

# NOTAS GEOCIENTÍFICAS

## MOUNT VESUVIUS

### A Monument to Nature's Raw Power and Human Vulnerability

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An aerial view of Mount Vesuvius, looking north, photo by Ross Elliott (CC BY 2.0)

#### **INTRODUCTION**

Mount Vesuvius, is the birthplace of the science of volcanology. Mount Vesuvius is a somma–stratovolcano located on the Gulf of Naples in Campania, Italy, about 9 km east of Neapolis (Naples), and a short distance from the shore (Figure 1). It is one of several volcanoes forming the Campanian volcanic arc. Vesuvius consists of a large cone partially encircled by the steep rim of a summit caldera, resulting from the collapse of an earlier, much higher structure.

The first documented description of a volcanic eruption took place at Vesuvius when Pliny the Younger (61-112 AD), a future lawyer and magistrate of Rome, described the famous 79 CE explosion that destroyed Pompei, and which also killed his uncle Gaius Plinius Secundus known as Pliny the Elder (23/24–79 AD), a roman naturalist and army commander, who was attempting to rescue people from the inferno of the eruption.

The eruption began with a high eruptive column depositing a thick airfall pumice deposit to the South East of the volcano, and it was followed by the emplacement of destructive glowing avalanches formerly called pyroclastic flows and surges which are

now defined Pyroclastic Density Currents (PDC), which destroyed not only Pompeii, but also the cities of Herculaneum and Stabiae, as well as country villas, suburbs over a radius of more than 10-18 kilometers from the volcano. The former city of Pompeii was initially covered by the airfall deposit 2.5-3.5 meters thick, and later by the emplacement of PDCs; Herculaneum was mostly destroyed by PDCs (Scandone et al, 2019).

Most of the vesuvian territory was buried under a thick pyroclastic deposit and the memory of the lost cities vanished until 1738, when the first excavations revealed the extent of the eruptive destruction first at Herculaneum, and later at Pompeii (1748) and surrounding areas.

The vesuvian eruption is estimated to have ejected a cloud of volcanic bombs, ash, and toxic gases 33 kilometers into the atmosphere, with lava and pulverized pumice erupting at 600,000 m<sup>3</sup> per second. The exact death toll is unknown, but close to 2,000 people was the estimation of died people because the eruption, in the surrounding areas. The Pompei victims were mainly killed by pyroclastic surges, the ash falls

and the heat. Herculaneum was much closer to the crater and was saved from tephra falls by the wind direction, but was buried under 23 meters of pyroclastic surge material.



Figure 1. Location of the Mt. Vesuvius and the roman cities of Pompeii, Herculaneum, Stabiae and Neapolis. Source: <https://volcano.oregonstate.edu/well-known-volcanic-tsunami-events>

### **VESUVIUS AS A LANDMARK REFERENCE BEFORE THE 79 AD ERUPTION**

Vesuvius was an important geographical landmark (as a "mountain," not a volcano) prior to the eruption of 79 AD, which has been confirmed in some historical and literary works, particularly in matters of war. For example, the relatively early history of Rome refers to the so-called Battle of Vesuvius, during the Second Latin War in 340 BC, fought by the consuls Titus Manlius Torquatus and Publius Decius Mus, against the Latins. Decius having sacrificed himself following an oracle, Manlius won the battle against the Latins and determined Roman supremacy, after pursuing them into Campania (Soto, 2014). This was written by the roman historian Titus Livius (59 BC–17 AD) in his "The History of Rome".

The famous Thracian gladiator Spartacus, having rebelled with his troops, took refuge in the crater of Vesuvius and staged the Battle of Vesuvius nearby in 73 BC, defeating the Romans, as reported by Appian of Alexandria (95-165 AD): "Around that same time in Italy, Spartacus, a Thracian who had once served in the Roman army and who, as a prisoner [for desertion], had been sold as a gladiator, which is why he was attending a gladiatorial school in Capua, persuaded seventy of his companions to go out and risk their lives for freedom rather than for spectacle; and, after defeating the guards with them, they escaped. They armed

themselves with daggers they took from some wagons they found and took refuge on Mount Vesuvius. (Appian, Wars civilians, 1, 116, from Soto, 2014).

### **THE 79 AD ERUPTION NARRATED BY PLINIAN THE YOUNGER**

Pliny the Younger wrote two letters (LXV and LXVI) to the historian Cornelius Tacitus describing the events that led to the death of his uncle, Pliny the Elder, because of the eruption of Vesuvius. Pliny the Younger narrative, written mainly to exalt the heroic role of the Elder was driven not only by scientific curiosity but also by the attempt to rescue the inhabitants living at the foot of the exploding volcano. In the second letter the role of the Younger is that of a true Roman citizen observing the catastrophe. The descriptions are too precise and fitting the dynamics of the eruption, that they truly reflect the remembrance of a catastrophe that must have remained carved in the memory of a young, seventeen age boy even 25 years after the event.

These letters are probably the very first detailed description of a volcanic eruption. The eruption column with its umbrella-shaped cloud that is also found at other volcanoes was named after him (Plinian eruption column). Using University of Arkansas (2025) translations from the 2 letters and highlighting only some passages of volcanological relevance, the accounts of the eruption were as follows:

#### **LXV To Cornelius Tacitus**

*You ask me to send you an account of my uncle Pliny's death, so that you may be able to give posterity an accurate description of it ..... My uncle was stationed at Misenum, where he was in active command of the fleet, with full powers. On the 24th of August, about the seventh hour, my mother drew his attention to the fact that a cloud of unusual size and shape had made its appearance ..... Those who were looking at the cloud from some distance could not make out from which mountain it was rising - it was afterwards discovered to have been Mount Vesuvius - but in likeness and form it more closely resembled a pine-tree than anything else, for what corresponded to the trunk was of great length and height, and then spread out into a number of branches .....*

Although earthquakes and minor volcanism were well known in Campania, there was no record of major volcanic eruptions at the time of the Vesuvius eruption



in 79 AD, and Pliny the Elder, the great scholar of natural history, could not fail to find out more about a matter of such magnitude, much less when it occurred in his admiralty territories of the Tyrrhenian fleet.

*To a man of my uncle's learning, the phenomenon appeared one of great importance, which deserved a closer study. He ordered a Liburnian galley to be got ready, and offered to take me with him, if I desired to accompany him, but I replied that I preferred to go on with my studies, and it so happened that he had assigned me some writing to do. He was just leaving the house when he received a written message from Rectina, the wife of Tascus, who was terrified at the peril threatening her - for her villa lay just beneath the mountain, and there were no means of escape save by ship - begging him to save her from her perilous position. So he changed his plans, and carried out with the greatest fortitude the task which he had started as a scholarly inquiry. He had the galleys launched and went on board himself, in the hope of helping not only Rectina but many others ..... He hastened, therefore, towards the place whence others were fleeing, and steering a direct course, kept the helm straight for the point of danger, so utterly devoid of fear that every movement of the looming portent and every change in its appearance he described and had noted down by his secretary, as soon as his eyes detected it .....*

In this passage, Pliny the Younger reports the occurrence of the strongest and long-lasting seismic events along with the occurrence of a Tsunami and a stronger fall of volcanic debris:

*Already ashes were beginning to fall upon the ships, hotter and in thicker showers as they approached more nearly, with pumice-stones and black flints, charred and cracked by the heat of the flames, while their way was barred by the sudden retreat of the sea and the litter of the mountain on the shore. He hesitated for a moment whether to turn back, and then, when the helmsman warned him to do so, he exclaimed, "Fortune favours the bold; try to reach Pomponianus." The latter was at Stabiae, separated by the whole width of the bay .....*

*They held a consultation whether they should remain indoors or wander forth in the open; for the buildings were beginning to shake with the repeated and intensely severe shocks of earthquake, and seemed to be rocking to and fro as though they had been torn from their foundations. Outside again there was danger to be*

*apprehended from the pumice-stones, though these were light and nearly burnt through, and thus, after weighing the two perils, the latter course was determined upon. With my uncle it was a choice of reason which prevailed, with the rest a choice of fear ....*

*They placed pillows on their heads and secured them with cloths, as a precaution against the falling stones. Elsewhere the day had dawned by this time, but there it was still night, and the darkness was blacker and thicker than any ordinary night. This, however, they relieved as best they could by a number of torches and other kinds of lights. They decided to make their way to the shore, and to see from the nearest point whether the sea would enable them to put out, but it was still running high and contrary. A sheet was spread on the ground, and on this my uncle lay, and twice he called for a draught of cold water, which he drank. Then the flames, and the smell of sulphur which gave warning of them, scattered the others in flight and roused him. Leaning on two slaves, he rose to his feet and immediately fell down again, owing, as I think, to his breathing being obstructed by the thickness of the fumes and congestion of the stomach, that organ being naturally weak and narrow, and subject to inflammation. When daylight returned - two days after the last day he had seen - his body was found untouched, uninjured, and covered, dressed just as he had been in life. The corpse suggested a person asleep rather than a dead man .....*

*Pliny the elder, died the second day of the eruption, when it intensified after dawn, and he had endured an intense pumice fall during the early hours. According to the nephew's account, it may well have suffocated to death by the gases and fine ash that invaded Stabiae during the most violent phase of the eruption. However, Stabiae was 16 kilometers away from the vent, and his companions were unaffected by the volcanic gases. It is more likely that the corpulent Pliny died from another cause, such as a stroke or heart attack*

#### **LVX To Cornelius Tacitus**

*For many days previous there had been slight shocks of earthquake, which were not particularly alarming, because they are common enough in Campania. But on that night the shocks were so intense that everything round us seemed not only to be disturbed, but to be tottering to its fall .....*

*For although the ground was perfectly level, the vehicles which we had ordered to be brought with us began to*

*sway to and fro, and though they were wedged with stones, we could not keep them still in their places. Moreover, we saw the sea drawn back upon itself, and, as it were, repelled by the quaking of the earth. The shore certainly was greatly widened, and many marine creatures were stranded on the dry sands. On the other side, the black, fearsome cloud of fiery vapour burst into long, twisting, zigzag flames and gaped asunder, the flames resembling lightning flashes, only they were of greater size .....*

*Soon afterwards the cloud descended upon the earth, and covered the whole bay; it encircled Capri and hid it from sight, and we could no longer see the promontory of Misenum ..... Then the ashes began to fall, but not thickly: I looked back, and a dense blackness was rolling up behind us, which spread itself over the ground and followed like a torrent ..... We were considering what to do, when the blackness of night overtook us, not that of a moonless or cloudy night, but the blackness of pent-up places which never see the light. You could hear the wailing of women, the screams of little children, and the shouts of men; some were trying to find their parents, others their children, others their wives, by calling for them and recognizing them by their voices alone .....*

*A gleam of light now appeared, which seemed to us not so much daylight as a token of the approaching fire. The latter remained at a distance, but the darkness came on again, and the ashes once more fell thickly and heavily. We had to keep rising and shaking the latter off us, or we should have been buried by them and crushed by their weight ..... At length the blackness became less dense, and dissipated as it were into smoke and cloud; then came the real light of day, and the sun shone out, but as blood-red as it appears at its setting. Our still trembling eyes saw that everything had been transformed, and covered with a deep layer of ashes, like snow .....*

#### **THE VOLCANOLOGICAL LEGACY OF THE PLINIANS**

The description of the eruption of Vesuvius by Pliny the Younger's letters to Tacitus have been used by volcanologists to understand the eruptions of enormous energy and size, which in his honor were named "Plinian". and are still known as such. In the Encyclopedia of Volcanology (Volcanic plumes) by Carey and Bursik (2000), one of the most respected texts on volcanology today, there is a clear reference to this subject:

"Large-scale volcanic plumes are generated during the continuous discharge of fragmented silicic magma and gases from a single vent. A classic example of this was the 79 A.D. eruption of Mount Vesuvius that buried the ancient cities of Pompeii and Herculaneum. This style of volcanism is referred to as plinian, in honor of Pliny the Younger, who provided the first written description of an explosive eruption. He described the appearance of the plume over Vesuvius as resembling a giant tree with the main part rising along a trunk but then spreading out at the top like a series of branches".

Plinian eruption is now the geologic term used for this type of explosive eruption where a steady, turbulent stream of magma and magmatic gases is released from a volcanic vent at high velocity. For centuries, volcanologists described volcanoes by comparison to Vesuvius.

#### **THE VESUVIUS**

Vesuvius is a large cone-shaped volcano that has grown inside the caldera of an older stratovolcano, Mt. Somma. The Somma-Vesuvius volcanic complex stands over a large sedimentary plain consisting mainly of volcaniclastic deposits formed by the remobilization of pyroclastic deposits. A somma volcano is used as the geologic term for a volcanic caldera that has been partially filled by a new central cone.

The Somma-Vesuvius complex together with the Phlegrean Fields Volcanic District are part of a series of active volcanic complexes developed within an extensional graben. The complex formed at the intersection of two main NE-SW and NW-SE fault systems inside of the Campanian plain half graben. This is the most densely populated and dangerous volcanic region in the world, with upwards of 3 million people at risk.

The Somma stratovolcano began building about 40,000 years ago, and the caldera formed about 22,000 years ago, after four major Plinian eruptions. From then until the major eruption of 1631 CE, eruptions were within the caldera. Since then, the Vesuvius cone has been the focus of activity.

Since 1750, seven of the eruptions of Vesuvius have had durations of more than five years. The two most recent eruptions of Vesuvius, 1875–1906 and 1913–1944, each lasted more than 30 years. In March 1944, during WWII, the United States Army Air Forces 340<sup>th</sup> Bombardment



Group was based at Pompeii Airfield near Terzigno, Italy, just a few kilometers from the eastern base of the volcano. The tephra and hot ash from multiple days of the eruption damaged the fabric control surfaces, the engines, the Plexiglas windscreens and the gun turrets of the 340th's B-25 Mitchell medium bombers. Estimates ranged from 78 to 88 planes destroyed. Different perspectives and the damage caused to the local villages were recorded by USA Air Forces photographers (Figure 2) and other personnel based nearer to the volcano.



Figure 2. B-25s from the 447th Squadron of the 321st Bombardment Group on their way to bomb targets (March 1944). Source:

<https://alcpres.org/kaizer/vesuvius/index.html>

During 1944 eruption, lava overflowed the crater to the north, moving toward the town of San Sebastiano, causing the evacuation of the residents. The “river” of magma is still clearly visible from the road ascending the Vesuvius (Figure 3).

Today, layers of lava, ash, scoria and pumice make up the volcanic peak (Figure 4). Their mineralogy is variable, but generally silica-undersaturated and rich in potassium, with phonolite produced in the more explosive eruptions. Vesuvius is still regarded as an active volcano, although its current activity produces little more than sulfur-rich steam from vents at the bottom and walls of the crater (Figure 5).



Figure 3. Parallel to the Somma old crater, a grey “river” of solidified lava spilled during 1944 eruption, can be observed. Author’s photography.



Figure 4. View of the northern internal wall of the crater, observing the layering of lava, ash and pumice. Author’s photography.



Phlegrean Fields, a name derived from the Ancient Greek “to burn”.



Figure 5. View of the southwest internal wall of the crater. Sulfur-rich steams can be observed. Author's photography.



Figure 6. Trail at the summit of the volcano.



Figure 7. The author at the border of the crater.

### **ASCENDING THE VESUVIUS**

Ascending Mount Vesuvius involves following a well-established trail up the mountain's main cone, reaching the crater rim (Figure 6). The hike is generally considered easy and suitable for most fitness levels, taking about 2 hours round trip. The trail begins at the ticket gate at 1,050 meters of altitude and climbs to 1,170 meters, offering views of the Bay of Naples and surrounding areas. The trail is a gravelly path of switchbacks that winds upward for 800 meters, challenging but manageable, with a round trip is approximately 4 km. with no special equipment or experience needed. The trail isn't a loop hike so you are unable to walk around the entire volcanic rim (Figure 7). Instead, you will walk a further kilometer or so until you reach a viewpoint and then turn around and head back.

### **CAMPI FLEGREI SUPERVOLCANO**

Campi Flegrei supervolcano poses an immediate and deadly threat. It is 13 kilometers wide supervolcano complex located near Mt. Vesuvius and to the west of Naples, Italy (Figure 8). It is commonly known as the

The area consists of two nested calderas (containing at least 24 craters) that lie half onshore and half offshore, centered on the town of Pozzuoli. Hydrothermal activity and fumaroles can be observed on land, such as at Solfatara Crater, the mythological home of Vulcan, the Roman god of fire. This crater is characterized by high temperature hydrothermal fluid discharge, boiling pools, and diffuse CO<sub>2</sub> emissions.

Campi Flegrei doesn't have the obvious appearance of a volcano because the caldera complex has the shape of a gentle depression 12-14 km across. This explains why almost 400,000 people now live on its top. More recently, in the 1950s, 1970s, and 1980s, tens of thousands of small earthquakes have occurred during these periods, particularly around the coastal town of

Pozzuoli. The town has undergone several episodes of bradyseism (a gradual uplift or descent of part of the Earth's surface caused by the filling or emptying of an underground magma chamber), with the ground beneath the town creeping upwards at ~10 cm/yr over the past decade. The area is intensely monitored because a rapid release of magmatic gases or new magma intrusion could trigger a significant eruption. An eruption at Campi Flegrei could easily devastate the Naples metropolitan area, with a population around 3 million people.



Figure 8. Location of Campi Flegrei and Mt. Vesuvius,

This caldera formed about 39,000 years ago in the Campanian Ignimbrite eruption, one of the largest in the history of Europe. This ignimbrite consists of mainly trachyte, an extrusive igneous rock primarily composed of alkali feldspar. The eruption ejected so much material (volume ~500 km<sup>3</sup>) that it caused a volcanic winter, drastically affecting life across the planet and is speculated to have nearly wiped out the Neanderthals.

Since 2020, seismic activity has been rising. Intense seismic activity continued, with a swarm of 150 earthquakes in a few hours on May 20, one of magnitude 4.4 causing fear among the population of Pozzuoli. A new seismic swarm has been ongoing since mid-February 2025 with shocks of maximum magnitude of 3.9. On 13 and 14 March 2025, two earthquakes of magnitude 4.4 occurred between Pozzuoli and Bagnoli.

Borgia et al, (2005) integrated geologic, structural, leveling and differential SAR Interferometry data to show that specifically, the Vesuvius began to spread onto its sedimentary substratum about 3,600 years ago at a rate of a few mm/year, and it will be spreading for a time estimated to be about twice as long.

## THE STUDY OF THE VESUVIUS EVOLUTION AND PRESENT DANGER

Borgia et al, (2005) defined 4 stages in the evolution of Vesuvius: A building phase (1) characterized by lava flow eruptions (VEI = 1) that built the ancient Vesuvius, from about 25 to 18 ka BP; a Compressive Phase (2) characterized by mainly Plinian eruptions (VEI = 5) from about 18 ka to 79 AD. During the final part of this phase a Basal Thrusting phase begins, from around 3,600 a BP, leading to the proper Spreading Phase (3), which continues today; this is characterized by summit rifting, basal thrusting and the eruption of voluminous lava flows preceded by explosive activity of decreasing intensities (VEI from 4 to 1) in time.

The Spreading phase was accompanied by decreasing the volcanic explosivity index (VEI) and silica content with the emplacement of voluminous lava flows. Moreover, the authors modeled the detected deformation with a solution of the lubrication approximation of the Navier-Stokes equations to show that spreading may continue for about 7,200 years more. Correlation of volcanic spreading with phases of the eruptive activity suggests that Plinian eruptions, which are thought to pose the major hazard, are less likely to occur in the near future (Figure 9). Instead, voluminous fissure eruptions, preceded by moderate explosive phases, appear to be a more probable scenario.

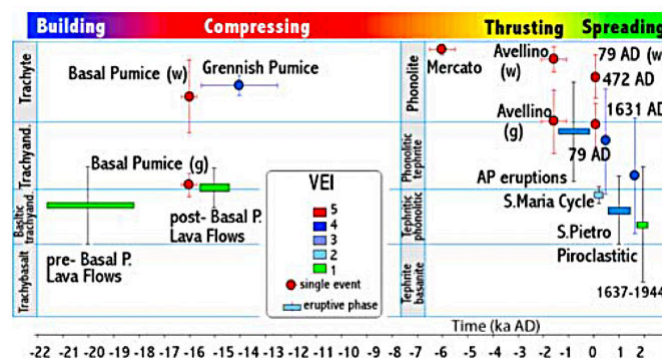


Figure 9. Comparison between petrological composition of erupted products, VEI, and volcanic spreading phases.

Source: Borgia et al. (2005)

## THE ANCIENT POMPEII AN ITS PRESERVATION

The city's origins can be traced back to the 8th century BC, with settlements by the Oscans, Greeks, and Etruscans. Pompeii later became a Roman colony and flourished under Roman rule. The eruption of Mount Vesuvius in 79 CE released immense quantities of ash,



pumice, and hot gases, burying Pompeii and surrounding areas.

Largely preserved under the ash, Pompeii offers a unique snapshot of Roman life, frozen at the moment it was buried, as well as insight into ancient urban planning. It was a wealthy town of 10,000 to 20,000 residents at the time it was destroyed. The 79 AD Vesuvius eruption started during October 24-25 and lasted for two days. The first phase was of pumice rain (lapilli) lasting about 18 hours, allowing most inhabitants to escape. At some time in the night or early the next day, pyroclastic flows began near the volcano, consisting of high speed, dense, and scorching ash clouds, knocking down wholly or partly all structures in their path, incinerating or suffocating the remaining population and altering the landscape, including the coastline.

Mastrolorenzo et al, 2010 investigated the possible causes of mortality in Pyroclastic Density Currents (PDC) at Pompeii and surroundings areas during the 79 AD eruption, on the bases of a multidisciplinary volcanological and bio-anthropological study. Field and laboratory study of the eruption products and victims merged with numerical simulations indicating that heat was the main cause of death of people, even though it was supposed to have died by ash suffocation. The results showed that exposure to at least 250 °C hot surges at a distance of 10 kilometers from the vent was sufficient to cause instant death, even if people were sheltered within buildings. Despite the fact that impact force and exposure time to dusty gas declined toward pyroclastic currents periphery up to the survival conditions, lethal temperatures were maintained up to extreme depositional limits.

Only those inside the houses at Pompei and its suburbs, and Stabiae, survived the first phase of the eruption, protected by the distance from the volcano. Only those that left the houses during the first grey pumice fall, had some chance to survive. Later, the people and buildings of Pompeii were covered in up to twelve different layers of tephra, in total, up to 6 meters deep. Finally, the caldera collapsed, reaching the surface activating a massive release of pyroclastic material from multiple vents (Scandone et al, 2019). Some new studies showed that on top of that, some buildings collapsed due to one or more earthquakes during the eruption, killing the occupants.

Extensive excavations, started in the 18th century, having uncovered various features of Pompeii, including streets, buildings, public spaces, and private homes. Pompeii is a major archaeological site and a UNESCO World Heritage site, offering valuable insights into Roman society, culture, and daily life.

The most important buildings in the city of Pompeii are the Forum, the Amphitheater, the Great Theater, the Odeon, the House of the Faun and the Lupanar. The Pompeii Forum was the center of trade, politics, culture and religion in ancient Rome. It was also a thriving market and the seat of many beautiful temples, administrative quarters and legal offices in Pompeii, a once-sophisticated Roman city. While political activities were confined to the northern corners of the Forum, the rest of the area was expanded into large markets and public gathering spaces. It occupied quite a large area measuring 157 x 38 meters with a superb view of Mount Vesuvius (Figure 10).



Figure 10. Partial view of the Forum and the statue of Apollo (Pompeii), with Mount Vesuvius looming in the background. Author's photography.



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