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Radon soil increases before volcano-tectonic earthquakes in Colombia

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Abstract. Continuous studies of radon concentration changes in soils for the purpose of earthquake monitoring have been carried out in three colombian districts and in the edifices of Galeras and nevado del Ruiz volcanoes since 1995. In zones of active faulting have been measured radon soil emissions between 1000 and 2500 pCi/L. In an intersection of two active geological faults have been measured levels of 25 000 pCi/L.

In the present work appears a compilation of examples of the registered anomalous radon emissions in several stations before earthquakes of tectonic character. Examples of registered radon increases before: (1) events of magnitudes between 2 and 4; (2) the occurrence of seismic swarms; and (3) the Quindío (Colombia) earthquake ($Mw = 6, 2$) of January 1999, are described. A model of transport mechanism for the studied isotopes is presented.

1 Introduction

In studies of geological fault traces and researches of tectonic activity state, isotopic studies have been gotten up since few decades. Radon-222 is the isotope that more had been investigating. Simultaneously are measured some gases like helium, hydrogen, carbon dioxide (Garzon, 1996); and isotopes like thoron (Rn-220), radium-226 and carbon-13 (Heiligmann et al., 1997). Gas concentrations from the Earth's interior are controlled by lithology and structure of the studied zone (Williams-Jones et al., 2000). But in the time their emissions can change by geodynamic and/or meteorological influences.

Radon-222 is in constant emission from the Earth's interior towards the atmosphere. For several decades it had been proposed: (1) the existence of anomalous emissions of this gas on active geological faults; (2) temporary variations related to changes of atmospheric conditions; and, (3) its possible forerunner manifestation before an earthquake (Ulomov and Mavashev, 1971; Moran et al., 2001).

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2 Methodology

At the present time in Colombia, its installed a network of 22 isotopic stations near Pasto city at Nariño district; four stations near Purace town at Cauca district; and six stations between Manizales city and nevado del Ruiz volcano at Caldas district.

With the purpose to measure radon emissions on active geological faults, in all three Volcanological and Seismological Observatories at INGEOMINAS is used the E-perm system (Electret Passive Environmental Radon Monitor) proposed by Kotrappa et al. (1988). A Pylon instrument with a Lucas cell is used for radon measurements in a gas telemetrical system, which is tested from 1997 at some fumaroles in the center of active crater at Galeras volcano (Faber et al., 2002).

3 Results and discussion

The most relevants radon soil increases measured for our working group, before seismic events are:

1. For a time period of ten months Garzon (1996) reported some radon soil increases in Barranco station at isotopic network installed by the Pasto's Volcanological and Seismological Observatory. Radon soil increase was of 350 pCi/L, which apparently preceded the occurrence of microearthquakes of magnitudes until of 2,1 in the Richter scale in a radius from the isotopic station $<$6,0 Km.

2. Comparative studies between radon soil emissions and number of volcano-tectonic earthquakes ($M > 1, 5$) registered by the Pasto's seismological network were carried out. In the same Barranco station and for a time window of five years, radon soil increases were

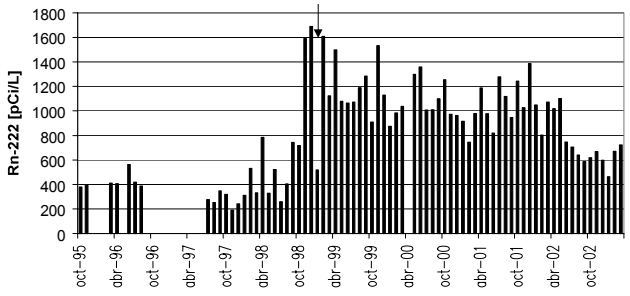

Fig. 1. Radon soil emissions at OVSM isotopic station (September 1995 – March 2003). The arrow shows the occurrence of Quindio (Colombia) earthquake ($Mw = 6,2$) on 25 January 1999. Each data indicate a monthly averange radon soil emission.

observed during and before the occurrence of the main volcano-tectonic (VT) events.

3. For a time period of one year, Garzon and Serna (2001) reported a comparison between radon soil emissions in Sismo 1 station at Pasto's isotopic network and two seismic events of tectonic nature of magnitudes of 2,3 and 3,2.

4. Before the ocurrence of VT seismic swarms on the trace of Termales geological active fault, in the Hotel station were measured increases of radon soil emissions of 2000–3000 pCi/L.

5. Previous to the Quindio (Colombia) earthquake ($Mw = 6,2$) of 25 January 1999, were registered radon soil increases in the OVSM station at Manizales isotopic network. In Fig. 1 are showed the behavior of radon soil emissions from 1995 to 2003. The arrow shows the day of earthquake when many buildings were destroyed, 1171 people dead and 4500 injured. Radon soil anomalies were registered during years of afterquakes. It is clear observed that background of radon emissions was modified from 300 pCi/L to 600 pCi/L.

In agreement with radon monitoring carried out by our research group its possible to do more detailed furerunner seismic works using radon stations on active geological faults and in the intersections of those.

Above presented cases of radon soil increases before VT earthquakes have been registered in some isotopic stations. Forerunner anomalies were not possible to measure in all installed radon stations. With the purpose to stablish which are the differences between "sensitivities" of radon stations, were carried out detailed studies of soil profiles and genesis of trapped gases. It was demostrated differences between radon stations in their depths of organic and natural soil profiles. Those stations in which gases are trapped in organic soil layers do not show radon anomalies before earthquakes. As its well known, organic materials contain carbon atoms, which is used world-wide as an adsorbent material of gases. In this case organic soil layer works as a "sealing" system, hindering the flux of gases from the Earth's interior to the detector system.

To confirm this hypothesis were installed a trapping system for carbon dioxide and were made measurements of C-13 vs. C-12 isotopic relation. It was established a more positive values of $\delta^{13}(CO_2)$ between $-14,6$ and $-6,8$‰ PDB for stations like Barranco, Sismo 1, OVSM, Hotel, which suggest a more deeper source of trapped gases and active faulting. For those stations located outside active geological faults and trapping gases from organic soil layers, measured $\delta^{13}(CO_2)$ was between $-31,5$ and $-18,4$‰ PDB, which suggest a surficial biogenic component.

4 Conclusions

The observed response to tectonic events, suggest that soil gases like radon, can be useful in the understanding of seismic behavior. As radon soil emissions increases prior the occurrence of VT earthquakes, radon measurements can be used as an initial warning sign of formation of a seismic focus.

A first step to monitor radon soil emission is to study soil profiles and sources of trapping gases in the future station. Very importan to install radon station on an active geological fault or in the intersection of those.

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