Utilization of ASTP Photographs in the Study of Small Structures in Abu Rawâsh and Wâdi el Natrûn, Egypt

Hassan A. El-Etr [a] *and Farouk El-Baz* [b†]

ABSTRACT

This paper deals with a study of geologic structures using 8× enlargements of Apollo-Soyuz Test Project color photographs. The two study areas are Abu Rawâsh and Wâdi el Natrûn; both are in the northern part of the Western Desert of Egypt. Because the structures are small, aerial photographs were studied and field checks were made to verify the findings from Apollo-Soyuz photographs.

The Apollo-Soyuz photographs of Abu Rawâsh clearly show structural uplifts that brought white chalk deposits to the surface. The photographs also depict the distribution of dark volcanic rocks in the region and clearly delineate complex structures including several domes and plunging anticlines. Differences and similarities between these structures are clearly displayed in the Apollo-Soyuz photographs.

Wâdi el Natrûn is an elongate depression that is probably tectonic in origin. The Apollo-Soyuz photographs display its structures as well as the string of salt lakes within it. The natural color of these photographs enables distinction between these lakes on the basis of color. Natural color also enables recognition of the barren nature of the northern and southern extremities of the depression. The photographs also reveal that there is a potential for increasing the area of cultivated land on the eastern slope of the depression.

INTRODUCTION

Three sections in this volume describe the utility of Apollo-Soyuz Test Project (ASTP) photographs in regional studies of the Western Desert of Egypt. These reports address (1) photolineaments and major structures, (2) color zones and their geologic meaning, and (3) sand dunes and their distribution. A common aspect of these reports is the study of ASTP data and the extrapolation of observations to other parts of the Western Desert

In this section, the authors have investigated the utility of ASTP photographs of Egypt in detailed studies of small structures. The two areas selected for this investigation are just west of the Nile Delta in the northeastern part of the Western Desert (fig. 1). A common feature of the two areas is the difference in color between the structures of interest and the surrounding terrain. These two localities include the complex structures of the Abu Rawâsh area and the numerous lakes in a depression called Wâdi el Natrûn.

The ASTP crewmembers obtained photographs of these two areas with a handheld 70-mm camera. In addition, Wâdi el Natrûn was covered by photographs obtained with the bracket-mounted 70-mm mapping camera. The handheld-

[a] Ain Shams University, Cairo, Egypt.

[b] National Air and Space Museum, Smithsonian Institution.

[†] Principal Investigator.

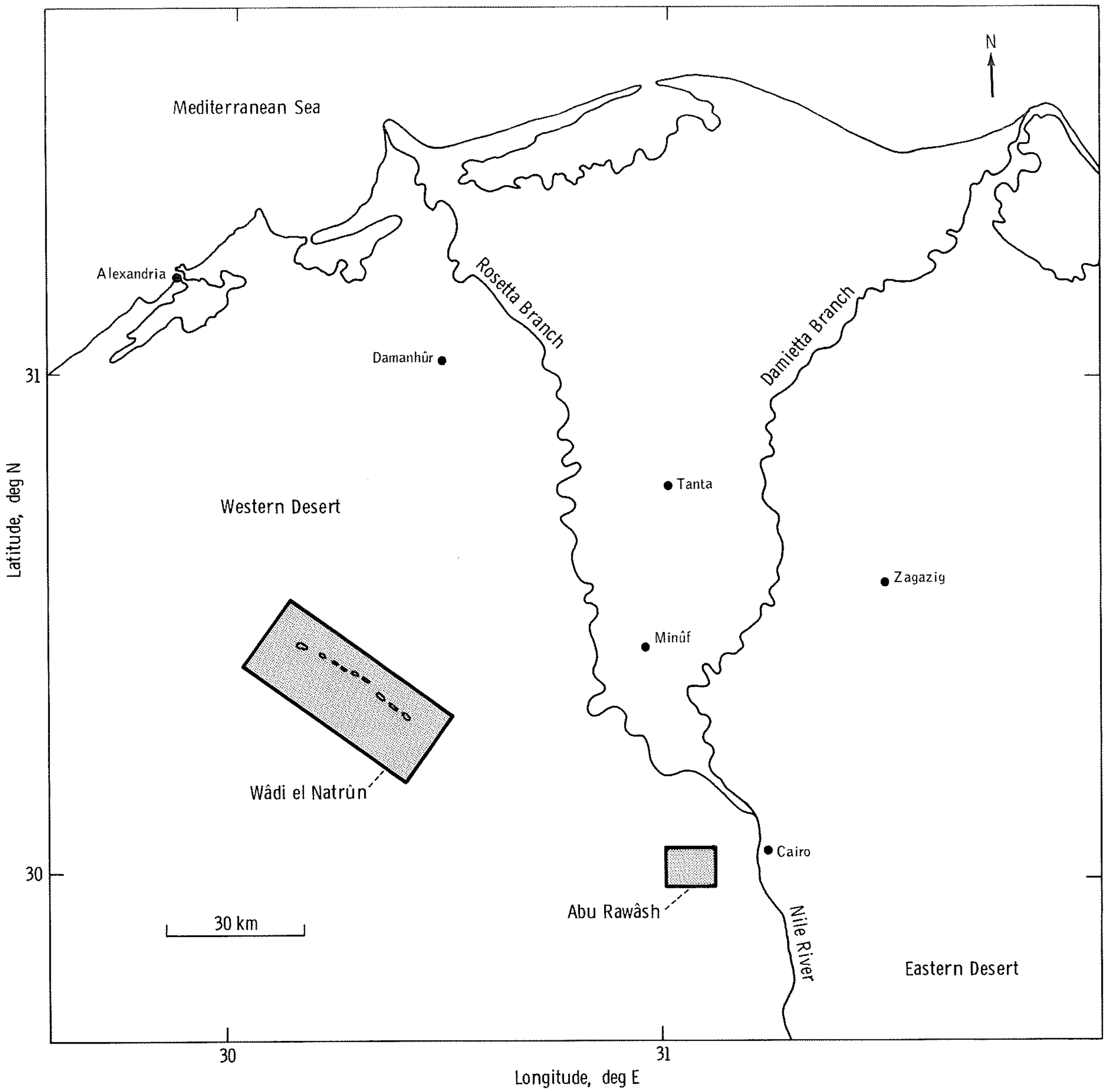

FIGURE 1.—Sketch map of the Nile Delta region showing the location of the two areas studied in this report, Abu Rawâsh and Wâdi el Natrûn.

camera photographs are low oblique, but this did not affect their use in photogeologic interpretation.

The structures portrayed on these photographs are small and cannot be easily studied on 1:1 000 000-scale (20 by 25 cm) photographic prints. For this reason, 8× enlargements were especially made from the original 70-mm film by the Photographic Technology Laboratory at the NASA Lyndon B. Johnson Space Center. These enlargements faithfully reproduced the color variations on the original film, which were important to the study.

It was important to make certain that the findings from the ASTP photographs were real and were not affected by inherent limitations in the photographic prints. For this reason, available aerial photographs were studied and compared to the Earth-orbital photographs. Also, a field trip was made to the two areas to collect ground-truth information.

ABU RAWÂSH AREA

The ASTP photographs show an elliptical, light-toned area whose long axis is oriented in an east-northeast/west-southwest direction (e.g., fig. 2). This area is known as the Abu Rawâsh uplift; it is characterized by exposures of Upper Cretaceous chalky white limestone that are easily demarked from the surrounding buff-tinted plain. This plain is strewn with sand and gravel of Oligocene to lower Miocene age and underlain by Eocene limestones that are exposed farther south in the Pyramids plateau.

The occurrence of Cretaceous rocks at Abu Rawâsh is rather significant in Egyptian geology because it represents an inlier of older rocks. This is the only location at this latitude where Cretaceous rocks are exposed on the surface of the Western Desert. The occurrence of Cretaceous outcrops owes its existence to folding and faulting that took place during the Upper Cretaceous (ref. 1).

Several authors have reported on the geology of this district, particularly Faris (ref. 2) and Jux (ref. 3). Figure 3 (ref. 1) is a detailed geologic map of the district. Comparison between this map and the ASTP photograph (fig. 2(a)) shows how the size and shape (geometry) of the Abu Rawâsh structure are clearly and accurately expressed on the space photograph.

In addition to the main structure, the ASTP photograph (fig. 2(a)) shows several east-northeasterly elongated dark patches that are spatially related to the Abu Rawâsh structure. Field study indicated that these patches are Tertiary (Oligocene) basalt extrusions (refs. 4 and 5) and/or related hydrothermally indurated ferruginous quartzitic grits. Volcanic activity was probably guided by regional fractures of an east-northeasterly orientation. Such a relationship is not evident from the geologic map (fig. 3), because of its limited coverage. However, the relationship of volcanism to regional fractures was particularly emphasized through the use of the ASTP photographs.

In detail, the field-based geologic map (fig. 3) shows eight geologic units; namely: Cenomanian sandstones, marls, and shales (unit 1), Turonian limestones (unit 2), Santonian Plicatula limestones (unit 3), Campanian to Maestrichtian chalk (unit 4), Eocene limestones and sandy limestones (unit 5), Oligocene basalt (unit 6), Oligocene to lower Miocene fluviatile sands and gravels (unit 7), and wadi alluvium (unit 8). On the ASTP photographs, the units that are easily discerned are unit 1, a moderately dark-toned unit; units 2 through 5, which are very light toned; unit 6, which is grayish; and units 7 and 8, which are more yellow.

Unit 1 is exposed in the eastern and southern parts of the study area, and units 2 through 5 form the main part of the uplift. These latter units are not easily differentiated on the space photograph. On the ground, they are distinguished by paleontologic rather than lithologic criteria. Thus, the number of mappable rock units on the space photograph may be reduced to four (figs. 2(a) and 2(b)). These four units are easily recognizable and their contacts are readily discernible.

From these observations, it is recommended that geologic mapping be based on distinct rock units as much as possible so as to benefit from the capabilities of space (and complementary aerial) photography. Subdivision of these rock units may be performed at a later time for relatively small districts of particular interest on the basis of paleontologic (or generally stratigraphic) grounds; i.e., on the basis of time-rock units.

Figures 4(a) and 4(b) show the main structures of the Abu Rawâsh uplift, as portrayed on aerial photographs. The aerial photomosaic shows several structures, particularly El Hassana dome, El Ghigiga dome, the Sudr el Khamis plunging syncline, and the Wâdi el Talun plunging anticline. Faults modify these fold structures to varying degrees. The ASTP photographs (figs. 2(a) and 2(b)) also show virtually all of these structures. They are discerned through the bedding traces of the exposures of the limestone and sandstone units (fig. 3, units 2 through 5 and unit 1, respectively). The photographic texture of the bedding traces is enhanced by the presence of yellowish-peach-tinted wadi alluvium (unit 8). The drainage network of the district is evidently highly dependent on the lithologies and structures present.

Figure 2(b) shows the structures identified on the space photographs of the district. The difference in size between El Hassana dome and El Ghigiga dome is quite evident on the ASTP photograph (fig. 2(a)), although it is indistinct on the geologic map (fig. 3). In addition, the similarity in style of these structures is clear on the space photograph. The plunging Sudr el Khamis syncline and Wâdi el Talun anticline are also similar in structural style, but are markedly distinct from the aforementioned domes. Disharmony of the overall structural pattern of the region is thus revealed in the space photographs. This was not perceived from the previously published geologic map (fig. 3).

To substantiate the findings from the ASTP data, the more detailed aerial photographs (scale 1:20 000) were studied stereoscopically. From this study (figs. 4(a) and 4(b)), it became evident that (1) the fold structures of Abu Rawâsh uplift are disharmonious; (2) the prominent faults dislocating these folds are the longitudinal and transverse type; (3) some bedding plane displacement is locally manifested; e.g., in El Ghigiga structure; (4) diapiric mobilization occurred in the relatively incompetent horizons; e.g., in the Sudr el Khamis and El Ghigiga structures; and (5) the actuating mechanism is probably complicated, and the maximum stresses are believed to be of vertical internal origin. The incompetent character of the oldest exposed (Cenomanian) sandstones and marls of the district is probably of prime significance in determining the disharmonic structural style referred to earlier. It must be stated that geophysical investigations (ref. 6) support the contention that the Abu Rawâsh uplift is deep-rooted and expresses a basement high, the actuating faults of which may possibly have subcrustal extensions.

From this part of the study, it is evident that structural interpretations, even of a complicated region, may be performed satisfactorily with space photographs as augmented by the use of selected aerial photographs and by field checking.

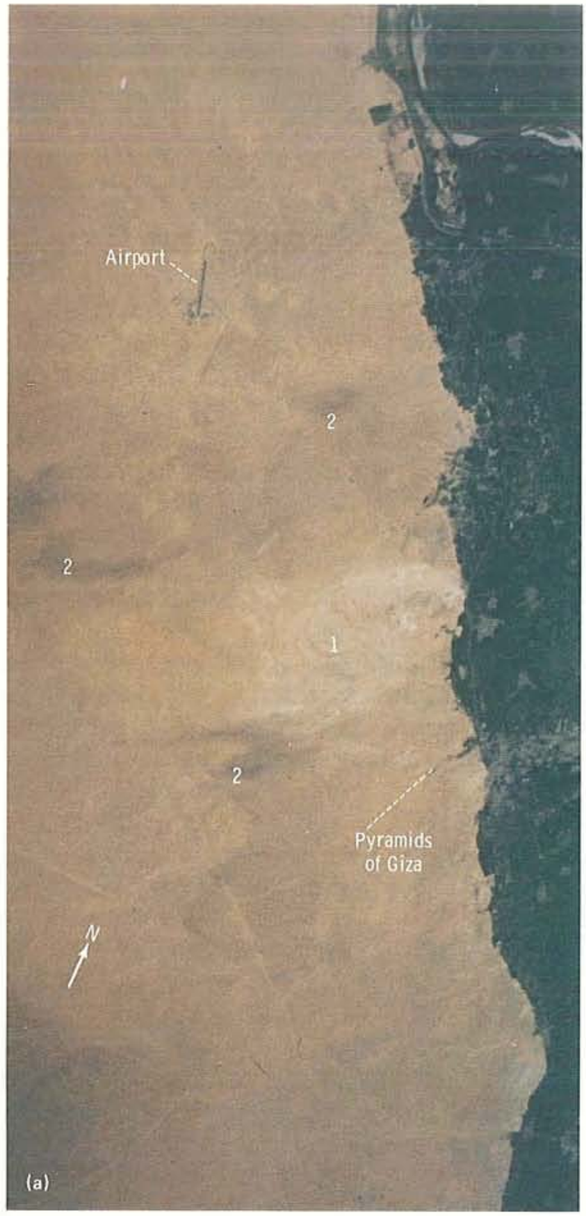

FIGURE 2.—Orbital photograph detail of Abu Rawâsh. (a) Part of ASTP photograph AST-2-136 showing the Abu Rawâsh area west of the Nile Delta. The dark green-gray color on the right edge represents vegetation and the shades of dark earthy gold are those of desert formations. Note the whitish color in the area of folded and faulted structures (1) and the dark-gray color of eroded basalt exposures (2). (b) Drawing of an enlargement of part of the area illustrated in figure 2(a). Within the light-toned area, dashed lines indicate structural elements, arrows give direction of plunge of folds, and solid lines indicate faults. Shaded areas are covered by debris from volcanic (basaltic) intrusions in the otherwise sedimentary surface.

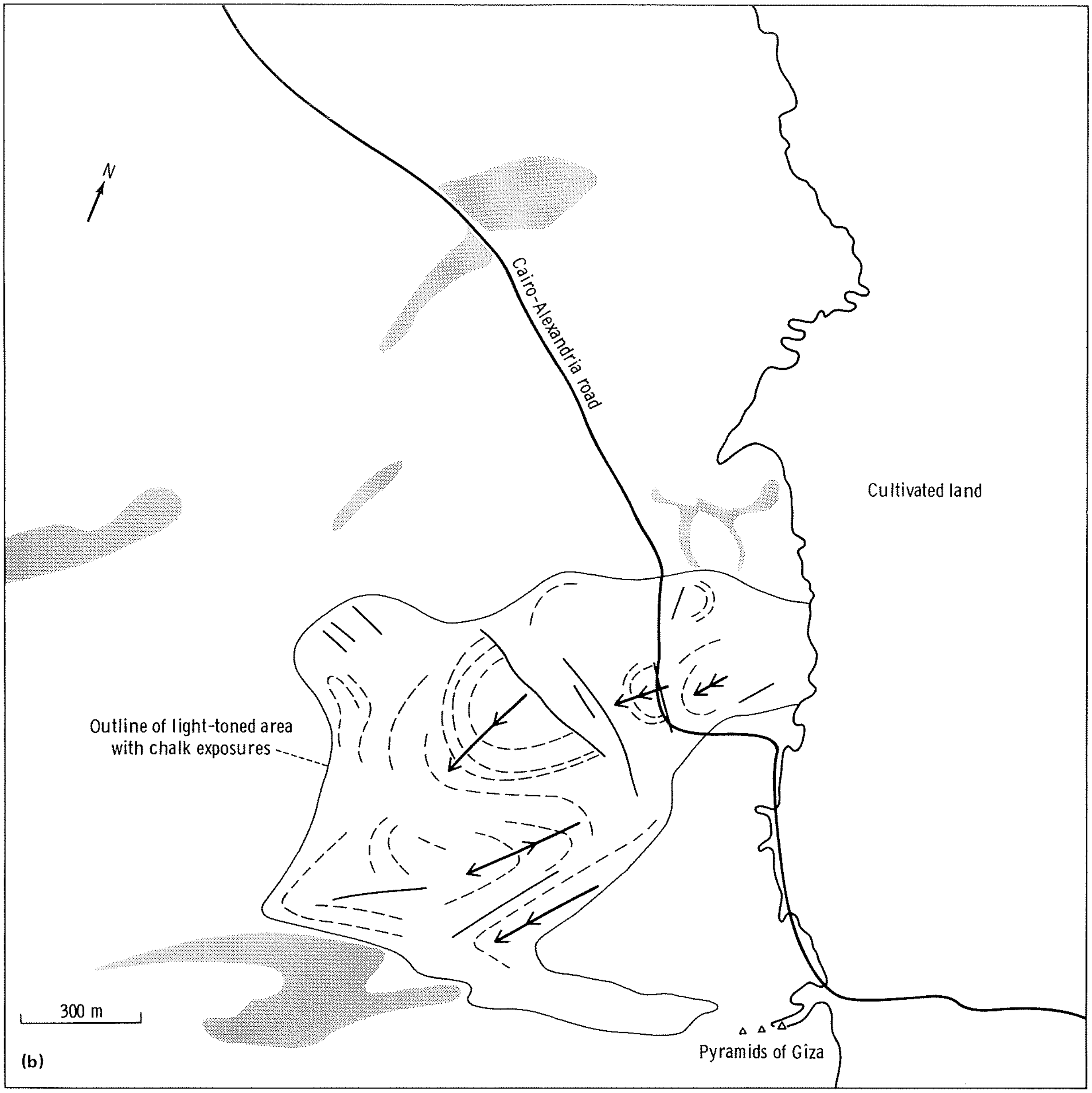

FIGURE 2.—Concluded.

WÂDI EL NATRÛN

The Apollo astronauts photographed a northwesterly elongated, linear depression approximately 40 km west of the Nile Delta. The depression is known as Wâdi el Natrûn; it extends for some 60 km and has an average width of 10 km (ref. 7). The lowest point of this wadi (valley) is approximately 23 m below sea level, and the central lowland is generally 50 m below the level of the surrounding plain.

On the ASTP photographs (e.g., fig. 5), the northern and southern extremities of this physiographic feature are lighter yellow than the

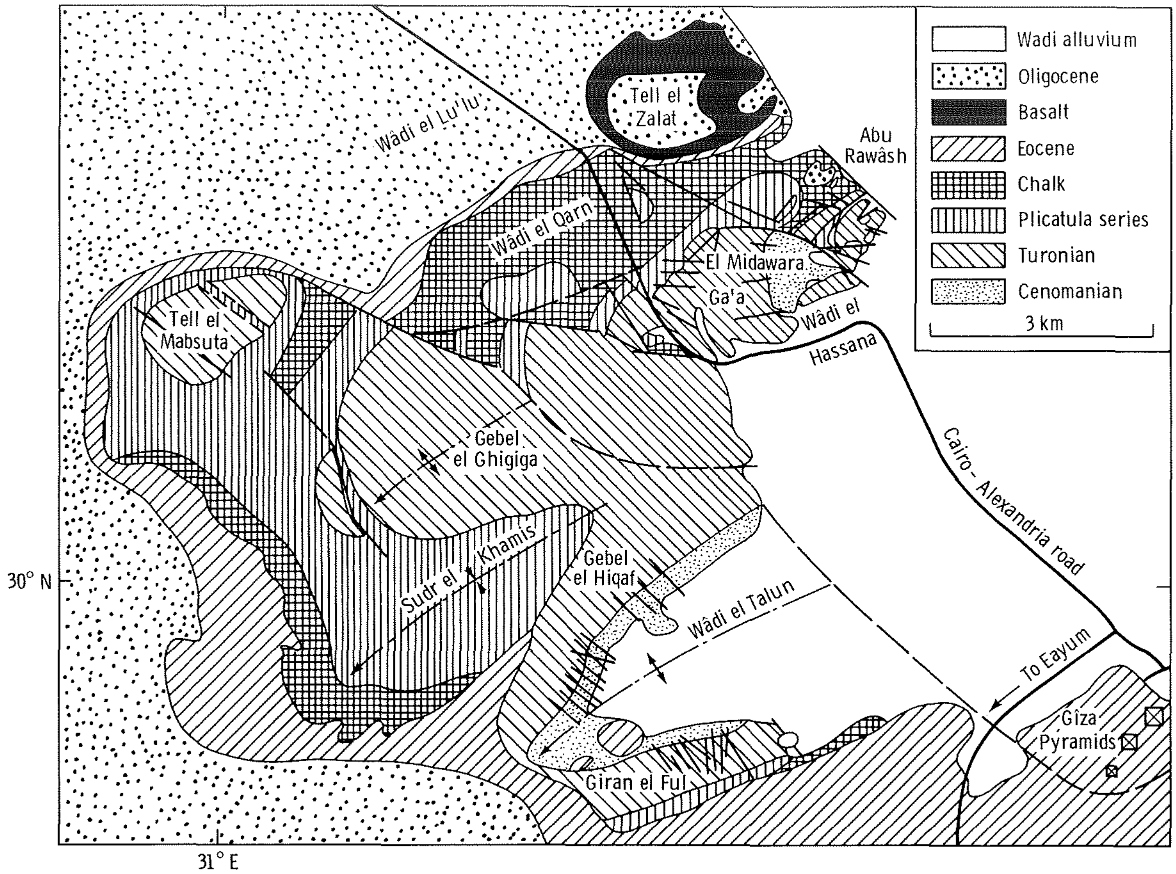

FIGURE 3.—Geologic map of the Abu Rawâsh area (ref. 1, p. 198).

surrounding desert plain. The smooth texture of each end is due to the fact that they are covered by drifting sands. Because of this covering, these extremities are essentially barren. The central part of the depression, however, shows a series of colors; the dark, mottled strips and patches denote vegetation, and the white, brownish-red, and dark-blue patches are soda lakes and associated saline deposits. These salt deposits were known to the ancient Egyptians and were commonly referred to as "natron," or soda salt. In pharaonic times, the natron was in common use and was used in cooking, bleaching linen, and manufacturing glass and glaze. In addition, natron was extensively used in medical works, in purification ceremonies, and in mummification (ref. 8).

The Wâdi el Natrûn region is covered by Quaternary lakebeds and old alluvial deposits of sand and gravel. These deposits were laid down when the sea encroached north of the depression and the Nile River flowed through the area. The lake deposits and alluvium are underlain by sedimentary rocks of Pleistocene and Pliocene age that consist of sand and gravel interbedded with thin layers of clay (ref. 1). These, in turn, are underlain by sandstones, shales, and limestones of Miocene age; basalts underlain by sandstones and shales of Oligocene age; and Eocene and Cretaceous limestones.

The main morphotectonic subdivisions of this region have previously been well studied and mapped (ref. 7). On the eastern side of the depression, a series of gravel terraces is present. These are recognized as old Nile terraces and are cultivated. The ASTP photograph (fig. 5) shows three such cultivated terraces extending for several

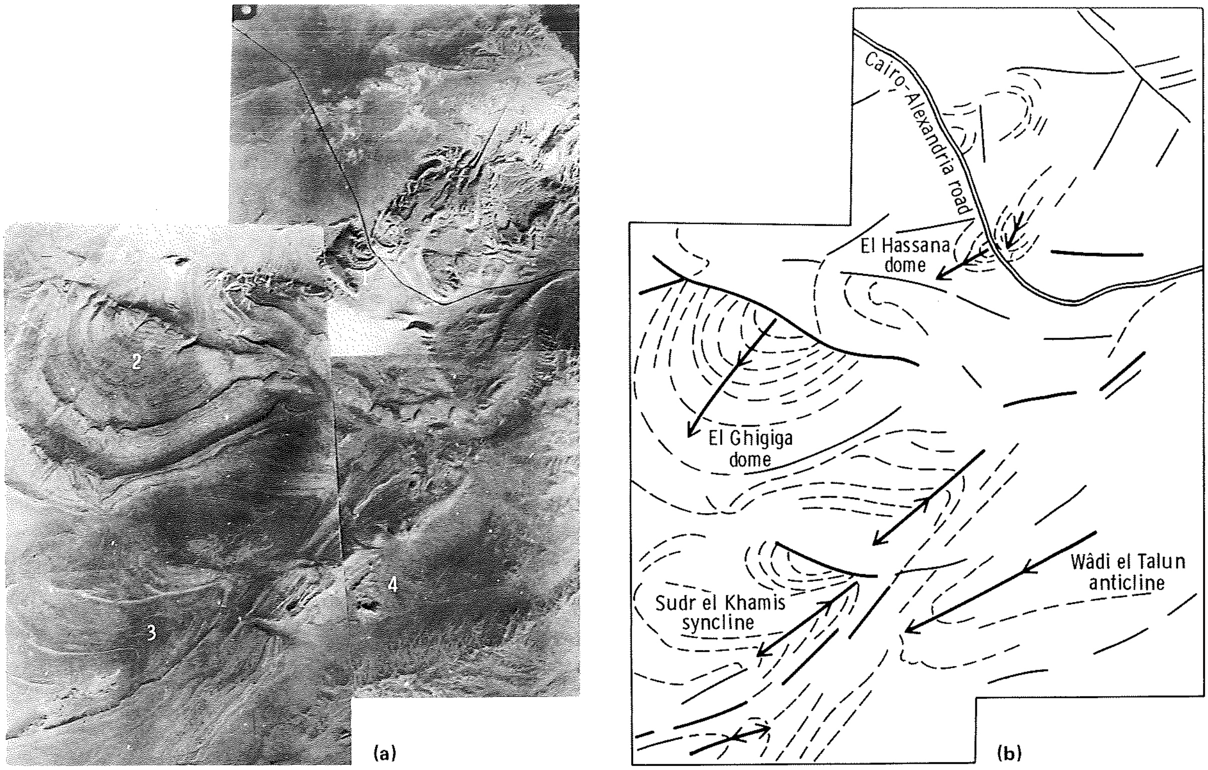

FIGURE 4.—Aerial photograph detail of Abu Rawâsh. (a) Aerial photographs showing the complex structures in the Abu Rawâsh area: (1) El Hassana dome, (2) El Ghigiga dome, (3) Sudr el Khamis plunging syncline, and (4) Wâdi el Talun plunging anticline. (b) Drawing of the structures displayed in the aerial photographs shown in figure 4(a). Solid lines indicate faults; dashed lines, fold boundaries; and arrows, fold plunge directions.

kilometers near the north-central part of the depression. Irrigation on these terraces depends on underground water that is pumped from deep aquifers. This water has moderate to good irrigation qualities. On the central lowland of the wadi, cultivation is mainly concentrated on the eastern side and extends for approximately 30 km. Here, irrigation depends on the shallow subsurface water present 1 or 2 m below the surface. This water is generally saline.

Because of their color sensitivity, the ASTP photographs are well suited to study the numerous lakes within the depression (fig. 5). These soda lakes are mainly confined to the western side of the central lowland of the depression. Some 20 lakes are present, the largest of which is approximately 2.5 km^2 in area. The main lakes are illustrated in figure 6. These lakes are generally asymmetric. Their longer axes are on the eastern side; their other sides commonly taper to the west. Smaller lakes are merely arms of the larger ones that have been cut off by drifting sands. Such small lakes dry up partly or wholly in the summer (ref. 9).

The water levels of the Wâdi el Natrûn lakes generally show seasonal fluctuations. A number of freshwater springs flow energetically all year round from the bottom of some of these lakes, particularly near their northeasterly sides (ref. 9). The source of water in the lakes is accordingly believed to be due partly to seepage along faults of ground water from deep aquifers, and partly to infiltration from the Nile through porous and permeable shallow sandy sediments. On the western side of the depression, the presence of some "fossil" surface-drainage lines denotes earlier sur-

FIGURE 5.—Enlargement of ASTP photograph AST-16-1256 showing Wâdi el Natrûn and its numerous median lakes. The color of the lakes is a function of chemistry, salinity, and bacterial content.

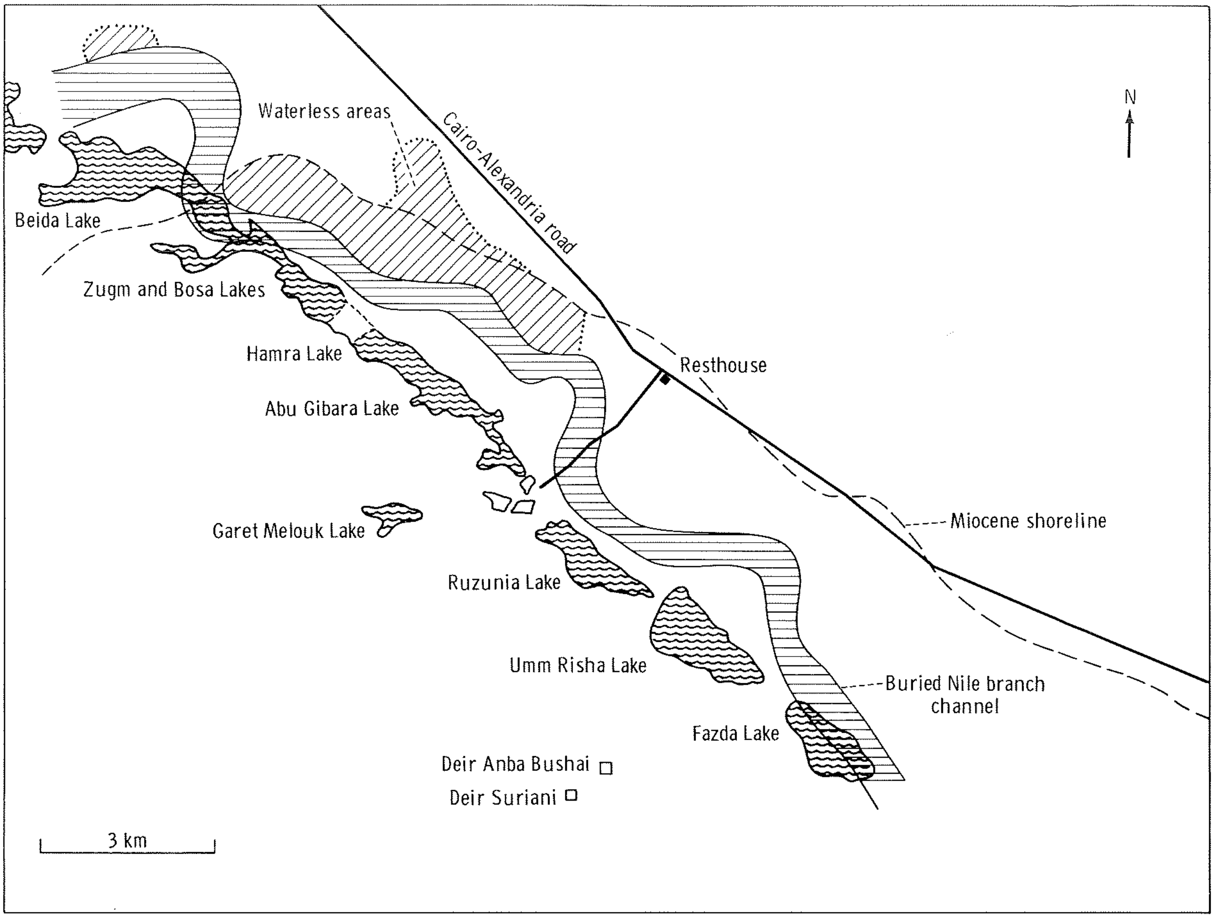

FIGURE 6.—Sketch map of part of Wâdi el Natrûn showing the old course of a Nile River branch, the Miocene shoreline, and the shape of lakes within the depression (courtesy of A. Shata).

face runoff contributions to the lakes in pluvial periods (fig. 7). These drainage tributaries are also clear on the ASTP photograph (fig. 5). Present-day water runoff is small and averages approximately 33 mm/year.

Along the bottom and rims of the lakes, saline deposits are common. They are presently in the process of formation. The main salts are chlorides, carbonates, and sulfates of sodium. The most abundant minerals (ref. 10) are halite (NaCl), thenardite (Na_2SO_4), trona ($NaHCO_3 \cdot Na_2CO_3 \cdot 2H_2O$), burkeite ($2NA_2SO_4 \cdot Na_2CO_3$), hanksite ($Na_{22}KCl(CO_3)_2(SO_4)_9$), sylvite (KCl), and aphthitalite ($(K, Na)_3Na(SO_4)_2$). The quantities of such salts and the relative abundance of the different constituent minerals are variable in the different lakes.

The color of water in the lakes is mostly pinkish- to violet-red (fig. 8), although some lakes are lighter in color. The water itself is generally alkaline (pH 9 and more), and dissolved salts may reach a density of 200 g/liter. The reddish color has been attributed by some authors to the existence of a type of small crustacean named *Artemia salina,* whose color changes from green during life to red after death (ref. 9). Other authors argue, however, that such crustaceans are not commonly present throughout the year but the deep water color is. For this reason, they attribute the color to the presence of cocci-type bacteria instead (ref. 9). Such bacteria are known to exhibit a red coloration and grow abundantly in the lakes. These bacteria seem to be sensitive to the water salinity and consequently their increase causes deeper water

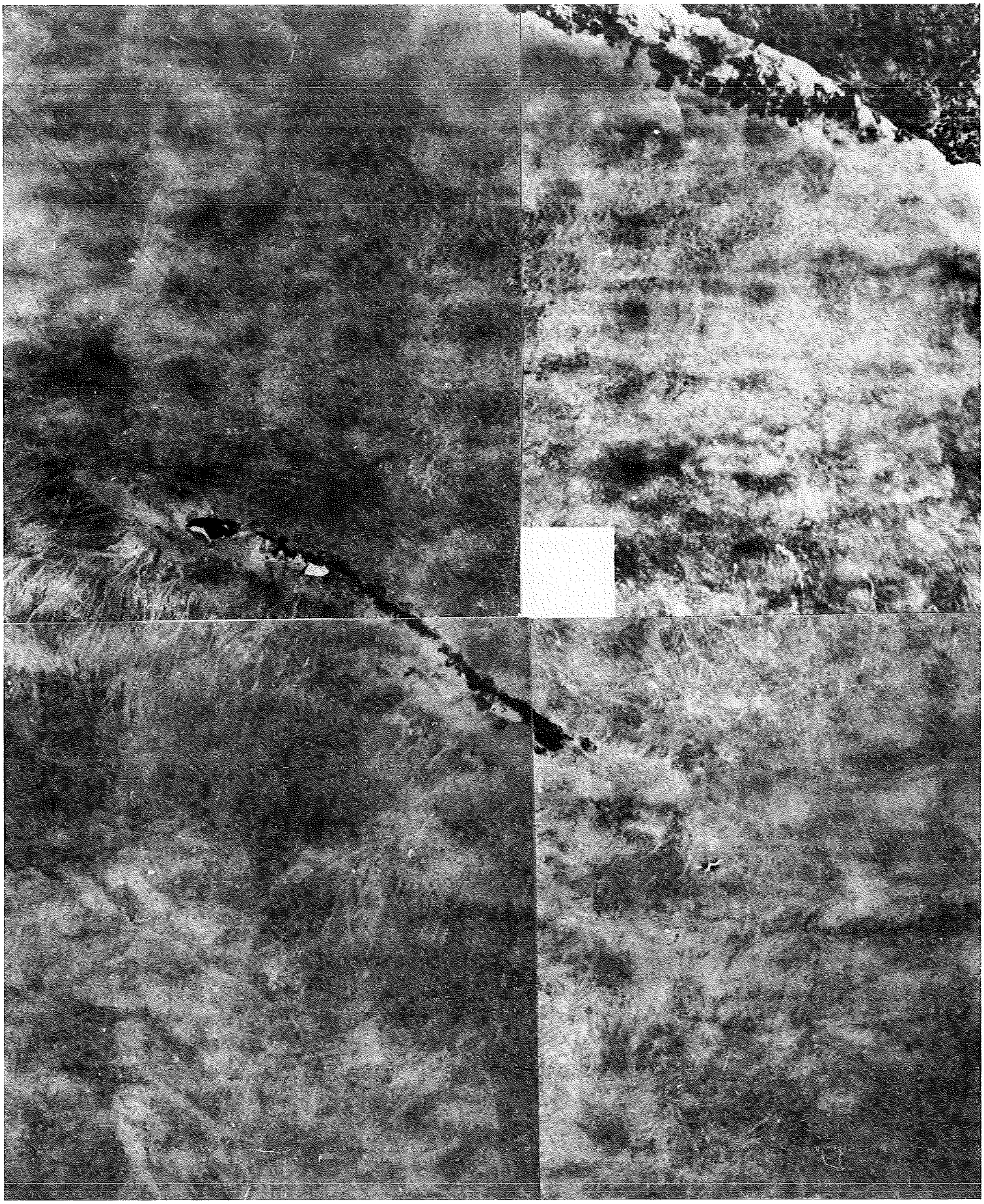

FIGURE 7.—Mosaic of four aerial photographs of the Wâdi el Natrûn region. North is at the top. The dark region in the upper right corner is part of the vegetated Nile Delta. The narrow black region represents the lakes and vegetation within the Natrûn depression. To the west, a complex drainage network of dry valleys is clearly visible.

FIGURE 8.—A crust of pinkish-white salt in the process of formation at the edge of Ruzunia Lake in the middle of Wâdi el Natrûn. The purple-brown color of the water is similar to that described and photographed by the Skylab 4 and the ASTP astronauts in the northern half of the Great Salt Lake in Utah (ref. 11). The salt layers in this region display a pink color (photograph by Farouk El-Baz).

coloration. On space and aerial photographs, this color may be taken as an indicator of the degree of salinity. This situation is somewhat similar to that of Utah's Great Salt Lake whose northern, more saline half is redder than its southern half because of the presence of algae (ref. 11).

In addition, the deposition of salts in the Wâdi el Natrûn lakes is believed to be biochemically controlled. If this proves to be true, the abundance of bacteria will reflect the more favorable sites of deposition in the different lakes or parts of lakes. This, in turn, may enhance salt mining exploration and exploitation.

Based on the authors' photogeologic studies and field observations, the Wâdi el Natrûn is believed to have been formed by tectonic (fault) initiation, developed by water (fluvial) erosion in pluvial (Pleistocene) periods, and modified by later (sub-Recent) arid deflation. The tectonic phase is evidenced by the linear contrast in fresh to brackish water input on the eastern and western sides of the depression. This water is more abundant on the eastern side and nurtures all vegetation in the region. The concentration of saline lakes on the western side and the presence of freshwater springs in the bottom of some of them, particularly on their northeasterly sides, add evidence. The tectonic phase is further substantiated by regional geophysical studies (ref. 12), which emphasize the deep nature of the depression. The actuating faults (or fault) are believed to be deep seated (basement) extensions. Block faulting is probably a common structural style in the basement. As stated earlier, the role of fluvial erosion is evidenced by the "fossil" drainage network on the western side of the depression (fig. 7), and the role of wind deflation is attested by present-day wind manifestations.

The Wâdi el Natrûn region is economically important for two reasons: because of its potential for farming and for soda salts mining. This study of ASTP photographs shows that there is a strong possibility of increasing the cultivated lands on the eastern slopes of the depression. In addition, the study outlines the total dimensions of the depression and points to the barren nature of its northern and southern extremities due to desertification. The contribution of this study to the improvement of the salt mining operations in the region will be the subject of a future study that will involve the size-shape distribution of the lakes, their detailed spatial distribution and control, and a correlation between their chemistry, bacterial content (water coloration), and salt deposition.

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