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Volcanic phenomena between media simplification and the need for a better understanding of human-environment interaction, with particular reference to Italy

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Abstract

Correct scientific information is particularly necessary when dealing with hazardous phenomena like volcanic eruptions. Many journalists and even popular media divulgators often use incorrect terms, emphasizing dramatic aspects that are not always necessary, in an attempt to raise public awareness to volcanic phenomena. Often the beneficial aspects of volcanoes are overlooked and there is no understanding of the reason of so frequent human settlements around volcanoes. In this paper we discuss the most widely errors made by generalist media and misunderstanding of volcanic phenomena as well as the unknown beneficial aspects of volcanic activity. We discuss in detail also some poorly known aspects of the excavations of Pompeii which could serve as a tool for understanding volcanic hazard. We report the undocumented loss of volcanological data, that could permit a better understanding of the development of an eruption and suggest behaviour of survival during an explosive one.

Keywords: Media Communication, Lava Flow, Pyroclastic Products, Volcanic Activity, Volcanic Risk

1. Introduction

When talking in public about volcanology, or even more generally about geology, the first obstacle to overcome is the amount of wrong information and clichés that have been created due to the hasty, incomplete or inaccurate news spread by the media. It is not uncommon for authoritative journals or famous science communicators to resort to definitions or use notions far from an acceptable scientific level. To argue that certain simplifications help to clarify complex phenomena is not a good reason to misrepresent fundamental concepts. The Italian territory is subject to different types of geological risks and it is necessary for the population to develop a culture in the field of Earth Sciences, rather than being tormented by sensational announcements and approximate information. Poor information does not help people to develop the care for natural phenomena and their impact on humans and the environment.

A good starting point for understanding each other, between people exchanging information, is the appropriate use of the terms which, in the case of volcanology, are those that define the products of the eruptions, the eruptive processes, the different variables that occur and that allow us to understand the volcanic activity itself and to decipher its possible consequences.

Errors and false news can originate from bad faith, ignorance, superficiality or other, due to lack of accuracy in the opinions expressed and in the verification of those that are collected, even if they come from competent figures or institutions. The possibility of trivial errors has further expanded with the use of the net and social media that are able to spread the most varied theories like wildfire, without any possibility of control.

There are also complex circumstances, in which an incorrect assessment can derive from the objective difficulty of interpreting the evolution of natural events and cases that require dealing with uncommon situations, with a large margin of possibility of unsuitable choices.

In this paper we illustrate some of the more common errors or misrepresentation of volcanic phenomena and attempt to better explain the correct meaning of volcanological terms. We do not mention single articles but explore the arguments that are poorly understood by the majority of divulgators with a few notable exceptions.

2. Commonly misunderstood volcanic terms

The process underlying volcanic activity, the formation of magma, is one of the topics that most stimulate the imagination of science communicators and journalists. It happens to see images, even graphically very accurate, in which magma rises from the core of the Earth and reaches the surface giving rise to eruptions. The error is twofold and serious. If material at a temperature of 1,000-1,200 °C were able to rise from a depth of 2,900 km, the outer limit of the liquid core, to the Earth's surface, the very stability of the Earth would be in question. Just as it would be if at the depth of the upper mantle, where it is presumed the formation of magma, between 100 and 200 km of depth, entire portions of rock were to pass to the liquid state.

The second mistake is to consider magma as a mass of molten rock. The fusion affects only some minerals of the rocks that form the Earth's mantle, each passing into a liquid state under certain conditions of temperature and pressure. The liquid phase of the magma results in a progressive sequence of mineralogical species, starting from those that melt before others.

It is not uncommon to attribute the melting to the geothermal gradient that increases with depth, but even this assumption is incorrect. The extent to which the temperature increases from the surface towards the interior of the Earth is, in the first kilometres of the crust, around 1 °C every 30 m, with extreme cases of 1 °C every 140 m and 1 °C every 10 meters. This increase, measured with perforations that reach a shallow depth into the Earth's crust, cannot follow a constant trend, because the temperature would reach, after a few tens of kilometres, values such as to melt any type of mineral (Brown et al., 1992). On the other hand, the mantle is a predominantly solid area, as revealed by the propagation of transverse seismic waves that do not propagate in liquids.

Even the magma's ascent towards the Earth's surface encounters some difficulties in the less rigorous disclosure. The simplest mechanism to justify the movement of a liquid phase surrounded by a highly viscous solid is that of buoyancy, effective as long as there is a density contrast. When they have a same value the magma slows to a halt, and something has to disturb the equilibrium reached, to move it again. If this happens, the magma reaches the surface, causes an eruption and its name becomes lava or pyroclast, depending on the mechanism by which it is expelled (Sigurdsson, 1999)[1].

[1] The geo-tectonic contexts of magma formation and ascent are different, all widely described in the geological literature.

3. The terms that define eruptions and products

In the description of volcanic phenomena, the use of improper terminology is particularly frequent: magma often becomes synonymous with lava or other volcanic products, whose names are mentioned at random.

In many television news items, the eruptions with incandescent material are always catastrophic, while the jet of gas, pumice and ashes of the most violent explosions is easily defined as smoke. Clarifying these concepts in an accessible way to everyone should be an undertaking if not really easy, at least a duty.

Eruptions are essentially of two types: effusive and explosive (e.g.: Rittmann, 1936). In the first case the magma, once it reaches the surface and has lost most of the gases it contains, takes the name of lava and flows down along the slope of a volcano because of gravity. Lava flows can have very different aspects depending on their temperature, chemical composition, emission rate, morphology of the volcano and other characteristics, many of which remain imprinted in the cooled flow and can also be read after some time. The same shapes on the surface of the lava flow make it possible to give different names to the lava, but the generic term lava flow can be considered, in non-specific works, suitable for all types (Scandone and Giacomelli, 1998)[2].

Explosive eruptions, on the other hand, require greater precision, above all in school and educational communication. The recent (2020-21) activity of Etna (Italy) has received a lot of attention in journalistic and television reports, with worldwide dissemination of outstanding images and movies. The explosions that occurred on Etna consisted in the continuous emission, for several hours, of incandescent material, a phenomenon that takes the name of lava fountains. These fountaining phases were alternated with discontinuous explosions, (Figure 1) interspersed with pauses, typical of eruptions defined as Strombolian, often accompanied by the emission of lava flows (Figure 2). Although these eruptive episodes are often depicted as the maximum violence that a volcano can express, they are those, among the explosive eruptions, with lower energy. The incandescent material never reaches great heights but remains confined between hundreds of meters and a few kilometres above the crater. As a consequence, a cone of volcanic material forms around the eruptive vent as the products fall to the ground at a distance proportionate to the height reached (Figure 3). This phenomenon does not occur when the eruptive column reaches greater heights, and the emitted products are dispersed by the winds at high altitudes. (Figure 4).

At the other extreme of the explosive eruptions are the grey or dark grey eruptive clouds, which rise vertically above the crater for tens of kilometres. The images do not always give the idea, if not adequately described, of the violence of the eruption, although the most serious consequences of the volcanic activity derive from these events, called Plinian. Their impact on public opinion is less than that obtained from lava fountains, also because there is usually no precise reference to the relative scale between the two types of eruptions: the safe distance from which the lava fountains can be observed is far less than that which must be maintained from a Plinian eruptive column. Anyway, the glowing fire seems ever more threatening than a grey plume of pumice and ash[3].

The danger of the Plinian columns increases further when they become very dense and collapse along the flanks of the volcano, forming those streams of pyroclastic products, fast and at high temperatures, which are the most damaging

[2] Fluid lavas are defined with Hawaiian terms: “pahoehoe” when they have a surface with rope structures, small corrugations created by the plastic deformation of the thin surface crust; “aa” if the lavas are more viscous and covered by a debris produced by the fragmentation of a thick solid crust. Very viscous lavas can have little ability to move and accumulate around the point of emission forming reliefs called lava domes.

[3] For this reason, the graphic or cinematographic reconstructions of the eruptions with only the emission of pyroclastic products, such as that of Vesuvius in 79 AD, which destroyed Pompeii, add with absolute imagination copious throws of fiery shreds and red lava flows.

volcanic events of all, impossible to capture closely, but also from far away or from above, given their unpredictable development (Figure 5). The term pyroclastic flow encompasses any process in which the products of explosive eruptions are distributed by volcanic clouds flowing to the ground. In volcanology the phenomenon is subjected to further distinctions[4] but, also in this case, the generic term could be considered correct, if it were not deformed with improbable and obsolete terms such as Nuée Ardente or ash-coulee (Cas and Wright, 1987). On the other hand, the word pyroclastic, considered too arduous by the media, has the simple and precise Greek literary meaning: stone of fire.

While the lavas can all be indicated with the same term, although they are different from each other, the name of the products of explosive eruptions, pyroclasts, is relevant even in non-strictly scientific communication. The terms that define the dimensions of the individual pyroclasts, range from ash (from microscopic to 2 mm), to lapilli (between 2 and 64 mm), to bombs and blocks[5]. Even intuitively, it can be understood that the emission and fall to the ground of ash, lapilli or bombs implies different energy and consequences. As for the ash, particles that can be very small, the effects of the fall to the ground depend on the height at which they were thrown, which in turn determines the area of dispersion. To the practical classification made on the basis of dimensions, one can add that, which takes into account the nature of pyroclasts. Scoria often has a different chemical composition than pumice. The ash is made up of small or very small fragments of any type of volcanic product. Pumice and scoriae are bits of magma which cool rapidly and take on a disordered molecular structure, similar to that of glass. Scoria often has a different chemical composition than pumice, that results also in a different colour. The ash formed by small particles of pumice and scoriae is, therefore, similar to glass splinters, a very important detail when considering the effect of the emission of large quantities of volcanic ash into the atmosphere. So, for example, when we talk about lapilli, we do not indicate what they are, but only how big they are and if we write pumice, we indicate a glassy product of light colour, but not its size. To give correct information, the two terms should be combined. In popular language, only the terminology based on dimensions can be considered acceptable, avoiding expressions such as “lava ash”, a non-existent volcanic product, yet more and more frequent in the news.

Figure 1. Etna lava fountains (November 15, 2002).

[4] The substantial difference consists in the different ratio between solid particles and gases which form the flow and which condition its flowage. The terms surge (volume of the gas phase more abundant than the solid) and pyroclastic flow s.s. otherwise, are now superseded by the English expression pyroclastic density current; indeed, a single flow of pyroclastic material can be formed by zones of different density and with different propagation capacity.

[5] The bombs are large pyroclasts (more than 64 mm) ejected from the crater in the liquid or semi-liquid state; the blocks are fragments of the same range of size ejected in the solid state. They mainly derive from the volcanic system or material from previous eruptions. Both are typical of the so-called Vulcanian explosions, a term derived from the eruption of Vulcano (Aeolian Islands) of 1888-89.

Figure 2. Etna lava flow emitted from a crater at an altitude of 2,750 m asl (November 30, 2002).

Figure 3. A cone in formation with bursts of little violence, slightly asymmetrical due to the fall of pyroclasts according to the direction of the wind.

Figure 4. A particularly violent explosive phase on Etna, with a dense column of ash that does not exceed 3 km above the crater (November 2002).

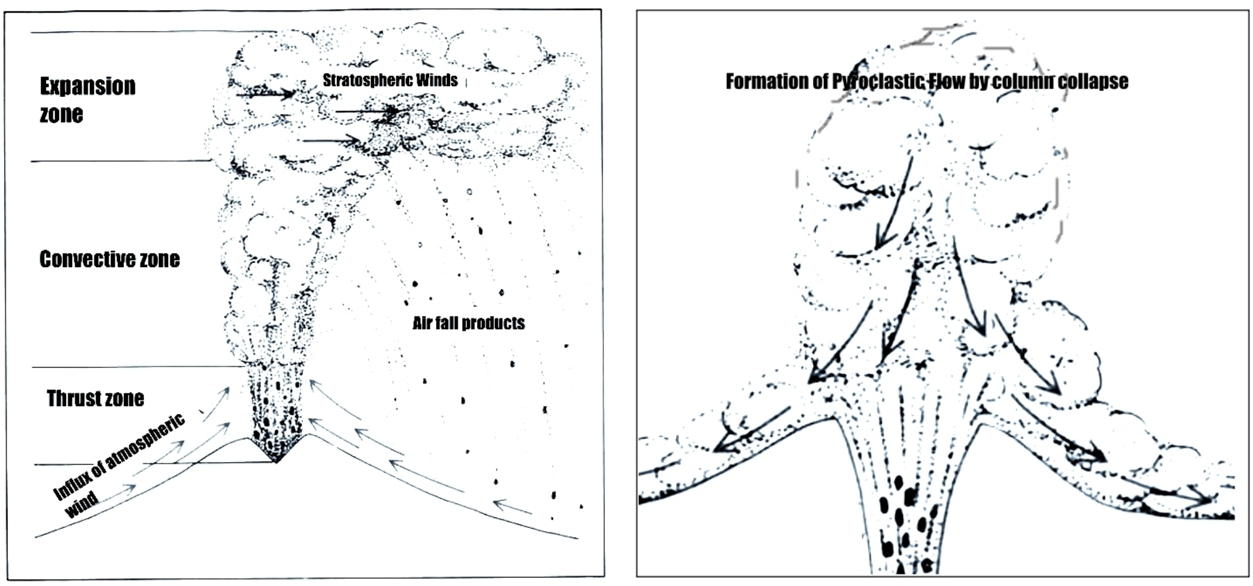

Figure 5. Scheme of formation of a Plinian eruption column with the inrush of atmospheric air that mix with the jet of gas and pyroclasts, and permits the convective rise of the eruptive mixture; and mechanism of formation of Pyroclastic Flows by the collapse of the eruptive mixture along the flanks of the volcano. Modified from Scandone and Giacomelli, 1998.

4. Misunderstandings and media exaggerations

As a real surprise, an ongoing eruption (from February 2021) of the Fagradalsfjall volcano in Iceland (Scott, 2021), was proposed by the media as peculiar because it was in an area where no eruptions had occurred for at least 800 years. Only a few inexperienced journalists might be surprised by the length of this quiescence, since they compare the periods of inactivity and life of a volcano with those of human beings. In the particular case of Iceland, it is known that the island was formed on a stretch of oceanic ridge, the only one to emerge along the approximately 60,000 km length on the ocean floor, all affected by volcanic activity for several million years. Every point of the island has been, is or may be in the future the site of eruptions. The images released daily, with the mass of people lined up next to the incandescent flowing lava, alone explain how low the damage caused by these events is, if the places are not inhabited, and how negligible is the risk for the people who observe the event closely. The news, to be more compelling, tends to exaggerate the accidental and unexpected factor of the eruption.

An unusual case of completely incorrect information, furthermore, given by geologists and Institutes of surveillance of volcanoes, occurred in 2008 in Chile, at the Chaitén volcano (Carn et al., 2009). The long mountain range that accompanies Chile for almost its entire length (4,329 km) is dotted with active volcanoes and the National Geological Service is busy dealing with their frequent emergencies. For this reason, the Chaitén, quiet for centuries, if not millennia, covered with trees with large trunks to the top, was not monitored like other volcanoes considered more dangerous. The earthquakes, which had been increasing before the eruption, were considered normal phenomena of a geologically unstable land and the plume of ash that suddenly appeared in the background of the Corcovado Gulf was attributed to the Michinmahuida volcano which had been active in historical time as observed by an exceptional eyewitness, Charles Darwin, in 1835. The origin of that eruptive column was revealed only through satellite images, just in time to evacuate the people from the village of Chaitén, before the ashes accumulated on the nearby volcano (Figure 6) were rushed down from the rains and flowed down the Rio Blanco river, burying part of the town. This is certainly not a typical case of false news, but an example of how many circumstances can give rise to errors, even involuntary ones.

Figure 6. The top of Chaitén volcano, with the cone still growing after the 2008 eruption.

5. Effects of medium intensity volcanic explosions in relation to morphology

Information on the danger of volcanic activity does not always take into adequate account the morphology of a volcano. For example, Etna has a predominantly effusive activity from the summit craters. Although accompanied by spectacular lava fountains, these events pour most of their lava flows into the Valle del Bove, the large valley (8 km long and 5 wide) produced on the side of the volcanic building by successive explosions and landslides starting from about 60,000 years ago (Tanguy and Patanè, 1996). Only when this structure is completely filled, will the Etna volcanic risk have other parameters (Figure 7).

The situation is different if the eruption occurs at lower altitudes and the lava flows threaten the most densely inhabited centres. The most dramatic example, in historical times, is the eruption of 1669, which occurred from a vent opened at around 700 m of altitude, near the town of Nicolosi. The lava flow reached the sea, crossing Catania. That eruption was probably the first in which some farmers tried to divert the path of the lava but had to desist due to protests from the owners of the land on which it was artificially directed (Salvi et al., 2006).

Morphology conditions the path of a lava flow, making it almost predictable, thus permitting its diversion by barriers and embankments. But the size and length of the flow depend on other factors in which it is not possible to interfere. In the prolonged eruption of 1991-93, the lava threatened the town of Zafferana, reaching the lower limit of the Valle del Bove. Numerous embankment and diversion works were attempted, with great media coverage, at a time when internet did not exist. Explosives and concrete blocks were released to break the solid crust of lava tunnels and allow it to disperse heat (Barberi et al., 1993), but it is likely, also observing other cases, that the artificial containment of lava flows was not entirely obtained, and they stopped only when the feeding from the vent decreased.

Etna is not only almost always active, but it is also over 3,300 m high above sea level, two characteristics that keep inhabited centres and people away and consequently reduce the danger. Only once in the last one hundred years has a village on the flank of Etna been invaded by a lava flow such as Mascali in 1928, and even in this case without loss of lives.

Its dimensions must be taken also into account when reading the data released by the official news: in March 2021, the INGV-Osservatorio Etneo press release indicated ash columns 10 km high (above sea level), that is, within the stratosphere, where jet streams are capable of dragging the tiniest particles around the globe. A similar height places the eruption among the Plinian ones, which is quite unusual, if not in the older history of the volcano. The real height of the column is obtained subtracting 3,300 m of the volcano height. If it absolutely does not change anything as for the dispersion of ash, it is on the contrary very important for evaluating the energy involved, that is the violence of the eruption, which is not a secondary factor in the study of the behaviour of the volcano and its evolution over time.

In the most recent eruptions, the columns of Etna rarely exceeded two to five kilometres in height above the crater (7-8 km above sea level). This data may seem comforting as far as the violence of the volcano is concerned, but it is not so for its effects. The high eruptive columns, reaching the stratosphere, are dragged by the jet streams and their products fall over a large area in an almost constant direction (Wilson and Walker, 2009), but those at lower altitudes are dispersed by local winds that can change direction in a short time. In this case, the damage to the territory is distributed at 360° over the whole area around the volcano and not in a single direction and so the economic loss is higher than one would expect from a low energy eruption. In the eruption that took place between October 2002 and early 2003, the ash damaged many citrus fruit and winter vegetable crops in the whole region. The inconvenience to the population, the obstruction of the sewage systems and the closure of Catania airport are frequent and have been repeated often, even in the most intense phases of 2020-21. The interruption of air flights occurs because volcanic ash, formed mainly of glassy particles, is particularly abrasive on mechanical parts and can cause damage to engines, with serious consequences (Casadevall, 1994). But often the news shows the airport covered in ash, suggesting that the danger to the planes could be eliminated by clearing the runways.

Stromboli (Aeolian Islands), a volcano only apparently a little less than 1,000 m above sea level, but with at least double of its volume below the sea, has a side carved by a valley, the Sciara del Fuoco, into which most lava flows are channelled (Figure 8). The Sciara, normally considered a structure that reduces the danger of the volcano, showed all its fragility on December 30, 2002, when a sector of it, weighed down by the lava coming out of the summit craters, collapsed into the sea. Ten million cubic meters entering the water raised a wave that on the island reached 8-9 m in height, causing damage to the buildings closest to the sea, but no victims, given the winter season and the absence of people on the beach (Barberi et al., 2009). Motivations linked to the tourist flow have often minimised the extent of this event, altering the perception of volcanic risk in the opposite sense to what happens for the lava fountains.

It therefore appears inadequate to talk about the danger of a volcano and evaluate its consequences by limiting oneself to images of the active crater, without considering its shape which, in turn, depends on the very ability of the eruptive activity to cause continuous demolition and construction.

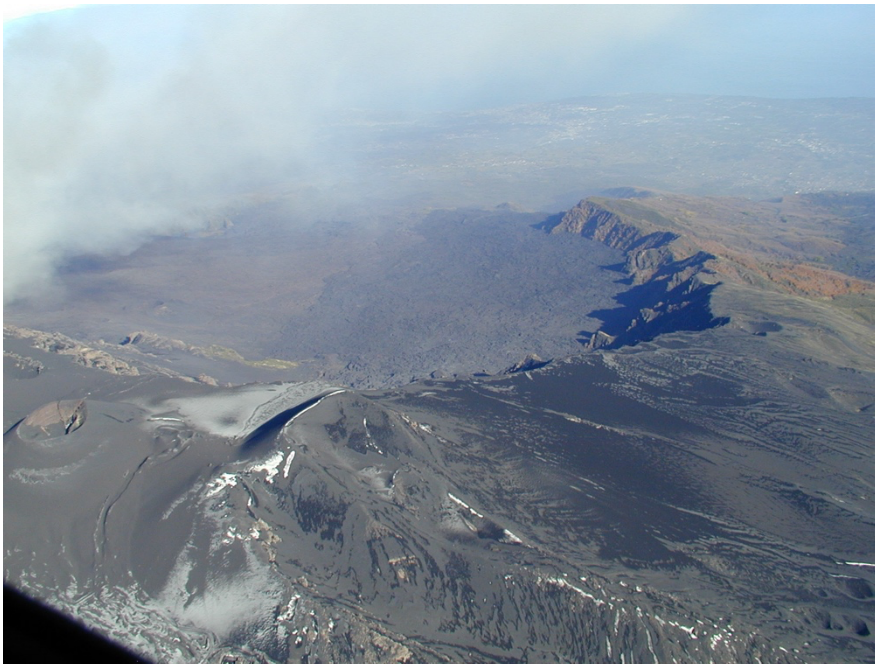

Figure 7. The Valle del Bove on the south-eastern flank of Etna.

Figure 8. The summit craters and the Sciara del Fuoco on the north side of Stromboli. The steam that rises from the sea, on the left, is caused by the entry into the water by two thin lava flows (March 2003) that spring from the niche of the landslide of 30 December 2002.

6. Surprises of nature. Unexpected effects of eruptions

A complete knowledge of the volcanic activity, the eruptions, their products, their complex case history may still be not sufficient in order to live with such an extraordinary phenomenon, capable of influencing the development of people life and businesses, since ancient times. And it is perhaps for this complexity that the tight deadlines of the news or the pages of newspapers that focus on news of strong appeal are unable to fully analyse the evolution and the sometimes completely unexpected implications of natural events. For example, the famous Icelandic eruption of 2010, which occurred at the Eyjafjallajokull volcano in Iceland[6], seemed to be one of the most violent of the century, even if actually it had limited consequences on the territory, damaging a couple of farms, (Figure 9) which however recovered quickly thanks the removal of ash and also to the construction of a small museum, a must for every tourist passing by it. But the economic damage was worldwide, quantifiable with a loss of 200 million dollars a day for the air companies that had to avoid the European airspace from 15 to 23 April. The consequences were proportional to the assets exposed to risk from a rich yet fragile society and did not derive, in this case, from the violence of the natural event (Schmitt and Kuenz, 2015).

Iceland had already had eruptions in the past whose effects were, for various circumstances, completely unexpected. In 1973, on the island of Heimaey, in front of the south coast of Iceland, on a night in which all 5,300 inhabitants were in their homes, not having gone out fishing due to the stormy sea, the first explosions and a cone began to grow a short distance from the inhabited centre, followed by a lava flow. Everything seemed lost: the houses, the port, the fish processing plants and the inevitable sheep. The images of the water pumps trying to slow down the advance of the lava towards the sea with jets of water are famous. The first circumstance that turned out to be favourable was the fishing boats available in the port which, with the addition of some planes, managed to evacuate and bring to the safety on the larger island, in only four hours, people, cars, many machineries of factories and even sheep. After 5 months and 5 days, 417 houses had been buried by the lava flow or by ash, but a 220 m high cone remained that sheltered the town from the winds (Figure 10); the lava flow not only had not closed the port, as feared by the inhabitants, but had made it more sheltered from sea storm (Morgan, 2000). Within two years, almost the entire population had returned to the island and, from 1982, a pioneering plant was built that exploited the residual heat of the lava, serving for more than ten years (Björnsson, 1980). Finally, a remote and unknown island for the rest of the world, became a tourist and scientific centre, as well as home to an elegant and instructive volcanological museum.

An emblematic case, of a completely opposite type, is an eruption that occurred in 1783, in an area of Iceland still almost uninhabited today. On a 25 km long fracture, fountains of lava, accompanied by lava flows, formed 130 cones (Figure 11). It was an eruption with the emission of a large volume of magma, about 15 km3, but all the explosions were not of great violence, the lava was channelled mainly along the Skaftà river and a few isolated farms were damaged. Yet this eruption marked a point of no return in the history of the island and in part also of Europe, because together with the lava, 500 million tons of volcanic gases were emitted that poisoned the pastures, causing the death of 50% livestock and, and the famine that followed, caused the death of 25% of the already small population. The "black haze" as Benjamin Franklin called it, affected the whole of Europe, causing what in Great Britain was called the "summer of sand" and the cold winter of 1783-84. The dust caused respiratory diseases with tens of thousands of deaths and famines that were, along with the raising of taxes, the likely engine of many far-reaching social unrests, perhaps even the impetus for the riots that culminated in the French Revolution (Thordarson and Höskuldsson, 2014).

[6] The news about the eruption invariably began with the "unpronounceable name" of the volcano, so much so that a witty T-shirt with the words "it's easy to pronounce" is on sale at the local museum.

Figure 9. Five years after the eruption, the pastures around the farms damaged by the Eyjafjallajokull volcano in Iceland, hidden by the glacier at the top. The black areas in the ice covering the volcano are ash from the 2010 eruption.

Figure 10. Panorama of the town and port of Heimaey, Iceland, from the edge of the cinder cone of the 1973 eruption.

Figure 11. A crater filled with water from the 1783 Laki eruption.

7. The (unknown) resources of volcanic areas

Several eruptions have a strong destructive power, although not comparable, especially in terms of loss of human life, with other natural disasters, such as earthquakes and floods. However, the news and many reconstructions of important events favour the negative aspect, as if the interest of the people is solicited only by the disasters. While all over the world the areas of active volcanism can enjoy a great tourist attraction and, where the conditions exist, the exploitation of geothermal resources, the areas with quiescent and extinct activity, albeit with a wide range of differences, do not have fewer opportunities. For example, the same devastated soils return very fertile in a relatively short time, thanks to the minerals transported to the surface by the magma and justify the recovery within a few generations of territories which have always been subjected to alternating phases of activity and volcanic quiescence. The whole Piana Campana in Southern Italy has known this phenomenon since prehistoric times, with continuous destruction and reoccupation of places that offered the populations of that time, as well as those of today, more advantages than dangers (De Vivo et al., 1993). In the same way, the unexpected fortune of the Aeolian Islands and the small Palmarola island, in the Pontine Islands in Italy, occurred in prehistoric times with the use of a peculiar lava, the obsidian, for the sharp tools that were traded all over Europe, until the advent of metals (Bigazzi et al., 1992; Bigazzi and Radi, 1998).

Where the activity is dormant, as in Ischia (Italy), the springs connected to the volcanic nature of the island constitute the main economic resource, with thermal tourism that extends for almost the whole year. An often-forgotten detail is that Ischia's fortune began with the decline of the nearby Campi Flegrei, after the eruption of Monte Nuovo in 1538. This too was not a particularly violent eruption (it built a 130 m high cone and caused no victims, except a group of onlookers who wanted to go on top of the crater), but destroyed forever the economy of the area, which was based on thermal waters, then almost the only remedy against any type of disease (Giacomelli and Scandone, 2012).

In large areas of the Italian peninsula where volcanic activity is considered extinct – e.g. the volcanic areas of Lazio, Roccamonfina, Vulture (Figure 12) – only the advantages of the ancient eruptions can be appreciated, from the articulated morphologies, with lakes and wooded reliefs, to the rocks of volcanic origin, tuffs, soft to dig but resistant to loads, used by the Etruscans for their necropolises, as well as in many villages and cities to develop multi-storey buildings, unthinkable without modern tools and with different rocks (Giacomelli and Scandone, 2007).

In each of these locations there are tourist guides that illustrate the peculiarities of the territory, from gastronomy to botany, and important volumes of human history, but volcanology rarely goes beyond a few lines. Realities close to Italy, the small region of Garrotxa, in Spain (40 volcanic cones and some lava flows) (Figure 13), and in France, in the Auvergne region (about 80 small and medium volcanoes), although not comparable in terms of size and volume of volcanic products with the extinct Italian ones, without counting those still in activity, enjoy consideration and have developed exceptional forms of hospitality, tourist and scientific, suitable for such an important natural event and of which, even after the millennia that have gone by, we still have a clear and precious testimony[7].

8. A case of civil protection: Pompeii beyond archeology

The media news regarding Pompeii is often not false, but incomplete. In most of the large number of documentaries, magazines, forums and reports of new finds, the site has an exclusively archaeological importance, while its origin is neglected, summarised in the best of cases. Yet, its entire immense archaeological value derives from having been buried by an eruption (Giacomelli and Scandone, 2001; Scandone et al., 2019a). In Pompeii, Herculaneum and many other less extensive sites, there was more information on a Plinian eruption than in any other part of the world: it was the only one to hit a territory with populous cities, the only one to be totally unexpected, although it had precursors, which were not considered as such, since they began 17 years earlier, too far from the main event, as could probably still happen today.

[7] For specific insights and many examples see: Giacomelli and Pesaresi, 2019.

Figure 12. The panorama of the Monticchio lakes formed inside two craters dated at 130,000 years ago of the extinct Vulture volcano in Southern Italy.

Figure 13. A dismissed quarry that dissected a scoria cone in the Spanish region of Garrotxa transformed into a very popular didactic environment. Almost identical structures are common in Italian volcanic areas, but often used as a landfill.

Figure 14. Cast of victims of the Pompeii eruption, the only ones left at the place of discovery, on about three metres of pumice, and a few centimetres of ash. The bodies were covered by few metres of pyroclastic flow material that overwhelmed them.

The eruption was also the first one in history to be described by an eyewitness, Pliny the Younger. Furthermore, it occurred from a volcano, Vesuvius, which is still a potential threat to millions of people today (Scandone and Giacomelli, 2008). The works of archaeology sometimes have a brief volcanological introduction, but never a real link between the two disciplines, which should be inseparable. Volcanology works are rarely contemporary to the archaeological excavation and even these lack the cultural fusion between the two fields of research. Considering that what for volcanology is a fundamental datum, for archaeology it is material to be thrown away, we understand how much information does not converge to outline a complete vision of an event that in a few days erased a vast territory and that cannot be excluded from occurring in the future (Sigurdsson et al., 1985; Pesaresi et al., 2008; Giacomelli and Scandone, 2019).

The volcanology works, based on the products visible mainly outside the archaeological sites, have reconstructed the characteristics of the eruption, recognising two main phases: in the first 12-20 hours, in the direction of Pompeii pumice fell from a column that exceeded 30 km above the crater. After this phase, which left a uniform blanket of about 3 meters of pumice in Pompeii, the eruptive column, accompanied by strong earthquakes, collapsed and slid, first towards Herculaneum, then also over Pompeii (Figure 14). For this reason, the two cities have suffered different consequences and are surrounded by very different layers of volcanic products (Sigurdsson et al., 1985).

In Herculaneum there is a thickness of 30 and more meters of material mixed with a lot of ash, left by the pyroclastic flows, while in Pompeii, above the pumice, there is the material of the pyroclastic flows of about 3-4 m (Sigurdsson et al., 1985; Scandone and Giacomelli, 2000).

But the data that overwhelms the importance of any other, arises from the study of the victims of Pompeii. Those who had taken refuge indoors, in the safest areas of the buildings, suffocated. Those who sought escape outside, perhaps driven by the late strong earthquakes, were overwhelmed by the pyroclastic flows. These were located above the layer of pumice, incorporated and covered by the ashes (De Carolis et al., 1998). Therefore, their position indicates that many had survived, for as long as the pumice fell. In Herculaneum over 300 victims were found on the beach, where they sought refuge. Also in this case, whilst elsewhere pumice fell and the sky became increasingly dark, there was still time to get to safety, before the arrival of the torrid ash waves (Giacomelli et al., 2003; Scandone et al., 2020). The errors that led to Pompeian and Herculaneese deaths, in 79 AD, are today a wealth of knowledge that allows us to have a glimpse of the comforting possibility of salvation even in the case of a very violent explosive eruption, provided that the mechanisms and consequences are known and that you know how to react.

An attempt to raise the attention of archaeologist and Public Authorities to the preservation of volcanic deposits as a testimony of the impact of an eruption on the edifices and inhabitants of Pompei, was made by Carlo Doglioni, President of the *Istituto di Geofisica e Vulcanologia* (Corriere del Mezzogiorno, 5 March 2019). It received scarce or no attention at all. The appeal was reiterated by the Italian volcanological community (Corriere del Mezzogiorno 25 May 2019) with similar results. A letter sent to *Nature* (Scandone et al., 2019b) received attention in a local newspaper of Naples and a wider one in the international press but scarce or verging on none from Italian Authorities, that only after repeated appeals conceded minor attention to the matter.

Pompeii and Herculaneum not only remain an example on which current civil protection initiatives should be based, but they exemplify the scarce attention that not only media but also archaeologists pay to the volcanic eruption. The eruption of 79 AD is also the unconscious case of a first rescue attempt, tried in vain by Pliny the Elder. A piece that adds to the already detailed chronicle of this important Vesuvian eruption.

9. The importance of correct information for the education and awareness of the population

There are communications that tend to reassure and others that blame the populations that live around the volcanic areas. Both are wrong information, because the excess of security where the volcanoes are dormant (Vesuvius, Campi Flegrei, Ischia, some Aeolian islands, where only Stromboli is in continuous activity; Figure 15) can cause a fatal drop in attention and an increase in population density up to irrecoverable situations. Blaming individual citizens for the chaotic development of an area that should have been subjected to strict controls by those who are legally put in charge of supervising the territory, is not very reasonable. The Campi Flegrei, perhaps the Italian area with the highest volcanic risk together with the nearby Vesuvius area, has a population living also inside some craters, and its density has increased irreversibly since the end of the 1800s (Figure 16)[8], with the establishment of industrial activities that have proved to be unsuccessful adventures and have crushed any other type of initiative, such as the spa, less invasive and in harmony with the nature of the territory.

Those who live near an active volcano must know how to adapt their needs with the possible risks and must receive precise directives from competent and responsible bodies on the behaviour to be adopted in the case of an eruption.

[8] In 1886, the English firm Amstrong Whitworth & C. inaugurated a plant in Pozzuoli to build naval artillery, active until 1943 and then converted to other productions. Permanently closed after 100 years of activity and many changes of ownership (IRI, SOFER, Breda, Ferrovie). The Ilva Steel factory opened in Bagnoli in 1905, then Italsider, also destined to face a series of crises and temporary rescues since 1911. The activity officially ceased in 1992, but the plant had already been in decline since 1985, two years after an expensive modernisation. In 1914, a torpedo factory was active between Baia and the islet of San Martino, demolished by the bombings of 1943. Initially, the industries brought a secure income to a community of fishermen and farmers. In addition, the large workforce and workers from outside favoured the development of a lively social environment. It seemed like a miracle, but the consequences were disastrous. The industry has left deep scars, both human and environmental, on the Phlegraean territory, still not healed and perhaps incurable.

The population must be informed and continuously updated on the various eruptive mechanisms, the only way to be able to save themselves in the face of an event, even unforeseen, and must also be prepared to face a possible false alarm[9]. Through continuous initiatives, collective awareness must be created, ensuring that people are able to react independently, without expecting miraculous rescues from the outside, avoiding panic situations, as much as possible. Everyone must know that the phenomena that precede the awakening of volcanoes may or may not exist, be too close or too far in time, may be understood or not, local authorities may not be willing or able to take responsibility for mass evacuations in the uncertainty of an event[10].

Permanent education on civil protection must be made not only at all levels of school but also by scientific Institutions such as the University and the *Istituto di Geofisica e Vulcanologia* even if outside their institutional role. Civil Protection Authorities have to increase the knowledge of hazardous phenomena peculiar to each area on a permanent basis since primary schools.

The geological history of each territory contains a treasure of information on events that have guided and influenced human history, sometimes even abruptly.

It is the duty of everyone, especially of those who have the power to inform and instruct, to consciously use every notion, to admit that many fundamental concepts on the phenomena of nature still escape our knowledge, but to work hard to ensure that what is known is transmitted to everyone, as well as possible.

Figure 15. Distribution volcanoes of Italy, active or with age lower than 1 Million years. Modified from Google Earth.

[9] Even today, in Pozzuoli, the controversy over the preventive evacuation of a dilapidated part of the town during a seismic crisis of 1971, not followed, as could have been expected, by an eruption, still drags on. The eviction took place without warning, with methods that today would fortunately not even be conceivable. However, the possible resistance of the population to the evacuation, an intention still declared today, partly justifies the abrupt measure.

[10] Historical examples of serious calamities show that a false alarm is punished more severely, not only in terms of public opinion, than a missed alarm. The excess of prudence, dictated by the limits of human knowledge, has heavier consequences compared to the endless trials without guilty of those who predicted a salvation that proved impossible or underestimated a danger (Scandone and Giacomelli, 2018).

Figure 16. The caldera of Agnano, formed about 4,000 years ago, with the hippodrome, houses and productive activities. This is the area where new vents are likely to open in the case of renewal of volcanic activity in the Phlegraean Fields.

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