SPECTRAL EVIDENCE OF SIZE DEPENDENT SPACE WEATHERING PROCESSES ON ASTEROID SURFACES;

M. J. Gaffey [RPI]; J. F. Bell [U. Hawaii]; R. H. Brown [JPL]; T. H. Burbine [SAO]; J. L. Piatek [ASU]; K. L. Reed, and D. A. Chaky [RPI].

Most compositional characterizations of the minor planets are derived from analysis of visible and near-infrared reflectance spectra. However, such spectra are derived from light which has only interacted with a very thin surface layer. Although regolith processes are assumed to mix all near-surface lithologic units into this layer, it has been proposed that space weathering processes can alter this surface layer to obscure the spectral signature of the bedrock lithology. It has been proposed that these spectral alteration processes are much less pronounced on asteroid surfaces than on the lunar surface [1-3], but the possibility of major spectral alteration of asteroidal optical surfaces has been invoked to reconcile S-asteroids with ordinary chondrites [4-6]. The reflectance spectra of a large subset of the S-asteroid population have been analyzed in a systematic investigation of the mineralogical diversity within the S-class [7]. In this sample, absorption band depth is a strong function of asteroid diameter. The S-asteroid band depths are relatively constant for objects larger than 100 km and increase linearly by factor of two toward smaller sizes (~40 km). Although the S-asteroid surface materials includes a diverse variety of silicate assemblages, ranging from dunites to basalts, all compositional subtypes of the S-asteroids conform to this trend. The A-, R-, and V-type asteroids which are primarily silicate assemblages (as opposed to the metal-silicate mixtures of most S-asteroids) follow a parallel but displaced trend. Some sort of textural or regolith equilibrium appears to have been attained in the optical surfaces of asteroids larger than about 100 km diameter but not on bodies below this size.

The relationships between absorption band depth, spectral slope, surface albedo and body size provide an intriguing insight into the nature of the optical surfaces of the S-asteroids and space weathering on these objects. Figure 1 plots absorption band depth versus asteroid diameter for the sample of 39 S-objects. If the two points for 354 Eleonora (near diam=160 km and depth=0.24; see below) are omitted, the S-asteroid band depths are relatively constant for objects larger than 100 km and increase steeply toward smaller sizes. For the larger S-asteroids, there is a relatively constant spectral contribution from the mafic silicate phases in the surface materials of different objects. For S-objects below 100 km diameter, the mafic spectral contribution increases with decreasing body size. The smaller S-asteroids in the Earth-approaching population exhibit stronger mafic mineral absorption features than the larger main belt S-asteroids [8], so it appears that this trend extends to even smaller sizes. The various compositional subtypes of the S-asteroids are distributed randomly within the trend, and therefore the correlation is not due to differences in silicate mineralogy between the subtypes. This behavior must arise from some systematic size-dependent differences in the regolith properties which control the optical surfaces of these objects.

An abundant metallic FeNi component has commonly been invoked to explain the relatively steep spectral slopes, the weaker absorption features and the lower albedos of the S-asteroids. Several asteroidal space weathering or regolith processes can be tested if it is assumed that regolith maturity - however incomplete - correlates with body size. This is plausible since larger bodies should more efficiently retain ejecta and on average should have older surfaces than the smaller bodies in a collisionally evolved population. These two factors combine to increase the average lifetime of a typical regolith particle on larger objects.

There is no correlation between albedo and diameter for the full set of S-asteroids or for the individual subtypes, as would be expected if simple particle comminution [9], melting and recrystallization [10,11], contamination of the surface by dark material, or shock darkening of silicates [12-15] were primary causes of these band depth differences. The full set of S-objects shows a weak negative correlation of spectral slope with diameter, but there is a strong negative correlation between spectral slope and asteroid diameter within the S(IV)-subtype which includes the possible (i.e., not excluded by silicate compositions) main-belt ordinary chondrite parent body candidates. The preferential fragmentation of metal has been proposed to produce the steep spectral slope of the S-asteroids [16,17]. It has also been suggested that the initial development of regolith results in the increased retention or production of impact melt products [18]. Both of these processes should produce positive correlations between spectral slope (i.e., degree of metal fragmentation or agglutinate formation) and body size (i.e., regolith maturity), opposite to the observed trend. Band depth and albedo versus spectral slope do not show the expected negative correlation, nor does band depth versus albedo show the expected positive correlation that such mechanisms should produce.

Figure 1 indicates that the apparent abundance of the silicate phases on S-asteroid surfaces decreases with body size up to about 100 km diameter, and thereafter remains relatively constant. This suggests some sort of textural equilibrium has been attained in the optical surfaces of S-asteroids larger than about 100 km diameter but not on bodies below this size. It is possible that 100 km represents the transition to a fully developed regolith. However, the transition from a rocky surface to a particulate surface should increase the band depth, opposite to the observed trend. The observed relationship could be explained by some process that involves selective depletion of the silicate phase in the optical surface layer at larger body diameters to produce some equilibrium silicate/metal abundance ratio substantially lower than that in the substrate. Such a model does not explain the apparently similar (but displaced) trend exhibited by the more strongly featured mafic silicate-dominated A-, R-, and V-type asteroids plus the anomalous S-asteroid 354 Eleonora.

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