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Natural radiation and geochemical data for rocks and soils, in the North International Douro Cliffs (NE Portugal)

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ABSTRACT

A cross-border multidisciplinary project has been developed in the region of Bemposta (cliffs of the Douro River) for the definition of walking trails, contributing to the promotion of health. The proposed routes traverse different lithologies of the region, visiting the interior of some "bodegas" (wineries in caves). The geochemical and radiometric characterization of lithologies revealed values of K, U and Th higher in granites and migmatites than the average crustal rocks and lower in sediments, which is in good agreement with results from a few hundred absorbed dose measurements. Soil gas radon and thoron concentrations, measured at a depth of 80 cm, also correlate well with geochemical information and indicate a low to moderate risk in the region. A preliminary assessment of the maximum contribution of the external radiation dose to the annual effective dose for an exposure scenario of 4 h/day shows an estimate of 0.19 mSv/year in the interior of the "bodegas" and 0.04 up to 0.19 mSv/year in trails according to the different lithologies, these values being reduced to 0.006 and 0.01 up to 0.006 mSv/year for a more likely scenario of exposure of 4 h/month. Exposure to radon gas is estimated not to exceed inside the "bodegas" 0.36 mSv/year for the latter scenario.

1. Introduction

There exists an innate human tendency to be drawn to the natural world and, in this context, the physical and emotional health benefits of a connection to nature have been well documented (Maller et al., 2009; Thompson et al., 2011).

The region of Bemposta is located in the Natural Park of Douro International, particularly in cliffs of Douro International, implanted in the Mirandês Plateaux. This is a unique region with a highly attractive landscape by the geological, faunistic, floristic and heritage features, which can sustain the provision of nature tourism and outdoor activities, namely trekking.

The rocks have different concentrations of radioactive isotopes (K, U and Th), the most important from the point of view of exposure to ionizing radiation. The distribution of those isotopes thus determines the external gamma radiation produced by rocks and also soils. There is still a current perception that natural radioactivity only affects people who live in the vicinity of uranium mines. However, all rocks contain uranium, some more than others, and depending on the concentration of this element and the subsequent contribution of certain geological factors, they also influence the presence of radon in the air. The emanation of radon gas is specifically dependent on lithology and geological structures. Thus, basement geochemistry influences the spatial distribution of radon levels at the soil/atmosphere interface (Buttafuoco et al., 2010). In the general environment, the natural radon isotopes contribute with more than 50% to the radiation dose received by individuals from natural radiation sources, and they have been identified as the second leading cause of lung cancer after tobacco smoking (UNSCEAR, 2000; WHO, 2009). Comparing the results of gamma dose rates in air inferred from the concentrations of radionuclides in rocks and soils obtained in Portugal with values of other European countries, according to the reports of UNSCEAR (2000, 2008), we can conclude that Portugal has a higher average dose rate than all other European countries studied (86 nGy/h). Granitoids exist in a significant portion of the Portuguese territory and have a tendency to incorporate higher amounts of uranium and thorium, compared to the crustal average. The distribution of these elements determines the gamma dose rate in air produced by rocks and soils, which explains the high average values found in Portugal.

Border multidisciplinary projects have been developed in the region of the Douro cliffs for the definition of tracks and take full advantage of the natural patrimony, undoubtedly contributing to health promotion. The walking trails studied cross several lithologies, visiting the interior of some "bodegas" located in Fermoselle (Spain) and Urrós (Portugal). The objective of this work is the geochemical and radiometric characterization of the outcropping rocks and carries out a preliminary assessment of environmental risk associated with natural radioactivity, showing which routes are subjected to less exposure.

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2. Geological setting

The Bemposta region (Northeast of Portugal) is a part of the northwestern edge of the Variscan dome of Tormes that extends to Spain (Fig. 1). The dome of Tormes is a granitic batholith located in the inner area of the Iberian Massif characterized by the development of a plutono-metamorphic dome of complex geometry and the most significant feature of it is the presence of migmatites associated with anatectic granites.

Cambrian and Ordovician metasedimentary country rocks from the North Douro International cliffs are locally migmatized and intruded by diverse granitic rocks, and the pre-Mesozoic rocks are locally covered by Tertiary sedimentary deposits. The granites are syn-tectonic with an elongated massive shape and are consistent with the NW–SE Variscan structures, revealing geometry and kinematics constrained by the Bemposta-Carviçais sinistral shear zone that strike ENE–WSW. Tonalite, three muscovite–biotite granites and muscovite granite are the granitoid facies recognized in the area. The tonalite outcrop in lenticules and the rock is dark, with a fine- to medium-grain, and exhibits strong foliation. The Bemposta granite is a medium-grained, muscovite–biotite and porphyritic, with phenocrysts of potassium feldspar generally less than 2×0.7 cm and strongly deformed. The Peredo de Bemposta granite is a medium-grained, muscovite–biotite, slightly porphyritic with phenocrysts below 1.5×5 cm. The Assumada granite is a fine- to medium-grained muscovite rock. The Urrós granite is a medium- to coarse-grained muscovite–biotite, and slightly porphyritic with phenocrysts of K-feldspar. Part of the granites and metasediments is covered by Cenozoic sedimentary deposits that extend across the Mirandês Plateaux and are well expressed in the vicinity of Sendim. The walking trails at the Douro cliffs are excellent for the practice of outdoor activities and consequently for the development of geotourism, crossing different lithologies and a large diversity of landscapes and forms. Some walking trails include visits to caves ("bodegas") in the Urrós and Fermoselle villages.

3. Materials and methods

Representative samples of all granites and metasedimentary rocks were collected and analyzed at the University of Bristol (UK). Major elements were determined by X-ray fluorescence with a detection limit of 0.01% and an accuracy better than ± 1%. U and Th were determined by ICP-MS with detection limits of 0.01 and 10 mg/kg and an accuracy of 5%. Minerals were analyzed in polished thin sections using a Jeol JXA-8500F electron-microprobe at the National Laboratory of Energy and Geology (LNEG) (Porto, Portugal).

A radiometric survey was conducted in several lithologies of the region using the portable gamma-ray spectrometer GF Instruments — Gamma Surveyor compact 2, equipped with a NaI detector, able to measure the gamma dose rate in air (nGy/h) and estimate in situ the concentrations of K, U and Th of the rocks. Several profiles were performed to characterize each lithology. In selected locations (n =284) the external radiation was measured with the spectrometer placed at 1 m above the rock or soil, and concentrations of radiogenic elements K, U and Th were estimated in outcrops with a large amount of rock exposed.

After a preliminary evaluation of the regional radiometric background, the determination of the soil-gas concentrations of radon and thoron was carried out in 37 representative places of the dominant lithologies by alpha emanometry, using a Scintrex RD200 equipment, according to the protocol described in Pereira et al. (1998). Sampling depth was 0.8 m and radon/thoron was discriminated following three consecutive one minute measurements.

4. Results and discussion

4.1. Geology and geochemistry of rocks and minerals

Rocks such as granites contain more uranium than other rock types and consequently should give rise to higher radon levels at

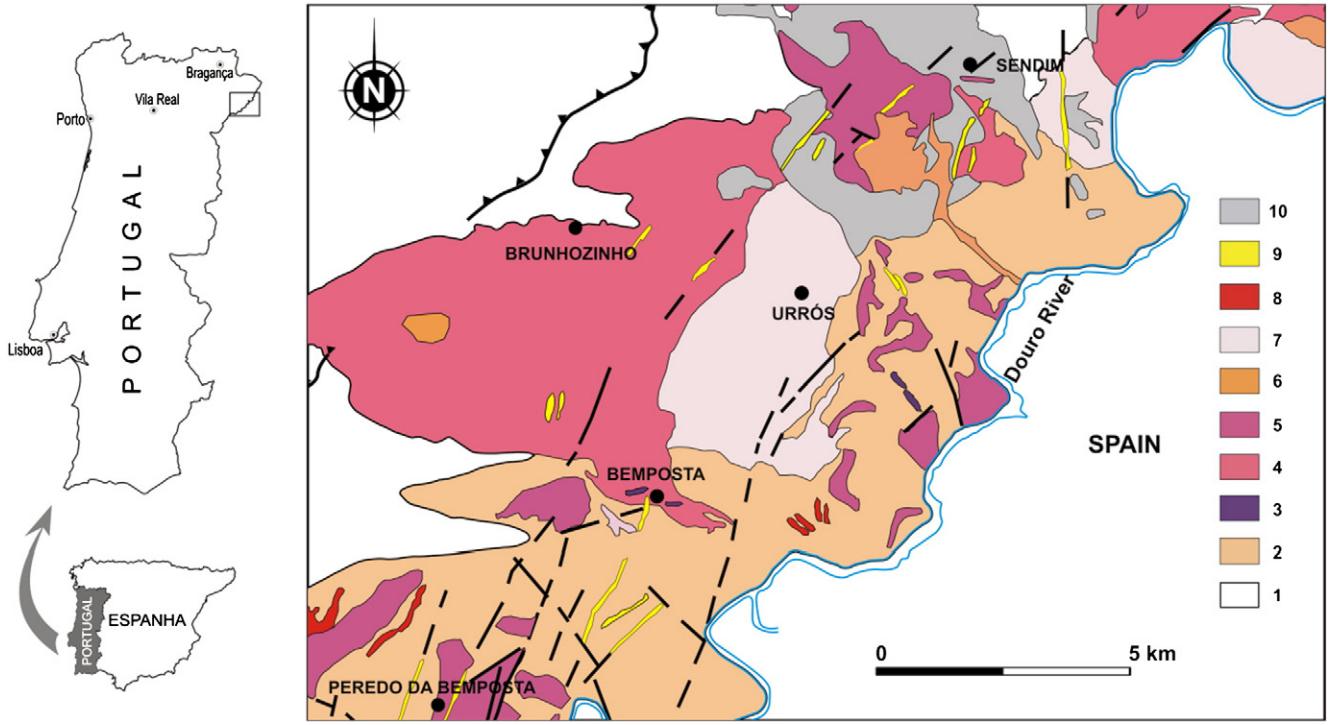

Fig. 1. Simplified geological map in the region of Bemposta and location on the maps of Iberian and Portugal. Legend: 1. Paleozoic metasediments, 2. Migmatites, 3. Tonalite, 4. Bemposta granite, 5. Peredo de Bemposta granite, 6. Assumada granite, 7. Urrós granite, 8. Aplite–pegmatite veins, 9. Quartz veins and 10. Sedimentary deposits of the Cenozoic age.