ROCK MORPHOLOGY OF BASALTS IN THE WESTERN DESERT OF EGYPT: IMPLICATIONS FOR VIKING LANDER SITES ON MARS, J.B. Garvin and J.W. Head, Dept. of Geological Sciences, Brown University, Providence, Rhode Island 02912; and Farouk El-Baz, National Air and Space Museum, Smithsonian Institution, Washington, D.C. 20560.

The hyperarid Western Desert of Egypt has been described [1] as the one place on Earth least affected by water-related processes such as rainfall and solution weathering. Only the Atacama desert of Peru and Chile is on the same scale in terms of aridity [1]. For this reason, it is important to characterize the rocks found in locales of different lithologies in the vast eolian pedeplain that is the Western Desert. It is undoubtedly the one region where water-induced erosion has not overshadowed the effects of the wind, at least in the last 10,000 years [1,2]. Two sites in the Western Desert from which photographic coverage of Mars-like blockfields was available were selected for study on the basis of their known lithology and weathering environment [1]. The same data collection and analysis techniques employed in [3] for Viking lander imagery were used in the investigation.

The two sites that were characterized are both in the Gilf Kebir region of the Western Desert, and are dominated by fine-grained massive basalts of a relatively homogeneous nature [1]. One locality is situated at the base of a Quaternary basalt hill that intruded the Wadi Mashi sandstones; Figure 1 shows a small portion of this area, where most blocks are angular and 20-40 cm in diameter. This Wadi Mashi basalt hill (WMB) is noted for the wind-pitted and fluted nonvesicular olivine basalts found there [1]. Facets in these blocks are probably related to joint-controlled fracturing that occurred during their emplacement. The other site consists of massive basalts perched atop a desert pavement or reg. In Figure 2, blocks 20-50 cm across with abundant flutes and pits can be observed. This Gilf Kebir reg (GKR) probably contains rocks that were transported by floods during infrequent pluvial episodes in the Western Desert. As at WMB, the origin of the pits, flutes, and grooves in the GKR basalts must be attributed to wind abrasian, since virtually all of the rocks observed at the site were aphanitic and massive [1].

The salient rock morphology characteristics of the Egyptian sites based on our observations are --- *A*) Wadi Mashi basalt hill: 1) rocks primarily equidimensional; 2) angular, faceted rocks are most common; 3) small to medium sized cavities (< 4 cm) dominate rock surfaces; 4) virtually all rocks possess some form of fluting; 5) planar fractures are frequently observed on the blocks; 6) most rocks are slightly embedded in the sandy substrate; perched or unburied rocks are rare; 7) many blocks (> 50%) have linear features such as cracks on them; 8) fillets, moats, and wind-tails are generally absent; 9) most blocks have an intermediate albedo; highly reflective surfaces are uncommon. *B*) Gilf Kebir reg basalts: 1) rocks are generally elongated; 2) subangular rocks dominate; 3) most fragments have medium sized cavities (< 4 cm in diameter); 4) bimodal surface textures are common; 5) planar fractures do occur, but they are not ubiquitous; 6) highly buried rocks are rare; most rocks are slightly embedded in the desert pavement; 7) cracks and fissures occur on most rocks (69%); 8) virtually no obstacle scour features are observed (i.e. sediment moats, fillets, wind tails); 9) relative rock albedoes are variable; few reflective rocks are seen.

Observations most pertinent to rock modification history at the Egyptian localties are considered next. Fluting and pitting is important in this

context [1] especially in the Western Desert. At WMB the basalts are covered with linear or wedge-shaped flutes; a significant percentage of the rocks also possess sinuous or rille-like flutes. Both parallel and crosscutting networks of flutes abound. Many of the flutes have pits or chains of pits inside of them. In general, the density of flutes on these rocks is low to medium. The erosional markings (i.e. pits and flutes) give the rocks an outwardly vesicular appearance, but interconnecting cavities often characteristic of vesicular basalts are not seen (Fig. 1). Most of the WMB blocks are multi-faceted, displaying 2,3, and 5 facets. This is typical for columnar joint fragments.

The Gilf Kebir reg basalt blocks are characterized by their abundant linear and scallop shaped flutes, most of which are of medium size (< 5 cm) and medium depth (< 1 cm). Sinuous flutes are generally absent as are crosscutting patterns of flutes. Parallel fluting arrangements are common. The majority of flutes are lacking internal pits, though some do exist. Rocks with a high density of erosional markings are rare at GKR (Fig. 2). Keel-like (2 sided) or pyramidal (3 sided) facets are most abundant at this locality.

Major morphologic differences between the rocks at the two Egyptian sites are: 1) WMB rocks are more equant than their elongate counterparts at GKR; 2) WMB blocks are multifaceted and highly angular, unlike the subangular, simply faceted GKR rocks; 3) planar fractures are ubiquitous at WMB, but not so at GKR; 4) linear features such as cracks and fissures abound at GKR, but are far less common at WMB; 5) GKR rocks have a more uniform cavity distribution than WMB; 6) sinuous flutes, crosscutting flute patterns, and pits inside flutes are far less common at GKR than WMB; 7) The coarse sand substrate at WMB is very reflective unlike the desert pavement surface at GKR. While the differences listed above are significant, it is important to recognize the fundamental similarities between the two sites in terms of their lithologies, modification histories, and local geologic environments. The rocks at GKR and WMB have been pitted and fluted by dust- and sand-laden winds [1]. They are slightly buried, somewhat angular, faceted, and lack obstacle scours such as fillets, wind-tails, or moats. There is a tendency toward elongation (form ratios < -0.25). Negative form ratios are typical for isotropic weathering rocks such as basalts and other fine-grained igneous rocks [3].

Multiparameter clustering analysis can be used to objectively discover related subgroups of rocks within large populations [3]. This is especially true when there are several morphologic parameters that should be given equal weight in a statistical analysis. Application of clustering to the Egyptian rock populations as was done in [3] for Mars has demonstrated that differences in the degree of erosion as manifested by cavity size, depth, and distribution on rock surfaces is the critical factor in separating morphologic groups. Other modification effects play a secondary role in classification when similar rock types (basalts) are subjected to the same weathering phenomena.

The two Egyptian sites are well-suited for comparison with the Viking lander sites on Mars for several reasons. In terms of aridity, lack of vegetation, dominance of eolian processes (wind-blown dust and sand), and rock type (nonvesicular fine-grained basalts), the GKR and WMB localities are excellent analogs to the martian sites. A first-order rock morphologic comparison yields the following generalizations: 1)WMB correlates well with VL-1 and VL-2 in terms of overall rock form; form ratios in the range of

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-0.25 to -0.30 imply elongation; 2) GKR closely matches the Viking sites in average rock roundness; 3) fluting on Mars is less pronounced than in the hyperarid desert of Egypt, possibly due to sandblast in Egypt and its absence on Mars; 4) facets are equally abundant at VL-1 and GKR; 5) the Viking sites display rocks with fewer linear features and planar fractures than the Egyptian ones; 6) obstacle scours are more common at VL-1 than at VL-2 or the Egyptian localities; 7) martian blocks are more uniform in their surface textures; 8) VL-1 and VL-2 agree with GKR and WMB in terms of cavity size patterns; 9) there are more unburied rocks on Mars than at either of the Egyptian desert sites.

From these observations and clustering analyses of the Egyptian and martian sites [3], it is possible to conclude that there are rocks on Mars that morphologically resemble massive basalts from the Western Desert of Egypt. These martian blocks could represent basalt fragments modified by dust-laden martian winds and may not have been originally vesicular [4]. The rocks observed at VL-2 are generally more highly pitted than those at VL-1 or in Egypt, and possess deep, irregular cavities often interconnected [3,4]. Since there are VL-2 blocks that do not follow the pattern of pitting and fluting observed in Egypt, these rocks could represent originally vesicular fragments that have been wind affected. To test this hypothesis, however, rock morphologic studies of wind-eroded vesicular basalts in terrestrial arid regions must be undertaken. In general, studies of single lithology block fields under known weathering conditions can prove useful in constraining the possible rock types and modification processes on Mars. References: 1) J.F. McCauley et al. (1979) JGR 84, 8222. 2) F. El-Baz et al. (1979) JGR 84, 8205. 3) J.B. Garvin et al. (1981) The Moon and the Planets, in press. 4) T.A. Mutch et al. (1977) JGR 82, 4452.

Fig. 1: Wadi Mashi basalt hill (WMB) locality. Note that faceted wind-pitted rocks are ubiquitous, Rock labelled "A" is 30 cm across.

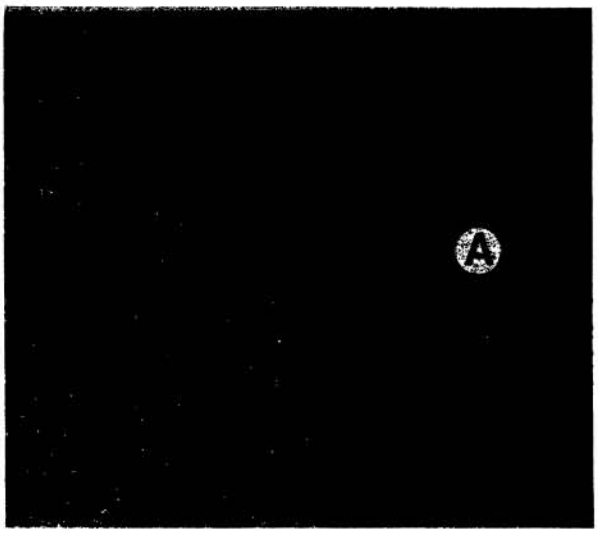

Fig. 2: Gilf Kebir desert pavement (GKR) with 20-50cm basalt blocks superimposed. Note pits and flutes in the 45 cm long boulder (A).