‘BALLEN QUARTZ’ FROM THE DHALA IMPACT STRUCTURE AND ITS CRYSTAL ORIENTATION PATTERN BY ELECTRON BACK SCATTERED DIFFRACTION (EBSD). Y. Kuriyama1, N. Nakamura1, J. Muto1, T. Nagase1, and J. K. Pati2, 1Department of Earth Science, Tohoku University, 6-3 Aoba, Aramaki, Sendai 980-8578 Japan (love.the.earth021@gmail.com, n-naka@m.tohoku.ac.jp), 2Department of Earth and Planetary Sciences, University of Allahabad, Allahabad-211 002 India (jkpati@gmail.com)

Introduction: Ballen quartz in impact melt rocks is characterized by a ‘fish-scale like’ texture consisting of incompletely closed loops under a polarized microscope. Carstens [1] concluded that ballen texture represented pseudomorphs as a result of volume shrinkage upon the high-low inversion of cristobalite that had replaced lechatelierite initially formed by shock-induced thermal transformation of quartz at a shock pressure above 30GPa and temperature of 1200°C. There are five categories of ballen quartz: \( \alpha \)-cristobalite ballen with homogeneous extinction (type I); \( \alpha \)-quartz ballen with homogeneous extinction (type II), or \( \alpha \)-quartz ballen with heterogeneous extinction (type III), \( \alpha \)-quartz with intraballen recrystallization (type IV); and chert-like recrystallized ballen \( \alpha \)-quartz (type V) [2, 3]. Previous studies focus on the mineralogy and formation mechanism, but there is no crystallographic orientation analysis for their five categories. Here we report the first trial of an electron backscattered diffraction (EBSD) study on ballen quartz in an impact melt rock from the Dhala impact structure, India.

Sample and Method: The ballen quartz samples were carefully selected from quartz clasts in impact melt rock found in terrestrial impact craters of the Dhala impact structure, northern India [4], because there are also lots of rounded quartz clasts of hydrothermally precipitated grains which show polycrystalline extinction without any undulatory extinction. The ballen quartz show rare examples of planar deformation features (PDFs) in \( \alpha \)-quartz associated with ballen (Fig. 1). The thin section was polished using a colloidal silica suspension (MasterMet2; Buehler ltd.) to minimize surface damage, then coated with carbon to limit charging effects. EBSD provides the full crystallographic orientation of crystals in thin section using a back scattered electron signal called a Kikuchi pattern [5]. Using conventional computer software, Oxford HKL Channel 5 software, we can index the Kikuchi pattern and recalculate the pattern to an orientation of the crystal (e.g., quartz) relative to a reference orientation. For EBSD analysis, the SEM (Hitachi S-3400N) was operated at an accelerating voltage of 20kV, a probe current of 70nA and working distance of 18mm, with the thin section tilted at an angle of 70° with respect to the beam for EBSD spot analysis and mapping. The step sizes for mapping is ~2µm. We also employ the universal stage (U-stage) analysis on the optical microscope to reveal the development of PDFs parallel to quartz’s crystallographic planes due to high hydrostatic component of the shock wave-associated stress.

Results: The U-stage analysis of PDFs in quartz clasts showed the development of PDFs in a few rhombohedral planes in quartz, most frequently parallel to planes of {1013} and {1012} forms (Fig. 2), suggesting their quartz grains in our samples are suffered from high hydrostatic component of shock.

Fig. 1: A quartz clast with ballen texture (type II) and planar deformation features (PDFs): a) plane polarized light, b) cross polarized light, in an impact melt rock from the Dhala impact structure. There are three different domains with a corresponding extinction. Each domains show different orientation of ballen fish-scale texture (arrows).

Fig. 2: Histogram of angles between c-axis and poles to PDF (202 sets in 96 grains)
wave-associated stress of 20-25GPa without the involvement of shear [6]. Fig. 1 shows type II ballen quartz grain with PDFs, and the grain consists of three different domains. While hydrothermal quartz grains show polycrystalline extinctions with scattered c-axes distribution, the type II and III ballen quartz from the Dhala impact structure exhibited the clustering of quartz c-axes for each domain (Fig. 3). Each domain has its own c-axes $\{0001\}$ clustering with corresponding a-axes $<1120>$ normal to the c-axes. The c-axes orientations appear to be parallel to the orientation of closed loop direction in ballen fish-scale texture. Type IV intraballen recrystallized quartz indicated the scattering of c-axes such as hydrothermally precipitated grains. Type V chert-like ballen quartz showed the clustering of c-axes. We identified no type I ballen quartz in this study although the EBSD channel 5 software indexed the presence of cristobalite and coesite in a point near grain boundaries (possibly misindex).

**Discussion and Conclusion:**

We have measured EBSD pattern of ballen quartz (type II, III, IV, and V) from the Dhala impact structure for the first time. Although previous studies showed a variety of ballen textures (type I, II, III, IV, and V) by optical microscope, we determined crystallographic orientations and their likely associations of closed loop direction in ballen fish-scale texture with corresponding c-axes orientations through EBSD. According to the coexistence of ballen with PDFs, our ballen quartz is considered to be formed under high hydrostatic component of the shock wave-associated stress of 20-25GPa. The EBSD pattern reveals that type II and III ballen quartz preserved the characteristic shock-induced crystallographic orientation, associating with ‘fish-scale like’ texture. On the other hand, type IV ballen may record the signature of late recrystallization. The c-axes clustered EBSD pattern of type V ballen may indicate also the characteristic of shock-induced crystallographic orientation. In the presentation, we will present a detailed consideration.

**References:**

![Fig. 3: Stereographic projection and its contoured plot (upper hemisphere) of c-axes [0001] and a-axes $<1120>$ orientation of ballen quartz with three domains by EBSD analysis.](image)