PHYSICAL PROPERTY MEASUREMENT SYSTEM AND ATOMIC FORCE MICROSCOPE THERMAL CONDUCTIVITY MEASUREMENTS OF CARBONACEOUS CHONDRITES. C. M. Gilmour[1], P. Such[1], J. Freemantle[1], and M. G. Daly[1]. [1]Centre for Research in Earth and Space Science, York University, Toronto, Canada. (email: cgilmour@yorku.ca)

Introduction: Carbonaceous chondrite meteorites hold clues about the evolution of the early solar system due to their primitive nature. Specifically, we can constrain some physical (i.e., Yarkovsky and Yarkovsky-O'Keefe-Radzievskii-Paddack (YORP) effects) and chemical (i.e., thermal evolution) parameters of carbonaceous chondrite parent bodies through meteorite thermal conductivity studies [e.g., 1-4]. Currently, there are only two carbonaceous chondrite thermal conductivities between 5 and 300 K that have been measured directly [1,2]: NWA 5515 (CK4, find) and Cold Bokkeveld (CM2, fall). As CK carbonaceous chondrite parent bodies have been subject to secondary metamorphism up to type 4 or higher, the thermal conductivity of NWA 5515 has the potential to provide insight into the thermal history of its parent body [e.g., 5]. However, because thermal conductivity is dependent on composition and porosity [1,2], and NWA 5515 is a moderately-weathered find, there are concerns surrounding how representative this meteorite is of its parent body due to the effects of terrestrial secondary alteration on composition and physical state [6]. Alternatively, Cold Bokkeveld is considered to be a representative sample of its parent body, as well as some of the most primitive carbonaceous material, given its observed fall (i.e., little to no terrestrial alteration). Cold Bokkeveld has one of the lowest reported thermal conductivity measurements of 0.5 W/m·K at 200 K [1,2]. In this study, we perform thermal conductivity measurements on CI and CM carbonaceous chondrites to confirm if the thermal conductivity of Cold Bokkeveld is typical of primitive carbonaceous chondrites or an anomaly.

Objective: Thermal conductivity measurements of carbonaceous chondrite meteorites will be collected using a Physical Property Measurement System (PPMS) and an Atomic Force Microscope (AFM) located at the Planetary Instrumentation Laboratory (PIL), York University (Toronto, Canada) (Fig. 1). The PPMS used in this study is similar to the one used by Opeil et al. [1,2]. There are no reported AFM measurements of carbonaceous chondrite thermal conductivities. We are currently building a thermal conductivity database of minerals common to meteorites (i.e., olivine, enstatite, serpentine, magnetite, etc.) prior to meteorite analysis. These mineral measurements will be used to validate the PPMS and AFM measurements of carbonaceous chondrites.

We intend to collect several thermal conductivity measurements of CI and CM carbonaceous chondrites (at least 10) with the PPMS and AFM. As composition is a major component of the overall thermal conductivity, the same carbonaceous chondrites will be analyzed with a Fourier Transform Infrared (FTIR) spectrometer to understand the similarities between composition and the distribution of heat flow in their asteroid parent bodies.

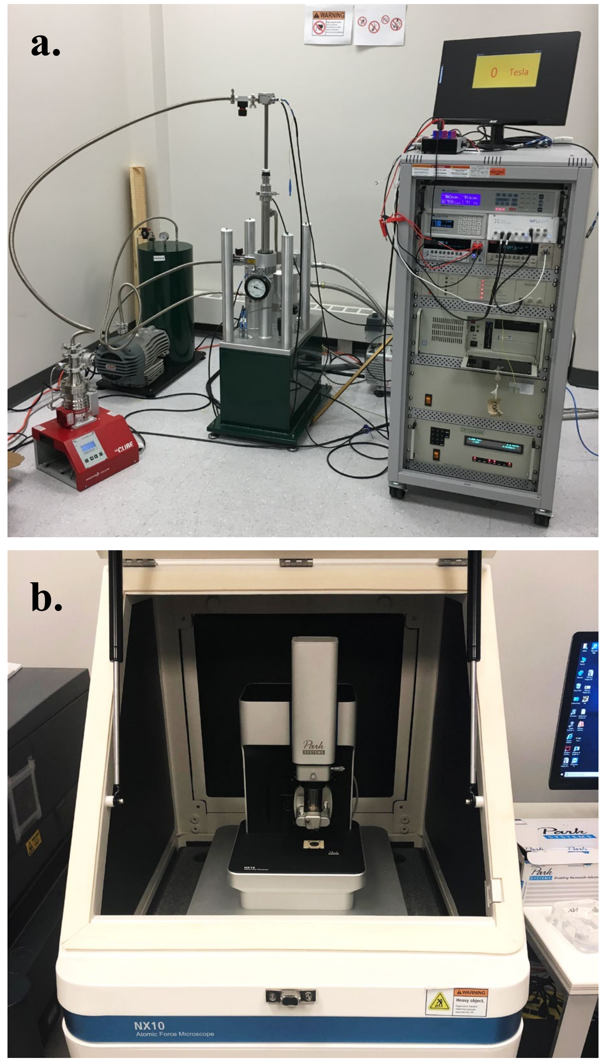

Fig. 1. The thermal measurement instruments at the Planetary Instrument Laboratory (PIL) at York University. **a.** Physical Property Measurement System (PPMS). **b.** Atomic Force Microscope (AFM).

The PPMS: The PIL houses a mini-Cryogen Free Magnet System (mCFMS) PPMS. Our PPMS is capable of measuring thermal properties between 5 and 300 K under a vacuum of 10^{-4} hPa. To measure the thermal conductivity of carbonaceous chondrites, samples will be cut into 2 x 2 x 20 mm bars. These dimensions are greater than those used by Opeil et al. [1,2] which ranged between 2 and 10 mm, giving us the advantage to measure thermal conductivity along a greater path. The sample bar is connected to a thermocouple and heater assembly via silver (Ag) epoxy (Fig. 2). The heater supplies heat to the sample on the hot junction end of the thermocouple. The temperature change across the sample is measured between the hot and cold thermocouple junctions. The sample is then connected to a platform consisting of a heat sink that houses a heater to control the temperature of the sample on the cold junction end and a Cernox™ thermometer to record the temperature of the sample platform. The sample platform is then covered with a radiation shield and mounted to the end of a measurement probe. To ensure that the sample is thermally isolated from the PPMS, the assembly is housed in an inner vacuum chamber (IVC) that is evacuated to and maintained at 10^{-4} hPa. The measurement probe is then inserted into the PPMS, where small pulses of heat are applied to a given sample at various temperatures creating temperature gradients across the sample. The PPMS records these temperature differences, and the power to maintain them, to produce thermal conductivity profiles.

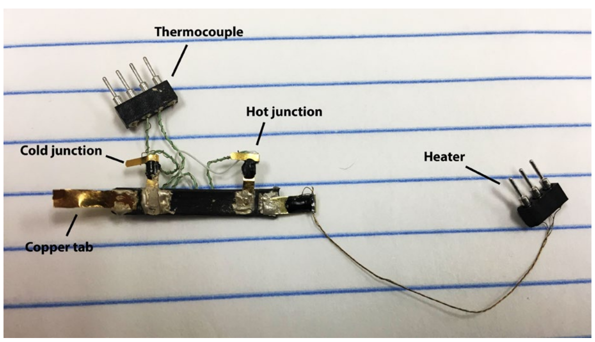

Fig. 2. Sample connected to the thermocouple and heater assembly for PPMS analysis.

AFM System: The Atomic Force Microscope in the PIL is a NX10 Park System instrument. The AFM utilizes the Scanning Thermal Microscopy (SThM) mode to collect thermal contrast data of carbonaceous chondrites at the nanoscale. Thermal contrast is representative of the thermal diffusivity at the surface and subsurface (nanoscale) of a given sample, which can be used to derive the thermal conductivity of the carbonaceous chondrite compositions.

Measurements on the AFM are completed via the interaction of a heated cantilever (55°C) with the surface of a sample. All measurements are completed at ambient atmospheric pressure. During analysis, the tip of the cantilever moves across the sample's surface, where the variation in temperature across the surface causes a measured change in the resistance of the current probe. The data collected by the AFM are represented by thermal maps that show variations in topography and temperature (Fig. 3).

Significance: As missions to carbonaceous asteroids are only capable of remotely measuring thermophysical surface properties, there is little known about the internal thermal structure of these small bodies. By analyzing the thermal conductivity of carbonaceous chondrites, we can conceptualize how heat is distributed throughout their parent asteroid. This data will support the construction of complete thermal models for primitive asteroids of similar composition. These models can aid in constraining the formation and evolution of asteroids throughout the solar system. Beyond thermal modelling, this research will be a significant contribution to our understanding of the thermal properties of meteorites and their asteroid parent bodies at the macro and micro scales.

References: [1] Opeil C. P. et al. (2010) *Icarus 208,* 449-454. [2] Opeil C. P. et al. (2012) *Meteor. Planet. Sci. 47,* 319-329. [3] Beech M. et al. (2009) *Planet. Space Sci. 57,* 764-770. [4] Yomogida K. & Matsui T. (1983) *J. Geophys. Res. 88,* 9513-9533. [5] Yomogida K. & Matsui T. (1984) *Earth Planet. Sci. Lett. 68,* 34-42. [6] Bland P. A. et al. (1998) *Geochim. Cosmochim. Acta 62,* 3169-3184.

Acknowledgements: Thank you to Stephen Connaught and David Gillingham of Cryogenic Limited for their support with the PPMS.

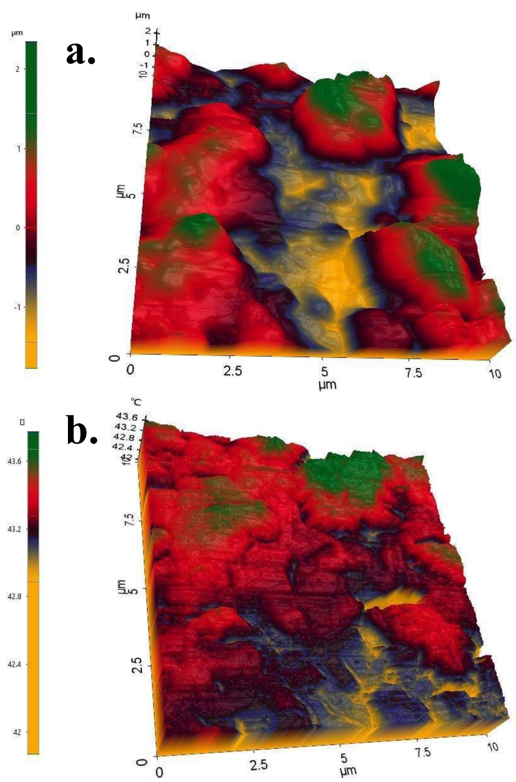

Fig. 3. AFM thermal maps of the Murchison carbonaceous chondrite (CM2) matrix. **a.** Topographic. **b.** Thermal contrast.