Development of spectral data analysis tool for investigating water environment of Mars.

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1. Introduction: Many studies suggest that water had once existed on Mars (e.g., [1]). It is believed that water has evaporated and migrated into space or under the ground partly being stocked as permafrost. The exact conditions of pressure, temperature, and time to support water on Mars are not well understood.

The purpose of this study is to determine the distribution of water-related minerals and try to understand the specific conditions and timing of the presence of water on the Mars. We also aim to clarify the relationship between the distribution of surface minerals and subsurface structure (e.g., ice layers).

Various spectroscopic data acquired by the Mars Reconnaissance Imaging Spectrometer (CRISM) and SHAllow RADar (SHARAD) have been used to study the water environment of Mars (e.g., [2]). The CRISM is a VIS-NIR spectrometer that can detect phyllosilicate, a type of hydrous minerals (e.g., [3]). The SHARAD is a sounding radar that can penetrate subsurface materials. If there is a layer with different dielectric constants like ice under the ground, such discontinuous interface is detected by the SHARAD (e.g., [4]).

To achieve the purpose, we develop the spectral data analysis tools for investigating water environment of Mars. We visualize and analyze the CRISM and SHARAD data to discuss the relationship between the surface minerals and the subsurface structure.

2. Requirements for the Spectral Analysis Tool: The spectral analysis tool is divided into a CRISM part, and a SHARAD part as shown in Figure 1.

In the CRISM data analysis, the user first performs correction using ENVI/CAT [5]. Then the user normalizes and smooths the spectra. Then, absorption bands specific to each hydrous mineral are quantitatively detected. The type of hydrous minerals is also identified.

In the SHARAD data analysis, on the other hand, the user performs binary transformations, echo calculations, and then detection of the first and second signal peaks. The presence or absence of dielectric interfaces is clarified.

The essence of the analyses results is then reflected in a GeoTiff image for discussion. The user merges the two kinds of the analyses results using geographical information. The potential relationship between the two distribution maps can be visualized and discussed.

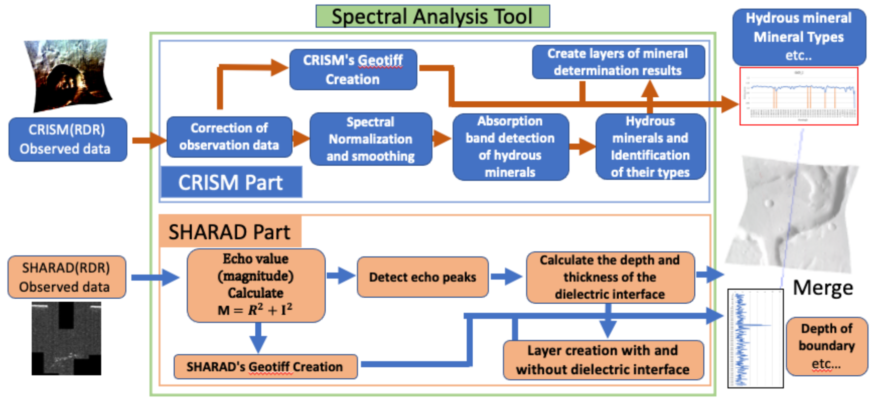

Fig.1: Overall design of the spectral analysis tool.

3. Implementation results: The spectral analysis tools which satisfy the requirements described in section 2 was developed. Then we conducted the analysis using the developed tools and the following test data.

We chose the Ceraunius Tholus region as the test area. We used the data observed there as the test data (Fig. 2). The example of the analysis results is shown in Fig. 3. The phyllosilicate was detected in the upper left zone of the CRISM image (Fig.3 (a)).

The type of hydrous mineral in this zone seems to be saponite or smectite based on the characteristics of the absorption bands of the spectra.

The SHARAD data show a dielectric interface below the surface (Fig. 3 (b)). A second peak indicating a dielectric interface was identified at ~125 m depth.

Finally, synthesis of the two results indicates that a dielectric interface exists in the vicinity of hydrous minerals on the surface.

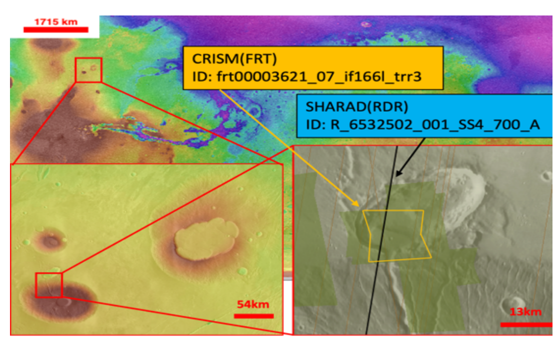

Fig.2: The test area around Ceraunius Tholus (24.25°N, 262.75°E). The observed data are used for the test. (modified from PDS website)

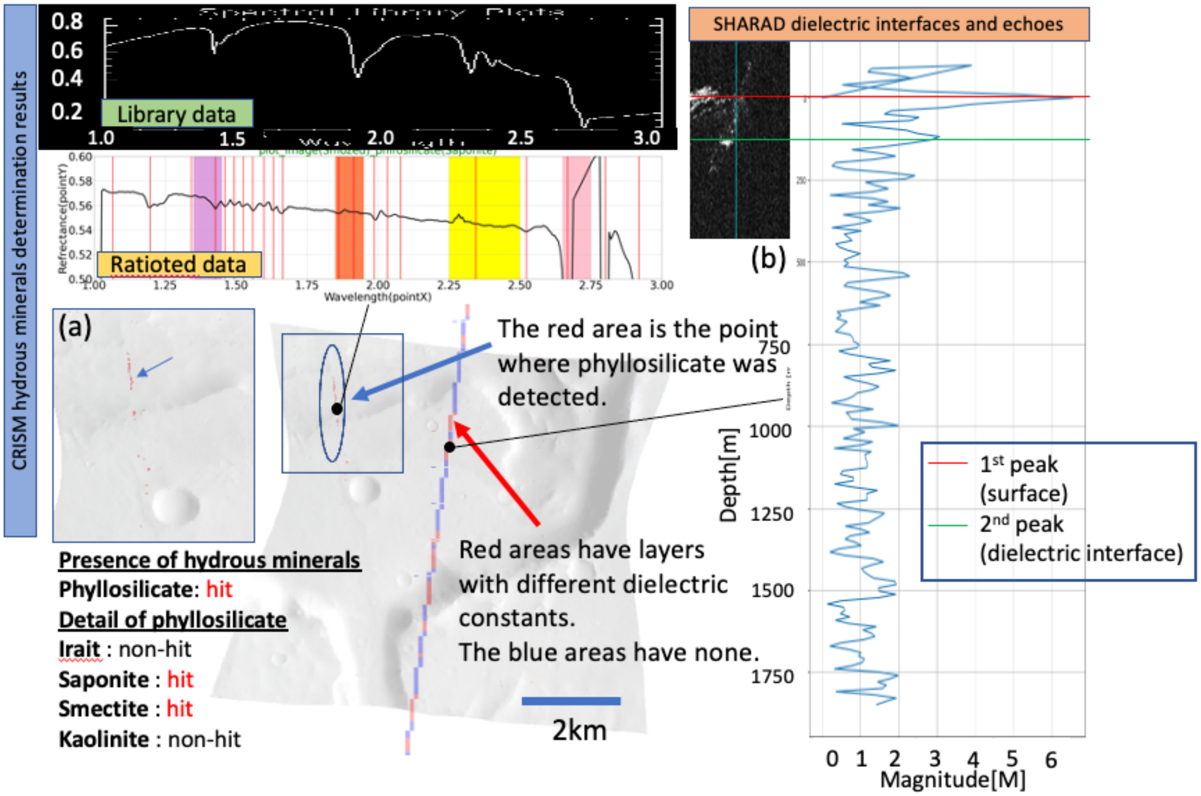

Fig.3: An example of the data analysis in the test area around Ceraunius Tholus (see Fig. 2). Part of the outputs from the spectral analyses tool developed in this study is shown.

4. Discussion: The CRISM data analysis tool developed in this study can detect the absorption bands of the spectra. The tool also can identify the type of the detected hydrous minerals. The SHARAD data analysis tool can output the depth of the dielectric interface. The results from both the CRISM data analysis and the SHARAD data analysis can be integrated as different layres using the geographical information. We can examine and discuss the presence or absence of dielectric interfaces indicating possible underground ice.

5. Conclusion: The spectral data analysis tools for understanding water environment of Mars have been developed. The analysis tools successfully visualize both observation data from the CRISM and the SHARAD onboard MRO. By using this tool, the user can detect hydrous minerals, identify each mineral and clarify the distribution. The tool also can determine the presence or absence of different dielectric interface under the surface.

By synthesizing the analysis results on the entire image, the relationship between the distribution of hydrous minerals and dielectric interfaces (possibly ice) can be discussed over a wide area on Mars.

References: [1] Carr (1996) Oxford Univ. Press. [2] Mustard, J, F., et al. (2008) Nature, 454, 305-309, doi:10.1038/nature07097. [3] Sheppard, R. Y. et al., (2022) Icarus, 383 [4] Cook, C. W., et al. (2020) Icarus, 348. [5] Seelos, K. et al. (2012) CRISM 2012 Data Users' Workshop. MTRDR Data Analysis Walk-Through.