Gruppo Nazionale di Geofisica della Terra Solida

BOOK OF ABSTRACTS
42nd NATIONAL CONFERENCE

13 - 16 FEBRUARY 2024

FERRARA

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e di Geofisica
Sperimentale

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EUROPEAN ASSOCIATION OF GEOSCIENTISTS & ENGINEERS
SEG
SOCIETY OF EXPLORATION GEOPHYSICISTS
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Towards a multi-risk deterministic scenario in the Mt. Etna area

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1. Multi-risk analysis in the Panacea project

Etna (Sicily, Italy) is an active volcano characterized by effusive and explosive eruptions, often accompanied by intense seismic activity. Its densely urbanized territory on the eastern flanks can suffer severe impacts due to lava flows, earthquakes, and tephra, while pyroclastic flows only affect the summit area of the volcano.
As part of the Panacea project (Probabilistic AssessmeNt of volCano-related multi-hazard and multi-risk at Mount EtnA), seismic and volcanic hazard scenarios were generated; consequently risk scenarios for built-up places, lifelines and communication systems were assessed at very different scales, from local to sub-regional. In general, in case of a multi-risk project, it is necessary to identify the elements exposed to the volcano's effects, assess their vulnerability to each different hazard and proceed to complex risk analyses (Meroni et al., 2022, Pessina et al., 2022).
Mt. Etna's hazard studies provided interesting insights (Del Negro et al., 2019) but it is the first time that a multi-risk analysis has been carried out in the area. For this reason, in this study the analyses have been limited to the estimation of direct losses (in terms of structural damage, victims, and loss of functionality) and more complex risk analyses, such as multi-risk and cascade assessments, have not yet been taken into consideration.

2. The hazard scenarios

During the three years of the project, deterministic damage scenarios were created for the calibration and development of damage estimation methods. In this short note, we present

the risk results for 6 municipalities in the Etna area (Milo, Giarre, Riposto, Santa Venerina, Zafferana Etnea, Acireale) for a hypothetical reference scenario.

Two days after the Etna eruption of 24 December 2018 (Alparone et al., 2020), a strong earthquake (M_W 5.0) hit the lower south-eastern flank of the volcano, causing extensive damage in the area between the municipalities of Acireale and Zafferana, with over 1,100 homeless (Pessina et. Al, 2021). It represents the largest event occurred in the area in the last 70 years.

The flank eruption at the volcano started with an intense degassing from the summit craters, an opening of eruptive fissure with a lava flow that ended on December 27.

The (hypothetical) Tephra and Lava scenarios were generated assuming that the 2018 eruption was not interrupted, and significant values of input parameters were assumed in the simulation process to create realistic scenarios of lava invasion and ash ground loads, which are sufficiently important to cause damage to buildings and infrastructure. Fig. 1 shows the seismic scenario of December 26th 2018, and hypothetical scenarios for lava and tephra loads. More comprehensive studies are being published (Sandri et al.)

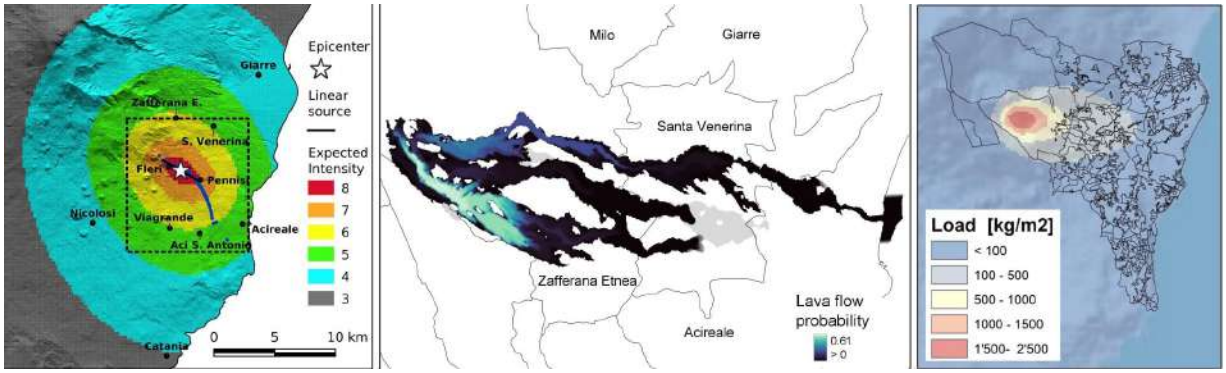

Fig.1 – From left to right: seismic scenario, represented in terms of EMS-98 Intensity, for the December 26, 2018 earthquake, and hypothetical scenarios for lava flow and tephra loads.

3. The risk scenarios

Damage assessment was calculated for residential buildings. Using data collected by the Italian Institute of Statistics (ISTAT, 2011), that are updated and spatially detailed, residential buildings were classified as masonry, reinforced concrete (RC) and other construction type, according to the method illustrated in Dolce et al. (2021). For the assessment of the seismic vulnerability and damage we used the model of Lagomarsino et al. (2021) for masonry buildings and that of Rosti et al. (2021) for RC ones.

Since the new models use both pga values, it was necessary to develop an ad hoc conversion relationship between EMS98 intensity and pga, for this type of event of volcanic origin in the Etna area. The new conversion relationship is the following:

$$\log_{10}(pga) = 0.346\ I_{EMS\text{-}98} - 0.190$$

With reference to the definition of the 5 damage levels of the EMS-98 scale (Grünthal, 1998), Fig. 2a shows the number of heavy damaged buildings (damage level (D4 + D5) in each census tract).

Through remote sensing analysis, the project's colleagues estimated the percentage of pitched and flat terrace roofs of the buildings. These distributions, together with the analysis of AeDes data for the identification of building types and their vulnerability, made it possible to identify the distribution of roofs in four vulnerability classes (Spence et al., 2005). The distribution of buildings with total collapse of the roof due to tephra load – if no cleanup action is taken- is shown in Fig 2c, but it is necessary to highlight the very low probability to have such a level of loads.

In case of lava flow hazard, the level of risk is independent of the vulnerability of the buildings. For each ISTAT census section, the number of buildings damaged by lava is calculated proportionally to the percentage of the section's area occupied by the flow (Fig. 2b).

Once assessed the damage level of the buildings, the totally collapsed buildings, the unusable one, the number of the possible victims or of homeless are calculated in each census section.

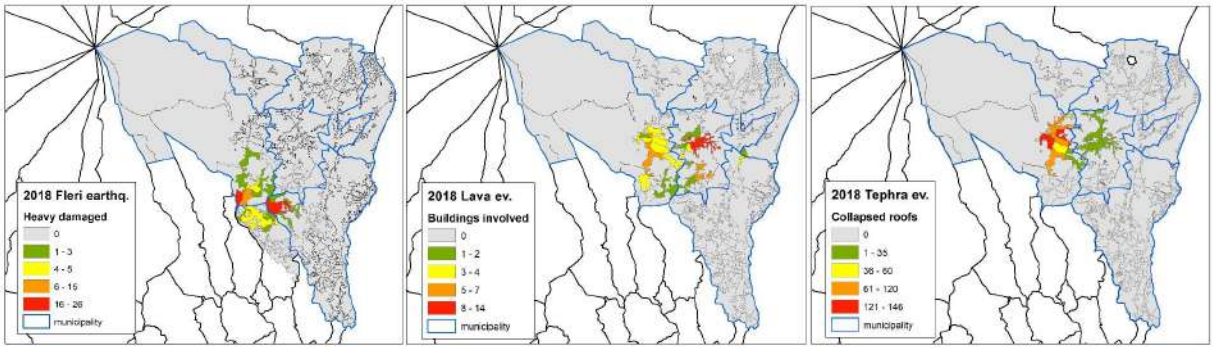

Fig.2 – Damage map of residential buildings due to the earthquake, lava and tephra flows scenarios.

Damage scenarios due to ash loads, lava flows and earthquakes have been estimated to road and power systems, too. Tab. 1 illustrates damage to the power system (pylons, medium voltage (MV) and high voltage (HV) substations and transformers) reach by lava flow with different probability of invasion, as well as the length of invaded road and number of affected buildings.

Tab. 1 – Damage due to the 2018 lava flow scenario

POWER SYSTEM	Road system	Residential

Probability	Pylons	Power MV	Power HV	Transformer	[km]	buildings
0.000358	15	52	1	10	23.82	737
0.005	2	10	-	1	6.27	181
0.01	4	23	-	2	12.61	596
0.025	3	20	-	4	15.69	639
0.05	2	3	-	3	5.37	148
0.1	4	14	-	1	8.31	205
0.3	0	4	-	-	0.74	1
0.5	1	1	-	-	0.79	2
Tot	31	127	1	21	73.6	2509

4. Conclusions

High-impact deterministic scenarios were generated to test the models to be applied for the seismic and volcanic risk of buildings (residential and strategic) and lifelines (electricity grid, roads, etc.) in the Etna area.This exercise, among other things, led to the implementation of a PGA-intensity conversion relationship for Etna earthquakes, as well as the characterization of roof vulnerability in the study area.

Apart from earthquake, expected damage from tephra and lava flow are unlikely to reach high level of damage(D4 and D5). Anyway the interruption of services and other inconveniences are foreseeable at lower damage levels (D2 and D3).

Due to the characteristics of Mount Etna eruptions, lava flow (which are slow) or ash accumulation does not generate victims. Instead, it is possible to find an interdependence on risk scenarios: even a thickness of a few centimetres of ash can make roads dangerous or even just unusable, making rescue operations difficult in the event of an earthquake or in the event of a fire triggered by the eruption.

Thanks to a probabilistic estimate of the expected damage, still in progress, it will be possible to quantify the influence of seismic hazard, lava flow and tephra accumulation in appropriate exposure times.

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