

Short Communication

The Santorini Seismic Crisis – A New Challenge for Seismology

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Abstract

A short informative note about the started seismic crisis near Santorini Island is prepared discussing all proposed scenarios by the scientific community. Avoiding speculations of non-specialists all factors "pro" and "anti" of the discussed scenarios are systemized and presented as a comparative table. An expert assessment of the probabilities of occurrence of each scenario is shown and defended by the arguments of "pro" and "anti". The unusual appearance and development of the earthquake swarm have strong societal and scientific resonance. This generated large preventive measures from the national and local authorities. These initial measures are targeted to the people's evacuation, civil defense preparation and presence "at the spot", warning issues to the population to near located islands, scientific equipment deployment in and around the affected area, etc. The presented opinion is just to focus the attention for wider and deeper investigations of such phenomena.

Introduction

The intensive seismic swarm between the Greek islands of Santorini and Amorgos in the Aegean Sea surprises all seismological communities with the process displayed by nature. Starting on 27th of January 2025 with several small magnitude seismic events ($M \sim 3$) the process accelerated producing over 13 000 earthquakes with different magnitudes ranging between 1 and 5+ (to 12th Feb. 2025). From 3rd Feb to 12th Feb 9 earthquakes with magnitude 5 and above have been registered and widely felt in eastern Mediterranean. More than 50 earthquakes of M4 are located over the area of seismic swarm and their mechanisms show clear geodynamic extensional force. Such intensive seismic energy release in this area felt by many people is not familiar to the seismology at all. This provoked large discussions between specialists and the wider public about the intended development of the earthquake sequence.

According to our view, several scenarios are possible, most of them supported by different groups of specialists (The Euro Mediterranean seismological Center [1] published several reports by various specialists) such as:

- Precursor swarm to expect stronger tectonic earthquake (with or without tsunami generation) – dangerous scenario [2],
- Preceding seismic activity of impending volcano eruption of Santorini volcano (with variants of

Columbus underwater volcano eruption (located near the swarm) or newborn underwater volcano) – dangerous scenario depending on the intensity of eruption [3]


- A combination of strong earthquake and volcanic eruption – most dangerous scenario [4]
- Only swarm that will decrease seismic activity by natural process – less dangerous scenario.

The last possibility is extracted from the previous experience of the Japan swarm – the Matsushiro swarm lasted from 1965 to 1967. The following information can be found [5].

"In the initial phase of the earthquake swarm, the activity was within an elliptical area with N-S axis measuring 12 km and E-W axis measuring 7 km, and the corresponding focal depths were 2-8 km. Accompanying the activity area had expanded with time, the frequency of shocks had been declining gradually. Although significant shock had seldom observed around Matsushiro since 1967, micro-earthquakes have been occurring in the bygone source area even at present." The Matsushiro swarm generated about 1 million earthquakes. The total sum of energy from all the tremors was approximately equivalent to an M6.4 earthquake. The phenomenon was clearly identified as linked to a magma uplift, perhaps initiated by the 1964 Niigata earthquake (M7.6) which happened one year ago [6].

More Information

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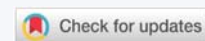


Table 1: Geodynamic “pro” and “anti” factors that influence the possible scenarios.

Possible Scenario	“Pro” factors	“Anti” factors	Probability of occurrence
Precursor swarm of strong earthquake	Intensive seismic activity. Historical analogue of the 1956 (M7.7) event and tsunami. Existence of possible active faults. Typical extension mechanisms of stronger M4+ observed seismic events.	No typical behavior of foreshock activity. No capacity of the faults to generate stronger M7 earthquakes.	~ 10% - 15%
Preceding seismic activity of volcanic eruption	Historical data of Santorini eruption 16 th century BC. Migration of hypocenters to and from the volcanoes. Possible effects of lava uplift and water intrusion. Uplift of the caldera of Santorini - measured.	No clear relationship to the volcanoes' lava cameras. No seismic signals that are typical for eruption. Typical extension geodynamics.	~ 15% - 20%
Swarm before strong earthquake and volcanic eruption	Historical events of XVI century BC and 1956 seismic event and tsunami. Typical extension geodynamics.	No clear geodynamic relation between strong earthquakes and volcanic eruption	~ 5% - 10%
Swarm decrease by nature	Typical behavior of pulsation of seismic energy release. The Matsushiro swarm analogy. Possible magma intrusion.	Unknown origin of the swarm	~ 70% - 55%

The Santorini swarm up to now (12th February 2025) has about 13,000 earthquakes, epicenters located in an oval area with approximate NE-SW ax (about 30 km) and NW-SE ax (about 25 km). The elongation is in the NE-SW direction.

What is known for now?

- Typical very intensive tectonic swarm of earthquakes with unknown origin
- Existence of underwater faults with NE-SW direction
- Location of the swarm is just over the volcanic arc to the North of the Aegean subduction zone
- Lack of relationships with the calderas of Santorini and Columbus volcano
- Extensive geodynamic regime in the area of the swarm. All seismic events show typical extensions extracted by the earthquake mechanisms.

What could be the trigger of the swarm?

Following the Matsushiro swarm's relationship with the Nagano earthquake and analogy and similarity the Santorini swarm might be triggered by the Turkish earthquake of 6th February 2023 [7]. The earthquake happened about two years ago and a magma uplift and intrusion might be accepted as a source of this unusual seismic activity.

To be able to assess the probability of the expected geodynamic events a table was created assessing the all known factors pro and anti of each of them – Table 1. This table was created considering the main factors influencing the seismic process. The methodology used is an expert analysis of these factors. Most of them have been well-studied by specialists throughout the years. The most important factors are the space-time relationship of the observed seismic events, the magnitude-depth and magnitude number per time unit (1 day) dependence, the geodynamic regime (in our case proved extension), the migration of earthquakes hypocenters, the known tectonic faults and their activity, the distances between the swarm and near well-known and familiar to the professionals potentially active seismic sources

located around, and so on. All this information was integrated and used by expert judgment and using such methodology, probabilities were assessed. It is important to mention that the accuracy is rather low due to the lack of information on how the seismic crisis will end.

What else could be done to resolve at this stage the unusual seismic swarm?

An urgent trip of geophysical marine vessels equipped with magnetometers and gravity meters. It gives the possibility to detect possible magma uplift. Additionally, the temperature bottom measurements can add useful information, if the temperature in the area is rising.

- Seismic bottom profiling by seismic exploration methods. They can help the recognition of the recent fault's activity and detect more density bodies of magma uplift if they exist.

Conclusion

A short review is prepared on the basis of published information about the Santorini earthquake swarm - 2025. Possible scenarios for the further development of the seismic activity are outlined. A table about the probability of each scenario occurrence is constructed and analyzed.

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