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Editors:

ADLI BISHAY
The American University in Cairo

WILLIAM G. McGINNIES
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THE WESTERN DESERT OF EGYPT, ITS PROBLEMS AND POTENTIALS

FAROUK EL-BAZ
Research Director, Center for Earth and Planetary Studies, Smithsonian Institution, Washington, D.C. U.S.A.

ABSTRACT

The Western Desert occupies two thirds of the area of Egypt. It is basically a platform of sedimentary rocks crossed by numerous belts of sand dunes that inundate whatever stands in their way. The flat terrain is broken by numerous depressions enclosing oases that provide the only respite from the prevailing harsh conditions. Early exploration in the 1920's by Hassanein and Kamal El-Din and in the 1930's by Sanford, Peel, and particularly Bagnold provided the basic data on this desert. However, to this date much of the desert is relatively unexplored. Space photographs and images provide a useful tool in the selection of areas for detailed field study.

The most potentially valuable aspect of the Western desert is the occurrence of clayey, fertile soils in many locations. Some of these lie above a reservoir of fossil underground water, which if carefully used could supply enough water for irrigation. Additional possibilities for development include deposits of iron, phosphates and other valuable minerals as well as a vast reservoir of building materials, particularly those necessary for cement production.

INTRODUCTION

The Western (Libyan) Desert of Egypt lies on the northeastern border of the North African Sahara. It occupies 681,000 km^2 or more than two thirds the land area of Egypt. Early travelers, geographers and explorers are credited with contributing to our knowledge of this desert and its ways.

The ancient Egyptians are known to have traveled extensively in the Western Desert and settled in many parts of it. The interest in this desert continued through the time of the

Romans as indicated by their numerous remains. However, the first truly scientific account of part of this desert was that of Mohamed Ibn-Abdulla Ibn-Batuta. Starting in 1325, he spent twenty years traveling in North Africa and the Arabian Peninsula meticulously recording his observations.

After Ibn-Batuta little progress was made until the end of the eighteenth century when the "Association for Promoting the Discovery of the Interior Parts of Africa" was established by Sir Joseph Banks in 1788. For nearly a century, the exploration of Africa captured the imagination of westerners much as spaceflight did in the 1960's. Although the main expeditions were dedicated to finding the source of the Nile and charting its course, much information was gathered on the Sahara Desert.

Scientific exploration of the Western Desert began with Gerhard Rolfs. He was a German soldier who, in order to prepare himself for desert travel, joined the Foreign Legion in Algiers. He made an expedition in 1874 traveling over 650 kilometers from Sallum on the Mediterranean coast to the heartland of the desert crossing the Great Sand Sea. Zittel[1] and Beadnell[2,3,4] described parts of the desert. Also, two major expeditions were conducted in the 1920's by two Egyptian explorers, Mohamed Hassanein Bey and Prince Kamal El-Din, who reached the remotest corner of Egypt at the border intersection with Libya and Sudan. Another notable geomorphological contribution was made by Ball[5].

Ralph Bagnold of the Royal Corps of Signals pioneered a new era of desert exploration in the 1930's. Using Ford automobiles, his select team of explorers covered vast tracts of the Western Desert reaching most of its remote corners. His explorations and their accounts (Bagnold)[6,7,8,9] provided much of the basic information on the Western Desert in general and on the movement of dune sand in particular. Other classical works were written during the same period such as those by Sanford[10] and Peel[11].

More recent and detailed geological studies of the Western Desert were reviewed and summarized by Said[12]. The regional geology of this desert has also been summarized in the map that was published in 1971 by the Geological Survey of Egypt. During the last decade, orbital photographs obtained by astronauts of the Gemini, Apollo, Skylab, and Apollo-Soyuz missions (e.g., El-Baz)[13] and images transmitted by the unmanned Landsat missions (e.g., El-Shazly et al)[14] have been used in studying the Western Desert and its features.

TERRAIN CHARACTERISTICS

The Western Desert is a physiographic region of Egypt that stretches westward from the Nile Valley to the Libyan border and northward from the border of Sudan to the Mediterranean Sea (figure 1). It is basically a rocky plain which slopes gently to the north. The generally flat plateau desert of sedimentary rocks is broken by depressions, which enclose oases, and by granitic mountains in the Oweinat region at the border intersection between Egypt, Libya and Sudan. These mountains and the Gilf Kebir plateau just to the northeast constitute the only prominences that are higher than 1000 m above sea level. The rest of the central and southern parts of the desert average 200 to 500 m in elevation, and rocks of the northern belt are less than 200 m above sea level.

The seven major depressions in the Western Desert are bounded by escarpments which appear to be erosional features. However, the boundaries of some indicate control by intersecting faults. This suggests that the original cause of the depressions was the fracturing of the sedimentary platform. Fracturing allowed erosional mechanisms to excavate the rock along the zones of weakness.

The largest of the Western Desert depressions is the Qattara, which occupies, below sea level, approximately 19,500 km^2, or 1/15 the land area of Egypt (figure 1). This depression also contains the lowest point on the continent of Africa, being 134 m below sea level. Approximately 5,800 km^2 of the floor of the depression is covered by *Sabkha*, which is made of water saturated salt that is thinly covered by sand. The rest of the floor is covered by sand, pebbles, clay, and exposures of limestone. Much like other depressions in the Western Desert, its northern borders are clearly marked by a distinct scarp, whereas the depression grades into the terrain to the south.

The Qattara Depression figures prominently in plans for development of the Western Desert. A project now under study aims at the generation of electric power using two natural phenomena: the flow of water from higher to lower levels, and its evaporation by the sun's heat. It will entail bringing water from the Mediterranean Sea to the edge of the depression via an open canal or an underground pipeline. The gravity flow of water will be used to run turbines to generate electricity. The high rate of evaporation will assure removal of water until a layer of salt is formed in the depression. It

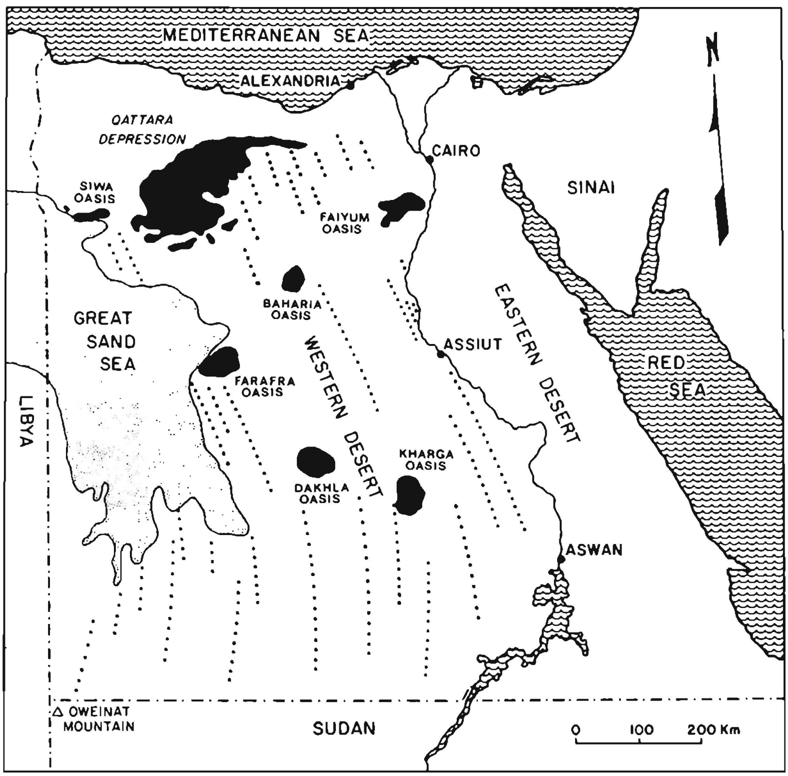

Figure 1: Map of Egypt showing the location of the seven major depressions in the Western Desert. Dunes of the Great Sand Sea occupy much of the west central part of the desert. In addition, numerous longitudinal dunes occur throughout. Some of these are made of one enormous dune like Ghard Abu Muharik, which stretches from Baharia to Kharga. Others are made of dune bundles, e.g., near Qattara.

is calculated that the electric power to be generated from this project would be up to a maximum of 10,000 megawatts, which is nearly five times that generated at the High Dam south of Aswan. Apparently the required electricity output in Egypt by the year 2000 will equal approximately 15,000 megawatts. It must be stated that the effects of the "Qattara Salt Lake" on the underground water reservoir in the northern Western Desert are not yet known. Also the project plan requires detailed topographic maps of the region which are not available.

The depression in which Siwa Oasis occurs is irregularly-shaped and generally elongate in an east-west direction. It is the farthest depression from the Nile Valley and is approximately 50 km long and covers 300 km^2. The irrigated area within the depression is 90 km^2 and parts of it are 60 m below sea level. About 15 km east of the Siwa Depression is another depression about two thirds its size; both are bounded by faults that intersect in an "X" pattern. In both places the lowermost stratum is a non-porous shale layer. This layer prevents easy drainage of irrigation water, which is allowed to stagnate and evaporate leaving a crust of salt on the land. Potentially valuable rocks in the Siwa Depression include marble, highly pure crystalline limestone, and good quality Egyptian alabaster.

The southern borders of the Siwa Oasis blend with the northern boundary of one of the largest dune fields of the Sahara, the Great Sand Sea. Near Siwa, the dunes of this sand mass are reminiscent of the Algodones dunes southeast of the Salton Sea in California. However, the Great Sand Sea displays some of the largest dunes in the world and covers an area that is 200 times that of the California dunes. The Great Sand Sea's formidable zone is 500 km long and 200 km wide. The main sand mass is characterized by enormous whaleback dunes with superposed sharp-crested longitudinal dunes. The gently sloping whaleback dunes are relatively static, whereas the longitudinal dunes shift as the wind blows the sand southward.

The Faiyum Depression is closest to the Nile Valley and occupies a circular area of approximately 1,700 km^2, much of which lies below sea level. The Bahr Youssef canal carries Nile water to the depression where it drains into Lake Qaroon (200 km^2) in addition to El-Gharaq, a small enclosed basin on the south side of the depression. Herodotus, who visited the area in 450 B.C. described an artificial lake 3,600 furlongs in circumference and 50 fathoms deep. According to him, water from the Nile flowed into the Lake during six months of the year and drained back to the Nile the other six months. This Lake Moeris is now believed to have existed in the southern part of the depression where large embankments exist. The cliffs of the Faiyum Depression expose limestone of good quality for use as building material and/or in a cement industry.

The Baharia Depression is spindle-shaped and is elongate in a northeast direction. It is approximately 95 km long and 45 km wide and covers an area of 1,800 km^2. The escarpment that bounds the depression enclosing it on all sides, is approximately 100 m high. In addition to this feature the depression is unique among others in the Western Desert in that hills form a discontinuous line in its center. Many of these hills such as Gebel Hefhuf and Gebel Mendisha are partly made of the black-colored dolerite rock or capped by it. Also aligned with these hills are basaltic intrusions, particularly in the northeast part of the Depression.

The Baharia area has two essential elements for economic development. First, iron ore occurs in the area; it is mined at El-Gedida and is being evaluated in several other localities. El-Gedida ore is shipped by rail to the steel mill at Helwan south of Cairo. Second, the floor of the depression is composed of sandstone and variegated shale; many patches of it constitute arable soil. Also ground water exists in sandy subsurface horizons. Wells occur along the central line of the depression and near its eastern boundary.

The Farafra Depression is roughly triangular in shape and is bounded by high scarps on the east and west and a low scarp on the north. It is open towards the south where it meets the Dakhla escarpment some 200 km away. Most of the exposed rock in the depression is chalk of Maastrichtian age (Said).[12] The eastern half of the depression is covered by dune sand. Field observations indicate that this sand mass is similar to that of the Great Sand Sea. The large dunes are low-sloping whaleback dunes, several kilometers across. Superposed on these dunes are sharp-crested, partly sinuous longitudinal dunes.

Because of the prevalence of thick sand deposits in the Farafra Depression, the only areas where soil is suitable for agriculture is in the vicinity of Qasr El-Farafra, and particularly to the south near Abu Minqar. This is significant because in the latter location the ground-water reservoir is larger, less saline and under higher pressure (up to 20 times the atmospheric pressure) than farther southeast of Dakhla and Kharga.

The Dakhla Depression lies south of an escarpment that trends west-northwest from Kharga for approximately 250 km. South of the escarpment the exposed rock belongs to the Nubia Sandstone formation, which covers most of the southern half of the Western Desert. However, the erosion of the chalk and shale layers that are exposed on the scarp provides a layer of arable soil. For this reasons, agricultural communities are lined parallel with the scarp.

In addition, east of Dakhla at Abu Tartur Plateau, a phosphate layer occurs that is up to 6 m thick and 15 km long. Experimental mining of this deposit has begun and it promises to be one of the major phosphate deposits in North Africa. This is particularly true since low-grade phosphates cropout in a nearly continuous layer, 60 to 100 cm thick, all along a scarp that stretches from Abu Tartur in a west-southwest direction for some 300 kilometers.

The Kharga Depression is the only one in the Western Desert that is aligned in a north-south direction. The succession of rocks from the floor upward begins with Nubia Sandstone, which is overlain by purple and variegated shales, phosphatic beds, Dakhla shale, chalk, Esna shales, Thebes limestone, and travertine and loess on top. The depression is open to the south and southwest. The southern opening made the Kharga Oasis easy to reach by camel caravans from the interior of Africa along the celebrated Darb El-Arbein road. The width of the depression varies from 20 km in the north to 80 km in the south. The communities in the Kharga Depression occur along a line that trends in a north-south direction. This line is a major fault, which allowed the settlers to reach underground water that used the fault as a channel way for upward movement. The underground water reservoir at Kharga is smaller, more saline and is under less pressure than those farther to the west. It is believed to be made of fossil water (old and not rejuvenated) that is, some 30,000 years old (E. Degens, pers. comm.). Less is known about the underground reservoir of the region due south of the Kharga Depression, which is known as "Ganoub El-Wadi" or the South New Valley.

Bundles of active sand dunes hamper the development of Kharga and to a lesser extent Dakhla. The sand atop the high plateau to the north accumulates in broad dunes of the longitudinal type. The prevailing sand-carrying winds are towards the south as indicated by the numerous north-south-trending lines (figure 1). As these broad dunes reach the scarp, the sand creates patterns that are reminiscent of waterfalls. After the sand is carried south of the scarp, it forms small and relatively fast moving barchan dunes. The speed of the Kharga barchan dunes has been measured to vary between 20 and 100 m per year (Embabi).[15]

These barchans inundate roads, telephone lines, agricultural fields, and houses along their way. In some instances, entire villages in the Kharga Depression have been completely buried by the shifting sands, for example Ginah village whose inhabitants had to abandon it in 1970 and settle elsewhere. Barchan dunes are also encroaching on the Kharga-Assiut road which is the life line of communications between Kharga and Dakhla oases and the Nile Valley.

Beyond Kharga and southwest of the other oases, the terrain of the Western Desert is flat to undulating; it is interrupted by two major highs in the southwestern corner of Egypt. The Gilf Kebir plateau is made up of dark, resistant layers of Nubia Sandstone, which Issawi[16] prefers to designate the "Gilf Sandstone." The sandstone is locally interrupted by basaltic intrusions up to a kilometer across (Peel).[17]

Farther to the south, the region consists of flat-lying, Cretaceous sandstone overlying Paleozoic sandstone that rests unconformably on basement rocks. This sequence is interrupted by 800 to 1400 m high mountains. The most prominent of these is the Gebel Oweinat that is composed of a Precambrian complex of granites and metamorphic rocks, which have not yet been studied in detail. It is conceivable that the Oweinat area has economic concentrations of rare or radioactive elements such as uranium. These usually occur in granitic plugs or as weathering products of granites.

Detailed study of the Gilf Kebir-Oweinat area is hampered by the remoteness as well as by the lack of detailed maps. The existing maps of the southwestern part of the Western Desert are at 1:1,000,000 scale with 100 m contours and poor feature portrayal.

DEVELOPMENT CONSIDERATIONS

The population of Egypt has been increasing at the alarming rate of nearly 1,000,000 persons per year. This increase has been accompanied by a rise in food consumption beyond the present output of the Nile Valley. Dependence on foreign loans to augment the food that is consumed yearly in Egypt has disrupted the country's economy and promises to cripple it if the situation is not remedied.

This situation has increased the interest in the development potentials of the large expanses of unused land in the Western Desert. Emphasis is placed on agricultural land, particularly in view of the fact that the output of the Nile Valley lands has been decreasing due to three main reasons: (1) migration of people from farms to urban areas; (2) decrease of silt that is held behind the High Dam; and (3) encroachment of sand on arable land at the western borders of the Nile Valley (figure 2).

Reclamation of land from the desert is not new to Egypt. It is known that the Ancient Egyptians regulated the flow of water along the Nile for use in irrigation. In fact the agricultural land of the Faiyum Depression (figure 3, top) is due to a successful land reclamation project that was started by Amenemhet III who died in 1801 B.C. The present irrigation system in Faiyum made use of canals dug during the reign of this pharoah. The land of Faiyum is among the most fertile in Egypt, and some areas have been reclaimed in recent years at the oasis' northern boundary at Kom Oshim.

Also a strip of land just west of the Nile Delta was reclaimed from the Western Desert (Shata and El-Fayoumy).[18] This reclamation project encountered several problems, particularly because it was started in a sandy zone in the southern Tahrir Province. However, its continuation in the north was more successful since it began in a clay-rich zone (El-Baz and El-Etr).[19] Comparison of two orbital photographs taken ten years apart by the Gemini and Apollo-Soyuz astronauts indicated that nearly 1,100 km^2 of land have been reclaimed from the desert (figure 3, bottom).

These reclamation projects, however, were started close to the Nile and benefited from its water and human resources. Clayey soils elsewhere in the desert are very far from the Nile except for the area west of Kom Ombo. These areas must be reclaimed either by underground water or Nile water transported via pipelines or both. In addition, because of the sparse population in the desert, these areas lend themselves to large agricultural schemes that must be economically attractive for agribusiness investors, local and/or foreign.

From the above it follows that any agricultural development scheme in the Western Desert must be based on detailed study of water resources. The selection of areas for such

Figure 2: Aerial view of dunes that are encroaching on agricultural land west of the Nile Valley town of El-Minya, 200 km south of Cairo.

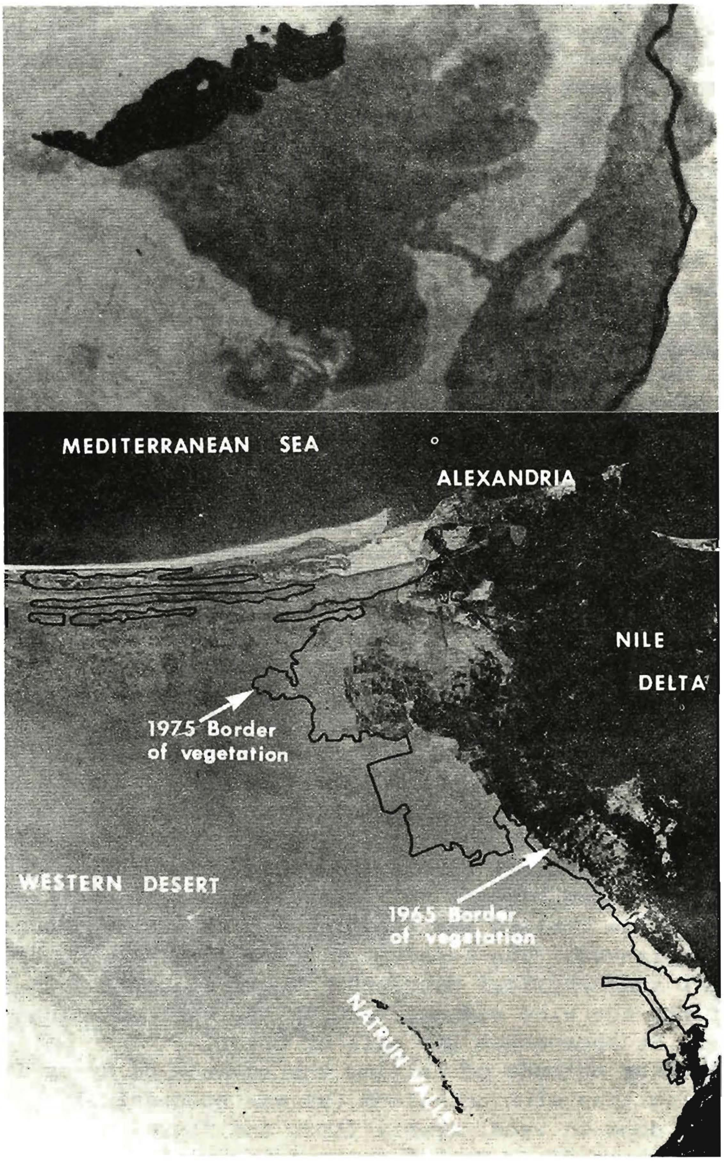

Figure 3: Examples of successful reclamation projects in the Western Desert at Faiyum (top) and west of the Nile Delta (bottom).

development must be based on the effective utilization of these resources. This includes use of modern irrigation technology such as spray or drip irrigation. Water in the Western Desert is far too valuable a resource to waste by the presently used methods of irrigation.

It is also important to consider agricultural potentials in areas of mining and industrial development. The development of the Western Desert resources must be thought of in terms of self-sufficient settlements, where food and water is plentiful and services are adequate for the community of developers. Over-dependence on products shipped from the Nile Valley increases the cost of living in the desert and hampers its development.

One factor that must be considered in the development of the Western Desert resources is the motion of sand dunes. Space photographs and images have recently been used to map the general distribution patterns of dunes (Gifford et al.)[20] 1978). However, more detailed aerial photographs are necessary to map and monitor the migrating sand dunes.

In dealing with shifting sand dunes, one could avoid them, try to halt their advance, or learn how to live with them. Avoidance of migrating dunes can be done by planning in advance. For example, if a dune belt is moving at the rate of 50 m per year, then a settlement should be built at least 25 km farther to the south. This would allow the settlement to exist without the danger of inundation for about 500 years.

The most popular method of halting the advance of dunes is planting trees in their path. In the Western Desert oases, *tamarisk* trees are usually used for this purpose, although some farmers plant palm trees instead. The trees in this case serve as a physical barrier downwind. They are effective until the dune becomes tall enough to engulf the trees themselves. In Tunisia and Algeria, higher eucalyptus trees are being planted. The eucalyptus trees work as wind breakers rather than physical barriers. Their height (up to 100 m) disturbs the wind regime, forcing the wind to unload the sand before it approaches the wall of trees.

Other methods of halting the advance of dunes include spraying them with petroleum, as was successfully but expensively done in Saudi Arabia (Kerr and Nigra),[21] or with chemicals such as "Sand Seal," a non-toxic water emulsified blend of liquid polymers and silicate derivatives. Stabilizing dunes by seeding them with grass would not work in the Western Desert because of the scarcity of water and lack of humidity.

However, it must be stated that inserting dry palm fronds on dune crests has been successfully applied in reducing the migration rate of dunes at Kharga from 30 to 4 m per year.

From nature we know that rock is eroded by sand until the aerodynamically stable prominences called "yardangs" are formed. These yardangs are spindle-shaped with rounded ends toward the wind and tapering tails downwind. It is conceivable that yardang-shaped frames made from appropriate materials can be placed in the path of advancing dunes in rows allowing the sand to pass between them. Gradually changing the orientation of such man-made yardangs in these rows might result in directing the shifting sand away from the area requiring protection. This method, however, has not yet been tried in the laboratory or in the field.

THE DEVELOPMENT BELT

The idea of a restricted zone for economic development in the Western Desert was studied by Gen. Mohamed Mohsen.[22] It proposes a development belt stretching from the western shores of the High Dam's Lake Nasser in the south to the Mediterranean coast in the north, and includes all the oases and other depressions.

This belt is bounded by rocky plateaus to the east and sand accumulations of the Great Sand Sea to the west. As shown in figure 4 the parts of this belt that are adjacent to water bodies are most suitable for developing tourism and fish industries. The rest of the belt encompasses all the land that includes patches of arable soil; clayey soil also exists near the southwest border of Egypt, but it is covered by a 15 to 25 cm layer of sand (A. El-Barqouqi, pers. comm.).

It is interesting to note that the most promising region in this belt is the one closest to Lake Nasser. The area west of the Nile between Aswan and Kom Ombo includes "nilotic" sediments as far as 50 km west of the present-day river course (Issawi and El Hinnawi).[23] These silts are mixed with sandy clay and gravel that form a plain that extends for nearly 200 km long and 10 to 40 km wide. The general slope of the plain is toward the north with a drop of about 50 m from south to north.

This area should receive more attention than other parts of the development belt because it is close to the fresh water lake and also to the densely populated Nile Valley. A development scheme may be recommended for this area in which silt-

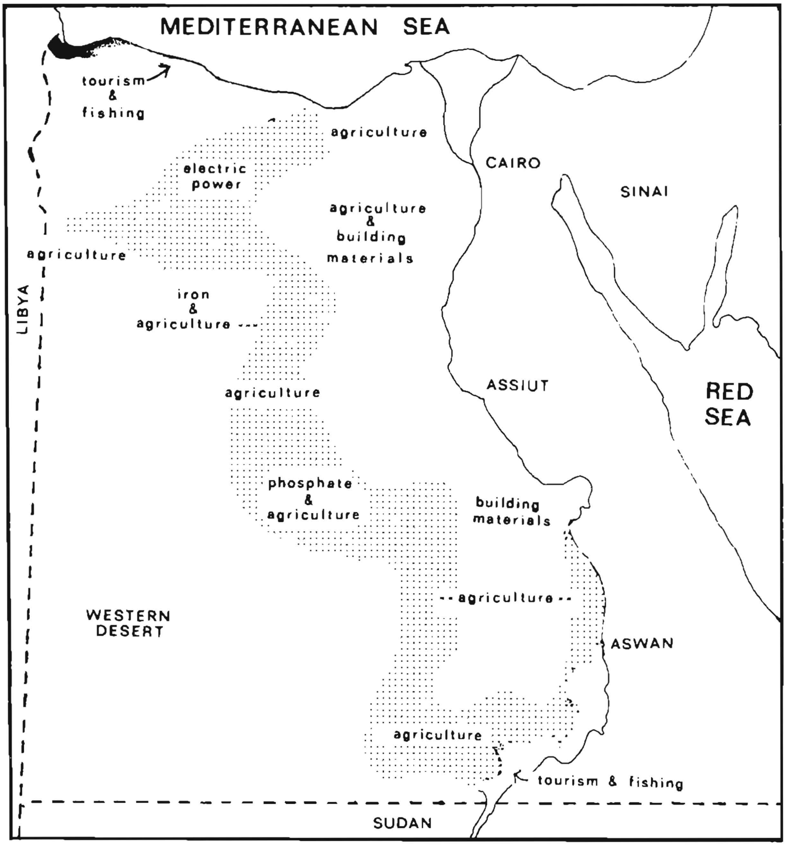

Figure 4: Map of Egypt showing the maximum extent of "the development belt" in the central part of the Western Desert (patterned area). This belt includes the seven major depressions and the South New Valley region. It also includes the coastal zones of the Mediterranean Sea and the High Dam Lake.

laden water is pumped from the lake and transported via a pipeline on the edge of the western scarp. Water may flow eastward by gravity via branch pipelines to reclaim the arable patches in the region. However, the effects of such a project on the narrow zone of agricultural land adjacent to the Nile River need to be thoroughly studied.

The southernmost segment of the development belt, the South New Valley, is estimated to contain 1,300,000 feddans surrounding the Toshka Depression. If confirmed as suitable for agriculture and later developed, it would increase the total cultivated land of Egypt by 22%. However, the problems of undulating topography, underground water availability, necessity for elaborate drainage systems, and high costs of operation are likely to reduce this figure by a factor of ten, to about 130,000 feddans.

The central segment of the belt includes the depressions of Kharga, Dakhla, Farafra, and Baharia. These oases have their own resources of good soil in patches that vary from 100 feddans (suitable for individual or family ownerships), 1,000 feddans (suitable for agricultural cooperatives) or 100,000 feddans (suitable for large-scale agricultural development). All three forms of development are necessary in solving the problems of redistribution of Egypt's population and the production of enough food for local consumption and conceivably for export.

In addition to agricultural development of the belt's central segment, its mining potentials are confirmed. In addition to phosphates and iron, the existence of limestone and shale strata in the same areas allows their exploitation for cement industries. Such industries would serve the development projects in the oases as well as the needs of the Nile Valley to the east.

The northern segment of the development belt includes the depressions of Qattara, Siwa and several smaller ones. These depressions include land that can be reclaimed for agriculture if the drainage problem is resolved. Also in Siwa, layers of marble, crystalline limestone and alabaster can be mined, particularly after the road from Siwa to Mersa Matruh is completed for shipping of products to national or international markets.

The full development of this northern segment will depend on whether or not the Qattara project will come into being. If electric power is to be generated via the flow of sea water into the depression, this will open the way for numerous industries. The "Qattara Lake" would also be used in fish industries, salt and other chemical industries, and tourism. The activities in the area would also attract part of the population from the overpopulated Nile Delta.

CONCLUSIONS

The Western Desert will figure prominently in the future economic development of Egypt because of its many potentials. These include areas of arable land that can be used to produce badly needed food for a growing population. They also include mineral deposits such as iron, phosphates, carbonates, clays, etc. However, the desert must be more thoroughly studied to allow thoughtful planning.

Self-sufficient settlements of various sizes appear to be the most suitable way of developing this desert along the median "development belt." Agricultural development may require the use of modern irrigation technology such as mechanized spray or drip irrigation. Also, the underground water reservoir may require augmentation by fresh water from the Nile. The latter may best be obtained south of the High Dam, because of the need for silt, and carried to reclamation areas via pipelines to minimize water loss by evaporation and seepage.

Based on the above it is clear that although the Western Desert has several potentials in agriculture, mining and industry, many of its features must be studied in more detail. The necessary studies include the making of topographic base maps, at 1:50,000 scale or larger. These maps would allow thorough study of areas being considered for development projects, and exploration of the yet unexplored tracts of the Western Desert.

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