IR-Raman correlation of shocked minerals in Csátalja meteorite – clues for shock stages

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Introduction: The analyzed meteorite called Csátalja is a H chondrite (H4, S2, W2), and based on the differences between its certain parts, probably it is a breccia. The meteorite was found in August of 2012, some km east of the village of Csatalja (46.006° N, 18.991°) in Hungary (Kovács et al. 2015). The meteorite shows high iron abundance (25-31%), its main minerals are: orthopyroxene, olivine (fayalite content 16-20 mol%), 15-19% reduced Ni-Fe metal and 5% troilite. In this work we analyse typical meteorite minerals, including shock altered ones in order to demonstrate some useful capabilities and also the limits of the methods, by correlating the infrared observations with better established Raman measurements for phase identification and characterization (Fintor et al., 2014), as with Raman much more standardized data are available. Optical analysis was also used mainly to characterize the isotropy of mixed phases. The aim besides the methodological testing is to characterize the shock deformation and estimate formation conditions, related small scale heterogeneity and reconstruct shock history.

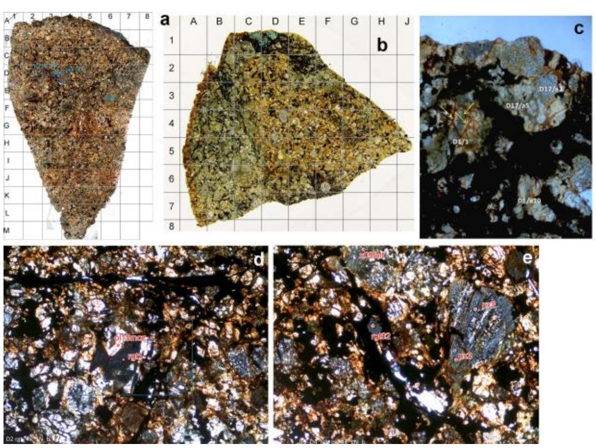

Fig.1: Raman and IR measuring points of Csátalja-1 (a, d, e) and Csátalja-2 (b, c) samples.

Materials and Methods: The mineral assemblages and textures of two 30μm thickness thin sections (Csátalja -1, and Csátalja-2, Fig. 1) were characterized with a Nikon Eclipse LV100POL optical microscope. Phase analytical measurements were made by THERMO Scientific DXR confocal Raman microscope (532 nm laser, 10 mW laser power, 100X objective lens, 5 μm pinhole confocal aperture) in the laboratory of the Department of Mineralogy, Geochemistry and Petrology, University of Szeged; and used Bruker Hyperion 20000 FTIR-ATR microscope (tip of the germanium (Ge) crystal of 100 μm in diameter, ,performed for 30 sec at 4 cm^{-1} resolution, Bruker Optics' Opus 5.5. software) at Research Centre for Astronomy and Earth Sciences of Hungarian Academy of Sciences.

Results: Comparing the shock impact produced mineral alterations in two thin sections of the recently found Csátalja meteorite indicates that the most significant differences can be observed in mineral clasts: 1) the clasts in Csátalja-1 show homogeneous mineral composition (pyroxene, olivine) and characterized by mosaic extinction, which indicates shock stage <15 GPa. 2), while the Csátalja-2 mineral clasts contain subgrained pyroxene and olivine with feldspar melt along subgrain boundaries without any evidence for high pressure transformation (e.g. akimotoite, ringwoodite) indicating shock pressure in 15-17 GPa range.

With increasing shock stage the peak positions of Raman and infrared spectra of mineral clasts shifted in wavenumber relatively to the unshocked references. We confirmed that both Raman and infrared peak shifts and FWHM values correlate to each other with correlation factors between 0.6-0.9. The best correlation parameter occurred in shocked pyroxene between the two methods (Raman FWHM-shock induced shift, r^2=0.97). The Csátalja-1 pyroxenes showed a bit stronger correlation values, than pyroxenes in Csátalja-2 sample, because of less disordering of structure by less shock stage. In case of feldspars Raman FWHM-shock induced shift showed weak correlation because those occur as mixed melts with Ca-rich pyroxene. Pure feldspar spectra could be detected only by FTIR spectroscopy which shows moderate, but weaker correlation value than the pyroxenes (r^2=0.84 infrared shock drivel peak shift-FWHM, r2=0.91 Raman FWHM-FTIR FWHM) (Fig. 2).

In case of mixed mineral clasts formed by selective melting around subgrain boundaries and fractures by-shock annealing, the IR and Raman FWHM values show weaker correlation 0.42 of Csátalja-2 than 0.72 of Csátalja-1 according to the higher shock level of Csátalja-2. The FWHM values with shock induced shifts correlated well with both in case of FTIR and Raman spectroscopy. In summary the joint usage of Raman and infrared provide deeper insight into the shock produced changes and its spatial inhomogeneity.

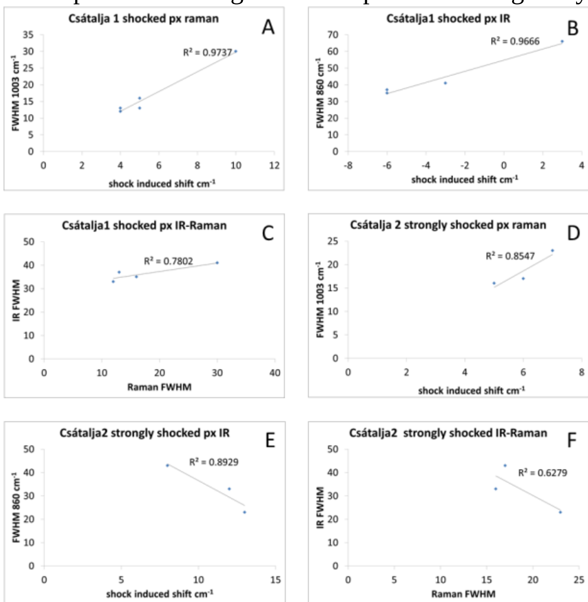

Fig. 2: Raman-IR correlation of shocked pyroxenes

Conclusion: The clasts in Csátalja-1 show homogeneous mineralogical composition, separated parallel shock veins, the shock pressure did not exceeded 15 GPa. While the Csátalja-2 mineral clasts have mixed mineralogy, larger shock melt volume, the pyroxene and olivine clasts are surrounded by feldspar melt along the subgrain boundaries, indicating >15-GPa shock pressure – but below 17 GPa as transformation to akimotoite and ringwoodite were not observed. The different shock levels could be observed by the peak shift and FWHM change both in olivine and pyroxene.

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