Mineralogy and spectroscopy of terrestrial mud volcano in northwest China and implications for the mud volcano formation on Mars. Wenxi Chen, Xiaohui Fu*, Lingxi Zhang, Jiang Zhang, Zhongchen Wu Shandong Provincial Key Laboratory of Optical Astronomy and Solar Terrestrial Environment, Institute of Space Sciences, Shandong University, Weihai, China (fuxh@sdu.edu.cn).

Introduction: Several pitted cones have been identified based on analysis of Viking Orbiter image [1][2][3]. Most of the kilometer to sub-kilometer cones were located in Eastern Acidalia and Utopia-Isidis-Elysium Planitia[2]. Various formation mechanism of these pitted cones have been proposed, such as rootless cones, mud volcanoes, terrestrial Maars and pingos[4][5][6][7]. Many cones are identified in the southern part of Utopia Planitia, within the landing site of Zhurong rover[8]. They are also considered as the mud volcano candidates on Mars.

Mud volcano is a geological structure on the earth's surface or sea floor formed by the eruption of subsurface fluid-sediment mixtures under specific geological and hydrological condition, which mainly occur at convergent plate margins[9]. There are more than 40 mud volcano development areas and more than 220 mud volcanoes found on the land. China's mud volcano are predominately distributed in Xinjiang and Taiwan, among which the representative mud volcanoes are distributed in Horgos, Dushanzi and Baiyanggou.

In this study, we used multi-spectral method to analyze the mineralogical composition of the terrestrial mud volcano sample from Dushanzi, Junggar, Xinjiang. Then, we are aimed to compare terrestrial mud samples with mineralogy and spectroscopy of pitted cone on Mars obtained by remote sensing. This work could provide insights for the identification and formation of pitted cones on Mars. These pitted cone also of particular scientific interest since they may indicate the presence of water or ice near the surface.

Samples and methods: Mud samples were collected from in Dushanzi mud volcano on the southern margin of the Junggar Basin in the Xinjiang Uygur Autonomous Region, NW China (Fig. 1). Then samples were stored in a clean airtight bag. All tools and containers used for samples treatment were pre-cleaned. Before being tested, samples were desiccated in a oven (50 °C) and a portion was ground into fine powders in an agate mortar and pestle. Powder was collected and stored in a glass bottle.

In order to determine the mineral compositions of mud samples, XRD patterns were collected with a Rigaku Ultima IV diffractometer. Mid-Infrared spectra of the mud samples were measured using a VERTEX 70 (Bruker) Fourier Transform Infrared Spectrometer (FTIR). VIS-NIR spectra were collected using an ASD portable spectrometer.

Figure 1: Dushanzi mud volcano in Xinjiang Uygur Autonomous Region, NW China

Results: XRD pattern of the mud sample is illustrated in Fig. 2. Quartz, plagioclase, muscovite, chlorite, smectite and calcite were identified based on their characteristic diffraction peaks. These minerals are typical components of classic sedimentary rocks, including those which constitute the Mesozoic–Cenozoic lacustrine sequences of northwestern China [10].
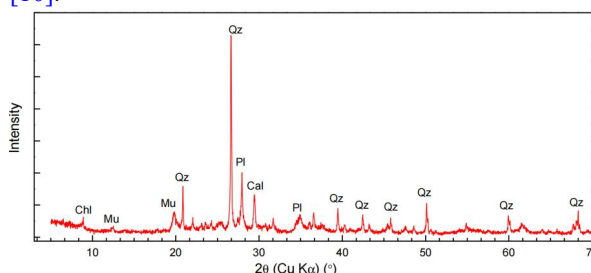
Figure 2: X-ray diffraction pattern of the desiccated mud sample. Notations are as following: Chl-chlorite; Mu-muscovite; Qz-quartz; Pl-plagioclase; Cal-calcite.

Mid infrared ATR spectrum of the desiccated mud sample was shown in Fig. 3. Note that a strong absorption peak at about 1000 cm^{-1} is due to the anti-symmetric stretching vibration peak of Si-O-Si, which is the characteristic feature of silicate. The weak and broad absorption band in 1300 -1600 cm^{-1} is possibly assigned to the carbonate in the mud sample. Another

broad absorption range from 3200 to 3600 cm^{-1} is caused by adsorbed water molecules or inter-layer waters with in phyllosilicates. On the shoulder of the absorption band, there is a strong peak at 3616 cm^{-1} , which is the vibration peak of structural OH.
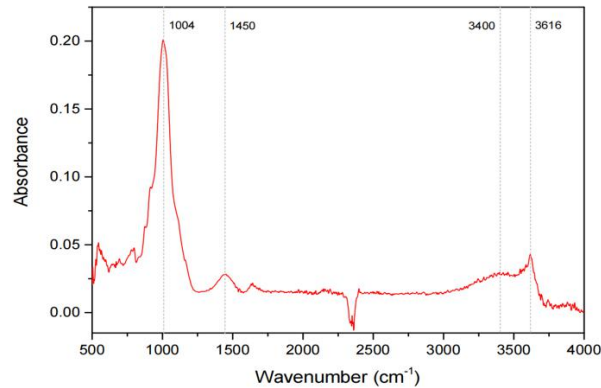
**Figure 3: Attenuated total reflection spectrum of the desiccated mud sample.**

VIS-NIR spectrum of the wet mud and fine powders are shown in Fig. 4A. For both of them, there is three obvious absorption peaks, which are located at 1.41 μm , 1.91 μm and 2.21 μm. The peak at 1.41 μm could be assigned to overtones of OH and H2O stretching vibrational modes. The band within 1.9 μm is due to a combination of H2O stretching and bending vibrations. The absorption at 2.21 μm may be caused by Al-OH vibration. Among all identified minerals, the spectral of reference minerals containing structural OH are shown in Fig. 4B. Based on the comparison, we confirmed that the Al-OH vibration is possibly due to the presence of muscovite in the mud sample. In general, the desiccated powder sample has high reflectance values comparing with the wet mud sample (Fig. 4A). We also noted that the strength of two absorption bands at 1.4 and 1.9 μm both significantly decrease after the desiccation process.

Discussions: Here we only identified the minerals in the mud samples. In our future work, we will determine their specific abundance of these mineral using the rietveld refinement method. The obtained mineral and spectral data are valuable for understanding the formation of mud volcano and identification of possible martian mud volcano. If the pitted cones on Mars were of sedimentary volcanism origin, the spectral of these structures may share many commons with terrestrial mud volcanos in terms of mineralogy and spectrology. VIS-NIR spectral data can serve as a link between laboratory data and orbital observations. In next step, we plan to recognize those pitted cones close to the landing site of Zhurong rover in south Utopia Plantia through the remote sensing image, and compare their spectrum data from CRISM

with our sample data to determine whether those pitted cones on Mars are mud volcanoes.

Then, more important is to discuss their geological formation mechanism. We are planing to characterize the geological properties of Dushanzi mud volcano. Then the necessary formation conditions will be summarized, such as tectonic background, the source of mud materials, and the origin of fluids and gases. If these pitted cones were mud volcanoes, its formation may be related to underground fluid/gas activities or subsurface water/ice on Mars, and gas releasing and high-pressure processes.

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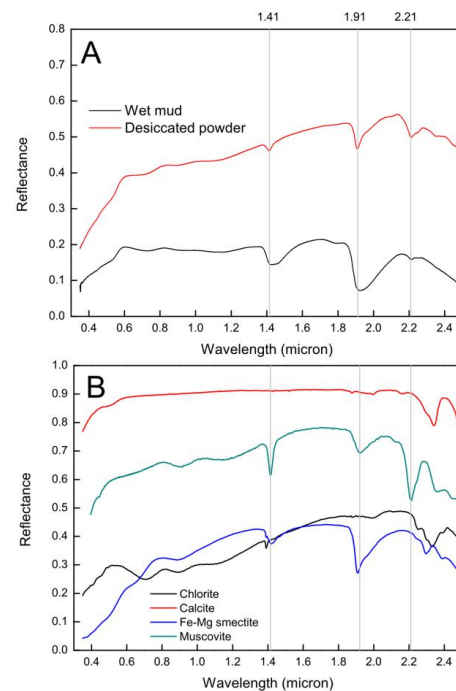
Figure 4: Visible-near infrared spectrum of the wet and desiccated mud samples (A) and reference minerals in laboratory (B). The reference minerals data are derived from RELAB at Brown University.