Composition of Near-Earth Asteroids

Larry A. Lebofsky

Lunar and Planetary Laboratory

The University of Arizona

Abstract

The continuing goal of this study is to determine whether any of the near-Earth asteroids or the satellites of Mars contain hydrated phyllosilicate (clay) minerals. If these minerals are present, they would provide a ready source of water for propellant generation and use in life support systems. Many of the dark mainbelt asteroids have been shown to contain hydrated phyllosilicate minerals. Some of the near-Earth asteroids are also dark, but telescopic detection of water on these near-Earth asteroids is complicated because of the faintness of these small asteroids and because thermal emission masks the diagnostic spectral features beyond 3\μ due to water of hydration for objects within 2 AU of the Sun. New techniques for asteroid classification based on spectral reflectance *and* mineralogy will be necessary to determine whether the water absorption features are present on any of the near-Earth asteroids. This past year, we have begun looking for better ways to classify "wet" vs. "dry" asteroids in the main belt. This new classification may allow us to determine the presence of water of hydration in the surface minerals of near-Earth asteroids even when we can only observe them at wavelengths that are not affected by thermal emission.

Introduction

The CI1 and CM2 carbonaceous chondrite meteorites are known to contain hydrated phyllosilicate (clay) minerals. However, the fine grain size has made it difficult to determine the specific minerals present. Some of the CI1 meteorites contain evaporite minerals which are believed to have been deposited when a heating event allowed liquid water to migrate through the parent body, eventually depositing the evaporates. Asteroidal-sized bodies with these compositions would prove to be rich sources of water and oxygen, and the resources might be easier to extract from phyllosilicates than from other oxides.

Reflectance spectra of the hydrated carbonaceous chondrites meteorites are similar to telescopic spectra of some of the dark C-class asteroids in the main asteroid belt, implying similar mineralogy. Unfortunately, it is difficult to obtain accurate telescopic spectra of dark asteroids, and the dark components in their surface mask the diagnostic, near-infrared absorption features of the silicate minerals presumed to be present. The major water-of-hydration absorption feature at approximately 3\\μ is sufficiently strong that it is not masked by the dark components of the surface, which makes it possible to determine whether hydrated phases are present, even if it is not possible to determine the exact mineral species. Detection of water on Ceres by Lebofsky confirmed both the presence of water in the asteroid belt, and the feasibility of detecting it telescopically. It also led to the general idea that all dark asteroids were primitive and volatile rich.

Telescopic surveys by Lebofsky and coworkers have shown that many of the dark asteroids do contain hydrated minerals, but not all (*Figure 1*), which has forced a re-evaluation of the simple idea that dark necessarily means volatile rich. They have proposed that the dark asteroids in the main asteroid belt accreted from water ice and anhydrous silicates, and heating events later melted the water in some of them, producing hydrated silicates. If this explanation is correct, then at least the dark asteroids in the outer asteroid belt probably do contain volatiles, even if they are no longer present at the surface. An additional complication for the inner asteroid belt has been proposed by Dan Britt who has shown that black chondrites, which are shock darkened ordinary chondrites (which are totally anhydrous) are spectrally indistinguishable from some of the dark asteroids in the visible and near-infrared. Both ideas together explain many problems in interpreting the history of the asteroid belt, but they complicate the determination of the composition of individual asteroids tremendously.

The near-Earth asteroids are dynamically much easier to reach than the mainbelt asteroids, which

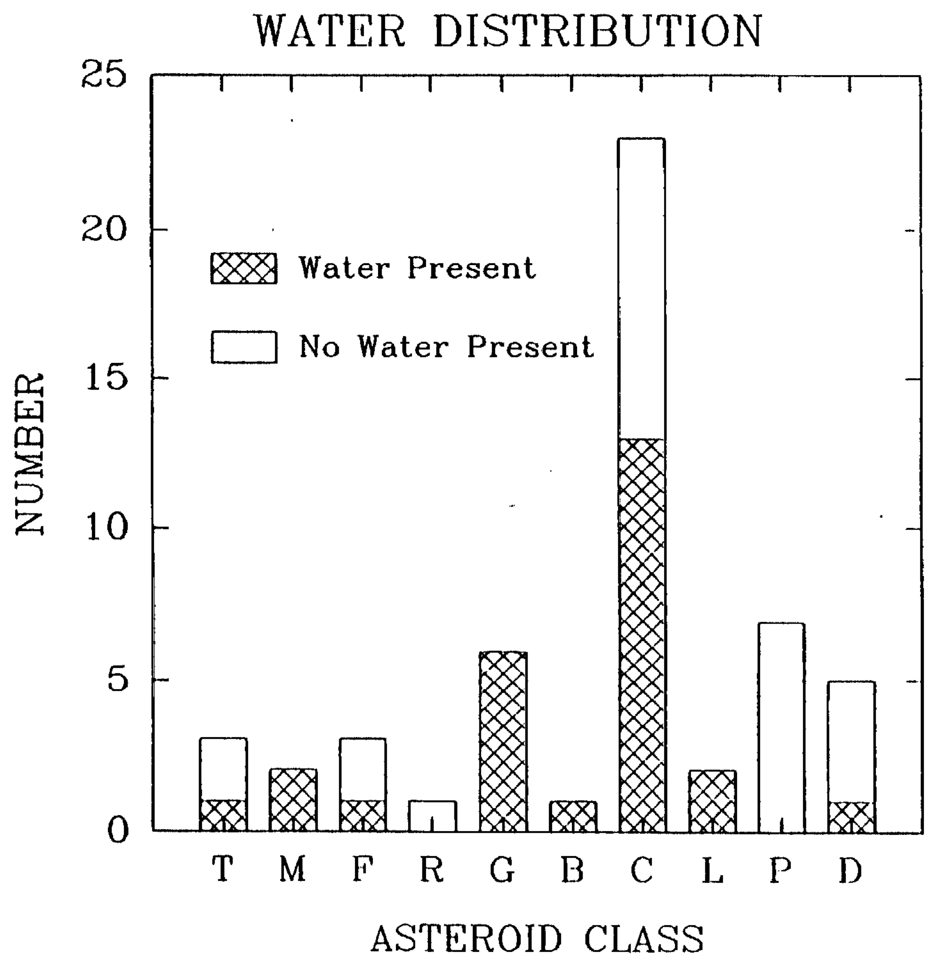
WATER DISTRIBUTION
25
20
15
10
5
0
NUMBER
Water Present
No Water Present
T M F R G B C L P D
ASTEROID CLASS

FIGURE 1

would make them more feasible resource targets. Most of the taxonomic C-class asteroids known in the main asteroid belt have been found in the near-Earth asteroid population, as well as one which has not yet been detected in the main belt. Unfortunately, as the previous paragraph mentioned, asteroids which are the same taxonomic type may well be compositionally different because the taxonomy was originally defined using only visible and extremely-near-infrared wavelengths, which do not include the wavelengths which are sensitive to hydrated minerals. This makes it impossible to predict which dark near-Earth asteroids will contain water without more extensive telescopic spectra. In addition, the near-Earth asteroids are nearer to the Sun than the main belt, which makes them warmer, which in turn moves the peak of their thermal emission to shorter wavelengths. This is particularly true of the dark asteroids. For the dark near-Earth asteroids, the thermal emission is large enough to mask the absorption feature caused by hydrated minerals. Simple thermal models can be used for the mainbelt asteroids because they are much cooler, but these models are insufficient to correct the near-Earth asteroids for thermal emission.

Over the past few years, we have been attempting to model, simultaneously, the reflected light and thermal emission from near-Earth asteroids. However, we have found this to be a less than productive task. It appears that we may never be able to accurately remove the thermal component from spectra in order to be able to see the 3-\μ feature when the thermal emission dominates this spectral region. Therefore, it has become necessary to try to find other ways of identifying asteroids that may have hydrated silicates in their surface materials.

Results for this Year and Proposed Work

We finished a review paper on asteroid composition for the *Resources of Near-Earth Space* book, in conjunction with Dan Britt. The paper will update the existing review papers on asteroid compositions, and provide comprehensive spectral figures of all the asteroid and meteorite types in one place for the first time. Several abstracts have been written and papers presented relating to our ongoing asteroid studies. We have also submitted a paper on asteroid taxonomies using neural networks which we discuss below.

Funds for this project have gone, in part, to support the work of graduate student Ellen Howell. She has been studying the relationship between comets and asteroids and has been involved the observations of the mainbelt and near-Earth asteroids and in the development of the new taxonomic system using neural networks. Because near-Earth asteroids are faint, and thus difficult to observe, we have been able to get only limited visual and near-IR observations of about 10 near-Earth asteroids over the past 2 years. However, we have been much more successful in our overall study of the low-albedo asteroids. To date, we have observed and studied about 75 low-albedo asteroids and small satellites out to at least 3\μ. Our goal for the next year is to study, in detail, the spectra of these mainbelt asteroids and make new observations, if necessary. By using neural networks, we are now attempting to categorize these asteroid spectra as a first attempt to classifying them based on spectrum *and* mineralogy. By looking at the spectra in this way we have been able to determine the validity of the taxonomic classification of asteroids as a determinator of asteroid mineralogy (*Figure 2*).

The next step is to see if the neural network technique can correctly classify asteroids that have limited signal to noise and spectral range (only out to 2.5\μ) as is the case for most near-Earth asteroids. It is our hope that we will be able to distinguish between "wet" and "dry" (the presence or absence of water of hydration) asteroids even when we do not have date in the 3-\μ region.

/E. Merenyi/ plot_grid   pgrid.par   w14s2.K_o.lst

SOM of 14-color asteroid spectra, water study

w14s8, SOM, Mod=1; aux2-1, (-1,1), aut. scale, full data set

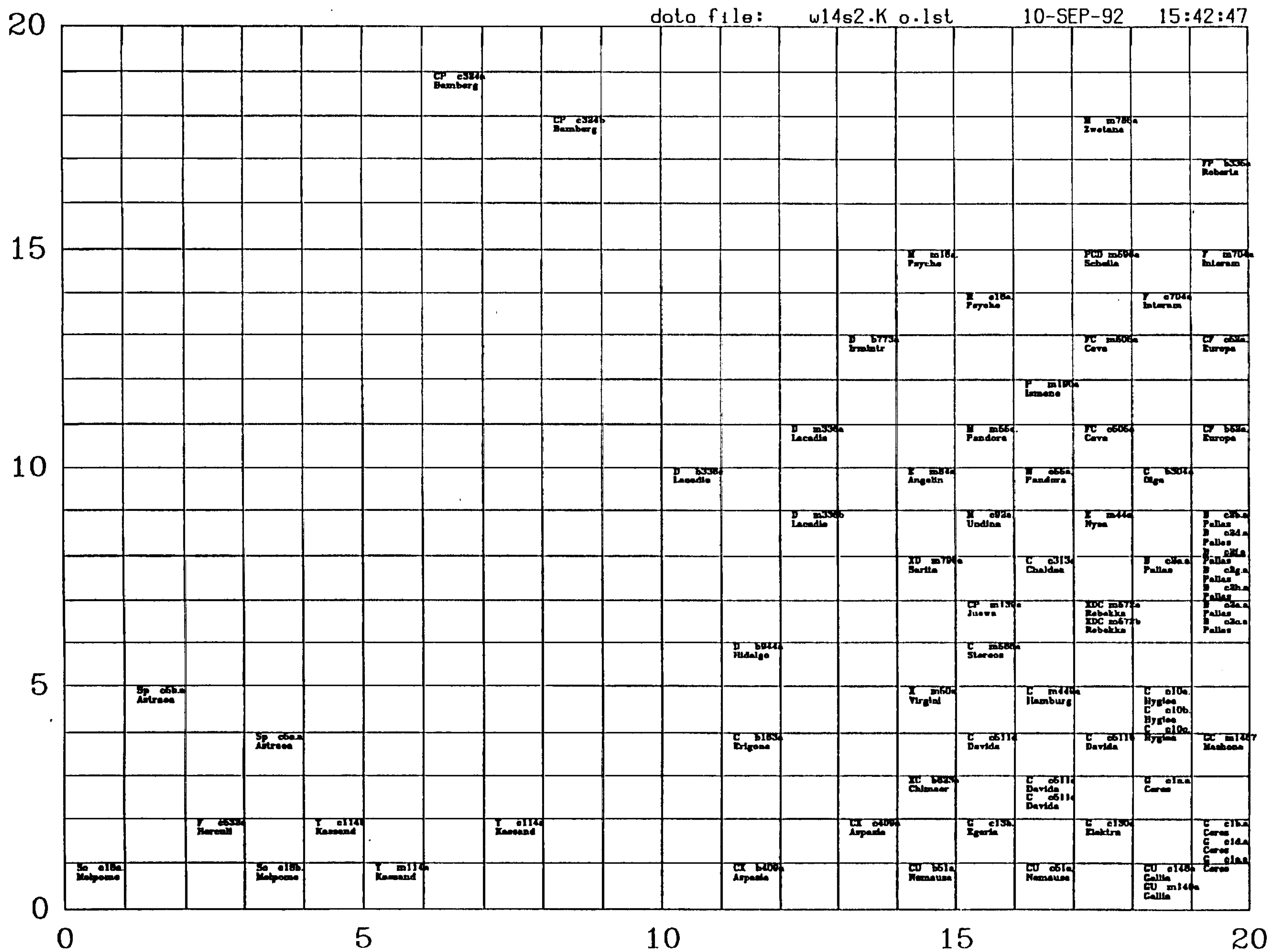

FIGURE 2