SOURCE AND EVOLUTION OF VAPOR DUE TO IMPACTS INTO LAYERED CARBONATES AND SILICATES. C. A. Eberhardy and P. H. Schultz, Brown University Box 1846, Providence, RI 02912 (cae@brown.edu).

Introduction: Impacts into volatile-rich targets produce detectable vapor plumes that expand above the crater and into the transient cavity [1,2]. Most experimental and theoretical models of impact vapor production use homogeneous targets, however, most planetary surfaces are not homogenous. For example, the high latitude terrain on Mars has surface deposits of volatile H_2O and CO_2 [3] and the nuclei of comets possibly have layered volatile and nonvolatile deposits.

Impact vapor should primarily be produced in the upper surface of the target near the point of impact where the shock pressures and temperatures are highest. In order to investigate where the impact vapor is produced and the effect of nonvolatile particulate layers on vapor production, a new set of experiments were designed using the NASA Ames Vertical Gun Range (AVGR). Spectroscopic measurements determine the location, composition and relative abundance of the vapor. Interestingly, it was observed that silicates underlying a small layer of volatile carbonates enhance vapor production relative to the vapor produced in homogeneous volatile targets.

Experiments: The experiments were performed at the AVGR with an oblique impact angle of 60° from horizontal and an average impact velocity of 5.4km/s. The projectiles (6.35mm diameter spherical Pyrex) fail completely upon impact at hypervelocities and do not contribute significantly to the observed spectroscopic signal. The projectiles impact next to a thick clear acrylic window (a quarter-space target) and expose the interior of the transient crater. In other words, the target is effectively a cross-sectional view of crater formation. All impacts occurred under near-vacuum conditions (<0.5Torr) in order to minimize any atmospheric interactions.

The targets vary by changing the thickness of a powdered dolomite layer over sand (average grain size ~500μm). The targets consist of a thin layer of dolomite over a deep substrate of sand or a target containing dolomite only. Previous experiments [1,2,4] show that the carbonate (powdered dolomite) vaporizes easily at experimental impact conditions. For this reason and because it is stable at room temperatures, dolomite is a useful surrogate for planetary volatiles. At laboratory impact conditions, sand is not volatile. We varied the thickness of the dolomite layer above the sand from a thickness of 1*a* (where *a* is 1 projectile diameter), to 2*a*.

Spectra were collected with McPherson monochromators using Oriel gated, intensified CCD cameras [5]. Short exposure lengths (5μs) captured the first moments of impact. The monochromators have a 0.35m focal length and the gratings are interchangeable, thereby allowing a variety of spectral ranges. These experiments use a grating with 300grooves/mm for a broad spectral range. The chosen spectral range (425-575nm) contains many Ca and Mg atomic lines and CaO and MgO molecular features.

Seven aspheric telescopes simultaneously pinpoint discrete regions of the evolving impact vapor plume. Fiber optic cables are used to direct the light emitted during an impact from the telescopes to the spectrometers. The seven telescopes are arranged in a semicircle above and around the point of impact. Three telescopes point downrange, three uprange and one above the point of impact. Each detection region is 2.5cm from the point of impact and captures the very early stages of vapor expansion. In one of the experiments with 1*a* layer of dolomite over sand, the telescopes were rearranged to view below the target surface inside the transient cavity.

Results: Comparison of the line strengths in the various detection regions for all target types reveals how the impact vapor cloud expands. If vapor is only generated at the point of impact, the minimum expansion velocity is 5km/s for the vapor to reach the detection regions during the exposure time of 5μs, consistent with previous observations [1]. The downrange regions are significantly brighter than the uprange regions due to the downrange momentum of oblique impacts, which carries most of the vapor downrange. The lowest spectral intensity at these early times is observed uprange, directly along the impact trajectory. Vapor is detected 2cm below the point of impact (inside the transient crater cavity). Spectra from the downrange region are plotted in Figure 1. In the experiment with a layer of dolomite 1*a* thick, the strength of the atomic lines is enhanced compared to the dolomite only and the 2*a* thick dolomite layer targets.

Atomic Ca lines can be compared with the strength of the molecular CaO lines for the various thicknesses of dolomite over sand for all the detection regions. The ratio (Ca/CaO) is greatest for the

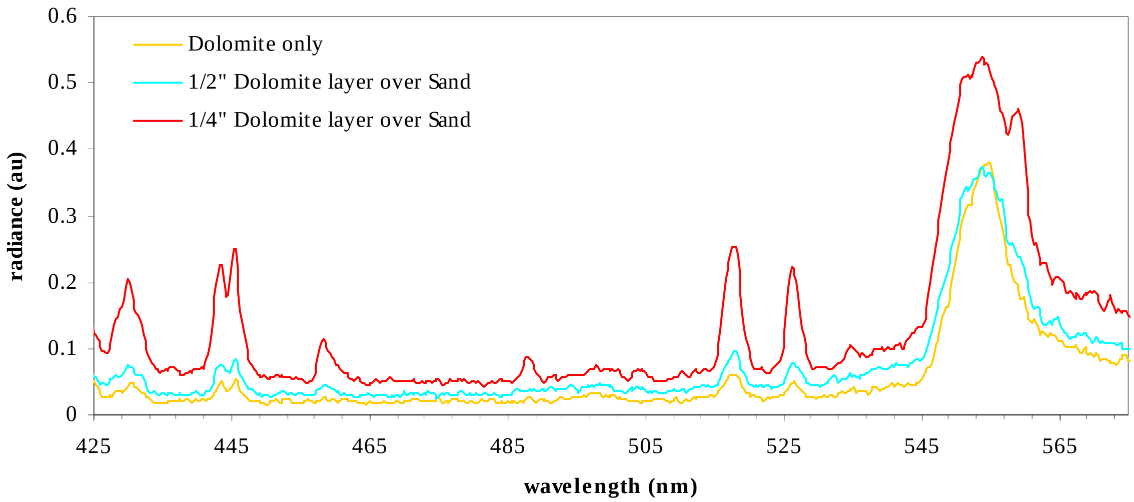

Figure 1: Spectra from three separate experiments with the same impact conditions but different targets. The orange spectrum is from an impact into a homogenous dolomite target. The red spectrum is from an impact into 1 projectile thickness of dolomite over sand. The blue spectrum is from an impact into 2 projectile thickness of dolomite over sand. The spectra each have an exposure length of 0-5microseconds from the time of impact. They are all from the same region 2.5cm away from the point of impact and downrange. Most of the features are atomic Ca lines and the broader feature around 550nm is due to CaO.

thinnest layer (1*a*) of dolomite over sand. The homogenous dolomite target and the thicker layer (2*a*) of dolomite target over sand have similar ratios, with slightly larger ratios for the dolomite-only target. The temperature history of the vapor plume controls the Ca/CaO ratios with higher temperatures producing stronger atomic lines.

Discussion: The most striking result of these experiments is the enhancement of the atomic emission lines for targets with layers of dolomite and sand. Since the observed emission lines do not originate in the sand, additional interactions must occur between the sand and the dolomite.

There are two possible mechanisms to account for the enhanced vapor production in layered targets. First, the change in impedance and/or shock reverberations between the layers may enhance the shock coupling to the surface layer of dolomite. Second, increased shear between the dolomite and the underlying sand may increase the thermal decomposition of the dolomite.

Conclusions: The early transient cavity contains atomic vapor dissociated from the dolomite, even in targets with only a thin surficial layer of dolomite. Targets with a thin layer of volatiles overlying a nonvolatile substrate result in greater vapor production. This enhanced vaporization could result from improved coupling of the impact shock with the upper surface of the target. Alternatively, heated silicates could provide a secondary thermal source that thermally decomposes the upper dolomite layer. These results imply that planetary surfaces with volatile layers, such as the upper latitudes of Mars or cometary nuclei, could result in increased impact volatilization. Future experiments will investigate mixtures of carbonates and silicates in order to understand the processes controlling the enhanced vaporization in layered targets.

References: [1] Schultz, P.H., et al. (1996) *JGR* 101(E9), 21,117-21,136. [2] Eberhardy, C.A. and P.H. Schultz (2004) *LPSC XXXV*, #1855. [3]. Feldman, W.C, et al. (2002) *Science* 297, 75-78. [4] Sugita, S., et al. (1998) *JGR* 103(E8), 19427-19441. [5] Eberhardy, C.A. and P.H. Schultz (2003) *LPSC XXXIV*, #2039.