sandy soil.
73. *Aerua pseudo-lomentosa* Blatt & Hall. Found on shifting sand dunes.
74. *Achyranthes aspera* Linn.
75. *Amaranthus* sp.
76. *Chenopodium murale* Linn.
77. *Digera arvensis* Forsk.

**NYCTAGINACEAE**

CARYOPHYLLACEAE (pink family)

79. *Spergula arvensis* Linn.

NYMPHAEACEAE (water-lily family)

80. *Nelumbo nucifera* Gaertn.
   Syn. *Nelumbium speciosum* willd.

RANUNCULAEAE (crowfoot family)

81. *Ranunculas sceleratus* Linn.

MENISPERMACEAE (moonseed family) A climbing vine found growing in the river valleys.

82. *Cocculus hirsutus* Deils.
   Syn. *Cocculus villosus* D. C.
83. *Cocculus pendulus* Deils.
   Syn. *Cocculus Leaeba* D.C. Found growing on rocky surfaces.

CRUCIFERAE (mustard family)

84. *Brassica campestris* Linn. Cultivated in the Las Bela area.
85. *Farsetia jacquemontii* Hook. A perennial that has deep tap roots to resist dry season.

CAPPARIDACEAE (caper family)

86. *Capparis decidua* (Forsk) Edgew.
87. *Capparis horrida* Linn.
90. *Cleome viscosa* Linn. Found growing mainly on rocky surfaces.
91. *Gynandropeis gynandra* (Linn) Grig.
   Syn. *Gynandropeis pentaphylla* DC.
MORINGACEAE (morning glory family)

92. **Moringa oleifera** Lamk.  

LEGUMINOSAE (pulse family)

Sub Fam. I. MIMOSOIDEAE

93. **Acacia arabica** Willd. (babul, Kikar) One of the most common trees in the area. Wood is used for many agricultural and domestic purposes.

94. **Acacia jacquemontii** Benth (bavuri) Occasionally found growing in sand dunes.


96. **Albizia lebbeck** Benth. A naturalized crop.

97. **Pithecolobium dulce** Benth.

98. **Prosopis spicigera** Linn (kanda jandi) One of the more common trees of the area. Found on older alluvium and at a higher elevation than *Acacia arabica*. Leaves used for fodder. Fruit called sanghar is used by native people when famine occurs.

Sub. Fam. II. CAESALPINOIDAE

99. **Cassia fistula** Linn.

100. **Cassia obvata** Collad.  

101. **Parkinsonia aculeata** Linn.


Sub Fam. III. PAPILIONOIDAE

103. **Alhagi camelorum** Fisch. (kandera) Has deep tap roots.

104. **Crotalaria burhis** Hamilt. (sinn) (dranu) Found on shifting sand dunes. Used locally to make strong ropes.

105. **Cyamopsis psoralioides** DC (quar) Used as a fodder for animals.

106. **Indigofera argentea** Burm. (chail)
Indigofera cordifolia Heyne.

Phaseolus mungo Linn. (mung) One of the main crops of the area.

ZYGOPHYLLACEAE (caltrop family)

Fagonia cretica Linn. (dramah) This perennial plant is found on gravelly and rocky surfaces.

Tribulus alatus Delile. (tricandi) A perennial plant with deep tap roots. Can sustain long, dry weather.

Zygophyllum simplex L. (loak) Found on the slopes of the Haro Range.

BURSERACEAE

Commiphora mukul Engl. Found on rocky surfaces.

EUPHORBIACEAE (spurge family)


Euphorbia hirta Linn.

Euphorbia hypericifolia Linn.

Euphorbia tirucalli Linn. A cultivated plant in the area.

MELIACEAE (mahogany family)

Azadiratchta indica Juss.

ANACARDIACEAE (cashew family)

Mangifera indica Linn. A cultivated plant.

Rhus mysorensis Heyne. Found growing on rocky surfaces and in crevices.

CELASTRACEAE (staff-tree family)

Gymnosporia montana Benth. Found on the slopes of the Mor Range. Cut for fuel and fences.
RHAMNACEAE (buckthorn family)

123. Zizyphus nummularia W. & A. (karkan, ber)
124. Zizyphus rotundifolia Lamk.

TILIACEAE (linden family)

125. Corchorus tridens Linn.
126. Corchorus depressus stocks.

MALVACEAE (mallow family)

129. Abutilon bidentatum Hoscht.
130. Abutilon fruticosum Guill. (kanghi)
131. Abutilon indicum G. Don. Found north of Uthal on stony surfaces.
132. Abutilon polyandrum W. & A.
133. Hibiscus cannabinus Linn. (bhindi). A crop grown in the area.
134. Hibiscus esculentus L. (bhindi)
135. Senna incana Cav. Found in the Hab River area.
136. Sida spinosa Linn.

STERCULIACEAE (chocolate family)

137. Melhania denhamii R. Br.

TAMARICACEAE (tamarisk family)

138. Tamarix aphylla Karst.
    Syn. T. articulata Vahl. (farash, lai) Grows to 15 feet. Wood used for fuel, grain measures and house building. Leaves are fodder for camels. A remedy for cattle suffering from fever.
139. **Tamarix dioica** Roxb.  
   *Syn. T. gallica* Linn. *pilchi* One of the main shrubs along river beds.

140. **Tamarix troupii** Hole. *jhay* One of the main trees along river beds. Grows best in alluvial soil.

**VIOLACEAE** (violet family)

141. **Viola stocksii** Boiss. Found on rocky surfaces.

**LYTHRACEAE** (crepe-myrtle family)

142. **Sonneratia acida** Linn.

**RHIZOPHORACEAE** (red mangrove family)

143. **Rhizophora conjugata** Linn. (mangrove)
144. **Bruguiera gymnorrhiza** Lamk.
145. **Ceriops candolleana** Arn.
146. **Ceriops roxburghiana** Arn.
147. **Rhizophora mucronata** Lamk.

**COMBRETACEAE** (white mangrove family)

148. **Terminalia catappa** Linn. A cultivated plant in the area.

**MYRTACEAE** (guava family)

149. **Eugenia jambolana** Lamk. A crop grown in the area.

**MYRSINACEAE**

150. **Aeticeras majus** Gaertn. (red mangrove)

**SALVADORACEAE**

151. **Salvadora oleoides** Dene. *(van, whan, jal)* Used as a fodder for animals. Stays green throughout the year.
152. **Salvadora persica** Linn. Used as a fodder.

**APOCYNACEAE** (periwinkle family)

153. **Rhazya stricta** Decue. Found growing on rocky surfaces.
ASCLEPIADACEAE (milkweed family)

154. Calotropis procera R. Br. (ak, awk, madar) Found on the sand dunes, saline plains and drier portions of the marshes.
156. Leptadenia pyrotechnica (Forsk) Syn. Leptadenia spartium Wright. Found on shifting sand dunes.
158. Pentatropis cynanchoides R. Br. A climbing vine found on rocky surfaces.
159. Pentatropis spiralis Decne. A climbing vine.
160. Periploca aphylla Decne.
161. Sarcostemma stocksii Hook.

CONVOLVULACEAE (morning-glory family)

162. Convolvulus microphyllus Sieb. ex Spreng. (patkwar).
163. Convolvulus pluricaulis Choisy. (kiranji) A perennial plant with deep tap roots that can withstand the dry season.
164. Cressa cretica Linn. (oen)
165. Ipomoea aquatica Forsk.
166. Ipomoea eriocarpa R. Br. A vine found on sand dunes near the coast.

BORAGINACEAE (heliotrope family)

167. Arnebia hispidissima DC.
168. Cordia myxa Linn.
169. Ehretia aspera Roxb.
170. Heliotropium curassavicum Linn. Found on the sand dunes near the coast.
171. Heliotropium undulatum Vahl. Found on the sand dunes near the coast.
172. Heliotropium marifolium Retz. Found on the sand dunes near the coast.
173. Sericostoma pauciflorum Stocks. (kharsan)
174. Trichodesma indicum R. Br.

VERBENACEAE (verbena family)

175. Avicennia officinalis Linn. (mangrove, timmar)
Wood used for fuel, leaves are a favorite food for camels. Formerly wood was exported to Bombay for cremation purposes.

176. *Bouchea marrubiifolia* Sch.

**Solanaceae** (potato family)

179. *Lycium barbarum* Linn. (*morari*)
181. *Lycium mauritiana* Linn.
183. *Withania coagulans* Duna.

**Scrophulariaceae** (figwort family)


**Bignoniaceae** (catalpa family)


**Orobanchaceae** (broom-rope family)

186. *Cistanche tubulosa* Wight. Found on sand dunes near the coast.

**Acanthaceae** (acanthus family)

188. *Lepidagathis rigida* Dalz.
189. *Peristrophe bicalyculata* Nees. Found growing on rocky surfaces and in rock crevices.

**Cucurbitaceae** (melon family)

190. *Cucumis prophetarum* Linn. A vine found growing on rocky surfaces.
191. *Citrullus colocynthis* Schd. (*trui*) Found on shifting sand dunes.
COMPOSITAE (sunflower family)

193. *Artemisia scoparia* Waldst. & Kit. Found on the higher hill slopes.


196. *Inula grantioides* Boiss. Found growing on rocky surfaces.

197. *Launaea chondrilloides* Hook. Found growing on sand dunes near the coast.

198. *Launaea nudicaulis* Hook (*bhastrī*) A perennial plant with deep tap roots that can withstand the dry season.

199. *Pluchea lanceolata* Oliv. (*kura sana*)


The following 25 earthquakes are the major ones which occurred in the Baluchistan Area from 1919 to 1948 (data from the Geophysical Institute, Geological Survey of Pakistan, Quetta, 26 October 1959). The coding for "Intensity" is Feeble--I; Slight--II; Moderate--III; Great--IV.

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APPENDIX C

Shells collected from the Las Bela Coastal Plain were identified by Fritz Haas of Chicago Natural History Museum and W. S. S. van der Feen van Bentheim Jutting of Zoölogisch Museum, Amsterdam.

1. The specimens listed below were collected from Sonmiāni beach zone, 30 miles west of Karāchi, Pakistan.

   Mytilus (Chloromya) viridis (Linné)
   Modiolus (Modiolus) arcuatulus (Hanley)
   Dorsanum (Dorsanum) melanoides (Deshayes)
   Littorinopsis (Littorinopsis) scabra intermedia (Philippi)
   Bullia (Bullia) mauritiana (Gray)
   Diadora funiculata (Reeve)
   Turritella (Turritella) bacillum (Kiener)
   Puncticulis (Pionoconus) magnus (Linné)
   Telescopium telescopium (Linné)
   Begunia (Carditamera) cumingii (Deshayes)
   Lioconcha semiarata (Dunker)
   Lioconcha callipyga (Born)
   Laevicardium (Trachycardium) flavum (Linné)
   Cellana rota (Gmelin)
   Cardium (Cerastoderma) latum (Born)
   Turbo (Lunella) coronatus (Gmelin)
   Gafrarium (Gafrarium) divaricatum (Chemnitz)
   Polinices (Polinices) aurantia (Lamarck)
   Erronea (Adusta) pallida (Gray)
   Purpura (Purpura) bufo (Lamarck)
   Oliva (Carmione) inflata (Lamarck)
   Monodonta (Monodonta) labio (Linné)
   Japas sertum (Lamarck)
   Solen (Solen) abbreviatus (Philippi)

2. Two weathered marine shells were collected inland from the coast. The first was obtained from a sand ridge on the west side of the Las Bela Valley. The second shell was obtained from a sandy surface east of Siranda Lake.
Tibia fusus (Linné)
Turbo (Lunella) coronatus (Gmelin)

3. Two species which generally are found in brackish water were obtained from the mud flats and mangrove zone of Miani Hor. Weathered samples of these shells were also collected from the east shore of Siranda Lake which is today an enclosed playa lake.

Telescopium telescopium (Linné)
Terebralia palustris (Linné)

4. The following five specimens are freshwater species. According to Mrs. van Benthem Jutting, Melanoides tuberculata occurs from North and Central Africa through Arabia, India, Burma, Malaya, Malay Archipelago, to Hawaii. Bellamya is confined to India and Pakistan. Indoplanorbis exustus is found in Pakistan, India, Burma, Malaya, Sumatra, and has been introduced during the last war into Java and Celebes.

Melanoides tuberculata (Müller)
Bellamya bengalensis (Lamarck)
Indoplanorbis exustus (Deshayes)
Bithynia sp.
Brotia (Antimelania) variabilis spinosa (Benson)

5. In addition, across the Las Bela Plain, large numbers of one species of land shells were collected. These shells are found in the beach ridges close to the coast, in the Pleistocene sands, and close to the playa lakes.

Zootecus insularis chion (Pfeiffer)
VITA

Rodman Eldredge Snead was born in Atlantic City, New Jersey, May 1, 1931. He received his Bachelor of Arts degree from the University of Virginia, Charlottesville, June, 1953. From June, 1953 to June, 1955, he was enrolled as a graduate student in the Department of Geography at Syracuse University, and received his Master of Arts degree.

From 1955-1956, he served as Geographic Specialist, Department of the Army, Area Analysis Branch, G-2, Pentagon, Washington, D. C. He was also Geographic Specialist, Office of the Army Attaché, American Embassy, Karāchi, Pakistan from 1956 to 1958. From 1958 to 1962 he was a graduate student in the Department of Geography, Louisiana State University, and Contract Fellow, Coastal Studies Institute, and is now a candidate for the Doctor of Philosophy degree in June, 1963. At present he is serving as assistant professor of Geography, Clark University, Worcester, Massachusetts.
Candidate: Rodman Eldredge Snead

Major Field: Geography

Title of Thesis: Physical Geography of the Las Bela Coastal Plain, West Pakistan

Approved:

[Signature]

Major Professor and Chairman

[Signature]

Dean of the Graduate School

EXAMINING COMMITTEE:

[Signature]

[Signature]

[Signature]

Date of Examination:

29 January 1963