Chapter 1

JOURNEY TO EGYPT'S FARTHEST CORNER

FAROUK EL-BAZ
National Air and Space Museum
Smithsonian Institution
Washington, D.C. 20560

ABSTRACT

The Gilf Kebir-Uweinat expedition of 1978 was organized to verify geologic interpretations of Apollo-Soyuz photographs. These photographs and Landsat images showed features that are reminiscent of those depicted by Mariner and Viking missions to Mars. It was therefore intended to field study these features in order to better understand their morphologic analogs on Mars. For two weeks, an inter-disciplinary group of sixteen researchers investigated the extremely arid tracts across 2500 km from Kharga Oasis south-southwest to the border intersection of Egypt, Libya and Sudan. The convoy of vehicles consisted of six Soviet Gaz desert jeeps, two Volkswagen type 181 cars, two 4.5-ton tanker trucks for water and gasoline, and one 12-ton lorry loaded with food and camp supplies. The findings of the expedition lend support to other indications that climate change played a significant role in the formation of the eastern Sahara. These findings also reveal that correlations between the eolian features in southwestern Egypt and the wind-blown patterns on the surface of Mars will result in a better understanding of eolian activity on both planets.

INTRODUCTION

The seeds of the 1978 expedition to southwestern Egypt were planted four years earlier during the planning for astronaut observations and photography on the Apollo-Soyuz Test Project (ASTP). As principal investigator for the "Earth Observations and Photography" ASTP experiment, I was responsible for selecting and flight-scheduling of sites for study from Earth orbit (El-Baz and Mitchell, 1976). At the same time, a joint research project between the Smithsonian Institution and Ain Shams University was organized to study "Desert Erosion and Sand Movement in Egypt".

Study of the photographs of the Western Desert of Egypt taken prior to ASTP revealed interesting eolian features, although detailed study of some required additional photography. Thus, the area of Uweinat Mountain was selected as one of the primary sites of observation on the ASTP mission. When the mission was accomplished in July 1975, the ASTP astronauts were debriefed on what they observed. Further study of their observations and the photographs they obtained added to the significance of the locality, particularly in terms of analog correlations with wind-blown features on Mars (El-Baz, 1977, p. 80).

In the course of discussions with colleagues from both the United States and Egypt, it became apparent that a field investigation of the Uweinat region utilizing the added perspective of Earth orbital photographs would be very worthwhile. The purposes of the investigation were manifold, and included:

1. Field checking of photogeologic interpretations based on Apollo-Soyuz observations and photographs as well as Landsat images.

2. Study of wind-blown features revealed in the Earth orbital photographs and images for comparison with eolian features revealed on the surface of Mars by Mariner 9 and Viking 1 and 2 spacecraft.

3. Investigation of fluvial landforms, particularly the dry wadis of the Gilf Kebir plateau, for comparison with martian channels.

4. Collection of information on the Quaternary and Recent deposits that may be significant to the understanding of the origin of the Western Desert of Egypt.

5. Gathering data on prehistoric human habitation in the region for a better understanding of the environmental factors that prevailed in the region during the past few thousand years.

6. Study the potential of the southern and southwestern parts of the Western Desert of Egypt in terms of agriculture and/or economic mineral deposits.

Because of the above, it was necessary to put together a multidisciplinary team of investigators for the expedition, and it also became necessary to secure funding from various sources to support the journey. The trip was made possible through the cooperation of many individuals and numerous agencies in both the United States and Egypt. The group assembled in Cairo and proceeded from Kharga Oasis to Bir Tarfawi West, to the Gilf Kebir, Uweinat Mountain, and back (Fig. 1.1). Field work was conducted during two weeks between 25 September and 8 October, 1978. Preliminary results of the expedition were published in the Geographical Journal (El-Baz and others, 1980).

THE TEAM

The scientific investigation team was composed of seven American and nine Egyptian specialists in the fields of geology, planetology, Quaternary geology, geography, archaeology, and botany, including:

Loutfy Boulos, National Research Center, Cairo: Botanist specializing in plant taxonomy with much experience in desert flora, who visited the Uweinat region in 1968.

Carol Breed, U.S. Geological Survey, Flagstaff, Arizona: Geologist with much experience in the classification of dune types from orbital images and in the formation of sand dunes.

Atif Dardir, Geological Survey of Egypt, Cairo: Geologist specializing in igneous petrology and economic mineral deposits.

Hamid Dowidar, Geology Department, Ain Shams University, Cairo: Graduate student (Ph.D), presently working on the structural setting of the southern part of the Western Desert.

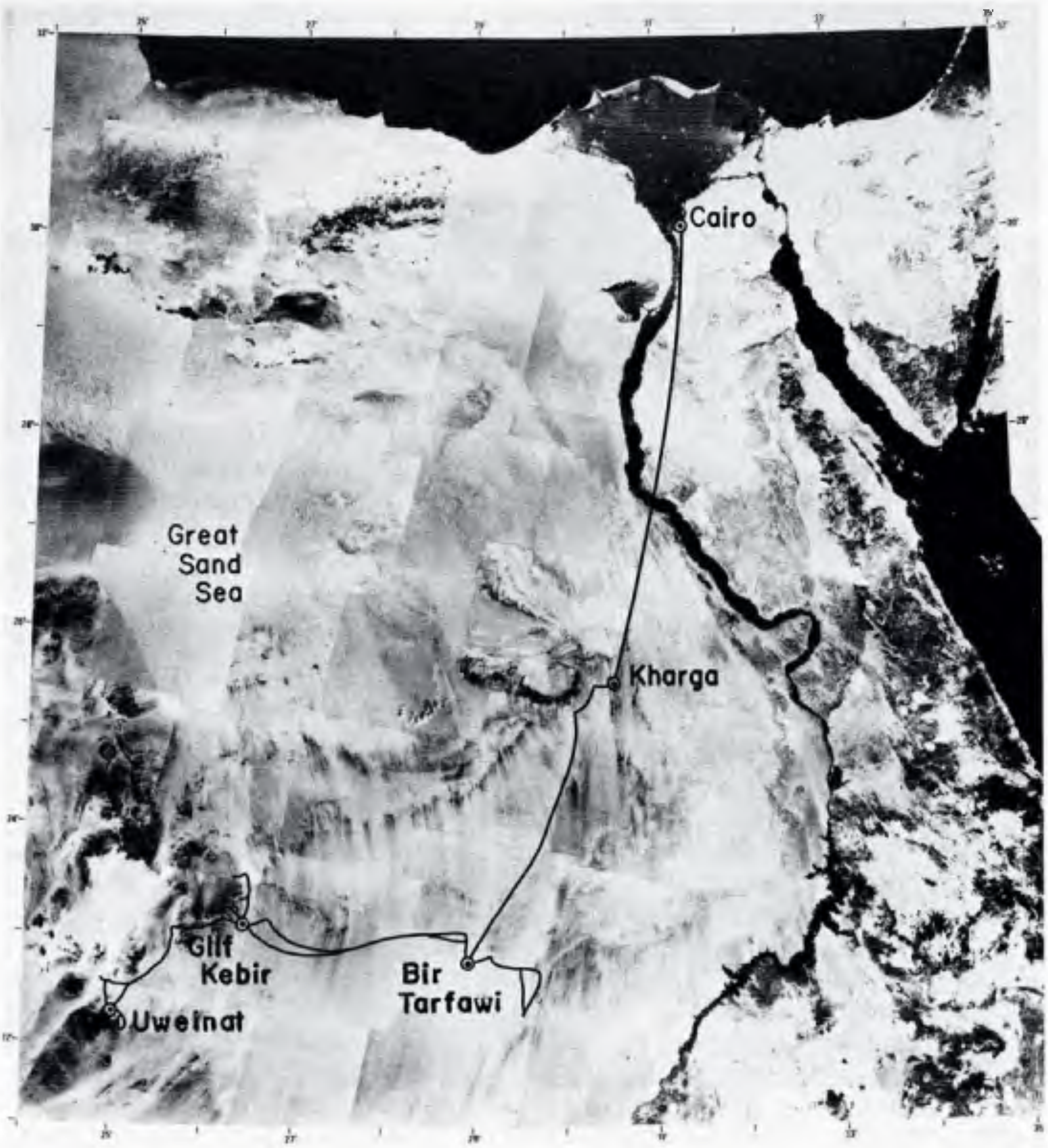

Figure 1.1 Generalized route of the 1978 journey to Gilf Kebir and Uweinat as plotted on a Landsat image mosaic of Egypt.

Farouk El-Baz, National Air and Space Museum, Smithsonian Institution, Washington, D.C.: Geologist specializing in desert studies and planetary geology; Co-Principal Investigator of the research project on "Desert Erosion and Sand Movement in Egypt", and Science Advisor to President Sadat.

Hassan El-Etr, Geology Department, Ain Shams University, Cairo: Structural geologist and Co-Principal Investigator of the research project on "Desert Erosion and Sand Movement in Egypt".

Nabil Embabi, Geography Department, Ain Shams University, Cairo: Geomorphologist who specializes in dune forms and rates of sand transport; now teaching at the University of Qatar, Doha.

Maurice Grolier, U.S. Geological Survey, Flagstaff, Arizona: Astrogeologist with much experience of mapping of planetary surfaces with photographs from space.

Vance Haynes, Departments of Anthropology and Geosciences, University of Arizona, Tucson, Arizona: Quaternary geologist who spent eight field seasons in the Western Desert of Egypt.

Mohamed Ibrahim, Geological Survey of Egypt, Cairo: Geologist who is charged with field investigation in the Western Desert.

Bahay Issawi, Geological Survey of Egypt, Cairo: Senior geologist and field guide of the expedition who mapped the area in 1971.

Ted Maxwell, National Air and Space Museum, Smithsonian Institution, Washington, D.C.: Geologist specializing in geomorphology and sedimentology who was charged with the radio transmissions to the Nimbus-6 satellite.

John McCauley, U.S. Geological Survey, Flagstaff, Arizona: Astrogeologist with much experience in planetary geology and specialist on eolian features of Mars.

William McHugh, GAI Consultants, Inc., Kansas City, Missouri: Archaeologist who investigated the implements collected by Oliver Myers in 1938 from archaeological sites in the Gilf Kebir.

Adel Moustafa, Geology Department, Ain Shams University, Cairo: Geologist now working on a Ph.D. in photogeology at the Geology Department, University of Texas at Austin.

Mahmoud Youssef, Geology Department, Ain Shams University, Cairo: Geologist who specializes in remote sensing particularly the use of Landsat data.

In addition, Hatim Farid, science editor of Cairo's October Magazine joined the expedition. He wrote several articles on the expedition and its results in October (Farid, 1978). Sixteen employees of the Geological Survey of Egypt supported the expedition as drivers, mechanics, and cooks, making a total of 33 participants.

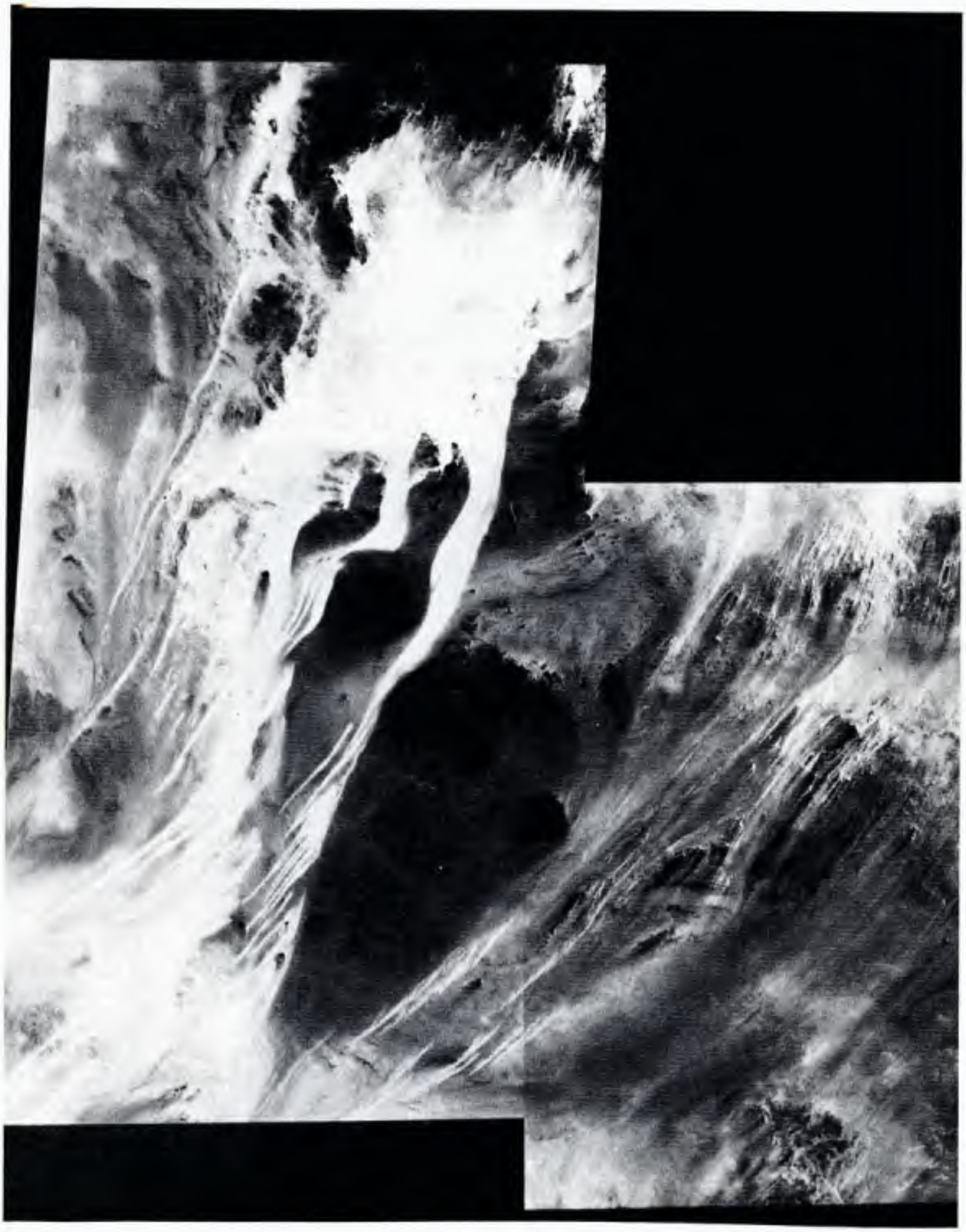

Figure 1.2 Computer generated mosaic of Landsat images of the Uweinat region showing bright streaks of sand over darker rock surfaces. (Courtesy of Goddard Space Flight Center).

LOGISTICS

When the trip was first planned in 1977, the Military Survey of Egypt was to provide necessary logistical support. However, in the summer of 1978, the Military Survey decided to postpone their expedition to Uweinat. This necessitated organizing the logistical support through the Geological Survey of Egypt.

In preparation for the trip, I took care of administrative arrangements and secured the necessary approvals from the American and Egyptian Governments. Hassan El-Etr acted as quartermaster, and was responsible for procurement of field supplies and food. Vance Haynes duplicated photographs of areas visited by previous expeditions and William McHugh provided team members with reprints of O. H. Myers' unpublished maps of archaeological sites in the Gilf Kebir area. The Smithsonian Institution procured a small scale mosaic of computer-enhanced Landsat images of the Uweinat area (Fig. 1.2) and the U.S. Geological Survey prepared enlargements of selected Landsat images along the route.

Figure 1.3 Photographs of some of the vehicles used on the journey including a water tank truck (top), the truck that carried food and camping supplies shown here during an attempt to get it unstuck (middle), and a VW "thing" parked near the bones of a camel, with a camel caravan in the background in the Darb El-Arba'in (bottom).

The basic logistical support was provided by the Egyptian Air Force and the Geological Survey of Egypt. The Egyptian Air Force very kindly flew the scientists from Cairo to Kharga and back in a Convair-280 airplane usually reserved for military staff. Bahay Issawi supervised the preparation of Geological Survey vehicles and the selection of support personnel. The organization was very carefully done with regards to schedules, itinerary, transportation of personnel and supplies, camping, sanitation, and cooking. All vehicles, except for the two German Volkswagen cars, were Soviet made as other equipment that found its way into the civilian sector of the Egyptian economy before termination of Soviet aid in the early seventies. The convoy of vehicles (Fig. 1.3) included: One 12-ton 3-axle truck, which carried tents, bedding, food and medical supplies, and some drinking water and fuel; one 4.5-ton tanker truck for gasoline; one 4.5-ton tanker truck for drinking water, and six 4-wheel drive 7-seater 1969 Gaz Jeeps. It is beyond the scope here to evaluate in detail the performance of these vehicles in the field. Breakdowns were minor and few, mostly due to engine overheating. Air ventilation inside the passenger cab was a little inadequate, but system redundancy was superb. Only once did one Jeep run out of gas, and rescue from the lead Jeep came within one-half hour.

The southern part of the Western Desert of Egypt consists to a large extent of a discontinuous eolian peneplain (Fig. 1.4). It extends for hundreds of kilometers, and is interrupted here and there by sand seas, low ridges, escarpments, dissected plateaus, and shallow flat-bottomed valleys. The surface is covered by thin, densely-packed sand sheets mantled in places by desert lags ranging in size from sand to granule, cobble stones. The landscape is old, and the sand and the lag are mature, making travel at speeds of 60-80 km/hr across the trackless desert a surprisingly easy accomplishment. In places, this speed can be maintained over continuous distances of hundreds of kilometers. Our guides navigated from one major landmark to another, but dead reckoning by compass was also used. The large truck, and at least one of the two 4.5-ton tankers traveled one day ahead of the convoy, so that camp could be set up before the arrival of the passenger Jeeps. Only the 12-ton truck had some difficulty in negotiating the worst areas of loose sand.

For planning purposes, the rule of thumb used by the Geological Survey of Egypt in calculating water rations adequate for work in the desert is: 3 gallons per day, per scientist; 1.5 gallons per support personnel. As a matter of fact, century-old experience proves that corpulent, let alone obese persons, drink more water than lean ones. Thus, a very severe selection process favoring lean workers over fat ones is applied to Egyptian labor working in the desert. These water rations and also gasoline rations are augmented from 10 to 50 percent to take into account leaks and other unforeseen contingencies. Upon completion of the journey and return to Kharga Oasis, there was a 500-gallon (2-ton) surplus in the water truck, representing a 50 percent redundancy on the party's actual requirements, and therefore a large margin of safety.

Figure 1.4 Photographs illustrating the peneplained nature of the Western Desert of Egypt. Photograph at bottom shows cairns along the Darb El-Arba'in.

Camping in the open, in light sleeping bags, was quite possible and even pleasurable, both at the northern slope of Gebel Uweinat and 100 km south of Kharga Oasis. Nevertheless, we stayed most of the time in 2-man or larger conical tents. These, like the cone-shaped or multifaceted pyramidal hills in the regional landscape, seem to

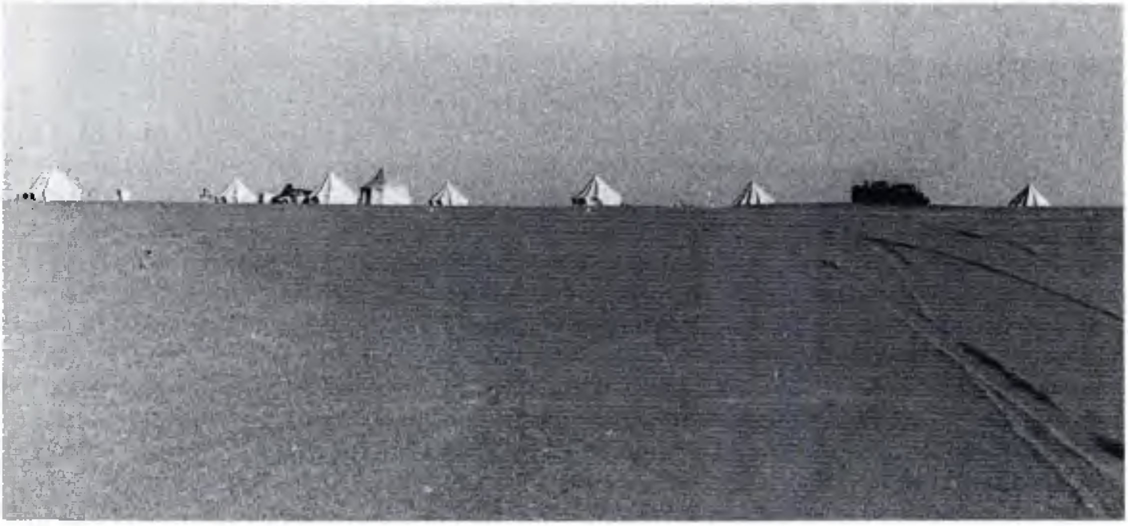

Figure 1.5 Camp at Bir Tarfawi West showing the wind-resistant conical tents.

conform to the shape offering the least resistance to the wind (Fig. 1.5). Sanitation practices current in any military camp were observed. Food, cooked in the Egyptian style, was adequate, and hot tea was the main beverage. Egyptian wine and stronger alcoholic drinks were available to those who liked them. Fresh meat, besides canned meat, was provided by live domesticated ducks brought from a duck-raising ranch at Kharga Oasis (Fig. 1.6).

Time of travel was ideal. Temperatures ranging up to 40°C rarely became a problem, except in midday, because of the low moisture content in the air. The breeze was surprisingly constant (average wind velocity: 20 km per hour), except around Gebel Uweinat, where the weather was very calm. Flies were found at some oases and around Gebel Uweinat, probably because of the nearby presence of herds of

Figure 1.6 White ducks from Kharga that provided the fresh meat supply during the journey.

domesticated goats and occasional feral donkeys and wild gazelles.

THE ROUTE

Our expedition greatly benefited from the knowledge gained from thirteen previous journeys to Uweinat from various localities in Egypt, particularly the 1938 Bagnold expedition (Bagnold and others, 1939). Based on this knowledge, we plotted our route on maps and space photographs and were thus ready to begin. On the morning of 25 September 1978, our plane departed from Cairo's Almaza Airport, and during the next two hours we observed and photographed many interesting features from the air. At Kharga we met with the jeeps that had arrived a day earlier from Cairo. We used some time to study the Kharga "mud lions", which are wind sculpted yardangs of lacustrine deposits with blunt fronts and aerodynamically shaped bodies. On the following day we started our drive to the south-southwest.

From Kharga we drove west on the Kharga-Dakhla asphalt road and at the 60-km mark we made a turn toward the south-southwest, leaving the last asphalt surface we saw for the rest of the trip. Our target was Bir Tarfawi West (Fig. 1.1) where the heavy vehicles awaited. We reached our destination long after sunset.

In the vicinity of the camp at Bir Tarfawi West we visited a patch of burned organics along an ancient, now dry, lake shore. Because of the known age of gastropods and snails embedded in the dry lake strata, archaeologists were able to assign a relative age to the abundant manmade artifacts in these strata. The visited site, Vance Haynes noted, may have hosted human settlements at least 30,000 years ago. The water at the well dug by the Geological Survey of Egypt was reached at 2 m depth. As we drove toward a red-colored field of barchan dunes, we encountered flint implements that were estimated to be about 6,000 years old. A few inches in the soil below, Vance Haynes found pieces of ostrich egg shells.

On 28 September we headed east to Qaret El-Maiyit, which is Arabic for "hill of the dead", because of the human skeleton that was discovered there in 1922. The exposed granitic rock (Fig. 1.7) displayed a long down-wind tail of dark surface that was surrounded by light-colored sand on either side. The streak appeared very similar to those photographed by Viking spacecraft in the Cerberus region of Mars (El-Baz and Maxwell, 1979a; Chaikin and others, 1980). Weathered products of orthoclase from intervening pegmatite veins in the granite gave this tail a dark red tone. Nearby were large sandstone and granite blocks arranged in crude circles; we assumed that these represented an ancient human settlement (Fig. 1.8). We continued the drive towards the fabled Darb El-Arba'in caravan route, which is nearly 20 km wide where we intersected it. At its border we examined the mineralized products of a geyser, which turned out to be mostly silica and iron.

As we continued the exploration southeastward toward Bir Sheb, we came upon a ghost settlement at Bir Kurayim that was established by the Egyptian Desert Development Organization in 1964. The buildings,

Figure 1.7 Granitic rocks of Qaret El-Maiyit in the foreground with a dark tail surrounded by sand deposits in the background.

Figure 1.8 Remains of a prehistoric house, marked by large rocks arranged in a 4 m diameter circle.

Figure 1.9 A typical 2 m high yardang with a blunt side facing the wind.

which were half-filled with sand, were made of galvanized metal and glass, materials one would least expect in a desert environment.

On the following day, we were up at sunrise to break camp. We drove north for 32 km to a block of conglomerate that sprung from the featureless plain. Saleh, the most conscientious of our support crew erected a 2 m high cairn on top of it to lead other drivers. Along the route we stopped several times to wait for the heavy vehicles. It took many men to get these unstuck using two huge chain ladders. At one stop a sheet of sand, a few grains thick, moved hurriedly along the surface. The wind velocity was measured to be 16 km/hr. It appeared that most grains were rolling rather than saltating on the surface.

We continued westward on 30 September and with the morning light our first stop was to study a field of yardangs (Fig. 1.9). Several of these were 2 m high and exhibited very straight windward faces. As we approached the southeastern scarps of the Gilf Kebir we headed to "Bagnold's camp" (Fig. 1.10). The 1938 tracks of his trip were partly covered by a 1 km longitudinal dune. The side of the dune adjacent to the camp site had partly submerged the low structure. Wooden boxes at the site showed the effects of wind erosion; a piece of wood that was 13 mm in thickness on the nailed side, was only 2 mm thick at the exposed surface. We established camp at the entrance of Wadi Wassa near the southeasternmost tip of the Gilf Kebir (Fig. 1.11).

On 1 October 1978, we traveled northward to Wadi Mashi. On top of the Gilf Kebir, William McHugh discovered a site where implements were strewn near "core" blocks of quartzite, from which they were

Figure 1.10 Group assembled at the site of the camp erected in 1938 by Bagnold and his team of explorers at the southeastern edge of the Gilf Kebir plateau.

chipped, perhaps 100,000 years ago. Geologists studied the fluvial landforms that were highly modified by wind action as the archaeologist studied the site down to 20 cm below the surface. At the head of Wadi Mashi we noticed the smooth dome-like appearance of basalt hills. The columnar basalt pieces were dense and fine grained inside, but pitted by wind action on outer surfaces (Fig. 1.12). Back at camp we decided to break the expedition into two groups, one to stay at the Gilf, and the other to head for Uweinat Mountain to the southwest.

For the next three days two-thirds of the expedition investigated details of Wadi El-Bakht and Wadi Ard El-Akhdar. At Wadi El-Bakht, the archaeological site of neolithic age discovered by Oliver Myers in 1938 was studied. Geologists examined the wind and water erosion in the lower part of the wadi. Pebbles and cobbles of friable sandstone on the floodplain showed abundant evidence of wind erosion in the form

Figure 1.11 Setting of the camp at Gilf Kebir as depicted in drawing by Hamid Dowidar.

Figure 1.12 A block of columnar basalt, 30 cm long, with a pitted outer surface and a dense, fine-grained interior exposed at left.

of delicately-etched projections along bedding planes aligned with the wind. The team also studied the relationships of falling and climbing dunes, yardangs and ripples, and surveyed the wadis' topographic profiles.

At Wadi Ard El-Akhdar, the Gilf party excavated additional archaeological sites, surveyed the topography and investigated the relationships of present setting to the blockage of a narrow part of the wadi. The wadi constriction must have been blocked in prehistory to allow water to form a lake upstream. Members of the team were divided in opinion; some maintained that a presently active dune must have blocked the wadi, while others argued that sand is not good enough for a dam and the blockage must have been by a wedge of fanglomerate, parts of which were exposed in the wadi wall at the constriction. The controversy lingered on.

Meanwhile, the Uweinat party headed westward in Wadi Wassa, whose floor kept a record of rainy seasons in the form of mud layers. The team's botanist, Loutfy Boulos, once again was able to put his expertise to use (Fig. 1.13) since the expedition had left the last plants behind at Bir Tarfawi West. From the condition of vegetation, he estimated that it had not rained there for approximately 20 years. The party left the Gilf Kebir through a pass, 10 km north of Wadi Diyaq, where kaolinized material was exposed at the base of the cliffs. The Mehashimat, a low lying and highly fractured plateau, loomed in the distance as the mountains of Gebel 1114 and Peter and Paul appeared. All of a sudden, the sandstones of the Gilf Kebir gave way to dark volcanic rocks of basalts and trachytes with surrounding aprons of flagstones and pea-size pebbles. Some volcanic craters appeared to be marked crater rims, without any volcanic rock within. By nightfall the Uweinat party arrived at the north entrance of a small unnamed valley just west of Karkur Talh where we found many trees, petroglyphs in caves, and a prehistoric milling stone (Fig. 1.14).

Figure 1.13 Botanist Loutfy Boulos samples a Zilla spinosa in Wadi Wassa at the southern edge of the Gilf Kebir. Mud-cracked surface surrounds the plant.

Figure 1.14 A 40 cm wide milling stone with its spherical grinding stone from a valley, Karkur Talh, in Gebel Uweinat.

Exploring the northern slopes of Gebel Uweinat we were most impressed by the power of wind, which came from the north. The wind had sculpted the rock into eerie shapes of frozen dinosaurs and other giant animals. The exposed rock surfaces were all pitted. Where sand grains were lodged in these pits they twirled around as the wind gusted, enlarging the pits. Fluted rock surfaces formed from pits that were lined up in rows (Fig. 1.15).

On the return journey from Uweinat we wanted to achieve the last objective before rejoining the other party at the Gilf Kebir. This was reaching the broad sand mass just east of Gebel Babein. I wanted to sample the sand there in order to compare it to sand samples from other parts of the Great Sand Sea that were collected on an earlier expedition. This would increase the geographic spread of our samples and allow us to study the reddening of sand as the distance from source increases. We were unable to find an active slip face on the dune. The sand was accumulated in a giant whaleback dune with gentle slopes. On top of the dune, approximately 1 km away from the desert surface, we encountered pencil-sized, tube-like pieces of rock. Nothing could have carried these objects to the eastern flank of the whaleback dune but a fierce wind storm.

The reunited party broke the Gilf Kebir camp on the morning of 5 October 1978 and headed eastward back to Bir Tarfawi West. We passed by remains of World War II; an English army truck that was disassembled with pieces strewn in the sand. The engine hood had created a small wind shadow that resulted in the formation of an 8 m sand tail in its lee. The heavy trucks were left to return at their own slow pace with one jeep for emergencies.

During the return trip, several areas of iron-rich sandstone were noted. In one place, hematite was exposed as a thinly laminated red layer of unknown depth (Fig. 1.16); we dug over 40 cm without reaching the base. Within this red layer were dark brownish-black nodules of iron and manganese oxides. We drove for 11 km over this iron ore, which we estimated to be about 150 km west of Bir Tarfawi. We recommend to the Geological Survey of Egypt the assessment of the economic potential of this particular deposit.

We arrived back at Kharga about midday on 6 October. The first item on the agenda was to shave and shower for the first time since we left Kharga eleven days earlier. After a meal that was more like a banquet, a group assembled to study the Kharga barchan dunes. In the evening we met with local geologists, hydrologists, engineers, and agricultural experts to discuss our findings on the expedition and the pros and cons of large scale agricultural development in the New Valley province. It was stated that although underground water supplies were plentiful, the irrigation schemes were wasteful of the water. Also, the available data did not allow a resolution of whether or not the underground water supply was being replenished from the south and west.

On the following day the party was again split into two groups; one headed toward the plateau north of Kharga depression, and the

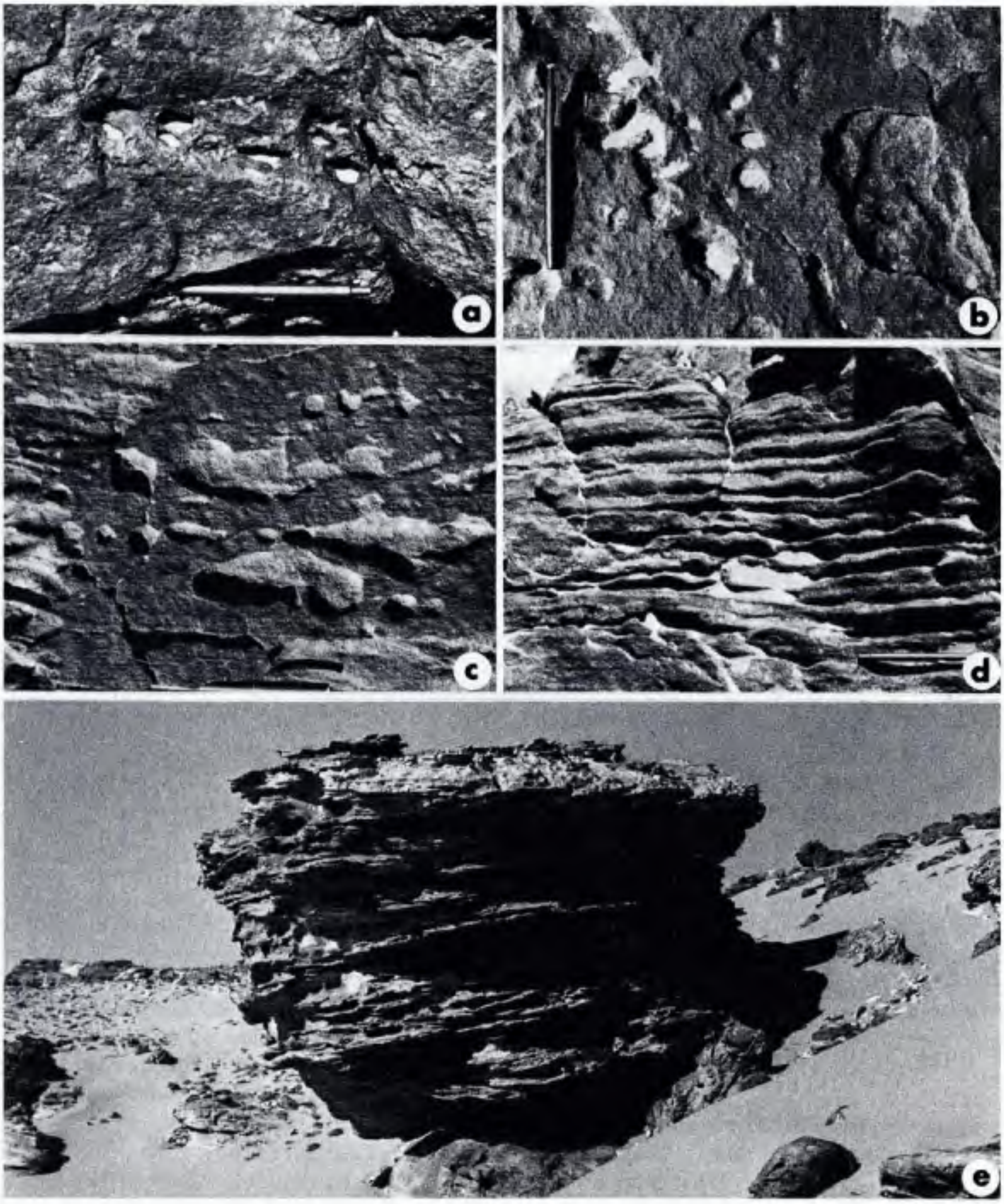

Figure 1.15 Photographs showing the effects of sand-blasting of sandstone rocks along the northern face of Gebel Uweinat showing elongate pits (a;b), coalescent pits (c), flutes (d), and the appearance of a pitted and fluted rock (e).

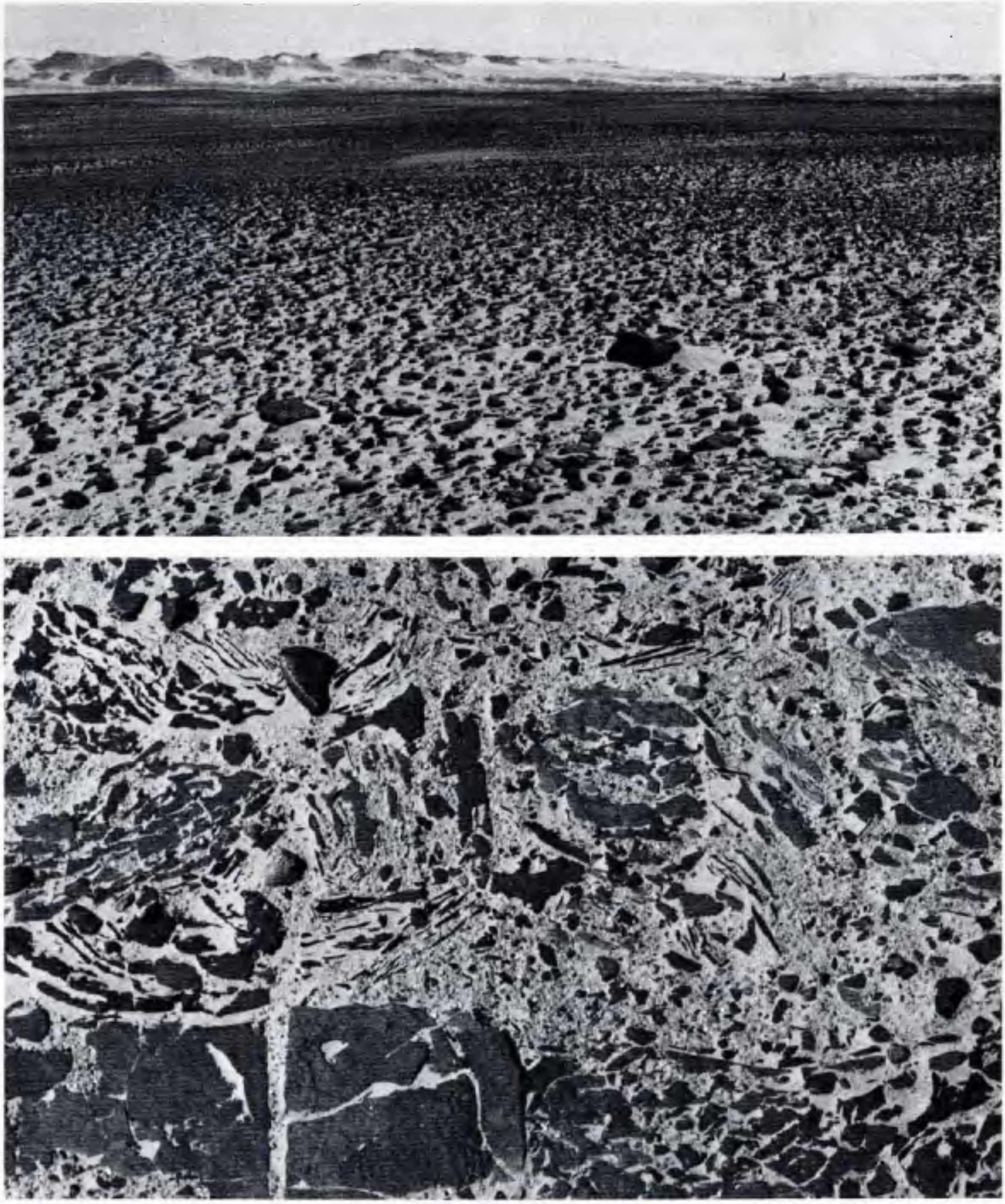

Figure 1.16 Dark hematitic nodules cover the surface 150 km west of Bir Tarfawi (top), and thinly laminated hematitic sandstone (bottom).

other headed south towards Baris Oasis. On top of the plateau more of the wind-formed features were studied. There, the wind had carved yardangs in the extremely resistant crystalline limestone. Within the depression, the other group observed mounds that marked ancient springs, which were aligned along north-south trending faults. Fault boundaries were marked by tamarisk trees and bamboo growths in the salty soil. We also studied remains of irrigation canals built in Roman times and lined with palm tree bark. Evidence of deflation of the soil by wind was clear everywhere. At Ein El-Shorafa, Vance Haynes estimated that nearly 55 m of soil had been deflated during the past 3000 years, or 18 mm per year. In the evening, the two groups returned to Kharga to exchange experiences and discuss the findings.

The field work at Kharga ended in the morning of 8 October 1978. Some of the hours of the day were spent in sorting of the samples and separating those to be left at Kharga. One of the results of the expedition was to interest the local unit of the Geological Survey to keep samples from all expeditions at the newly established Kharga Museum. In the afternoon our plane was ready to fly us back to Cairo. As it took off, the lighting was perfect for a view of the enormous concentration of yardangs north of Kharga, probably one of the largest fields in the world. We reached Cairo at sunset, ending a most interesting expedition and starting new thoughts on desert landforms and wind-blown features on both Earth and Mars.

ACKNOWLEDGMENTS

Numerous organizations and individuals significantly contributed to the success of this journey. The financial support of the following institutions is acknowledged: Ain Shams University for providing food, photomosaics and some camping needs; the Egyptian Air Force for providing an airplane to transport the scientists between Cairo and Kharga; the Geological Survey of Egypt for making available the necessary vehicles, gasoline, support personnel, and camp equipment; the National Geographic Society for making available the two Volkswagen type 181 vehicles; Goddard Space Flight Center for providing a Landsat mosaic of the Uweinat region and the transmitting apparatus and satellite tracking data; and the New Valley Governorate for providing the space for lodging, meals, and lectures and seminars at Kharga.

International travel was also financed by several organizations, including: the National Air and Space Museum (for T. Maxwell); the National Geographic Society (for V. Haynes); the National Science Foundation (for the author); the Smithsonian Foreign Currency Program (for C. Breed and J. McCauley); and the U.S. Geological Survey (for M. Grolier). William McHugh paid his own way. The Planetary Geology Program Office of the National Aeronautics and Space Administration (NASA) covered the salaries of C. Breed and J. McCauley during the expedition.

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