MICROSTRUCTURAL RECORD OF PHASE TRANSFORMATION IN SHOCKED METAL SPHERES IN CB CHONDRITE QC 001. F.E. Brenker[1,2], D.J. Prior[3], C. Cayron[4], T. Koch[1], A.N. Krot[2], M. Bizzarro[5]. [1]Goethe University Frankfurt, Altenhöferallee 1, 60438 Frankfurt am Main, Germany, [2]Hawai'i Institute of Geophysics and Planetology, School of Ocean and Earth Science and Technology, University of Hawai'i at Mānoa, Honolulu, HI 96822, USA. [3]University of Otago, Department of Geology, 360 Leith Street, Dunedin 9016, New Zealand. [4] EPFL IMX LMTM, Rue de la Maladière 71b, 2000 Neuchâtel, Switzerland, [5]Centre for Star and Planet Formation, Natural History Museum of Denmark, Copenhagen, Denmark. *f.brenker@em.uni-frankfurt.de

Introduction: CB chondrites are a rare group of metal-rich carbonaceous chondritic meteorites with characteristics that sharply distinguish them from other chondrites [1]. Further, they reached higher shock stages (S3–S4) than most other carbonaceous chondrite groups, except a few rare cases like Leoville a CV3 chondrite showing similar shock levels [2]. They contain high-pressure phases, and have a high content of silicate and metal shock melts. The silicate shock melts are significant more FeO-rich than the chondrules [3]. In the study presented here we focused our work on shock melted metal droplets.

FeNi alloy occurs in several modifications based on the respective temperature and pressure (Fig. 1). Phase transformation leaves behind diagnostic orientation relationships which can be identified by electron backscatter diffraction (EBSD) studies [4,5].

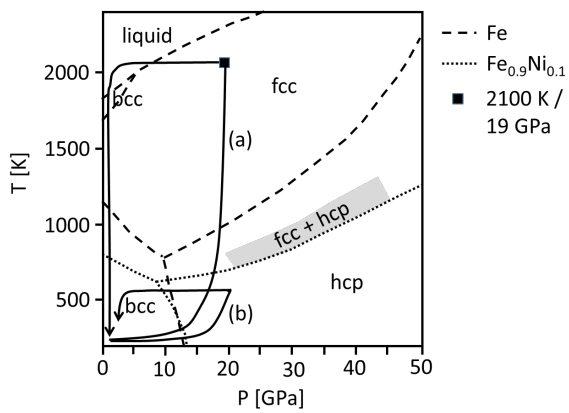

Figure 1: Phase diagram of Fe metal [6] and $Fe_{0.9}Ni_{0.1}$ [7]. The rectangle indicates the estimated shock conditions from silicate polymorphs in CB chondrites [8,9]. Two different P,T-paths (a) and (b) are shown. A P,T-history along path (a) followed by a second shock pulse along path (b) are required to explain all indications for phase transformation found in metal spheres.

Methods: The chemistry and texture of metal melt droplets in Quebrada Chimborazo (QC) 001 were studied using high resolution field-emission gun scanning electron microscopy (FEG-SEM) with an attached EBSD system. With this nano-EBSD set-up a spatial resolution down to several tens of nanometers can be reached. Several regions containing a large number of metal spheres were studied by EBSD mapping. Parallel to each EBSD study an energy dispersive x-ray elemental map was collected. The work was performed at the University of Otago, New Zealand.

Results: The shock melts studied are composed of silicate matrix with numerous micron to tens of microns sized Fe,Ni-metal droplets. They are located along fractures in chondrules and chondrule fragments and along their respective grain boundaries (Fig. 2). The metal in QC 001 has a mean bulk composition of about 93.5 wt% Fe, 6.1 wt% Ni and 0.38 wt% P with highly variable Ni content [6].

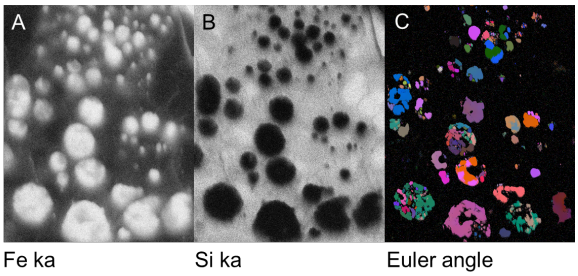

Figure 2: Metal melt spheres within a silicate matrix. Fe-distribution in A, Si-distribution in B and Euler angles in C are shown for one of the a regions studied are shown.

EBSD studies show that all metal spheres occur in the low-temperature low pressure bcc structure. However, the measured lattice preferred orientation (LPO) of metal grains in each sphere show a diverse picture. Most spheres are composed of single crystals or polycrystals with only slight orientation variation within a single sphere. In some rare cases, metal spheres show a complex internal structure. Two different kinds of LPOs were detected (Fig. 3). Reconstructions of possible orientation relationships between fcc and bcc, and hcp and bcc, respectively, were performed. In one case, a compelling evidence for the fcc to bcc transformation was found (Fig. 3A,B). For another sphere we found indications for the hcp to bcc transformation but with an unusual orientation relationship (Fig. 3C,D).

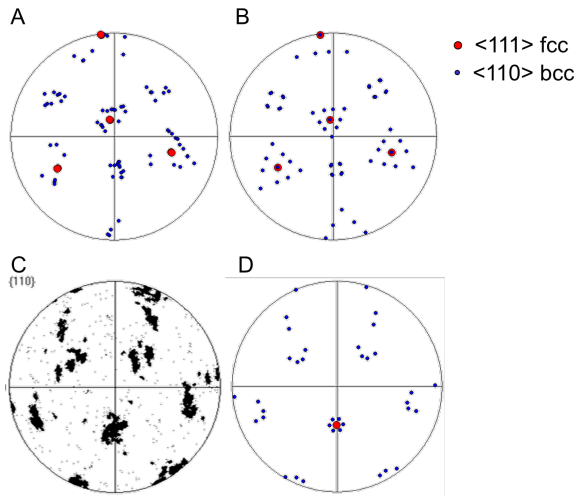

Figure 3: Measured LPO data (A,C) vs. respective reconstruction (B,D) of two different metal melt spheres (A and B, C and D). Examples are for fcc-bcc (A-B) and hcp-bcc (C-D) phase transformations observed.

Discussion of the shock history: From our studies on high pressure silicate melts and solid state transformation in chondrules we were able to estimate the shock conditions to about 19 GPa and 2100 K [8,9]. In order to produce the observed structural transformations in metal spheres, the P,T-path must follow a constant temperature decompression path with later low pressure cooling in order to allow metal melt to be formed (Fig. 1). This path would ultimately explain the observed fcc to bcc transformation and at the same exclude the hcp metal to be formed (path (a) in Fig. 1). As a consequence, if our interpretation of hcp to bcc transformation is correct, a second lower temperature shock pulse is required to reach the hcp stability field (path (b) in Fig. 1).

References: [1] Weisberg M. K. et al. (2001) *Meteorit. Planet. Sci.*, 36, 401–418. [2] Scott, Stoffler & Keil (1992) *GCA* 56, 4281-4293. [3] Meibom A. et al. (2005) *Meteorit. Planet. Sci.*, 40, 1377–1391. [4] Cayron C. (2010) *Acta Crystallogr.*, A69, 498–509. [5] Cayron C (2014) Materials Charact., 94, 93– 110. [6] Boehler R. (1993) *Nature* 363, 534–536. [7] Dubrovinsky L. et al. (2007) *Science* 316, 1880-1883. [8] Koch, T. E. et al., (2016) *79th An. Meet. Met. Soc.*, #6287. [9] Weisberg M. K. and Kimura M. (2010) *Meteorit. Planet. Sci.*, 45, 873–884.