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APPLICATION OF LANDSAT IMAGERY IN THE GEOLOGICAL AND SOIL INVESTIGATIONS IN THE CENTRAL WESTERN DESERT, EGYPT

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ABSTRACT

The investigated part in the central Western Desert of Egypt covers a large area between latitudes 29°N and 26°N, and it is limited to the east by the River Nile and to the west by the Egyptian-Libyan border. The northern boundary of the area lies at distances ranging from 200 to 600 km to the south of the Mediterranean Sea and its western boundary is separated by a maximum distance of some 580 km from the River Nile.

Mapping and studies have been carried out for the investigated part of the central Western Desert on a scale of 1:500,000 through LANDSAT imagery interpretation combined with adequate field work, where hundreds of soil profiles and lithostratigraphic sections have been sampled, and laboratory analysed. The first generation of the maps produced include those of the soils, geological and environmental units, structural lineations, and surface drainage. Computation of the data of the structural lineations and surface drainage maps has led to the construction of a lineation density map as well as drainage density and drainage basins maps respectively. This multidisciplinary approach has led to the choise of locations for desert development in the area of investigation and to the arrangement of the locations so chosen according to priorities.

INTRODUCTION

The area of investigation is covered by arid desert with little rain which falls essentially during the winter season. The Nile Valley bounding the area to the east is irrigated by the River Nile and is covered by transported soil of Nile alluvium. The rest of the area, however, is covered by soils developed under the influence of the present and past desert conditions and the previous pluvial periods. Water available for irrigation and human consumption is predominantly provided by artesian groundwater tapped in the depressions notably in the Bahariya Oasis and Farafra Oasis Depressions. Other large and important depressions bound the investigated area northwards and southwards. These are the Qattara and Siwa Oases Depressions, and the Dakhla and Kharga Oases Depressions (Fig. 1).

The depressions especially those of Bahariya and Farafra Oases have been sites of human agricultural activities for thousands of years, while recently the largest iron ore mine in Egypt has been established at El Gedida in the

environs of Bahariya Oasis. The development of desert areas in Egypt is gaining great importance especially in view of the fast growing population, most of which at present occupy the Nile Valley. The latter represents about three percent of the total land coverage of Egypt with the desert occupying the remaining ninety seven percent. LANDSAT imagery interpretation has proved to be a powerful tool in the elucidation of the natural features and resources on a regional scale of such arid desert areas. In this context the present work has been conducted taking into consideration the accumulation of soils and the geological and environmental factors acting on soil development and essentially on soil utilization and land use.

SOIL DEVELOPMENT AND ITS RELATION TO GEOLOGY AND ENVIRONMENT

Soil maps have been constructed for the investigated part of central Western Desert on a scale of 1:500,000 based on field studies including the measurement and sampling of two hundred and ninety three soil profiles, laboratory analyses (Soil Survey Staff, 1951) and LANDSAT imagery interpretation. As these and other maps constructed for the investigated area by LANDSAT imagery interpretation are too large in size to be published in this Symposium (El Shazly, Abdel Hady, El Shazly, Sanad, Attia, El Ghawaby and Khawasik, 1976, El Shazly, Abdel Hady, El Shazly, Haraga, Sanad, Attia, El Ghawaby, and Khawasik, 1977), a small part of the mapped area in the environs of Farafra Oasis has been used for illustration in the present communication. At the same time only the maps of soils (Fig. 6), geological and environmental units (Fig. 5), structural lineations (Fig. 4), and drainage basins (Fig. 3) are shown here.

The mapped soil units in the area of investigation have been classified according to their potential land use into arable and non arable. The arable are further subdivided according to their priority in agricultural development into the following: Grade I Soils of the River Nile flood plain and adjacent desert fringes, Grade II Soils of the pediplain and depressions, Grade III Soils of the playas, bajadas and lacustrine clays, Grade IV Soils of the scrub-by sand plains, and Grade V Soils of the old river terraces, dry valleys, fans, out washed plains and locations surrounding salty marshes. On the other hand, the potentially non arable soils are divided into the following grades which are considerably inferior to the previously mentioned five grades: Grade VI Soils of the sand dune belts, and Grade VII Soils of the desert pavements, talus slopes, Hammadas, rocky exposures and dry sabkhas.

Soils belonging to grade I has no relation to the desert environment, they are actually transported by the River Nile and deposited in its flood plain and adjacent desert fringes. The source of the soil material is essentially the River Nile drainage in Sudan, Ethiopia and other African countries. The grade of soils under discussion is not shown on the map of soils of Farafra Oasis environs (Fig. 6) as it is confined to the Nile Valley which started to build its alluvial filling material since the Late Pliocene and continuing through the Holocene.

Grade II Soils

Grade II soils are restricted in their distribution in the area of investigation to the depressions and the pediplain. In Fig. 6 they are well represented in Farafra Oasis Depression and El Sheikh Marzuk in its southern extension. These soils have mainly accumulated, from the weathered material of the surrounding rock units, during the previous pluvial periods, and they show normally relation to the most dense drainage lines (Fig. 2) which have acted as channels for the transportation of the weathered material into the drainage basins notably Farafra Basin and to a lesser extent Ain Khalifa Basin, East Abu Minqar Basin, Bir Murr Basin, etc. (Fig. 3). These drainage basins are structurally controlled especially by the NW-SE and NNW-SSE fractures and faults and by the folds with apparent axial traces of ENE-WSW and NNW-SSE directions (Fig. 4). It is clear also from the map of the geological and environmental units that the depressions have been excavated in lithologically favourable geological units where water, especially notable in the past pluvial periods, has been the most active agent, while wind erosion during the intervening and present dry periods has been of subordinate nature. The geological units of Cretaceous, Paleocene and Eocene age (Fig. 5) have also greatly in-

fluenced the constitution and texture of the resulting soils.

Grade II soil profiles mostly exceed 1 m in depth and they consist of dense sticky shale and clay. This type of texture is not consistent with adequate drainage, while other environmental impacts on the soils in question are caused by the movements of sand dunes which are exemplified in the environs of Farafra Oasis by El Ghard Dune (Fig. 3) which is an extensive dune belt assuming a NNW-SSE trend depending to a considerable extent on the directions of the prevailing winds.

Grade III Soils

The soils of grade III cover the playas, bajadas and lacustrine clays in the area of investigation. In Farafra Oasis environs (Fig. 6) they are found as widely separated patches of limited extension to the north and south of Abu Minqar, east El Quss Abu Said and further northwards at South El Heiz. Priority in land reclamation is given to the last two localities due to the presence of wide flat playas and the existence in their vicinity of springs and deep wells.

Soils belonging to grade III have an average depth of profiles exceeding 0.5 m, while the soil texture is lighter than in the case of grade II soil texture which decreases the former's water holding capacity. In constitution on the soils of the playas may range from calcareous on the limestone table land of El Quss Abu Said and clayey in the pediplain south of Abu Minqar where rocks of clayey constitution are abundant. In the former case the transportation of the weathered calcareous rock material is not long enough and the chemical reactions are not drastic enough to dissolve the carbonates completely. Grade III soil localities are related to drainage lines (Fig. 2) which have been acting as channels for the material accumulating during the erosion of the original rocks. However, the drainage of these localities is rather limited and the constituent material would have been transported only for relatively short distances. Such conditions eventually lead to greater increase in soil salinization in comparison to grade II soils.

Grade IV Soils

The soils of the scrubby sand plains belong to grade IV as far as their suitability for agricultural development is concerned. In the environs of Farafra Oasis (Fig. 6) the soils in question are encountered in elongated stretches of land in the northeastern part of Farafra Oasis, at El Sheikh Marzuk and at Abu Minqar. These stretches are mainly located round the peripheries of the sand dune belts, namely El Ghard Dune and the Great Sand Sea, where the drainage lines (Fig. 2) provide them with enough water to allow scrubbs to grow and to render the sand relatively stable. At the same time the stretches extend also at the peripheries of the drainage basins including Farafra Basin, East Abu Minqar Basin, Ain Khalifa Basin, Bir Murr Basin and North Gebel Shawshaw Basin (Fig. 3).

The soil profiles belonging to Grade IV are mostly sandy in nature with notable natural vegetation. They are present in sandy plains which possess flat or hammocky to undulating surfaces. The coarse texture of the soils in question, their surface topography and their relative instability render them not so easy to reclaim.

Grade V Soils

Soils belonging to grade V include those of the old river terraces, dry valleys, fans, out washed plains and locations surrounding salty marshes. The depths of the soil profiles, the soil textures, the topography of the soil surfaces and the degreee to which they have been subjected to salinization influence their suitability for reclamation for agricultural purposes. In the investigated part of the central Western Desert the soils under discussion have been mainly encountered as a zone several km in width bordering the Nile Valley westwards. Moreover, smaller patchy locations have been found surrounding the salty marshes in the environs of El Bahrein Depression in the northwestern side of the investigated part of the central Western Desert.

However, these soils are not represented on a regional scale in the environs of Farafra Oasis. The soils in the zone bordering the Nile Valley are genetically different from those surrounding the salty marshes although they are classified in the same grade regarding their amenability to reclamation processes.

Grade VI and Grade VII Soils

The potentially non arable or hardly arable soils include those belonging to grade VI and grade VII. The former are represented by the soils of the sand dune belts, especially those huge more or less parallel belts running roughly in NNW-SSE direction and including in particular from west to east the Great Sand Sea, El Ghard Dune and Ghard Abu Muhariq. The two former dune belts are encountered in the map of Farafra Oasis environs (Fig. 6). The mobile and coarse textured nature of these dunes render them hardly suitable for any land reclamation processes of a reasonable scale.

The soils of the lowest grade 'VII' include those of desert pavements, talus slopes, Hammadas, rocky exposures and dry sabkhas. These are normally unamenable to reclamation, however, in certain cases where the bedrock is constituted of clay-shale, as exemplified by Abu Minqar location and by the stretch of land eastwards of the Great Sand Sea (Fig. 6), the soils may be hardly amenable for reclamation under certain conditions if especially treated.

The soils belonging to grade VI and grade VII are mostly present in relatively high lands where the drainage lines do not supply them with any notable surface run off water. The overall picture of the priority given to the reclamation and land use of the seven soil grades is apparently not only linked with soil characteristics but it is also closely connected with water availability and environmental factors of dune sand migration, impact of salinization, etc....

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FIGURES: 1, 2, 3, 4, 5, 6.

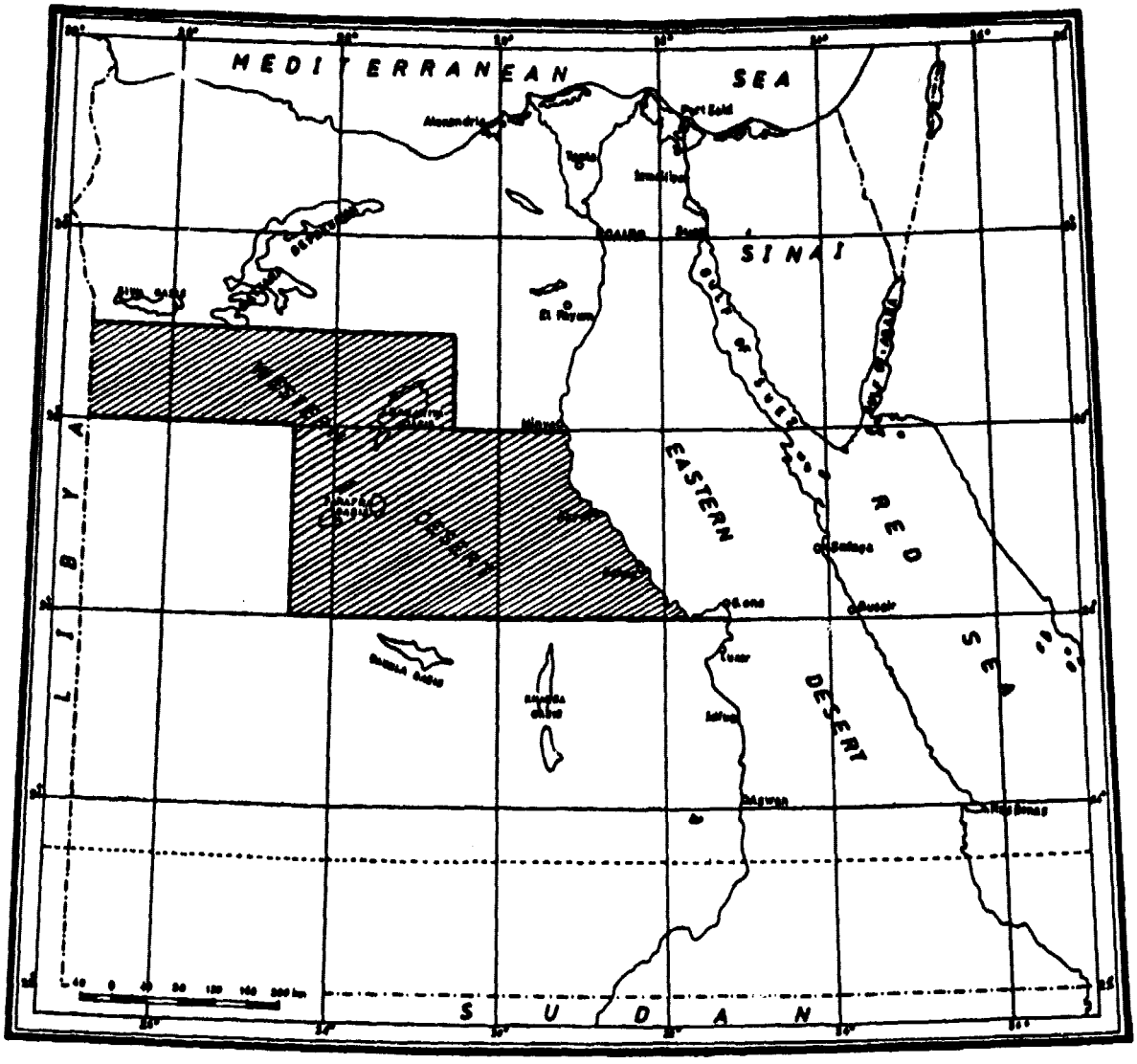

FIGURE 1. INDEX MAP SHOWING LOCATION OF THE PART OF THE WESTERN DESERT PRESENTLY STUDIED BY LANDSAT-1 IMAGERY INTERPRETATION.

FIGURE 2. DRAINAGE MAP OF FARAFRA OASIS ENVIRONS CONSTRUCTED THROUGH LANDSAT-1 IMAGERY INTERPRETATION.

- *Sand Dunes*
- *Drainge Lines*
- *Springs and Water Wells*
- *Boundary of Escarpments*
- *Elevation Point Above Sea Level in m*

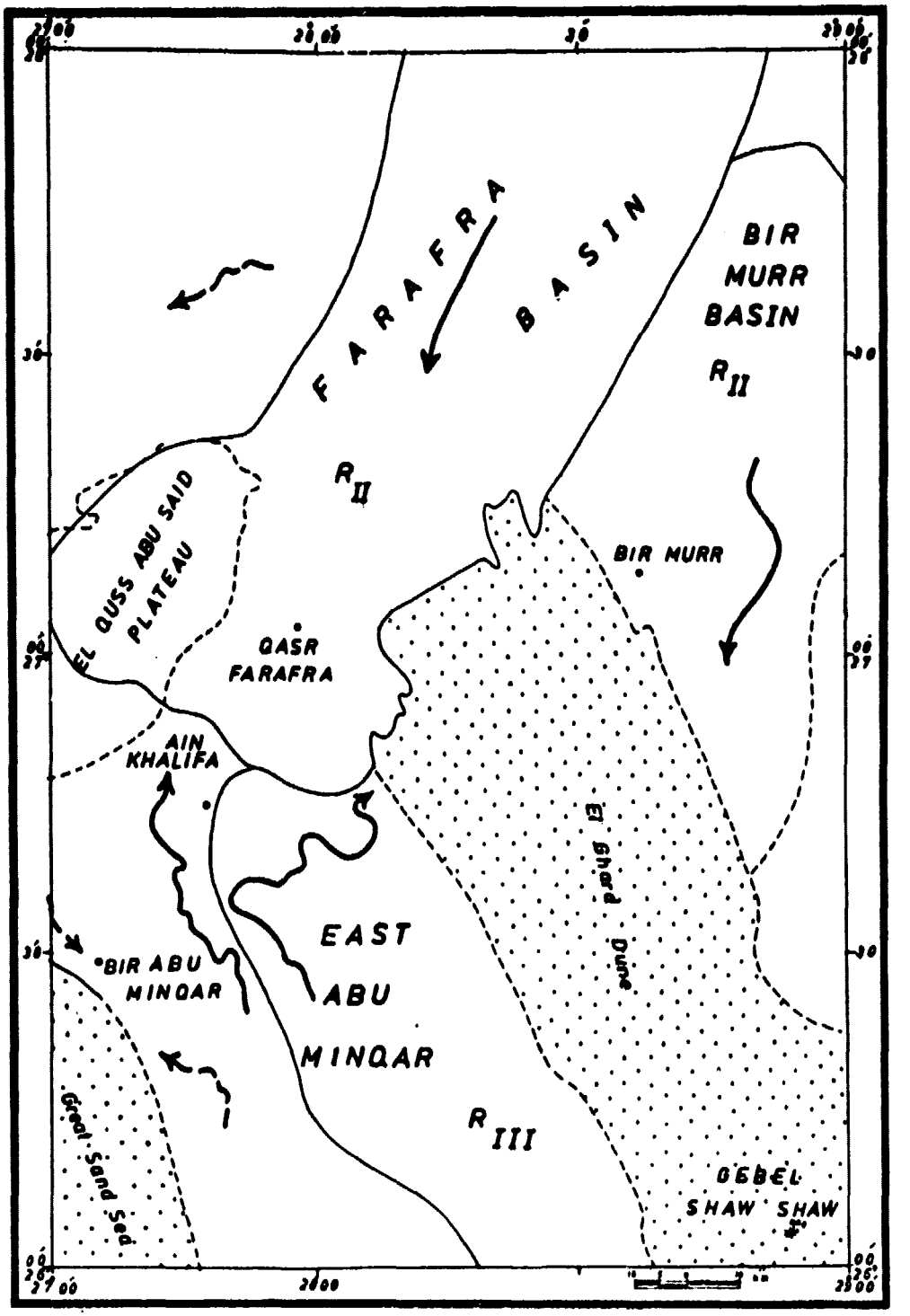

FIGURE 3. DRAINAGE BASINS MAP OF FARAFRA OASIS ENVIRONS BASED ON LANDSAT-1 IMAGERY INTERPRETATION.

Sand Dune Belt
Stream of the Highest in Each Basin
R_{II} *Second Order Drainage Basin*

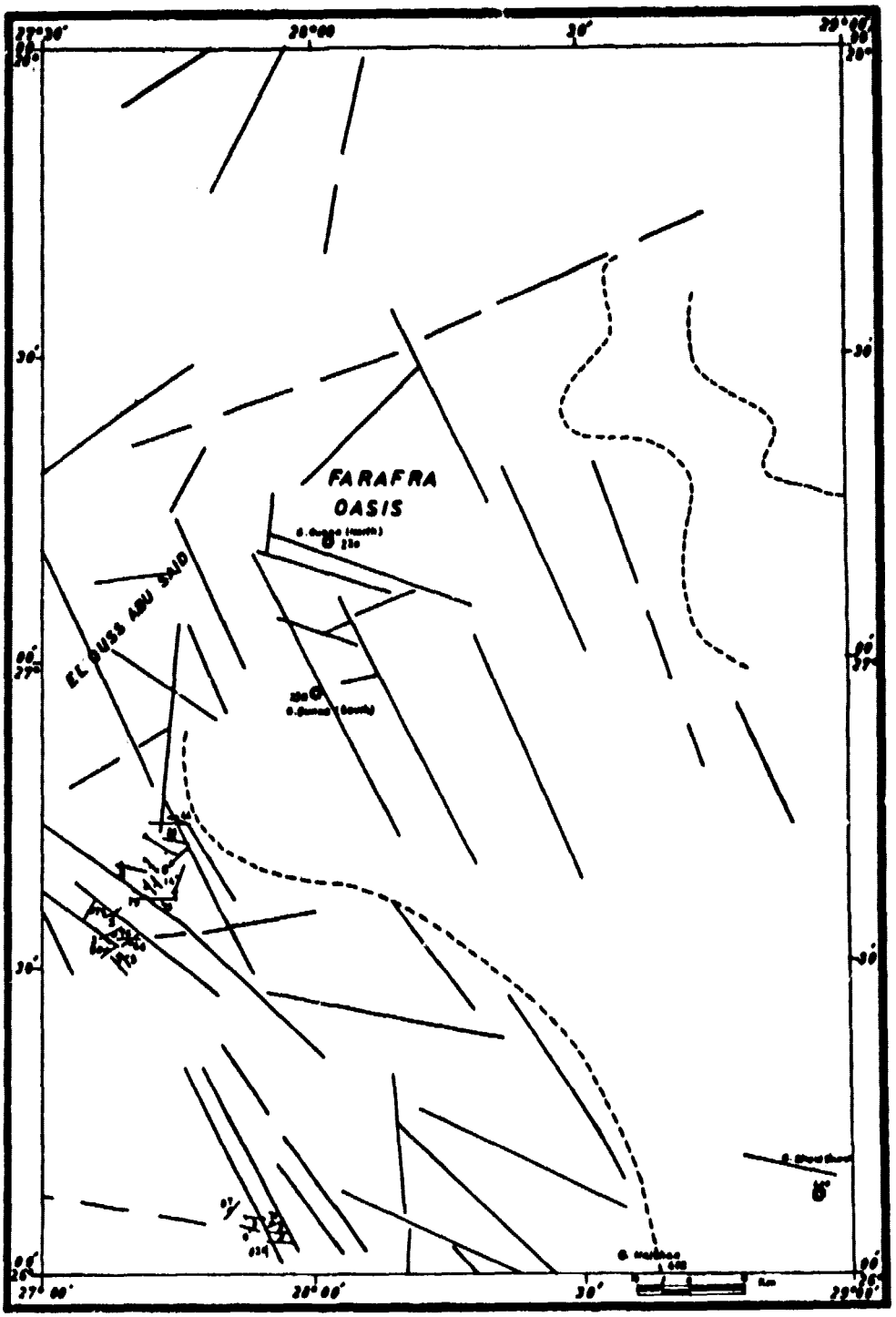

FIGURE 4. STRUCTURAL LINEATION MAP OF FARAFRA OASIS ENVIRONS CONSTRUCTED THROUGH LANDSAT 1 IMAGERY INTERPRETATION.

- Fold Traces
- Fractures Including Faults and Other Lineaments.
- Bedding
- Foliation
- Jointing
- Gypseous Veinlet
- Lineation
- Primary Horizontal Lineation

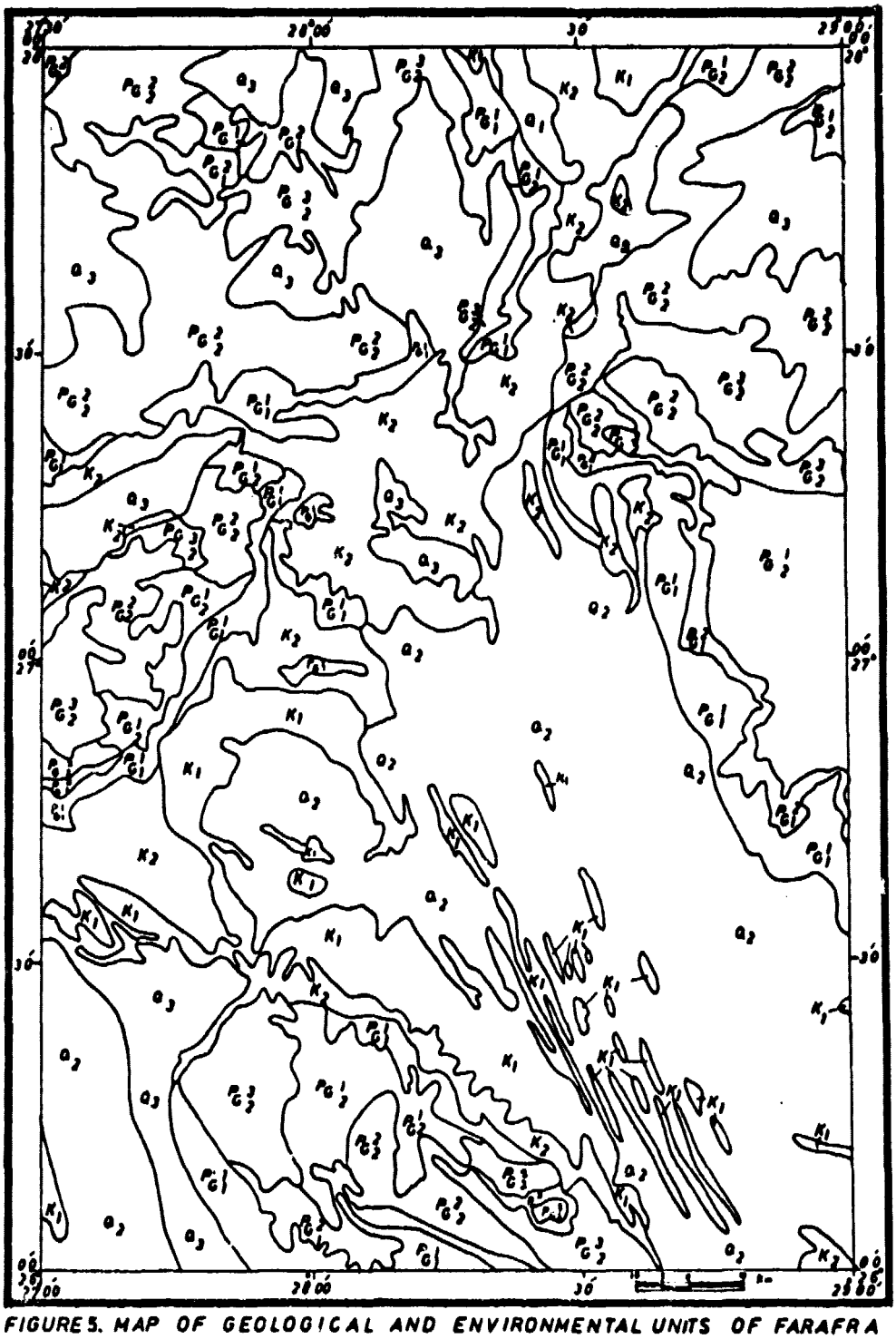

FIGURE 5. MAP OF GEOLOGICAL AND ENVIRONMENTAL UNITS OF FARAFRA OASIS ENVIRONS BASED ON LANDSAT-1 IMAGERY ENTERPRETATION AND FIELD INVESTIGATIONS.

- Q_3 Eolian Sand and Sandy Loam
- Q_2 Sand Dune Belts and Sand Dunes
- Q_1 Alluvial Deposits
- P_{G_2} Gebel Serai Formation
  - $P_{G_2}^3$ Reddish Crystalline Limestone
  - $P_{G_2}^2$ Compact Limestone
  - $P_{G_2}^1$ Chalky white Limestone
- P_{G_1} Upper Esna Formation
  - $P_{G_1}^2$ Clayey Limestone
  - $P_{G_1}^1$ Brownish Shale
- K_2 Gebel Garra Formation
- K_1 Lower Esna Formation

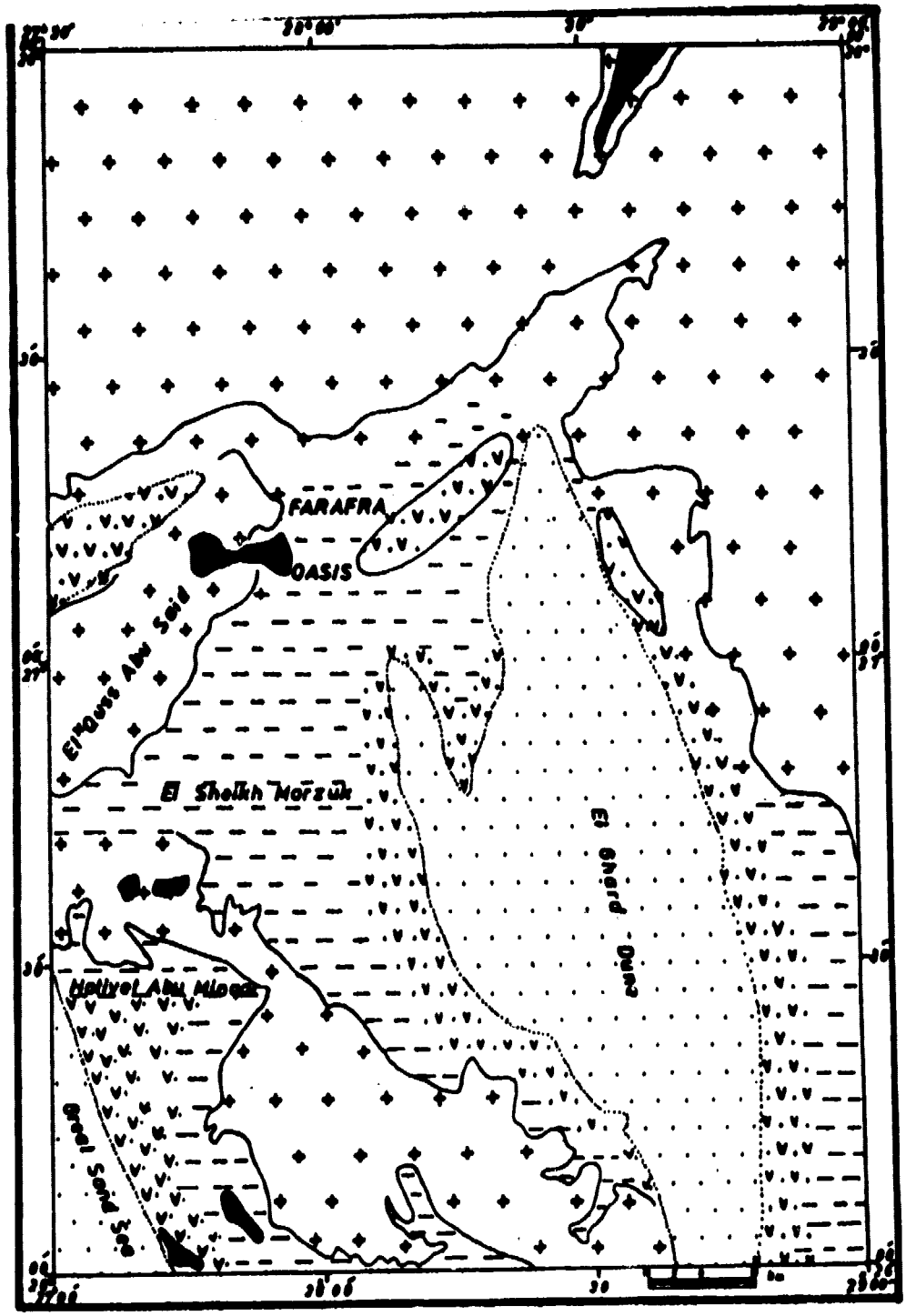

FIGURE 6. SOIL MAP OF FARAFRA OASIS ENVIRONS BASED ON FIELD INVESTIGATIONS AND LANDSAT-1 IMAGERY INERPRETATION.

ARABLE LAND:

Grade II — Soils of pediplain and depressions
Grade III — Soils of playas, bajadas, lacustrine clays
Grade IV — Soils of scrubby sand plains

NON ARABLE LAND:

Grade VI — Soils of sand dune belts
Grade VII — Soils of desert pavements, talus slopes, Hammadas, rocky exposures and dry sabkhas