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From Regio IX, Pompeii to Pinatubo Volcano Observatory

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Volcanoes are a force of nature that remind us of the primitive stages of Earth's formation and the ongoing evolution of our planet. Recent excavation at Regio IX of Pompeii show that a strong earthquake occurred just before the 79 CE eruption, causing the first fatalities. Soon after, presence of hot ash clouds very high in the horizon prompted Pliny the Elder to set sail and rescue people nearer the eruption.

Predicting volcanic eruptions remains an onerous, complex and uncertain task because pre-eruptive paths remain difficult to decipher. Understanding each volcano and seeking the evidence, seismological and otherwise, known to proceed eruptions, is a demanding task but one that scientists can use to mitigate disasters. In the largest eruption in the last 100 yr century, scientists of the Pinatubo Volcano Observatory, in June 1991, had to monitor the volcanic unrest with transportable equipment flown around the world to the Philippines, with only a few seismic stations recording on drum recorders and limited helicopter time. Nowadays, data sharing and machine-learning analytical capabilities make it possible to track seismic-volcanic crises in unprecedented detail with high-resolution images of the Earth system. But still more data assimilation and deeper understanding of earth processes around volcanoes is required before advance warnings can be provided. How far have we progressed from the Plinian 79 AD to the ultra-Plinian 1991 eruption, and what are our challenges and hopes for the future?

Studying a volcano has to be a multidisciplinary endeavour, including such tasks as Distributed Acoustic Sensing (DAS) seismology, machine-learning based earthquake detection (including volcanic tremor and long-period signals), analysing gases released, tectonic geomorphology to trace past eruptions, geomagnetism to understand placement of pyroclastic flows and geodetic observations and satellite imagery to monitor deformation and plume heights. For submarine volcanoes the list grows to include, tsunami run ups, marine geophysics and seismology and tide-gauge monitoring. Analysis might include time-lapse tomography and gravity measurements to track the evolution of magma chambers and discovering new evidence by reanalysis of past data with more powerful techniques.

We at GJI, devote our recently announced special issue, *Seismic Crises in Volcanoes*, to the scientists responsible for the collective progress we have made in understanding this fierce power of nature. We are honoured to welcome as a Guest Editor, Dr Stephanie Prejean, from the Volcano Disaster Assistance Programme (VDAP) of the US Geological Survey. In our community, the excellent and sometimes perilous, work of the VDAP team has shaped scientific progress, and helped populations at risk. In this special issue, we invite geophysical research contributions covering all disciplines to expose how powerful data stacking will become to evaluate and mitigate future catastrophes. We also invite related data sharing in the form of *Data Notes* articles and *Viewpoint* articles that provide stories from the field and/or testimonies for how to communicate science to disaster mitigation personnel in times of crises.

In preparing this editorial, I had the chance to chat with a dear friend and one of the scientists on the ground in the hot summer of 1991 during the Pinatubo volcanic eruption, Professor of Kyoto University, Jim Mori (JM), who started by saying that 'Pinatubo was actually very cooperative'.

'The earthquakes started in April, and they ramped up really quickly. The eruption was in June, so there were three months in between. It just took off. The US Geological Survey (USGS) team arrived early on, monitored the volcano because there were no seismic stations before, and got everyone out. But most other places where you have these early earthquakes, and then seismicity and deformation go away, and it dies off. And then, all of a sudden, it erupts. So, it is really, really hard to predict (a volcanic eruption).'

MS: What was the scientific response in the first days of the volcanic seismicity back in April?

JM: 'Philvocs (the Philippines National Institute for Monitoring Earthquakes, Volcanoes and Tsunamis) had some stations out there. The volcano was close to the Clark Air Base and that is how US Geological Survey got involved, sending out people within the month. In the beginning, there were a few swarms of low-magnitude earthquakes and then, at the end of May things just picked up. They just ramped up so fast (in terms of) the numbers and earthquake magnitudes. A few low-frequency events (were detected). Not a whole lot but the seismicity increased, steam was coming out, you would say that was (almost) erupting already.

MS: How did scientists manage back then to have a close eye on the volcano?

JM: They (USGS) had helicopter trips every day to check it out. Some volcanoes you wait for decades and still they have not erupted. In the 80 s, we had an eye on Long Valley, which had not erupted yet, the Campi Flegrei and Rabaul. It took ten years—for Rabaul to erupt; the main chamber there was about at 4–5 km depth and the seismic activity was above it. It is just a complicated process. When things are moving it is clear, the magma is moving creating a lot of pressure, a lot of earthquakes, a lot of deformation. And then it is probably just sort of hit or miss, if it finds an easy path to get to the surface or not.

MS: How certain scientists were for the impending eruption?

JM: People (fellow scientists) expected the eruption, and the really good thing was we did not have these long periods of sitting around waiting for something to happen which is very typical for the Unzen volcano in Japan. Often in places, crises go for years and people get tired thinking 'maybe this is not going to erupt'.

Jim recalls the experience of flying in the day just in time to witness the big plume in the early hours of the day, '3–4 times that morning and early afternoon, the drums (pens) started going faster and clipping more often. In about 30 min later, the ash was blowing over from the volcano to the base, which was 20 km away from the volcano. Then things started to really get exciting'. Following a large eruption, 'the closest seismic station went dead, and around 10 min after that another one, and another one.' 'So we had no instruments, the ash was pretty much constant, and it was pitch black outside'. 'After 1–2 hr we decided to leave.'

Jim remembers vividly the sound of pumice falling on the tin roofs making speaking to each other impossible and the grey, fine-grain ash that covered just about everything while they were evacuating. 'A really low roar was coming from the background as well.'

Perhaps the last detail of my discussion with Prof. Mori that struck my mind is that a few weeks after the eruption, the team of scientists started reinstrumenting the volcano. 'There were tons of earthquakes after the eruption that looked completely different, and they were in completely different places. They were much deeper—10 to 15 km deep. We were 30–40 km away at the evacuation site, but we could still feel them'. In the months after the Pinatubo eruption, floods were also a cause of concern since 'ashes filled up the river valleys'. If anything, his story illustrates the complexity of volcanic environments and the multihazard, multirisk scene of those natural disasters.

Past experiences, such as the one above, have surely influenced and will continue to shape how we plan instrumentation and where analysis should focus when dealing with volcanic crises but also how we communicate our findings to cross-disciplinary scientists and to non-experts. In a few words, it prepares the scientific community for what *Science* does best, and that is explaining *What is happening*, while fostering a safer society.

Dr Margarita Segou, *GJI* Editor-in Chief