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Records of Gamma Radiation from the Ground and Beta Radiation from Radioactive Debris in Sweden, 1950—1955. Part I

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Abstract

The γ radiation of the ground from natural and artificial radioactivity, and the β radiation from radioactive debris in the atmosphere, have been recorded in Sweden since 1950. On several occasions increased radioactivity has been observed, sometimes producing effects by far exceeding the variations of the normal level. Observations are reported on the influence of rain and snowfall, with and without the effects caused by transportation of radioactive debris from nuclear explosions.

The γ radiation from the ground and β radiation from atmospheric debris have been continuously recorded since June 1950 at four places (fig. 1, I – IV), and since February 1953 at two additional places (fig. 1, V – VI). The chief aim was to elucidate any increase of ionizing radiation due to the nuclear explosions, which were more frequent year by year. It seemed desirable to register at an early stage the variations of the natural radiation too, in order to judge what effects could be attributed to changes in the natural level and what effects were probably referable to nuclear explosions. When the work was started in 1948, it was required that such investigations should be made without publicity and as a measure of preparedness. Hence the instruments were so designed that they could be managed by completely unskilled persons without knowledge of the purpose of the work. Since it was impossible to know in advance what amounts of radiation would appear, the methods used had to provide records within a very wide range, from the radiation common in nature up to levels representing increases of at least 1,000 – 10,000 times; that is to say, 1 – 10 *r* per week. Moreover, a very high degree of reliability was imperative, since the instruments were located at small places too far away for competent supervision. A technically trained person could only be sent out two or three times a year for checking the equipment.

Under these circumstances it was not possible with the modest grants and personnel (one technician) available, to arrange for more than quantitative measurements under constant conditions of the ionization in order to be able to observe small variations in the radiation level; any thought of a detailed analysis of the radiation observed thus had to be abandoned. Only a comparatively rough estimate of the radioactivity in the atmosphere could be carried out, and the detection of diminutive quantities months after nuclear explosions was very unlikely.

Methods and Instruments

The method of recording will be seen from fig. 2. The central electrode of the ion chamber, *I*, is connected to the fixed plates, P_1, of a specially designed electrostatic instrument, the moving balance of which is provided with

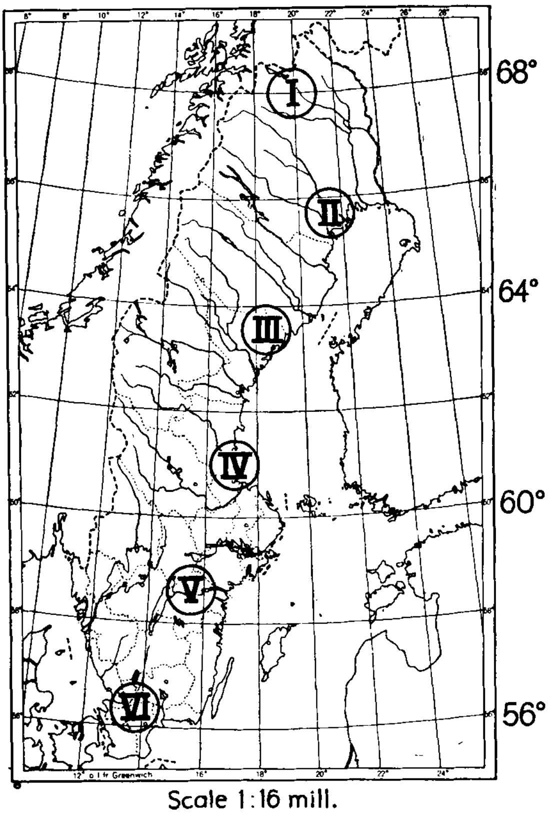

Fig. 1. Approximate sites of the recording stations.

plates P_2, and with two contacts. One of the latter, K, discharges plates P_2 when a certain voltage is reached; the other, F, gives a safe connection to the relay, R_1, when the balance on which the plates P_2 are fixed falls to its zero position. Relay R_1 works on a system of dry batteries, B, condensers, C, and another relay, R_2, the main arrangements of which are seen in the figure. When the system is discharged a short trace on the telegraph recorder, T, is obtained. The recorder has six magnets, two of which are used for the ion chambers, two for time registrations (every 10 minutes and 6 hours), and two for indicating temperature changes in the instrument room and for control of a fan for suction air through a debris chamber. A record is shown in fig. 3. When evaluating the records, the average of three consecutive points was used.

Schematic drawings of the ion chambers—one chamber for radioactive debris and one pressure chamber (7 atm. N_2) for γ radiation—are shown in fig. 4, which needs no further explanation.

Since it was essential to know the long-term reliability of the records, six complete recording apparatuses with closed ion chambers were

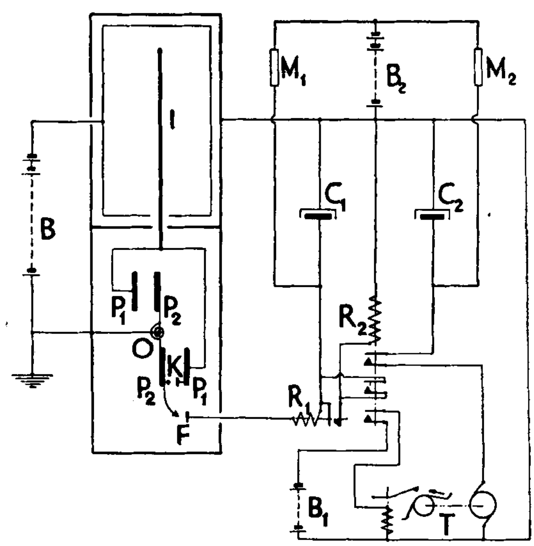

Fig. 2. Method of recording the ionization.

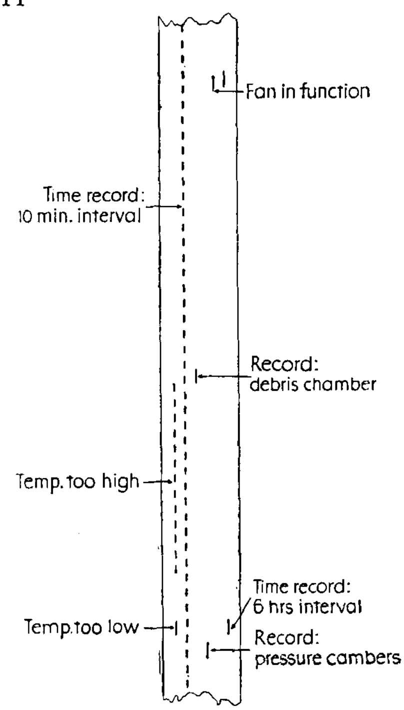

Fig. 3. Record strip.

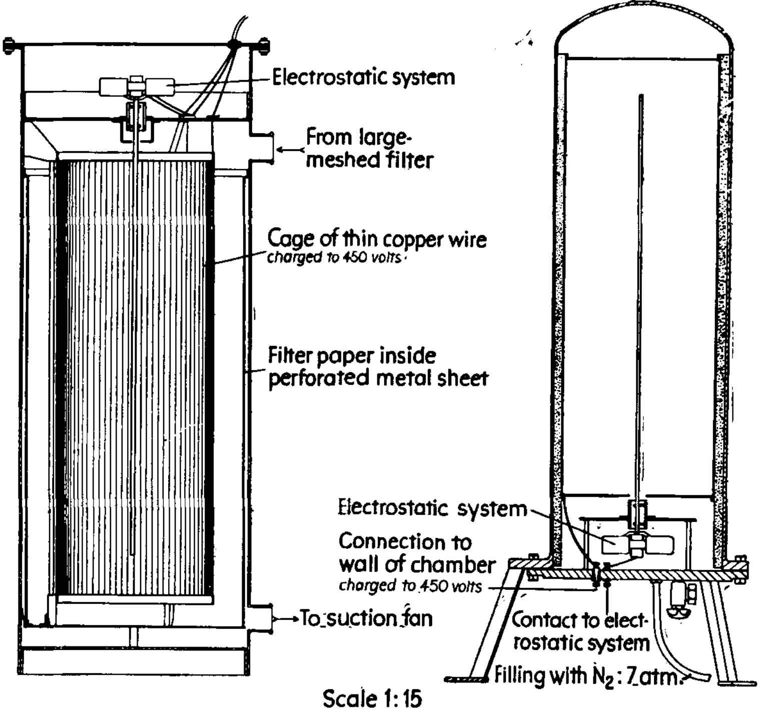

Fig. 4. Ion chambers; left, for measurement of radioactive debris; right, for γ ray measurements.

placed in a well ventilated cellar for several months. The maximum deviations from the mean proved to be less than $\pm$ 1 % of the natural γ-radiation of average intensity or about $\pm$ 10 microroentgen per week.

The instruments are at present placed in small detached wooden houses situated on open ground. The houses are heated electrically with the use of thermoregulators, and indoor temperatures and barometric pressures are recorded by means of ordinary instruments. During a two-day period each week, about 1,000 m^3 air is drawn through the filters of the debris chambers and they are then filled with old air and hermetically sealed. — To check the correct running, tests were made by using two similar instruments in two of the houses. Fully satisfactory agreement was found, as will be seen from the records in fig. 5.

The effective running times are shown in table 1. In the period of failure, calibrations by means of a radioactive source are also included.

At every place where records are taken there

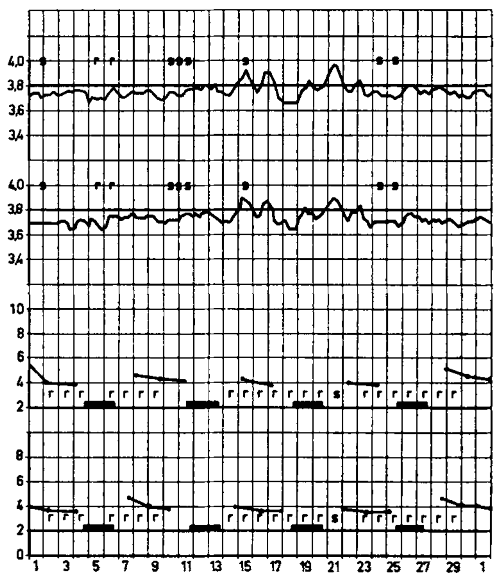

Fig. 5. Simultaneous records with two chambers of the same type at the same station over one month. VI: γ ray chambers; V: debris chambers. Suction periods (2 days) marked by black rectangles. Rain and snow indicated.

Table I.

Place	Time of useful records in % of total period					
	γ radiation:			radioactive debris:		
	1950—51	1952—53	1954—55	1950—51	1952—53	1954—55
I.	87	89	97.5	88	86	99
II.	93	90	87	87	81	87
III.	90	91	99.5	89	85	94
IV.	87	95	98	87	92	98
V.	—	93	81	—	85	82.5
VI.	—	93	96.5	—	91	96
Mean I—VI	89.3	90.2	93.2	88.8	86.7	92.7

is a person in charge of the very simple tending of the instruments, which amounts to less than half an hour's work per week. He keeps the small laboratory in order and checks the suction of air through the debris chamber and the observations mentioned above. This work has been carried out satisfactorily during the whole time, by workers living near by, and occasionally by their families too. All records are sent to Stockholm together with annotations of the pressure in the pressure chamber, voltmeter readings of the batteries and meteorological data, especially as to rain and snow. The evaluation and registration of the results take about one hour per week per station.

As pointed out above, the ion chambers are calibrated by means of radioactive sources. From the calibrations it is evident that there are sometimes long-term changes in the sensitivity of the electrostatic systems, but no abrupt ones that might obscure the results have been observed. Only in the rare cases where the electric heating of the houses has failed have slight changes sometimes occurred. Temporary disturbances have happened but are very rare and easy to detect, and have not caused any serious complications.—Nevertheless, a single record is never judged as a real effect unless supported by another independent observation, or unless a series of results makes the effect sufficiently plausible.

In all diagrams in this paper the observed radiation refers to the ionization in ion pairs per cm³ per second in normal air in the ion chambers.

The barometric effect of cosmic radiation is taken into account and a correction applied

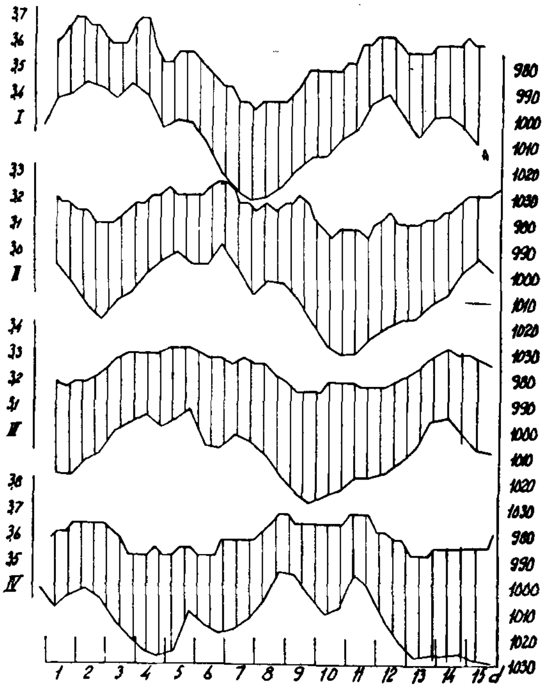

Fig. 6. Barometric effect of cosmic radiation recorded by the pressure chambers at four stations during periods of 15 days. Upper curves and figures on left side ionization; lower curves and figures on right side barometric pressure.

as determined from series of records made in 1950—1951 (*cf.* fig. 6) during periods when nuclear explosions did not take place. This correction proved to be 0.005 ion pairs per millibar and is used for the pressure ion chambers only. Solar flares have not hitherto been found to produce any detectable effects on the records, except in one case demonstrated in table II and fig. 7.

The average amounts and the maximum variations of radon and thoron, including their decay products, in the air at the recording sites caused some trouble in one station (fig. 1, II) and made the observed level of artificial debris to some extent uncertain. However, major quantities of artificial radioactivity could never be confused for such reasons.

To be on the safe side, a question mark nevertheless follows results which may possibly have been caused by variations of the natural radiation or by instrumental errors.

Table II. Increase of penetrating radiation caused by eruptions on the sun in the morning of February 23rd. 1956.

(The time intervals for the different observations are collected here. It has been impossible to state with sufficient certainty whether or not the apparently earlier occurrence of the increase of radiation observed at station IV may have been confused by the time record being wrong. The other times given can be considered as correct within 10—20 minutes. Consequently, the maximum of the radiation seems to have been registered between 05^{00} and 08^{00},)

Station	I	II	III	IV	V	VI
Average ionization before and after effect observed	3.21	2.77	2.46	2.85	3.49	3.13
Time of observation.... Increase of ionization...				07^{10}—16^{10} —0.07		
Feb. 22	15^{40}—22^{30} —0.04					
				16^{10}—01^{00} *0.28*		
					19^{10}—02^{20} —0.08	
						19^{40}—02^{30} 0.03
	22^{30}—05^{00} 0.12					
		21^{50}—05^{00} 0.04				
			21^{40}—05^{00} 0.09			
				01^{00}—07^{20} *1.03*		
					02^{20}—07^{40} *1.10*	
						02^{30}—07^{50} *0.91*
	05^{00}—08^{00} *4.01*					
		05^{00}—10^{20} *1.38*				
Feb. 23			05^{00}—10^{40} *1.13*			
	08^{00}—14^{10} *0.30*					
					07^{40}—14^{30} 0.09	
						07^{50}—14^{30} 0.10
				07^{20}—15^{20} *0.17*		
		10^{20}—18^{10} 0.06				
			10^{40}—18^{50} 0.03			
	14^{10}—20^{50} 0.06					
					14^{30}—21^{30} 0.01	14^{30}—21^{30} —0.04
				15^{30}—00^{00} 0.03		
			18^{50}—03^{10} —0.01			
Feb. 24		18^{10}—03^{50} 0.00				

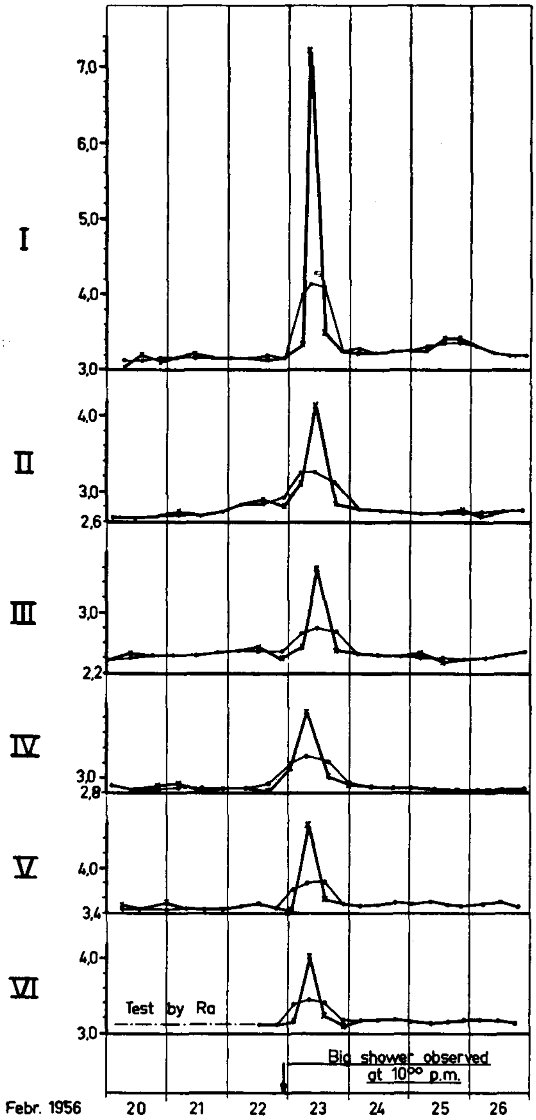

Fig. 7. Increase of cosmic radiation in the morning of February 23. The peaks indicate the single observations; the lower curves are obtained by using three point averages. A big shower was obseved at 10^{00} p.m. on Feb. 22 by means of a very sensitive high pressure ionization apparatus (SIEVERT, Strahlentherapie, 99, p. 186, 1956) placed in a rock about 50 m below earth surface.

Results

Th γ radiation from the ground is constant when there have been no recent nuclear explosions and the weather is dry. Rain and, particularly, snow occasionally cause typical effects even during periods when there is no

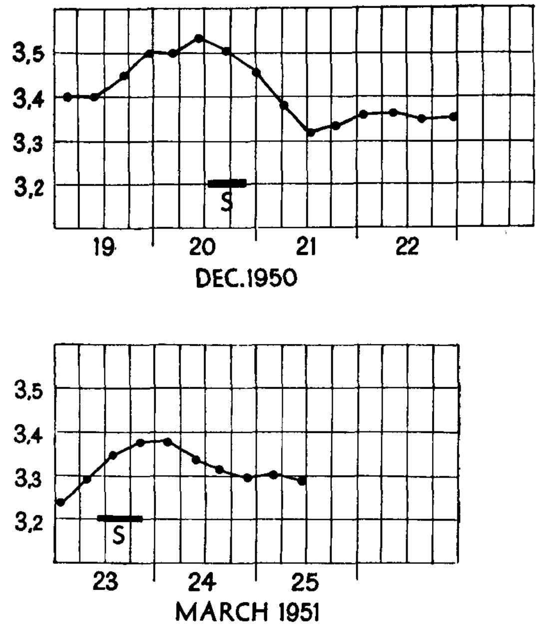

Fig. 8. γ radiation during and after snowfall.

reason to allow for any appreciable amount of artificial radioactivity in the atmosphere. Rain sometimes causes a brief increase in the γ radiation produced by the decay products from radon and thoron. Snow also produces a similar change, but here the absorption of the γ radiation from the ground surface complicates the results.

If the snowfall is heavy, the absorption predominates and results in a decrease of the radiation. In cases of abundant radioactive debris there is an increase followed by a decrease, provided the snow remains unmelted. Typical curves for these two alternatives are shown in fig. 8. Evidently, the γ radiation observed after a snowfall is very much dependent on the specific activity of the outermost part of the snow cover; hence even a very small quantity of new snow may often cause a marked increase in radiation, if the snow has been produced in atmosphere containing a high concentration of radioactive debris. In the case of a heavy snowfall it may be assumed that the first portion of snow takes up the major part of the activity in the atmosphere. This is also supported by the experience that after rain and snowfall an appreciable effect has rarely been detected with the debris chamber.

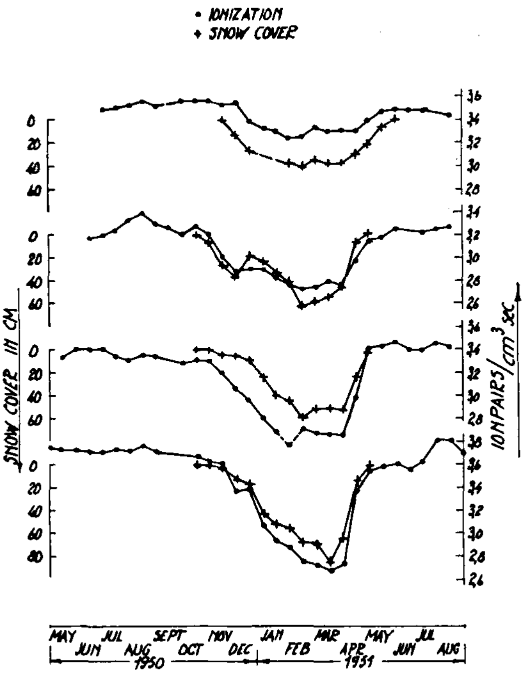

Fig. 9. Snow cover and natural γ radiation.

The absorption by a snow cover is so great that it can be used for estimation of the thickness of the snow layer or, more correctly, of its average mass per unit of area. Fig. 9 shows the correlation between snow layer and γ radiation during the winter of 1950—1951 for the four northernmost stations, and fig. 10 the absorption by snow layers of different thicknesses.

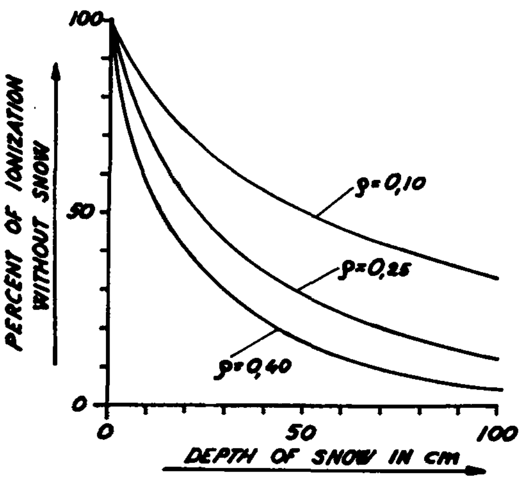

Fig. 10. Calculated absorption of γ radiation from the earth crust by snow of varying volume weight.

After nuclear explosions, especially those produced in northern latitudes, radioactive debris has been observed in the atmosphere over Sweden on several occasions. A typical example is seen in fig. 11 a and b, which should be compared with fig. 12, showing a set of normal curves obtained during a "quiet" month. The slope of the curves as will be seen from fig. 13 is nearly the same in three consecutive records. Since these curves are not likely to represent debris of equal age caused by different explosions, the most probable explanation is that a short-lived radioactive element was predominant for 1—2 weeks after the explosion. This is indeed the case, as neptunium 239 is produced by atomic bombs, probably due to the use of uranium 238 as a tamper. As will be seen from the collected decay curves in fig. 13, the half life is of the magnitude of 2.5 days, in close agreement with the figure 2.31 ± 0.11 given for neptunium 239, as a small additional amount of fission products may have contributed to prolonging the half life. The first recorded value is excluded in the upper curves of the graph. This has been done because of the possible influence of short-lived decay products of radon and thoron during the early period after suction.

With regard to the γ radiation, in only a few cases has an increase been of such magnitude as to leave no doubt of its origin. One of these cases is shown in fig. 14. The effect observed was caused by the thermonuclear bomb exploded on August 12th, 1953. Since no rainfall was reported in the locality where the highest radiation was recorded, there may have been a sedimentation of comparatively large particles in the atmosphere. It may be open to doubt whether determination of the half life of the radioactivity in this case serves any purpose. However, according to the record from place III, the half life is obviously 4—5 days, which is in fairly close agreement with the $t^{-1.2}$ law, if the debris was produced at an explosion 4—5 days before; that is, 12th—13th August. This indicates that the active material was being precipitated during the comparatively short time of less than two

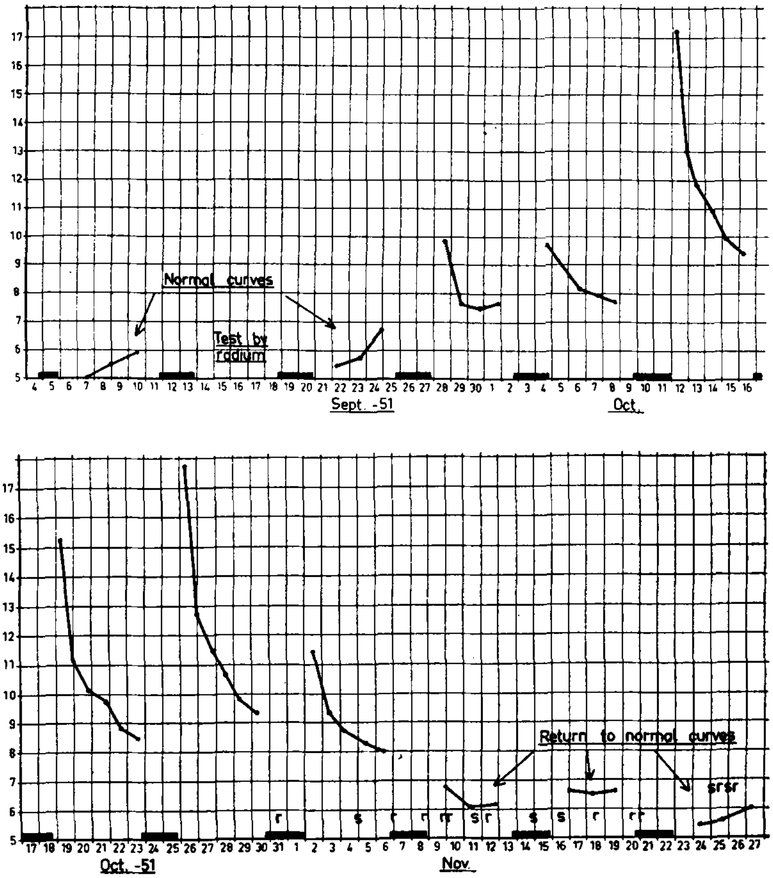

Fig. 11 a and b. Debris records during September and October 1951. The chamber was at this time not absolutely airtight, and therefore small amounts of radon influenced the records as seen from the curves before and after the effects of increased radioactivity.

Table III. Number of occasions on which the ionization observed was of such magnitude or half life that it could not reasonably have been caused by normally occurring natural radioactivity only. (Figures in brackets refer to ionization above 10 ion pairs per cm³ and sec.)

Station	1951		1952		1953		1954		1955		Total
	debris	γ rad.	debris	γ rad.	debris	γ rad.	debris	γ rad.	debris	γ rad.	
I	0	0	0	0	0	1	0	0	0	0	1
II	1	0	8 (4)	0	2	1	3 (1)	0	3	0	18 (5)
III	2	0	1	0	6	1	0	0	0	0	10
IV	6 (3)	0	0	0	1	1	0	0	2	0	10 (3)
V	—	—	—	—	10	0	0	0	1	0	11
VI	—	—	—	—	7 (1)	0	0	2	10 (7)	0	19 (8)
Total	9 (3)	0	9 (4)	0	26 (1)	4	3 (1)	2	16 (7)	0	69 (16)

In measurements of the debris, those occasions only have been included on which radiation measurements showed an increase of at least 4 ion pairs per cm³ and sec. in the ion chamber. In measurements of the γ radiation, all effects of short duration have been excluded, since it is difficult to determine with a sufficient degree of certainty if they are caused by nuclear explosions or by other effects. The debris records of station VI may be affected to an unknown extent by variations in natural radioactivity.

Table IV. Number of occasions on which max. increase in ion pair per cm³ and sec. in the debris chamber amounted to:

Year	(S = spring, A = autumn)														Total
	4—6		6—8		8—10		10—12		12—14		14—16		16—18		
	S	A	S	A	S	A	S	A	S	A	S	A	S	A	
1951	0	4	1	1	0	0	0	1	0	2	0	0	0	0	9
1952	0	2	1	1	1	1	1	1	0	0	1	1	0	0	10
1953	3	14	1	5	0	1	0	0	0	0	0	1	0	0	25
1954	1	1	0	0	0	0	0	0	0	0	0	0	0	1	3
1955	2	3	1	2	1	1	1	4	0	0	0	1	0	1	17
Total	6	24	4	9	2	3	2	6	0	2	1	3	0	2	64

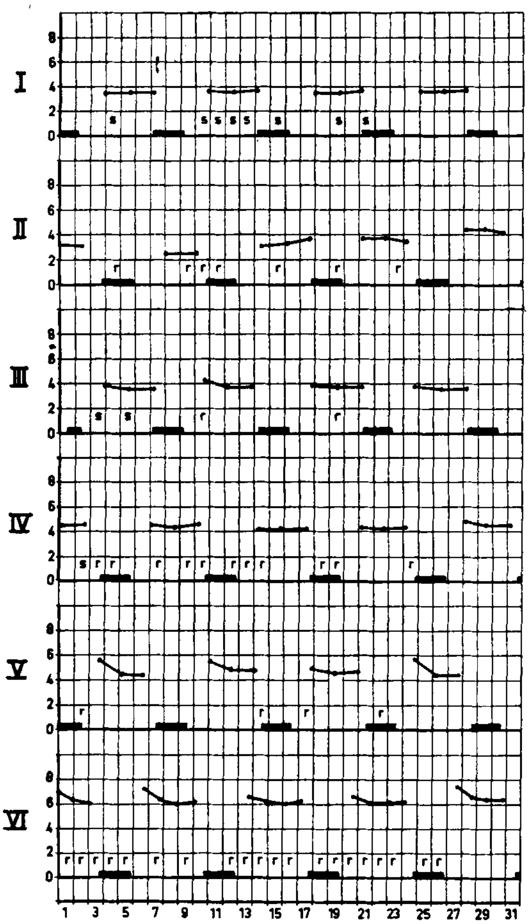

Fig. 12. Debris records during a "quiet" month.

days. A study of the meteorological conditions makes this quite possible.

Tables III and IV contain some data showing the different observations with respect to the magnitude and distribution among the different years and stations.

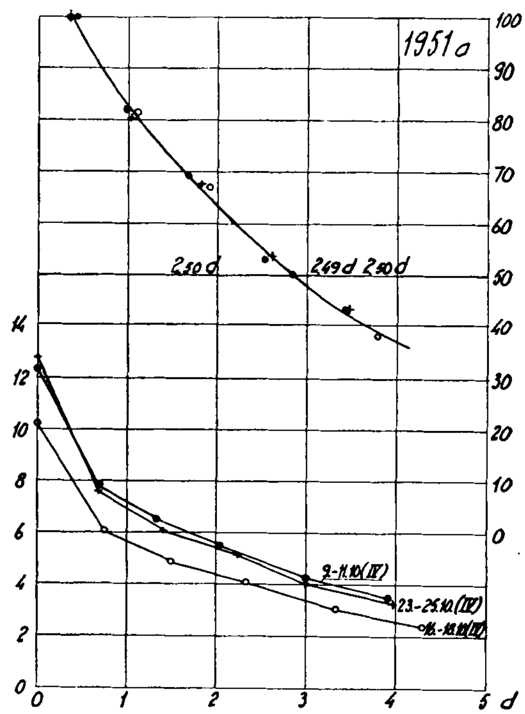

Fig. 13. Decay curves from fig. 11 corrected for background radiation. The lower curves (left scale) show the ionization observed in the chamber in ion pairs per cm³ and sec. and the upper curve (right scale) the decay calculated from the five last points on the lower curves.

A survey of the records of 1951—1955 together with the decay curves obtained and the meteorologic data prior to the more marked increase of radiation will be reported in a subsequent communication.

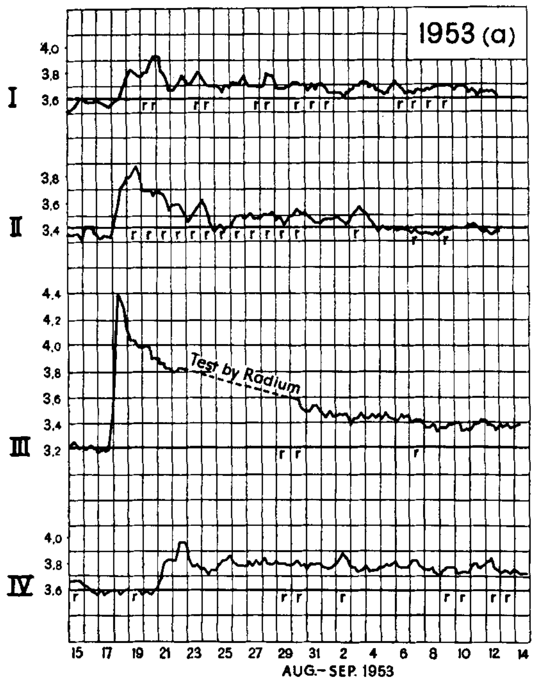

Fig. 14. γ radiation records during August 1953. The peak in curve III corresponds to ca. 1.5 curies fission products per sq. kilometres of 5 days age.

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