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Bimodal Seismic Anisotropy at Cotopaxi volcano (Ecuador): Possible implications

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A shear wave splitting analysis was performed on Cotopaxi volcano, one of Ecuador most active and hazardous volcanoes, in order to investigate the stress state under this volcano.

Cotopaxi volcano is located in a highly populated area including the capital Quito. It's eruptive cycle is approximately 120 $\pm$70 years and apart from possible minor eruptions in 1942 and 1903-1904, the last volcanic activity dates from 1878-1885. Moreover, 15 years of increasing seismicity with some major crisis during the 1995-2010 periods, lead to the current very high seismic level. Finally two years of gas monitoring suggest that the Cotopaxi's emissions are currently intermittent and passive, but non negligible.

We analyzed 102 regional tectonic events recorded between 2006 and 2009 at a network of five broad-band three-component seismic stations. These stations are located on all flanks of Cotopaxi. The events used were from several seismic sources located inside a radius of 200 kilometers from the volcano and illuminate all space directions. Seismic events were manually chosen based on their clear shear wave component in regards to the compression wave and to the noise. The data were computed using Matlab software. Polarization directions and delay times of split shear waves were found using a method based on the cross correlation of displacement waveforms of shear-waves at all possible rotation angles.

Our results show a bimodal anisotropic behavior. One of the fast-directions axes follows the regional Ecuadorian tectonic general strain with a ESE direction. The other trend was found to be perpendicular to the regional strain.

Other studies have shown that a 90º flip may take place either prior, during, or just after the main eruptive phase, or during hydraulic injections. This 90º flip is probably relied to micro cracks filling and pressuring, creating a local reverse strain field. There is not clear trend on temporal evolution of anisotropy distribution on our data. Only one anisotropic direction (NNW) was constrained in time (2007). There are clear spatial differences in the results in regards to the stations position. Ongoing analysis will cover the November 2009 seismic crisis.

To use this kind of analysis as a diagnostic tool of a possible eruption, one needs to distinguish between an existing inherited bulk anisotropy (due to the heterogeneity of the volcanic edifice or the underlying crust) and a fairly temporal change in the anisotropic characteristics (due to volcanic activity). At Cotopaxi, seismicity and other parameters have been dramatically increasing over the past three years. Therefore, we interpret the observed anomaly as due to magma movements under Cotopaxi.