permitindo: *a*) a progressiva montagem de um banco de itens de Fisiologia do Sistema Endócrino, dotados de atributos necessários à elaboração de melhores testes; *b*) um aumento do índice médio de discriminação dos testes dessa unidade; *c*) adequar-se os testes, segundo a sua dificuldade, aos diferentes cursos; *d*) abreviar-se o tempo dispendido na elaboração de provas, sem prejuízo da sua qualidade, além de reduzir-se a incidência das falhas inerentes ao processo.

REFERÊNCIAS

1. Bradfield, J.M. e Moredock, H.S. 1963. *Medidas e testes em educação.* Rio de Janeiro, Fundo de Cultura.
2. Gronlund, N.E. 1974. *A elaboração de testes de aproveitamento escolar.* São Paulo, EPU.
3. Lindeman, R.H. 1974. *Medidas educacionais.* Porto Alegre, Globo.
4. Medeiros, E.B. 1977. *Provas objetivas: técnicas de construção.* Rio de Janeiro, Fundação Getúlio Vargas.
5. Vianna, H.M. 1976. *Testes em educação.* Rio de Janeiro, IBRASA.

RADON DETECTION IN SOILS BY SOLID STATE NUCLEAR TRACK DETECTORS

MARCO ANTONIO P.V. DE MORAES and **MARÍLIA T.F. CESAR KHOURI**, Nuclear Physics Division, Instituto de Pesquisas Energéticas e Nucleares, Comissão Nacional de Energia Nuclear[1].

Recebido para publicação em 6/5/1985

RESUMO. *Detecção de radônio em solos pela técnica dos detectores de traços.* A técnica para a detecção de radônio em solos usando os detectores de traços foi desenvolvida para a aplicação na prospecção de urânio.

Os filmes sensíveis a partículas alfa utilizados foram o LR-115* e o CA 8015*. Foram feitas simulações em laboratório e no campo para a verificação das possibilidades do método..

Mapas de 3 anomalias da cidade de Caetité – Bahia, Brasil foram feitos, comparando os resultados com o método cintilométrico.

ABSTRACT. The solid state nuclear track detectors technique was developed to be used in radon detection, by alpha particles tracks, and its application in uranium prospecting on the ground.

The sensitive films to alpha particles used are the cellulose nitrate films LR 115 and CA 8015. Several simulations experiments and field measurements were carried out to verify the method possibilities.

Maps of some anomalies in Caetité City (Bahia, Brazil) were made with the densities of tracks obtained. The results were compared with scintillation counter measurements.

1. Caixa Postal 11049, 01000 São Paulo, SP, Brasil.

* Fabricados pela Kodak-Patté, França.

1. INTRODUCTION

Radon is an inert gas element of atomic number 86. There are three Radon isotopes: ^{222}Rn (usually named as radon), ^{220}Rn (called thoron) and ^{119}Rn (also called action). ^{222}Rn is a member of the decay serie of ^{238}U, ^{220}Rn comes from ^{235}U. These isotopes are the only gaseous elements of the chains. Radon isotopes are alpha emitters (^{222}Rn with a half-life of 3.82 days, ^{220} with $T_{½} = 51.5$ sec and ^{119}Rn with $T_{½} = 3.92$ sec). The detection of these alpha particles provides a sensitive way of detecting radon.

Radon monitoring is of importance in connection with three main aplications: *1.* uranium / thorium prospecting(3); *2.* radon dosimetry in uranium mines(2); *3.* earthquake prediction(4).

In this work the Solid State Nuclear Track Detectors Technique was developed to be used in radon detection by alpha particles tracks and it was applicated to uranium prospection from the top soil.

2. EXPERIMENTAL METHOD

2.1. Solid State Nuclear Track Detectors

Ionizing particles deposit energy along their path when they travel through matter. In some insulating materials called solid state track detectors this energy loss creates a submicroscopic cylinder of damaged molecules, the so-called latent track. This latent track is not visible under optical microscope examination. However, if the detector material is placed in a convenient chemical reagent the volume around the track will be etched out preferencially so that the track of the nuclear particle become visible under optical microscope.

All of these materials are mostly insensitive to light, X and gamma rays and electrons (1).

2.2. Radon Detection

Radon isotopes are constantly released in soils, water and the atmosfere. The migration of radon may be considered as (1) formation and (2) difusion and/or transportation through the soil (7).

The possibility of using radon (^{222}Rn) as an uranium prospecting tool was first suggested nearly 50 years ago (5) but it has only been during the last 10 years that solid state nuclear track detectors have been used for this purpose.

The alpha particle realeased due to the decay of thoron (^{220}Rn) will also penetrate the film detector. Thoron has a very short hald-life as compared to that of ^{222}Rn. Therefore, as it decays away very fast, thoron can be expected only in the very vicinity of thorium bearing minerals. In this case it is not possible to discriminate alpha tracks from ^{222}Rn against those from ^{220}Rn. Thorium minerals located at more than 30 to 40 cm from the place of detection are not likely to have any appreciable influence on track counts.

The basic principle of the method is quite simple. A number of closed tubes (inverted) are placed in holes (60 cm deep) in the ground and then covered. In each tube there is a piece of alpha sensitive plastic film. Then radon starts accumulating into the tube and decays away by emitting alpha particles that are recorded. The tube is left in place for several weeks. The alpha track densities on the film be proportional to the amount to accumulated gas.

After the exposition time the pieces of film are removed and submitted to chemical etching. The films are read to determine the number of alpha tracks recorded.

For the detection of alpha particles the Kodak-Pathé cellulose nitrate films CA 8015 and LR 115 type 2 were used. The films were etched in a 10% NaOH solution at a temperature of 60.0 ± 0.5 ^{o}C for 120 minutes with constant stirring. After chemical etching the films are rinsed in running cold water, for 30 minutes and dried. The number of tracks was determined by couting them with the aid of a Reichert screen microscope at a 140 X magnification (6).

3. RESULTS

3.1 Detector Features

Several pieces of film LR 115 and CA 8015, after being exposed in Rn and daughters radiation, were etched under the above conditons for variable length of time.

The results (LR 115) are plotted in Fig. 1 with the corresponding values for background on the films. We chose 120 minutes as a convenient etching time due the arising value of the background. The CA 8015 detector has a similar performance but it is more efficient and it has a larger intrinsic background than the LR 115 film. Both films can bear densities up 400.000 tracks/cm^2 then we can use them in field measurements. The LR 115 is easier to scan in optical microscope due the fact that tracks appear as bright spots against a deep red background.

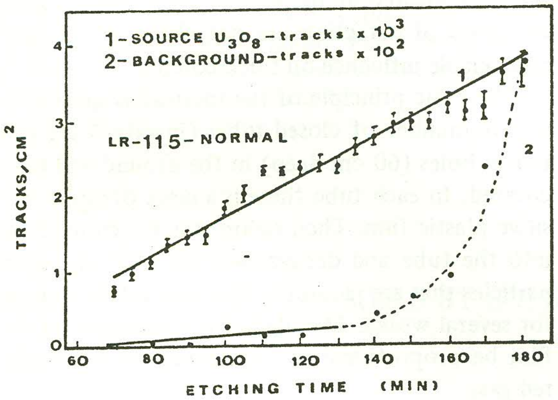

Fig. 1. Track density as a function of etching time. Curve 1 – Curve obtained using a source of U_3O_8. Curve 2 – It was plotted with background track density. The erros bars are statistical only.

A series of experiments was carried out to observe the variation in track density with the size of the tube containing the detector and with the detector in the tube position as wall (Fig. 2).

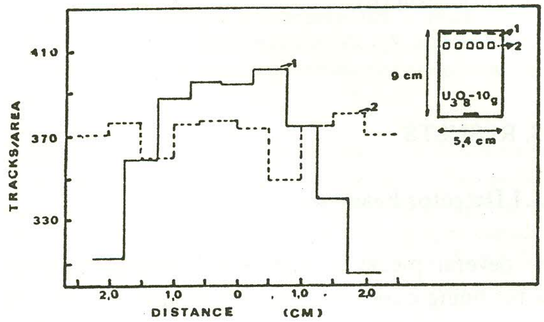

Fig. 2a. Efficiency of detection as a function of the film position in the detectors. The best position was found in the middle and in the upper part of the detector.

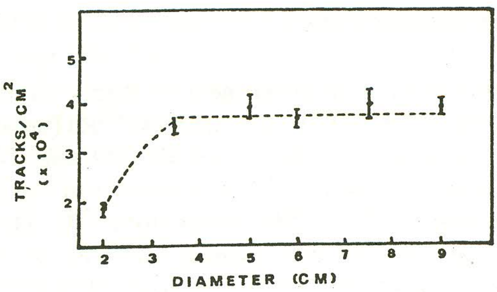

Fig. 2b. Efficiency of detection as a function of detectors diameter. The errors bars are statistical only.

The tubes used are 5.4 in diameter and 9 cm long and the film was placed as shown in Fig. 3.

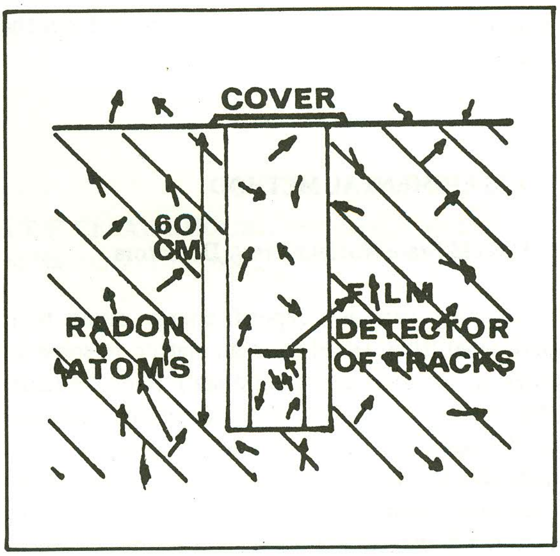

Fig. 3. Position of the detector in the field measurements.

3.2. Laboratory Experiments

We carried out simulation experiments in laboratory. Uranium samples (U_3O_8) of different activities were buried in sand and detectors were placed as shown in Fig. 4. The results (Fig. 5) prove that the location and identification of ore bodies, with the help of alpha sensitive plastic films, is feasible.

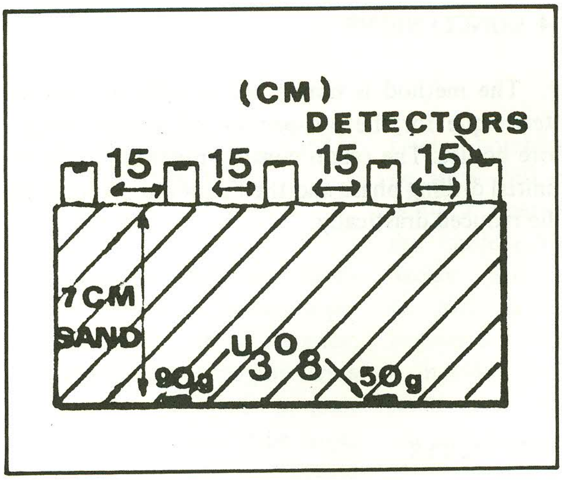

Fig. 4. Simulation experiments carried out in laboratory with uranium samples buried in sand.

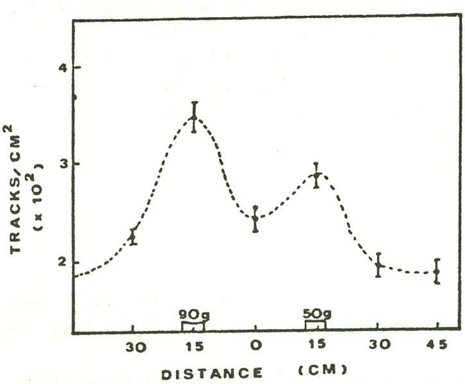

Fig. 5. The results show the location and identification of ore bodies.

3.3. Field Measurements

Maps of three anomalies in Caetité City region (Bahia, Brazil) were made the track density results obtained with detectors placed in a grid pattern form. In this region there is a mineralization of uraninite in albite.

Anomaly 7 – 80 detectors were placed at knots of a grid 50 X 50 meters.

Anomaly 8 – 98 detectors were distributed in an area of 40 X 50 meters.

Anomaly 9 – 50 detectors in 80 X 100 meters.

In each point of the grid, after digging the holes, radiometric measurements with scintillometer within each hole were carried out.

The track densities obtained were used as input data to a computer which gives the results as a contour map showing the most promising places for ore localization (Fig. 6). The results were compared with scintillation counter measurements perform in the same area and they are similar.

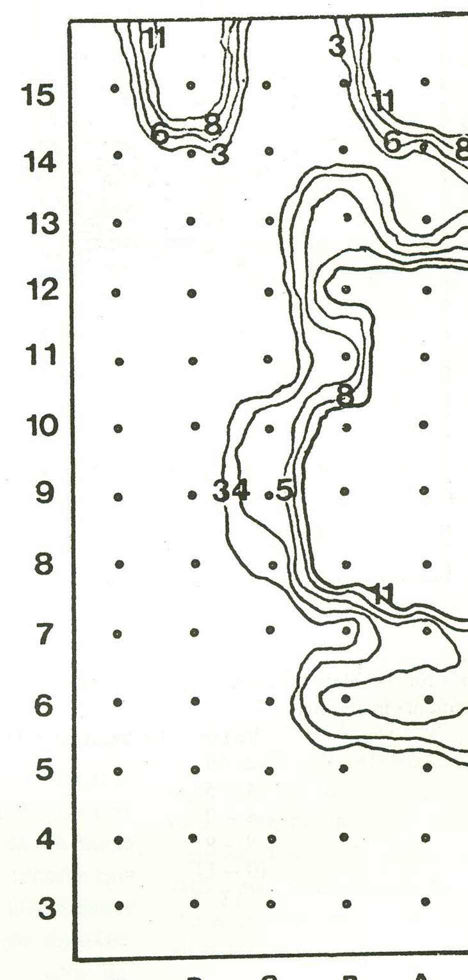

Fig. 6a. Contour Map obtained with track detector measurements in anomaly 07.

Line	Values (background = 1)
3	7 – 9
4	10 – 11
5	11 – 13
6	13 – 15
8	17 – 19
11	23

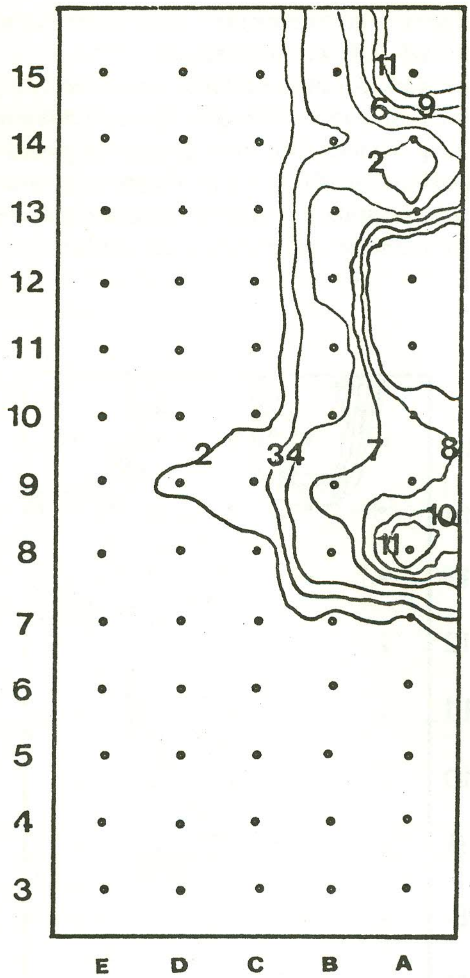

Fig. 6b. Contour Map obtained with scintillation counter measurements in anomaly 07

Line	Values (background = 1)
2	2 – 3
4	4 – 5
6	6 – 7
8	8 – 9
10	10 – 11
11	11

4. CONCLUSIONS

The method is simple and an effective auxiliar technique for the prospection of buried uranium ore bodies. The radon contour maps can guide the initial drilling phase and then exploration costs can be reduced drastically.

REFERENCES

1. Fleischer, R.L., Price, P.B. and Walker, R.M. 1985. *Nuclear tracks in solids – principle and applications.* Berkeley, Cal. University of California.
2. Fleischer, R.L., Giard, W., Mogrocampero, A. and Turner, L. 1980. Dosimetry of environmental radon methods and theory for low dose; integrated measurements. *Health Physics,* **39**: 957-962.
3. Gingrich, J.E. and Fisher, J.C. 1976. Uranium exploration using the track-etch method. *In* International Atomic Energy Agency. *Exploration for uranium ore deposits: proceedings of a symposium held in Vienna,* 29 March-2 April, p. 213-25.
4. King, C.Y. 1978. Radon emanation on San Andrea foult. *Nature,* **271**: 516-519.
5. Miller, J.M. and Ostle, D. 1972. Radon measurements in uranium prospecting. *In* International Atomic Energy Agency. *Uranium exploration methods proceedings of a panel on ... held in Vienna,* 10-14 April. Vienna 1973.
6. Moraes, M.A.P.V. de. 1982. Radon detection in soils by solid state nuclear track detectors technique. Master thesis, IPEN, Universidade de São Paulo.
7. Tanner, A.B. 1964. Radon migration in the ground: a review. *In* Adams, J.A.S. and Lower, W.M. eds. *The natural radiation environmental: first international symposium on ... held in Houston Texas,* April 10-13, 1963. Chicago, Ill., Univ. Chicago.