

CHEMICAL COMPOSITIONS OF MARTIAN SOILS AND ROCKS AT TIANWEN-1 LANDING SITE: PRELIMINARY RESULTS FROM MARSCODE ONBOARD ZHURONG ROVER. C.Q. Liu¹, Z.C. Ling^{1*}, E.B. Shi¹, S.K. Tian¹, J. Zhang¹, P. Liu¹, Y.Q. Xin¹, and Z.C. Wu¹, ¹Shandong Key Laboratory of Optical Astronomy and Solar-Terrestrial Environment, School of Space Science and Physics, Institute of Space Sciences, Shandong University, Weihai 264209, China (zcling@sdu.edu.cn).

Introduction: China's first Mars exploration mission named Tianwen-1 has landed in southern Utopia Planitia on 15 May 2021 [1-4] (Figure 1a), within one of the most widespread deposit units called the Late Hesperian-aged Vastitas Borealis Formation (VBF) [1, 4-6]. Several Martian targets have been investigated across the landing area, including the pancake-like ejecta, rampart craters, pitted-wall craters, and giant polygonal troughs. These targets are related to the release of volatiles [1, 4]. In addition, the craters with a low depth/diameter ratio in VBF also suggest a substantial amount of ice [7]. Some previous work inferred that VBF was sediments of an ancient ocean [6, 8] or outflow channels from highland and lowland sources [5, 9]. The in-situ detections of the Zhurong rover may provide critical clues for the origin of VBF on the northern plains of Mars.

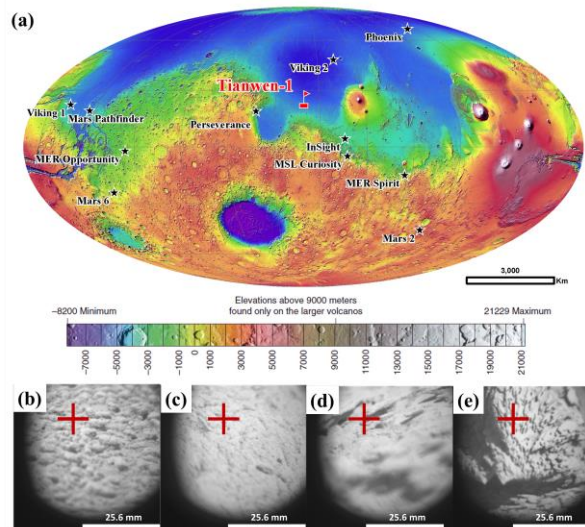


Figure 1 Landing site and Martian targets investigated by Zhurong rover. (a) The landing site of Tianwen-1 and other Mars exploration missions overlay on the base image of Mars Orbiter Laser Altimeter (MOLA) global map. (b-e) Micro-images of coarse soil (b), fine soil (c), layered rock (d), and rock (e).

The Zhurong rover carried a Mars Surface Composition Detector (MarSCoDe) instrument suite. MarSCoDe consists of a Laser-Induced Breakdown Spectroscopy (LIBS) spectrometer to investigate elemental compositions (Si, Al, Fe, Ca, Mg, K, Na, O, H, etc.), and a Short-Wave Infrared (SWIR)

spectrometer for mineralogy investigation, as well as a Micro-Imaging Camera to obtain textures of Martian targets [10].

Dataset and Processing: The level 2B MarSCoDe dataset is acquired from China National Space Administration, including 32 LIBS spectra of Martian targets and 20 spectra for 8 silicate on-board calibration targets (Hypersthene, Andesite, Olivine, Basalt, Norite, K-feldspar, Nontronite, and Montmorillonite). The continuum background spectra are subtracted from the LIBS spectra. Subsequently, several emission lines of major elements (Si, Ti, Al, Fe, Mg, Ca, Na, K, and O) are identified according to the NIST database (as shown in Figure 2) [11].

Results: The LIBS spectra of Martian soils and rocks are normalized using the total intensity of all emission lines as shown in Figure 2. All LIBS spectra exhibit obvious emission lines of major elements (Si, Ti, Al, Fe, Ca, Mg, K, Na, and O). The Martian rock has a low intensity for all major elements, which may be due to its low SNR (Signal to Noise Ratio). The high noise can also be observed near the H emission line in Figure 2. In addition, the layered rock has the highest intensity of K, Na, and Ca. For Martian soils, the fine soil has the highest intensity of Mg, and coarse soil exhibits a high intensity of Fe. Moreover, the fine soil has the highest H intensity, while the coarse soil exhibits almost no LIBS peak of H.

The distribution of relative intensity values of these emission lines is given in Figure 3. All points of Martian targets are near the points of igneous onboard calibration targets, especially Basalt.

The degree of chemical alteration can be demonstrated using the (olivine + plagioclase + clinopyroxene)/Ti vs Si/Ti [12], and chemical index of alteration (CIA) [13]. The scatter points of most igneous targets lie in a straight line except K-feldspar, Nontronite, and Montmorillonite (Figure 2a). Points of Martian targets are along the straight line, indicating an absence of open-system alteration.

Moreover, CIA can be reflected by the intensity ratio between Al and (Al + Na + Ca + K) (Figure 2b). The points of igneous calibration targets including Olivine, Norite, Basalt, and Hypersthene lie along a straight line, while Nontronite and Montmorillonite are at the right of the line. Points of Martian materials are

along the straight line, indicating low CIA and low degree of chemical alteration.

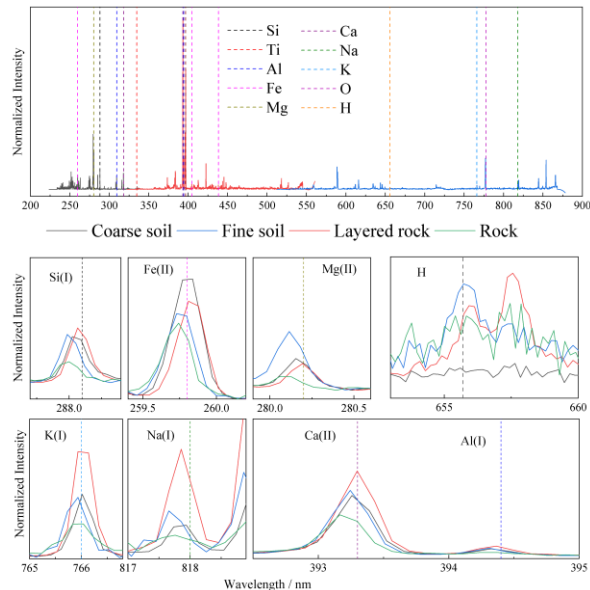


Figure 2 LIBS spectra of Martian soils and rocks shown in Figure 1. Dotted lines are emission lines of major elements according to the NIST database [11].

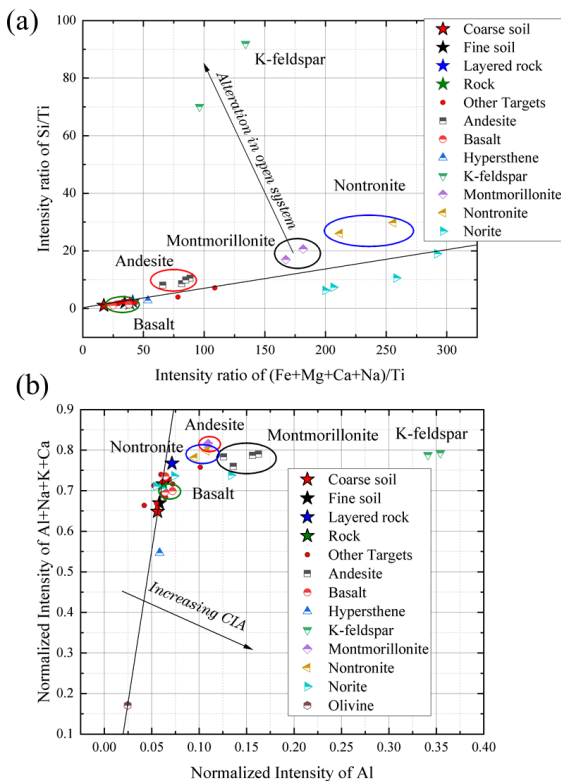


Figure 3 Intensity comparison (Si/Ti vs $(\text{Fe}+\text{Mg}+\text{Ca}+\text{Na})/\text{Ti}$, $\text{Al}+\text{Na}+\text{K}+\text{Ca}$ vs Al) of Martian targets and calibration targets.

On-going and Future Work: The quantitative compositions have not been obtained using MarSCoDe spectra. We have prepared more than 300 standards and will collect their LIBS spectra using the MarSCoDe prototype for the future work. Reliable compositions can be derived using the model and will provide critical clues for the chemical alteration of VBF at the Tianwen-1 landing site.

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