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Ground gamma-ray survey of the Solforata gas discharge area, Alban Hills-Italy: A comparison between field and laboratory measurements

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A B S T R A C T

Measurements of environmental radioactivity by HPGe gamma-spectrometry were carried out with the aim of investigating the distribution of natural radionuclides in a volcanic area and to compare two different methodologies – an *in situ* gamma-survey of the area and high accuracy laboratory measurements of soil samples. Results demonstrate good performance of the *in situ* technique, also confirmed by a correlation analysis between the results obtained by the two methodologies. A volcanic gas discharge area was chosen as the test site for the presence of natural long-lived radionuclides such as ^{40}K and ^{238}U, ^{235}U and ^{232}Th, and their decay chain members. Clear evidence of ^{222}Rn degassing in the area was confirmed by ^{226}Ra values measured by the *in situ* technique. Higher ^{40}K values measured by the *in situ* technique may be attributed to the presence of vegetation in the study area.

1. Introduction

Natural radioactivity in the environment is mainly produced by long-lived radionuclides such as ^{40}K and ^{238}U, ^{235}U and ^{232}Th decay chain daughters. The activity of these elements in soils is well documented (UNSCEAR, 2000), and they represent one of the main sources of the lithospheric thermal budget.

In situ radiometric surveys of the distribution of natural radionuclides in soil have been a standard technique used either for radioecological investigations or for geophysics studies (Tyler, 2004; Perrin et al., 2006; van der Graaf et al., 2007). As HPGe detectors with electrical cooling have become commercially available, they have replaced previously utilized NaI(Tl) detectors which suffered a low energy resolution which, in environments with multiple gamma-ray sources, caused problems in quantitative high resolution analysis of radionuclides (Povinec et al., 1996).

Some of the Italian volcanic sites have already been investigated using the *in situ* techniques (Chiozzi et al., 2003, 2007), as well as laboratory analyses (Bellia et al., 1997). However, no detailed *in situ* radiometrics surveys have been carried out in parallel with systematic laboratory comparisons.

The aim of the present study has been to investigate the distribution of natural radionuclides in a geologically active area using *in situ* field gamma-spectrometric survey and laboratory analyses of soil samples. We chose as the test site the Solforata of Pomezia, a volcanic gas discharge area located south of Rome. The results obtained by a direct *in situ* activity measurement are compared with laboratory analysis of soil samples. In both cases gamma-spectrometry with HPGe detectors was chosen as the best compromise between the high energy resolution and reasonable detection efficiency for gamma-ray emitters. Preliminary results of these investigations have been published by Di Paolo et al. (2011).

2. Samples and analytical methods

2.1. Geological setting

The Solforata of Pomezia is a gaseous discharge area located 8 km south of Rome, on the southwestern flank of the Alban Hills volcanic complex. The site lies on a flood valley which crosses the

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overlapping products of the III and VI pyroclastic eruptions of Tuscolano-Artemisio phase (De Rita et al., 1988). The Alban Hills complex has been subject to volcanic activity from about 600 to 20 ky BP, with three eruptive phases (De Rita et al., 1995). The first one, Tuscolano-Artemisio phase between 600 and 300 ky BP, was the most intense and ended with a collapse leaving a 10 km wide caldera. The second, Faete phase between 300 and 200 ky BP, was characterized by postcalderic scoria cones, strombolian activity and large extrusions forming the Faete edifice. The last phase, from 200 to 20 ky BP was mainly hydromagmatic, concentrated on the western flank of the volcano. During the whole eruptive story, pyroclastic flows covered an area of about 1500 km^2 (Chiodini and Frondini, 2001). The most recent phenomena related to the presence of magma are low-magnitude seismic swarms and uplift close to the Albano Lake on the western side of the complex (Amato and Chiarabba, 1995).

Solforata is located close to a subsiding area bordered by a complex fault system called *Ardea fault zone*. This is a 30–40 km long and 10 km wide half-graben structure bordered by 40°N normal faults with a roll-over structure on the hanging wall, crossing an NW-SE fault system (De Rita et al., 1995). The spatial distribution of scoria cones of the last eruptive phase of the volcanic complex is clearly aligned along these faults.

Related to this fault system, the site shows some of the most intense degassing in the Alban Hills area. The presence of exhalations in the Solforata has been historically well known since the Roman age. In 1877 an intense CO_2 discharge occurred in coincidence with an earthquake localized nearby (Funiciello et al., 2002). During this period other similar instantaneous degassing events occurred, showing a relationship between fracturing processes and gas emissions. The active fault system in the Alban Hills area, and especially in the Solforata site, represents the main path for gases released from the geothermic reservoir to reach the surface.

At present, the degassing at Solforata (both in terrain and water) is well documented (Giggenbach et al., 1988; Chiodini and Frondini, 2001; Voltaggio et al., 2001; Voltaggio and Spadoni, 2009). The gases consist mainly of CO_2, with minor amounts of H_2S, ^{222}Rn and N_2. Chiodini and Frondini (2001) measured a mean CO_2 release of 4.62×10^7 g/day. Voltaggio and Spadoni (2009) measured in spring 2007 a H_2S flux of about 1208 kg/day. Voltaggio et al. (2001) reported a mean activity concentration of ^{222}Rn in the effluents of 150,000 Bq/m^3. Voltaggio and Spadoni (2009) reported H_2S concentrations in terrain exceeding 30 ppmv nearby the main pool of the Solforata; sulphur is abundant in this zone and a mine was active until 30–40 years ago. The intense emission of acid gases is also demonstrated by the absence of vegetation in the area and bubbling inside the pool. Water temperature is low, about 20 °C, but a value of about 50 °C was reached at *Pozzo CO.MI.RO* (near Solforata pools) during the 1981 seismic crisis (Calcara et al., 1995).

The presence of sulphur in water and gases seems to be connected with a deep source. Cavarretta and Lombardi (1992) suggested, on the basis of salinity and sulphur isotope data, that the water discharge in the volcanic and perivolcanic areas of Latium has two components: meteoric water circulating and interacting with the carbonate basement which is mixed with a deep component rich in gas, rising along the major regional tectonic lineaments.

2.2. Sampling methodology

Sampling points at the Solforata gas discharge area were chosen from satellite images and aerial photographs. We considered as the main area of the investigation the zone around the pools (where the most intense degassing vents are located). Two other study areas were located nearby. Three square grids with side length of 50 m were designed using a Geographic Information System (GIS). Once in the field, using a GPS we were able to reach the centre of each square. We were not able to reach many sampling points because of the roughness of the terrain. Fig. 1 depicts all sampling points. Altogether 47 soil samples were collected Fig. 2 shows the isolines of altitude above sea level (m a.s.l.) with sampling points.

Area 1 is located on a hill NW of the pools, with steep slopes. At the time of survey it was completely covered by vegetation, showing a clear absence of degassing. 15 soil samples were collected in this area.

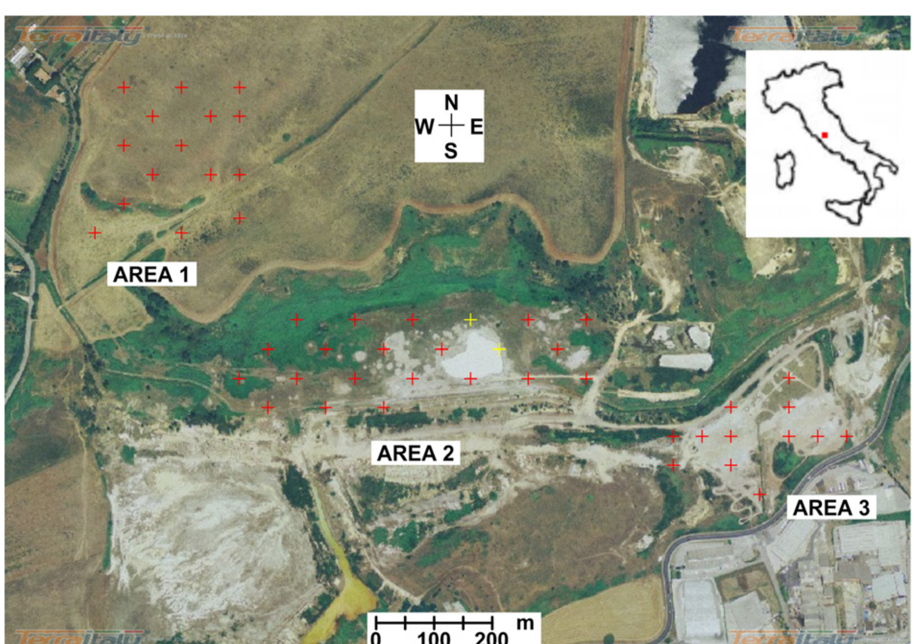

Fig. 1. Sampling points for both *in situ* and laboratory measurements (in red), and for *in situ* measurements only (in yellow). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)