PETROGRAPHIC AND MID-INFRARED SPECTROSCOPY STUDY OF SHOCKED FELDSPAR IN ASUKA-881757 LUNAR GABBRO METEORITE SAMPLE.

I. Gyollai[1], A. Gucsik[2] Sz. Nagy[1] , J. Fürj[1], Sz. Bérczi[1], Zs. Szekrényes[3] M. Veres[3]. [1]Eötvös University, Faculty of Science, Institute of Physics, Dept. Material Physics, H-1117 Budapest, Pázmány P. s. 1/a, Hungary, *(gyildi@gmail.com)* [2]Planck Institute for Chemistry, Dept. of Geochemistry, Joh.-J. Becherweg 27, D-55128, Mainz, Germany, [3]Institute for Solid State Physics and Optics H-1121 Budapest Konkoly-Thege M. út 29-33., Hungary).

Introduction: The Asuka-881757 was found in northeastern Nansen Field, near Asuka station, eastern Antarctica [1] [2] [3]. Koeberl et al. [2] concluded that it is a metamorph-recrystallized VLT basalts with unequiblirated composition. We investigated shock metamorphism in our sample with petrography and infrared spectroscopy.

We investigated three types of shocked feldspars in Asuka-881757,531-2 sample with mid-infrared spectroscopy (reflectance mode). In the petrographic microscope the three types of sites were characterized by (1) undulatory extinction, (2) undulatory extinction with isotropic patches and decreased interference color, (3) isotropy, for lath-shaped feldspars, indicating maskelynite.

Measurements and observations: Feldspar minerals subjected to high shock pressures exhibit structural changes with increasing pressure (e.g., brittle fractures, plastic deformations, formation of diaplectic glass, and complete melting). Diaplectic glass is an amorphous phase of crystals (maskelynite for feldspars) formed from shock wave compression and pressure release, which preserves the shape and internal structure of the precursor crystal [6]. The degradation of these shocked minerals can be attributed to the lattice disordering and also to the increasing glass content, especially at shock pressures above ~20 GPa [4] [5]. Modest disordering of feldspar (undulatory extinction, kink banding, mosaicism), generally begins in the 15–20 GPa pressure range. The feldspars transforms to maskelynite (diaplectic glass) forms between ~30–45 GPa. Even more significant transformation of the feldspar structure, the melting occurs above ~45 GPa [4] [6].

We measured three types of shocked feldspars with infrared spectroscopy. The first type measuring point was an area with undulatory extinction. The second type was area with strong undulatory extinction together with isotropic patches and highly decreased interference color. The third type area was a lath-shaped isotropic feldspar, i. e maskelynite

Optical microscopy observations: The sample is extra coarse-grained, with granular texture. The size of the main minerals are as follows: for pyroxenes 1,2 mm, for plagioclase between 2 and 4 mm, for olivines between 2 and 3 mm. (Fig. 1.) The whole 3 mm-sized olivine grain was pervasively alterated to aggregation of hexagonal shaped smaller crystals. Olivines have wormy intergrowth with pyroxenes, (symplectites) (Fig. 1.). On the basis of the petrographic characteristics of the mineral areas the following shock stages can be estimated according to the Stöffler scale. In the whole sample the minerals exhibit common wavy extinction, and this corresponds to the minimum S3 shock-metamorphic stage. The pyroxenes are strongly mechanically twinned and this corresponds to the S3-S4 shock stage. There are feldspars with strong mosaicism corresponding to the S4-S5 shock stage. There are lath-shaped plagioclases in the sample and all of them is isotropic indicating the presence of the diaplectic glass, i.e. maskelynite. This phenomenon corresponds to the S5 shock stage. A section of the sample is crisscrossed by several shock veins and opaque grains (troilite) also occur inside these shock veins. This phenomenon corresponds to the S6 shock stage.

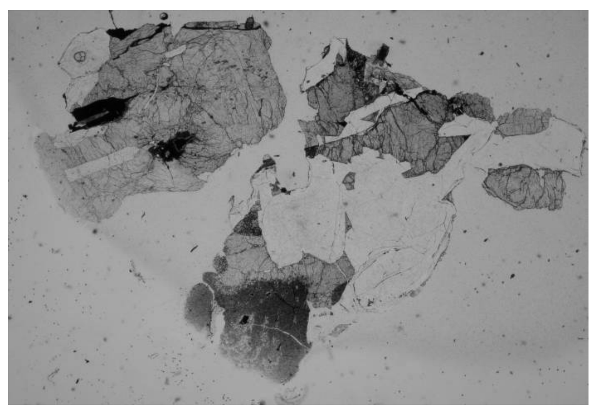

Fig. 1. Photomicrograph of our lunar gabbro meteorite Asuka-881757,531-2 in transmitted light with crossed polars. The width of picture is 6,5 mm. The white grains are feldspars, (A) the light gray grains are pyroxenes, and the middle-gray grains are olivines. The opaque grains are troilite inclusions in the veins. On the lower part of the sample a darker area is connected to the pyroxene: it could have been melted melted by the shock and the boundary had been penetrated mutually by the neighbor phases forming simplectite (B).

Infrared spectroscopy: In order to measure by Raman spectroscopy a laser beam wavelength of 532 nm and 60 μm diameter laser light spot is required. However our Renishaw-1000 Raman-spectrometer is characterized by a laser wavelength of 785 nm, and 1-15 μm diameter laser light spot (with focused energy of

8 mW). This strong laser light penetrates through the thin mineral section without ordered structure and mostly measures the epoxy instead of maskelynite. Therefore instead of Raman spectroscopy we measured the feldspars by infrared spectroscopy [7] [8]. Most of the infrared spectroscopy data refer to the feldspars but less can be found on other shocked minerals (olivine, pyroxene). This is the main cause we use the reflectance infrared measurements only for feldspars, but not for the other shocked minerals. We measured three types of shocked feldspars in Asuka-881757,531-2. The first was an area with weakly shocked feldspar showing wavy extinction; the corresponding spectrum was spectrum-1. The second area was a moderately shocked feldspar showing strong mosaicism and undulatory extinction; the corresponding spectrum was spectrum-2. The third was an area with isotropic feldspar (maskelynite); the corresponding spectrum was spectrum-3.

Generally, in all three spectra there the fluorescence causes high background level. The highest fluorescence background was observed at spectrum-3 of the maskelynite. This indicates that fluorescence depended on disordering of crystal lattice.

We could use the spectra to identify chemical compositions of the observed areas on the basis of the peaks and bands. One of peaks at 1234 cm^{-1} wavenumber corresponds to the Cristiansen anorthite composition feature. This peak occurred both in spectrum-1 and spectrum-2. The other peak at 1245 cm^{-1} wavenumber corresponds to the Cristiansen maskelynite composition feature. This peak occurred in spectrum-3. This way we could recognize that the peaks of our IR spectra helps in identifying the chemical composition of our mineral phases [8].

With IR spectroscopy we observed three vibration types of crystal lattice structures in our spectra: (1) peaks of depolimerisation of SiO_4 tetrahedra (500-650 cm^{-1}, 950-1150 cm^{-1}), (2) peaks of stretching and bending vibration of SiO_6 octahedra (750-850 cm^{-1}), and (3) Si-O stretching vibration of SiO_4 units [9-11]. There is another vibrational peak at 1009 cm^{-1} wavenumber, too, which is characteristic to unshocked feldspars. This peak disappears above 35 GPa. All these vibration type peaks were observed at the lower shocked sites. In the spectrum of the highly shocked maskelynite site only a broader band near 1000 cm^{-1} was observed which is the main vibration band of maskelynite [8].

We observed the depolimerisation peaks of SiO_4 tetrahedra (500-650 cm^{-1}, 950-1150 cm^{-1}), the stretching and bending vibration of SiO_6 octahedra (750-850 cm^{-1}) and Si-O stretching vibration of SiO_4 units in spectrum-1 and spectrum-2. The broad band near 1000 cm^{-1} main vibration band of maskelynite was observed in spectrum-3.

From our spectra, following [7] we can give a pressure interval for our measured anorthites. The peak at 1009 cm^{-1} wavenumber (which was near 1007 cm^{-1} at Johnson, 2003) is an adsorption band of unshocked feldspar at pressures less than 35 GPa. The peaks between 950-1150 cm^{-1} wavenumber interval are vibration bands of SiO_4 tetrahedra between 17 and 56 GPa. On the basis of our spectral peaks our feldspar in Asuka-881757,531-2 sample we can give the 17-35 GPa pressure interval for the shock event, what resulted in S3-S4 shock stage in the sample.

Conclusion: We investigated Asuka-881757,531-2 sample with mid-infrared spectroscopy (reflectance mode). The three types of sites were first characterized by optical microscopy and from the IR spactra of the selected areas estimations were given to the shock stage of the mineral phase anorthite. After interpretation of the optical and infrared data for undulatory extinction areas 17-35 GPa shock pressure (S3-S4 shock stage), for undulatory extinction with isotropic patches and decreased interference color areas 35-40 GPa shock pressure (S4-S5 shock stage), and for isotropic, for lath-shaped maskelynite area 56-75 GPa pressure range (S5-S6 shock stage) was calculated and after interpretation of the infrared data . The IR spectroscopy spectra were also useful for the chemical composition estimations, too.

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