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A physico-chemical and geo-microbiological study of ten different lakes located in the Danakil depression

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Abstract

The Danakil depression harbors one of the best representative volcanic rift zone analogue to Martian rift zones. It is also one of the most extreme places on Earth, located in a salt desert at the confluence of three tectonic plates. In the north east of the Danakil depression, the Dallol volcano is surrounded by several very different sized and shaped lakes. Ten of these lakes were extensively characterized during the Europlanet 2018 Danakil field expedition. The *in situ* measurements showed the extreme physicochemical nature of all ten lakes. The laboratory analyses of rock, water and filtered samples confirm the *in situ* observations of the extreme nature and add that the environment of the ten lakes is dominated by salty minerals like halite, sylvite and anhydrite. Samples of six different lakes contain extractable DNA which is currently further investigated. Elucidating the identity of the microorganisms and finding the logic link with their extreme physicochemical habitat might provide better insights on how microbes are able to survive in extreme volcanic rift zones.

1. Introduction

Volcanic rift zones are among the most emblematic analogue features on Earth and Mars [1, 2]. Most of these volcanic rift zones are extreme environments, not only for the physical parameters like temperature and humidity, but also from a chemistry point of view. The region of the Dallol volcano located in the Danakil depression (Ethiopia) is considered as one of the most extreme places on Earth. The water of ponds and lakes in the vicinity of the Dallol volcano evaporates quickly, leading to very extreme physicochemical conditions. So the Dallol region is the ideal place to investigate whether and how microbes are able to survive such harsh physicochemical conditions. To make this investigation of extremes as reliable as possible well designed and robust *in situ* field sampling techniques are required. Not only the preservation of the geochemistry of samples has to be ensured, but it is also necessary to guarantee that samples have not been contaminated with foreign microorganisms.

2. Site location and description

The Europlanet 2018 Danakil field expedition made *in situ* sampling of the rift zone of the Dallol volcano possible. The names, the GPS location and the type of samples gathered, are summarized in table 1.

Table 1: The names and the location of the ten lakes that were sampled during the Europlanet 2018 Danakil field expedition.

	GPS location	rock samples	water samples	filtered samples
Central green pool	14°14'10.8" N 40°18'00.5" E	Yes	Yes	Yes
Left green pool	14°14'10.6" N 40°18'00.2" E	Yes	Yes	No
Right yellow pool	14°14'10.8" N 40°18'00.8" E	No	Yes	Yes
White chimney	14°14'11.5" N 40°17'59.5" E	Yes	Yes	No
Black lake	14°13'18.4" N 40°17'10.6" E	Yes	Yes	No
Yellow lake	14°12'48.1" N 40°19'17.1" E	Yes	Yes	No
Fault zone Yellow lake	14°13'40.4" N 40°19'08.1" E	Yes	Yes	No
Fault zone Red lake	14°13'41.7" N 40°19'06.3" E	Yes	Yes	Yes
Ashalla karst hole	14°06'57.6" N 40°20'53.2" E	Yes	Yes	No
Karum Lake	n.a.	Yes	Yes	No

The first four lakes are lakes located at the main outcrop of the Dallol volcano. Yellow lake, Fault

zone Yellow lake and Fault zone Red lake are three lakes located in a previously unreported 4.5 km long hydrothermal fissure on the Lake Asale salt flats, the Erta Ale - Dallol segment of the southern Red Sea rift. It is considered as one of the best geological analogues of Martian rift zones [3]. To our current knowledge we present here the first data of the Fault zone Yellow lake, Fault zone Red lake and the Ashalla karst hole, discovered near a huge diapir in the salt plane of the Danakil depression.

3. Mineralogy

The rock samples, mainly composed out of very hygroscopic minerals, were taken and excellent preserved in heat-sealed Aluminium – Polyethylene coated vacuum bags. All our mineralogical analyses, XRD, SEM-EDX confirm that the geology in the close proximity of the ten lakes is dominated by the mineral salts halite and sylvite. Other observed but less dominant minerals are gypsum, kutnohorite magnesian, anhydrite, ankerite, bischofite, carnalite, tachyhydrite.

4. Chemistry

All ten lakes show show very high ionic conductivity values (EC), starting from a value of 373 [$mS.cm^{-1}$] for the Ashalla karst hole and going up till a value of 598 [$mS.cm^{-1}$] for the Yellow lake. The latter thus seems to be most salty lake of all ten investigated lakes. pH was the lowest, highest acidity level, in the four major outcrop lakes with values near 0 and not passing 1. The other lakes were a little bit less acidic, but the pH never went up above a value of 4.6. The element analyses performed on representative water samples of all ten lakes are in good agreement with the observed mineralogy. The dominant cations are: $Na^+>K^+>Mg^{2+}>Ca^{2+}$ for the four lakes of the major outcrop of Dallol, $Mg^{2+}>Ca^{2+}>Na^+>K^+$ for the Black lake, $Ca^{2+}>Mg^{2+}>Na^+>K^+$ for the Yellow lake, $Na^+>Ca^{2+}>Mg^{2+}>K^+$ for the Fault zone yellow lake, the Ashalla karst hole and the Karum lake and $Ca^{2+}>Mg^{2+}>K^+>Na^+$ for the Fault zone red lake. The major anion for all the lakes is clearly Cl^-. F^- and Br^- are present in minor, millimolar, concentrations in the major outcrop lakes, the Yellow lake, the Fault zone yellow and red lake. No F^- is detected in the Black lake, the Ashalla karst hole and the Karum lake.
Water samples taken with the newly developed “Closed vial sampling technique” showed identical result than samples taken in open bottles.

5. Microbiology

Until now, detectable DNA was extracted out of rock samples of six different lakes. Further investigation has to be performed to find out whether this DNA originates from surviving microorganisms or has to be considered as an external contamination. Positive identification of surviving microorganisms might provide a better understanding of how microbes are able to survive such extreme volcanic rift zones.

6. Summary and Conclusions

At least two different types of samples, rock and water, could be collected from all of the ten investigated lakes of the Dallol volcano region (Danakil depression, Ethiopia). Rock as well as water samples were excellent preserved during transport and storage. The mineralogy and observed chemistry were found to be in complete agreement with each other and data reported in reference literature. Positive DNA extraction from samples of six different lakes gives a first indication of the possible presence of microbes. Further investigation aims to elucidate whether the DNA originates from real surviving microorganisms.

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