Cities on Volcanoes 10, Naples, Italy

Pozzuoli 1970
When the Earth Danced to a Dangerous Tune

Via Pesterola in Rione Terra, Pozzuoli:
one of the first streets to be evacuated in 1970.
Painting by Antonio Isabettini.

A Companion to Workshop W.10
Eruption Forecasts and Warnings at Long-Quiescent Volcanoes

08 September 2018

Pozzuoli 1970
When the Earth Danced to a Dangerous Tune

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Warnings and Alerts during Volcanic Emergencies:
Scientific Practice Informed by Community Experience

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Il Comune di Pozzuoli

Lunch prepared by the *Ristorante Frasca*, Pozzuoli

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Notes on the illustrations

The full collection of paintings of Pozzuoli before 1970 by Antonio Isabettini can be viewed at www.rioneterra.it/?p=5402.

For information on additional photographs of Pozzuoli in 1970 from the Lux-in-Fabula archive, contact Claudio Correale at info@luxinfabula.it.

Rione Terra today. The small square in front of the workshop venue (Palazzo Migliaresi) is above the bottom left corner. North is to the bottom. The image is about 300 m wide. (*Detail from*: www.archeoflegrei.it/la-storia-del-rione-terra/)

Foreword

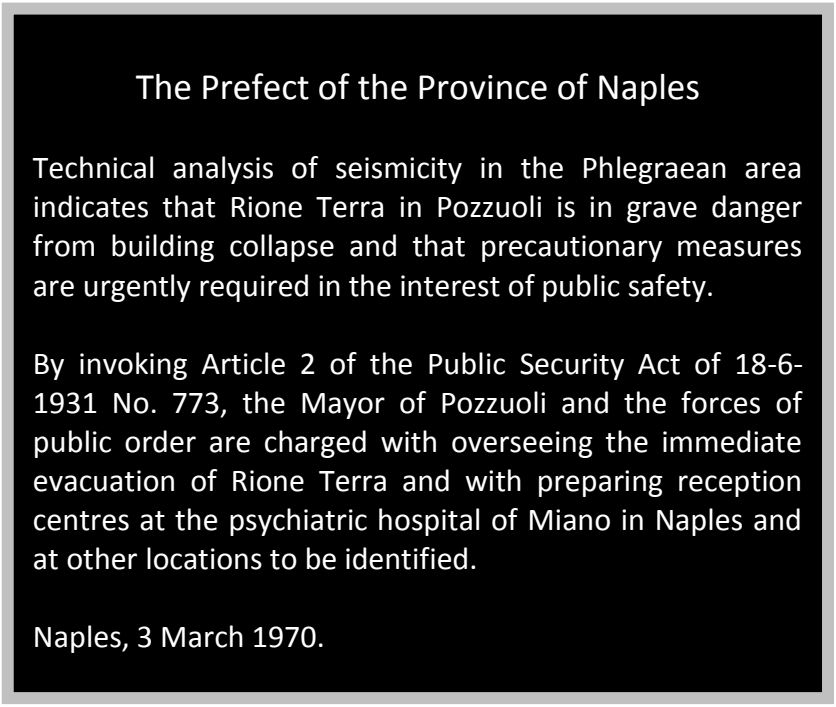
1970 was the year that life changed forever in Pozzuoli. For 430 years, the coastal town at the centre of Campi Flegrei had been subsiding into the sea at 15-20 cm a decade. By the start of the Twentieth Century, streets behind the port were being regularly inundated with water; by the start of the Twenty-first, the whole front was expected to have slipped beneath the waves. They said a new Venice would be born just a stone's throw from Naples. It was the first of many forecasts about Pozzuoli that were destined to fail.

Sometime around the summer of 1969, gentle sinking gave way to rapid upheaval. By the following February, the town had been raised by 80 cm - moving ten times faster than before in the wrong direction. On Tuesday, 3rd March, 6,000 people were forcibly evicted from Rione Terra, the symbolic heart of the community. It sparked a spontaneous exodus that would empty most of Pozzuoli within days.

The contemporary accounts collected here tell the story of uncertainty, fear and distrust as scientists scrambled to understand why Campi Flegrei was being lifted out of the sea for the first time in twenty generations[1]. Events are seen through the eyes of Eleonora Puntillo, the reporter who first broke the news in the national media; of Mario Sirpettino, a *Puteolano* who lived through the emergency; and of the scientific teams who analysed the unrest and openly challenged the opinions of colleagues.

In the end, no natural calamity occurred. It was a salutary reminder that Campi Flegrei is alive - a reminder that smoothed the response to renewed uplift ten years later on. Even so, the story still colours public attitudes to warnings of Campi Flegrei's volcanic behaviour. Can scientists reliably forecast eruptions? Is uplift an excuse to clear poor districts for developers to create luxury accommodation? These questions must be addressed to reassure communities before warnings are released. Good warnings come not only from understanding a volcano, but also from understanding the people who have made it their home.

[1] The news reports and diary entries have been freely translated from the Italian. A key goal was to capture the mood of the moment. Any misrepresentation is unintentional, but remains the responsibility of the translator.



The official decree that triggered full evacuation from Rione Terra.
(The original courtesy of Lux in Fabula.)

What the reporter saw

Extracts from reports by Eleonora Puntillo for l'Unita[2], 1970-1979.

Is the earth burning beneath Pozzuoli?

22 February 1970

For ten days the ground and coastline at Pozzuoli have been causing alarm: deep lesions have appeared in old and new buildings; glass rulers have snapped across widening cracks; the sea has retreated against a rising seafloor; beaches are becoming bigger; and jetties along the quayside are standing higher out of the water. Ferries are docking with difficulty and the fishing port is too shallow for the hundreds of boats that normally moor there. And the main vent at Solfatara has widened so much in the past 7-8 months that it has been fenced off to prevent tourists from falling in.

The mayor announced the latest changes yesterday to the Minister for Public Works. Only geologists and volcanologists can say what is happening in the bowels of Campi Flegrei, where the clusters of volcanic craters have been compared with the moon's surface[3].

The warning signs are clear. The normal bradysesimic movement of the ground has reversed direction to become a rapid uplift... Bradyseism is the name given to slow oscillations of the ground seen not only at Campi Flegrei. The normal rates of movement are centimetres over a century or so. They often pass unnoticed except along the coast. Pozzuoli is a typical example: the columns of the Serapeo show the characteristic holes made by clams (whose shells can be found hidden inside) at heights of 3.6 to 5.3 m above their bases. Since they were built, the columns must have subsided to about 6.3 m below the sea level (in Medieval times), before rising and then subsiding again until recently[4]. The lowest parts of the columns are untouched, because they were buried by volcanic ash[5].

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[2] The articles are from the Lux-in-Fabula archive. l'Unità was the national newspaper of Italy's Communist Party. Apart from its political views, it had established a reputation for reporting on disasters, such as the 1963 Vajont dam tragedy in the Italian Alps (Kilburn & Petley, 2003).

[3] At the time, whether lunar craters were produced by volcanism or by meteorite impact was still a matter of debate (*e.g* Guest & Murray, 1969)

[4] The description of the Serapeo's long-term movement follows the classic interpretation by Parascandola (1947). Compare with Bellucci et al. (2006).

[5] The material is now recognised as reworked volcanic deposits, washed down the cliff behind the Serapeo (Bellucci et al., 2006).

The change in movement has affected the entire coastline of Campi Flegrei... The speed of upheaval is remarkable, at about 8 cm in the last eight months, and has unsettled the whole of Pozzuoli and its 60,000 residents.

Dissent is growing in the old, crumbling and overcrowded Rione Terra: just a week ago, the town council evacuated buildings in Piazza San Gelso and Via Pesterola. But the whole of Rione Terra sits on unexplored caves: the danger from ground movement is plain to see.

Ten days ago, cracks unexpectedly opened down the walls of the town hall. It is a robust building from the turn of the Century, made of tuff from the upper part of Pozzuoli. The nearby church of Santa Maria delle Grazie and buildings in the Piazza della Repubblica have suffered greater damage. Discharge pipes from drains that are normally submerged have appeared out of the water, together with the raised Caligoliano quayside.

Similarly rapid movements are said to have occurred shortly before the eruption of 29 September 1538, which created Monte Nuovo within two days. It is an example of a perfectly normal cone (cited in volcanology text books) 140 m high and 1,250 m across at its base. It burst into life about 2 o'clock in the morning, on the plain between Monte Barbaro and Lake Averno, where a new fracture spewed out smoke, scoria and lapilli. The explosive outburst was preceded by upheaval of the ground where the Lucrino beach complex stands today. It is not certain that events are about to repeat themselves, even though Campi Flegrei (that is, "burning", as described by the ancient Greeks and Romans) is not considered to be extinct.

The mayor, Prof. Angelo Gentile, made his dramatic announcement about recent events when he visited the Minister of Public Works yesterday in Rome. The Director of Public Works in Campania, Ing. Travaglini, confirmed that his office was monitoring events. It is obvious, though, that more is needed to watch the vast area involved. We can also be sure that Nature cannot be relied upon to find only one outlet, such as the widening mouth at Solfatara. The PCI[6] has decided to form a commission of enquiry to evaluate the full extent of the phenomenon and to ensure that all protective measures are being taken.

[6] The Italian Communist Party.

Pockmarks from clams (*lithodomus lithophagus*) on marble columns at the Serapeo.
(*Photos*: CRJ Kilburn)

Six thousand forced from their homes, but where will they go?

03 March 1970

Last night seismometers recorded a "weak" shock beneath the Bay of Pozzuoli. It might be the precursor to something more. At 11 o'clock this morning, the Prefecture, Police and Fire Brigade received orders from the Ministry for the Interior to begin Emergency Plan A, that is the complete evacuation of the old and dilapidated Rione Terra, in addition to the 43 eviction orders that have already been issued for dangerous buildings.

Only a thousand of the 6,000 residents have left so far, to avoid being relocated to the new psychiatric hospital in Naples[7]. Another 7,000 spontaneously left today from the rest of Pozzuoli to stay with friends and family.

By 1 o'clock, Pozzuoli was under seige. Under the command of the chief constable, about 1,000 carabinieri, police, UN troops, soldiers and traffic police blocked routes into the town. Fifty coaches for the exodus arrived thirty minutes later with police escorts. There was panic in the streets, as police and carabinieri were surrounded by people scared of an imminent earthquake.

The vice-commander of the Fire Brigade, Ing. Andriello, set up an operations centre at the Aeronautical Academy, while a column of buses, military trucks and other vehicles arrived outside the Flavio amphitheatre in upper Pozzuoli.

...As highlighted five days ago by this newspaper, the plans to take people away did not include where they could go... The option to use holiday villages along the coast at Miliscola and Licola had to be postponed, because the owners of the properties could not be found. Some accommodation was eventually arranged in parts of the holiday villages, as well as in Qualiano, inland from the Phlegraean area, and in the new psychiatric hospital at Camaldoli in Naples.

At 4 o'clock, the chief constable and the colonel of the carabinieri led their men into Rione Terra. The Christian Democrat mayor, Angelo Gentile, explained where the evacuees would go. He was met with protests. Evacuated workers would not be able to commute daily to the Olivetti,

[7] The hospital was newly built, but not yet in use.

Sofer[8] and other factories in Pozzuoli; fishermen would have to leave their boats, their fishing equipment, everything behind. "We don't want to end up the same as the earthquake evacuees in Sicily[9]". "Don't destroy our livelihoods". "Where are the houses we were promised ages ago?"

The crowds argued to move instead to the "Villaggio Coppola" on the coast by Castelvolturno. The mayor dismissed this possibility. In the summer holidays, the luxury appartments are enjoyed by notable Christian Democrats. They must not be disturbed, even in an emergency.

Residents with friends or family near Pozzuoli began to leave Rione Terra around 5 o'clock. The eviction continued until late in the evening. Hundreds of carabinieri and UN troops cordoned off the rione to stop anyone trying to enter. The population outside were invited to stay calm: a car patrolling the streets broadcast over a loudspeaker that only Rione Terra was being evacuated and that the rest of the town was not in danger. Telephone lines crashed and remained engaged all day. Armed forces at the port guarded the fuel dump for ships; not for the first time, the dump was considered unsafe and only a miracle prevented it from catching fire.

Lorenzo Natali, the Christian Democrat Minister of Public Works arrived in the evening to see the evacuation at first hand, together with Ing. Franco, President of the Public Works Council, and other dignatories. They were greeted with jeers and whistles. The visit was brief. On TV, the minister announced that the evacuation was "purely a precaution" and that the seismic shocks recorded beneath Rione Terra (one reaching Grade 4 on the Mercalli scale) were a threat only to buildings already recognised as unsafe.

More news is arriving as we write. People are torn between fear of remaining and terror at being abandoned by the authorities, like the evacuees after the earthquake in Sicily[9]. The state railway has organised 24 carriages - 1,920 seats - to provide shelter, heat and water at Napoli-Campi Flegrei station, and another 40 trains are being prepared in case of a full evacuation from Pozzuoli.

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[8] Olivetti and Sofer were major employers in Pozzuoli. Olivetti specialised in typewriters and computers; it is now part of Telecom Italia. Sofer specialised in transport engineering, such as railway rolling stock; it closed in 2003 after 120 years of operation.

[9] On 14 January 1968, six earthquakes with magnitudes of 5.0-5.4 struck the Belice Valley in Southwest Sicily (Monaco et al., 1996). It left as many as 100,000 people homeless.

When they emptied Pozzuoli

22 February 1979

A 60-metre tower rises above the hills between Pozzuoli and Bacoli. It supports a drill that has reached almost one and a half kilometres below the surface. It's searching for geothermal energy to generate electricity. Today the newspapers have announced that the ground boiling under Pozzuoli will bring a definite benefit – ENEL, AGIP and SAIPEM[10] aren't exploring there with the latest equipment for nothing. On the same day nine years ago, 22nd February 1970, the announcement that heating of the earth had upheaved the ground by more than a metre was the prelude to a calamity. The news portrayed the uplift as a great, marvellous and important scientific phenomenon that would attract the attention of scientists from around the world. For this reason, l'Unità reported the phenomenon as front-page news. Ten days later, Pozzuoli had instead become the setting for a tragedy whose consequences are still being felt.

The natural phenomenon of ground uplift – frightening because unknown and made worse by secrecy, jealousy, conflict and arrogance among the official scientific community - was used to evict and deport the population.

After a small seismic shock had been recorded on 2nd March, Prof. Giuseppe Imbò, Chair of Volcanology [at the University of Naples] declared that an eruption "might be possible from one moment to the next", but also "within ten years", or "by the end of the century", "perhaps offshore in the gulf", "but also possibly beneath a populated area". Similar comments were made by illustrious experts at a round-table discussion organised by the *Corriere della Sera*. The provincial authorities and the military entered into action. Six thousand people were ordered to leave Rione Terra. The first 1,500 were forced onto trucks. Panic spread like wildfire through Pozzuoli at the sight of the evacuation and the sobs and tears of the evicted; 20,000 people packed their cars and fled.

Sergio D'Oriano, elected only a few days ago as Pozzuoli's communist mayor, remembers: "I was a 20-year-old student, just 48 hours after an appendix operation ... the hospital was the first to be evacuated. Everyone was scared and nobody trusted what they were being told. We were

[10] Italian energy companies.

loaded by stretcher onto trucks, before starting an extremely long journey on roads jammed with those heading to Naples and inland."

At the time, Christian Democrats ran the town council and the mayor, Prof. Gentile, limply opposed the evacuation by threatening to resign – a threat that he later withdrew.

"I would respond differently if this should happen today," said D'Oriano. "No catastrophe struck Pozzuoli – and, even if one had, the geological features of Rione Terra (built on an immense rock with foundations kilometres below the surface) would render it among the safest places to be. Instead, it was precisely that impoverished district which was chosen for the frightening deportation 'experiment'."

Three days after the evacuation, workers were returning to their factories, even though the media were shouting they had been damaged and that an eruption and tsunami were waiting to happen. Giuseppe Luongo, lecturer in physical volcanology at the university and in charge of seismology at the Vesuvius Observatory, remembers that the behaviour of the official scientists made matters worse.

"We never convened round-table meetings to discuss and compare our ideas and experience. The youngest and the rebellious were excluded. Some of us took measurements at Pozzuoli during the night, but in the morning these were shut away in the Institute."

...Indeed, when volcanologists Haroun Tazieff and Izumi Yokoyama arrived from France and Japan in mid-March, they soon left in desperation.

"The people need to gain control of the sources releasing so-called scientific information and replace these with a more transparent and democratic process that would provide a more balanced view of these natural phenomena," says Luongo.

He cites the case of the Centre for Studying the Bradyseism at Campi Flegrei. "This initiative was deliberately allowed to fail. It is important to re-launch it as a centre for encouraging new scientific research and for providing reliable information for urban and agricultural development, as well as for geological studies."

Today, the land beneath Pozzuoli is stable, after an uplift of 1.5 m by 1972, followed by a slight subsidence of 10 cm. From the great fires below the surface, the borehole will supply much needed energy for the development of the whole district – the mayor is already in negotiation with public companies.

Evacuation from Pozzuoli in 1970. Cars in the top photo line the approach to Rione Terra; the building with two windows facing left was damaged by the uplift and later demolished. (Courtesy of Lux in Fabula.)

What the resident saw

Extracts from: Sirpettino, M (1971) Pozzuoli: la città che trema (Pozzuoli: the town that trembles). Conte: Pozzuoli.

Diary of a town in upheaval

February 1970. The ground is no longer sinking at two or three millimetres a year[11], but is now rising out of the sea. A small beach has appeared on the coast in front of the Serapeo, where only a few years ago the sea was more than a metre deep. Signs of uplift can also be seen along the coastline near La Pietra. No-one can deny the uplift any more. Scientists say this is dangerous.

Mayor Angelo Nino Gentile has gone to Rome to discuss the danger to buildings. The previous known uplift occurred before the eruption of Monte Nuovo in 1538. He is reassured that the movements have been under observation for some time. Even so, no seismometer is in place.

22 February. The Minister for Public Works confirms the official view of the uplift. Prof. Giuseppe Imbò, Director of the Institute of Terrestrial Physics at the University of Naples [and Director of the Vesuvius Observatory] adds that "we are measuring as precisely as possible the rates of uplift and their variation from place to place."

25 February. The first families are evacuated from old buildings in via Giovanni De Fraja (in the centre of Rione Terra). In an interview for *Il Mattino*, the mayor announces that buildings showing cracks are being instrumented to monitor their movements. The buildings include the town hall, schools, churches and private homes. Repeated mention of 29 September 1538 is doing nothing to allay fears. In only one night, a volcano grew where the village of Tripergola had been. And the ground had been rising and shaken by earthquakes[12] since 1511.

26 February. Sensational headlines are appearing everywhere. The evacuation of Rione Terra has been ordered. The coast along the port has

[11] The average rate of subsidence at Pozzuoli had been about 1.5-2.0 centimetres a year since Campi Flegrei's last eruption in 1538 (Bellucci et al., 2006).

[12] Uplift is now considered to have started at least 100 years before the 1538 eruption (Bellucci et al., 2006; Di Vito et al., 2016)

risen 1.2 m and it is increasingly difficult for boats to dock in the shallow water.

Tide gauges and seismometers are being installed in Pozzuoli. Scientists and public officials announce there is no cause for alarm. No-one is listening.

27 February. The hospital "Santa Maria delle Grazie", the Istituto Magistrale "Virgilio", the Capitaneria del Porto and a building in via Pergolesi have been evacuated.

Two evacuation plans are being prepared: Plan A is restricted to the lower part of Pozzuoli; Plan B involves the whole town (with more than 60,000 people in the town centre). The aim is to use miltary transports to move everyone "in just six hours" to the railway stations of Villa Literno and Napoli-Campi Flegrei, from where they can be moved inland.

Reports continue to arrive about cracks in buildings and roads. Prof. Imbò confirms that the situation is "completely under control".

28 February. The population is asked to keep calm as the pace of evacuation is increased. Renowned scientists have been called in from abroad to evaluate the situation. Alarming rumours are spreading, mostly unfounded. The possibility of an eruption is openly discussed. Scientific opinion is that "an eventual eruption can probably be predicted days or months beforehand – certainly with enough time to complete the evacuation."

01 March. According to *Il Mattino*, Pozzuoli is built on a very porous layer of rock, full of liquid [water], that is underlain by calcareous rock. The water is being heated by very hot gas rising through a fracture [in the calcareous rock]. The heated water is expanding and causing the uplift. An oceanographic ship is heading to Pozzuoli from Montecarlo.

02 March. The port area at Pozzuoli is confirmed as the epicentre of the uplift. All the old buildings in the town are being assessed (and there are lots of them!). Some earthquakes have been recorded.

The decision is taken to evacuate Rione Terra. About 5,000-6,000 people live in its unhealthy conditions. The civil defence is mobilised. The population is afraid. "If they are sending us away, it must mean something serious is about to happen."

The exodus begins. This is how a town dies. The evacuees are scattered. Many are sent to the psychiatric hospital at Miano[13].

"We may as well dissolve the town council; soon there won't be any town to administrate."

Headlines around the world declare a catastrophe is in the making: "the town that has disappeared"; "a volcano will replace Pozzuoli"; "an eruption is imminent", and so on.

03 March. Panic is speading like an oil stain. People are leaving not just from Rione Terra, but from the whole town. 30,000-40,000 people are on the move. We have suffered an "earthquake of fear".

05 March. The scientific committee, chaired by the CNR's[14] Prof. Caglioti, excludes the possibility of a sudden disaster. Integrated measurements will be conducted on the ground, in the air and at sea and co-ordinated by Prof. Imbò . They will consist of:

1. Surveys onland and offshore to identify changes in temperature caused by the movement of magma at depths of 3 km. The surveys will combine geothermometry, magnetics and infrared measurements.
2. Structural surveys and direct sampling of the sea floor across the Bay of Pozzuoli.
3. Analysis of gas and thermal waters sampled onland and offshore.
4. Integration of measurements with seismic data from existing networks.

Prof. Imbò explained the new programme in an interview with *Lo Specchio* on 8th March [*sic*].

"The probable cause of the uplift is an intrusion of magma at shallow depth. Such a circumstance had not previously been anticipated. Now, however, the evolution of the upheaval can be followed by analysing data from seismometers, gravimeters, tide gauges and geothermometers... Several years ago, I proposed that a permanent geophysical monitoring station should be established in the Phlegraean area, because it is an active volcano, but the request was not supported."

Interviewer: "Would a permanent station have been able to monitor the day-to-day evolution of the phenomenon?"

"Yes, that's correct. From the terrible seismicity that shook the Phlegreaean basin on 29 September 1538 to the end of 1968, the

[13] The hospital was newly built, but not yet in use.
[14] The CNR is Italy's National Science Research Council.

bradiseism had continued at about 13 mm a year[15]; at the start of February this year, our measurements showed an uplift of about 80 cm. We have no information about what happened between the end of 1968 and the beginning of February 1970, because we did not have the necessary equipment. We would not be in this position if a geophysical station had been operating."

Tax payments are suspended. About 30 families refuse to leave Rione Terra. The President of the Republic[16] has opened the villa Rosebery at Posillipo [in Naples] to some of the evicted families.

Author and journalist Giovanni Artieri writes in *Il Tempo* on 4th March:

"I confess that I can't feel sorry about the geological events at Pozzouli and Campi Flegrei. Perhaps it's because I'm a Neapolitan and Phlegraean myself that I have the innately fatalistic view of someone who has grown up in the mouth of a volcano. Volcanoes, eruptions, glowing lava flows, the infernal puffs and boiling of Solfatara - for we Phlegraeans, these are spectacles and not reasons to be afraid... It is normal for a region that moves like the breasts of a sleeping woman. Ups and downs have been continuing for hundreds of centuries - movements measured in millimetres and centimetres, scientists tell us...

The Phlegraean people, like those on Etna, have learned to fear institutions, but they are not scared by the untamed forces of Nature. The sea, earth, volcanoes - even earthquakes - are friends of Southern Italians. Shelter from the earth, food from the sea and wine from the land all stir a loyalty not given to others... It is completely understandable that the fishers of sea and tillers of the soil have greater faith in the workings of God than a man from Rome in his sky-blue limousine..."

06 March. Stories spread of dead fish being seen in a bubbling sea. It is nothing new: just like Solfatara, the fumaroles in the Gulf of Pozzuoli have always been there.

In an interview with *France Soir*, Prof. Haroun Tazieff, who has been invited to advise the CNR, raises the question of whether the uplift is localised or affects a larger area, especially under the sea.

The seismologist Bendandi, from Florence, says that Vesuvius regulates the stability of the Phlegraean area. All is well as long as Vesuvius remains quiet for only short intervals. But when it has been quiet for a long time -

[15] See Footnote 12.
[16] Giuseppe Saragat, President 1964-1971.

as is the case today - its internal equilibrium is disrupted and can have unexpected results.

There is talk of a spent volcano under the sea. Rumours abound, out of control.

08 March. Prof. Izumi Yokoyama has visited Pozzuoli. He is a geophysicist from the University of Hokkaido in Japan. He is surrounded by journalists, photographers and residents, all anxious for his opinion. The events at Pozzuoli are making the television news around the world - the United States, France, Great Britain, Switzerland, Germany, Japan and more.

09 March. The town is virtually deserted, especially the centre. A levelling survey shows that the rate of movement has slowed down. This is reassuring. Pozzuoli is out of immediate danger. Roman statues from the Serapeo are being transferred to the National Museum of Archaeology in Naples. Earthquakes are recorded by the seismometer at the bishop's residence in Rione Terra.

10 March. The town's economy has collapsed. Shop fronts remain shuttered. Studies of the sea floor continue. More seismometers have been installed and register small tremors. The evacuation continues.

Prof. Yokoyama reports that "although there is no immediate cause for concern, monitoring must continue as a precautionary measure."

Tazieff declares that "The bradysesim at Pozzuoli is not a prelude to an eruption. The vibrations being recorded are normal for a volcanic area. There are no warning signs yet. So no earthquake, no submarine volcanoes, no eruption."

The atmosphere is calmer. There is talk of exaggerated alarm.

18 March. Warning sirens are installed, just in case. Conflicting interpretations are offered to explain the bradysesim.

21 March. People are returning, but the economy is still on its knees.

27 March. In *Le Monde*, Tazieff writes that the events at Pozzouli have not yet finished. Understanding what is happening has been hindered by a lack of monitoring. Monitoring must continue even in volcanic areas that appear to be quiet, because it reveals the normal levels of small earthquakes that cause the so-called background noise... The idea of a submarine volcano was absurd - as was the evacuation of Rione Terra... I was told on 18th March that the evacuation was not prompted by concern for a submarine eruption, but to prevent people from being buried by the collapse of old buildings should the bradyseism become stronger.

The idea is floated of drilling into the volcano to let gases escape.

February 1971. A year has passed. The economy has collapsed, but people are determined to bring the town back to life. It mustn't ever happen again. Only a small upset may still bring back the fear.

They say that the earth has always danced here, but that the music changes tone. For us, the bradyseism was deafening.

The evacuation begins from Rione Terra.
Photo: *Il Mattino Illustrato* 8, 24 February 1979.
(Courtesy of Lux in Fabula.)

What the scientists saw

A selection of extracts 1971-1979.

Scientific and not-so-scientific opinions

From: Tazieff, H (1977). La Soufrière, volcanology and forecasting. Nature 269, 96-97.

A submarine eruption was claimed to have burst out offshore of the city of Pozzuoli, approximately 2 km west of the well-known Solfatara solfataric field. After the mass-media told of possible explosions, ash-falls and sea-waves, the Army and the *caribinieri* (police) helped the frightened population to evacuate the city. The claimed symptoms were an upheaval of the ground in the whole area, which had been pushed up about one metre in a "very short while"; extremely shallow earthquakes, located 1 to 2 km offshore; a conspicuous temperature-rise of the Solfatara's fumaroles; and the outflow of hot fluids on the bay's floor, inferred from dead boiled fish fishermen took in their nets.

The last three items were subsequently proved totally false by a team of six scientists led by myself, and I disclosed the fact at a press conference. On the other hand, the upheaval, the so-called brady-seism of Pozzuoli, had not been faster than usually noticed over the centuries during which up-and-down level variations of that peculiar area had been classically observed. Eventually it was stated that deliberately wrong data had been produced by the scientist in charge of the geophysical institute of Naples*. This was connected to a construction operation in which high-rank people were involved. The evacuation of the inhabitants was proved to be expensive and useless.

[*Prof. Giuseppe Imbò, who was also Director of the Vesuvius Observatory. His reply follows.]

From: Imbò, G (1979). Seismic prediction at Pozzuoli. Nature 277, 511.

Tazieff (8 September 1977, page 96) makes accusations that I deliberately put about wrong data in 1970 concerning warning signs that an eruption could occur in the vicinity of the city of Pozzuoli... I can state that it is completely untrue that I was the source of bulletins or news of an impending eruption in Campi Flegrei. Indeed to the best of my knowledge no such news was spread at all.

...During my involvement in these matters I acted according to my moral duties without any external pressure. Only after the order to move out of tottering houses (not the city, as Tazieff declares) could I rest peacefully, and even then of course hardly with much pleasure at seeing poor people evicted. In fact eviction saved lives, maybe as many as fifty because buildings fell down in 1970 and 1972. Tazieff indeed supported a motion on 18 March 1970 which excluded the possibility of people reinhabiting old crumbling houses.

Very briefly, my involvement was this. I first reported the inversion of the Phlegrean brady-sesim to the authorities on 12 February 1970, mentioning a ground upheaval of about 80 cm in little more than a year. I warned of the possibility of seismic phenomena and that even the continuation of the brady-seism might unsettle the buildings in the area. At the first shock (1 March 1970) a decree evacuating tottering buildings was issued, as a precaution. 650 shocks were recorded up to 16 November 1970, six felt in Pozzuoli itself at up to IV on the Mercalli scale. Three died in November from falling masonry and rocks. In my letter of 12 February I had foreseen a sesimic, not an eruptive phenomenon.

...Tazieff states arbitrary conclusions in order to give value to the serious charge of a supposed participation in a "construction operation". He gives no direct proof, nor does any exist, while the indirect ones he reports are wrong or deliberately altered. Therefore all of his statements are nothing but products of fancy.

From: Yokoyama, I (1971). Pozzuoli event in 1970. Nature 229, 532-533.

According to Parascandola (1947), the floor at Serapeo has subsided by about 11 mm per year, and been raised several times by calamities... Recently Oliveri [del Castillo] and Quaglieriello (1969) presented a theory of origin of the *bradisismi* at Pozzuoli, interpreting the subsidence as self-loading compactions and the upheavals as variations in the flow of ground water filling porous pyroclastics[17].

...The most recent event was an anomalous upheaval in March 1970. Changes in height of bench marks around Pozzuoli between 1953 and March 1970 show that the maximum upheaval amounted to about 90 cm, assuming that the easternmost point, about 4 km from Pozzuoli, was unchanged. The uplifted zone was circular, centred on Pozzuoli. The upheaval probably began in October 1969.

It is remarkable that no earthquakes were felt at Pozzuoli during the upheaval... If the upper part of the crust is visco-elastic, one can expect the following two stages: the first when deformation is proportional to the frequency of earthquakes, and the second when there are no earthquakes. The Pozzuoli event may be an example of the latter stage[18].

...In conclusion, the rapid upheaval at Pozzuoli, not accompanied by any conspicuous shocks, can be interpreted as a phase of visco-elastic activity in the upper crustal material. Volcanic tuffs would have been affected by some volcanic reactions, such as intrusion of magma or steam. This interpretation does not contrast with the theory of Oliveri [del Castillo] and Quaglieriello (1969).

[17] See also Casertano et al. (1976).

[18] See Kilburn et al. (2017) for an alternative interpretation in terms of elastic-brittle deformation.

From: Corrado G, Guerra I, Lo Bascio A, Luongo G, Rampoldi R (1976-77). Inflation and microearthquake activity of Phlegraean Fields, Italy. Bull Volcanol 40, 169-188.

The uplift of the Phlegraean Fields probably began in the summer of 1969...The greatest observed uplift was about 170 cm at bench mark no. 11 [c. 1 km east of Rione Terra]... The area involved in the ground uplift, which lies around Pozzuoli, has a radius of 5-6 km.

...These results suggest that the origin of the ground uplift in the Phlegraean Fields can be attributed to the intrusion of magmatic masses into a heterogeneous medium... The hypothesis...[of] a magmatic intrusion at a depth of a few kilometres had been proposed earlier (Guerra et al., 1973; Finetti & Morelli, 1974).

...It has been possible to estimate the maximum magnitude possible for an earthquake occurring in the present phase of seismic activity... [For] a focal depth ... [of] about 5 km ... the possible magnitude ...[is] 4.4[19].

[19] The largest earthquake that has since been recorded (until July 2018) had a magnitude of 4.0 (Branno et al., 1984).

What the poet saw

Neapolitan author and poet Luisa de Franchis has specially translated two poems on Pozzuoli, from her 2016 collection Oltre il muro un sorriso[20].

Our history

Among the wavy basalts
mindful of lava stories
every house has its own story
and every room has its memory

Tra gli ondulati basalti
memori di storie laviche
ogni casa ha la sua storia
ed ogni stanza un suo ricordo

Luisa de Franchis in Rione Terra.
(*Photo:* Fiorella Passante.)

[20]The complete collection of poems by Luisa de Franchis can be downloaded from https://cittavulcano.files.wordpress.com/2017/04/luisa-de-franchis-oltre-il-muro-un-sorriso-poesie.pdf. She can be contacted at: d.luisa@email.it.

Rione Terra

My hands
they touched the wall
trying to push it further.
Today I close my eyes
and return
when everything had crumbled
in my fragility.
Ruins of a past
from which I ran away
to escape from myself
and instability.
I find myself among ancient walls
completed by transparent walls.
I walk between the streets and among the people
of my new earth
with a new dress
and a new book in my hands.
My gaze faces the sea
and from the stones
shells re-emerge.

Le mie mani
toccavano il muro
tentando di spingerlo più in là.
Oggi chiudo gli occhi
e ritorno
a quando tutto si era sgretolato
nella mia fragilità.
Rovine di un passato
dal quale sono scappata via
per sfuggire da me stessa
e dall'instabilità.
Mi ritrovo tra pareti antiche
completate da pareti trasparenti.
Cammino tra le strade e la gente
della mia nuova terra
con un vestito nuovo
ed un nuovo libro tra le mani.
Il mio sguardo si affacia al mare
e dalle pietre
riemergono conchiglie.

Afterword

By 1972, Pozzuoli had returned to its normality of subsiding at 15-20 cm a decade. Overall, it had been uplifted by about 1.6 m. The evacuees from Rione Terra were permanently relocated elsewhere; the rione itself remained empty.

Ten years later another uplift began. The town was raised by about 1.75 m in two years. On this occasion, however, uplift was accompanied by persistent trembling of the ground that caused greater damage to buildings than in the 1970s. As a result, some 40,000 people were again evacuated from the town around Rione Terra. The second evacuation was completed with greater collaboration between the community, authorities and scientists. By general consensus, three key changes made all the difference. First, the trembling ground was clearly unstable. Second, the scientific community released just one message to the public. And third, Giuseppe Luongo, Director of the Vesuvius Observatory, ensured that monitoring scientists were regularly seen in Pozzuoli - a strategy that built confidence between themselves and the community.

Papers in the scientific literature continue to debate the relative contributions to unrest from magmatic intrusions and hydrothermal pore pressure. A new view gaining momentum is that the uplifts are not independent events, but belong to a connected sequence of unrest. If so, the previous uplifts should not be seen as failed eruptions, but as a necessary preparation before an eruption can take place.

There is no guarantee that an eruption will occur. Even so, it is important to explain to the community at large that an eruption is possible. For the explanation to be accepted, it must accommodate how the community sees its own volcano. This is the immediate aim of WAVE:SPICE[21], an interdisciplinary consortium founded by the UCL Hazard Centre, the community associations Lux in Fabula[22] and Le Ali di Dedalo in Pozzuoli, the INGV-Vesuvius Observatory and the Department of Social Sciences at the University of Naples. A longer-term goal is to join forces with similar consortia elsewhere, because, wherever we are, making sure a forecast is believed is as important as making the forecast itself.

[21] Warnings and Alerts during Volcanic Emergencies: Scientific Practice Informed by Community Experience. Contact Christopher Kilburn at c.kilburn@ucl.ac.uk.
[22] See https://bradisismoflegreo.wordpress.com/

References

Bellucci F, Woo J, Kilburn CRJ, Rolandi G (2006). Ground deformation at Campi Flegrei, Italy: implications for hazard assessment. In, Troise C, De Natale G, Kilburn CRJ (eds) Mechanisms of activity and unrest at large calderas. Geol Soc Spec Pub 269, 141-157.

Branno A, Esposito EGI, Luongo G, Marturano A, Porfido S, Rinaldis V (1984). The October 4th, 1983 Magnitude 4 earthquake in Phlegraean Fields: macroseismic survey. Bull Volcanol 47, 233-235.

Casertano L, Oliveri del Castillo A, Quaglieriello MT (1976). Hydrodynamics and geodynamics in the Phlegraean fields area of Italy. Nature 264, 161-164.

Corrado G, Guerra I, Lo Bascio A, Luongo G, Rampoldi R (1976-77). Inflation and microearthquake activity of Phlegraean Fields, Italy. Bull Volcanol 40, 169-188.

Di Vito MA, Acocella V, Aiello G, Barra D, Battaglia M, and 7 others (2016). Magma transfer at Campi Flegrei caldera (Italy) before the 1538 AD eruption. Sci. Rep. 6. doi: 10.1038/srep32245.

Finetti I, Morelli C (1974). Esplorazione sismica a riflessione dei Golfi di Napoli e Pozzuoli. Boll Geof Teor Appl 16, 175-222.

Guerra I, Lo Bascio A, Luongo G, Nazzaro A, Talarico G (1973). Bradisismo flegreo: rapporto no. 5, T R Osservatorio Vesuviano, Napoli.

Guest JE, Murray JB (1969). Nature and origin of Tsiolkovsky crater, lunar farside. Planet Space Sci 17, 121-141.

Kilburn CRJ, Petley DN (2003) Forecasting giant, catastrophic slope collapse: lessons from Vajont, Northern Italy. Geomorphology 54, 21-32.

Kilburn CRJ, De Natale G, Carlino S (2017). Progressive approach to eruption at Campi Flegrei caldera in southern Italy. Nat Commun, doi: 10.1038/ ncomms15312.

Monaco C, Mazzoli S, Tortorici L (1996). Active thrust tectonics in western Sicily (southern Italy): the 1968 Belice earthquake sequence. Terra Nova 8, 372-381.

Oliveri del Castillo A, Quaglieriello MT (1969). Sulla Genesi del Bradisismo Flegreo. Atti Geof It, XVIII Convegno, Naples.

Parascandola A (1947). I Fenomeni Bradisismici del Serapeo di Pozzuoli. Genovese, Naples.

The approach to Rione Terra before 1970. The building in the foreground was damaged during ground uplift and later demolished. See p.14.
Detail from painting by Antonio Isabettini.