MEASUREMENTS OF EMISSION TEMPERATURES FROM SHOCKED BASALT: HOT SPOTS IN METEORITES. S. T. Stewart[1], A. Seifter[2], G. B. Kennedy[1], M. R. Furlanetto[2], and A. W. Obst[2], [1]Harvard University, Department of Earth and Planetary Sciences, 20 Oxford St., Cambridge, MA 02138 (sstewart@eps.harvard.edu), [2]Los Alamos National Laboratory, Physics Division, P-23, Los Alamos, NM 87545.

Introduction: The temperature history of meteorites provides valuable information about the impact ejection process [1], the thermal evolution of their parent bodies [2], and even the paleoclimates of other planets [3]. Shock events from impact processes are useful as chronological markers by resetting thermochronometer isotope systems. Shock deformation, however, produces a heterogeneous pressure and temperature field which can complicate the interpretation of the meteoritic record. Here, we present the results from shock pyrometry experiments on basalt that illuminate the nature of shock heterogeneity and the formation of hot spots in meteorites.

Experiments. Time-resolved post-shock temperatures were collected from mechanical impact experiments and a multi-channel pyrometer. Spatially-resolved temperatures were studied using explosively-driven shocks and an infrared camera. Columbia River flood basalt (CRB) specimens, from Snake River Valley near Clarkston, WA ($\langle\rho\rangle$=2.83±0.10 g/cm3, $\langle V_P\rangle$= 5.73±0.28 km/s, $\langle V_S\rangle$=3.46±0.04 km/s), are cored and cut from hand samples into nominally Ø34×2 mm discs. The basalt and driver plate are lapped plane parallel and polished to an optical (~100 nm) finish.

Impact experiments. Planar shock waves, with peak pressures up to ~45 GPa, were generated in basalt using the 40-mm single stage powder gun in the Harvard Shock Compression Laboratory [4]. Simultaneous particle velocity and radiance measurements are recorded from the downrange, free surface of the samples enclosed in a <1 microtorr [5, 6]. The free surface emission is collected by a 0.65-μm photomultiplier tube and a high-speed, infrared (IR), four-wavelength (1.8, 2.3, 3.5, 4.8 μm) pyrometer [7]. The IR pyrometer is sensitive to radiance temperatures as low as 400 K and has a temporal resolution of ~17 ns. The observed area is a ~4-mm diameter spot for the pyrometer .

Explosive experiments. The same basalt samples were studied using explosively-driven shocks, with peak pressures between 9 and 15 GPa, at the Bechtel Nevada Special Technologies Laboratory in Santa Barbara, CA. 0.5-μs exposure length images were recorded by an IR Camera (Model SBF-134, 14 bit, 256x256 pixel InSb detector [8]) with 40 μm spatial resolution.

The calibrated radiation temperature is converted to an apparent temperature for each wavelength using an emissivity of 0.8. If the apparent temperature of all four channels overlap, as in the case of our validation experiments on aluminum 2024 [6], then the apparent temperature is considered to be the true temperature of a homogeneous surface. If not, then the surface temperature is not homogeneous.

Results. After release from peak shock pressures between 2 and 45 GPa, free surface thermal emission temperatures range from 440 K to >1200 K. The emission measurements show a departure from a quasi-single temperature surface above about 13 GPa, where, at pressures well below that required for bulk melting of basalt, emission temperatures >1500 K are detected. In this pressure range, partial melting in fractures and pores produce a bimodal temperature distribution comprised of a continuum and hot spots. The area fraction of stress concentration hot spots increases monotonically with shock pressure. In addition, the free surface particle velocities indicate a steep release pressure-volume path due to phase changes. The inferred hot spot distributions are in excellent agreement with petrographic studies of localized melting and generation of high pressure phases in basaltic meteorites from Mars shocked to similar pressures. However, the measured continuum temperatures in Columbia River basalts are >100 K higher than inferred for Martian meteorites.

Conclusions. Measured shock temperature distributions directly illustrate the heterogeneous nature of shock processing in natural materials. Melt pockets and veins may form as a result of pore collapse. High pressure/temperature phases that form within hot spots are not representative of the shock deformation of the bulk rock.

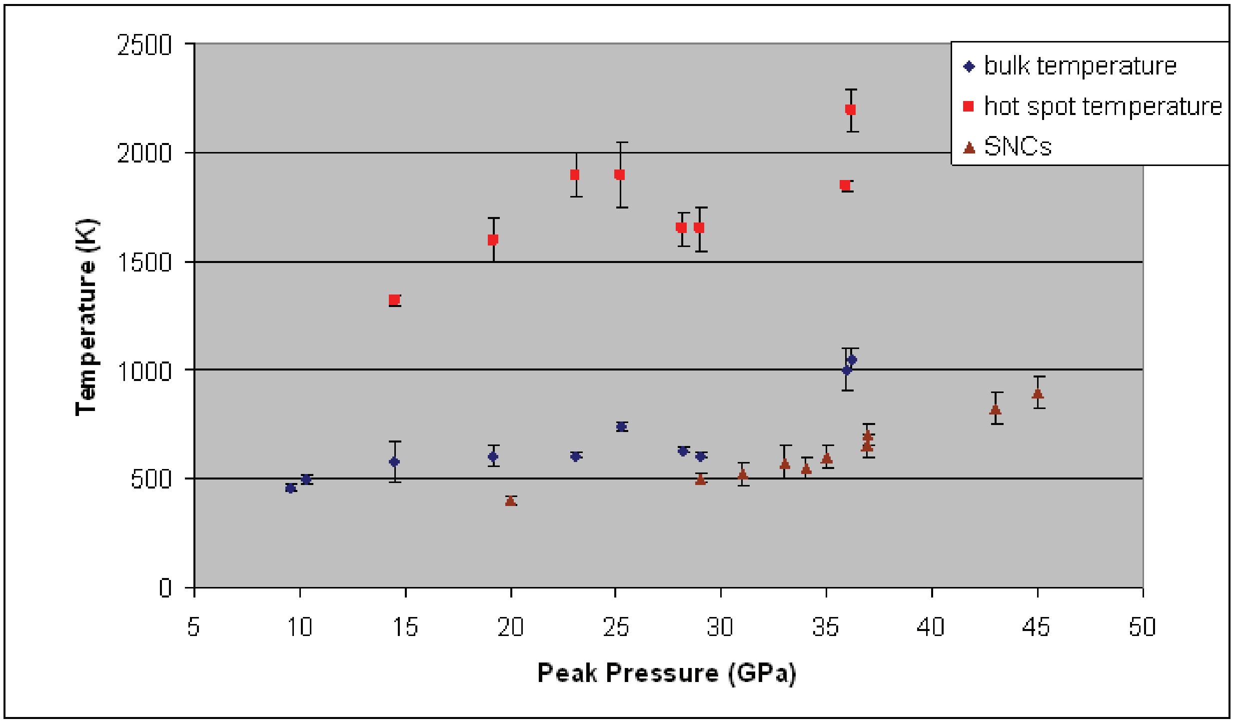

Fig. 1. Pyrometery results compared to SNC meteorites [9]. Bulk temperatures over typical range of meteoritic shock pressures show modest increase after shock, while hot spot temperatures reach melting.

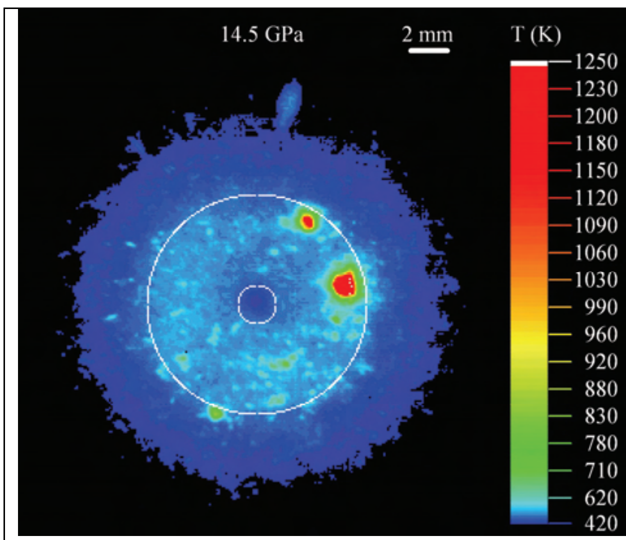

Fig. 2. IR image of basalt shocked to 14.5 GPa. Hot spots correspond to open pore spaces at the sample free surface.

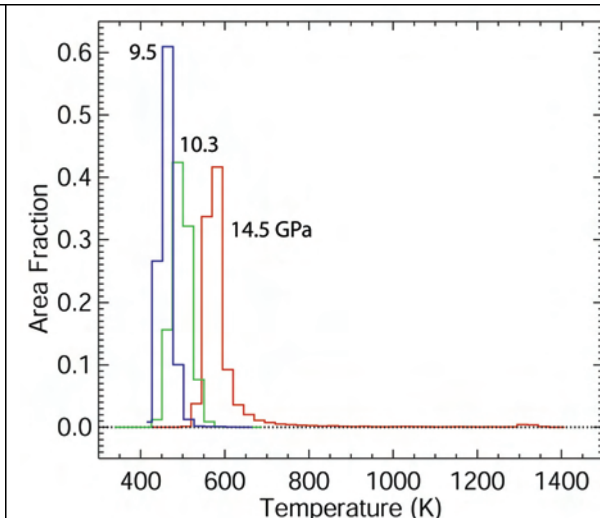

Fig. 3. Histograms of IR camara data from 9.5 to 14.5 GPa. At 14.5 GPa, there is a <1% area fraction of hot spots in a bimodal temperature distribution.

References.
[1] Melosh, H.J. (1984) *Icarus* **59**, 234-260. [2] McSween, H.Y. (2006) *Meteorites and their Parent Planets*: Cambridge University Press. [3] Shuster, D.L. and B.P. Weiss (2005) *Science* **309**(5734), 594-597. [4] Stewart, S.T. (2004) *LPSC* **XXXV**, Abs. 1290. [5] Stewart, S.T., et al. (2006) *Shock Compression of Condensed Matter -- 2005*, American Institute of Physics, p. 1484-1487. [6] Seifter, A., et al. (2005) *14th APS Topical Conference on Shock Compression of Condensed Matter*, Abstract #E6.00001. [7] Boboridis, K., A. Seifter, and A.W. Obst (2003) *VDI-Bericht* **1784**, 119-126. [8] Lutz, S.S., et al. (2002) *Shock Compression of Condensed Matter -- 2001*, p. 1239-1242. [9] Nyquist, L.E., et al. (2001) *Space Science Reviews* **96**(1-4), 105-164.