STUDIES OF THE COATINGS ON SAND GRAINS FROM THE GILF KEBIR, SOUTHWEST EGYPT

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INTRODUCTION

Field investigations have established that the red color of desert sand is due to the presence of iron-oxide coatings on individual grains (Van Houten 1973, Folk 1976, Walker 1967). True color earth-orbital photographs of the Egyptian desert show distinct variations in desert color. Sand grains become redder as the distance from their source increases. Based on color, El-Baz (1978) recognized three relative-age zones which do not correspond to boundaries of geological formations. We have initiated an investigation of sands from the Egyptian desert to determine what minerals are contributing to the color, and whether the observed geographic variations in color are due to varying thicknesses and mineralogy of the coatings on individual sand grains.

MINERALOGY & MORPHOLOGY OF THE COATINGS

The sand grains examined were collected from a dune in Wadi Bahkt, a valley in the southeast corner of the Southern Gilf Kebir plateau in the Egyptian desert. This region is included in El-Baz’s zone 3, the area displaying the darkest color. Heavily-coated quartz sand grains and those with coatings concentrated in pits or cracks were chosen for X-ray powder diffraction study using the Gandolfi camera. The coating was gently scraped from many individual grains in order to concentrate sufficient material for analysis. Hematite and kaolinite (7Å clay mineral) were identified in the scrapings. Diffraction lines from kaolinite suggest a well-crystallized material. In contrast, hematite displayed diffuse lines inferring poor crystallinity and very fine grain size. Additional grains were fractured under liquid freon to expose the interior of the grains and a cross section of the coating. The grains were examined by SEM at magnifications from 100X-200,000X. Energy dispersive x-ray analysis (EDXA) was used to qualitatively determine the chemistry of the coating and attached crystals. EDXA indicates that the coating is much richer in Al than Fe. This suggests that the coating is predominantly a clay material with very finely disseminated hematite.

All of the grains studied had an irregular, pitted surface with a ubiquitous coating of fine-grained material. The coating has a well-defined contact with the underlying quartz surface (Fig. 1) and conforms closely to grain morphology. Its thickness varies from 0.5 µm to 4.5 µm over the surface of a single grain. The coating exhibits a complex morphology and is composed of randomly-oriented particles ranging in size from a few hundred angstroms to about 2 micrometers. Many of the particles are hexagonal platelets (Fig. 2). Individual platelets have a
grainy surface, with small platelets occurring on the surfaces of the larger plates. This may indicate that books of platelets are formed as the result of in-situ growth of small platelets on larger, preexisting ones. Additionally, we have observed incipient growth of coating crystals on a quartz grain surface (Fig. 1). The coating shows no evidence of successive layers of deposition over most of the surface area of the grain. No systematic changes in morphology (crystal size or orientation), mineralogy, or chemistry were observed. However, in a few pitted regions, some preferred orientation of platelets in response to grain morphology was seen. Twisted platelets and oriented platelets occur within pits and in areas surrounding pits. Recognized abrasion features include extensive grooving, cracking, and degrading of the coating, and polishing of protruding ridges on the grains. Additionally, secondary crystals of gypsum and halite, and small areas plastered with silica were noted.

DISCUSSION

The occurrence of small platelets on the surfaces of larger platelets, and the growth of coating crystals directly on the quartz grain surface are consistent with in-situ nucleation and growth processes. The lack of layering also suggests gradual growth on a preexisting coating. These features imply that nucleation and in-situ growth processes are the predominant mechanisms for coating formation, rather than a mechanical plastering of clay particles on the quartz substrate.

We propose to examine grains from El-Baz's other color zones and the parent rock (Nubian sandstone) from Egypt to determine where and how the coating originates. We are seeking microscopic evidence relevant to the hypothesis that the coating develops during aeolian transport. We have compared the mineralogy of the coating to desert varnish. Work by Potter and Rossman (1977, 1979) on desert varnish indicates that clay minerals (montmorillonite and mixed-layer illite) comprise more than 70% of the varnish, and are necessary for varnish formation. They also note that both clays and Mn and Fe oxides are always found in varnish. The importance of clay and Fe oxides in varnish is in accordance with our results on sand grain coatings. However, Potter and Rossman have observed no crystallinity in their varnish materials (Rossman 1979, pers. comm.). The reason for this difference is as yet unresolved; however, it likely results from different conditions of formation. For example, in extremely arid environments the coating on desert sands may develop by slow growth which allows crystal development, while the desert varnish studied by Potter and Rossman develops in a more humid environment at the soil-water interface involving successive rewetting episodes and a complex chemical environment. Therefore, the processes involved may not be directly comparable.

The study of the mineralogy and morphology of these coatings is necessary to evaluate their effect on the spectral characteristics of deserts as observed in satellite photographs. Results discussed here
may have significant implications to the signatures of planetary regoliths obtained by spectral reflectance measurements. In fact, the fine dust on Mars could coat grain surfaces and might be thick enough to strongly affect the observed spectral characteristics.

References

Figure 1. Coating crystals growing along the contact with the quartz grain surface. At 10,000X, width of field of view is 9 micrometers.

Figure 2. At 30,000X, Randomly-oriented books of hexagonal platelets. Width of field of view is 3 micrometers.