A detailed study of the initiation process of a small (M_w4.4) normal fault earthquake in the middle lower crust

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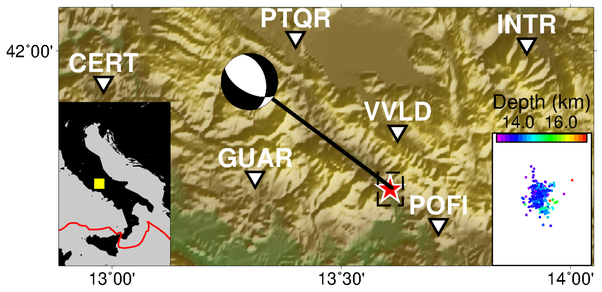
1. Introduction

On 7^{th} November 2019 a small normal faulting earthquake occurred in central Italy:

General mainshock data

Magnitude	M_w 4.4
Lat (°) / Lon (°) / Depth (km)	13.61 / 41.78 / 14.0
NP1: Strike / Dip / Rake	299 / 58 / -120
NP2: Strike / Dip / Rake	166 / 42 / -51
Reported activity	≈ 150 events
# Stations < 100 km	6 (thanks INGV!)



Our goal is to study the activity before and after this quake to better understand the physics and patterns exhibited before and after the shock.

☞ **The patterns and physics in small earthquakes might be similar to the ones of larger events**

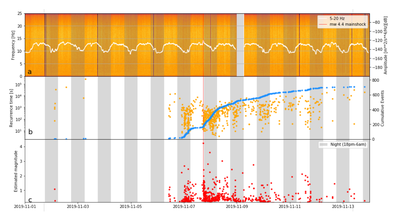
2. Templates

Continuous data from 22/09/2020 to 1 5/11/2020 was scanned (Beaucé et al., 2017) using 23 templates at 6 stations to detect possible hidden events.

Templates

Magnitudes	from M_l 1.1 to M_w 4.4
P / S arrival times	266 (all templates)
SNR > 3	from 5 to 20 Hz ensured

3. Detections



- 714 events
- 165 foreshocks
- 548 aftershocks
- ≈ 7 times more than reported

Significant better detection at night time.

Anomalous activity occurred right before the mainshock (lack of detections, as for other quakes).

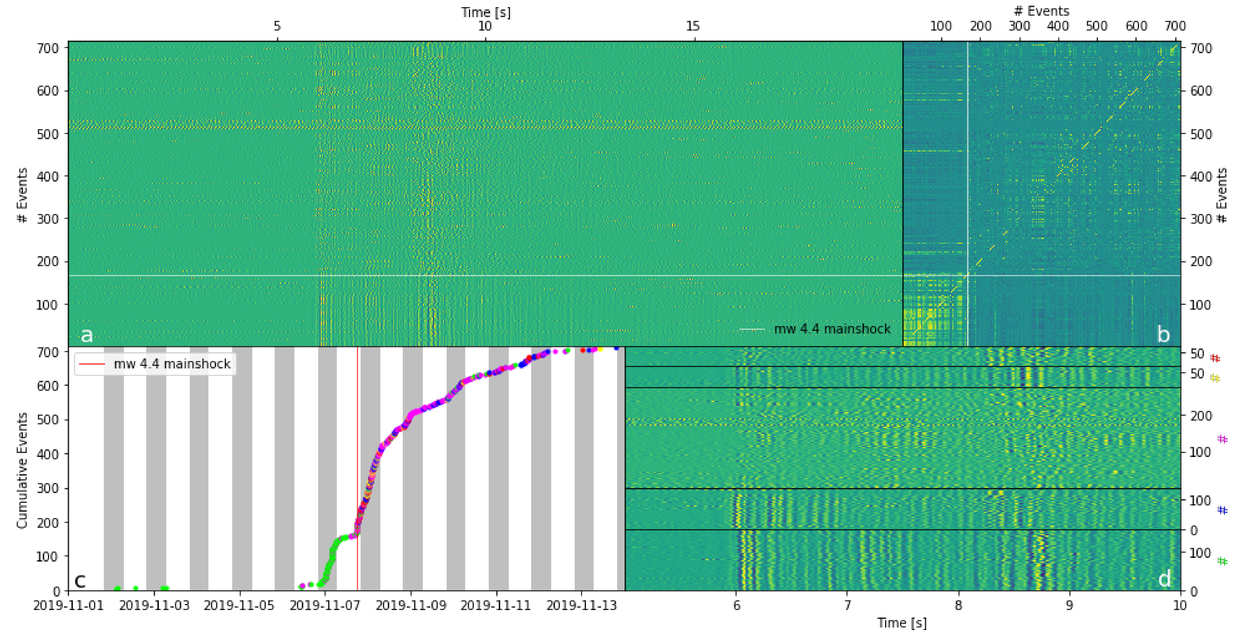
(Kato et al., 2012)

4. Clustering of the seismic sequence

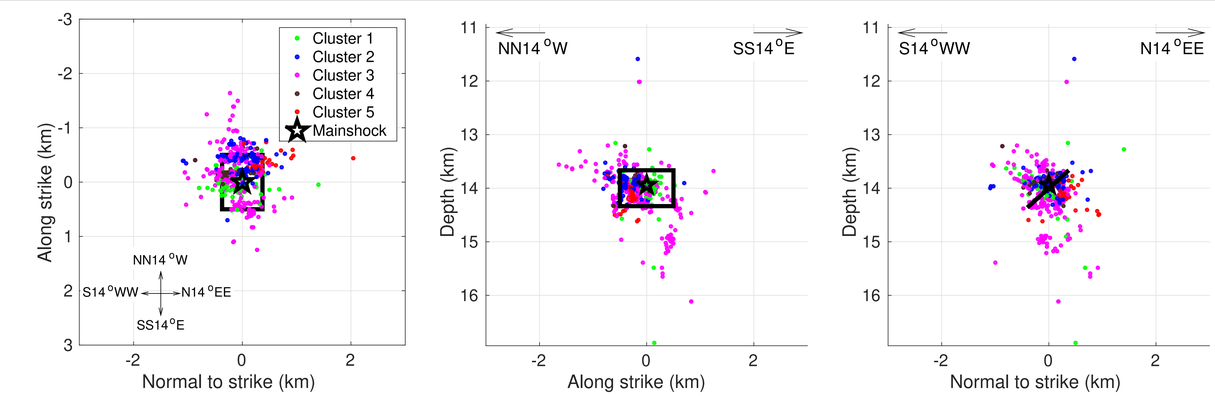
The 714 events were divided into 5 clusters taking as distance-feature the waveform correlation coefficients.

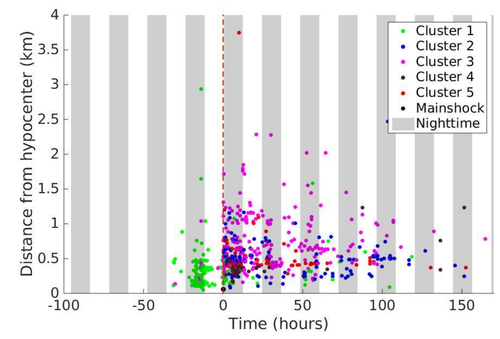
(a) Wiggle plot of 714 events detected. (b) Correlation matrix.

(c) Cumulative plot identifying cluster IDs. (d) Wiggle plot grouped according to cluster IDs.



5. Spatio-temporal evolution of the seismic activity





☞ Cluster 1: High correlated closest shocks to the hypocenter, the foreshock sequence, seems to be along an antithetic fault.

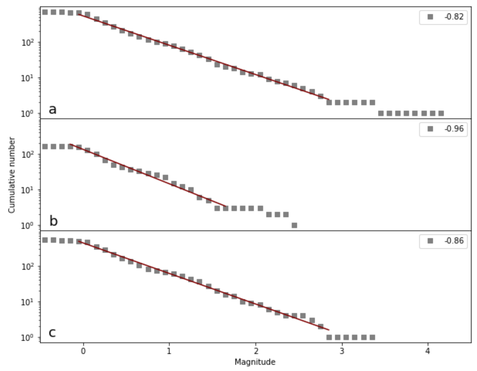
☞ Cluster 2: High correlated aftershocks, at the interface and parallel directions. In 6 days its active volume is reduced.

☞ Cluster 3: Low correlated, spread throughout the volume in parallel or orthogonal patterns.

☞ Cluster 4: High correlated, between 0.25-0.6 km from the hypocenter, occurred during first 12hrs after the mainshock.

☞ Cluster 5: Mostly on the footwall, focused at 0.5 km from the hypocenter, follows parallel and orthogonal directions

6. Stress changes?



The b-value decreased from 0.96 to 0.86 (10 %) before and after the mainshock, respectively.

A significant decrease of magnitudes > 0.5 right before the mainshock is observed. Evidence of a relative change in the differential stress ($\Delta\sigma = \sigma_1 - \sigma_3$)

7. Conclusion & discussion

- High correlated waveforms of foreshocks.
- Relocation agrees with clustering results: there are different phenomena happening!
- Same location, same mechanism: same asperity?
- Foreshocks follow an antithetic direction.
- There are still more shocks but not all stations are able to detect them.
- Foreshock activity moved to smaller magnitudes before the mainshock (sometimes undetectable)

Acknowledgements

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Some references

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