UV-NIR SPECTRA AND NANOINDENTATION OF CHELYABINSK TO INFER THE MECHANICAL PROPERTIES OF HAZARDOUS ASTEROIDS.

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Introduction: Every asteroid from the Near-Earth Asteroid (NEA) population has experienced a different evolution since they formed at the Main asteroid Belt (MB) until they moved towards the near-Earth region [1]. Most of them have intense collisional histories, often including the catastrophic disruption of their primitive parent bodies and breccification [1-3]. The Chelyabinsk meteorite, with ~1000 kg of specimens available to be studied [4], has a relatively high S4 degree of shock [4], consistent with the evolutionary scenario described before. This meteorite is an ordinary chondrite (OC) originally described as an LL5 [4], but further studies have revealed a mixture of different lithologies that point towards being a breccia, including some LL6 material [5]. The most abundant lithology is light-colored, with abundant shock veins, although some fragments include chondrule relicts and minor or no shock veins [4-6]. The second most common lithology in this meteorite is described as dark-colored, or shock-darkened, due to the amount of interstitial spaces filled with opaque material (metals and troilite) as a consequence of shock mobilization [4-6]. A fine-grained impact melt lithology has been defined separately from the previous two, being also produced by shock [4,5]. Therefore, this lithology has experienced the consequences of shock to a larger extent than the dark-colored lithology, suffering extensive melting [4-6], but they are almost identical from an spectroscopic point of view [7]. This kind of shock-darkened materials in OCs are relatively common, and their consequence in the ultraviolet to near-infrared (UV-NIR) spectra of meteorites have been studied extensively [8]. In the case of Chelyabinsk, particularly, the spectroscopic distinction of light and dark lithologies has allowed to tentatively explain the unusual spectral properties of the Baptistina Asteroid Family, showing that different combinations of these lithologies can explain some spectral variations of asteroids [7]. Since the processes responsible for the formation of the different lithologies can also have strong effects in their physical properties, spectroscopic studies showing the amount of shock-darkened material on an asteroid would allow us to gain insight about the mechanical properties of its forming materials. We analyze several UV-NIR spectra of Chelyabinsk, and relate them with the mechanical properties obtained after nanoindentation experiments, and extrapolate the results to asteroids. Since most NEAs are S- or Q-class asteroids related to LL meteorites [9,10], the abundant fresh Chelyabinsk meteorite specimens are good proxies for this kind of study.

Experimental: We studied a thin (~30 µm) section of the Chelyabinsk meteorite (PL13049) kindly provided by Addi Bischoff. A high-resolution mosaic was created from images obtained with a Zeiss petrographic microscope. An UMIS equipment from Fischer-Cripps Laboratories was used for the nanoindentation tests, using a Berkovich pyramidal-shaped diamond tip, in order to study the mechanical properties of the different lithologies and materials found in this meteorite. Finally, several ultraviolet to near-infrared spectra (~0.2 to 2.0 µm) were obtained from the different lithologies of the Chelyabinsk meteorite, using a Shimadzu UV3600 UV-Vis-NIR spectrometer.

Results and Discussion: Shock-driven processes affected the darkened regions of Chelyabinsk and introduced changes in their mechanical properties. We have seen that bodies with a higher percentage of shock-darkened materials tend to be harder, and more easily friable than those composed by the light-colored lithology. The differences in strength need to be taken into account for future asteroid deflection missions. .

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