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Vesuvius Before the 1631 Eruption

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A manuscript codex dating back to 1571, of which a printed transcription will shortly be published [*Guidoboni*, 2006], provided new data concerning the activity of Vesuvius 60 years prior to its last great eruption, on 16 December 1631. This activity, which had until now been unknown to modern science, calls for a re-evaluation of the current conditions of the volcano and of possible precursors to the next major eruption.

Vesuvius is one of the most dangerous volcanoes in the world: Its activity can affect an area comprising 18 municipalities that are inhabited by more than 700,000 people in an area less than eight kilometers away from the volcano vent. The volcano has been dormant since 1944, but the history of Vesuvius has been punctuated by violent and destructive, albeit infrequent, Plinian-type explosive eruptions, during which material is continuously ejected at a high velocity and at a great height (up to a few tens of kilometers) from the vent, forming a typical eruptive column with an umbrella cloud. In the past 3500 years, in between one Plinian eruption and the following one, several minor eruptive events have taken place, ranging from subplinian eruptions to more or less violent Strombolian activity and lava flow emissions.

A Brief History

The most famous eruption in historical times was that of 79 A.D., which was described by Pliny the Younger (whose name is given to the type of eruption he witnessed) in his letters [see *Mynors*, 1963]. This was the eruption that buried the cities of Pompeii and Herculaneum beneath pumice, lava, and mud, effectively obliterating them. The second great historical eruption occurred in 472 A.D. The third and last great eruption was the small-scale Plinian event in December 1631, which was broadly described by contemporary authors and is well known to volcanologists [e.g., *Rolandi et al.*, 1998; *Rosi et al.*, 1993].

The period between 79 A.D. and 1631 has been studied by the volcanologists to define the number, quality, and time distribution of eruptions and volcano-related phenomena prior to the 1631 event. The trend in the eruptive activity of Vesuvius from 79 A.D. to 1631, as currently described in the literature, is summarized in Figure 2**,** according to the data so far available [see *Principe et al.*, 2004, modified and integrated]. This chronology indicates that the 79 A.D. to 1631 period of activity is split into two phases by the 472 A.D. Plinian-type eruption. From 79 to 472 A.D., few explosive events are listed in the chronology and no lavas from that period have been found outside the Monte Somma caldera rim, the vent of the 79 A.D. eruption. Furthermore, from 472 A.D to 1139, according to the volcanological literature, ten eruptions occurred, as identified by early 20th century scholars [*Alfano*, 1924, confirmed by *Figliuolo and Marturano*, 1998] on the basis of historical data, of which two are uncertain events.

After the last recorded eruption, in 1139, no traces have been detected—either in the stratigraphic records or in the hitherto historical records [according to *Nazzaro*, 1998; *Principe et al.*, 2004]—of magmatic activity before the great deflagration in 1631. Volcanologists, therefore, have believed that there must have been a centuries-long silence preceding the 1631 eruption. In actual fact, the issue is more complex, because there are at least three further 'doubtful' eruptions from the twelfth to the sixteenth centuries that have been documented in the written record but have not yet been verified (see Smithsonian Institution Global Volcanism Program, at http://www.volcano.si.edu/world) and that await analysis by specialist historians (i.e., Figure 1, row D).

The sixteenth century appears to be a crucial period for understanding the volcano's history. If a centuries-long silence in volcanic activity did not actually exist, but was just a research gap, it could mean that another great eruption might be due in the near future because it would indicate that the time between major eruptions could be shorter than has been assumed. Information on the 'long-term precursor phenomena' in the years leading up to the 1631 eruption (Figure 2), which might reveal the presence of a magma chamber relatively close to the surface prior to the eruption, is important to evaluating hazard and risk.

Since Vesuvius is located in an area that has had human habitation since ancient times and since that population has had a written culture, it is reasonable to expect that

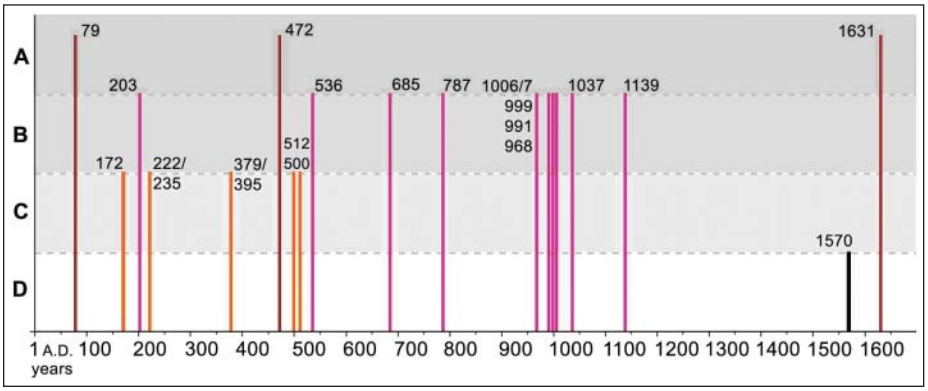

Fig. 1: Vesuvius activity between 79 A.D. and 1631 from historical data (after Principe et al. *[2004], integrated from Smithsonian Institution Global Volcanism Program and this paper). A, B, and C use the* Walker *[1973] classification. (A) Plinian and small-scale Plinian eruptions. (B) Subplinian and violent Strombolian eruptions, the latter in which liquid magma fountains from the vent. (C) Activity with eruptions spanning from the violent Strombolian to Strombolian; this includes eruptions of ash and, if verified, the new event that is described in this paper. (D) 'Doubtful' or uncertain events (events supported by written accounts that have yet to be verified by specialist historical research) in the Smithsonian Institution Global Volcanism Program (see http://www.volcano.si.edu/world).*

BY E. GUIDOBONI AND E. BOSCHI

historical records may have been produced that contain important descriptive elements for better understanding the history of Vesuvius's activity. However, only recently has more specialized attention—from philological and historical standpoints together with greater scientific sensibility—focused on finding and interpreting new historical data, within the scope of a new dialogue between historians and volcanologists.

Recent attention has focused on the sixteenth century, and specifically on a handwritten treatise from 1571—previously unknown to modern volcanologists—that contains specific references to such activity that may have lasted for several years on Vesuvius.

New Evidence of Vesuvius Activity

That treatise is the codex Ja II 15 (preserved in the State Archives of Turin), 28th volume of the *Antichità Romane* (Roman Antiquity), written by Pirro Ligorio. Vesuvius is not described as being a completely spent force in the sixteenth century, as has been supposed by present-day investigators. Instead, the text indicates that inside the Vesuvius crater, a vigorous fumarolic field was present, with continuous activity sustained by a large flux of gases. The text mentions "fire by night," suggesting the presence of incandescent rocks at the surface. The text also provides evidence that small explosions occurred from time to time.

Ligorio (1513–1583) was born into an ancient Neapolitan family and became a famous architect and intellectual of the pontifical court in Rome. After the death of Michelangelo (1564), Ligorio took over the management of the works of the church of St. Peter's; and in 1568, he became the antiquarian and historian for the family of the Este, princes of the Duchy of Ferrara, in northern Italy, one of the most important courts of the day.

In this treatise, which was written in a few months during a seismic sequence that hit the city of Ferrara from November 1570 to the end of 1571, Ligorio developed some thoughts on the causes that triggered off the earthquakes, described various seismic events of the ancient and Byzantine Mediterranean, and provided a detailed description of the Ferrara earthquake, to which he was an eyewitness. In the thinking of the day, still grounded on the Aristotelian theory, earthquakes and volcanoes often were believed to be the effects of the same cause (underground winds) and thus could be closely associated in natural philosophy, as in this case. This treatise also contains a pioneering plan for an antiseismic house, the first one known in the Western world, an element that confirms the rationalist framework of this work [*Guidoboni*, 1997].

The references to Vesuvius's activity are explicit. The author refers to a period that spans from the time when this treatise was written, in the winter-spring of 1571, to a number of years earlier. In the text, Ligorio describes the state of Vesuvius in his time, as an introduction to the description of the 79 A.D. eruption. The reference to the renowned Plinian activity thus is preceded by a description (*folio* 5 and 5v) of how the volcano appeared at the time of Ligorio (the original version in old Italian is available at http://www.sga-storiageo.it/Ligorio_Vesuvius_1571.pdf):

Fig. 2. 1631 Vesuvius eruption, painted in 1663, Österreich Nationalbibliotek, Wien, Atlas Blaeu, Volume 9, Tab. 51.

"From the summit to the lowest part, there is no fire whatsoever, but wild bush, such that, except for this lower part, all that remained of the ridge, even to the circumstances of the mount itself, is transformed into ashes by the aforesaid burning [that of 79 A.D.], and so it was then and even today, as from such burning and consuming of time the summit is made concave in the way of an amphitheatre; and around this summit there are beautiful vines and shrubs, which, lying beyond the large belt created a very great distance from the fire, make its fruit delicious."

Ligorio thus attested that until his day and age, there was vegetation from the slopes up to the crater. His description of the crater is realistic and is confirmed by other independent sources that preceded his text. This is how Ligorio described the crater of the summit:

"This abyss effuses smoke by day and fire by night, whereupon one feels certain odors evaporate as if sacrifices were being made here, ceasing neither by day nor by night to emit either small or large vapors, at times more and at times less, but very often, ash; and sometimes, being obliged by some great violence and force, it expels stones, which today we call pumice-stones; at other times, being attacked by a certain spirit and by the wind, it lets out a great billowing and a certain great screaming, but not being obliged by any of these causes, it breathes with some vents it has hidden, and this is the nature and the essence of Mount Vesuvius, which for a long time and many years has been doing such things."

According to Ligorio, this activity from Vesuvius's crater was considered by the eyewitnesses as a "very great" and "unusual" event; the word "unusual", i.e., "*insolite*" in the original Italian, may have the dual meaning of "rare" or "peculiar." However, the author stresses (*folio* 5v) that all of this activity was relatively little in comparison with what had happened in 79 A.D.:

"Nonetheless, although such things as have occurred seem both very great and unusual to everyone, they were but small occurrences in comparison with the things we shall be speaking of."

Historical Perspective

From an historical point of view, it may be asked why, in spite of Ligorio's account, the 1631 great eruption, described in dozens of historical reports, caught the inhabitants of the Naples area completely unaware. When the eruption began on 16 December 1631, it seemed to the contemporaries that the 'giant' was stirring from its centuries-long 'sleep.' That is what volcanologists also believed. However, in the opinion of the authors of this article, the treatises written soon after the great eruption in 1631 have been considered too literally by volcanologists, without critically examining those broad statements.

Authors who witnessed and described the 1631 eruption believed that there had been no Vesuvius activity prior to that year 'in the memory of man.' It may be asked if the terms 'memory of man' was used rhetorically to indicate a very long and indefinite length of time, centuries long, or if it had a literal meaning, with no eruptions occurring in the memory of those alive. The question is relevant because the concept of the length of time is relative in various cultural contexts. The measure of time became a precise concept, in the common meaning of the term, only from the half of the nineteenth century and only for urbanized and industrialized areas.

So, in 1631, the statement that Vesuvius had 'not been active in the memory of man' may be difficult to comprehend today, in particular if it is discovered, as in this case, that there was Vesuvius activity 60 years before 1631. Perhaps then the witnesses wanted to refer to two different concepts: (1) There had not been an eruption of comparable strength to that of 1631 since the last eruption in 1139, so for a multi-century long period; or, (2) the expression 'the memory of man' means a period just a few decades long, in which no Vesuvius activity has been detected.

But could the philosophers, scholars, and intellectuals of Naples and the surrounding Vesuvius area (authors of treatises and reports) have witnessed the volcanic activity described by Ligorio, which had occurred 60 years earlier? The average life span in those days was much shorter than today, and the authors of the treatises on the 1631 eruption were at the height of their intellectual development. But it is unknown whether other episodes of activity, such as the one described in Ligorio's treatise, that had occurred at Vesuvius had much chance of being described as an important fact by any intellectual who was living in Naples, since the episodes did not cause any damage to property or people. Ligorio's manuscript, written and preserved in places far from Naples, may have had no bearing on historical memory of such events.

In any case, Vesuvius's 'extraordinarily' long sleep, on which the Neapolitan authors who described the 1631 eruption agreed, had shown some signs of coming to an end at least some 60 years before the eruption actually started. These new data indicate the need for a re-evaluation of potential geological events that took place during the sixteenth century in the area of Vesuvius, including a reassessment of correlations with volcanic earthquakes, hitherto wholly neglected in the historical volcanological research.

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Author information

Emanuela Guidoboni, SGA-Storia Geofisica Ambiente, Bologna, Italy; E-mail: guidoboni@sga-storiageo.it; and Enzo Boschi, Istituto Nazionale di Geofisica e Vulcanologia, Rome, Italy.

Preseismic Lithosphere-Atmosphere-Ionosphere Coupling

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By M. Kamogawa

Preseismic anomalous states in the atmosphere and ionosphere as well as those in the near-Earth (telluric) currents and ultralow-frequency electromagnetic variations have been, since the 1970s, reported as occurring prior to earthquakes. These preseismic phenomena have not yet been universally accepted, partly because the low occurrence frequency of large earthquakes has hindered establishing their statistical significance. Recent achievements in this respect, however, seem to be highly encouraging for promoting further studies on preseismic lithosphere-atmosphere-ionosphere (LAI) coupling.

LAI Coupling: Research History

Liu et al. [2000] investigated the relationship between large earthquakes and ionospheric anomalies in and around Taiwan. As an index of ionospheric anomalies, they used critical plasma frequency, f_oF_2, measured by ionospheric sounding instruments (ionosondes), corresponding to the maximum electron density of the ionospheric *F* layer (160–400 kilometers in altitude), a region characterized by ion compositions and plasma dynamics. The *F* layer, dividing into F_1 and F_2, contains most of the electrons in the ionosphere. Liu and colleagues found that f_oF_2 significantly decreased locally during afternoons within a few days before $M \geq 6$ earthquakes occurred.

For example, Figure 1a shows that f_oF_2 measured above northern Taiwan decreased three and four days before the *M* 7.6 Taiwan Chi-Chi earthquake of 21 September 1999. Electron density depression above Taiwan also was observed by the global positioning system's (GPS) total electron content (TEC) measurements, as shown in Figure 1b [*Liu et al.,* 2001].

From such observations, *Liu et al.* [2006] constructed a set of quantitative definitions for ionospheric anomalies and examined the statistical correlation between thus defined ionospheric anomalies and all of the Taiwan $M \geq 5$ earthquakes (184 in number) during the period 1994–1999. The results indicated that anomalies appeared within the five days prior to the earthquakes. The statistical correlation was found to be dramatically enhanced for earthquakes with magnitude greater than 5.4 and with epicentral distance from the ionosonde instrument less than 140 kilometers.

Earlier, *Gufeld et al.* [1992] explicitly pointed out the existence of preseismic anomalies in the lower ionosphere, by using the transmission of very low frequency (VLF) electromagnetic waves (10–20 kilohertz), emitted from a radio beacon transmitter, which propagate through the waveguide formed by the conductive Earth-surface and ionospheric *D* layer (around 50–90 kilometers in altitude). The received intensity and phase of VLF waves are associated with the variation of Earth-ionosphere waveguide between the transmitter and receiver. Therefore, this observation is often used to monitor the plasma variation of the *D* layer. They observed anomalies in the intensity and phase of the received waves prior to major earthquakes in Russia when the epicenter was located between the transmitter and receiver.