Collisional effects on Magnesium-rich Minerals found in Comets and Asteroids

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While generally touted to be the least-altered bodies remaining from the age of the solar system's formation, comets and asteroids have undergone evolutionary processing throughout the 4.5-billion-year lifetime of the solar system. They have suffered the effects of collisions by impactors ranging in size from micrometeoroids to other comets and asteroids. As such, we must ask ourselves: can we detect these evolutionary effects remotely through telescopic observations? With this in mind, a suite of experiments were conducted, impacting magnesium-rich minerals as analogues to those that have been detected in the spectra of both asteroid surfaces and in the dust of cometary comae, including forsterite (Mg2SiO4, olivine), orthoenstatite (Mg2SiO3, pyroxene), diopside (MgCaSi2O6, monoclinic pyroxene), and magnesite (MgCO3, carbonate).

These minerals were impacted at velocities ranging from 2.0 km/s to 2.8 km/s using the vertical gun in the Experimental Impact Laboratory (EIL) at NASA Johnson Space Center. These speeds mimic typical velocities of impacts occurring in the Kuiper belt [1]. Two classes of projectile were used: spherical alumina ceramic, whose density mimics that of rock, and cylinders made from the same material that they impacted (e.g., forsterite impactors for forsterite targets, etc.). The peak shock pressure varies significantly, depending on the target and impactor materials and the velocity; thus, shock effects differed in targets impacted at the same velocity but with compositionally different projectiles. The results indicate both (a) how varying the impactor-density might change the outcome from a scientific viewpoint, as well as (b) possible contamination effects of the ceramic projectile in the resultant spectra of the target minerals from an experimental perspective. Temperature effects were also investigated by impacting samples at both 25°C and -25°C to (a) probe whether the varying temperatures experienced by small bodies plays a role in the resultant spectra, and (b) constrain necessary experimental parameters.

Analysis of Fourier Transform Infrared (FTIR) spectra obtained from the experimentally shocked materials shows clear indications of spectral shifts in wavelength, as well as a change in relative peak strengths of the spectral signatures at one wavelength compared with another, in all minerals except magnesite. Samples of the forsterite and orthoenstatite that displayed the spectral changes were examined with a transmission electron microscope, which revealed evidence of planar dislocations. The density of the dislocations in the experimentally shocked minerals mimicked the dislocation densities measured in both forsterite and enstatite grains recovered from Comet Wild 2 by the Stardust mission [2, 3, 4]. Further discussion on analyses of peak shock pressure and temperature-dependent effects can be found in Jensen et al., this meeting.

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