SHOCK METAMORPHISM IN A QUASI-OPEN SYSTEM II: MELT VEINS IN BASALT AT SHOCK STAGE 2. H. Ono\(^1\), K. Kurosawa\(^1\), T. Niihara\(^2\), T. Mikouchi\(^3\), H. Genda\(^4\), N. Tomioka\(^5\), M. Kayama\(^6\), M. Koike\(^7\), Y. Sano\(^8\), W. Satak\(^1\) and T. Matsui\(^1\), \(^1\)Planetary Exploration Research Center, Chiba Institute of Technology (2-17-1, Tsudanuma, Narashino, Chiba 275-0016, Japan, o_taruka@pec.it-chiba.ac.jp), \(^2\)Dpt. of Systems Innovation, The Univ. of Tokyo, \(^3\)The University Museum, The Univ. of Tokyo, \(^4\)Earth-Life Sci. Inst., Tokyo Inst. of Tech., \(^5\)Kochi Inst. for Core Sample Research, JAMSTEC, \(^6\)Dpt. of General Sys. Studies, The Univ. of Tokyo, \(^7\)Dpt. of Earth and Planet. Sys. Sci., Hiroshima Univ., \(^8\)Atmos. and Ocean Res. Inst., The Univ. of Tokyo.

Introduction: Shock metamorphism recorded in chondrites has been classified into progressive stages based upon petrological and mineralogical textures. Peak pressures and post-shock final temperature required for leading such textures have been also estimated mainly with shock recovery experiments [1]. It should be noted here that the pressure and temperature at each shock stage have not been determined independently. For example, the post-shock final temperatures up to stage S4 were estimated based on the pressures determined by the textures under the assumption where shocked materials released by following an isentropic path. Recently, Kurosawa & Genda, 2018 [2] pointed out the possibility that the temperatures are expected to be underestimated in the shock stage classification [1], particularly <1,000 K.

We have developed a procedure pertaining to shock recovery by using an expanding shock wave in a metal container [3]. Since the shock wave expands nearly hemispherically, we could recover the shocked materials experiencing a variety of pressures and temperatures simultaneously from single shot. The shocked samples suffer a single shock compression and a large degree of shear deformation in the same way as natural impact phenomena. In addition, our method avoids the effect of further compression due to reflected compressive waves from the walls of metal container, which has been pointed out as a problem underlying conventional shock recovery [e.g., 4]. Therefore, our recovery method is highly suitable for understanding the shock effects caused by high pressure and high temperature. In this study, we demonstrate that a localized melting in terrestrial basalt samples occurs at the shock stage S2, indicating that the averaged post-shock final temperature may be much higher than expected by the conventional estimate.

Experimental methods: The experimental method employed in this study is the same as developed by a companion study [3]. Terrestrial basalt samples (Inner Mongolia), which composed mainly of plagioclase, pyroxene and olivine were used. Since the space is highly limited, we present the results only from Shot #471 at 7.3 km s\(^{-1}\) of impact velocity. Figure 1a shows a schematic diagram of the impact experiment with the actual dimensions.

Pressure & temperature estimation: Experienced pressures and temperatures in the target were estimated by the iSALE pertaining to a vertical impact at 7.31 km s\(^{-1}\). The isobaric lines for 5 GPa and 10 GPa are also shown as the red lines. (c) A backscattered electron (BSE) image of the recovered sample around the epicenter of the basalt samples. The red lines show the location of shock melt veins. The enlarged BSE image in the green rectangle is shown in Figure 3.

Analytical procedures: We analyzed a thin section made from the cross section across the impact-generated depression of the recovered sample, and observed it by an optical microscope and scanning electron microscopes (the JEOL JSM-6510LA at Chiba Institute of Technology and JEOL JSM-7000F at the University of Tokyo). Quantitative chemical analyses were performed using the JEOL JXA-8530F and JXA-8900L electron microprobe analyzers at the University of Tokyo.
Discussion and Conclusions: Our microscopic observation suggests that the recovered sample is classified into the shock stage S2 in the Table M proposed by [1]. This observation is consistent with the peak pressures estimated by the iSALE (Figs. 1b and 2). In contrast, the presence of the SMVs indicates that the shocked sample is classified into the shock stage S3. The microscopic observation suggests that the materials being the SMVs have also experienced well below 20 GPa because of no PDFs in the plagioclase adjoining the SMV. The melting textures of the SMVs indicate that the materials in the SMVs experienced the temperature at least higher than the solidus of basalt, 1,360 K [11] even at the peak pressure of ~15 GPa. Consequently, our experiment shows that the local temperature fluctuation is much larger than previously expected based on the shock stage classification.

Acknowledgments: We thank the developers of iSALE, including G. Collins, K. Wünnemann, B. Ivanov, J. Melosh, and D. Elbeshhausen. We also thank T. Davison for the development of the pySALEPlot.