PROBING IMPACT-GENERATED VAPOR PLUMES. C. A. Eberhardy and P. H. Schultz, Brown University, Dept. of Geological Sciences, Box 1846, Providence, RI 02912 (Clara_Eberhardy@brown.edu)

Introduction: Laboratory-produced impact vapor plumes cannot be completely characterized without understanding their temperature and pressure conditions, and their composition. Spectroscopy can define these parameters but it lacks the spatial resolution of high-speed imaging. High-speed imaging captures the source region but the composition cannot be characterized. Spectroscopy allows the detection of tenuous vapor plumes and enables the measurement of composition and temperature. Targeting several small and discrete regions simultaneously can then be used instead of imaging. By looking inside and around the growing crater using quarterspace experiments, we are able to characterize vapor plume evolution.

High-speed spectroscopy reveals the evolving composition of impact vapor. Previous studies have used high-speed spectroscopy to study the jetting phase [1]. Atmospheric interactions with the vapor plume also have been analyzed with spectroscopy, resulting in the identification of new molecules synthesized in the vapor plume [2]. The study here improves the understanding of where the impact vapor is forming and how it evolves.

Experiments: The experiments used the NASA Ames Vertical Gun Range (AVGR) to vary the impact angles with unconsolidated targets. Looking inside the crater formation process was possible with a quarter-space target configuration. The target material is fine powdered dolomite that vaporizes easily during the impact process. Projectiles are Pyrex spheres (6.35mm diameter) that minimize the spectral contribution from sources other than the target. All experiments are performed under near-vacuum conditions (<0.5Torr) in order to minimize any atmospheric interactions. Impacts were produced at angles of 30°, 45°, 60°, and 90°. The average projectile velocity used to produce these hypervelocity impacts was 5.7km/s.

Observations of each experiment are made with spectrometers as described elsewhere [3]. Fiber-optics are used to direct the light emitted during an impact from telescopes to the spectrometers. Seven telescopes pinpoint discrete regions of the evolving impact vapor plume. Two telescopes look inside crater formation by looking below the surface of the impact along the anticipated trajectory. Each of the two regions below is progressively deeper inside the transient crater. One of the seven telescopes looks uprange back along the line of approach. One telescope is just above the point of impact. Three telescopes are arranged to look downrange of the point of impact: two are low near the surface (3cm and 6cm downrange from the impact) and one is 3cm above the surface (and 3cm downrange). The multiple views of a single event help define the source region and expansion process of the early vapor plume.

Spectra acquired during the experimental impacts have several defining features. Exposures are short (50μs) and capture the first moments of crater evolution. We chose the spectral range of 400nm – 570nm to study the calcium and magnesium lines abundant in that range. Many strong atomic emission lines in this region are produced by Ca and a few by Mg. There are also strong, wide molecular bands of CaO. The continuum of the spectra is produced by the thermal blackbody temperature.

Data Analysis: Impact flash spectra reveal more than the composition of the vapor plume. Thermal dust temperatures can be measured from the blackbody continuum. Gas temperatures are measured by comparing the atomic species line intensities with their respective excitation energies. The negative inverse slope of a plot of the natural log of normalized line intensities versus excitation energies gives the temperature. The Boltzmann plot is often used to calculate gas temperatures in plasma physics [4]. This method has also been used in impact flash experiments [i.e., 1, 5]. Preliminary calculations suggest that the temperatures measured in this study are similar to temperature ranges found in these previous impact flash experiments.

The emission line intensities are affected by both the vapor density and gas temperature. The integrated intensity, line and band strengths, and the temperature of the regions all indicate the position and the condition of the vapor plume. A dim integrated intensity can mean either that the vapor plume is very thin in that region or that it has not expanded fast enough to reach the field of view for that particular instrument in the allotted exposure time.

Results: Spectra of the various regions reveal different processes. Spectra from all the regions detected for one impact event are shown in Figure 1. In this event, the spot just above the point of impact is brightest and has the strongest atomic and molecular lines. This represents vapor created at first contact (including the jetting phase) and subsequent shock-induced vapor expansion above the impact point. The next two brightest spectra correspond to regions downrange near and above the surface closest to the impact. All three downrange regions included the jetting phase.

Regions below the impact plane represent vapor contained by transient crater growth.

Temperatures calculated for three regions of another impact event further document changing vapor plume conditions (Figure 2). Temperatures for the downrange region and the region above the point of impact are high. These high temperatures represent a combination of the jetting phase and later vapor expansion. Below the point of impact, the vapor temperature is lower. Nevertheless, these experiments demonstrate that the jetting process is not the only source of emitting vapor for impacts into dolomite.

Conclusions: These experiments capture the evolving environment of the expanding vapor plume. Continuing experiments will investigate vapor source materials, vapor source regions, and vapor spatial evolution. Our goal is to define the processes that produce the different components of the vapor plume, such as the early high speed jetting, the slower expansion of the shock-induced vapor plume above the impact, vapor contained in the growing cavity, and cooler components above the impact. This first step demonstrates that vaporization is not only produced during the jetting phase but also fills and expands above the transient cavity. Each component exhibits different conditions with varying ratios of atomic to molecular emission intensities: uprange vapor is dominated by lower values of atomic/molecular whereas cavity-contained vapor has a greater atomic/molecular ratio compared with the other regions. During the entire 50μs exposure for all regions, atomic and molecular emissions dominate with very little blackbody.

References:

[1] Sugita S. and Schultz P.H. (1999) *JGR* 104(E12), 30825-30845. [2] Sugita S. and Schultz P.H. (2003) *JGR* 108(E8), 5051. [3] Eberhardy C.A. and Schultz P.H. (2003) *LPS XXXIV*, Abstract #2039. [4]Griem H.R. (1997) *Principles of Plasma Spectroscopy* 366pp. [5] Sugita S. et al (1998) *JGR* 103(E8), 19427-19441.

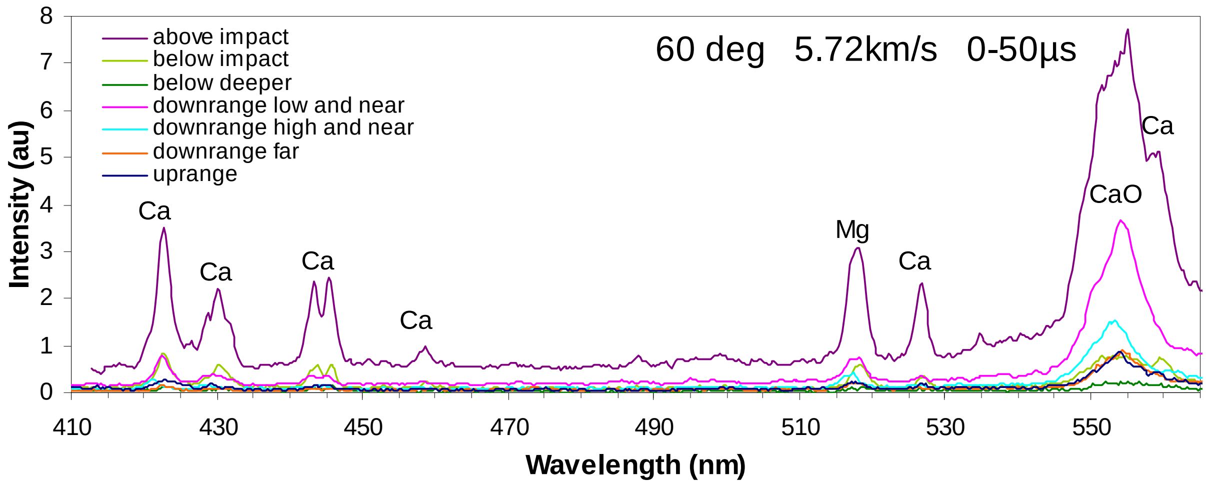

Figure 1: Vapor plume emission spectra from a 60° impact into a quarterspace of fine dolomite powder with a 6.35mm spherical Pyrex projectile. The detectors viewed the impact from the side with several looking inside the transient crater. Some atomic and molecular emission lines are labeled.

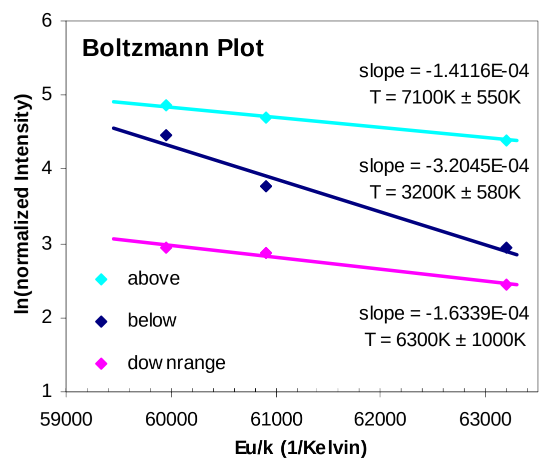

Figure 2: Boltzmann plot of the natural log of the normalized line intensity versus the excitation energy of each line. The exposure time for this event is 2-20 μs. All other conditions are the same as Figure 1. The high temperatures of the regions above and downrange from the impact point could be an indication of the jetting phase.