4.1.2. The Gargano promontory survey

The Gargano promontory is a ENE-WSW ridge extending in the Adriatic Sea (fig. 11). The geodynamics of the Gargano developed within the Adriatic micro-plate, which played the role of foreland for the NE-vergent Apennines as well as for the SW-vergent Dinarides (Channell and Horvàth, 1976). Although apparently part of the Apulian Foreland «stable» block, several geological and geophysical patterns distinguished the Gargano sector from the rest of the foreland: the geomorphological patterns, the crustal thickness, the historical-instrumental seismicity -inland and off-shore, the presence of gravimetric and magnetic positive anomalies, the relatively higher heat flow, up to 60 mW/m^2, and the recently discovered fluid geochemistry anomalies (Console *et al.*, 1993; Lombardi *et al.*, 1999; Salvi *et al.*, 2000). In particular, remarkable seismic sequences were recorded between 1986 and 1990, located in the offshore too, demonstrating that the Adriatic Sea is not aseismic inside. More recently, instrumental data showed a moderate seismicity both offshore (maximum magnitude 5.3 in 1988, strike-slip fault) and inland, with a maximum magnitude of 4.4 in 1995, which occurred in the central sector of the promontory. Destructive earthquakes are reported to have occurred in historical times, with felt effects in the area up to XI MCS (Console *et al.*, 1993; Boschi *et al.*, 1997). Extensive damage and casualties were referred to those events (*i.e.*, Lesina zone: 30/07/1627, M_m = 6.9 near the recent event M_d = 4.0 on November 3, 1988), but the exact location of the seismogenic structure is still uncertain. A recent work (Salvi *et al.*, 2000), exploiting the geochemical methods in searching for active faults, emphasized a possible link between a WSW-ENE buried fault system and the 1627 probable seismogenic structure (see fig. 11, S. Spirito Fault).

In the southern margin of the promontory, two evident morphological steps joined the rugged land-forms of the carbonate succession to the plain located south and south-west, *i.e.* the Candelaro and Rignano faults (fig. 11). At this boundary, the Foggia Plain is filled with the terrigenous sediments of the Apennine fore-deep basin, topped by recent continental and marine deposits. The most evident structure inside the promontory is the Mattinata Fault, a sub-vertical E-W fault, whose complex kinematics history was inferred (Funiciello *et al.*, 1988; Lombardi *et al.*, 1999), as testified by the presence of a pull-apart basin (Pantano S. Egidio) and to compressive deformation (S. Marco in Lamis area), related to the strike-slip activity of the fault.

An extensive fluid geochemistry survey was performed by ING from 1996 to 1997, aimed to refine fluid geochemistry methods for Seismic Hazard Assessment (SHA) studies (Lombardi *et al.*, 1999). About 120 sites were sampled uniformly throughout the promontory (despite the scarcity of sampling sites in the central sector of the promontory, as a consequence of the karstic hydrogeology).

Besides radon measurement, the physico-chemical parameters, dissolved gases (CO_2, H_2S, NH_3, N_2, CO_2, Ar, CO_2, He, CH_4, etc.) and isotopic analyses (C, He, O, D, B, Cl) were performed, as discussed elsewhere (Quattrocchi *et al.*, 1999; Lombardi *et al.*, 1999; Salvi *et al.*, 2000). The radon groundwater content was measured by ASM-LCC for all the samples, while a subset of samples was selected for CTM-ACC analysis (table IV).

A significant correlation between fluid geochemistry spatial anomalies and fault system location was discovered (fig. 11), most of all for the radon parameter. Its content in groundwater was related to the lithology, *i.e.* a low U minerals background (high in red-clays deposits), but mostly to the fault systems (Quattrocchi *et al.*, 1998): the anomalous values were peaked along the above-mentioned fault systems, *i.e.* the Candelaro and the Mattinata Faults as well as in peculiar locations as in the S. Egidio pull-apart basin and along the S. Spirito buried fault. The highest radon value was observed at the Monte Granata Well, along the Candelaro Fault, where it crosses a N-S structure. Here the highest $^3He/^4He$, Hg, groundwater thermality, magnetic, gravimentric and heat flow anomalies throughout the Gargano-Capitanata area were found.

Regarding the cause of radon enrichment in the above-mentioned sites, we suggested convection-advection processes along fault system, as a consequence of the intensive fracture field, while we excluded a predominant role of carrier gases as observed both in the Eastern Alps area and in the Colli Albani area, because of the low CO_2 content and the low dissolved gas volume in the area, that reach only 3-4 times the ASW content (Air Saturated Water at 20 °C; total dissolved gas 8.65 × 10-4 mol/L).

Table IV shows that a good agreement was found between the ASM-LCC and GSM-CTM methods, used in the frame of the Gargano surveys: in particular almost all the samples show the GSM-ACC values within 2 σ of the ASM-LCC value method (fig. 10).

4.1.3. The Ardea Basin survey (Colli Albani)

The Colli Albani quiescent volcano is one of the ancient volcanoes along the NW-SE extensional belt of the Tuscan-Latium peri-thyrrenian margin, built up since the Plio-Pleistocene, also called in literature the Roman Comagmatic Province (RCP). Along the RCP the carbonate basements under the volcanic edifices have different seismogenic behavior, probably due to different fluid circulation and pore pressure regime at depth (Quattrocchi and Calcara, 1998). The quiescent volcano is considered a seismogenic structure (Amato *et al.*, 1994). Most of the Colli Albani seismic activity was condensed over the Western sector of the volcano, with swarm hypocenters clustered between 3 and 6 km at depth: a cut of seismicity exists around 10 km. On the other hand, the recent Rome earthquake (June 12, 1995, $M_d = 3.6$, fig. 12) showed different seismicity patterns with respect to the typical swarm activity of the Colli Albani region, defining a limited seismogenic fault segment in the southern sector of Rome (Basili *et al.*, 1996).

The volcano was defined as a fading off geothermal system (Giggenbach, 1988; Quattrocchi and Venanzi, 1989). Recently the hypothesis of a strict link between the recorded seismicity and the volcano uplift and deformation was strengthened (*i.e.* Colli Albani unrest, Delaney *et al.*, 1996), just in the sectors where fluid geochemistry spatial and temporal anomalies (CO_2, H_2S, ^{222}Rn, B, NH_3, etc.) have been discovered (Quattrocchi and Venanzi, 1989; Quattrocchi and Calcara, 1998; Pizzino *et al.*, 1999). Normally, within the Colli Albani region, the recent volcanic rocks overlap the seismogenetic layer of Meso-Cenozoic Latium-Abrutium Carbonate Platform (5-10 km). Otherwise the RCP belt may also be characterized by recent basins filled by thick sequences of marine clastic deposits dating back from the Messinian to the early Pleistocene. It is the case of the Ardea Basin, defined as a transfer-related basin (Faccenna *et al.*, 1994): the common characteristics of these transfer structures are that the slip vector along the transfer fault is mainly dip-slip, meaning that the local extension direction is orthogonal to the regional direction, with development of narrow and deep half-graben basin structures.

In this structural framework we found more developed diffuse gaseous gushing pools, groundwater convection and hydrothermal activity, as a consequence of the increased facility to deep-fluids uplift. Convective circulation may be easily inferred by groundwater temperature and radon, the highest in the Colli Albani area, just at the ARDH and ARD sites.

In particular, the S. Stefano-Ardea thermal spring (ARD site, 21°C, see fig. 12) is the oldest commercial thermo-mineral water over the area, showing both a slight temperature anomaly as well as high CO_2 and ^{222}Rn content, deserving interest for geochemical monitoring (Quattrocchi and Calcara, 1998; ING-ENEA unpublished data). The interest of the Ardea Basin was enhanced recently, by the drilling of the S. Stefano-Ardea thermal Well (ARDH site): this is the hottest CO_2-H_2S rich Na-HCO_3 groundwater (with 54 °C at 85 m depth) discovered to date in the Colli Albani area, near the new gushed pools named FSGD (Quattrocchi and Calcara, 1998). The δ^{13}C and ^{3}He/^{4}He analyses undertaken at these sites suggested a clear deep input and a slight mantle signature (unpublished data of the GSZ EC program, Lombardi *et al.*, 1999). The new experimental evidence suggested the possibility to revise the gas geothermometric estimates provided in the past (Giggenbach *et al.*, 1988; Duchi *et al.*, 1991), that constrained the Colli Albani deep-carbonate geothermal reservoir to low-medium enthalpy range.

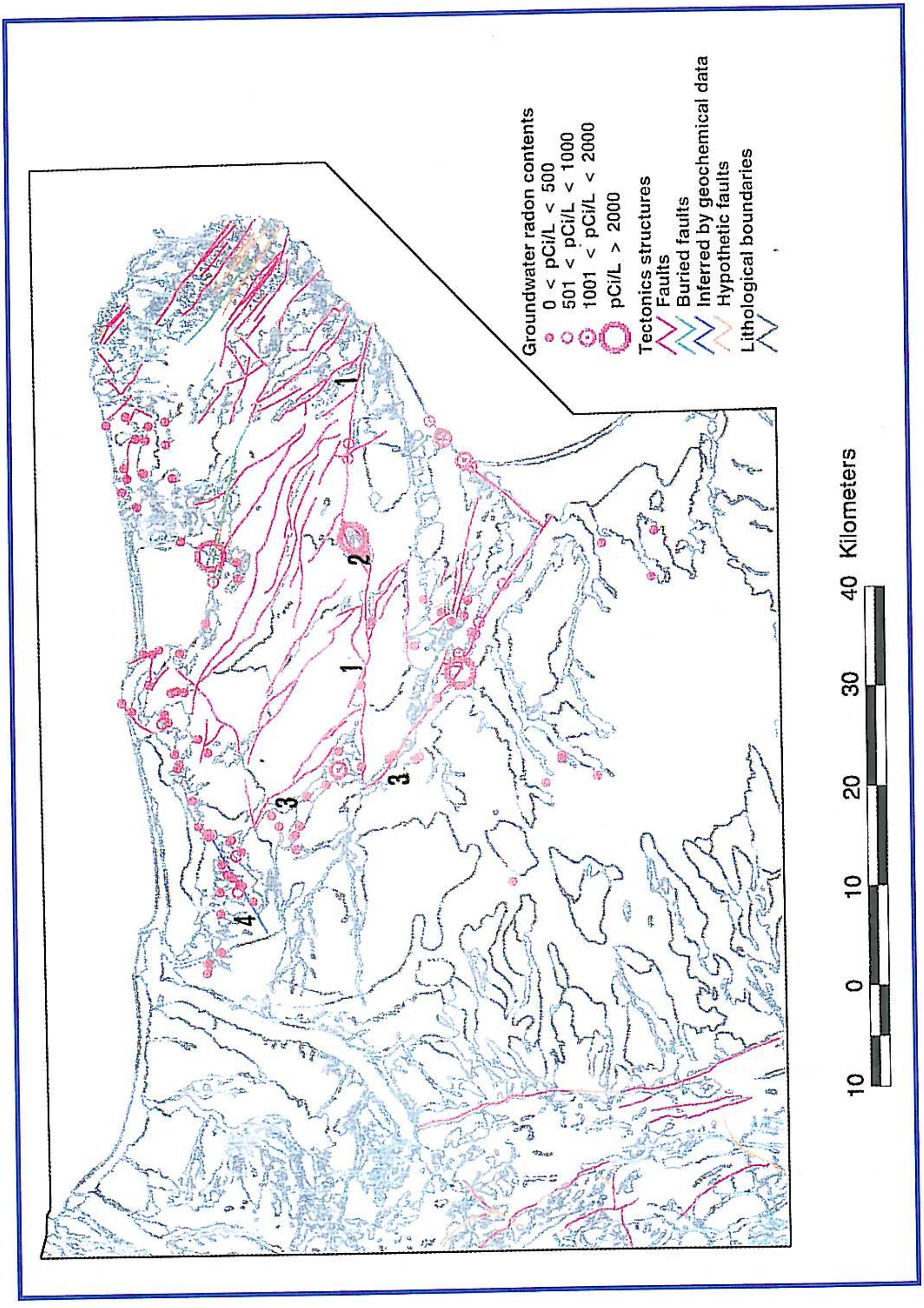

Fig. 11. Radon concentration in the Gargano groundwater, the main anomalies are located along the regional fault system: 1 = Mattinata Fault; 2 = Pantano S. Egidio pull-apart basin; 3 = Candelaro Fault; 4 = S. Spirito Fault. The geo-structural data were selected from Salvi *et al.* (2000).

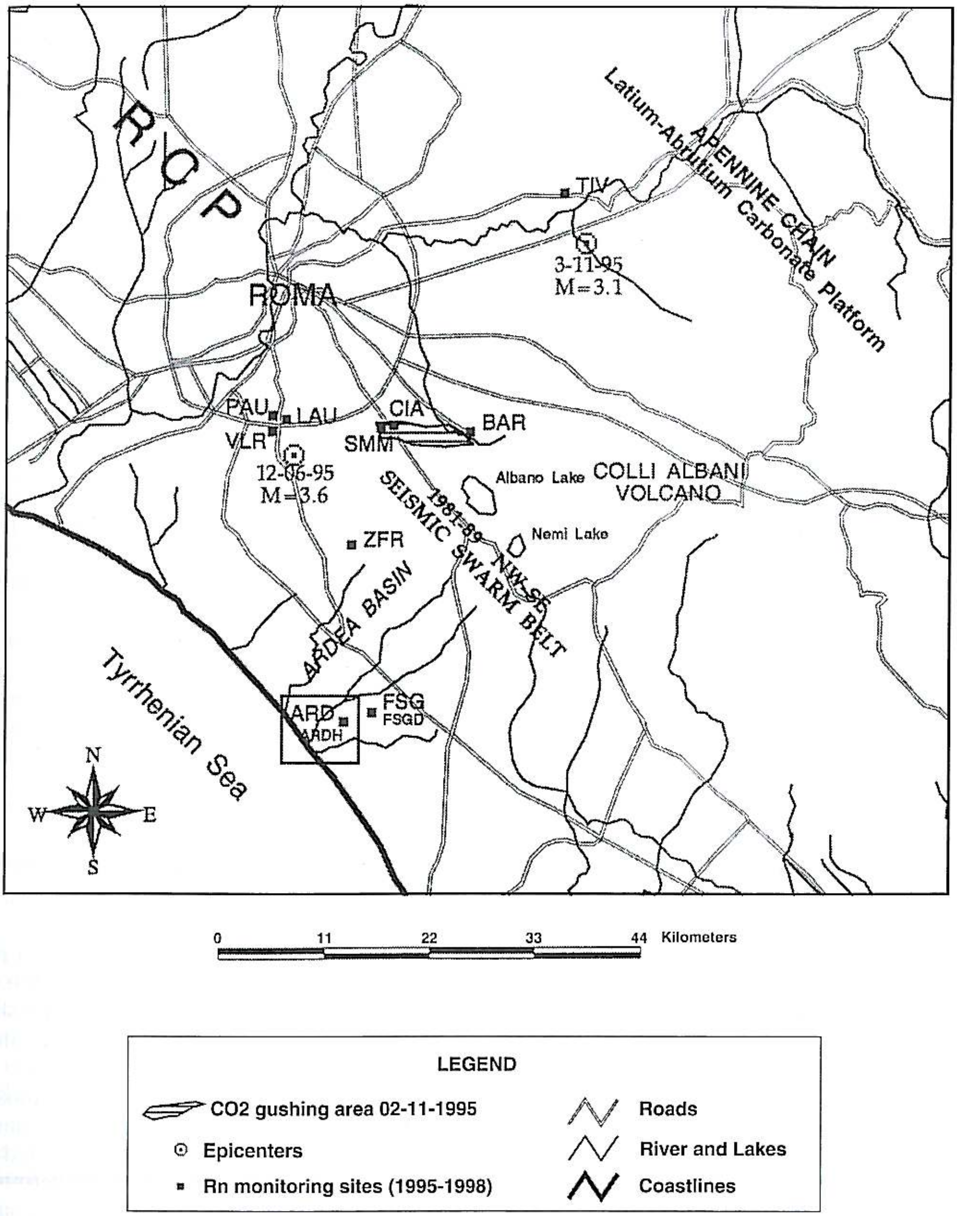

Fig. 12. Map showing the location of the Ardea Basin within the Rome-Colli Albani quiescent volcano area. With black squares ING radon monitoring sites are indicated: ARD = Ardea S. Stefano spring; ARDH = Ardea S. Stefano thermal well; FSG = Fossignano 1 pool; FSGD = Fossignano 2 pool; ZFR = Zolforata pool; BAR = Barozze well; CIA = Ciampino town; SMM = Santa Maria delle Mole town; VLR = Valleranello well; LAU = Acqua Laurentina spring; PAU = Acqua S. Paolo spring; TIV = Tivoli town; RCP = Roman Comagmatic Province.

Table V. Comparison of results of radon measurements obtained by the GSM and ASM-LCC methods, performed at the Ardea S. Stefano (ARD) site, within the Colli Albani area on 13 September 1996. The units are in Bq/L. ACC = Active Charcoals canisters; BM = Beaker Marinelli; LCC = Lucas Cell Counting.

Measure	Average BM	ING LCC (1)	Average ACC	ING LCC (2)
1	266	160	268	113
2	269	218	269	139
3	266	149	264	131
4	266	199	278	161
5	270	229	279	193
6	268	173	266	123
Average	267.5	188.0	270.7	143.3
Standard deviation	1.8	32.3	6.3	29.3

At the new ARDH well the highest Rn content to date was found within the Colli Albani region (up to 1185 Bq/L), inferring the existence of a deep and fast hydrothermal circulation through a widespread fracture system. While the Rn concentration at the ARDH and FSGD sites seems to vary with time, considering the few available data recorded up to now, the ARD site Rn content denoted a noteworthy constancy with time: this fact spurred us to select this site for the present intercalibration of different methods.

The role of CO_2 as carrier for Rn, verified over the Colli Albani area as a whole, was also confirmed for the Ardea Basin sites, as inferred by the strict relationships between CO_2 flux from soils/groundwater and Rn anomalies (G. Chiodini and S. Lombardi data). This area may be exploited to verify the CO_2 diffuse flux over a quiescent volcanic area, whose global contribution should not be under-evaluated (Brantley and Koepenick, 1995; Pizzino *et al.*, 1999).

At this site, the inter-calibration sampling procedure between ASM-LCC and GSM methods (table V) provided steps of concomitant refilling of both the ING RU200 Unit glass cylinder, the BM and the CTM stripping-bottle to fill the ACC (performed alternatively and repeated six times, during a period two hours).

The collected samples both by CTM-ACC and by BM underwent γ-spectrometry analyses at the DINCE Laboratory the day after, by 600 s counting, extended to the representative two *rois*. The measures were repeated on September 16, 1996, with a counting time of 900 s, and the average of the obtained results was considered. Table V reports the radon concentration obtained by ING and by DINCE analyses. The results obtained by ASM-LCC are in noteworthy disagreement with those obtained by the GSM methodologies. The ING data are also characterized by a scarce precision and reliability of the entire system, comprising the degassing units and Lucas Cells.

4.2. *Discussion on the intercomparison between methods on the field*

A comparative analysis of the radon results obtained throughout the three selected areas (Gargano, Eastern Alps and Colli Albani) showed that the radon concentration values obtained by ING using the ASM-LCC method are about 62% lower on average with respect those obtained by DINCE using the GSM methods. Moreover the ASM-LCC data presented noteworthy fluctuations (fig. 13). After defining the ASM-LCC/GSM-CTM ratio for each sample, with obvious significance, all the measures with the ratio > 3.0 were been removed: despite this restriction, the standard deviation of the ratios distribution (with an average value of 0.62) was 0.37, meaning 60% of the average value. This result dramatically disclosed the low precision of the ASM-LCC method used by ING.

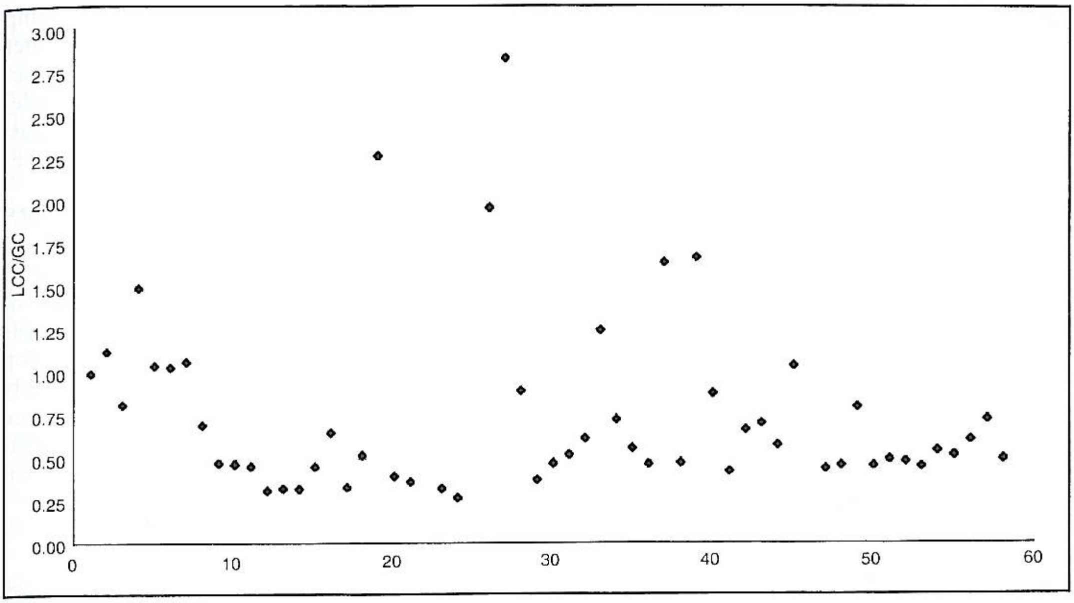

Fig. 13. Diagram of the Alpha Scintillation by Lucas Cell Counting (ASM-LCC) – Gamma Counting (GC as GSM in the text) ratios *versus* the number of the analysed samples referred to the inter-calibration measurements as a whole (Gargano, Eastern Alps, ARD site).

Regarding the radon concentration values found in the different surveys as a whole, it may be possible to infer the need to have high radon (> 50 Bq/L) content to obtain comparable results.

The Minimum Detection Limit (MDL) of the two methods have been inferred as 1 Bq/L.

In conclusion, the analysis of the inter-comparison performed on the field inferred that the GSM method adopted by DINCE, in particular the GSM-CTM(ACC), is more reliable than the ASM-LCC method used by ING, particularly as verified at the ARD site, the error being less than 10% with respect the ASM-LCC method, which error exceeds 20% for higher Rn concentrations.

The ASM-LCC configuration showed some failings: in particular the Pylon Inc™ type glass-cylinder configuration is unable to minimize the air-contact and the sampling routine is not easy to standardize. Therefore, the pre-requisite conditions to obtain precision are not easy to accomplish, *i.e.* the measure appeared to be dependent on the handling of the operator (gas bubbling minimization, exact volume refilling, air-stripping valve switching, time selected for stripping, etc.).

To overcome these drawbacks, the DINCE Laboratory first made up a different glass cylinder configuration (with a removable cap, described above), trying to assure the sample refilling with a rigorously constant volume, minimizing the air contact during sampling. After a first screening, this substitution did not seem to have brought an appreciable best-fitting in the inter-comparison data sets. The second attempt was to optimize the diffusing filter, used during the degassing time, with the final aim to enhance the stripping efficiency.

On the other hand, the EDA Instruments Inc™ Lucas Cells failings were inferred to be the true cause of the lack of reliability of the ASM-LCC method as a whole. Therefore, we decided to submit these $ZnS_{(Ag)}$ devices to serious accurate calibration in the laboratory both for each ING Lucas Cell and for each glass-cylinder refilling modality, when linked to the air re-circulation unit (RU200 Unit).

5. Laboratory inter-calibration between ASM-LCC and GSM methods

5.1. *Method: the DINCE Standard Radioactive Source (DSRS)*

The results of the inter-calibration during the field surveys suggested investigating the problem, starting an inter-calibration routine among the three methods, ASM-LCC, GSM-CTM and GSM-BM, in the laboratory too.

This procedure needed, in this specific case, to build up a standard aqueous solution with an adequately high radon concentration, *i.e.* about 500 Bq/L or more. This was accomplished as a DINCE Standard Radioactive Source (DSRS). The main DSRS pre-requisite was to permit the parallel and concomitant sampling of water aliquots by the diverse mentioned methodology (fig. 14).

In the DINCE laboratory, two liquid sources were available, made up of an aqueous solution, each containing around 15000 Bq of ^{226}Ra. As suggested by the EPA (Environmental Protection Agency), the solutions contain nitric acid, in such a concentration sound to buffer the pH around 2, and barium chloride, to avoid radium diffusion from the internal walls of the containers. The solution is normally preserved in a glass cruet, designed in the laboratory, made up of a candle-shaped diffusive filter, with zero porosity and by two glass taps, allowing the extraction of air saturated by radon.

During the laboratory inter-calibration it was soon collected above the free surface of the solution. The method used for the preparation of the «high radon standard water» provided the re-circulation through the water volume of radon enriched air, drawn off the cruets filled with the liquid solution.

The main criteria of the DSRS design were as follows: i) the form and dimensions (8 liters) to assure sound and powerful re-circulation; ii) the capability to avoid the re-entry of water inside the circuit of the re-circulation pump (a PVC disk was added, that separated the water from the air above); iii) the possibility to accomplish more than one sampling on parallel lines; iv) steadfastness and proof to radon gas; v) minimization of the exchange surface between water and the air above.

The principle of functioning of the DSRS was simple: with a specific syringe, fitted with a small Tygon® tube, and air-tight materials, an aliquot of air overlying the liquid sources of ^{226}Ra was drawn off. Subsequently, the air was injected into the plastic lung located at the top of the cylindric container, which was already filled with water, by a tap located behind. Once the connections were established and the vent-hole through a needle (with the function of in-

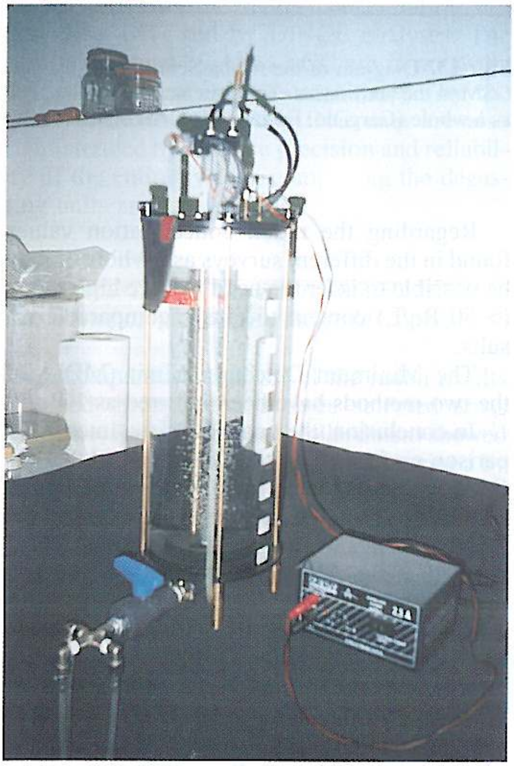

Fig. 14. The DINCE Standard Radioactive Source (DSRS) as described in the text.

troducing a noteworthy hydraulic resistance) were opened, the re-circulation pump was switched on for a time interval around 10-20 min (a small membrane pump with a 1 l/minute flow). The radon enriched air passed through the candle-shaped filter located at the bottom of the container, gurgling within the water, and then returned to the pump through the small tube. In this way, a huge fraction of the radon inside the air, and most of all of the short-life daughters were transferred to the liquid mass. At the end of the re-circulation stage, and after waiting to reach secular equilibrium, the water was ready to be drawn off and analyzed.

During the sampling, it was necessary to ensure an air re-entry, to avoid creating a depression, which, in agreement with Henry's law, may involve an alteration of the radon distribution between air and water.

The above-described DSRS radon-rich water (around 24 h constant radon concentration achieved by DINCE) was used for a laboratory inter-calibration between the ASM-LCC and the GSM methods at the same time, as described previously.

5.2. *Results*

The total number of Rn concentration measurements accomplished by the DSRS comprised eleven cycles of measurements, for each ING Lucas Cell (a total of 14 cells available). Another ten cycles were performed using the GSM method (alternatively by the BM or by ACC samplers) finally resulting in 154 measures with ASM-LCC and 10 measures with GSM. The measuring procedure remained unchanged during the experiment as a whole, strictly adopting the same routines used on the field. Moreover, a cross-check was made between the described DINCE customized water-stripping glass-cylinder and the Pylon™ type one used by ING. In the text and figures the two cylinders are mentioned as open (ING one) and closed (DINCE one). The test routine was accomplished both by the open and by the closed cylinders at the same time. Each $ZnS_{(Ag)}$ cell was always coupled with the same kind of cylinder throughout the experiment.

The results obtained are summarized in the table VIa,b (*a* = open cylinder; *c* = closed cylinder). Table VIb shows the efficiency value (calculated with respect the GSM methods) of each $ZnS_{(Ag)}$ cell, for each measurement cycle; moreover the average values of the efficiency and data dispersion, expressed as standard deviations are reported (table VIb). Then, the Proper Calibration Factor (PCF) for each cell was calculated, with the relative statistical error associated. The divergence of the values was almost wide, inferring a scarce precision of the measures made by the available Lucas cells.

However, taking into account the calculated PCF for each cell, the expeditious radon measure, performed on the field during the geochemical surveys, may be considered reliable for the purposes of the research. The concomitant use on the field of both methods is strongly recommended, the former to have real-time knowledge of the radon distribution *in situ*, the latter for a more accurate radon study.

6. Conclusions

The on field and laboratory inter-calibration comparisons between the Alpha Scintillation Method by Lucas Cell Counting (ASM-LCC) method adopted by ING and the Gamma Spectrometry (GSM) methods adopted by DINCE, using both the Beaker Marinelli (BM) and the Active Charcoal Collectors (CTM-ACC) was very useful to discriminate the respective failings, disadvantages and critical aspects, in different logistic and geodynamic settings.

In fact, radon concentration in groundwater was highly variable in different seismotectonical and lithological settings, as a consequence of *i.e.*, the presence of active faults involving convection of groundwater (*i.e.* the Pejo, Giudicarie and Tonale lines over the Eastern Alps, and the Candelaro and S. Spirito lines over the Gargano area, the graben faults of the Ardea Basin), CO_2 gas-carrier presence, peculiar physico-chemical conditions, volcanic or metamorphic lithology with high radon background, etc.

All this evidence stresses the need to make a parallel use of both methods, during the ING geochemical surveys, aimed at seismotectonical

Table VI a,b. Results of the measurement cycles for the RD 200-RU 200 Units (EDA Instruments) Lucas Cells calibration, used by ING: in (a) values in Bq/L obtained with respect to the BM and ACC values are reported; o = open cylinder, c = closed cylinder (DINCE provided). In (b) standard deviation and efficiency values for each cell are reported.

No. of cells	Date 22/12/96 (Bq/L)	Date 10/01/97 (Bq/L)	Date 28/01/97 (Bq/L)	Date 4/2/97 (Bq/L)	Date 20/02/97 (Bq/L)	Date 25/02/97 (Bq/L)	Date 3/3/97 (Bq/L)	Date 12/3/97 (Bq/L)	Date 17/3/97 (Bq/L)	Date 19/3/97 (Bq/L)
9 o	278	646	197	269	362	401	335	311	337	457
10 c	510	995	344	465	478	580	507	558	459	595
1 o	584	1120	429	581	547	769	641	697	646	758
2 c	553	996	393	517	635	709	596	616	601	715
6 o	563	1448	434	405	595	800	719	703	633	818
16 c	495	1207	391	532	614	730	611	324	556	691
7 o	595	1486	420	616	625	838	632	630	719	838
13 c	261	515	377	224	514	661	537	580	436	623
4 o	573	1415	413	565	585	773	680	718	713	787
14 c	483	1147	357	458	496	639	502	585	546	574
8 o	468	1090	342	182	500	566	615	614	494	658
18 c	474	1102	350	545	554	639	602	567	595	550
11 o	547	1314	356	477	640	785	608	688	623	607
17 c	564	1208	352	527	528	648	621	632	580	638
Beaker 1	625	1375	474	636	596	724	627	658	605	702
Beaker 2	625	1375	474	636	596	724	627	658	605	702
Collector 1	–	–	–	–	–	–	–	650	607	688
Collector 2	–	–	–	–	–	–	–	666	602	704
Collector 3	–	–	–	–	–	–	–	647	609	681
Collector 4	–	–	–	–	–	–	–	660	614	692

(a)

Table VI a,b *(continued)*.

No. of cells	Date 22/12/96 (efficiency)	Date 10/01/97 (efficiency)	Date 28/01/97 (efficiency)	Date 4/2/97 (efficiency)	Date 20/02/97 (efficiency)	Date 25/02/97 (efficiency)	Date 3/3/97 (efficiency)	Date 12/3/97 (efficiency)	Date 17/3/97 (efficiency)	Date 19/3/97 (efficiency)	Medium efficiency values	Standard deviation
9 o	0.44	0.47	0.41	0.42	0.61	0.55	0.53	0.47	0.56	0.65	0.51	0.08
10 c	0.82	0.73	0.72	0.73	0.80	0.80	0.81	0.85	0.76	0.85	0.79	0.05
1 o	0.93	0.82	0.91	0.91	0.92	1.06	1.02	1.06	1.07	1.08	0.98	0.09
2 c	0.88	0.73	0.83	0.81	1.07	0.98	0.95	0.94	0.99	1.02	0.92	0.10
6 o	0.90	1.06	0.92	0.64	1.00	1.10	1.15	1.07	1.05	1.17	1.00	0.16
16 c	0.79	0.88	0.82	0.84	1.03	1.01	0.97	–	0.92	0.98	0.87	0.16
7 o	0.95	1.09	0.89	0.97	1.05	1.16	1.01	0.96	1.19	1.19	1.04	0.11
13 c	0.42	0.38	0.80	0.35	0.86	0.91	0.86	0.88	0.72	0.89	0.71	0.23
4 o	0.92	1.04	0.87	0.89	0.98	1.07	1.08	1.09	1.18	1.12	1.02	0.10
14 c	0.77	0.84	0.75	0.72	0.83	0.88	0.80	0.89	0.90	0.82	0.82	0.06
8 o	0.75	0.80	0.72	0.29	0.84	0.78	0.98	0.93	0.82	0.94	0.78	0.19
18 c	0.76	0.81	0.74	0.86	0.93	0.88	0.96	0.86	0.98	0.78	0.86	0.08
11 o	0.88	0.96	0.75	0.75	1.07	1.08	0.97	1.05	1.03	0.86	0.94	0.13
17 c	0.90	0.88	0.74	0.83	0.89	0.89	0.99	0.96	0.96	0.91	0.90	0.07
o (total opened)	0.82	0.89	0.78	0.70	0.92	0.97	0.96	0.95	0.98	1.00	0.90	0.10
c (total closed)	0.76	0.75	0.77	0.73	0.92	0.91	0.91	0.84	0.89	0.89	0.84	0.07

(b)

studies, *i.e. in situ* fault recognition, water-rock interaction studies, earthquake prediction experiments, Rn-indoor studies, etc., as a consequence of the need to obtain sound instrumentation for all the situations encountered. In particular, this need arises from the evidence that the ASM-LCC method is strongly lacking in accuracy and precision. A standardization of the ASM-LCC method was almost impossible, as a consequence of the intrinsic gas stripping strategy, the kind of Pylon™ glass cylinder configuration, the difference between each Lucas Cell, the Lucas Cells drifting or consumption, the air re-circulation circuit employed, operator handling , etc. The ASM-LCC method adopted by ING requires a periodic inter-calibration with other methods, *i.e.* by GSM methods.

The ASM-LCC method was found particularly sound for expeditious field radon measurement, to have a gross evaluation of the radon concentration in groundwater, during geochemical surveys, *i.e.* during an ongoing tectonic/volcanic event, or to follow *in situ* the trace of a buried fault zone and of a peculiar lithologic body, but not sound enough to collect exact radon concentration values. In fact, if expeditious and quick information in the field is not required, the GSM methods are particularly convenient for the routine simplicity and low-cost devices. The detection limit was found still lower with respect to the ASM-LCC method one. The global errors due to the instrumental assembly were above 7-10% with respect the ASM-LCC method (above 20%).

The experimental devices made and the results collected during this work may be useful to improve ING-DINCE collaboration: the assembly and inter-calibration of ASM-LCC and GSM radon continuous monitoring stations, still in progress, exploiting the DINCE experience on radionuclides measurement and overcoming the ING-Civil Protection surveillance needs, as well as adopting the ING geochemical network criteria (GSM II prototype).

We are strongly convinced that the earthquake prediction approach must be changed, mostly considering the study of seismic forerunners as a multivariable and multidisciplinary study of the seismic cycle as a whole: in this sense fluid geochemistry methods exploited by ING have proved powerful tools in understanding the seismic cycle fluid-related processes in the pre-seismic phase too. Baseline continuous and discrete data also in aseismic periods are necessary to understand the observed anomalies and to refine the earthquake prediction algorithms formulated to date.

The overall radon information gathered in this work is pre-requisite to define the prone-areas where the deepening of Rn-indoor studies must been accomplished. This is a new open problem in Italy, recently highlighted by EC directives and laws.

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