NON-CLUSTERED ACTIVITY OF "LONG PERIOD" EVENTS IN COTOPAXI VOLCANO, ECUADOR

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INTRODUCTION

The Cotopaxi Volcano is one of the most important volcanoes of the Ecuadorian Andes due to its very active history during the last 5.000 years, the variety of volcanic hazards linked to its activity, and the highly populated area located in the probable affected zone.
Its seismic behavior shows many interesting features, including high rates of the so-called "long period" events, which are studied in this paper.

SEISMICITY OF COTOPAXI VOLCANO

The Cotopaxi volcano is continuously monitored, since 1986, by an 1Hz vertical seismic station located at 5.8 km of the crater. Three additional stations were installed in 1990 at distances of 7.0, 9.2 and 10.4 km from the sommital crater. Using this network, 3868 local seismic events have been recorded from January 1991 to December 1995. We classified them as High Frequency A Type (HFA), High Frequency B Type (HFB) and "Long Period" (LP) events, following the criteria of Minakami (1974) and Chouet (1994). The (LP) events are the most observed (77 % of the recorded events ; figure 1).

THE L.P. EVENTS

The Cotopaxi LP events have fundamental frequencies in the range of 0.8 to 2 Hz. The power spectra densities of 26 LP events recorded by the station closest to the crater from October 1993 to December 1994 show peaks in the same frequency range (figure 2). The Cotopaxi LP events have the same characteristics pointed out by Chouet (1994) : 1) an abrupt onset with a burst of high frequency energy evident at small epicentral distances, 2) an extended monochromatic coda (figure 3), 3) sharply peaked velocity spectra , and 4) stability of the spectra peaks across multiple stations (figure 2).
Since 1991, two stages of activity have been recognized in the monthly number of LP events. The minor one runs from January 1991 to December 1992, and the more active one from January 1993 to December 1995 with averages of 21.5 and 66.3 events/month respectively. However, during the period 1991-1995 a stable behavior of the distribution of fundamental frequencies, magnitude ranges and monthly energy release is observed. No peaks of activity nor total calm periods have been observed in the LP activity of the Cotopaxi volcano.

We were able to reliably locate only 42 LP events (RMS ≤ 0.5 sec. and condition number <90) using HYPOINVERSE (Klein, 1978). The top of the velocity model used for the location has been set at 6 km above sea level, i.e., the elevation of the Cotopaxi volcano.
These 42 events are widely distributed in and around the volcanic cone, with a cluster (20 events) located beneath the flanks of the cone (figure 4). They are distributed between the summit of the volcano and 17 km depth ; 15 % only are shallower than 4 km, while 66 % fall in a range between 8 to 18km, confirmaing the intermediate depth characteristic of the LP Cotopaxi events.

DISCUSSION AND CONCLUSION

Prior to the Redoubt volcano eruption, events with frequency characteristic lying in a range of 1.3 to 1.9 Hz and 1.9 to 2.3 Hz occurred (Stephens et al, 1994), as well as before the 1993 eruptions of Galeras volcano (Fisher et al., 1994) . As pointed out by Chouet et al. (1994), swarms of LP events preceded the 1958 and 1983 eruptions of Asama Volcano, the 1987 eruption of Meaken-dake volcano, the 1981 eruptions of St. Helens, the 1982 eruption of El Chichon and the 1991 paroxysmal eruption of Pinatubo, and less intense activity of LP preceded the 1988-1989 eruptions of Tokachi-dake, the 1985 eruption of Nevado del Ruiz. These observations were strongly in favour of using LP events activity as an important clue to volcanic eruption prediction (Chouet, 1994), leading to the elaboration of several pre and co-eruptions models in order to explain the LP activity origin.
Long period events are indicators of pressure transients or transport of fluids involving both liquid and gas phases in cracks or conduits beneath the volcano (Chouet, 1994). Julian (1994) proposed that LP events were provoked by oscillations caused by disturbances of a steady flow such as earthquakes near the fluid-carrying channel or sudden changes in the channel network, without great impedance contrast between the fluid and the channel walls. Fisher et al. (1994) relate LP events to degasing in open vents. Nishimura et al. (1990) found that LP events have a shallower origin than explosion event. Hamaguchi et al. (1992) mentioned vertical forces associated to collapses or landslides as LP generators Shallow LP events are interpreted by Gil-Cruz et al. (1987) and Martinelli (1990) as produced by thermal interaction between magmatic heat and a separated ground water system. Finally, Weaver and Malone (1976) associated LP events recorded in St. Helens to glacier movements.

In the Cotopaxi case, the spatial distributions of epicenters and focal depths discard an origin of LP events inside the ice-snow cap as Weaver and Malone (1976) found in St. Helens. The sign, fundamental frequencies, spectra and long coda of the Cotopaxi LP events suggest an volcanic-related origin. There is no evidence of collapses or landslides to support a source controlled by the action of a vertical force in the generation of these events as found by Hamaguchi et al. (1992). There are minor fumaroles in the sommital crater and on the upper flanks of the volcano, but it is thought not to be enough to produce these events, and at the time present there is not any evidence of a relationship between those and the LP events. Despite small and constant fumarolic activity, there is no signal of important unrest of the volcano which could be linked to the LP activity. The stability of many parameters such as the temporal distribution of the frequency content, magnitude and energy release, since the LP seimicity started being monitored in 1991, suggest that the LP activity is a normal pattern of the Cotopaxi volcano, possibly produced by transient of fluid at intermediate depth beneath the volcano.

REFERENCES

Chouet, B., in press 1994. Volcano seismology as an approach to eruption forecasting, Nature.
Chouet, B., Page, R., Stephens, C., Lahr, J., Power, J., 1994. Precursory swarms of long-period events al Redoubt Volcano (1989-1990), Alaska: Their origin and use as forecasting tool. J. Volcanol. Geotherm. Res., 62, p. 95-135.
Bonilla, A., 1995. Identificación de Eventos Sísmico-Volcanicos en base a un Sistema Neuronal Artificial, Tesis Previa a la obtención de Mestría en Informítica del Programa Escuela Politécnica Nacional-Universidad Andina Simón Bolívar, Ecuador, 97 p.

Fisher, T., Morrissey, M., Calvache, M.L., Gómez, D., Torres, R., Stix, J., Williams, S., 1994. Correlations between SO2 flux and long-period seismicity at Galeras volcano, Nature,Vol. 368, p-135-137.
Gil Cruz F., Meyer H. J., Chouet B. and Harlow D., 1987. Observation of long period events and tremors at Nevado del Ruiz volcano, 1985-1986, Abstr. Hawaii Symp. How Volcanoes Work, 19-25, Jan. 1987, Hilo, Hawaii, p90.
Hamaguchi, H., Nishimura, T., and Zana, N., 1992. Process of the 1977 Nyiragongo Eruption Inferred from the Analysis of Long-Period Earthquakes and Volcanic Tremors, in Geophysical Study on the Hotspot Volcanoes in the Africa Continent, Faculty of Science, Tohuko University, Japan, p. 33-54.
Julian B. R., 1994. Volcanic tremor : nonlinear excitation by fluid flow, Journ. Geoph. Research, 99, B6, 11859-11877.
Klein, F.W., 1978. Hypocenter location program HYPOINVERSE, U. S. Geol. Surv.,Open File Rep., 78-694.
Martinelli, B., 1990. Analysis of seismic patterns observed at Nevado del Ruiz, Colombia during August-September 1985, J. Volc. Geoth. Res., 41, 297-314.
Minakami, T., 1974. Seismology of volcanoes in Japan. In: Civetta, L., Gasparini, P., Luongo, G., and Rapolla, A. (Eds.), Solid Earth Geophysics, Physical Seismology. Ed. Elsevier, p. 1-27.
Nishimura, Y., Miyamachi, H., Ueki, S., Nishimura, T., Shimizu ,H., Ohmi, S., and Okada, H., 1990. Joint Seismometrical Observations by the National University Team during the 1988-1989 Eruptive Activity of Mt. Tokachi, Hokkaido. Bull. Volcanol. Soc. Japan, Ser. 2, Vol. 35, No. 2, p. 163-173.
Stephens, C., Chouet, B., Page, R., Lahr, J., Power, J., 1994. Seismological aspects of the 1989-1990 eruptions of Redoubt Volcano, Alaska: the SSAM perspective. . Volcanol. Geotherm. Res., 62, p. 153-182.
Weaver, C., and Malone, S., 1976. Mt. Saint Helens seismic events: volcanic earthquakes or glaciar noise?. Geophys. Res. Letters, V. 3, No. 3, p. 197-200.

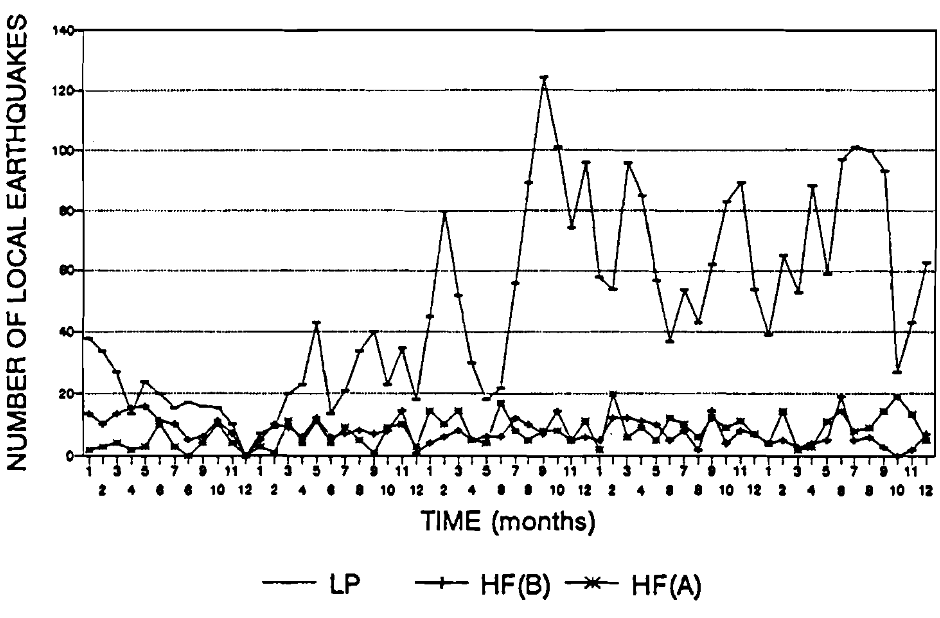

Figure 1 : Monthly distribution of LP, HF(A) and HF (B) earthquakes of the Cotopaxi volcano from 1991 to 1995, recorded at the closest (5km) station from the crater.

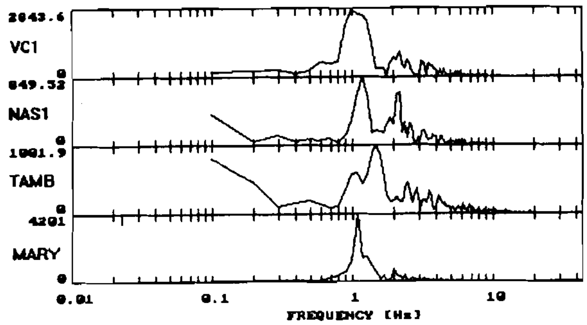

Figure 2 : Example of spectra obtained at the four Cotopaxi seismic stations for a LP event, signal of this event is shown in figure 3.

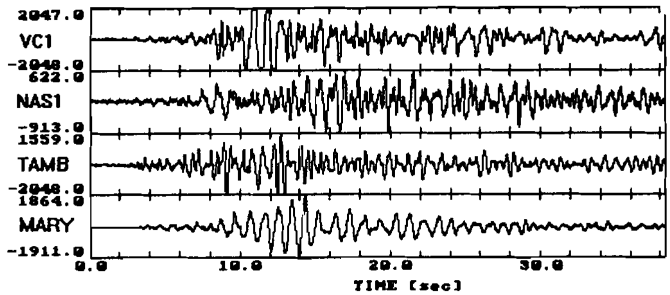

Figure 3 : Example of a LP event signals recorded at the four Cotopaxi seismic stations.

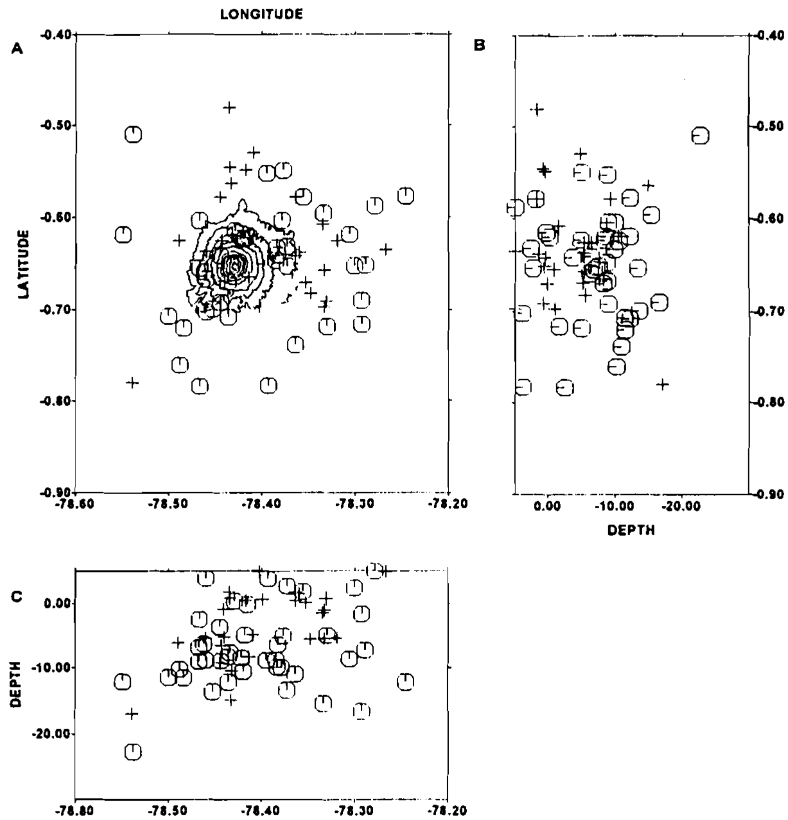

Figure 4 : Spatial distribution of the best located earthquakes in the Cotopaxi area. A : map view ; B N-S cross-section ; C : E-W cross-section.