Natural Radioactivity of Miami Soils

Abstract. An important part of man's radioactive environment is the natural radioactivity of soils. This radioactivity varies with soil type and with depth in the soil profile. The relation between gross gamma activity and soil depth for a particular soil (Miami silt loam) is presented, together with a discussion of the contribution of K^{40} and the uranium and thorium series and of the effects of fallout from bomb tests in increasing the radioactivity of a thin layer of surface soil.

The presence in trace amounts of natural radioelements in the soil has long been recognized as a factor in our radioactive environment. In 1912 Rutherford (*1*) discussed radium and thorium as sources of radioactivity in soils. Not until recently, however, has much progress been made in evaluating and understanding such radioactivity. Gibbs and McCallum (*2*) in 1955 studied the gamma and beta radioactivity of certain New Zealand soils and found that radioactivity measurements in the field were useful in classifying and identifying different soil types. Gustafson, Marinelli, and Brar (*3*) in 1958 reported on a study of the natural radioactivity of soil in relation to fallout and demonstrated that the fission products in fallout then contributed only 7 mr/yr to the total background dose rate for points 3 ft above the ground, as compared with 77 mr/yr for the natural radioactivity of soil.

The role of soil and rocks in the circulation of radioactive isotopes in the biosphere was recently discussed by Arnold and Martell (*4*). The distribution and abundance of uranium, thorium, and potassium in various types of rocks in the earth's crust are discussed in *Nuclear Geology* (*5*).

Our interest in radioactivity in soils was aroused by James Thorp, who became aware of such radioactivity as a possible tool for classifying soils during a visit in Australia in 1956. It has been our purpose, since then, to learn more about the natural radioactivity of soils, its variation with soil type and throughout the soil profile, the sources of radiation and their relative contributions, and the distribution of various radioelements in relation to the gradual development of a soil profile from the parent soil material (*6*).

Preliminary attempts to detect and measure the radioactivity of local soils by means of a survey-type gamma scintillator (type 111C Precision Instrument scintillator) revealed small but detectable differences. Experience led us to conclude that making measurements in the field with a survey-type meter is attended by rather serious difficulties. In the absence of heavy shielding the count rate is measured from a large and heterogenous body of soil. When a large body of soil is involved, self-absorption effects become important, but are difficult to evaluate. Also, the upward diffusion of radon from deeper layers may obscure readings close to the surface. Another complication in making field measurements is the variable amount of background radiation arising from radon in the atmosphere. The radon content of the atmosphere varies with wind velocity, atmospheric pressure, and relative humidity. Thus it would seem difficult to interpret field measurements such as those reported by Lieftinck (*7*).

Making measurements with a scintillator probe and scaler in the laboratory proved to be a more sensitive method and provided better control of the variables involved. Our present method is based on counting gamma radiation from a 1-kg soil sample. Samples are placed in a can consisting of an inner cylinder which surrounds a crystal approximately 2 in. in diameter and 2 in. high, and an outer cylinder 5 in. in diameter. A lead shield was designed and constructed to enclose probe and sample. By this means a total count-to-background ratio of approximately 5 to 1 was achieved, and 10-minute counts could be reproduced to within 3 or 4 percent. All pulses above 100 kev were passed through a discriminating circuit and counted by a scaler.

Samples were identified in the field as to soil type and soil horizon. Each sample was crushed, passed through a screen of 0.25-in. mesh, and thoroughly mixed. A sufficiently large portion was withdrawn to provide 1 kg after oven-drying overnight at 105°C. Counting was started within 5 minutes after the sample had been removed from the oven, weighed, and sealed in the can with electrical tape. After this first counting, each sample, still sealed, was set aside, counted again 1 week later in order to determine the increase in count rate because of radon build-up.

The solid line (1959) in Fig. 1 represents the relative gamma activity in net counts per minute as a function of depth below the surface for Miami silt loam soil. Samples were taken in April 1959 from a woodland approximating a virgin forest. The dotted line (1950) represents the same relationship for soil dug from the same site 9 years earlier. The displacement between the solid line and the dashed line (1959, radon) corresponds to the increase in count rate caused by the accumulation of radon in the sealed cans during a 1-week period. The contrast between the 1950 and 1959 gamma activity of the undecayed surface litter (A_{00}) and the decayed surface organic matter (A_0) shows that the fission products in fallout from bomb tests are effectively filtered by the surface layers, even though some penetration to a depth of 3 or 4 in. is indicated. A gamma spectrum of the recent A_{00} and A_0 activity positively identified the source as fission products of fallout nuclei.

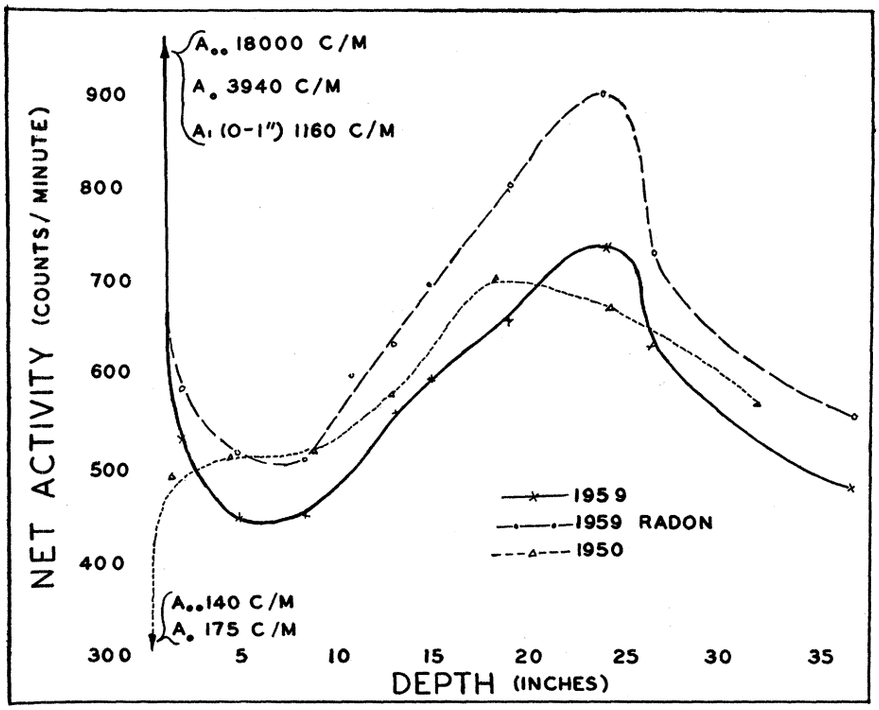

Fig. 1. Gamma radioactivity of Miami silt loam at various depths in the soil profile. A_{00} refers to the undecomposed, and A_0 to the decomposed, vegetable matter at the surface of the soil. The transition from horizon A to horizon B occurs at about 12 to 13 in. and that from horizon B to horizon C, at about 25 to 26 in.

The accumulation of radon in the sealed cans was scrutinized more closely by taking daily counts on a sealed sample from the lower B horizon (19- to 25-in.) during a 3-week period. The rise in count rate followed very closely an inverted decay curve with the characteristic half-life of radon (3.8 days).

A series of chemical analyses of total potassium as a function of depth were made by Donald Coonrod (values lay within the range 1.48 to 1.83 percent). A close correlation was found between total potassium content and gamma activity versus soil depth (the confidence limits were 0.986). We therefore calibrated the counting equipment for potassium. Our method was suggested by Gustafson, Marinelli, and Brar (*3*) of the Argonne National Laboratories. A "mock soil" was made by mixing enough KCl into uncontaminated sodium phosphate to give the same mass of potassium as that contained in one of the 1-kg soil samples and to give the same counting geometry. The counts obtained in this way were interpreted as counts from soil potassium only. By this method we concluded that the radioactive isotope of potassium (K^{40}) accounts for about 21.3 percent of the total count in the A horizon, 19.3 percent in the B, and 18.5 percent in the C. It seems highly probable that the remaining 78.7 to 81.5 percent of the count arises from radioelements of the uranium and thorium series. The emanation of radon (Rn^{222}), previously mentioned, can arise only from radium, (Ra^{226}), but because of soil leaching and weathering the radium will not necessarily be in equilibrium with its longer-lived parents.

The increased count rate as one goes from the A through the B horizon would appear to be accounted for partly by the greater concentration of potassium, and therefore of K^{40}, in the lower soil horizons and partly by a similar trend for radium. The greater accumulation of radon in the B horizon must be accompanied by a higher radium concentration. This was not expected, since radium is known to behave chemically somewhat as calcium does, and calcium (in these soils) has been leached from the B horizon but occurs at higher concentrations in the underlying glacial till (C horizon). It is possible that the leaching of uranium from the A horizon and its adsorption on clay surfaces in the B horizon are important here.

In order to learn something about the absorption of radioelements on clay surfaces, a study of particle size was made. Clay, silt, and sand-size particles were separated by wet-sieving followed by sedimentation (the U.S. Department of Agriculture's mechanical analysis procedure was adapted for studying large samples). The gamma activities, in counts per minute per gram, were found to be as follows: clay, 6.95; silt, 5.40; sand, 1.38. The fact that the silt and clay activities are of the same order of magnitude would seem to indicate that a substantial portion of the radioelements are held in mineral form in the silt range. This is in agreement with the findings of Hoogteijling and Sizoo (*8*). Some adsorption of radioelements on clay surfaces may also occur.

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References and Notes

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Resetting the Sporulation Rhythm in Pilobolus with Short Light Flashes of High Intensity

Abstract. The "clock-controlled" endogenous sporulation rhythm in the fungus *Pilobolus sphaerosporus* has been investigated as part of a comparative study aimed at elucidating characteristic common features of circadian (*1*) rhythms. *Pilobolus* was chosen for inclusion in this study because of its demonstrated rhythm and sensitivity to light, and because it is a relatively simple plant. It has been shown that a single, high-intensity, 1/2000 second light flash will completely reset (shift the phase of) a rhythm persisting in continuous dim red light at constant temperature, and that one or more transient cycles occur before the phase shift is complete. The significance of these results is discussed.

The fungus *Pilobolus sphaerosporus* ejects spores at periodically timed intervals. The organism possesses an endogenous, temperature-compensated, rhythmic system which can be synchronized by appropriate light-dark cycles or temperature cycles but which persists with approximately a 24-hour period in continuous darkness or continuous dim red light (*2*). This "clock-controlled" sporulation rhythm is especially sensitive to light, and we have therefore examined the phase-shifting characteristics of the rhythm in response to light flashes of short duration and high intensity. This investigation (*3*) is part of a comparative study in which the general characteristics of the biological clocks of such diverse organisms as mammals (*4*), insects (*5*), and microorganisms (*6*) have been investigated.

From the comparative point of view it is desirable to know whether the properties of the "clock" system in microorganisms are qualitatively similar to those in higher organisms. As a tool for the comparative study, we have attached considerable significance to the way in which the phase of a persistent rhythm is shifted in response to single light stimuli (*7*). The fact that a new steady state is not achieved immediately, but only several cycles after a phase-shifting light signal, has been interpreted by us in terms of a generalized coupled-oscillator model. The transient approach to new phase is interpreted in terms of a gradual re-entrainment of one oscillator (not reset by the light signal) by another oscillator which is reset by the light signal. These transients, which may continue for seven or eight cycles in hamsters and three or four cycles in *Drosophila*, are difficult to detect in microorganisms and plants. The present demonstration of their occurrence in *Pilobolus*, together with the previous claim for their existence in *Euglena*, is evidence that the underlying features of the clock system which they reflect require neither the complexity of multicellular organization nor the presence of a nervous system.

Pilobolus sphaerosphorus was cultured on Bovung-oatmeal-agar of the following composition: 200 gm of Bovung (Walker-Gordon dried cow manure) boiled in 1 liter of water for 20 minutes and filtered through cheesecloth; 60 gm of oatmeal boiled 60 minutes in 1 liter of water and filtered through cheesecloth; 1.2 gm of K_2HPO_4; 1 gm of KH_2PO_4; and 40 gm of agar. The total volume was brought to 2 liters with water, and the medium was autoclaved for 20 minutes and poured into petri dishes 50 mm in diameter.

Agar-block transfers were made at 3- to 4-day intervals, and the plates were kept in a 25°C cabinet maintained on a light cycle with 12 hours of white fluorescent light per 24 hours. Sporulation started 6 or 7 days after inoculation. Ejected spores were collected with a specially constructed device consisting of a moving carriage holding eight petri plates which are slowly (56 mm/hr) pulled beneath eight glass strips just above the petri plates. The ejected spores adhere to the glass strips. Every 24 hours the glass strips were removed and replaced