Radon Prone Areas characterization and indoor measurements aimed at the health risk assessment in the Eastern sector of Mt. Vulsini volcanic district (northern Latium, Central Italy)

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14th INTERNATIONAL WORKSHOP GARRM

Geological Aspects of Radon Risk Mapping

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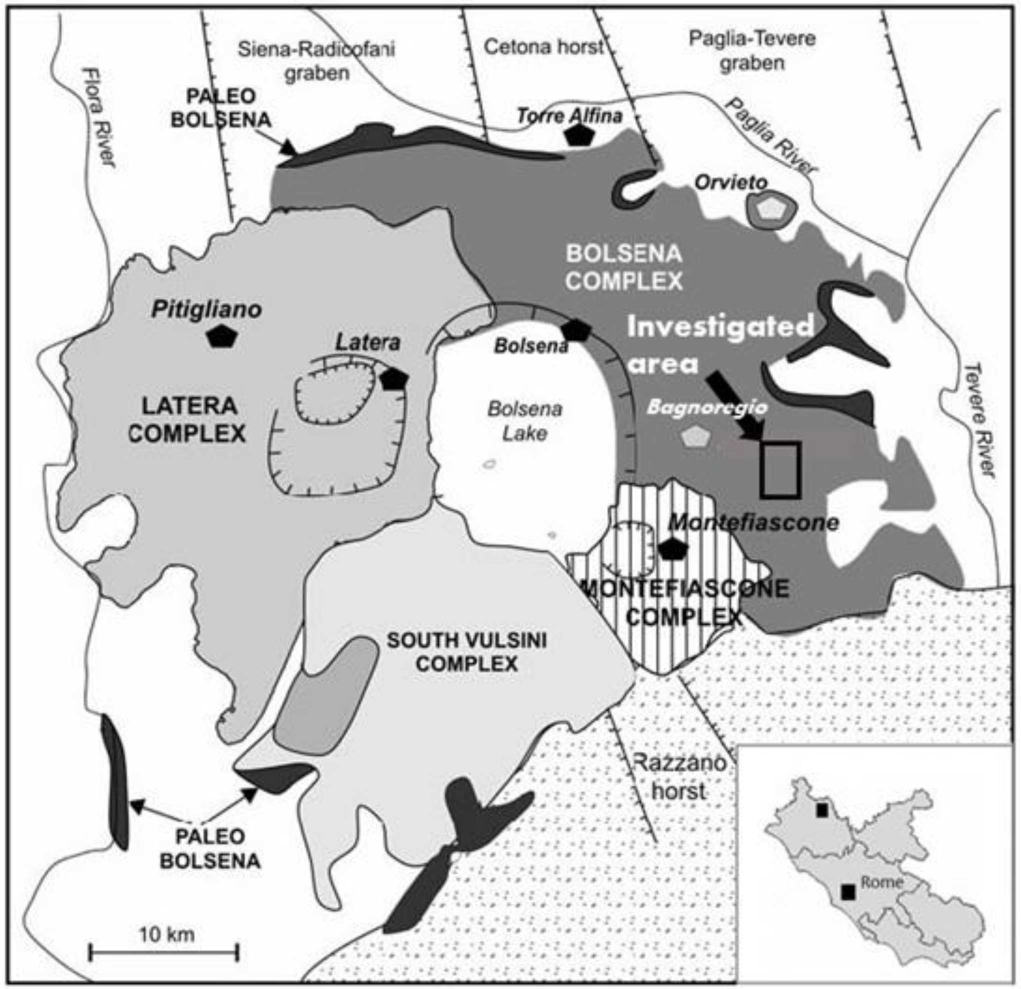
Aim of the Study

- Elaborate soil-gas Rn anomaly maps;
- Characterize presence and location of Radon Prone Areas (RPAs);
- Support the "Radon National Plan" art. 103/3 of Euratom Directive 59/2013 *Basic Safety Standard;*
- Provide local Administrations with thematic maps as a useful tool for land-use planning and to prompt effective strategies in Radon risk assessment;
- Assess an operational protocol of investigation techniques leading to properly analyze collected data.

Adopted Work Methodology

- Preliminary bibliographic studies;
- Radon and CO_2 measurements in soil gases, performed with an AlphaGuard PQ2000Pro® Radon monitor and a Draeger X-am®7000 multigas device;
- Soil gas data processed with geostatistical methods aimed at the development of georeferred Rn and CO_2 anomalies maps;
- Indoor Radon measurements: both medium-term analyses and short-term investigations;
- Data interpretation.

Geology of the Vulsini Volcanic Complex



- Volcanic and volcano-sedimentary deposits aged between 490K and 127K years ago;
- Explosive activity, tuffs and pyroclastic flows;
- Silt and silty sand of marine environment are also present, covering Pleistocenic pelitic clays, of deep facies;
- Widespread geogenic degassing phenomena, that occur on the surface with several post-volcanic mainfestations, such as thermal springs, travertine deposits and CO_2-rich endogenic gaseous leakages.

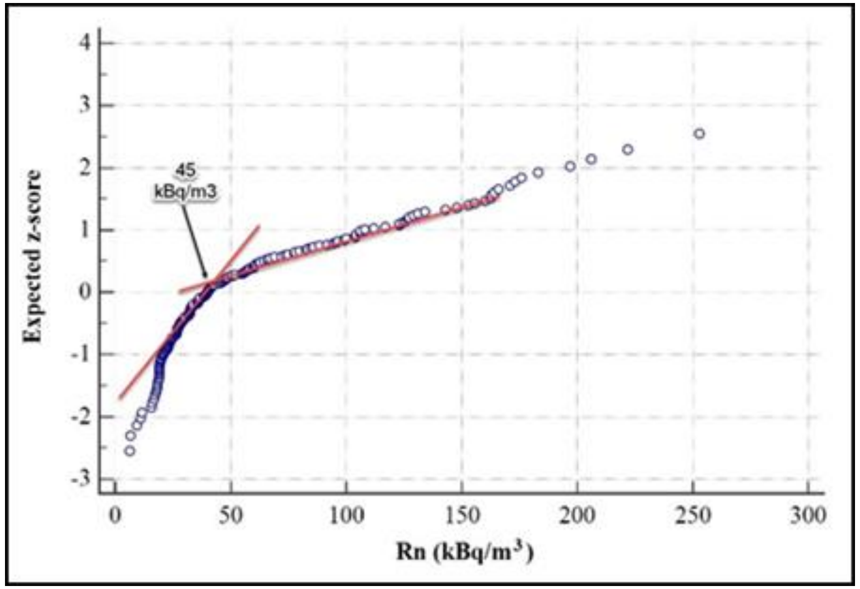
Rn and CO_2 soil-gas measurements

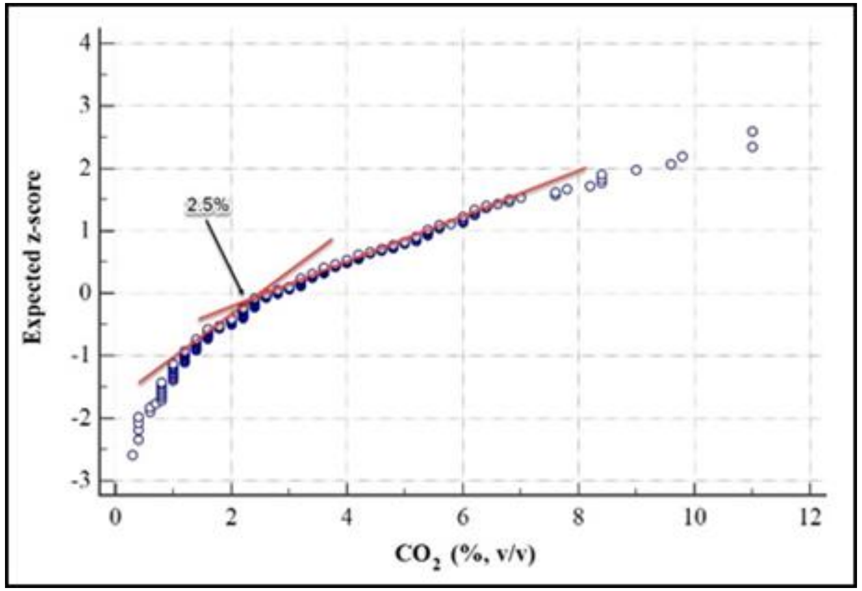
- Stainless steel probe pounded down at about 80 cm depth with a coaxial hammer;
- Radon measurements were performed with an AlphaGuard PQ2000Pro® Radon monitor;
- Each Rn measurement lasted 10 minutes;
- Draeger X-am®7000 was used for the analysis of soil-gas CO_2 values;
- Rn and CO_2 data collected on an area of about 25 km^2, acquiring about 200 Rn and CO_2 soil gas samples;

INAIL

Soil gas samples statistical parameters

	N	Mean	Geom. M.	Median	Min.	Max.	QI (25%)	QS(75%)	Stand. Dev.
Rn (kBq/m^3)	184	60,00	45.14	40.19	6.44	253.60	26.43	80.41	48.75
CO_2 (%, v/v)	204	3,27	2,68	2,80	0,30	11,00	1,6	4,45	2,17





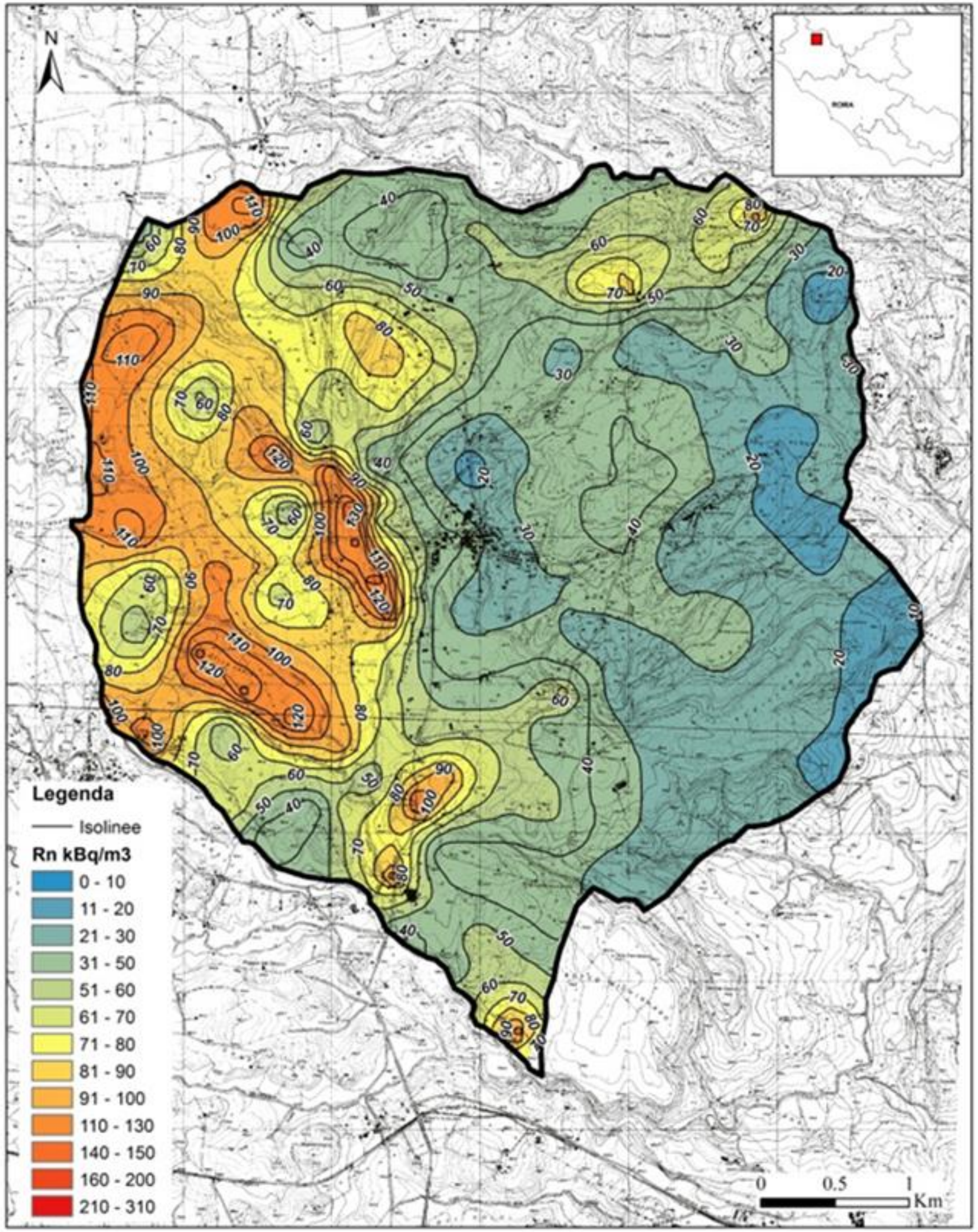
-Cumulative probability graphs

-Different populations of data,

-Anomaly value characterization (Sinclair, 1991)

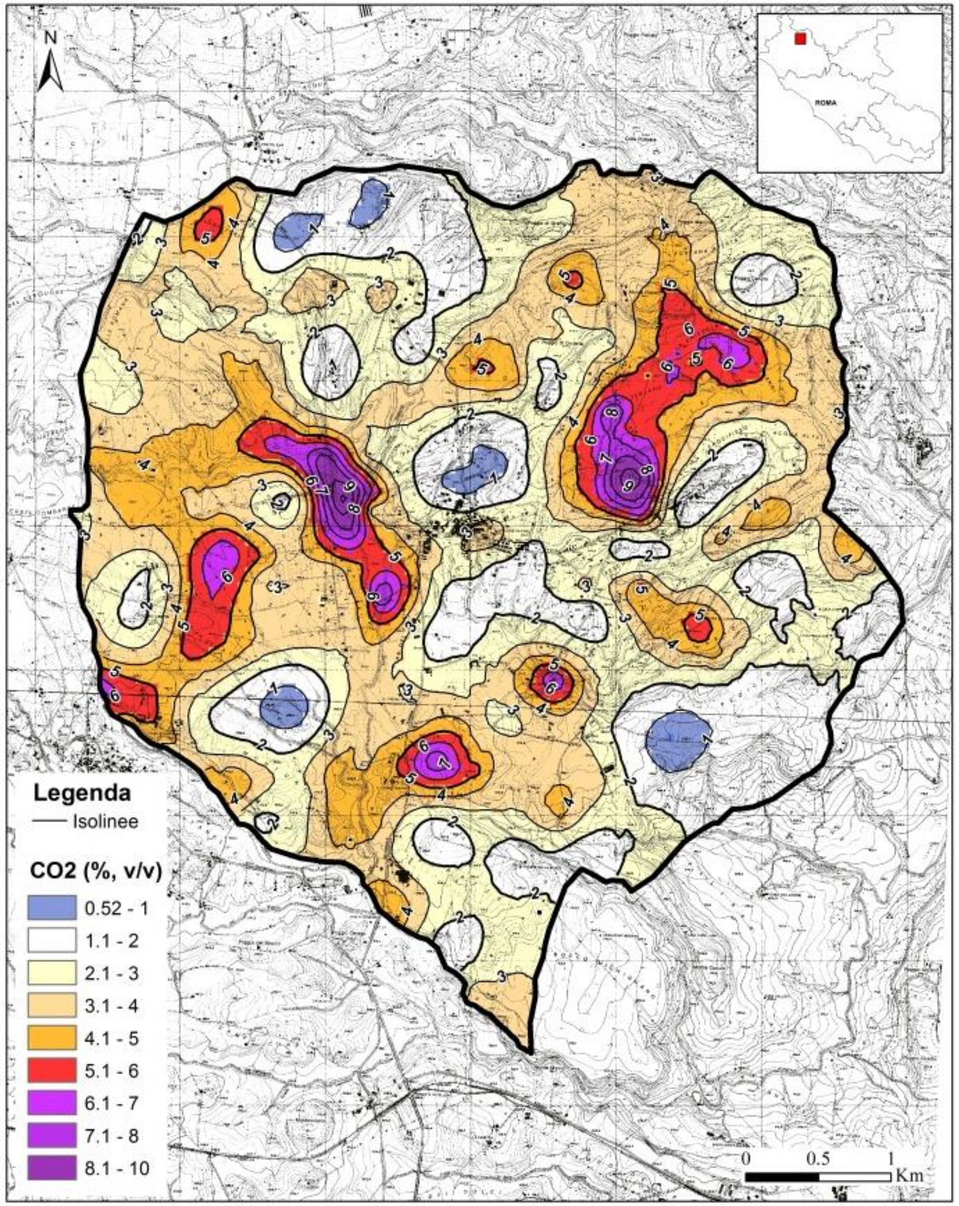
Rn soil-gas anomalies distribution

- Soil gas samples elaborated with geostatistical methods (kriging algorithm);
- Elaborated georeferred maps run in a GIS environment
- Rn anomalies mainly located in the western sector, with a NW-SE alignment;
- Sharp correlation with: geology, structural features, permeability;
- An usefull tool for Radon Prone Areas (RPAs) characterization



CO_2 soil-gas anomalies distribution

- Both CO_2 and Rn anomalies distributions have similar distribution;
- Majority of outlier samples occur as discrete anomalies along structural lineaments;
- CO_2 is much more abundant than trace elements and migrates quickly on the surface;
- CO_2 act as “carrier gas” for Radon;
- Permeability of faults and tectonic structures provide a vertical pathway for upward gas migration

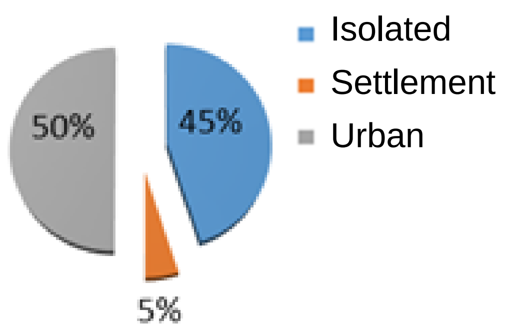


Radon Indoor measurements

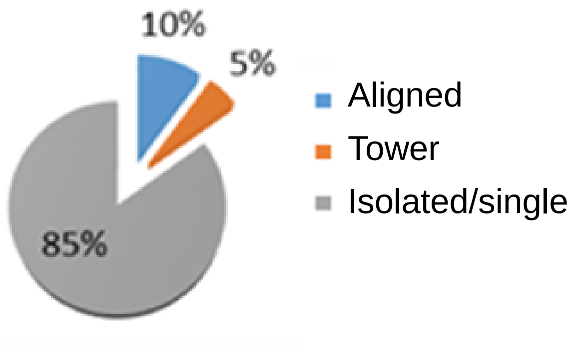
- ✓ Measurements were carried out in 20 houses. In each house two dosimeters were placed on different floors;
- ✓ Houses located both in low and high Rn geogenic potential;
- ✓ Analyses lasted for a medium term period (6 months).
- ✓ Questionary was given to house-owners to keep information on building characteristich and family-life habits;

Buildings characteristics based on Questionaries

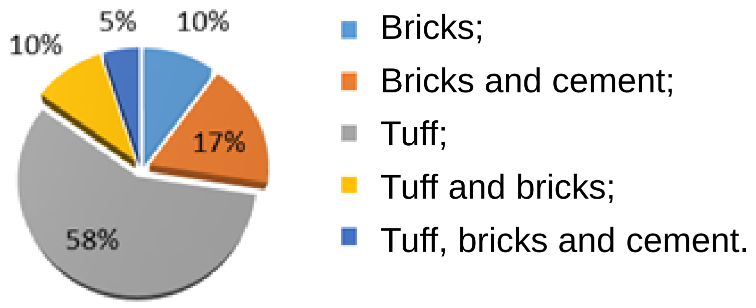
Type of area



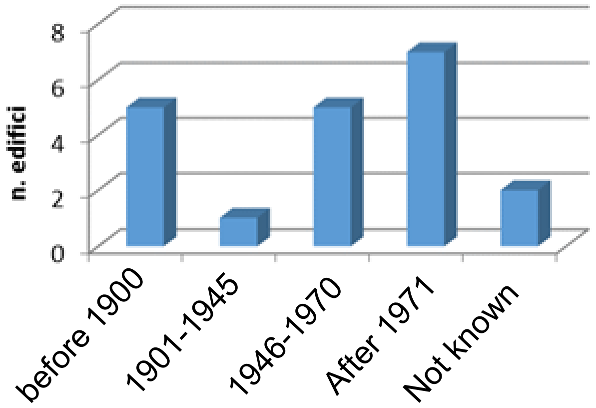
Type of building



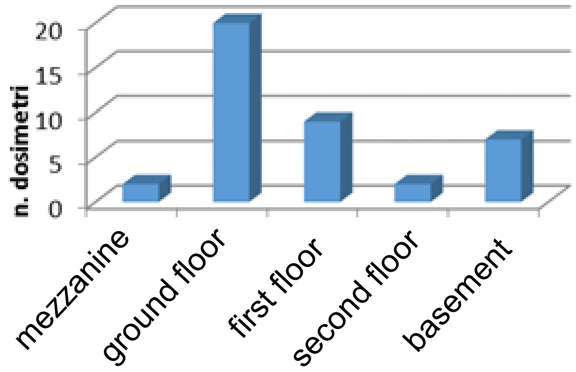
Construction material



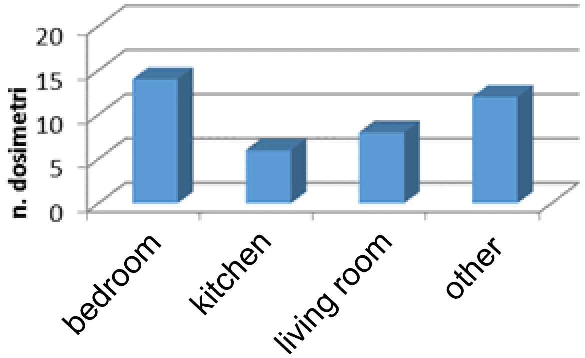
Construction year



Sampled floor



Use of room

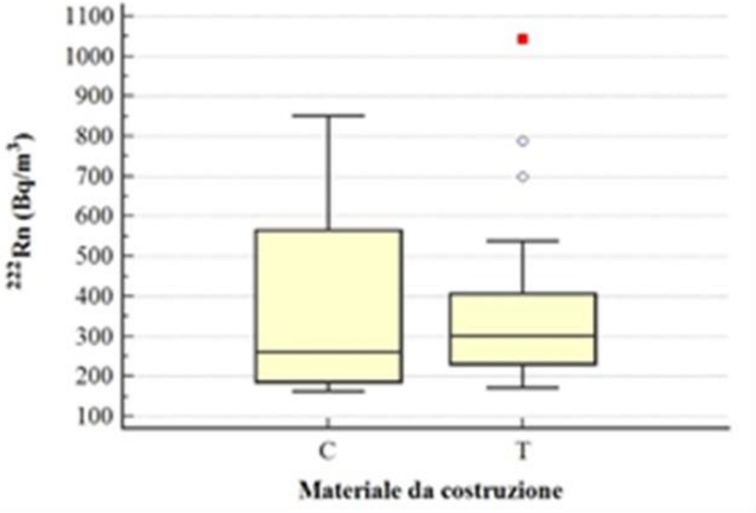


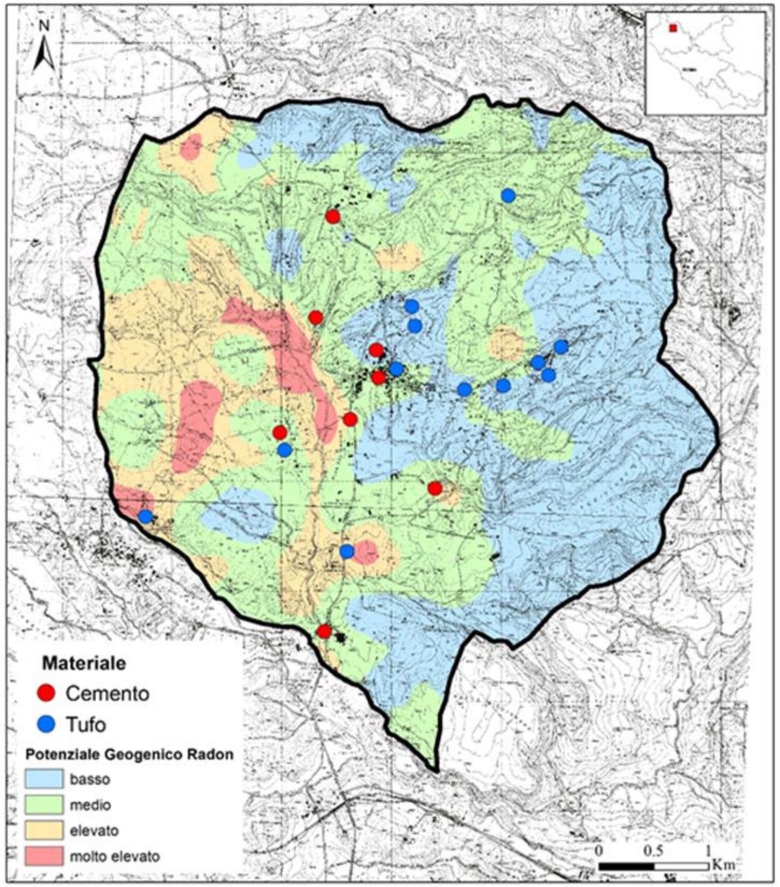
Indoor Radon statistical parameters

	N	Mean	Geom. mean	Median	Min.	Max.	QI (25%)	QS(75%)	Dev.Stand.
Rn (Bq/m^3)	40	468	347	302	162	4256	221.8	437.3	648.9

- Indoor radon Italian mean is 77 Bq/m^3 (APAT, 2003)

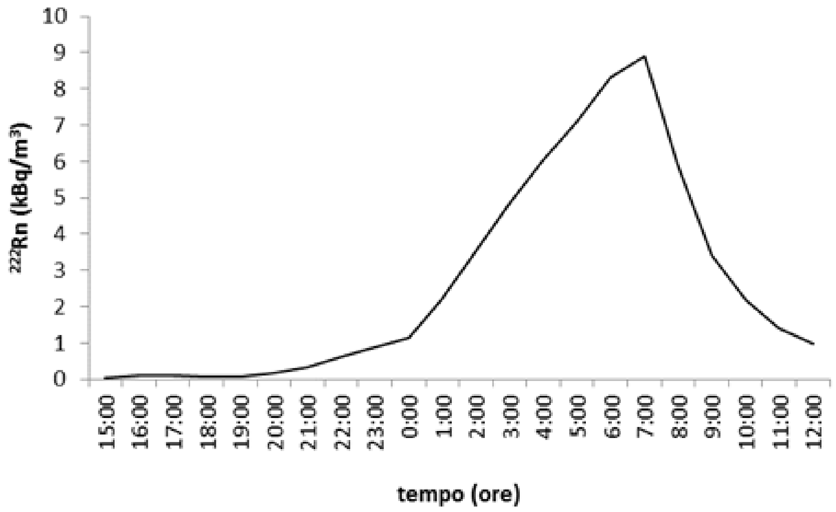
Box-plot diagram of indoor Rn distribution in concrete (C) and tuffs (T) buildings.



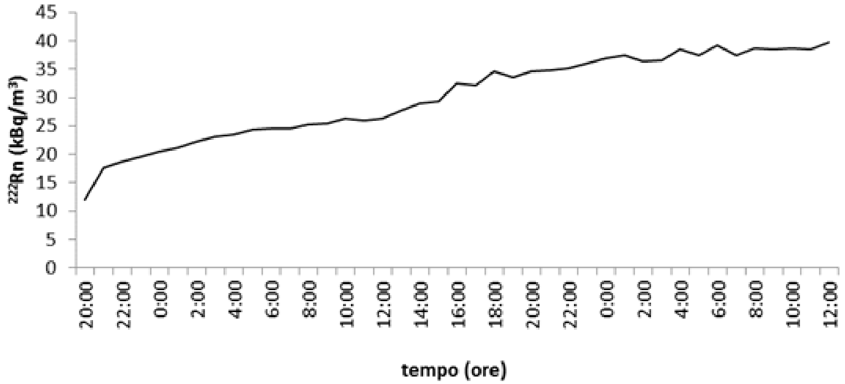


Short-term indoor Radon measurements

- *Alphaguard PQ 2000 Pro*
- *Diffusion mode*



22-hrs sampling carried out into a bedroom placed in the ground floor (July, 2017).
Rn in soil gas: 45 kBq/m^3



40-hrs sampling carried out into a cellar placed in the basement of a building and dug in tuff formation (July, 2017).
Rn in soil gas: 38 kBq/m^3

Conclusions

- In the Eastern sector of the Vulsini volcanic complex, Radon Prone Areas (RPAs) are mainly located in the western part of the studied area;

- Rn and CO_2 anomalies show sharp correlation with geological and structural features. Geogenic CO_2 acts as carrier gas for Radon;

- The interpolation and direct correlation of Radon indoor values can not be configured as a effective technique for radon risk mapping;

- Many variables strongly affect indoor Radon values, such as geological characteristics, building construction materials, environmental conditions and life-habits;

- Geostatistical elaboration and mapping of Rn soil-gas data help to fit the issue; yet these do not represent the health risk connected to Radon exposure, but a territorial classification on the *probability* of identifying high indoor Radon concentrations;

- Rn anomalies maps provide a useful tool for Competent Authorities in territorial planning, and for decisions on which techniques to be undertaken for prevention, mitigation and remedy.