La Soufrière, volcanology and forecasting

Last year Haroun Tazieff, of the Laboratoire de Volcanologie, Centre de Faibles Radioactivitiés, Gif-sur-Yvette, France, had to leave his post as director of the Service Volcanologique at the Institute of Physics of the Globe over the eruption of La Soufrière. Below, his account of the problems

IN THE past six years at least four erroneous volcanological diagnoses, based either on wrong interpretations of actual facts or on deliberately false data, have induced governmental authorities in four countries to take unnecessary and expensive measures. Together they show that volcanologists may sometimes be confronted with quite serious socio-economic consequences of their own forecasts.

● The first case was in 1970 in Italy's Neapolitan area. A submarine eruption was claimed to have burst out offshore of the city of Pozzuoli, approximately 2 km west of the well-known Solfatara fumarolic field. After the mass-media told of possible explosions, ash-falls and sea-waves, the Army and the *carabinieri* (police) helped the frightened population to evacuate the city. The claimed symptoms were an upheaval of the ground in the whole area, which had been pushed up about one metre in a "very short while"; extremely shallow earthquakes, located 1 to 2 km offshore; a conspicuous temperature-rise of the Solfatara's fumaroles; and the outflow of hot fluids on the bay's floor, inferred from dead boiled fish fishermen took in their nets.

The last three items were subsequently proved totally false by a team of six scientists led by myself, and I disclosed the fact at a press conference. On the other hand, the upheaval, the so-called brady-seism of Pozzuoli, had not been faster than usually noticed over the centuries during which up-and-down level variations of that peculiar area had been classically observed. Eventually it was stated that deliberately wrong data had been produced by the scientist in charge of the geophysical institute of Naples. This was connected to a construction operation in which high-rank people were involved. The evacuation of the inhabitants was proved to be expensive and useless.

● The second case happened during the 1972 eruption of St Vincent's Soufrière in the West Indies. Notwithstanding the clearly expressed and reassuring opinion of Dr J. Tomblin, the volcanologist in charge, an alarming cable from a scientist some thousand kilometres away was taken into consideration. This 'televolcanologist' had deduced his frightening conclusions from earth-satellite imagery and the whole population was consequently moved away. Here too it proved both expensive and useless.

● The third case happened in 1973 during the last days of the Heimaey eruption. Persuaded by a somewhat inexperienced foreign volcanologist, Icelandic authorities agreed to use fire-boats to sprinkle water on a tongue of the thick lava flows which over several weeks had progressed at a distressing speed towards the harbour entrance. No arguments could prevent the exercise: not even the evidence that the Atlantic ocean itself, with all its water, had not been able to stop the main part of the flows which had crawled over the sea-floor for two months.

● The fourth error occurred in 1976 during the eruption of La Soufrière in Guadelope in the West Indies. Here too, in spite of the firm statement of the volcanologist in charge that no danger lay ahead, the authorities followed the alarmist opinion expressed first by a petrographer and then by a geochemist, both of whom lacked experience of eruptive phenomena. Consequently 73,600 people were evacuated on 16 August and were kept away from their homes and jobs for $3\frac{1}{2}$ months. It proved very expensive, dramatic for the population, and totally useless.

A volcanologist is actually as responsible for his diagnoses as is a physician—even more so, because of the number of people involved and because the costs are usually far bigger. This implies that some sort of deontological code, similar to the medical one, should exist for practising volcanologists, and that illegal practice should be prohibited in this field just as it is for medicine. Whatever their field, scientists cannot remain detached from the eventual effects of their work on the everyday life of other people.

The easiest course for the authorities is naturally to choose, amongst various scientific counsels, the most pessimistic if not necessarily the best one. Their responsibility is then shielded against the worst, and if the catastrophe eventually does not occur the only reproaches they suffer are minor ones that are swiftly forgotten. To express a volcanological forecast is always an awkward business. Like civil administrators, many a volcanologist will naturally tend to be pessimistic rather than optimistic, if only to avoid exposing people to some danger he would have disregarded; he would want to avoid being accused if his own optimistic forecast proved unfounded. Though understandable enough, such an attitude is not in accord with the deontology code; a deliberately pessimistic physician is not necessarily considered a good medical doctor.

But some points seem clear. First of all, no volcanologist should state any opinion if his knowledge of eruptive phenomena is below a minimum level. Secondly, the consultant volcanologist should express his scientific opinion without altering it in either an optimistic or pessimistic way. An honest volcanologist, whatever his experience, all too frequently will not be able to describe much more than his incapacity to tell what will follow next. Nevertheless, a valuable forecast is sometimes possible and our own experience shows examples of it.

It actually happened in 1976 at the Guadelope Soufrière, when a rather unusually flat and valid conclusion seemed evident to any experienced volcanologist: absolutely no risk existed that the volcanic event which the whole Caribbean population most feared—*nuées ardentes* (glowing avalanches) of the Mt Pelée type—could happen at all in the near future. I delivered this view, while several other scientists claimed the opposite. But it was obvious that the eruptive events, which were started during the autumn of 1975 by a volcano-seismic crisis, had then passed to phreatic kinds of outbursts in which no fresh magma at all was involved, and would not develop into *nuées ardentes*. The French government nevertheless chose not to listen to this plain argument, asked geologists unskilled in volcanology and proceeded to evacuate the entire population of 73,600 people. The whole issue developed in phases.

● The seismic activity of the volcano started in October 1975 when the seismographic array of the Soufrière Observatory began recording swarms of microearthquakes. For several months, these swarms increased in both number and intensity; the first felt earthquake occurred in late March 1976. At this point several scientists expressed anxiety, more because of the high number of recorded microearthquakes than because of their actual energy. None amongst them had any experience in eruptive phenomena.

The opposite opinion was based upon the two following facts. First, far more frightening volcano-seismic crises had previously been observed in the Carribean, and many more still in Japan, where the most earnest attempts in the world have been made in volcanological forecasting. At the Omuro volcano in 1930, for example, 4,880 shocks located between 2–7 km below the surface were recorded in less than three months; at the Hakone volcano in 1959–60, the foci of the recorded earthquakes were located 0.8–5 km below the surface, but on the basis of the complete lack of any B-type earthquake shallower than 0.8, Minamaki predicted that no volcanic eruption would happen and he was right. In the Carribean, two volcano-seismic crises occurred at Montserrat island in 1897–98 and 1933–36, and are well know to volcanologists; neither of these well-studied crises finished with volcanic eruption. It therefore made sense not to be unduly alarmed by the 1976 seismic events of the Soufrière.

Secondly, the focal depths of the earthquakes during the Soufrière crisis were located at 2–6 km, depths quite similar to those which had characterised the Hakone and the Omuro crises. This meant that many months, or more probably years, should be necessary for the Soufrière viscous magma to reach the surface, for any magma is supposed to be far slower than its own lavas, and all the Soufrière lavas had obviously been comparatively viscous and slow. Experience has shown that most frequently the average speed of lava flows of the same kind as those of the Soufrière varies between less than 1 and about 100 cm h^{-1}. From a spot located below 6 km down, the corresponding feeding magma should therefore require several years to reach the surface. If any factors had been overlooked, or if the magma velocity would drastically increase, several months seemed a minimum for it actually to become eruptive. Consequently one could quite confidently speak of a period of several weeks, at least, before the start of any magmatic event.

To the objection that a body of molten (and therefore not seismical) magma could be stored *above* the uppermost foci, that is, between the surface and the 2 km depth —meaning that a hypothetical reservoir was located within the 1,400 m thick volcanic heap itself—the answer was that both the temperatures measured close by in the geothermal field of Bouillante (70 °C near the surface and 240 °C 350 m down) and the gas composition of the Soufrière fumaroles (in vol % : CO_2, 90–93%; H_2S, 0.6–1%; CH_4, 0.5%; H_2, 0.5–1.2%) proved such a hypothesis to be quite improbable.

● On 8 July 1976 the eruption started its second, actually eruptive, phase when so-called 'ash' outbursts were superimposed on the almost continuously increasing volcano-seismic activity. This second phase lasted eight months, during which 20 phreatic eruptions occurred, the last one on 1 March 1977. Each outburst lasted only a few minutes (less than 20) and expelled steam and water droplets mixed with some volcanic gases laden with ejecta. These ejecta, 'ashes', sands and blocks, were exclusively composed of old rock material, with no trace of any fresh magmatic material. The first of these phreatic eruptions started noiselessly and propelled a dark mushroom hundreds of metres above the top of the mountain. This plume was then driven south-westwards by the wind. From the volcano windwards, the sky became totally dark, and a thick rain of small lapilli and dust started, which lasted for about 20 minutes. Several thousand people fled as soon as the darkness cleared up.

The scientists called by the authorities were divided. Some of them felt afraid, firstly because they feared that these 'ash explosions' could lead either to *nuées ardentes* or to mud-flows, or both. The opposite opinion was that these risks did not exist because this eruption obviously belonged to the phreatic kind: gas analyses, measured steam temperatures, as well as examination of ejecta showed that no fresh hot magma or lava were involved and that, consequently, no *nuées ardentes* could be expected. On the other hand, as in phreatic eruptions, the very first outburst usually is the strongest one, and as the 8 July one had generated only a small mud-flow, it was to be supposed that further lava hazards would be minor. In spite of an apparent tendency to prefer pessimistic diagnosis to reassuring ones, the government authorities were consequently prevented from evacuating people.

The second phreatic outburst occurred on 24 July. Asked by the *prefet* and having obtained the data from and opinion of my collaborators, now permanently monitoring the fluid and solid exhaltation of the volcano, I concluded that there was no more danger ahead than two weeks before.

● The third outburst happened on 9 August. I was in the Ecuadorian Andes involved in a volcanological expedition with two of my collaborators, but our three colleagues were still on La Soufrière, mainly to monitor the chemical and physical evolution of the gas phase, which may be considered as a good indicator of the eruptive volution itself. These skilled volcanologists declared that no threatening change was to be feared in the eruptive events. This was because of the following facts: first, the gas composition had not changed. The proportion of CO to CO_2 was about 10^{-3}–10^{-4}, and of H_2S to SO_2 was about 10; in addition, the focal depth of the earthquake had not moved, no trace of any magmatic activity was detectable anywhere, either in the erupting area or on the lower slopes of the volcano, and old rocky material *exclusively* was to be found around the eruptive vents.

Disregarding these volcanologists' opinions, the civil authorities nevertheless called from France two geologists without any experience in the field of eruptive activity. The first decided to have the whole population immediately evacuated; the second decided to enforce the precautions and maintain them for several months on.

Their diagnoses were based, first, on the assumption that the seismo-volcanic crisis—up to 1,257 shocks, half a dozen of which had been slightly felt, in one day—had reached such a climax that nothing but a catastrophe could proceed, and secondly on the claimed presence of fresh volcanic glass in the erupted 'ashes', the meaning of which was the imminence of *nuées ardentes*. Professor C. Allègre, on 5 September 1976, produced an official report in which he stated that 50–60% of fresh volcanic glass was present in the erupted ash. He was later compelled to admit that actually no trace of fresh material had ever been detected.

According to *Le Guern* (in press) the twenty outbursts which occurred between the first (8 July 1976) and the last one (1 March 1977), as well as the more or less continuous emission observed at the active vents throughout the same period, have poured out a total output of the order of 6–10×10^6 tons of steam and 1.5–2×10^6 tons of 'ashes' and blocks. According to the same author, a surface less than 1 km long and 300 m wide received a total 'ash' fall 300 m thick for the whole nine-months-long event. The closest town, Matouba, some 3.5 km west (windwards) from the craters, got a total 'ash' fall of 5–15 mm according to the spots. The closest city, St-Claude, 4.5 km west-south-west from the erupting vents, got a total 2–5 mm thickness of 'ash'. The longest mud-flow, which resulted from the first ran eastwards over less than 3 km.

These figures show how modest was the scale of this eruption. The above mentioned criteria and their interpretation explain how our so-called 'optimistic' diagnosis had been attained. The main lesson of this unfortunate experience is perhaps to confirm the absolute necessity for a good volcanological interpretation of all the available, geological, geophysical, chemical and phenomenological data before expressing any forecast. Volcanologists, just as medical doctors, should be responsible, skilled, experienced, different specialists closely co-operating with each other. And they should keep as cool as a cucumber. □