

The 21 August 2017 M_d 4.0 Casamicciola Earthquake: First Evidence of Coseismic Normal Surface Faulting at the Ischia Volcanic Island

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ABSTRACT

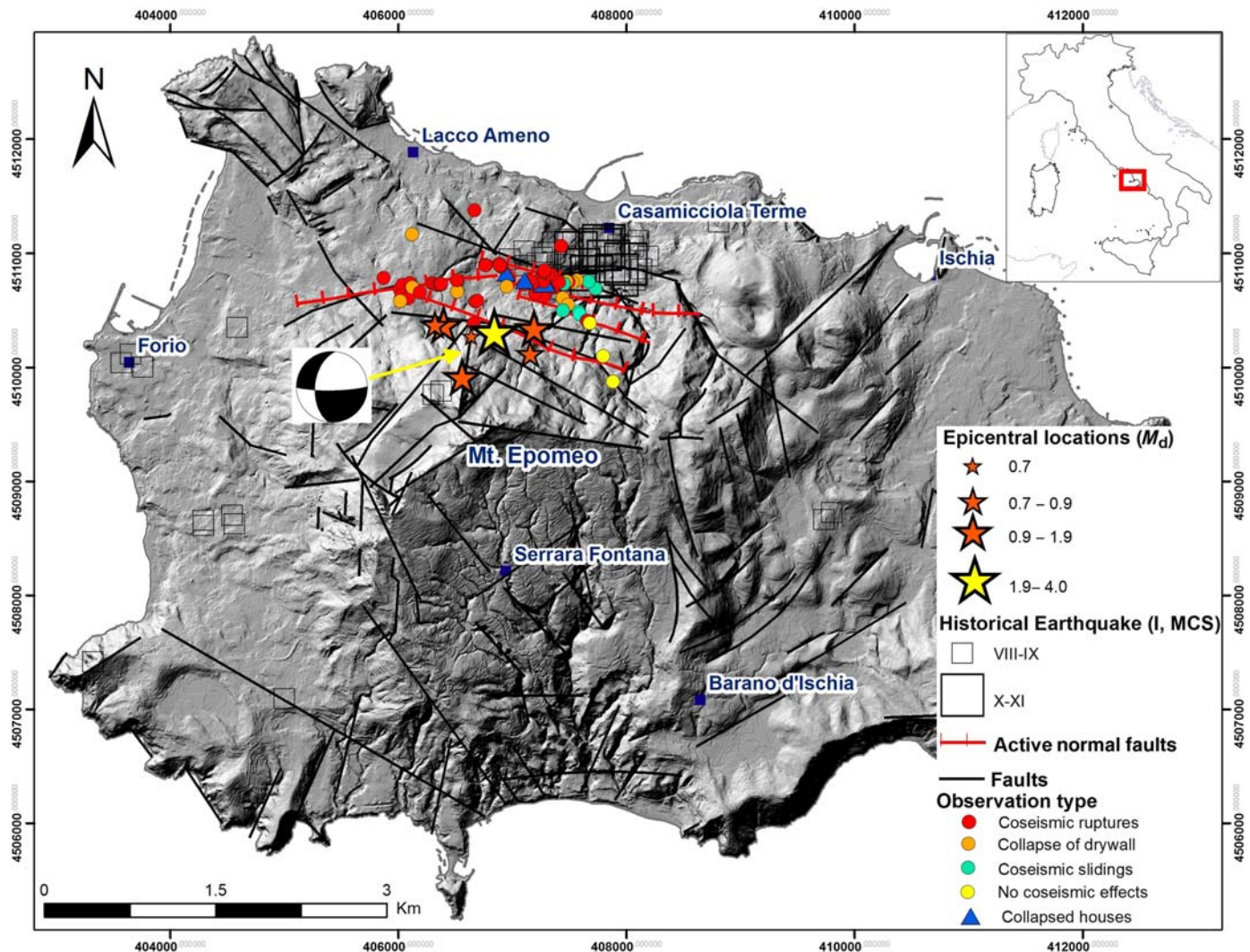
On 21 August 2017, a shallow earthquake of M_d 4.0 struck the Casamicciola Terme village in the north of Ischia volcanic island (Italy). It caused two fatalities and heavy damage in a restricted area of a few square kilometers. Casamicciola Terme has been recurrently destroyed in the last centuries by similar volcano-tectonic earthquakes (1762, 1767, 1796, 1828, 1881, and 1883). After the catastrophic 1883 Casamicciola event (2343 casualties), this is the first heavy damaging earthquake at Ischia that provides, for the first time, the opportunity of integrating historical seismicity, macroseismic observations, instrumental information, and detailed mapping of coseismic geological effects. Soon after the 2017 mainshock we surveyed the epicentral area to collect data on the coseismic ground effects, recording more than 100 geological field observations. Mapped effects define a belt which closely follows the trace of the Casamicciola E–W-trending normal fault system, bounding the northern slope of Mt. Epomeo, previously known as a Latest Pleistocene to Holocene normal fault with a slip rate of ~ 3.0 cm/yr. We found significant evidence for coseismic surface faulting, testified by a main alignment of ruptures for a 2 km end-to-end length and normal dip-slip displacement of 1–3 cm. The geometry and regularity of the structural pattern, together with constant kinematics of the coseismic ruptures with the north side down, strongly suggest a primary tectonic origin for the mapped ruptures and strongly supports an E–W normal-faulting focal mechanism for the 2017 Casamicciola earthquake. Macroseismic information supports the notion that previous historical events also had a similar style of faulting.

Electronic Supplement: Database of the coseismic geological surface effects following the M_d 4.0 Ischia earthquake that hit the Ischia Island on 21 August 2017.

INTRODUCTION

On 21 August 2017, at 19:57 GMT an earthquake with M_d 4.0 (Latitude 40.74°, Longitude 13.90°, [Gruppo di Lavoro INGV sul terremoto dell'isola di Ischia, 2017](#)) and hypocentral depth of about 1.2 km ([De Novellis *et al.*, 2018](#)) hit the volcanic island of Ischia (Gulf of Naples, southern Italy). This event, termed as the Casamicciola earthquake, was followed by a short seismic sequence including about 30 small aftershocks up to the end of 2017, with the most detectable ranging from M_d 0.7 to 1.9 (Fig. 1). The earthquake has the typical characteristics of volcano-tectonic events recorded at active volcanoes. The focal mechanism of the mainshock shows E–W-striking dip-slip fault plane ([De Novellis *et al.*, 2018](#)). The mainshock heavily damaged the hilly sector of Casamicciola Terme village (Fig. 2), reaching a maximum intensity of VIII in Mercalli–Cancani–Sieberg (MCS) scale, and causing two fatalities. Widespread damages also occurred in the Fango district (Lacco Ameno village) where the intensity reached VII MCS.

The epicentral area has been repeatedly damaged in the last three centuries, notably by the very strong earthquakes in 1796, 1828, 1881, and 1883 (with intensity between VIII and XI MCS; [Mercalli, 1884a,b](#); [Johnston-Lavis, 1885](#); [Alessio *et al.*, 1996](#); [Cubellis and Luongo, 1998](#)) (Table 1). Soon after the mainshock, a reconnaissance survey of the geological and environmental impact was conducted by a joint team from the Emergeo Working Group and Consiglio Nazionale delle Ricerche/Istituto Ambiente Marino e Costiero (CNR/IAMC). The group collected data on both primary (surface ruptures directly related to the earthquake causative fault) and secondary effects (mostly related to ground shaking and permanent ground deformation, e.g., landslides and hydrological variations) (e.g., [Keller and Pinter, 2002](#); [Michetti *et al.*, 2007](#)).



▲ **Figure 1.** Location of the coseismic geological effects on the shaded relief map by Nappi *et al.* (2010). Faults (in black) are from Acocella and Funicello (1999) and de Vita *et al.* (2010), and geomorphological lineaments (in black) from Nappi *et al.* (2010); active faults (lines with thick marks on down-thrown side) are from Vezzoli (1988) and Tibaldi and Vezzoli (1998); historical seismicity from Alessio *et al.* (1996). The 21 August 2017 mainshock (the biggest star) with its focal mechanism and the main aftershocks (the smallest stars) are from De Novellis *et al.* (2018). (Inset) The study region in a larger map around Italy. MCS, Mercalli–Cancani–Sieberg. The color version of this figure is available only in the electronic edition.

Although surface faulting has commonly been reported following moderate to strong earthquakes ($M > 5.5$, Wells and Coppersmith, 1994; Stirling *et al.*, 2013), it has only rarely been documented in volcanic areas, which are characterized by low-energy earthquakes with magnitudes typically less than 4; classic examples are the ruptures caused by low-magnitude, shallow earthquakes (less than 3 km) on Mt. Etna in Sicily (Azzaro, 1999; Azzaro *et al.*, 2000; Ferrelì *et al.*, 2002; Azzaro, 2004).

The 21 August 2017 event is the first well-documented instrumental earthquake at the Ischia island. It is also the first time that a detailed study on coseismic effects has been conducted and evidence observed for extensional surface faulting (Emergeo Working Group, 2017; Nappi *et al.*, 2017). As shown in the next few sections, results of our analysis allow (1) to define the geological model of the main local earthquake source and

(2) to discuss empirical relations between magnitude and surface faulting for very shallow volcano-tectonic events.

GEOLOGICAL SETTING

Ischia is an active volcanic island on the northwest side of the Gulf of Naples and belongs to the Campanian volcanic province, which includes the Campi Flegrei. The island is the subaerial portion of a volcanic complex that has been active since at least 150 ka B.P. (Vezzoli, 1988). Activity has been dominated by the caldera-forming Green Tuff eruption 55 ka B.P. This has been followed since at least 30 ka B.P. by block resurgence within the caldera to form Mt. Epomeo that today forms the highest point on the island at 787 m.a.s.l. (Orsi *et al.*, 1991). The last period of volcanic ac-



▲ **Figure 2.** Houses collapsed and heavily damaged by the 21 August 2017 earthquake in the hilly historical center of Casamicciola Terme (Ischia island). Photos by S. Porfido. The color version of this figure is available only in the electronic edition.

Table 1
Main Historical Earthquakes of the Ischia Island since Thirteenth Century and the Relative Observed Environmental Phenomena

Date (yyyy/mm/dd)	Latitude (°)	Longitude (°)	Epicenter	Intensity MCS	M_d	Environmental Effects
1275/11/02	40.733	13.917	Ischia	VIII–IX	4.01	Landslides
1302	–	–	Ischia	VIII	–	Arso eruption, landslides
1557	40.721	13.953	Ischia	VI–VII	3.5	
1762/07/23	40.746	13.909	Casamicciola Terme	VII–VIII	3.5	
1767	40.735	13.919	Casamicciola Terme	VII–VIII	3.5	Landslides
1796/03/18	40.746	13.909	Casamicciola Terme	VIII	3.88	Landslides
1828/02/02	40.746	13.909	Casamicciola Terme	VIII–IX	4.01	Landslides/fractures/hydrothermal variation (fumaroles)
1841/03/06	40.749	13.899	Casamicciola Terme	VI	3.25	
1863	40.746	13.909	Casamicciola Terme	V	2.87	Landslides and hydrothermal variation (fumaroles)
1867	40.746	13.909	Casamicciola Terme	V–VI	2.99	
1881/03/04	40.747	13.895	Casamicciola Terme	IX	4.14	Landslides/fractures/hydrothermal and hydrological variation (fumaroles)
1883/07/28	40.744	13.885	Casamicciola Terme	XI	5.2	Landslides/fractures/hydrothermal and hydrological changes

MCS, Mercalli–Cancani–Sieberg.

tivity started 10 ka B.P., with eruptions in the eastern sector of the island including the most recent eruption of Arso in 1302 (de Vita *et al.*, 2006; de Vita *et al.* 2010). Resurgence has been attributed to repeated injections of magma at depths of 2–3 km (Rittmann, 1930; Fusi *et al.*, 1990; Orsi *et al.*, 1991; Cubellis and Luongo, 1998; Tibaldi and Vezzoli, 1998; Acocella and Funicello, 1999; Molin *et al.*, 2003; Carlino *et al.*, 2006; Paoletti *et al.*, 2009; Sbrana *et al.*, 2009; Carlino, 2012). It has been asymmetric with a maximum displacement on the northern flank, owing to the control of an E–W normal fault system (Vezzoli, 1988; Orsi *et al.*, 1991; Tibaldi and Vezzoli, 1998; Acocella and Funicello, 1999; Tibaldi and Vezzoli, 2004; de Vita *et al.*, 2010; Nappi *et al.*, 2010).

Based on the distribution of marine deposits, eustatic variations and basin subsidence, the maximum uplift has been estimated at 920–970 m along the northern flank of Mt. Epomeo (Barra *et al.*, 1992; Tibaldi and Vezzoli, 1998) yielding a mean rate of 33 m per thousand years since 30 ka B.P. The northern flank of the uplifted block is separated from the more stable coastal area by a parallel system of ENE-striking normal faults that dip 60°–85° N and have produced a Holocene graben structure in the hanging wall (Tibaldi and Vezzoli, 1998). The net upward movement contrasts with a general subsidence of as much as 1 cm yr⁻¹ across the south-central part of the island since 1913 (Manzo *et al.*, 2006; Del Gaudio *et al.*, 2011; Castaldo *et al.*, 2017).

Combined with the seismic activity and the presence of the hydrothermal system, the high rate of resurgence has produced steep slopes on the flanks of Mt. Epomeo. The steep angles and geotechnical properties of the outcropping weathered Green Tuff have favored slope instability resulting in shallow mass movements and in large rock and debris avalanches (Mele and Del Prete, 1998; Del Prete and Mele, 1999; Violante *et al.*, 2003; Della Seta *et al.*, 2012; Marmoni *et al.*, 2017).

HISTORICAL AND RECENT SEISMICITY

Evidence for intense seismic activity on Ischia date back to pre-historical times (Bonito, 1691; Covelli, 1828; Mercalli, 1884a,b; Johnston-Lavis, 1885; Baratta, 1901). The seismicity has clear volcano-tectonic characteristics with shallow hypocenters located mostly beneath the Holocene graben on the northern flank of Mt. Epomeo. The maximum observed MCS intensities range between VII and XI (Table 1) decreasing rapidly in value with distance from the epicenters (Alessio *et al.*, 1996; Cubellis and Luongo 1998; Carlino *et al.*, 2010). The main earthquakes since the thirteenth century (Fig. 1) and their environmental impacts are reported in Table 1 (data from seismic catalogs: CPTI04, CPTI15, CFTI4Med, and scientific papers: Alessio *et al.*, 1996; Cubellis and Luongo, 1998; Molin *et al.*, 2003; Del Prete and Mele, 2006; Luongo *et al.*, 2006). The best documented earthquakes occurred in 1762 (VII–VIII MCS intensity), 1767 (VII–VIII MCS), 1796 (VIII MCS), 1828 (VIII–IX MCS), 1881 (IX MCS), and 1883 (XI MCS). They all claimed numerous victims and caused extensive damage to villages on the northern sector of Mt. Epomeo, where they triggered rock

falls and debris slides, and produced surface fractures and hydrological variations along the main fault zones in the north of the island (Mele and Del Prete, 1998; Esposito *et al.*, 2006). The most catastrophic earthquakes occurred on 4 March 1881 (IX MCS, Alessio *et al.*, 1996) and on 28 July 1883 (XI MCS and $M = 5.2$, Cubellis and Luongo, 1998). Both events destroyed Casamicciola village and its surroundings, killing 120 and injuring 140 people in 1881 and claiming 2343 lives in 1883.

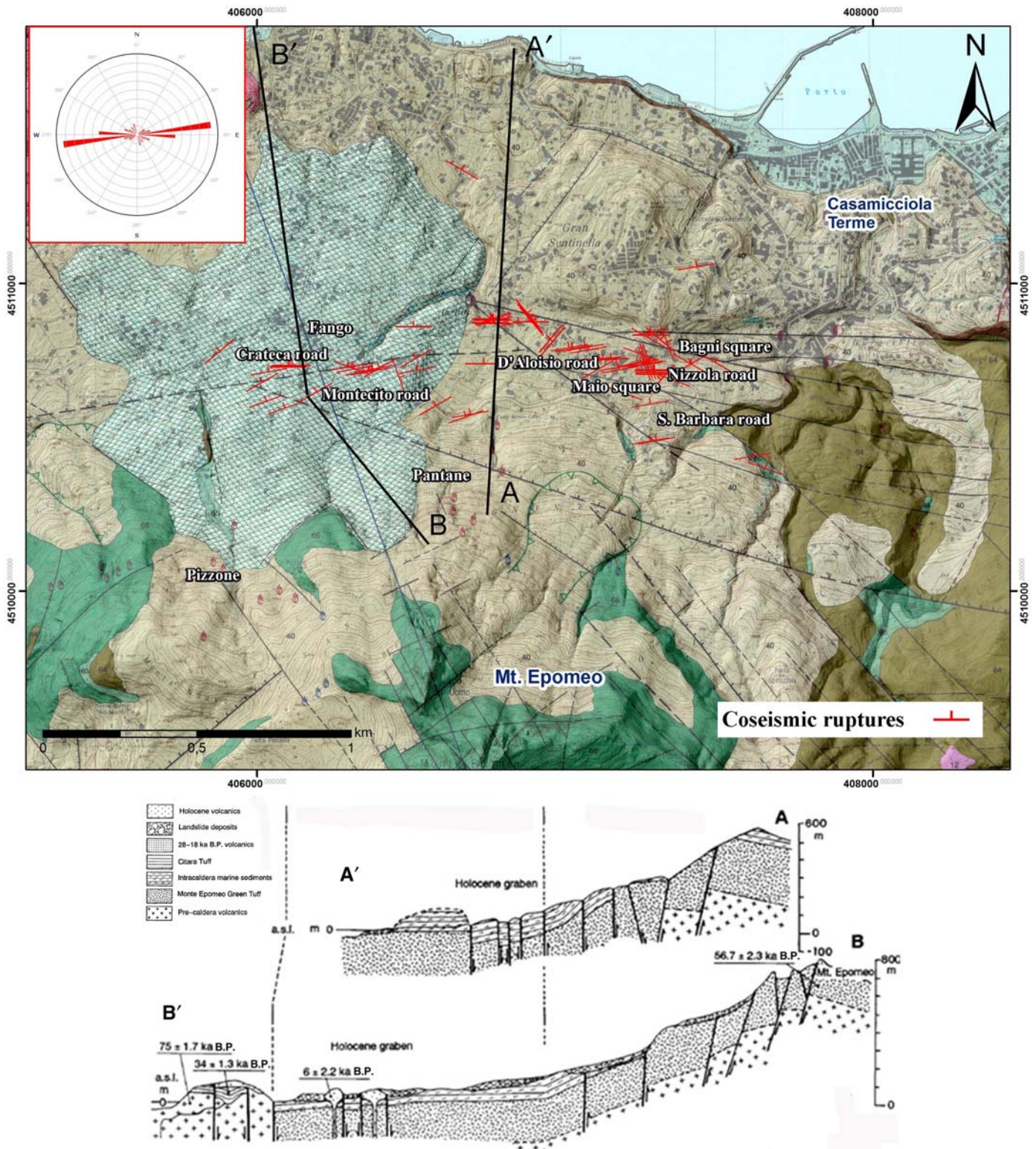
The 1881 and 1883 macroseismic fields show an E–W elongation in isoseismal lines along the northern sector of the island between Lacco Ameno and Bagni Square in Casamicciola Terme (Alessio *et al.*, 1996; Cubellis *et al.*, 2004). Only low-magnitude seismicity has occurred since 1883. For example, since 1999 about 50 events with M_I 2.3 or less and depths shallower than 2 km have been recorded by the three seismic stations of the permanent Ischia seismic network of the Istituto Nazionale di Geofisica e Vulcanologia-Osservatorio Vesuviano (INGV-OV, Plinio Database Naples). The 21 August 2017 M_d 4.0 earthquake with hypocentral depth at about 1.2 km is thus the first severely damaging earthquake at Ischia since 1883.

COSEISMIC GROUND EFFECTS INDUCED BY THE 21 AUGUST 2017 M_d 4 CASAMICCIOLA EARTHQUAKE

A response team from the Emergeo Working Group and CNR/IAMC arrived on Ischia the day after the mainshock on 21 August 2017 to survey the coseismic geological effects at the surface (Emergeo Working Group, Nappi *et al.*, 2017; Gruppo di Lavoro INGV sul terremoto dell'isola di Ischia, 2017). We conducted field mapping and data management using the standard procedures applied by the Emergeo Working Group for the 2012 Emilia and the 2016–2017 Amatrice–Visso–Norcia seismic sequences aftershock investigations (Emergeo Working Group, 2012, 2016; Pucci *et al.*, 2017). The primary survey was performed using digital mobile devices equipped with specific software (Rocklogger mobile app and Earthquake Geo-Survey, see Data and Resources) and using accelerometer, gyroscope, electronic magnetometer, and Global Positioning System to determine the exact orientation and position in space. The devices allowed accurate structural data to be collected and shared in real time. The whole data set was stored and managed in a georeferenced database on an Environmental Systems Research Institute ArcGIS platform. Further data were acquired using remotely piloted aircraft systems (RPAS) equipped with a Sony Alpha 6000 camera and a Flir SC655 thermal camera.

We collected more than 100 observations across the epicentral area and its surroundings (Fig. 1, ⊕ Table S1, available in the electronic supplement to this article). Most of the coseismic geologic effects were observed along the E–W piedmont belt of Mt. Epomeo, which extends for about 2 km between the Fango (Lacco Ameno) and Bagni Square in Casamicciola (Fig. 3).

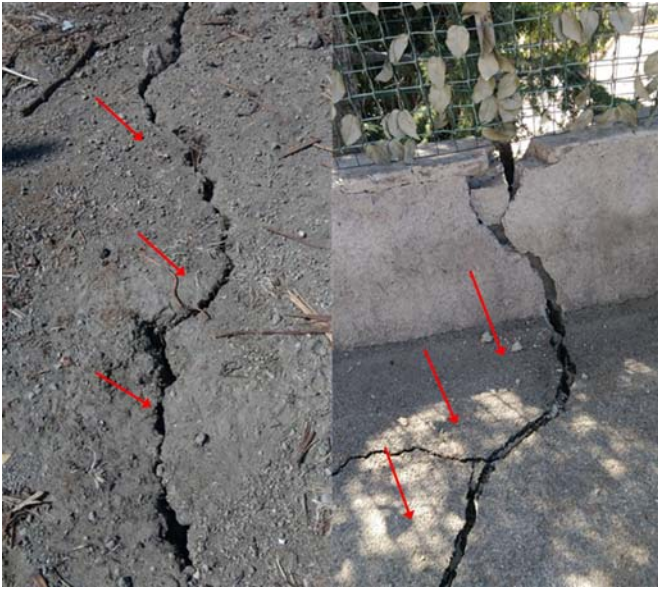
Altogether, we measured 18 coseismic fractures (small open cracks with vertical offset ≤ 1 cm), 68 coseismic ruptures (open cracks with vertical offset ≥ 1 cm), a few modest gravitational phenomena such as small size collapses (some cubic meters)



▲ **Figure 3.** Map of the coseismic ruptures in the surveyed area (© Table S1), with the rose diagram of the strike of the mapped ruptures on top left, overlapped on the geological map of [Vezzoli \(1988\)](#) and geological sections A'A and B'B modified by the authors from [Tibaldi and Vezzoli \(1998\)](#) which traces are in the map on the top. The color version of this figure is available only in the electronic edition.

and small landslides in volcanoclastic deposits; and widespread effects related to shaking, such as the collapse of drywalls made of green tuff and lava and known locally as “parracine.” Along

the Cratecca street (Fango, Lacco Ameno), on the western sector of the epicentral area we observed a system of parallel ruptures that cut the ground, the road pavement, and man-made struc-



▲ **Figure 4.** Coseismic ruptures (oblique arrows) affecting both soil (on the left) and man-made structures (on the right) on Crateca road (see Fig. 3 for location, from stop 1 to 6 in Table S1). The color version of this figure is available only in the electronic edition.

tures (Fig. 4), with lengths ranging from few meters to more than 30 m, vertical offset of about 2 cm, maximum opening of 3 cm, with prevalent strike $N70^{\circ}$ – $N90^{\circ}$ (Fig. 4) and dip toward the north-northwest with a vertical offset of 2 cm. We also

observed numerous collapses of drywalls both along the street and in terraced vineyards.

Along the Montecito road (Casamicciola), on the central sector of the epicentral area, we mapped an almost continuous, $N80^{\circ}$ striking alignment of coseismic ruptures for an overall length of about 150 m. The ruptures cut across ground, the road pavement, and man-made structures (Fig. 5) and follow the E–W Montecito fault system at the base of Mt. Epomeo's northern slope. The dip was again toward the north-northwest and the vertical offset was about 2 cm. We also observed a rotated pillar (Fig. 5), the collapse of drywalls and modest gravitational movements from south to north. Using thermocouples and thermal cameras, we recorded temperatures of 98°C in the fumarolic fields at Pantane and Pizzone along the Montecito fault system (Fig. 3); these values are similar to those obtained between 2008 and 2014 (Emergeo Working Group, 2017). Probable coseismic rockfalls were also identified by RPAS in the impervious Pantane area (Fig. 6).

The most damaged area was the Maio square, D'Aloisio road, and Santa Barbara road, in the hilly historical sector of Casamicciola. We again observed several ruptures on the ground, pavement, paved road, and man-made structures (Fig. 7). The ruptures were aligned $N80^{\circ}$ and dip northward, with a vertical offset of almost 1 cm. In several places, drywalls had also collapsed from south to north.

DISCUSSION

The coseismic ruptures display remarkably consistent movements along the entire 2 km of the E–W piedmont belt



▲ **Figure 5.** Coseismic ruptures (the arrows in the middle picture) cutting ground, road pavement and man-made structures along Montecito road (middle picture from stop 60 to 70 in Table S1); the arrows pointing toward right and left indicate two details of the middle picture: on the right rotated pillar is shown, on the left the man-made structures fractured (Fig. 3 for location). The color version of this figure is available only in the electronic edition.



▲ **Figure 6.** Coseismic rockfall located in the impervious Pantane area by remotely piloted aircraft systems (Fig. 3 for location). The color version of this figure is available only in the electronic edition.

of Mt. Epomeo (Fig. 3). At scales from ~ 0.01 to ~ 100 m the ruptures show vertical displacements toward the North regardless of topography, including pre-existing landslides. The extensional movement has opened fractures by as much as 3 cm and with maximum offsets of 2 cm. The ruptures are preferentially aligned from $N80^\circ E$ to $N110^\circ E$ (Fig. 3). The variability of 30° is largely confined to a limited portion of the eastern sector (from Bagni square to Nizzola road) whereas the western and central portions of the surveyed area (from Crateca road to Bagni square) show a more regular strike of $N80^\circ$. Secondary coseismic effects, such as small rockfalls and debris flows in volcanoclastic deposits, are concentrated along the eastern sector of Mt. Epomeo's northern slope (Fig. 8). In contrast, drywalls collapsed mainly toward the north over the whole area.

The consistent geometry, regularity, and kinematics of the coseismic movements strongly suggest a primary tectonic

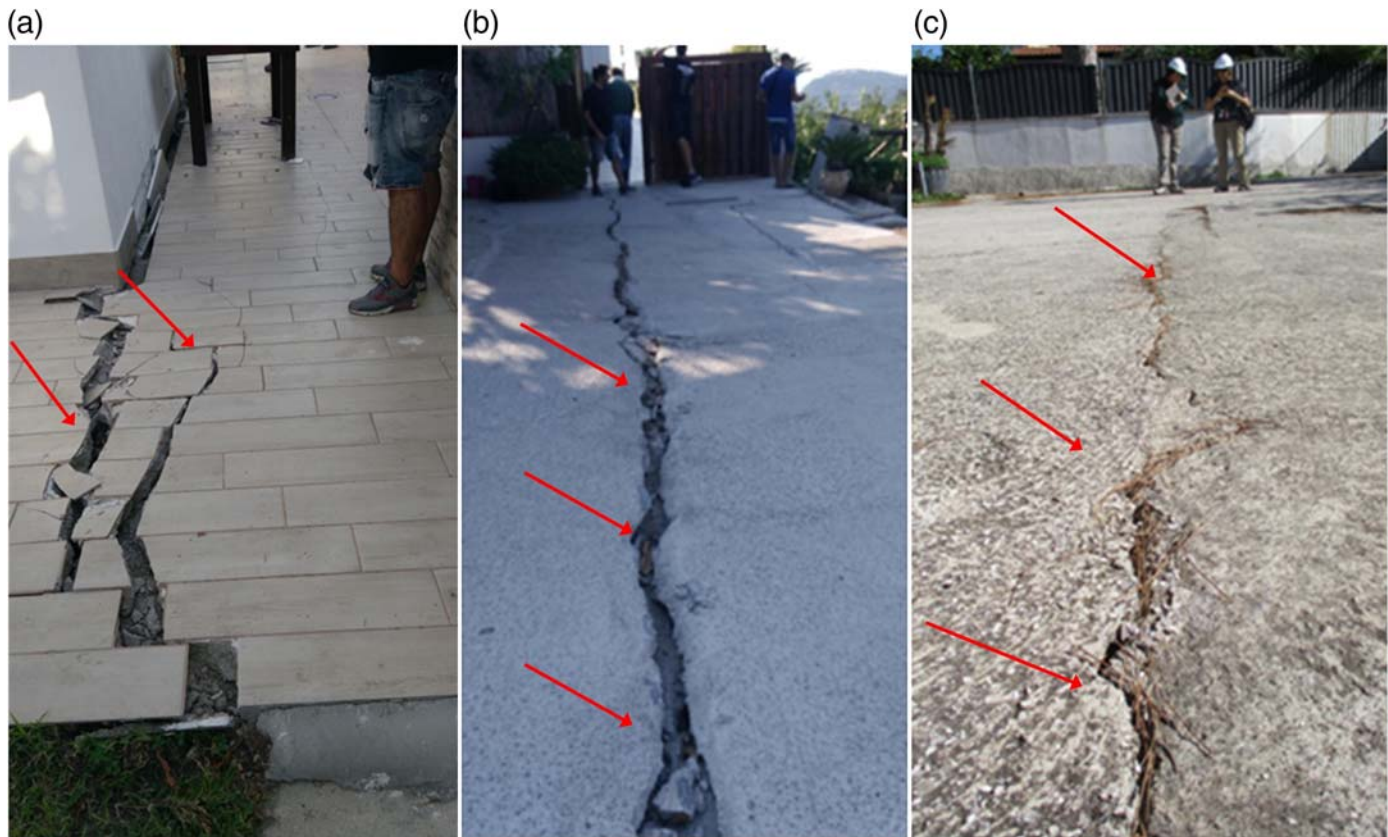
origin for the mapped ruptures (i.e., the propagation up to the surface of the seismogenic motion occurred at depth).

Moreover, some ruptures cut across old landslides with no evidence of curvilinear shape expected from purely gravitational phenomena. Most of these ruptures were visited after the rainy season, in November 2017, and no evidence of postseismic reactivation has been observed, supporting their primary rather than gravitational origin.

We therefore suggest that the 21 August earthquake was caused by a reactivation of the E–W fault systems associated with the uplift of Mt Epomeo's northern flank since the Holocene (Vezzoli, 1988; Tibaldi and Vezzoli, 1998). Fault reactivation is supported by the fact that the macroseismic fields of Ischia's largest historical earthquakes show the same E–W elongation of isoseismal lines (Alessio *et al.*, 1996; Cubellis *et al.*, 2004) and produced coseismic ground effects and damage comparable to those for the 21 August earthquake (Table 1, Fig. 9). Cubellis and Luongo (1998) argued that the most recent strong earthquake in 1883 was controlled by a subvertical fault (length about 2 km and depth about 1.5–2 km) located on the northern side of Mt. Epomeo, with E–W or ENE–WSW strike. The characteristics of the 21 August earthquake are consistent with the same fault system. The 21 August event thus represents a reference earthquake that can be used to calibrate and validate the entire historical seismic dataset and presents an extraordinary opportunity to constrain kinematic models of the north-flank fault system of Mt. Epomeo.

Recently, De Novellis *et al.* (2018) published a geophysical model for the causative source of the Casamicciola earthquake based on Differential Interferometric Synthetic Aperture Radar, continuous Global Positioning System (cGPS), and seismological data, through analytical techniques. On the basis of their focal mechanism data, they found a plane P1 E–W trending with a dip of $82^\circ \pm 28^\circ$, therefore a subvertical plane, where the hanging block (northern part of Mt. Epomeo) moved downward. This plane is similar to our proposed fault plane as causative source and is also proposed by them as probable fault plane. On the other hand, their final model provides an E–W plane with south-dipping high-angle plane (70°) with dip opposite to our hypothesized dip. We want to remark that this model does not take in account the overall geological model of the recent evolution of the northern slope of Mt. Epomeo. Moreover the cGPS data are affected by uncertainty due to the location of the used instruments (cGPS Monte Epomeo [MEPO] and Osservatorio di Casamicciola [OSCM] stations) that are not close to the hanging wall and footwall of the seismogenic fault, so that they could not provide a reliable measurement of the slip distribution.

Our model with a subvertical fault with fault dip toward north, opposite to the model by De Novellis *et al.* (2018), is a reasonable hypothesis for the Casamicciola earthquake source because it is based (a) on the significative and large collected geological dataset, with the whole coseismic ruptures found in the hanging wall, as usually observed for normal faults; (b) on the comparison with previous historical events which deformation field pattern is in good agreement with our data; and



▲ **Figure 7.** Coseismic ruptures on ground, pavement, paved road, and man-made structures (a,b) between the Maio square and the Santa Barbara road, (c) d'Aloisio road (see Fig. 3 for location). The color version of this figure is available only in the electronic edition.

(c) on the conformity with existing long-term geological models (Tibaldi and Vezzoli, 1998, and references therein).

A further element supporting the interpretation of primary surface faulting for the 21 August 2017 earthquake arises from the comparison with the scaling law suggested by Riuscetti and Distefano (1972), who first made this observation about the peculiar relations between earthquake magnitude and surface faulting for the low magnitude, very shallow seismic events on the eastern flank of Etna volcano. Successively, Azzaro *et al.* (2000) examined the volcano-tectonic earthquakes of Etna with magnitude $3 < M < 5$ able to generate surface faulting (Fig. 10). Inside the active volcanic areas as the Ischia island, characterized by very shallow seismic sources and low-stress drops, the magnitude value above which surface faulting can occur depends on the rheology of rocks and the stress pattern at hypocentral depths (Buchanan-Banks, 1987; Grindley and Hull, 1986). The surface rupture length of about 2 km observed for the Casamicciola earthquake is in good agreement with surface rupturing versus magnitude for the volcanic area of the Etna by Azzaro (2004) (Fig. 10). It shows that volcano-tectonic events with hypocentral depths shallower than 2–3 km might generate coseismic surface displacement following scaling laws between earthquake magnitude and surface faulting that are very different from the ones described in the literature (Wells and Copper-smith, 1994) and recently discussed by Stirling *et al.* (2013). Moreover, the observed surface deformation is consistent with

the deformation detected from the Synthetic Aperture Radar analysis and precision leveling survey carried out after the earthquake, describing a ground subsidence of up to 3 cm in the northern slope of the Mt. Epomeo (De Novellis *et al.*, 2018).

CONCLUSIONS

Our data and analysis strongly suggest that the source of the 21 August 2017 Casamicciola earthquake is about 2 km long, north-dipping normal fault (Fig. 3), consistent with the well-known E–W Holocene extensional system (Tibaldi and Vezzoli, 1998).

Summarizing the study of ground effects for the 21 August 2017 earthquake suggests that:

1. the M_d 4.0 normal-faulting earthquake in the Ischia island is able to generate primary surface rupturing (Fig. 3);
2. the E–W normal fault identified has the same geometric characteristics of the faults that generated the eighteenth–nineteenth centuries strong earthquakes (Alessio *et al.*, 1996; Cubellis and Luongo, 1998) in the northern sector of the Ischia island;
3. the 21 August 2017 earthquake can be considered as a reference seismic event for the future calibration of the entire seismic historical dataset and represents an useful chance to better constrain the seismotectonic model of the most catastrophic events occurred in the Ischia island; and



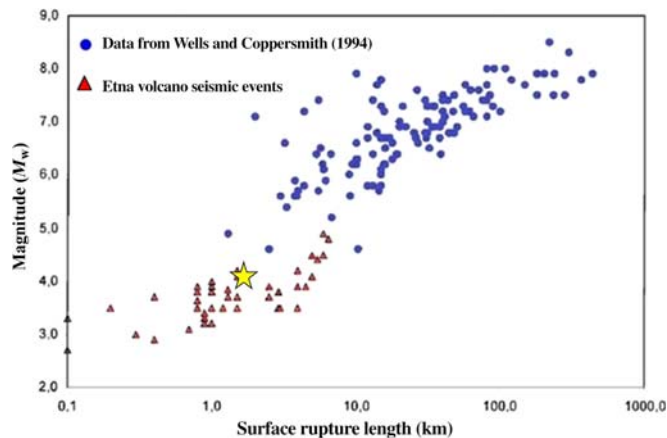
▲ **Figure 8.** The secondary coseismic effects observed: (a,c) collapse of drywall and man-made structure, (b,d) small rockfall and small debris flow in volcanoclastic deposits. The color version of this figure is available only in the electronic edition.

4. the new data and insights for understanding the surface-faulting mechanism due to small-size or moderate earthquakes in volcano-tectonic context are very useful to complete the gap of the available database (e.g., [Wells and Coppersmith, 1994](#);

[Azzaro, 2004](#); [Stirling et al., 2013](#)) that are significantly lacking information for magnitude range $3.0 < M < 5.0$. In conclusion, we underline that the $M_d 4$ Casamicciola earthquake has had catastrophic consequences on local



▲ **Figure 9.** Coseismic fractures and drywall collapses due to the 28 July 1883 historical earthquake along Campomanno road (near Santa Barbara locality) on the left (Ferretti, 1883), compared to the recent coseismic ground effects of the 21 August 2017 earthquake at the same location on the right. The color version of this figure is available only in the electronic edition.



▲ **Figure 10.** Updated empirical relationships between magnitude and surface rupture length (Azzaro, 2004, modified). The star indicates the 21 August 2017 Casamicciola earthquake. The color version of this figure is available only in the electronic edition.

communities which cannot be neglected for seismic hazard evaluation and land use planning in the Ischia island, one of the most crowded touristic destinations worldwide.

DATA AND RESOURCES

The historical seismological dataset was extracted from Catalogo Parametrico dei Terremoti Italiani (CPTI04, <https://emidius.mi.ingv.it/CPTI04/>, last accessed December 2006), (CPTI15, <https://emidius.mi.ingv.it/CPTI15-DBMI15/>, last accessed July 2016), (CFTI4Med, <http://storing.ingv.it/cfti4med/>, last modified December 2015); the instrumental seismic data were extracted from Plinio Database INGV-Naples <http://sismolab.ov.ingv.it/sismo/index.php?PAGE=SISMO/last&area=Ischia> (last accessed January 2018). The shaded relief maps (Fig. 1) are based on the digital elevation model processed by Nappi *et al.* (2010). We collected fault data set (Fig. 1) from scientific paper published and listed in the References. Rocklogger© mobile app can be accessed at www.rockgecko.com (last accessed November 2017) and Earthquake Geo-Survey was available at <http://earthquakegeosurvey.weebly.com/> (last accessed November 2017). ✉

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