THE ACTIVITY OF MOUNT VESUVIUS IN THE LAST 2000 YEARS

Roberto Scandone and Paolo Gasparini
Università di Napoli, Italy

Abstract

Mount Vesuvius had eruptions ranging between VEI 5+ to 0-1 during the last 2000 years. Infrequent explosive eruptions are recorded during the period 79 AD to 1631. Since the violent explosive eruption of 1631, the volcano has been in persistent activity, rebuilding the morphology that it had before that eruption. A succession of explosive and effusive eruptions occurred until 1944, with a predominance of short and violent episodes until 1872 and longer effusive eruptions since that date. The long quiescence since 1944 may be followed by an explosive eruption similar to the one of 1631.

1. SHORT VOLCANOLOGICAL NOTES WITH EXPLANATIONS OF THE MOST USED DEFINITIONS

A simple classification based on the violence of the event is:

Effusive eruptions: characterized by low explosivity and emission of lava flowing along the flanks of the volcano.

Explosive eruptions: characterized by a very high explosivity; they form an eruptive column expanding on ascent due to turbulent mixing with atmospheric air; it has a typical mushroom or cauliflower shape. They are also called "Plinian eruptions" after Pliny the Elder, who died during the 79 AC eruption of Vesuvius, and Pliny the Younger, who described the same eruption.

Phreato-magmatic eruptions: characterized by an explosivity due to the interaction between magma and water.

The eruptions can be also called by different names according to the volume of erupted products, their dispersal, and violence:

Hawaiian, Strombolian, Vulcanian, Pelean, Plinian, Ultraplinian.

The volcanic explosivity Index is a qualitative index roughly proportional to the emission rate of magma. A volcanic explosivity index of three indicates approximately a volume flux of 103 m3/sec of magma with a density of 2500 kg/m3 and temperature of about 1000°C.

1.1 The products of eruptions

An effusive eruption produces mostly lava flows. Very viscous lava can form small hills, of circular shape, called domes.

Magma is fragmented during explosive eruptions before being emitted under the form of pumice, scoria, bomb, and ash, generally called pyroclastic products. Pyroclastic products can be classified according to the mechanism of emplacement:

Fall-products are those ballisticaly ejected from the crater or falling from a convecting plinian column. They can be recognized because they uniformly mantle the pre-existing topography. The thickness regularly decreases away from the source. The products are deposited with regular layers and the particles are angular.

Pyroclastic-flow deposits form when the plinian column is too dense and not able to rise, consequently dense clouds flows along the flanks of the volcano. The pyroclastic flows can reach velocities up to 100 km/hr and distances of tens of kilometers from the source.

Pyroclastic flow deposits have a chaotic aspect, in the proximity of the vent; the particles are sub-rounded because of erosion during flow. The deposits thicken in the valleys and against obstacles which they are not able to overcome. They are not present on high-angle slopes, and often there is no regular decrease in thickness with distance from the vent. Sometimes, flow deposits are called tuffs or ignimbrites.

Surges products are deposited by clouds, similar to a plinian column, but horizontally directed. Surge clouds are richer in gas than pyroclastic flows and solid particles are more dispersed.

Surge deposits are rich in blocks ejected from the conduit in the proximity of the vent, embedded in an ashy matrix, often with accretionary lapilli (small spheres, also called pisolites, formed by the aggregation of wet ash). At a larger distance from the vent, the deposits are made up by regular layers of fine ash with a dune shape, often containing accretionary lapilli. With respect to the pre-existing topography, surge deposits tend to thicken in depressions, but can also mantle low-angle slopes and small hills with a decrease in thickness.

Surges and pyroclastic flows are generally called pyroclastic flows; they are among the most dangerous phenomena related with explosive volcanism, because of their high velocity of emplacement and high temperature.

Mudflows are often associated with explosive eruptions (they are also called with the indonesian name of Lahars). They form because of the accumulation of ash and loose material on the flank of a volcano. Rain, glacier ice, or water vapour, emitted during the eruption, can mobilize the material and channelize it in creeks and rivers transporting rocks as heavy as few tons, tree trunks, and destroy everything in its course.

The most violent explosive eruptions can modify the morphology of a volcano. There is both deposition of new material and destruction of part of the cone. Sometimes, the rapid drainage of magma can produce the collapse of a large circular area, called a caldera.

2. INTRODUCTION

Vesuvius is one of the most studied volcanoes in the world, because of its long time interval with historic eruptions (2000 years; one of the longest eruptive history in the world) and its easy accessibility. The discovery and excavation of Pompeii and Herculaneum in the 1700s added to its fame and it became the volcano on which new theories of Earth Science were tested. Many neapolitan and foreign scholars described with accuracy the numerous eruptions during this long period, and, since 1600, several chronicles described not only the main eruptions but also the slight changes of volcanic activity.

The aim of our paper is to review the volcano's history in the last 2000 years in order to identify the main factors controlling its activity.

3. THE 79 AD ERUPTION

Pliny the Younger's letters to Tacitus have been frequently recalled as the first vivid description of an explosive eruption.

We do not know if the description made by Pliny the Younger of the eruption of 79 AD is reliable or not (he explicitly mentions in the end of the first letter that other persons reported to him most of the facts); we will however recall some of the more important points in his account.

3.1 The first letter

The beginning of the eruption is uncertain: the two Plinys observe the cloud at the seventh hour of the day (1 PM) [1] . We must presume that the eruption began sometime earlier to allow the arrival, at about the same hour, of a messenger sent from the vesuvian area. [1] suggest that the event prompting Rectina, wife of Tascus, to send the messenger, was a phreatic explosion at the very beginning of the eruption.

3.1.1 The Cloud

The cloud was directly observed by Pliny the Younger from a distance of 21 km, so that he could fully appreciate its total extent and behavior. Subsequent scholars of Vesuvius eruptions have frequently used the same description for other eruptions.

The description gives us the idea of the typical explosive eruption ("It resembled a pine {Mediterranean pine} more than any other tree. Like a very high tree, the cloud went high and expanded in different branches,. I believe, because it was first driven by a sudden gust of air (recenti spiritu eiecta), then, with its diminution or because of the weight, the cloud expanded laterally, sometimes white, sometimes dark and stained by the sustained sand and ash (pondere suo victa in latitudinem vanescebat, candida interdum, interdum sordida et maculosa prout terram cineremque sustulerat)."

3.1.2 The route of Pliny the Elder

Pliny the Elder, on his course to the endangered area, has the wind blowing at his back, from the north-west. We do not know where he intended to land, but he changed his mind because a new shoal formed by the eruption prevented the landing. At this moment he observes red-hot stones and pumice falling on the ships, so he must already be at the south-east of the volcano as suggested by the area distribution of pumice [2]. We may infer that he was trying to reach the Pompeii port and that he could not land because of the floating pumice, so, he changed his mind and sailed toward Stabiae to reach the friend, Pomponianus, who could not leave because of the opposing wind.

The decision of reaching Stabiae was a fatal one because brought the rescuers to a place where sea escape was impossible. Stabiae was separated by the center of the gulf where the shore made a gentle arc and the waves rushed in ("Stabiis erat diremptus sinu medio (nam sensim circumactis curvatisque litoribus mare infunditur"). The ancient coastline formed probably a more pronounced gulf than nowadays. The northwestern wind favoured the entrance into the gulf (" Quo tunc avunculus meus secundissimo invectus" - most favourable to the route of my uncle-) but prevented the escape on the next day during the paroxismic phase of the eruption ("Placuit egredi in litus, et ex proximo adspicere, ecquid iam mare admitteret; quod adhuc vastum et adversum permanebat " - They decided to reach the shore and look if the sea permitted the escape. But the sea was still stormy and did not allowed the departure-).

3.2 The second letter

During the time of the eruption, Pliny the Younger stayed in the proximity of Misenum from where he observed the eruption along with his mother (Pliny the Elder's sister). In the second letter, he describes what occurred there.

3.2.1 Earthquakes

During the night of the first day of the eruption, and for most of the morning of the next day, the houses of Misenum where shaken by earthquakes that caused much panic. Pliny the Younger and his mother escaped; they reached a place from which Vesuvius, Capri and Cape Misenum were visible. The only place where such view is possible is the "Monte di Procida" hill. On the top of the hill, wheeled-charts on flat land were shaken back and forth even if chocks were placed against the wheels. Given the distance from Vesuvius, we may presume that the seismic activity, or a strong seismic tremor, ranged in magnitude between 4 and 5.

3.2.2 Tsunami

("Praeterea mare in se resorberi et tremore terrae quasi repelli videbamus "- Further on, we saw the sea retreating as if pushed by the earthquakes-) The retreat of the sea observed in Misenum is probably related with a tsunami associated with the climax of the eruption; a similar occurrence has been described during the eruption of Vesuvius of 1631.

3.2.3 Black clouds at Misenum

"Ab altero latere nubes atra et horrenda, ignei spiritus tortis vibratisque discursibus rupta, in longas flammarum figuras dehiscebat " - From the other side, black and horrible clouds, broken by sinuous shapes of flaming winds, were opening with long tongues of fire- The description suggests strong explosions that - After a little while descended onto the land, opened the sea, covered Capri and prevented the sight of Misenum- (" Nec multos post illa nubes descendere in terras, operire maria; cinxerat Capreas et absconderat, Miseni quod procurrit abstulerat "). The clouds reached the place where Pliny the Younger and his mother where ("densa caligo tergis imminebat, quae nos torrentis modo infusa terrae sequebatur. (......) et nox non qualis inlunis aut nubila, sed qualis in locis clausis lumine exstincto." - A dense haze was impending at our backs, following us like a stream flowing on land (....) and the night fell on us, not like a night with clouds or without stars, but like the night in a closed place without a lamp)-. After a while they were reached by another cloud - Again the obscurity, again the ash, dense and heavy. We raised some time to shake away the ash as we could have been covered and choked by its weight- ("Tenebrae rursus, cinis rursus, multus et gravis. Hunc identidem adsurgentes excutiebamus; operti alioqui atque etiam oblisi pondere essemus ".

We can exclude that these phenomenona can be ascribed to air-fall ash. The distribution of the pumice driven by stratospheric winds is toward the south-eastern side of Vesuvius [1, 2]. Low altitude winds were blowing from north-west (as the course of Pliny the Elder testifies. We have to conclude that the phenomena in the proximity of Misenum were due to a pyroclastic surge as also suggested by [1].

If such description is truthful, it raises however some new questions about the extent of damage caused by the eruption. Any pyroclastic surge reaching Misenum, causing breathing difficulties and obscuration of the sky must first have passed the city of Naples.

4. THE PERIOD BETWEEN 79 AD AND 1631

We have no information on the state of Vesuvius immediately after the eruption of 79. The first account of continuing activity is from Galenus (c.172 AD) who testifies that "the matter in it (Vesuvius) is still burning " .

Dio Cassius in 203 AD reports a violent eruption heard in Capua, some 40 km from the volcano. The same eruption is reported by another source (Manuele) referred to by [3].

Two large eruptions occurred in 472 and 512.

Marcellinus Comes reported that, on the 6th of November, 472, "Vesuvius (...) erupted the burning interiors, caused night during the day and covered all Europe with fine ash ". This eruption is also confirmed by Manuele [3].

Information about the eruption of 512 is more detailed. Cassiodorus, an officer of king Teodoricus, wrote a letter to ask the exemption of taxes for the people affected by the eruption; in his letter he reports that " a burnt ash flies in the sky, and, forming ashy clouds, it rains with ash droplets also in the provinces beyond the sea (...). It is possible to see ash rivers flowing like liquid, bringing hot sands and (....) the fields grow suddenly up (the fields are covered with sand)to the top of the trees (.....) and are ravished by the sudden heat. " .

Several other eruptions are reported in 685 (Paulus Diaconus), 787 and 968. [3] suggest that the first testimony clearly referring to a lava flow is for the eruption of 968. Leo Marsicanus reports in a chronicle of the Cassino Monastery that "Mount Vesuvius exploded with flames and emitted a great amount of gluey and sulphurous matter that formed a river hurriedly flowing to the sea " .

Several authors report other eruptions in 991, 993 and 999 [4] but they must be regarded as suspicious because of the belief of the end of the world in 1000 AD. Leo Marsicanus refers of another eruption on the 27 of January, 1037, that lasted for six days. The chronicle of the Cassino monastery records an explosive eruption between 1068 and 1078 [3]. The last eruption before a long quiescent period occurred on the 1st of June, 1139. Several sources refer to it as a strong explosive eruption (Falcone Beneventano, the Chronicle of the Monastery of Cava dei Tirreni, John of Salisbury). It lasted eight days and ashes covered Salerno, Benevento, Capua and Naples. No reliable report of volcanic activity is available until 1500, when Ambrogio di Nola reports a small explosion. From 1500 until to 1631, no eruption occurred on Vesuvius. Records are good during this period, and none mention volcanic activity.

5. THE PERIOD BETWEEN 1631 AND 1944

The great eruption of 1631 is the largest explosive eruption of Vesuvius since those of 472 and 512 AD. It occurred after 131 years of quiescence. Large trees covered the Gran Cono, the cone within the Somma Caldera, and local people did not remember it being a volcano. The mountain was called "La Montagna di Somma" (the Mountain of Somma, a small town on its northern side).

Several months before the beginning of the eruption, people near the volcano felt some earthquakes [5]. They were not particularly scared because earthquakes from the nearby Apennine chain were often felt in the area (a large one had occurred three years before in Apulia, in 1628). The seismic activity became more severe in the few days before the eruption. Nevertheless, the awakening of Vesuvius in 1631 surprised the inhabitants. A strong explosive eruption started in the night between 15 and 16 December of 1631 and its paroxysmal stage lasted two days.

The eruption started a period of persistent activity that lasted, with a few breaks, for more than three centuries until 1944. After the violent eruption of 1631, the inhabitants living at the base of the volcano, became accustomed to its activity and were inclined to record only the most notable events. However, a few individuals (mostly belonging to the ecclesiastic or noble classes) started to maintain detailed chronicles of its activity only sixty years after the great eruption. They describe, since 1694 not only the main eruptions, but also the slight changes of volcanic activity. These careful descriptions of the volcano activity permitted to [6,7] to formulate models of activity between 1631 and 1906 based on recurring cycles of activity. Each cycle was characterised by the succession of:

a) A period of repose (generally not exceeding a few years);

b) A phase of strombolian activity with the building of a conelet within the crater, and, eventually, the emission of some lava flows (either within the crater or outside it);

c) A violent eruption usually with a lava flow and strong explosions followed by a new repose.

Carta et al [8] made a statistical model of the activity similar to that proposed by [7]. They reproduced the pattern of activity with a Markov chain of four states of activity (repose, persistent activity, intermediate eruption, final eruption). The transition probabilities from one state into another were determined by the observed times of permanence in each state. Their model described well the activity between 1694 and 1944, but was unable to explain the long repose since the last eruption of 1944.

We counted 99 magmatic eruptions, following the1631 one; 5 FE had a VEI of 3+ (1737, 1779, 1794, 1822, 1906), and 12 had a VEI of 3. 53 eruptions were accompanied by (or were entirely) explosive phenomena. Explosive activity was predominant until 1872 (49 events); since this date, effusive eruptions became more numerous and there was a slow accumulation of lava either on the flanks of the cone (building of several lava domes between 1872 and 1899) or filling of the crater and outpouring of lava from it. Since 1872, the length of IE became longer [8], and there is the suspicion that a new magma batch became available.

At least 41% of FE and 21% of IE were preceded by a collapse of the conelet inside the crater before the eruption; 77% of the FE, and 31% of IE started with a fracture of the main cone or of the near areas at the beginning of the eruption. Since 1913, no more fracturing of the cone was observed.

The Final Eruptions (occasionaly also the IEs) are characterized by a peculiar trend. They often begin with an effusive phase with lava outpouring from a fracture in the cone, and end with an explosive phase.

The lava emission is accompanied by strombolian explosions, and occasionally intermixed or followed by violent episodes of lava fountains (in some cases, up to 1-4 km height; as, for example, in 1737, 1822, 1872, 1906, 1929, 1944).

A collapse of the crater generally occurs at the end of this phase (for example in 1737, 1779, 1794, 1822, 1834, 1839, 1850, 1872, 1906, 1944), and is often accompanied by strong earthquakes. The crater is then hundreds of meters deep (216 m in 1822, 285 in 1839 and 1850, 250 m in 1872, more than 250 m in 1906 and 1944).

The last phase is characterized by the formation of a sustained eruption column, 5-15 km high, eventually with phenomena indicating magma-water interaction (wet ash, or pisolites and relevant lahars: for example, in 1779, 1794, 1822, 1906, 1944).

Obviously, such a scheme is highly simplified and the different phases may alternate each other during the same eruption; however, there is always a progression from a purely effusive phase toward a more explosive one.

6. DISCUSSION AND CONCLUSIONS

The last 2000 years of activity of Vesuvius show a variety of eruptive styles similar probably to those of its entire lifetime. Eruptions with VEI ranging from 5+ to 0-1 have occurred during this time. The most violent have occurred after long periods of quiescence, but important explosive eruptions have also occurred after short quiescence (512 AD) or during periods of persistent activity (1779, 1822 and 1906).

Many of the phenomena, observed during the period 1631-1944 (as for example, explosive activity, collapse of the crater, lahar and water emission), occurred with an enhanced character during the eruption of 1631. The immense emission of water from the volcano, during the eruption of 1631, troubled very much the contemporary scholars, and many of them invoked the entrance of sea-water into the volcano.

We suspect that much of the explosivity of Vesuvius is related with an important aquifer in the carbonate rocks below Vesuvius. A relevant amount of water can gain access to the magma only if important collapses of the hydrothermal system of the volcano occur during the eruption.

Large explosive eruptions reshape the volcano with the formation of a caldera. We do not know the age of formation of the Somma caldera, but it is likely that it was the result of several eruptions similar to the one of 79 AD. After such eruptions it is likely an activity that tends to restore a hydrostatic equilibrium shape of the mountain through a sequence of explosive and effusive episodes.

Dio Cassius reports, in 203 AD, that Vesuvius had an amphitheatre shape. Already in the VI century, the volcano had a shape similar to the present one, as shown in an engraving with Saint January in between the Somma rim and the Gran Cono [3].

Before 1631, Vesuvius was higher than the Somma, and after the eruption it lost at least 168 m. The slow rebuilding phase took the following 313 years with a predominance of explosive events in the beginning and of effusive ones in the end.

The explosive eruptions during the rebuilding phase may be the result either of an influence of external factors as the arrival of a tensional pulse produced by tectonic earthquakes or of purely morphological factors. The opening of a fracture on the cone or a lateral intrusion may cause a sudden drainage of the magma column and a decrease of pressure propagating downward. Such pressure decrease produces a sudden water-exsolution and bubbling at the exsolution level so driving the start of the eruption with rapid magma emission. The sequence of fracturing of the cone, or conelet collapse, and following rapid lava flow formation indicate this phenomenon.

BIBLIOGRAPHY

[1] Sigurdsson H., Carey S., Cornell W., Pescatore T., 1985, Nat. Geog. Res. 1, 332-387;

[2] Lirer L., Pescatore T., Booth B., Walker G.P.L., 1972, Geol. Soc. Am. Bull. 84, 759-772;

[3] Gasparini P., and Musella S., 1991, Un Viaggio al Vesuvio, Liguori Editore, 307 pp.

[4] Alfano G.B., 1924, Le eruzioni del Vesuvio fra il 79 ed il 1631; Valle, Pompei (Roma, Istituto Pio IX tip.);

[5] Braccini G.C., 1632, Dell'Incendio fattosi al Vesuvio a' XVI Dicembre 1631, e delle sue cause ed effetti, Roncaglioli, Napoli, 224 pp.;

[6] Baratta M., 1897, Il Vesuvio e le sue Eruzioni, Società Editrice Dante Alighieri, Roma, 203 pp.

[7] Alfano G.B., Friedlaender I., 1929, La storia del Vesuvio illustrata da documenti coevi, Karl Hohn Verlag, Ulm;

[8] Carta S., R. Figari, G. Sartoris, E. Sassi R. Scandone, 1981, Bull. Volcanol. 44-2, 129-151;