

NEGATIVE SEARCHES FOR EVIDENCE OF AQUEOUS ALTERATION ON ASTEROID SURFACES.

F. Vilas, Planetary Astronomy Group, NASA Johnson Space Center/KR, Houston, TX 77058, Faith.Vilas-1@nasa.gov.

Introduction: Small bodies in the Solar System preserve evidence of the processes occurring during early Solar System formation, unlike the larger planets that undergo continuous churning of their surfaces. We study these bodies to understand what processes affected different stages of Solar System formation. The action of aqueous alteration (the alteration of material by the interaction of that material with liquid formed by the melting of incorporated ice) of near-subsurface material has been inferred to occur on many asteroids based on the spectrophotometric evidence of phyllosilicates and iron alteration minerals [1]. The definitive indication of aqueous alteration is the 3.0- μm absorption feature attributed to structural hydroxyl (OH) and interlayer and adsorbed water (H_2O) in phyllosilicates (clays) (hereafter water of hydration). A weak absorption feature centered near 0.7 μm attributed to an Fe^{2+} \square Fe^{3+} charge transfer transition in oxidized iron in phyllosilicates has been observed in the reflectance spectra and photometry of ~50% of the main-belt C-class asteroids [c.f., 2,3,4]. An ~85% correlation between this 0.7- μm feature and the 3.0- μm water of hydration absorption feature was found among the low-albedo asteroids [2]. The feature is usually centered near 0.68 μm in asteroid spectra, and ranges in wavelength from ~0.57 to 0.83 μm . Serendipitously, three of the Eight Color Asteroid Survey filters – the *v* (0.550 μm), *w* (0.701 μm), and *x* (0.853 μm) – bracket this feature well, and can be used to determine the presence of this feature in the reflectance properties of an asteroid, and probe the aqueous alteration history of larger samples of asteroid data [2]. Two efforts to search for evidence of aqueous alteration based on the presence of this 0.7- μm absorption feature are presented here.

Near-Earth Objects: Currently, there is no known NEA showing spectral properties similar to the CM2 carbonaceous chondrites. Spectra of the aqueously-altered CM2 carbonaceous chondrites show both the 0.7- μm and 3.0- μm spectral absorption features. Inspection of CCD reflectance spectra of NEOs shows no evidence for the existence of the 0.7- μm feature in any of the spectra obtained to date [5,6]. Proximity to the Sun generates thermal emissions at shorter wavelengths, and thus limits the capability to detect the 3.0- μm feature in spectra of NEOs. Searches for near-Earth objects draw on the subset of NEAs that becomes visible during a given

year due to the asteroids' proximity to the Earth during that year. Thus, except for the larger NEAs known for some time (e.g., 433 Eros, 1685 Toro), an observer concentrating on NEA observing during one year likely taps an entirely different batch of asteroids from an observer a year later. During this era of NEA discovery, there is very little overlap in objects from observer to observer, and examining the observations of every observer is potentially fruitful. Here, new ECAS photometry of 79 NEAs [6] was tested for the presence of the feature: no evidence of it was detected. A set of tabulated VRI photometry of NEOs [7] was also examined, however, the quality of the data precluded an accurate conversion to ECAS photometric values (as was done with VRI data for irregular outer solar system satellites [8]).

The near-Earth objects are small bodies in unstable, young orbits, destined to degrade into the Sun. The main asteroid belt is heavily populated with C-class asteroids, and dominated by asteroids showing these characteristics in the 2.6- to 3.4-AU aqueous alteration zone. The lack of CM2 chondrite analogues in the NEA population suggests that the mechanism for feeding these type of objects into the NEA region is very limited [5], despite possible parent sources near transport regions [9]. Cosmic ray exposure ages of CM2 carbonaceous chondrites suggest that they have short exposure times (< 0.5 Myr) [10]. Thus, parent bodies of these meteorites must be fragile, and few or no daughter fragments currently exist in near-Earth space.

Sloan Digital Sky Survey Moving Object Catalog: The Sloan Digital Sky Survey (SDSS) consists of photometry taken in five broadband filters using a large format mosaic CCD at the Apache Point telescope. To date, photometry of 58117 moving objects from 87 observing runs through 15 Dec 2001 has been tabulated in the PDS Small Bodies Node. This survey represents a major reservoir of photometry of small-diameter asteroids (probably the dominant moving objects). The chance to test theories of the distribution of aqueously-altered objects in the Solar System and increasing compositional diversity with decreasing size [e.g., 11] drove an effort to search for the 0.7- μm absorption feature in the SDSS photometry. This search is more difficult, however, because the central wavelengths place the filters spectrally in locations not optimal for defining this feature's presence. Four of the 5 filters could be used to address the feature's

presence. The g' ($\lambda = 4825 \text{ \AA}$, FWHM = 1379 \AA) and z' ($\lambda = 9097 \text{ \AA}$, FWHM = 1370 \AA) filters that could define the endmember wavelengths are located outside of the spectral starting and ending points for the feature, in regions where the spectrum of these C-class asteroids is dropping (on the lower wavelength side due to the UV/blue Fe^{3+} IVCT, and on the upper wavelength side due to a small Fe^{2+} CT feature near 0.9 μm). The 0.7- μm absorption feature ranges in depth from ~ 2 to 5% of the background continuum in asteroid reflectance spectra. The broadband nature of these filters covers a large spectral range, reducing subtle changes in surface reflectance needed to define this feature. The feature is generally centered near 0.68 μm in narrowband asteroid spectra. The r' ($\lambda = 6261 \text{ \AA}$, FWHM = 1382 \AA) and i' ($\lambda = 7672 \text{ \AA}$, FWHM = 1535 \AA) filters are almost equally spectrally spaced on either side of 0.68 μm , leaving the maximum depth of the feature smeared. The shallow feature is generally superimposed on a spectrum with a small increase in reflectance with increasing wavelength (reddening). The background slope must be removed from photometry, or the subtle depth of the feature could be masked by this reddening [2]. Johnson V filter magnitudes derived from the g' and r' SDSS filters are tabulated with the SDSS values. Equations relating the V - I and I - R colors (where these are Kron-Cousins I and R filters) to the r magnitude and $r' - i'$ color are derived [12] from stellar observations. Using these relationships, V - R and V - I were derived for all SDSS moving object observations. These were then converted to ECAS v - w, v - x colors, and tested for the presence of the 0.7- μm feature. The 62 asteroids observed commonly with the ECAS or the SMASSII or both were then cross-checked with the SDSS for consistency: 55% of the identifications were consistent among the data sets (a "no" in one was a "no" in the other), but 45% were not consistent. Even allowing for surface variegation in the presence of the 0.7- μm feature in an asteroid's spectrum, this disagreement appears to be too great. The inconsistencies included identifications of the 0.7- μm feature in SDSS photometry of S-class asteroids. The nature of the earlier studies means that the common asteroids were numbered objects, and their spectral properties are not in question. Re-consideration of the results will be conducted, but the first reaction is that these data cannot be used to probe small diameter asteroids for aqueous alteration.

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