# Observations on recent Stromboli activities and their effects

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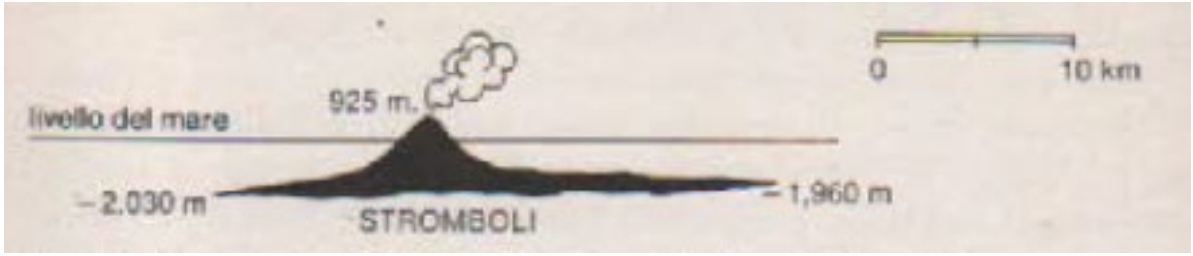
**Giuseppe Rolandi**[a] **, Luciano Nunziante**[b]
[a]Former Full Professor of Volcanology , [b]Former Full Professor of Solids and Structural Mechanics
University of Naples Federico II-Italy

## Background

The volcano Stromboli, which gives its name to the island of the same name in the Aeolian archipelago in Italy, is one of the few volcanoes on earth in almost continuous activity, rising more than 920 meters above sea level, towering above a base that deepens about 2,000 meters below sea level.

Stromboli volcano (north side) seen from the sea, June 1997. On the left is seen the town of Stromboli. The active craters, located about 200 m below the summit, with steam emission.(1). Photo by Boris Behncke.




(4)

Stromboli's activity is one of the most studied in the world and has taken place from about 200,000 years to the present day according to volcanic events that volcanologists, on the basis of geological studies, agree to divide into five main periods: it would therefore be a difficult gamble in the face of this thousand-year history to think of recognizing “new” facts in the volcano's activity.

( ) In round brackets are informative bibliographic and documentation references.
Author’s contact mail: a) pepperolandi@gmail.com , b) nunsci42@gmail.com

The main purpose of this communication is the explication of the observations recently made on the volcanic events at Stromboli and on the identification of the possible risks involved, in order to be able to better combat and mitigate the harmful consequences manifested recently.

## History of recent events

The Stromboli eruptive activity produced by the three active craters in recent decades can be classified into the following four modes.

S) A basically continuous activity of low-energy explosions every 25-35 minutes, with ejection of bombs, ash and lapilli falling around the crater area. This mode referred to as “Strombolian activity” has entered the international language of volcanologists.

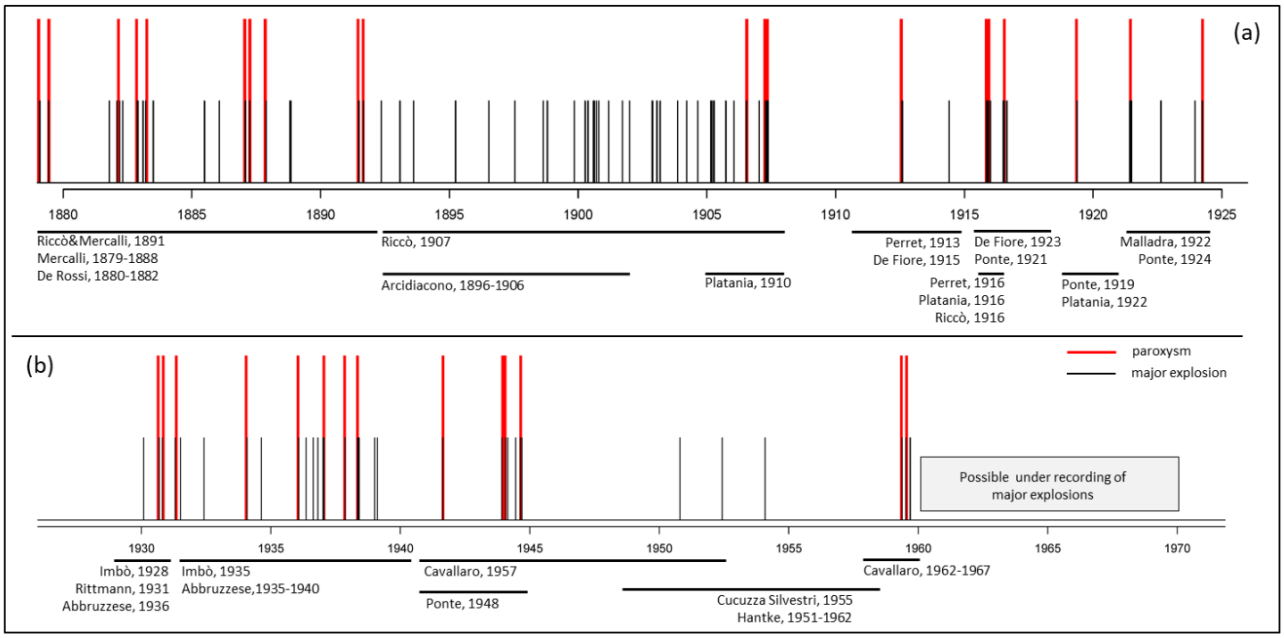
E) Violent and sudden explosions, with ejection of incandescent material falling back on the summit portion of the island.

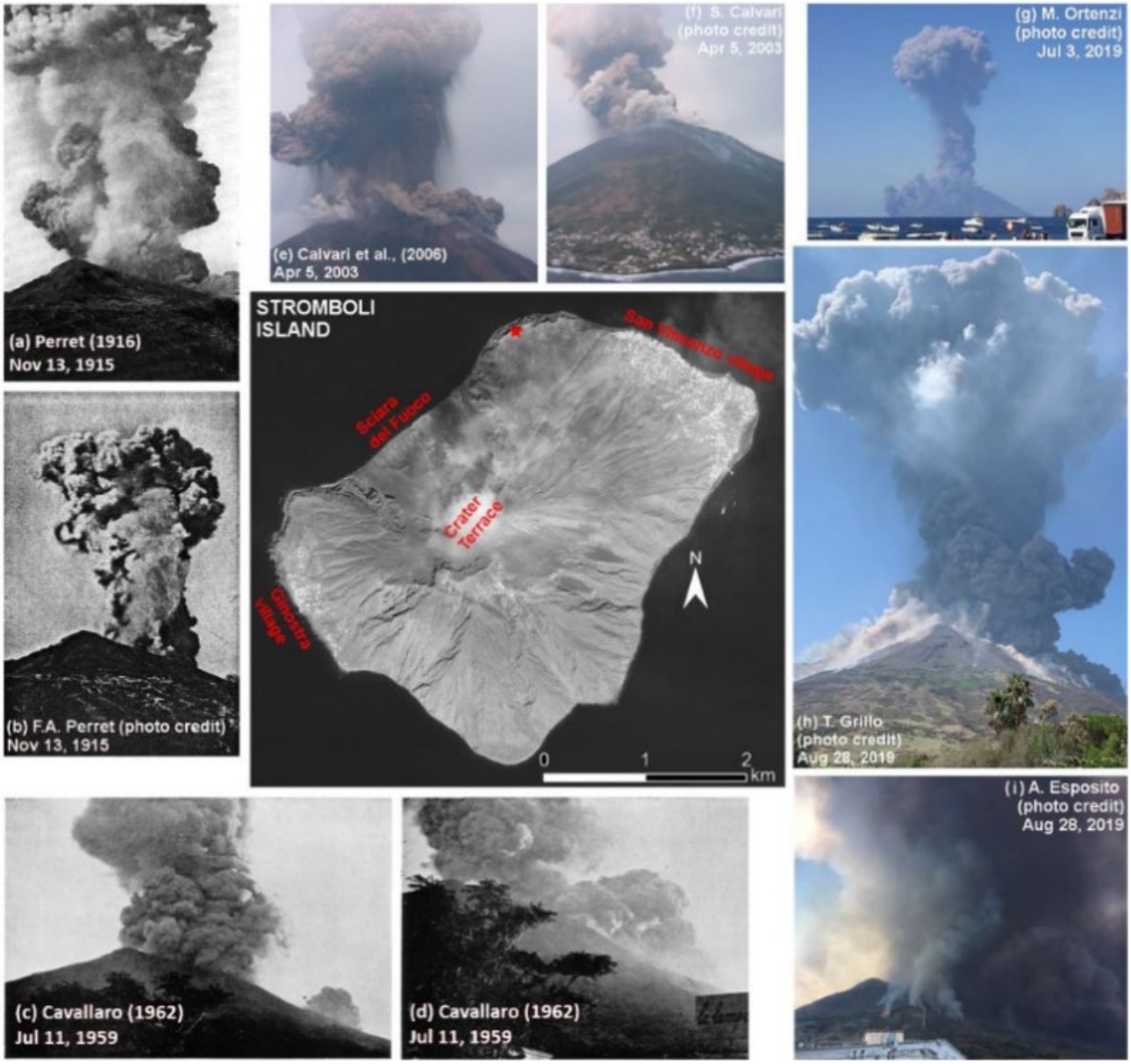
P) More rarely, very violent explosions with ejection of incandescent and lithic material falling over very large areas, even to the extent of damaging the two villages on the island, sometimes accompanied by pyroclastic flows.

FL) Lava flows originating from the summit craters, descending the walls of the Sciara del Fuoco.

The following graph (1) shows on the time axis the historical succession from literature of the main violent explosions E with black lines, and that of the paroxysms with red lines that occurred at Stromboli in the period 1879-2020. In the following, the most recent events, from 2019 and up to the present, will be highlighted.

Historical catalog of major explosions and paroxysms at Stromboli in [1879, 1960]



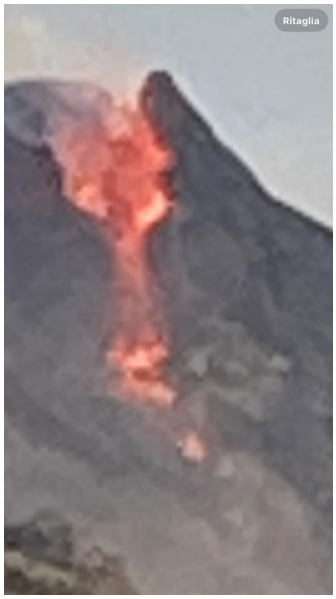


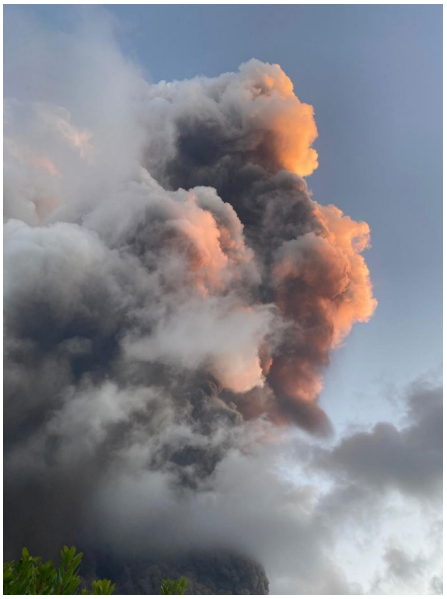

The following are the relevant events that have occurred from 2019 to the present (1),(2),(3).

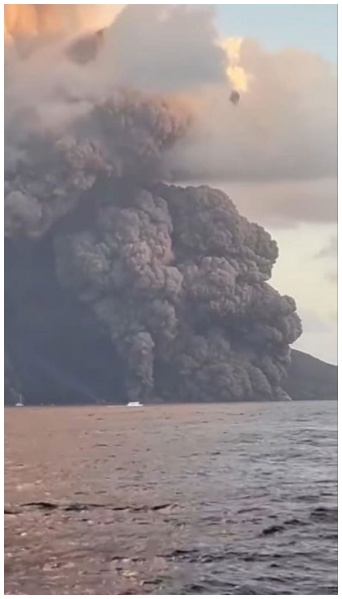
- July 3, 2019 . Paroxysmal event with explosion whose materials consisting of a column of ash, lapilli, debris, reached 4 km above sea level with pyroclastic flows towards Sciara del Fuoco side, with fire of the slope up to the town of Ginostra (1 victim).
- August 28, 2019. Paroxysmal event with 4-km-high column of ash, lapilli debris, sands, and pyroclastic flow propagated seaward on Sciara del Fuoco side, with copious material fallout in Stromboli locality from Scari to Piscità and massive pyroclastic flow on Sciara del Fuoco side and fire in Stromboli from Piscità to Punta Lena that destroyed flora and fauna.
- 2019 - 2022 - Strombolian activity and lava flows.
- May 25, 2022. Massive fire that lasted two days, caused by the crew of an outside company for a RAI production, in which burned much of the island's vegetation for about 242 hectares, which came to lap the town.
- August 12, 2022. A heavy rainfall definable as a water bomb caused a massive flooding phenomenon, facilitated by the effects of the May fire and the lack of vegetation, with mudslides in the Stromboli area carrying mud, shrubs, debris, rocks and boulders even on the order of a ton, along with other materials in the riverbeds, into the built-up area. The effects were roads completely invaded by mud and debris up to heights of m. 1.70, demolition of low walls and damage to houses some invaded by mud and materials up to the height of m. 1.60 , a few injured.

- 2022 to 2024. Strombolian activity events.

- On 03/04/05/06/07 of July 2024. Intense sequence for five days of lava flows toward the Sciara del Fuoco with collapse of a flank of that volcanic cone with dozens of landslides, paroxysmal explosions with deposits of very fine ochre-colored ash covering the entire mountain, with pyroclastic currents reaching the sea at the Sciara del Fuoco causing columns of saline water vapor rising up the sides of the mountain that goes to cover the previously deposited ash deposits. Lava flows reaching the sea coupled with spattering and explosive activity. (See the INGV Web Bulletin for details).

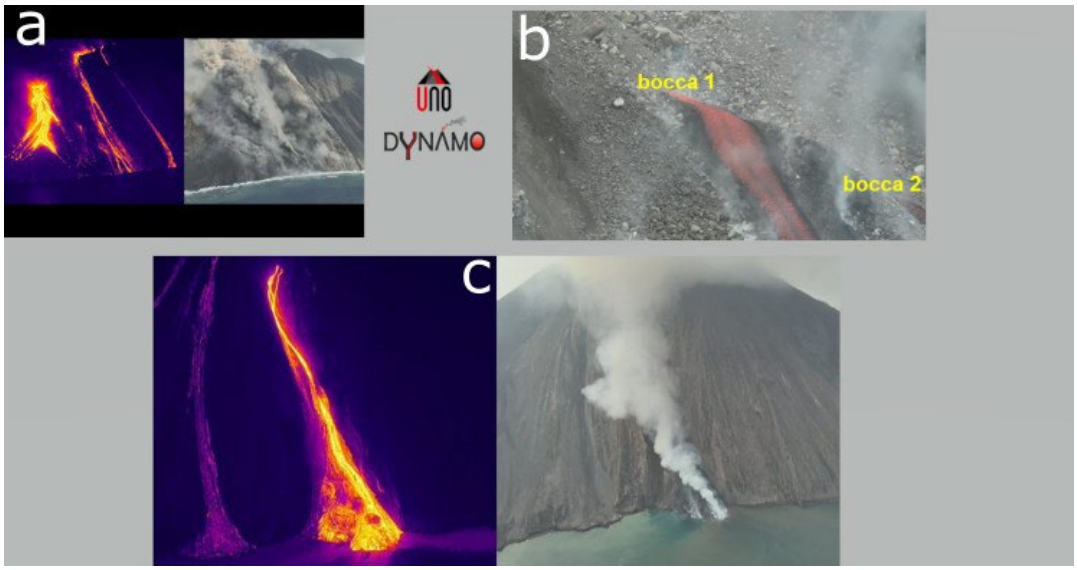




## The formation of the solidified-impermeable surface layer of deposited ash promotes the formation of rushing mudflows

Stromboli's effusive activity further intensifies during the night of July 6-7, 2024, with two flows produced by the two vents located at 510 and 485 m above sea level that converge to create a single lava flow reaching the coastline and forming a lava delta. The lava flow, in contact with sea water causes the formation of a vapor cloud. Also observed is the rolling of incandescent lava blocks which, falling into the sea, cause small phreatic explosions and modest oscillations of the water surface.




On July 11, 2024, the Stromboli volcano manifested new activity; at 2:07 p.m. there was a loud roar, distinctly felt by the population even outside the island, and a massive eruptive column with pyroclastic flow rose from the volcano's summit craters. Much of the erupted material fell back toward the sea towards Sciara del Fuoco, continuing out to sea for several minutes and tens of meters before coming to a halt.

People on the shoreline were moved away from the sea, and there was no damage to buildings or people. In conjunction with this paroxysm, the surveillance network of INGV's Etnean Observatory recorded a seismic tremor that reached very high levels, associated with a series of volcano explosions that lasted a total of 8 minutes.

The ochre-colored erupted ash deposited on the surface of the mountain in the events of July 2024, in the area between altitudes 400 and 700 m. above sea level, as a result of the cloud of water vapor coming from the sea resulting from the fall of pyroclastic currents or lava flows, loaded with salt, solidifies to thicknesses ranging from centimeters to decimeters in a short time presenting a solid appearance and forming a hard and impermeable mantle over the entire surface. This mantle is non-draining and impermeable, such that it favors the surface runoff of water from rainfall events even on the order of millimeters.

From August to November 2024, four new impetuous mudflows occur in Stromboli during rainfall events of limited intensity, carrying also large debris and large stone elements, which reach the built-up area with damage to roads and homes.

These events of intense and violent mudflows and other transported materials cannot but be related to the solidification and consequent waterproofing of the surface layers of ash deposited in July 2024, present both in the steep slopes at +400 m up to altitudes +700, and also present in the area of the band of scarce and recent spontaneous vegetation present, regrown after the last fires of 2019/2022 from +400 up to the altitude of the town center. These flows determine with their impetuous passage deep furrows on the mountain in the area between altitudes +400 to +700 above sea level.

The mudflows pouring into the historic valleys and then into the stream beds particularly in the Piscità locality (San Bartolo and Montagna Russo streams, Scalo Balordi, etc.) have caused the elevation of the stream beds with sands up to reach of heights of 3-5 m., occlusions of roads, with transportation of rocky boulders of more than 2 tons, silting up of beaches, etc.

At Forgia Vecchia, the original steep sandslide from the summit, after the Molo di Scari location, sand flows and landslides have resulted in deep ruts that have caused an intense landslide of materials deposited on the beach.

Mudslides first affected the locality of Ginostra, with descent from the Portella di Ginostra peak at an altitude of + 700 of debris material mixed with vegetation, rocky boulders, black sands, and other materials affecting the town center, the small square, the road system, and reaching copiously to the sea where they caused both the occlusion of the small Pertuso marina and the creation of small beaches under the Church and Lazzaro.

At the furrows in the mountains on the north side on Stromboli, in addition to the melting of solidified ash slabs, a landslide is found for the first time, even deep in the coarse black/dark brown sands/debris/scales that originated from old paroxysmal events (from 2019/2024) caused by eruptions prior to those of early July 2024.

The Authors during the month of November 2024, assisted by a staff with volcanological, physical, chemical and hydrological expertise, began the study of the physical-chemical-mechanical characteristics of pyroclastic materials whose solidification process was observed starting from the ash deposited in July 2024, which saw the formation on the mountain of an extensive solid and impermeable layer, capable of favoring during rainfall events the conveyance of rushing mudflows to the built-up area.

On samples of the pyroclastic materials produced in the recent July 2024 events, morphological, particle size, physical testing, and petrographic and geological chemical analyses have begun.

A first mechanical investigation of a sample of solidified ash slab from the July 2024 deposits on Russo Mountain at an elevation of about +400 m a.s.l. was carried out on 11/29/2024 in the Laboratory of the Department of Structures for Engineering and Architecture of the University of Naples Federico II- Italy, and allowed the determination of apparent density of value $\rho$ = 1498 daN/m$^3$, compressive strength with value of the order of 2-3 daN/sq.cm., and average Young's modulus of the solidified material of value 16.22 daN/sq.cm.

Below is the stress-strain diagram obtained from the test, which was performed with Mohr&Federhaff testing machine and centesimal comparators, at the average stress rate of 1.76 x 10$^{-3}$ daN/(sq.cm sec).

The mechanical properties of solidified ash, as determined by testing, are quite comparable to those of very soft rocks or very soft clays.

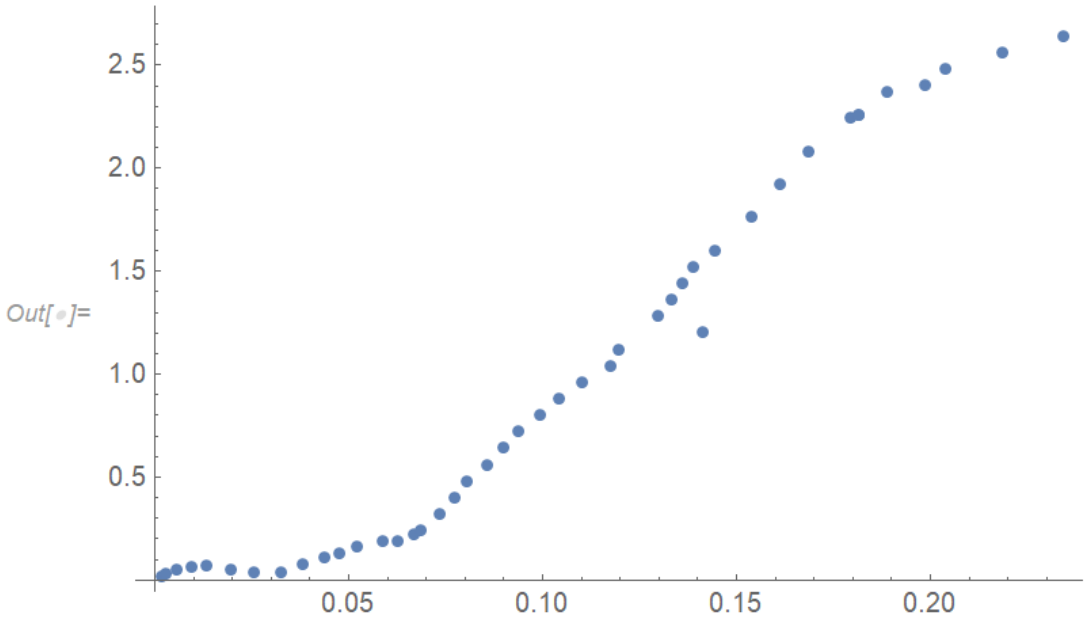
These products, which come from a process of “solidification” of ash that consists of granular material, are of physical characteristics quite different from those of the loose ash that is usually displaced by sweeping; they appear as real solids, in that they retain their shape and are hard to break down and difficult to remove even by mechanical excavation; in addition, their compactness makes them impermeable.

Moreover, when placed in water, they dissolve, losing their solid form.

In situ, the action of the first rains removes their surface parts, while subsequent repeated rainfall events cause them to dissolve.

Stress – strain diagram σ ,ϵ ; Wolfram Mathematica 12.1

σ in daN/sq.cm




From testimonies collected it appears that the surface coat solidified after July 2024 is still present after the rains of about five months, with a persistence of about 30/40 %.

Further granulometric, morphological and chemical/physical analyses are being conducted on these products, which will deepen our understanding of them in order to be able to devise appropriate ways to limit their harmful effects on the environment.

Likewise, the study of theories for the mitigation of the risk coming from the formation of these solidified layers and operational techniques for solving the problem of mobilization of mudflows has already been planned and initiated by the staff of scholars involved by the writers, endowed with volcanological, structural, physical, chemical and hydrological expertise, and is proceeding hand in hand with the advancement of tests and studies on the physical/chemical nature of the pyroclastic materials under analysis.

In particular, studies are already underway on the hydrological/hydraulic characteristics of the area upstream of population centers.

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- Authors would like to thank the scholars and practitioners involved in the ongoing activities, who with their testimony, knowledge and/or research are contributing to the insights on the recent volcanic events on Stromboli volcano and on the identification of the possible risks involved, in order to be able to better combat and mitigate the harmful consequences.
- Authors thank Eng. Marco Cocca manager of the testing laboratory and technician Mr. Giovanni Belfiore, of the Experimental Laboratory of the Department of Structures for Engineering and Architecture of the University of Naples Federico II - Italy, for their cooperation in carrying out the mechanical tests.

**Informative bibliographic and documentation references.**

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*3) Pro Loco Amo Stromboli APS - Italy.*
*4) Fred M. Bullard. The volcanoes of the earth. Newton Compton, 1978.*