11th International INQUA Meeting on Paleoseismology, Active Tectonics and Archeoseismology (PATA), 25 – 30 September 2022, France

Site selection for creepmeter fault monitoring in a complex volcano-tectonic framework: the Mt. Etna eastern flank as an example

Giorgio Tringali [a, b], Pia Victor [b], Raffaele Azzaro [c], Domenico Bella [d], Alessandro Bonforte [c], Silvia Crosetto [b], Gianluca Groppelli [e], Alessandro Maria Michetti [a,f], Rosario Pettinato [d], Morelia Urlaub [g], Thomas Ziegenhagen [b]

(a) Università degli Studi dell'Insubria, Dipartimento di Scienza e Alta Tecnologia, Como, Italy; (b) Helmholtz-Zentrum Potsdam, Deutsches GeoForschungsZentrum (GFZ), Potsdam, Germany; (c) INGV – Istituto Nazionale di Geofisica e Vulcanologia, Osservatorio Etneo, Catania, Italy; (d) Studio di Geologia Domenico Bella, Acireale, Italy (e) CNR – Consiglio Nazionale delle Ricerche, Istituto di Geologia Ambientale e Geoingegneria, sezione di Milano, Milano, Italy; (f) INGV – Istituto Nazionale di Geofisica e Vulcanologia, Osservatorio Vesuviano, Napoli, Italy (g) GEOMAR Helmholtz Centre for Ocean Research Kiel, Kiel, Germany

1. INTRODUCTION AND GEOLOGICAL SETTING

- ***Complex-volcano tectonic framework*** (Fig. 1), the result of an interaction between ***regional tectonic, magmatic processes and gravitational collapse*** (Azzaro et al., 2013; Urlaub et al., 2018) .
- ***Several active fault segments affect the eastern flank with normal and transtensive kinematics*** (Azzaro et al., 2012; ITHACA Working Group, 2019).
- **Surface faulting is produced by moderate magnitude earthquakes** (Mw 4 to 5; EMS VIII-IX) **and aseismic creep events** (Rasà et. al, 1996; Azzaro et al., 2012).
- **Creepmeters will improve the ongoing monitoring system** (GNSS network and 2 extensometers held by INGV-OE on land; 5 GEOMAR transponders offshore; Fig.1) ***providing new time series of displacement accumulation across monitored fault segments with high spatial and temporal resolution (1 µm)***, as already observed in other tectonic environments (Bilham et al., 2004; Victor et al., 2018).
- In this work ***we show the first results of field investigations and geophysical surveys to find suitable sites for the installation of the creepmeters*** in this highly urbanized area. With these results, ***we were able to install already two creepmeters along the Macchia Fault*** in July 2022 .

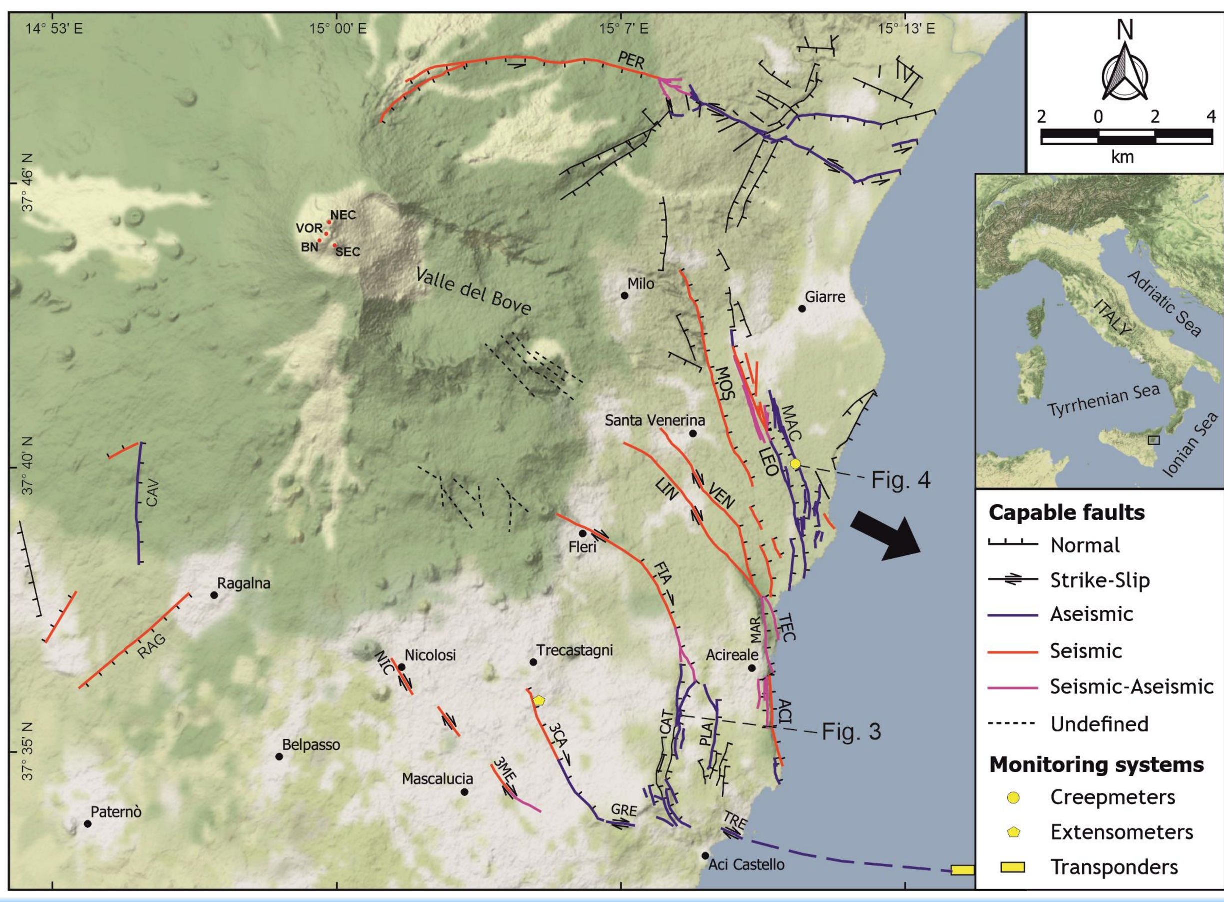


Fig. 1: Mt. Etna eastern flank volcano-tectonic map, the white coloured sectors are the urbanazed areas. The big black arrow indicates the flank sliding movement direction.

2. CREEPMETER FAULT MONITORING SYSTEM

The creepmeters used in this project have the following features (Fig. 2):

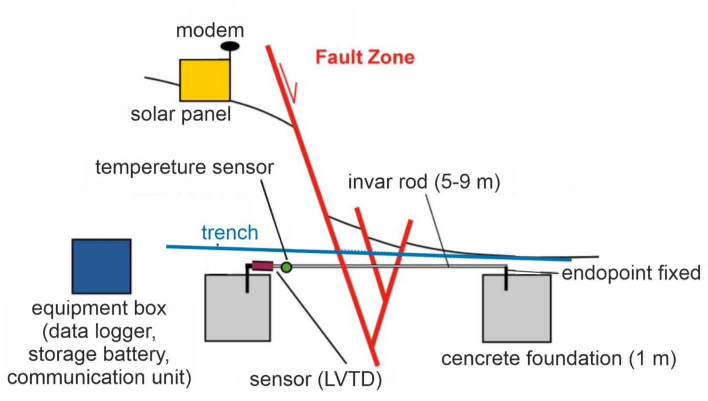


Fig. 2: Sketch of creepmeter setup across a normal fault.

- fault displacements measured along a 12 mm thick Invar rods, which passes through a PVC pipe, attached to concrete foundations on both sides of the fault;
- measurement process is performed by an LVDT (linear variable differential transformer) with a range of 15 cm.
- displacement is recorded as voltage change and stored on a data logger with a sampling rate of 2/min;
- LVDT equipped with a sensor to monitor temperature;
- buried at a depth of 1 m;
- data stored locally is sent to the GFZ via modem.

3. SITE SELECTION METHODOLOGY FOR CREEPMETER INSTALLATION

Main challenge is to have access in a suitable site in areas generally characterized by (1) **high urbanization**; (2) **private properties**; and (3) **unprotected public places** (e.g., squares and parking areas).

STEP 1: ***Analysis of published data***: a) ITHACA capable faults catalogue (ITHACA Working Group, 2019); b) the volcano-tectonic map of Etna volcano 1:100.000 scale (Azzaro et al., 2012); c) a pilot GIS database of active faults of Mt. Etna (Barreca et al., 2013).

STEP 2: ***Preliminary selection of potential sites located along creeping faults*** (Table 1). Some sites are located along the Fiandaca Fault that showed coseismic surface ruptures in 2018 mapped in great detail (Civico et al., 2019; Tringali et al., 2022).

STEP 3: ***Field survey*** to evaluate:

- ***ground ruptures*** (Fig. 3)
- ***localized deformation;***
- ***fault plane geometrical parameters***
- ***gravitational effects;***
- ***distributed displacement;***
- ***possibility of obtaining permission;***
- ***logistical problems during installation***
- ***anthropogenic noise.***

STEP 4: ***Geophysical survey*** with seismic refraction profiles where needed.

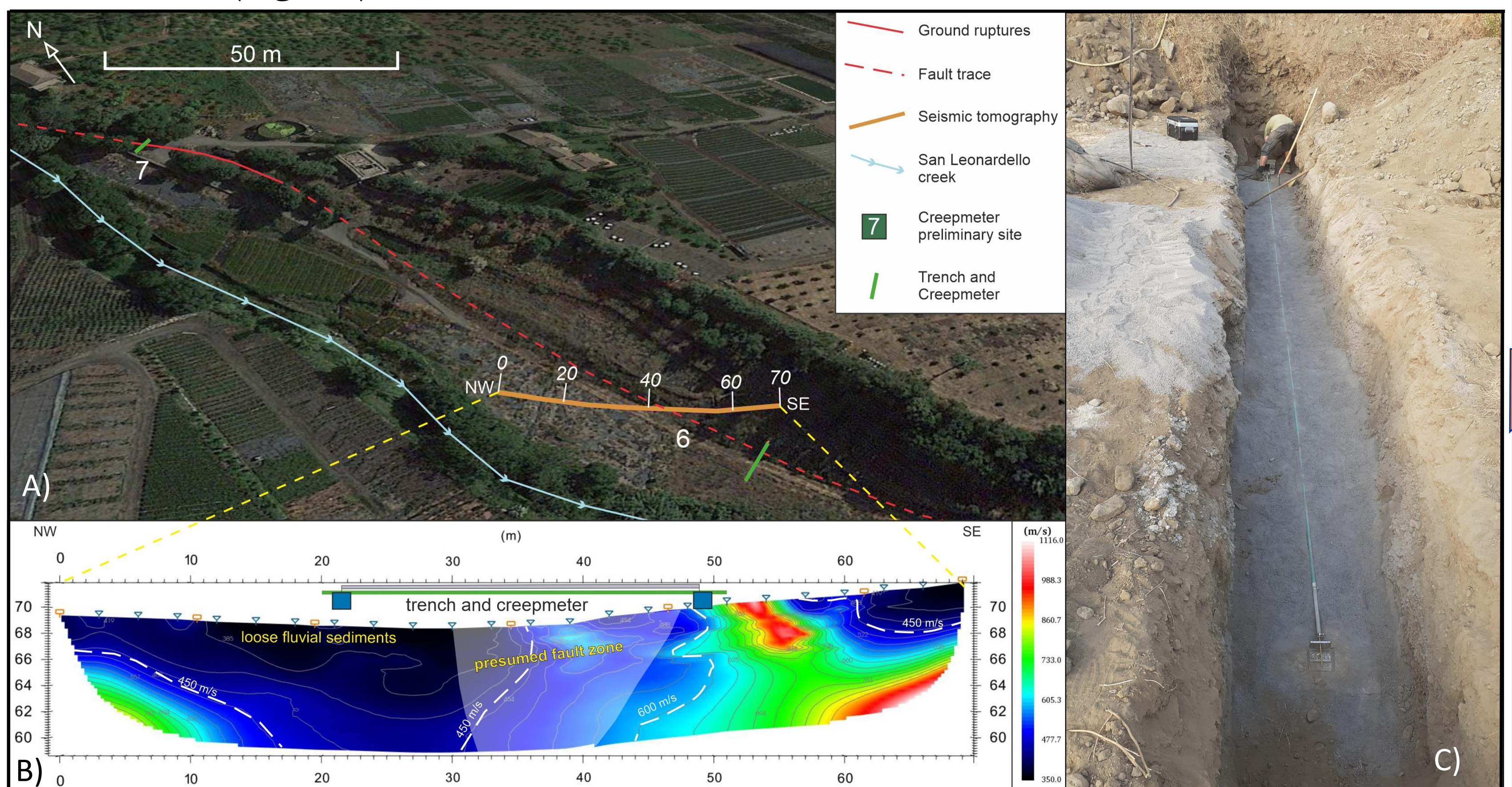
Fig. 3: Ruptures on the ground and a wall along the Aci Catena Fault.

N	Locality	Municipality	Fault	Surface litology	Latitude	Longitude	Ownership
1	Santa Tecla	Acireale	Santa Tecla	Alluvial deposit	37°38'1.73"N	15°10'20.93"E	Private
2	Pozzillo	Acireale	San Leonardello	Lava flow	37°40'7.18"N	15°10'55.32"E	Private
3	Pozzillo	Acireale	San Leonardello	Lava flow	37°40'16.20"N	15°10'49.10"E	Private
4	San Leonardello	Riposto	San Leonardello	Chiancone/Lava flow	37°41'1.75"N	15°10'26.28"E	Private
5	Macchia	Giarre	San Leonardello	Lava flow	37°42'40.12"N	15° 9'32.28"E	Private
6	Malpassoti	Riposto	Macchia	Chiancone	37°40'37.78"N	15°11'4.10"E	Private
7	Malpassoti	Riposto	Macchia	Chiancone	37°40'43.67"N	15°11'2.12"E	Private
8	San Leonardello	Giarre	Macchia	Chiancone	37°41'51.93"N	15°10'28.76"E	Private
9	Santa Maria La Stella	Acireale	Fiandaca	Lava flow	37°37'33.10"N	15° 8'6.72"E	Private
10	Fiandaca	Aci Sant'Antonio	Fiandaca	Lava flow	37°38'10.82"N	15° 7'47.34"E	Private
11	Pennisi	Acireale	Fiandaca	Lava flow	37°38'38.74"N	15° 7'26.73"E	Private
12	San Giacomo	Aci Catena	Aci Catena	Lava flow	37°36'16.52"N	15° 8'20.05"E	Public
13	San Giovanni la Punta	San Giovanni la Punta	Trecastagni	Lava flow	37°34'42.60"N	15° 5'29.62"E	Public
14	San Giovanni la Punta	San Giovanni la Punta	Trecastagni	Lava flow	37°33'57.73"N	15° 6'6.35"E	CAS
15	Tremestieri Etneo	Tremestieri Etneo	Tremestieri	Lava flow	37°34'9.34"N	15° 4'38.44"E	Public
16	San Gregorio	San Gregorio	San Gregorio	Lava flow	37°33'51.18"N	15° 6'43.33"E	Public

Table 1: Preliminarily sites information for creepmeters installation.

4. RESULTS AND DISCUSSIONS

- ***Faults with strike-slip kinematics*** (e. g., Tremestieri and San Gregorio faults) ***show a wider deformation zone up to about 20 m*** due to the formation of Riedel fractures along the shear zone.
- ***Normal E-dipping faults*** (e. g., Aci Catena and the San Leonardello faults) ***show a narrower deformation zone, averaging less than 10 m*** (Fig. 3).
- We conducted ***seismic refraction profile along the normal west dipping Macchia Fault*** (Fig. 4A). ***The tomographic survey revealed an area with low Vp velocity values (≈ 450 m/s)*** that could be ascribed to ***a damaged fault zone or loose fluvial sediments*** (Fig. 4B).



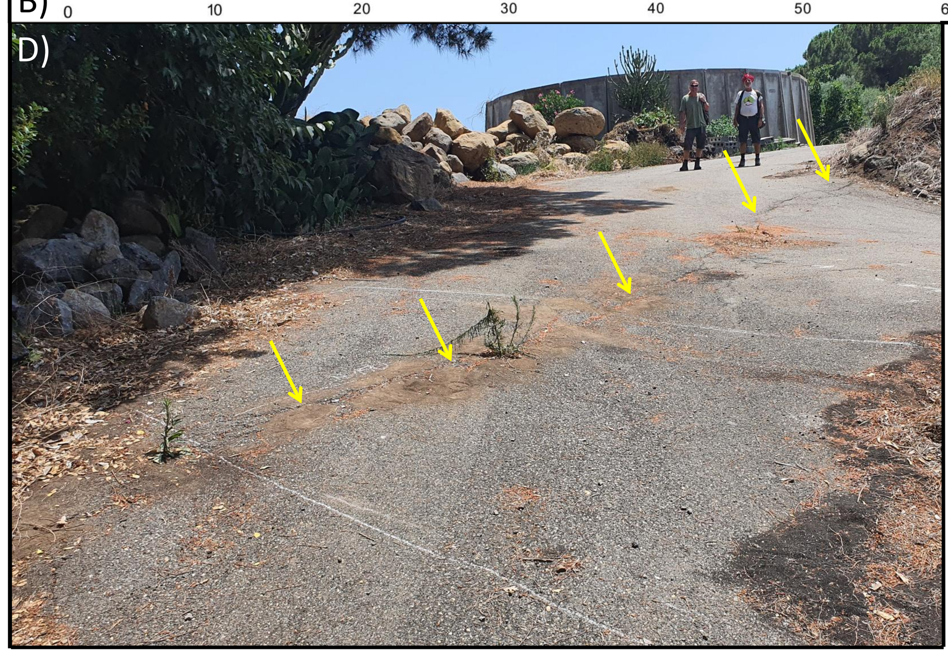


Fig. 4: A) Map showing the Macchia Fault study area. B) Trench and creepmeter of the site 6 projected into the seismic tomography. C) Site 6 trench and creepmeter. D) Ground ruptures on the asphalt in the site 7 where a second creepmeter has been installed.

- We performed a trench (Fig. 4C), with a length of 12 m, close by the seismic tomography of the site 6.
- The interpretation of the trench stratigraphy is still ongoing.

work in progress

5. FINAL REMARKS

- This methodology allowed us to select some favorites sites and ***we already installed 2 creepmeters along the Macchia Fault (Fig. 4C and D)***.
- **Sites evaluation** for new installation **is still ongoing** and we are planning **new paleoseismological trenches**.

work in progress

- ***Volcanic processes at Mt. Etna can cause stress variations along faults*** triggering **earthquakes** and **fault creep**, often in the framework of **flank instability events**.
- ***Monitoring these faults with creepmeters could provide us new data to better understand these complex interactions in a volcano-tectonic environment.***

Acknowledgements: We are deeply grateful to the local people who allowed us to enter their properties and install the instruments. We thank the local authorities for their willingness to implement the current Etna monitoring system. We also thank the bachelor thesis student Sofia Brando for her valuable help during the creepmeters installation. Part of the fieldwork and the creepmeters assembly have been supported by M. Urlaub HGF funds.

REFERENCES

Azzaro, R., Branca, S., Gwinner, K., Coltelli, M., 2012. The volcano-tectonic map of Etna volcano, 1:100.000 scale: an integrated approach based on a morphotectonic analysis from high-resolution DEM constrained by geologic, active faulting and seismotectonic data. Italian Journal of Geosciences. 2012; 131 (1): 153–170.

Azzaro, R., Bonforte, A., Branca, S. & Guglielmino, F., 2013. Geometry and kinematics of the fault systems controlling the unstable flank of Etna volcano (Sicily). Journal of Volcanology and Geothermal Research 251, 5–15.

Barreca, G., Bonforte, A., Neri, M., 2013. A pilot GIS database of active faults of Mt. Etna (Sicily): A tool for integrated hazard evaluation, Journal of Volcanology and Geothermal Research, Volume 251, Pages 170-186, ISSN 0377-0273.

Bilham, R., Suszek, N., Pinkney, S., 2004. California Creepmeters. Seismological Research Letters 2004; 75 (4): 481–492.

Civico, R., et al., 2019. Surface ruptures following the 26 December 2018, Mw 4.9, Mt. Etna earthquake, Sicily (Italy). J. Maps 15 (2), 831–837.

ITHACA Working Group, 2019. ITHACA (ITaly HAzard from CApable faulting), A database of active capable faults of the Italian territory. Version December 2019.

Rasà, R., Azzaro, R. & Leonardi, O., 1996. Aseismic creep on faults and flank instability at Mount Etna volcano, Sicily. Geological Society, London, Special Publications 110, 179 192.

Urlaub, M. et al., 2018. Gravitational collapse of Mount Etna's southeastern flank. Science Advances 4, eaat9700.

Victor, P., Oncken, O., Sobiesiak, M., Kemter, M., Gonzalez, G., Ziegenhagen, T., 2018. Dynamic triggering of shallow slip on forearc faults constrained by monitoring surface displacement with the IPOC Creepmeter Array. Earth and Planetary Science Letters, Volume 502, 2018, Pages 57-73.

Tringali, G., Bella, D., Livio, F.A., Ferrario, M.F., Groppelli, G., Blumetti, A.M., Di Manna, P., Vittori, E., Guerrieri, L., Porfido, S., Boso, D., Pettinato, R., Paradiso, G., & Michetti, A.M. (2022). Fault rupture and aseismic creep accompanying the December 26, 2018, Mw 4.9 Fleri earthquake (Mt. Etna, Italy): Factors affecting the surface faulting in a volcano-tectonic environment. Quaternary International. ISSN 1040-6182.

If you have questions contact me: ***gtringali@uninsubria.it*** or ***tringali@gfz-potsdam.de***