

## **SEISMIC SWARM IN QUITO (ECUADOR): TECTONIC OR VOLCANIC ORIGIN?**

Alcinoe CALAHORRANO<sup>(1)</sup>, Hugo YEPES<sup>(1)</sup>, Bertrand GUILLIER<sup>(1,2)</sup>, Mario RUIZ<sup>(1)</sup>,  
Mónica SEGOVIA<sup>(1)</sup>, Darwin VILLAGÓMEZ<sup>(1)</sup> and Daniel ANDRADE<sup>(1)</sup>

(1) geofisico@accessinter.net. Apartado postal 2759, Quito-Ecuador

(2) bguillier@ednet.net. Apartado postal 2759, Quito-Ecuador

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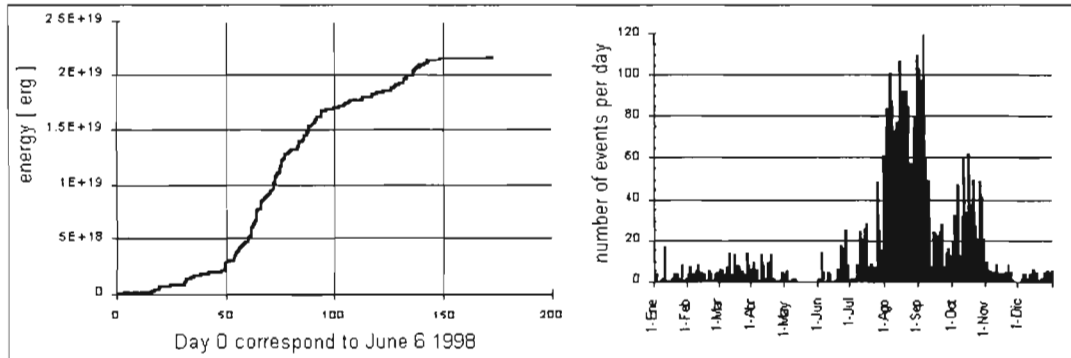
### **INTRODUCTION**

The city of Quito (1.5 million pop.), Ecuador, located in the interandean valley, is limited on the west side by Guagua Pichincha Volcano and on the east side by a series of slopes aligned NNE, in accordance with the Andean trend. This latter morphological feature is the superficial expression of the Quito Active Fault System. Since June 1998, an anomalous increase of seismic activity was registered in the northern part of Quito, and two months later, an increase of volcanic and seismic activity at Guagua Pichincha Volcano (located 16 km SW of the swarm) was registered. Characterization and relationship between these two seismic activities are important to understand both processes and to advise people living in Quito and its surrounding areas

### **SEISMICITY**

Since June 1998, a very intense seismic swarm of about 4000 events has been registered in Quito. During July 24 and October 31, the swarm shows an average of 40 events per day, and a maximum of 120 events daily, while in the first half of the year the average seismic activity was not bigger than 3 events per day. Two peaks of activity are clearly defined: the first between the end of the first days of July and September, and the second on October (figure 1a). The average magnitude was 2.7 while the

maximum calculated magnitude was 4.1. The seismic signals show frequencies from 1 to 12 Hz, with peaks at 2.3 and 3.2 Hz on the nearest seismic stations. The total energy accumulated by the swarm, from June 6 1998 to the end of the year, shows two important increments related to the seismic peaks in August-September and October. (Figure 1b)



**Figure 1 a** Accumulated energy released in 1998 Quito Seismic Swarm, from Jun.6 to Dec. 31

**Figure 1 b** Number of events registered in 1998

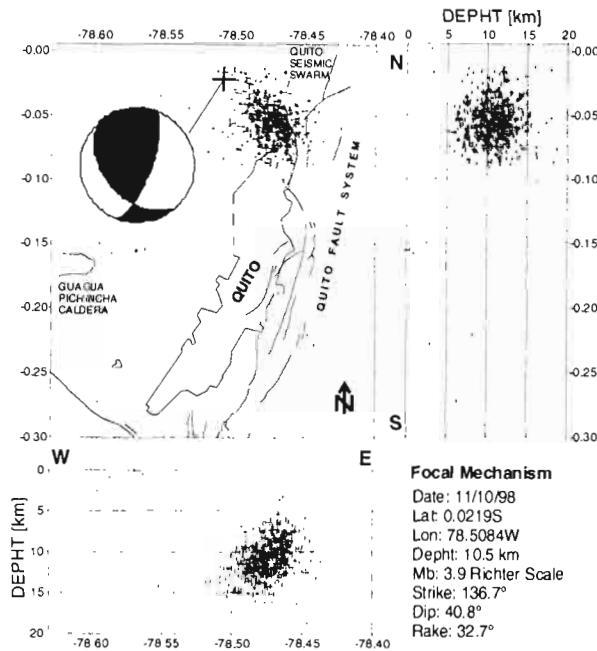
## DATA PROCESSING

The seismic data were processed using HYPOELLIPSE (Lahr, 1995) and a local velocity model. 2190 events from a total of about 4000 events were selected according to the following criteria: rms < 0.3, errx < 0.7, erry < 1.0 and errz < 2.0. A ratio  $V_p/V_s = 1.68$  was determined using the P-P vs S-S diagram (Chatelain, 1978). The epicentral distribution presents a slight NW-SE orientation while depth foci are constrained between 5 and 15 km showing a possible plane dipping  $40^\circ$  to the W (Figure 2).

## FOCAL MECANISMS

Geomorphological observations (Ego, 1995; Yepes, 1995) suggest a NNE reverse active fault dipping to the west. This structure is supposed to be bifurcated and absorbed by a local sinistral fault in the northern part (Soulas et al., 1991). The focal mechanism, obtained for a 3.9 event occurred on October 11, shows a reverse movement. The plane striking  $N136^\circ E$  and dipping  $41^\circ$  to the SW roughly coincides with the weak orientation of the epicenters. It also shows a small left lateral component associated with this motion. The strike of this fault plane does not agree with the NNE-SSW trend of the main fault system, but it could be explained as the motion along a secondary branch of the Quito Fault as suggested by Soulas et al. (1991). The main compression axis responsible for the seismic swarm coincides with the regional stress pattern (Guillier, non-published data), where the main compression axis ( $\sigma_1$ ) has a ENE-WSW direction. A component of the volcanic stress generated inside Guagua Pichincha volcano could

also change the stress field in its surroundings. The magma chamber could also accounts for the occurrence of the seismic swarm, if the concurrent reactivation of the volcano is taken into consideration as well as the sort distance between the swarm and the caldera.



**Figure 2.** Swarm foci distribution and focal solution for 3.9 October event.

## VARIATION OF THE b-VALUE

b-value were computed using windows of 200 events 25 % overlapped. For 1997 data, the observed value was 0.5340, while it was 1.467 and 1.07 for 1998 and 1999 respectively. In 1997 random distribution of seismicity without any evidences for a swarm is observed. In 1998 and 1999 the b-value increased, especially in 1998 when the swarm began. Temporal analysis of the b-value for 1998 shows two important increases around July 22 and September 10, with values that range from 1.2 to 1.7. The lower values correspond to the period of more seismic activity during

August. Factors that could alter the b-value include increased heterogeneity of the material (Mogi, 1962) and increase in the stress field (Scholz, 1968; Wyss, 1973). Then, this parameter could be representing a newly fractured material or a variation in the stress field, explained equally well by the movement and cracking of the fault, and/or the increase of the gas pressure in the magma chamber underneath Guagua Pichincha.

## CONCLUSIONS

An intense seismic activity was registered in the northern part of Quito since June 1998 to the present day. This type of activity was not observed before in this area, and presents two important peaks of around 40 events  $m_b=2.0$  or above per day, between July 24 and October 31.

Epicentral distribution of the events shows a particular NW-SE orientation, while hypocenters suggest a plane dipping around  $40^\circ$  to W. The focal mechanism solution agrees with the rough swarm epicentral distribution and the regional compressive field. A possible compressional component coincident with the direction of Pichincha volcano is suggested, but additional focal mechanisms should be analyzed to better understand the stress fields in this area.

An important change in the b-value from 0.53 in 1997 to 1.467 in 1998 was observed. The appearance of the 1998 Quito seismic swarm could explain this difference by increases in the heterogeneity of the crustal materials (Mogi et al., 1992) and/or by variations in the stress field (Scholz, 1968; Wyss, 1973).

Both focal mechanism and foci distribution suggest that a structure striking NW-SE, could be the source of this seismic activity. This structure does not agree with the Quito Fault System trend, but it could be explained as a northern termination of the main structure with a NW-SE trend. Quito seismic swarm was initially attributed to the active Quito Fault System, corresponding to a tectonic origin. Nevertheless, the August 1998-March 1999 volcanic crisis at Guagua Pichincha, which presents b-value variations related with changes in the stress field beneath the volcano (Villagómez, this volume), could give new ideas about the origin of the swarm.

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