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Discovery of a hydrothermal fissure in the Danakil depression

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Abstract

Volcanic rift zones are among the most emblematic analogue features on Earth and Mars [1-2], with expected differences mainly resulting from the different value of a single parameter, gravity [3]. Beyond the understanding of the geology, rift zones provide appropriate hydrothermal environments for the development of micro-organisms in extreme conditions which depend at first order on endogenic processes, and weakly on the planetary climate conditions. The Europlanet 2018 Danakil field campaign enabled identifying 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 and one of the best geological analogues of Martian rift zones. We present the first geologic analysis of this fissure and preliminary data on its hydrochemistry.

1. Introduction

The Dallol-Erta Ale rift, a continental segment of the Red Sea rift, separates the Nubian tectonic plate and the Danakil microplate. Volcanic activity associated with magma centres has been frequent, with magma chamber withdrawal recorded in the last 25 years at the Gada ‘Ale, Alu - Dala Filla, Erta ‘Ale volcanoes and a sub-Dallol magma body [4-7]. A 15 m diameter pond purportedly formed in response to a phreatic eruption next to Black Mountain in 1926 [8]. Magmatic accretion through dyke injection is however intermittent, with the last seismicity-related intrusion in Oct-Nov 2004 [6]. Interferometric modelling inversion suggests that this dyke, injected from beneath the Dallol dome, was accompanied by normal faulting. Seismic normal faulting along the rift margins north of Dallol has been recorded in 1993 [9].

2. Yellow Lake Fissure

A 4.5 km long fissure parallel to the local Danakil rift trend displaying echelon patterns (Figure 1) was identified north and south of Yellow Lake (also known as Oily Lake and Gaet’Ale). It is manifested by (1) salt polygon geometry directly influenced by the underlying fracture; (2) bubbling pools; (3) dead pools; (4) shallow sinkholes; (4) a variety of other micromorphologies related to free or pressurised upflow of gas and fluids; and (5) rare evidence of fumarolic activity. In this context, the Yellow Lake appears as a possible salt karst feature [10] the location and growth of which is controlled by relay zone deformation between the fissure segments.

3. Hydrothermal fluids

The physico-chemistry of fluids and minerals from two small pools located along the Yellow Lake Fissure, as well as the Yellow Lake, have been analysed (Table 1).

Table 1: Characterisation of hydrothermal fluids and main mineral composition. pH and conductivity ($\mu S.cm^{-1}$) are measured in the lab at 25°C.

	Yellow pool	**Red pool**	**Yellow Lake**
T (°C)	32.0	35.1	41.2
pH	3.7	3.5	3.4
Conductivity	395	494	598
Minerals	Halite Tachyhydrite	Sylvite Carnalite	Halite Sylvite Tachyhydrite
Dominant cations	$Ca^{2+}>Na^{+}>Mg^{2+}>K^{+}$	$Ca^{2+}>Mg^{2+}>K^{+}>Na^{+}$	$Ca^{2+}>Mg^{2+}>Na^{+}>K^{+}$

The three pools all contain warm bubbling water and are extremely salty. From a chemical point of view, the three pools are quite similar, although small differences are observed for some parameters. Salt precipitations contain Cl^{-} as the main anion, while various cations (Ca^{2+}, Mg^{2+}, Na^{+}, and K^{+}) are present in different proportions from one pool to another, resulting in the precipitation of halite, sylvite, tachyhydrite and carnalite.

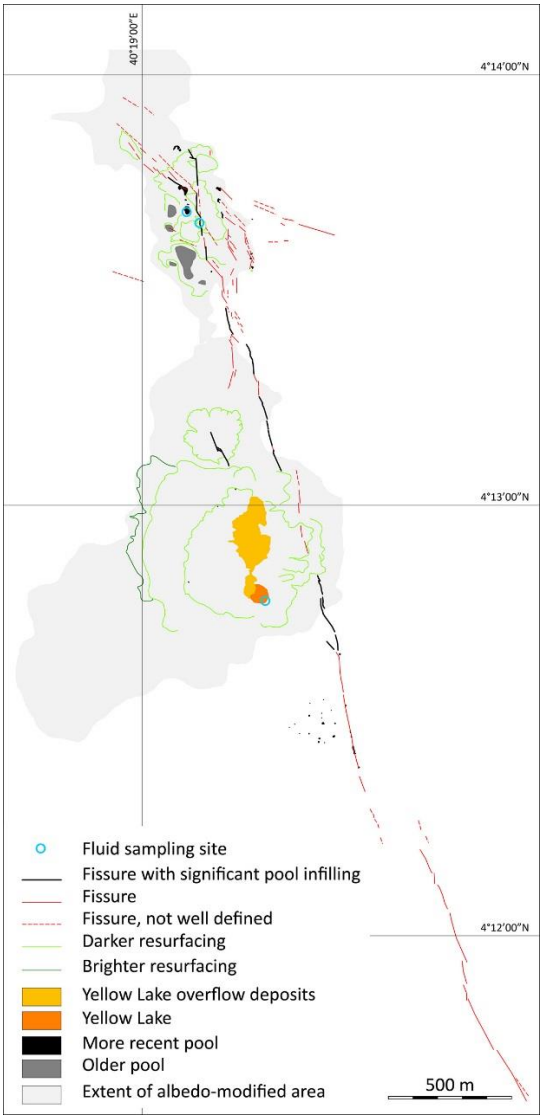

Figure 2. Map of the Yellow Lake Fissure area

4. Timing and origin

The fissure was tracked back using Landsat 7, ASTER, and OrbView-3 satellite images. It is well developed on June 10th, 2005. On February 18th, 2005 it is not apparent on Landsat and ASTER images. Hydrothermal activity increased at Yellow Lake and along the fissure future path in the preceding months. The fissure is parallel to the dyke that propagated in 2004, which is located 2.5 km westward [6].

5. Perspectives

More satellite data are being collected. Systematic time series analysis will be conducted to determine the evolution of tectonic and hydrothermal activity since the early 2000's. A field magnetic campaign is being prepared to determine the evolution of the geometry of the fissure at depth through its influence on surrounding rock alteration, and identify potentially associated magmatic intrusions. The origin and composition of hydrothermal fluids will be determined and compared. Extremophiles have been identified and their

DNA analysis is in progress, shedding light on the possible nature of extremophiles to be sought on similar sites identified on Mars.

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