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Very high-resolution ground magnetics characterisation of hydrothermal processes in the Danakil depression

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Abstract

Understanding hydrothermal processes in salts has applications on Mars, where thick salt (sulfate) sequences are common and past or present hydrothermal systems probably widespread. Due to dissolution, hydrothermal circulation alters rock magnetization. High-resolution magnetic surveying is therefore able to distinguish between areas of strong and weak hydrothermal activity, as well as associated structural discontinuities. We present preliminary results from very high-resolution magnetic surveying at unprecedented resolution in Lake Asale, Danakil depression, near Dallol. Preliminary results indicate that hydrothermal circulation patterns as from the survey are very well correlated with geologic evidence at surface such as open fissures, hydrothermal pools and noise generated by subsurface bubbling.

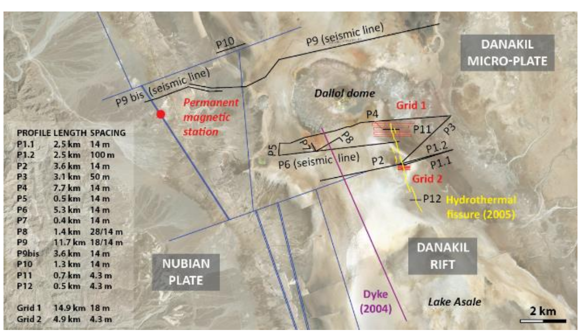

Figure 1: Location of the ground magnetics profiles and grids. Yellow: YLF [5]; violet: dyke intruded in 2012 [10], blue: faults identified by seismics [7].

1. Introduction

Hydrothermal systems should have been common in the history of Mars, based on rover visits to impact craters [1-2] as well as very long-lasting shield volcanism activity [3]. From orbit, thick sequences (kilometers) of sulfate-rich rocks have been advocated to have formed by hydrothermal precipitation [4]. In order to understand better how hydrothermal circulation proceeds in thick salt accumulations, a very high resolution ground magnetics survey was conducted in Lake Asale, where ongoing hydrothermal activity has been identified [5], and occurs, from borehole and seismic data ([6-8]), in a 0.5-2 km thick salt sequence overlying a basement of controversial composition. Calculations showed that large convection cells in the salt can explain salt disturbance observed in seismic profiles [9].

2. Study area

Data were obtained in January 2019 in the northern and southern vicinity of the Dallol dome (Figure 1). We focus here on the Yellow Lake hydrothermal fissure (YLF), mapped in January 2018, which is active since 2005 [5].

3. Data acquisition and processing

Ground magnetics surveying was conducted with two high precision Overhauser magnetometers GemSystems GSM-19 throughout the survey. A base magnetometer installed temporarily 5 km west of the Dallol dome collected ambient scalar magnetic field every 1 minute to correct the other magnetometer data for diurnal variation. We collected 12 long survey profiles and 16 shorter profiles for gridding across the YLF. The magnetic field data were collected 1.8 m above the ground with constant spacings, usually 4.3 or 14 m, exceptionally 18, 28, 50 or 100 m (Figure 1). GPS location was acquired one point ahead of the magnetic field measurement points along the survey line within 3 m horizontal accuracy.

Most geologic features visible at the surface of the salt flat at a short distance from the survey lines were also recorded in a notebook and photographed.

To investigate short-wavelength surface processes taking place in the salt layer such as hydrothermal circulation and local sediment deposition, we removed wavelengths longer than 2 km due to large-scale tectonic and magmatic features.

4. Results

The gridded magnetic anomaly is shown in Figure 2. Many low-amplitude (5-10 nT), short-wavelength magnetic anomalies are related to hydrothermal features in the middle of the grid. Surprisingly, the YLF itself, although active in places, is not defined by a specific trend. The zone of highest anomaly rather corresponds to the intersection between the YLF and a NW-trending fracture system usually poorly defined on the ground, but well marked by lower magnetization. Unfractured areas of active hydrothermal active are equally marked by low and high anomaly peaks. Anomaly peaks on the western part of the survey are probably due to hydrothermal circulation as well. Conversely, the eastern, hydrothermally inactive area shows smooth anomalies.

5. Summary and Conclusions

The observed short wavelength magnetic anomalies are derived from the cumulative effects of a number of randomly distributed upwelling hydrothermal vents as well as fracture-controlled vents. These anomalies are only identified on near-surface magnetic data and cannot be seen on data acquired at a higher altitude such as aeromagnetic data. The collection of near-surface magnetic data allows to infer the presence and patterns of hydrothermally active areas that are not observed at the surface.

Acknowledgements

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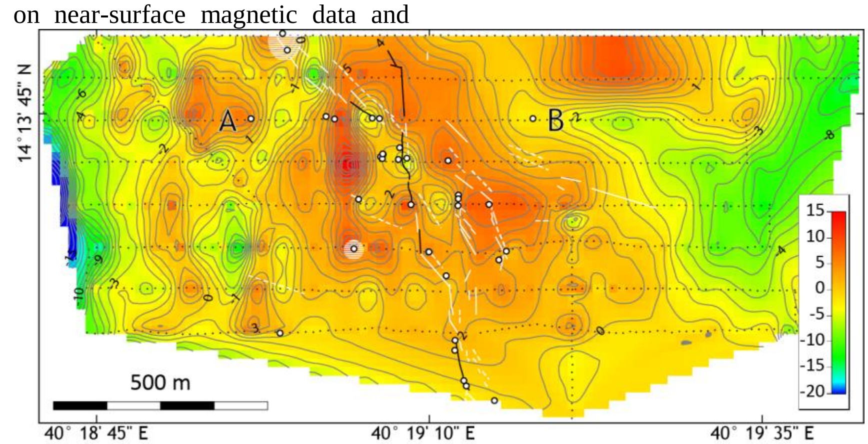

Figure 2: Gridded short-wavelength magnetic anomaly (nT) in the northern part of the YLF (Grid 1 on Figure 1). Gridding was done using natural neighbour interpolation from 874 data points (black dots). Contours spacing is 1 nT. Black lines indicate active fissure segments. Solid white lines other well defined fissure segments. Dashed white lines are poorly defined fracture lines visible on satellite imagery. White dots indicate surface evidence of hydrothermal activity during the survey: either subsurface bubbling with salt fumarole activity, bubbling salty pools (Ø < 1 m), or elongated pools along fissure. The light blue pattern on top corresponds to recent sulfide resurfacing, and the white pattern corresponds to a very actively bubbling salt salt lake of diameter ca. 30 m fed by local surface streams. The surface between dots A and B is muddy salt.