MINERALOGICAL VARIATION OF CHELYABINSK WITH DEPTH FROM THE SURFACE OF THE PARENT METEOROID. S. Yoshida[1], T. Mikouchi[1], K. Nagao[2], M. K. Haba[2], H. Hasegawa[1], M. Komatsu[3], M. E. Zolensky[4,5], [1]Dept. of Earth and Planetary Science, University of Tokyo, Hongo, Tokyo 113-0033, Japan (2804593275@mail.ecc.u-tokyo.ac.jp), [2]Geochem. Res. Center, University of Tokyo, Hongo, Tokyo 113-0033, Japan, [3]Waseda Inst. for Advanced Study, Waseda University, Nishiwaseda, Tokyo 169-8050, Japan, [4]ARES, NASA Johnson Space Center, Houston, TX 77058, USA. [5]Center for Lunar Sci. and Exploration, Natl. Lunar Sci. Inst.

Introduction: The Chelyabinsk meteorite, which passed over the Chelyabinsk Oblast, Russia on Feb. 15th, 2013, brought serious damage by the shock wave and airburst. The diameter of the parent meteoroid is estimated to be approximately 20 m in diameter [1]. It was reported that the impact by this meteorite shower was 4,000 times as large as the TNT explosive and this was the largest airburst on Earth since the asteroid impact in Tunguska, Russia in 1908. The mineralogy and geochemical study of the recovered samples shows that Chelyabinsk is an LL5 chondrite [1].

In this study we analyzed several fragments of Chelyabinsk whose noble gas compositions have been measured and depths from the surface of the parent meteoroid were estimated [2]. We examined how mineralogical characteristics change with depth from the surface. This kind of study has never been performed and thus may be able to offer significant information about the evolution of meteorite parent bodies

Samples and Methods: We examined 9 fragments of Chelyabinsk (HR-1, 2, 3, 4, 7, 7B, MZ-1 and 2). First we observed these thin sections by optical microscope and FEG-SEM (Hitachi S-4500) with EDS. We also used EPMA (JEOL JXA8900L) to obtain elemental maps and perform quantitative analysis. In addition, we employed a micro-Raman spectrometer (JASCO NRS-1000) to detect high-pressure minerals in shock melt veins.

Results: HR-7 and HR-7B are the shallowest samples (depth: ~3 cm). HR-7 is characterized by shock melt veins running on the whole. Olivine composition is $Fa_{28.1}$. Low-Ca pyroxene is $Fs_{22.9}Wo_{1.1}$. Plagioclase is $An_{14.5}$. HR-7B is a dark-color fragment and the thin section also shows a dark appearance. Olivine, low-Ca pyroxene and plagioclase are $Fa_{28.4}$, $Fs_{23.5}Wo_{1.4}$, and $An_{14.9}$, respectively.

HR-3 is the second shallowest sample (depth: ~21 cm). This sample contains shock melt veins. Olivine is $Fa_{28.1}$, Low-Ca pyroxene is $Fs_{23.6}Wo_{1.3}$. Plagioclase composition is $An_{13.3}$.

HR-4 is also characterized by dark appearance (depth: ~64 cm). Olivine, low-Ca pyroxene and plagioclase are $Fa_{28.2}$, $Fs_{23.0}Wo_{1.3}$, and $An_{14.0}$, respectively.

HR-1 and HR-6 were at the same depth (~83.0 cm) and both samples contain large chondrules. The mineral compositions of HR-1 are olivine: $Fa_{28.2}$, low-Ca pyroxene: $Fs_{23.5}Wo_{1.2}$ and plagioclase: $An_{11.3}$. In HR-6 shock veins run on the whole. FEG-SEM observation of the shock melt shows the presence of rounded grains (1-2 μm) with the pyroxene composition similar to majorite in shergottites [3] and high pressure trigonal merrillite is in fact reported in Chelyabinsk [4], but Raman spectra show that they are pyroxene. Olivine in HR-6 is $Fa_{28.2}$, low-Ca pyroxene is $Fs_{23.5}Wo_{1.3}$ and plagioclase is $An_{13.7}$.

The depth of HR-2 is ~1 m. Olivine is $Fa_{28.2}$ and low-Ca pyroxene is $Fs_{23.3}Wo_{1.3}$. Plagioclase is $An_{11.7}$.

MZ-1 and MZ-2 are the deepest samples (depth: ~3 m). In both samples olivine is $Fa_{27.6}$. Low-Ca pyroxene compositions are also identical: $Fs_{22.8\text{-}22.7}Wo_{1.4\text{-}1.3}$. Plagioclase in MZ-1 is $An_{12.1}$.

Discussion and Conclusion: Olivine and pyroxene compositions are almost the same among all samples (Table 1, Figs 1 and 2). The distribution of shock melt appears more abundant in shallower samples, but this may be due to sample heterogeneity because the analyzed fragments are all smaller than 1 cm. Consequently mineralogical characteristics do not show clear differences with depth from the surface of the Chelyabinsk parent meteoroid at least on the scale of 3 m. Analysis of deeper samples is required to further explore these relationships.

References: [1] Popova O. P. et al. (2013) *Science*, *342*, 1069–1073. [2] Haba M. K. et al. (2014) *LPS XLV* (this volume). [3] El Goresy A. et al. (2013) *Geochim. Cosmochim. Acta*, *101*, 233-262. [4] Trigo-Rodriguez J. M. et al. (2014) *LPS XLV* (this volume).

Table 1. Mineral compositions of each sample and depth from the surface of the Chelyabinsk meteoroid.

Sample	Oliv (Fa)	Low-Ca px (Fs)	Plag (An)	Depth [cm]
HR-7	28.1	22.9	14.5	3
HR-7B	28.4	23.5	14.9	3
HR-3	28.1	23.6	13.3	21
HR-4	28.2	23.0	14.0	64
HR-1	28.2	23.4	11.3	83
HR-6	28.2	23.5	13.7	83
HR-2	28.2	23.3	11.7	107
MZ-1	27.6	22.8	12.1	300
MZ-2	27.6	22.7	-	300

Fig 1. Fa content of olivine in each sample of Chelyabinsk

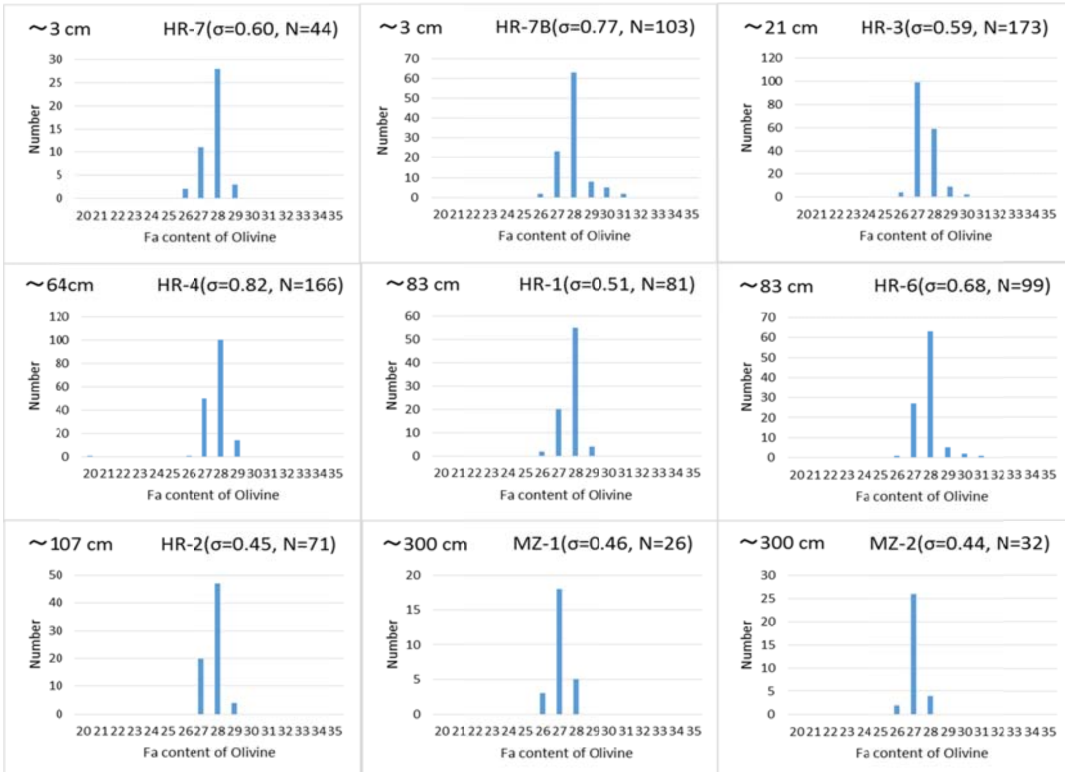

Fig 2. Fs content of low-Ca pyroxene in each sample of Chelyabinsk