HEATING EXPERIMENTS ON PHYLLOSILICATES-EVAPORITE MIXTURES: IMPLICATIONS FOR THE SURFACE COMPOSITION OF C ASTEROIDS. D. R. Ostrowski[1], D. W. G. Sears[1,2], C. H. S. Lacy[1,3], and K. M. Gietzen[1], [1]Arkansas Center for Space and Planetary Sciences, (dostrow@uark.edu), [2]Department of Chemistry and Biochemistry, [3]Department of Physics, University of Arkansas, Fayetteville, AR 72701, USA.

Introduction: The complex of C and X asteroids constitutes about 40% of both the debiased near-Earth and main belt asteroid populations [1], but due to the spectral features being weak or absent, little is known about their detailed mineralogy. Many of the C complex asteroids contain a feature at 3 µm caused by water absorption [2], and this feature has been correlated with a broad, weak 0.7 µm feature stated to be due to Fe^{3+} in phyllosilicates [3, 4]. Similar features are observed in CM chondrites. The C asteroids and the C chondrites both show relatively featureless spectra, especially when compared with spectra for phyllosilicates and evaporites (Fig. 1). However, it is still assumed that the C chondrites are related to the C asteroids and therefore the surfaces C asteroids are composed mostly of Fe-rich phyllosilicates, with other minerals such as opaque minerals and evaporites. However, there are three caveats that should be kept in mind. One is that the silicates in C chondrites are highly complex intermixtures of phases, which generally are poorly characterized. The second caveat, is that due to the mechanical weakness of C chondrites they are rare on earth and there are almost certainly major selection effects in the delivery of meteoirites to earth [5]. The material reaching Earth may not be representative of the C and X asteroid complexes. The third caveat is that some of the evaporites might be terrestrial origin [6], but given the amount of evaporites in these observed falls, we suspect that any terrestrial component is minor.

We are proposing an alternative approach, which is to characterize a small set of phyllosilicates mixed with evaporites that are both known to be in C chondrites. A simple mass-balance calculation demonstrates that evaporites may constitue as much as 45.06% by mass in Alais and 26.93% in Orgueil. A well-known characteristic of asteroid surfaces is that they have been heavily impacted, heated, and mixed in regolith [7]. Such processes have been well-studied using meteorites and lunar samples and the net effect is heating [8]. Thus we have subjected the suite of phyllosilicate-evaporite mixtures to heat treatments and obtained their near-IR spectra. We compare the results with data for C and X complex asteroids and for C chondrites.

Experimental: The phyllosilicates serpentine and chlorite are the most common phyllosilicates in C chondrites. These phyllosilicates have been mixed with the evaporates epsomite and gypsum, which are common evaporates in C chondrites. Numerical mixing of the reflectance spectra of the silicates and the evaporites was conducted to produce the flattest (most asteroidal) spectra. These mixtures were heated between 100 and ~1100°C for 24 hours, 8 hours for the two higest temperatures, and the IR spectra obtained

Since the heat treatments weaken and remove absorption features, to produce the relatively flat spectra we see on asteroids, we focus on the slopes of their continua as seen in Fig. 1. We chose the spectral regions 1.0-1.75 and 1.8-2.5 µm because there often seemed to be a discontinuity at ~1.8 µm in the phyllosilicates, but within these intervals the spectra are reproducible and well-characterized [9,10].

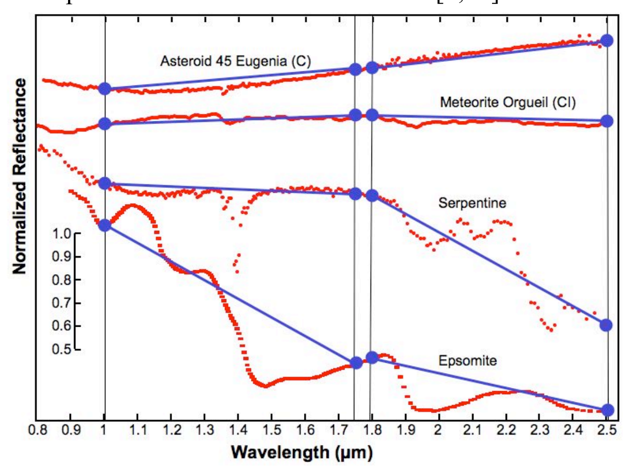

Fig. 1. Representative spectra explaining how continua slopes were determined. The spectra are normalized to 0.875 µm and are displaced vertically for clarity. Slopes appear to be an excellent way to characterize and compare the spectra of C and X complex asteroids because their spectra are for the most part featurless.

Results: Figure 2 summarizes the results of work. The phyllosilicates occupy a large field with negative slopes over the longer wavelength interval. The mixture of phyllosilicates and evaporites plots in or near the terrestrial phyllosilicates field. Ovals for the C and X asteroid complexes and for CM chondrites are above the phyllosilicates because of an overall flat to slight increasing slope. Upon heating, the data points migrate through the phyllosilicate field. Above 600°C for the mixes with gypsum and above 1000°C for the mixes with epsomite the data leave the phyllosilicate field and move close to or into the CM chondrite field.

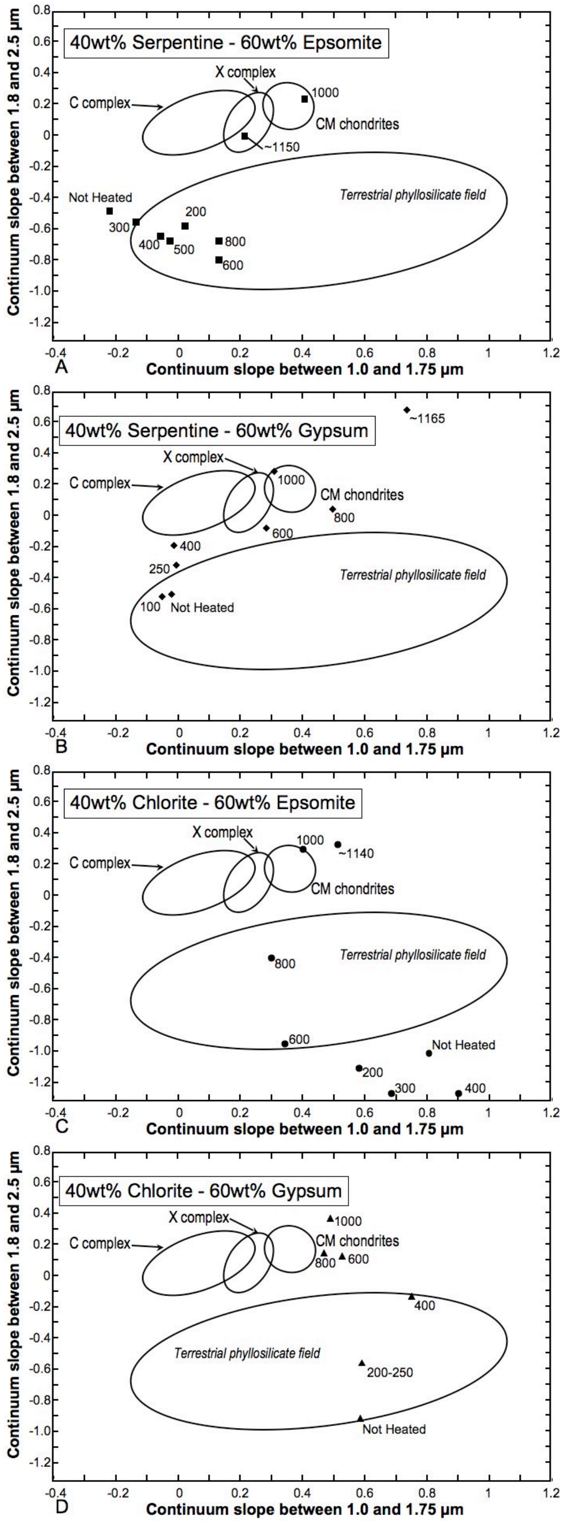

Fig. 2: Continuum plots for mixtures of phyllosilicates and evaporites. All of the mixtures migrate towards the CM chondrite field after heating above ~800°C. The sample of 40wt% serpentine-60wt% epsomite heated to 1150°C plots in an asteroid field, the X complex after the heat treatment.

Discussion: The sample of 40wt% serpentine-60wt% epsomite heated to 1150°C is the only mixture to plot in an asteroid field, the X complex. The experiments are consistent with the idea that CM chondrites are composed of any one of these mixtures heated to or above 1000°C, above 800°C in Fig 2d. Most C chondrites, the major exception being the CMs, plot in the C asteroid field [10]. Yet, none of the mixtures heated to any temperature plot in the C asteroid field. This is because they maintain, at higher treatment temperatures, a slightly steeper continuum slope in the 1.8 to 2.5 µm region. The only sample that plots close to the C asteroid field is the 400°C 40wt% serpentine-60wt% gypsum, where it plots just below the field. This is most likely due to the minerals retaining water of crystallization. The increasing positively-sloped continuum past 1.8 µm could be flattened out by the minerals being "painted" with an opague (possible organic) substance.

An issue for C asteroid and C chondrite spectroscopic studies is why the CM and CI chondrites can contain up to 10 and 20 volume % water respectivally, are supposed to be composed of phyllosilicates and some evaporates. Both of these mineral specices can contain large amounts of water. It is possible for both of them to jointly hold most of the meteorite water [11]. The high temperatures required to cause the mixtures spectra and continuum data to be similar to the asteroids and meteorites would remove all forms of water and turn the minerals into decomposition products or an amorphous state. The question is what is happening with the water? It is most likely subsurface to allow these minerals to form and is lost to space weathering effects when impact and gardening brings it to the surface. In the case of the CM chondrites consisting of impact dehydrated minerals the water could be added later. The heating experiments of Hiroi are also consistent with the surfaces of C asteroids being heated equivalents of the CM and CI chondrites [12].

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