SHOCK EFFECTS IN PRE-HEATED BASALT: SEARCH FOR THE CRITERIA FOR PRODUCING MOSAICISM. H. Ono[1], K. Kurosawa[1*], T. Niihara[2], T. Mikouchi[3], N. Tomioka[4], T. Okamoto[1], and T. Matsui[1], [1]Planetary Exploration Research Center, Chiba Institute of Technology (2-17-1, Tsudanuma, Narashino, Chiba 275-0016, Japan, *kosuke.kurosawa@perc.it-chiba.ac.jp), [2]Dpt. of Applied Science, Okayama Univ. of Sci., [3]The University Museum, The Univ. of Tokyo, [4]Kochi Inst. for Core Sample Research, JAMSTEC.

Introduction: Shock metamorphic features have been recorded as evidence of collisional events in the solar system. The degree of shock metamorphism (shock stage) has been widely explored and summarized [e.g., 1]. In this study, we focus on one of the key indicators in the shock stage classification, which is referred to as mosaicism. Mosaicism comes from the formation of microscopic-size of domains (<3–5 μm [1]) within a single crystal, leading to be a specific extinction pattern under a polarized microscope with crossed nicols [1]. Although the formation mechanism of mosaicism has been in still debate, one hypothesis is that a number of dislocations in a single crystal are produced due to stress, and then, lining up of the dislocations forms sub-grain boundary. We designed an experiment in the light of this hypothesis. The former process requires a sufficient stress, i.e., shock pressure of > a few tens GPa, and the latter one needs the temperature where the dislocations are able to migrate within the crystal, i.e., the post-shock temperature of > several hundred K [1]. In this study, we conducted shock recovery experiments using a pre-heated sample with the temperature slightly higher than the temperature required for generating mosaicism estimated in [1], to investigate the pressure effect on the formation of the mosaicism more clearly.

We performed a shock recovery experiment with a decaying compressive pulse. The recovered samples experienced a wide range of temperatures and pressures [2], which is the same geometry to natural impact events.

Methods: We conducted an impact experiment with a two-stage light gas gun placed at the Planetary Exploration Research Center of Chiba Institute of Technology, Japan. The experimental method and sample were the basically same as those used in [3], except for the initial temperature of the target. We used a terrestrial basalt sample (Inner Mongolia) and a metal container with a detachable front plate made of Ti. In this study, we newly introduced a cylindrical heater into the experimental system. We applied the "Table M" summarized in [1] to the basalt as the shock stage classification. According to the Table M, mosaicism occurs above shock stage 3 (S3) and required shock pressure and corresponding post-shock temperatures are 20–30 GPa and 500–550 K, respectively. In this study, the basalt sample was heated up to 630 K via radiation from the device prior to the shot. Our method produced a shock compression of ~10 GPa near the epicenter, which is about 1/2–1/3 of the required shock pressure for producing mosaicism. If the migration process of the impact-induced dislocations is controlled strongly by temperature, mosaicism may be produced under the pre-heating condition. The temperature of the target surface was measured with a thermocouple. We confirmed that the temperature difference between the Ti front plate and rear surface of the basalt was within ~30 K. The impact velocity was 7.0 km s^{-1}. Experienced pressures and temperatures in the target were estimated with the iSALE-2D [4-6]. The Tillotson EOS [7] for polycarbonate and the ANEOS [8] for basalt [9, 10] were employed for projectile and target, respectively. We analyzed the polished thin section of the recovered sample and observed it by an optical microscope and a scanning electron microscope (SEM) (the JEOL JSM-6510LA at Chiba Institute of Technology).

Results: Figure 1 shows an optical photomicrograph of the recovered sample with an open nicol. The isobaric line and isotherms estimated by the iSALE are also shown.

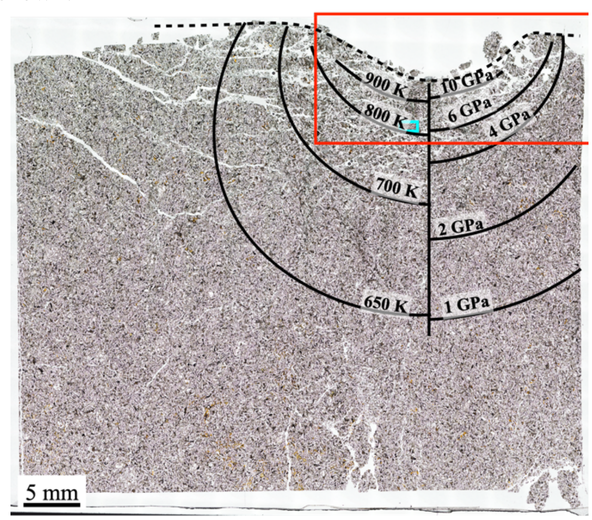

Figure 1. Optical photomicrograph of the recovered sample shot 512 (plain polarized light). The isobaric lines and the isothermal lines are shown as the black lines. The lines calculated by iSALE. A close-up view of the region corresponding to the cyan rectangle is presented in Figure 2.

Optical microscopic observation: We found that large cracks were developed especially at the region experienced >3 GPa, and silicate minerals around the epicenter showed undulatory extinction as well as our previous experiment [3]. Figure 2 shows a close-up of the rectangular region in Fig. 1 under the crossed nicols. We did not identify mosaicism in major silicates in the sample even around the epicenter (>5 GPa).

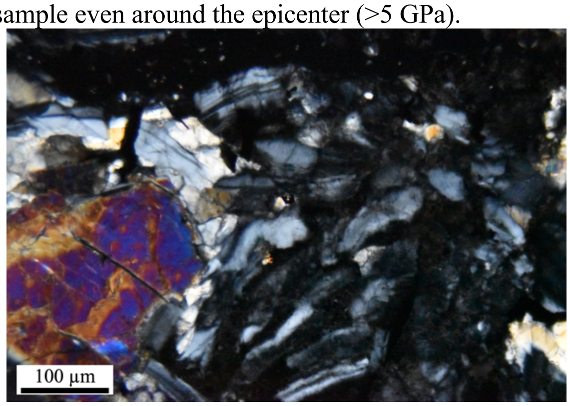

Figure 2. Enlarged optical photomicrograph of cyan square of Fig. 1 (crossed nicols). (white-gray: plagioclase, white-yellow: pyroxene, magenta-blue: olivine)

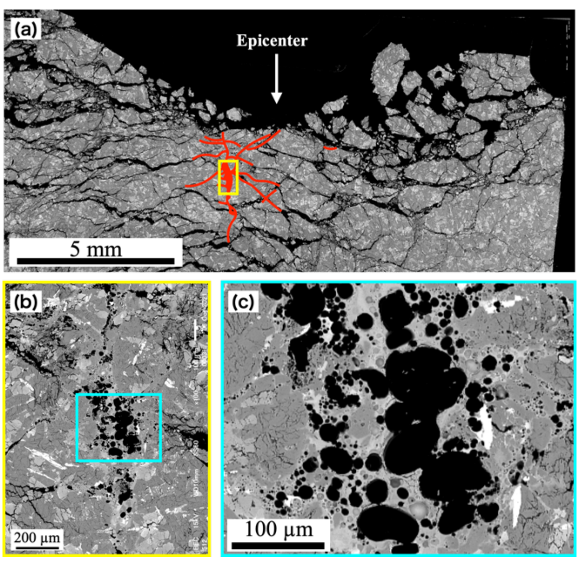

Figure 3. (a) An enlarged backscattered electron image of the recovered sample around the epicenter of the basalt sample in this study, which is shown as red square of Fig. 1. The red lines show the location of melting (shock melt veins and melt pockets). (b) The enlarged image of the yellow square in (a). (c) Enlarged image of the cyan square in (b).

SEM observation: In our previous experiment at room temperature [3], six shock melt veins with a width of about 4 μm were formed as the local shock metamorphic texture. Figure 3 shows a backscattered electron image around the epicenter. We found that a melt structure was formed over 3 mm in length below the epicenter. Several shock melt veins with the width of <40 μm connects with each other (Fig. 3a). We also observed a melt pocket-like structure (200 x 700 μm in size) at the center of the network (Fig. 3b). There are vesicles much larger (>80 μm in diameter) than those observed in our previous experiment at room temperature (Figs. 3b, c).

Discussion & Conclusions: Mosaicism in the shocked silicates was not generated even under the pre-heating condition of 630 K. If the required post-shock temperature for producing mosaicism means the sufficient migration distance of dislocations, the experimental result rather indicates that dislocation density is not enough to construct sub-grain boundaries. This suggests that mosaicism may be used as a shock indicator of >12 GPa compression independently on post-shock temperature. We present a preliminary result only from a single experiment. Further studies are clearly needed prior to obtain firm conclusions. For example, we are planning to directly investigate the dislocation microstructures and densities in major silicates around the melt pocket with a transmission electron microscope.

We successfully collected a melting structure including the network of the shock melt veins and a melt pocket-like region with the pre-heating method as shown in Fig. 3. Since higher initial temperatures up to ~1,000 K can be archived with our heating device, we are also planning to explore the formation and development process of impact melt veins by changing initial temperatures systematically in future experiments.

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References: [1] Stöffler D. et al. (2018) *MaPS, 53,* Nr 1, 5-49. [2] Kurosawa et al., *In revision* [3] Ono H., et al. (2021) *LPI Contribution No. 2548*. [4] Amsden A. A., et al. (1980) *LANL* ReportLA-8095. 101 p. [5] Ivanov B. A., et al. (1997) *IJIE*, *20*, 411. [6] Wünnemann, K., et al. (2006) *Icarus*, *180*, 514. [7] Tillotson, J. H. (1962) *Tech.Rep.* GA-3216, General Atomic Report. [8] Thompson, S. & Lauson, H. (1972), *SNL Rep.*, SC-RR-71 0714:113p. [9] Sato, M., et al. (2021) *GRL.*, *48*, 8. [10] Pierazzo et al. (2005) *MaPS, 43,* Nr 12, 1917-1938.