Supplemental information
to
2025 Santorini-Amorgos crisis triggered by a transition from vulcanic to normal tectonic activity

Lippiello E.[1,*], Petrillo G.[2], Godano C.[1,3], Papadimitriou E. [4], Karakostas V. [4] & Anagnostou V. [4]

[1] *Department of Mathematics and Physics, University of Campania "L. Vanvitelli", 81100 Caserta, Italy.*

[2] *Earth Observatory of Singapore, Nanyang Technological University, Singapore*

[3] *Istituto Nazionale Geofisica e Vulcanologia, Napoli, Italy.*

[4] *Geophysics Department, Aristotle University of Thessaloniki, GR 541 24 Thessaloniki, Greece*

Suppl. Sec.1 Tectonic setting

The study area belongs to the extensional back–arc Aegean region that includes south Bulgaria and former Yugoslavia, northern and central Greece, southern Aegean volcanic arc, and the southwestern and central western Turkey (Fig. Suppl. Fig.1). The Aegean region is one of the most active tectonic regions of the Alpine–Himalayan belt, with its most prominent tectonic feature the subduction of the eastern Mediterranean lithosphere under the Aegean Sea [1] along the Hellenic Arc. The seismicity is very high throughout the arc, which is dominated by thrust faulting with a NE–SW direction of the axis of maximum compression. The top layer of the subducted east Mediterranean lithospheric slab is seismically very active at depths 60 – 110km and 140 – 170km and that its low seismicity part (110 – 140km) is under the volcanic arc. This observation, geochemical data and tomographic results suggest that the primary magma reservoir of the Hellenic volcanic arc is in the mantle wedge between the subducted Mediterranean and the overriding Aegean slabs, at depths 60 – 90km. The genesis of earthquakes at the shallow part of the subducted Mediterranean slab is attributed to dehydration embrittlement of basalt, the low seismicity at intermediate depths is due to increase of temperature and confining pressure and the increase of seismicity in the lower active part of the slab to a second dehydration embrittlement of hydrous eclogite [2]. The Santorini volcano is an active stratovolcano, with several smaller craters in addition to the main caldera, which collapsed around 1625 BC (known as Minoan eruption).

Volcanic centers (volcanoes, fumaroles or solfatara fields), epicenters of strong shallow earthquakes (with focal depths up to 20 km) and epicenters of intermediate depth strong earthquakes (with focal depths between 120 and 160 km) can be grouped into five, well defined, linear clusters trending about N60°E [3]. This lineation is attributed to five normal faults named after the corresponding volcanic centers (Sousaki, Methana, Milos, Santorini and Nisyros). The largest earthquake ($M_0 = 4.9 \cdot 10^{27}$ dyn·cm) of the 20th century in the territory of Greece occurred south of Amorgos Island causing extensive destruction in the southern Aegean area. It occurred on an ENE–trending normal fault that is seated parallel to the Island's southern coastline [4].

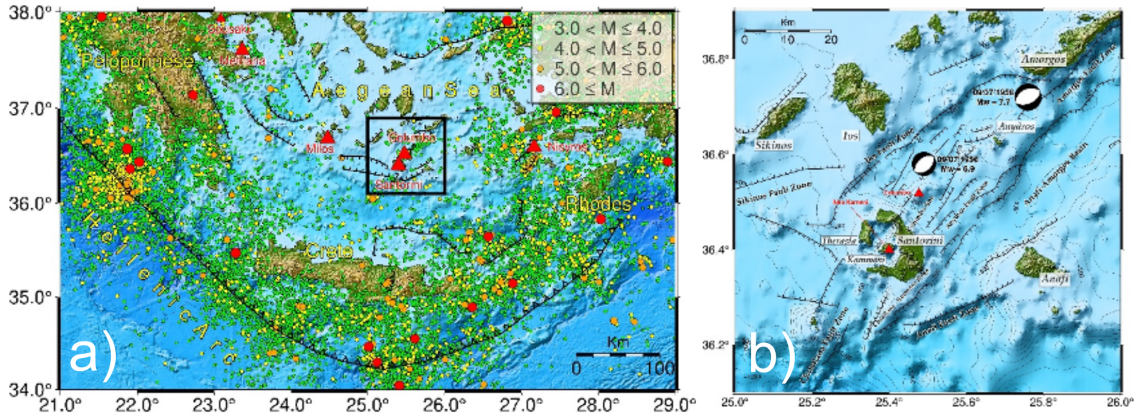

Figure Suppl. Fig.1: a)The area of southern Aegean along with the Hellenic Arc shown by a continuous line and major faults (according to http://doi.org/10.5281/zenodo.3483136). The study area is indicated by the rectangle. 1b. Epicenters and fault plane solutions shown as equal area lower hemisphere projections for the large 1956 earthquakes associated with the Amorgos and Anydros fault segments (M7.7 & M6.9, respectively).

Suppl. Sec.2 Yearly epicentral maps from 2010 to 2025

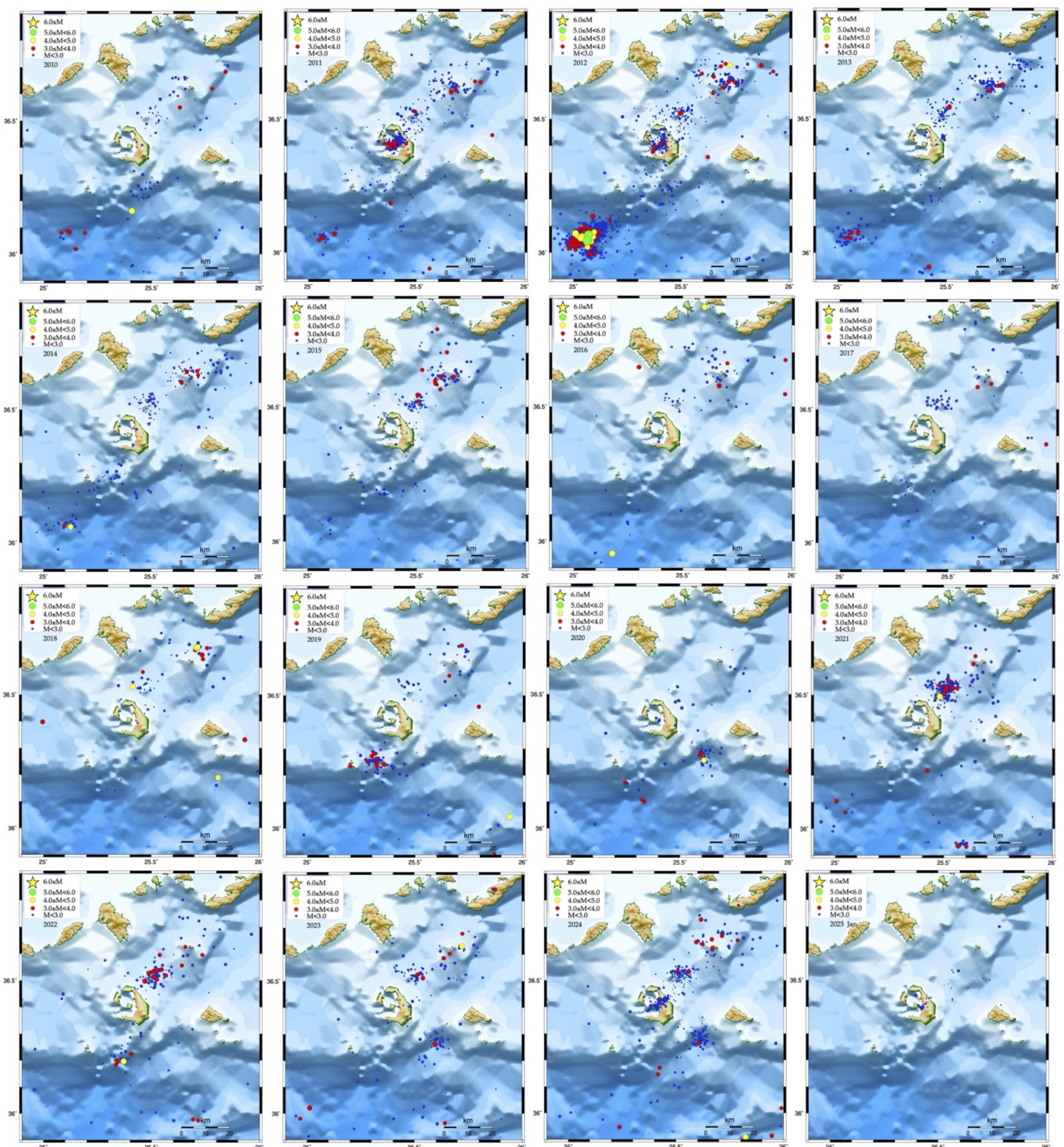

Figure Suppl. Fig.2: Seismicity recorded in the region of interest from 2010 to 2025, shown year by year. The panels are arranged in chronological order, starting from the top left and proceeding to the bottom right. Symbol color and size are scaled according to earthquake magnitude, as shown in the legend.

Suppl. Sec.3 Epicentral maps during the 5 phases.

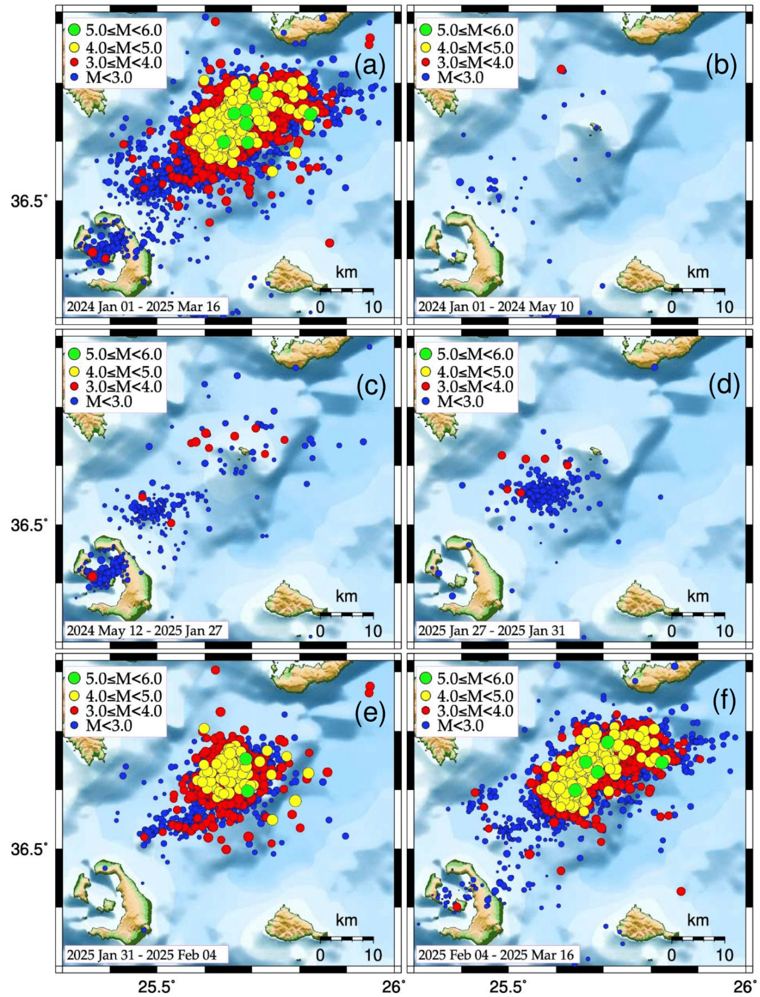

Figure Suppl. Fig.3:

Panel a) From 2024 January 01 up to 2025 March 16: The epicentral distribution of all earthquakes (7083 in number) comprised in our data set. The maps that follow depict seismicity in different periods of its manifestation, with symbol color and size scaled according to earthquake magnitude, as shown in the legend. Panel b) PHASE 1 (2024 January 01 up to May 10): During this period sparse seismicity is observed mostly around the Columbo reef, in the offshore area to the northeast of Santorini Island. Panel c) PHASE 2 (2024 May 11 up to 2025 January 27): Elevated seismic activity is observed in this phase, with heightened seismicity inside the caldera of Santorini Island, where the denser spatial cluster is formed. A second cluster around Columbo and a noticeable number of $3.0 < M < 4.0$ earthquakes (red circles) in the area of Anydros islet, between Santorini and Amorgos Islands. Panel d) PHASE 3 (2025 January 27 up to 31): Significant seismic activity in the last 5 days of January 2025 including 6 earthquakes in the $3.0 < M < 4.0$ range around the Columbo reef, drew significant scientific attention, particularly due to near–total cessation of seismicity within the caldera of Santorini Island. Panel e) Phase 4 (2025 January 31 up to February 04): An unprecedented burst of seismicity took place in a previously low activity area (look at the previous 3 maps), around the Anydros islet. Two earthquakes with magnitudes exceeding M5, tens of $4.0 < M < 5.0$ and hundreds of $3.0 < M < 4.0$ occurred in less than five days, compressed in an area with maximum length of ~ 30 km, with the $M > 4.0$ confined in a remarkably dense cluster with length less than 15km. The remarkably dense earthquake cluster appeared to be bounded in Anydros basin, with almost null activity beyond both its edges. We may note here that the activity in Columbo site remains stable, with small magnitude earthquakes occurring at a rather steady rate. Panel f) Phase 5 (2025 February 04 up to March 16):

The activity continued at the same high rate as in the last period and expanded more bilaterally, with this migration being more evident towards Amorgos Island, to the northeast. Five $M > 5.0$ earthquakes, tens of $M > 4.0$ and hundreds of $M > 3.0$, keeping the high occurrence rate that started in the last period. Following that day, seismicity declined sharply, though not to background levels, but to a moderate rate comparable to those observed in regular seismic sequences.

1. Papazachos, B. & Comninakis, P. Geophysical and tectonic features of the aegean arc. *Journal of Geophysical Research* **76**, 8517–8533 (1971).

2. Papazachos, B., Dimitriadis, S., Panagiotopoulos, D., Papazachos, C. & Papadimitriou, E. Deep structure and active tectonics of the southern aegean volcanic arc. In *Developments in volcanology*, vol. 7, 47–64 (Elsevier, 2005).

3. Papazachos, B. & Panagiotopoulos, D. Normal faults associated with volcanic activity arc. *Tectonophysics* **220**, 301–308 (1993).

4. Papadimitriou, E., Sourlas, G. & Karakostas, V. Seismicity variations in the southern aegean, greece, before and after the large (m7. 7) 1956 amorgos earthquake due to evolving stress. *pure*

and applied geophysics **162**, 783–804 (2005).