Elevated Radon Concentration At The Entrance Of An Unused Old Coalmine Near An Urban Area, Western Crete, Greece

Pantinakis A.[1], Manoutsoglou E.[2] and Markopoulos Th.[2]

[1]Technical University of Crete, Department of Sciences, Section of Physics, University Campus, Akrotiri, 73100 Chania, Greece, e-mail: apostol@science.tuc.gr
[2]Technical University of Crete, Department of Mineral Resources Engineering, University Campus, Akrotiri, 73100 Chania, Greece, e-mail: emanout@mred.tuc.gr, markopou@mred.tuc.gr

ABSTRACT

Previous studies have found two areas in Greece with relatively high radon concentrations both indoors and in the ground, one of which is located in Vrysses Apokoronou, Western Crete. This study investigates the hitherto remaining unknown origin of the reported high radon values in the Vrysses area. Our study is focused in a location where lignite mining was in operation till 1961. The lignite deposits are situated within Miocene marls in a depth of 30 meters below surface approximately. In this work an unusually high concentration of radon gas namely 7000 Bq/m^3, has been measured at the entrance of the collapsed old mining tunnel, in the air, one meter below the soil surface. The continuous radon monitor CRM 1028 was used for the collection of data. Elevated radon concentrations have also been measured in air further away from the lignite mine entrance.

1. INTRODUCTION

Over several decades now, the adverse effect of radon to the human health has been studied and its correlation to lung cancer is now established (Zeeb 2007). Radon is a naturally occurring radioactive gas, emitting alpha particles, with a half life of 3.8 days. Radon originates from radium, which has a very much longer half life of 1601 years. In particular ^{222}Rn contributes about 55% of the annual radiation dose to the general population from all sources and 70% from natural radiation sources (George 2007).

A wide scale radon survey has been carried out in Greece for the measurement of radon concentration inside dwellings (Nikolopoulos et al 2002). In these studies several areas of elevated radon concentration as well as two ‘radon prone’ areas were identified and depicted on a map (Fig. 1).

Although a possible explanation for the origin of radon for the ‘radon prone’ area at Arnaia Chalkidikis has been given, as due to its lying above a granitic rock, no explanation has been proposed for the second ‘radon prone’ area near Vrisses Apokoronou, in Western Crete (Louizi et al 2005).

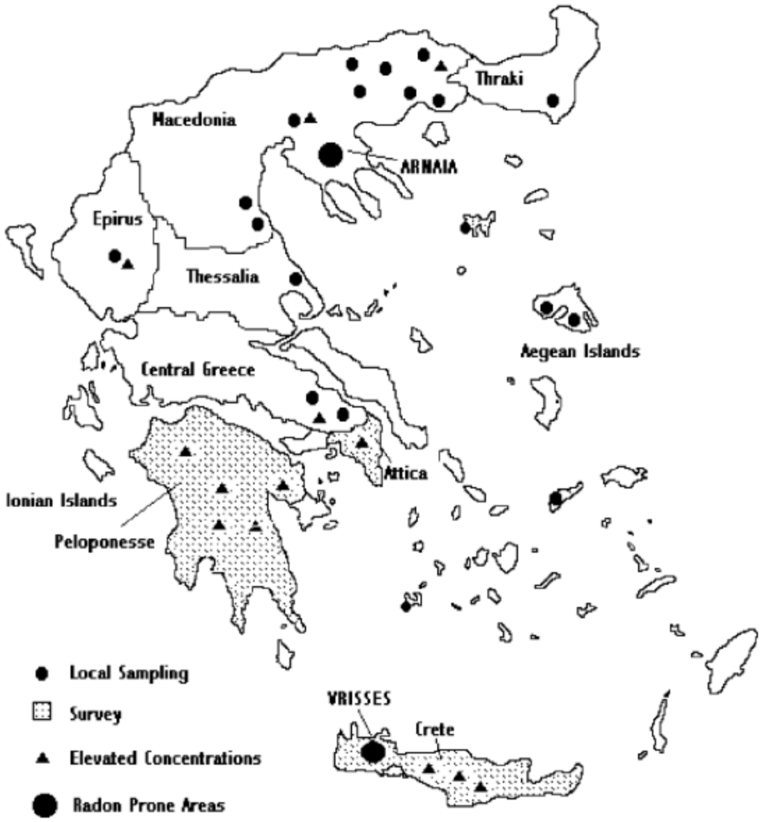

Figure1. Map showing the radon surveyed areas in Greece (after Nikolopoulos et al 2002).

The relationship between geology and radon has been documented since the late 1970s most notably in uranium exploration literature. Rock types most commonly associated with high indoor radon include: 1) Uraniferous metamorphosed sediments, volcanics, and granite intrusives. 2) Glacial deposits derived from uranium-bearing rocks and sediments. 3) Black shales. 4) Soils derived from carbonate rock. 5) Uraniferous fluvial, deltaic, marine, and lacustrine deposits. The geology factor is complex and actually incorporates all geological characteristics. Geological information indicates not only how much uranium is present in the rocks and soils but also gives clues for predicting general radon emanation and mobility characteristics (Gundersen and Schumann 1996).

This work aims to investigate possible geological causes for the elevated concentration of radon in the area of Vrisses Apokoronou, by radon measurements in the field. This will allow us to consider the relationship between the elevated radon levels in Vrysses Apokoronou, as measured indoors (Nikolopoulos et al 2002), with the radon levels as measured in the field in the present study. To approach the problem a geological outline of the area is necessary.

2. MATERIALS AND METHODS

2.1 Geological outline

Interplay between the African and European plates gave rise to the present-day structural and geomorphological configuration of Mediterranean and especially of Crete. The island of Crete is located north of the Hellenic trench. The geological framework consists largely of nappes of contrasting lithologies and metamorphism that were stacked southwards during an Oligocene to early Miocene N-S compression. Most of the whole nappe stack of continental Greece is recognised in Crete. It has however a reduced thickness. The nappes are stacked from top to bottom, i.e. from the most internal to external units in the following order: Asterousia nappe, Miamou nappe, Arvi nappe, Pindos-Ethia nappe, Tripolis nappe, Phyllite nappe and Trypali nappe. The Plattenkalk Group represents the lowermost known tectonic unit beneath the nappe pile of Crete and their formation has been involved in the tectonometamorphic process during the Oligocene-Miocene (Manutsoglu et al 2003). During the Neogene, new sedimentary basins developed above the Alpine substratum. The sedimentary history and palaeogeography of the Cretan Neogene is one of frequently changing land-sea distribution because of the complex interaction between fault blocks delimiting the different sedimentary basins (Drooger and Meulenkamp 1973, Meulenkamp et al 1979).

Neogene sediments have a wide extension in the low, hilly, coastal plains in the northern part of the Chania province. These sediments were initially distinguished in 11 formations (Freudental 1969). According to Freudental (1969), the lowermost Neogene strata in the Apokoronou District, near Vrysses, belong to the Kissamou Formation. They are overlain by the Khairetiana Formation, which passes laterally in several directions, but mainly to the south, into the Akrotiri Formation. The main body of the Kissamou Formation consists of blue or purple amorphous clays, but locally these clays are laminated. Within these clays strongly indurated, graded and ungraded, sandstones, calcarenites and organic limestones occur at various stratigraphic levels. At several localities sand or gravel layers, without any clear graded bedding, occur within the blue and purple amorphous clays at various stratigraphic levels. They are often indurated by calcareous matter. The total thickness of the Kissamou Formation amounts to 175 m.

Meulenkamp et al (1979) subdivided the Neogene sedimentary sequence of Crete into six major lithostratigraphic units: the Tefelion, Prina, Vrysses, Hellenikon, Finikia and Aghia Galini Groups. The Vrysses Group covers most of the area around Vrysses overlies conformably the Tefelion Group or unconformably overlies the preneogene basement, indicating ongoing subsidence during deposition of the Vrysses Group. An outcrop along the main road Khania -

Rethymnon shows fossiliferous, fluvio- lacustrine - brackish - shallow marine marly limestones, silty clays and lignites of the Pandanassa Formation of the Miocene Tefeli Group. In the past, lignite was mined at this spot. The lignite revealed mammal remains. The deposits of the Pandanassa Formation pass upwards into open marine, silty clays of the Apostoli Formation (Tefeli Group), which belong to the *Neogloboquadrina acostaensis* Zone (Tortonian).

van Hinsbergen (2004) reviews the age that was given to these sediments by Meulenkamp et al (1979) and proposes a Messinian age without revising the paleoenvironment of deposition.

In the island of Crete the lignite deposits are located into the Miocene fluvial-lacustrine formations, with exception of Kandanos to the West and Almyri Panagia in the Central and South part of the island basins. Lignite was deposited into fluvial-lacustrine formations consisting of clays, sands and marls. Four lignite beds were located in the area of Vrysses Apokoronou as shown in Fig. 2 (Papastamatiou et al 1966, Karageorgiou et al 2010).

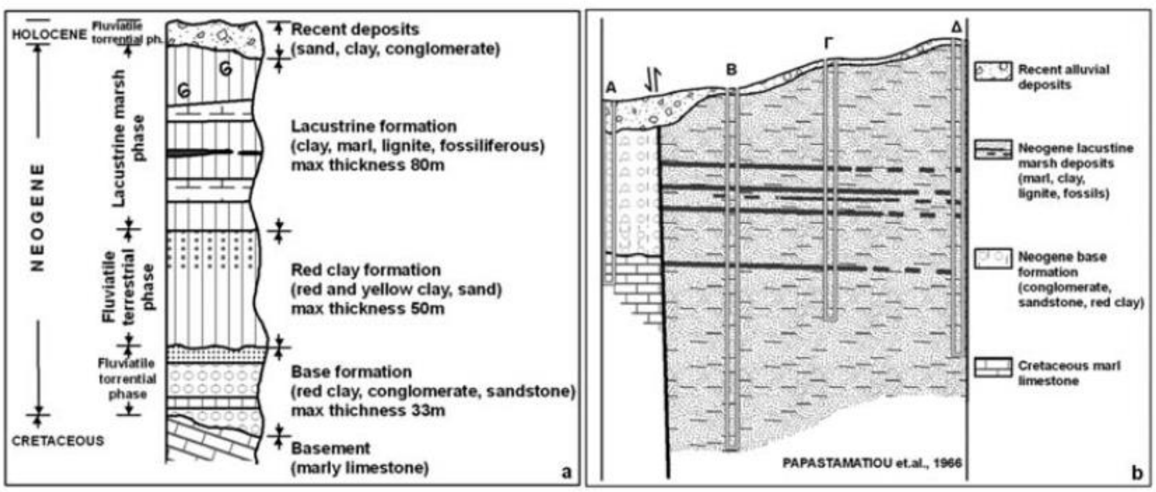

Figure 2. Stratigraphic column of Vrysses area; (b): Geological section of boreholes in Vrysses area (after Karageorgiou et al 2010)

A Messinian 'Salinity Crisis', implying isolation and deep desiccation of the Mediterranean (Riding et al 1999), is a widely accepted part of relatively recent geological history. This concept of recurring of the Mediterranean, an essentially evaporative sea that continues to require replenishment by Atlantic water, was suggested by Hsü et al (1973, 1977) to account for thick Messinian evaporite deposits below the deeper basins. In the beginning and after this event the lignite deposits likely represent the syntectonic deposition occurring at the isolated margin basin due to a progressively growing carbonate ramp.

2.2. Measurements in the field

Two types of field measurements were made. Firstly total radioactivity in air was monitored, by using a pancake-type Geiger counter, model RM-80 of Aware Electronics, incorporating a 1'' mica window, sensitive to alpha, beta and gamma radiation. This allowed the rapid surveillance of an area for the existence of radon and its daughters. Secondly, dedicated radon concentration measurements were performed, in air, by using a continuous radon monitor, model 1028, of Sun Nuclear Corporation, incorporating a solid state diode detector.

3. RESULTS

Following the geological inspection of the area, the vicinity of an old unused lignite mine was selected for the measurements, where elevated Geiger rates were detected, as shown in Fig. 3.

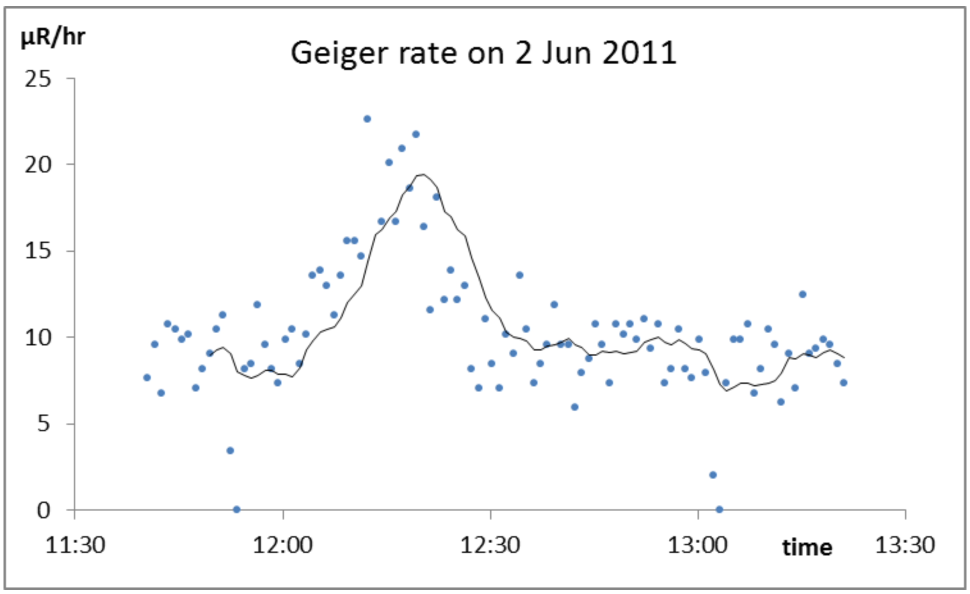

Figure 3. Radioactivity in air, 2m from the mouth of the gallery, now collapsed, leading to the abandoned mine. A mica-window Geiger is used, handheld. Firstly approaching to the mouth, then stopping near it and finally retreating from the place. The solid line joins the 10- point (10 mins) moving averages.

The measured radioactivity in air was found to be higher than normal background levels by a factor of 2-3. The elevated radioactivity was confirmed by a second series of measurements, using two Geiger counters, monitoring simultaneously the radioactivity at two different distances from the mine entrance (Fig. 4). The data show elevated counts and also that, under the same atmospheric conditions, the radioactivity in air is higher nearer the mine entrance.

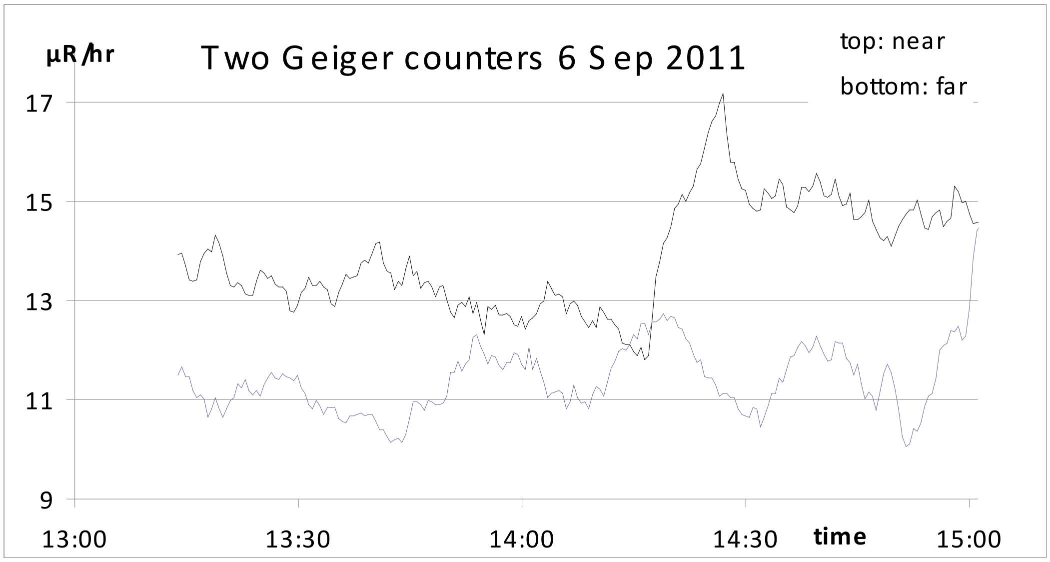

Figure 4. Radioactivity, in air, monitored by two Geiger counters, positioned at two points, one near (2m) and the second far (10m) from the mouth gallery of the abandoned mine. The solid line joins the 20- point (10 mins) moving averages.

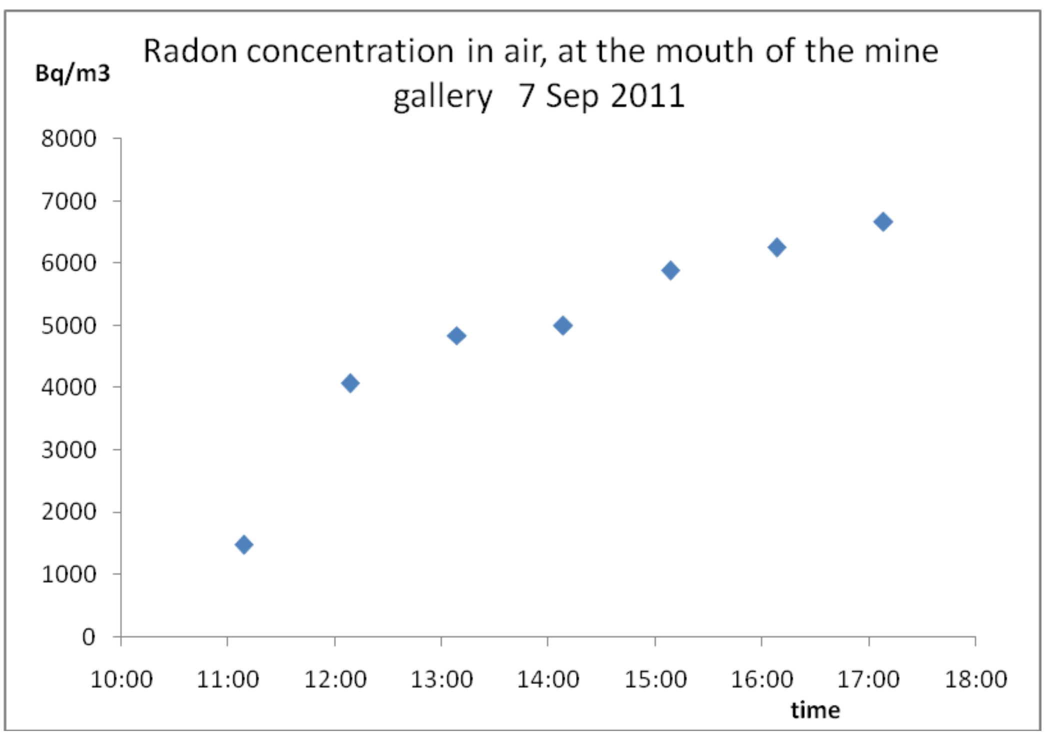

Figure 5. Radon concentration, in air, monitored by a continuous radon monitor, positioned 1 m within the mouth of the gallery of the abandoned mine.

The elevated radioactivity detected by geiger counters was finally confirmed by measuring, specifically, the radon concentration in air. The continous radon monitor was suspended 1m within the mouth of the mine gallery. These measurements are shown in Fig. 5. The data presented in this work identify for the first time a source of radon in the area capable of producing radon concentrations three orders of magnitude above typical radon concentrations in air.

4. CONCLUSIONS

There are no volcanic or granitic rocks in the study area that could explain the origin of the elevated radon concentration observed. Also no large faults occur in the area. The only relevant geological feature in the area is the existence of four lignite beds at a relatively small depth. These lignite deposits were formed before the Messinian salinity crisis in a period of increased erosion and weathering processes due to climatic conditions. It is known that a high uranium concentration exists in peat and lignite mines (Read et al 1993). In the area of Vrysses Apokoronou, the lignite was mined from a depth of approximately 30 m. Since 1960s mining has stopped and today the mine gallery has collapsed and only its mouth exists as a relic. The very high radon concentrations that were measured in air in the present research are likely to originate from the lignite beds of the clastic sediments in the area.

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