The Chelyabinsk meteorite fall from 2013 – new results on mineralogical and physical properties.

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Introduction

The atmospheric explosion and fall of the (later) Chelyabinsk meteorite of 15th February 2013 was the most extraordinary event of its kind within the last 100 years. Numerous fragments in kg – size or less of the meteorite have been collected in the meantime. The more than 500 kg main mass could be located and finally found in Lake Cherbakul. The Chelyabinsk meteorite was classified as LL 5 ordinary chondrite (shock degree S4 and weathering W0) (MetBull 2014).

In our contribution we will present results of our investigations on the mineralogy, phase composition and the magnetic signature of the meteorite. Important focus of our Raman spectroscopy experiments was on determining the shock stage and investigating the potential presence of high pressure phases within the shock melt veins.

Samples

We used several up to 3cm sized individual stones for our investigations whereby the fusion crust was partly missing (fig. 1). A polished thick (PS) and a thin section (PTS) were also available for our studies. Both black and white lithologies could be analyzed including several melt veins of up to mm sized thicknesses (see figs. 2,3).

Fig. 1a: 3cm sized individual, and (b) view of the interior of a 1cm sized fragment.

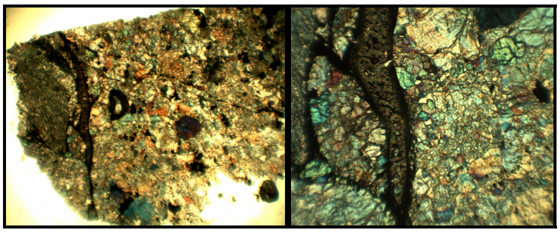

Fig. 2a: PTS overview: dark/light matrix, melt veins, and chrondule relicts can be seen (magn. 25x). (b): Detail of a melt vein (magn. 100x).

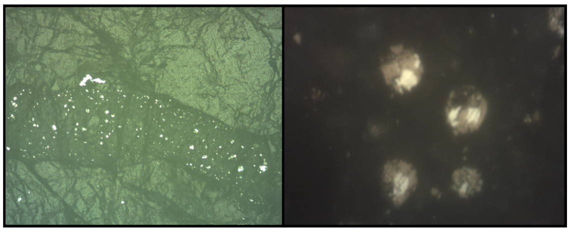

Fig. 3a: Details of a mm-sized melt vein (magn. 100x) with numerous opaque phases consisting of intergrown troilite/kamacite micro-particles (b, magn. 1000x).

Methods

Quantitative chemical data of the observed phases in Chelyabinsk LL 5 chondrite have been obtained by Electron Microprobe Analysis (EMPA) using a Cameca SX100 system operated at 15KeV. All analyses were performed on a PS. Raman spectroscopy was also performed on non prepared surfaces which has the advantage of avoiding any cutting or preparation effects. A Horiba Xplora Integrated confocal LASER micro Raman system was used for our studies (mostly the 532/638 nm LASERs). Magnifications were between 100 and 1000x (LD) with acquisition times of 3-5 sec and accumulation numbers of 2-5.

Results

The following phases could be identified so far, more details will be given in our contribution (poster): olivine, (ortho-) pyroxene, plagioclase, (Mg, Al) chromite, kamacite/taenite, (Cr) troilite, Na-merrilite, whitlockite, apatite, calcite (see fig. 4 for typical Raman spectra). Our preliminary Raman analyses could not find any indication for the presence of high pressure phases in the shock melt veins (see fig. 2, 3). High pressure minerals can form either by solid-state transformation of low pressure minerals or by crystallization from melts at high pressure.
EMPA data of a set of selected phases are shown in table 1.

Rare plagioclase grains showed typical plagioclase Raman patterns indicating weak shock effects (S 1-2), see fig. 4c). This finding is not in a good agreement with earlier published results (Metbull 2014).

The magnetic signature is dominated by soft magnetic kamacite which does not carry a stable (paleo-) magnetic information. The role of other magnetic phases such as chromite which sometimes might record strong magnetization components at low temperatures (space conditions) is currently under investigation.

References

[1] Chelyabinsk meteorite, in MetBull 2014.

Wt.%	Olivine	Plagioclase	O'pyroxene	Chromite	Troilite
K_2O	b.d.	0.80±0.06	b.d.	b.d.	
Na_2O	b.d.	8.05±0.22	b.d.	b.d.	
MgO	35.02±0.58	b.d.	27.20±0.42	1.59±0.10	
Al_2O_3	b.d.	21.36±0.14	0.25±0.20	5.98±0.15	
FeO	27.52±0.87	0.72±0.09	16.19±0.23	32.67±0.39	
Fe					64.25±0.84
CaO	0.02±0.01	2.14±0.05	0.76±0.13	b.d.	
MnO	0.48±0.05	b.d.	0.50±0.02	0.48±0.05	
TiO2	b.d.	0.05±0.02	0.18±0.03	2.19±0.27	
Cr_2O_3	b.d.	b.d.	0.13±0.04	54.96±0.51	
Cr					0.36±0.28
NiO	0.08±0.08	0.13±0.08	0.15±0.15	00.12±0.12	
Ni					0.06±0.03
SiO_2	37.33±0.70	67.70±0.15	55.41±0.38	0.09±0.04	
S					35.27±0.82
Total	100.5±0.5	100.99±0.28	100.86±0.46	98.15±0.45	99.95±1.35

Tab. 1: Electron microprobe analyses (EMPA) data of some selected phases.

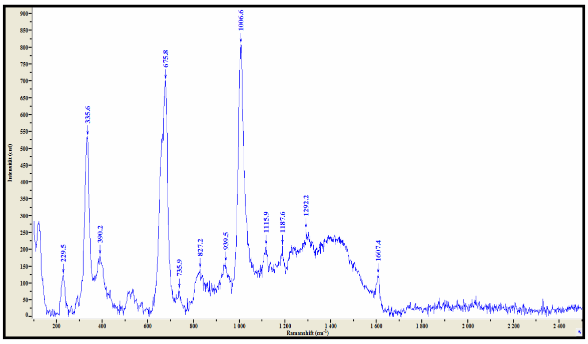

Fig. 4a: Raman spectrum of a typical pyroxene phase (opx).

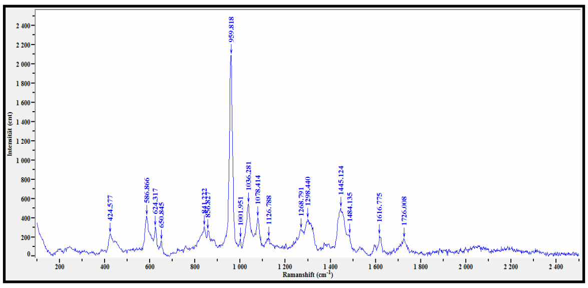

Fig. 4b: Raman spectrum of a whitlockite – merrilite component.

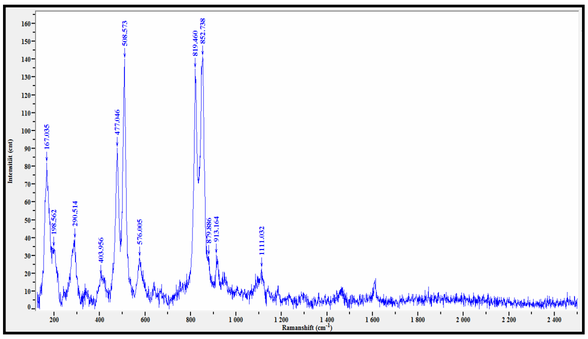

Fig. 4c: Raman spectrum of plagioclase and olivine. The sharp plagioclase Raman pattern indicate weak shock effects in the range of less than 20GPa (S1-2).