Seismic catalogues of the 2018-2019 volcano-seismic crisis offshore Mayotte, Comoro Islands
(http://doi.org/10.5880/GFZ.2.1.2019.004)

Simone Cesca[1], Sebastian Heimann[1], Jean Letort[2], Hoby N. T. Razafindrakoto[1], Torsten Dahm[1], Fabrice Cotton[1]

1. *GFZ German Research Centre for Geosciences Potsdam, Germany, Section 2.1 Physics of Earthquakes and Volcanoes*
2. *IRAP - Observatoire Midi Pyréenées, Toulouse, France*

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2. Citation

When using the data please cite:

Cesca, S.; Heimann, S.; Letort, J.; Razafindrakoto, H. N. T.; Dahm, T.; Cotton, F. (2019): Seismic catalogues of the 2018-2019 volcano-seismic crisis offshore Mayotte, Comoro Islands. V. 1.0 (October 2019). GFZ Data Services. http://doi.org/10.5880/GFZ.2.1.2019.004

The data are supplementary material to:

Cesca, S., Letort, J., Razafindrakoto, H.N.T., Heimann, S., Rivalta, E., Isken, M.P., Nikkhoo, M., Passarelli, L., Petersen, G.M., Cotton, F., Dahm, T. (2020). Drainage of a deep magma reservoir near Mayotte inferred from seismicity and deformation. Nature Geoscience, 13(1), 87–93. https://doi.org/10.1038/s41561-019-0505-5

3. Abstract

In May 2018 a volcano-seismic sequence accompanied the upward migration of a magmatic intrusion from Moho depth to the seafloor, which led to the drainage of the deep magmatic reservoir and to the birth of a submarine volcano offshore the island of Mayotte, Comoro Islands. This process of magma transport was accompanied by an intense seismic swarm and peculiar long-duration very long period signals. Between 1 January 2018 and 1 May 2019 we detected 407 sources of very long period signals and 6990 volcano-tectonic earthquakes. This report collects detection, location and source parameters catalogues for these two sets of earthquake sources.

4. Methods

This document describes the catalogues of very long period (VLP) signals and volcano-tectonic (VT) earthquakes, as discussed in Cesca et al. (2020). Here, methods and data used to create the different catalogues are only briefly discussed; a more accurate description is given in Cesca et al. (2020), which furthermore discusses the different processes of dike migration, undersea eruption, deep reservoir drainage and overburden sagging which are responsible for the seismic activity.

1.1. Very long period (VLP) signals

Long-duration VLP signals at Mayotte are characterized by monochromatic signals with dominant frequencies between ~15.2 and ~15.6 s and durations of up to ~40 min (typically ~ 10 min to ~ 40 min). They have been detected by the simultaneous identification of amplitude increase in the raw waveforms of selected stations at regional distances, after bandpass filtering in the frequency range 0.05 and 0.10 Hz.

VLP source parameters (centroid location and depth, moment tensor components, dominant frequency and damping factor) have been derived assuming a damped oscillating moment tensor by modeling full waveform displacement data at regional distances, using an ad-hoc extension of the grond moment tensor optimization tool (Heimann et al. 2018).

1.2. Volcano-tectonic (VT) earthquakes

VTs have been studied separately using two approaches: (1) a single station analysis, based on recordings at the YTMZ strong motion station on Mayotte, and (2) a regional moment tensor inversion, based on the modelling of waveform data of broadband stations at regional distances.

1.2.1. VT earthquakes, single station analysis

The visual scanning of YTMZ records from 1 May 2018 to 1 April 2019 led to the identification of 6990 VT events with single station P and S picking, which are included in the first VT catalogue. Out of these 6990 VTs, we identified a subset of 1904 events with better quality. The 1904 VTs have been selected imposing a minimum moment magnitude of 3.5 and a minimum peak ground acceleration (PGA) of 0.001 m/s2, after applying a bandpass filter in the frequency range 0.2-4.0 Hz.

Note that the magnitude condition is imposed after estimating the magnitude, based on the estimated distance to YTMZ (estimated upon the S-P differential time), the measured peak acceleration and a scaling law obtained from larger earthquakes, for which magnitude and peak accelerations were available (see Supplementary Information in Cesca et al. 2020 for more details). The following attributes have been computed for the 1904 VT events catalogue: differential S-P time, PGA, P wave particle motion rectilinearity and orientation, amplitude ratio among horizontal and vertical components of the P wave, and amplitude ratio among the S and P wave amplitudes. Methods details for estimating these attributes are provided in the Supplementary Information accompanying Cesca et al. (2020).

1.2.2. VT earthquakes, regional moment tensor inversion

The last VT catalogue is the result of a regional centroid moment tensor (MT) inversion using the software grond (Heimann et al. 2018). For the MT inversion, displacement full waveforms in the frequency band 0.01-0.03 Hz were fitted in the time domain, assuming different layered velocity models (see Cesca et al. 2020 for details). The procedure provides the following source parameters:

centroid location and depth, scalar moment, magnitude, moment tensor components, DC percentage, CLVD percentage, isotropic percentage and rupture duration.

Note that, beside the fact that the MT inversion was performed for large events only and that the catalogue contains mostly events in the magnitude range Mw 4.5-5.9, few of these events may not be included in the single station catalogues. The general reason is that, due to their signal overlap with other VTs and/or VLPs, their P and/or S seismic phases could not be accurately picked. An alternative reason can be a temporal malfunctioning of the YTMZ station.

5. File description

The content is composed of six seismic catalogues, three referring to VLP sources and three to VT sources, respectively. The size and format of each catalogue are provided below.

1.3. weakVLP_detections.txt: catalogue of detected VLPs, until early May 2019 as discussed in Cesca et al. (2020)

The catalog contains 407 events. Each line of the catalogue (excluding commented lines starting with the symbol "#") corresponds to a single event. Each line, parsed by spaces, provides the following sorted fields: #1 Date: date of the earthquake, formatted YYYY-MM-DD #2 Time: origin time of the earthquake, formatted HH:MM:SS.SSS #3 Magnitude Ms: Mean Ms magnitude estimated from selected regional stations (MSEY, ABPO, LSZ and FURI) #4 Dominant Period [s]: Mean dominant period estimated from selected regional stations #5 Q factor: Mean Q factor estimated from selected regional stations

1.4. weakVLP_detections_extended.txt: catalogue of detected VLPs for an extended time period until August 2019

The catalogue contains 431 events. Each line of the catalogue (excluding commented lines starting with the symbol "#") corresponds to a single event. Each line, parsed by spaces, provides the following sorted fields: #1 Date: date of the earthquake, formatted YYYY-MM-DD #2 Time: origin time of the earthquake, formatted HH:MM:SS.SSS #3 Magnitude Ms: Mean Ms magnitude estimated from selected regional stations (MSEY, ABPO, LSZ and FURI) #4 Dominant Period [s]: Mean dominant period estimated from selected regional stations #5 Q factor: Mean Q factor estimated from selected regional stations

1.5. strongVLP_moment_tensors.txt: catalogue of source parameters for VLPs

This catalogue contains 21 events. Each line of the catalogue (excluding commented lines starting with the symbol "#") corresponds to a single event.

Each line, parsed by spaces, provides the following sorted fields:

#1. Date: date of the earthquake, formatted YYYY-MM-DD
#2. Time: origin time of the earthquake, formatted HH:MM:SS.SSS
#3. Latitude [deg]: centroid latitude
#4. Longitude [deg]: centroid longitude
#5. Depth [km]: centroid depth
#6. Magnitude Mw: estimated by centroid moment tensor inversion

#7. Scalar Moment [Nm]: estimated by centroid moment tensor inversion
#8. Mnn [Nm]: North-North component of the moment tensor (MT) estimated by centroid moment tensor inversion
#9. Mee [Nm]: east-east MT component
#10. Mdd [Nm]: down-down MT component
#11. Mne [Nm]: north-east MT component
#12. Mnd [Nm]: north-down MT component
#13. Med [Nm]: east-down MT component
#14. Strike1 [deg]: strike of plane 1 of the double couple (DC) component of the MT
#15. Dip1 [deg]: dip of plane 1 of the DC component of the MT
#16. Rake1 [deg]: rake of plane 1 of the DC component of the MT
#17. Strike2 [deg]: strike of plane 2 of the DC component of the MT
#18. Dip2 [deg]: dip of plane 2 of the DC component of the MT
#19. Rake2 [deg]: rake of plane 2 of the DC component of the MT
#20. Duration [s]: Resonance duration

1.6. weakVT_detections.txt: catalogue of VTs detected by single station analysis

The catalogue contains 6990 events. Each line of the catalogue (excluding commented lines starting with the symbol "#") corresponds to a single event. Each line, parsed by spaces, provides the following sorted fields:

#1. Date: date of the earthquake, formatted YYYY-MM-DD
#2. Time: origin time of the earthquake, formatted HH:MM:SS.SSS
#3. Date tP: date of the P phase at station YTMZ, formatted YYYY-MM-DD
#4. Time tP: time of the P phase at station YTMZ, formatted HH:MM:SS.SSS
#5. Date tS: date of the S phase at station YTMZ, formatted YYYY-MM-DD
#6. Time tS: time of the S phase at station YTMZ, formatted HH:MM:SS.SSS
#7. tS-tP [s]: differential time among S and P picks at station YTMZ

1.7. weakVT_singlestation.txt: Catalogue of VTs located by single station analysis

This catalogue contains 1904 events. Each line of the catalog (excluding commented lines starting with the symbol "#") corresponds to a single event. Each line, parsed by spaces, provides the following sorted fields:

#1. Date: date of the earthquake, formatted YYYY-MM-DD
#2. Time: origin time of the earthquake, formatted HH:MM:SS.SSS
#3. Latitude [deg]: epicentral latitude
#4. Longitude [deg]: epicentral longitude
#5. Depth [km]: source depth in km; an "f "suffix denotes a fixed depth
#6. Magnitude Mw: estimated upon an empirical relation based on PGA and differential S-P time, which scale with the distance to the earthquake source
#7. tS-tP [s]: differential time among S and P picks at station YTMZ
#8. Backazimuth [deg]: backazimuth estimated from P wave horizontal particle motion
#9. Rectilinearity: P wave rectilinearity coefficient
#10. Ph/z ratio: ratio among P wave amplitude on horizontal and vertical components

#11. Cluster Id: cluster identification, based on joint clustering of differential time and waveform similarity

1.8. strongVT_regional.txt: catalogue of source parameters for VTs File name

The catalogue contains 67 events. Each line of the catalogue (excluding commented lines starting with the symbol "#") corresponds to a single event. Each line, parsed by spaces, provides the following sorted fields:

#1. Date: date of the earthquake, formatted YYYY-MM-DD
#2. Time: origin time of the earthquake, formatted HH:MM:SS.SSS
#3. Latitude [deg]: centroid latitude
#4. Longitude [deg]: centroid longitude
#5. Depth [km]: centroid depth
#6. Magnitude Mw: estimated by centroid moment tensor inversion
#7. Scalar Moment [Nm]: estimated by centroid moment tensor inversion
#8. Mnn [Nm]: North-North component of the moment tensor (MT) estimated by centroid moment tensor inversion
#9. Mee [Nm]: east-east MT component
#10. Mdd [Nm]: down-down MT component
#11. Mne [Nm]: north-east MT component
#12. Mnd [Nm]: north-down MT component
#13. Med [Nm]: east-down MT component
#14. Strike1 [deg]: strike of plane 1 of the double couple (DC) component of the MT
#15. Dip1 [deg]: dip of plane 1 of the DC component of the MT
#16. Rake1 [deg]: rake of plane 1 of the DC component of the MT
#17. Strike2 [deg]: strike of plane 2 of the DC component of the MT
#18. Dip2 [deg]: dip of plane 2 of the DC component of the MT
#19. Rake2 [deg]: rake of plane 2 of the DC component of the MT
#20. tS-tP [s]: differential time among S and P picks at station YTMZ
#21. Backazimuth [deg]: backazimuth estimated from P wave horizontal particle motion
#22. Rectilinearity: P wave rectilinearity coefficient
#23. Ph/z ratio: ratio among P wave amplitude on horizontal and vertical components
#24. Cluster Id: cluster identification, based on joint clustering of differential time and waveform similarity

6. References

Cesca, S., Letort, J., Razafindrakoto, H.N.T., Heimann, S., Rivalta, E., Isken, M.P., Nikkhoo, M., Passarelli, L., Petersen, G.M., Cotton, F., Dahm, T. (2019). Drainage of a deep magma reservoir near Mayotte inferred from seismicity and deformation, Nature Geoscience, in press.

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