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Raman and infrared spectroscopy of feldspars in lunar meteorites (Asuka-881757 and Yamato- 86032)

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Abstract: We investigated shock metamorphism of two lunar meteorites (Asuka-881757 and Yamato-86032). We measured shocked lunar feldspars with infrared and Micro-Raman spectroscopy. These methods are very sensitive for changing crystal lattice after amorphisation derived to shock metamorphism. With infrared spectroscopy were four different stage schocked feldspar measured, and with Micro-Raman spectroscopy 3 maskelynite grains were measured.

Samples and Experimental Procedure: The mineral assemblages and textures of our samples were characterized with a Nikon Eclipse LV100POL optical microscope using plane polarized and reflected light modes (at Eötvös University, Budapest).

The infrared spectra were taken in Central Research Institute for Physics (KFKI) Budapest, using Bruker infrared microscope attaching to Bruker Tensor 37 Fourier transform infrared spectrometer, using reflectance mode (standard was gold coated disk), the mid-IR (400-4000 cm^{-1}) at a resolution cf 1 cm^{-1}

The maskelynites were also measured in KFKI by a Renishaw-1000 Raman spectrometer: the laser wave lenght was 785 nm, with focused energy of 8 mW. The maximal focus was driven to 1μm diameter spot.

Introduction: Our lunar regolith from NIPR thin section set is originated of an impact crater from the Moon. For understanding of impact cratering of Earth is very important the investigation of shocked lunar meteorites.

The lunar regolith breccia was sampled by JARE 27 (1982-1983) expedition, which coated by fusion crust. [1] Detailed investigation about this impact breccia derived from lunar highland, far from Ibrium mare. [2] The Asuka-881757 was found in northeastern Nansen Field, near Asuka station, eastern Antarctica. [1,2,3]. Koeberl et al. [4] concluded that it is a metamorph-recrystallized VLT basalts with unequiblirated composition.

Results: *Petrography*

Yamato 86032 (lunar meteorite, regolith breccia)

The sample is an impact derived polymict breccia with more lithologies: light gray and middle-gray clasts (their size 1-5 mm), and a dark matrix showing flow-structure, which similar to suevite breccia in Crater Bosumtwi [7] . liThe sample is crossed across by shock vein. In microscope observed minerals are in range 70% feldspar, 20% pyroxene (mainly orthopyroxenes) and 10 % olivine

The feldspars in matrix show strong mosaicism. The pyroxenes are commonly mechanical twinned.

With infrared spectroscopy was feldspars in two clast measured: (1) impact derived melt pocket, (2) strongly brecciated clasts, the feldspars show wavy and mosaic extinction.

Asuka-881757 (lunar meteorite, gabbro)

The sample is extra coarse-grained, with granular texture. The size of pyroxene 1,2 mm, the size of the plagioclase is between 2 and 4 mm, the size of olivines is between 2 and 3 mm. The 3 mm-sized olivine grain is whole alterated to hexagonal shape, smaller-sized aggregation, and have worm intergrowth with pyroxene, i. e. symplectite. (S5-S6) . Where the mineral is strongly fractured, it shows weaker interference color. The whole lath-shaped plagioclase is isotropic confirming the presence of the diaplectic glass, i.e. maskelynite. This suggests that the meteorite is of S5 shock stage [6]. The pyroxenes are strongly mechanically twinned. In the whole sample the minerals show common wavy extinction (min. S3 shock stage).

Infrared spectroscopy

Yamato-86032

In the Yamato-86032 regolith breccia sample two shocked feldspar were measured. The first measurement was in a melt pocket on a feldspar needle (Fig. 1. A, and spectrum 2.). The second

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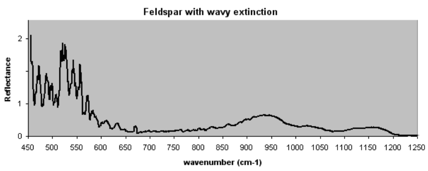
measurement was in an anortosithic clast shown in Fig. 1. B. (and Fig 2., spectrum 1.)

Our spectra of 1 and 2 show the differences in strengths of broad absorption band between 900 and 1200 cm^{-1}: (Table 2) in the case of feldspar in the melt pocket it is more broader, than in the case when the feldspar is in the anortosithic clast. This spectral difference expresses that there is a greater disordering of structure of feldspar occurring in the melt pocket, than those occurring in the anortosithic clast.

There are another differences between spectrum 1 and spectrum 2. We compared two peaks which can be found at unshocked feldspars near to 536 and 581 cm^{-1} wavenumbers. These peaks also appear at our shocked feldspars, too. But they were with smaller intensity at feldspars in melt pocket than those in the anorthositic clast.

In anortositic clast the feldspar was moderately shocked showing wavy extinction, and in patches mosaicism (Fig 1/B). The spectrum of this feldspar exhibits variations in reflectance with pressure indicative of the degree of shock-induced disorder and melting.



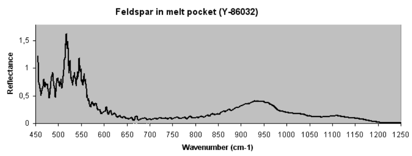
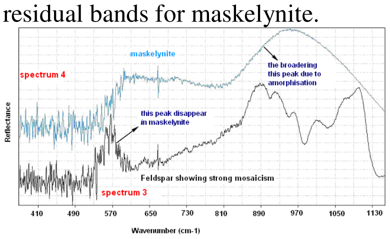


Fig. 1-2: Infrared spectra of shocked feldspars

Asuka-881757

We compared a feldspar showing strong mosaicism (spectrum 3) and a maskelynite (spectrum 4) in Asuka-881757. In spectrum 3 and four disappeared the main vibration bands in lower wavenumber, which due to stronger shock metamorphism In spectrum 3 can be observed a residual band at 500-650 cm^{-1}, which depending on depolymerisation of SiO_4 tetrahedra [7,8], this band disappeared in spectrum 4. In spectrum 3 appeared just main residual bands for maskelynite.

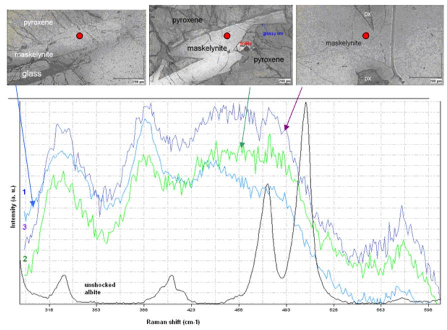


Measured feldspars	450-650 cm^{-1}	650 cm^{-1}– 850 cm^{-1}	850 cm^{-1}-1250 cm^{-1}
Feldspar with wavy extinction (Y-86032)	20	110	110
Feldspar in melt pocket (Y-86032)	40		150
Feldspar showing (Asuka-881757)	60	181	120
Maskelynite (Asuka-881757)	270	320	

Fig. 3-4: Infrared spectra of shocked feldspar showing strong mosaicism and a maskelynite

Raman spectroscopy

As standard was used an unshocked anorthite spectrum in Crystal Sleuth program. The peaks of unshocked albite (unoriented, 748 nm) as follows: 328, 400, 406, 416, 478, 506 . We measured in 3 maskelenites, and they have different crystallized stage. Generally, in all maskelynete spectra are the doublet (478 and 506 cm^{-1}) disappeared, (Fig 2) just a large, broadered „peak" can be seen, which due to amorphisation of feldspar and disordering of SiO4 tetrahedras [1]. But near 328 and 405 cm^{-1}) wavenumber by three makelynites can be observed this peaks, but they are differently broadered, which possibly due to different crystallisation stage, which show the FHWM calculations. (Fig 5-6 Table) However, the 405 cm^{-1} peak of unshocked albites [10, 11] appears in maskelynite spectra, but broadered and shifted to lower 388 cm^{-1} wavenumber. Generally, all maskelynite spectra have a high groundline, which possiibly due to great fluorescence of maskelynites. The FHWM calculation shows, the Maskelynite 2 is highest disordered, and Maskelynite 1 preserved best crystal structure. The three maskelynites possibly has 5 GPa difference in shock pressure.



	Below 350 cm^{-1}	350 – 450 cm^{-1}	Above 450 cm^{-1}
Unshocked albite	12	11	12
Maskelenyte 1	35	20	40
Maskelenyte 2	31	19	70
Maskelenyte 3	30	23	69

Fig 5-6: Raman spectra of maskelynites with measuring points and below FHWM calculations

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