Radon measurements in association with earthquakes (*)

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Summary. — A network of three radon stations has been established in the Langadas basin, North Greece. Newly made devices with plastic tubes are in operation with α-particle track detectors (ATDs) in registering α-particles from radon and radon decay products exhaled from the ground, every two weeks, starting from December 1996, by using LR-115, type II, nonstrippable Kodak films. Simultaneous measurements are made by using Lucas α-scintillation cells for instantaneous measurements of radon in soil gas, before and after setting the ATDs at the radon stations. The new devices used have the advantage of not using heating systems nor electrical power in the nearby area of the stations. Radon flux registrations ranged between 507 and 85880 tr cm^{-2} or 1.5 and 188.9 tr cm^{-2} h^{-1}, in the period of measurement, while radon concentrations in soil gas ranged between 528 and 35095 Bq m^{-3} at the same time.

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1. – Introduction

There have been many reports dealing with the measurements of radon concentration in soil gas emanating from the ground along active faults which may provide useful signals before seismic events [1-7]. Anomalous changes in subsurface radon concentrations may be expected prior to large earthquakes according to the dilatancy-diffusion model for earthquake occurrence [8]. Several investigators currently monitor radon by using a variety of techniques such as the charcoal trap technique [9], nuclear track-etch technique [10] and aerosol filtration technique [11].

Previous radon measurements in Greece in association with earthquakes were carried out at the Stivos fault in the Langadas basin, North Greece, in the period

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November 1982-June 1985 [12] and at the Thessalian fault, Central Greece, in the period August 1992-April 1994 [13]. At the Stivos fault, in the Langadas basin, large earthquake events have been registered since the beginning of this century ($M_L = 6.5$ on July 5, 1902; $M_L = 7.0$ and 7.5 on April 4, 1904; $M_L = 6.5$ on October 8, 1905 and $M_L = 7.5$ on November 8, 1905 [14].

This paper reports data obtained from field measurements over one year period, starting from December 1996, at the Langadas basin by continuous monitoring of radon emanating from the ground by using solid-state nuclear track detectors (SSNT Ds) as probes (integrated measurements) on the one hand, and on the other hand by using Lucas α-scintillation cells for instantaneous measurements in soil gas, before and after the SSNTD records, in order to explore the possible relation between radon changes and earthquakes.

2. – Instrumentation and siting

The radon monitors that have been developed in our Laboratory for integrated measurements were based on the registration of α-particle tracks on cellulose nitrate films. The α-particles originated mainly from the decay of radon and radon decay products and much less from thoron and thoron decay products. It has been shown experimentally that a very small number of tracks of thoron α-particles (less than radon α-particles by a factor of 1000) were registered [15]. Hence, appropriate corrections have been made in our measurements. Care had been taken to prevent humidity

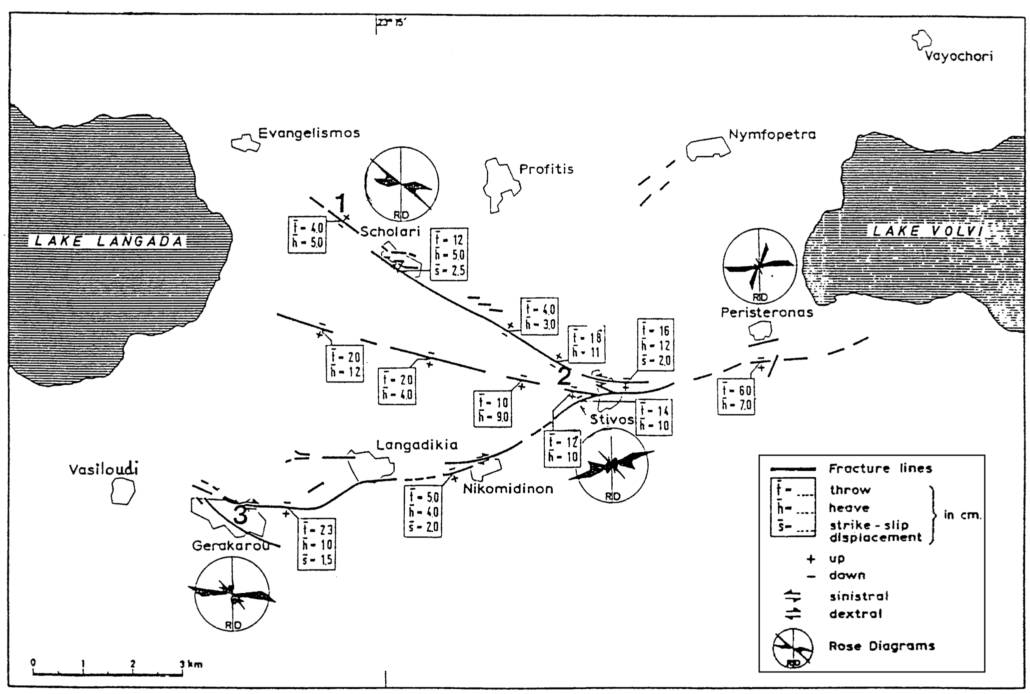

Fig. 1. – Fracture lines in the epicentral area of the June 20, 1978 earthquake in the Langadas basin.

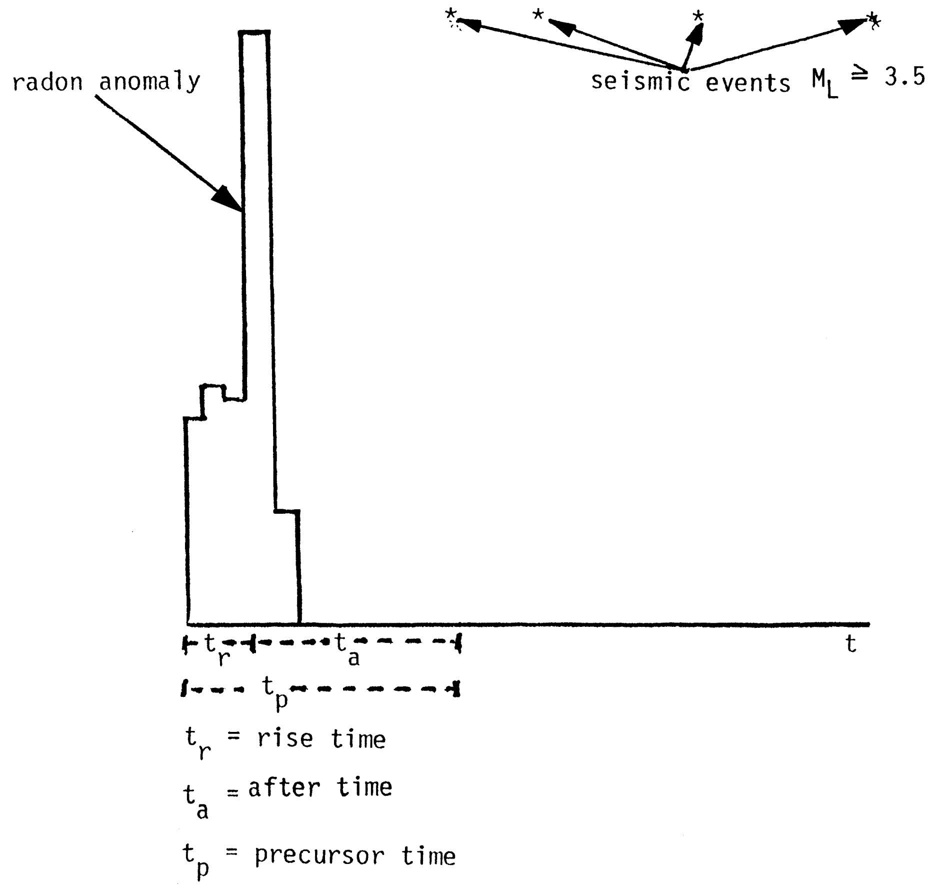

Fig. 2. – A radon anomaly in the radon registration spectra.

and temperature problems on the α-particle tracks registration by insulation of the instrument vault by which all of the diurnal variations of the above-mentioned meteorological parameters were eliminated. The detectors (type-LR-115, type-II, nonstrippable Kodak cellulose nitrate films) were exposed for two weeks. The retrieved films were chemically etched (NaOH 2.5 N at 60° for 2.5 h) and then counted under a microscope. The radon concentration was expressed in terms of tracks per cm^2 per hour (radon flux).

Three radon monitoring stations with two devices each were installed in boreholes 1 m deep in the Langadas basin along active faults at the sites of Sholari, Stivos and Gerakarou (fig. 1). The station at Sholari had three devices, as one needed to be pretty close to a drilling for water irrigation. Each device consisted of a plastic tube, 44 mm inner diameter, 50 mm outer diameter and 300 mm in length, the detectors being on the top of the tube, holded appropriately. The sites were preselected by seismologists of the Laboratory of Geophysics, Aristotle University of Thessaloniki.

Instantaneous radon measurements were performed by Lucas α-scintillation cells (PYLON type 110 and 300 A) linked to an appropriate data acquisition system by a

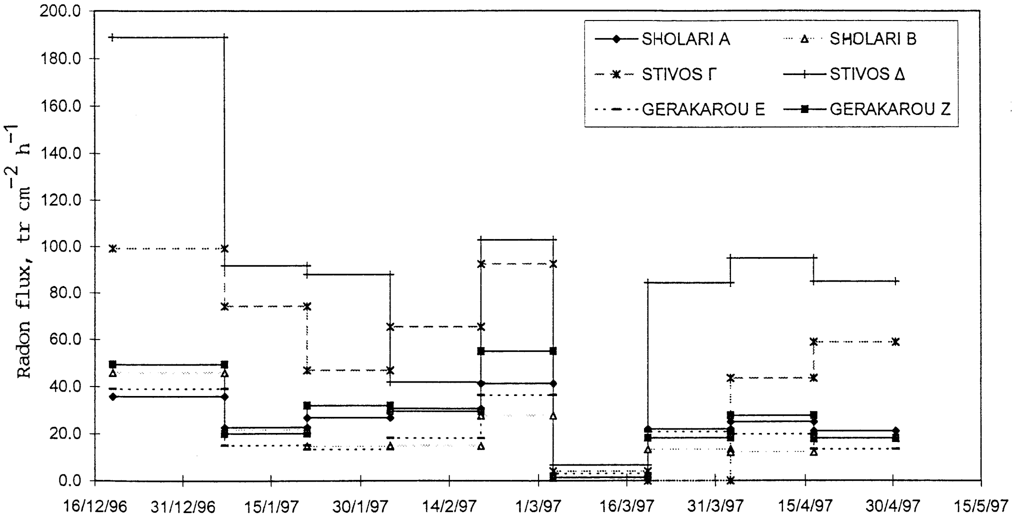

Fig. 3. – Radon flux measurements in the Langadas basin.

TEL detector. These measurements were carried out at two or three different points near the radon stations, every two weeks, before and after the SSNTD records.

3. – Results and discussion

In the radon spectra illustrating a histogram of radon flux *vs.* time, a radon anomaly is shown as a peak having the shape of fig. 2. In that peak we can distinguish and then determine the following times:

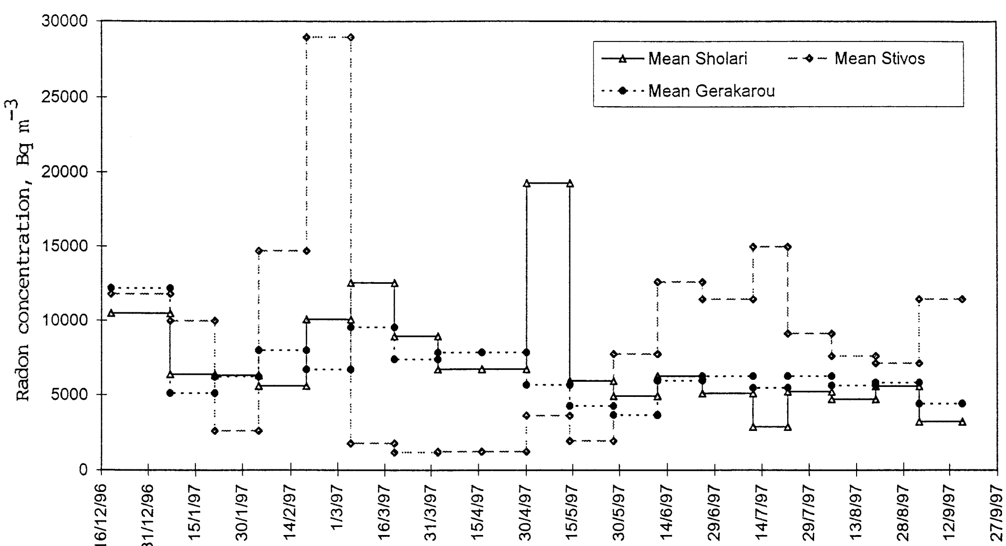

Fig. 4. – Radon concentration in soil gas in the Langadas basin.

i) the precursor time interval, t_p, defined as the time period from the onset of radon anomaly until the time of earthquake,

ii) the rise time t_r, defined as the time period from the onset of radon anomaly until the time of maximum radon flux, and

iii) the after time, t_a, defined as the time interval between the maximum radon flux and the time of the seismic event.

It is evident that the precursor time interval, t_p, is the sum of the rise time, t_r, and the after time, t_a, that is, $t_p = t_r + t_{a_2}$.

In fig. 3, the radon flux in terms of α-particle tracks per cm^2 per hour is shown for three different radon stations for the period of measurement. Since no significant seismic events (not larger than $M_L = 3.0$) occurred at the Langadas basin in that period, no clear radon peaks were observed in the spectrum of fig. 3. The same spectrum was obtained from the data of the instantaneous measurements of radon in soil gas in terms of becquerels per m^3, fig. 4. The data of figs. 3 and 4 shows the trend of increase or decrease of radon depending on some parameters, such as soil temperature, atmospheric pressure and rain precipitation.

The data obtained from the station at the Stivos fault shows significantly high radon records as compared with the data obtained from the other stations (figs. 3 and 4). It must be noted that on 20 June 1978 a $M_L = 6.5$ earthquake occurred at the Stivos fault (40° 65′N, 23° 30′E, 28 km long and 10 km deep) and 17 years later (4 May 1995) a $M_L = 5.8$ earthquake occurred at the same fault.

Radon peaks of the shape of fig. 2 were observed in the previously obtained data, fig. 5, when large seismic (larger than $M_L = 3.0$) events followed radon anomalies during an almost 3-year period, November 1982-March 1985, at the Stivos fault.

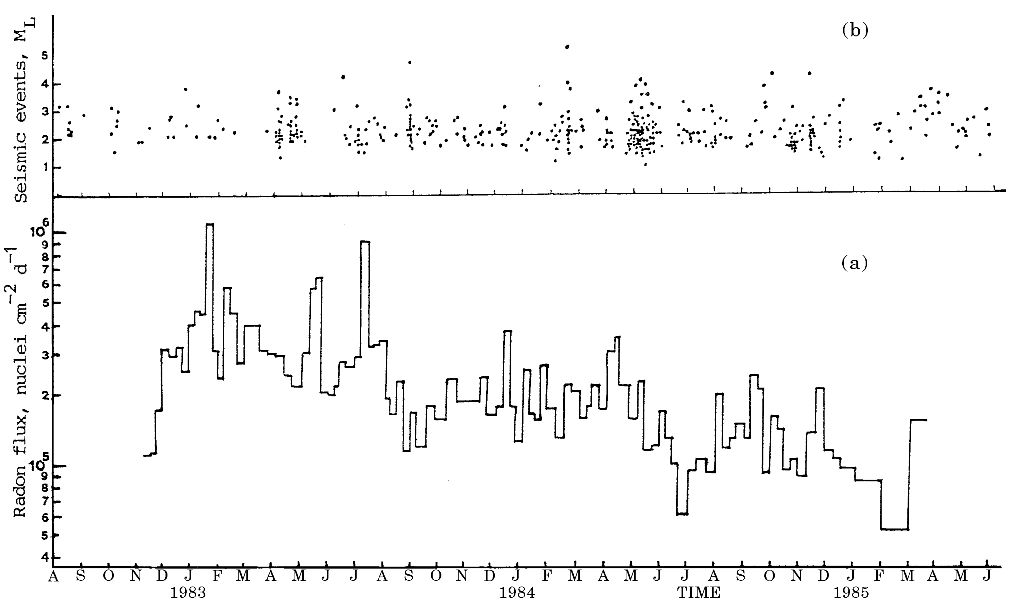

Fig. 5. – Radon flux (a) and seismic events (b) at the Stivos fault for the period November 1982-March 1985.

Radon monitoring at various sites in a seismic area (radon mapping) may be used as a tool in defining the location of faults associated with the seismic activity where large-magnitude earthquakes occurred or might occur in the future.

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