Note that the Mississippi Valley leads (Fig. 1*C*) vary in composition from ordinary lead to J-leads even more radiogenic than the outer growth zones of the crystal. The data for the crystal, when extrapolated (dashed line) in the direction of ordinary lead, intersect our lead evolution curve (*5*) at about 300 million years. It is therefore permissible to interpret the crystal as a product of simple mixing of such ordinary lead, having model age of 300 million years, with radiogenic lead. The data for the crystal, extrapolated in the opposite direction, give a solution for radiogenic lead composed of Pb^{206}, Pb^{207}, and Pb^{208} in the ratio 1.0:0.055:0.75. Radiogenic lead of this composition would have been forming in an environment with Th/U about 2.2, at a time about 200 million years ago. The radiogenic component would account for about 9 percent of the mixture in the core of the crystal, and about 11 percent in outer growth layers.

Translated into terms of geologic process, these isotopic variations seem to imply progressive leaching of lead, probably during a protracted period of time, from rocks with appropriate content of lead, uranium, and thorium. The data seem to imply source rocks younger than Precambrian, presumably some of the Paleozoic sedimentary rocks within which the Tri-State ores were deposited. Growth of the zoned crystal would seem to have occurred intermittently, during part or all of a period some 300 to 100 million years ago, equivalent to late Paleozoic and Mesozoic time on the Holmes time-scale.

With the help of appropriate geologic sampling and more precise isotopic measurements, further studies of isotopic variations of this kind will ultimately show whether this simple hypothesis, or some other, best explains the genesis of Mississippi Valley J-leads.

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16 August 1963

Strontium-90 Accumulation on Plant Foliage During Rainfall

Abstract. *Accumulation of strontium-90 in field-grown crops was measured during the spring of 1962. Each rainfall markedly increased the strontium-90 content of the crops, except when the plants were very small. Accumulation between rains was comparatively small, about equal to the expected uptake from the soil.*

Much of the strontium-90 in agricultural crops in recent years has accumulated by direct deposition of fallout on the plants (*1*). During early 1962, the rate of strontium-90 fallout was greater than that in previous years. During this period the effect of rainfall on accumulation of strontium-90 in crops was studied.

Four crops were grown at a humid location (Everglades Experiment Station, Belle Glade, Florida) and an arid one (Southwestern Irrigation Field Station, Brawley, California). Sweet corn, cabbage, and potatoes were grown at both locations. In addition, snap beans were grown at Belle Glade and soybeans at Brawley. One acre of each crop was grown according to recommended commercial practices in each area.

The crops were sampled several times weekly during a 6-week period of active vegetative growth in April and May. At least three randomly selected subplots of 4 square meters each were harvested to make up each crop sample. The sample was cut at from 5 to 7 cm above the ground. Care was taken to avoid soil contamination, but the samples were not washed. They were dried and ground at the field locations. At the end of the sampling period, nine samples of each crop were selected for strontium-90 analyses. At Belle Glade, the selected samples were those taken immediately before and after three rainy periods which occurred during the sampling period, and at nearly equal intervals between rains. Since no rainfall occurred at Brawley, the selected samples were those taken at nearly equal intervals over the entire sampling period.

Concurrently with crop sampling, samples were taken to determine strontium-90 concentrations in rainfall, air, and soil at each location. Rainfall was collected in pans, in which a layer of dilute strontium nitrate solution was maintained. Dust that settled in the pans during dry periods was analyzed in addition to the rainfall samples. Airborne strontium-90 was collected by drawing air through a highly efficient cellulose-asbestos filter, 20 cm in diameter, at the rate of about 1200 m^3/day. Core samples of soil were taken in several increments to a depth of 45 cm at Belle Glade and 35 cm at Brawley.

The strontium-90 content of the samples was determined at Beltsville, Maryland. Crop samples were dry-ashed and dissolved in HCl. Rainfall samples were evaporated to dryness and digested in 6*N* HCl, as were the air filters. Soil samples were extracted with 1*N* $Sr(NO_3)_2$ to obtain only the exchangeable strontium-90. All strontium-90 determinations were made after radioactive equilibrium had been re-established by separating the yttrium-90 daughter and following its radioactive decay.

All crops increased many times in dry weight during the sampling period. At both locations, sweet corn attained the greatest weight at the final harvest, 840 g/m^2 at Belle Glade, and 560 at Brawley. The corresponding weights at the first harvest were 45 and 20 g/m^2. Similar weight increases were obtained with the other crops. The final harvest weights (g/m^2) were: at Belle Glade, snap beans, 340; cabbage, 230; potatoes, 150; at Brawley, cabbage, 300; soybeans, 150; and potatoes, 110. The weights of all crops increased steadily over the sampling period without marked increases after rainfall at Belle Glade or irrigation at Brawley.

Strontium-90 contents on an area basis (Fig. 1) were obtained by multiplying the concentration in each sample times the corresponding yield from the

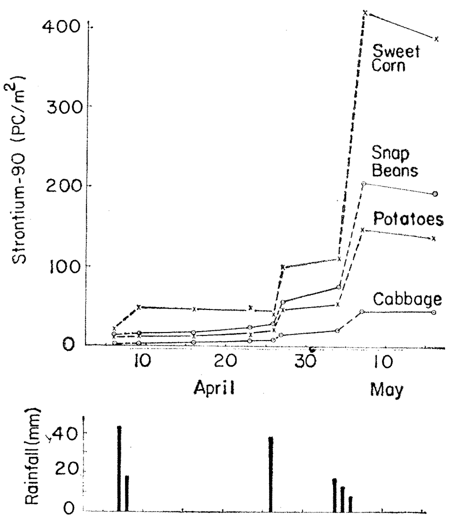

Fig. 1. Strontium-90 content in four crops grown at Belle Glade, Florida, in relation to date and amount of rainfall.

refined growth curve. We estimate that the average errors associated with the values in Fig. 1 are ± 12 percent for cabbage and sweet corn, and ± 15 percent for snap beans and potatoes. Strontium 90 content increased greatly during each interval with rainfall except when the crops were very small. There was comparatively little accumulation during intervals without rain. The changes in strontium-90 content between 7 and 16 May were smaller than the average errors associated with these contents.

The strontium-90 accumulation during rainy intervals may have resulted largely from interception of rain by the foliage and subsequent evaporation. Interception by a fully grown crop of corn may amount to 5 mm, increasing with increasing duration and decreasing intensity of rain (*2*). This amount would have been an appreciable fraction of the rains which fell separately on the afternoons of 4, 5, and 6 May, depositing a total of 410 pc of strontium per square meter. Less interception would have been expected in smaller crops, in agreement with the observations for other crops on the same date and for all crops on earlier dates. The earlier rains deposited a total of 310 pc of strontium-90 per square meter on 7 and 8 April, and 280 pc on 26 April.

Strontium-90 in rain which penetrated the crop cover would have been expected to enter the crop through its root system slowly over extended periods of time. The strontium-90 would have been absorbed on the soil within a few centimeters of the surface, and might have been taken up through shallow roots. Had this occurred with the Belle Glade crops, it should have continued as long as the surface soil moisture remained above the wilting point and should not have been confined to the interval during which rainfall occurred. We believe that penetration of strontium-90 through the crop cover, with subsequent uptake from the soil, was not an important pathway of contamination with these crops.

Any accumulation of strontium-90 in the crops between rains could have resulted either from uptake from the soil or from deposition on foliage. At Belle Glade, an accurate estimate of this accumulation was impossible. However, at Brawley all of the accumulation occurred without rainfall. The yield of dry matter and strontium-90 content increased quite uniformly throughout the sampling period. Although growth differed considerably at the two locations, the observed accumulation of about 25 pc of strontium-90 per square meter in the crops grown at Brawley was consistent with the possible accumulation between rains at Belle Glade.

Since the uptake of exchangeable calcium and strontium from soils are roughly proportional (*3*), the uptake of strontium-90 could be estimated from knowledge of the rooting habits and calcium contents of the crops. Each crop grown at Brawley took up about 0.2 percent of the exchangeable calcium in the top 35 cm of soil. The exchangeable strontium-90 content in the same layer of soil was 7000 pc/m^2 so that uptake of about 14 pc/m^2 would have been expected. Therefore, a substantial fraction of the observed strontium-90 content in the Brawley crops was derived from soil uptake. Similarly, the uptake of strontium-90 from the soil was about 37 pc/m^2 in the crops grown at Belle Glade.

It was possible that accumulation between rains arose from deposition of dust on foliage. Total deposition of strontium-90 in the rainfall collection pans at Brawley was 35 pc/m^2 and that between rains at Belle Glade was 84 pc/m^2. However, during dry periods there was no apparent correlation between increments of strontium-90 content in the crops and concurrent concentrations of strontium-90 in the air (from 0.044 to 0.095 pc/m^3 at Brawley and from 0.045 to 0.105 pc/m^3 at Belle Glade).

Thus it appears that the occurrence of rainfall was very important in the contamination of these crops by fallout. While there may have been some contamination from the atmosphere between rains, we could not determine the quantity in this experiment (*4*).

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Steric Factors in the Chemistry of Polypeptides, Poly-α-Amino Acids and Proteins

Abstract. *An application of the rule of six for the estimation of steric hindrance in reactions of dipeptides and polypeptides, and conformational preferences of polypeptides and proteins, is described.*

Steric factors have a pronounced influence on the rates of hydrolysis of dipeptides and proteins (*1–3*), on the dependence of main chain conformation of proteins and polypeptides on amino acid sequence and composition (*4*), and on many other aspects of protein chemistry. The recognition of the importance of steric factors in organic chemistry has increased significantly in the past two decades (*5*).

The "Rule of Six" states: "In reactions involving addition to an unsaturated function containing a double bond, the greater the number of atoms in the six position the greater will be the steric effect." Numerous examples demonstrating the validity of this rule have been reported (*5,* chap. 4). Cor-