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Volcanic Eruption: Case Studies of Italy Country

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Abstract

It is a well-known fact that among all the major natural disasters, earthquakes and volcanic eruptions have a special place because they originate inside the earth. While an earthquake can occur anywhere although there are preferred areas of high seismicity, volcanic eruptions take place through the existing vents in the earth's crust. These vents or volcanoes are known locations although new vents or volcanoes can also take birth by volcanic activity. The mainland of our country has no history of such hazards. There are two minor volcanoes in the Andaman Islands and one of these has been silent for long. Fortunately, India is not much affected. However, other countries like Ethiopia, Italy, Canada, Japan, Mexico, USA, Colombia, Iceland, New Zealand, Indonesia, Philippines, and USSR are among those facing volcanic activity, quite serious at times. It can be stated without fear of contradiction that Italy is the country with a long history of volcanic eruptions, some of which have been notoriously disastrous. Therefore, in this research paper discuss a few case studies with special reference to the famous volcanoes of Italy, like Mount Etna, Mount Vesuvius, Stromboli and Vulcano.

Keywords: volcanic, erupted, lava flow, toxics gases and hot streams

1. Volcanic Eruptions: Case Studies of Italy

Four volcanoes (Mt. Etna, Mt. Vesuvius, Vulcano Island and Stromboli land) have been chosen for case studies in this research because they present some very special features besides having historical importance.

1.1 Mt. Etna and Mt. Vesuvius

There are numerous volcanoes, which go restless every year in one part of the globe or the other. Countries in volcanic zones are more susceptible to volcanic hazards. Italy is one of such countries, where number of volcanoes are found with a very long history of volcanic eruptions. Volcanism of this entire region stretching from Spain to the Caucasus is largely the result of convergence between the Eurasian plate and the African plate with a diverse and complex geology. The principal volcanic centers of the region are due to the subduction under the Greek Islands and Southern Italy. Few of the Famous volcanoes of Italy are Mount Etna, Mount Vesuvius, and islands of Stromboli and Vulcano. The Island of Vulcano takes its name from the considerable volcanic activity that has taken place over the past thousands of years. In ancient mythology, this island was considered to be 'the forge of Efesto', the Greek God of fire, then replaced by Vulcano, the equivalent Roman God. As time passed, the term volcano was applied to all the world's mountains emitting ''Fire and Smoke''. This term changed to

"Volcano" over the period of time. Vulcano, Stromboli and Etna were the only volcanoes known to ancient Greeks and Romans, till the year A.D. 79, when Vesuvius erupted and buried two cities.

1.2 Mount Etna

A shield volcano of 3350-metre height in northeastern part of the island of Sicily. This volcano is Italy's highest and most voluminous, which has the world's longest documented record of volcanism. Etna has erupted lava flow innumerable tines since activity was first reported in 1500 B.C. Two styles of eruptive activity occur at Etna. Persistent explosive eruptions, sometimes with minor lava eruptions, take place from one or more of the three prominent summit craters the central crater, northeast crater and southeast crater. Flank vents, typically with higher effusion rates, produce eruptions from fissures that open progressively downwards from near the summit. The last eruption at Etna was in 1996.

Due to high volcanic activity at Etna, a sophisticated monitoring network is used to detect any precursory signs of volcanic activity. The monitoring network at Mount Etna presently consists of 12 seismic and 9 ti1t stations. Both short period and broadband seismometers are operated on the volcano slopes from about 400 m up to 3000 in elevation a.s.1. (above sea level). Shallow borehole biaxial tilt-meters with 0.1 to 0.01 microrads sensibility are located on the volcano flanks between 1400 m and 2800 m a.s.1. Tilt stations are equipped with data loggers and solid-state memories to sample data and to prevent their loss in case of telemetering system fault instrument readings are spaced half an hour, but sampling frequency can be remotely modified.

1.3 Mount Vesuvius: Somma

Vesuvius volcanic complex is of 1281-meter height, a stratovolcano east of Naples on mainland Italy. Mount Vesuvius is most famous for its A.D. 79 eruption that buried the ancient cities of Pompeii and Herculaneum. The volcano has erupted more than fifty times in its life span. The volcanic eruptions are characterized by explosive eruptions followed by lava flows. Last eruption on this volcano was in 1944; since then, the volcanic activity is restricted to moderate seismicity and intra – crater fumarolic activity. On August 24 A.D. 79, the Vesuvius volcano suddenly exploded and buried the cities of Pompeii and Herculaneum. Before the eruption, volcano was considered extinct as it had been quiet for centuries. However, signs of activation of the volcano emanated through a series of earthquakes in A.D. 63. Yet an eruption on this volcano was unexpected. Air fall ash followed by pyroclastic flows buried the cities thoroughly until they were rediscovered in 1709. As we now know, the most destructive volcanic eruptions are those that generate pyroclastic flows, avalanches and lahars. Due to these phenomena, along with ash fall, about 2000 people were killed in Pompeii alone, about 10 kilometers away from Mount Vesuvius in AD 79.

1.4 Vulcano and Stromboli

Southern Italy (near Sicily), is one of the most active volcanic belts in the world. This archipelago comprises seven islands and is the upper portion of a large volcanic complex, most of which lies under the sea. It is about 200 km long in the Tyrrhenian Sea. This area is a subduction zone, where African Plate slides beneath the European Plate, producing the volcanic arc of Aeolian Islands and forming a very active seismic zone. The upper portion of the eruptive complex formed in the last million years, while underwater portion dates back even more. The oldest among these islands is the island of Sisifo, which is 1-3 million years old. At least three volcanic islands of Lipari, Vulcano and Stromboli are still active in this archipelago. The last big eruption on Lipari dates back to the year 729 AD; on Vulcano to 1880-1890; while Stromboli has been uninterruptedly active for the last 2000 years.

1.5 Vulcano Island

Vulcano is one of the islands in the Aeolian archipelago with an area of 22 sq. km. It is entirely made of volcanic rocks and has a maximum height of about 500 m above sea level. The' island represents only a small part of a large volcanic edifice that extends under the sea down to 1 **km.** depth. The Vulcano Island has an active cone, which is 391 m high a.s.1. with a base diameter of 1 km. The eruption history of the volcano constitutes a high level of risk in the region. This situation is becoming more serious as population continues to grow near Vulcano. This Island has experienced great development of tourism activity in recent years. To cater to the enhanced need of the tourism sector, number of buildings have been constructed at the very foot of the eruptive cone.

Recent eruptions on the island took place at two well-defined volcanic edifices, "Vulcanello" and "**La** Fossa" in the northern part of the island. The volcanic products that form these structures mainly consist of pyro clasts, with less volume of lava flows. At present, volcanic activity is restricted to fumaroles degassing, mainly at 'La Fossa', with maximum temperature ranging between 200-300°C. Significant temperature increases have been observed occasionally during historical times t I (61 5OC in 1924 and 700°C in the 1990s). At present, the temperature is almost constant in the range of 500°C. The gases emitted from the fumaroles consist mainly of water vapour and then in order of abundance, of **CO,** SO, CO, H, S, HC1 and HF.

The island is made up of five main volcanic structures, namely:

Primordial Volcano -formed between 120,000–100,000 years ago

- Piano Caldera
- Lentia
- La Fossa Caldera
- Vulcanello – still active part of the island

1.6 History of Eruption of Vulcano

The 'La Fossa' cone of the Vulcano Island is the most active part of this island. Five eruptive cycles Kave been described in its activities; the most recent includes the last major eruption in 1880-90. These eruptive cycles show a characteristic transition from phreatomagmatic to magnetic activities, often ending with the emplacement of a viscous mixed lava flow. Based on the historical evidence of eruption cycles, it may be assumed that each cycle began with the formation of a new explosion crater coupled with the construction of a tuff cone. The degree of water melt interaction within each cycle has decreased with time. The cycles began with surge deposits and ended with pumice fall or lava flows.

Assuming that future activities at the 'La Fossa' vent will be similar to its past activities, a few tentative predictions can be made like:

- The repose period prior to the start of a new cycle could be at least a few hundred years.
- The location of the new vent should be to the west (or north) of the present.
- The next central eruption should begin with a new cycle of activity by forming a new crater and tuff ring.

Volcanic Hazards Faced **by Vulcano** Island

The 'La Fossa' cone of the island has shown considerable signs of activation during the last **many** years. The future activities at this cone could produce several types of phenomena, which may cause danger to the local people and tourists on the volcano. Various hazards on the island are listed below:

- **A** few periods of intense fumarolic activity have occurred since the 1888-90 eruption. Toxics gases and hot streams may be dangerous for tourists hiking to the crater. High concentration of gases may also be harmful to the tourists on the beaches.
- Lava flow presents little risk except on steep slopes, where blocks could fall from the margins of flow.
- Ash fall deposits present a moderate risk. Ash could be highly dangerous to livestock and machinery.
- Ejection of large bombs, as ejected during last eruption, are very dangerous; these bombs may be ejected with very high power. **A** bomb of approximately (-) 500cm. diameter may go up to 600 m and a bomb of 15 cm may go up to 1100 m from the vent.
- Dry surges (of pyroclasts / tephra) are common in all cycles on the **'La** Fossa'. Their propagation is strongly controlled by topography and poses a greater hazard to the settlements.
- Rock fall / landslides triggered due to earthquakes or eruption phenomenon could harm the locals **and** tourists visiting the crater rim**.**

1.7 Island of Stromboli

The island of Stromboli is the small upper part of a great volcanic edifice. The surface area of the island is about 12.5km² which is 25 times smaller than the undersea base area of the entire volcano. The maximum height on the Island is 924m a.s.l. The main island of Stromboli was formed in different phases, each marked **by** progressive migration towards northwest of the eruption center and characterized by the alternating emissions of lava flows and explosive products. The volcanic activity on the island consists of a continuous emission of gas

and frequent explosions with jets of hot gas up into the atmosphere and fragments of glowing lava and solid blocks of the conduit walls. This typical phenomenon is unique and has earned the name of Strombolian type. This activity has been going on for the last 2000 years. The brightness of the explosions, which is visible from great distance in the sea, has earned another name for the volcano, as, the 'Lighthouse of the Mediterranean Sea'. The explosions occur from various vents located within the crater. The jet speed varies from 20-120 m/s and the height varies from 100-200m and average frequency of an eruption is 10-20 minutes. The volcano was rather inactive for 2 years during 1908-1910.

The ongoing activity of this volcano is accompanied, sometimes, by major eruptions as well. In such events violent explosions accompanied by lava flow activity take place.

Major explosions occur on an average twice a year They can occur without any specific precursory sign. In such events, jets may go up to 500 m high and debris may fall within arrange of several hundred metres. In major explosions, lava flow events take place on an average, once every year. The lava flow on the island however does not pose any threat to habitation.

2. Monitoring of Volcanic Activities

The volcanic activities of these volcanic islands are monitored on a regular basis. In recent years, research has been directed towards volcanic surveillance particularly geophysical monitoring. Geophysical monitoring of all the Islands in the region is carried out by the International Institute of Volcanology, Cataria, Italy, within the framework of the activities supported and coordinated by the National Group of Volcanology of the National Research Council of Italy.

On these islands, a seismic network of eight seismic stations equipped with both short period and broadband seismometers operates. The maximum concentration of the stations is on the Vulcano island. The data from these stations is telemetered to an observatory on the island of Lipari and recorded on both paper and magnetic tapes. Geophysical monitoring in the area is being carried out both by discrete and continuous measurements of the ground deformations. **A** geodimeter trilateration network was designed for the area in 1975. This network covers parts of Lipari Island and the whole of the Vulcano island. The network consists of 13 benchmarks and 37 lines and is usually measured twice a year. Continuous recording bore hole tilt stations (three each on Vulcano and Stromboli islands) are also providing digital data which is telemetered to the central observatory at Lipari and recorded on magnetic tapes.

Geodimetric surveys, carried out in mid-seventies, had shown that Lipari-Vulcano area has undergone ground deformations, particularly horizontal movements. Similar results were observed through this network in 1996 as well. During 1996, a new phase of volcanic activity was characterized by a significant increase in the gas/ steam ratio and CO, concentration. Around the same time, remarkable variations in temperature and chemical composition were recorded in one of the observation wells. Following a maximum temperature of 700°C in 1993, the temperature of the fumaroles inside the crater has shown a general decrease, reaching a temperature of 400°C in 1996:

The chemical and isotopic changes in the fumarolic gases, together with their spatial and temporal correlation, suggest an input from deep feeding, which may lead to an eruption on the Island in future.

In 1930, about 6 people died and 24 wounded, besides huge economic losses due to an explosion **017** the island of Stromboli. The great explosion with great energy affected residential areas with the fallout of lava fragments, blocks, ash and gas clouds with lava fragments in the form of glowing E avalanches. This event along with a tsunami (about 30 m high), due to a seaquake, had an adverse effect on the island in terms of depopulation

3. Forecasting of Volcanic Eruptions

Volcanology research helps in forecasting an eruption, anticipating the time of eruption and probable damage pattern regarding habitation etc. The volcanic risk due to a volcano depends upon various factors like the characteristics of the volcano and the pattern of habitation around the volcano. Past activities of the volcano are quite helpful in determining the eruption characteristics and associated risk levels. Monitoring of the volcanoes described in the previous section is a complex phenomenon involving observation of the physical, chemical

and geological characteristics of the volcanoes. In case of reactivation of volcano, magma, rising to the surface produces following effects:

- Uplift of the volcanic edifice
- Increase in seismic activity
- Gravimetric, magnetic and electric anomalies
- Changes in temperature and chemical composition of water in wells, springs 2nd water vapour in fumaroles.

All these precursors are carefully observed and monitored on a regular basis, which **may** enable forecasting of an eruption. Therefore, surveillance is essential. Following methods are very commonly used for geo-chemical and geo-physical surveillance.

3.1 Geochemical Surveillance

On an active volcano, the following geo-chemical surveillance is curried out on a regular basis:

- The most active vents in the fumarolic fields are sampled in routine. The temperature and piezometric level of aquifers are continuously monitored with digital hydrometers in wells.
- Gas species determinations (He, Hz, N, 0, CH_4, *CO,* CO_2, H_2S, SO, CI, F1, and H_2O) and isotopic analyses (mainly C and He) are regularly carried out by gas-chromatography and mass spectrometry.
- Gas flux measurements in soils are carried out.

3.2 Geophysical Surveillance

Geophysical surveillance provides an effective input for forecasting of an eruption. Various methods used for this purpose in Italy are:

i) **Ground deformations**

- Levelling network
- Trilateration network
- GPS network
- Tiltmetric network
- Tide gauges network
- Gravimetric network

Seismology (Earthquake Activity)

It is difficult to predict an eruption in a continuously active volcano like Stromboli. However, to build up data base for research, various equipment to monitor different precursory phenomena are placed on the Stromboli and are regularly observed.

3.3 Hazard Prevention and Mitigation Efforts on the Islands

In recent years many advances have been made in the study of volcanoes, particularly in eruption prediction. The problem with volcanoes is that, though there may be similarity between volcanoes, every volcano behaves differently and has its own sets of hazards. Therefore, it is important to study and monitor volcanoes. Although the more famous or more active volcanoes are regularly monitored, many active volcanoes near populated areas have not been sufficiently studied to assess risk(s).

When scientists study volcanoes, they]nap past volcanic deposits and use satellites to look at volcanic features, ash clouds and gas emissions. They also monitor seismic activity, ground deformation, and geomagnetic, gravimetric, gravimetric, and geothermal changes at or near. a volcano. They study and monitor volcanic gases arid monitor temperature, flow rates, sediments transport and water level of streams and lakes near the volcano.

By studying the volcanic deposits, scientists produce hazard maps, these maps indicate the types of hazards that can be expected in a given area. Dating of these volcano deposits helps to determine the frequency of and probability of an eruption each year. Monitoring of a volcano, over a long period of time, could indicate changes in the volcano before it erupts. These changes can help in predicting when an eruption may occur. Despite all the advances in volcano prediction and risk assessment, volcanoes are erupting and causing much damage to life and property on almost regular basis. To prevent the future losses due to various hazards associated with a volcano, further research is needed. Some of the important research areas may include, structure and dynamics of volcanoes, eruptive mechanisms, eruption history, genesis and evolution of magma, modeling of volcanic eruptions, volcanic hazard mapping, and history of volcanology of the region.

4. Governmental Efforts and Response

Based on the description of the two volcano islands in the previous sections, it is clear that a definite volcanic risk exists on the islands of Vulcano and Stromboli. To take care of the

hazards existing on these islands, the Civil Protection Department, Government of Italy, has established the following facilities:

- Volcano observatories

- Emergency Centre (gas masks and other emergency equipment are available)

- Medical facilities

Both the islands have a risk mitigation plan. According to their plan, a mock drill is carried out every ten years. On the basis of experience and research it has been suggested that there are certain pockets on Vulcano island, which are more vulnerable than the other areas, and require more attention. To achieve this objective, it has been recommended that:

- Public participation has to be enhanced to make the risk mitigation plans successful.

- Building guidelines and better land use controls must be applied on the islands to reduce the structural, economic and environmental vulnerabilities.

Mock drills may be organized more frequently than at present.

- Awareness campaigns are the key for successful mitigation programmes. Tourists and natives of these islands must be made aware of the risks and precautions on a regular basis.

Volcanoes have a beneficial aspect also as they produce fertile soil and provide valuable minerals, water reservoirs, geothermal resources and attract tourism. But volcanoes can be very dangerous as well.

5. Conclusion

Volcanic hazards pose great danger to the human beings and infrastructure as complete cities have been totally destroyed in the past, e.g., Pompeii and Herculaneum, which were completely buried under the pyroclastic flows and ashes emanating from the nearby volcanoes. In the recent times, it has become somewhat possible to forecast an eruption and make necessary evacuations. This has been possible due to recent scientific advances and use of sophisticated equipment. Regular monitoring, forecasting and awareness generating efforts are necessary to reduce the impact of Volcanoes.

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