The Slãnic-Prahova (Romania) Salt Mine Ultra-low Background Radiation Laboratory

O.G. Duliu
University of Bucharest, Department of Atomic and Nuclear Physics

R. Mãrgineanu, C. Simion,
S. Bercea, D. Gheorghiu, A. Stochioiu
National Institute for Nuclear Engineering, Bucharest

M. Matei
SALROM AR, Bucharest

The construction and exploitation of low-background radiation laboratories represents a great challenge for nuclear as well as for elementary particle physics, first of all in order to diminish the ubiquitous cosmic radiation.

For this reason, one of the best ways to reduce the background radiation consists of using deep underground mines or tunnels for location of this kind of laboratories.

Irrespective of some practical inconveniences, the great advantage offered by deep underground locations has stimulated the construction in different countries such as Germany, United States, United Kingdom, Japan, Italy, Spain, France, Russia, Ukraine and Canada more than a dozen of such laboratories.

In these laboratories are successfully there are performed various high class scientific experiments such as the investigation of solar neutrino emission, neutrino emission from supernova and black hole formation, dark matter, double beta decay and elusive proton decay.

At the same time, underground laboratories offer ideal conditions for investigation of low level radioactive materials, animal and human contamination with various natural as well as artificial radionuclides or for a better calibration of detectors used in radiation metrology.

To reduce the level of natural rocks background radiation, for underground laboratories are preferred locations in rocks with a low content of natural radionuclides such as limestone, coal or salt. In the last case, the natural process of salt fractional crystallization in a supersaturated marine brine partially remove potassium chloride as well as other heavy metals salts, and thus significantly reducing the presence of natural radionuclides.

Romania is rich in natural deposits of salts, some of them forming massive salt domes, which appear to result from pressure, which pushes the salt up through the rocks from great depths. Such domes, mainly encountered in the sub-Carpathian region have been worked since ancient times and now host a multitude of active as well as in conservation salt mines, the last one representing ideal location for low background radiation laboratories.

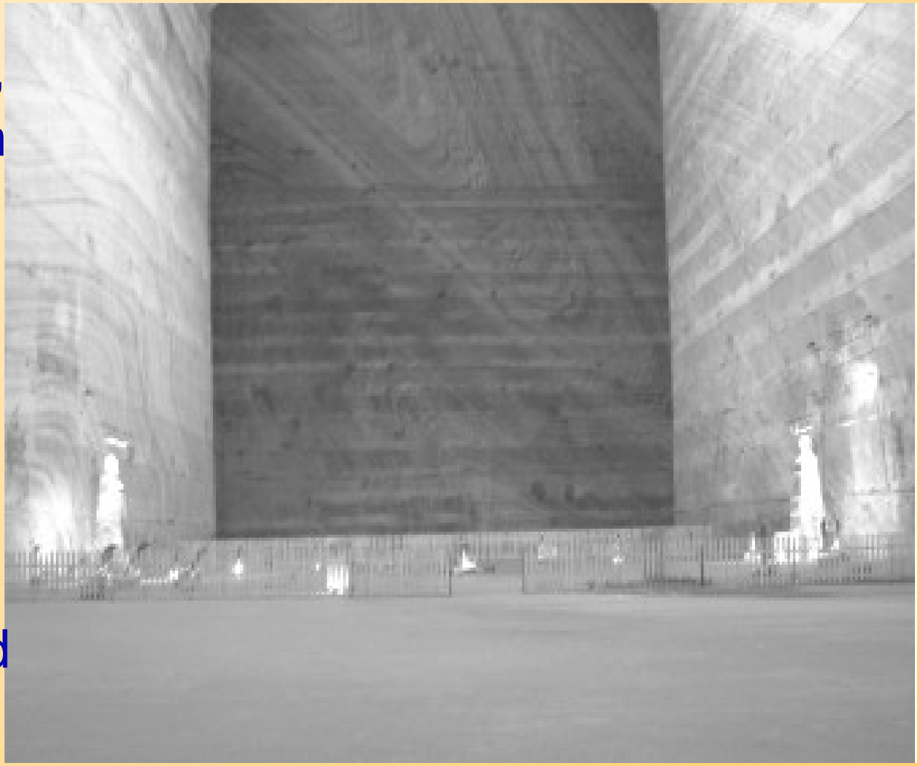
For this purpose, we have investigated existing facilities as well as the level of background radiation of three in conservation salt mines, all of them located in the Romanian sub-Carpathian region, i.e. Praid, Cacica, and Slanic Prahova.

A radiological mapping performed by using a high resolution gamma spectrometry and an Eberline FH40G dosimeter indicated the the **Unirea** salt mine from **Slanic Prahova** town as the best location.

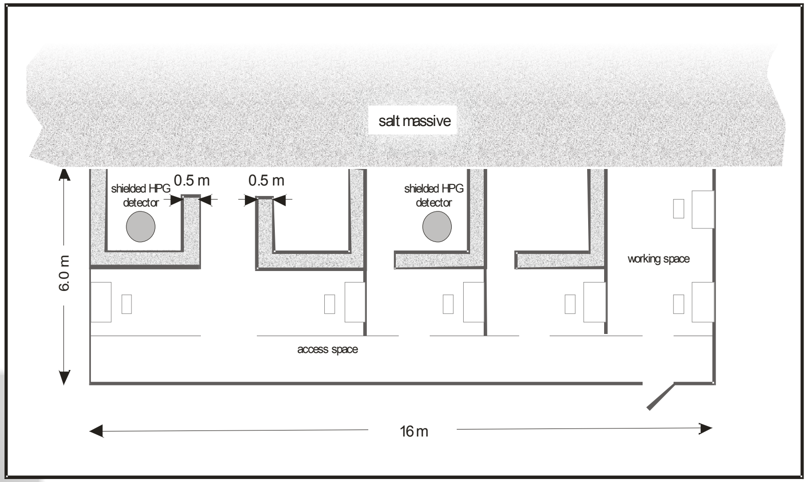
Slănic-Prahova is located in the outer Carpathians area (Prahova County), 45 km NE of Ploieşti. From a geological point of view, this locality belongs to the post-tectogenetic cover of Tarcău Nappe one of the most important ones cropping out in the Eastern Carpathians. It includes Cretaceous, Paleogene and lower Miocene sedimentary successions. Towards Prahova County, this nappe ends on two main anticlines, Homorâci and Văleni, separate by two synclines, Slănic and Drajna, both filled with Miocene molasse. The post-tectogenetic sedimentary cover of Tarcău Nappe begun to accumulate in early Miocene (23.7 Ma) and ended in Sarmatian (5.3 Ma).

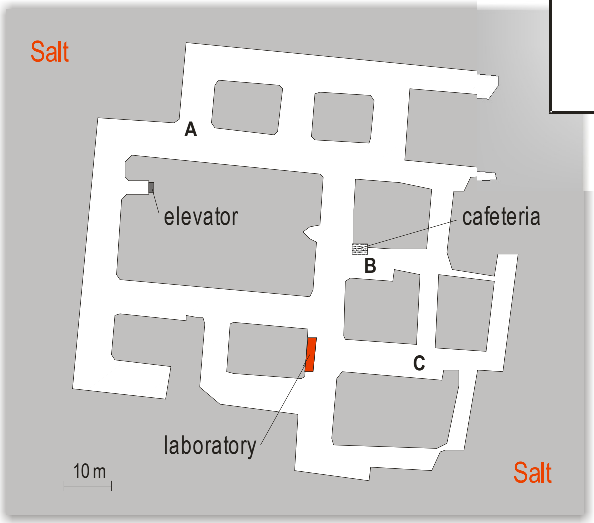
The sedimentary environment in the region of actual Slanic Prahova was dominated by the Middle Badenian evaporitic condition covering the interval from the last stage of carbonates precipitation to halite, however, without reaching the stage of K and Mg salt precipitation.

During evaporitic condition, authigenic minerals such as carbonates, sulfates and halite precipitated simultaneously with an a certain amount of sediments from the adjacent areas whose presence can be remarked as interbedded layers in the salt formation.



In this environment, we have chosen to construct the Ultra-low Background Radiation Laboratory (ULBL), more exactly in the Unirea mine situated at a depth of 208 m beneath the surface at water-equivalent thickness of 560 m. This mine consists of a hive-like structure composed of more galleries 34 to 36 meters wide and 54 to 58 m height.





Also it must be pointed out the remarkable stability of the micro-environment characterized by a constant temperature all over the years of 12.5 º C, a relative humidity of 60 to 65 % and a germ load of about 700 germ/m^3.

The ULBL is situated at about 200 m from elevators, on the Southern part of mine.

To reduce further the background radiation, the laboratory was constructed entirely by polyvinyl profiles and Lucite windows.

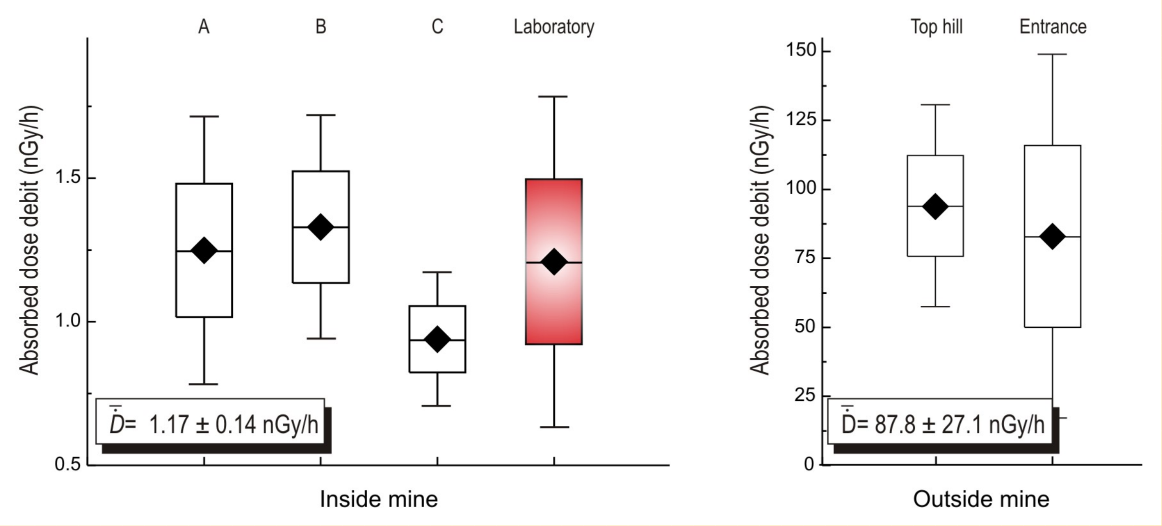
Because the background was to low, the presence of personnel in the vicinity of detectors was able to increase significantly the background. To avoid such unwanted effects, each room was delineated and separated from neighbor ones by 0.5 m thick walls made also by polyvinyl, but filled with high purity salt.

The 20 m long and 6m wide laboratory consists of four multifunctional rooms, each of them connected to a local electricity network and a room for personnel. It is worth to mention the there is a full access to Internet by means of a built-in mobile phone network.

To obtain as many as possible confident date concerning the radiation background within the laboratory by respect to surface, we have used five different kinds of detectors:

- GR 200A (LiF: Mg, Cu, P) thermoluminescence (TL) dosimeters
- Eberline FH 40G dose ratemeter
- Berthold UMO 123 dose ratemeter provided with a BF6 neutron gauge certified by PTB (Germany) Federal Metrology Authority
- ORTEC portable HPG with a relative efficiency of 33% by respect to a standard 3"×3" NaI(Tl) and a FWHM of 1.75 keV for the 1332.5 keV ^{60}Co line

In the last case, gamma spectra were recorded for an energy interval between 40 and 3000 keV for 8192 channels and analyzed by means of a DigiDART portable gamma ray spectrometer provided with the Maestro code.



The extremely low background of the Unirea mine determined us to use for the ionization chamber measurements an extrapolation technique to estimate the equivalent dose debit. For this purpose, we carefully calibrated an Eberline FH 40G dose ratemeter by using ^{60}Co and ^{137}Cs sources in both collimated and panoramic exposure.

In this way we have been able to determine the calibration factor equal to 0.17 nGy/imp. By extrapolating the impulses number versus time calibration curve for measurements performed in the laboratory, we estimated the electronic noise of the instrument at 1.43 imp/h. Irrespective of these precautions, we only were able to estimate the background radiation to be between 1.6 and 9.8 nGy/h, lower than 12.7 nGy/h, the equivalent of instrument electronic noise.

The background of the natural neutrons field at the laboratory level measured twice for 20 hours by means of a BF6 neutron gauge attached to a Berthold UMO 123 dose debit ratemeter yield 3 impulses in 40 hours, that enabled us to presume that at laboratory level the neutrons background is significantly below the detection of commercial instruments.

In these conditions, we come to the conclusion that both radiation dose debit ratemeters (Eberline FH and Berthold UMO 123), in spite their excellent performances on ground laboratories, are nor suitable for measuring ultra-low radiation field and only specially designed for this purpose detectors will allow to perform confident measurements.

Accordingly, the only significant results obtained by using the existing instruments were those furnished by gamma-ray spectrometry.

- The total count rates from 40 keV to 3 MeV of collected spectra in the laboratory is of 2.19 cps, about 80 times lower compared with a spectrum collected in the same conditions in open field of 175.6 cps.

- Furthermore, in the energy interval between 2615 keV (the maximum energy of 208Tl) and 3000 keV the laboratory background is about 40 times smaller then the corresponding background measured outside mine, this fact representing the best illustration of the shielding of cosmic radiation by the earth stratum that separates the laboratory from exterior.

- The discrepancy between ^{226}Ra and ^{222}Rn descendents activity can be better explained by the radon introduced in mine by elevators that act as a *sui generis* air pump, by taking into account that there is no artificial ventilation in the mine.

- The presence of ^{40}K radionuclide in mine is mainly due to traces of potassium from the mineral impurities of the salt as determined by Neutron Activation Analysis as well as to the human presence in the vicinity of detectors.

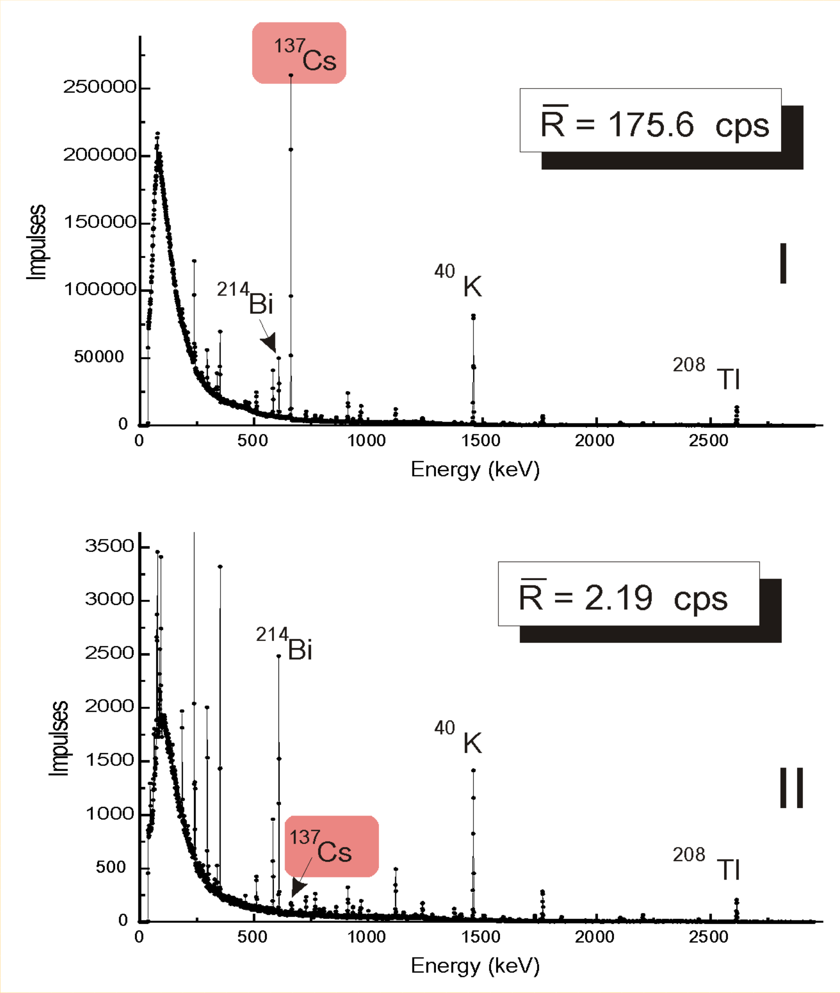
The most representatives data concerning gamma-ray spectra measured in laboratory as well as outside it (impulses/1000 s).

Energy (keV)	Radionuclide	Laboratory			Outside		
		Net peak area			Net peak area		
46.57	Pb-210	25.4	±	3.4	-	±	-
185.98	Ra-226	72.4	±	3.9	2002.5	±	397.8
209.36	Ac-228	3.7	±	3.2	998.6	±	793.0
238.71	Pb-212	272.5	±	5.3	18254.8	±	630.1
351.99	Pb-214	14.2	±	2.1	9550.6	±	288.4
661.8	Bi-214	193.6	±	2.9	9590.6	±	227.0
1460.75	K-40	158.4	±	2.5	59394.2	±	429.9
2613.86	Tl-208	30.8	±	1.2	5468.2	±	130.8

Due to a high background the ^{210}Pb gamma line was not observable outside laboratory

Two experimental gamma spectra of the background radiation measured on the ground outside mine (I) and in the Ultra-Low Background Radiation Laboratory (II).

The cvasiabsence of ^{137}Cs peack in the laboratory background radiation can be remarked.



By its natural conditions the Ultra-Low Background Radiation Laboratory are comparable with the other deep-ground laboratories. Preliminary measurements showed a global reduction of the absorbed dose due to natural factors of about 39 times.

Within the experimental errors and by using commercial instruments, no traces of neutrons of cosmic origin were evidenced.

The total gamma spectra between 40 keV to 3 MeV is at the laboratory level 100 times lower compared with a spectrum collected in the same conditions in open field while within the energy interval between 2.615 and 3.0 MeV it is about 40 times smaller then the corresponding background measured outside mine.

All these experimental facts recommend the Slanic-Prahova Ultra-Low Background Radiation Laboratory, at present time fully operational, as very suitable for various measurements that needs an ultra low background.

Thank you for attention!!!