EXPERIMENTAL STUDY OF SHOCK-INDUCED VAPORIZATION OF ROCKY PLANET CONSTITUENTS. E. J. Davies[1], S. Root[2], S.T. Stewart[1], D.K. Spaulding[3], S. B. Jacobsen[3]. [1]Department of Earth and Planetary Sciences, U. California, Davis, CA (ejdavies@ucdavis.edu), [2]Sandia National Laboratories, Albuquerque, NM, Department of Earth and Planetary Sciences, [3]Department of Earth and Planetary Science, Harvard University, Cambridge, MA.

Introduction: Recent discoveries of planets in extra-solar systems (exoplanets) with very high masses and extended atmospheres have challenged our theoretical understanding of planetary structures ([1]; [2]). These exoplanets challenge current notions of planetary formation. It is critical to understand the material properties within the interiors of the largest Earth-like planets in order to constrain our understanding of their formation and subsequent evolution. The relative proportions of most rock-forming elements in stars in our galaxy is thought to be relatively constant [3], and it has been shown that the minerals olivine [$(Mg,Fe)_2SiO_4$] and enstatite [$(Mg,Fe)SiO_3$], along with Fe-rich metal (with ~5% Ni) are the most abundant solids from which Earth-like planets accrete [4]. These materials are subject to ultra-high pressures and temperatures (approaching 10TPa and 10,000 K) during planetary formation and in the present day interiors of large rocky planets.

Here we describe experimental methods to probe these extreme conditions in the laboratory in order to examine vaporization of rocky planet constituents upon shock and release. Flyer plate (impact) experiments are carried out on the Z Machine at Sandia National Laboratory. Planar, supported shock waves are generated in single crystal samples, permitting observation of both the compressed and released states. Such experiments have been carried out to provide Hugoniot data and access the temperature-volume-entropy vapor curves for forsterite up to its critical point.

Experimental Setup: Shock compression experiments with the Sandia Z machine use a magnetic drive generated by an intense current pulse from the Sandia Z accelerator capable of producing currents and magnetic fields greater than 20 MA (500 ns duration) and 10 MG, respectively. The large current and field densities generate magnetic pressures up to 650 GPa that can accelerate flyer plates up to 40 km/s [6] (Lemke et al. 2005). Figure 1 shows an experimental schematic. Laser interferometry (VISAR) permits observation of the shock velocity. Entropy/Temperature along the Hugoniot are inferred as described in ref [5].

Critical Point: Figure 2 shows model predictions for the Hugoniot and liquid-vapor phase boundaries of the major mineral phases in rocky planet interiors. The liquid-vapor boundaries, also called the vapor dome, have a peak, which corresponds to the critical point at which there is no longer a phase change between a liquid and a gas. During large impacts, material is shocked to a point on the Hugoniot and subsequently releases isentropically to the vapor dome. This isentropic cooling is a vertical line in the T vs. entropy plot in figure 2 that connects the Hugoniot and liquid-vapor dome. The entropy achieved along the Hugoniot therefore controls whether melting or vaporization occurs upon release. The relative proportion of liquid and vapor produced upon release from high pressure therefore depends on where the liquid-vapor dome is intersected and is determined using a lever-arm rule.

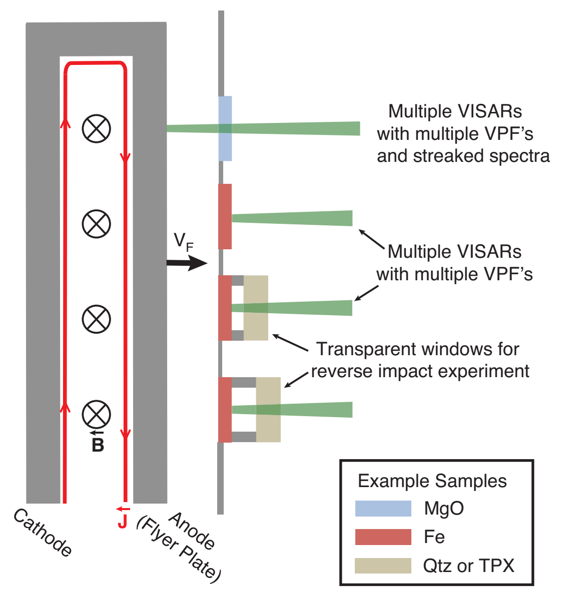

Figure 1. A simplified schematic of the experimental configuration for planar shock and release experiments on the Z machine. With current density, J, induced magnetic field B, and a flyer plate velocity V_F. The aluminum flyer plate induces a planar shock in our samples, although iron is replaced with forsterite in our case. The flyer velocity and tilt are measured through three transparent windows on the target panel. When the shock reaches the free surface of the sample, the samples decompress and expand across the gap, impacting a standard window. VISAR measurements of the steady shock state generated in the standard window are used to derive the density of the sample on the liquid branch of the liquid vapor dome. This figure is not to scale.

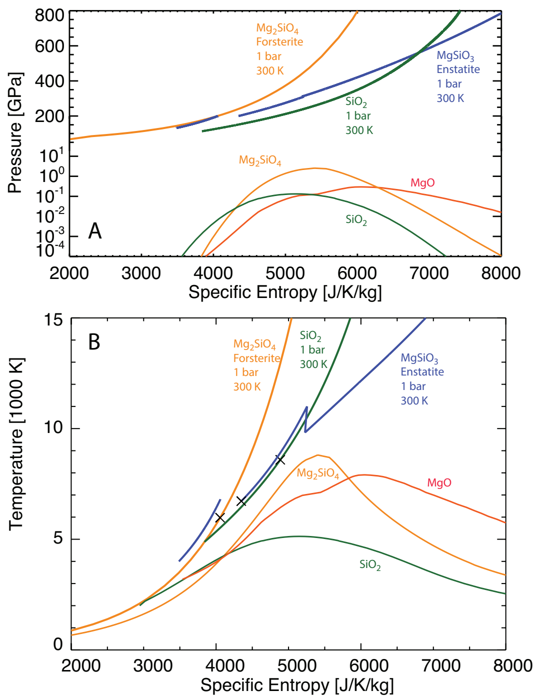

Figure 2. Equation of state model predictions for entropy on the Hugoniot and liquid-vapor phase boundaries for major silicates in (A) pressure-entropy space, and (B) temperature-entropy space. Data points show with an × on the Hugoniots that release to the lower end of liquid branch of the liquid-vapor phase boundary for olivine series and pyroxene series minerals can be achieved using a 2-stage gas gun. The Z machine is required to reach and exceed the critical points of these phases.

Discussion: We have conducted experiments up to impact velocities of 14.7 km/s by aluminum flyer plates, to measure Hugoniot (equation of state) and associated release states for forsterite. These results will be discussed along with plans for future scheduled shots.

Acknowledgements: Sandia National Laboratories is a multiprogram laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Securities Administration under Contract No. DE-AC04-94AL85000. Supported by the Z Fundamental Science Program at Sandia National Laboratories.

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