A Warning System for Active Volcanoes and Response to Warnings

Dr. R.S. Punongbayan
Department of Science and Technology
Philippine Institute of Volcanology and Seismology

Abstract

The final and crucial component of all volcanic disaster mitigation efforts is the response of the public concerned (policy makers, civil defense officials/workers and endangered inhabitants) to long-, medium- and short-term warnings. Forecasts, no matter how accurate and timely, are meaningless and useless in mitigating disasters if these fail to stimulate appropriate protective actions. Our experience to date has shown that responses to long term forecasts and warnings which have windows of years to decades ahead usually vary from indifference, scepticism to outright hostility. Long term mitigation measures such as restricting land uses and development activities in active volcanoes with fertile or rich resources are often unpalatable. Similarly, medium term (weeks to months ahead) and short term (hours to weeks ahead) forecasts and warnings have been received with indifference, scepticism and hostility. However, our experience at Pinatubo Volcano in 1991 demonstrated that these initial responses could and should be overcome through painstaking public education and information dissemination efforts initiated by the scientists themselves and subsequently sustained by civil defense officials, the enlightened media representatives, non-government organizations and other sectors concerned.

The Pinatubo Volcano eruption experience in 1991 can be considered a success warning system story: the unrest was diagnosed early enough; the hazards were identified and the vulnerable areas were forecast, based on interpretation of the historical and geologic record of the volcano's past eruptions; the most destructive phase of the eruption was predicted; timely warnings were issued; key civil defense officials and disaster response workers, though sceptical at first, were eventually won over to the cause of disaster mitigation and helped to override/overcome the scepticism or hostility of their colleagues and those of the endangered communities; the majority of the inhabitants at risk were evacuated on time. Thus, the human losses were small despite the magnitude and violence of the eruption, which is one of the world's largest this century.

The factors that make the Pinatubo story a classic are not only its success factors but also its near-misses - the things that could easily have gone wrong but luckily did not, which provide valuable lessons for developing warning systems in particular and volcanic risk mitigation plans in general. The positive aspects of the experience highlighted the following: the value of state-of-the-art monitoring equipment/techniques, international co-operation and 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 the one hand and the civil defense officials on the other; and good relations between scientists and the media. The near-misses or the potentially negative aspects of the experience underscored the need to conduct geologic data base studies and hazard zonation on all active volcanoes long before the onset of unrest. We were lucky because Pinatubo gave us sufficient lead time to study and forecast its climatic eruptions and to warn/educate the sectors concerned into taking appropriate protective actions. We know that we will not always be as lucky. So we intend to pursue long-term studies of all our active volcanoes and try to design a Pinatubo education campaign that would erode indifference, scepticism and hostility to long-term volcanic disaster mitigation.

INTRODUCTION

Ideally, for a nation to effectively minimize or prevent disasters from volcanic phenomena, it must be able and willing to: 1) identify its high risk volcanoes; 2) assess the hazards posed by these volcanoes, and delineate the areas likely to be affected by these hazards in hazard zonation maps; 3) monitor and forecast/predict the eruptions of these volcanoes; and based on the outputs of these three, 4) adopt measures or take actions that would reduce potential losses to volcanic hazards, such as : a) volcanic hazards constrained land use and development planning, b) relocation, c) structural protection measures, d) contingency planning, and e) volcano emergency response.

These four volcanic disaster mitigation components require two major sets of people and activities: the scientists on one hand to do the first three and on the other, the concerned policy makers, disaster management officials/organizations and endangered communities to do the fourth. The scientific findings of the former must be communicated effectively to the latter who in turn must plan and implement appropriate mitigation measures and actions. The chain linking these two sets of people and activities, ensuring that scientific findings are translated into concrete loss reduction/prevention actions is--the warning system.

The chain or the warning system can and often fails both in developed and developing countries of the real world, due to any or a combination of the following causes:

--failure of the science people to correctly identify and forecast hazards--inability to locate the harmful event in space and time and to measure the involved uncertainties;

--failure of the science people to formulate the warning message correctly;

--failure of transmission channels to transfer the warning information to intended recipients; and

-- failure of the recipients of warning to perceive the message correctly, and consequently their inability to take suitable actions.

Each link in the chain--monitoring and forecasting, warning message formulation, transmission and response to warning --is important; any weakness or failure in one component could render the whole system ineffective in preventing or averting volcanic disaster.

The final and crucial component of all volcanic disaster mitigation efforts is the response of concerned publics (policy makers, civil defense officials/workers and endangered inhabitants) to long-, medium- and short-term warnings. Forecasts, no matter how accurate and timely, are meaningless and inutile in mitigating disasters if these fail to stimulate appropriate protective actions. Our experience to date has shown that responses to long term forecasts and warnings

which have windows of years to decades ahead usually vary from indifference, skepticism to outright hostility. Long term mitigation measures such as restricting land uses and development activities in active volcanoes with fertile or rich resources are often unpalatable to the warning recipients. Similarly, medium term (weeks to months ahead) and short term (hours to weeks ahead) forecasts and warnings have been received with indifference, skepticism and hostility. However, our experience at Pinatubo Volcano in 1991 demonstrated that these initial responses could and should be overcome.

The Pinatubo Volcano 1991 eruption experience can be considered a success warning system story: the unrest was diagnosed early enough, the hazards were identified and the vulnerable areas forecast based on interpretation of the historical and geologic record of the volcano's past eruptions, the most destructive phase of the eruption was predicted, timely warnings were issued, the disaster response machinery was mobilized, and the endangered populations were evacuated on time. Thus, all except about 250-300 of the more than 20000 dwellers in the areas overrun by the destructive agents unleashed by Pinatubo's climactic June 12-15 eruption, escaped certain death. This death toll is small considering the magnitude and violence of the eruption which is one of the world's largest this century.

But what make the Pinatubo story a classic are not only its success factors but also its near-misses-- the things that could easily have gone wrong but luckily did not, which provide valuable lessons for developing warning systems in particular and volcanic risk mitigation plans in general. We keep discovering more and more of these "lessons" each time we recall and retell the Pinatubo story. So we shall keep recalling and retelling the story till we exhaust its treasure of lessons.

The Pinatubo story recounted in this paper shows how the warning system evolved as scientists, disaster response officials and workers, and the endangered inhabitants responded or acted in each scene of the unfolding Pinatubo Volcano drama. For additional information on the story, see Punongbayan et al (in press) and Newhall and Punongbayan (in press) on which this paper was mainly based.

VOLCANIC RISK MITIGATION EFFORTS BEFORE THE 90'S

Of the 220 or so Quaternary volcanoes in the Philippine Archipelago, we have classified as active 22 that have erupted during historic time, or within the past 600 years. Parker Volcano was added to the list this year as it yielded carbon 14 date of 250 years. We have yet to systematically and seriously identify our potentially active and "high risk" volcanoes.

Before the 1980's, our agency which used to be called Commission on Volcanology or COMVOL, had a reactive orientation, watching out for volcanic unrest or eruption and responding whenever one was detected. Hence, the volcano monitoring network inherited by

the Institute when it was transformed into the research and monitoring body PHIVOLCS is now, covered only the five volcanoes with short repose periods and growing populations (and therefore high risk), namely Mayon, Bulusan, Taal, Canlaon and Hibok-Hibok.

During the 1980's, we at PHIVOLCS started upgrading and expanding the monitoring network with the addition of a sixth permanent station at Mt. Banahaw. We also initiated a long term program of basic studies on these five monitored volcanoes plus several other known active volcanoes like Banahaw and Iriga. These studies aim to generate information for deciphering past eruptive behavior, understanding current behavior and making long term forecasts of the volcanoes' activities. Hazard assessments and zonation were also conducted on these volcanoes and the hazard zone maps produced have been disseminated to concerned land use and development planners, policy makers as well as local leaders of endangered communities. However, the results of these hazards assessments and our long term (looking years to decades ahead) forecasts and warnings have been largely ignored or met with skepticism and/or outright hostility. Long term mitigation measures such as restricting land uses and development activities for a mere "probable" event in the not-too-distant to distant future are often unpalatable to both policy makers and citizens.

During this same decade, three of the monitored volcanoes erupted--Mayon, Bulusan and Canlaon. In these volcanic crises, our medium-short term forecasts and warnings were often received with skepticism. Luckily, with the exception of Mayon's eruption in 1984, the other events were mild and did not necessitate evacuation. During the Mayon Volcano 1984 eruption, the respondents to a post eruption survey claimed that they evacuated more on the basis of their own perception of the volcano's activity than on warnings from government and media sources (Tayag et al.,1985).

PINATUBO VOLCANO, CLASSIFIED AS ACTIVE BUT NOT HIGH RISK, AND UNMONITORED

Pinatubo Volcano is one of these 21 active volcanoes (Punongbayan,1987), classified as such on the basis of the youngest age yielded by radiocarbon dating of Pinatubo volcanic deposits--635+/-80 radiocarbon years (Ebasco Services,Inc.,1977), which we took as the date of the latest eruption of Pinatubo Volcano.

In view of the limitations of our monitoring capability and the priority given to volcanoes with short repose periods, Pinatubo Volcano which has a long repose period was not covered by the PHIVOLCS monitoring network when it started showing signs of restiveness.

Pre-eruption Pinatubo Volcano used to be the home of Aeta or Negrito tribes which were scattered on the slopes of the volcano straddling the three provinces of Zambales, Tarlac and

Pampanga. Traditionally semi-nomadic, these tribes thrived on kaingin or slash and burn farming, producing mostly coffee, rootcrops and bananas.

CHRONOLOGY OF PINATUBO'S ACTIVITIES AND SCIENTIFIC RESPONSES

July-August 1990

On 16 July 1990, a M 7.8 earthquake was generated by the Digdig Fault segment of the Philippine Fault Zone and whose epicenter was located about 100 km northeast of Pinatubo Volcano. A few hours after the main shock, a small magnitude earthquake occurred about 10 km southeast of the volcano. Quakes continued to be felt around the volcano area during the following weeks. We do not know, and will probably never know, whether these earthquakes were local or distant aftershocks of the July 16 earthquake.

In early August, indigenous Aytas living on the slopes of Pinatubo accompanied by nuns of the Franciscan Missionaries of Mary, reported to PHIVOLCS audible rumbling sounds, ground cracking and increased steaming from the pre-existing thermal area. A quick response team was dispatched by PHIVOLCS to investigate the reported phenomena. The team concluded that the observations were related to the landslide which was triggered by the continuing aftershocks of the regional earthquake and the heavy rains in the area. The team reported that "Preliminary findings indicate that the phenomenon is not related with any volcanic activity...The parameters necessary for deducing an approaching... volcanic eruption were not observed in the locality" (Ramos and Isada,1991).

April 1991

On 02 April 1991, an explosion at the volcano's crater, accompanied by rumbling sounds and intense new steaming from several vents, prompted the same nuns and Aytas to again call on us at PHIVOLCS on 03 April.

We immediately dispatched a Quick Response Team which conducted ocular and aerial observation with the help of the Office of Civil Defense and the Philippine Air Force. The team found all the reported manifestations as well as a fissure and new craters at the northeast end of the line of steaming vents.

A temporary seismic station was installed on 04 April at Sitio Yamut, about 12 km WNW of Pinatubo. This recorded about 500 high frequency volcanic earthquakes, some large enough to be felt at varying intensities. Convinced that Pinatubo was showing definite signs of unrest, we declared on 07 April a 10 km-radius permanent danger zone, and advised evacuation of the residents therein.

Warnings issued by PHIVOLCS at this stage took the form of volcano bulletins which contained daily earthquake counts, visual observations and assessments of the volcano's condition. Uncertain of the applicability of the Alert Levels previously used for the monitored Philippine volcanoes, the term "unstable" was used for describing the volcano's conditions.

The updates were prepared in the field then radioed to the PHIVOLCS central office for review and release. From the PHIVOLCS Central Office in Quezon City, these volcano bulletins were transmitted to the National Disaster Coordinating Council (NDCC) through the Office of Civil Defense (OCD), the Office of the President and the Department of Science and Technology (DOST). The updates were also radioed back to volcano monitoring field stations, for local dissemination.

Additional seismograph units were later installed to augment the monitoring network. Electronic Distance Meter (EDM) stations were also set up at Sitio Yamut.

With Taal Volcano also restive at that time, we called up the United States Geological Survey (USGS) and asked for the assistance of the Volcano Crisis Assistance Team (VCAT). A three man USGS team led by Dr. Christopher Newhall arrived on 23 April.

A PHIVOLCS-USGS team was formed and with logistical support from the US Air Force based at Clark Air Base, set up a telemetered seismic network around Pinatubo and started measurements of sulfur dioxide emissions. A central station was installed at Clark Air Base on 26 April. Thus the Pinatubo Volcano Observatory (PVO) was created (Fig. 1).

The state of the art monitoring system installed at Pinatubo enabled us to confirm that magma was indeed rising beneath the volcano.

May 1991

We realized that the Volcano Bulletins were inadequate media for disseminating information on the volcano's condition and activities and for transmitting advisories on appropriate precautionary actions and safety measures to concerned civil defense officials, disaster response organizations and the public. With no baseline monitoring data for the volcano, no information on precursors of its previous eruptions and practically no information about precursors of large explosive eruptions anywhere, we felt that we could not promise a specific prediction. But we thought that we could offer a simple, multi-level description of unrest. So, we designed a 5-level scheme of Alert Levels (Table 1) patterned after schemes used at Rabaul (Papua New Guinea), Redoubt (Alaska) and Long Valley (California), and in the generic model described in UNDRO-UNESCO (1985). This scheme did not technically make predictions, but simply pointed out increasing levels of unrest and corresponding decreasing assurances that an eruption would not occur within a specified period of time. The scheme was formally adopted on 13 May and Alert Level 2 was declared on the same day.

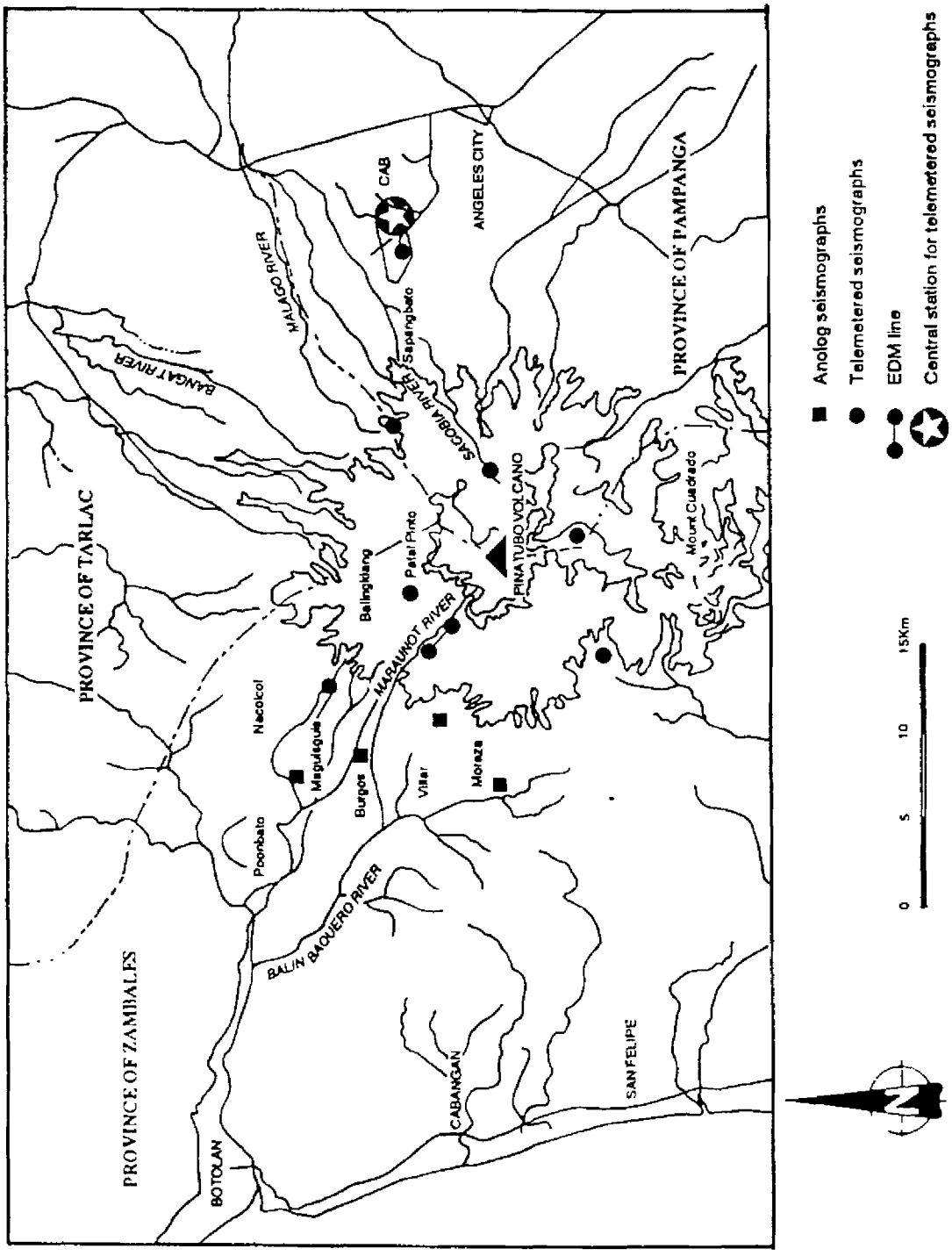

Fig. 1. Seismic and ground deformation networks of PVO, set up by PHIVOLCS with USGS assistance.

Table 1
Alert levels/signals for Pinatubo Volcano.
Adapted starting May 13,1991.

Alert Level	Criteria	Interpretation
No alert	Background; quiet	No eruption in foreseeable future
1	Low level seismicity, other unrest	Magmatic, tectonic or hydrothermal disturbance; no eruption imminent
2	Moderate level of seismicity,other unrest, with positive evidence for involvement of magma	Probable magmatic intrusion; could eventually lead to an eruption
3	Relatively high and increasing unrest incl. numerous b-type earthquake; accelerating ground deformation; increased vigor of fumaroles, gas emissions.	If trend of increasing unrest continues, eruption possible within 2 weeks
4	Intense unrest, including harmonic tremor and/or many "long period" (=low frequency) earthquakes	Eruption possible within 24 hours
5	Eruption in progress	Eruption in progress

STAND-DOWN PROCEDURES:

In order to protect against "lull before the storm" phenomena, alert levels will be maintained for the following periods AFTER activity decreases to the next lower level:

From Alert Level 4 to 3: Wait 1 week
From Alert Level 3 to 2: Wait 72 hours

By this time, we had enough data to conclude that an eruption was entirely plausible. Our next question was, how large and extensive would the eruption be? What areas are likely to be affected?

Together with the USGS geoscientists, we conducted topographic map and airphoto analyses and field verification to identify hazards that could be unleashed in the event of a Pinatubo eruption. We identified three major hazards: pyroclastic flows, ashfalls and lahars. Areas likely to be affected by these hazards were delineated by analyzing airphotos, topographic maps and particularly for ashfall, prevailing wind patterns. The resulting hazard zonation maps showed 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 (Figs. 2-3). However, the aggravating effect of a typhoon like typhoon Yunya was not anticipated and reflected in the hazard zone map for ashfalls. We also found out later that worse eruptions had occurred at Pinatubo more than 35000 years ago. Had the 1991 eruption been as large as that of more than 35000 years ago, out 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 centered on the volcano. As mentioned earlier, as early as 07 April, a ten-km radius danger zone centered on the volcano's active vent was declared. This danger zone was to be expanded later as the danger escalated.

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 that they faced--enough for them to take appropriate defense 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 wherein 22000 people died as a result of 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 skeptical as most of them had never heard or witnessed an eruption, Pinatubo had been dormant all 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 defense officials, then among the endangered inhabitants.

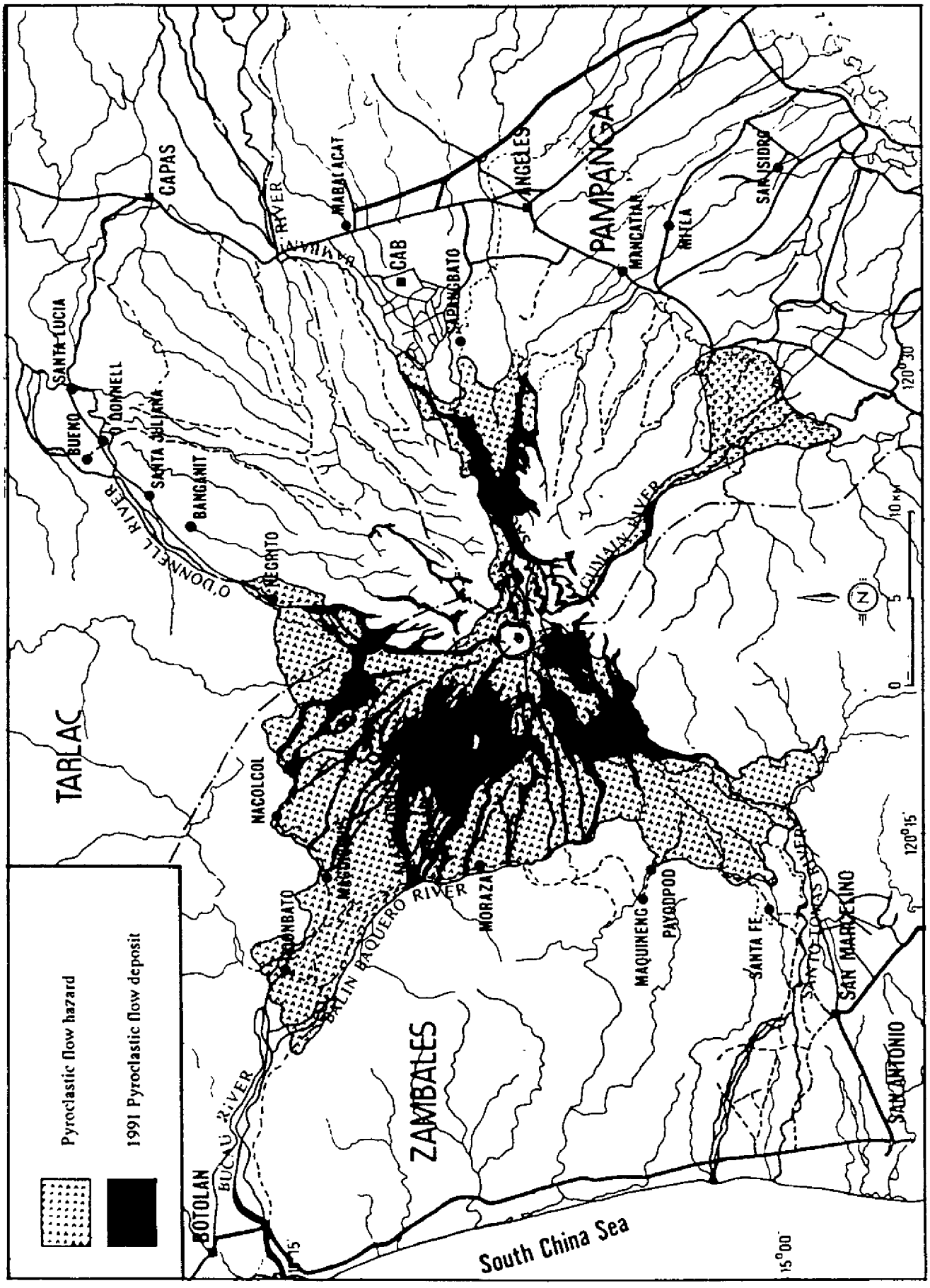

Fig. 2. Areas affected by pyroclastic flow compared to May 1991 hazard zone map for pyroclastic flow.

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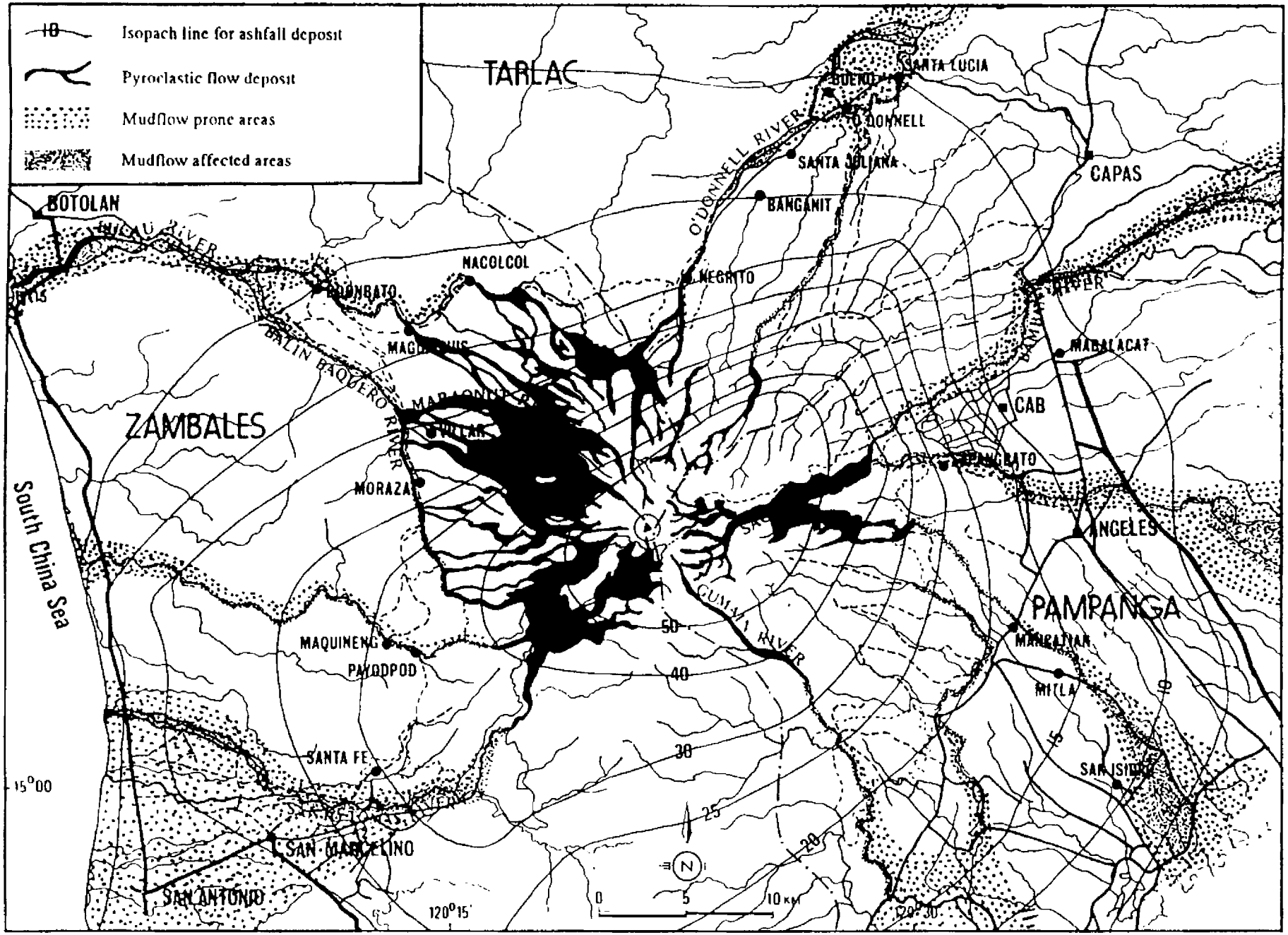

Fig. 3. Areas affected by lahar compared to May 1991 hazard zone map for lahar.

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. We showed only the segments on ash flows, ashfall and lahars during each briefing session because of the short attention span 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, Pres. Aquino, then Secretary of Defense and Chairman of the National Disaster Coordinating Council (NDCC) Fidel 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 were 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. Usually, warnings are coursed by PHIVOLCS through the concerned Disaster Coordinating Council which upon receipt of 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.

01-11 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 epicenters 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 07 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 06 to 07 June. A lava dome, measuring about 150m 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 09 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 25000 inhabitants, mostly Aytas, were evacuated from the barangays closest to the volcano. Some 14500 US personnel and their dependents were also evacuated from Clark Air Base to Subic Naval Base, leaving behind a 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 09-11 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.

12-15 June

When the large explosive eruptions began on 12 June, the volcano spoke mainly for itself. At the height to 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 national 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 tens who were buried by pyroclastic flows and the 200 victims of collapsed roofs, increasing the casualty number to 250-300.

16 June - 4 December 1991

After 16 June, Pinatubo's activities gradually abated. The danger zone was officially reduced to 20 km radius on 18 June. Most of our warnings and concern since then till the volcano's renewed activity in 1992 were about lahars and secondary explosions. The last eruption of 1991, a small puff, occurred on 04 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 04 December 1991, the eruption alert level was lowered to 2 but the 10 km radius danger zone was retained.

PUBLIC RESPONSE TO THE PINATUBO WARNINGS

Not all the civil defense 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 skeptical till the volcano proved us right. The most vocal skeptic was the then mayor of Angeles City who refused to meet with national civil defense officials and USGS-PHIVOLCS scientists, 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, non-government 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 Defense, an engineer, appreciated both the value and the uncertainties of scientific investigations, and provided us with considerable support in our monitoring activities as well as in our education and information dissemination campaign.

The Regional Disaster Co-ordinating 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, causing undue panic among the people at risk was avoided. These reports 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, the majority (58%) 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: 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 Krafft's. 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; they believed that their god, Apo Namalyari which is Pinatubo Volcano, would not let them come to harm (Tayag et al., 1992).

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 co-operation, 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 the one hand and civil defense 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 forecast Pinatubo's activities as accurately.

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 data base 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 discovered later, 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 defense 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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