Natural radioactivity in Sardinian granite dimension stones

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INTRODUCTION

About 6000 km^2 of Sardinia consist of the Sardinia-Corsica batholith made up of several plutons emplaced between 311 and 286 Ma (OGGIANO *et alii*, 2005; GAGGERO *et alii*, 2007). The wide emplacement time-span allowed large compositional variability of these intrusions, which range from quarzodiorites-tonalites to leucomonzogranites. These stones represent a considerable economic resource; the first evidence of its exploitation dating back to the 15th century BC in the building of *nuraghi.* Moreover the Roman quarries, active during the Roman Empire and still visible on the north eastern coast (POGGI & LAZZARINI, 2005).

Nowadays, granite quarrying activity is located in the central-north Sardinia, mainly in Gallura and Goceano regions, where several commercial varieties are exploited.

All these stones are widely exploited and represented the main building materials in the past. Besides, these granites have been widely exported around the world as tiles, flooring, columns or other architectonic element. Moreover the north-eastern Sardinia granite was largely employed for ashlars used in the building of dwellings until the sixties. Taking into account the large diffusion of the Sardinian granites, the knowledge of their natural radioactivity is basic for the evaluation of the amount of public exposure because people spend most of their time (about 80%) indoor (NGACHIN *et alii,* 2007 and their references).

The aim of this work is therefore to determine the K, U and Th isotopic concentration in these materials.

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METHODS

For this purpose a portable gamma-ray spectrometer at the National Lab of Legnaro (INFN) was developed (Fig. 1).

Fig. 1 – Portable gamma-ray spectrometer in a quarry during the acquisition of K-U-Th isotopic concentration.

The equipment consists of one liter thallium-activated sodium iodide scintillator [NaI(Tl)], digiBASE by *Ortec* and a netbook which manages also humidity and temperature sensors. By using the *Jradview* software is possible to process the data in real time and to determine uranium and thorium (in ppm), expressed as equivalent units, and potassium concentration (in %) as well as total activity expressed in Bq kg^{-1}. Following the IAEA guideline (IAEA-TECDOC-1363, 2003), the gamma-ray spectroscopic analysis is performed by monitoring three spectral windows: 1.37-1.57 MeV for ^{40}K, 1.66-1.86 MeV for ^{214}Bi and 2.41-2.81 MeV for ^{208}Tl.

The concentrations of U/Th are estimated by ^{214}Bi/^{208}Tl decays, under the assumption that the U and Th decay series are in secular equilibrium. This occurs when the parent half life is much longer than the daughter half life and then the number of atoms of a daughter isotope essentially becomes constant after some time. Two conditions are necessary for secular equilibrium. First, the parent radionuclide (^{238}U/^{232}Th) must have a half-life much longer than that of any other radionuclide in the series. Second, a sufficiently long period of time must have elapsed, to allow for ingrowth of the decay products. The state of secular

Commercial varieties	Measures number	Activity ^{40}K (Bq/kg)	Activity ^{238}U (Bq/kg)	Activity ^{232}Th (Bq/kg)	Total Activity (Bq/kg)	H_{ex}
Rosa Cinzia	1	1501	75	79	1655	0.82
Ghiandone	7	1361±106	74±14	91±15	1526±108	0.83±0.11
San Giacomo	2	1473±108	77±18	71±14	1621±111	0.79±0.13
Grigio Malaga	4	925±110	39±6	68±2	1032±110	0.56±0.04
Grigio Perla	10	1288±133	38±8	67±11	1393±133	0.63±0.06
Bianco Sardo	3	1351±72	49±12	60±7	1460±73	0.64±0.06
Rosa Beta	4	1183±110	43±11	59±5	1285±110	0.59±0.07

Tab.1 – Commercial varieties considered and mean values of $A^{40}K$, $A^{238}U$, $A^{232}Th$, Total Activity and H_{ex} (About Rosa Cinzia, was not calculated the uncertainty because we performed only a single measure)

equilibrium in natural U and Th ores is significantly altered when they are processed to extract specific radionuclides, in particular Ra and Rn.

Assuming secular equilibrium, in order to evaluate the external gamma-radiation dose from building materials, the following model (HAYAMBU *et alii*, 1995) was used as criterion. This model uses the External Hazard Index (H_{ex}) defined as:

$$H_{ex}= A_U/370 + A_{Th}/259+A_K/4810$$

where A_U, A_{Th} and A_K are the activity concentration of ^{238}U, ^{232}Th and ^{40}K, respectively, in Bq kg^{-1} in building materials. To limit the external gamma radiation dose from building materials to 1.5 mSv $year^{-1}$, H_{ex} must be less than unity in order to maintain the radiation hazard negligible (XINWEI, 2004).

The average radioactivities of ^{238}U, ^{232}Th and ^{40}K and H_{ex} measured in different commercial varieties of Sardinian granites are given in Table 1.

RESULTS AND CONCLUSIONS

The data acquires show that the ^{40}K average activities vary from 925±110 Bq kg^{-1} in Grigio Malaga to 1501 Bq kg^{-1} in Rosa Cinzia. The ^{238}U, average activities range from 38±8 Bq kg^{-1} in Grigio Perla to 77±18 Bq $kg^{-}1$ in the San Giacomo. The highest average activity of ^{232}Th was 91±15 Bq kg^{-1} in Ghiandone and the lowest average was 59±5 Bq kKg^{-1} in Rosa Beta.

About the H_{ex}, the commercial varieties showed the highest values were, in order, Ghiandone (0.83±0.11), Rosa Cinzia (0.82) and San Giacomo (0.79±0.13).

Finally, all commercial investigated varieties have H_{ex} value below 1, hence, generally, the corresponding rocks can be safely used as building materials for dwelling construction also in indoor conditions.

REFERENCES

GAGGERO L., OGGIANO G., BUZZI L., SLEJKO F. & CORTESOGNO L. (2007) - *Post-Variscan mafic dykes from the late orogenic collapse to the Tethyan rift: evidence from Sardinia*. Ofioliti **32**, 15-37.

HAYAMBU P., ZAMAN M.B., LUBABA N.C.H., MUNSANJE S.S., MULEYA D. (1995) – *Natural radioactivity in Zambian building materials collected from Lusaka.* J. Radioanal. Nucl. Ch., **199** (3), 229-238.

IAEA-TECDOC-1363 (2003) - *Guidelines for radioelement mapping using gamma ray spectrometry data*.

NGACHIN M., GARAVAGLIA M., GIOVANI C., KWATO NJOCK M.G. NOUREDDINE A. (2007) – *Assessment of natural radioactivity and associated radiation hazards in some Cameroonian building materials.* Radiat. Meas., **42**, 61-67.

OGGIANO G, CHERCHI G.P., AVERSANO A., DI PISA A., ULZEGA A., ORRÙ P. & PINTUS C. (2005) – *Note illustrative della Carta Geologia d'Italia. Foglio 428 Arzachena,* S.EL.CA, Firenze.

POGGI D. & LAZZARINI L. (2005) – *Il granito sardo: cave e cavatura. Usi, diffusione e aspetti archeometrici.* Marmora, **1,** 49-68.

XINWEI L. (2004) – *Natural radioactivity in some building materials and by-products of Shaanxi, China*. J. Radioanal. Nucl. Ch., **262**, 775-777.