HYDROUS MINERALOGY OF CM AND CI CHONDrites FROM INFRARED SPECTROSCOPY AND THEIR RELATIONSHIP WITH LOW ALBEDO ASTEROIDS. P. Beck¹, E. Quirico¹, G. Montes-Hernandez¹, L. Bonal², J. Bollard¹, F-R Orthous-Daunay¹, K. Howard¹, B. Schmitt¹ and O. Brissaud¹. ¹Laboratoire de Planétologie de Grenoble, OSUG, UJF/CNRS, 122 rue de la piscine, 38000 Grenoble France. ²University of Hawai`i at Mānoa, Honolulu, HI 96822, USA. ³Impacts and Astromaterials Research Centre (IARC), The Natural History Museum, Mineralogy Department, London SW7 5BD, UK

Introduction: Infrared spectroscopy, is one of the few techniques that can directly probe chemical bonds involving protons and then OH and H₂O groups. This technique is widely used in planetary sciences to identify ice and hydrated minerals at the surface of asteroids and planets from solar reflectance spectroscopy [1-3]. Previously, the diffuse reflectance IR spectra of several carbonaceous chondrites were measured by [4] to quantify the amount of hydrous minerals they contain. The intensity of the so-called 3-µm band absorption feature is the combination of the stretching \( \nu_1 \) and antistretching \( \nu_3 \) vibration modes of water. This intensity was found to slightly correlate with the total hydrogen content of the samples [4]. However, the correlation with the amount of phyllosilicates appeared unclear [4]. A major limitation of this previous study is that spectra were measured at ambient conditions. Thus, the amount of adsorbed water is high and potentially dominates the reflectance spectra of the samples [2]. Here, we report on mid-infrared measurements of the matrices of several CI and CM chondrites in a dry environment allowing the removal of the spectral contribution of adsorbed terrestrial water. Transmission spectra were obtained using an environmental cell that can be heated and kept under primary or secondary vacuum. This approach enables us to remove weakly bonded water molecules and to observe the mineralogical signatures of structural OH and H₂O.

Samples and analytical methods: Twelve meteorites having experienced aqueous alteration on their parent bodies were considered in the present work, among which 9 CM and 3 CI chondrites. The selected CM samples span almost the full range of aqueous alteration (from 2.6 to 2.0) as defined by [5]. They are: QUE 97990 (2.6), Murchison (2.4), Murray (2.4/2.5), QUE 99355 (2.3), Cold Bokkeveld (2.2), Mighei, Boriskino, and Nawapali (not studied by [5]). The CI chondrites we studied are Alais, Ivuna, and Orgueil. Samples were provided by the Museum National d'Histoire Naturelle (Paris-France) and the Johnson Space Center – NASA (Houston-USA).

Infrared spectra were obtained with a BRUKER HYPERION 3000 infrared microscope at the Laboratoire de Planétologie de Grenoble (LPG, France). Spectra were measured at 4 cm⁻¹ spectral resolution with a MCT detector cooled with liquid nitrogen. Particular care was devoted to sample preparation, which is a critical issue in infrared microspectroscopy. Samples were prepared and loaded into an environmental cell designed at LPG. This cell enables temperatures up to 300°C to be reached under primary or secondary dynamic vacuum (from 10⁻⁴ down to 10⁻⁷ mbar). Samples were progressively heated up to 300°C with typical steps at 100 °C, 150°C, and 200°C. Spectra were recorded at each temperature step.

Results of heating experiment: For each of the meteorite sample, IR spectra were measured at different steps upon heating the samples. Results obtained for Orgueil are presented in the 3-µm H₂O and –OH absorption region in Figure 1. Upon heating at 100°C significant amount of water is released by the sample, revealing that adsorbed water is present. With increasing heating to 300°C some additional water is released, likely interlayer water in phyllosilicates. This figure shows that dry conditions are required to acquire IR spectra. Indeed, the room temperature spectra are dominated by atmospheric water, in the form of adsorbed and interlayer water.

High-temperature spectra of CI and CM chondrites in the 3 µm region: The infrared spectra of all studied samples measured at 300°C and under primary vacuum are presented in Fig. 2. Among CM chondrites, two end-member spectral signatures were identified with type samples Murchison and Cold Bokkeveld. The spectrum of Murchison shows a broad asymmetric feature with a maximum around 3580 cm⁻¹, while the spectrum of Cold Bokkeveld reveals a sharp asymmetric feature with a well defined peak at 3675 cm⁻¹ (Fig. 3). Among CM chondrites, there appears to be a continuous evolution between these two end-members. But some variability within a sample is also encountered (Fig. 3). The spectra of CI chondrites look similar to some of the CM chondrites, in particular to Cold Bokkeveld and Nogoya. Although the room temperature spectra might have a contribution from ferrhydrite, it should be negligible at high temperature due to decomposition of this metastable phase [6]. The 3-µm band is thus likely to be controlled by phyllosilicates only. The strong absorption maximum at 3675 cm⁻¹
observed in Cold Bokkeveld-like meteorites suggests
the presence of Mg-rich serpentines that display sharp
OH stretching absorptions in the near-IR spectral re-
gion [7, 8]. However, the 10-µm region reveals that
the phyllosilicate phases encountered in the CM and
CI chondrites are spectroscopically distinct from
commonly encountered terrestrial serpentines. Previ-
ous TEM and XRD studies show that there is no single
poly-type of serpentine in these samples hence we are
likely measuring contributions from multiple inter-
grown serpentine phases that may also be highly dis-
ordered as shown by TEM.

Our results on CM chondrites indicate a continuous
spectral evolution of the 3-µm feature between the
demembers Murchison and Cold Bokkeveld types.
This evolution appears in agreement with the progres-
sive alteration scheme of [5] (Fig. 2). More, the spec-
tral serie is also in good agreement with the classifica-
tion of [9] obtained from bulk modal analysis. Because
serpentine minerals were shown to become enriched in
Mg as alteration progresses [10] we interpret the spec-
troscopic evolution to be an effect of the bonding
cation on the hydroxyl stretching mode. IR spectra on
synthetic serpentine minerals with various Fe/Mg ra-
tios are required to strictly confirm this interpretation.

The CM chondrite / asteroid connection:
C-type asteroids are the most abundant asteroids in the
main belt and display spectral features that suggest a
relationship with carbonaceous chondrites. In particu-
lar, C-type asteroids have a low albedo and some of
them exhibit an IR absorption around 3-µm [11].
These asteroids have been tentatively connected to
specific meteorite groups by comparing observed solar
reflectance spectra to laboratory measurements.
The spectra obtained at low pressure and moderate
temperature in the present work reveal that terrestrial
adsorbed water significantly perturbs the IR signature
at 3 µm. In the case of Murchison (CM), the spectrum
at ambient conditions is dominated by a broad peak
centred at ~3300 cm⁻¹ (2.95 µm), while the spectra
recorded in “dry” atmospheric conditions show an
asymmetric peak centred at ~3670 cm⁻¹ (2.72 µm) with
a broad long wavelength wing. The signature of ad-
sorbed water is the most likely present in all labora-
tory reflectance spectra measured at ambient condi-
tions. Thus most of the published infrared spectra of
terrestrial minerals and chondrites are likely biased for
asteroid comparison. At the surface of asteroids, only
minute amounts of adsorbed water can be expected. In
order to obtain valid analogs of infrared reflectance
spectra for altered parent bodies, meteorite (e.g., CM,
CI) reflectance spectra acquired in dry vacuum condi-
tions are required.

References
88, 172-192.