THE PISAYAMBO, ECUADOR, SEISMICITY NEST : TOWARDS THE BIRTH OF A VOLCANO ?

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INTRODUCTION

The center of the Pisayambo seismicity nest is located at about 1.1°S 78.3°E. This nest is very active : about 40 % of the activity detected by the permanent Ecuadorian network comes from this nest at the 3.1 magnitude detection level of the network. This nest produces very few events big enough to be detected by the worldwide network (45 events with magnitude ≥ 4.2 from 1963 to 1991). The only other nest of activity observed in Ecuador is located about 75 km to the SE, known as the Puyo nest, shows opposite characteristics, i.e. it is only constituted of magnitude > 4.2 events (126 events from 1963 to 1991) located by the worldwide network, while the permanent local network does not detect small magnitude events. It also shows a much more sporadic activity.
The very steady and important small magnitude events activity of the Pisayambo nest is concentrated in a small 20 by 20 km. zone, located in-between and a little bit East of the Tungurahua and Cotopaxi volcanoes (Figure 1). Above the nest is located a hydroelectric dam with a reservoir of about 0.1 km^3, as well as several smaller lagoons. Very little geological information of the zone is available. Only Yepes et al. [1979] and Bonilla et al. [1992] describe a network of SW-NE trending faults above the nest.

DATA

Data used for this study come from two sources : the earthquakes recorded by the Ecuadorian permanent network from 1989 to 1995, and data obtained with the Lithoscope experiment from December 1994 to May 1995. A station of the Lithoscope experiment was installed above the nest. A station of the permanent network is working above the nest only since July 1995. The permanent network has been extended from 7 stations in 1988 up to 33 stations in 1995
The earthquakes were localized using the HYPOINVERSE [Klein, 1978] and HYPOCENTER programs, with a one dimension flat layered velocity model taken from the results of the inversion by Prévot et al. [1996], a Vp/Vs ratio of 1.737 obtained with a (S-S) versus (P-P) diagram [Chatelain, 1978]. From the initial set of 2297 events, a final set of 737 events were selected with the following criteria : a root mean square residual (RMS) less than 1.0 sec and a condition number less than 1.0. Out of these 737 events, 51 are recorded in 15 stations or more.

The earthquakes were then used (1) to show their spatial distribution, (2) to evaluate the Gutemberg Richter b-value, and (3) to test the dependency in time of the occurrence of the events in order to find an explanation to the presence of the only nest of persistent seismic activity in Ecuador.

SPATIAL DISTRIBUTION OF THE EARTHQUAKES

The distribution in map view of the best located events shows that the activity of the nest is confined to a small 20 by 20 km zone where 50 % of the events occur, located East of the line defined by the Tungurahua and Cotopaxi volcanoes and in-between them, centered on 1.1°S - 77.3° E (Figure 1).

In depth the nest is clearly composed of two clusters ; the first between 0 and 10 km , the second between 17 and 20 km. (Figure 2). Both clusters appear in both data sets obtained with the two programs used for the location, and appear also clearly on the Lithoscope data set for witch a station was located above the nest. We therefore assume that this gap is real and not an artifact of the localization process.

The Pisayambo nest is a 20x20x20 km column divided in depth in two clusters separated by about 7 km

GUTEMBERG-RICHTER b-VALUE

While for all Ecuador b-value is 1.13, estimation of this parameter for the nest taken as a whole leads to a 1.71 value. This value becomes 1.51 for the shallowest cluster, and 1.86 for the deepest cluster when considered separately. These values are quite high, and quite different between the two clusters. B-value of the shallowest cluster is in the rank of observation of values linked to highly fractured zones [e.g. Scholz, 1968], while b-value of the deepest cluster is in the rank of values observed for volcanic related events [e.g. Talandier and Okal, 1984].

APPLICATION OF THE POISSON PROCESS

The temporal distribution of the earthquakes in a 10 km radius circle centered on 1.1°S - 78.3 ° W does not fit a simple Poisson process, i.e. the events are time dependent. The events in the upper cluster fit a generalized process when taken by groups in 13 hours windows (Figure 3) and the lower cluster events when taken by groups in 25 hours windows (Figure 4), with a confidence level of 90%. Therefore the events are time dependent within 13 or 25 hours in groups which are time independent. The E parameter is found to be 2.1 and 2.5 for the upper and deeper clusters respectively. Values of $E \geq 2.5$ have been associated to tectonics events, while values ≤ 2.0 have been associated with volcanic events [Savage, 1972 ; Udias and Ruffle, 1975 ; Bottari and Neri, 1983 ; De Natalle and Zollo, 1986]. We therefore find a second characteristic, after the differences observed for b-value, that tends to differentiate the origin of the two clusters between tectonics and volcanic.

Analysis of the groups within the two time scales used for the generalized Poisson process also show distinctive patterns. In the groups of the upper cluster the event with the highest magnitude tends to be in the center of the sequence, while it is not the case for the groups of the lower cluster (Figure 5). Mogi [1985] interpreted the occurrence of the main event in the middle of earthquake sequences as related to highly heterogeneous zones, with a concentration of efforts in the volume where the sequences occur.

DISCUSSION AND CONCLUSION

The Pisayambo nest occupies a 20x20x20 km volume. This nest is divided into two clusters, separated by about 7 km, occurring on top of each other. The upper cluster presents characteristics

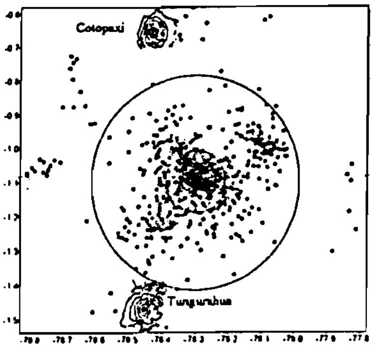

Figure 1. Disribution of the selected events of Pisayambo nest recorded from 1989 to 1995. The two 10 km and 35 km radius circles used for the study of the Poisson process are also shown.

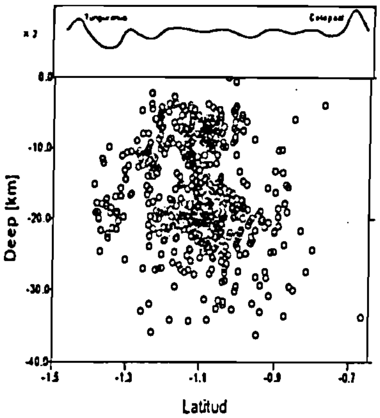

Figure 2. Depth distribution of the selected events in the zone of the Pisayambo nest, along a South-North cross section. Note the two swarms separated by about 7 kilometers.

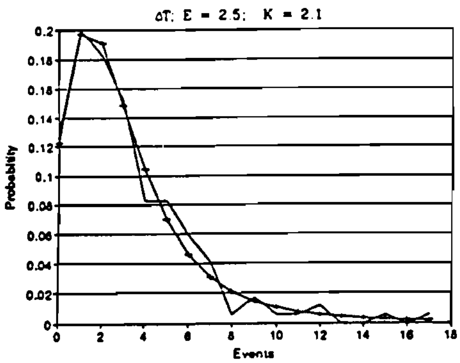

Figure 3. Generalized Poisson process applied to the shallowest swarm of the Pisayambo nest for the events included in the 10 km radius circle shown in figure 1.

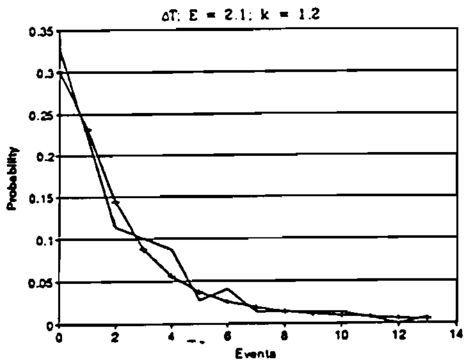

Figure 4. Generalized Poisson process applied to the deepest swarm of the Pisayambo nest for the events included in the 10 km radius circle shown in figure 1.

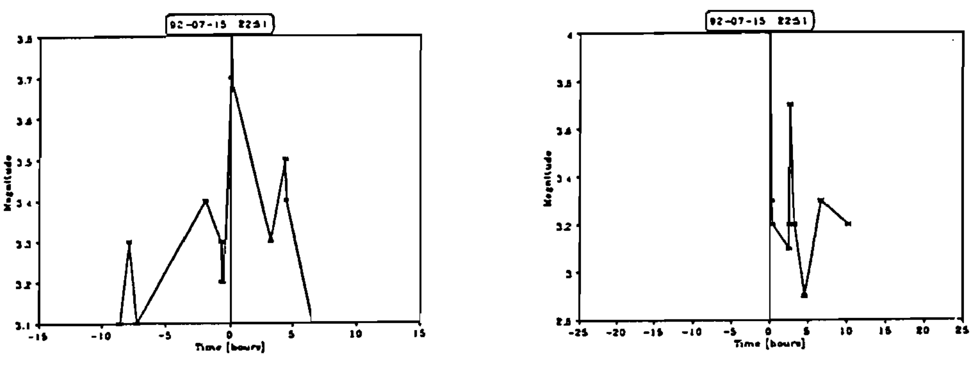

Figure 5. Magnitude versus temporal distribution 13 hours before and after the main event of a sequence of dependent events in the shalowest swarm (left) ; 25 hours before and after the main event of dependent events in the deepest swarm (right).

of tectonics events occurring in a highly fractured area, while the lower cluster presents characteristics of volcanic events. Behavior of other parameters, such as slight P-wave velocity and Vp/Vs decrease with depth in the upper cluster can be linked a saturated, i.e. highly fractured zone. Finally, the Pisayambo nest is located in the upper plate right above a seismicity gap in the subducting plate (see figure 2 of Guillier et al., this volume).

All things considered a plausible explanation for the presence of the Pisayambo nest could be the following :

- the gap in the descending plate can be interpreted as due to a detachment of the bottom part of the plate ;
- hot mantelic material is uprising where the subducting plate is absent towards the surface ;
- uprising of the hot material produces bulging of the upper crust, fracturing and weakening it, which could conduct to its rupture giving birth to a volcano, in the best of the cases, or a caldera.

Focal mechanisms and aerial photo analysis, other geophysics and field studies will be carried out to see if their results fit into this hypothesis.

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