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Assessment of lithogenic radioactivity in the Euganean Hills magmatic district (NE Italy)

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A B S T R A C T

The Euganean Hills of North East Italy have long been recognised as an area characterized by a higher than average natural radiation background. This is due to two main reasons: a) primary lithogenic radiation due to rhyolitic and trachytic outcrops, which are "acidic alkaline" magmatic rocks potentially enriched in uranium and thorium; b) secondary sources related to a geothermal field – widely exploited for spa tourism in the area since the Roman age – producing surface release of radon-enriched fluids.

Though radioactivity levels in the Euganean district have been often investigated in the past – including recent works aimed at assessing the radiation doses from radon and/or total gamma radiation – no effort has been put so far into producing a thorough assessment linking radiation protection data to geological-structural features (lithology, faults, water, organic matter content, etc.). This work represents the first part of the interdisciplinary project "Geological and geochemical control on Radon occurrence and natural radioactivity in the Euganean Hills district (North-Eastern Italy)", aimed at producing detailed results of the actual radiation levels in connection mainly with lithological parameters.

A detailed sampling strategy, based on lithostratigraphy, petrology and mineralogy, has been adopted. The 151 rock samples collected were analyzed by high resolution γ-ray spectrometry with ex situ HPGe detectors. Statistical and geostatistical analyses were performed, and outlier values of U and Th – possibly associated with anomalies in the geological formation – were identified. U, Th and K concentration maps were developed using both the entire database and then again after expunging the outliers; the two were then compared. In all maps the highest values can be associated to trachyte and rhyolite lithologies, and the lowest ones to sedimentary formations. The external dose due to natural radionuclides in the soil – the so called terrestrial gamma dose rate – has been calculated using the U, Th and K distribution measured in the bedrock samples.

1. Introduction

Indoor radon is recognised as a most hazardous substance (WHO, 2009). It is responsible for approximately half of the average radiation dose to population, which explains the radiation protection concerns it elicits worldwide (UNSCEAR, 2008). Awareness of this hazard arose several decades ago, spurring a range of monitoring strategies and the early introduction of regulations to assess the risk associated to this radioactive gas and to regulate the management of this risk.

Various experimental techniques are in use to assess radon risk. The historical approach is indoor radon measurement: albeit it provides directly radiation dose rate information, it is often biased by localized factors such as such as the nature of the building materials and the structural characteristics of the building itself. These factors introduce significant inhomogeneities in the data that are detrimental to numerical approaches that require homogeneous data, as geostatistics does.

It is largely recognised how most of the variability in radon

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hazard is related to the geological background of the area considered (Miles and Appleton, 2005). This is mainly due to the inhomogeneity of rock outcrops over the landscape and to the related variability of NORM (Naturally Occurring Radioactive Materials) content. A good assessment of radon hazard requires associating radon exposure to geological and geophysical features of the territory under investigation (Bossew, 2015). Rock classification based on lithology and on NORM content is a needed companion data to indoor radon measurements in assessing radon hazard in the area investigated. A variety of experimental techniques are available, based on gamma spectrometry (both in- and ex-situ) and/or radon emanation-soil radon techniques: however, none of those alone can yield a conclusive radon assessment. Also, uncertainty can be added by possible bias due to geochemistry-related NORM disequilibrium in the bedrocks investigated. This disequilibrium information might be lost or underestimated by detectors with scant resolution (e.g., NaI detectors modest resolution may interfere with dose assessment both in the case of gamma spectroscopy and in the case of exposure measurements; see for example Gilmore, 2008). In a nutshell, effective radon risk assessment requires contributions from such varied fields as physics, geochemistry, radiation protection, radiation metrology and statistics.

In this paper, we present the results from the first part of an integrated research project aimed at assessing radon hazard in the Euganean Hills of northeastern Italy bringing together the criteria outlined above. This area has been long known for its higher than average indoor radon levels: those are related to the acidic volcanic rocks typically outcropping in this area (Milani et al., 1999; Maritan et al., 2013; Bartoli et al., 2015), and also to a geothermal field (widely exploited for spa tourism in the area since the Roman age) producing surface releases of radon-rich fluids. The area, which is densely populated and heavily exploited for agricultural and touristic purposes, has been often investigated for radon related problems (Trotti et al., 1994, 1998, 1999), but no systematic approach has been attempted so far. Previous research works extending over the whole Veneto region – the region where the Euganean Hills are located – resulted in a detailed map of indoor radon levels (Trotti et al., 1994, 1998, 1999), while Strati et al. (2014) produced a map of total natural radioactivity, obtained from both activity concentrations of representative samples and γ-ray measurements with airborne large-volume NaI detectors. Yet, in connection with this area no effort has been put so far into a thorough assessment of the link between radiation protection data and geological-structural features. Moreover, no estimation of the total gamma dose rate has been provided so far. The overall project in which the authors are involved and whose experimental part is still ongoing, aims at collecting data based on the requirements just discussed. Data presented here are the result of off-site, high-resolution γ-ray spectrometry conducted on an accurately space-resolved sample set collected on the rock outcrops of the Euganean hills. Geostatistical analysis was performed on the data to produce an accurate evaluation of NORM distribution over the area of interest based on detailed geological information.

2. Geological setting

The Euganean Hills form an isolated body within the Venetian alluvial plain. They are located approximately 10 km South-West of Padua, and cover an area of over 100 km^2. The geology of the Euganean Hills (Fig. 1) is dominated by two rock series: volcanic and sub-volcanic rocks, and mainly carbonate and marl sedimentary ones. Igneous rocks were formed during two main volcanic

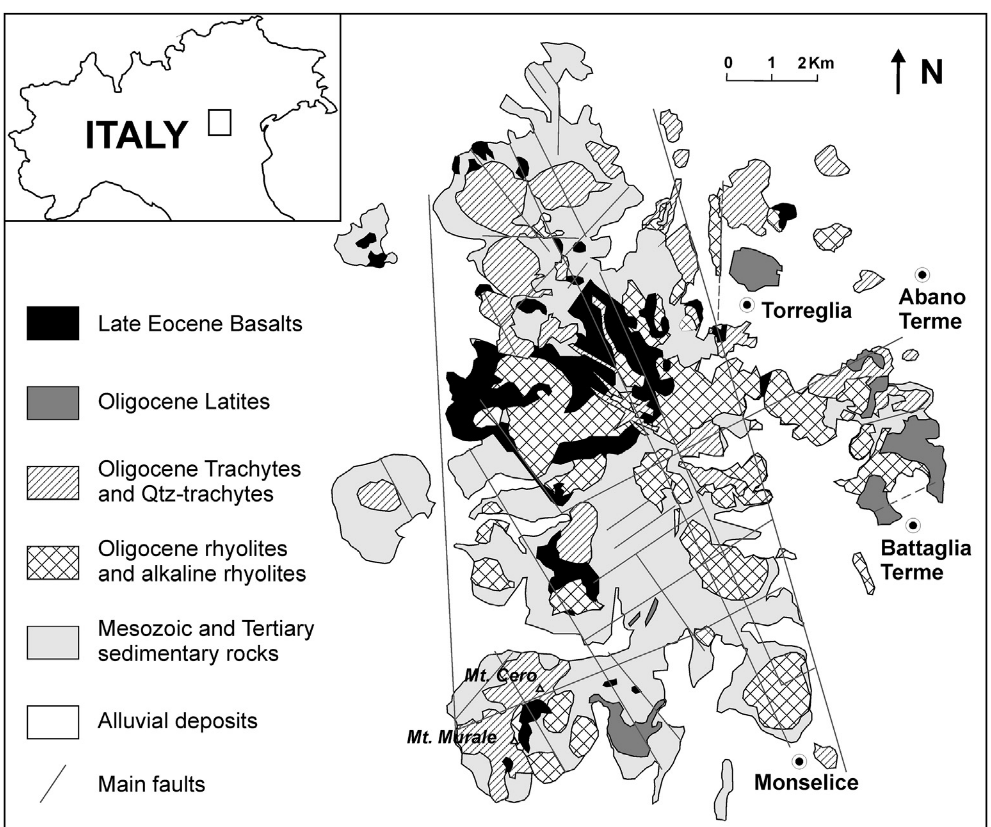

Fig. 1. Simplified geological map of the Euganean Hills in North-East of Italy (modified after Sassi et al., 2004).