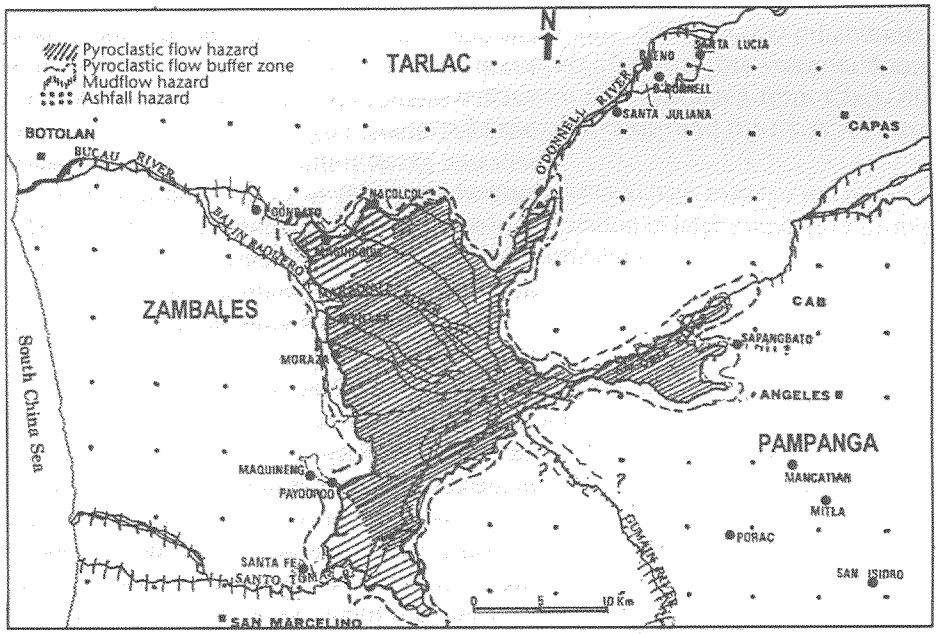
what we thought was a composite worst case scenario, based on the geologic record. These were completed on 23 May 1991 and immediately disseminated to local government officials of the provinces at risk, namely: Zambales, Pampanga and Tarlac. Events were soon to mimic the hazard zone maps for pyroclastic flows and lahars (Figure 2). However, the aggravating effect of typhoon Yunya was not anticipated and reflected in the hazard zone map for ashfalls. We also later found out that worse eruptions had occurred at Pinatubo more than 35 000 years ago. Had the 1991 eruption been as large as that of more than 35 000 years ago, our hastily prepared hazard zone maps would not have held and tens of thousands of people would have died We were just lucky. We shall have to do better in future by doing the baseline geologic and hazard mapping of all active volcanoes long before they become restive.

Zones for evacuation based on the hazard maps were designated as danger zones and were delineated as circular zones of increasing radius centred on the volcano. As mentioned earlier, as early as 7 April, a ten-km radius danger zone was declared, centred on the volcano's active vent This danger zone was to be expanded later as the danger escalated.



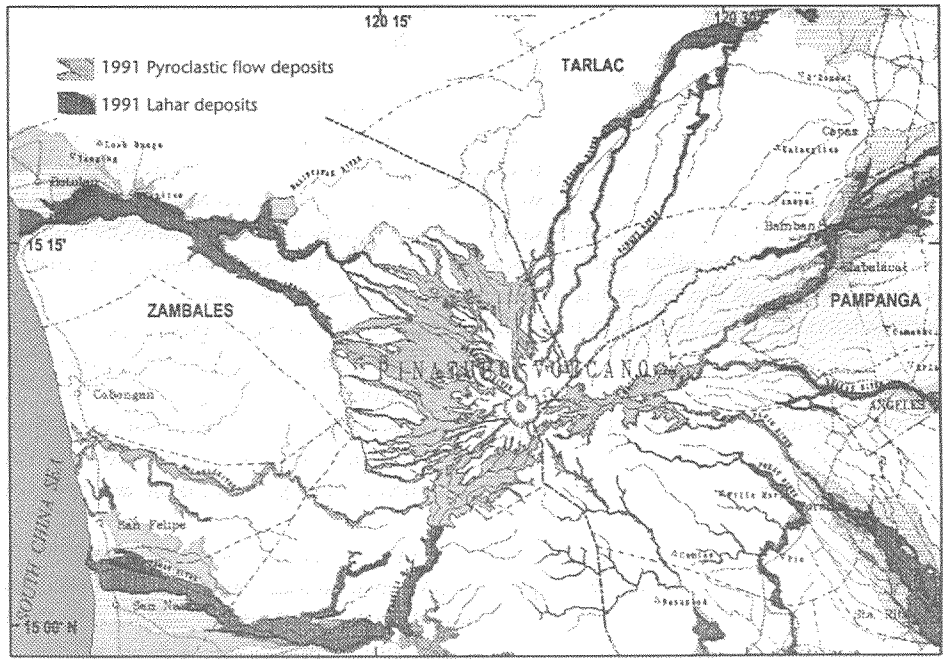


Figure 2. Above: Pinatubo volcano preliminary hazard map issued on 23 May 1991 and showing areas that may be affected by pyroclastic flows, lahars and ashfall. Below: Map showing areas covered with pyroclastic flow and lahar deposits after the major eruptions of Pinatubo Volcano in June 1991.

Having devised several ways of expressing the warning messages, our next problem was how to make the concerned officials, community leaders and endangered inhabitants appreciate the dangers they faced — at least to the extent that they could take appropriate defence or protective actions. How could we explain to them the hazards, the need for action as well as the uncertainties in our warnings with possibilities for both false alarms and unpredicted eruptions?

Nagging at us was the tragedy of Nevado del Ruiz in 1985 where 22 000 people died as a result of the failure of key officials to heed and act on the hazard assessments and warnings of the scientists (Hall, 1990; Voight, 1990). We were determined that such a tragedy would not be repeated but we were faced with a similar problem. The people at risk and their leaders were understandably sceptical as most of them had never heard or witnessed an eruption, Pinatubo had been dormant throughout their and their grandfathers' lifetime, and such terms as pyroclastic flows, ashfalls and lahars were new to them. So we launched an aggressive and intensive education campaign, first among the concerned civil defence officials, then among the endangered inhabitants.

We took advantage of briefing sessions for government officials. We found that we could catch audience attention most effectively by showing the video entitled *Understanding Volcanic Hazards* produced by the late Maurice and Katia Krafft for the International Association on Volcanology and Chemistry of the Earth's Interior (IAVCEI). The video shows dramatic examples of hot ash flows, ashfalls, lahars, large volcanic landslides, volcanogenic tsunami, lava flows and volcanic gases. It illustrates the nature of each hazard, how fast and far it travels and what it does to people and objects on its path. For maximum impact, we showed only the segments on ash flows, ashfall and lahars during each briefing session to retain the attention of government officials and because these were the major hazards that Pinatubo may unleash when it erupts.

We showed the video to as many audiences as we could reach — the then President of the Republic, Corazon C. Aquino, the then Secretary of defence and Chairman of the National Disaster Coordinating Council (NDCC) Fidel V. Ramos, Department Secretaries, Governors and other provincial officials, base commanders, municipal/city officials, students, religious leaders and barangay residents. We made about 50 copies of the tape and left a copy with each group that we briefed; an untold number of second generation copies were made. Initial response was, typically, shock and disbelief or denial, but somehow, the tape must have jolted many viewers into preparing for a possible eruption.

We also had to see to it that the information and warnings we were disseminating to higher government and military officials were being transmitted to the inhabitants on the volcano. PHIVOLC usually channeled warnings through the concerned Disaster Coordinating Council which upon receipt of the warning, sets in motion its machinery for warning transmission and response. In the case of Pinatubo, we reached out to the villages, whenever we could. We conducted intensive information drives among the inhabitants in the barangays just outside the Clark Air Base. A similar grassroots educational campaign was also conducted in the villages at the western flank of Pinatubo, by PHIVOLCS staff with the assistance of the Franciscan Missionaries of Mary and the LAKAS, an organization of Aytas in Zambales. Our monitoring personnel staying in the villages at risk entertained and answered the queries of the villagers.

To expand the coverage of the campaign, we involved the national and local media. Press, radio and TV people practically camped at the PHIVOLCS main office and at the field station in Zambales, grabbing every information which they felt would make the headlines. The quality and actual contributions of media coverage to the pre-eruption education campaign remain to be assessed but there is no doubt that media involvement was a key factor in rapid and widespread dissemination of information

3.4 1-11 JUNE

During the first few days of June, shallow seismicity and the amount of ash in the steam plume gradually increased The clusters of earthquake epicentres also started to shift from the NW to the active vent area and were located at shallower depths. More high frequency or rock fracturing earthquakes were being recorded but some of these had a lower

frequency component. On 05 June, SO_2 values suddenly decreased, suggesting that some new material from below was plugging the path of these gases. Some of the steaming vents had also stopped steaming and ash emission increased. These developments prompted us to raise the alert level to 3, indicating that eruption was "possible within 2 weeks". On 7 June , we raised the alert level to 4 (meaning eruption possible within 24 hours) due to further increase in seismicity, and the noticeable shift in the earthquake type —from a dominant high frequency to a low frequency type, suggesting shallow earthquake source and/or magmatic origin. A telemetered tiltmeter installed at the steaming vent area also showed progressive tilting from 6 to 7 June. A lava dome, measuring about 150 m long, 100 m wide and 50 m high was sighted near the most active steam vent the next day. This dome was the first visible manifestation that magma had risen to the surface. At this point, we began to question the appropriateness of alert level 4 because technically, dome growth is an eruption in progress.

On 9 June, when the monitoring team in Zambales reported the sighting of a pyroclastic flow (this was actually a pyroclastic flow-like ash cloud) rolling down the northwest flank of the volcano, we declared Alert Level 5 (meaning "eruption in progress") and recommended a 20 km radius danger zone on all sides of the volcano. The declaration of Alert Level 5 convinced more people to evacuate before the large eruptions actually began. By 10 June, about 25 000 inhabitants, mostly Aytas, were evacuated from the barangays closest to the volcano. Some 14 500 US personnel and their dependents were also evacuated from Clark Air Base to Subic Naval Base, leaving behind skeleton security and the Clark Air Base Command (CABCOM) personnel.

The evacuation of the endangered inhabitants should have made us feel relaxed, but at that time, it made us feel uncomfortable. Evacuation of large numbers of people is costly, and the "eruption in progress" on 9-11 June did not appear to warrant such massive evacuation. We were under considerable pressure to prove that our forecasts were correct and that our recommendations were necessary.

3.5 12-15 JUNE

When the large explosive eruptions began on 12 June, the volcano spoke mainly for itself. At the height of the climactic eruption on 15 June, we expanded the danger zone radius to 40 km, fearing that a large sector of the volcano edifice might collapse as a result of a large caldera eruption. However, during this time, our monitoring operation was temporarily disabled and radio link was disrupted while our personnel were fleeing from the volcano. We re-established our monitoring station some 25 km northwest of Pinatubo. The enlarged evacuation zone had been immediately transmitted to the concerned communities with the assistance of major radio stations. On 16 June, we were able to tell the country that the caldera-forming eruption had already created a 2 km-diameter summit caldera and that the worst had probably passed.

A typhoon happened to pass by on the same day, its winds carrying Pinatubo's ash to distant lands. Pinatubo's ash reached Metro Manila, giving the nations' policy makers and leaders a direct experience of the eruption and possibly inspiring their meaningful responses to the ongoing disaster. Classes in the city were suspended and the Ninoy Aquino International Airport was closed. The typhoon brought rains, wetting the ash that accumulated on roofs, causing roof collapse. About 200 persons died under roofs that collapsed. The typhoon-triggered lahars claimed more lives in addition to the several dozens who were buried by pyroclastic flows and the 200 victims of collapsed roofs, increasing the casualty number to 250-300.

3.6 16 JUNE - 4 DECEMBER 1991

After 16 June, Pinatubo's activities gradually abated. The danger zone was officially reduced to a 20 km radius on 18 June. Most of our warnings and concern since then until the volcano's renewed activity in 1992 were about lahars and secondary explosions. The last eruption of 1991, a small puff, occurred on 4 September, the same day on which the alert level was lowered from 5 to 3 and the 20 km radius danger zone was reduced from to 10 km radius

On 4 December 1991, the eruption alert level was lowered to 2, but the 10 km radius danger zone was retained.

4. PUBLIC RESPONSE TO THE PINATUBO WARNINGS

Not all the civil defence and public officials and community leaders whom we reached were responsive to our warnings and advisories. Some provincial and municipal groups and military commanders remained sceptical until the volcano proved us right. The most vocal sceptic was the then mayor of Angeles City who refused to meet with national civil defence officials and USGS-PHIVOLCS scientists, and accused us of speaking in ignorance and berating the Americans at Clark Air Base of overreacting to a non-existent threat !

However, most of the key officials and groups who mattered were responsive and supportive. First and foremost, the then Chairman of the National Disaster Coordinating Council (Secretary Fidel V. Ramos) who later became President of the Philippines, actively participated in promoting mitigation and preparedness among the local and national officials, nongovernmental organizations and endangered communities. He personally visited the vulnerable communities, held briefings and dialogues with concerned officials and saw to it that the President and her Cabinet were informed about the volcano's activities and potential hazards. Without being asked, he also gave substantial additional operating funds to PHIVOLCS for carrying-out monitoring activities with the USGS.

Second, the Administrator of the Office of Civil defence, an engineer, appreciated both the value and the uncertainties of scientific investigations, and provided us considerable support in our monitoring activities as well as in our education and information dissemination campaign.

The Regional Disaster Coordinating Council officials of Region 3 and a number of NGOs, including the Franciscan Missionaries of Mary, were equally supportive. Several individuals in the commands and ranks at Clark Air Base and Subic Bay Naval Station, supported us and volcano emergency planning in the face of scepticism among their colleagues.

Many media reporters established and maintained strong "friendly" links with us and helped us promote public awareness of the impending hazards. They were ever present around the volcano during the unrest and crisis and shared and cross-checked with us whatever news or information they gathered in the field. In this manner it was possible to avoid causing undue panic among the people at risk. These reporters also heeded our plea to refrain from venturing into the declared danger zone and helped us convince others to comply.

How about the affected inhabitants, how did they respond to the warnings ? To assess this, a post-eruption survey was conducted by a PHIVOLCS team. Results show that a majority (58 per cent) took defensive/adaptive action and evacuated immediately as and when advised. Communities covered by the LAKAS, an organization of Aytas or natives, showed the most exemplary operation of the system, namely transmission was total and response was consistently appropriate. These communities were reached by information drives which featured the showing of the tapes on volcanic hazards produced by the Kraffts. Results of the study indicated some weakness in the transmission system and the failure of some endangered inhabitants to fully appreciate the risks and take protective action. Those who did not evacuate immediately when, and as advised, gave various reasons, such as. they thought the eruption would not be strong enough to affect their place; they were reluctant to leave behind their properties, livestock and crops — especially as it was harvest time; they had no ready means of transport and some community members could not walk long distances; and, they believed that their god, Apo Namalyari which is Pinatubo Volcano, would not let them come to harm (Tayag *et al.*, 1996).

5. INSIGHTS AND LESSONS FROM THE EXPERIENCE

From the positive aspects of the experience, the following insights were highlighted: the value of state-of-the-art monitoring equipment and techniques, international cooperation, intensive public education on volcanic hazards; the active involvement of scientists in awareness promotion and warning dissemination; the open and speedy communication lines between the science people on one hand and civil defence officials on the other; and the good relations between scientists and the media.

Without the state-of-the-art monitoring equipment loaned (and later donated) to us by the USGS and the assistance of our American geoscientist

friends who spent sleepless nights and hectic days with us to the end, we doubt if we could have been able to forecast Pinatubo's activities as accurately as we did.

We also believe that if we had simply confined ourselves to the responsibility of studying, forecasting and releasing warnings and did not take the pains of educating the concerned officials, the media and the endangered inhabitants, making them understand/appreciate the hazards, and ensuring that they took appropriate protective actions — more lives would have been lost and the Pinatubo crisis would have created another Nevado del Ruiz tragedy.

From the near-misses or potentially negative aspects, the experience underscored the need to conduct geologic database studies and hazard zonation on all active volcanoes long before the onset of unrest. Had we done these before Pinatubo, we would not have had to cram and prepare hazard zonation maps hastily. The hazard zone maps would have reflected the worst worst-case scenario which we later discovered, and perhaps the ashfall hazard map would have been more accurate. Many of our conclusions were tentative, based on the sketchiest of data and review. Our warnings and emergency preparations by civil defence and other officials, were only one step ahead of Pinatubo. We were only lucky that Pinatubo gave us this short lead time, and then followed a remarkably straight and rapid course toward eruption once we declared its eruption deadline in our hastily prepared Alert Level scheme.

It is our goal at PHIVOLCS to identify all our active and potentially active volcanoes, study them in sufficient detail to determine which of them are the most dangerous and likely to erupt within our lifetime, conduct hazards assessments, produce hazards zonation maps and see to it that these are reflected in land use and development plans, establish adequate monitoring networks that would enable us to make medium-term, as well as short-term forecasts of these volcanoes' activities and accordingly issue timely warnings and appropriate advice to reduce if not prevent volcanic disasters. It is also our objective to pursue a sustained education and information dissemination program to promote and sustain awareness of volcanic hazards and appreciation of the need for mitigation or prevention.

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