ACOUSTIC VELOCITY AND MECHANICAL PROPERTIES OF STONY METEORITES. D. R. Ostrowski[1,2], [1]Bay Area Environmental Research Institute, Ames Research Center, Moffett Field, CA, USA, [1]NASA Ames Research Center, Moffett Field, CA, USA. E-mail: daniel.r.ostrowski@nasa,gov.

Introduction: Physical properties provide information to understand the behavior of meteors during atmospheric entry. These measurements help determine methods to deflect potentially hazardous objects [1] and are essential to determine the characteristics of parent bodies [2]. The strength of the meteorite is a critical input for how the meteoroid will fragment during atmospheric entry [3]. Complexity arises in the analysis of meteorites because they contain multi-phase minerals and exhibit a range of mechanical properties at various length scales. The range in mechanical strength of most stone meteorites is between 6 and a couple hundred MPa [4, 5]. A limited number of meteorites have been crushed to determine their strength. Elastic moduli can be used as a non-destructive method to approximate the mechanical strength of meteorites. It has been shown for Allende and Tamdakht that the elastic modulus from sound velocity is similar, but usually slightly lower, to elastic modulus derived from compression test [6].

Experimental: The physical properties of density, porosity, and both longitudinal and shear acoustic velocity are measured of nine previously unmeasured meteorites. Bulk density is determined from 3D laser scanner, while grain density is determined using a gas pycnometer, both of these values are used to calculate porosity. Acoustic velocity is obtained using an Olympus 45-MG, with the V103-RB transducer to measure longitudinal velocity and the V153-RB transducer to measure shear velocity. Couplants are used to reduce the acoustic impedance mismatch caused by the air between the face of the transducer and cut meteorite surface. Acoustic velocities are measured across all three axis. Acoustic velocities are used to calculate the Young's (E) and shear (G) moduli of the meteorites from equations 1-3 [7]. Where ρ is density, V_L is longitudinal wave velocity, V_S is shear wave velocity, and ν is Poisson's ratio.

$$\nu = \frac{1-2\left(\frac{V_S}{V_L}\right)^2}{2-2\left(\frac{V_S}{V_L}\right)^2} \quad (1)$$

$$E = \frac{V_L^2\rho(1+\nu)(1-2\nu)}{1-\nu} \quad (2)$$

$$G = V_S^2\rho \quad (3)$$

Results: Table 1 list the new average acoustic velocities measured. Averages are for the whole meteorite cube from all three axis irrespective of any single axis the that may have a chip, crack, or large metal grain. The longitudinal and shear velocities for the new ordinary and carbonaceous chondrites are within the range of values for both reported groups, (fig 1) [5]. Within a specific meteorite group there is no trend for petrological type. Higher petrological type, 5 and 6, cover the full range of velocities and type 3 and 4s are intermixed among the range. The lone diogenite, NWA 5480, has values similar to that of eucrites, but both classes have velocities much higher than their counterpart howardites.

Table 1: *Acoustic velocities of newly measured meteorites.*

Meteorite	Type	Longitudinal Velocity (m/s)	Shear Velocity (m/s)
NWA 5480	Dio	3791±13	2175±6
LAR 12002	CV3	3978±12	2705±9
GRA 95208	H3.7	6234±16	3101±10
LAR 12003	H6	4137±18	
GRA 06119	L6	4986±14	2981±14
RTB 04266	L6	5341±19	3103±16
Kheneg Ljouâd	LL5/6	3791±7	2177±4
LAR 06250	LL6	3859±10	2589±6
PRA 04422	LL6	3938±13	

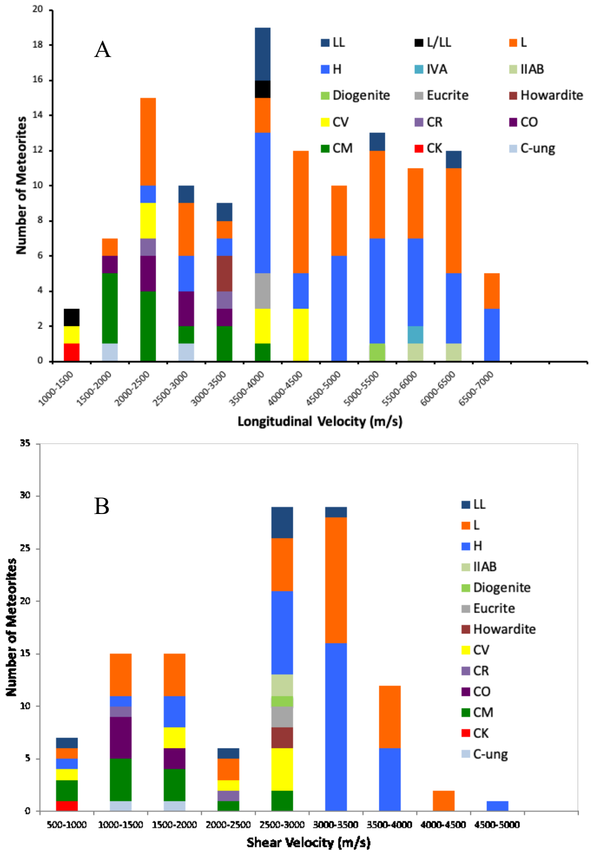

Figure 1. *Number of meteorites for each group with (a) longitudinal velocities between 1000-7000 m/s and (b) shear velocities between 500-5000 m/s. Meteorite velocity count contains newly measured meteorites and all velocities reported in Ostrowski and Bryson 2019.*

Table 2: *Mechanical properties of newly measured meteorites.*

Meteorite	Type	Poisson's Ratio	Young's Moduli (GPa)	Shear Moduli (GPa)
NWA 5480	Dio	0.353 ±0.003	45.0±0.8	16.6 ±0.1
LAR 12002	CV3	0.197 ±0.002	56±1	23.7 ±0.2
GRA 95208	H3.7	0.329 ±0.004	84±2	31.8 ±0.4
GRA 06119	L6	0.151 ±0.001	63.1±0.9	27.4 ±0.2
RTB 04266	L6	0.178 ±0.002	86±2	36.6 ±0.5
Kheneg Ljouâd	LL5/6	0.255 ±0.001	37.3±0.4	14.85 ±0.03
LAR 06250	LL6	0.135 ±0.001	48.0±0.7	21.4 ±0.2

The mechanical properties of the one fall meteorite, Kheneg Ljouâd, has the lowest of measured moduli. Past studies of ordinary chondrites give a wide range for Young's modulus with most meteorites being below 85 GPa and for shear modulus below 35 GPa [4]. This would put the ordinary chondrites in this study in the average value of for both moduli. In comparison to previous studies for carbonaceous chondrites [4, 5] the Young's modulus for LAR 12002, CV3, is higher than normal, but the shear modulus is within the range of reported values.

Conclusion:

The acoustic velocity and mechanical properties for nine previous unmeasured meteorites have been measured. All meteorites studied are around the average value for their group. For the acoustic velocities, the petrologic type of ordinary chondrites does not have an effect on both the longitudinal and shear velocity.

NWA 5480 is the first diogenite to have its mechanical properties determine by acoustic velocity. Using Young's modulus as an estimator of strength, the higher-than-normal modulus of CV3 meteorite LAR 12002 implies it is stronger than most carbonaceous chondrites.

Future work entails comparison of results with the measured strength and moduli values from compression test.

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