STRESS TENSOR ANALYSIS OF THE 1998-99 TECTONIC SWARM OF NORTHERN QUITO RELATED TO THE VOLCANIC SWARM OF GUAGUA PICHINCHA VOLCANO, ECUADOR.

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KEY WORDS : stress tensor, volcanic and tectonic swarm, Guagua Pichincha volcano, Ecuador.

INTRODUCTION

Phreatic activity and subsequent dacitic dome growth in 1998-99 at Guagua Pichincha volcano, Ecuador, was associated with two seismic swarms: One located in the northern part of Quito and another one, just below the active volcano, about 15-20 km SW from the first one. We registered more than 3.200 events (among which 2.354 events of 1.4 $\leq M_L \leq$4.2) between June 1998 and December 1999, at [-2 km; -17 km] depth. Approximately 130.000 events were registered between September 1998 and December 1999 at [+2.4 km; -3.5 km] depth. We study here the stress tensors of these two swarms deduced from the polarities of P first motions and compare them to the regional stress tensor deduced from CMT Harvard focal mechanisms. Movement of fluids (magma, gas and/or groundwater) produced by the close active Guagua Pichincha volcano seems to have influence in the acceleration of generation of seismic events.

SEISMOLOGICAL NETWORK AND DATA:

In this study, we use 35 of the 40 stations of the Ecuadorian network (Figure 1), mainly 1 Hz vertical component with a good azimuthal distribution and distance range with respect to both swarms. In the period 1998-99, about 130 000 tectonic and volcanic events have been recorded by the IG-EPN. In this study, we only select the best events and relocated them with a new velocity model (Villagómez et al., 1999; Villagómez, 2000; Calahorrano et al., 1999; Calahorrano, 2001). We show (Figure 2) the most reliably constained events of the swarm of Quito (1.662 over more than 3.200 events) corresponding to a RMS<0.5 and at least one S arrival time.

STRESS TENSOR ANALYSIS:

The joint inversion for focal mechanisms and stress tensor shape and orientation has been performed. The best stress tensors are shown in Figure 3. For Quito swarm two principal kinds of focal mechanisms exist: strike slip and reverse faults. These differences can be expected with the shape factor R = -1. Focal mechanisms of Guagua Pichincha are very different from these of the swarm of Quito. They are mainly normal and strike slip faults, compatible with respect to a 0.4 R shape factor.

A classical question is to check whether the stress tensor beneath a volcano is the same as the regional stress tensor. In order to answer this question, we compare the local Quito and Guagua Pichincha stress tensors with respect to the regional tectonic stress tensor. We consider focal mechanisms of large ($M_w \geq 5$) and shallow (depth$\leq$50 km) earthquakes (Figure 4). The corresponding data split naturally into 2 regions called the coast and the cordillera. Hence, we calculate the stress tensor for each region. The results are shown in figure 4 and show an almost identical stress tensor for both regions. This regional tectonic stress tensor with σ_1 aligned E-W is consistent with compression caused by the convergence between the Nazca and South America plates. Additionally, the subduction collision of the Carnegie Ridge may locally increase plate coupling (Gutscher et al., 1999a and 1999b) and is similar to Quito swarm.

CONCLUSIONS

Quito swarm stress tensor (Figure 3 bottom-right) has a major compressive stress direction σ_1 almost in a horizontal direction, oriented N116.5°E, compatible with 1) the regional plate motion direction of N102°E deduced from GPS (Kellogg and Vega, 1995) 2) the results of Ego et al., 1996 and 3) the σ_1 N91.5°E direction we found using large earthquakes of the cordillera of Mw≥5 (Figure 4 up-right). The extensional direction σ_3 of the swarm of Quito (Figure 3 bottom-right) is almost vertical, in agreement with the regional stress tensor (Figure 4). Hence, the stress tensor of the swarm of Quito is similar to the regional stress tensor, small differences can be due to the effect of the close active Guagua Pichincha volcano, situated 15-20 km SW.

In contrast, the stress tensor of Guagua Pichincha volcano (Figure 3 middle-left) is very different from the regional tectonic (Figure 4) and the Quito swarm (Figure 3 bottom-right) ones. This suggests a very local stress regime directly associated to Guagua Pichincha volcano activity. The horizontal σ_3 direction beneath the volcano is compatible with what should be expected under a volcano were many up-going fluids (water, gas and/or magma) can generate such horizontal extensional direction.

We speculate that Quito swarm is directly submitted to the regional stress tensor, slightly modified by the close (15-20 km) active Guagua Pichincha volcano, whereas the stress tensor of the swarm under the volcano is a local response to this regional stress tensor.

The presence of two stress tensors relatively different within a small region (at about a distance of 15-20 km) suggests that the stress tensor may be rather heterogeneous in that region, and that the volcano may have an influence upon the regional stress tensor within a distance of at least 20 km from which Quito swarm is located.

Acknowledgements:

We thank all the staff (technicians, researchers, engineers and students) of the Instituto Geofísico of the Escuela Politécnica Nacional of Quito (IG-EPN) for the monitoring and the maintenance of the seismological stations in Ecuador. We thank the IFEA (Institut Français d'Etudes Andines), the IRD (Institut de Recherche pour le Développement) and the MAE (Ministère des Affaires Etrangères) for supporting portions of this study.

Al amigo, Diego Viracucha, quien cayó el domingo 14 Enero del 2001 en el crater del Guagua Pichincha. Un recuerdo sincero para todos tus efuerzos y devoción a la volcanología. Te dedicamos este pequeño trabajo.

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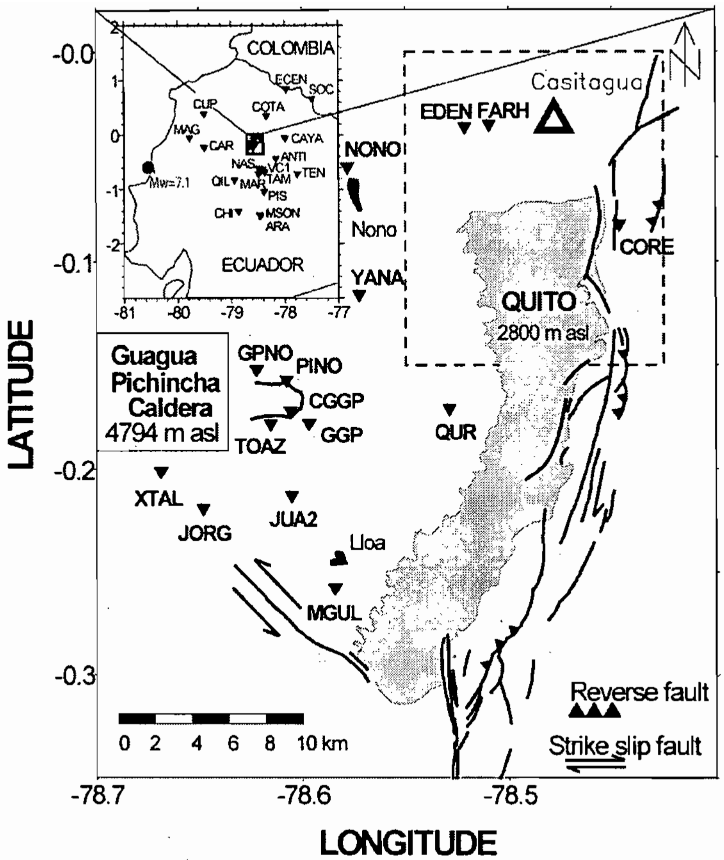

Fig 1. **Up-left rectangle**: The 35 seismic stations (inverse triangles) of IG-EPN used for this study. The rectangle corresponds to the limits of the main figure.

Main figure: Local seismic stations and main faults near Quito. The station TERV is at the same place as CGGP. The open triangle corresponds to the Casitagua (3519 m) old volcano. We represent also the 4675 m limit of the caldera of Guagua Pichincha volcano (4794 m). The rectangle corresponds to the limits of Quito swarm.

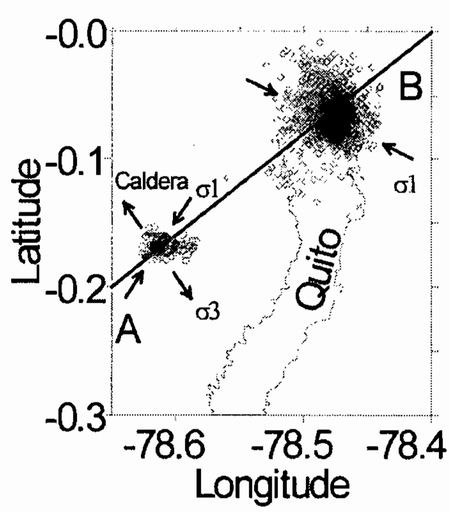

Fig 2. Location of the events of Quito swarm (diamonds) and VTs swarm under the Guagua Pichincha caldera (circles). The line AB corresponds to a vertical cut of figure 3.

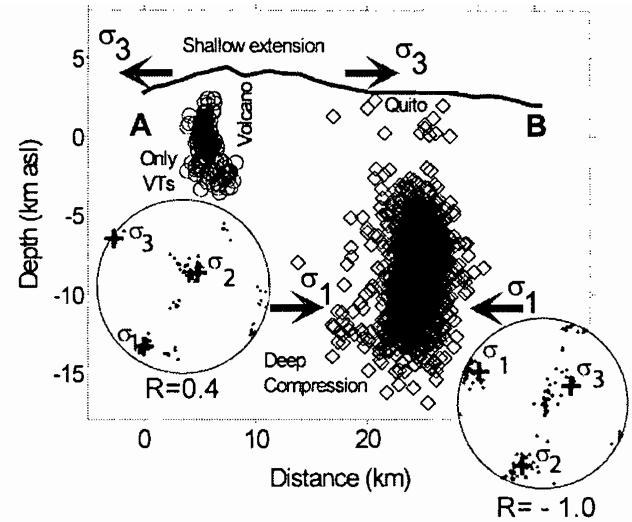

Fig 3. Vertical cut AB of figure 2. Stress tensors of the swarm of VTs swarm below Guagua Pichincha volcano (up-left) and Quito swarm (bottom-right). The direction σ_1 may affect the deep events under Quito (diamonds) and generate a deep compression (convergent arrows) and a shallow extension at the level of the volcano (divergent arrows). The stress tensors are represented in the inferior half sphere, equal-area Schmidt projection. $\sigma_1>\sigma_2>\sigma_3$ are the eigen directions of compression, intermediate and extension respectively. The 50 best solutions are plotted, the cross corresponds to the best solution.

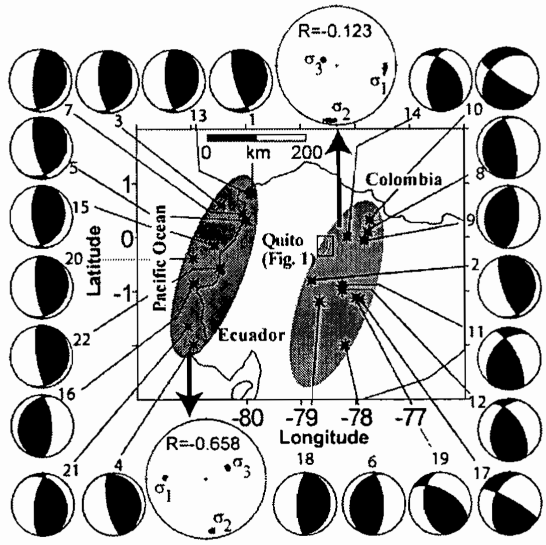

Fig 4. CMT Harvard focal mechanisms of shallow earthquakes (less than 50 km deep), and $M_w \geq 5$. $\sigma_1>\sigma_2>\sigma_3$ are the eigen directions of compression, intermediate and extension respectively. The square corresponds to limits of figure 1.

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APPUIS FINANCIERS
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L'organisation de l'ISAG 2002 et les bourses accordées à un certain nombre de collègues latino-américains ont été possibles grâce au soutien financier de l'IRD (notamment de la Délégation à l'Information et à la Communication), de la région Midi-Pyrénées, de l'Université Paul Sabatier et de l'Andean Comittee de l'ILP.