Characteristic features shock-induced on Mócs chondrite (L6)

I. Gyollai[1,2], K. Fintor[3], Sz. Nagy[3], Sz. Bérczi[2], H. Nishido[4], A. Gucsik[5,6]

[1]*Department of Lithospheric Research, Impact Research Group, Althanstrasse 14., 1051-Vienna, Austria.,* [2]*Institute of Physics, Department of Material Physics, Cosmic Material Space Research Group, H-1117 Budapest, Pázmány Péter sétány 1/a., Hungary,* [3]*University of Szeged, Department of Mineralogy, Petrology and Geochemistry, H-6722 Szeged, Hungary,* [4]*Okayama University of Science, Department of Biosphere-Geosphere Science,1-1 Ridai-Cho, Okayama 700-0005, Japan.* [5]*Konkoly Thege Miklos Astronomical Institute, Research Centre for Astronomy and Earth Sciences, H-1121 Budapest, Konkoly Thege Miklós út 15-17., Hungary,* [6]*Department of Geology, University of Johannesburg, Johannesburg, 2600 Auckland Park, South Africa*

Introduction:

The Mócs L6-type chondrite was found in Kolozs-county (Transylvania) in 1882. Raman spectroscopy of the sample revealed the shock-induced deformation microtextures in the vein-forming olivine, exhibiting strong mosaicism [1]. No shift of the major Raman vibration has been observed in the spectra of the olivine. This fact implies almost no p-T transition in the adjacent mineral assemblage. Chen et al. [2] reported characteristic K-Na fractionation in shock-induced veins. In this study, therefore, the fracture/vein system of Mócs meteorite has been investigated ,to clarify a signature of shock-induced melting.

Methods:

Petrographical studies were worked out using LV100POL microscope under plane polarized light and crossed polarized light modes with a polarizing microscope at Eötvös University, Budapest (Hungary). The polished thin section of 35 μm thickness was coated with carbon for the SEM-EDX, BSE, and element mapping studies, which were done at University of Szeged, Hungary by using a Hitachi S4700 electron microscope (10 kV acceleration voltage) combined with a Röntec QX2 energy dispersive X-ray fluorescence spectrometer.

Petrography:

The Mócs meteorite corresponds to L6-type, where shock metamorphosed and recrystallized matrices and several well-distinguished chondrule remnants have been observed. The chondrules in the meteorite are characterized by the follows: 3 pieces of pyroxene radial chondrules (1-3mm diameter), 4 pieces of olivine porphyritic chondrules (2 mm diamater), 2 pieces of recrytallized glassy chondrules (1mm diameter), 1 granular olivine chondrule, 1 composite chondrule and several porphyritic chondrule fragments. In the matrix we recognized a zoned part (~2mm) composed of feldspar, which was crossed by melt inclusion linked to fractures toward the rim.

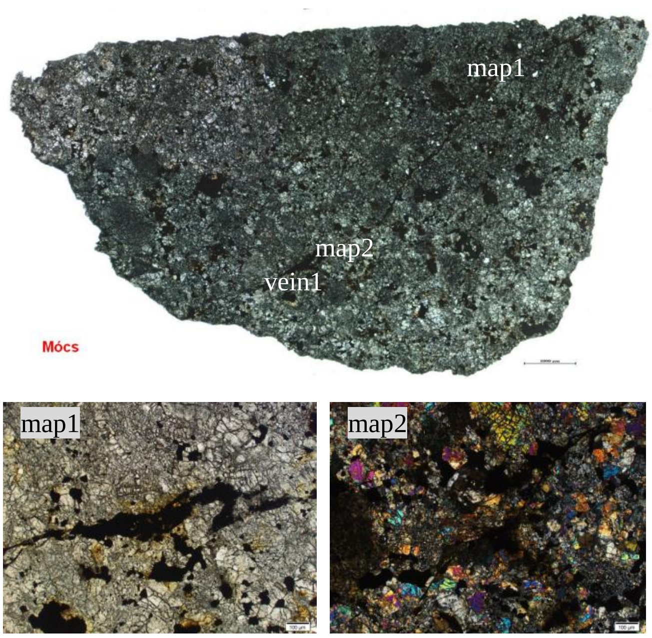

Figure 1: Stereomicroscopic image of thin section of Mócs meteorite marked with the measuring areas. Optical microscopic photos of area map1 (plain polarized light) and map2 (crossed polars)

Shock metamorphic effects:

The Mócs meteorite exhibits highly dense fractures or fissures, mostly which are filled by opaque minerals (iron-oxide and troilite), mineral fragments and melt. In the case of L6-type chondrites such as Tenham and NWA-5011[2], mineral assemblages indicating shock-induced phase transformations have been observed. Hence, two wide parts in a vein with 500 μm width were selected for the BSE measurements and element mappings. Several chondrules were also selected for the BSE imaging for checking inhomogenities, which show the signature of partial melting or the presence of the relict with lower metamorphic petrologic type. Among the chondrules, large the higher acoustic-impedance opaque mineral assemblages (troilite and chromite) could enhance shock wave velocity and peak shock p-T in adjacent olivine grains resulting strong mosaicism and deformation microstructure. One of the wide part in the shock vein (vein1 in Fig. 1) and 2 chondrules (map1 and map2 in Fig. 1) were selected for the element mapping.

Elemental mapping:

The map1 area contains chromite grains (Fig. 2A), which is altered to iron oxide via secondary processes. According to the composite map (Fig. 2B), the melt pocket area indicates near composition of feldspar minerals, whereas chondrules are composed of both pyroxene and olivine. The melt packet is enriched in Na compared to its vicinities (Fig. 2C). The P and Ca enrichments correspond to the area rich in K (Fig. 2D).

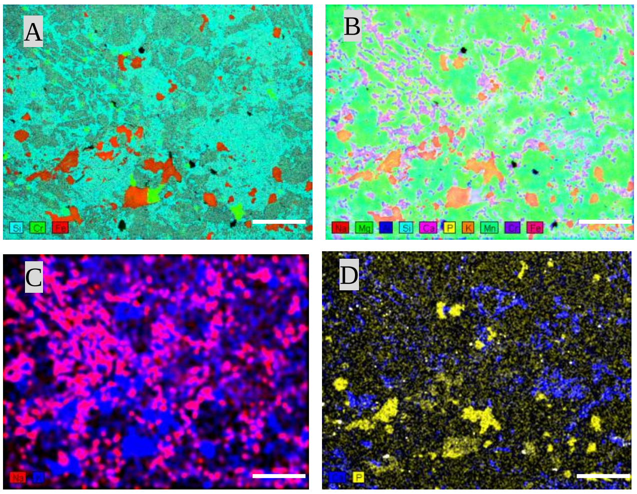

Fig. 2. Composite element maps of upper part in shock vein (map1 in Fig. 1.) including chondrule fragments (A: Si-Cr-Fe, B: composite element map of major elements and Cr, C: Na-K, D: Ca-P, scale: 200 µm)

The map 2 shows chromite grains (with high Cr concentration), troilite (with higher Fe and S concentrations), suggesting the oxidation with iron oxide phases with only higher Fe concentrations (Fig. 3A). The dark area in SE map is enriched in Na, which is significant for melt pockets. Moreover, the high Al content in Fig. 3/B confirms the presence of feldspar. On the Mg-Si-Ca-Fe elemental map (Fig. 3D), there are well distinguishable by the presence of olivine (Mg-Si), pyroxene (Ca-Si), and the opaque (Fe) phases. The chondrule fragments are mostly made up of olivine, whereas pyroxenes are concentrated in the groundmass and the melt regions.

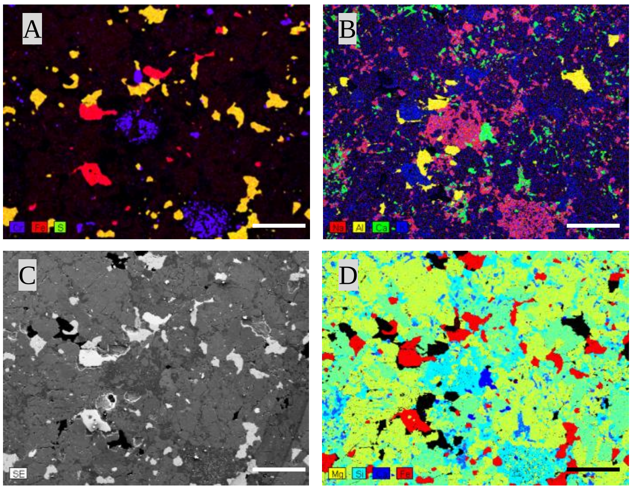

Fig. 3. Composite element maps of lower part of shock vein (map 2 area) including mineral and chondrule fragments (A: Cr-Fe-S, B: Na-Al-Ca-K, C: secondary electron image, D: Mg-Si-Ca-Fe, scale: 200 µm)

The map 2 within the vein is characterized by Cr, P, S, Al, Ca enrichments comparing to the neighboring large mineral grains (Fig. 4A). However, the vein is not so rich in Na comparing to its environment, which is not concordant with the presence of mineral melt. The upper left part in the map is occupied by an olivine grain (higher Fe and Mg concentrations), whereas the lower right part with higher Ca-Si is a pyroxene (Fig. 4B). The vein is composed of troilite and iron-oxide. The patchy-like Cr enrichment corresponds a chromite inclusion. The Ca has moderately enrichment near to the pyroxene- vein boundary, whereas Fe is dominant in the inner part of the vein. The tiny lath-shaped particles in the vein have higher Na and K at their boundaries, which might be identified to the feldspar.

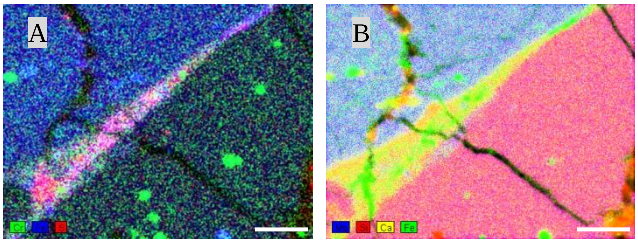

Fig. Thin vein cutting across olivine and pyroxene grains (near the map 2 in Fig. 1.). (A: Cr-Fe-S, B: Mg-Si-Ca-Fe, scale: 200 µm)

Conclusion:

The petrologic texture observed in Mócs meteorite results from both of thermal and impact metamorphic processes. The lack of the high-pressure olivine polymorphs suggests that shock pressure pulsation was not enough to reach the activation energy for its phase transformation. Therefore, the patchy olivine corresponds to an intermediate phase formed by postshock temperature involved in shock metamorphism.

Acknowledgement

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References:

[1] Gyollai, I. et al. (2009) *AIP Conference Proceedings*, *1163*, 75-85,[2] Chen, M. et al. (2004) *European Journal of Mineralogy*, *16/2*, 203-211, [3] Nagy Sz. et al. (2010) *Lunar and Planet. Sci. Conf.*, abs#1228.