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Implications of infrared reflectance spectroscopy of CM/CI carbonaceous chondrites for outer Main Belt asteroids

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Abstract

We present infrared reflectance spectra of CM/CI carbonaceous chondrites. The spectra are measured under dry conditions in order to remove adsorbed terrestrial water molecules. Spectra of CM/CI carbonaceous chondrites are used to correlate the spectral properties of the 3-µm absorption band with petrological and geochemical indicators of aqueous alteration. This correlation is crucial for interpreting telescopic spectra of outer Main Belt asteroids, especially in the 2.5 < a < 3.0 AU region.

1. Introduction

Our project aims to quantify the degree of aqueous alteration in CM/CI carbonaceous chondrites, obtain spectra of these chondrites, and measure spectra of possibly related outer Main Belt asteroids in order to explore the nature of aqueous alteration on these asteroids. Laboratory analyses of CM/CI chondrites in addition to telescopic observations of outer Main Belt asteroids have the potential to place crucial constraints on how, when, and where this aqueous alteration occurred, and provide a unique glimpse at the effects of asteroidal processing on early solar system materials. Of particular interest is the question of the abundance of water in the early solar system and its significant role in the evolution of the mineralogy and cosmochemsitry of a number of diverse solar system bodies. Two alteration scales [1,2] are being applied to quantify the degree of aqueous alteration in ten CM/CI chondrites (Table1), using detailed petrographic observations and electron microprobe analyses. Additionally, high-quality spectra of outer Main Belt asteroids spanning the 2.5 < a < 4.0 AU region have been measured [3,4], using the SpeX spectrograph/imager at the NASA Infrared Telescope Facility (IRTF). Here, we present infrared (IR) reflectance spectra of CM/CI carbonaceous chondrites.

2. Methodology

The IR reflectance spectra of CM/CI chondrites are being measured at the USGS Spectroscopy Laboratory, using two spectrometers, an Analytical Spectral Devices (ASD) portable field spectrometer (model FR) covering the range from 0.35 to 2.5 µm, and a Nicolet Fourier transform infrared (FTIR) Interferometer Spectrometer covering the range from ~1.3 to 15.5 µm [5]. The samples were measured at ambient conditions and at higher temperatures (up to 200 ^{o}C) and low pressure. At ambient conditions, the 3-µm band is affected by adsorbed terrestrial water molecules, and at dry conditions these molecules are removed.

Table 1: CM/CI chondrites that are being used in this project

CM/CI Chondrites	Type
QUE97990	CM1
ColdBokkeveld	CM2
Bells	C2-ungrouped
LAP02277	CM2
MIL07700	CM2
LAP03786	CM2
MAC20606	CM2
MET00639	CM2
QUE99038	CM2
Ivuna	CI1

3. Results

To show that at 200^{o}C hydroxyl groups remain stable, x-ray powder diffraction patterns of serpentine (lizardite) were obtained. The x-ray pattern of serpentine powder heated at 200^{o}C for 12 hours is found to be quite similar to the one of serpentine powder not heated (Figure 1). IR reflectance spectroscopy of CM/CI chondrites at dry conditions have revealed a significant change of the 3-µm band shape, suggesting that the adsorbed terrestrial water molecules are removed at higher temperatures and lower pressure (Figure 2). The spectrum of Bells at dry conditions matches well the spectrum of 54 Alexandra, which is an outer Main Belt C-type asteroid (a=2.71AU).

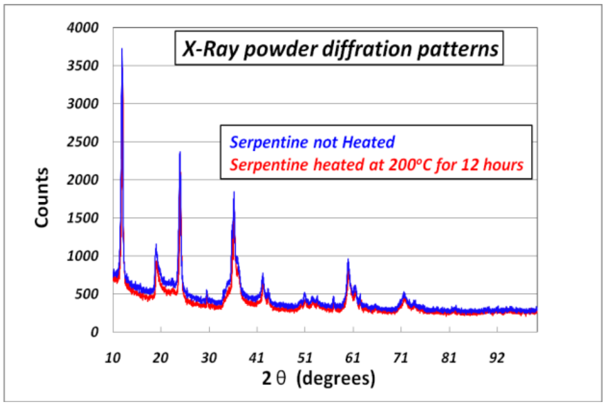

Figure 1: X-rays powder diffraction patterns of serpentine not heated (blue) and heated at 200^{o}C for 12 hours (red).

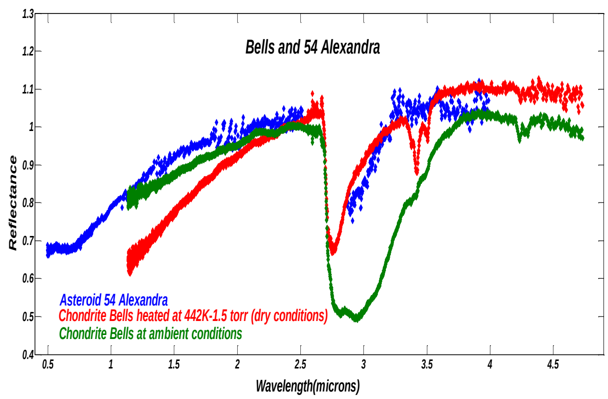

Figure 2: Spectrum of asteroid 54 Alexandra (C-type, a = 2.71 AU) and spectra of the carbonaceous chondrite meteorite Bells at both ambient and dry conditions.

4. Implications

Spectra of CM/CI carbonaceous chondrites are used to correlate the spectral properties of the 3-µm band (e.g., shape, depth, width, band center) with the petrological and geochemical indicators of aqueous alteration, obtained by detailed petrographic observations and electron microprobe analyses. When coupled with telescopic spectra of asteroids, IR reflectance spectroscopy of chondrites under dry conditions will allow a better understanding of the nature and the degree of aqueous alteration of outer Main Belt asteroids, especially in the 2.5 < a < 3.0 AU region, and will lead to crucial constrains on how, when, and where this alteration occurred.

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