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GPR Measurements of Subsurface Structures of Lacustrine Sediments in the Qaidam Basin

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Abstract

The stratigraphic profile of paleolakes on Mars preserves a record of past climatic, hydrological and sedimentary environment. Future martian missions will employ ground penetrating radar (GPR) on board rovers to investigate the shallow subsurface structure of paleolake basins. In this case, ground experiments are required to test the ability of GPR. This study performs GPR experiments operating at 100 MHz and 200 MHz in Dalangtan Palaya of Qaidam basin, one of the analogue sites for martian paleolake environments, to detect the subsurface structure of lacustrine sediments and measure the relative permittivity of sediments with both laboratory instrument and GPR data.

1. Introduction

Paleolakes on Mars could be potential habitable environments, where past climatic, hydrological and sedimentary environment information and possible biomarkers are preserved, so they are prioritized candidates of in situ and sample return landing sites for Martian missions [1]. Radar could be used to detect the structure and distribution of buried lacustrine sediments in addition to the layered sediments exposed by outcrops and rims of craters. However, obiter radar sounders rarely detect the subsurface reflector in open basin lakes [2]. Future Martian missions plan to bring GPR on board the rover to investigate the subsurface structure and search for sample locations, e.g. the WISDOM, RIMFAX, and the subsurface penetrating radar on China's 2020 Mars mission.

In this work, we perform analogy study of GPR experiments in Dalangtan Playa, Qaidam basin (Fig. 1) on Earth to find out if it is applicable to detect subsurface paleolake sediments and the hydrated material with GPR and measure dielectric properties of deposits formed by lacustrine processes. In addition, we use GPR to study the formation process of polygonal patterned terrain, which also have been identified in paleo-lake basins on Mars [3]. This result also sheds light on interpreting the formation mechanism of raised-rim polygonal structures on Mars.

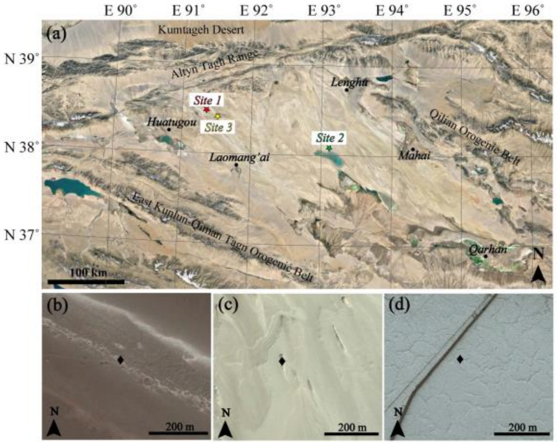

Figure 1: Locations of GPR measurements in Qaidam Basin. (a) Satellite image of the Qaidam Basin. Site 1, site 2, and site 3 are GPR surveying sites, which is shown in (b), (c), and (d), respectively.

2. Data and Method

The instruments performed for the surveying was pluseEKKO system (Sensors & Software, Inc.) using unshielded antennas with separate transmitter and receiver. The radar system operating at 100 MHz and 200 MHz worked in reflection mode. In site 1 and site 2, the survey lines were located on the top flat of the yardangs, whereas the survey lines in site 3 were on the surface of the polygon terrains. In addition to GPR measurements, we also measured the permittivity of samples collected in three survey sites by using the Keysight PNA N5230A network analyzer in the laboratory. We collected two modes of radar data: common offset (CO) and common midpoint (CMP). The relative permittivity of subsurface layers can be derived from the velocity analysis based on CMP data.

3. Results and Discussions

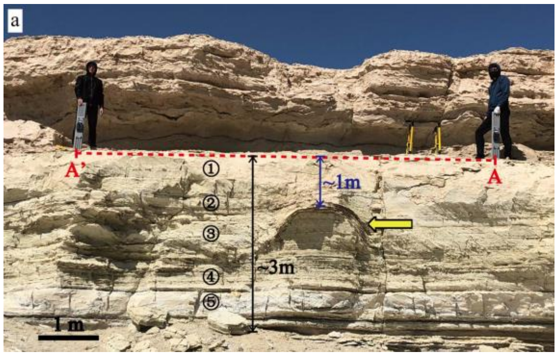

Figure 2: Image of the yardang at site 2.

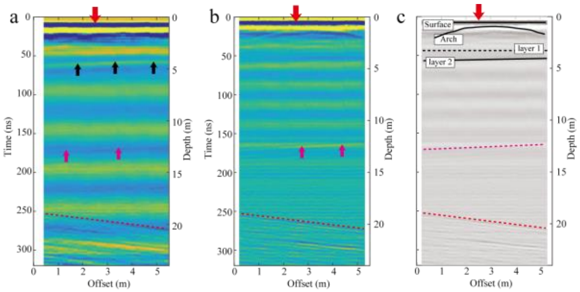

Figure 3: Site 2. (a) Radargram of 100 MHz CO data. (b) Radargram of 200 MHz CO data. (c) Interpretation of the subsurface reflections.

We collected 5 samples from each distinguishing layer of the outcrop of the yardang (Fig. 2). All the samples are mudstones which are easy to be eroded. The relative permittivity of the samples is 3.79-4.38. Reflectors from an arched anomaly are recognizable in Fig. 3(a, b). The depth of the top of the arched anomaly is ~1 m (Fig. 3). Multiple waves (light bars in Fig. 3) in the CO radargrams show multiple horizontal layers, which have similar thicknesses, strongly influence the detection of this yardang. Black arrows in Fig. 3 (a) denote the interface between layer 1 and layer 2, but reflections are hard to distinguish in radargrams. A tilted layer indicated by dashed red lines is confirmed at the depth of ~20 m because the sloped reflections firstly emerge at the location. Pink arrows denote another possible subsurface layer with a slight slope at the depth of 12.5 m, which is not exposed by the outcrop.

Results at site 3 suggest that the subsurface structures under polygon rim are different from those under polygon interior. An obvious reflector at the depth of 3.27- 3.73 m is observed under polygons with permittivity value is much lower in rim region than in interior area, which could be explained by different amount of water/brine content. The finding will contribute to the formation mechanisms of polygon terrains and help GPR search for sample locations related with potential biological traces.

4. Conclusions

The sediments of three sites in Qaidam Basin have varied compositions, density and porosity, and have a wide range of relative permittivity values, which could be used as terrestrial reference for future GPR data interpretation. The GPR penetration depth of lacustrine sediment could reach 20 m in our experiments. The ground experiments suggest that similar GPR on Martian rover could detect the near-surface structure of lacustrine sediments, e.g. deposition anomaly, interfaces of drastic permittivity change such as buried ice/brine considering the design frequency is close to our equipment or even lower.

Acknowledgements

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