ELASTIC PROPERTIES OF THE TAGISH LAKE FALL (C2, UNGROUPED)
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Introduction: Carbonaceous chondrites (CCs) represent ~4% of the total meteorite falls; however, their reputed parent bodies – dark asteroids – represent at least half the Earth-crossing asteroid population [1]. CCs have become increasingly important as the only physical samples that provide some constraints on dark asteroid lithologies; constraints that are needed now to better develop sample return missions from asteroids, such as Bennu and Ryugu [e.g. 2, 3]. Measurements of CCs physical (microporosity) and elastic properties provide the only approximation of how a dark asteroid surface responds to impact processes. Micro- and macroporosities and the elastic properties of asteroids play a major control on energy transfer (and attenuation) during collisions [4]. In this study, we present preliminary measurements of elastic wave velocity of the Tagish Lake meteorite; Ungrouped C2 with affinities to CM-chondrites [5]. The samples studied represent the high inclusion phase of Tagish Lake. These data complement a previous survey that included 49 carbonaceous chondrite falls, of which 12 samples were CM-chondrite falls [6]. Tagish Lake represents the highest measured microporosity and lowest elastic wave velocities among CM-chondrites (see Figure 1).

Methodology: Measurements of the elastic wave velocity were carried out using a manually controlled electric pulse generator(receiver (Olympus Model 5077 PR) with a 35 MHz ultrasonic bandwidth, a 100-MHz-bandwidth Oscilloscope (Tektronix Model DPO2014), a pair of 13-mm-diameter P-wave ultrasonic contact transducers (Olympus V153), and a digital micrometer. Slabs of Tagish Lake were prepared – using a wire saw to minimize material consumption and contamination – for better coupling with the transducers. A vise was used to produce pressure on the transducers, which improved coupling with samples surfaces (and the quality of the signals). The bulk volume necessary for bulk density measurement was measured using a desktop laser scanner (NextEngine Desktop 3D Scanner Model 2020i) [7]. A helium pycnometer (Quantachrome Instruments, Model MVP-D160-E) was used to measure porosity and grain density.

Results and Discussion: Preparing slabs of Tagish Lake reveals a brecciated texture, which will be further examined petrographically. Comparison of the elastic properties of Tagish Lake with a suite CM-chondrite falls suggests that Tagish Lake has the lowest values of bulk density (1.54 ± 0.03 gm/cm³), porosity (0.45 ± 0.001) and P-wave velocities (1240 ± 10 m/sec). The measured bulk density and porosity values are consistent (within uncertainty) with previous measurements of other samples measured approximately 18 years ago indicating adequate isolation from the terrestrial atmosphere in curation [8]. The low elastic wave velocities measured for Tagish Lake were expected based on bulk density–elastic wave velocity relationships observed in terrestrial rocks and in ordinary and carbonaceous chondrites. The low P-wave velocities for Tagish Lake are also consistent with the high microporosity. Tagish Lake provides the observed lower limits of density and seismic velocities of CM-chondrite-like lithologies, and, by proxy, their parent bodies.

Figure (1): P-wave velocity of CM-chondrites versus Fall Date. Tagish Lake is represented by blue (grey) diamond data point. Note that the downward trend vs. fall date is mostly resulting from the fastest (Cold Bukkeved, Vp = 3460 m/sec) and the slowest meteorite (Tagish Lake, Vp = 1240 m/sec). Most CM-chondrites range from 1500 to 3000 m/sec.

Implications: Tagish Lake shows the lowest values of seismic wave velocities and elastic moduli among CM-chondrites. Such low velocities result in anomalously low values of bulk (volumetric elasticity) and Young moduli (tensile elasticity). Bulk modulus denotes the tendency of bodies to deform in all directions under uniformly applied pressure, an extension of Young’s modulus to three dimensions. In the case of analogous parent bodies, these low values of the elastic moduli may suggest a strong collapse response (along the axis of applied stress) to collisions.

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