Fluid-driven anthropogenic micro-seismic activity while drilling towards supercritical conditions in the Larderello-Travale geothermal field

[1,2]Riccardo Minetto, [3]Domenico Montanari, [1]Thomas Planès, [3]Marco Bonini, [3,4]Chiara Del Ventisette, [1]Verónica Antunes and [1]Matteo Lupi
[1]Department of Earth Sciences, University of Geneva, Geneva, Switzerland, [2] Université Grenoble Alpes, Université Savoie Mont Blanc, CNRS, IRD, IFSTTAR, ISTerre, Grenoble, France,
[3]Institute of Geosciences and Earth Resources, National Research Council of Italy (CNR), Florence, Italy, [4]Department of Earth Sciences, University of Florence, Florence, Italy

INTRODUCTION

SUPERCRITICAL FLUIDS

Fluids in supercritical conditions (T > 374 ◦C and P > 21 MPa for pure water) have several times more power-producing potential compared to fluids in a liquid or vapor phase. However, their exploration is hindered by engineering challenges related to the extreme temperatures, chemical compositions, and pressures that can be encountered at depth

VENELLE 2

In this study we investigate the microseismic events recorded during the deepening of the Venelle 2 well, which is one of the most recent attempts to tap supercritical fluids. The drilling took place in 2017 at the Larderello-Travale geothermal field (Italy), in the framework of the DESCRAMBLE project.

The drilling attempted to reach supercritical fluids supposedly located at 3000 m depth, but it was stopped at 2,900 m after encountering prohibitive temperatures greater than 500 ◦C. Supercritical conditions were measured, but no supercritical fluids were detected.

DATASET

The data used for this study were acquired from 23 June 2017 to 21 January 2018. The acquisition was carried out using a local seismic network composed of nine broadband stations (eight temporary stations of the University of Geneva and one station of the public INGV network). See Figure 3.

METHODS

We record events that greatly differ from typical tectonic earthquakes. Such signals were never observed in the area before. To characterise them we adopted the methods explained below.

EVENT DETECTION

The seismic events were detected by cross-correlating a template with the continuous recordings at station ESTA (template matching). The template was selected among the events part of a particularly energetic swarm. A correlation coefficient of 0.40 was set as threshold.

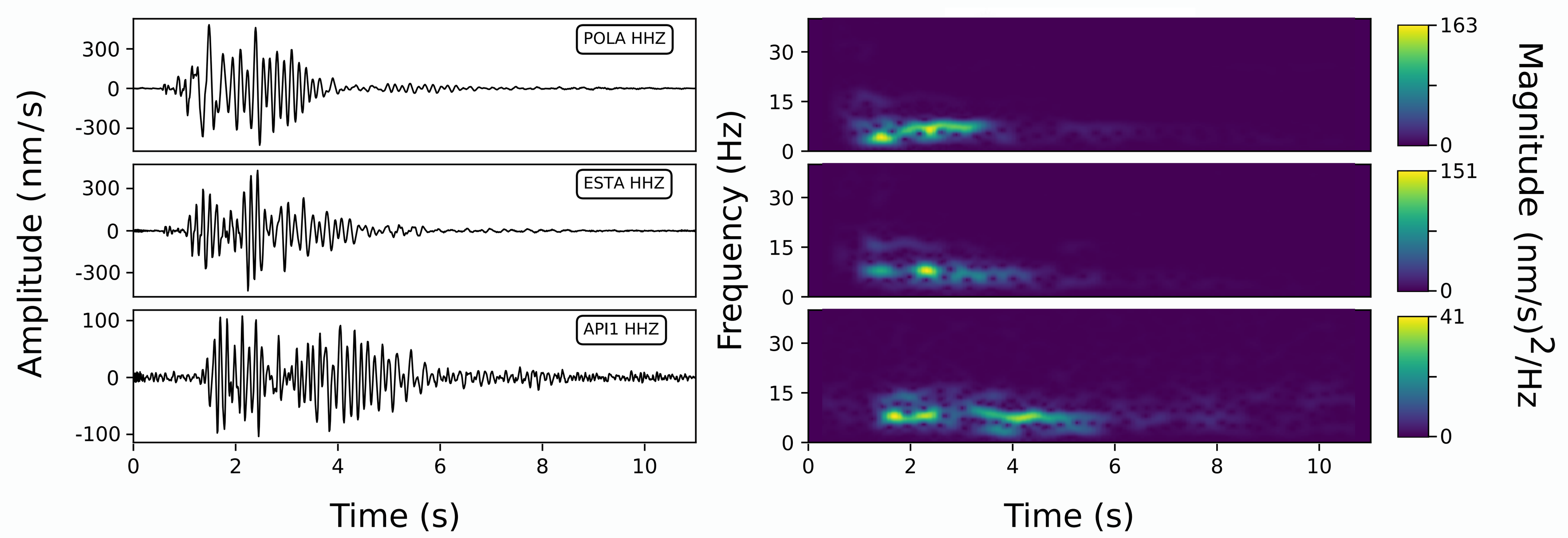
EVENT LOCALISATION

The location of the events was obtained using a grid search method based on cross-correlation. Only four stations (the ones with a sufficiently high signal-to-noise ratio) were considered . The wave velocity was set at a constant value of 4,000 m/s.

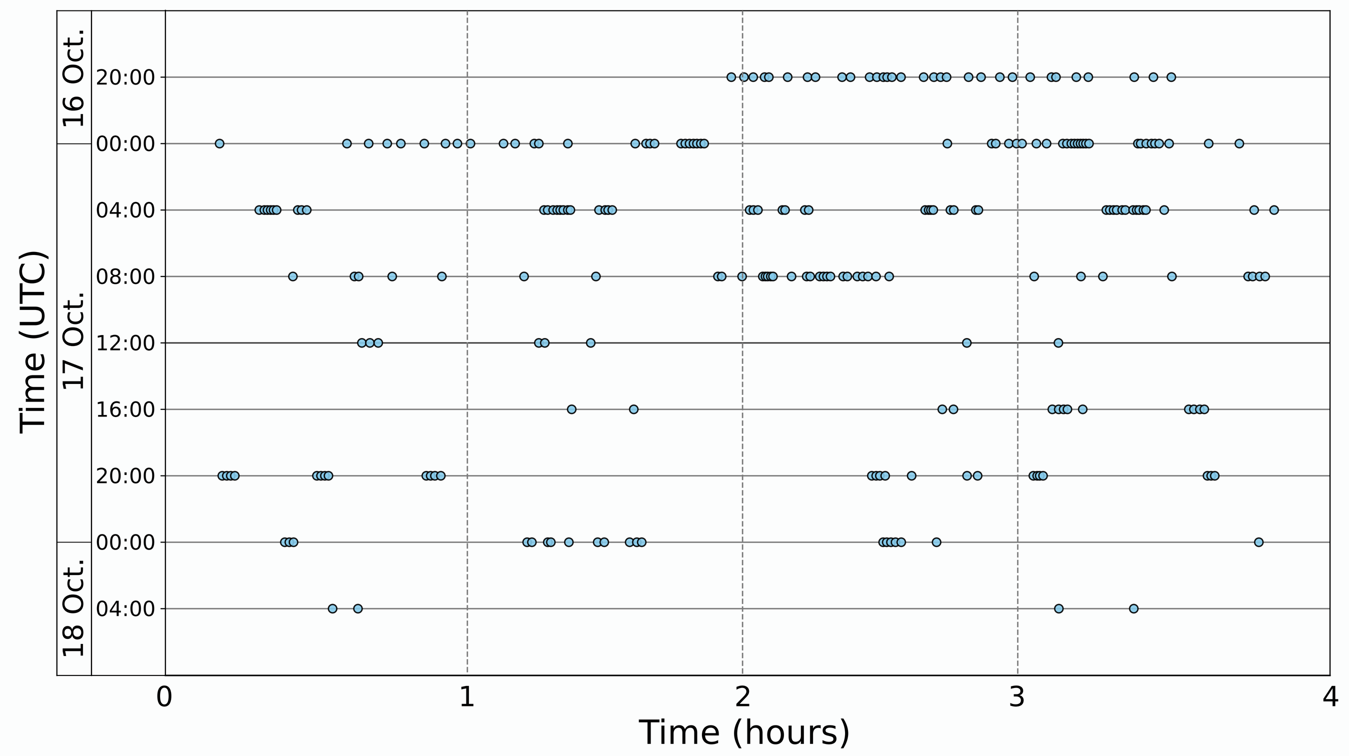
In order to improve the locations, the signal-to-noise ratio of the input waveforms was improved by stacking events with correlation coefficient > 0.9.

RESULTS

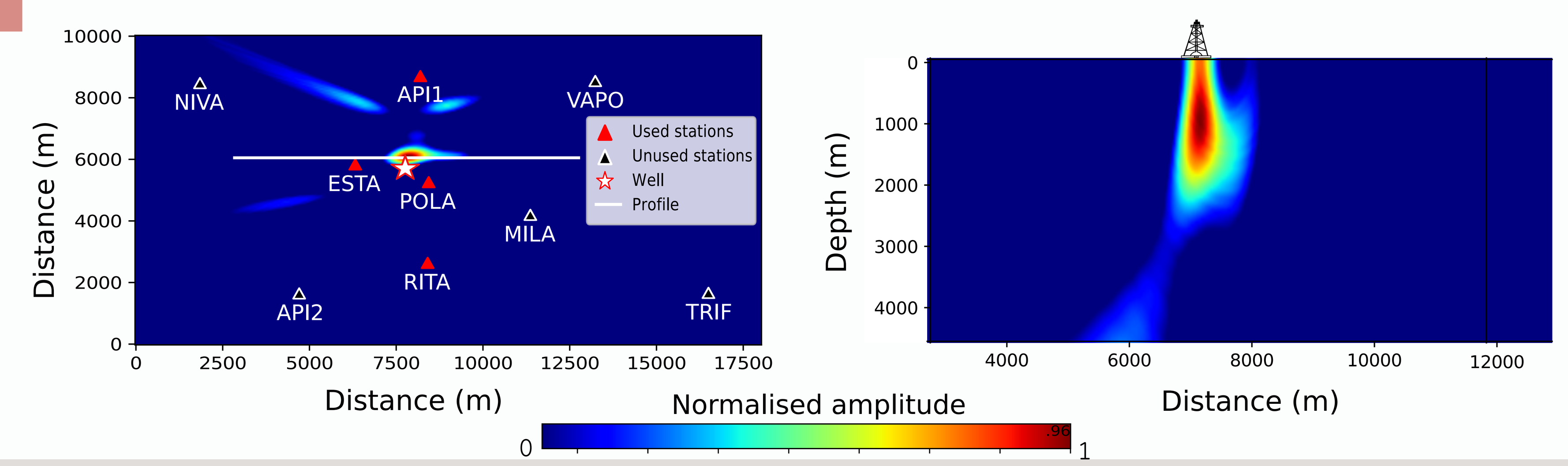
1 The events have very high correlation coefficients (>0.9), a low frequency content (< 15 Hz), and their waveforms greatly vary from station to station. P, and especially S wave arrivals are unclear. Their amplitude is larger at stations that are close to the well.



2 The events are observed until two weeks after the closure of the well, and they occured in spasmodic swarm sequences. The most energetic of such swarms (shown below) counted 247 events and preceded a major loss of circulation experienced at the Venelle 2 well at about 2700 m depth.



3 The locations obtained with the cross-correlation-based method indicate a source located below the Venelle 2 well. Notice that the available data do not allow to well constrain depth.



INTERPRETATION

The location of the epicenters, and the fact that the main swarm occurred a few days before an important loss of circulation in the well are evidence of a possible link with the Venelle 2 drilling.

The features showed in Figure 1 recall long-period (LP) signals that have often been associated with fluid motion at depth.
We suggest that the events are due to advective processes promoted by the perturbation imposed by the drilling at depth.

We also propose that the swarm recorded few days before the loss of circulation may have been generated in a region where supercritical conditions may be found.
When the loss of circulation occurred at about 2700 m, temperatures above 400 ◦C and pressures of about 30 MPa (i.e. supercritical conditions) were present. Mud density was decreased and mud was then finally replaced with water.

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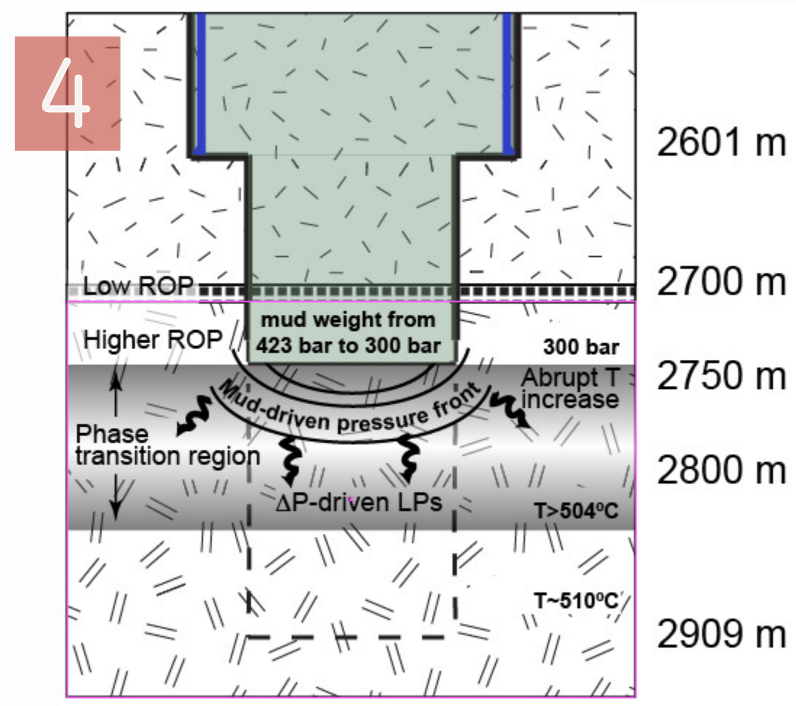

The sudden unload of internal pressure of the well may have caused a disequilibrium within the geological formations. The change of the pressure state may have led to a mud-driven pressure front that resulted in an advective fluid flow and potentially to a phase transition from supercritical to fluid phase. See Figure 4.

REFERENCES

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