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ORNL-4293
UC-80 – Reactor Technology

DATA OBTAINED ON SEVERAL POSSIBLE LOCALES FOR THE AGRO-INDUSTRIAL COMPLEX

T. Tamura
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CONTENTS

FOREWORD

The work described in this report was performed as part of the general study on the technical and economic feasibility of nuclear-powered agro-industrial complexes. In addition to the five specific locales discussed in this report, an appendix prepared by H. E. Goeller is included which summarizes selected data on the 37 countries having coastal deserts. This report is part of a series of reports on nuclear energy centers and was sponsored by the U.S. Atomic Energy Commission. The other reports in this series are:

ORNL-4290 Nuclear Energy Centers: Industrial and Agro-Industrial Complexes

ORNL-4291 Nuclear Energy Centers: Industrial and Agro-Industrial Complexes – Summary Report

ORNL-4292 Potential Agricultural Production from Nuclear-Powered Agro-Industrial Complexes Designed for the Upper Indo-Gangetic Plain

ORNL-4294 I. Steelmaking in an Industrial Complex. II. Acetylene Production from Naphtha by Electric Arc and by Partial Combustion

ORNL-4295 The Problems of Implementation

ORNL-4296 Generalized Capital and Operating Costs for Power-Intensive and Allied Industries

DATA OBTAINED ON SEVERAL POSSIBLE LOCALES FOR THE AGRO-INDUSTRIAL COMPLEX

T. Tamura W. J. Young M. M. Yarosh

ABSTRACT

This report provides supplementary information to Chapter 8 of ORNL-4290, *Nuclear Energy Centers: Industrial and Agro-Industrial Complexes.* Information collected on the several locales chosen as representative of those which might have potential for future development of the energy center concept is discussed and documented. In addition to the data given for specific locales, principally in developing countries of the world, an appendix contains selected data on the 37 countries having coastal deserts.

1. INTRODUCTION

It was not intended that the study of industrial or agro-industrial complexes[1] be directed at or for a particular country or region. However, it was believed to be necessary to collect information on several general areas in order to establish ranges for input design variables which to some extent reflect real world conditions in order to give some answers to the following questions:

1. Are there areas in the world that satisfy the premises underlying the agro-industrial complex concept?
2. Are such areas unique, or is there a broad applicability for the concept throughout the world?
3. What impact would such a complex have on a number of specific locales?

The purpose of this report is to document the information collected on the several locales chosen as representative of those which might have potential for future development of the industrial or agro-industrial complex concept.

In the selection of suitable locations, the primary consideration is whether significant on-site agriculture is to be carried on or if the complex will center on industrial processes only. If significant on-site agriculture is to be conducted at the complex, the land area requirements and the agricultural requirements are the dominant parameters and almost exclusively determine the selection of suitable locales. This is due to the fact that the constraints imposed by agricultural considerations are much more restrictive than those concerned primarily with industrial processes. For this reason primary emphasis was given to selection of typical sites for a complex which included agriculture as a major part. In order to attempt an assessment of the possible differences when the agricultural constraints were removed, alternate sites were considered for each of the general areas on which data had been collected. Two special situation locales were also briefly examined as potential sites for industrial complexes. These two locales were Florida, in the southeastern United States, and Morocco, in northern Africa.

The initial criteria for screening potential agricultural areas for further investigation included consideration of:

1. proximity to and elevation above the ocean (the desalting plant requires a large source of saline water; therefore, areas in or near the oceans were selected);
2. climatic conditions favorable for the production of two or more crops per year (this limited potential locales to those between 35° north and 35° south latitudes);
3. use of land not now under active intensive cultivation (this limited consideration to desert and semi-

[1] *Nuclear Energy Centers: Industrial and Agro-Industrial Complexes*, ORNL-4290.

desert areas receivir;' less thin 15 in. annual rainfall);

4. suitability of soil and topography for agricultural purposes;

5. land area required [this was established on the basis of the amount of water to be produced by the desalting plant; for a plant producing 1 billion (10^9) gal of distilled water per day, the average land required is approximately 275,000 acres, or 425 sq miles, assuming that each acre grows two crops per year and each crop requires approximately 2 ft of water].

In addition, several factors of importance to both an agro-industrial and an industrial-only complex were considered:

1. the availability of a source of cooling water for the reactor system and the industrial processes,

2. the desirability of freshwater production for local industrial or municipal needs,

3. the presence of raw materials which are important to energy-intensive proposed processes and to competitive processes (raw materials such as methane as a source of hydrogen for ammonia production to compete with the proposed process of obtaining hydrogen from the electrolysis of water, and sulfur for sulfuric acid used in the wet acid production of phosphate fertilizers as a competitor to phosphorus produced via the electric furnace method).

Finally, the general problems associated with any large industrial complex were reviewed. These include consideration of the transport facilities, particularly available harbor facilities or the potential for port development and the available rail facilities. The type and proximity of local markets for the products of the complex are of importance as well as the availability of a power grid into which surplus power might be marketed and from which emergency power might be withdrawn.

From these considerations, five areas in the world were selected (Fig. 1) as being typical arid coastal regions. These are the west coast of Australia near Carnarvon, the Kutch Peninsula of India, the Magdalena Plain of Baja California, in Mexico, the Sechura Desert of the northwest Peruvian lowland, and the Sinai-Negev Desert (of the Middle East) along the southeastern Mediterranean coast. These five areas do not exhaust the potentially suitable areas in the world,[2] but they do appear to exhibit certain characteristics which are common to most coastal deserts; however, each locale has characteristics unique to its own setting.

The physical factors significant in locale selection were limited to those which are especially relevant to relatively undeveloped coastal deserts. Data were collected on the surface configuration, climate, water resources, soils, mineral resources, transport facilities,

[2] P. Meigs, "Geography of Coastal Deserts," Series No. 23 in *Arid Zone Research*, UNESCO, 1966. See Appendix.

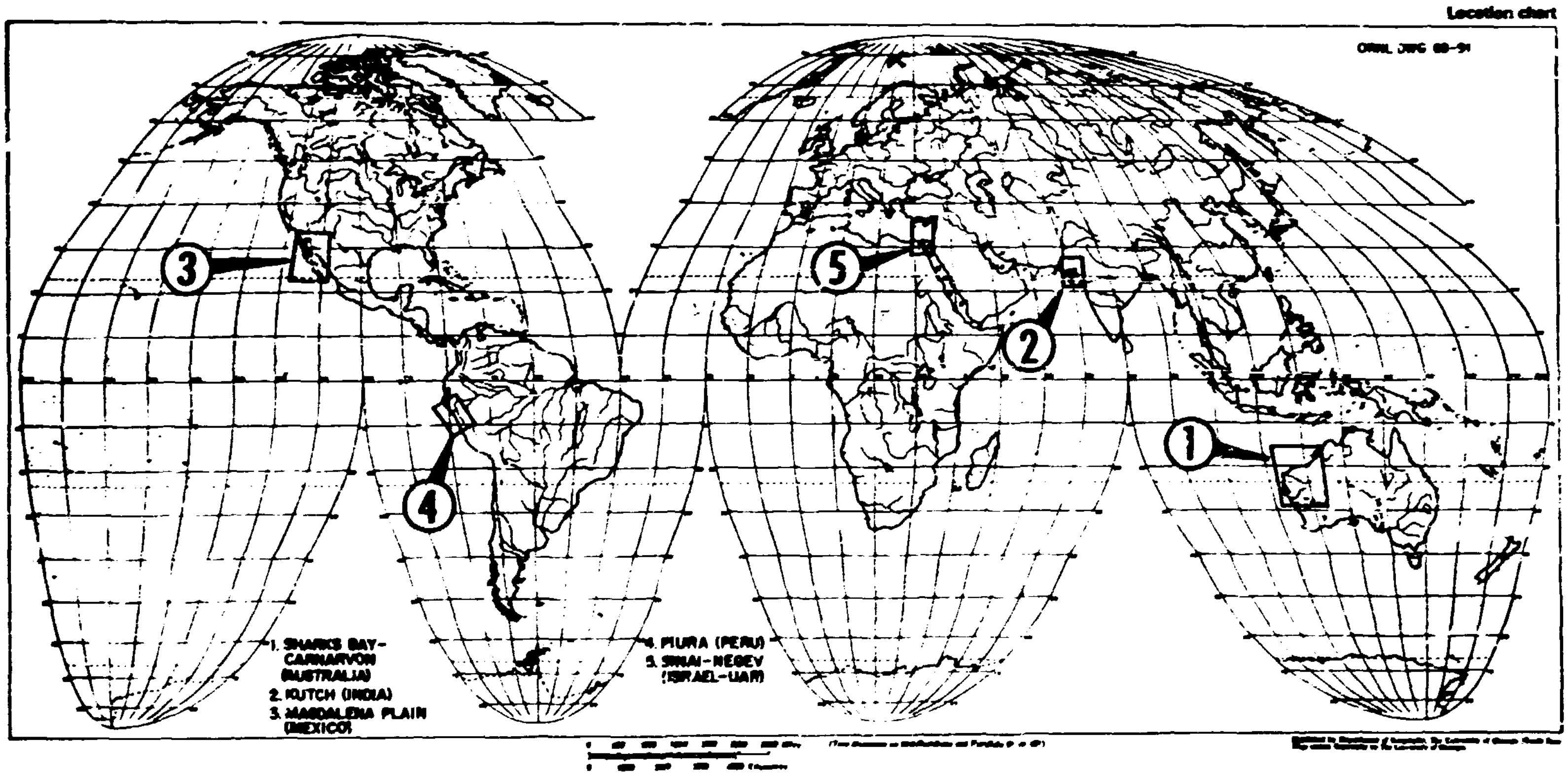

Fig. 1. World Location of Five Locales Selected for Study.

and electric power grid availability for the selected locales. In addition, such general information as could be obtained on the population and potential food and industrial markets was included. A general discussion of the particular relevance of these factors is contained in Chap. 8 of the report of the study group[1] and therefore will not be repeated here.

Section 2 presents the data collected on agro-industrial locales. Section 3 contains a discussion of the locales with reference to an industrial-only complex, and Sect. 4 sets forth the general conclusions and recommendations.

2. AGRO-INDUSTRIAL LOCALES

2.1 Summary

Of the five arid littorals studied as possible sites for an agro-industrial complex, Peru and Australia are in the southern hemisphere, while India, Baja California Sur, and the Sinai-Negev area are in the northern hemisphere. As shown in Table 1, the Kutch area of India receives the greatest rainfall of the littorals studied; it comes as a monsoon during the hot summer months and thus should help to reduce peak irrigation requirements for desalted water. In contrast, the other four locales receive rainfall during the cool months of the year, when normal irrigation requirements are lowest, and therefore the rainfall would have a minimum effect on the amount of desalted water required. The heavy monsoonal rains and the relatively high water table in India make a subsurface drainage system a necessity for a successful agricultural enterprise located in the Kutch area. The Sechura Desert area of Peru exhibits the most uniform climate of the five areas studied and thus is more suited to the constant output of fresh water from a desalination plant with the result that water storage facilities are minimal.

The surface elevation of land suitable for cultivation has some bearing on the cost of irrigation. Although the Western Australia littoral has the highest maximum elevation (see Table 1), it also has the greatest amount of available coastal land, and it would probably not be necessary to utilize any of the higher elevation lands for agriculture.

The location of raw materials such as bauxite, iron ore, or phosphate rock near an agro-industrial complex would enhance the competitive position of the complex in the production of products based on the nearby raw material. Of the five locales studied, Australia is the most well endowed with indigenous raw materials. Large deposits of iron ore exist near Mount Newman, which is about 450 miles northeast of the Carnarvon-Sharks Bay locale. A large fraction of world bauxite deposits exist on the Cape York Peninsula, along with major phosphate rock deposits near Mount Isa in Queensland, although the latter is not advantageously located with respect to the Carnarvon area.

The recent discovery (late 1968) of high-grade phosphate rock near Udaipur, Rajasthan, India, comes at an opportune time. The "green revolution" in India is producing new, strong demands for fertilizer materials, which must be met by increased imports. The discovery of this new indigenous source of phosphate rock should help alleviate the critical foreign exchange problems of India. Other major resources available for an Indian complex are iron ore and bauxite.

Iron ore is a major indigenous resource of Peru, with reserves located south of Lima estimated to be about 400 million tons. Low-grade phosphorites, in major quantity, have been discovered in the Sechura Desert. Petroleum has been the major source of energy for Peru, but depletion of existing reserves and lack of new discoveries may result in future oil shortages in that country.

The southeastern Mediterranean region is somewhat devoid of significant deposits of mineral resources except for phosphate rock. Bauxite is completely absent, and iron ore is present only in limited quantities. A substantial deposit of phosphate rock is located about 30 miles southeast of Beersheba, Israel, with reserves estimated to be on the order of 100 million tons. Other phosphate deposits are located in the United Arab Republic along the Red Sea at Quseir, Safaya, and Hamravein, with reserves estimated to be 200 million tons. Coal is absent in Israel, but deposits of noncoking coal are located in Sinai with estimated reserves of about 40 million tons at El Maghra.

The Baja California peninsula of northwestern Mexico is the locale with the lowest potential for supporting an agro-industrial complex. Population of the peninsula is small, and significant mineral resources are apparently absent. Mexico itself has significant deposits of iron ore, coal, and petroleum on the continent; however, delivery of raw materials to Baja California Sur would have to be via ocean transport since a transportation network on the Baja peninsula is nonexistent.

2.2 Data on Agro-Industrial Locales

The presentation of information for each of the locales follows the general format of a brief description, information on population and population density, a section on factors particularly related to agriculture,

Table 1. Summary of Agro-Industrial Locale Data

Location	Latitude	Maximum Surface Elevation (ft)	Climate: Mean Temp. (°F) Max	Climate: Mean Temp. (°F) Min	Climate: Average Humidity (%)	Climate: Average Winds (mph)	Climate: Average Rainfall (in.)	Climate: Sunshine (hr/year)	Climate: Global Radiation (Kcal cm^{-2} year^{-1})	Soils: Group	Soils: Require Reclamation	Population: Density (No./sq mile)	Population: Total[a] (millions)	Mineral Resources	Potential for Harbors	Electrical Grid Capacity (MWe)
Western Australia (Carnarvon)	24°S	<500	80	63	[illegible]3	~10	8.6	2500	140	Arid red earth	No	0.06	~12	Iron, bauxite	Good	9
India (Kutch) (Gujarat)	22°21'N	<300	84	73	72	~10	13.9	3000	180	Reddish brown and solonchak	Yes	25–100	500	Bauxite, phosphate rock	Fair	10
Mexico (Baja California Sur)	24°21'N	<300	81	66	80	~10	4.8	2900	160	Sandy red deserts (with sand dunes)	Yes	3.4	0.095	No significant ones	Good	None
Peru (Sechura)	5° 30'S	<300	89	66	61	0–3	2.7	2600	160	Sandy red deserts and solonchak and dunes	Probably	50–75	7	Phosphate rock, oil, and gas	Good	1.2
Middle East (Sinai-Negev)	31°17'N	<300	77	57	69	5	3.8	3500	180	Reddish brown and sand dunes	Yes	2–50	UAR = 33 Israel = 3	Phosphate rock, iron coal	Fair	 1.5 0.8

[a]Total population of the country, except for the Baja littoral, where the listed population is of Baja California Sur.

and a section on factors more related to industrial and public utility considerations, for example, mineral resources, transportation, power grid, etc.

While most of the information is readily understandable by the typical reader, the particular importance of the soil characteristics to the potential agricultural productivity has necessitated the use of terminology which may not be familiar. A brief introduction to this aspect follows.

The dry and irregular climate of arid zones produces soils which are commonly shallow in depth, have soluble salts in the profile, are low in organic matter, are rich in primary minerals, and have poorly defined structures. These characteristics differ depending on age, parent material, topography, vegetation, and climate. Of particular significance to the locales for our study is the origin of the parent material; these soils are derived from materials which have been transported to the area from elsewhere. The materials of the deserts of India, Mexico, and Peru, for example, were transported from higher elevations by rivers and streams and deposited in areas subsequently raised above the ocean level. In the Sinai-Negev Desert, most of the soils are derived from deposits of material carried by the wind, while in Australia the soils appear to have been transported from higher elevations and subjected to weathering under a more humid condition than now prevails. Thus in the selected areas, soils normally have deeper unconsolidated materials than their desert counterparts formed on crystalline rocks.

The soils frequently found in the locales situated in desert and subhumid regions include, in decreasing order of natural agricultural productivity, sierozems, arid red earths, red deserts, reddish brown, dunes, solonchaks, and solonetz. The red deserts and sierozems are generally formed under 4 to 10 in. annual rainfall; the low rainfall results in minimal profile development. The reddish-brown soils are found in areas of higher rainfall (10 to 15 in./year) which is irregularly distributed and are usually of heavier (clayey) texture. Lime, if present, is usually leached from the surface and accumulates at about 15 to 30 in. below the surface, while gypsum and soluble salts accumulate at 30+ in. Arid red earth is unique to Australia and represents a soil which had once undergone development under more humid conditions than now exist. Arid red earths are acid in reaction, in contrast with a neutral to alkaline reaction of the other soils. Dunes are an accumulation of sands blown to an area by wind. Solonchaks are saline soils where the soluble salt content in a saturated paste is sufficient to give conductivity readings greater than 4 millimhos/cm at 25°C. The solonetz soils have a low soluble salt content, but the absorbed cations on the clays contain over 15% sodium. The latter condition causes dispersion of the clays when irrigated; thus the soils have low permeability and are difficult to manage. Dunes require the establishment of vegetation, solonchaks require leaching, and solonetz soils require an improved salt balance (usually by the addition of calcium salts) before optimum yields can be expected.

2.2.1 Western Australia (Sharks Bay–Carnarvon)

The state of Western Australia has an area of 975,920 sq miles and covers more than one-third of the continent of Australia. Its boundaries are defined by the Indian Ocean on the north, west, and south and by the states of Northern Territory and South Australia on the east. In the broadest sense this state can be divided into two physical regions: a dissected plateau occupying the whole of the interior and a low-lying narrow coastal plain running almost continuously from Albany in the southeastern portion of the state to Broome in the north. The Sharks Bay–Carnarvon locale is situated on this low-lying coastal plain approximately 600 miles north of Perth and midway between Geraldton and Onslow. The 25° south latitude line passes through the selected area (Fig. 2).

A. Population and Population Density

According to the latest population census taken in Australia (1961), the state of Western Australia, although comprising almost one-third of the total area of Australia, contained little more than 7% of the population. In 1961, the total population for the whole of Australia was 10.5 million, and that of the state of Western Australia was about 736,000. Western Australia had a population density at the 1961 census of only 0.75 person per square mile, compared with an average of 3.54 for Australia as a whole.

Western Australia is divided into a number of municipal districts for the purpose of local government administration. The most densely populated portion of the state is the Metropolitan Statistical District, which centers on the city of Perth. At the time of the 1961 census, it had a population of 420,133 and an area of 192 sq miles, representing a density of 2190 persons per square mile. In contrast, the Northwest Statistical District, in which the Sharks Bay–Carnarvon locale is situated 600 miles north, had a population of 4563 and an area of 75,732 sq miles, representing a density of 0.06 person per square mile. The town of Carnarvon

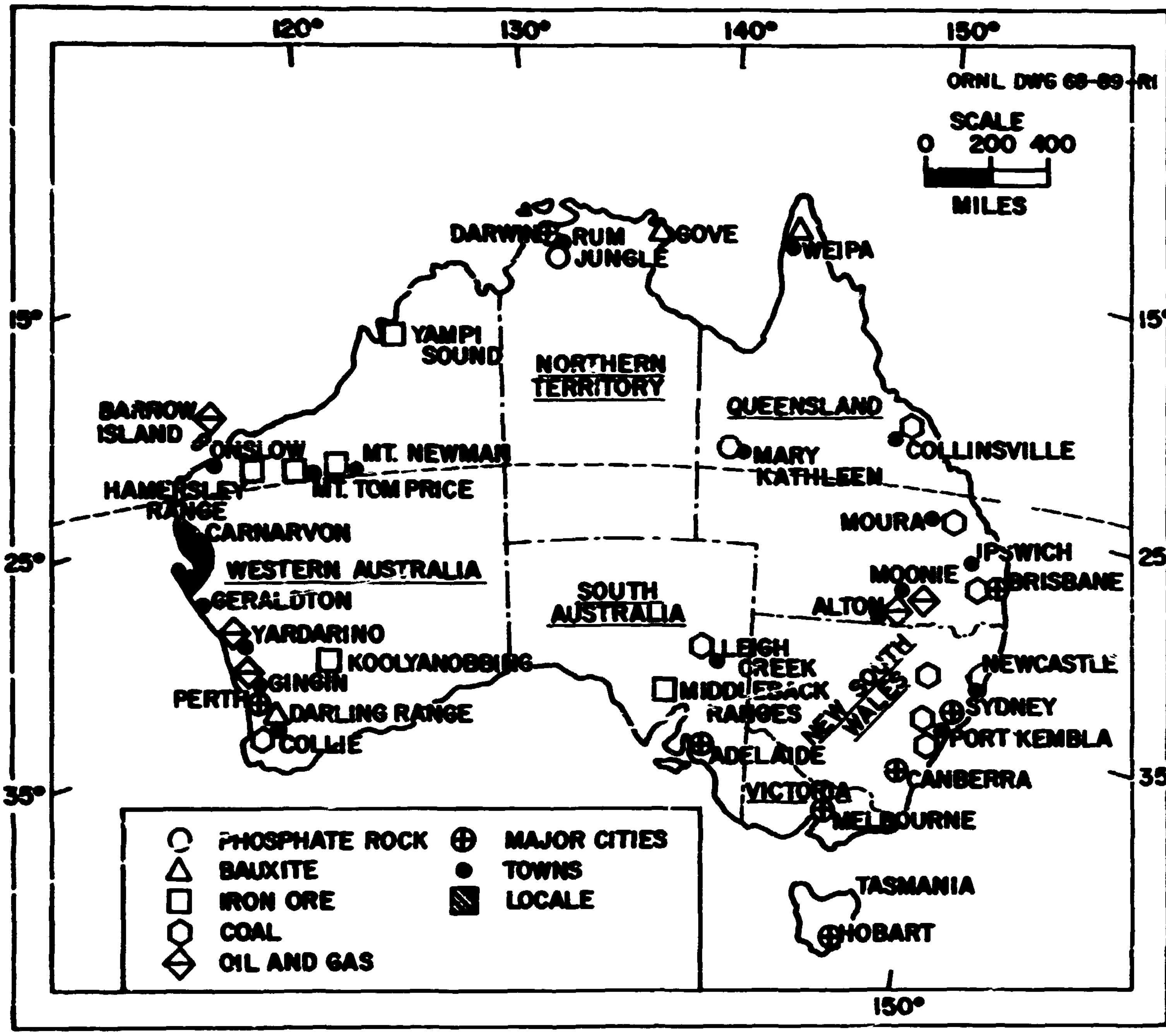

Fig. 2. Agro-Industrial Locale and Mineral Resources of Australia.

had 1800 of the total population of the Northwest Statistical Division.

Western Australia's rate of population growth was 2.2%/year between 1954 and 1961, which is 0.2% below the national average. Nearly 75% of the increase was in the Perth metropolitan area; only 4% was in the rural areas, although approximately one-quarter of the state's population was classified as rural in 1961.

B. Agricultural Considerations

1. Surface Configuration. – Due to insufficient data, a detailed description of the surface configuration was not obtained for the Sharks Bay–Carnarvon locale. Based on scanty data extracted from maps of a 1:1,000,000 scale, it appears that, in the area centering on Carnarvon, there is a considerable area of land with elevations ranging from sea level to 500 ft. From Carnarvon and extending eastward, this belt of low-lying land is more than 75 miles wide. Along the immediate coast of the area, narrow bands of moving sand dunes are known to exist. Although a much more detailed study of the surface configuration in terms of elevation and slope would have to be made before one seriously considered this area as a locale for an agro-industrial complex, it is not at all unreasonable to expect that there is a sufficient quantity and quality of land to support a complex.

2. Climate. – The climate of the Sharks Bay–Carnarvon area, according to the Koeppen scheme of classification, is classified as steppe or semiarid. The average annual rainfall as recorded at the Carnarvon weather station is a relatively low 8.6 in./year. The distribution of precipitation is uneven, with more than 60% of the yearly total falling in May, June, and July. Both north and south of Carnarvon the annual rainfall amount increases, with the stations at Geraldton and at Onslow showing average yearly totals of 12.5 and 18.2 in. respectively.

Temperatures recorded at the Carnarvon weather station vary from a mean daily maximum of 80.2°F to a mean daily minimum of 62.7°F. Maximum temperatures, both monthly and annually, occur in January and February, while minimum temperatures occur in June and July. Although the daily temperatures of northwest Australia are at times quite erratic due to the rapid heating and cooling of the continental interior, the lowest average range of daily temperature is 17.5° recorded at Carnarvon, where insolation is not as great as farther north and where temperatures are moderated by the influence of the sea.

Frosts are at times widespread over the southern part of Western Australia and occasionally extend into the tropics, but they are not particularly troublesome since they normally occur during that period of the year when crops are least susceptible to frost damage. The weather station at Carnarvon has recorded no days with temperatures less than 36°F over the past 43 years, giving the area 365 frost-free days annually. Data on the climate of Carnarvon are given in Table 2.

3. **Water Resources.** – Agricultural development in parts of Australia is greatly limited by poor water resources. The total average annual discharge of Australian rivers has been estimated at 280 million acre-feet per year,[3] but 60% of the total occurs on the eastern seaboard and around the Gulf of Carpentaria. The surface water resources of the Sharks Bay–Carnarvon area are not great. The average annual discharges, which are spasmodic, of the principal river systems in the area, the Ashburton, Gascoyne, and Wooramel, amount to approximately 1.5 million acre-feet (see Table 3). The catchments are large and relatively bare, and large floods are experienced at times. In general, salinity of surface water is not a problem in the area except in some parts of the upper Gascoyne. The total surface water resources of this part of Western Australia could be several million acre-feet per year, but high evaporation rates and uncertainty of flow make storage a difficult proposition. Presently, irrigation farmers around Carnarvon and the lower Gascoyne River are experiencing water shortages.

[3] Australian Water Resources Council, *Australia's Water Resources*, 1963.

Table 3. Average Annual Discharge to the Indian Ocean of Three Rivers in Western Australia[a]

River Basin	Average Annual Discharge (acre-ft)
	x 10^3
Wooramel	338
Gascoyne	480
Ashburton	777
Total	1595

[a]Source: *Year Book of Western Australia*, 1965.

Table 2. Climatic Data for the Sharks Bay–Carnarvon Locale, Australia[a]

Station: Carnarvon, Australia; latitude 25° S, longitude 115° E, elevation 15 ft

	J	F	M	A	M	J	J	A	S	O	N	D	Annual
Temperature (°F)													
Mean maximum	87	88	87	84	78	74	72	73	75	77	81	84	80
Mean minimum	72	72	72	66	58	54	52	53	57	61	66	69	63
Mean	80	80	79	75	73	64	61	63	66	70	73	77	71
Rainfall (in.)	0.21	0.95	0.05	0.31	1.68	1.98	1.68	0.70	0.18	0.17	0.08	0.03	8.62
Relative humidity:	May through October, 63%; November through April, 63%												
Mean wind velocity (mph)[b]	11	11	10	8	8	8	9	9	9	10	11	11	9.7
Cloudiness (tenths of sky covered)	2	2	2	2	3	3	3	[illegible]	2	2	2	2	2
Sunshine:	January, 350 hr; July, 250 hr; total, 2500 hr												
Global radiation:	140 kcal cm^{-2} $year^{-1}$												

[a]Sources: *Official Year Book of Western Australia*, No. 5, 1965, and *Year Book of Australia*, 1966.
[b]Data for Perth, Australia.

Reports on the groundwater resources of the Carnarvon area indicate that three water-bearing strata yield limited quantities of potable water; one well produced 6000 gpd. As much as 2,000,000 gpd of water that, at best, is suited only for stock has been obtained from other aquifiers in this area which are from 200 to more than 2000 ft deep. Although one well was drilled to 4000 ft, groundwater exploration has been inadequate for reliable predictions of reserves and quality of water. It may be tentatively concluded that prospects for large quantities of groundwater suitable for irrigation are poor.

4. **Soils.** – The distribution of soils in the Carnarvon area is shown in Fig. 3. In the Carnarvon area the principal soils are the arid red earths. These are

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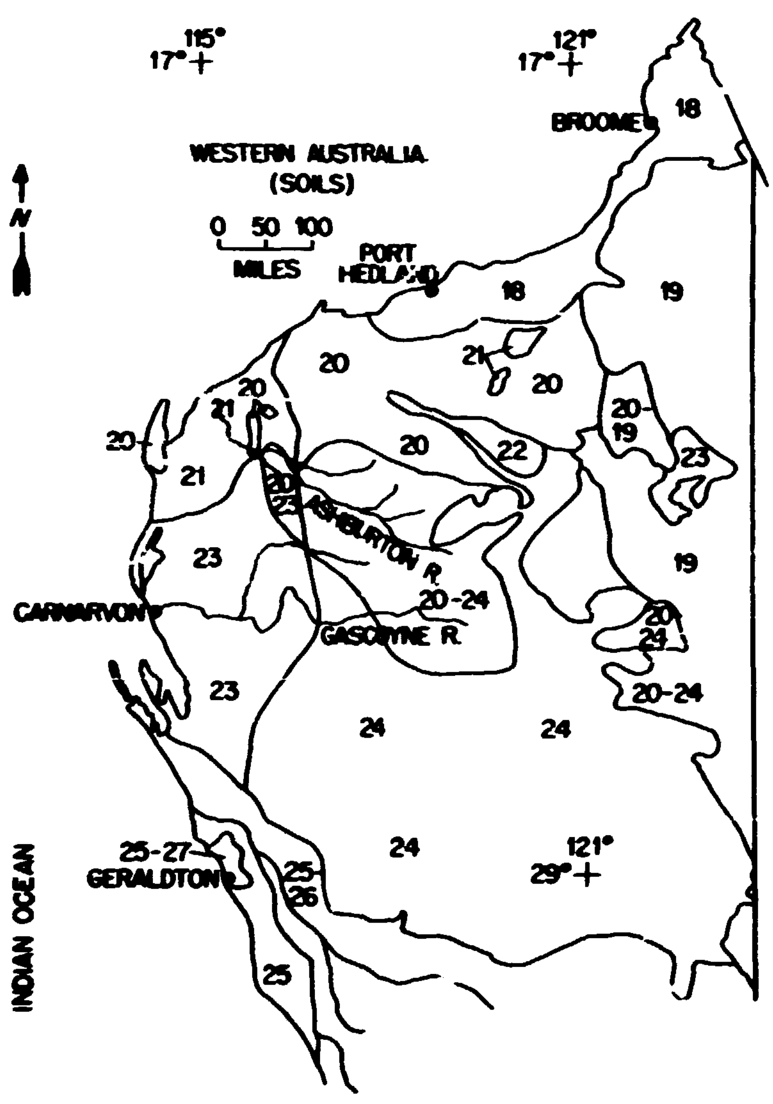

Fig. 3. Soils of the Western Portion of Australia. Soil of primary interest near locale is arid red earth (23). Others are brown soils of light texture (18), desert sandhill (19), skeletal soils (20), desert sandplain soil (21), gray and brown soils of heavy texture (22), red and brown hardpan soils (24), lateritic podzolic soils (25), solonized brown soils (26), and black earths (27).

generally deep soils of coarse to medium texture and of porous vesicular structure. These soils are acid in reaction at the surface, becoming calcareous with depth. They are generally found in the low area surrounding higher rugged land. Stephens[4] reports that these arid red earths offer the greatest prospect for agricultural development if water becomes available.

North of Carnarvon, the soils are classified as desert sand plain soils. These soils are found in fully arid areas and are associated with lateritic red earths. The agricultural potential of desert sand plain soils appears promising if water is made available. To the south of Carnarvon the rainfall increases somewhat, and the soils are lateritic in nature. Near Geraldton the soils are presently used for agriculture, and the potential exists for agriculture in the solonized brown–lateritic podzolic soils north of Geraldton. However, the area must be carefully evaluated to ascertain the sodium status (solonized) of the clays.

Of the coastal soils shown in Fig. 3, the brown soils of light texture along the northern coastline may be of interest. Like the arid red earths, these soils appear to be paleosols formed and weathered at a time when more moisture was present than is the case now. As with other paleosols, they may be productive if water is made available.

5. **Food Markets.** – In the past, agricultural production in Western Australia has been determined by the size of the local market and the distance from the main metropolitan centers. Within this general limitation, individual crops have largely followed the pattern known to be appropriate to local climate, soils, and topography. The seasonality and unreliability of the rainfall have been a basic problem in northwest Australia. Part of the solution has been found in irrigation, and the areas where agriculture has so far been established are those where soils, topography, and water resources permit or make irrigation feasible. But even in the areas of northwest Australia where irrigation agriculture is being conducted, supplies of water are dependent upon the flow of the rivers, and the position of the growers becomes precarious during drought periods.

A limited amount of agricultural production has been carried on in the Carnarvon area since 1930 based on irrigation water from the Gascoyne River. The original production consisted mainly of banana growing, but since the 1950's there has been a significant interest in

[4]C. G. Stephens, *The Soil Landscape of Australia*, Commonwealth Scientific and Industrial Research Organization, Soil Publication No. 18, Melbourne, Australia, 1961.

the growing of fresh vegetables. Traditionally, the market for the agricultural products of the Carnarvon area has been metropolitan Perth, although in recent years some of the vegetable crops have found a ready market in the southeastern cities of Melbourne and Adelaide. It may be assumed that an increasing market for agricultural products will open up in the north as the Pilbara mining developments of the Hamersley Range progress. Based on the present cropping pattern of the Carnarvon area, the possibility of new export markets in south and southeastern Asia are remote. since these areas already produce tropical fruits and vegetables. But if sufficient amounts of water for irrigation were available the year round and the cropping pattern consisted of the production of basic grains, then perhaps in the future the possibility of south and southeastern Asian markets would not seem so remote.

C. Industrial Considerations

1. **Mineral Resources.** – Australia is well endowed with minerals and rocks of economic and industrial importance. However, because of the size and inaccessibility of the country, the development of its full potential has been a rather slow process. In recent years substantial increases have been made in the production of coal, iron ore, base metals, and beach sands. New discoveries include very large deposits of iron ore, manganese, phosphate rock, and bauxite and Australia's first oil field. In the past, overseas capital has played a vital role in the mineral development of Australia, and there is no reason to suppose that it will be of lesser importance in the future. The locations of the major mineral resources are shown in Fig. 2.

a. Bauxite. – Australia contains two major deposits of bauxite: the Weipa and Gove deposits around the Gulf of Carpentaria and the Darling Range deposits of Western Australia. The great potential of these deposits has been realized only in the past decade, although their existence has been known for many years.

It has been estimated that the Weipa deposits of the York Peninsula of Queensland are probably the largest single occurrence of bauxite in the world. Economic-grade bauxite covers at least 200 sq miles between Urilya and Archer Bay, and the probable reserves of bauxite exceed 2000 million tons. The Weipa deposit ranges in thickness from a few feet to 30 ft and has an Al_2O_3 content of more than 50%. Bauxite deposits at Gove and Marchinbar Island in Arnhemland, on the west side of the Gulf of Carpentaria, are similar to, but not as extensive as, the Weipa deposits. Reserves at Gove are probably about 200 million tons. Both Weipa and Gove deposits are located a considerable distance from the Sharks Bay–Carnarvon area, 2000 to 2600 miles by ocean-going vessel.

Bauxite deposits occur within an area 200 miles long and 25 miles wide in the Darling Range of southwest Western Australia. The deposits are presently being mined at Jarrahdale, approximately 30 miles southeast of Perth. The average thickness of bauxite is 10½ ft, with a maximum of 50 ft. Proven reserves amount to nearly 80 million tons, with a reasonable indication of a further 100 million tons.

b. Phosphate Rock. – Presently the chief sources of Australia's phosphate supplies are Christmas Island (Indian Ocean about 1000 miles from Carnarvon), Nauru, and the Gilbert and Ellice Islands in the Pacific. Nauru has a reserve of 64 million tons. The phosphate rock of the Pacific islands is held in joint trust by the British, Australian, and New Zealand governments.

In recent years a major phosphate deposit has been discovered in Australia. An Australian mining company, Broken Hill South Ltd., has indicated that the phosphate deposits found by the company in the Mount Isa–Duchess area of western Queensland may contain as much as 1.3 billion tons, a vast reserve.

c. Iron Ore. – Iron ores have been known to be widely distributed throughout Australia, but the vast magnitude of the ore reserves has been realized only in recent years. In 1959, measured and indicated reserves were only 369 million tons, and large-scale mining operations were confined to the Middleback Ranges and Yampi Sound deposits. In all deposits the ore consists essentially of bedded hematite and has an iron content of 50 to 60%. Phosphorus and sulfur are usually less than 1%. The manganese content is generally below 0.5%, but locally it may be as high as 30%. The iron deposits of Middleback Ranges, located in South Australia about 250 miles northwest of Adelaide, crop out over a distance of nearly 40 miles. In the Middleback Ranges, indicated and measured reserves amount to 169 million tons of ore with 60 to 64% iron. The iron ores in the Yampi Sound area in the north of Western Australia average 63.3% iron and are mined chiefly at Cockatoo and Koolan Islands. The ore bodies on Cockatoo and Koolan Islands are overturned hematite beds. In 1965, total measured and indicated reserves in Yampi Sound amounted to 71 million tons.

d. Coal. – Although measured and indicated reserves are not large by world standards, Australia possesses considerable quantities of good-quality black coal. Reserves, both indicated and measured, as quoted by the Australian State Department of Mines in

1964–1965 amounted to 4663 million tons, including 3080 million tons in New South Wales and 1243 million tons in Queensland. Coal of bituminous rank is limited almost exclusively to New South Wales, Victoria, and Tasmania. The only deposits of black coal in South Australia (Leigh Creek) and Western Australia (Collie), with measured and indicated reserves of 404 million tons, are subbituminous in rank.

The greatest deposits of black coal in Australia are found in the Sydney Basin of New South Wales and in the Bowen Basin of Queensland. Caloric values (air-dried basis) of the Sydney Basin coals as mined are mostly about 12,500 to 13,500 Btu/lb; the caloric values of the Bowen Basin coals are rather more variable but are generally comparable.

The nearest commercial deposit of black coal to the Sharks Bay–Carnarvon site is the Collie coalfield 100 miles south of Perth. Estimated and indicated reserves at the Collie field are greater than 50 million tons. The coal from the Collie field is generally of much lower quality than that found in the eastern coal basins and is not of coking quality.

e. Natural Gas and Oil. – Commercial oil production is relatively new to the Commonwealth of Australia. In 1965 the only producing oil field was at Moonie in south Queensland, discovered in 1961. The oil quality is high and occurs in rocks of Jurassic age. An estimate in 1965 placed the recoverable reserves at 38 million barrels. The Alton field, located west of Moonie, has not yet been fully tested, but recoverable reserves in 1965 were estimated to be 5 million barrels. Both oil and gas deposits have been encountered on Barrow Island, located off the northwest coast of Western Australia, but as far as is known the quantity has not been fully determined. Substantial flows of oil and gas have also been found in several wells at Gingin and Yardarino in Western Australia (north of Perth). It has been reported that Australia is presently engaged in exploration of possible oil-bearing rocks on the Gippsland shelf off the coast of Victoria. The extent of the Gippsland field will perhaps determine whether or not Australia will one day be capable of meeting all her own petroleum requirements.

Many wells drilled around Roma, in southern Queensland, have yielded substantial gas flows. Individual gas flows are mostly less than 5 million cubic feet per day, but aggregate recoverable reserves were quoted in early 1965 as possibly 70 to 100 billion cubic feet. At Mereenie, in the Northern Territory, gas has been encountered, and recoverable gas reserves are possibly 1000 billion cubic feet. Recoverable gas reserves at Gidgealpa, in South Australia, are possibly 500 billion cubic feet.

f. Limestone. – Good-quality limestone is common, especially in the Paleozoic rocks of eastern Australia. The distance of the deposits from industrial centers is such that reserves and grades of many deposits have not been established. Marulan, Kandos, and Portland, in New South Wales, provide large quantities of limestone for cement making and iron smelting. Large Paleozoic deposits are known in eastern Victoria and have been mined to some extent, but the bulk of the limestone used for cement making in Victoria, at Geelong, is Tertiary in age. Paleozoic deposits are exploited in the lower center and north of the east coast, while dead coral dredged from Moreton Bay provides the main source of limestone in southern Queensland. Lower Proterozoic limestone near Cloncurry is used for flux at the Mount Isa smelter. Southern Australia's main sources of limestone are the Proterozoic to Cambrian beds of Rapid Bay and Angaston, the Miocene beds of Klein Point, and Pleistocene and Recent dunes composed of shell remains at Wardang Island, Coffin Bay. Western Australia produces a rather low-grade limestone from dunes along the coast which are Tertiary in age. Vast tonnages of shell fragments are found along the shores of Hamelin Pool near the Sharks Bay–Carnarvon locale. Tertiary limestone underlying the Nullarbor Plain has not yet been exploited.

g. Gypsum. – The semiarid areas of southern Australia contain widespread deposits of gypsum. The deposits are found on the floors of dry or intermittently flooded lakes and as dunes around the larger lakes. The most extensive deposit known in Australia is at Lake MacDonnel in South Australia. Here the reserves of high-grade material exceed 600 million tons. The gypsum content of this deposit exceeds 94%. South Australia is known to have several other large high-grade deposits. The other important sources of gypsum in Australia are in northwestern Victoria, in west-central New South Wales, and in the interior of the southwestern area of Western Australia. Many of these deposits are not high grade, but an acceptable product is produced by washing.

2. **Transport Facilities.** – *a. Rail.* – In Australia the construction and operation of railways have been a function of governments. Because Australian settlement grew independently from the different state centers, Australian railroads developed as separate state systems, and not as a single system. As a result there are on the mainland of Australia five separate railway systems centered on the capital cities. There are only ten interstate links, including the link effected by the

Commonwealth-owned Trans-Continental Railway. The most unfortunate feature of the Australian railway systems is that they have been built to different gages. Attempts have been made to standardize the rail gages to 4 ft 8½ in., which would coincide with the transcontinental link, but these attempts have met with only moderate success.

In Western Australia, only the southeastern portion of the state is served by rail transportation. Here, the railroad system is centered on the capital city of Perth and consists of 3 ft 6 in. gage track. The Western Australian system is linked with the 4 ft 8½ in. gage transcontinental link at Kalgoorlie. The Sharks Bay–Carnarvon site is totally devoid of a railroad system. Geraldton, 275 miles to the south, represents the closest link with the Western Australia Railway System. Carnarvon's only land connection with Perth is via one heavy-duty road. If the Sharks Bay–Carnarvon area is to be developed for agricultural and industrial purposes, a considerable capital investment may have to be allotted for the development of a railway system.

b. Water.[5] – Australia has a coastline measuring over 12,000 miles and is served by about 100 commercial ports. The principal ports in descending order of total trade in recent years are Sydney, Melbourne, Newcastle, Fremantle (port for Perth), Adelaide, Geelong, Port Kembla, Whyalla, Brisbane, and Hobart. In addition to the commercial ports there are also many smaller seaports.

Western Australia's sea traffic is concentrated on the port of Fremantle, with a number of outports handling a smaller volume. The major outports are at Geraldton, Bunbury, Busselton, Albany, and Esperance in the more highly developed southwestern part of the state, and Carnarvon, Onslow, Port Hedland, Broome, Derby, Yampi, and Wyndham in the less-developed areas of the northwest and north.

In 1964 the Western Australian port of Fremantle handled over 8 million tons of cargo. The outward cargoes consisted mainly of primary products including minerals. Cargoes discharged at the smaller ports of the north and northwest were predominantly intrastate, as also were the shipments from many of them. The port of Carnarvon is small and in 1964 handled only 13,565 tons of cargo. The cargoes consisted largely of gasoline, building materials, refrigerated cargo, vehicles, and livestock. The possibilities for the enlargement of the port facilities at Carnarvon are unknown but should be investigated if future industrial and agricultural development is anticipated for the Sharks Bay–Carnarvon area.

3. **Power Grid Availability.** – In 1965, Australia had a total installed electrical generating capacity of 8710 MW(e), of which 75% was thermal and 25% was hydroelectric. Table 4 shows the installed capacity, production, and per capita consumption of electricity in Australia in 1965–1966; the data include, for comparison purposes, similar information for the other locales and the United States.

The State Electricity Commission of Western Australia produces 90% of the electricity required for Western Australia. The remainder is produced by small power stations run by local governments or private operators. The most important source of fuel for electricity generation in Western Australia is coal mined at Collie, 100 miles south of Perth. There are no proven

[5] Commonwealth Bureau of Census and Statistics, *Official Year Book of Western Australia*, No. 5, 1965.

Table 4. Plant Capacity and Electric Production – 1965[a]

Location	Type of Current (Hz)	Installed Capacity (millions of kilowatts)			Production (billions of kilowatt-hours)	Population (millions)	Kilowatt-hours per Capita
		Hydroelectric	Thermal	Total			
Australia[b]	50	2.15	6.56	8.71	34.2	11	3000
India[c]	50	4.04	6.00	10.04	37.2	483	77
Israel	50	0	0.74	0.74	4.0	2.6	1570
Mexico	50, 60[d]	2.33	2.91	5.24	16.7	43	390
Morocco	50	0.29	0.08	0.37	1.3	13	95
Peru	60	0.68	0.47	1.15	3.8	12	323
U.A.R.[e]	50	0.35	0.98	1.34	4.9	29	170
U.S.	60	44.49	210.03	254.52	1157.6	195	5960

[a] *World Power Data – 1965*, Annual Publication of the Federal Power Commission, U.S. Government Printing Office.
[b] For year ending June 30, 1966.
[c] For year ending Mar. 31, 1966.
[d] To become all 60 Hz by 1970.
[e] For 1964.

Table 5. Power Generation and Number of Consumers for Western Australia[a]

	Year ending June 30 –		
	1951	1956	1961
Installed capacity (MW)	128	227	331
KWhr generated ($\times 10^6$)	369	635	894
Number of consumers ($\times 10^3$)	112	156	184

[a]Department of National Development, Electricity, in *Atlas of Australian Resources*, Second Series, 1962.

commercial oil resources in Western Australia, and except for a small unit at the Wellington irrigation dam, there are no hydroelectric installations. The Kimberley Division, in the north of the state, offers considerable hydroelectric potential. Table 5 shows the growth of generating capacity and electrical consumption to June 1961. In 1961, tenders had been called for the construction of a new station with an initial capacity of 240 MW(e), comprising four 60-MW(e) units at the Muja open-cut coal deposits near Collie. The first unit should have been in service in 1965.

The Sharks Bay–Carnarvon area is supplied with power from the Perth-Fremantle stations to the south.

2.2.2 India (Kutch-Gujarat)

The state of Gujarat, covering 72,140 sq miles, is situated in the northwestern portion of India. Its boundaries are defined by the Arabian Sea on the west and the states of Rajasthan on the northeast, Madhya Pradesh on the southeast, and Maharashtra on the south. On the north the Rann of Kutch separates the state from West Pakistan. The territories of the state fall into two broad physical regions: the alluvial plain of the eastern half and the Kutch-Saurashtra peninsula to the west. The Kutch-Gujarat site is located on the low-lying coastal plain of the Kutch portion of the peninsula between the Rann of Kutch and the Gulf of Kutch and centers on the town of Mandvi (Fig. 4).

A. Population and Population Density

In 1961 India had a population of 434 million and contained nearly one-fifth of the world's population. By 1965 the total population had increased to 483 million and was expected to double in 26 years to 975 million. India's population growth rate, which averaged 2.1% during the period 1950 to 1965, reached a level of 2.4% by 1964 and is expected to increase to an even higher rate. In 1961 the population density for all of India was 384 persons per square mile; the density per square mile of arable land was approximately 600.

The state of Gujarat had a population of 20.6 million in 1961. The population density was 286, compared with 384 for India as a whole. The density for the Kutch portion of the state was 25 to 99 persons per square mile. The eastern half of the state is more densely populated than Saurashtra or Kutch, partly because of more favorable agricultural conditions and partly because of a higher level of industrial development. The most populous districts in Gujarat are Ahmedabad (1,266,001), Surat (288,626), Baroda (298,398), and Rajkot (194,145).

B. Agricultural Considerations

1. Surface Configuration. – Along the southern coastal plain of Kutch, there is a considerable area of land with elevations ranging from sea level to 300 ft. From Mandvi this belt of low-lying land, 15 to 20 miles in width, extends eastward for approximately 40 miles and westward for over 50 miles. The land surface in this area is flat to gently rolling, with a slight amount of dissection and with slopes commonly less than 5%. Extensive areas of salt wastelands are located along the immediate coast 5 to 10 miles east of Mandvi and along the southwest tip of the Kutch peninsula. Sand dunes up to 80 ft high are common along the southeastern coast. Based on a preliminary investigation of the elevations and slopes present along the south coast of Kutch, there appears to be a sufficient quantity of land to support an agro-industrial complex.

2. Climate. – The southern coastal plain of Kutch is classified as semidesert in climate. The average rainfall as recorded at the Dwarka weather station, a coastal town on the Saurashtra peninsula, is 13.9 in. annually. However, most of the rainfall comes during the hot season of the southwest monsoon, June to August. The rest of the year is extremely dry (see Table 6). Eighty-three percent of the rain falls during the period of the southwest monsoon, and much of this rain, 7 in., is concentrated in July, the only really wet month. Variability is very great, both in the amount of rain in a given year and in the starting and ending dates of the rainy period. In Dwarka, for example, annual rainfall has varied from about 1 to 37 in. during the 40-year period from 1901 to 1940.

Temperatures recorded at the Dwarka weather station vary from a mean daily maximum of 84°F to a mean daily minimum of 73°F. The hottest time of the year in the Kutch area occurs in the spring, when the sun is approaching its zenith and just before the rains and clouds of the summer monsoon have tempered the heat. Along the immediate coast the daily maximum tem-

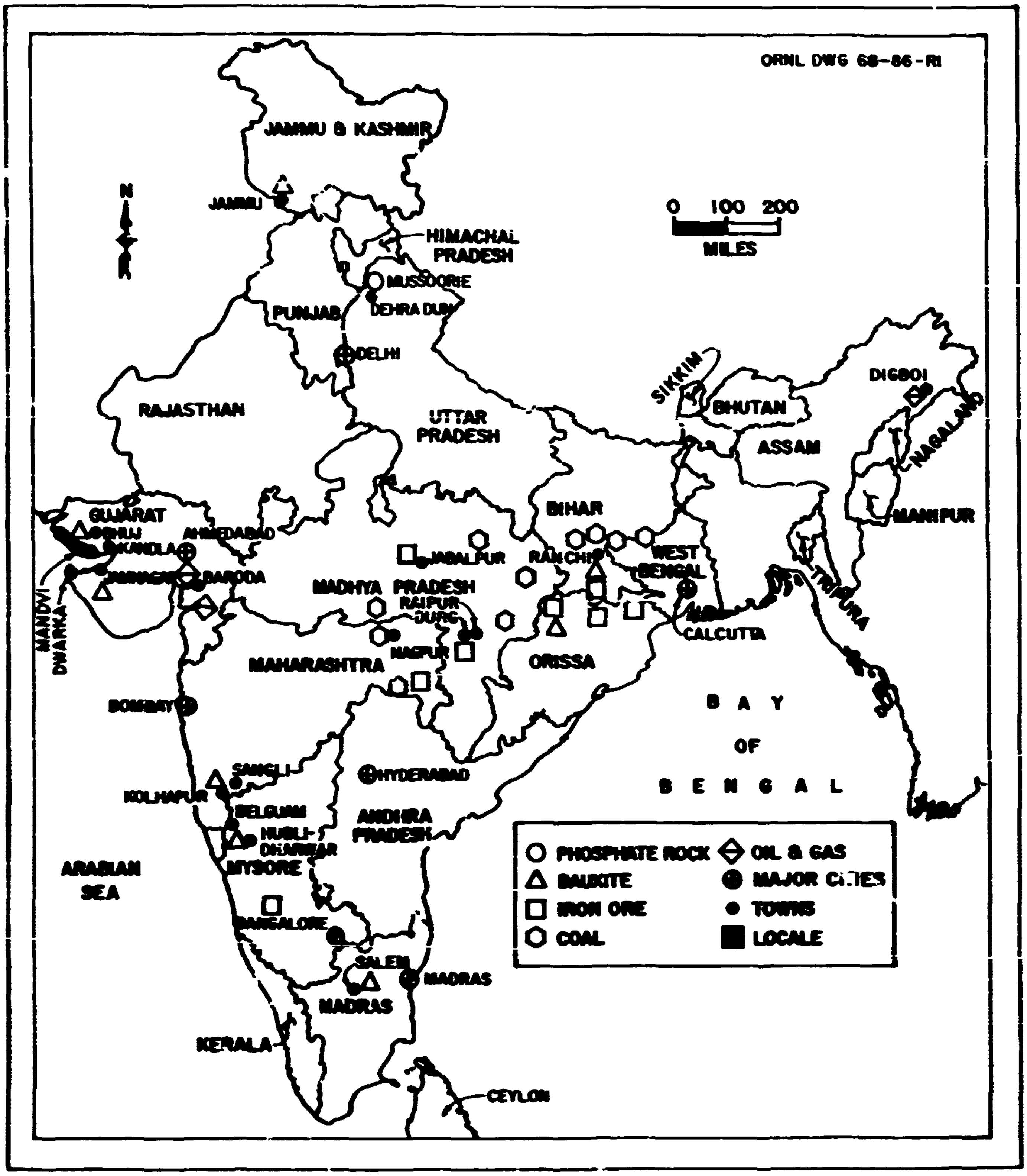

Fig. 4. Agro-Industrial Locale and Mineral Resources of India.

perature of spring and summer is 85 to 90°F, and relative humidity remains between 75 and 90% all day. The lowest temperatures occur in January and February, which average 69 and 70°F respectively. The area has a frost-free year-round growing season and is in this respect favorable for the production of two or more crops per year.

3. Water Resources. – The Kutch area of Gujarat is generally lacking in major sources of both surface and groundwater due to its climatic setting. Water being scarce, the success of agriculture depends on the careful husbanding of available water resources.

The surface water resources of the Kutch area are practically nil. All the streams that flow south from the Chanduva Hills to the Gulf of Kutch are intermittent and flow only during the monsoon rains. The greater percent of this is lost to the ocean through rapid runoff.

In recent years several investigations of the groundwater resources of the alluvial tracts of Gujarat have been made. One general problem with groundwater in

Table 6. Climatic Data for Gujarat-Kutch Locale (India)[a]

Station: Dwarka, Gujarat (India), latitude 22° 22′N; longitude 69° 5′ E; elevation 37 ft

	J	F	M	A	M	J	J	A	S	O	N	D	Annual
Temperature (°F)													
Mean maximum	78	78	82	85	88	89	87	85	85	87	87	81	84
Mean minimum	60	63	71	76	81	82	81	79	78	76	69	62	73
Mean	69	70	75	79	83	84	82	86	81	80	77	70	78
Rainfall (in.)	0.1	0.2	0.1	0.0	0.0	2.0	7.0	2.6	1.5	0.2	0.1	0.1	13.9
Relative humidity (%)													
8 AM	70	74	79	86	86	85	86	89	88	82	70	67	80
5 PM	44	57	64	74	77	77	80	78	[illegible]	75	49	38	65
Mean wind velocity (mph)	8	9	9	10	11	13	15	13	8	7	7	8	9.8
Cloudiness (tenths of sky covered)	2	2	2	2	3	5	8	8	5	2	2	2	4
Sunshine:	January, 300 hr; July, 100 hr; total, 3000 hr												
Global radiation:	180 kcal cm^{-2} $year^{-1}$												

[a]*Climatological Tables of Observatories in India*, 1953

much of Kutch is that the wells often yield waters which are so heavily charged with salts as to be unpalatable or even unfit for raising crops.

4. **Soils.** – The soils along the southern or gulf side of the Kutch are principally reddish-brown soils, and on the eastern and western borders the land is flooded during the monsoon season and remains a dry salt-crusted desert during the remainder of the year (Fig. 5). The reddish-brown soils are loams to silt loams in texture. These soils were formed under subarid conditions, and therefore the lime, gypsum, and soluble salts are leached from the surface and concentrated in the lower horizons generally about 6 ft down. Locally in depressions, solonchak and solonetz soils occur.

The land rises in elevation inland, and at about 300 to 500 ft elevation the soils are classified as regurs. These latter soils are silty clay loams and clays, and their subsoils are very sticky and plastic when wet.

The association of the reddish-brown with the regur soils strongly suggests a potential problem of subsurface drainage in these soils. In all the area, lithosol or rock outcrops cover most of the low hills and the slopes bordering stream valleys. Due to the monsoonal character of the climate, millets, pulses, and barley are grown in the area.

C. Industrial Considerations

1. **Mineral Resources.** – Generally, the mineral resources of India encompass a sufficient range of the useful products that are required to make a country industrially self-contained. This is not to say that India is, by any means, completely self-sufficient in all mineral resources. Minerals in which India has to depend largely or entirely on foreign imports are phosphate, petroleum, sulfur, potash, copper, lead, zinc, and tin. The major mineral deposits of India are shown in Fig. 4.

a. Bauxite. – India is self-sufficient in resources of bauxite, the chief raw material for the manufacture of aluminum. A good quantity of the mineral also finds an export market after meeting internal requirements. Presently, efforts are being made for the discovery of new deposits and the speedy exploration of known occurrences.

Bauxite deposits, mostly associated with laterite, occur as cappings on the plateau of peninsular India. Some of the more important regions of production are the Palamau and Ranchi districts of Bihar; the Kutch and Saurashtra areas of Gujarat; the Mandla, Jabalpur, and Balaghat districts of Madhya Pradesh; and the Kolhapur and Kolaba districts of Maharashtra. Other significant deposits are found in the states of Madras, Mysore, Orissa, and Kashmir. The bauxite deposits in Kutch in Gujarat state are unique in their occurrence in the laterite that spreads over extensive areas along the coastal tracts of the state. In 1963 the states of Bihar and Gujarat produced 49 and 32% of the Indian bauxite output.

The total bauxite reserves of India, including all grades, are said to amount to 276 million metric tons, of which nearly 73 million are estimated to be of high grade, containing more than 50% Al_2O_3. The estimated reserves of high-grade bauxite (over 50% Al_2O_3) in Gujarat are quoted as being 12.7 million metric tons.

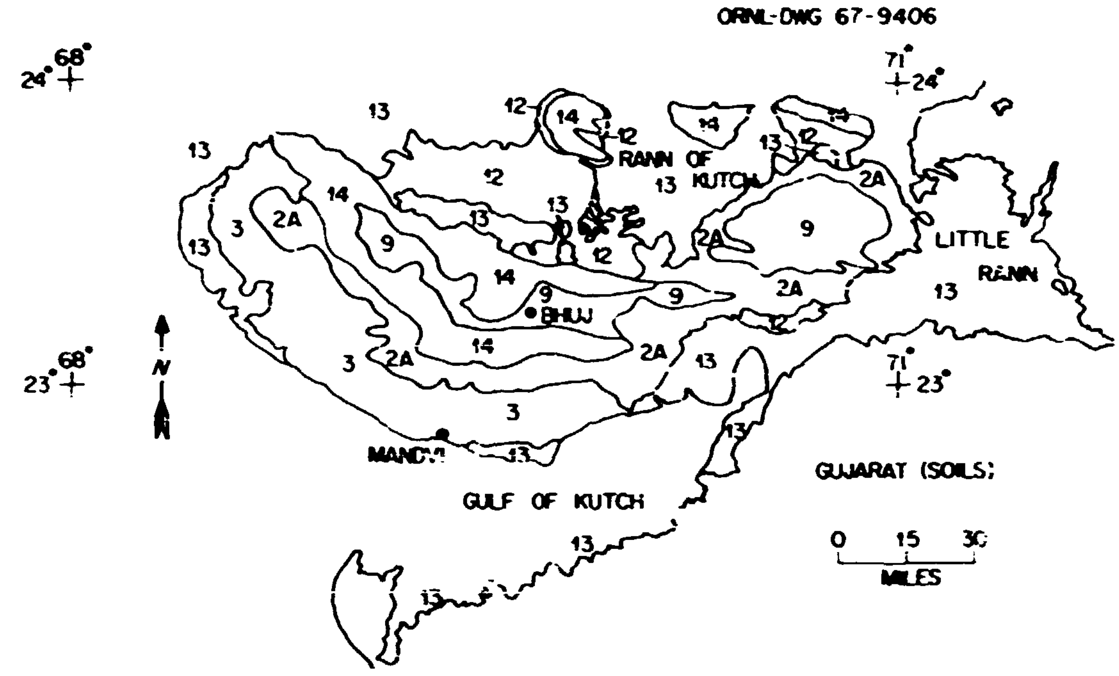

Fig. 5. Soils of the Kutch Peninsula in India. The soil of primary interest is the reddish brown (3). Others include regur soils (2A), reddish brown on hilly terrain (9), solonchak (12), saltwater marsh (13), and lithosols (14).

These deposits are nearly equally divided between the Kutch and Saurashtra portions of the state.

b. Phosphate Rock. – Natural phosphates comprising apatite and phosphate rock constitute the principal raw material for the production of commercial phosphatic fertilizers. At present, India has little in the way of sizable phosphate deposits, and the requirements of this mineral are mostly met by imports from the Middle East countries. With the growing demands for phosphate in the expanding agricultural programs of the country, the search for indigenous phosphorites has been accelerated in recent years by the geological survey of India.[6]

Presently, the production of phosphate ore is confined to two states in India, Bihar and Andhra Pradesh. Reserves in these two areas are small, and the ores are of a relatively low grade. Proven reserves in the Singhbhum district of Bihar are 1.09 million metric tons with 15.48% P_2O_5 content. Those reserves in the producing districts of Andhra Pradesh are quoted as being small.

Recently, investigations for indigenous sources of phosphate have been concentrated in the Mussoorie area of Uttar Pradesh. The results available to date indicate that phosphorite horizons with 20% or more P_2O_5 content occur in workable quantities in the Maldeota, Bhusti, Kimoi, Masrana, Midlands, Dhobighat, Pari Tibba Chamasari, and Nagini areas. The maximum thickness thus far encountered is about 6 m. The quality of the material found so far falls just short of the requirements for the manufacture of phosphate fertilizers, but beneficiation appears to be feasible.

c. Iron Ore. – India is the ninth largest iron-ore-producing country of the world. Her resources of high-grade iron ore are perhaps the greatest in the world, with the possible exception of Brazil. According to a United Nations committee, India's iron-ore reserves are estimated at 21,000 million tons, about one-fourth of the world's total resources.

Though deposits of iron ore of good quality are found in many parts of India, the most important fields are confined to Bihar and Orissa. The less important areas are in Madhya Pradesh, Madras, Mysore, and Maharashtra. In India, presently, the commercial exploitation is confined mainly to hematite ores, which are very abundant. Total reserves in Bihar are quoted as being 1047 million tons, averaging 55 to 70% iron. The major producing district in Bihar is at Singhbhum. In Orissa, proven and indicated iron ore reserves total 1696 million tons and average 60% iron. The major districts in Orissa are at Keonjhar, Sundergarh, and Mayorbhanj.

d. Coal. – Indian coals belong to two distinct geologic age groups. The first group, the lower Gondwana coalfields, accounts for about 98% of the total production of the country. These coalfields are spread over Assam, West Bengal, Bihar, Orissa, Madhya

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[6] A very recent discovery (1968) of high-grade phosphate rock has been made near Udaipur, Rajasthan. The Jhamar-Kotra phosphate has been identified as metasedimentary material of the Precambrian period. Preliminary estimates place the reserves at as much as 100 million tons, with 10 to 30% of this being very high-grade rock containing 32 to 37% P_2O_5 and the remainder lower-grade material containing 15 to 30% P_2O_5.

Pradesh, Maharashtra, and Andhra Pradesh. This coal is mostly bituminous except in North Bengal and Assam, where, due to intense pressure exerted during the Himalayan upheaval, the coal has become anthracitic. The second group, comprising Tertiary coalfields, is also of much importance and is of lignitobituminous type. These coalfields are distributed in Assam, Jammu and Kashmir, Madras, Gujarat, and Rajasthan.

The total reserve of coal in India has been estimated at 31,833 million metric tons down to depths of 300 m. In 1962, Bihar was the leading producer, accounting for 49% of the total output of India, followed by West Bengal with 30%, Madhya Pradesh with 12%, and Andhra Pradesh with 5%. Assam, Maharashtra, and Orissa together accounted for the remaining 4%.

The quality and quantity of recently discovered coal and lignite deposits of Gujarat have yet to be determined. Lignite deposits occur in the Lakhapat area of Kutch and in the Broach and Surat districts of Saurashtra. On a rough basis, the Lakhapat deposit is estimated to have 11 million tons of lignite, but it contains 3.6% sulfur. The quality of the Broach deposits has not been established.

e. Natural Gas and Oil. – The reserves of oil in India are placed at about 600 million barrels as of January 1963. In 1963 the indigenous production was 1.65 million tons, or about 20% of the total quantity refined in the country.

In India, the oil-bearing regions are in the Tertiary formations in Assam, Gujarat, and Punjab. In Assam a vast belt of oil-bearing formations extends southwest along the Brahmaputra River in the northeast portion of the state. The Assam fields are mainly oil bearing and not gas bearing. Historically, the field at Digboi has been the major oil field of India.

In Gujarat, the areas around Anklesvar, Kalol, and Baroda have been proven to be oil bearing and the Cambay area as gas bearing. The potential of the Gujarat oil and gas fields is being established. Early estimates indicate an oil reserve of 45 million tons and a gas reserve of 21,426 million cubic meters.

f. Limestone. – Limestone is mined extensively in India and ranks next to coal in production. It is consumed as one of the important raw materials in the various industries like iron and steel, chemicals, fertilizer, paper, and lime burning. The limestone deposits have a wide geographical distribution, and the suitability of the different limestones for various industries differs from locale to locale. One of the most urgent problems facing the limestone industry of India is to locate and demarcate the deposits suitable for the requirements of a particular industry.

Gujarat limestone deposits are found in the Dwarka area and in the Ganguwada, Dhanena Taluka, and Banaskantha districts. In the Dwarka area, reserves have been placed at 16.97 million tons with 44 to 48% CaO. Both crystalline and meleolite limestone occur in this state. Crystalline limestone is suitable for cement, while meleolite limestone is suitable for the chemical and cement industries.

g. Gypsum. – India can be considered to be self-sufficient in her resources of gypsum. The most recent estimate placed India's reserves at 998.5 million tons. The major source of gypsum is found in Rajasthan, in the Nagpur district. To a smaller extent, gypsum deposits are worked in the states of Madras, Gujarat, Uttar Pradesh, Jammu and Kashmir, and Maharashtra.

In Gujarat, gypsum occurs in the Kutch and Halar districts either as veins in shales and marls or as selenite. In addition, gypsum is found in Porbander, Broach, and other areas. The gypsum of Gujarat is generally of high grade, analyzing between 90 and 95% $CaSO_4 \cdot 2H_2O$. However, considerable earth work must be done in order to recover the gypsum.

2. **Transport Facilities.** – *a. Rail.* – In a land of great distance and extensive area, the railways have played an important role in the movements of people as well as of minerals and heavy commodities in India. The Indian railways system is by far the largest in Asia and the second biggest state-owned enterprise in the world, with 35,200 miles of railway lines in 1960.

Presently, the railway lines of India are grouped into eight zones: the Northern Railway, the North-Eastern Railway, the Eastern Railway, the Western Railway, the Central Railway, the Southern Railway, the South-eastern Railway, and the North-East Frontier Railway. The formation of these eight railway zones proceeded on the principle of amalgamating small independent lines and well-defined portions of railways in contiguous areas into self-sufficient systems in a compact region having economic unity. In India, railway lines operate on three gages: broad gage (5 ft 6 in.), meter gage (3 ft 3⅜ in.), and narrow gage (2 ft 6 in.). The frequent changes of gage and the scarcity of bridges across some of the bigger rivers are the major drawbacks of the Indian railway system.

The railway system in Gujarat is composed of all three gages, with meter gage being the most prevalent. The Kutch site is served by a meter-gage line in the vicinity of Kandla. The nearest broad-gage line is located 146 miles to the east at Jhund. During the Second Five Year Plan a proposal was made to connect the port of Kandla and Jhund with a broad-gage line, but in the course of this study it was not ascertained when this proposal would be implemented. Until the Kutch area is connected with broad-gage trackage, the smooth movement of traffic will be difficult because of the differences in gage, which necessitate costly trans-shipments.

b. Water. – India has a coastline of over 3500 miles, and merchant ships from all important maritime countries call at her ports. The sea routes radiate mainly from the six major ports of Calcutta, Kandla, Visakhapatnam, Madras, Bombay, and Cochin.

Historically, coastal shipping has been a weak link in the Indian transport system. Though the maritime states in India possess good seaboards and many good harbors, the level of economic development in the different hinterlands does not at present ensure an increasing volume of cargo. The coastal transportation is reserved for Indian-owned shipping, but, even then, foreign ships are required to participate in the trade during the peak periods of cargo handling. Wet cargo, like oil, is handled exclusively by foreign tankers.

In Gujarat, sea traffic is concentrated on the port of Kandla located immediately east of the proposed agro-industrial site. In 1963 the total handling capacity of Kandla was 1.69 million tons. Silting is a major problem at this port, and periodic dredging operations are necessary. The possibilities for the enlargement of the port facilities at Kandla are unknown but should be investigated if future industrial and agricultural development is to take place in the Kutch area.

3. **Power Grid Availability.** – In 1965, India had a total installed generating capacity of 10,040 MW(e), of which 57% was thermal and 43% was hydroelectric. Table 4 shows the installed capacity and power production for 1965.

The installed capacity of electric generation in the state of Gujarat was increased from 129 to 592 MW(e) between 1950 and 1966. The major additions were made in south Gujarat and in the Saurashtra region. The Kutch region's share of the total capacity is only 17 MW. Based on the present growth rate it is estimated that the installed capacity of the system might have to be raised to 1385 MW(e) by 1975. As late as 1960 the power system of Kutch was not interconnected with that of the rest of the state.

4. **Industrial Markets.** – The majority of the industrial products such as fertilizer and aluminum produced at an agro-industrial complex in Kutch would be consumed internally in India. A major market for aluminum would perhaps be the Bombay metropolitan area. Fertilizer would be distributed throughout the whole of India. Certain high-value products manufactured from aluminum would perhaps find a ready market in Japan and the Middle East countries.

2.2.3 Baja California Sur (Northwest Mexico)

The desert coasts of North America are confined to the Mexican peninsula of Baja California and the shores of the Gulf of California, a total of about 2000 miles of coastline.

The Baja California peninsula, with an area of 55,534 sq miles, occupies approximately 7% of the territory of Mexico. The peninsula is divided into two almost equal-area political divisions: the state of Baja California Norte, with 27,655 sq miles, and the territory of Baja California Sur, with 27,979 sq miles. Its boundaries are defined by the United States on the north, the Gulf of California on the east, and the Pacific Ocean on the south and west.

Geologically, Baja California is a huge fault block tilted upward on the eastern side and sloping rather gradually downward to the sea on the Pacific side. On the eastern side a high escarpment drops off precipitously to the Gulf of California. However, despite the general ruggedness of the peninsula, there are a few large plains covered with alluvial sediments. Two of these are the Vizcaino Plain, on the western side of the peninsula between 27 and 28° N latitude, and the Magdalena Plain, on the Pacific Coast behind Magdalena Bay. The locale under consideration is situated in the Magdalena Plain of Baja California Sur approximately 100 miles northwest of the city of La Paz (Fig. 6).

A. Population and Population Density

In 1965 the Baja California peninsula had a population of 886,055 persons, 2.1% of the total population of Mexico. Of the total, 791,415 persons were living in Baja California Norte, while only 94,640 persons were living in Baja California Sur. The population density for Baja California Sur was 3.4 persons per square mile. Approximately 25,000 of the persons living in Baja California Sur resided at La Paz, the territorial capital.

In the five-year period between 1960 and 1965 the population of Baja California Sur increased by 16%, just under the 17.2% increase over the same period for Mexico as a whole.

B. Agricultural Considerations

1. **Surface Configuration.** – The Magdalena Plain is a flat to gently rolling featureless plain of 5000 to 6000 sq miles. Elevations on the plain range from sea level to 100 m; the slopes are generally less than 5%, but slopes of up to 10% may be encountered. The surface is moderately dissected on the western edge. The coastline is fronted by long, narrow dune-covered islands.

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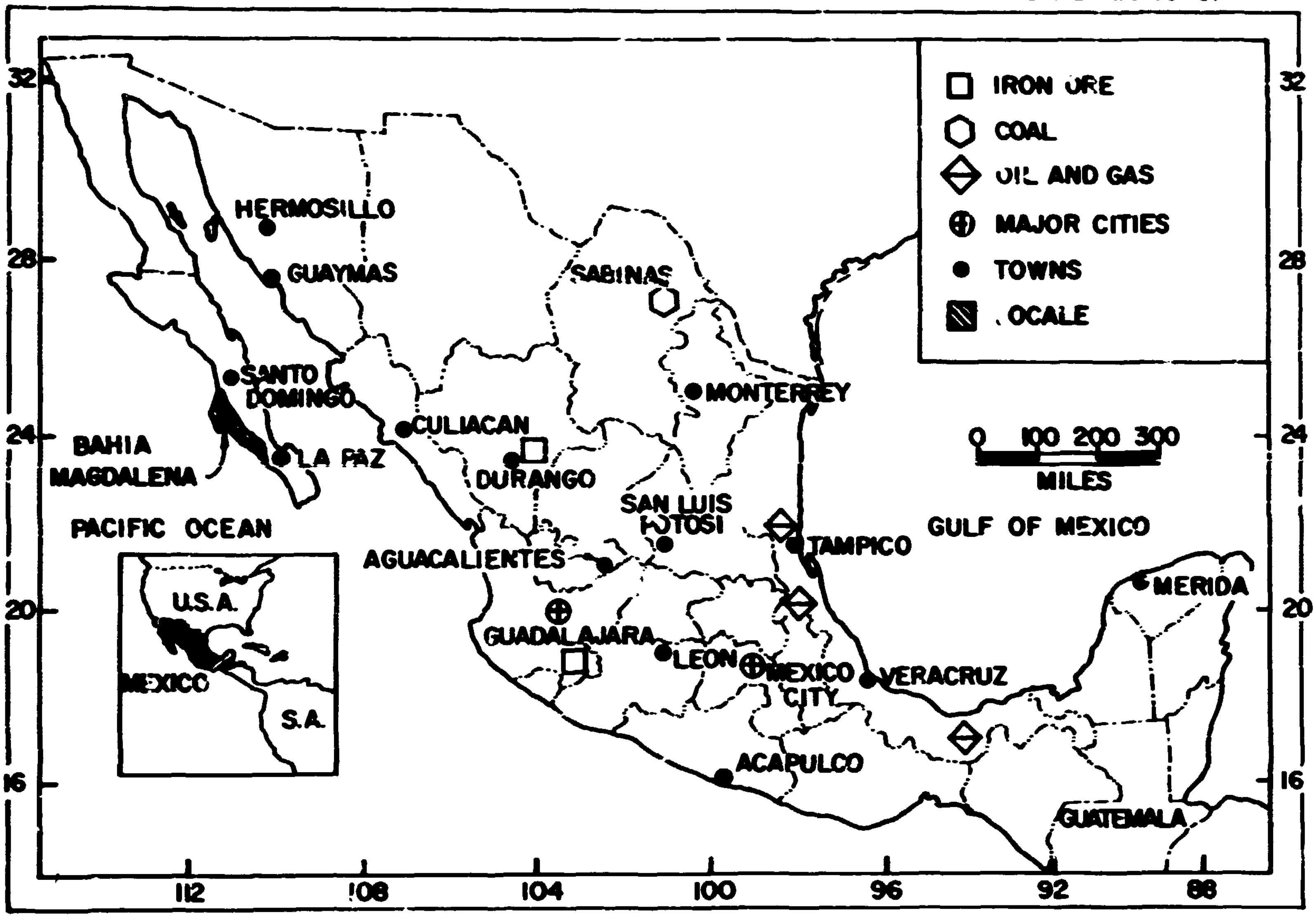

Fig. 6. Agro-Industrial Locale and Mineral Resources of Mexico.

Presently, this large flat-lying area is almost entirely unused because it is deficient in water resources; however, given a source of irrigation water, the Magdalena Plain would appear to have a rather large potential for agricultural development.

2. **Climate.** – The Magdalena Plain of Baja California Sur is classified as desert in climate. The average annual rainfall as recorded at Bahia Magdalena is 4.80 in. More than half the mean annual rainfall in southern Baja California comes with hurricanes, single storms often bringing several times as much rain as the annual mean. "Mean rainfall" has but slight significance, especially when based upon short periods of record. At Bahia Magdalena, for example, the published mean annual rainfall of 10.4 in. reported in 1942 is based on the four-year period 1937–1940; this period included the year 1939, when two chubascos[7] brought 27.6 in. of rainfall in September, more than the combined rainfall of the other 14 Septembers on record. As has been previously stated, the 15-year period 1936–1950 shows a mean annual rainfall of 4.8 in. If the year 1939 had not been included, the annual rainfall would have been only 1.3 in. for the other 14 years (Table 7).

The mean annual temperatures of the area average 72°F. Temperatures at Bahia Magdalena vary from a mean daily maximum of 81°F to a mean daily minimum of 66°F. The hottest time of the year is from July to December, when the mean daily maximum temperatures register in the low to upper 80's. The lowest mean daily temperatures occur in the months of January to April, which average near 6' F. The Magdalena Plain has a year-round growing season. The mean relative humidity for 5:00 AM averaged 84% and for 5:00 PM averaged 77%.

3. **Water Resources.** – Agricultural possibilities are limited by the scarcity of surface and groundwater. The best supplies in Baja California are in the north and south, where mountain ranges with considerable amounts of rainfall result in seasonal floods in the

[7] Local name for the hurricanes of the region.

Table 7. Climatic Data for Baja California Locale (Mexico)

Bahia Station, Magdalena, Mexico, Baja California Sur; latitude 24° 30'N; longitude 112° W; elevation 6 ft

	J	F	M	A	M	J	J	A	S	O	N	D	Annual
Temperature (°F)													
Mean maximum	77	77	77	77	77	79	84	86	88	86	84	81	81
Mean minimum	61	59	61	61	63	64	70	73	75	72	69	64	66
Mean	66	64	66	66	68	70	75	79	79	77	73	70	72
Rainfall (in.)	0.20	0.28	0.24	0.05	0.05	0.05	0.06	0.28	2.32	0.12	0.67	0.51	4.80
Relative humidity (%)													
5 AM	82	87	88	84	86	87	82	86	89	81	83	77	84
5 PM	76	79	84	78	80	80	80	78	82	72	70	68	77
Mean wind velocity (mph)													
5 AM	8	8	8	10	9	9	6	7	6	9	6	8	8.0
5 PM	5	10	11	12	16	14	11	13	10	14	11	11	12.0
Cloudiness (tenths of sky covered)	7	5	7	7	7	4	5	4	5	4	6	6	6
Sunshine:	January, 200–250 hr; July, 250 hr; total, 2800–3000 hr												
Global radiation:	160 kcal cm^{-2} $year^{-1}$												

"arroyos" that flow down to the coast. Though much of this floodwater is lost to the sea, some of it replenishes the groundwater en route and results in a few valuable springs or in some cases groundwater levels high enough to permit the successful drilling of wells. Where water is available, highly fertile oases have developed.

Deep wells drilled on the coastal plain may produce fresh or brackish water, but fresh water may be only of fair quality at best. Water levels may be high and yields may be satisfactory at first, but over the long time period, water levels and yields will drop progressively as pumping continues, since recharge is dependent on the rainfall, which is virtually nonexistent.

Shallow wells on the coastal plain tend to yield brackish or saline water. Fresh water, if present, would generally be available in only small quantities, only 10,000 gpd per well, and if larger quantities were pumped, the water would rapidly become brackish and then saline.

4. Soils. – Surrounding the Bay of Magdalena are many different soils, most of which are unsuited for agriculture (Fig. 7). The lithosols and salt marsh may be immediately eliminated. The more promising area includes the sandy red desert soils, but these appear to be associated with sand dunes or solonchaks. Sizable areas of shifting sand dunes also occur in the area. Any potential development for agriculture must stabilize the dunes prior to cropping and require careful delineation of the sandy red desert areas. The solonchaks would require leaching prior to intensive cultivation.

It is worth while to mention that in the Sonoran district of Mexico, sandy red deserts are successfully farmed. In the Santo Domingo Valley, which adjoins the proposed area, 60,000 acres of similar soils are presently irrigated successfully. These existing agricultural developments suggest that the soils in the Magdalena Plains are also potentially productive.

5. Food Markets. – To predict the destination for agricultural commodities leaving an agro-industrial complex in Baja California Sur is difficult because there appears to be no present export pattern from which one could extrapolate. Since no market analysis studies were made in the course of the project, statements treating potential markets should be regarded as speculation and not as fact.

The cropping pattern in Baja California Sur would certainly to a large extent determine the marketability of the agricultural commodities. Fruits and vegetables should be marketable in the large population centers of mainland Mexico. Early vegetables might find a ready market in the western United States. Basic grains such as wheat should not only be marketable in mainland Mexico but perhaps also in Central and South America.

C. Industrial Considerations

1. Mineral Resources. – Mexico's vast mineral wealth places it among the world's leading producers, and mineral extraction is one of the most highly developed and well organized industries. The great zone of metallic mineral deposits follows the direction of the

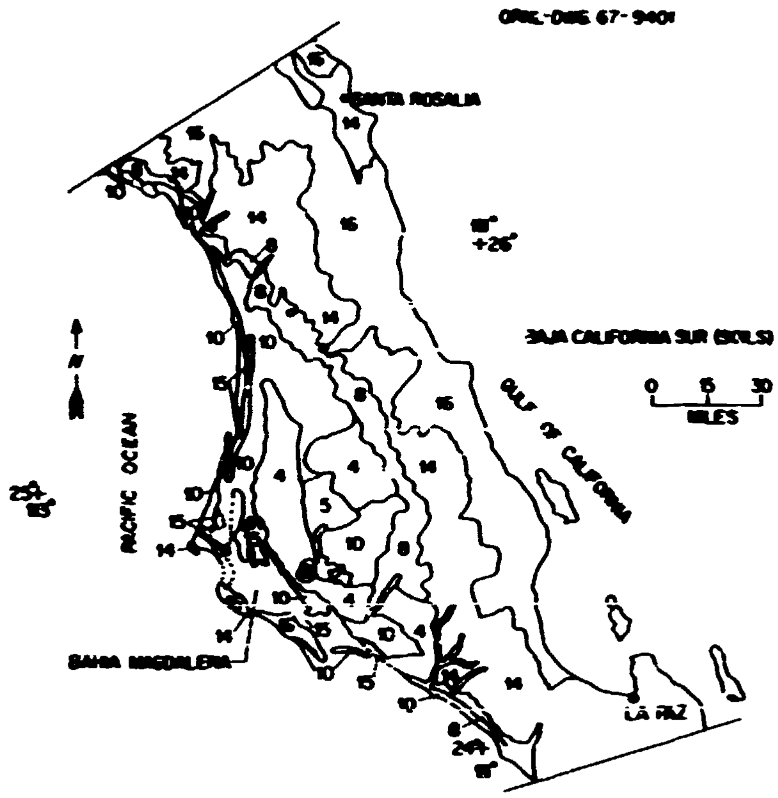

Fig. 7. Soils of the Southern Portion of Baja California. The soil of primary interest is sandy red desert associated with sand dunes (4). Other soils include sandy red desert associated with solonchak (5), gravelly red desert (8), shifting sand dunes (10), lithosols (14, 16), and sand dunes associated with salt marsh (15).

Sierra Madre range, extending from the United States boundary in the northwest to the Pacific Coast state of Oaxaca in the southeast.

Mexico's mining industry derives its importance from two main groups: precious metals, principally gold and silver, and three base metals, lead, zinc, and copper. To these, however, iron and coal should be added. While production of the precious and base metals is important from an international standpoint, the iron and coal are more vital from the domestic viewpoint. The locations of the iron, coal, and oil fields are shown in Fig. 6.

In contrast to the rest of Mexico, mining activity on the peninsula of Baja California has declined in recent years and no longer holds the importance that it once did. The copper mines at Santa Rosalia are still open, but they maintain only marginal production. Some gypsum and salt are mined on the peninsula. There appears to be some mining potential in Baja California, but new ventures will have to await other developments such as the growth of markets.

a. Bauxite. – As far as is known, Mexico has no domestic source of bauxite.

b. Phosphate Rock. – There are no data available on Mexico's reserves of natural phosphates. It seems that at the present time there are no known deposits of phosphate rock of any significance. A small quantity, valued for its fluorite content, is produced for export. In addition, there are known to be large deposits of sand on the coast of Baja California with low phosphorus content ranging from 3 to 5%, which makes the possibility of exploitation somewhat doubtful.

c. Iron Ore. -- The Banco Nacional de Comercio Exterior, S.A., published in 1964 a list of 92 Mexican iron ore deposits having combined estimated reserves of 570 million tons averaging 57% iron. Nine of the deposits which were carefully investigated contained 376 million tons of ore averaging 59%. This leaves only 34% of the estimated national reserves distributed among 83 deposits.

The most important deposits occur along the Pacific continental slope and over the northeastern and central part of the Central Plateau. The iron ore fields that are presently being mined in Mexico are located at Cerro del Mercado in the state of Durango, at La Perla and La Negra in the state of Chihuahua, at El Encino and Pihuamo in the state of Jalisco, at Solv Luna in the state of Zacatecas, and at Las Alazanas in the state of Coahuila.

Iron ore deposits that are presently being worked in Mexico are far removed from the Baja California site, but in the desert of northern Baja California, around San Fernando, there are iron ore deposits of considerable size. If reserves, grades of ore, and accessibility should prove adequate, there exists the potential for a steel industry in Baja California.

d. Coal. – In 1965 Mexico's coal reserves were estimated to be in the neighborhood of 13 billion metric tons. Much of Mexico's coal is found in broken seams and has a high ash content. The largest coal fields are in the north-central part of the country, where the Sabinas and Papau deposits are located. The production of coal is wholly of the bituminous type.

It has been estimated that the proven reserves of coking-grade coal amount to around 1700 million tons. These reserves are almost entirely in the northern part of the country in the Fuente, Sabinas, Esperanza, Saltillo, Lampazos, San Blas, and San Patricio fields of the states of Coahuila and Nuevo Leon. Smaller deposits are found in the northwest at the Yaqui field in Sonora. No coal deposits are known to exist in Baja California.

e. Natural Gas and Oil. – Mexico was the first Latin-American country to become an important oil producer. Exploitation of petroleum began over 50 years ago, and today (1965) Mexico produces 8% of the Latin-American oil on the world market.

The richness of the oil-bearing strata in the country together with a noteworthy intensification of exploratory studies resulted in an increase in proven reserves of hydrocarbons of 6% annually between 1938 and 1962, while the increase in the rate of production was 49% annually. In 1962 the proven reserves stood at 4995 million barrels. Of this reserve, 2455 million barrels were of crudes, and gas accounted for 2729 million barrels measured by its liquid equivalent. It has been calculated that at the present rates of production the duration of the reserves is of the order of 23 years for the crudes and 30 years in the case of gas.

The Gulf of Mexico oil fields, the major fields of Mexico, are located along the coastal plain which runs between the slopes of the eastern Sierra Madre and the Gulf of Mexico. The states of Vera Cruz, Tamaulipas, Tabasco, and San Luis Potosi are the major producers. Recent discoveries have been made on the continental shelf of the Gulf. The search for oil in southern Baja California has proved futile thus far.

f. Limestone. – Very little information is available concerning limestone deposits and reserves for the Republic of Mexico. However, two sources of limestone are reported to exist on the Baja California peninsula. At Punta China, on the coast south of Ensenada in Baja California Norte, limestone is presently being mined for cement manufacture in Ensenada. Limestone of high quality is reported to be abundant in various areas of northern Baja California.

g. Gypsum. – There is also a scarcity of information concerning gypsum deposits and reserves for Mexico. However, on examination of the production figures for 1964, it appears that the Republic has a rather large supply. In 1964 Mexico produced approximately 1.2 million tons of gypsum, and most of this was exported to the United States, Canada, and Japan.

The 1964 *Mineral Year Book* reported a deposit containing 2400 million tons of gypsum at La Borrega. Also, just southeast of Santa Rosalia (northeast coast of Baja California Sur) on San Marcos Island in the Gulf of California, the mining of gypsum for export to cement factories in California has become a large enterprise.

2. **Transport Facilities.** – *a. Rail.* – The national railway system of Mexico includes more than 20 separate railroads which it operates. The Yucatan Railway, operated by the state of Yucatan, and mileage controlled by foreign mining companies are the only exceptions. The major railway system is the Ferrocarriles Nacionales de Mexico, with two-thirds of the total trackage of 14,700 miles. It connects Mexico with the United States railway system at Reynosa, Nuevo Laredo, Piedras Negras, and Ciudad Juarez and extends southward to the Guatemalan border at Suchiate. To the west at Guadalajara, it connects with the Ferrocarril del Pacifico, which extends northward to the United States border at Nogales. Other smaller railways operate in the northwest and the southeast. As in most developing countries, the most unfortunate feature of the railway systems is that they have been built to different gages. During recent years Mexico has attempted to modernize her railroads by changing several lines from narrow gage to standard gage.

Rail transport in Baja California has been slow to develop. In 1962 only 116 miles of railroad existed in the whole of the peninsula. This small length of track is located in the extreme northeast of the peninsula and connects Mexicali with the state of Sonora. Baja California Sur is completely devoid of a rail network. The development of an agro-industrial complex on the Magdalena Plain may require a considerable capital investment for a railway system.

b. Water. – At the present time port facilities near the Magdalena Plain locale are virtually undeveloped. However, Magdalena Bay, adjacent to the locale, represents one of the most magnificent natural harbors on the entire Pacific coast and remains largely unused.

The small port of San Carlos, located at the head of the bay, is presently equipped to handle only small shipments, mostly agricultural products. It appears that Magdalena Bay would afford a very good location for the development of port facilities for support of an agro-industrial complex.

3. **Power Grid Availability.** – In 1965, Mexico had a total installed generating capacity of 5240 MW(e), of which 44% was hydroelectric and 56% was thermal. Table 4 shows the installed capacity and electric power production for 1965.

The total installed capacity on the Baja California peninsula was only 240.5 MW(e). Only 10 MW of this power was located in Baja California Sur. The entire southern peninsula is served only by a few scattered diesel stations that are not interconnected. Only one plant has an installed capacity of over 500 kW(e), that being the plant in Mulege, which is 3.8 MW.

4. **Industrial Markets.** – A large part of the industrial products manufactured at an agro-industrial complex in Baja California could be consumed in mainland Mexico. Perhaps a major market for aluminum would be the countries of Central America and western South America. Certain high-value products might be marketable in the United States and Canada. There is no doubt that because of its relative isolation from the rest of Mexico, the marketing of products would be a problem of some significance.

2.2.4 Peru (Sechura Desert)

The Sechura Desert is situated in the northwestern portion of Peru in Piura Department. Piura Department has an area of 20,548 sq miles and is bounded on the north by Tumbes Department and Ecuador, on the east by Cajamarca Department, on the south by Lambayeque Department, and on the west by the Pacific Ocean. The Sechura locale is situated on the level coastal plain north of Chiclayo and south of the Rio Chira. The town of Sechura serves as a reference point and is located approximately 5°30′ south latitude (Fig. 8).

A. Population and Population Density

In 1940, Peru had slightly more than 7 million inhabitants. By 1961, this number had increased to slightly more than 11 million. Thus, population growth over the last 20 years has taken place at an average rate of 2.5% annually. If the present growth rate remains unchanged, the population will double within 27.6

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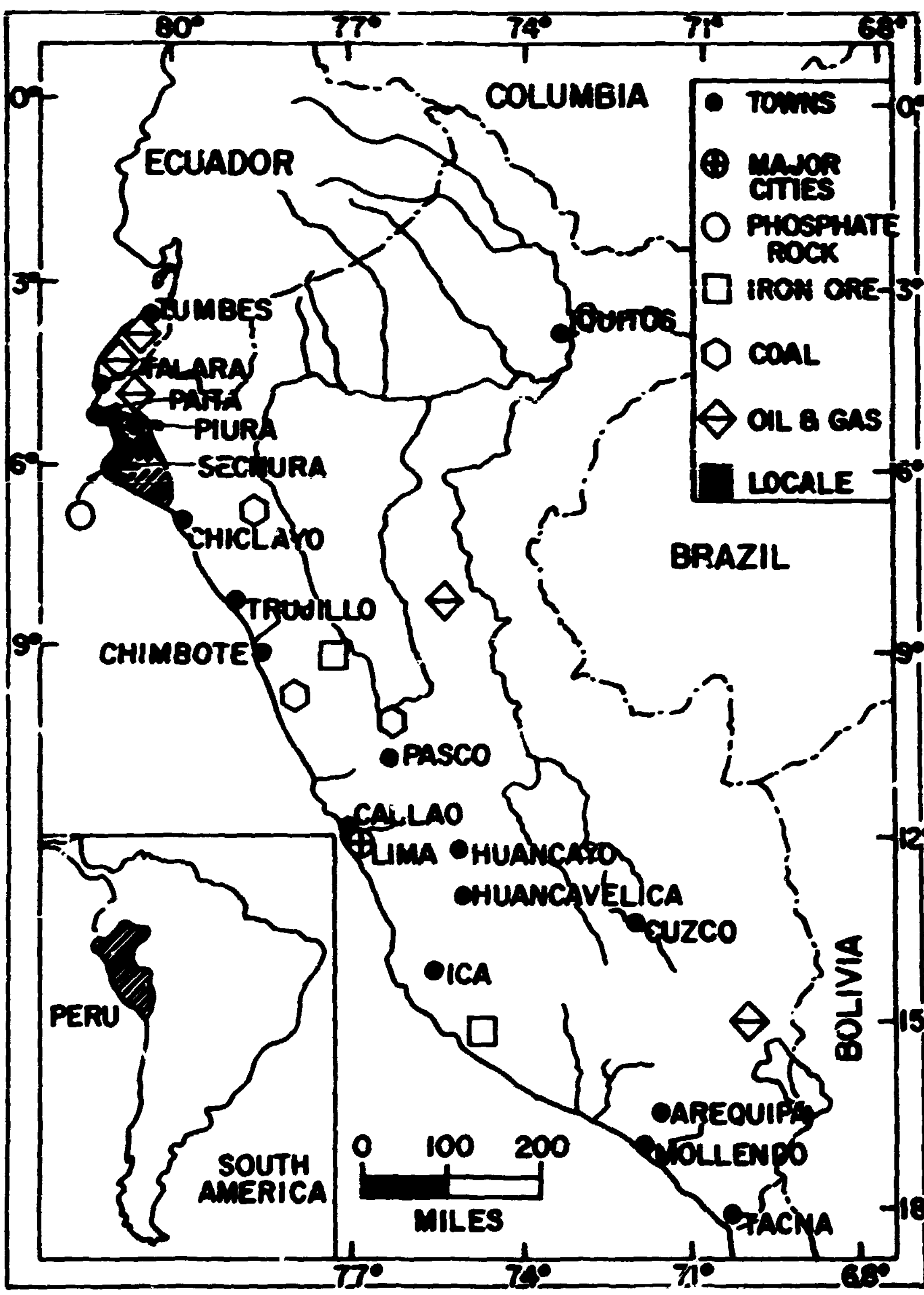

Fig. 8. Agro-Industrial Locale and Mineral Resources of Peru.

years. This means that Peru will have 22 million people by 1968.

The population of Piura Department in 1940 was 408,605 persons. By 1961, this number had increased to 716,954, an increase of 75.5% over the 20-year period. The overall population density for Piura is 50 to 65 persons per square mile. However, the majority of these persons live either in the major towns such as Piura and Talara or in the river valleys where agriculture is practiced. The Sechura Desert portion of the area remains virtually uninhabitated.

B. Agricultural Considerations

1. **Surface Configuration.** – The coastal plains of Peru lying between the western range of the Andes and the Pacific Ocean display considerable changes in elevation from one region to the other. As might be expected in an area so near to the immense and geologically youthful Andes, the coast has experienced a continuing condition of differential uplifting, with the result that the coastal plain varies not only in altitude but also in width. There are extensive stretches of coastline where the plains disappear altogether and the mountains reach all the way to the Pacific.

Along the coastal plain of Piura Department, of which a large portion is covered by the Sechura Desert, elevations normally range from sea level to 300 ft. From Tumbes Department in the north this belt of low-lying lands extends for more than 160 miles to Lambayeque Department in the south. It reaches its greatest width, approximately 100 miles, at Punta Aguja, south of the town of Sechura. The land surface in the area is predominantly flat to gently rolling sandy plains with numerous dune areas and scattered salt flats. Dunes up to 600 ft high line most of the immediate coast, and some dunes are present as far as 50 miles inland. Between the mouths of the Rio Chira and Rio Piura, coastal bluffs 150 to 300 ft high appear. The relief between the interstream areas and the valley bottoms is commonly less than 150 ft, and slopes in the area are largely less than 10%.

2. **Climate.** – The climate for the Sechura area is that of a true tropical desert; it is in fact one of the driest places on earth. Only parts of the Kalahari (Bechuanaland), the South Australian desert, and the Rub' al Khali (Saudi Arabia) exceed its extraordinary aridity. The average rainfall as recorded at Piura, 30 miles northeast of Sechura, is 2.7 in. annually. Most of the rain, 88%, occurs during the summer months of January through April, while the rest of the year is extremely dry. The rainiest month, March, receives 0.74 in. (Table 8). The amount of rain in a given year may vary greatly.

Mean annual temperatures as recorded at the Piura weather station average 77.5° F. They vary from a mean daily maximum of 89.4° F to a mean daily minimum of 65.5° F. The coolest month, July, averages 72.9° F, and the warmest months are February and March, with mean temperatures of 84.0° F.

In this northern part of the Peruvian Desert, the sun shines about twice as many hours (2600 hr) as in the foggy deserts of central and southern Peru. The mean

Table 8. Climatic Data for Sechura Desert Locale[a]

Station: Piura, Peru; latitude 5° 13′ S; longitude 80° 38′ W; elevation 162 ft

	J	F	M	A	M	J	J	A	S	O	N	D	Annual
Temperature (°F)													
Mean maximum	94	96	96	94	89	85	84	85	87	86	88	90	89
Mean minimum	70	72	72	69	65	64	62	62	62	62	62	65	66
Mean	82	84	84	82	77	74	73	73	74	74	75	78	78
Rainfall (in.)	0.43	0.68	0.74	0.57	0.003	0.001	0.001	0.002	0.000	0.002	0.004	0.24	2.7
Relative humidity (%)													
Maximum	82	81	82	83	84	85	86	85	87	83	87	86	84
Minimum	32	33	33	36	41	45	44	42	40	40	36	37	38
Mean	57	57	58	59	63	65	65	64	64	62	62	61	61
Wind:	0–3 mph approximately 100% of the time; dominant direction of wind, south												
Cloudiness (tenths of sky covered)	7	8	7	6	6	6	6	5	5	6	5	6	6
Sunshine:	January, 200 hr; July, 150–200 hr; total, 2600 hr												
Global radiation:	160 kcal cm^{-2} $year^{-1}$												

[a] *Servicio de Agrometerología e Hidrología*, 1962.

relative humidity averages 61%, and the area enjoys a frost-free season suitable for year-round agriculture.

3. **Water Resources.** – Agriculture is presently practiced in the Sechura area using water from the Chira and Piura Rivers as an irrigation source. But this source is not dependable, because the highland sources of water are without the stabilizing factor of melting snow and ice. The average yearly discharge of these two rivers fluctuates greatly from year to year, and in some years no water at all reaches the cultivated lands along the Piura (Table 9). Another limitation to agriculture in the area is the limited amount of land in the valley bottoms which can be irrigated with water from the rivers and streams. Considerable expansion of cultivated acreage would be possible if the water could be raised to the height of the surrounding plain, where agriculture would be feasible if water could be supplied.

No specific information was available on the groundwater resources of the coastal area of northern Peru. Reasoning from analogous situations leads to conflicting conclusions. Rainfall in the area is inadequate to maintain substantial supplies of groundwater at shallow depths. Water that does accumulate near the surface is probably brackish or saline. Water at moderate depths (hundreds of feet) or very deep (thousands of feet) may be present below the coastal plain and may originate in the mountains or foothill zones and may be recharged regularly in the area of origin. This water may be brackish or saline by the time it reaches the coast, or if favorable aquifers exist, it may be fresh. This hypothesis can only be tested by drilling. So far, petroleum exploration along the coast has not indicated the presence of fresh water.

4. **Soils.** – Along the coast near Sechura, the soil is sandy red desert with approximately 20 to 40% solonchak (Fig. 9). The soils are mainly sandy loams, though gravelly areas are also common. The solonchaks will require leaching prior to use to remove excess soluble salts. In the Piura River valley the soil is recent

Table 9. Hydrographic Summary of Coastal Rivers[a]

Average yearly discharge in millions of cubic meters

River	Numbers of Years Averaged	Average Discharge	Highest Yearly Discharge	Lowest Yearly Discharge
Chira	24	3775	11,035	1604
Piura	40	845	3,397	0.0

[a]D. A. Robinson, *Peru in Four Dimensions*, American Studies Press, Lima, Peru, 1964.

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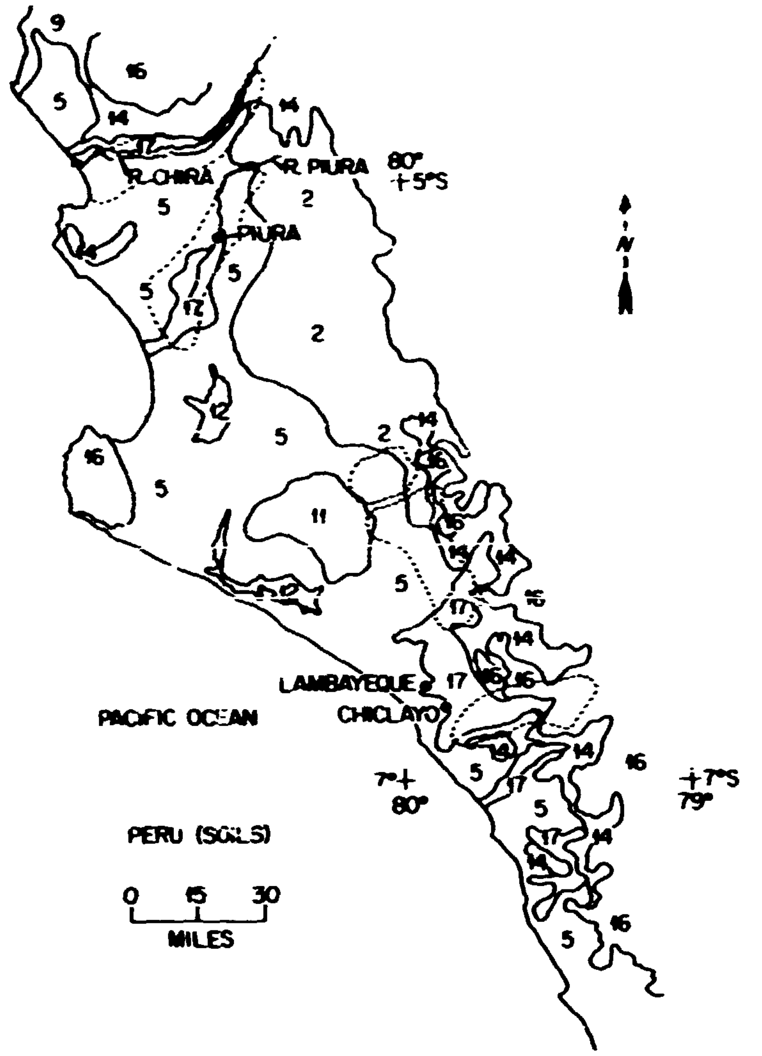

Fig. 9. Soils of the Sechura Desert Area of Peru. Soils of primary interest include the sandy red desert associated with solonchak (5) and sandy red desert (2). Others in the area include reddish-brown soils on hilly terrain (9), sand dunes with solonchak (11), solonchak (12), lithosols (14, 16), and alluvial soils (17).

alluvium. This area is presently cultivated by irrigation, but full development toward the coast is not possible due to the limited flow of the river.

Inland, approximately 15 to 20 miles from the coast, the soil is more uniformly sandy red desert. The elevation is less than 500 ft, and in local areas near streams cotton is being grown. Along with Western Australia the Sechura Desert area includes the largest area which appears to have good potential for agricultural development.

5. **Food Markets.** – Food production along the coastal region of Peru is insufficient to meet the needs of the local consumers. Most of the food products produced within an agro-industrial complex in Sechura could be used in Peru. Such high-value crops as cotton and sugar, presently the leading exports of Peru, would continue to be shipped to western European countries. Other items could be sold to various other countries in Latin America.

C. Industrial Considerations

1. Mineral Resources. – From the standpoint of mineral wealth, Peru is abundantly endowed. Ores of copper, lead, zinc, silver, tungsten, and iron are found scattered throughout the Andes. Coal and oil deposits are also substantial enough to meet Peru's present needs. Nonmetallic minerals such as phosphate and barite are now being exploited. Although Peru's mineral resources are already substantially large, there seems little doubt that there is yet much to be discovered. The locations of the major mineral resources are shown in Fig. 8.

a. Bauxite. – *The U.S. Army Handbook for Peru,* 1965, reported that a large deposit of bauxite existed near Morropón in Piura Department, but as of the present this information has not been substantiated.

b. Phosphate Rock. – The largest phosphorite deposit known in South America has been discovered recently in the Sechura Desert of Peru, near Bayovar. The phosphorus content is low, averaging 10% P_2O_5, and this entails preliminary treatment to enrich the material extracted. The practical implication is that Sechura will have to aim at large-scale production in order to achieve competitive operational costs, and a heavier investment will therefore be required. The volume of reserves is estimated at several hundred million tons.

c. Iron Ore. – Iron ore production is a relatively new development in Peruvian mining, having been started in 1953; however, Peru is already one of the largest producers in Latin America. Peru's iron ore reserves are quoted as being several hundreds of millions of tons.

Peru's largest known iron ore deposits are located in the departments of Ica and Arequipa in the southern portion of the country. The largest deposit is found at the Marcona mine in Ica Department, approximately 210 miles south of Lima. Iron ore reserves at Marcona are known to be over 400 million tons. The ore averages 58% iron with a sulfur content up to 2.5%.

The other major deposit is located at the Acari mine, 35 miles southeast of the port of San Juan in Arequipa Department. Acari production in 1963 amounted to 934,800 tons of ore averaging 64% iron. The ore reserve was reported to be sufficient for two to three years.

d. Coal. – Coal deposits of varying grades and types are found over a wide area in the mountain and coastal regions of Peru. At least 55 district deposits have been located between the Ecuadorian and Chilean borders. The types of coal found in this country vary in rank from anthracite to bituminous and subbituminous. There also exist deposits of lignite, which at present have little economic value.

The largest deposits now being worked are located at the Goyllarisquizga and Jatunhuasi mines in the Department of Pasco. The only other important deposits presently being mined are located in the Santa Valley of Ancash Department. Other known deposits are located in La Libertad, Huanuco, and Moquegua departments.

In Peru, coal is of only minor importance as a power plant fuel. The position of independent coal producers has never been strong. Low volume and diverse ownership have tended to keep costs high, and coal has never been competitive with petroleum as an energy source. Transportation costs also hamper the use of coal in Peru, except within limited areas. Coal reserves in the country have been estimated to be from a few billion to 100 billion tons, but the known reserves are nowhere near that extensive.

e. Natural Gas and Oil. – In Peru, petroleum is the most widely used fuel in existing thermal electric generating plants. Its low cost, high quality, and ready availability have made it the most important energy source next to hydroelectric power. Diesel electric generators are widely used throughout Peru.

Peru has been self-sufficient in petroleum products, except for certain high-quality lubricants, high-octane aviation gasoline, and, recently, fuel oil, which have to be imported. Continuous annual shipments of important quantities of crude oil and refined products have made the country a net exporter. The bulk of Peru's oil deposits are located in the northern coastal region in the departments of Piura and Tumbes. In 1960, 95% of the total crude oil was produced in the fields along the northern coastal plain. The remaining 5% was obtained from the small fields on the eastern slopes of the Andes.

The depletion of existing reserves in proven fields and the rising domestic consumption of petroleum products, which has increased fourfold in the last twenty years, has forced Peru to face the possibility of future oil shortages. Intensive exploration has been carried out in the Sechura Desert, just south of the largest producing fields, with no success. Operations undertaken on the continental shelf offshore along the northern coast have met with some success. Several wells on the ocean floor are producing 200 to 400 bbl/day; however, many dry wells have been drilled at great cost, and proven reserves are of no great importance so far. The greatest hope for future petroleum production in Peru appears to lie on the eastern slopes of the Andes.

f. Limestone. – In Peru, limestone is principally produced in the departments of Lima, Lambayeque, La Libertad, and Junin. Several other economically exploitable limestone deposits are known in various parts of the country, including the Pachitea River region in Central Peru, which places Peru in a position of potential self-sufficiency for future cement requirements.

g. Gypsum. – Over 95% of the crude gypsum mined in Peru is calcined for use in the construction industry. The principal commercial exploitation is confined to the department of Lima. Small amounts of crude gypsum are consumed in the domestic production of portland cement.

2. **Transport Facilities.** – *a. Rail.* – The railroads of Peru operate on a number of different track gages, and a great deal of the rolling stock is obsolete. Of the total trackage (approximately 2000 miles), 59% is in 4 ft 8½ in. gage, 23% in 3 ft gage, and the remainder consists of gages from 2 to 3½ ft.

The railroads fall into two main groups: the central and southern, which are built around two main lines and form the backbone to the Peruvian railroad system, and short feeder lines connecting remote centers with one another or with other transport facilities. One main line, the Ferrocarril Central del Peru, is strategically and economically the most important in the country. It links Callao (the port for Lima) with the rich mining districts of the central Andes. The other main line, the Ferrocarriles del Sur del Peru, connects the southern port of Mollendo with the Bolivian railway system by way of Lake Titicaca. The railroads of Peru are not interconnected and thus do not form an integrated network.

The Sechura Desert locale is served by a single stretch of feeder line (4 ft 8½ in. gage). It connects the seaport of Paita with the town of Piura and was built to serve the agricultural areas of the Piura and Chira valleys.

b. Water. – For a country so dependent on the sea for trade, Peru is very poor in natural harbors. Its whole coast is rugged and forbidding. Suitable harbors are few and far between, and even most of these can be developed only at great expense. In many of the harbors, ships must anchor off the coast and transfer their cargo to lighters before it can reach shore. This entails extra handling of c[illegible] results in higher costs.

Along the northern coast in the vicinity of the Sechura locale there are three small ports, Talara, Paita, and Bayovar, all of which require lighters. Talara, the largest one, serves the oil fields for imports of drilling and refining equipment and for the export of petroleum products. Paita, the second largest, is an outlet for the agricultural products of the region. There has been a proposal to construct new port facilities at Paita, including one deep-water pier with two berths, but it has not been determined whether a decision on this proposal has been made. Paita presently handles 100,000 tons/year and is located some 40 miles north of Sechura.

Bayovar, an open roadstead port, is located about 30 miles southwest of Sechura. It has a single landing pier with a depth of 4.6 m. The Bayovar port is of interest since the large phosphate deposits are near Bayovar. Plans are being made to develop the deposit, including development of the port and transport facilities.

3. **Power Grid Availability.** – In 1965, Peru had a total installed electric generating capacity of 1150 MW, of which 59% was hydroelectric and 41% thermal. Table 4 shows the installed capacity and electric power production for 1965.

The backbone of the power industry of Peru is located in the central departments, where most of the manufacturing and mining activities are concentrated. The Sechura locale is served by scattered stations, mostly diesel, located at Talara, Paita, Piura, Sullana, Sechura, and several other small towns. There is no grid within the area, and generating capacity is small.

4. **Industrial Markets.** – Phosphate fertilizers produced at an agro-industrial complex in Sechura would be distributed throughout Peru. Aluminum and aluminum products could be shipped to Lima and distributed throughout the industrial areas of the central departments. Those products not used internally should find ready markets among the countries of the Latin-American Free Trade Association and in Central America. High-value products might be marketable in western Europe.

2.2.5 Southeastern Mediterranean (Sinai-Negev)

The Sinai-Negev locale is situated along the southeastern coast of the Mediterranean between the towns of Gaza and Port Said. It centers on El Arish, the capital of Sinai (Fig. 10).

A. Population and Population Density

The United Arab Republic covers an area of 386,198 sq miles and in 1960 had a population of 25.6 million persons. However, very little of the territory is inhabitated. Most of the Egyptian population is concentrated on 13,500 sq miles of land in the Nile Valley, the Nile Delta, and a few watered oases. In these so-called "inhabitated areas" the population density is approximately 1900 persons per square mile.

The Sinai-Negev portion of the southeastern Mediterranean coast, which lies between the Suez Canal and Israel, is in general sparsely settled by a few nomadic pastoralists. The overall density of population in this area is 2 to 50 persons per square mile. The exception occurs along the Mediterranean coast, where rather high population densities occur around the coastal towns such as Port Said, El Arish, and Gaza.

The state of Israel (8000 sq miles) lies to the northeast of the Sinai-Negev locale. In 1961 Israel had a population of 2.2 million persons, with an overall population density of 115 persons per square mile. The Negev Desert portion of the country, which lies immediately east of the Sinai-Negev locale, is rather sparsely populated, with an overall population density of 0 to 62 persons per square mile. Much of the population in this portion of Israel is concentrated in the town of Beersheba (65,000).

B. Agriculture Considerations

1. Surface Configuration. – The land along the immediate coast of the Sinai-Negev locale and extending south of El Arish is generally flat to gently rolling, with the higher parts up to 30 m above the adjacent areas. These plains extend inland from a few miles to as much as 50 miles to the west of Port Said. The suitability of this land for agricultural uses is greatly hampered by the presence of sand dunes, which cover most of these plains and lie along most of the coastline. Also, a very large area south of Port Said is below sea level and is subject to frequent inundation.

The most suitable land for an agro-industrial complex in this area appears to be in an area which extends from El Arish north along the coast to Rafah and inland for 10 to 15 miles. Here the surface is largely rolling plains with some dissection. The intervalley areas range from 30 to 100 m above the adjacent valley bottoms, and the slopes are generally less than 5% except adjacent to the hills. Sand dunes are much less numerous in this area, and the soils are considerably better than on the coastal plains south of El Arish. A great deal more data than were available for this study would be needed in order to more accurately select a site for an agro-industrial complex in this area.

2. Climate. – The climate of the southeastern Mediterranean coast in the vicinity of El Arish is classified as desert. The mean annual rainfall as recorded at the El Arish weather station is 3.8 in. Most of the rainfall, 87%, occurs in the winter months, November to March (Table 10). In the summer months, June to September, no rain has fallen in the 35 years of record. The three rainiest months, December, January, and February, each average approximately $^3/_4$ in. annually.

The temperatures at El Arish vary from a mean daily maximum of 77°F to a mean daily minimum of 57°F.

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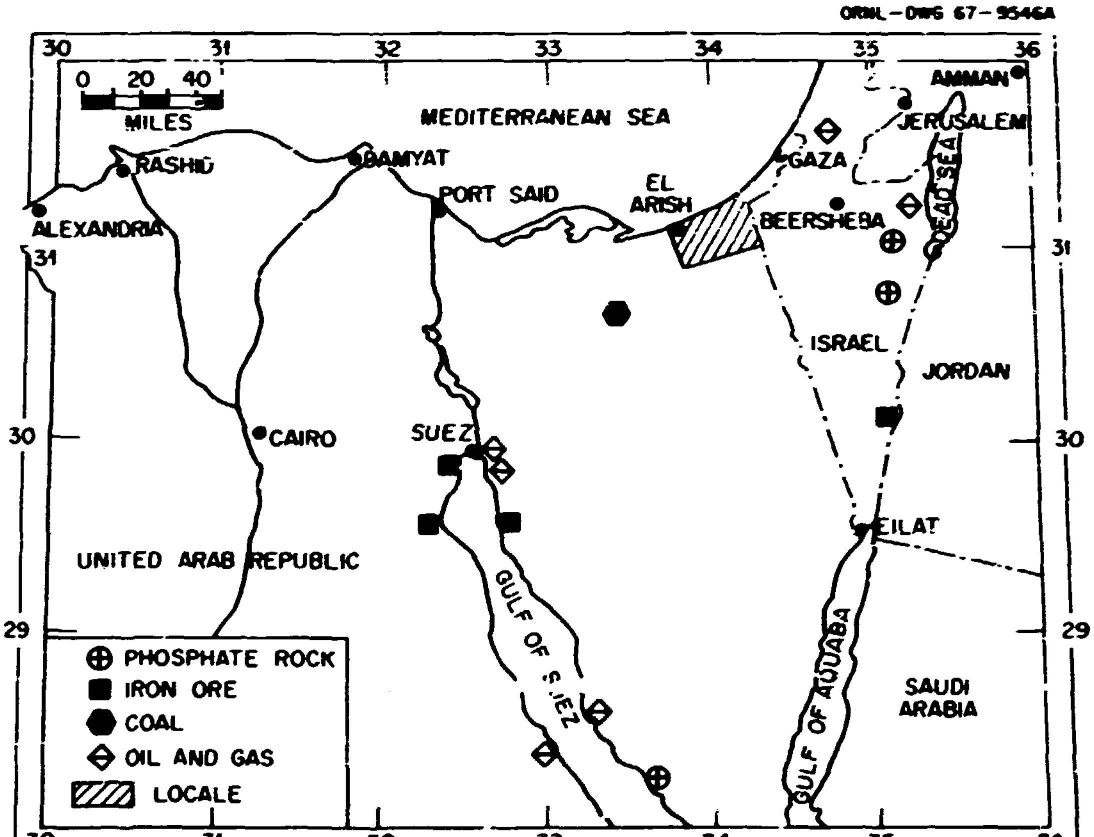

Fig. 10. Agro-Industrial Locale and Mineral Resources of the Southeastern Mediterranean.

Table 10. Climatic Data for Sinai-Negev Locale (Southeastern Mediterranean)[a]

Station: El Arish, U.A.R.; latitude 31° 17′ N; longitude 33° 45′ E; elevation 33 ft

	J	F	M	A	M	J	J	A	S	O	N	D	Annual
Temperature (°F)													
Mean maximum	64	68	70	75	81	84	86	88	86	82	73	70	77
Mean minimum	45	46	50	55	59	64	68	70	68	63	55	48	57
Mean	54	54	59	64	70	73	77	79	77	73	64	57	67
Rainfall (in.)	0.71	0.71	0.55	0.24	0.04	0.00	0.00	0.00	0.00	0.20	0.59	0.75	3.8
Relative humidity (%)													
8 AM	76	74	69	66	67	67	68	71	70	73	74	71	71
5 PM	68	67	65	63	63	67	66	66	67	70	71	66	67
Mean wind velocity (mph)	5	5	6	6	5	5	5	4	4	4	4	5	5
Cloudiness (tenths of sky covered)	3	3	3	2	2	1	1	1	1	2	3	3	2
Sunshine:	January, 150–200 hr; July, 350 hr; total, 3400–3600 hr												
Global radiation:	180 kcal cm^{-2} $year^{-1}$												

[a]Air Weather Service – USAF.

The hottest months of the year are July, August, and September, which average in the upper 70's. The lowest temperatures occur in January and February, which average 54 and 55°F respectively. In the coastal plains, freezing temperatures are rare, and citrus fruits and other crops sensitive to cold are only very rarely endangered by frost.

The relative humidity averages 69% annually. But despite the high temperatures and high relative humidity, this coastal area has just enough sea breeze to keep it from being unbearable in the heat of the day in summer.

3. **Water Resources.** – The Sinai-Negev locale is lacking in any major source of either surface water or groundwater that could be used for agricultural purposes. Careful conservation measures must be used in order to meet with any kind of agricultural success.

The Wadi El Arish is the only sizable stream reaching the Mediterranean coast in the Sinai-Negev area, but it is normally dry except during spells of heavy winter rainfall. Along the Wadi are alluvial terraces that might be used for agriculture if the water of the Wadi were stored or pumped from the subsurface deposits.

Along the coastal plain between El Arish and Rafah are numerous wells that yield very small to moderate quantities of groundwater. The wells in sand dune areas are generally 2 to 10 m deep and produce very small quantities of water, 1 to 10 gpm. The Pliocene and Pleistocene beds underlying the coastal plain yield moderate quantities of water, 100 to 1000 gpm. The wells in the Pliocene-Pleistocene aquifer may be 100 m or more deep.

The quality of the water along the coastal plain is generally good, less than 250 ppm of chloride, but if pumped at higher than recommended rates the quality deteriorates rapidly. The quality of water existing in two wells within a short distance of one another may also vary significantly. Both the quality and quantity of groundwater in the area decrease with increasing distance from the coastal plain.

4. **Soils.** – The area of interest is bounded on the coast by Gaza to the east and El Arish to the west. Immediately on the coast the land is marked by shifting sand dunes (Fig. 11). Inland, about a mile, the soil is classified as reddish brown mixed with sierozems and as sandy regosols. These soils, which are all closely related, are of aeolian-lacustrine origin.

A narrow strip of gravelly red desert soil at El Arish is surrounded to the east and west by shifting dunes. The gravelly red desert increases in area inland, following the Wadi plain draining the area. These soils in the Wadi plain were essentially formed by deposition from water, in contrast to the typical air-deposited soils of higher elevations.

Selection of land is complicated by the lack of information on land presently being farmed, especially near Gaza and the surrounding area of Israel. However, a reasonable area for a complex is obtained by limiting the eastern border to a line midway between Rafah and Gaza.

5. **Food Markets.** – Although time did not allow a market analysis of the various locales under consideration, certain assumptions can be made by examining the marketing patterns already established nearby. In the

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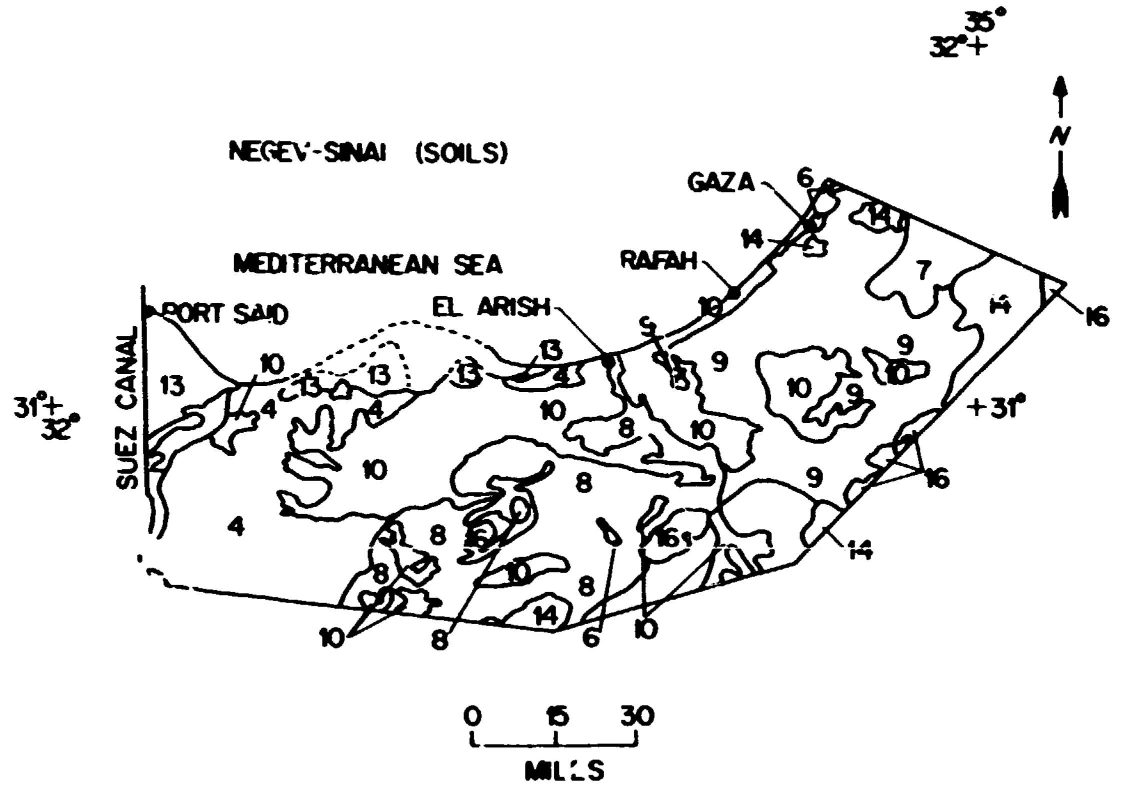

Fig. 11. Soils of the Sinai-Negev Area Along the Mediterranean Sea. Soils of the area include Terra Rosa-Rendzina complex (7), gravelly red desert (8), and reddish brown (9). The reddish-brown soil of this area is largely on rolling terrain. Other soils include sandy red desert associated with dunes (4), noncalcic brown soils (6), shifting sand dunes (10), salt marsh (13), and lithosols (14, 16).

case of the Sinai-Negev locale, many of the agricultural products can certainly be consumed locally within Egypt, Israel, and various other Middle-Eastern countries. Following the pattern of Israel's agricultural exports, high-value crops such as citrus and out-of-season vegetables can most likely be marketed in the countries of the European Economic Community and of the European Free Trade Association.

C. Industrial Considerations

1. Mineral Resources. – Mining assets are not especially bountiful in the southeastern Mediterranean area. Large quantities of good coal are yet to be discovered, bauxite is absent, only limited amounts of iron ore are present, and even oil and gas reserves have hitherto been found only in limited quantities in some countries such as Israel. However, marine rocks in the desert areas of the region have been found to hold valuable nonmetallic minerals such as phosphate, sulfur, and salt. The major mineral resources along this Mediterranean region are shown in Fig. 10.

a. Bauxite. – As far as could be ascertained by this study no deposits of bauxite have been discovered in the southeastern Mediterranean area.

b. Phosphate Rock. – Substantial deposits of phosphate rock are located approximately 60 miles from the Sinai-Negev locale in the Negev Desert of southern Israel. This deposit, now known as the Oron field, is situated some 30 miles southeast of the town of Beersheba. This deposit has not yet been studied in close detail, but its general outline has now been mapped. The phosphate formation covers a strip 20 miles long and from 1 to 2½ miles wide. In many places the phosphate layers crop out on the surface, but elsewhere they are covered by an overburden of various thicknesses. The main phosphate layer is 2 to 3 m thick, which seems to be characteristic of phosphate beds the world over.

The main phosphate bed is not uniform but shows variation in phosphate content. The variation in P_2O_5 content is usually between 24 and 26%, but occasionally a figure as high as 30% is encountered. No definite figures are as yet available on the total exploitable phosphate reserves, because only about 5% of the entire area has been explored in detail. Within this limited area there is evidence of 2 to 3 million tons of phosphates, averaging about 25%. The total reserves in the entire Oron field may be estimated conservatively at about 100 million tons, but part of this reserve can be exploited only by underground mining.

Other deposits of phosphate are known to exist in the United Arab Republic at Al Tur in southern Sinai and along the west shore of the Red Sea at Um Huweitat and Hemadat. The quantity and quality of these deposits were not ascertained during the course of this study.

c. Iron Ore. – In recent years small deposits of iron of intermediate quality have been discovered in Israel in the Negev and in Galilee. The iron content of these deposits varies between 28 and 65%. The deposit in the Negev is located in the Arava Valley, and the quantity of this reserve is negligible. The Galilee deposit is located near Qiryat Shemona, but no way has yet been found for its exploitation. The total estimated reserve for the whole of Israel is only 40 million tons.

In the United Arab Republic, deposits of iron of unknown quantity and quality are said to exist in southern Sinai at G Abu Mas'uD and along the western shore of the Red Sea at W'Araba, W. Dib, Abu Marwa, and Abu Geiida.

d. Coal. – Coal is absent in Israel, but significant quantities have been found in the United Arab Republic. In recent years coal has been found in Egypt at Ayoun Moussa, Baraa, and Thur, where reserves are estimated at 55 million tons. The Safa mine in the Maghara area of Sinai, 90 km southwest of El Arish, was inaugurated in July 1964. In 1966 it produced 15,000 tons, and it is estimated that production will rise to 620,000 tons in 1970 following exploitation of the neighboring areas containing an estimated 40 million tons.

e. Natural Gas and Oil. – Israel has a limited supply of oil and natural gas. Present production is only sufficient to provide about 10% of the oil consumed. Oil was first found in 1955 at Heletz in the northern Negev, where 28 producing wells have been drilled. The annual output is more than 150,000 tons. Reserves at Heletz are estimated at 15 million barrels. In 1963 at Kochar (adjacent to Heletz) an oil well was brought in with a production of 240 to 300 bbl/day. Israel's natural gas deposits are located at Rosh-Zohar, near the Dead Sea. Israel's proven reserves of natural gas are placed at 1.5 million tons of oil equivalent.

In Egypt small but insignificant oil fields have been worked for a long time along the western shores of the Gulf of Suez. In 1949, larger oil fields were discovered at Sudr and Asl along the eastern shores of the Gulf of Suez a few miles south of the city of Suez. The reserves were not ascertained in the course of this study.

f. Limestone. – In Israel, limestone exists in most parts of the country and is sufficient for the present needs. The Arad region in the northeastern Negev presently produces limestone for use in cement. Limestone is found in large quantities in Egypt at Moqattam and Hulwan, immediately south of Cairo, and along the Nile between Cairo and Asyut.

g. Gypsum. – Gypsum is plentiful throughout the southern Negev portion of Israel and in the Sinai peninsula of Egypt both north and south of the town of Suez.

Perhaps the largest deposit of gypsum in the Sinai-Negev area is located at Wadi Ramon, 45 miles south of Beersheba in the southern Negev. The gypsum beds in the Wadi Ramon extend over a distance of more than 10 km and in places reach a thickness of over 50 m. For the purposes of exploitation, it may be stated that these deposits are practically unlimited. The gypsum of the Wadi Ramon in its natural state is exceptionally pure. The average chemical analysis of a considerable number of representative samples has shown a gypsum content of 90 to 95%.

2. **Transport Facilities.** – *a. Rail.* – In Israel, road transport has in the past taken precedence over rail transport, but an effort is presently being made to improve rail transportation. In 1965 the total length of track in operation was only 430 miles. All the lines in operation are standard gage (4 ft 8½ in.). The main flow of traffic is from the port of Haifa and from the oil installations and industrial centers in the vicinity of Haifa and of minerals from Beersheba to the north. Most of the citrus destined for export is shipped by rail to Haifa. The bulk of the freight traffic consists of grain, cement, building materials, citrus, minerals, and oils. There is a single-track line that connects the Suez Canal and Israel by way of northern Sinai.

b. Water. – The Sinai-Negev locale is situated almost equidistant between two already established ports, Port Said, at the northern end of the Suez Canal, and Ashdod, in Israel a few miles from the Gaza Strip. Port facilities between Port Said and Ashdod are nonexistent, and development appears to be restricted by prohibitive maintenance and construction costs due to shoaling and shifting sandbars adjacent to the coast. Also, in some areas, cliffs rise abruptly from the sea to heights of 70 ft.

Port Said, Egypt's third largest port, lies about 90 miles west of El Arish and occupies both sides of the canal at its junction with the sea. In 1963 there were no wharves available for deep-draft vessels, although one was under construction and is perhaps completed by this time. All cargo is transferred by lighters. Numerous mooring berths are provided throughout the harbor and can accommodate vessels up to 850 ft long.

Because shipping is so decisive for Israel's links with the outside world, great efforts have been made for the rapid enlargement of her port capacity. The port of

Ashdod, some 75 miles from El Arish, is one of two new port facilities that have been started in recent years in order to boost the cargo-handling capacity of Israel. Ashdod was scheduled to be completed by 1966 or 1967 and was to have a handling capacity of 2.5 million tons.

3. **Power Grid Availability.** – In 1964, the United Arab Republic had a total installed electric generation capacity of 1340 MW(e), of which 74% was thermal and 26% hydroelectric.

With the completion of the Aswan High Dam in 1970 the installed capacity will be increased by 2100 MW(e). The power stations are interconnected in the lower Nile area, but many stations still remain unconnected to a power grid. The Sinai-Negev area is served by thermal power stations with no connection to the main grid.

In 1965, Israel had a total installed generating capacity of 740 MW(e), all thermal. Table 4 shows the installed capacity and power production for 1965.

The government of Israel has forecast that the maximum electric power demand will increase from 740 MW(e) in 1965 to 1110 MW(e) in 1970 and 1630 MW(e) in 1975. This forecast is based on detailed analyses of the expected consumption pattern of the main consumer groups up to 1975. The electric power for the Israel transmission and distribution network is generated in three thermal power stations using heavy fuel oil. The stations are located at Haifa, Tel Aviv, and Ashdod.

4. **Industrial Markets.** – The marketing of industrial products would perhaps follow the same pattern as that for agricultural products. A ready market for aluminum and fertilizers should exist in the various Mediterranean countries of north Africa and the Middle East. High-value products should find an outlet in the countries of the European Economic Community and of the European Free Trade Association.

3. INDUSTRIAL-ONLY LOCALES

A detailed examination for suitable industrial-only locales was not carried out by the study group due to time and manpower limitations; however, a number of potentially suitable areas were considered, with special consideration being given to sites in the general area of the agro-industrial locale. In addition, some information was developed on two special condition sites, one in Morocco and one in Florida. The following presents comments on the several potential locales.

3.1 Australia

An industrial complex located near Perth would have several advantages over the Sharks Bay locale investigated for an agro-industrial complex. Perth has a grid of about 350 MW(e) as a source and sink for power. The area is the largest market in Western Australia. The port of Fremantle (port for Perth) handled almost 4 million tons of cargo in 1964 and could be expanded to accommodate the complex. Railroads to the nearby mining areas are well developed, including those to the bauxite mines located in the Darling Range about 100 miles southeast of Perth. Reserves in this field are estimated at 80 million tons.

If one were to locate a complex more advantageously with respect to the primary resources bauxite and phosphate rock, an alternate locale might be in northern Queensland. Large bauxite deposits are present at Weipa on the York Peninsula, and a large deposit of phosphate rock has been found in northwestern Queensland 300 miles south of the Gulf of Carpentaria (Fig. 2). A complex located at the southern end of the Gulf of Carpentaria would be relatively near both of these prime raw materials. Tradeoff studies would have to be conducted to determine the most favorable location between the bauxite and the phosphate rock. The area is essentially undeveloped, with no power grid, connected rail network or adequate harbor facilities. The area is devoid of markets in the immediate vicinity, and essentially all products would be shipped out via a harbor, which would have to be constructed as part of the project. Characteristics of the sites of Perth and of the Gulf of Carpenteria are given in Table 11.

3.2 India

The locale on the Kutch Peninsula suffers from many of the same disadvantages as are present in the Sharks Bay, Australia, locale – the absence of developed transport facilities, of a power network, and of nearby market areas. Though some bauxite is available in Kutch, the deposits there are not large, and it appears that bauxite would come from the Saurashtra region of Gujarat across the Gulf of Kutch (Fig. 4). A major disadvantage of the Kutch locale is the absence of native phosphate rock. The nearest rock deposits appear to be the new discoveries in the Mussoorie area;[8] however, these are not of high quality. These deposits are approximately 1000 miles inland from Kutch, and the cost of transporting the rock would make it difficult to compete with rock obtainable by ship from world sources. Although India is a large market for

[8] A significant phosphate deposit has been discovered recently in Rajasthan; see ref. 6.

Table 11. Features of Industrial-Only Locales

Locale	Principal Sources of Primary Resources: Coal — Present Source	Coal — Approximate Distance from Locale (miles)	Oil and Gas — Present Source	Oil and Gas — Approximate Distance from Locale (miles)
Australia				
Gulf of Carpentaria	Queensland	550	Queensland	550
Perth	Collie	100	Gingin	50
India				
Ganges Plain	Bihar	750	Assam	1250
Florida	Alabama	400	Louisiana	500
Morocco	Atlas Mountain	100	Algeria	700
Peru				
Lima	Pasco	150	Piura	500
Piura	La Libertad	150	Piura	50

Locale	Bauxite — Present Source	Bauxite — Potential Source	Bauxite — Approximate Distance (miles)	Phosphate rock — Present Source	Phosphate rock — Potential Source	Phosphate rock — Approximate Distance (miles)
Australia						
Gulf of Carpentaria	Weipa		350	Nauru Island		2300
					Mary Kathaleen	250
Perth	Darling Range		125	Christmas Island		2300
India						
Ganges Plain	Bihar		750	Morocco		8700
				Tunisia		6950
					Mussoorie	Local
Florida	Jamaica		1900	Tampa Area		Local
Morocco	Surinam		4400	Khouribga		75
Peru						
Lima	Surinam		3800	Sechura		500
		Sechura	500			
Piura	Surinam		3300	Sechura		Local
		Sechura	Local			

Locale	Power Grid	Transport Facilities — Rail	Transport Facilities — Water
Australia			
Gulf of Carpentaria	Absent	No railroad connecting mineral deposits with locale; there are three short stretches of semi-narrow-gage railroad in the vicinity of the phosphate rock and one connecting the area with the port of Townsville on the east coast of Queensland	No harbor facility
Perth	320 MW (1965)	Good railroad net connecting Perth with mining areas	Good port facilities at Perth
India			
Ganges Plain	560 MW (1965)	Good rail network	Poor river transport facilities on the Ganges
Florida	5000 MW (1960)	Good rail network	Port facilities at Tampa
Morocco	370 MW (1965)	Standard-gage railroad connecting phosphate deposits with Casablanca and Safi	Good port facilities at Casablanca and Safi
Peru			
Lima	1000 MW (1965)	Small railroad network present	Good port facilities at Callao
Piura	Absent	No rail connection with phosphate	Port facilities at Talara and Paita

fertilizer products, the cost of transport of fertilizer products from a remote locale in Kutch to those areas which are heavy consumers of fertilizer would limit the potential market area for rail shipment of the product. This was illustrated in ORNL-4290, which showed the effect of shipping ammonia as a function of transport costs and the potential cost advantage of a complex over smaller, less efficient individual plants. The harbor potential along much of the Kutch coast is not considered to be good, although the nearest developed port, Kandla, might be expanded to meet the needs.

Alternative locations within India for an industrial complex appear to be those located nearer either market areas or raw material deposits. As shown in Fig. 4, bauxite is found throughout much of India, and deposits located nearer population centers with developed harbor, transport facilities, and power networks would be more promising. Such conditions exist near Bombay on the west coast and near Calcutta on the east. Distribution of products within India would probably require shipment of fertilizer from the Kutch complex via ocean carrier to the major ports of India for subsequent redistribution to surrounding areas. Thus a complex located at the distribution point would have a definite market advantage.

A major consuming center for fertilizer in India lies in the Indo-Gangetic Plain. It therefore appears reasonable to consider locating an industrial complex somewhere in this area to reduce the transport costs for fertilizer products. The presence of phosphate rock deposits in Uttar Pradesh near Mussoorie suggests that a plant located near this area might have an economic advantage; however, the grade of the rock is believed to be poor. The market area associated with Delhi and the power grid in the vicinity provide further advantages. Consideration of competing energy sources from hydroelectric facilities would be required. A plan for a nuclear complex in the Ganges Plain has been suggested by P. R. Stout of the University of California, who proposes nuclear power for pumping and distributing water and for fertilizer production, mainly nitrogen.[9] A major disadvantage of locating in this area is that the transport of all products would be by rail, and if market areas are not nearby, the transport costs may erase the initial competitive advantage of the complex (see Table 11). The transport of products by barge on the river systems of the area is at present not feasible. The river transport system in India is severely handicapped in general by the shallow draft limitations on barge shipments. Much of the Ganges River, for instance, is limited to 3- and 4-ft draft limits; however, future possibilities such as the use of air-cushion boats might conceivably help the transport picture.

3.3 Mexico

The Baja California locale selected for the agro-industrial complex does not appear to have many advantages as a location for an industrial-only locale (Fig. 6). There are no known phosphate rock or bauxite deposits in the peninsula, and there is no rail or power network in the area. However, the area selected appears to have very good potential for the development of deep-water port facilities. In general, Mexico appears to have little in the way of native phosphate rock or bauxite deposits. These raw materials would have to be shipped in. Areas located near major markets and developed harbor and transport facilities would appear to be more promising.

3.4 Peru

The agro-industrial locale in the Sechura Desert region is directly adjacent to very large phosphate rock deposits currently under development. The region north of Sechura contains Peru's largest petroleum fields, and Talara, in the Piura Department, has Peru's leading refinery (see Fig. 8). Large quantities of natural gas are present around Pucallpa, across the Andes some 450 to 500 miles from the Sechura locale, and naphtha could be produced at Talara as a potential competitive source for hydrogen by steam-naphtha reforming. The area at present has no established power network or rail facilities. The nearest large market area is Lima, some 500 miles down the coast.

A recent announcement on the development of the phosphate deposits indicates deposits of over 600 million tons of recoverable ore. Expenditures on development of port facilities at Bayovar are being planned.

A facility located near Lima, in contrast to the Sechura district, would benefit from the nearby market and from an established power network (Table 11). The port facilities at Callao could be expanded to accommodate the requirements of the complex, and currently the port is undergoing an extensive expansion and modernization program. Phosphate rock would have to be shipped down the coast to the complex.

Peru may not be the most favorable location for large production of aluminum because raw material would have to be shipped in and the present local market for

[9] P. R. Stout, *Potential Agricultural Production from Nuclear-Powered Agro-Industrial Complexes Designed for the Upper Indo-Gangetic Plain*, ORNL-4292 (November 1968).

aluminum is small. Currently there is no indigenous production of the metal. It is probable that an industrial-only complex in Peru would not include major production of aluminum as part of the complex.

3.5 Sinai-Negev

In common with the other agro-industrial locales, the Sinai-Negev is not directly adjacent to large market areas. The presence of phosphate rock some 80 miles from the locale is favorable, but bauxite is not locally available and would have to be shipped in. It seems highly unlikely that a large complex would be installed in this area without producing substantial quantities of water for municipal, industrial, and agricultural use.

3.6 Other Locales

Table 11 is a summary of some of the principal industrial parameters for three of the five industrial locales discussed. Also included in the table is information for two additional areas which were suggested to the study group during the course of its work. The Florida locale suggested is situated near Tampa, in the heart of the large phosphate rock deposits. The area is well developed, with good rail facilities and a large port facility at Tampa. The power grid in the area is large. Bauxite or alumina is currently imported through the port from Jamaica and Surinam.

The locale in Morocco would utilize the very large phosphate rock deposits of the area and the port facilities of Casablanca or Safi. Bauxite or alumina would have to be imported, probably from Surinam. Currently, the shortage of water imposes a limitation on the development of industrial activity in Morocco.

4. CONCLUSIONS AND RECOMMENDATIONS

This study on locale selection, accommodation, and implementation was necessarily of a preliminary nature. Nevertheless, as a result of the work carried out, a number of conclusions and recommendations can be enumerated.

1. A number of areas in the world, presently neither agriculturally nor industrially fruitful, can be made productive through the implementation of the agro-industrial concept.

2. It appears that some of these areas can be made agriculturally productive on a year-round basis provided the crop variety selected and its management are tailored carefully to the local climate.

3. Agricultural requirements impose significant limitations on the number of locations which can be considered for an agro-industrial complex. Many locales suitable for the agro-industrial complex would not be selected for an industrial complex and vice versa.

4. In the context of this study with its nuclear viewpoint, the locales suitable for an industrial complex would not have extensive fossil fuel or hydro energy sources, but they would take advantage of other natural resources and industrial markets. The basic ideas, however, for industrial and agro-industrial complexes would apply for locales having cheap and abundant fossil fuel, provided due consideration is given to the type of industrial processes used. The number of potential locales open to an industrial complex appears to be much greater than for an agro-industrial complex.

5. Additional information on the agricultural parameters, such as soils, topography, climate, crop water requirements, and water storage possibilities, as well as labor quality and availability, are required before a satisfactory final evaluation of an individual locale can be carried out.

6. The problems of markets and transport of agricultural products suggest much more detailed consideration of on-site food handling and processing.

7. The special study of markets, resources, and transport media, as well as the potential benefits derived, should be more regionally oriented, as opposed to the individual nation concept adopted for this study, to adequately reflect the influence of areas adjacent to the locales.

8. Additional consideration of the utilization and contribution of marine resources to the operation of an agro-industrial complex may yield extra benefits.

9. Much creative thinking is needed concerning the social, political, cultural, and financial problems of implementation for each locale and the ultimate effects on the host country.

Appendix A

POPULATION AND AREAS OF COASTAL DESERT REGIONS

H. E. Goeller

This Appendix summarizes accumulated and calculated data on areas and present and estimated future populations of the 37 nations with coastal deserts. Many of these nations have deserts along their entire coasts; others, particularly India and the United States, have only short coastal desert zones in which only a small part of their total population lives. In order to provide data of greater value, areas and population were broken down to the state or province level for nations with larger populations (>1,000,000). Area and population data are also given for 18 islands and island groups.

Table A.1 gives 1965 populations, areas, and population densities for all the areas evaluated. Province populations and areas are also given as percentages of the various national totals. Finally, values are presented for lengths of desert coasts, average depth from coast, and population density per mile of coast. Figures A.1 to A.3 show the locations of all listed nations and provinces.

Table A.2 provides population growth rates and estimates of future populations at five-year intervals through the year 2000 for all of the coastal desert nations; the nine nations of the Arabian peninsula are treated here as a single nation. The data at the left of Table A.2 are for coastal desert provinces only, and at the right for the entire nation. Several countries have been divided into two areas, rural and urban. The urban areas have been taken as metropolitan districts with over 1 million people and include Karachi, W. Pakistan; Casablanca, Morocco; Lima-Callao, Peru; the Nile Delta; and the southwestern corner of the United States (lower nine counties of California and Yuma County, Arizona). Totals for desert province regions include a rural and an urban total as well as the overall total. Urban population growth rates were assumed to be 20% higher than that of the particular nation. Totals for overall nations are given both with and without India and the United States, since both of these countries have very large populations, of which only a very small part is in a coastal desert region.

Table A.3 indicates the extent of present and future world coastal desert population as percent rural vs urban, percent of the containing nations, and percent of world population. Between 1975 and 2000 the percent rural remains fairly steady at about 62%. Excluding the United States and India, the desert provinces contain about 32% of the population of the nations of which they are a part. When the total populations of the United States and India are included, this value drops to 10 or 11%. Coastal desert provinces constituted 3.0% of the world population in 1965 and are estimated to constitute 3.6% in the year 2000. Excluding India and the United States, coastal desert nations now (1965) contain 9.2% of the world population; they are expected to increase to 11.7% by 2000. Including India and the United States the values are 30.0 and 31.8% respectively.

Table A.4 gives area, population, and population density data on 18 islands and island groups. These islands, all with 1965 populations of 100,000 or more and population densities greater than 100 persons per square mile, were selected from a list of 81 island groups as those most likely to require supplementary water before the year 2000 for municipal, industrial, and possibly limited agricultural use.

Table A.5 gives present and estimated future population data on a number of coastal desert cities. Both city and greater metropolitan area values are provided for some of the larger cities. Population growth rates 20% higher than those for the nations concerned were used because of rapid worldwide urbanization trends.

Table A.1. Data on Area and Populations of Coastal Desert Provinces

Country and Province	Population (1965)	Area (sq miles)	Population Density (people/sq mile)	Percent of National Population	Percent of National Area	Miles of Coast	Average Depth of Province (miles)	Persons per Mile of Coast
India								
Gujarat	22,655,000							
Kutch[a]	825,000	16,724	50	0.17	1.3	175	96	8600
Saurashtra[a]	4,542,000	21,451	212	0.95	1.7	400	54	83,500
Total	5,367,000	38,175		1.12	3.0	575		
West Pakistan								
Hyderabad	3,335,000	35,998	92	6.9	11.6	90	400	37,000
Kalat	839,000	98,975	8.5	1.7	31.9	320	310	2,620
Subtotal	4,174,000	134,973		8.6	43.5	410		
Karachi	2,100,000	812	2580	4.3	0.3	40	20	50,000
Total	6,274,000	135,785		12.9	43.8	450		
Iran								
Kerman	2,519,000	~130,000	19.4	10.9	20.4	400	325	6300
Fars	1,610,000	~80,000	20.1	7.0	12.5	500	160	3220
Khuzistan	1,486,000	~23,000	64.6	6.4	3.6	100	230	14,860
Total	5,615,000	233,000	24.1	24.3	36.5	1000		
Iraq								
Basra	541,000	4,747	114	7.7	2.7	30	160	18,000
Arabia								
Kuwait	405,000	6,200	65	100	100	90	69	4,500
Saudi Arabia (E)	2,000,000	400,000	5	100	100	325	(375)	5,160
Saudi Arabia (W)	5,000,000	430,000	11.6	100	100	1150	374	4,360
Bahrein	166,000	231	72	100	100	100	2.3	1660
Qatar	65,000	8,500	7.6	100	100	225	38	290
Trucial Oman	120,000	32,300	3.7	100	100	475	68	250
Muscat & Oman	580,000	82,000	7.1	100	100	1070	78	550
South Arabia	1,050,000	111,000	9.4	100	100	750	148	1,400
Aden	250,000	75	330	100	100	~10	7	25,000
Yemen	5,000,000	75,300	66	100	100	275	274	18,200
Total	14,636,000	1,145,606	12.8	100	100	4500	(250)	3,250
Jordan	1,900,000	37,738	50	100	100	10		
Israel[b]	2,520,000	7,992	315	100	100	120		
Somalia								
North	780,000	67,997	11.4	33	27.5	500	136	1,560
South	1,570,000	178,201	8.8	67	72.5	1300	136	1,200
Total	2,350,000	246,201	9.5	100	100	1800		
French Somaliland (Afars and Issas)	80,000	8,500	9.4	100	100	100	85	800

Table A.1. (continued)

Country and Province	Population (1965)	Area (sq miles)	Population Density (people/sq mile)	Percent of National Population	Percent of National Area	Miles of Coast	Average Depth of Province (miles)	Persons per Mile of Coast
Ethiopia								
Eritrea	1,300,000	45,946	28.2	6	10.1	520	88	2500
Sudan								
Kassala	1,220,000	131,528	9.3	9.1	13.6	420	310	2900
Egypt								
Red Sea	37,818	~77,200	0.5	0.13	~20	550	140	70
(Sinai, Red Sea) (Sinai, Medit.)	130,849	~19,200	6.9	0.45	~5	{ 350 120 }	41	300
Matruh	123,707	~38,600	3.2	0.42	~10	300	129	410
Subtotal	292,374	135,000	2.2	1.00		1320		
Nile Delta	21,051,245	~10,000	2100	73	~2.6	150	67	140,000
Total	21,343,619	145,000	147	74		1470		
Libya								
Cyrenacia	422,000	350,000	1.2	28	52	600	580	700
Tripolitania	1,080,000	110,000	9.8	71	7	450	240	2400
Total	1,502,000	460,000	3.3	99	59	1050		
Tunisia								
Medenine	212,000	~9200	23.0	4.6	19.0	50	184	425
Gabes	234,000	~21,000	11.1	5.1	43.5	50	420	470
Tozeur	123,000	~5200	23.6	2.7	10.8	0		
Total	569,000	38,400	14.8	12.4	73.3	100		
Morocco								
Casablanca	2,936,000	~9500	310	22.3	5.5	130	73	22,600
Marrakech	2,633,000	~16,700	158	20.0	9.7	180	93	14,600
Agadir	923,000	~22,200	42	7.0	12.9	175	127	5,300
Southern	~13,000	12,696	1	0.1	7.4	140	91	93
Total	6,505,000	61,100	106	50.4	35.5	625		
Spanish Africa								
Ifni	51,000	580	88	100	100	25	23	2040
Spanish Sahara	45,000	102,700	0.4	100	100	550	187	8
Total	96,000	103,300	0.9			575		
Mauritania	1,000,000	397,685	2.5	100	100	400	1000	2500
Senegal								
North[c]	1,000,000	38,000	26	28	50	225	170	4450
Angola								
Luanda	389,000	64,432	6.0	7.6	13.4	200	320	1,950
Cuanza Sul	454,000	17,317	26	8.9	3.6	110	157	4,120
Benguela	537,000	15,042	37	10.5	3.1	170	88	3160
Mocamedes	49,000	13,259	3.7	1.0	2.8	250	53	196
Total	1,429,000	110,050	13	28.0	22.9	730		

Table A.1. (continued)

Country and Province	Population (1965)	Area (sq miles)	Population Density (people/sq mile)	Percent of National Population	Percent of National Area	Miles of Coast	Average Depth of Province (miles)	Persons per Mile of Coast
Southwest Africa	555,000	318,261	1.7	100	100	850	375	650
South Africa[d]								
Cape Colony, West	~1,000,000	~100,000	10	17	36	450	220	2,220
Malagasy								
Tulear	1,105,000	75,208	14.9	15.7	33.3	700	107	1,580
Australia						{ ~1300		
Western	814,000	975,920	0.8	7.2	33	{ 450	560	465
South	1,042,000	380,070	2.7	9.2	12.8	500	760	2,100
Total	1,856,000	1,355,990	1.4	16.4	45.8	2250		
United States	9,072,000					260		
Mexico								
Sonora	887,000	70,484	12.6	2.2	9.2	550	128	1,610
Baja California, N	599,000	27,655	22	1.5	3.6	700	40	860
Baja California, S	96,000	27,979	3.4	0.2	3.7	1,050	26	91
Total	1,582,000	126,118	12.6	3.9	16.5	2,300		
Peru								
Tumbes	36,000	1,827	19.7	0.3	0.4	75	24	480
Piura	510,000	12,767	40	4.4	2.6	220	58	2,320
Lambayaque	272,000	8,973	30	2.4	1.8	90	99	3,000
La Libertad	546,000	6,404	85	4.7	1.3	140	46	3,900
Ancash	616,000	14,019	44	5.4	2.8	120	117	5,140
Ica	188,000	8,205	23	1.6	1.7	170	48	1,100
Arequipa	364,000	24,528	14.9	3.2	4.9	275	89	1,320
Moquegua	48,000	6,245	7.7	0.4	1.3	50	125	960
Tacna	51,000	5,701	9.0	0.4	1.1	60	95	850
Lima and Callao	1,105,000	13,087	85	9.6	2.6	230	57	4,800
Subtotal	3,736,000	101,736	37	32.4	20.5	1,430		
Lima and Callao City	1,877,000	~100	~18,000	16.3	0.1	10		
Total	5,613,000	101,856	55	48.7	20.6	1,440		
Chile								
Tarapaca	141,000	21,346	6.6	1.7	7.3	210	101	670
Antofagasta	247,000	47,515	5.2	2.9	16.3	330	144	750
Atacama	132,000	30,843	4.3	1.6	10.6	220	140	600
Coquimbo	353,000	15,401	23	4.2	5.3	200	77	1,770
Aconcagua	161,000	3,940	41	1.9	1.4	30	131	5,400
Total	1,034,000	119,045	8.7	12.3	39.9	990		

Table A.1. (continued)

Country and Province	Population (1955)	Area (sq miles)	Population Density (people/sq mile)	Percent of National Population	Percent of National Area	Miles of Coast	Average Depth of Province (miles)	Persons per Mile of Coast
Argentina								
Tierra del Fuego	10,000	7,996	1.2	0.1	1.0	270	30	37
Santa Cruz	59,000	77,843	0.8	0.3	7.2	550	141	107
Chubut	148,000	65,669	2.3	0.7	6.1	450	146	330
Rio Negro	46,000?	78,220	0.6?	0.3?	7.3	200	390	230
La Pampa	439,000	55,[illegible]03	8	2.1	5.1	0		
Total	702,000	284,831	2.5	3.5	26.7	1,470		
						25,200		

[a]Subprovince of Gujarat

[b]Excluding Post '67 Occupied Areas.

[c]Area north of Dakar.

[d]West Cape Colony referred to Cape Colony, not total South Africa.

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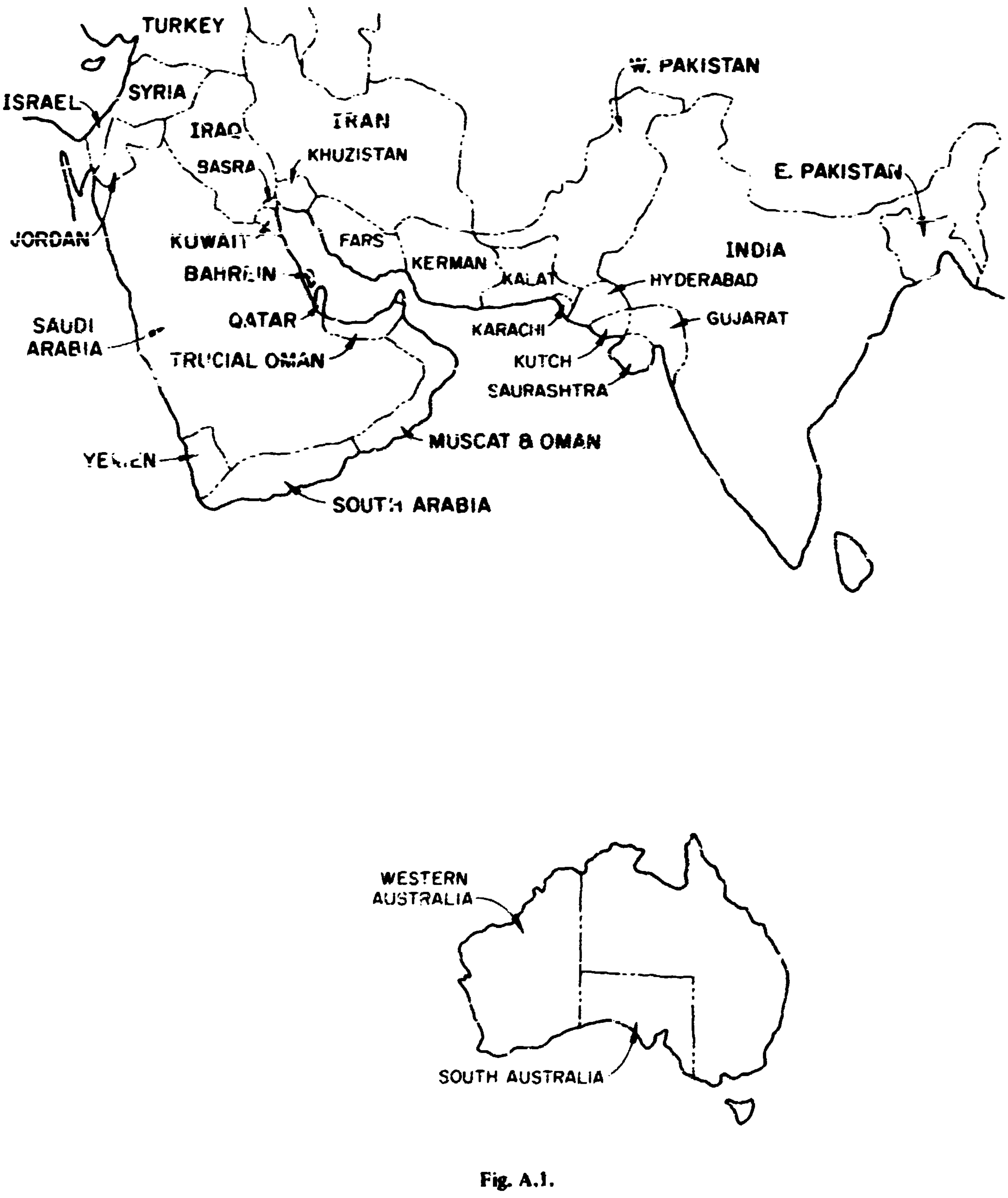

Fig. A.1.

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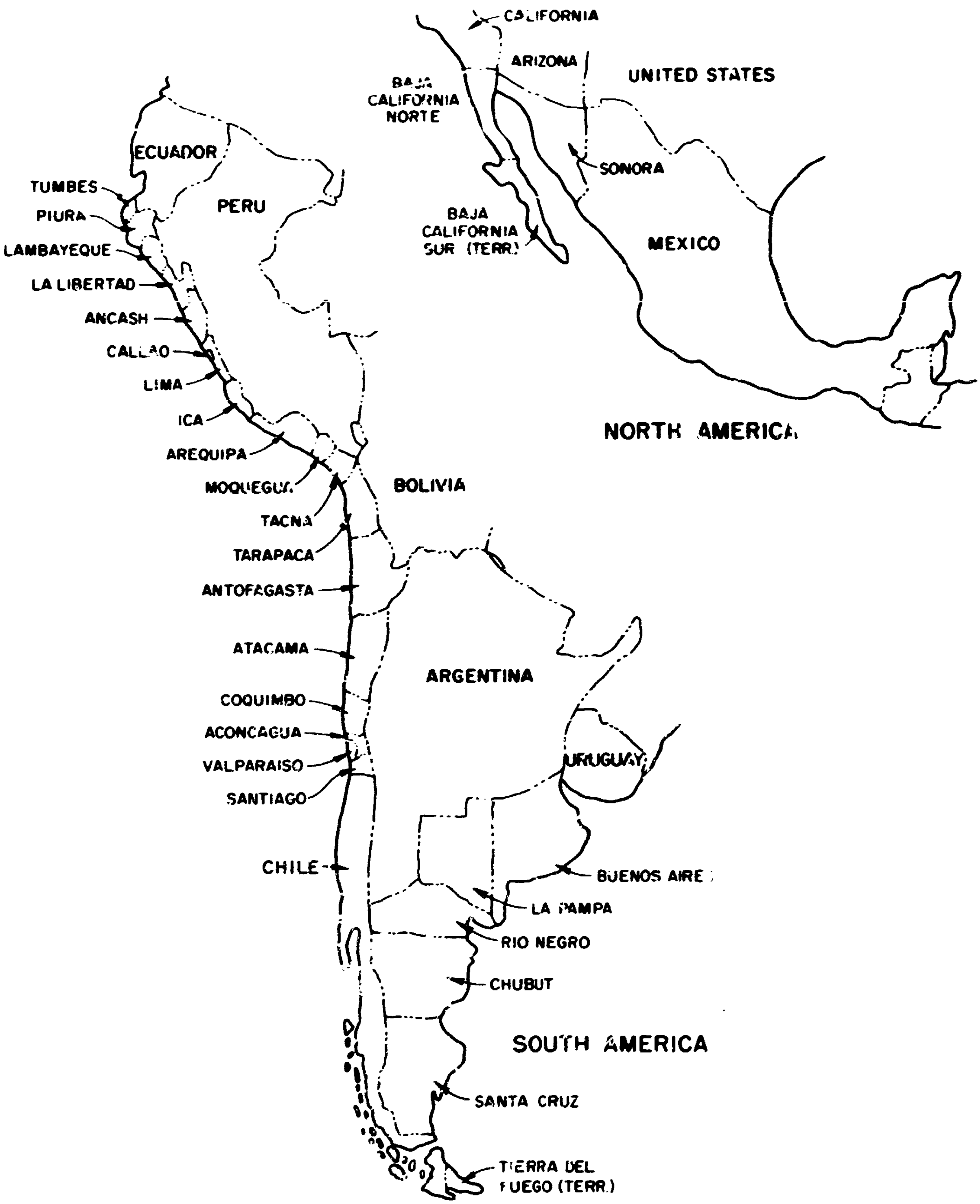

Fig. A.2.

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Fig. A.3.

Table A.2. Present and Estimated Future Populations of Provinces and Nations with Coastal Deserts

All values × 10^3

	Population (1965)	Increase (%/year)	Estimated Population of Coastal Provinces in 1970	1975	1980	1985	1990	1995	2000
India	5,367	2.1	5,955	[illegible]	7,330	8,133	9,023	10,011	11,108
W. Pakistan	4,171	2.8	4,792	5,501	6,315	7,250	8,323	9,555	10,969
Karachi	(2,100)	(3.36)	(2,477)	(2,922)	(3,448)	(4,067)	(4,798)	(5,660)	(6,677)
Iran	5,615	2.65	6,399	7,293	8,312	9,474	10,798	12,306	14,025
Iraq	541	2.3	606	679	761	853	203	1,070	1,199
Arabia	14,636	2.3	16,416	18,417	20,620	23,184	26,016	29,194	32,768
Jordan	1,900	2.3	2,129	2,385	2,672	2,994	3,355	3,757	4,211
Israel	2,520	1.6	2,728	2,954	3,197	3,462	3,748	4,057	4,392
Somalia	2,350	2.3	2,633	2,950	3,305	3,703	4,149	4,649	5,209
Fr. Somalia	80	2.3	90	100	113	126	141	158	177
Ethiopia	1,300	2.3	1,457	1,632	1,828	2,049	2,295	2,572	2,881
Sudan	1,220	3.32	1,436	1,691	1,991	2,345	2,760	3,250	3,827
Egypt	292	2.8	335	385	442	507	582	668	767
Nile Delta	(21,051)	2.8	(24,167)	(27,744)	(31,850)	(36,564)	(41,975)	(48,187)	(55,273)
Libya	1,520	2.8	1,724	1,980	2,273	2,609	2,995	3,429	3,949
Tunisia	569	2.1	631	700	777	862	957	1,061	1,178
Morocco	3,569	2.74	4,085	4,676	5,353	6,128	7,015	8,030	9,192
Casablanca	(2,936)	(3.28)	(3,450)	(4,054)	(4,763)	(5,597)	(6,576)	(7,727)	(9,079)
Span. Africa	96	2.8	111	126	145	167	192	220	252
Mauritania	1,000	2.8	1,148	1,318	1,513	1,737	1,994	2,290	2,629
Senegal	1,000	2.66	1,140	1,300	1,482	1,690	1,927	2,197	2,505
Angola	1,429	1.7	1,555	1,691	1,840	2,002	2,178	2,369	2,578
S.W. Africa	555	2.5	628	710	804	909	1,029	1,164	1,317
South Africa	1,000	2.5	1,132	1,281	1,449	1,640	1,855	2,099	2,375
Malagasy	1,105	2.3	1,238	1,387	1,554	1,732	1,951	2,186	2,449
Australia	1,856	1.29	1,979	2,110	2,249	2,398	2,557	2,726	2,907
Peru	3,736	2.95	4,321	4,997	5,779	6,683	7,729	8,939	10,338
Lima	(1,887)	(3.54)	(2,246)	(2,672)	(3,180)	(3,784)	(4,503)	(5,358)	(6,376)
Chile	1,034	2.17	1,151	1,281	1,427	1,588	1,768	1,969	2,192
Argentina	702	1.35	750	803	858	918	981	1,049	1,122
Mexico	1,582	3.54	1,883	2,240	2,666	3,172	3,775	4,492	5,346
United States	(9,072)	(1.18)	(9,620)	(10,211)	(10,818)	(11,471)	(12,164)	(12,899)	(13,678)
Rural Areas	60,748		68,452	77,193	87,055	98,315	110,296	125,479	141,862
Urban Areas	37,046		41,960	47,603	54,059	61,483	70,160	79,831	91,083
Total	97,794		110,412	124,796	141,114	159,798	180,312	205,312	232,945

	Population (1965)	Increase (%/year)	Estimated Population of Countries in 1970	1975	1980	1985	1990	1995	2000
India	479,000	2.1	531,452	589,648	654,217	725,856	805,346	893,527	991,172
W. Pakistan	48,100	2.8	55,222	63,398	72,785	83,562	95,934	110,138	126,446
Iran	23,100	2.65	26,327	30,005	34,197	38,975	44,421	50,627	57,700
Iraq	7,050	2.3	7,899	8,850	9,916	11,110	12,447	13,946	15,626
Arabia	14,636	2.3	16,416	18,417	20,620	23,184	26,016	29,194	32,768
Jordan	1,900	2.3	2,129	2,385	2,672	2,994	3,355	3,757	4,211
Israel	2,520	1.6	2,728	2,954	3,177	3,462	3,748	4,057	4,392
Somalia	2,350	2.3	2,633	2,950	3,305	3,703	4,149	4,649	5,209
Fr. Somalia	80	2.3	90	100	113	126	141	158	177
Ethiopia	21,500	2.3	24,089	26,990	30,239	33,881	37,960	42,531	47,653
Sudan	13,350	3.32	15,718	18,507	21,790	25,655	30,206	35,564	41,873
Egypt	29,000	2.8	33,294	38,223	43,883	50,380	57,540	66,404	76,236
Libya	1,580	2.8	1,814	2,083	2,391	2,745	3,151	3,618	4,154
Tunisia	4,600	2.10	5,104	5,663	6,283	6,971	7,734	8,581	9,520
Morocco	13,150	2.74	15;053	17,231	19,725	22,580	25,847	29,588	33,870
Span. Africa	96	2.8	111	126	145	167	192	220	252
Mauritania	1,000	2.8	1,148	1,318	1,513	1,737	1,994	2,290	2,629
Senegal	3,480	2.66	3,968	4,524	5,159	5,883	6,708	7,649	8,722
Angola	5,125	1.7	5,576	6,066	6,599	7,190	7,811	8,498	9,245
S.W. Africa	555	2.5	628	710	804	909	1,029	1,164	1,317
South Africa	5,830	2.5	6,596	7,463	8,444	9,553	10,808	12,229	13,836
Malagasy	6,200	2.3	6,947	7,783	8,720	9,770	10,949	12,265	13,742
Australia	11,335	1.29	12,085	12,885	13,736	14,647	15,617	16,650	17,752
Peru	11,500	2.95	13,300	15,381	17,788	20,573	23,792	27,515	31,821
Chile	8,450	2.17	9,407	10,473	11,660	12,981	14,452	16,089	17,912
Argentina	22,200	1.35	23,738	25,383	27,142	29,023	31,034	33,185	35,485
Mexico	40,250	3.54	47,897	56,996	67,825	80,713	96,044	114,291	136,004
United States	193,850	1.18	205,560	217,978	231,146	245,109	259,916	275,617	292,267
Subtotal[a]	298,937		339,917	386,864	440,653	502,460	573,379	654,857	748,552
Total	971,751		1,076,929	1,194,490	1,326,016	1,473,425	1,638,635	1,824,001	2,032,191

[a] Less India and the United States.

Table A.3. Statistics on Present and Future World Coastal Desert Populations

	1965	1970	1975	1980	1985	1990	1995	2000
Coastal desert provinces								
Percent rural	62	62	62	62	62	61	61	61
Percent urban	38	38	38	38	38	39	39	39
Percent of nations excluding India and U.S.	33	32	32	32	32	31	31	31
Percent of nations including India and U.S.	10.1	10.3	10.4	10.6	10.8	11.0	11.3	11.5
Compared to world population								
Coastal desert provinces, percent of world	3.0	3.1	3.2	3.3	3.4	3.4	3.5	3.6
Coastal desert nations, percent of world								
Less India and U.S.	9.2	9.6	9.9	10.2	10.6	11.0	11.3	11.7
Including India and U.S.	30.0	30.3	30.5	30.8	31.0	31.3	31.5	31.8

Table A.4. Population Data for Selected Islands

Island	Location	Area (sq miles)	Population Density	1965	Increase (%/year)	Estimated Population (× 10³) in –						
						1970	1975	1980	1985	1990	1995	2000
				$\times 10^3$								
Azores	N.W. Africa	893	372	332	2.02	367	405	447	493	545	601	664
Balearic	Spain	1936	234	453	1.35	484	518	554	592	633	677	724
Barbados	Caribbean	166	1458	242	1.81	265	290	317	346	379	415	453
Canary	N.W. Africa	2808	358	1005	2.02	1109	1225	1353	1493	1649	1820	2009
Cape Verde	N.W. Africa	1557	147	229	3.03	266	309	358	416	483	561	651
Channel	Engl.-France	75	1493	112	0.65	116	119	123	127	132	136	141
Comoro	Madagascar	838	229	192	2.3	215	241	270	303	339	380	426
Curacao, etc	Caribbean	173	769	133	2.5	150	170	193	218	247	279	316
Guadaloupe	Caribbean	687	448	308	2.64	350	400	455	519	591	673	767
Hawaii	Mid Pacific	6424	111	710	1.2	754	800	849	901	957	1015	1078
Madeira	N.W. Africa	308	877	270	2.02	298	329	363	401	443	489	540
Malta	Mediterranean	122	2664	325	1.12	344	363	384	406	429	454	480
Martinique	Caribbean	425	734	312	2.58	354	403	457	519	590	670	760
Mauritius	Madagascar	809	930	752	2.95	870	1006	1163	1345	1556	1799	2080
Reunion	Madagascar	969	397	385	3.34	454	535	630	743	875	1032	1216
Ryukyu	Japan	848	1108	940	2.8	1079	1238	1422	1635	1875	2152	2471
Samoa	W. Pacific	1173	124	145	4.0	176	215	261	318	387	470	572
Trinidad and Tobago	Caribbean	1980	485	960	2.78	1101	1263	1448	1661	1905	2185	2507

Table A.5. Present and Estimated Future Populations of Coastal Desert Cities

City and Country[a]	1965	Increase (%/year)	Estimated Population ($\times 10^3$) in –						
			1970	1975	1980	1985	1990	1995	2000
Cairo, Egypt	3,800,000	3.36	4,483	5,288	6,238	7,359	8,682	10,241	12,082
Met.	4,600,000	3.36	5,427	6,402	7,552	8,909	10,509	12,398	14,625
Alexandria	1,650,000	3.36	1,946	2,296	2,709	3,195	3,770	4,447	5,246
Lima-Callao, Peru	1,887,000	3.54	2,246	2,672	3,180	3,784	4,503	5,358	6,376
Met.	2,300,000	3.54	2,737	3,257	3,876	4,6[illegible]	5,488	6,531	7,772
Karachi, W. Pak.	1,550,000	3.36	1,829	2,157	2,545	3,002	3,541	4,177	4,928
Met.	2,100,000	3.36	2,477	2,922	3,448	4,067	4,798	5,660	6,677
Casablanca, Mor.	1,100,000	3.29	1,293	1,520	1,788	2,102	2,471	2,905	3,415
Met.	1,175,000	3.29	1,388	1,624	1,909	2,245	2,639	3,102	3,648
Santiago, Chile	640,000	2.60	727	827	941	1,069	1,216	1,382	1,572
Met.	2,400,000	2.60	2,728	3,102	3,527	4,010	4,559	5,184	5,893
Valparaiso	252,900	2.60	288	327	372	423	480	546	621
Met.	440,000	2.60	500	568	647	735	835	950	1,080
Guayaquil, Ecuador	510,804	3.6	610	728	868	1,036	1,237	1,476	1,761
Cape Town, S. Afr.	508,341	3.0	589	683	792	918	1,064	1,234	1,430
Met.	807,211	3.0	936	1,085	1,258	1,458	1,690	1,959	2,271
Dakar, Senegal	374,700	3.19	438	513	600	702	822	961	1,125
Met.	435,000	3.19	509	595	697	815	954	1,116	1,306
Abadan, Iran	302,000	3.18	353	413	483	565	661	772	903
Marrakech, Mor.	246,000	3.29	289	340	400	470	553	650	764
Rabat, Morocco	227,445	3.29	267	314	370	434	511	601	706
Met.	310,000	3.29	364	428	504	592	696	819	963
Port Said, Egypt	245,318	3.36	289	341	403	475	560	661	780
Luanda, Angola	224,540	2.4	253	285	320	361	406	457	515
Tripoli, Libya	212,600	3.36	251	296	349	412	486	573	676
Suez, Egypt	203,610	3.36	240	283	334	394	465	548	647
Basra, Iraq	164,623	2.76	189	216	248	284	325	372	427
Adelaide, Austral. Met.	660,000	1.55	713	770	831	897	969	1,046	1,131
Jidda, Saudi Arabia	147,900	2.76	169	194	223	255	292	335	384
Benghazi, Libya	136,000	3.36	160	189	223	263	311	367	432
Bahia Blanca, Arg.	136,000	1.76	147	160	173	188	203	220	239
Asmara, Ethiopia	131,800	2.76	151	173	198	227	260	298	342
Mogadisco, Somalia	120,600	2.3	135	151	169	190	213	238	267
Kuwait, Kuwait	98,860	2.76	113	130	149	170	195	224	256
Met.	151,247	2.76	173	198	227	260	299	342	392
Aden,	99,285	2.76	114	130	149	171	195	225	258
Met.	138,441	2.76	159	182	208	237	273	313	359
Trujilio, Peru	99,800	3.54	119	141	168	200	238	283	337
Antofagasta, Chile	87,900	2.60	100	114	129	147	167	190	216
Chiclayo, Peru	86,900	3.54	103	123	146	174	207	247	294
Port Sudan, Sudan	56,000	3.98	68	83	101	122	149	181	219
Iquique, Chile	50,700	2.60	58	65	75	85	96	110	124
St. Louis, Senegal	48,800	3.19	57	67	78	91	107	125	146
Djibouti, Fr. Somal	40,000	2.76	46	53	60	69	79	91	104
Bushehr, Iran	27,317	3.18	32	37	44	51	59	70	82
Comodoro Rivadavia, Arg.	25,651	1.62	28	30	33	35	38	42	45
Berbera, Somalia	20,000	2.76	23	26	30	34	40	45	52
Tulear, Malagasy	18,648	2.76	21	24	28	32	37	42	48
Benguela, Angola	15,399	2.4	17	20	22	25	28	31	35
Bandar Abbas, Iran	14,278	3.18	17	20	23	27	31	37	43
Ifni, Sp. Afr.	12,751	3.36	15	18	21	25	29	34	41
Dharan Saudi Arab.	12,500	2.76	14	16	19	22	25	28	32
Nouakchott, Mauritania	12,300	3.36	15	17	20	24	28	33	39
Walvis Bay, S.W. Afr.	12,235	3.0	14	16	19	22	26	30	34

[a]Met. = Metropolitan.