El Chichón's "surprise" eruption in 1982: Lessons for reducing volcano risk

R. I. Tilling
Volcano Hazards Team, U.S. Geological Survey, CA USA

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Resumen

Durante una semana (marzo 28- abril 4, 1982), tres erupciones explosivas (VEI 5) del volcán El Chichón causaron el peor desastre volcánico en la historia de México. Flujos y oleadas piroclásticas arrasaron nueve poblados matando cerca de 2000 personas. La caída de ceniza provocó sufrimiento a miles de habitantes de los estados de Chiapas y Tabasco. La inesperada y vigorosa erupción del 28 de marzo causó una evacuación apresurada y confusa. La actividad disminuyó notablemente los cinco días siguientes, pero después ocurrieron las erupciones más poderosas y letales del 3 al 4 de abril; trágicamente las autoridades habían permitido el regreso a casa de muchos de los evacuados.

Desafortunadamente las erupciones sorprendieron a los científicos y autoridades gubernamentales impidiendo la implementación oportuna de medidas de mitigación. Antes de la erupción, la actividad fumarólica y los sismos se incrementaron, por lo que los habitantes alrededor del volcán pidieron ayuda al gobierno de Chiapas y al gobierno Federal. La ayuda lenta, por parte de ambos gobiernos llegó después de la primera erupción. Probablemente la lección aprendida más importante fue que el científico a cargo y las autoridades militares que actuaron con su consejo, no tuvieron que haber considerado la disminución de la actividad (marzo 29 –abril 2) como una señal de que la erupción había terminado. A pesar de que las erupciones de 1982 causaron una tragedia nacional, también fomentaron estudios multidisciplinarios de los fenómenos eruptivos no sólo en el volcán El Chichón sino también de otros volcanes explosivos en el mundo.

Palabras clave: Volcán El Chichón, amenazas volcánicas, reducción de riesgo, gestión de emergencia volcánica.

Abstract

During one week (28 March-4 April 1982), three powerful explosive eruptions (VEI 5) of El Chichón Volcano caused the worst volcanic disaster in Mexico's recorded history. Pyroclastic flows and surges obliterated nine villages, killing about 2,000 people, and ashfalls downwind posed socio-economic hardships for many thousands of inhabitants of the States of Chiapas and Tabasco. The unexpected and vigorous eruption of 28 caused a hasty, confused evacuation of most villagers in the area. Activity was greatly diminished the next five days, and then the most powerful and lethal eruptions occurred 3-4 April—tragically, after many evacuees were allowed by authorities to return home.

Unfortunately, the eruptions came as an almost total surprise for scientists and government authorities, effectively precluding opportunities to implement timely mitigative countermeasures. During the months before eruption onset, fumarolic activity increased and inhabitants living close to the volcano felt occasional earthquakes, prompting the Chiapas government to request help from the Federal government. Both the Chiapas and Federal governmental actions were slow, and the requested assistance came after the volcano erupted. Perhaps the most important lesson learned from the disastrous outcome at El Chichón is that its decreased activity (29 March-2 April) should not have been assumed by the senior scientist on site—and the military authorities acting on his advice—to signal the end of eruption. While the 1982 eruptions caused a national tragedy, they also fostered multidisciplinary studies of eruptive phenomena, not only at El Chichón but also other explosive volcanoes in the world.

Key words: El Chichón Volcano, volcano hazards, risk reduction, volcanic emergency management.

Introduction

Prior to 1982, El Chichón—located at the northwestern end of the Chiapanecan Volcanic Arc in southeastern Mexico (Fig. 1)—was a heavily vegetated, little-studied volcano in the State of Chiapas. Then, near midnight on 28 March 1982, the volcano exploded suddenly, violently, and unexpectedly. This explosion and larger ones on 3-4 April combined to cause the worst volcanic disaster in Mexico's recorded history, killing more than 2,000 people. These eruptions and their deadly impacts soon gained worldwide notoriety—capturing the most attention paid to any Mexican volcano since the 1943-1952 activity of Parícutin (State of Michoacán), when the first detailed scientific observations were made of a historical eruption of a Mexican volcano (Luhr and Simkin, 1993, and references therein). As this Proceedings Volume of Geofísica Internacional and the Special Issue of Journal of Volcanology and Geothermal Research (Taran *et al.*, 2008) amply attest, the 1982 El Chichón eruption was a catalytic "…event that accelerated volcanological studies in Mexico" (Macías, 2007, p. 185), not only of El Chichón but also other Mexican volcanoes as well, for example Volcán Colima (Macías, 2007, and references therein) and Volcán Popocatépetl (see Delgado *et al.*, 2008, and references therein.)

In March 2007, an international conference was convened at San Cristóbal de las Casas (Chiapas) in commemoration of the 25th anniversary of the 1982 El Chichón eruption (Ramos and others, 2008). This conference showcased a broad sampling of the notable studies of El Chichón, as well as of other volcanoes in Mexico and elsewhere, made since 1982. Many and diverse papers were presented in 11 conference sessions, including several focusing on volcano hazards, risk assessment, and socio-economic impacts of the eruption (Espíndola *et al.*, 2007; Ramos *et al.*, 2008). This brief paper is adapted from my keynote presentation at the session titled "The 1982 eruption: History and lessons" (Tilling, 2007). Following the eruption, hundreds of multidisciplinary studies of El Chichón have been published in the geoscience literature (for a sampling, see Alcayde, 1983; Luhr and Varekamp, 1984; Macías *et al.*, 1997a; Espíndola *et al.*, 2000, 2002; Taran *et al.*, 2008; this volume, and references cited therein). This paper makes no attempt to review the many important findings or relevance of the post-1982 investigations of El Chichón. Instead, I will focus on the lessons learned from the El Chichón tragedy that might be applied to averting volcanic disasters from future eruptions, not only in Mexico but also in other countries.

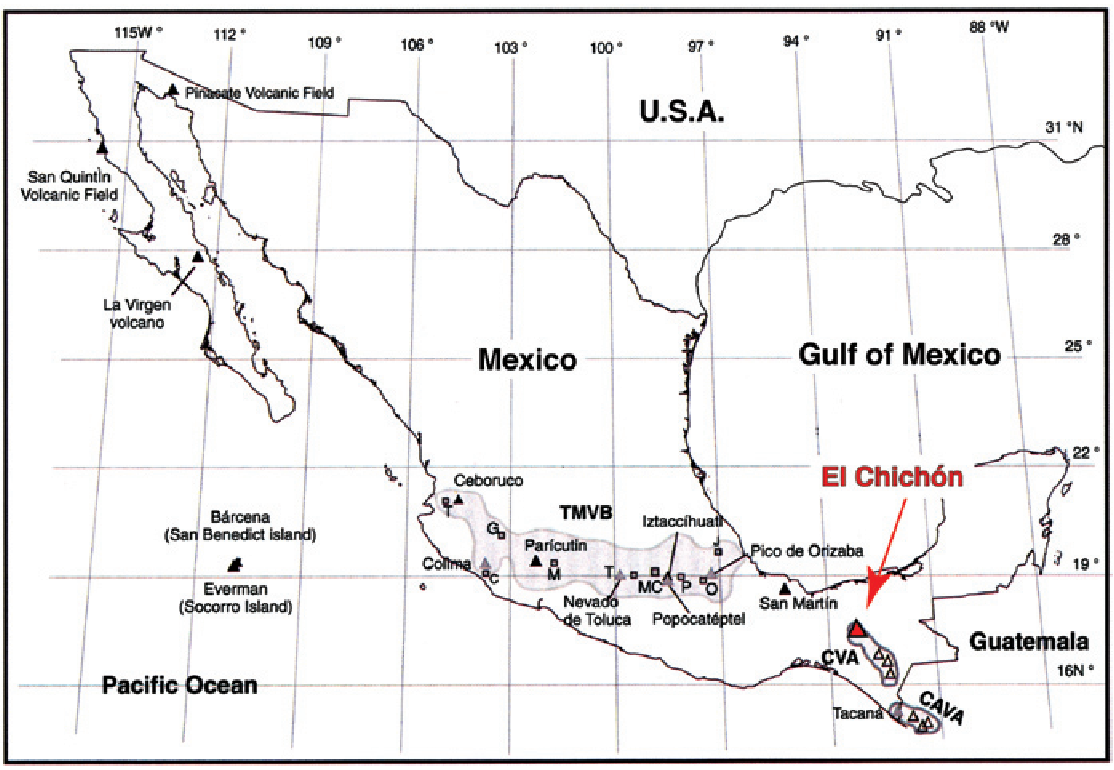
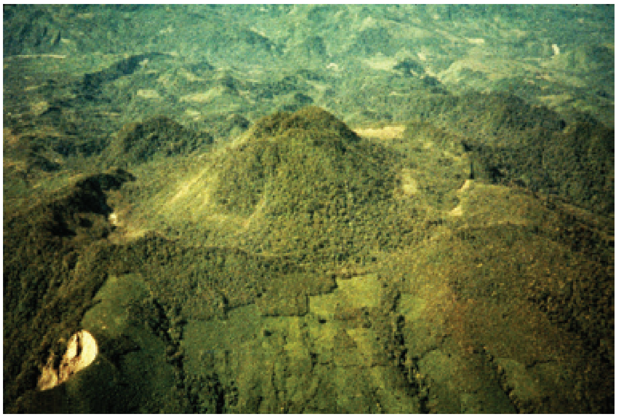


Fig. 1. Map showing the distribution of Mexico's active volcanoes and the location of El Chichón Volcano (indicated by red triangle). Abbreviations for volcanic zones: TMVB, Trans-Mexican Volcanic Belt; CVA, Chiapanecan Volcanic Arc; and CAVA, Central America Volcanic Arc. Volcán San Martín is part of the Tuxtla volcanic field. Abbreviations for cities: G, Guadalajara; C, Colima; M, Morelia; and MC, Mexico City. (After Macías, 2007, Fig. 1).

Before March 1982: Prelude to disaster

El Chichón was "discovered" in 1928 during geologic reconnaissance in the State of Chiapas and considered to be "active" (post-Pleistocene) by Frederich Müllerreid (1932, 1933), who described the volcano's general characteristics, youthful morphology, and fumarolic activity (Fig. 2). However, following its discovery and subsequent listing in the catalog of the world's active volcanoes (Mooser *et al*., 1958), El Chichón remained unstudied for nearly a half century. Then, beginning in the 1970s, a few investigations were conducted by the Comisión Federal de Electricidad (CFE) to evaluate its geothermal potential (e.g., González-Salazar, 1973; Molina-Berbeyer, 1974; Templos, 1981; Canul and Rocha, 1981). Apart from these CFE studies, the only other scientific study during the 1970s was that of Damon and Montesinos (1978), who made a survey of volcanism and metallogenesis of the State of Chiapas. Significantly, like Müllerreid (1932, 1933), all these works considered—explicitly or implicitly—El Chichón to be an active or potentially active volcano. Yet, it must be emphasized that, before 1982, the prevailing mindset was that this volcano posed no threat to life and property. However, we should not forget that, in the early 1980s, many (most?) volcanologists tended to regard the volcanoes with no record of historical eruptions as posing little or no potential danger. But this perception belies the reality: 12 of the 16 largest eruptions (≥ VEI 5) during the 19th and 20th centuries, including that for El Chichón in 1982, were the first historical eruptions for the respective volcanoes (Simkin and Siebert, 1994, Table 5).

Fig. 2. (a) Geologist Frederich Müllerried with his field party in 1928. (Photographer unknown?).



(b) Pre-eruption aerial oblique view toward west of El Chichón showing how the volcano looked during Müllerried's fieldwork. Note the summit dome complex within the somma crater. (Photograph by René Canul, CFE, in 1981).

The CFE studies resulted only in unpublished internal reports that did not come to light until *after* the 1982 eruption. As discussed later, the specific mention of possible volcanic danger contained in the report of Canul and Rocha (1981) turned out to be prescient when El Chichón violently awoke in March 1982 from its centuries-long slumber. The 28 March eruption came almost as a total surprise not only to villagers around the volcano, but also to government officials and scientists. Before 1980, no systematic volcano-monitoring data of any kind were available for El Chichón. In hindsight, however, perhaps the eruption need not have been a total surprise, because El Chichón did show signs of pre-eruption unrest, which unfortunately went unheeded. Throughout 1981 and into early 1982, local inhabitants felt occasional earthquakes and reported increased fumarolic activity and possible warming of streams, especially during the three months before eruption onset. *Post-eruption* analysis of data recorded by the CFE seismic network (installed in July 1979, operational by January 1980) around the Chichoasén hydroelectric plant (~ 50 km south of the volcano's summit) demonstrated the occurrence of precursory seismicity as early as January 1980, possibly even late 1979 (Jiménez *et al*., 1999). With the hindsight benefit of many more eruptions and studies made since the 1980s, worldwide experience indicates that precursory activity or "unrest" at a volcano does not inevitably culminate in eruption (e.g., Tilling, 2008). For example, the occurrence of seismicity at El Chichón during the late 1920s, which motivated the visit of Müllerreid (1932, 1933), did not end in eruption.

More significantly, during the period December 1980-February 1981, two CFE geologists (René Canul and Víctor Rocha) felt numerous earthquakes and heard rumbling sounds while doing fieldwork in the vicinity of the volcano. Clearly, this experience left a profound impression, leading them to state specifically in their internal report (submitted in September 1981 to the CFE office in Morelia, Mexico):

"…during December/80 – January/81, strong noises and small earthquakes were heard from the subsurface, being stronger and more frequent in the crater…Possibly, they are related to some subsurface magmatic activity and/or tectonic movements. *It is thus concluded that in this zone exists a high volcanic risk that must be considered if one wishes to develop a geothermal field*" (italics added). (Translated from Canul and Rocha, 1981, p. 26-27).

However, this report was transmitted only to the CFE office in Morelia (State of Michoacán), Mexico, so that its circulation was minimal at best. More importantly, it was not sent to a scientific journal or to civil authorities. Thus, Canul and Rocha's concern—raised six months before the eruption—that El Chichón possibly might reawaken and pose a volcanic danger, unfortunately went unheeded and only became known—to scientists and officials alike—*after* the eruption. Similarly, signs of pre-eruption unrest noticed by the local inhabitants and reported to local authorities resulted in no timely action by the Chiapas or Federal authorities. In hindsight, however, the slowness of action by government officials at the time is understandable, given the prevailing mindset that El Chichón, which until 1982 had no known historical eruptions, was not a volcanic threat.

March – April 1982: Explosive eruptions and consequences

Chronological narratives and studies of the 1982 El Chichón eruptions and their attendant processes, impacts, and products now are abundantly available in the geoscience literature. For overviews of the eruption and post-eruption investigations, the interested reader is referred to several informative summaries and collections of papers published elsewhere (e.g., Luhr and Varekamp, 1984; Macías *et al*., 1997a; Espíndola *et al*., 2002; Macías, 2007; Taran *et al*., 2008; this volume). The discussion below is drawn from multiple sources, to provide a temporal and spatial context for the next section of the paper (EMERGENCY AND SCIENTIFIC RESPONSE TO THE ERUPTIONS).

Near mid-night (local time) of 28 March, with no obvious upturn in volcanic seismicity, El Chichón exploded abruptly and vigorously; the eruption then continued until ~ 0600 the next morning. While not generating any pyroclastic flows and surges, this powerful explosive eruption fed a 20-km high eruption column and produced heavy ashfalls that collapsed many roofs (Fig. 3). Accumulations of ash also made many roads impassable and forced the closure of airports at the cities of Villahermosa and Tuxtla Gutiérrez, located about 75 km and 70 km, respectively, from the volcano summit. Not surprisingly, a totally unexpected eruption coming in the middle of the night terrified and panicked the local inhabitants. Dozens of people were killed by the ashfalls, and many hundreds began to flee the villages closest to the volcano, seeking the refuge of larger, more distant settlements (e.g., Ostuacán, Pichucalco, Chapultenango, Ixtacomitán). The 28 March eruption partially destroyed the summit dome complex within the somma crater (Fig. 4).

For the next six days (29 March-3 April), the eruptive activity continued intermittently at a much-reduced level, consisting of occasional small explosions accompanied by nearly continuous seismicity. During this period

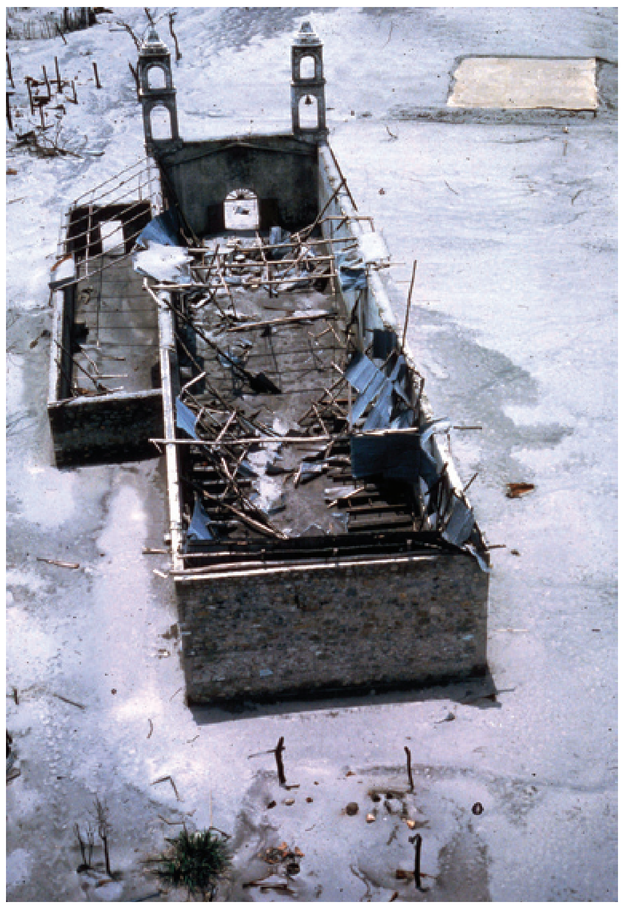


Fig. 3. Collapsed roof of the church in the village of Naranjo, located about 8 km south of Volcán El Chichón; later this village also suffered severe damage from pyroclastic surges of 3 April. (Photograph by Wendell Duffield, 2 June 1982).

Fig. 4. Oblique aerial view (essentially same as that in Fig. 2b) showing the partial excavation of El Chichón's summit dome by the 28 March eruption. This photograph was taken sometime after 28 March but before 3 April. Compare with Figure 2b and Figure 7. (Photographer unknown?).

of relatively minor activity, however, confusion and uncertainty among the affected populations did not diminish (see below). Then in the evening of 3 April (~ 1935) and early morning of 4 April (~ 0520), El Chichón's two most lethal eruptions occurred. While of shorter duration (each lasting less than 2 hours), both these eruptions were more powerful than the 28 March eruption. In addition to producing voluminous ashfalls, each eruption also generated pyroclastic flows and surges that swept all flanks of the volcano (Fig. 5) and caused most of the estimated 2,000 fatalities (Sigurdsson *et al.*, 1984; Macías *et al.*, 1997a). The total destruction of Francisco León (Fig. 6), located 5 km SSW of the volcano, accounted for the greatest number of deaths from the 3-4 April eruptions.

The March-April eruptions blasted away nearly all of the pre-1982 summit dome, creating a new crater about 1-km wide and 230-m deep (Fig. 7). Subsequent studies (Luhr and Varekamp, 1984; Sigurdsson *et al.*, 1984; Carey and Sigurdsson, 1986; Macías *et al.*, 1997b) of the 1982 deposits yielded a total eruptive volume of 0.5 km^3 (dense rock equivalent). Post-eruption analysis of seismic data collected by the Chicoasén network (nearest station about 35 km from the volcano's summit) shows that seismic-energy release actually decreased somewhat before the 28 March explosion, and then remained at a lower level before increasing sharply prior to the 3-4 April eruptions (Fig. 8).

El Chichón's magmas are exceptionally high in sulfur (Luhr *et al.*, 1984; Rose *et al.*, 1984; McGee *et al.*, 1987). Sulfur-rich aerosols in the drifting stratospheric volcanic clouds from the April 1982 eruptions affected global climate, lowering surface temperature by 0.2-0.5 ˚C in the northern hemisphere (Mitchell, 1982; Rampino and Self, 1984; Galindo *et al.*, 1984; Simarski, 1992). This climatic impact largely dissipated by 1985.

Eruptive activity essentially ceased after the 4 April eruption, except for a small phreatic event on 11 September 1982 that ejected some ash. During heavy rainfall, several secondary lahars were triggered in some valleys draining the volcano. The largest of such rain-induced lahars occurred on 26 May 1982 on the Río Magdalena, generated by the catastrophic failure of a natural dam of still-hot pyroclastic debris (Riva Palacio-Chiang, 1983; Macías *et al.*, 2004). Since September 1982, activity at El Chichón has been minor, only consisting of occasional rockfalls from the steep, unstable walls of the new summit crater and low-level, fluctuating hydrothermal activity within the summit crater lake (Casadevall *et al.*, 1984; Armienta *et al.*, 2000).

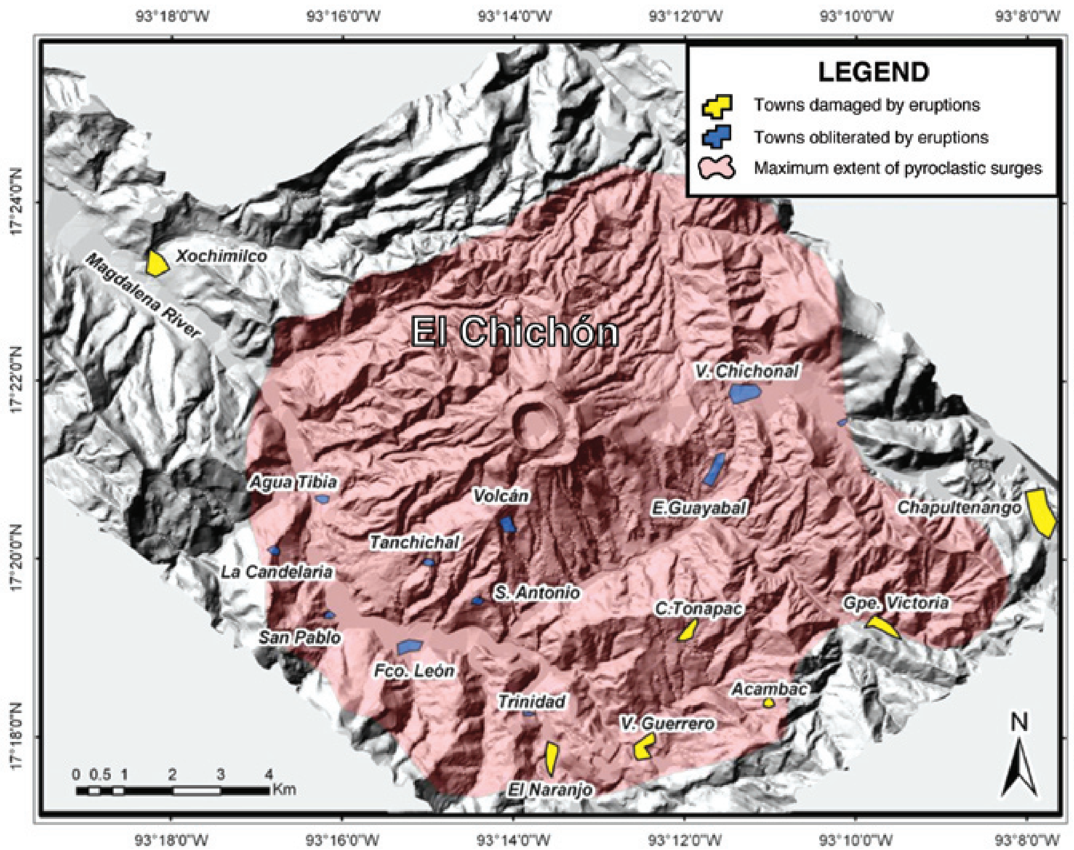


Fig. 5. Digital elevation model showing the area around El Chichón Volcano and the towns that were obliterated or damaged by ashfalls and pyroclastic deposits and surges of the 1982 eruptions. (After Limón-Hernández and Macías, 2009, Fig. 3a).

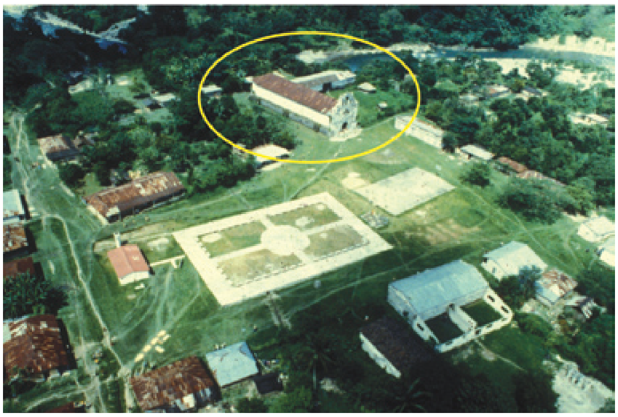


Fig. 6. (a) Pre-1982 oblique aerial view to north of the village of Francisco León, with its church as the most prominent structure (indicated by oval); Río Magdalena can be seen in background (top). (Photograph by Ricardo Meléndez).

(b) Oblique aerial view toward south showing the complete devastation of Francisco León; only the remains of the church are visible (indicated by oval). Note the strand line of the hot-water lake (indicated by thin dashed line) that formerly existed from damming of the Río Magdalena (foreground) by pyroclastic materials; the lake drained on 26 May 1982 from failure of the dam (Macías *et al*., 2004). (Photograph by author, 2 June 1982).

Fig. 7. Post-eruption aerial view from the northwest showing the nearly complete excavation of El Chichón's summit dome and the new crater formed in its place; compare with Fig. 2b and Fig. 4. (Photograph by author, 2 June 1982).

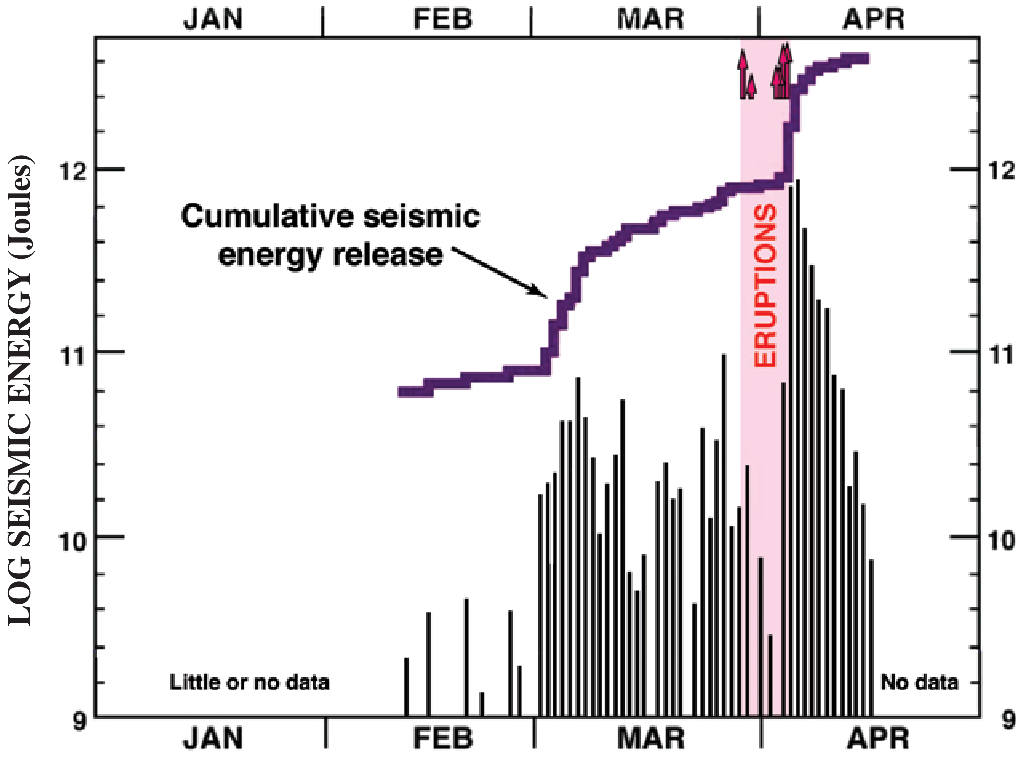


Fig. 8. Precursory seismicity and cumulative seismic energy release during February-April 1982. Red arrows indicate the six largest eruptions, as reflected in the seismic data and visual observations; length of arrow is roughly proportional to eruption vigor and size. (After Yokoyama *et al*., 1992, Fig. 6.)

The 1982 El Chichón eruption was the worst volcanic disaster in the recorded history of Mexico, causing many deaths and significant property and agricultural damage (Cervantes-Borja *et al*., 1983). However, eruption-related hardships persisted well beyond 1982: "Economic loss and social damage was also high as thousands of people lost their belongings and had to be resettled or remained on the surrounding areas for years working in whatever occupation was available,…(mostly) menial jobs with scarce reward." (Macías *et al*., 1997a, p. 19).

Emergency and scientific response to the eruptions

In 1982, Mexico did not have a single, designated governmental entity—regional or national—officially responsible for responding to, and managing, volcanic and other natural-hazards emergencies. Such a body—Sistema Nacional de Protección Civil—was established in 1986 after the devastating Mexico City earthquake (magnitude-8.1) in September 1985. Thus, when the El Chichón eruption began,the Mexican Army was put in charge of dealing with the volcanic crisis. By 30 March, the El Chichón area came under the control of the Army, which was tasked by President José López Portillo to implement a national emergency plan for disasters (Secretaría de la Defensa Nacional, 1983), under the direction of Mexico's Secretary of Defense, General Félix Galván-López.

Despite the arrival of the Army and the relatively low level of eruptive activity between the 28 March and 3-4 April major explosions, confusion and uncertainty still prevailed among the affected people as well as the military and other government officials. During this period (29 March-3 April), many people had already fled ("self-evacuated") their homes because of the heavy ashfalls from the first eruptive outburst. Because of the lull in activity, however, some of these people began to return home while others were contemplating such action. Also, at this time, there were many exaggerated and conflicting stories in the local and national media coverage of the eruption. The Mexican Army began to set up emergency medical centers and temporary refugee shelters in the more distant settlements as yet relatively unaffected by the eruption. It also began to evacuate more than 22,000 people using 32 military vehicles and 40 trucks provided by the Government of the State of Tabasco (Secretaría de la Defensa Nacional, 1983). In retrospect, because documentation is lacking, it is difficult, if not impossible, to assess the efficacy and consistency of these evacuation efforts; nonetheless, the eventual high toll of ~ 2,000 deaths following the 3-4 April eruptions implies that the evacuations were not strictly enforced, hence not entirely successful in moving people out of harm's way.

The time interval between the major explosive eruptions clearly was one of immense confusion and anxiety for the officials and the public alike. What will the volcano do next? Will the eruption stop soon? Is the eruption over? Lamentably, these critical questions could not be answered because of the lack of information about the ongoing eruption. Perhaps one of the more informative accounts (in English at least) of the situation during the evacuations is that of two American journalists from The Seattle Times who were on assignment in the El Chichón area during 1-4 April:

"…Throughout Tuesday (30 Mar) and Wednesday (31 Mar), military officials informed the villagers that they would be allowed back in their homes during the day to check on their plants and livestock. However, they were supposed to leave at night because of fear that El Chichón could erupt again…By Thursday, April 1, the fear of another major eruption was growing, and disaster officials became reluctant to allow villagers to return to their homes at all." (Guillen and Johns, 1982, p. A10).

Thus, it appears that at least these initial efforts were intended to be partial rather than total evacuations. Apparently, many people did not evacuate, or returned home after being evacuated because of the lull in eruptive activity, or chose to disregard the instructions from the military to return to the refugee shelters at nightfall.

It was during this time of confusion and disorder that scientists from Mexico City began to arrive at El Chichón. On 29 March (Monday), UNAM scientists from the Instituto de Geofísca (which included Servando De la Cruz-Reyna) and the Instituto de Ingeniería arrived to begin on-site seismic studies of the activity (De la Cruz-Reyna and Martin del Pozzo, this volume). By 1 April, two temporary networks of smoke-drum seismographs were in place to begin on-site seismic monitoring, but not in real time. These seismograms obtained from these two separate operations, after cursory examination, were to be sent to UNAM (Mexico City) for more detailed analysis (for additional information, see De la Cruz-Reyna and Martin del Pozzo, this volume). A scientific team of the CFE arrived on 30 March (Tuesday) to make field observations and to advise the military officials. The CFE team included a geologist, Salvador Soto Pineda, who unfortunately later was killed at Francisco León along with three soldiers and an unknown number of villagers by the pyroclastic surges of the 3-4 April eruptions.

Because the seismic monitoring by De la Cruz-Reyna and his UNAM associates was not in real time, the data collected necessarily were of limited use for volcanic-emergency management by the military and other government officials. It must be borne in mind that the seismic data recorded—by both the temporary networks and the telemetered CFE network (with the closest station ~ 40 km from the volcano)—were not analyzed in detail until months and years after the eruption ended (e.g., Havskov *et al*., 1983a,b; Jiménez *et al*., 1999; Medina *et al*., 1990, 1992; Yokoyama *et al*., 1992; De la Cruz-Reyna and Martin del Pozzo, 2009).

In retrospect, the role of the senior CFE scientist on site, proved to be controversial. During the week between the major eruptions, the military was contemplating decisions forbidding villagers to return to their evacuated homes during daylight hours, and even possibly evacuating Pichucalco, but the CFE scientist advised the officials not to act so hastily and drastically. For example, in a post-eruption interview he is quoted in advising the military officials on 1 April (Thursday) to be "…calm, calm, you shouldn't act so fast" (Weintraub, 1982, p. 667). The advice to the military presumably was based on the thinking that the 28 March eruption was the climactic event and that the worst of the volcanic crisis was over. At a meeting with General Galván-López the next day (2 April, Friday) at Army headquarters, the CFE Chief Scientist is further quoted as saying "…We decided to assume a position of waiting, not ask for the army to go in and evacuate everyone, because you can't do that. It's too drastic." (Weintraub, 1982, p.667). Apparently, at the time Galván-López accepted this advice and decided not to evacuate Pichucalco. Moreover, in a subsequent interview with The Seattle Times, Galván-López stated: "…(the CFE Chief Scientist) told us Friday (2 April) the volcano had passed point of activity…With that information, we told the people they could go home." (Guillen and Johns, 1982, p. A10). With this decision, through the daylight hours of Friday (2 April), many more evacuees were returning to their abandoned homes. The narrow, ash-covered roads around El Chichón became clogged with people either evacuating or returning to their homes (Fig. 9).

It should be noted that scientists of the UNAM teams were excluded from the meetings between the CFE team and General Galván-Lopez. The exclusion of UNAM scientists precluded the consideration of the seismograms recorded from the temporary networks in the decision-making process; cursory examination of the seismograms clearly indicated that the eruption had not ended (Servando De la Cruz-Reyna, written communication, 2008). Another problem was that the military officials apparently were receiving inconsistent messages and advice regarding the eruption. For example, an article published on 2 April in the Excelsior (the widest-circulation Mexican newspaper at the time) reported the CFE Chief Scientist on 1 April declaring that:

Fig. 9. During the relative lull between the major eruptions, the ash-covered roads (partially plowed by the military) in the El Chichón area were heavily trafficked by people evacuating or returning home after being evacuation. (Photograph by Servando De la Cruz-Reyna, 1 April 1982).

"…all inhabitants near the volcano should be evacuated, because the eruptions will turn more violent in the next three weeks…Many people will die if not evacuated." (Translated from Garza-Morales and Ruiz-Redondo, 1982, p. A10).

However, the next day (2 April), the CFE Chief Scientist is reported as saying:

"…although the eruption may continue indefinitely, the activity would not be severe (as the 28 March eruption)… There is no reason for evacuation…as the critical phase of the volcano has passed." (Translated from Ruiz-Redondo and Garza-Morales, 1982, p. A10).

Then, in the early morning (~ 0330) of 3 April, the first of El Chichón's two most powerful and deadliest eruptions occurred, tragically after many of the evacuees had been allowed to return home (Macías *et al*., 1997a; Espíndola *et al*., 2002). The 4 April eruption (~ 0530) was also deadly. General Galván-López, understandably shocked and upset by the disastrous turn of events, told The Seattle Times on 3 April (Saturday):

"(The CFE Chief Scientist) predicted that the volcano would not erupt again (as on 28 March), but it happened"….We had been making our actions based on (him). We can learn from that—don't depend on one person and do more of the thinking yourself." (Guillen and Johns, 1982, p. A11.)

That night, the military and government officials agreed that not only would they have to completely evacuate all the villages, but also Pichucalco as well (Fig. 10).

Jaime Sabines, a well-known Mexican poet—and also the brother of the Governor of Chiapas in 1982—experienced the eruption and its aftermath first hand. In a poignant, personal account of the El Chichón tragedy written in April 1982 soon after the devastating eruptions of 3-4 April, Sabines—referring to the CFE Chief Scientist—lamented:

"We have lost faith…in the volcanologist. He told us that everything had passed, that from here on out all would be tranquil." (Translated from Sabines, 1999, p. 11).

In retrospect, several post-eruption studies have recognized two main factors that contributed to the disastrous outcome at El Chichón in 1982: 1) at the time, Mexico had no governmental agencies charged with responses to natural disasters; and 2) there was no body of experienced specialists ("cuerpo de especialistas") to advise the emergency-management officials on the scene concerning the course of the eruption following the 28 March explosion (e.g., Macías *et al*., 1997a; Espíndola *et al*., 2002). Specifically, in 1982 volcanologists in Mexico had no prior experience in responding to a short-lived large explosive eruption—a scenario quite unlike the long-lived and much less violent 1943-1952 eruption of Parícutin Volcano four decades earlier (Luhr and Simkin, 1993). Finally, in the opinion of Macías and Aguirre (2006, p. 45):"…The Chichonal volcano eruption in 1982 revealed a deplorable state of neglect in emergency response."

Fig. 10. Evacuation of Pichucalco on 4 April following the major explosive eruption earlier that day (~ 0530). The decision to evacuate the city was made the night before, after the eruption of 3 April (see text). (Copyrighted photograph by Chris Johns, The Seattle Times).

Some obvious lessons for reducing volcano risk

From the preceding sobering discussion of the disastrous outcome of El Chichón, some key lessons for reducing volcano risk are painfully obvious:

• The most compelling lesson is that the "discovery" of the volcano in 1928 by Müllerreid (1932, 1933) should have been followed by more geoscience studies in the ensuing decades. Unfortunately, this did not happen. Worldwide experience indicates, and common sense requires, that basic geologic and dating studies must be conducted for any geologically young and morphologically youthful volcano (Fig. 11). Such studies are necessary to construct the volcano's eruptive history—especially its eruptive frequency—to form the basis for making long-term forecasts of possible future activity, volcano-hazards assessments, and hazard-zonation maps. Post-eruption studies (e.g., Duffield *et al*., 1984; Tilling *et al*., 1984; Espíndola *et al*., 2000) show the average repose interval of El Chichón to be 350 + 250 years. Had sufficient knowledge about El Chichón's prehistoric eruptive history and high eruption frequency been known before 1982, perhaps its historical eruption would not have come as a surprise.

• Baseline monitoring of high-risk volcanoes must be started at whatever level scientific and resources permit. Ideally, the volcano monitoring should be conducted in real time or near-real time (Tilling, 1989, 1995). The availability of long-duration baseline monitoring data allows the early detection of deviations from the volcano's "normal" level of inactivity or activity, thereby giving scientists and civil-protection authorities greater lead time in responding to potential volcanic emergencies. Unfortunately, at El Chichón there was no baseline monitoring for timely detection of the volcanic unrest beginning perhaps as early as late 1979. This fact, plus having no knowledge about El Chichóns history of frequent explosive eruptions, was an important factor why the volcano's precursory signals did not attract scientific and public attention. At present, there is still only one telemetered seismic station, which has been operating near the crater rim of El Chichón since 2004, but there are plans to install two additional stations, one at Francisco León, the other at Nicapa (Ramos-Hernández *et al*., 2007). Periodic geochemical monitoring of El Chichón crater lake is expected to continue (Tassi *et al*., 2003; Armienta *et al*., 2007; Rouwet *et al*., 2008, Rouwet *et al*., 2009; Taran and Rouwet, 2008).

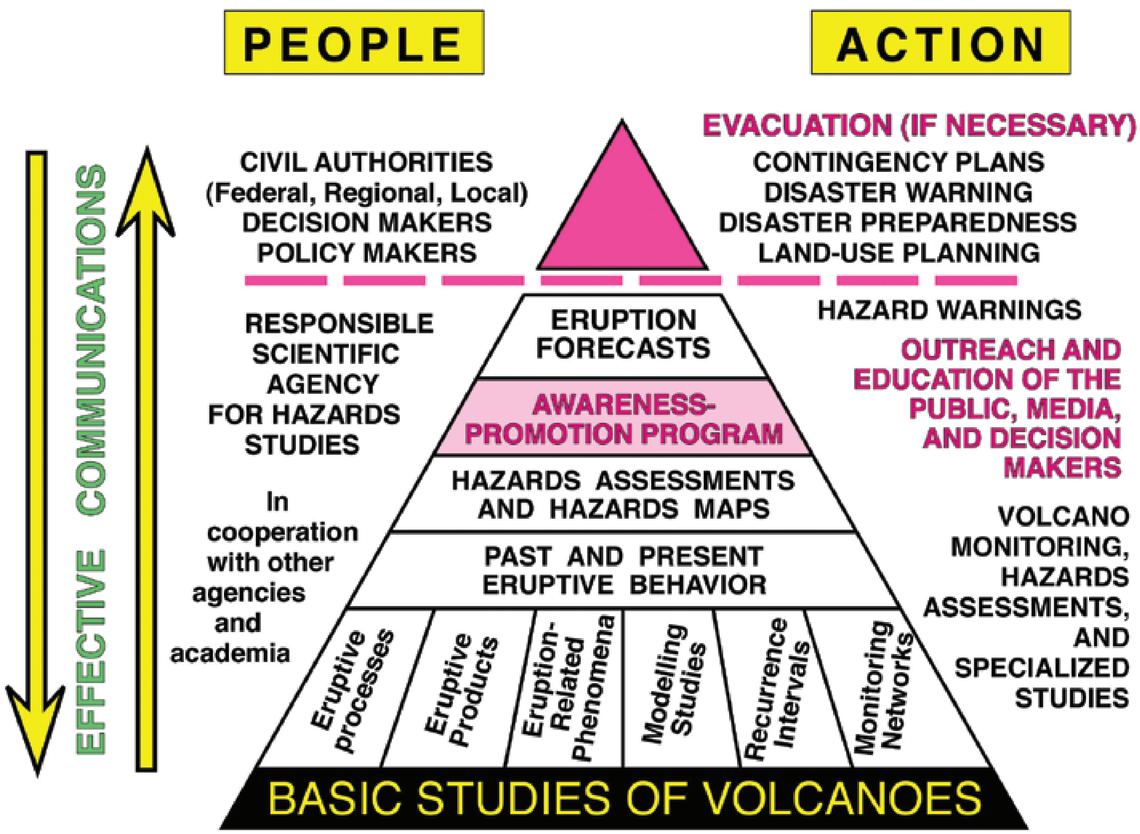


Fig. 11. Any effective program to reduce volcano risk must be grounded on a solid foundation of long-term basic studies of active and potentially active volcanoes, beginning with geologic mapping. The essential elements of such studies include geologic mapping, characterization of eruptive processes and products, and dating of the volcanic deposits. (Modified from Punongbayan and Tilling, 1989, Fig. 1.3).

Ideally, a volcano-hazards assessment and hazards-zonation map should be prepared before a volcanic crisis strikes. The availability of such studies makes it possible for scientists to make long-term eruption forecasts and to guide the deployment of volcano-monitoring networks. Equally importantly, such studies guide emergency-management officials in the development of contingency plans, including practice evacuation exercises, preferably well before a volcano begins to show signs of volcanic unrest. As with El Chichón before 1982, and at present with many other high-risk volcanoes in the world, there are inadequate geologic or baseline monitoring data to evaluate their potential for reactivation or escalation of eruptive activity and attendant hazards. A volcano-hazards assessment and hazards-zonation map for El Chichón are now available (Macías *et al*., 2008). This important study provides the starting point for emergency-management officials in preparing contingency plans should the current low-level, hydrothermal activity of El Chichón escalate in the future into more energetic explosive and potentially hazardous eruption.

• The significantly decreased level of activity during 29 March-2 April should not have been assumed to signal the end of eruption. From a compilation of duration data for Holocene eruptions worldwide, Simkin *et al*. (1981) found that the majority of large eruptions generally last much longer than a week. In an updated analysis of the durations of more than 3,000 eruptions, Simkin and Siebert (1994) report a median duration of 7 weeks (Fig. 12). However, these authors, noting the wide variability in volcanic behavior and eruption duration, even for a single well-studied volcano, cautioned that: "Predicting an eruption's end is no easier than predicting its beginning." (Simkin and Siebert, 1994, p. 20). -

In 1982, the military and other government officials lacked real-time monitoring data or consultations with a cadre of experienced volcanologists during the crisis at El Chichón in guiding their decisions regarding timely evacuations of populations at risk. Fortunately, the circumstances have greatly improved since 1982. Mexico now has many knowledgeable and experienced specialists in responding to volcanic crises and eruptions (e.g., the current activity at Volcán Fuego de Colima and Volcán Popocatépetl). Furthermore, because of the current ease of rapid communications and interactions among the volcanologists, volcanologists in Mexico can consult and cooperate with colleagues worldwide in responding to a volcanic crisis. In this regard, the U.S. Geological Survey's (USGS) Volcano Disaster Assistance Program (Ewert *et al*., 1998)—jointly funded by the USGS and the U.S. Office of Foreign Disaster Assistance (OFDA) has demonstrated some notable successes. Deploying integrated mobile volcano-monitoring systems (Murray *et al*., 1996), USGS mobile response teams have worked with their in-country counterparts in responding to volcanic crises and disasters in many parts of the world (e.g., Cape Verde Islands, Chile, Colombia, Democratic Republic of the Congo, Costa Rica, Ecuador, Guatemala, Indonesia, Mexico, Montserrat, Nicaragua, Papua New Guinea, Philippines).

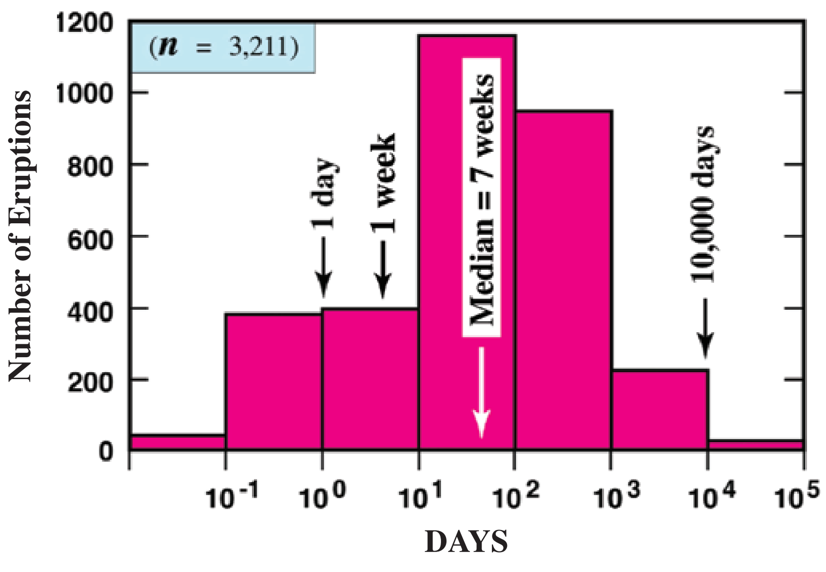


Fig. 12. Duration of 3,211 Holocene eruptions worldwide for which the starts and endings of an eruption are known or can be bracketed in time. The start of an eruption can be clearly documented, whereas the end of an eruption is often arbitrarily fixed because most eruptions tend to gradually decline in activity, rather than ceasing abruptly, in returning to its normal level of activity. (Compiled from the Volcano Database of the Smithsonian Institution, Washington, D.C.; diagram after Simkin and Siebert, 1994, Fig. 7.)

Concluding remarks

Finally, it must be reiterated that data about eruptive history and associated hazards and the availability of baseline volcano-monitoring data—no matter how good or timely—are worthless unless scientists can communicate such information effectively and quickly to civil-protection authorities and the general public, so that appropriate risk-reduction measures can be implemented in time. A key component in the effective communication of hazards information is knowing, and enhancing, the general public's perception of volcano risk. It is promising to note that important studies are underway in Mexico to gauge the public's perception of volcanic hazards and risks at Volcán Popocatépetl (López-Vázquez, this volume) and Volcán El Chichón (Limón-Hernández and Macías, this volume). Such studies should be extended to other Mexican volcanoes (e.g., Colima) and involve larger population sizes in the surveys.

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R. I. Tilling
Volcano Hazards Team
U.S. Geological Survey, Menlo Park, CA 94025-3591
**Corresponding author: rtilling@usgs.gov*