MEMOIRS OF THE COLLEGE OF SCIENCE, UNIVERSITY OF KYOTO, SERIES B,
Vol. XX, No. 2, Article 5, 1952.

A New Method of Radioactive Exploration Using Nuclear Emulsions and Comparison with Other Methods.

By

Zin'itirô HATUDA
Geological and Mineralogical Institute, University of Kyoto

(Received Febr. 4, 1952)

With 1 plate and 1 figure

Abstract

To determine the radioactivity of soil air, a photographic plate specially manufactured for recording tracks of alpha-rays is used with success. This device saves other special apparatus such as fontactoscope or Geiger-counter equipment than a microscope which will easily be available in most laboratories. Moreover, it has other advantages that (1) record of alpha-ray tracks ready for subsequent check is obtained, and (2) observation may be done at a time for a lot of stations so as to avoid the different influences due to possible change in meteorological conditions.

The method has been compared with other ones of radioactive exploration and the results are in fair concord.

Introduction

The methods of radioactive exploration usually adopted are (1) radon-in-soil-air method (briefly, radon method), (2) Ground-hole-ionization-chamber method (ground hole method) and (3) one using Geiger counter. In the first two methods radioactivity is ordinarily measured with electroscope. The author has tried to measure the concentration of radon contained in soil air with photographic emulsions specially manufactured for recording track patterns of alpha-particles. In the present test, exposure of photographic plate was made in ground hole 10 cm in diameter and 1 m in depth, which had been prepared for the ground hole method. Numbers of alpha-ray tracks 40 to 200 were obtained on the plate per square millimeter with 24 hour's exposure in the present test field the soil of which was mainly of granitic sand.

The method has been compared with other ones of radioactive exploration and given fairly concordant results. It has advantages over others in such respects that (1) no other special apparatus such as fontactoscope or Geiger counter equipment is necessary than a microscope which will usually be found in most laboratories, (2) real record of alpha-ray tracks ready for subsequent check is obtained and (3) observations (in this case, exposure of photoplate) are made with negligible difference of time in a considerable numbers of stations, resulting in eliminating the different influences due to possible change of meteorological conditions.

Principle of the method

Radioactive method of exploration is, briefly speaking, based on the fact that radioactive elements pervade in all kind of rocks, though very minute in quantity and in different proportions and that movements of them are subject to geological conditions. The most remarkable example of the latter case will be found along a fault where rocks are fractured to facilitate ascending of gases or water carrying radioactive substances from the depth. On crossing a fauft, one can find a notable increase of radon or other radioactive elements in the soil layer covering the bedrock faulted.

In the present test, concentration of radon in soil were determined by nuclear emulsion method in which photo-plate was exposed to radon-bearing air in a hole dug in the ground. After developing, the plate was examined under microscope to count the track patterns marked by alpha-particles ejected fiom radon and its disintegration products.

Practical procedure

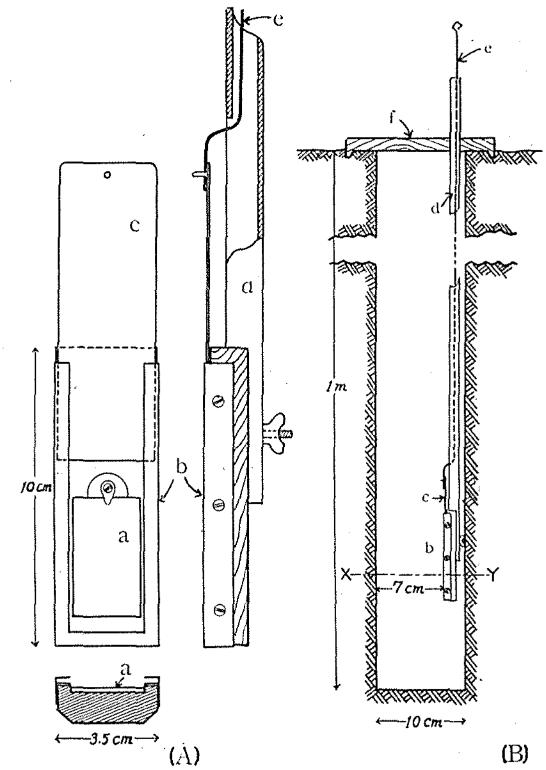
The plate used was of nuclear emulsions ET–2E type furnished by Fuji Photo Laboratory. The thickness of the emulsion film was 50 microns. According to H. Yagoda,[1] adequate thickness is 25 to 50 microns for counting the tracks from external sources. The plate was developed with Eastman D 19 for 7 to 8 min at 18° to 23° and fixed with Eastman F 5 for 2.5 hour.

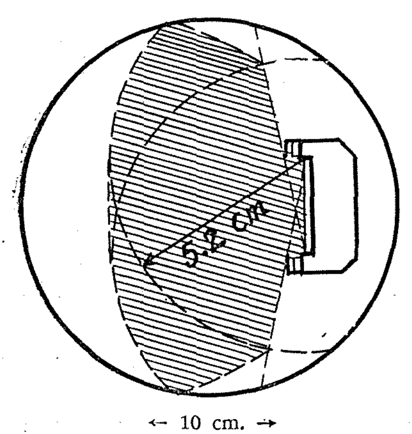
Under microscope with magnification of 150, number of alpha-tracks which passed across the cross hair of the field, as the mechanical stage was operated, was carefully counted. The *time required for inspecting the area* 0.5 *mm* (width of the field) $\times$ 10 mm (travel distance) in the field was usually 7 to 10 min, for the case of alpha-tracks about 200 in this area, 5 mm^2. In the case of this order of track density, it was found from ten observations for each contiguous strip of 0.5 mm $\times$ 10 mm in the central area of 5 mm $\times$ 10 mm of the plate that the mean value had a standard deviation of a few percent.

Background was also measured on an unexposed portion of the same plate and eliminated in the result. It is supposed to be due to radioactive contaminants present in glass and the components of the emulsion layer. If the emulsion surface is exposed to air in total darkness, background alpha-tracks will increase in number owing to the alpha-rays from radon in air. Background increases through the lapse of time since the manufacture of the photo-plate.

The photographic plate set in a dark-slide was inserted into the hole with a long bamboo holder, through which a thick wire was passed to facilitate opening and shutting the lid of the dark-slide from the outside of the hole. The construction and use are shown in Fig. 1. The dark-slide was set with its back close to the wall and about 10 cm above the bottom of the ground hole. As the effective ranges of alpha-particles system are 3.96 and 4.81 air-cm at N. T. P. for uranium and thorium series respectively,[2] the emulsion surface will be prac-

1) Herman YAGODA: Radioactive Measurements with Nuclear Emulsions. (1949), New York & London, p. 61.





X-Y Section

The oblique-lined area shows the space, within which alpha-rays from radon can give effect on the photo-plate.

Fig. 1 Construction of dark-slide (A) and its position in the hole (B).
a : photo-plate, b : dark-slide, c : shutter of dark-slide,
d : bamboo holder, e : handle, f : lid of ground hole.

tically free from bombardment of alpha-particles ejected from soil forming the wall, as observed in Fig. 1(B). On the other hand those for emanation (radon and thoron) series are 5.21 and 5.95 air-cm, so the sphere of alpha-particles attacking the plate (as shown oblique-lined in the section in the same figure) is constant regardless of the position of the dark-slide in the hole, and comparative measurement of radioactivity in different ground holes will be possible, under the assumption of uniformity of the distribution of radon and thoron in them.

Example of test of nuclear emulsion method and its comparisons with other methods

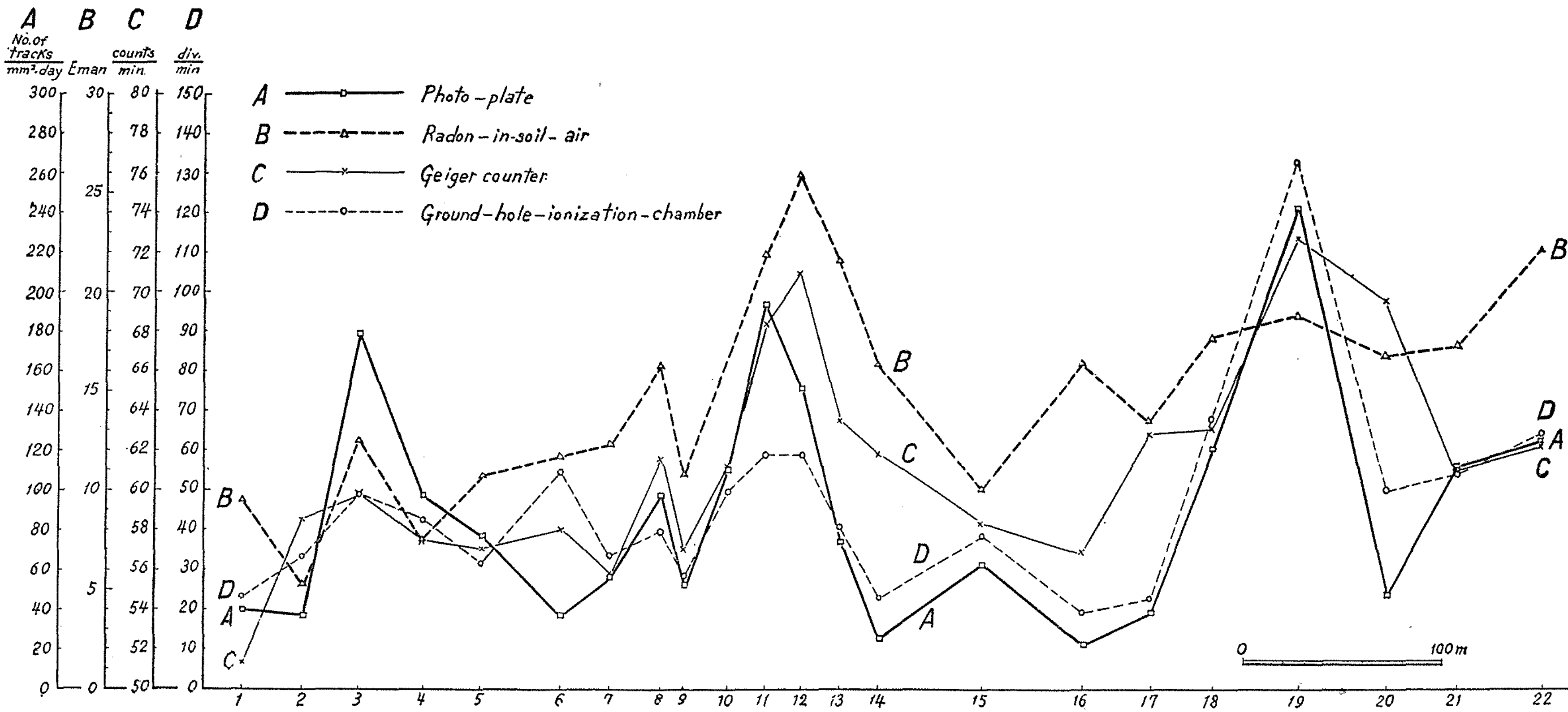
Test observation and the comparison observations were made in march, 1951 at Syûgakûin in Sakyô Ward, Kyôto City. The stations of measurements were mostly in barley-field, and arranged nearly in a line transversal to the underground faults which were located about one year ago by radon method. At each station a vertical hole 1 m in depth and 10 cm in diameter was dug in the ground. It was used as an ionization chamber in applying the ground hole method. Exposure of the nuclear emulsions was made in the same hole with its lid kept closed as illustrated in Fig. 1(B). In Geiger-counter measurement the hole was also used for the insertion of the counter tube in order to count incidence of gamma-rays from soil; counting was continued for 20 min for each station so as to minimize the statistical error.

Measurement of radon in soil air was also carried out by means of Schmidt-type fontactoscope after about two weeks since the three methods mentioned above were finished. The line of traverse was the same as before, but the position of station from which the soil air was taken was shifted about 2 m along the traverse line, so as to avoid possible influence of the ground hole previously dug.

As shown in Plate VI, the curves obtained by the above four different methods are in fairly good agreement. Of them all, we observe the curve of the photo plate method in a good agreement with that of the ground hole method. Thus observed, it may be said that the method of nuclear emulsions can be utilized in radioactive exploration, though leaving scope for the future improvements in further details.

From the results thus attained, it is very likely to be conjectured that with approach of the fault radioactivity increases not only in soil gas, but also in soil itself. If this should have been caused by only diffusing radon from the depth, the counter method would have failed in giving such peaks as seen in the radioactive profile C(PL VI), seeing that only a small fraction of total number of impulses counted by Geiger counter is due to radon while the rest to other members of radio-elements and cosmic rays.

In conclusion, the writer wishes to extend his sincere thanks to Prof. N. Kumagai for his encouragement as well as unreserved criticism and to Mr. I. Hayase, Assistant, to whose painstaking help in reading photo-record the success of the study is largely due, and also to Messrs. I. Yun and T. Shimizu for their helps in laborious field work. Thanks are also due to Dr. S. Fujisawa, Director and Mr. Y. Koseki. staff of the Fuji Photo Laboratory, who kindly provided us with the nuclear emulsion. Finally, this research was financially supported by the Scientific Research Expenditure of the Ministry of Education.



The results of comparative tests of different methods of radioactive exploration at Syûgakuin. Kyoto.