RADON SURVEY AT LA PALMA ISLAND (CANARY ISLANDS): FIRST RESULTS

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ABSTRACT

La Palma is one of the most volcanically active islands in the Canarian archipelago, with two eruptions in the last 50 years. At this island, a radon mapping was carried out in order to determine the normal levels of this gas in soils and in the underground environment during a quiescence period and to investigate possible active geological structures. Radon values are in general low, both at surface and in the underground, although weak anomalies were detected into a gallery in the north of the island (200 pCi/l) and at the southern rift (>180 pCi/l), the most active edifice in recent times.

1 • INTRODUCTION

Gas concentration anomalies are commonly associated to active zones such as volcanic areas and tectonic zones. Faults, open fractures or porous rocks may provide paths of least resistance along which terrestrial gases generated or stored in the earth can escape to the atmosphere. One of the most common tracers of gas transport is radon (^{222}Rn), a product of the decay series of ^{238}U. Radon is a noble radioactive gas with a half-life of 3.82 days. Once released from a source rock, by emanation, into the surrounding liquid or gas phases within the rock pores and crevices, it is liable to be transported without reacting with surrounding rocks. Diffusion distances of radon in air are of the order of a few meters. This distance is very short when compared to the possible deeper source of the volcanic activity. This means radon from deeper origin could only be detected if it is carried by other medium, usually a gas. In this case we may say radon is tracing the pathway of the carrying gas.

In volcanic contexts, degassing pulses can be mapped over large areas during eruptions and can occur in response to low-energy, low-volume eruptions. Recognition of these pulses depends on mapping anomalous ^{222}Rn zones during periods of quiescence and monitoring numerous ^{222}Rn stations around the volcano at frequent intervals (Connor *et al.*, 1996).

At La Palma island, an initial radon survey was carried out during the summer of 1997, aimed to study its distribution and relation to main volcanic structures. A first radon map of the island has been obtained. This work contributes to the characterisation of the radon levels at this island during an inter-eruptive period.

2 • GEOLOGICAL SETTING

La Palma is a volcanic island comprised of five main volcanic overlapping edifices, aligned and decreasing in age through a north-south direction (Navarro & Coello, 1993; Ancochea *et al.*, 1994; Carracedo *et al.*, 2001). At the north, the large Taburiente shield volcano is the oldest subaerial edifice, built from 1.7 to 0.4 Ma and presently destroyed by the formation of the Taburiente Caldera. It constitutes the northern half of the island, overlaying a partially emerged submarine edifice named Basal Complex (de la Nuez, 1984; Staudigel & Schmincke, 1984). In the central zone there are two stravolcanoes, nowadays inactive, namely Cumbre Nueva and Bejenado edifices. The Cumbre Vieja rift, younger than 0.4 Ma, occupies the southern half of the island. This edifice has been the most active in recent times, with seven eruptions in the last 500 years, the two last ones in 1949 and in 1971 (San Juan and Teneguía volcanoes) (Hernandez-Pacheco & Valls, 1982; Carracedo *et al.*, 2001). Residual volcanic manifestations at this island are fumaroles and thermal anomalies (>150 ^{o}C) at Teneguía volcano (Carracedo & Soler, 1984), diffuse CO_2 emissions along the southern Cumbre Vieja ridge and bubbling cold CO_2 emissions at Taburiente Caldera in the North (Bravo *et al.*, 1976). The present level of seismic activity is very low.

3 • METHODOLOGY

^{222}Rn determinations were done using Solid State Nuclear Track Detectors (SSNTD), applying an integration time of one month (Alter & Price, 1972;

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Fleischer *et al.*, 1972). Detectors were provided of a membrane to avoid the interference of ^{220}Rn in the measurements (Fleischer & Mogro-Campero, 1978). At surface, the detectors were placed at the bottom of a plastic cup and this was buried in an inverted position at about 50 cm depth in the soil (Alter & Price, 1972). Underground measurements were performed by placing the detectors along several water galleries. Galleries are blind tunnels excavated for water supply, usually several km long and about 2 x 2 m section.

At the southern ridge of Cumbre Vieja about 80 measurements in soil were made, with a sampling density of roughly 1 detector/km^2. In the northern part of the island four galleries were studied. The surveyed galleries penetrate the deep structure of the Taburiente shield volcano. A sampling density of approximately 1 detector/500 m was used, along a total length of some 10 km. In addition, the CO_2 emission areas in the caldera of this edifice (Taburiente Caldera) were also prospected for radon concentration (Fig. 1).

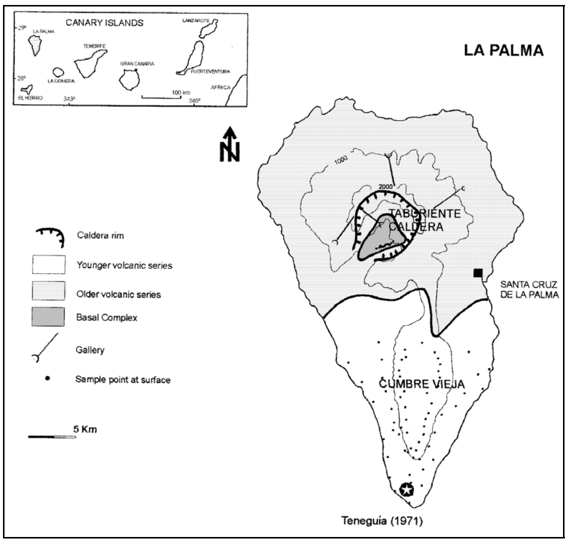

Fig. 1 - Simplified geologic map of La Palma (after Ancochea *et al.*, 1994) and sample location.

4 • RESULTS AND DISCUSSION

Table 1 summarises the statistical distribution of the data. Radon levels are in general low, both at surface and in the underground, ranging from 10 to 200 pCi/l, with an average of 37 pCi/l at surface and slightly higher, 83 pCi/l, in the subsurface. This agrees with the composition of the majority of the rocks units in the island, which are mostly of basaltic nature, with low uranium contents. Fig. 2. shows the box and whisker plots for the radon levels obtained at surface and in the subsurface. The low variability range is noted in the figure where the horizontal bar in the box refers to the median value, the ends of the whiskers to the maximum and minimum values and the top and bottom of the boxes includes half of the data between the median and the extreme of the range. The spatial contour map of Fig. 3a was made using SURFER (Golden software, 1993-1996), based on the kriking interpolation method. Radon profiles obtained in galleries are represented in the graphs of Fig. 3b.

TABLE 1. SUMMARY STATISTIC

	Surface	Subsurface
N	78	22
Min	9	27
Max	180	199
Average	36.6	83.2
Median	29	66
Std.Dev.	27.5	44.3

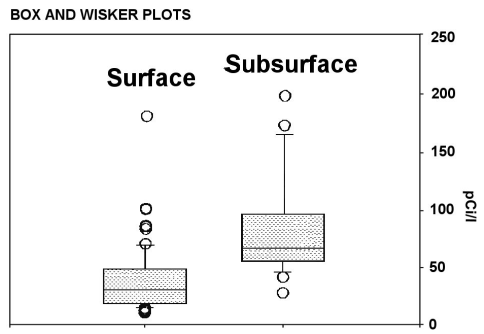

Fig. 2 - Box and whisker plots for the surface and subsurface data populations.

Although radon levels are slightly higher at the subsurface, no significant differences are observed when they are compared to radon levels at the surface (Fig. 2). Correlation was not found with either lithology, volcanic age or with areas of high gas emissions (Figs. 3a and 3b). However, at the Los Hombres gallery in the north, at about 2000 m from the gallery entrance, radon levels attain values of nearly 200 pCi/l, being this value relatively higher than those detected at the other galleries, in general lower than 100 pCi/l (Fig. 3b). Also, a weak anomaly (>180 pCi/l) was detected at the southern ridge, extending in a NW-SE direction (Fig. 3a). This could be related to fracture system in such direction. At the Cumbre Vieja edifice, eruptive centres are distributed forming a multiple rift, with the N-S as dominant direction and NW and NE as secondary rift directions (Carracedo *et al.*, 2001). The results suggest some structural control on the radon emission level and a monitoring program has to be considered in order to study temporal variations. The overall radon signature of the island differs considerably from those

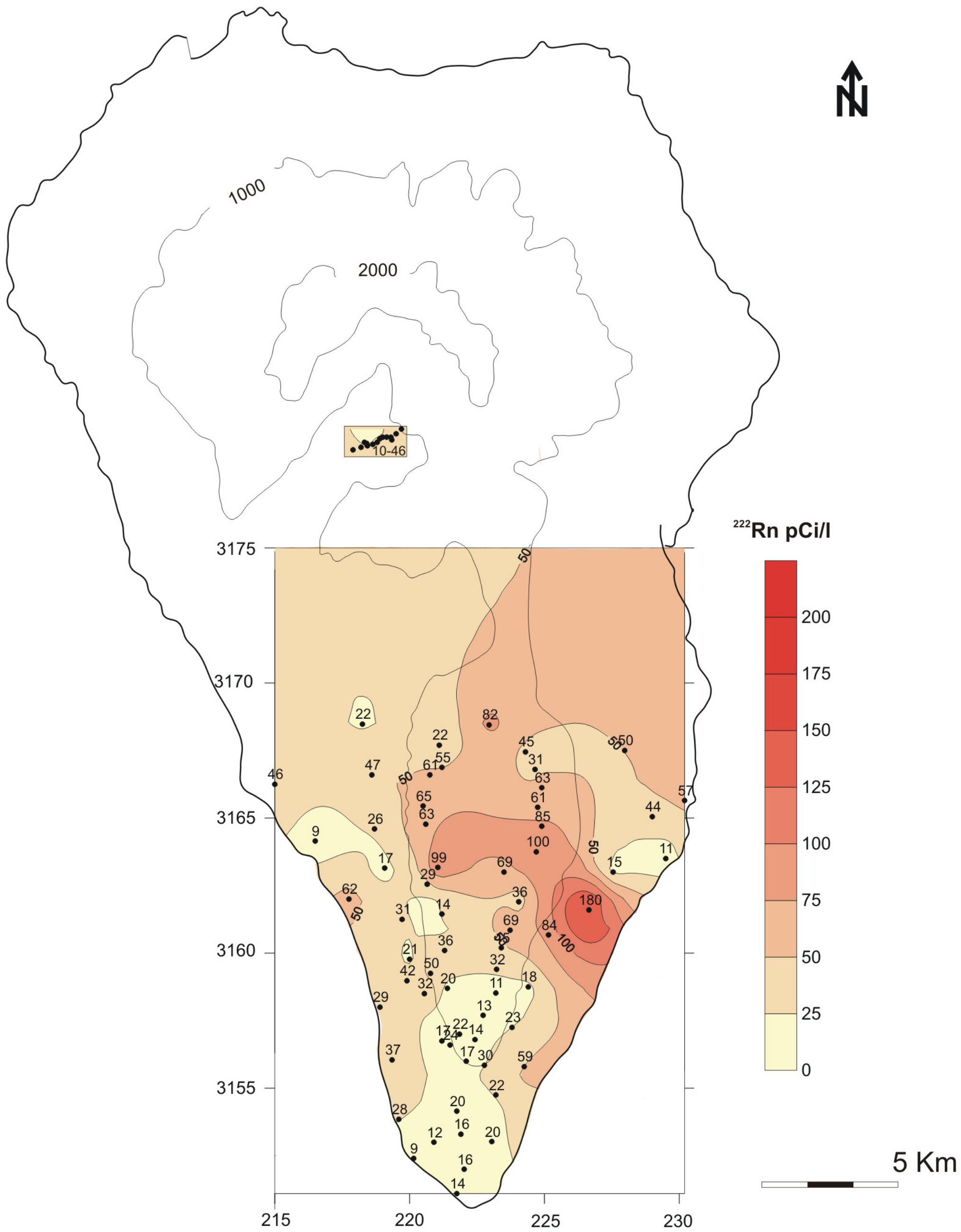

Fig. 3a - Radon distribution map at the Southern ridge (Cumbre Vieja edifice) and in areas of CO_2 emissions at Taburiente Caldera (summer 1997).

observed on Tenerife, another island of the Canarian Archipelago, 80 km to the east (Fig. 1). On the latter, high radon anomalies (>2000 pCi/l, local background of <50 pCi/l) are widely recorded in soils and in the underground environment (>3500 pCi/l). These anomalies are associated in a first approximation to structural features of the Tenerife volcanic edifice and with areas of CO_2 degassing (Coello *et al.*, 1993, de la Nuez *et al.*, 1995, Martín *et al.*, 1997; Martín, 2002).

Compared to Tenerife, radon levels at La Palma seem to reflect differences in the volcanic environment which may be related to the radon source rock, nature of the carrier fluids or gas and/or the geophysical processes governing the radon input into the system. Among these one should note: 1) La Palma is mostly of a basaltic nature. At Tenerife trachytic and phonolitic rocks are frequent and plutonic differentiates at depth may be the source rock for radon anomalies;

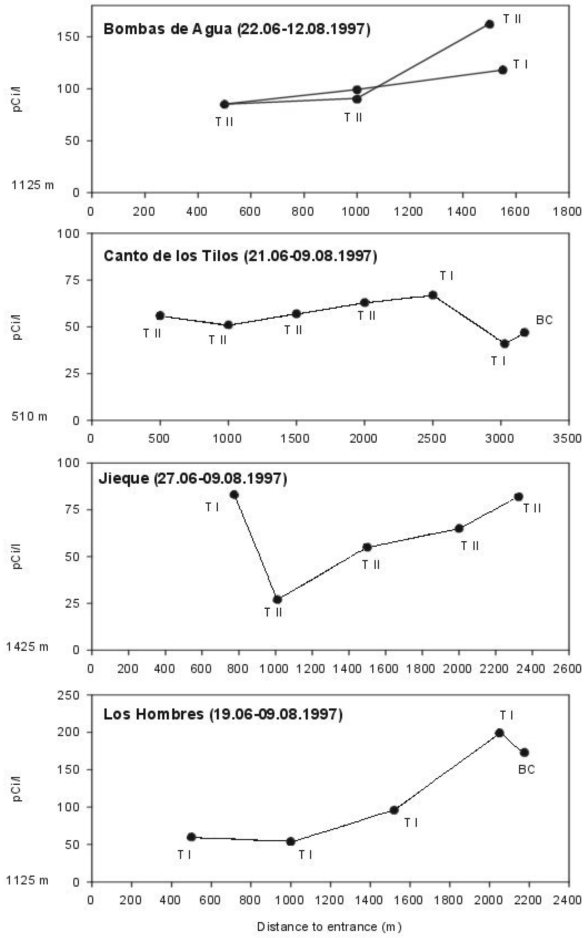

Fig. 3b – Radon profiles along galleries in the northern part of the island. The location of the samples are indicated by the length (distance form the entrance) an height (a.s.l.) of the gallery. Simplified geology is also indicated: BC =Basal Complex; TI = Taburiente I formation; TII = Taburiente II formation.

2) At Tenerife there is a constant level of microseismicity at the central volcanic complex of Las Cañadas Caldera. Such activity is not observed in La Palma; 3) Although there are degassing areas in both islands, the residual volcanic activity is wider and more intense in Tenerife than in La Palma. This is reflected in the large areas of CO_2 emissions, thermal and hydrochemical anomalies and the fumaroles active during hundreds of years at Teide volcano.

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