MID-INFRARED SPECTROSCOPY OF WELL-DEFINED ALKALI FELDSPAR SAMPLES IN PREPARATION OF MERTIS OBSERVATIONS.

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Introduction: The MERTIS (Mercury Radiometer and Thermal Infrared Spectrometer) instrument onboard BepiColombo will study the surface of Mercury in the mid-infrared wavelength region from 7 µm to 14 µm and determine the surface mineralogy of the entire surface [1]. For this purpose, a database with well-defined spectra of relevant minerals is indispensable for the correct deconvolution of the returned MERTIS spectra.

Feldspars are the most abundant mineral group in the Earth's crust. Their chemical composition can be described by three major components, $KAlSi_3O_8$ (Or), $NaAlSi_3O_8$ (Ab) and $CaAl_2Si_2O_8$ (An). Mid-Infrared (IR) spectra of feldspars are highly affected by the chemical composition and the state of Al,Si order, illumination and observation geometry, grain size, and space weathering [2,3]. Thus, any spectral database of Mercury-analog feldspar samples must reflect these factors.

Solid solutions between Or and Ab are termed alkali feldspars. K-feldspar, $KAlSi_3O_8$, occurs as two stable modifications: monoclinic sanidine at high temperatures, triclinic microcline at low temperatures. In sanidine, Al and Si are distributed on two twofold, symmetrically non-equivalent tetrahedral sites, T1 and T2. XAl_{T1} denotes the Al content on the T1 site and is a measure of the degree of order. At slowly decreasing temperature, XAl_{T1} increases from 0.27 to 0.35 corresponding to a temperature of ca. 480°C-450°C. Below that temperature, fully Al,Si ordered triclinic microcline is the stable polymorph. However, in the absence of a fluid phase, slow Al,Si exchange kinetics prevent long range ordering as in microcline so that a kinetically stranded structure results that is characterized by submicroscopic, coherently intergrown triclinic domains (orthoclase).

Adularia is a K-feldspar variety that is metastably grown in the stability field of microcline. It occurs in alpine fissures in a hydrothermal environment, which is not expected at Mercury. For completeness and comparison, we show one adularia spectrum in Figure 1.

Contrasting to K-feldspar, Na-feldspar, $NaAlSi_3O_8$, is monoclinic at high temperatures (monalbite) but transforms at rapid cooling via a displacive transition into a metastable tricline structure (analbite). At slow cooling, continous Al,Si ordering occurs, first resulting in partially ordered triclinic high albite, followed by fully ordered low albite. Mixed crystals between sanidine and monalbite/albite can form at high temperatures. However, they exsolve at temperatures below 600°C and slow cooling, depending on their chemical composition. Both scenarios, slow and rapid cooling, are possible on Mercury. Slow cooling might occur in larger magma reservoirs below the surface, whereas rapid cooling might occur at the surface after volcanic eruptions.

Samples: For our study, we used a natural K-feldspar sample of gem quality from Volkesfeld, Eifel, Germany. This sanidine has an Al site occupancy $XAl_{T1}=0.305(2)$ [4]. For ordered low albite, we used a natural sample from Cazadero, California. The adularia sample is from Caoradi, Switzerland. The orthoclase sample is from Honshu, Japan. The mineral names and numbers in Figure 1 refer to the IRIS (Infrared and Raman for Interplanetary Spectroscopy) database.

Methods: Our characterization of natural samples starts with thin section microscopy to investigate the sample homogeneity. We found that commercially available minerals, even of gem quality, are often contaminated with other minerals. With thin section microscopy, we could (1) exclude many impurities within our natural samples, and (2) could get preliminary knowledge of the structural state of the samples. After thin section microscopy, the chemical composition of the samples were analyzed with a JEOL JXA-8530F Hyperprobe electron probe microanalyzer (EPMA) at the Institut für Mineralogie of the Westfälische Wilhelms-Universität Münster (WWU). The Al,Si distribution has been determined from X-ray powder patterns taken with an Phillips X'Pert powder diffractometer, also at the Institut für Mineralogie of the WWU. Mid-IR measurements were performed at the IRIS lab at the Institut für Planetologie where we used a BRUKER 70v spectrometer equipped with a grazing angle unit A513. We used a liquid nitrogen-cooled MCT detector with a measuring range from 2 µm to 25 µm. All spec-

tral measurements were performed at a pressure of 2 hPa at room temperature (ca 23°C). The samples were crushed and sieved to grain sizes below 25 µm, from 25 µm to 63 µm, 63 µm to 125 µm, 125 µm to 250 µm, and the remaining fraction of grains larger than 250 µm. For background measurements, a commercially available diffuse reflecting gold standard INFRAGOLD^{TM} was used.

One part of the natural K-feldspar sample from Volkesfeld (ID 73) was heated at 850°C for eleven days so that the Al,Si distribution became further disordered from a starting value of $XAl_{T1}=0.31$ to $XAl_{T1}=0.28/0.27$ ($XAl_{T1}=0.25$ indicates full disorder which, however, is not achieved below the melting temperature). [4]. In Figure 1, the heated sample has ID 129.

Results: Figure 1 shows the spectra of highly disorded sanidine (ID 129), slightly ordered sanidine (ID 73) (An 0.0, Ab 15.3, Or 84.7) , adularia (An 0.0, Ab 10.7, Or 89.3), orthoclase (An 0.2, Ab 10.5, Or 89.4), and fully ordered albite (An 0.1, Ab 99.7, Or 0.2). The powder samples had a grain size ranging from 25 µm to 63 µm. Obviously, the spectra are influenced by both, the chemical composition of the alkali feldspars as well as their Al,Si distribution.. Or-rich samples with minor Al,Si-order show only two broad Reststrahlen bands (RB) with large shoulders between 8 µm and 10 µm. The spectra of 9 orthoclase and 8 adularia, which have about Or 89, show a somewhat pronounced shoulder at ca 9.90 µm compared to the spectra of 73 sanidine and 129 sanidine, which have Or 85. In contrast, the fully ordered albite spectrum has four to five clearly distinguished bands in this region. The effect of Al,Si order is clearly visible especially at the wavelength peak at 15.25 µm to 15.69 µm (thick black lines). This peak shifts systematically to shorter wavelengths with increasing degree of Al,Si order. In the spectrum of the largely disordered 129 sanidine, the peak occurs at 15.69 µm while in the somewhat ordered 73 sanidine at 15.65 µm. The peak is further shifted to 15.51 µm in the adularia spectrum and to 15.43 µm in the orthoclase spectrum. The same behavior was observed in absorbance spectra of various alkali-feldspars by [5,6]. This behavior is especially interesting for the adularia and orthoclase spectra. The spectra of the two minerals differ from each other even though the chemistry is more or less identical. The band shape of adularia and orthoclase is also slightly changed in the region of the RBs around 9 µm to 10 µm, which is in the relevant wavelength region for

MERTIS. The small peak at 9 µm in the albite spectrum decreases in absorption spectra with decreasing degree of order [3].
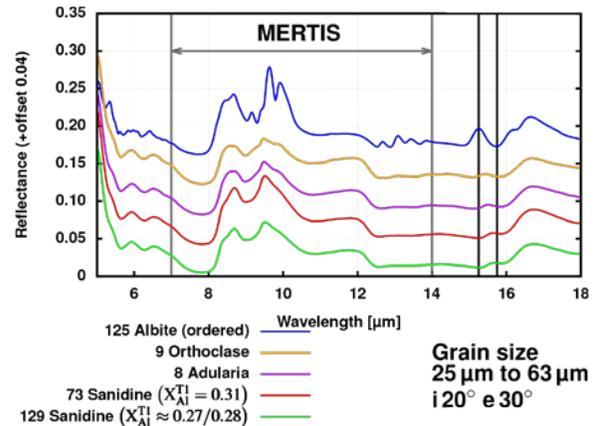

Fig. 1 Spectra of largely disordered sanidine, slightly ordered sanidine, adularia, orthoclase, and fully ordered albite. Thin gray lines indicate the wavelength region measured by MERTIS, thick black lines indicate features, which change in position with the state of Al,Si order.

Conclusion: The spectra of feldspars with similar chemical compositions but different states of Al,Si order display clear changes and shifts of bands within the mid-infared spectral region. This demonstrates that it is not sufficient for spectral databases and deconvolution of spectra returned by space mission to only account for the correct chemical compositions, temperatures, illumination geometries, and degrees of space weathering of the analog samples. Rather it is also essential to characterize their cation distributions.

It is well known that other minerals also show different distributions of ions in different atomic sites within the unit cell [7]. Therefore, it is necessary to test the effects of crystal ordering, i.e., different cation distributions, in spectra of other rock-forming minerals such as pyroxenes. This will help to reduce the error of deconvolution of spectra returned by space mission. Also, changes in ordering could be helpful to investigate the impact of space environment on the surface materials

References: [1] Hiesinger, H., J. Helbert and MERTIS co-I Team (2010) *Planet. Space. Sci, 58,* 144-165. [2] Nash, D. B., and Salisbury, J. W. (1991) *Geophys Res Lett, 18,*1151-1154. [3] Martin R. F. (1970) *Contr. Mineral. And Petrol., 26,* 62-74. [4] Kroll, H. and Knitter, R. (1991) *Amer Miner,76,* 928-941. [5] Hafner, S and Laves, F (1957) *Z. Kristallog. – Cryst. Mater., 109,* 204-225. [6] Laves, F. and Hafner, S. (1956) *Z. Kristallog. – Cryst. Mater., 108,* 52-63. [7] Putnis, A. (1992) *Introduction to Mineral Science*