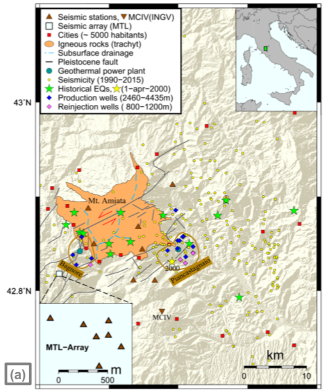
27° International Union of Geodesy and Geophysics - General Assembly | Poster Nr. S06p-314

Analysis of Microseismicity Recorded in the Geothermal Area of Mt. Amiata (Italy)

Thomas BRAUN [1,2], Simone CESCA [3], Francesco GRIGOLI [4], Sebastian HEIMANN [3], Marco CACIAGLI [1,5], Daniela FAMIANI [2], Torsten DAHM [3]

[1] INGV-Observatory, Arezzo (IT) | [2] INGV - Roma1, Roma (IT) | [3] GFZ-Potsdam, Potsdam (DE) | [4] ETH, Zurich (CH) | [5] INGV - Bologna (IT)

thomas.braun@ingv.it | simone.cesca@gfz-potsdam.de | francesco.grigoli@sed.ethz.ch | sebastian.heimann@gfz-potsdam.de | marco.caciagli@ingv.it | daniela.famiani@ingv.it | torsten.dahm@gfz-potsdam.de



SEISMIC ARRAY/NETWORK INSTALLATION

In a joint research collaboration, INGV together with GFZ-Potsdam deployed on Mount Amiata a seismic network for a three years period (06/2015 – 07/2018) in order to study the actual microseismicity recorded in the vicinity of the geothermal power plants of Piancastagnaio (SE) and Bagnore (SW).

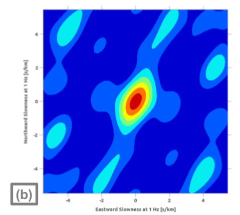


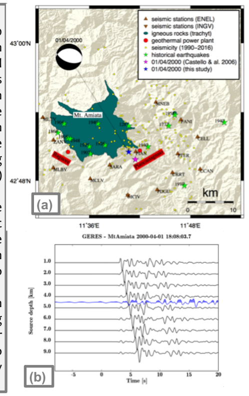
Fig. 1: (a) Configuration of the seismic network/array and (b) array response function (Braun et al., 2016)

INTRODUCTION

Mt. Amiata is an extinct volcano whose last eruptive activity was dated about 200 ky ago. Today, its underlying crustal volume is still characterized by a high geothermal gradient, which makes the area particularly suitable for geothermal exploitation. The crustal volume overlaying the former magmatic reservoir is characterized by permeable layers of highly fractured volcanic rocks, saturated with hot water and steam. Geothermal exploitation from these layers started in the 1960's. Since then, earthquakes close to the depth of the geothermal production level at about 3.500 m depth occurred, shallower than the typical seismicity in the upper Tuscany crust. However, because of the sparse permanent monitoring network at Mt. Amiata, depth resolution and magnitude of completeness (Mc) have been poor.

To improve the seismic monitoring inside the geothermal field of Mt. Amiata, we installed in 2015 for a 3-years recording period a dedicated 8-station seismic network in the vicinity of the productive geothermal power plants. The aim of the experiment was achieve smaller completeness magnitude Mc and to reduce depth uncertainty, in order to better understand the seismicity and to be able to discriminate between natural and anthropogenic events.

We scan the large dataset using an efficient waveform beam-forming grid search approach (LASSIE) for robust detection and key locations. In a second processing step associated earthquakes are re-located by a refined waveform-based locator (LOKI). Obtaining an improved seismic catalog with reduced Mc, we suggest to approach the discrimination problem by spatial-temporal correlation of seismicity with geotechnical time-series of geothermal production.

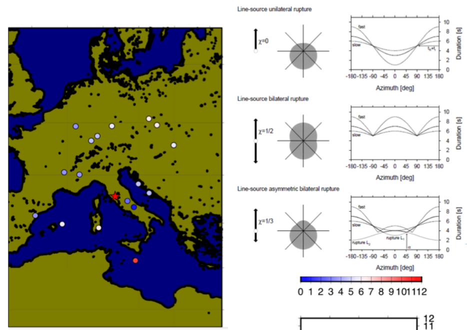


THE M_w4.5 SEISMIC EVENT of 01-APR-2000

The earthquake of 1 April 2000 raised strong concern among the general public, because the very shallow hypocenter of 4 km depth was responsible for damaging more than 50 buildings at Piancastagnaio. The proximate location of the geothermal power plant with respect to the macroseismic epicentre raised strong doubts about the natural origin of this earthquake. In order to control the focal depth, we used **Abedeto** (Array Beam Depth Tool), applying it to an independent dataset recorded by the GERESS array and compared the beam of the recorded array data with the synthetic array beam - calculated for the given epicentre and the focal solution – at different depths. The array beam (blue trace) fits the black coloured synthetic traces best at a depth of 4.5 km, a value that confirms the result obtained by classical hypocentral location (Fig. 2a).

Fig. 2: M_w4.5 event of 01-APR-2000
(a) Epicentre and focal solution
(b) Focal depth obtained by Abedeto (Braun et al., 2018)

Inversion, directivity



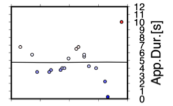
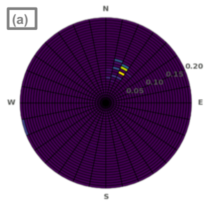
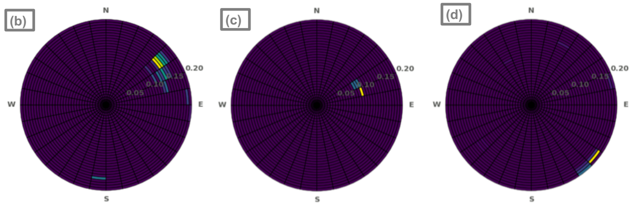


Fig. 3: Directivity analysis shows a clear pattern of variations of the apparent durations with azimuth, although the event is of moderate magnitude (M4.5), indicating a bilateral rupture, along the dip in direction NNE-SSW, rather than along the strike.

LOCATION OF LOCAL (ANTHROPOGENIC?) EVENTS BY USING ARRAY-ANALYSIS AND BEAM FORMING



25° - production zone Bag#25



50° - reinjection wells | 70° - production and drilling area | 130° - operations in quarry

Fig. 4: Distinction of seismic sources by f-k analysis: the arriving of the seismic energy from different backazimuths, suggests different anthropogenic sources: geothermal exploitation (a-c), quarry (d), (e) map view.

LASSIE: SEISMIC EVENT DETECTION AND LOCALIZATION (https://pyrocko.org)

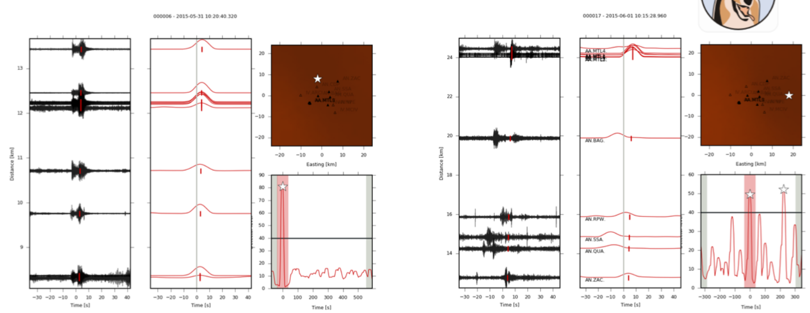


Fig. 5: Two examples of an automatic event detection and localization by using LASSIE (Heimann et al., 2007):
- Application of an STA/LTA the trace-envelope,
- coincidence criterion,
- hypocenter location by grid search ← → evaluation of coherence.

REFERENCES

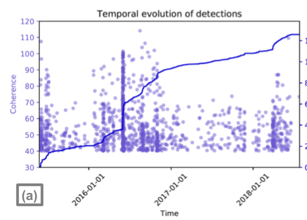
Braun, T., S. Cesca, D. Kühn, A. Martirosian-Janssen, T. Dahm (2018): Anthropogenic seismicity in Italy and its relation to tectonics: state of the art and perspectives. Anthropocene 21, 80–94. https://doi.org/10.1016/j.ancene.2018.02.001.

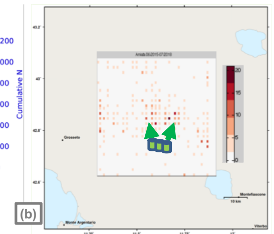
Braun, T., T. Dahm, F. Krüger, M. Ohrnberger (2016). Does geothermal exploitation trigger earthquakes in Tuscany? Eos 97, https://doi.org/10.1029/2016EO053197.

Heimann, S., M. Kriegerowski, M. Isken, S. Cesca, S. Daout, F. Grigoli, C. Juretzek, T. Megies, N. Nooshiri, A. Steinberg, H. Sudhaus, H. Vasyura-Bathke, T. Willey, Timothy, T. Dahm (2017): Pyrocko - An open-source seismology toolbox and library. V. 0.3. GFZ Data Services. http://doi.org/10.5880/GFZ.2.1.2017.001

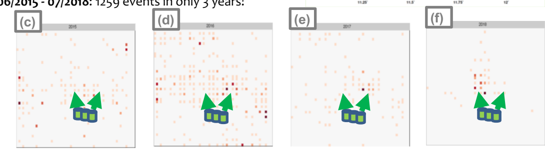
CONCLUSIONS

- Natural moderate earthquakes (M<5.3) occurred at Mt Amiata long before geothermal exploitation started.
- The April 2000 (M_w4.5) hypocenter is located in 4 km depth, similar as the geothermal production level.
- The INGV catalogue reports 300 seismic events on Mt. Amiata in 25 years 1.5<Mc<2.5 → 12 events/y.
- Our network detected automatically 1259 events in 3y concentrated near the areas of geothermal production.





06/2015 - 07/2018: 1259 events in only 3 years!



06-12/2015: 205 events | **2016:** 731 events | **2017:** 144 events | **01-07/2018:** 179 events

Fig. 6: Result from scanning the three years data-set recorded by the Amiata seismic network, including three additional stations from the INGV-network: (a) temporal variation of the coherence of the locations, and corresponding heat map: (b) cumulative, (c-f) annual 2015 – 2018.