

**Text S1: Maps of the areas affected by ballistics of 43 major explosions
from 1970 to 2023.**

Supporting Information for:

**Ballistic projectile hazard of major explosions and paroxysms at Stromboli (Italy) with
uncertainty quantification: 1. Mapping method and data analysis**

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In the following list of 43 descriptive files we present the reconstructions of the areas affected by the major explosions considered in our analysis. In particular, for every major explosion on the left of the simplified map based on circular sectors, we show a visual summary of the available information on ballistics, following the same schematics described for the paroxysms. Above the figures we report the references of the main sources, the date and time of the event; below the figures we report the description of ballistic projectiles and the field survey information if available. Some descriptions are referenced to the names of topographical features of the upper portion of the island; these place names are summarized in Figure 1 of this document. Finally, Table 1 of this document summarizes the fragmentary information on the ballistics of the major explosions that we could not map.

In addition to the scientific publications, we considered hundreds of monitoring and surveillance bulletins and reports regarding Stromboli volcano, issued by the “International Association of Volcanology and Geochemistry of the Earth Interior” (IAVCEI); by “Istituto Internazionale di Vulcanologia” (IIV) and “Gruppo Nazionale di Vulcanologia” (GNV) of “Consiglio Nazionale delle Ricerche” (CNR), by “Istituto Nazionale di Geofisica e Vulcanologia” (INGV), and by “Laboratorio di Geofisica Sperimentale” of Università di Firenze (UNIFI-LGS). We also considered the open documents on the “Stromboli Online” website by SwissEduc, the “Scientific Event Alert Network” (SEAN) and the “Global Volcanism Network” (GVN) of the Smithsonian Institution.

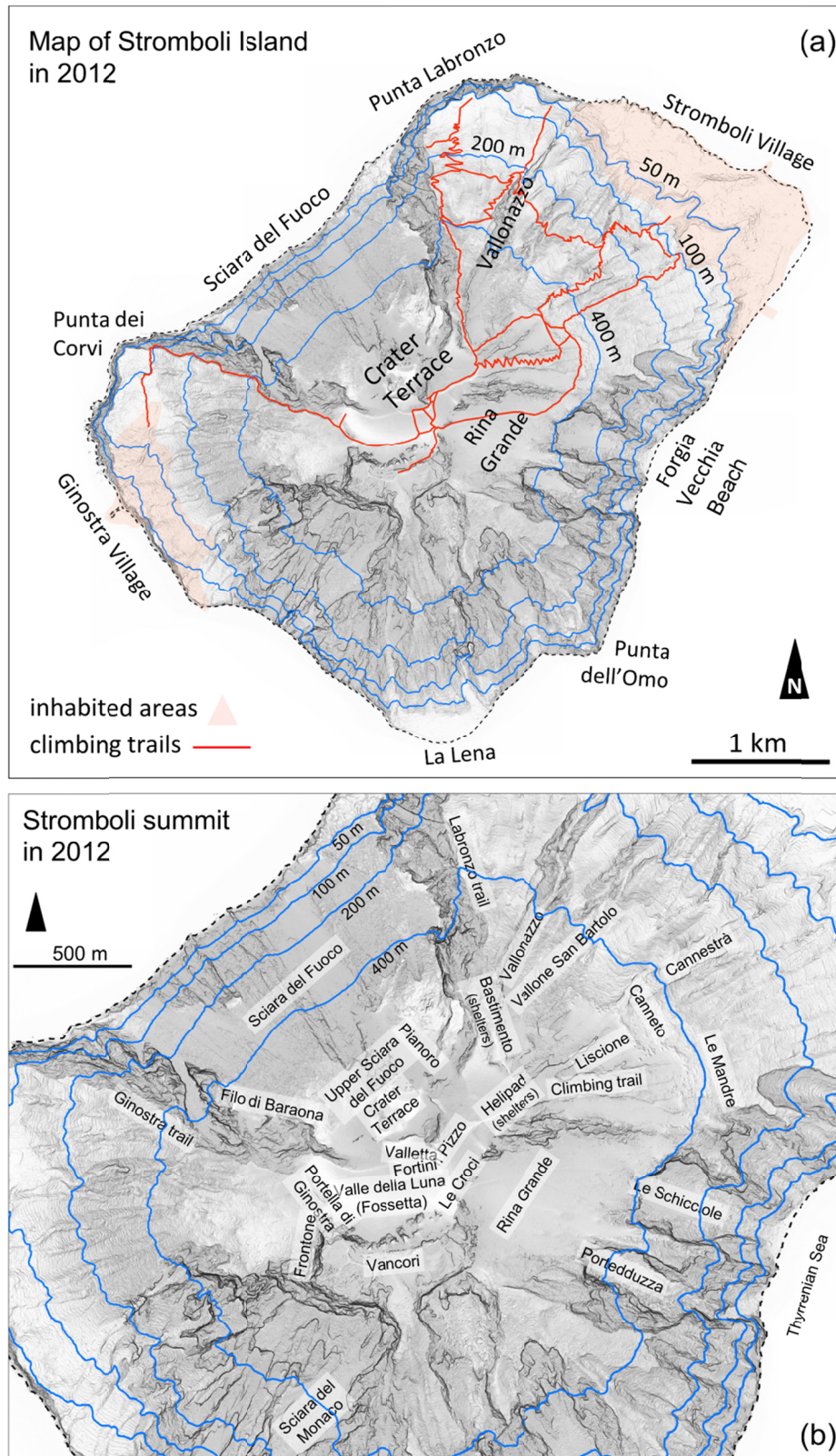
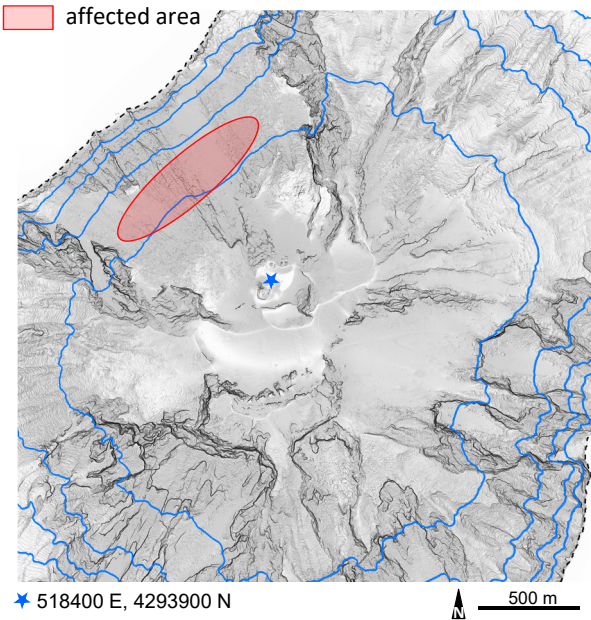


Figure 1. Hillshaded mappings with main place names labeled. (a) shows the entire Island of Stromboli and (b) its upper portion. See also Losacco (1973).

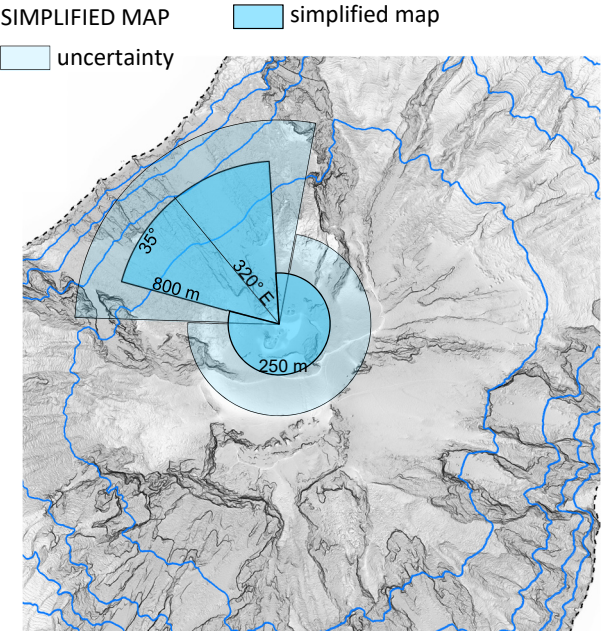
Descriptive File 1.

Main sources	Year	Month	Day	GMT
INGV - reports of volcanic activity; INGV - weekly bulletin; UNIFI-LGS reports	2022		7	25 02:56

FIELD DATA AND OBSERVATIONS



SIMPLIFIED MAP



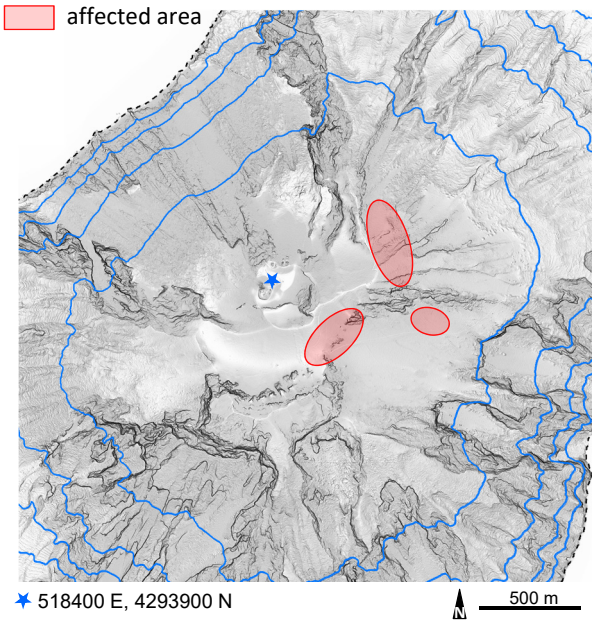
Ballistic projectiles
Abundant products in Sciara del Fuoco, not observed coarse products on Pizzo. Most intense explosion is from crater N2 - products > 300 m high and fell in Sciara del Fuoco (2 mins).

Several ballistics reach the coastline on Sciara del Fuoco. Followed by 6 mins lava fountaining; weaker explosion from S1 closes the sequence (8 s). Total duration 8 mins. Small cone destroyed in N sector

Descriptive File 2.

Main sources	Year	Month	Day	GMT
INGV - reports of volcanic activity; INGV - weekly bulletin; UNIFI-LGS reports; Landi - personal communication	2022		5	13 14:43

FIELD DATA AND OBSERVATIONS



Ballistic projectiles
Six main explosions, first is most energetic (8 s) - products 300 m high towards E and SE and affect Pizzo. Total duration 4 mins.

Adundant products fell in Sciarra del Fuoco and hot ballistics between 400 e 500 m asl towards E.

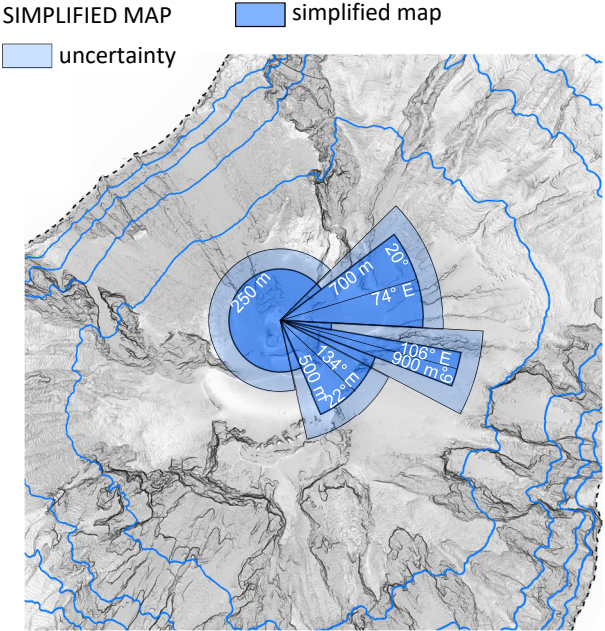
Field survey information
Field survey one day after the event. lowest elevation of products was 450 m asl, towards NE from the vents. Impact craters along trajectory implies that the products rolled down after a first landing.

Primary landing marks observed at 700-830 m asl, near the climbing trail ("Liscione"). They were all due to lithics. Lithic bombs, decimetric to metric, close to the elipad at 850 m asl. climbing toward Pizzo no impact marks or clasts, but a few were near the surveillance camera, undamaged.

On Pizzo there some juvenile scoriae, very light material, and stretched. Sporadic coverage, cm to dm sized. Towards "Fortini" on the S side (890 m asl), juvenile scoriae similar to those found on Pizzo. Observation of "Fossetta"- many clast or impact mark are evident. CS craters were found deepened and enlarged by the event.

Figure. Landing marks left by projectiles emitted during the May 13, 2022, explosion. Personal communication - Landi.

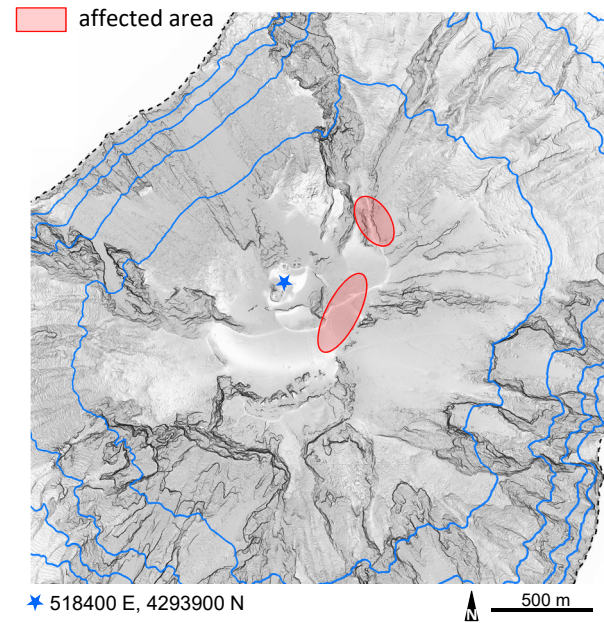
SIMPLIFIED MAP



Descriptive File 3.

Main sources	Year	Month	Day	GMT
INGV - reports of volcanic activity; INGV - weekly bulletin; UNIFI-LGS reports; Landi - personal communication	2021		10	6 14:17

FIELD DATA AND OBSERVATIONS



Ballistic projectiles
Abundant coarse products radially fell beyond crater terrace, on Pizzo and in Sciara del Fuoco (10 s).

Field survey information
Field survey - decimetric spatter bomb about 500 m from the craters, below the shelters at Bastimento.

SIMPLIFIED MAP

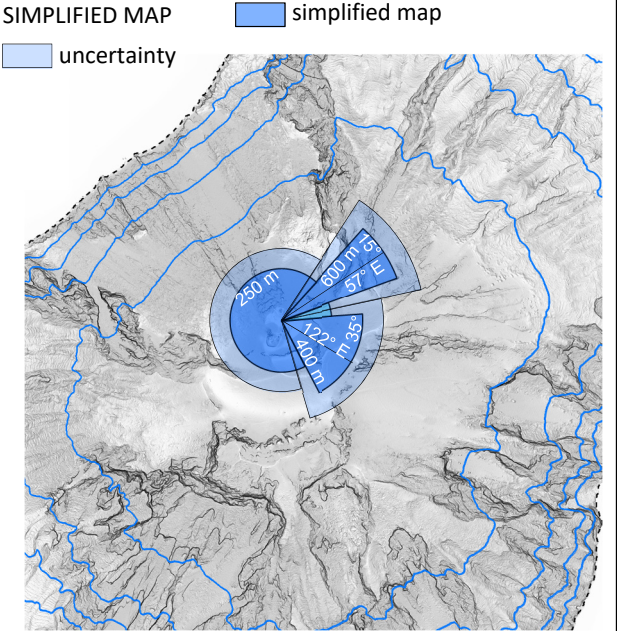
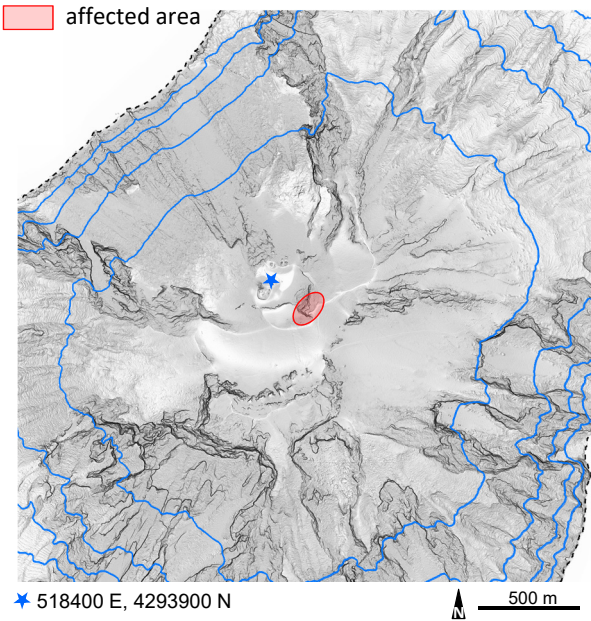


Figure. Some products emitted during the October 6, 2021, explosion at about 500 m NE from the craters. Personal communication - Landi.

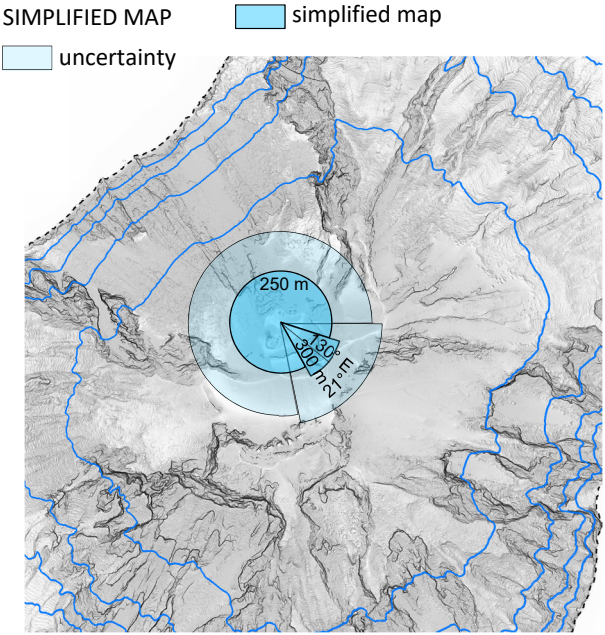
Descriptive File 4.

Main sources	Year	Month	Day	GMT
INGV - reports of volcanic activity; INGV - weekly bulletin; UNIFI-LGS reports	2021		8	1 20:01

FIELD DATA AND OBSERVATIONS



SIMPLIFIED MAP



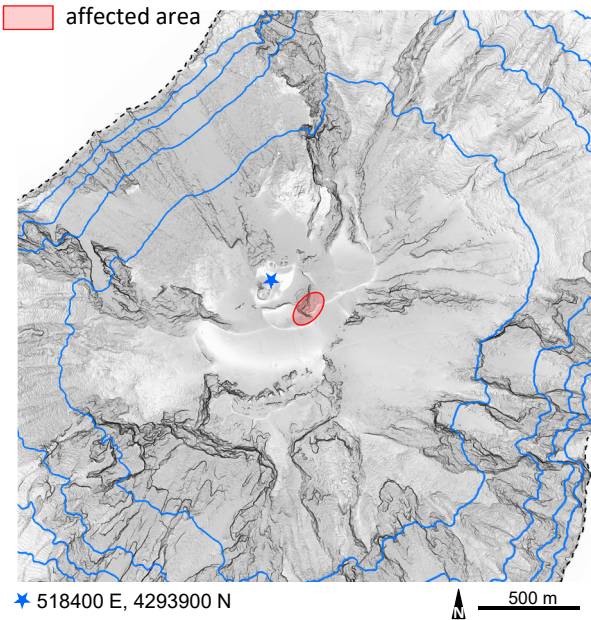
Ballistic projectiles

Products 150 m high,fell beyond crater terrace, including in Sciara del Fuoco, and affected Pizzo.

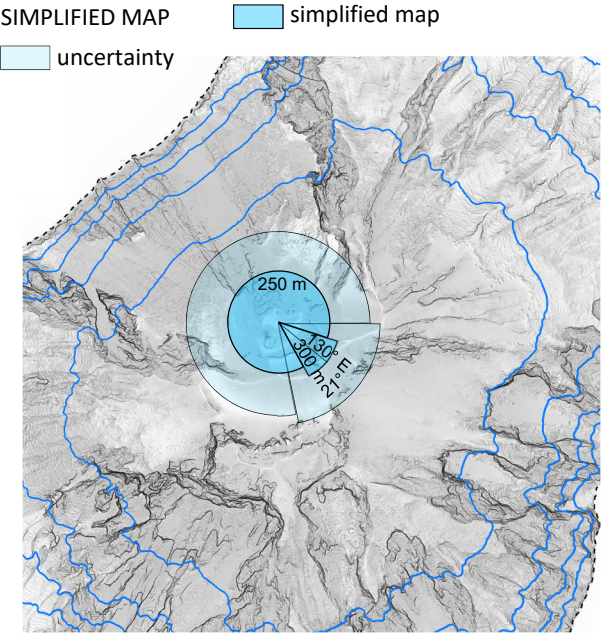
Descriptive File 5.

Main sources	Year	Month	Day	GMT
INGV - reports of volcanic activity; INGV - weekly bulletin; UNIFI-LGS reports	2021		7	28 14:47

FIELD DATA AND OBSERVATIONS



SIMPLIFIED MAP



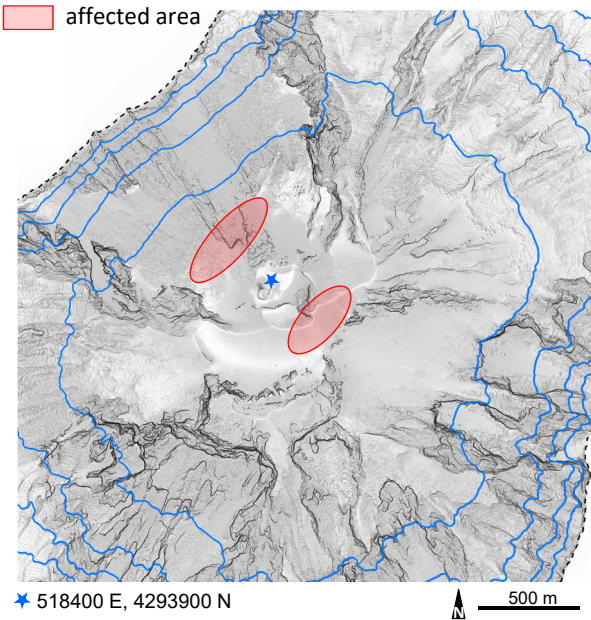
Ballistic projectiles

Products radially fell in Sciara del Fuoco, all crater terrace, and Pizzo, > 200 m high.

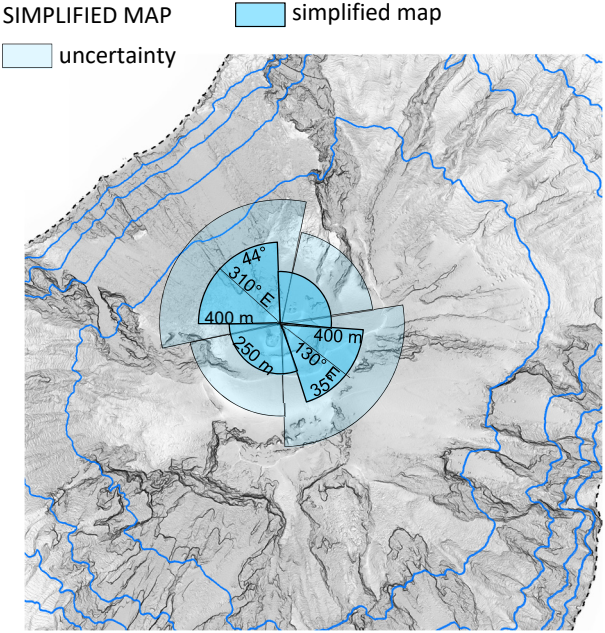
Descriptive File 6.

Main sources	Year	Month	Day	GMT
INGV - report of volcanic activity; INGV - weekly bulletin; UNIFI-LGS reports	2021		7	14 13:19

FIELD DATA AND OBSERVATIONS



SIMPLIFIED MAP



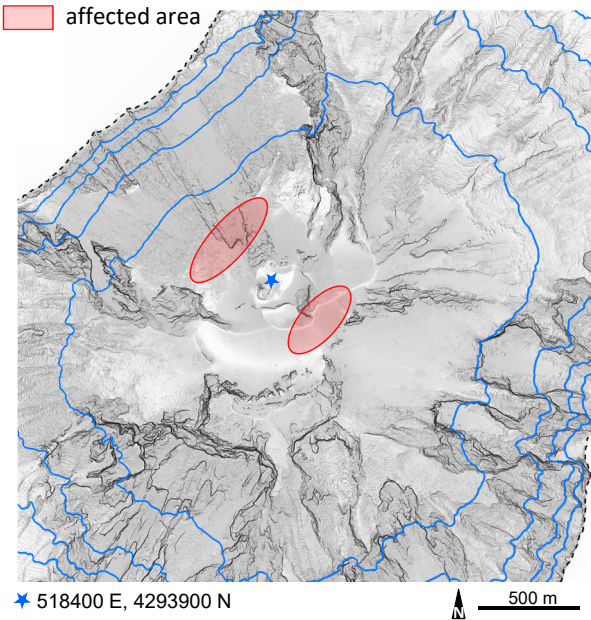
Ballistic projectiles

Products fell in Sciara del Fuoco and reached the area of Pizzo. Abundant products "beyond crater terrace". 1 min duration.

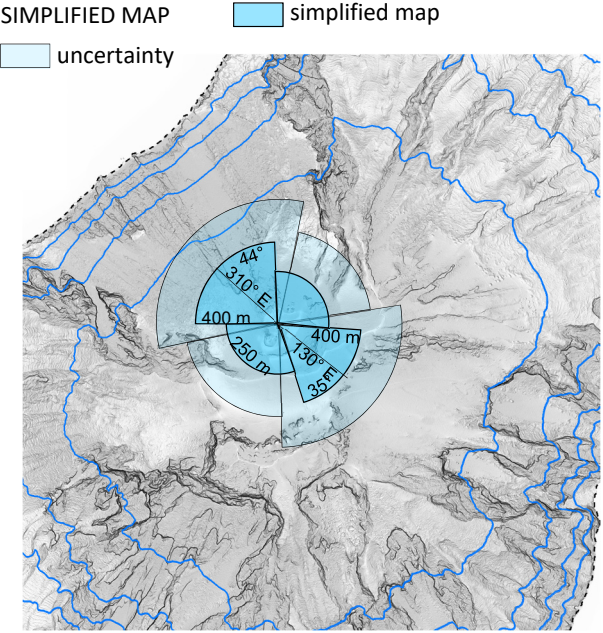
Descriptive File 7.

Main sources	Year	Month	Day	GMT
INGV - report of volcanic activity; INGV - weekly bulletin; UNIFI-LGS reports; Calvari et al. (2022)	2021		3	1 01:32

FIELD DATA AND OBSERVATIONS



SIMPLIFIED MAP



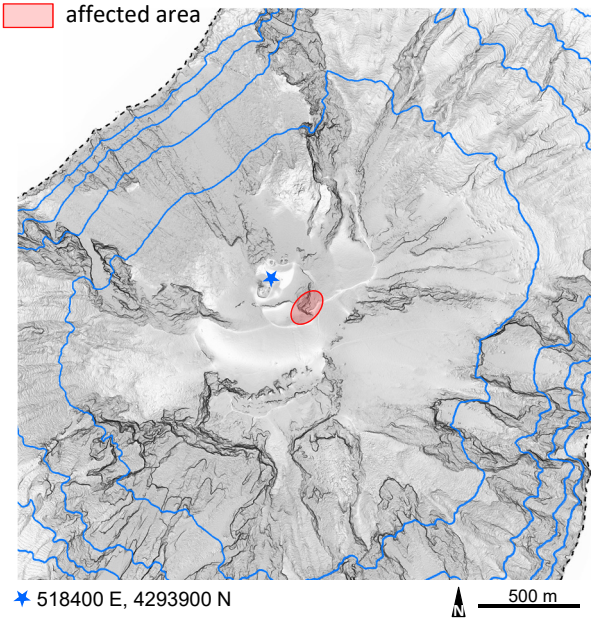
Ballistic projectiles
Three explosions, first most intense at crater N2.

Coarse products ejected >350 m high fell in Sciara del Fuoco towards W and beyond Pizzo towards E. Total duration 3m 30s.

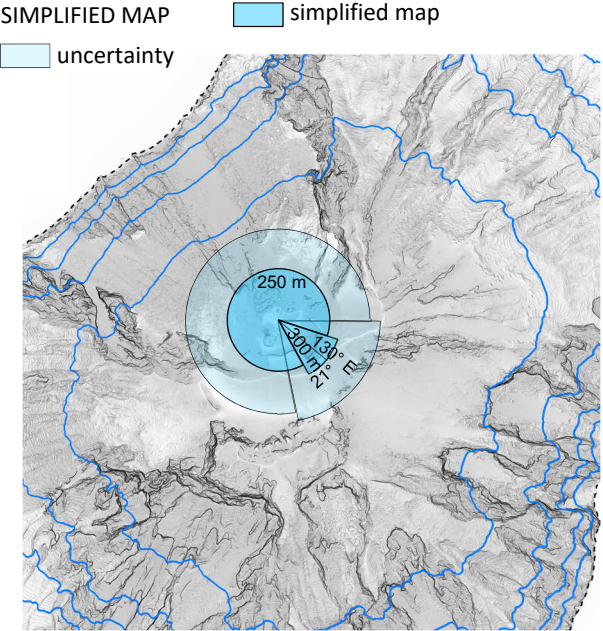
Descriptive File 8.

Main sources	Year	Month	Day	GMT
INGV - report of volcanic activity; INGV - weekly bulletin; UNIFI-LGS reports; Calvari et al. (2021)	2020		11	16
				09:17

FIELD DATA AND OBSERVATIONS



SIMPLIFIED MAP



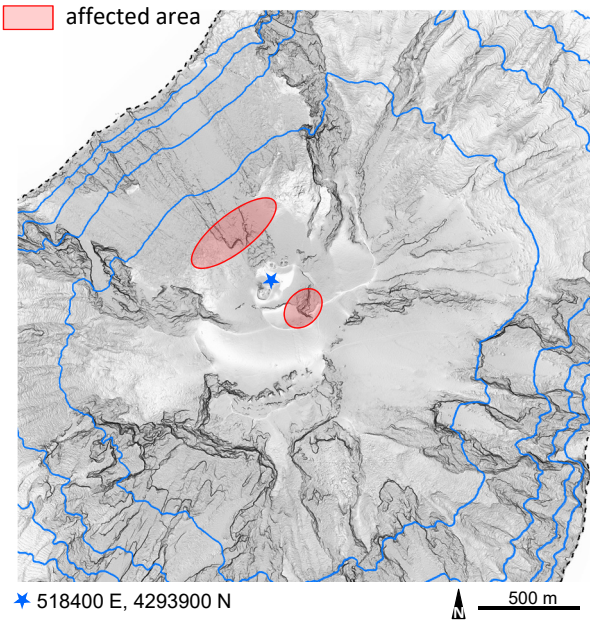
Ballistic projectiles

Radial ejection of products 300 m high (1 min). Significant products emission beyond crater terrace. Products over Pizzo.

Descriptive File 9.

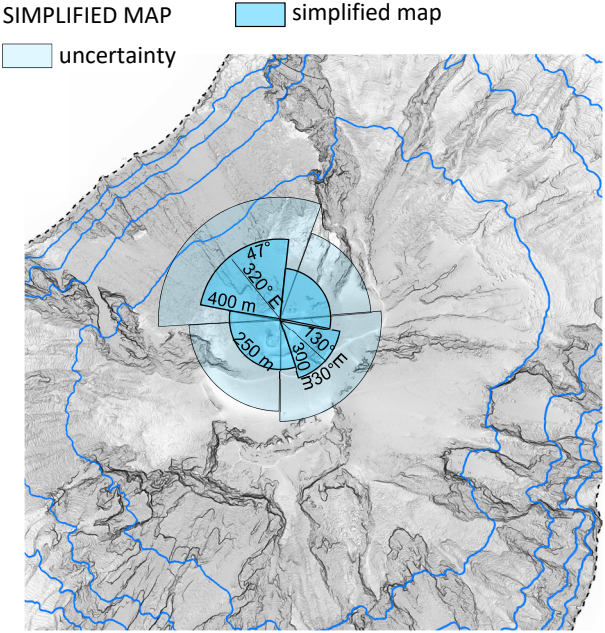
Main sources	Year	Month	Day	GMT
INGV - report of volcanic activity; INGV - weekly bulletin; UNIFI-LGS reports; Calvari et al. (2021)	2020		11	10 20:04

FIELD DATA AND OBSERVATIONS



Ballistic projectiles
Mostly in Sciara del Fuoco, but also to Pizzo.
Significant products emission beyond crater terrace.

SIMPLIFIED MAP

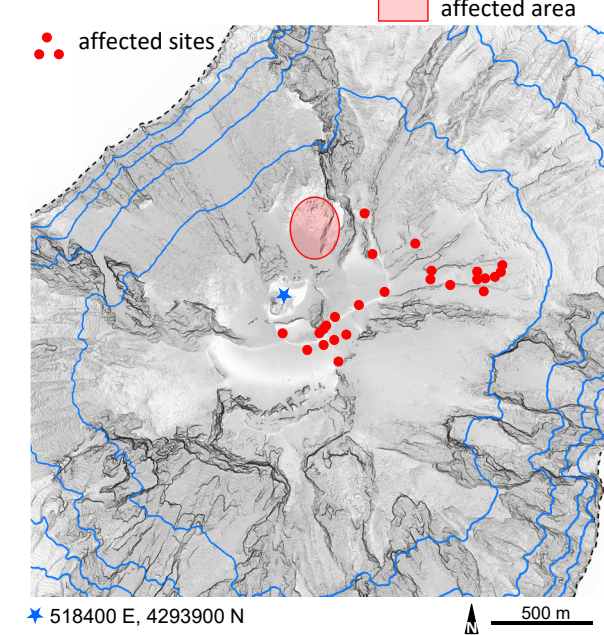


Field survey information
Elicopter survey - great metric blocks in Sciara del Fuoco and S sector of crater terrace.
Pizzo was concealed by clouds.

Descriptive File 10.

Main sources	Year	Month	Day	GMT
INGV - report of volcanic activity; INGV - weekly bulletin; UNIFI-LGS reports; Personal communication - Landi; Calvari et al. (2021); Landi et al. (2022); Voloschina et al. (2023)	2020		7	19
				03:00

FIELD DATA AND OBSERVATIONS



Ballistic projectiles

Three explosions (35 s). Products were radially distributed and reached ca. 500 m asl.

Field survey information

Field survey - ballistics up to 1200 m from the vents towards E (on the trail), and over Pizzo and Valle della Luna towards SE.

SIMPLIFIED MAP

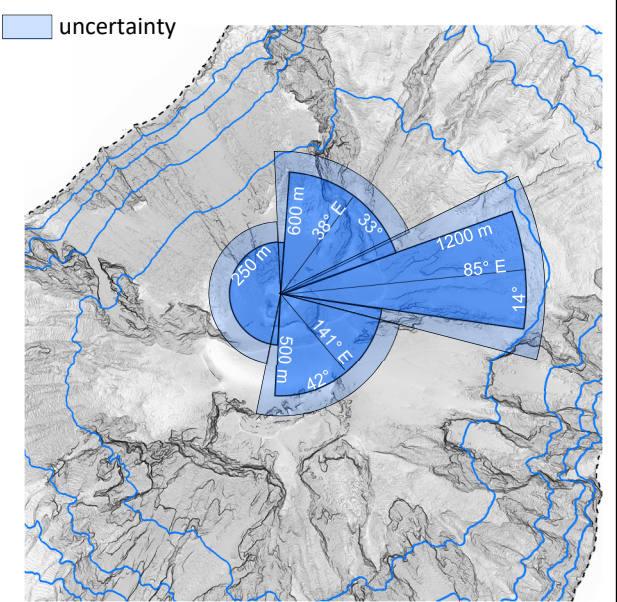
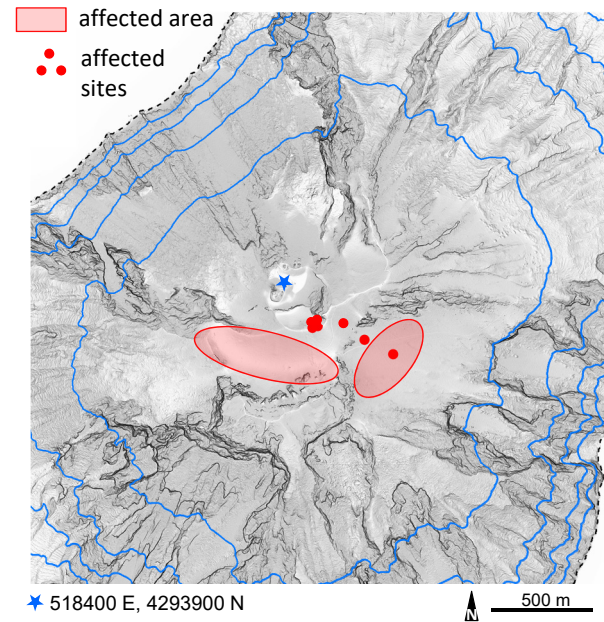


Figure. Data on dispersal of the products emitted during the July 19, 2020 explosion by D. Andronico (personal communication) and P. Landi.

Descriptive File 11.

Main sources	Year	Month	Day	GMT
INGV - report of volcanic activity; INGV - weekly bulletin; Calvari et al. (2021); Giordano&De Astis (2021)	2019	6	25	23:03

FIELD DATA AND OBSERVATIONS



Ballistic projectiles

Products fell in Sciara del Fuoco and in most of the crater terrace, prevalently S sector, with some blocks outside crater terrace.

Field survey information

Field surveys one day and again three days after the event, products fell abundantly in Valle della Luna (towards Ginostra).

Almost no ballistics along the ascent climb track. Southwards from the summit both lithic blocks and dark spatter bombs made of HP magma associated with impact craters up to some tens of cm deep.

Large bombs and blocks were scattered along the descent track with a southerly dispersal. The central crater rim was littered with large lithic blocks, and the crater floor was levelled out and covered by large coalescing spatter clasts; central crater enlarged. Fires below Rina Grande at ca. 500 m asl

SIMPLIFIED MAP

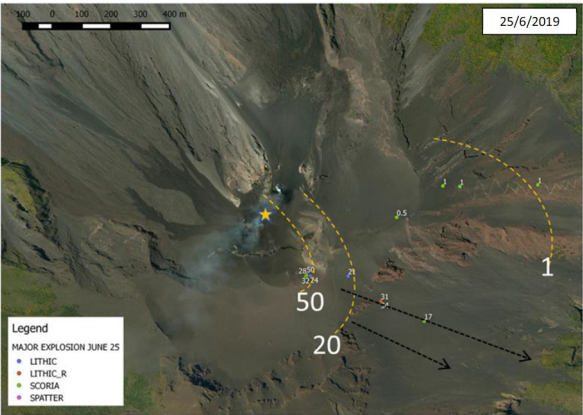
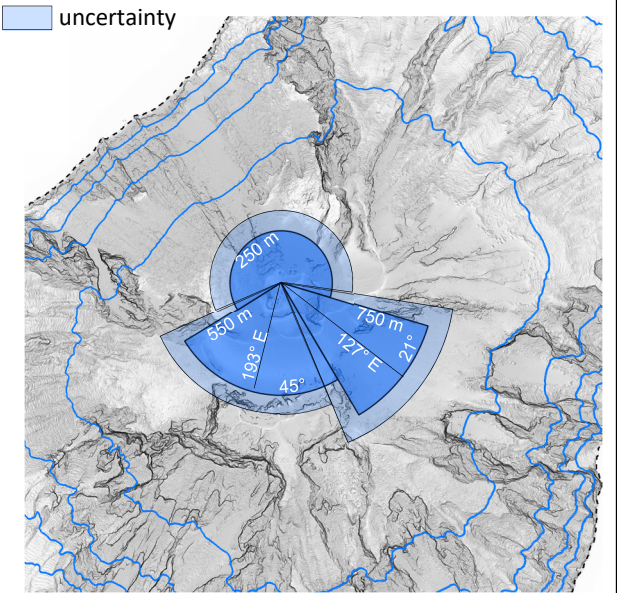
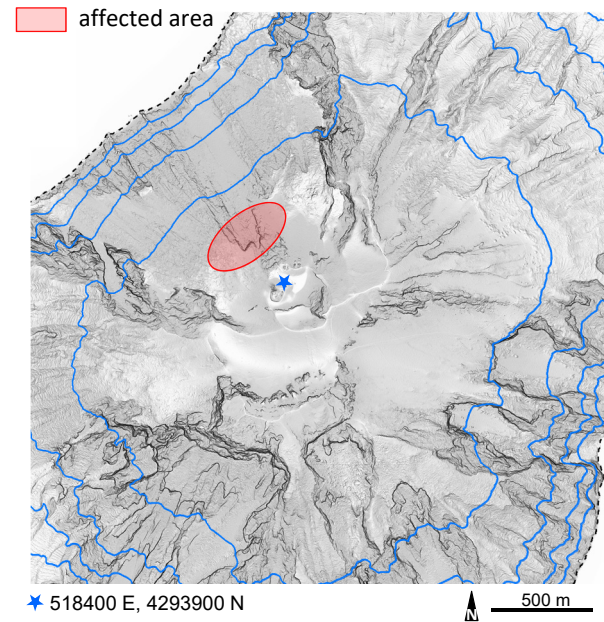


Figure. Partial map of dispersal of the products emitted during the June 25, 2019, explosion. Giordano & De Astis, 2021.

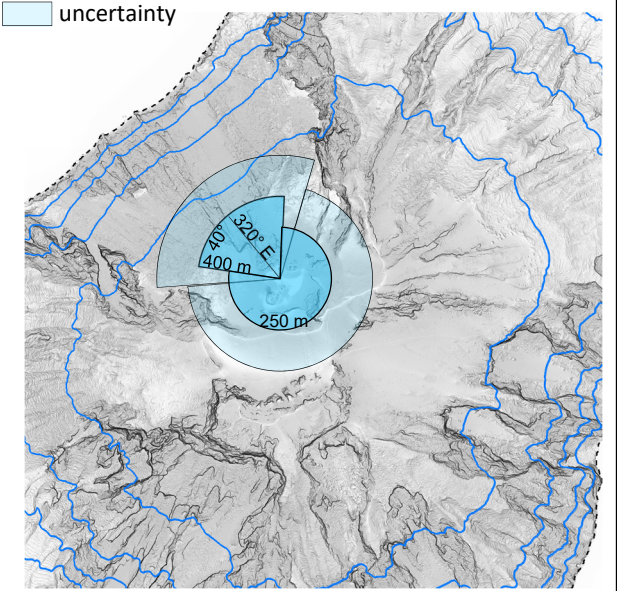
Descriptive File 12.

Main sources	Year	Month	Day	GMT
INGV - report of volcanic activity; INGV - weekly bulletin; Giudicepietro et al. (2019)	2018		3	7 12:48

FIELD DATA AND OBSERVATIONS



SIMPLIFIED MAP

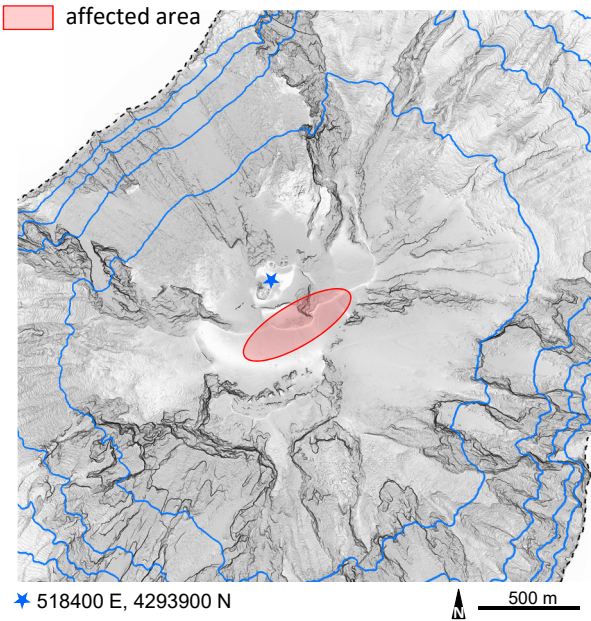


Ballistic projectiles
Lithic fragments radially distributed followed by fine products covering the N sector of crater terrace, and "beyond crater terrace".
Products ejected > 350 m high. Coarse products fell in upper Sciara del Fuoco.

Descriptive File 13.

Main sources	Year	Month	Day	GMT
INGV - report of volcanic activity; INGV - weekly bulletin; Giudicepietro et al. (2019)	2017	12	1	12:42

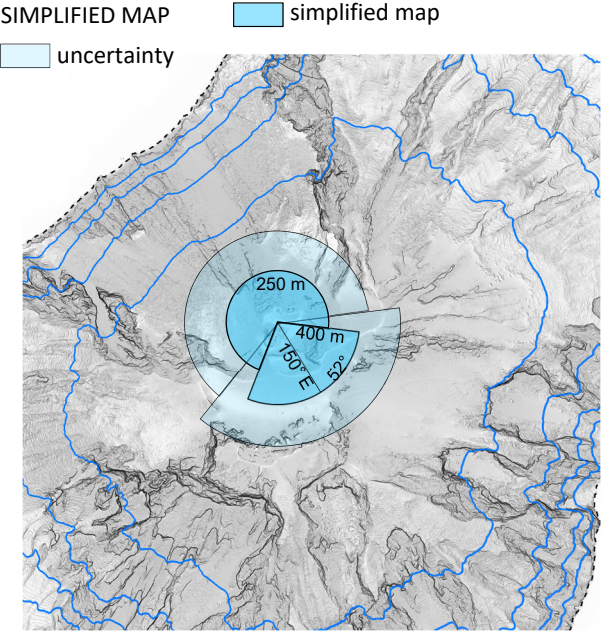
FIELD DATA AND OBSERVATIONS



Ballistic projectiles

Destroyed scoria cone.

SIMPLIFIED MAP



Field survey information

Field survey two weeks after the event. Several spatter bombs of dark scoriaceous material were observed on the final part of the trail from elipad to Pizzo.

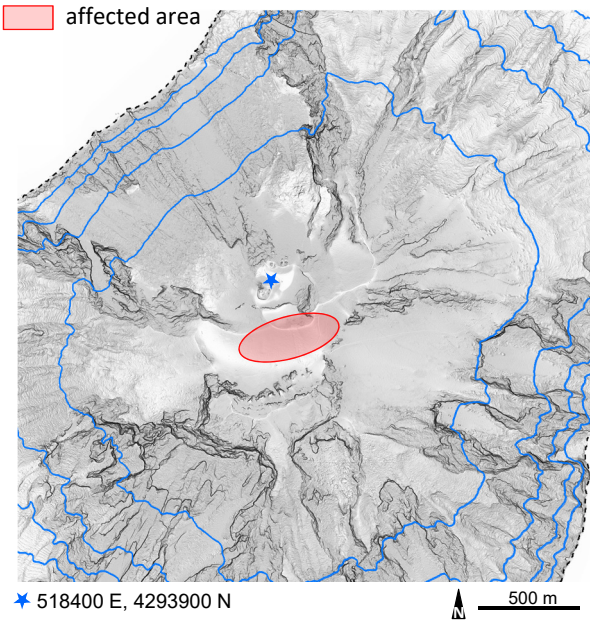
Size of largest spatter was between 20 and 40 cm (two were about 100 cm). This juvenile products are dispersed between SE and SW, above the products observed in November.

A few reddish lithics were also observed. In the same sector there also was abundant scoria of 5-6 cm on average, plausibly associated to ordinary activity .

Descriptive File 14.

Main sources	Year	Month	Day	GMT
INGV - report of volcanic activity; INGV - weekly bulletin; Giudicepietro et al. (2019)	2017		11	1 08:29

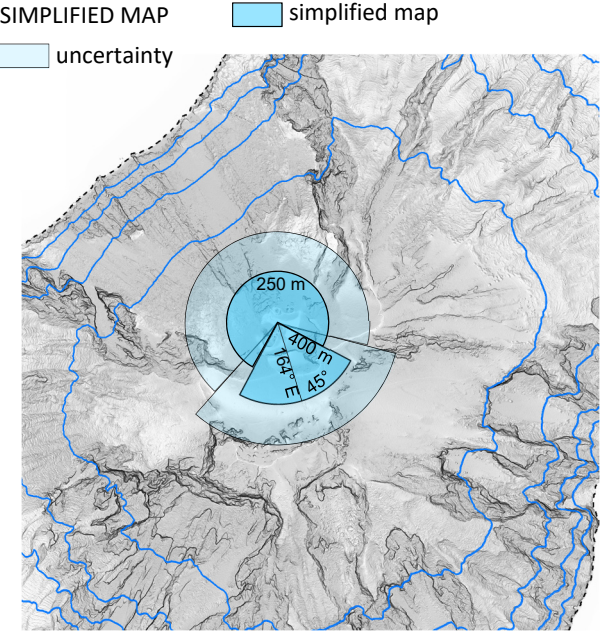
FIELD DATA AND OBSERVATIONS



Ballistic projectiles

Products radially ejected abundantly fell over crater terrace, > 300 m high. Ballistics fell on "Pizzo".

SIMPLIFIED MAP



Field survey information

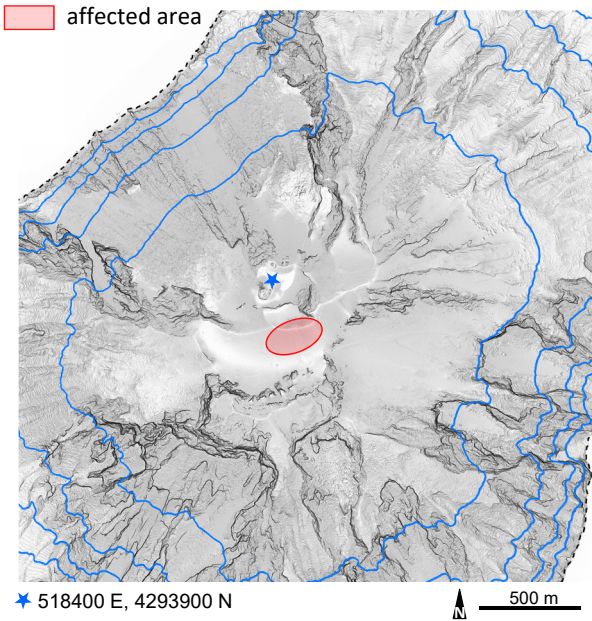
Field survey three days after the event - cumulative products of 23/10 and 1/11. Large depression and pit in CS sector, hornito in N sector.

Abundant dark scoriaceous spatters. This is observed all over the crater terrace and on the flank of Pizzo towards the craters. Some spatter also fell on the NW ridge of Valle della Luna and on the N flank. There were observed the largest clasts, about 2 m. Also, lithic blocks of reddish lava sparse in a large area between all crater terrace and the S side of Pizzo.

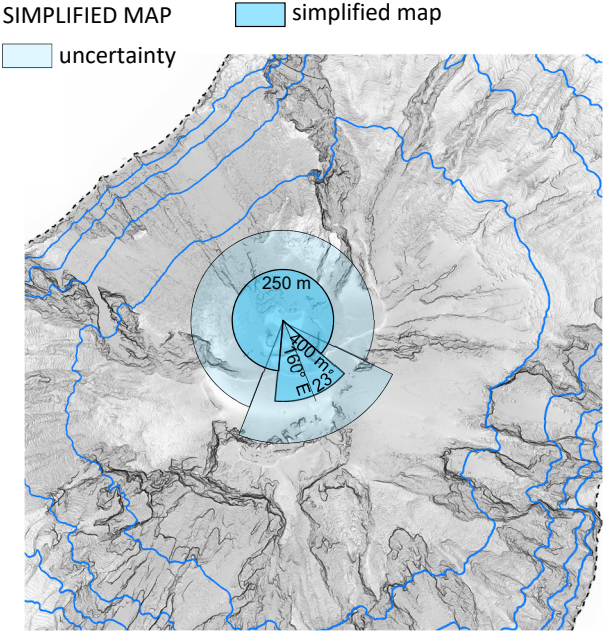
Descriptive File 15.

Main sources	Year	Month	Day	GMT
INGV - report of volcanic activity; INGV - weekly bulletin; Giudicepietro et al. (2019)	2017		10	23
				14:04

FIELD DATA AND OBSERVATIONS



SIMPLIFIED MAP



Ballistic projectiles

Destroyed scoria cone and products are > 250 m high. Products fell in Sciara del Fuoco and towards Pizzo, which was affected by ballistics. Smaller explosions follow, ballistics towards SW

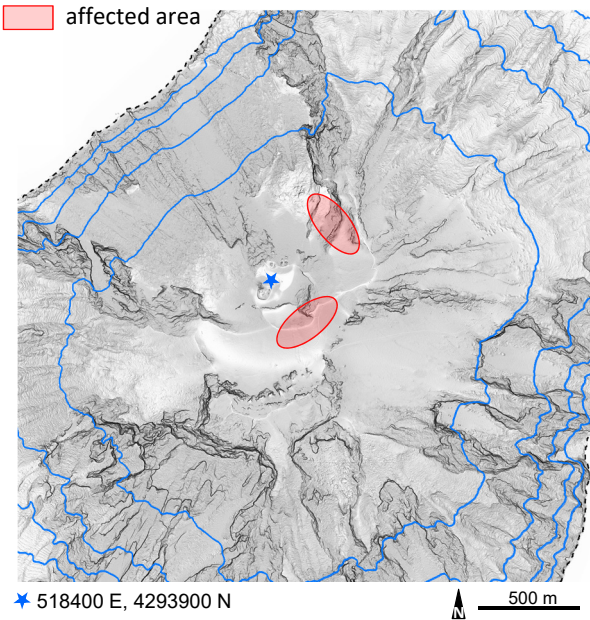
Field survey information

Field survey on 4/11 - cumulative products of 23/10 and 1/11. Light brown juvenile scoriaceous and light products dispersed towards S and SE, reaching Pizzo. Also, wide stripe of lithic impacts on the N flank of the West of Valle della Luna.

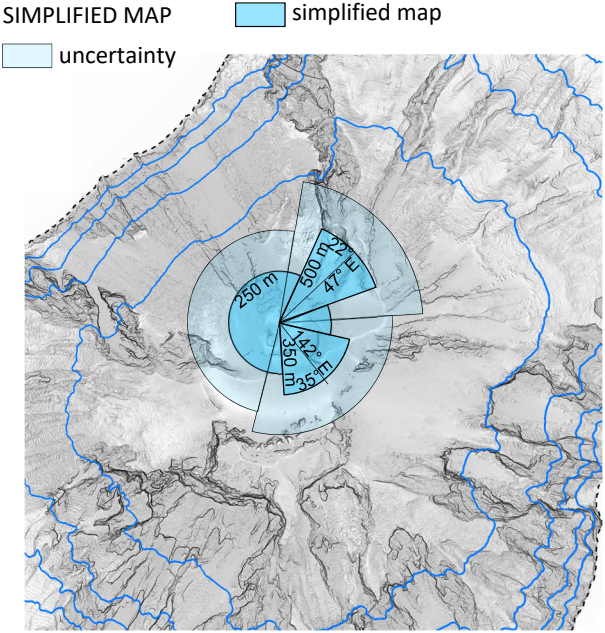
Descriptive File 16.

Main sources	Year	Month	Day	GMT
INGV - report of volcanic activity; INGV - weekly bulletin; Giudicepietro et al. (2019)	2017		7	26 17:57

FIELD DATA AND OBSERVATIONS



SIMPLIFIED MAP



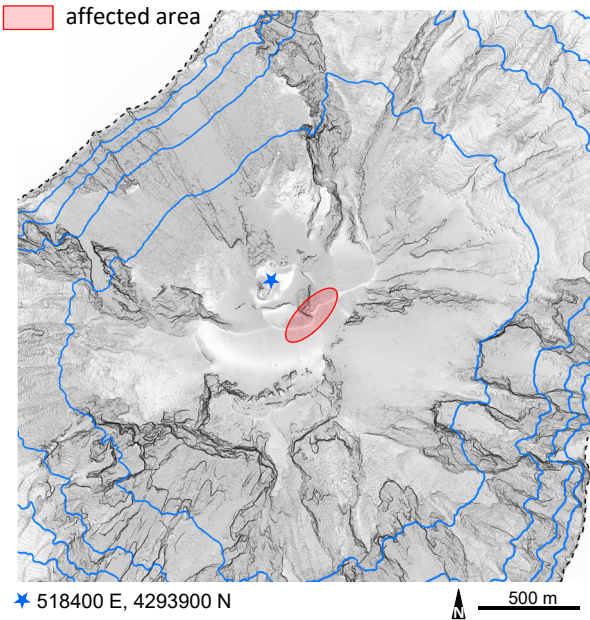
Ballistic projectiles
Products radially dispersed, > 250 m high. Then, second weaker explosion towards SE, and small lava fountain (50 m, 1 min).
Decimetric ballistics fell below shelters at 750 m and in upper Sciara del Fuoco.

Field survey information
Field survey by INGV personnel four days after the event.
On Pizzo, up to 850 m to the SW, max. dimension of clasts is 10 cm.

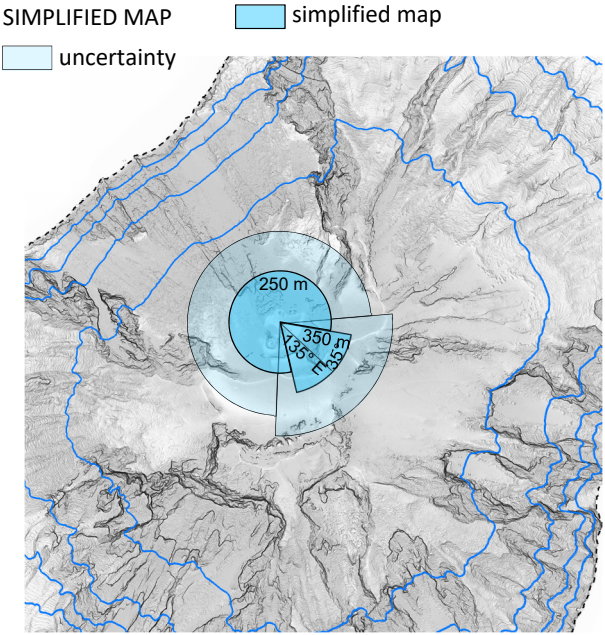
Descriptive File 17.

Main sources	Year	Month	Day	GMT
INGV - daily seismic report; INGV - weekly bulletin	2012		2	15 22:08

FIELD DATA AND OBSERVATIONS



SIMPLIFIED MAP



Ballistic projectiles

Explosive sequences from NEC with at least 5 pulses followed by a phase of intense fountaining, fallout of bombs on the Sciara and Pizzo. Found small bombs and lapilli on Pizzo and surrounding areas, up to "Valle della Luna", to the S.

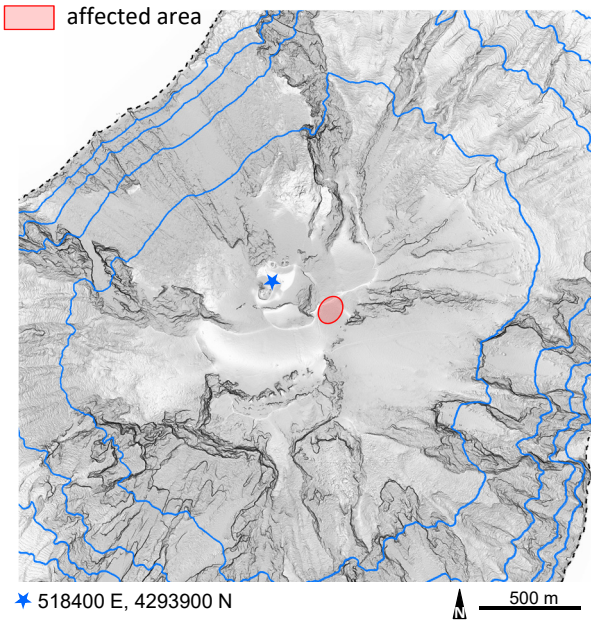
Field survey information

aVolcanology guides performed a field survey two days later and found small bombs and lapilli on Pizzo and surrounding areas, up to "Valle della Luna", to the S.

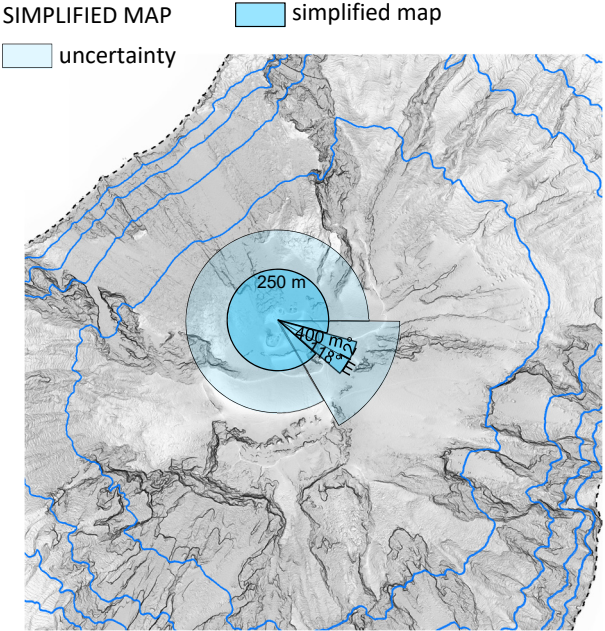
Descriptive File 18.

Main sources	Year	Month	Day	GMT
INGV - daily seismic report; INGV report; BGVN - weekly report; Personal Communication – Falsaperla	2011		7	5 02:43

FIELD DATA AND OBSERVATIONS



SIMPLIFIED MAP



Ballistic projectiles

Explosion with (3 pulses) from CC. High pyroclastic jet formed in the S part of Stromboli's crater terrace producing tephra that fell back onto "Pizzo".

Great amount of hot products ejected towards "Pizzo" and the surveillance camera.

Field survey information

Field survey of D. Andronico and M. Zaia two days after the event. products fell on a narrow stripe N to Rina Grande and reaching the coast N to Forgia Vecchia. Products found above 750 m asl. Pumiceous lapilli were observed floating in the sea and on the beach.

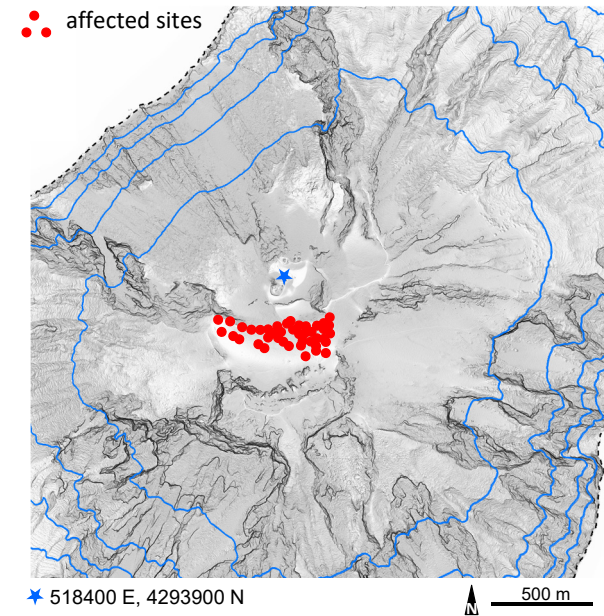
The zone around "Pizzo" was the most affected by ballistics. But products are irregularly distributed. Between crater terrace and "Pizzo" were not found pluridecimetric clasts.

There were four types of products. Mixed juvenile products - max. from 8 to 12 cm, average 4-6 cm, 5-10 clasts / m2. Dark scoriaceous clasts - relatively scarce lapilli of 3-4 cm average size plus a few bombs of 15-20 cm. Yellow pumiceous clasts - < 6 cm, and lithics - mostly reddish, max. 10 cm, average 1-3 cm, few clasts / m2. Fires at about 400 m asl.

Descriptive File 19.

Main sources	Year	Month	Day	GMT
INGV - daily seismic report; INGV - weekly bulletin; Gurioli et al. (2013)	2010		1	21 20:45

FIELD DATA AND OBSERVATIONS



Ballistic projectiles
Coarse products (lapilli and bombs) fell in the S sector of crater terrace, and beyond.

Field survey information
Two detailed field surveys 6 and 18 months after the January 2010 eruption. In total, 780 bombs were mapped. No other bombs were apparent within the crater area. Fires.

SIMPLIFIED MAP

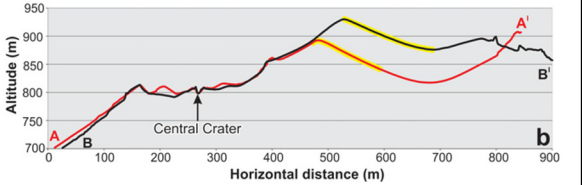
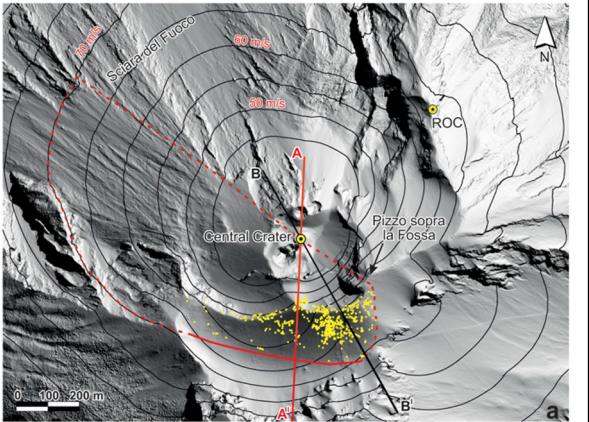
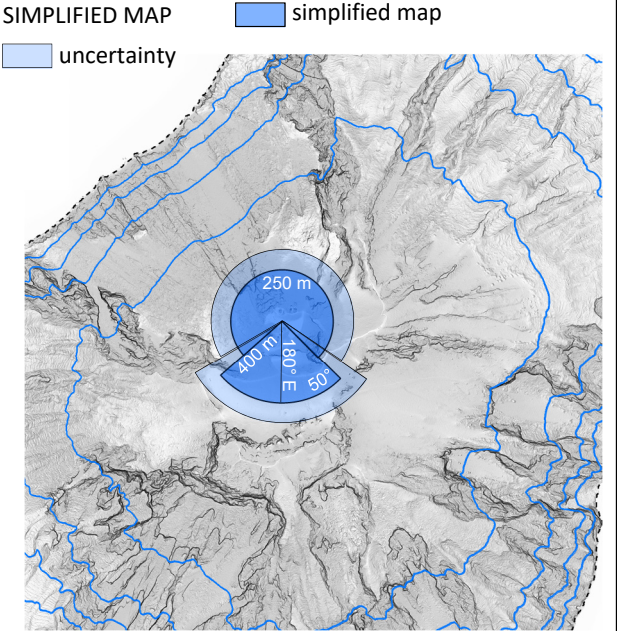
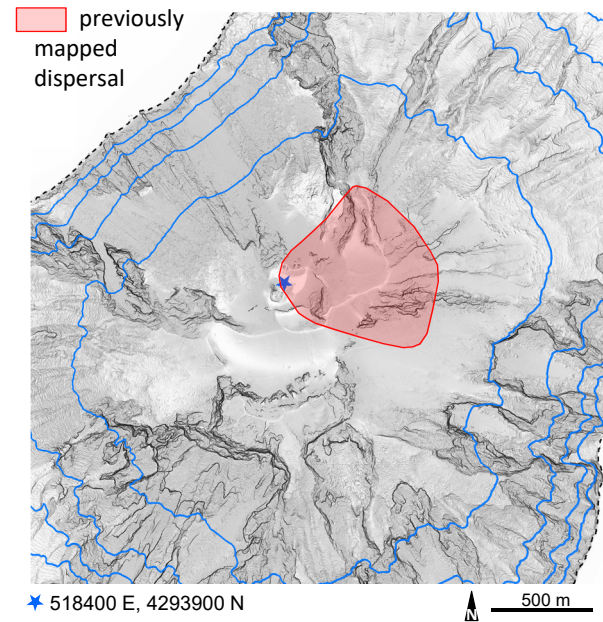


Figure. Gurioli et al. (2013).
(a) Dispersal of the ballistics emitted during the January 21, 2010, explosion (in yellow). Solid red lines indicate walked margins of the bomb field. Contours indicate travel distances reached by bombs launched with indicated velocities.
(b) Cross-section view showing topographic profiles along A-A' and B-B'; yellow highlighted areas define bomb field.

Descriptive File 20.

Main sources	Year	Month	Day	GMT
INGV - daily seismic report; INGV - weekly bulletin; BGVN; Rosi et al. (2013)	2010		1	10 14:48

FIELD DATA AND OBSERVATIONS



Ballistic projectiles
Bombs affect the crater terrace and "Pizzo", with an intense ballistic fallout of 12 s.

SIMPLIFIED MAP

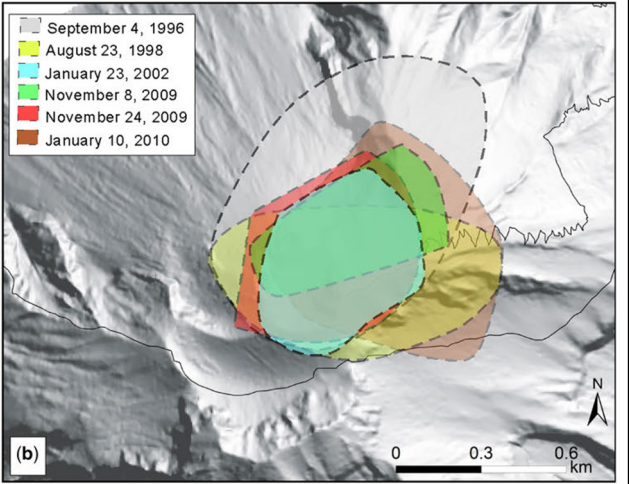
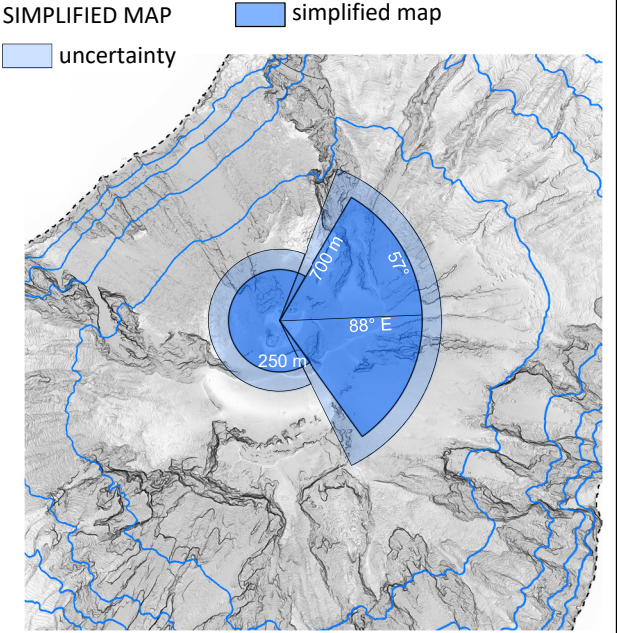
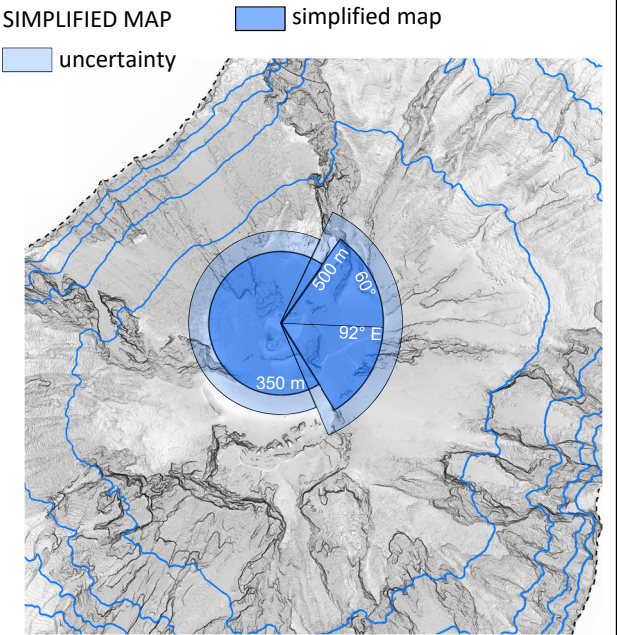
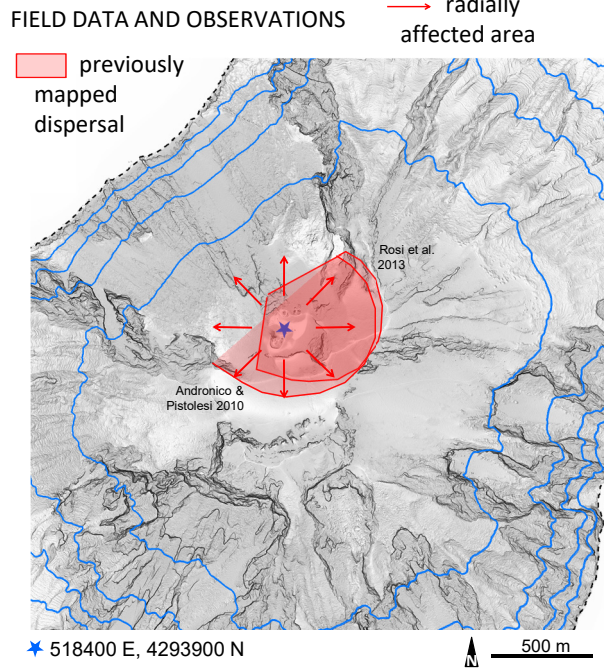


Figure. Dispersal of the ballistics emitted during various major explosions, including the January 10, 2010, explosion (in brown). Rosi et al. (2013).

Descriptive File 21.

Main sources	Year	Month	Day	GMT
INGV - daily seismic report; INGV - weekly bulletin; Andronico & Pistolesi (2010); La Felice & Landi (2011)	2009		11	24
				11:20



Ballistic projectiles

A first explosion produced abundant bombs and lava fragments including "Pizzo" sopra la Fossa.

After 15 s, another stronger explosion ejected coarse products radially, affecting the whole summit area, Pizzo included, at least 300 m from the vent.

Field survey information

The dispersal and volume of products erupted during 24 November were higher compared to 8 November. The tephra deposits consisted of: i) golden pumice (the highest dispersed material), ii) pluri-decimeter scoriae to over-metric sized spatters (confined in the proximal area), and iii) lithic clasts that caused evident impact craters in a more limited summit area.

A limited overlapping of tephra from both the 8 and 24 November fallouts was also observed close to the Helipad. The pumiceous products were dispersed from the summit to the eastern coastline; the maximum concentration on the ground (dispersal axis) was observed in the area between the Helipad and Pizzo.

There the deposit was not continuous, but constituted by abundant coarse pumice (several decimeter-sized clasts per m²), sometimes characterized by expanded clasts (post-landing expansion) with an inner empty cavity bounded by light glass. In the summit area clast sizes were variable, ranging from 7–8 to 20 cm. On the NE slopes (at 650 m a.s.l.), the Md was around 11 cm. Several fires below Rina Grande.

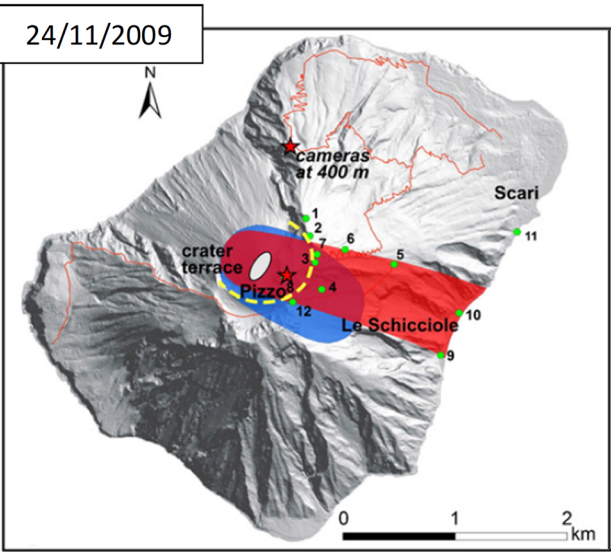
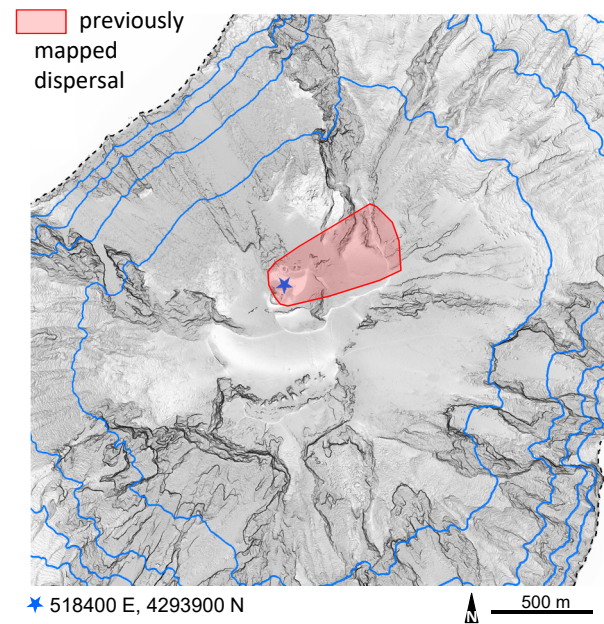


Figure. Dispersal of the products emitted during various major explosions, including the November 24, 2009, explosion (ballistics in yellow). Andronico & Pistolesi (2010)

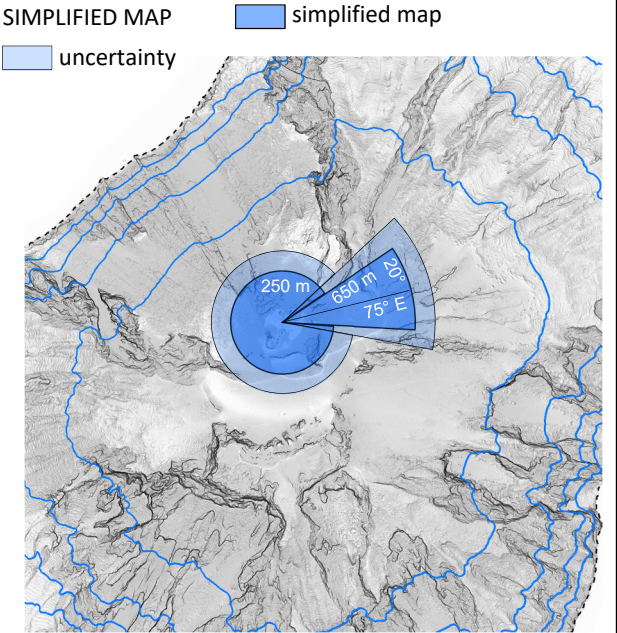
Descriptive File 22.

Main sources	Year	Month	Day	GMT
INGV - daily seismic report; INGV - weekly bulletin; Andronico & Pistolesi (2010); LaFelice & Landi (2011)	2009		11	8
				12:28

FIELD DATA AND OBSERVATIONS



SIMPLIFIED MAP



Ballistic projectiles

A first large explosion occurred from the central sector producing coarse incandescent material; two seconds later, the emission of abundant ash caused the envelopment of the coeval magma jets.

Then another large explosion occurred at the Southern Sector, ejecting coarse material and abundant ash.

Field survey information

The main direction of products was N and NNE - confirmed by M. Zaia. Between Bastimento (about 730 m) and the Helipad (865 m of elevation) products consisted of scattered flattened bombs and pumice. The highest concentration of clasts was observed close to the shelters at 790 m. There the juvenile clasts mainly consisted of ballistic spatters with a ground-density of clasts 5-10 m apart and a size ranging between 35 and 80 cm (mean 65 cm).

Spatters were typically sub-circular to elongated and flattened upon impact on the ground, with light to dark yellow colour and high vesicularity. They often appeared covered by decimetric-thick clumps of golden glass. No lithic blocks were found around the crater area. Around the shelter area, individual spatter bombs were covered by light pumice suggesting that pumice was deposited after the spatter.

The Md value decreased from ca. 20 cm (shelters), to ca. 10 cm to ca. 4 cm towards the Helipad. Fresh pumiceous material was brown to yellow, often iridescent; when observed under stereomicroscope, it appears strongly non-homogeneous with portions mingled with dark glass.

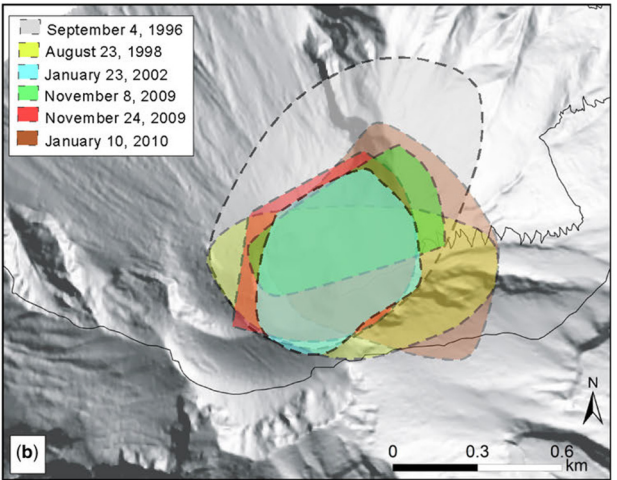
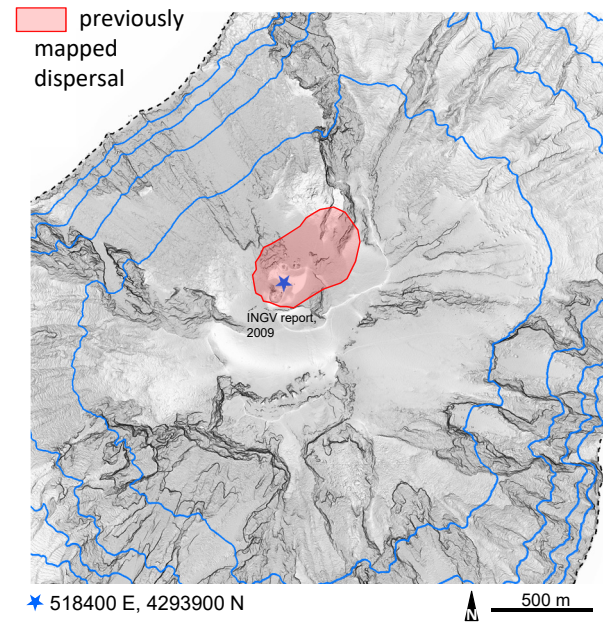


Figure. Dispersal of the ballistics emitted during various major explosions, including the November 8, 2009, explosion (in green). Rosi et al. (2013).

Descriptive File 23.

Main sources	Year	Month	Day	GMT
INGV - daily seismic report; INGV - surveillance camera report; INGV report; LaFelice & Landi (2011)	2009	5	3	14:58

FIELD DATA AND OBSERVATIONS



Ballistic projectiles
Strongest event since the paroxysms.

Two lobes of coarse products reaching 200 m height mostly fell inside crater terrace and also outside its NW sector

Then a second more intense explosion radially ejects ballistics over the whole camera range.

Field survey information

Metric dark spatter bombs are found around crater terrace, including the sector between Pizzo and the craters (also, one lithic clast every 5-10 meters) and towards the site where "fortini di Ginostra" were once located.

The limit of coarser products is a few tens of meters below "Pizzo", slightly below 900 m asl, where there are bombs of 30-40 cm.

Upper Sciara del Fuoco appeared continuously covered, but ordinary activity also affects that sector.

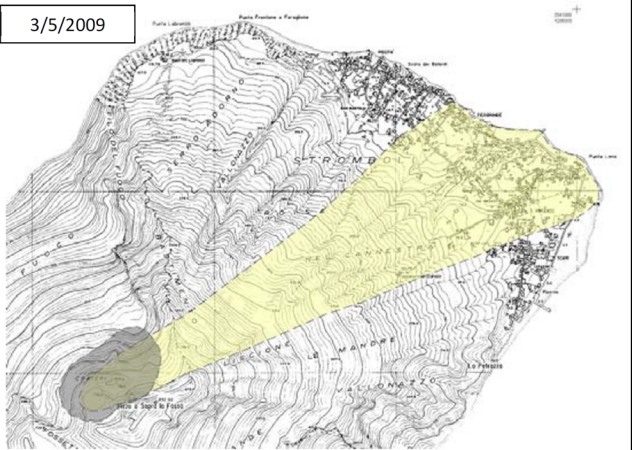
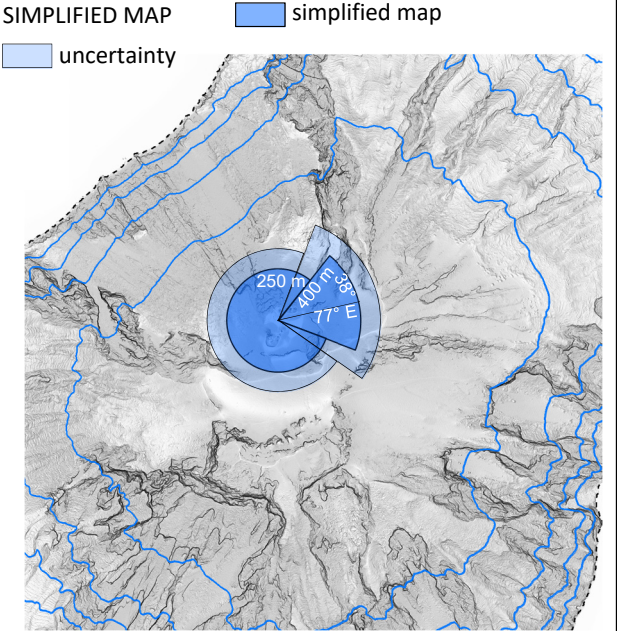
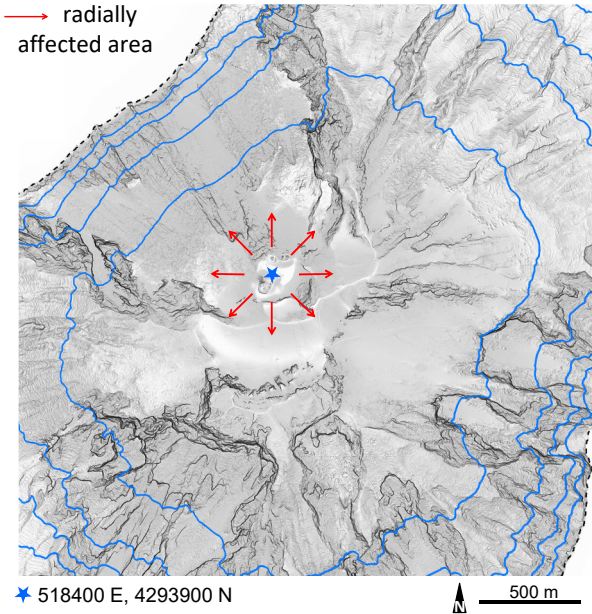


Figure. Dispersal of the products emitted during the May 3, 2009, explosion (ballistics in grey). INGV report by D. Andronico.

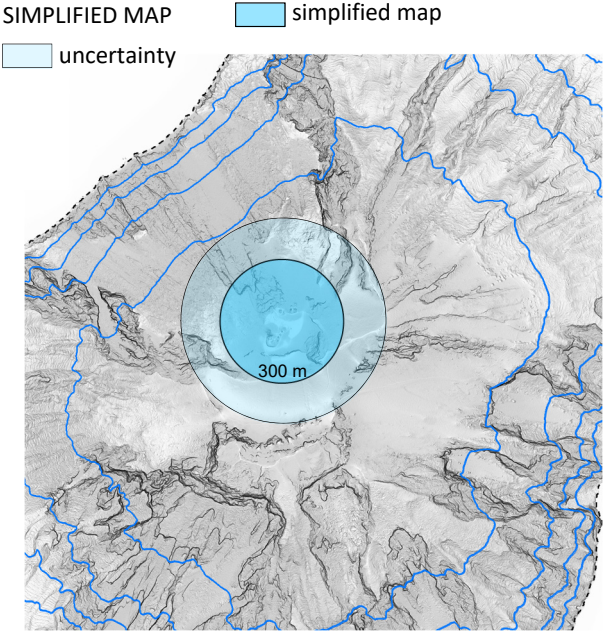
Descriptive File 24.

Main sources	Year	Month	Day	GMT
INGV - daily seismic report; INGV - surveillance camera report; INGV - petrologic monitoring report	2008		12	6 20:49

FIELD DATA AND OBSERVATIONS



SIMPLIFIED MAP

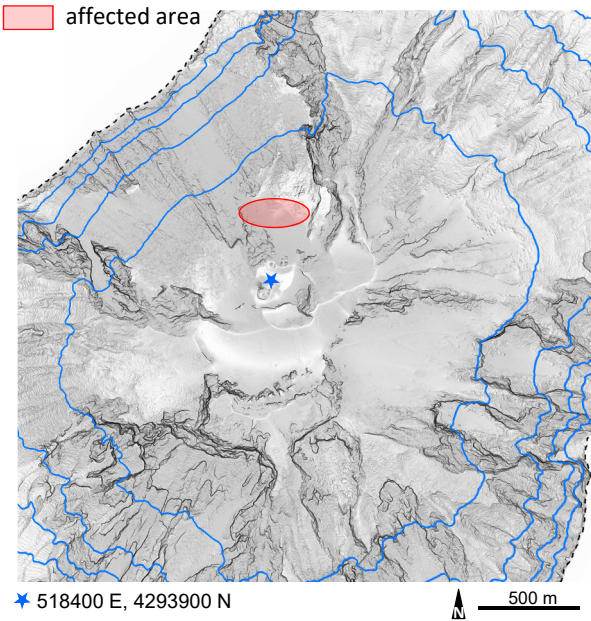


Ballistic projectiles Climactic explosive sequence of 15 s.	Field survey information
Products radially fell outside the crater terrace (> 300 m high) and sampled. towards Sciara del Fuoco.	Products reached metric size. At "Pizzo" a scoriceous bomb was

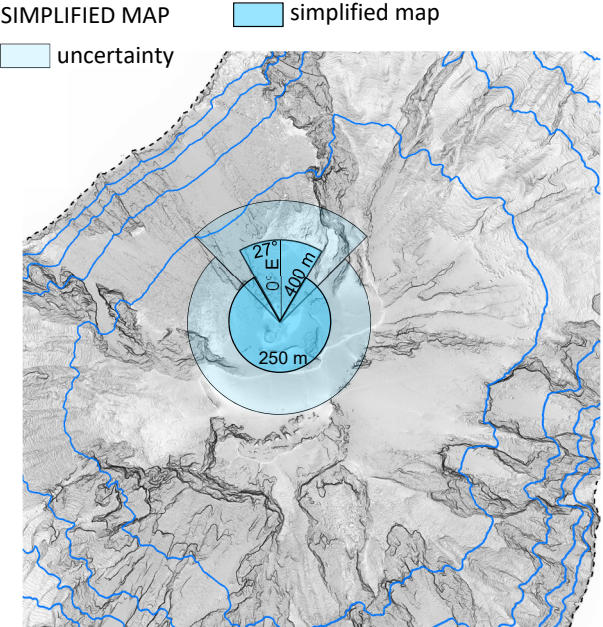
Descriptive File 25.

Main sources	Year	Month	Day	GMT
INGV - daily seismic report; INGV - surveillance camera report	2008		2	29

FIELD DATA AND OBSERVATIONS



SIMPLIFIED MAP



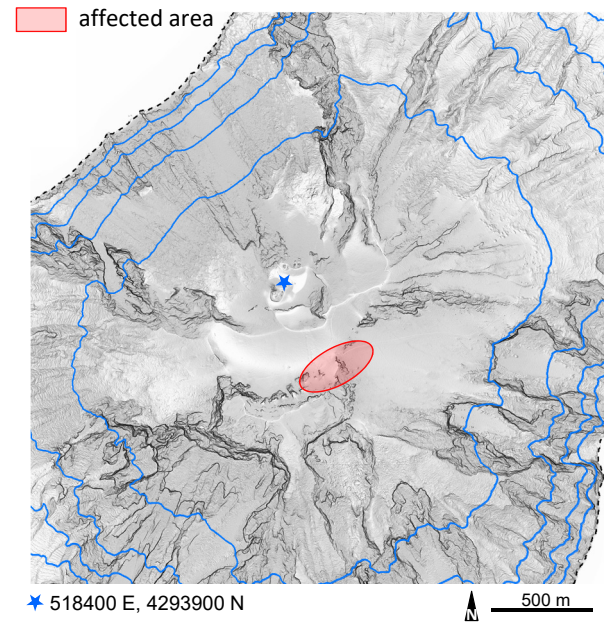
Ballistic projectiles
Strongest event since the paroxysm. Lava fountain 180m high (50s).

Products fell in the crater terrace, significantly outside the crater terrace towards N, and in the upper Sciara del Fuoco.

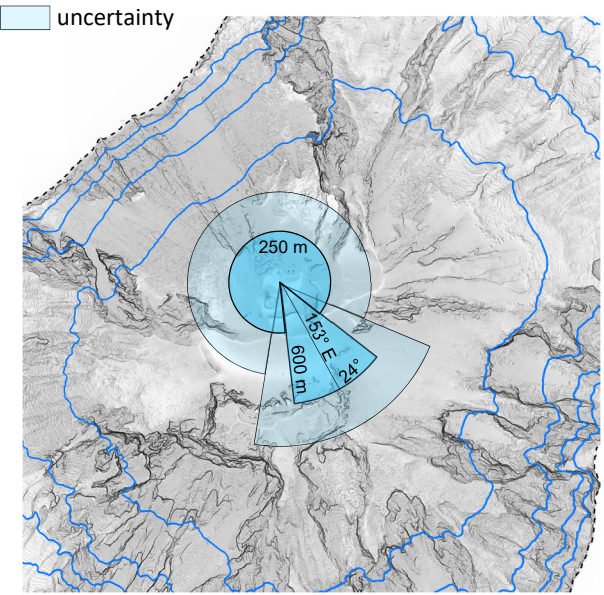
Descriptive File 26.

Main sources	Year	Month	Day	GMT
INGV - daily updates on the current eruptive phenomena; INGV - surveillance camera report; INGV; Stromboli Online	2005	8	5	11:08

FIELD DATA AND OBSERVATIONS



SIMPLIFIED MAP



Ballistic projectiles

Products higher than 200 m and fell behind the camera. Ballistics affect the S sector of crater terrace and towards "Pizzo".

Ash and ballistics up to 40 cm fell on Rina Grande.

Field survey information

Field survey a few hours after the event. Wind plausibly influenced the distribution, and affected S to SE - from "Valle della Luna" to "Rina Grande". Mapped dispersion may be underestimated.

Light-colored lithic clasts and fragments not vesiculated, and a few dark and vesiculated lithics. Size from 4 to 40 cm.

Several fires in Forgia Vecchia

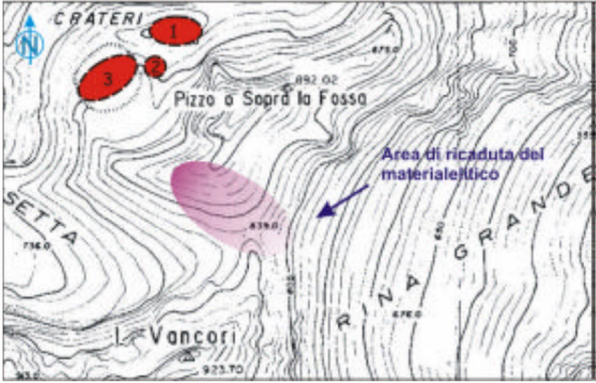
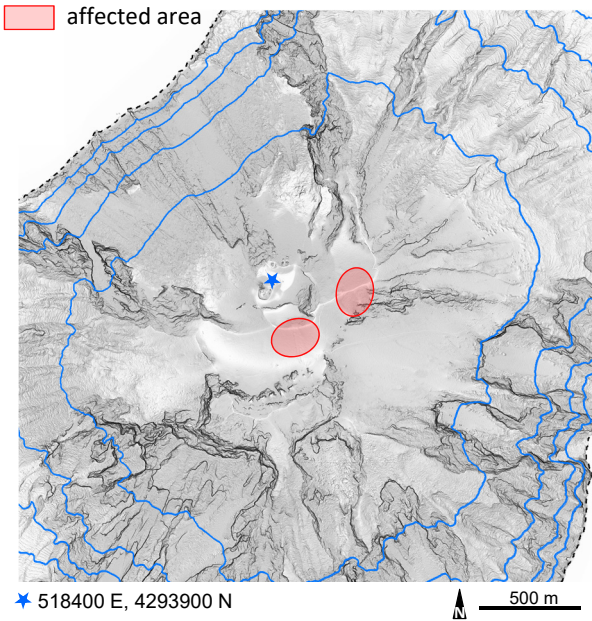


Figure. Some areas affected by the products emitted during the July 24, 2002, explosion. INGV report by G. Salerno and F. Murè.

Descriptive File 27.

Main sources	Year	Month	Day	GMT
INGV reports; BGVN; Stromboli Online	2002		7	24
				5:45

FIELD DATA AND OBSERVATIONS



Ballistic projectiles

Several rocks, including rather big ones, were tumbling down the slope in Rina Grande. The rocks were stopped by the soft ash of Forgia Vecchia and did not reach the beach.

4 people were descending through Forgia Vecchia. Nobody was hurt.

Field survey information

Helicopter survey one day after the event with thermal camera - not observed crater changes or hot products.

Ground survey a week after the event. On the ground dark scoriaceous bombs and lapilli, lithic blocks fumarolized, and yellow pumice lapilli. Higher concentration between elipad and "Pizzo".

Close to the geochemical station an impact crater of ca 1 m due to a scoriaceous comb of > 50 cm, and other impact craters of similar size, but due to blocks. No fresh material found on "Pizzo". Lapilli, ash and some dark bomb is found between crater 3 and Pizzo - maybe erupted by ordinary activity. Very few morphological changes of the craters except for a small collapse on crater 3.

SIMPLIFIED MAP

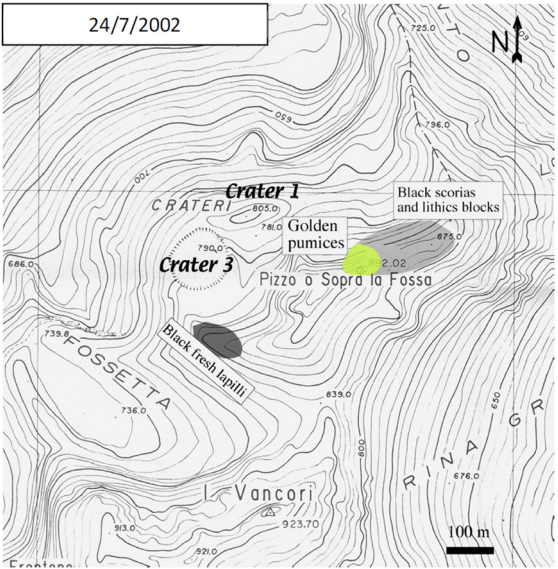
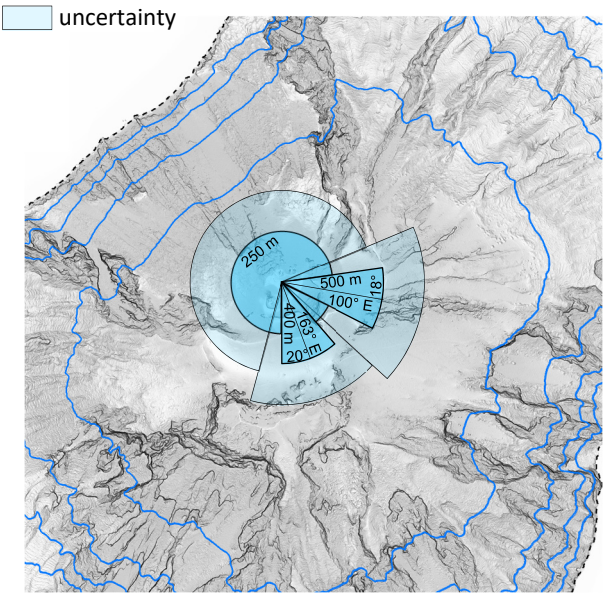
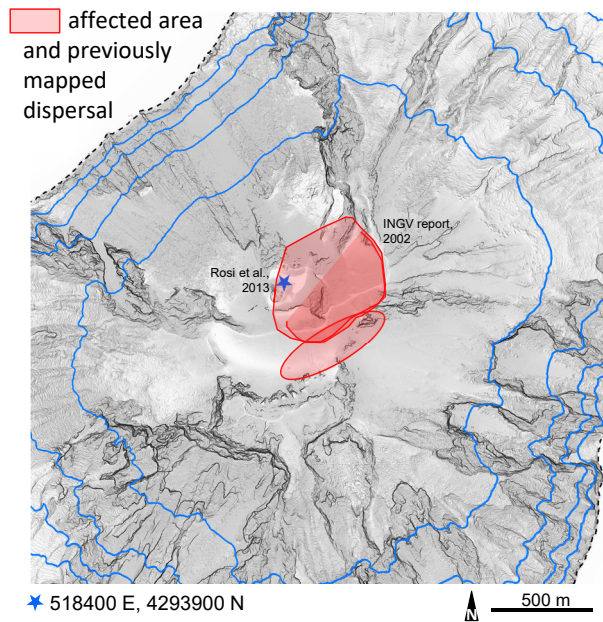


Figure. Some areas affected by the products emitted during the July 24, 2002, explosion. INGV report by M. Pompilio and M. Coltelli.

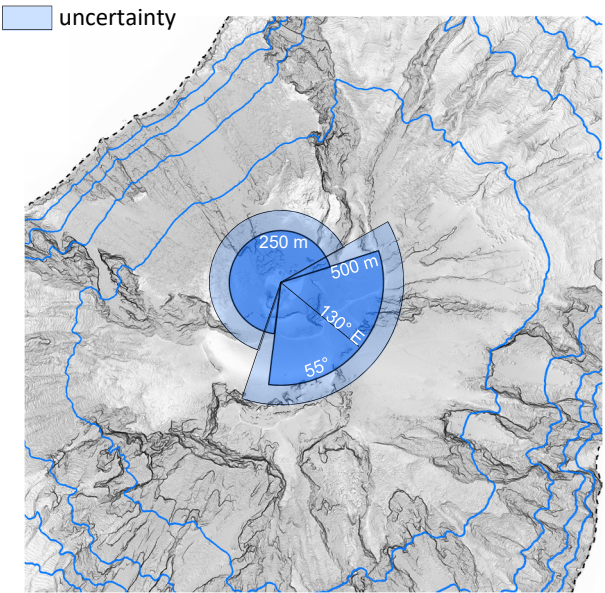
Descriptive File 28.

Main sources	Year	Month	Day	GMT
INGV reports; BGVN; Personal Communication - Landi	2002		1	23 19:54

FIELD DATA AND OBSERVATIONS



SIMPLIFIED MAP



Field survey information

In the morning of 24 Jan. - the field survey was carried out in the area of Il Pizzo Sopra la Fossa between the Bastimento and La Fossetta. This part of the volcano was covered with ash and blocks. Lithic material up to 60 cm in size, with minor amount of spatter up to 1.7 m in lenght.

The greater density of lithics on the ground in a belt about 200 m wide between the craters and Il Pizzo. Spatter was more frequent NE of Il Pizzo. Fine-grained material covered the crater zone and the NE flank of the volcano up to the village of Stromboli (2 km far). In the zone of Il Pizzo the fallout material formed an almost continuous carpet.

First isolated juvenile clast max. 10 cm 820 asl. At elipad shelters sparse blocks and large dark scoriae - one of 60 cm broke the edge of elipad. At about 20 m from elipad to "Pizzo" large spatter 60x170x7-10 cm. At 900 m elevation, many blocks and some scoria up to 20x30 cm. Lithics <20 cm up to 40 cm. Clasts also above this elevation. Blocks <10 cm on average, some of 16-18 cm and max. 60-70 cm. A few scoriae: one of 15-30 cm every 2-3 feet plus some smaller.

Density of clasts - climbing path to "Pizzo" over 4x4 m: 10 clasts <10cm; 10 clasts ~15 cm. Pizzo - 1.1x1.1 m: 58 lithic clasts of 2-5 cm; 4 lithic clasts of 10-12 cm; 5 lithic clasts of 5-8 cm; 5 juvenile clasts of 4-5 cm; 4 juvenile clasts of 7-10 cm. Lithics suddenly decrease towards "Fortini di ginostra" (one block every few meters) and stop at 300 m to W- SW from Pizzo. Sparse scoriae (1 every 20-25 m).

Rina Grande – several 1 m sized impacts up to 720 m asl (one with a block of 60 cm inside, most are empty). Blocks found at the base of Rina Grande. Fires.

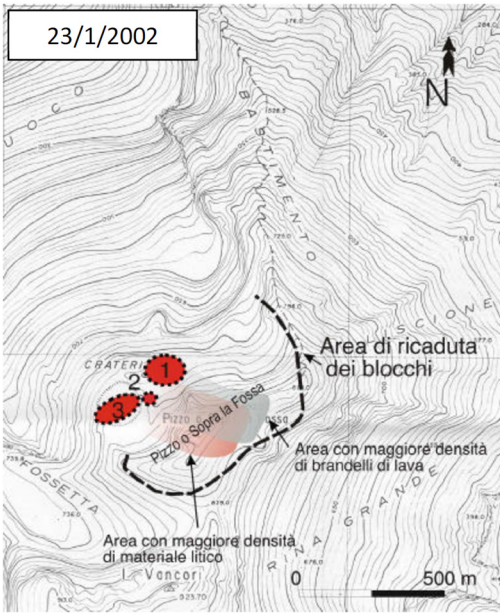
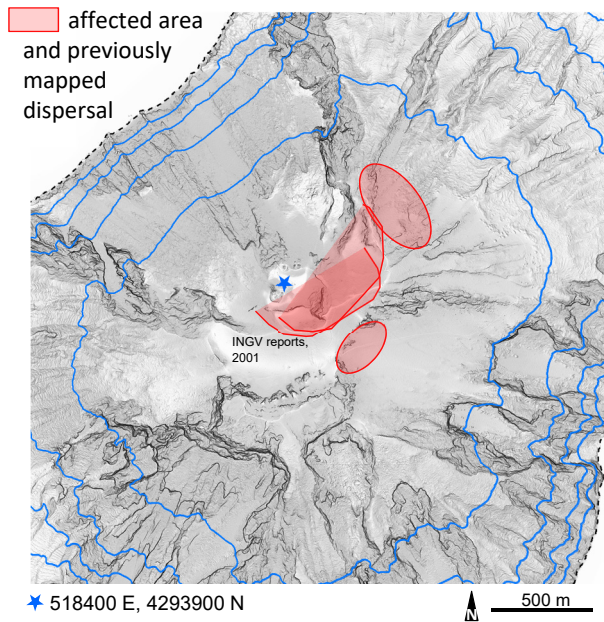


Figure. Partial map of dispersal of the products emitted during the January 1, 2002, explosion. INGV report by S. Calvari, M. Pompilio, D. Andronico.

Descriptive File 29.

Main sources	Year	Month	Day	GMT
INGV reports; BGVN; Stromboli Online		2001	10	20
				0:30

FIELD DATA AND OBSERVATIONS



SIMPLIFIED MAP

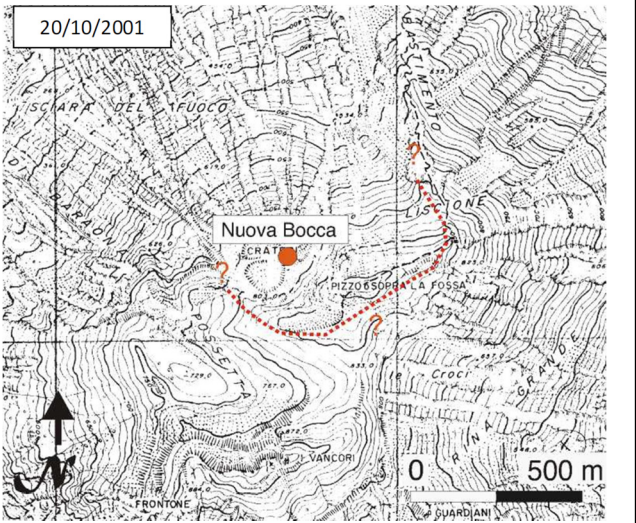
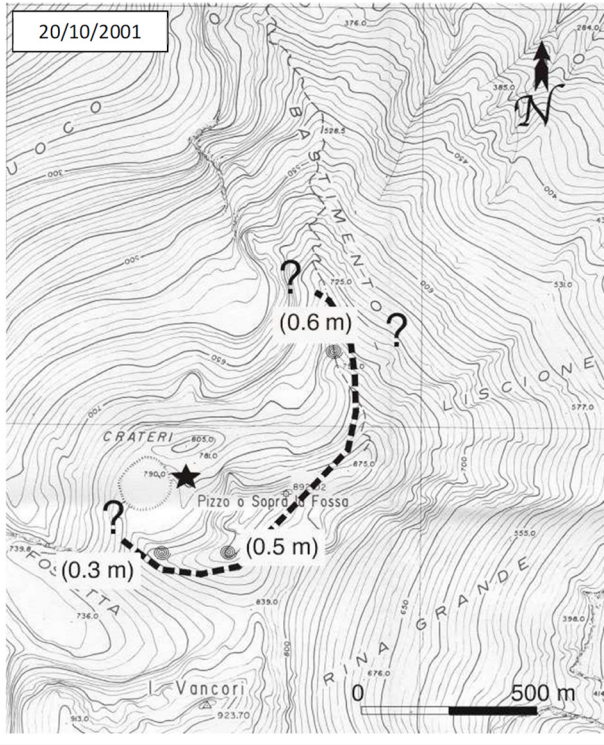
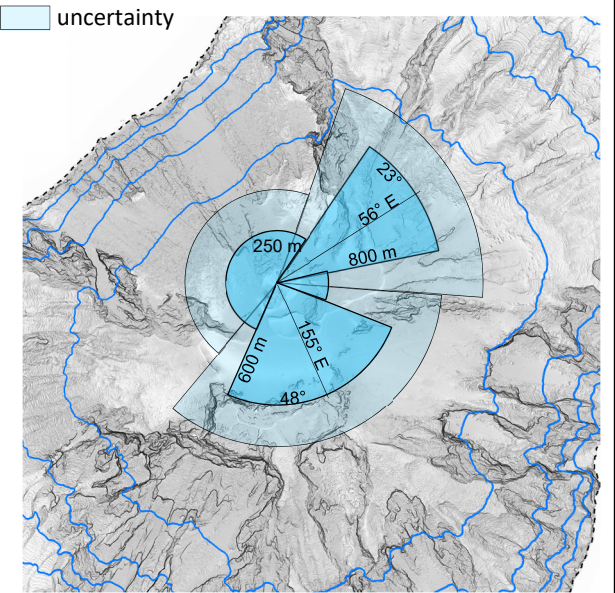


Figure. Two partial maps of dispersal of the products emitted during the October 20, 2001, explosion.

Question marks indicate uncertainly affected areas.
INGV reports by S. Calvari and M. Pompilio.

Ballistic projectiles

Crater 1 produces intense explosions but products are confined in crater terrace. Crater 3 ejects several incandescent blocks outside crater terrace.

Fishermen saw, from a distance, glowing rocks ejected by the volcano. Thermal camera recorded hot products on the south side of crater 3 and up to the saddle below "Pizzo". Dozens of people were on "Pizzo" when the explosion occurred. Other were on Vancori ridge. Two injured people; a German woman, was hit on her head, and died a few days later.

Field survey information

Field survey ca. 12 hours after the explosions. Impact craters and lithic blocks, also altered and fumarolized, ca. 20-30 cm size, are observed on the ridges of "Pizzo" towards W and E. Max. density of 1-2 blocks / m². Max. density and size between "Pizzo" and first "fortini verso Ginostra". To the West some dark vesiculated blocks (max 40 cm) maybe juvenile. Significant morphological changes of crater 3.

At 750m s.l.m. was found a block of 1,2 x 0,6 m - still hot a few hours after the event. Other bombs (ca. 20 - 70 cm) found later in Rina Grande, on the trail.

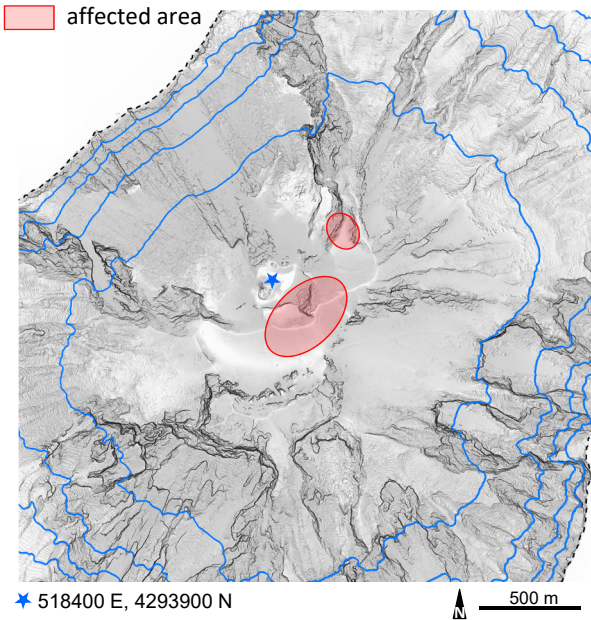
A survey by helicopter two weeks after the event. In the NE sector (area Bastimento-Liscione) there are lithic blocks. Also scoriceous bombs juvenili (max 0.3 m). Larger and more frequent clasts (1 every 2-3 m²; max 0.6 m) are observed between 730 and 800 m s.l.m. close to the seismic station of Univ. Udine. Not observed products on the trail below the elipad.

Fires towards NE - E side of "Bastimento". approx. 600 m.a.s.l.. Two areas on fire separated from each other by 200m.

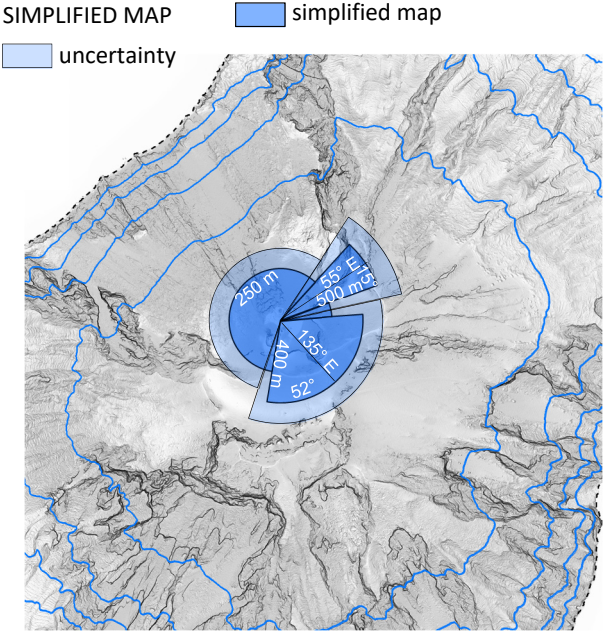
Descriptive File 30.

Main sources	Year	Month	Day	GMT
BGVN; Stromboli Online	1999	8	25	22:56

FIELD DATA AND OBSERVATIONS



SIMPLIFIED MAP



Ballistic projectiles

A typical explosion preceded a more intense one. Next, a larger explosion came from the vent in front of Crater 2.

Pyroclastic material was clearly visible from the village and fell over a wide area, including the path section with the observation points around the 700-m level. Also much "cold" material was ejected.

The evening tourist group descended the volcano and the night primitive shelters made by tourists in the summit area. Greatest group was still climbing. Ten tourists received injuries, mostly because of the sudden run from the craters. A total of seven people were on the summit.

One woman's hand was hit by scoriae. A girl suffered minor burns on her feet and hands. On the other side of Pizzo another person suffered burns on his belly.

Field survey information

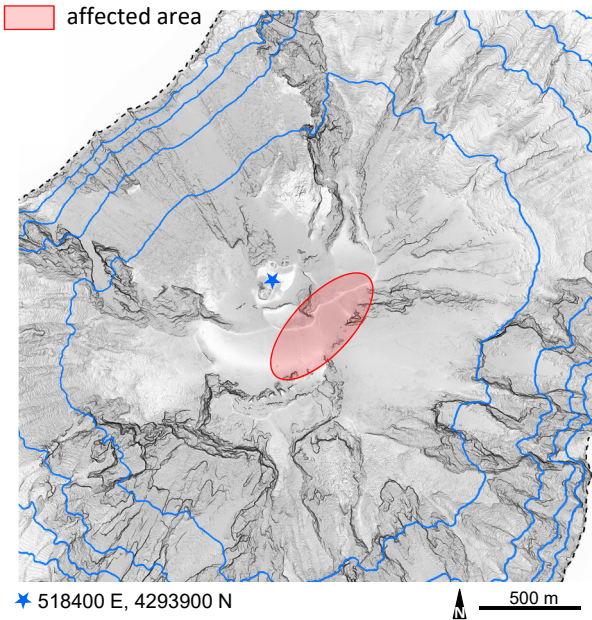
Numerous scoriaceous bombs on and around the Pizzo sopra la Fossa had flattened upon impact; many had diameters of 20 cm or more. In one case, a bomb had fallen on the rim of one of the primitive shelters made by tourists in the summit area. Greatest bomb over Pizzo was 50 x 30 cm.

Danielle Cottens saw some small fires from Scari.

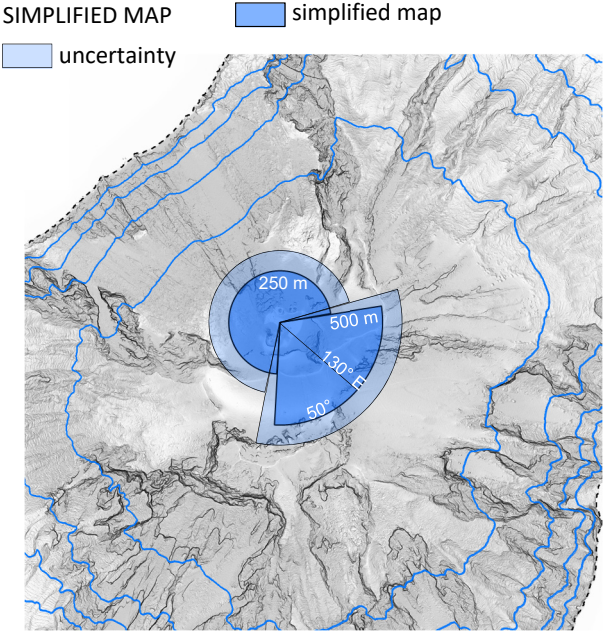
Descriptive File 31.

Main sources	Year	Month	Day	GMT
Bertagnini et al. (1999); BGVN; Falsaperla&Spampinato(2003); Stromboli Online; Personal Communication – Pompilio	1998		11	24 17:00

FIELD DATA AND OBSERVATIONS



SIMPLIFIED MAP

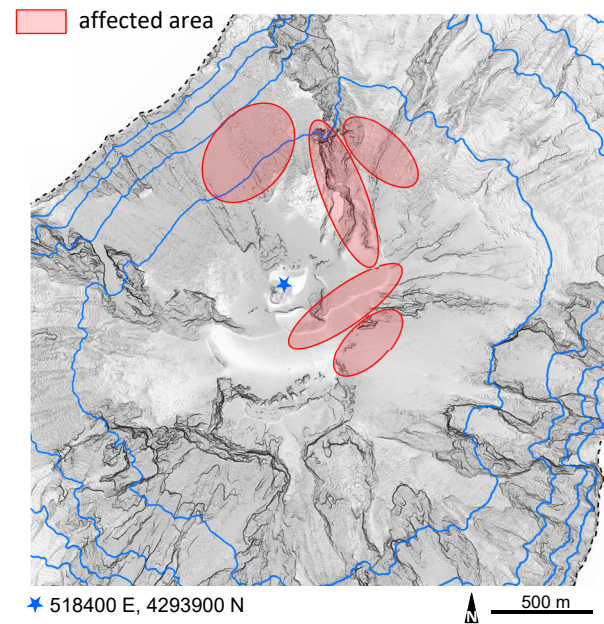


Ballistic projectiles	Field survey information
Pyroclasts clearly seen from the village, reaching estimated heights of at least 700 m over the craters.	The volcano guide Zazà climbed the volcano. He found all the summit covered by yellowish pumice.
Single large blast formed a 300 m high globe of red material followed by two pulses of 150 m high lava spattering, each lasting about 20 s.	Bombs ejected during the main explosion were mainly pumice, sampled by P. Landi.
Mountain was incandescent red, for about 15 minutes	

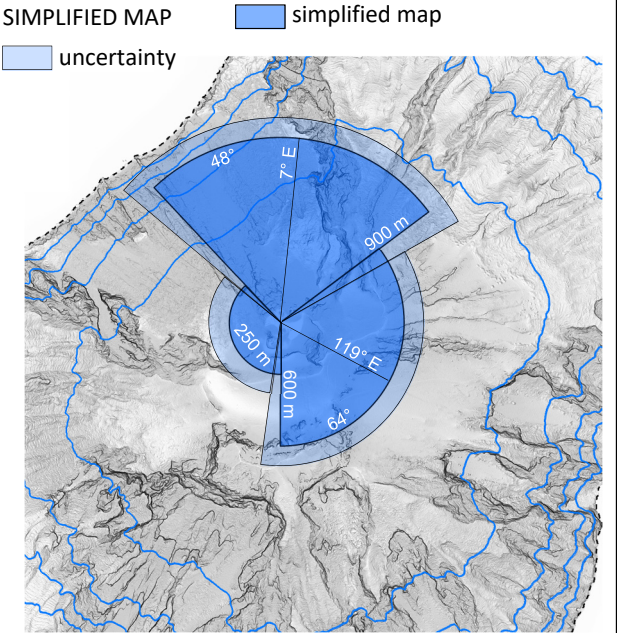
Descriptive File 32.

Main sources	Year	Month	Day	GMT
Bertagnini et al. (1999); BGVN; Stromboli Online; IIV report.	1998		9	8 17:13

FIELD DATA AND OBSERVATIONS



SIMPLIFIED MAP



Ballistic projectiles
Bombs and lapilli fell and roll in Sciara del Fuoco, on the NE slope (Bastimento) above 500 asl, and on the E slope (Rina Grande). Bombs over Pizzo.

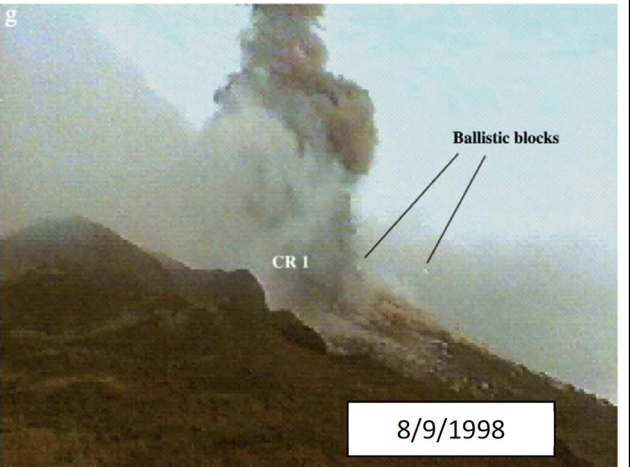
Ten people were in the summit area: five were at Pizzo, five including the guide (Mario Zaia) were at the "fortini" of Bastimento, 750 m asl. No one was wounded. Observed flying ballistics from Labronzo trail.

Field survey information
Crater 1 was enlarged and broken on the NE side. Other craters did not change significantly. Products affected two sectors of the summit area and Sciara del Fuoco. Two lobes observed are probably related to the craters' morphology.

First sector was 200 m wide region towards NE for slightly less than 1 km to the zone of fortini of Bastimento. Second sector was 400 m wide from elipad to Fossetta and towards ESE to Rina Grande. In both sectors products were lapilli and dark scoriaceous bombs (cowpie bombs or stripes). Not found lithics or yellow pumices. Greatest bombs (>1.5 m) fell between elipad and the transmitter of the surveillance camera.

Two fires. The first greater at 500-600 m asl between Vallonazzo and Cannestrà. The second at similar elevation between Schiccirole and Le Mandre.

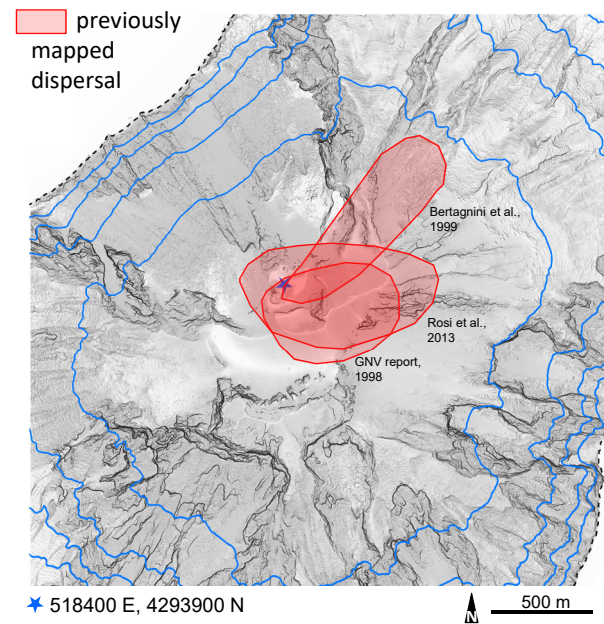
Figure. Snapshot of the crater #1 taken from the north (courtesy of Massimo Pompilio, INGV).



Descriptive File 33.

Main sources	Year	Month	Day	GMT
Bertagnini et al. 1999; BGVN; Stromboli Online; GNV report.	1998	8	23	15:26

FIELD DATA AND OBSERVATIONS



SIMPLIFIED MAP

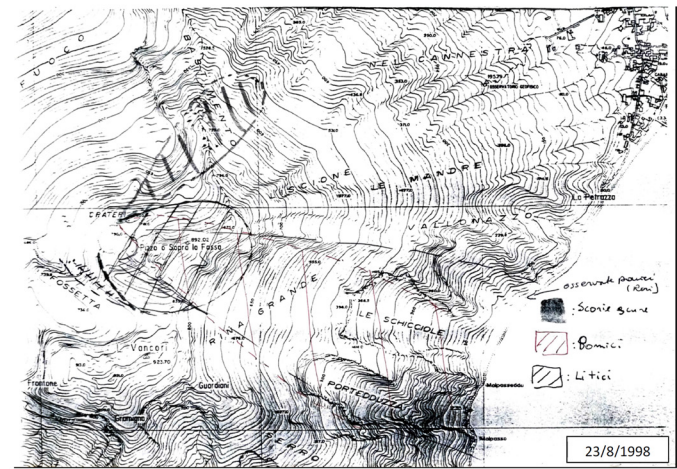
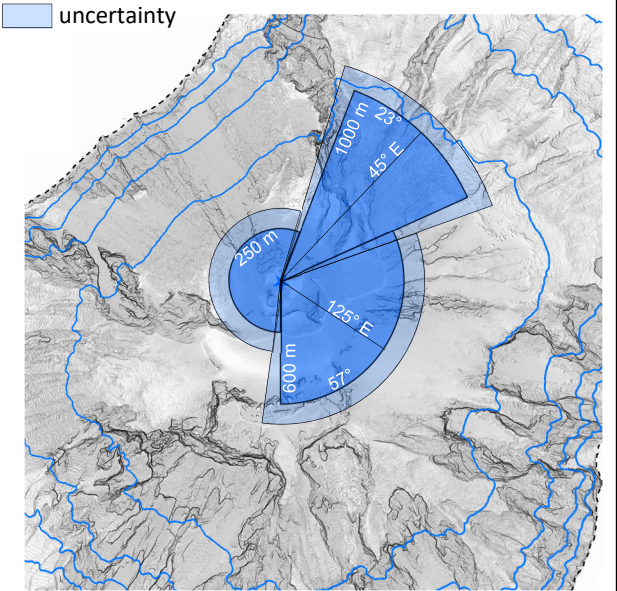


Figure. Dispersal of the products emitted during the August 23, 1998, explosion. GNV report by Rosi et al.

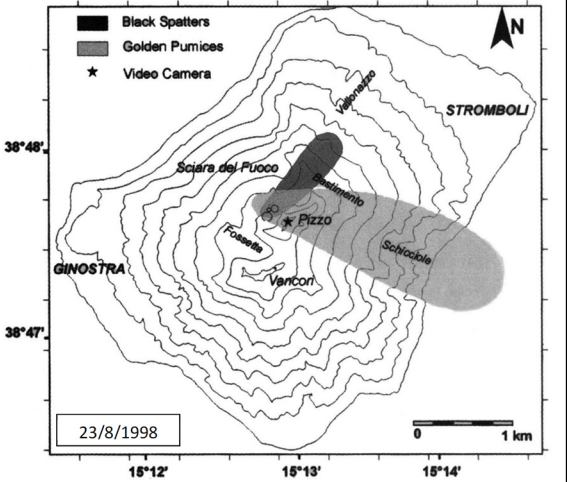


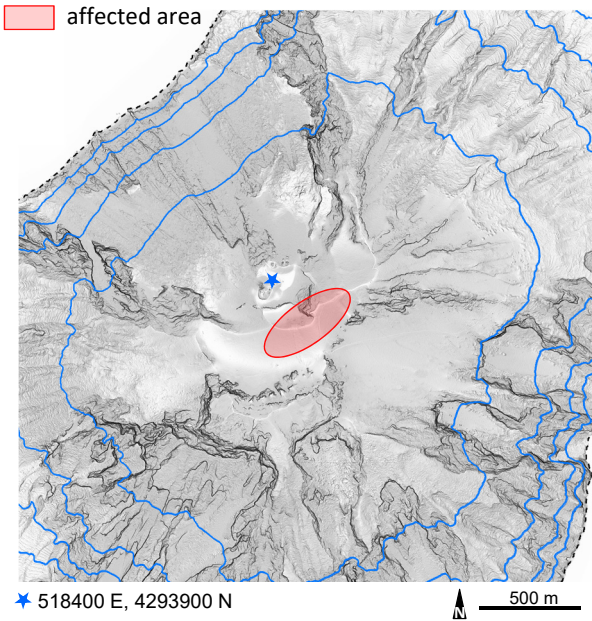
Figure. Dispersal of the products emitted during the August 23, 1998, explosion. Bertagnini et al. (1999).

Ballistic projectiles	Field survey information
Tracks of large blocks moving radially out from the northern side of Crater 1 at a speed close to 100 m/s were recorded. Dispersal of the erupted products showed two lobate fallout areas.	Scoriae and black spatter with Pele hair, max. dimension 30-40 cm, were observed above Vallonazzo at 670 to 790 m. Max. clasts / m2 = 2. At 790 m a.s.l. scoriaceous clasts were associated to unaltered blocks, some covered by scoriae. These weren't found on the path towards the elipad. Great black spatters (up to 1 m) fell 50-100 m toward the craters. Yellow pumices between elipad and the craters (up to 20-30 cm size hypothesized before impact).
The lobe stretching north-northeast was formed of scattered black spatters. The second, an east-southeast trending lobe, was formed of an almost continuous deposit of light-golden pumice, varying in size from bombs 1 m across to fibrous lapilli.	At Pizzo found fine products - millimetric pumice ash and scoriaceous black lapilli (max. 5-6 cm). Yellow pumices diminished towards SW from Pizzo to crater 3 and disappear at first "fortini" of Ginostra (890 asl, WSW from Pizzo). Metric spatter rich in pumice some mixed, become continuous on the ESE side of crater 3. This is interrupted sharply towards S. Yellow pumice fell towards ESE (Rina Grande) up to the beach below "Schicciolo" - max. clasts 4-5 cm.
Bombs on the tourist path down to an altitude of 750 m a.m.s.l. In other directions the bombs fell as low as 500 m a.m.s.l. Ginostra was not affected significantly.	Blocks up to 1 m size were found from the elipad to the ridge towards crater 3 and on the N side of Fossetta. They were from some meters to tens of meters distant. The explosion also caused significant morphological changes to the rim of Crater 1 towards North.
Although a high number of tourists were on the island, no one was hurt. The authorities immediately blocked public access to the upper part of the volcano.	Several fires were started in the vegetation on the upper volcano slopes (the biggest one, near Forgia Vecchia, was stopped only the following day). Another one in Vallonazzo.

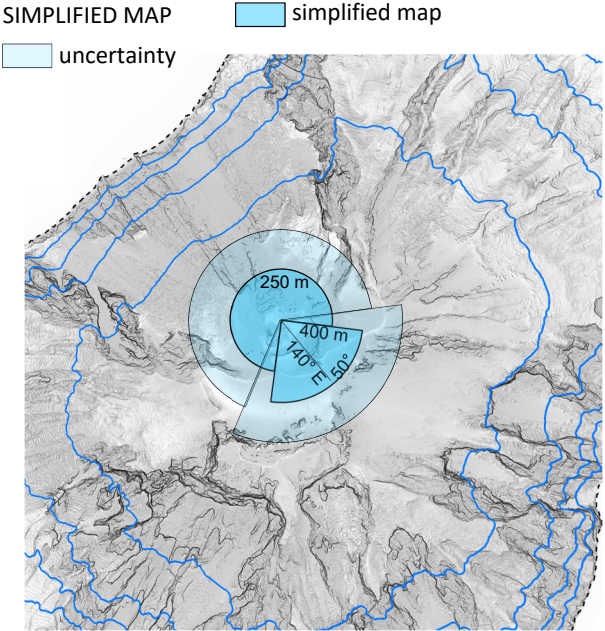
Descriptive File 34.

Main sources	Year	Month	Day	GMT
Bertagnini et al. 1999; BGVN; Stromboli Online; Personal Communication - Pompilio	1998		1	16 10:11

FIELD DATA AND OBSERVATIONS



SIMPLIFIED MAP



Field survey information

«Usual» pyroclastic material had fallen in the neighbourhood of the craters

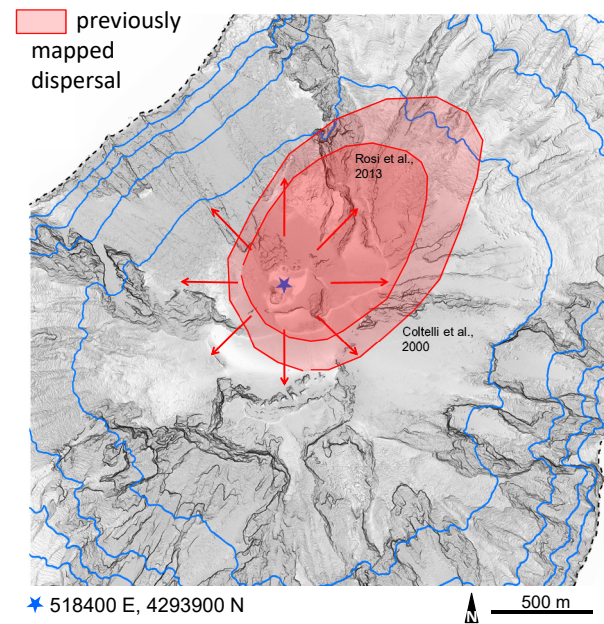
Products distributed between the last "fortino" of Stromboli and the first of Ginostra (located WSW to Pizzo). Mostly red lithics and juvenile blocks scarcely vesiculated. Few Pele hair. Rain washed away any ash. One bomb of 1m on "Pizzo" close to the camera.

Rain extinguished any wildfires.

Descriptive File 35.

Main sources	Year	Month	Day	GMT
Coltelli et al. (2000); BGVN; Stromboli Online	1996		9	4 13:43

FIELD DATA AND OBSERVATIONS



Ballistic projectiles
Blast of a bubble of viscous magma that expanded over the northernmost part of the crater causing the radial fallout of large spatters.

Some tourists were caught by the explosion in the crater area and six of them were slightly injured. After this, the Mayor of Lipari ordered the closure of the path to the craters.

Surveillance camera damaged by products.

Field survey information
The areas close to the craters and the flanks of the volcano (to 700 m a.s.l.) were completely covered by scoriaceous and pomiceus bombs and fumarolised lithic blocks (about 500 m from the craters)

Spatter bombs covered the entire summit area with a maximum in dimension (up to 2 m) and density in the E and NE sector, whereas lighter blocks were blown and fallen in the eastern side of the crater in an area more than 100 wide and stretched towards NE

Between Pizzo sopra la Fossa and la Fossetta many fumarolized lithic blocks, up to 1 m large, were concentrated. The small hornito in Crater 1 was destroyed as well that one in Crater 3.

Scoriaceous hot bombs and lapilli fell in lower parts of the volcano causing also some fires.

SIMPLIFIED MAP

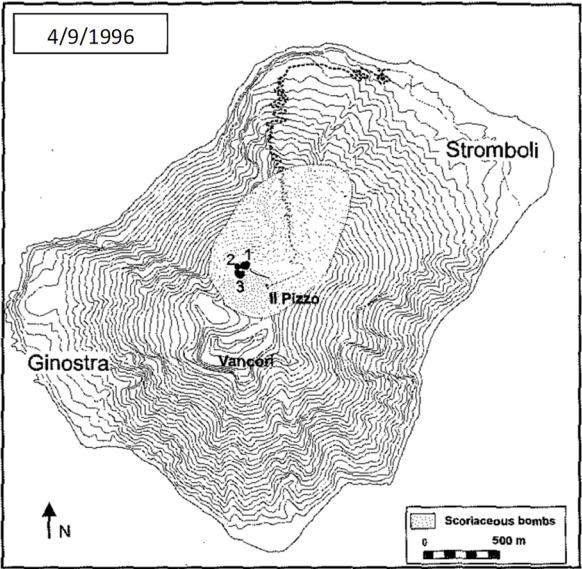
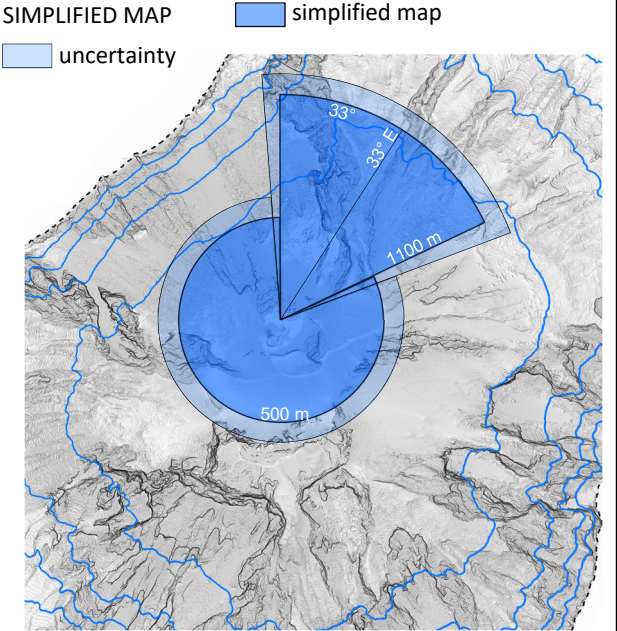
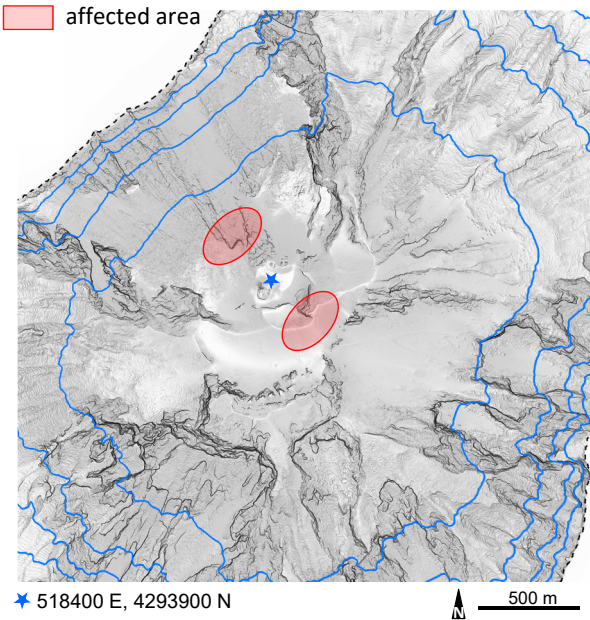


Figure. Lapilli and bombs fall dispersion of the 4 September 1996 major explosion. Numbers indicate active craters. Coltelli et al. (2000).

Descriptive File 36.

Main sources	Year	Month	Day	GMT
Coltelli et al. (2000); BGVN	1996		6	6
				4:52

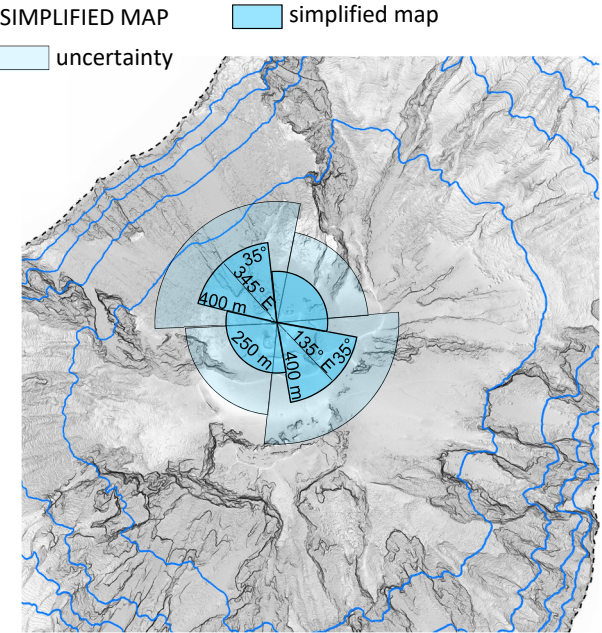
FIELD DATA AND OBSERVATIONS



Ballistic projectiles
Bomb fallout on the Sciara del Fuoco.

Very fast gray-brown jet that ascended at ~30 m/second at the larger explosion some bombs were thrown a few hundred meters upper limit of the camera view; most of the bomb and block fallout from the vents.
was behind the camera.

SIMPLIFIED MAP



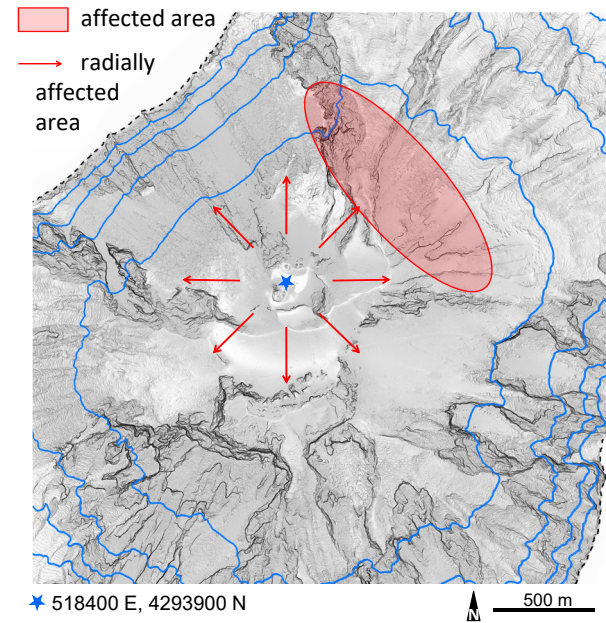
Field survey information

All pyroclastic materials fell close to the craters but during the larger explosion some bombs were thrown a few hundred meters from the vents.

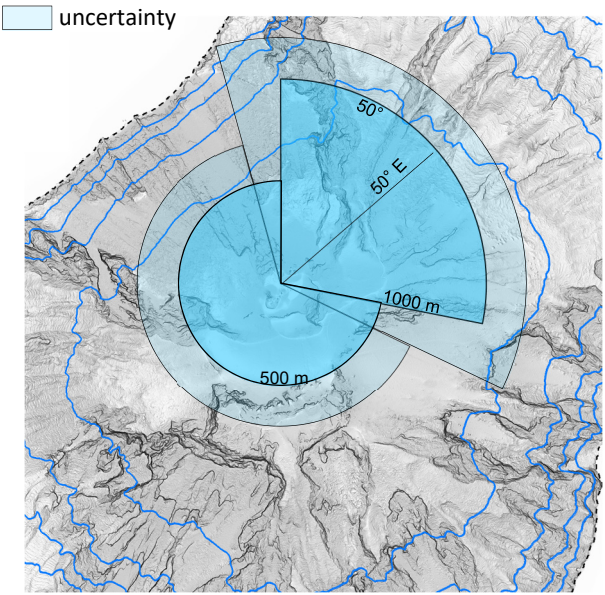
Descriptive File 37.

Main sources	Year	Month	Day	GMT
Coltelli et al. (2000); Stromboli Online; Personal Communication – Pompilio	1996	6	1	21:47

FIELD DATA AND OBSERVATIONS



SIMPLIFIED MAP



Ballistic projectiles

Fallout of red bombs on the upper northern slope.

The ejected material completely covered the summit, falling more than 500 m away toward S and E and reaching the vegetation 1,000 m in the N sector.

Very large blocks thrown to a considerable distance from the craters, especially into the zone of the "Canneto", uphill from the village of Stromboli-San Bartolo.

More than twenty tourists were visiting the summit. Some reported light burns caused by lapilli fallout. Seven tourists were sleeping near the summit, and four got injured.



Field survey information

The explosion occurred at Crater 1. The chain of hornitos inside this crater was blown out, leaving a large deep depression in the north side of the crater floor.

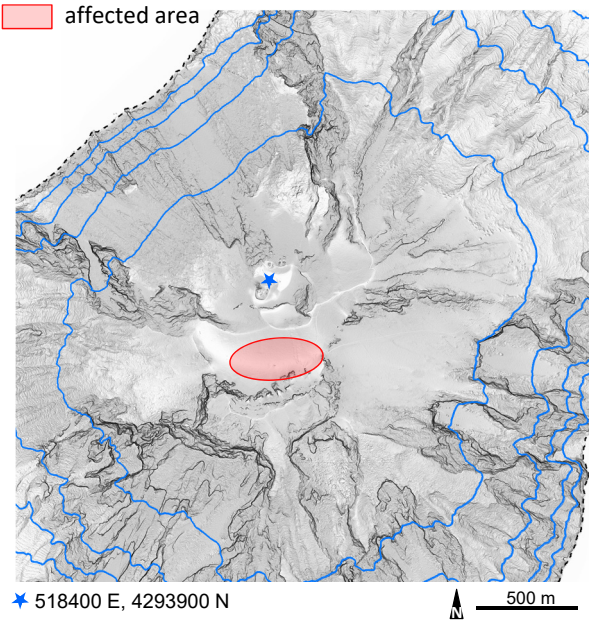
The deposit was made of black scoriaceous bombs, covered by Pele's hair, reddish blocks, and a minor amount of ash. On the "Pizzo" (250 m SE from the craters), the falling bombs were 10-50 cm in size and covered the area with a density of 3-4 bombs per m2.

Incandescent bombs fell on vegetation, causing a fire that was extinguished by Civil Defense aircraft in the late morning of June 2

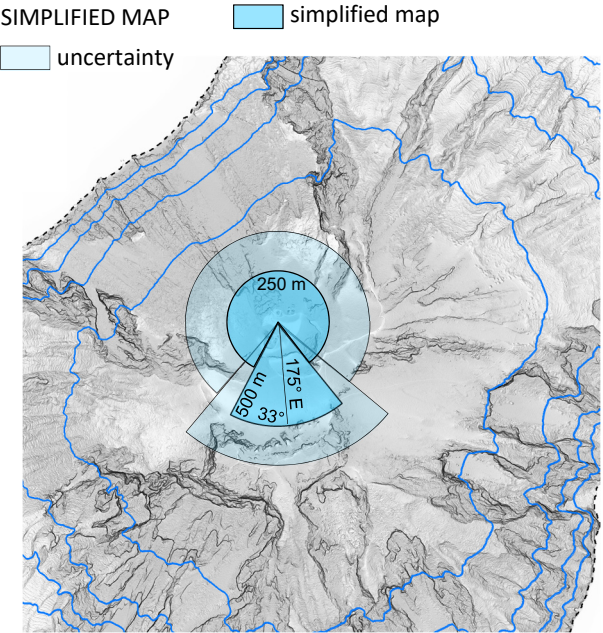
Descriptive File 38.

Main sources	Year	Month	Day	GMT
Coltelli et al. (2000); BGVN; Stromboli Online; Personal Communication – Pompilio	1996		2	16 23:58

FIELD DATA AND OBSERVATIONS



SIMPLIFIED MAP



Ballistic projectiles

Incandescent bombs throw and red glow according to the description of the inhabitants.

Field survey information

A large area 300 m wide and elongated toward S was covered by scoriaceous cowpie bombs, Pele's hair and fumarolised lithic blocks.

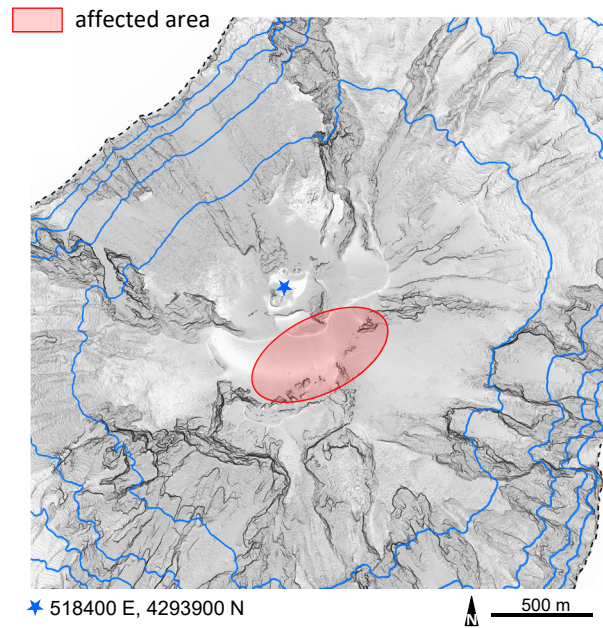
A portion of the products was formed by highly vesicular scoria.

No major change of the craters shape was observed after the eruption, but the vent that produced these materials was probably in Crater 2 or 3

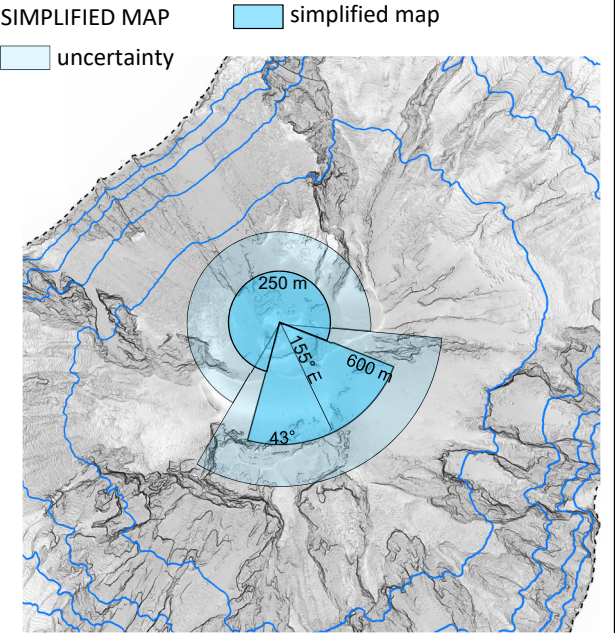
Descriptive File 39.

Main sources	Year	Month	Day	GMT
BGVN; Stromboli Online; Personal Communication - Pompilio	1995		3	5 17:43

FIELD DATA AND OBSERVATIONS



SIMPLIFIED MAP

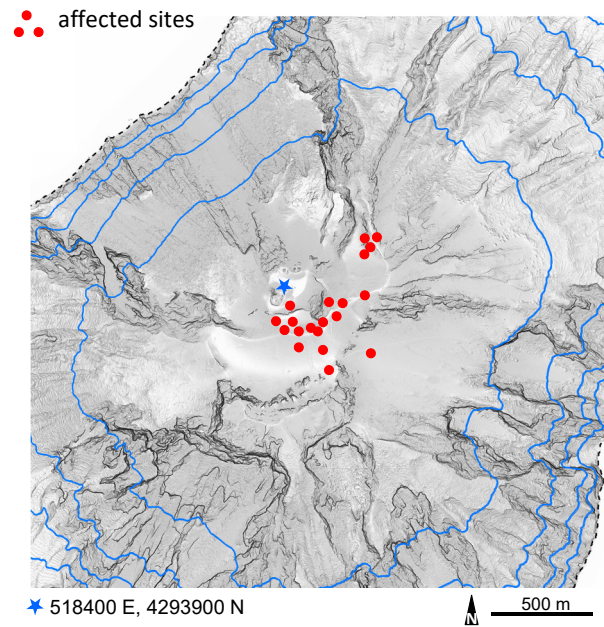


Ballistic projectiles	Field survey information
Explosion threw pyroclastic material high enough to be clearly seen from the village of Stromboli.	Explosion threw pyroclastic material towards Forgia Vecchia and Fossetta, a depression SW of the crater area.
	In "Valletta" lithics of about 70 cm and bombs of about 1 m. Sampled scoriae on "Pizzo".

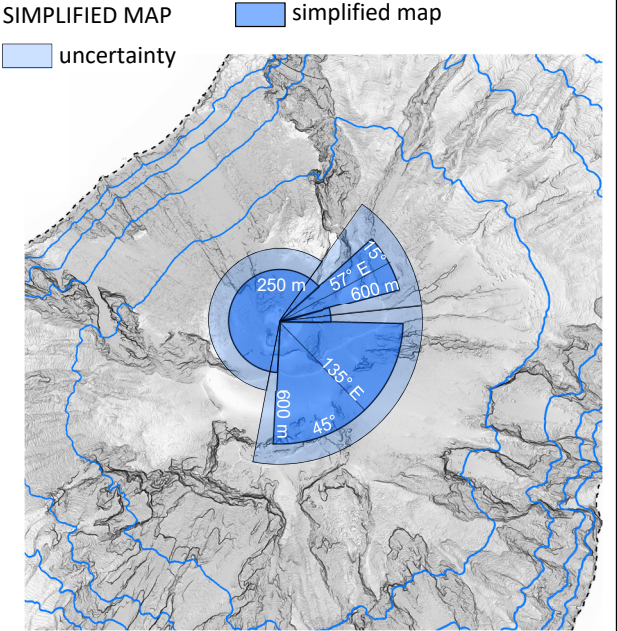
Descriptive File 40.

Main sources	Year	Month	Day	GMT
BVE 1993; Coltelli&Cardaci (1994); Langer&Falsaperla (1996); BGVN; Stromboli Online; Personal communication – Pompilio	1993		10	16
				1:07

FIELD DATA AND OBSERVATIONS



SIMPLIFIED MAP



Ballistic projectiles

Trust of lithic material. Bomb fallout up to 500 m from the vent. product dispersal affected the entire summit area.

Woman camper heavily wounded on the "Pizzo". Synthetic jacket ignited by hot bomb and lapilli fallout.

Field survey information

Large blocks and spatters reaching two meters diameter. All over the summit, but also on the path leading up from Stromboli village and on the ridge west of the summit.

Most distant ejecta were observed at a horizontal distance of approximately 600 metres from crater 3. Two pit depressions left on the crater bottom.

Some bushes caught fire along the slopes

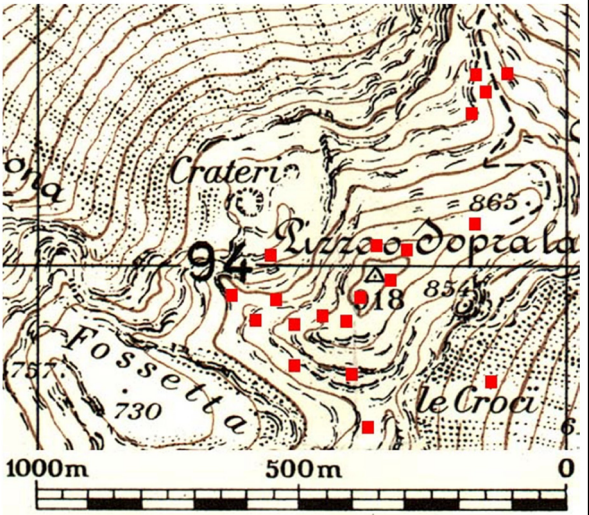
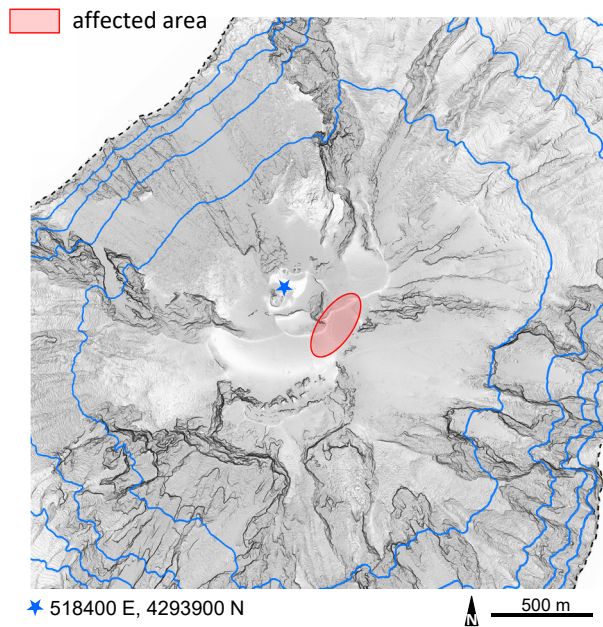


Figure. Map of the "fresh material" on Stromboli Online (J. Alean). Red squares indicate the largest scoria.

Descriptive File 41.

Main sources	Year	Month	Day	GMT
BVE 1992	1992		9	1 5:00

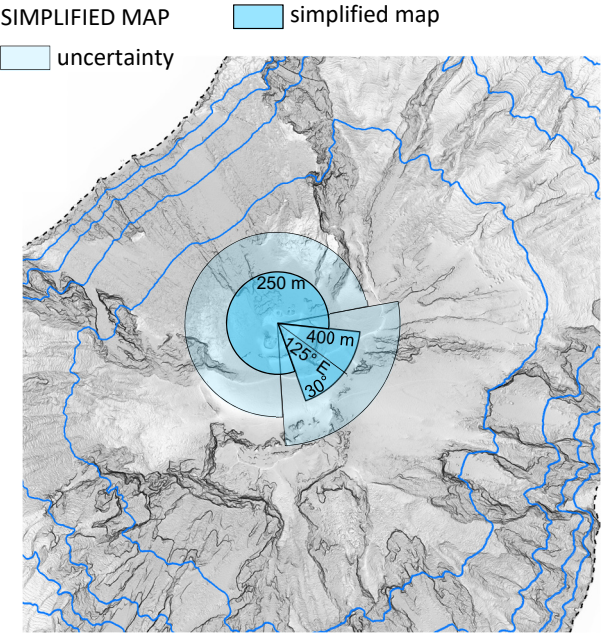
FIELD DATA AND OBSERVATIONS



Ballistic projectiles

Juvenile basaltic ejecta were thrown behind the "Pizzo".

SIMPLIFIED MAP



Field survey information

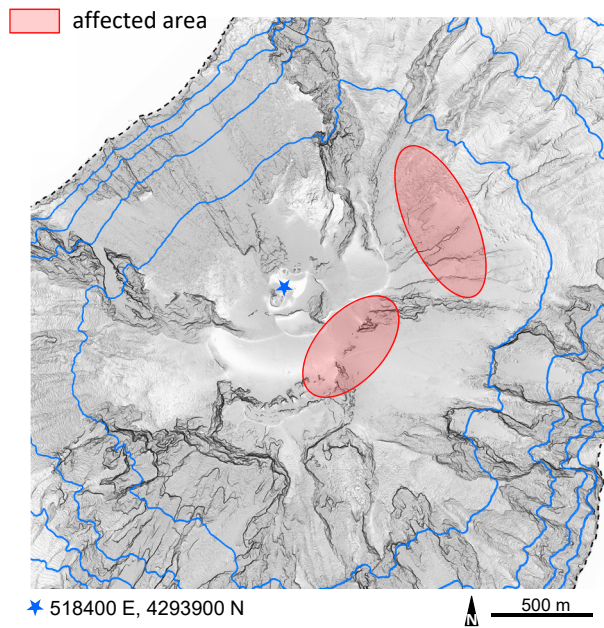
Spatter cone grown in 1991 was destroyed.

During summit visits on September 4-5 spindle-shaped scoriae up to 50 cm long were observed along the footpath just before reaching the "Pizzo" (850-900 m asl).

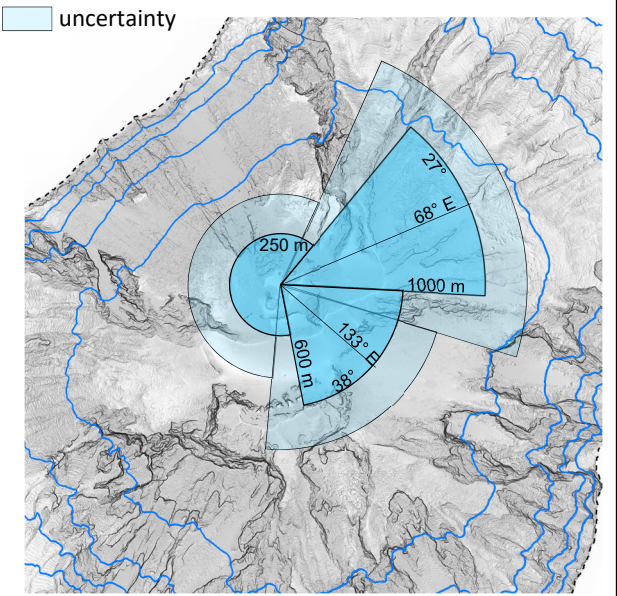
Descriptive File 42.

Main sources	Year	Month	Day	GMT
BVE 1989; SEAN 1989; Falsaperla et al. (1989; 1994); Falsaperla&Villari (1991); BGVN; Stromboli Online	1989		3	26
				7:27

FIELD DATA AND OBSERVATIONS



SIMPLIFIED MAP



Ballistic projectiles	Field survey information
Lapilli and scoria were thrown up and distributed over a fan-shaped area to NE to S of the crater extending up to more than 1 km away.	Large lithic blocks were spread out within an area of a few tens of meters from the crater.
The incandescent material reached the height of 500-550 m above the Crater Terrace, falling beyond "Il Pizzo".	Small fires broke out in the shrubby vegetation on the NE slope.
Tourists nearby were hit by the shower of tephra.	

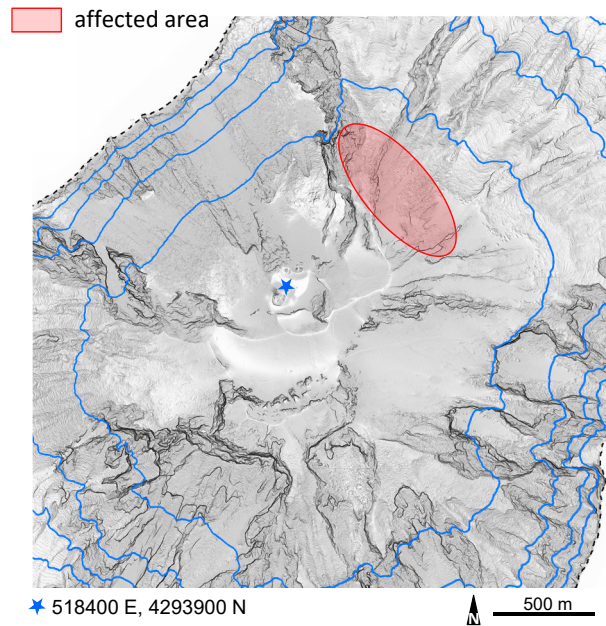


Figure. Photo from Stromboli village by Stromboli guide Nino Zerilli. Red arrows mark small white dust clouds and smoke caused by bombs falling onto the slope of the volcano, some of them causing small fires in the dry vegetation. Stromboli Online website.

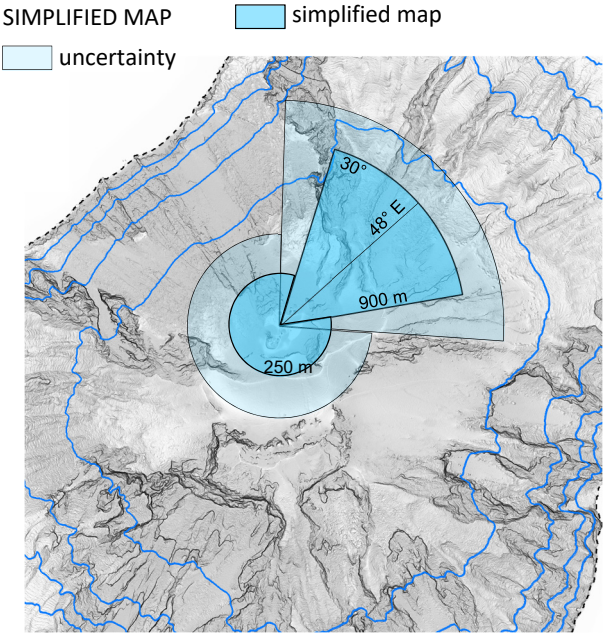
Descriptive File 43.

Main sources	Year	Month	Day	GMT	
BVE 1972; Nappi (1975; 1976a,b)	1972		12	4	?

FIELD DATA AND OBSERVATIONS



SIMPLIFIED MAP



Ballistic projectiles	Field survey information
Scoriae, spatter and bombs.	4 months after the major explosion.
Large fragments of old lava fell on the NE flank above San Bartolo	Trail to Il Pizzo covered by 20-30 cm lapilli at 750 m a.s.l.
	Large blocks ejected inside crater terrace

Table 1. List of the 8 major explosions for which there was insufficient information to map ballistics.

Main sources	Year	Month	Day	GMT	Ballistic projectiles	Field survey information
<i>BVE 1974; Nappi (1975; 1976a; 1976b)</i>	1974	9	19	00:10	-	Yes, destroyed scoria cones, enlarged craters, deep changes in the crater terrace.
<i>BVE 1988; Falsaperla&Villari (1991); Coltelli&Cardaci (1994); Langer & Falsaperla (1996)</i>	1988	8	30	01:12	It did not cause great morphological variations of the crater area or changes in volcanic activity. Similarly to 26/3/89 and 18/6/90 it produced bombs and lapilli fallout on the volcano summit and on the Sciara del Fuoco.	-
<i>BVE 1990; Falsaperla&Villari (1991); Falsaperla (1991); Langer&Falsaperla (1996); BGVN</i>	1990	6	18	15:12	Ejecta fell onto the NW flank's Sciara del Fuoco.	The crater area (Il Pizzo) was visited during the morning of the following day and still hot scoriae were sampled. The wall between craters 2 and 3 collapsed.
<i>BVE 1993; Coltelli&Cardaci (1994); Langer&Falsaperla (1996); BGVN; Stromboli Online</i>	1993	2	10	16:10	Lateral blast of reddish lithic material. Lithic blocks and lava fragments fell to 1 km from the summit.	A fire fountain of highly vesiculated magma took the place of the ash emission, forming a deposit of golden pumiceous spatters that blanketed the northern slope of Crater 1. Ash fall samples collected on the southern slope near to the Ginostra village. The ash is coarse grained and red -brownish. 10 kg bomb found at a site 0.3 km from the source,
<i>Falsaperla&Cardaci (1998); Personal Communication - Pompilio</i>	1995	5	10	22:41		Products included pumices.
<i>INGV - daily seismic report; BGVN; Calvari et al. (2014); Personal Communication - Falsaperla</i>	2010	6	30	16:33	Poor weather conditions.	Fallout from incandescent blocks triggered vegetation fires on the upper slopes.
<i>INGV - daily seismic report; INGV - weekly bulletin</i>	2012	3	6	06:43	Explosions from NEC with fallout of bombs to NNE, probably up to Bastimento, and at Pizzo. Lava fragments and bombs initially fell on the upper N sector of Sciara del Fuoco, probably up to low elevation for a cloud of fine products, i.e. 400 m asl. A second explosion ejected less bombs, but widely dispersed in the N and NE sectors, possibly affecting Bastimento, shelters, Pizzo.	Field survey a few hours after the event - not observed products on the trail between shelters and Pizzo. this does not exclude that any bomb affected the area.
<i>INGV - report of volcanic activity; Calvari et al. (2021)</i>	2019	8	29	20:43	Two fountaining during lava flow output .	-