THE CONTAMINATION BEHAVIOR OF FALLOUT-LIKE PARTICLES EJECTED BY VOLCANO IRAZU

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BACKGROUND DISCUSSION

From March 1963 to February 1965, volcano Irazú in Costa Rica erupted explosively, ejecting particles and steam that occasionally rose to heights of as much as 15,000 feet above the summit of the crater. The prevailing winds carried these particles over the central valley of Costa Rica where they settled on buildings, streets, people, and other objects in the villages and cities as well as on the vegetation and other exposed objects in the rural areas.

In February 1964, investigations on the contamination of vegetation by the volcanic debris were initiated to study the contamination behavior of the particles with the idea of applying the results to similar situations for radioactive fallout particles from nuclear explosions. The investigations, under sponsorship of the U.S. Office of Civil Defense, were concluded in February 1965 when the volcano ceased erupting.

The volcanic particles, for purposes of the study, simulated nuclear weapon fallout particles containing radioactive elements. The similarity in the shape of the volcanic fallout particles to the fallout particles from a nuclear detonation, whose particle cloud rose to the same altitude as those from the volcano is shown in the photomicrographs of Figures 1 and 2. The density of the volcanic fallout particles was almost identical to that of fallout particles from a land-surface nuclear detonation. The particle size ranges shown (44 to 88 microns and 88 to 175 microns) are characteristic of the volcanic particles that were deposited on the central valley of Costa Rica and of local fallout particles from nuclear detonations that would be deposited on areas receiving negligible blast and heat effects.

Because of the similarity in the physical properties of the volcanic fallout particles to those of the nuclear weapon fallout particles, it was concluded that the deposition and contamination behavior of the volcanic particles should be indicative of the behavior expected of nuclear weapon fallout particles. In other words, the behavior of the volcanic particles in landing on surfaces, in redistribution by wind and rain, and in decontamination and disposal, as observed in Costa Rica, can be used to draw conclusions about the expected behavior of nuclear weapon fallout (following a nuclear war) in other populated areas of the world with similar buildings, streets, vegetation, and climatic conditions.

The individual volcanic particles were dense, mostly irregular in shape (similar to beach sand), and dark brown to black due to the presence of magnetite (iron oxide) crystals. The nuclear weapon fallout particles are generally not as dark as the volcanic particles, and nuclear weapon fallout may contain more spherical particles (up to 5 percent by weight) but the major difference between the two types of particles is that fallout particles from nuclear explosions contain radioactive elements.

The volcanic particles contained no radioactivity. Thus the fallout from the eruptions of Irazú presented a unique opportunity to observe the behavior of fallout-like particles without hazard to the observer. The absence of radioactivity in the volcanic debris permitted immediate on-site observations not possible in nuclear tests; the presence of human habitation in the affected areas meant realistic simulation of fallout situations, unlike the uninhabited deserts and small coral islands where nuclear weapon tests have been conducted. In addition, the climatic conditions in Costa Rica, over the period of observation, were more like those of the populated areas in the United States and Europe than are the climatic conditions at the nuclear weapon test sites.

The volcanic explosions often formed particle clouds that looked like those formed by nuclear explosions. The occasional large eruptions hurled huge rocks high in the air. The impact of the rocks on the sides of the crater or on nearby mountain surfaces sounded like artillery fire at close range; a rumbling noise could be heard during the quiet of the night in the city of San José, 15 miles away. Due to their high temperature, the rocks glowed dark red at night but were not hot enough to present a visible glow in the daylight. While it was believed that molten lava existed at a depth of a mile or more below the vents in the crater, and spherical particles were occasionally found in collections of the debris, no molten material was ever found in the ejecta near the crater. The particle clouds shown in Figures 3 through 6 (seen from distances of 15, 9, 6, and 3 miles, respectively) resulted from separate and distinct eruptions.

Figures 7 through 8 are photographs of highly wind-sheared clouds formed from a rapid series of eruptions. These clouds are diffuse and broad but sufficiently dense so that the sun cannot be seen. Figure 7 was taken 15 miles from the volcano, and Figure 8 was taken 9 miles away.

During the course of the investigations, many photographs were taken of the behavior of the airborne particles after their deposit on exposed surfaces and objects. Several of these photographs have been selected for presentation in this report to illustrate, pictorially, several fallout environments that could occur in a nuclear war.

No technical data are presented; these are presented in separate technical reports.[1,2,3] The general subjects covered by the photographic material are (1) contamination of structures. (2) contamination of streets, sidewalks, and roads, (3) contamination of automobiles, (4) contamination of people, (5) contamination of vegetation, and (6) Costa Rican decontamination methods.

During the course of the experimental work, it was found that deposits of particles were easily visible when they amounted to 1 to 3 grams per square foot of surface. If this layer of material had been composed of fallout particles carrying radioactive atoms on a large flat open area, the radiation level would have been about 100 roentgens per hour, measured 3 feet above the ground at 1 hour after detonation of a nuclear weapon near the ground surface. This radiation level would generally require humans to remain in shelters for a few days to avoid detectable effects of radiation exposure.

The retention of particles by vegetation could have had two major consequences: (1) contact beta hazard to the plants and (2) contamination of food chains. Contact beta radiation would damage living plant tissue, and where the radiation doses are sufficiently large, many plants would die. Large-scale losses of vegetation on watershed areas could, in turn, result in serious erosion of the topsoil if heavy rainfall preceded regrowth of vegetation. In Costa Rica, very heavy deposits of volcanic particles killed all vegetation within 3 miles from the crater in the so-called dead area, shown in the cover photograph and in Figure 9.

Particle retention by foliage is the major pathway by which radionuclides on fallout particles enter food chains. As far is now known, the only short period food contamination problem is the entry of radioiodine into the milk supply, and this would be limited because the dairy cows could not be grazed on heavily contaminated pastures without serious radiation effects to both the cows and the dairymen.

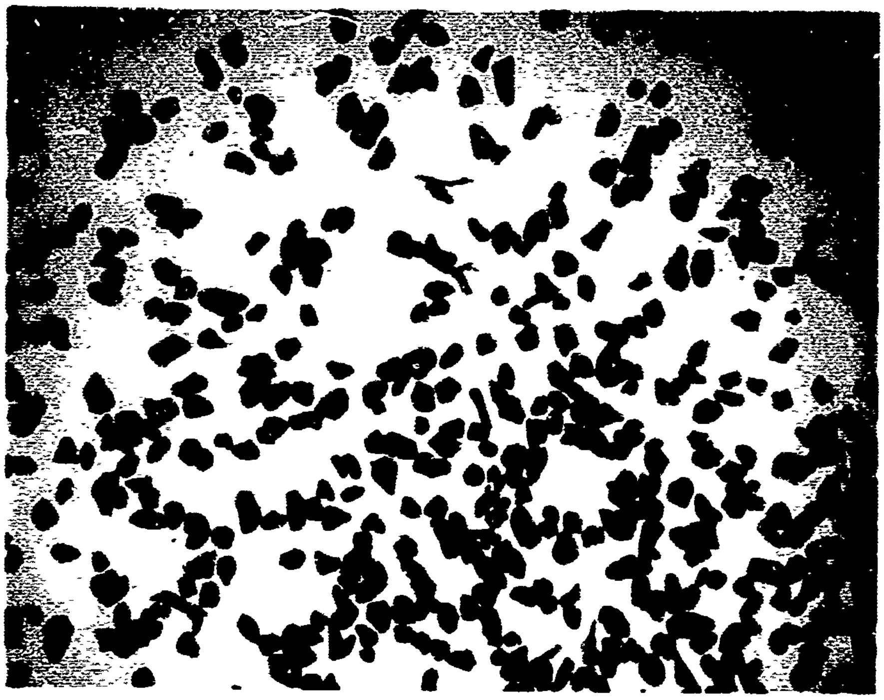
REFERENCES

1. Miller, Carl F., and Hong Lee, OPERATION CENIZA-ARENA: A Summary of Measurements on the Retention of Fallout Particles from Volcán Irazú (Costa Rica) by Plants and People, Part One, Stanford Research Institute, Project No. MU-5779, in preparation

2. Miller, Carl F., William B. Lane, and Jacqueline L. Joyce, OPERATION CENIZA-ARENA: A Summary of Measurements on the Retention of Fallout Particles from Volcán Irazú (Costa Rica) by Plants and People, Part Two, Stanford Research Institute, Project No. MU-5779, in preparation

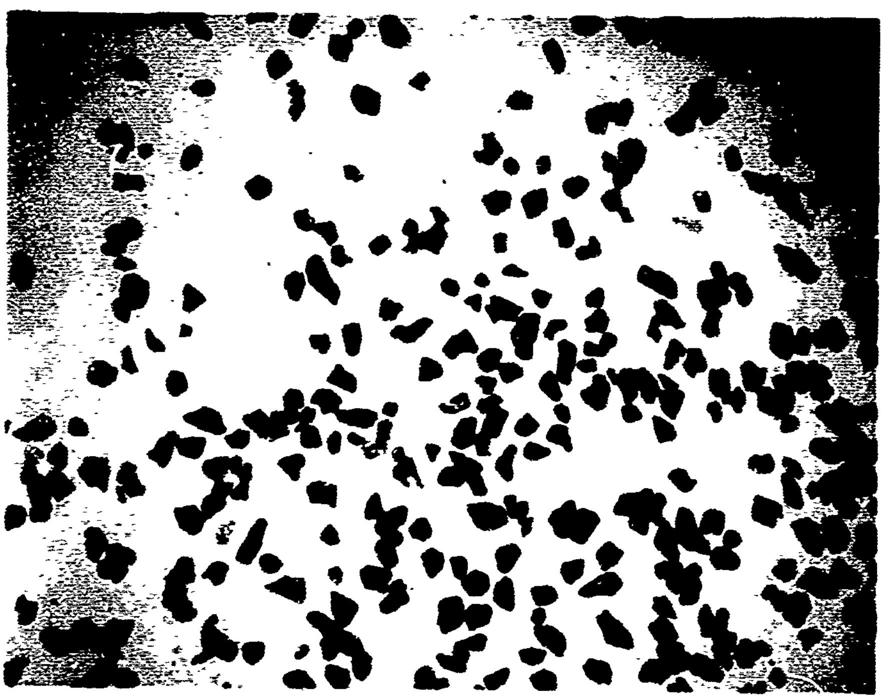
3. Clark, Donald E., Jr., and Hong Lee, Ceniza-Arena Cleanup in San José, Costa Rica: Operational Aspects as Related to Nuclear Weapon Fallout Decontamination, Stanford Research Institute, Project No. MU-5069, May 1965

Figure 1



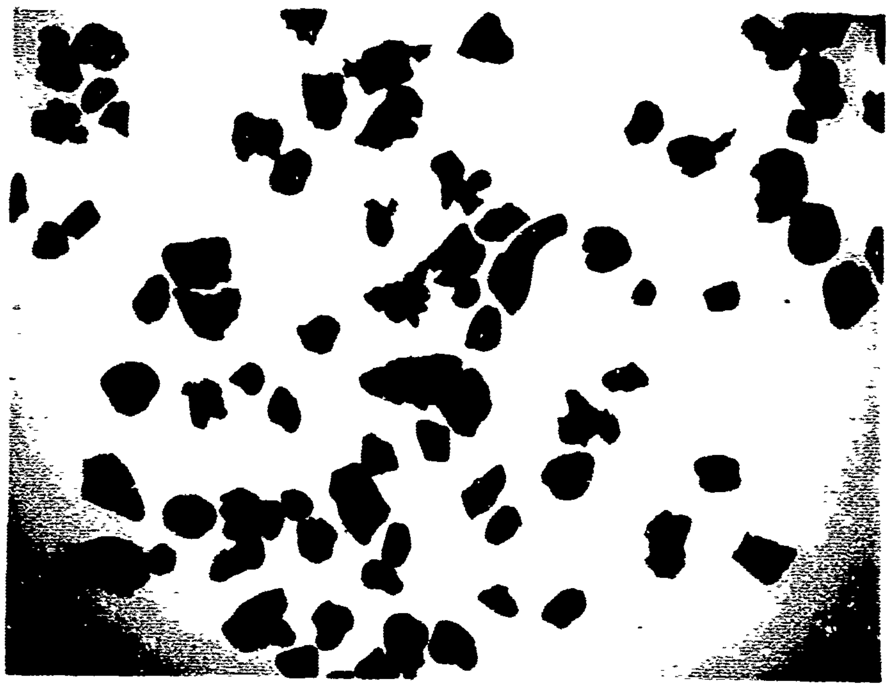
FALLOUT PARTICLES FROM A LOW-YIELD NEAR-SURFACE NUCLEAR DETONATION

Particle Size Range: 44 to 88 microns (mag 30X)



FALLOUT PARTICLES FROM AN ERUPTION OF VOLCANO IRAZU

Figure 2



FALLOUT PARTICLES FROM A LOW-YIELD NEAR-SURFACE NUCLEAR DETONATION

Particle Size Range: 88 to 175 microns (mag 30X)

FALLOUT PARTICLES FROM AN ERUPTION OF VOLCANO IRAZU

Figure 3

PARTICLE CLOUD

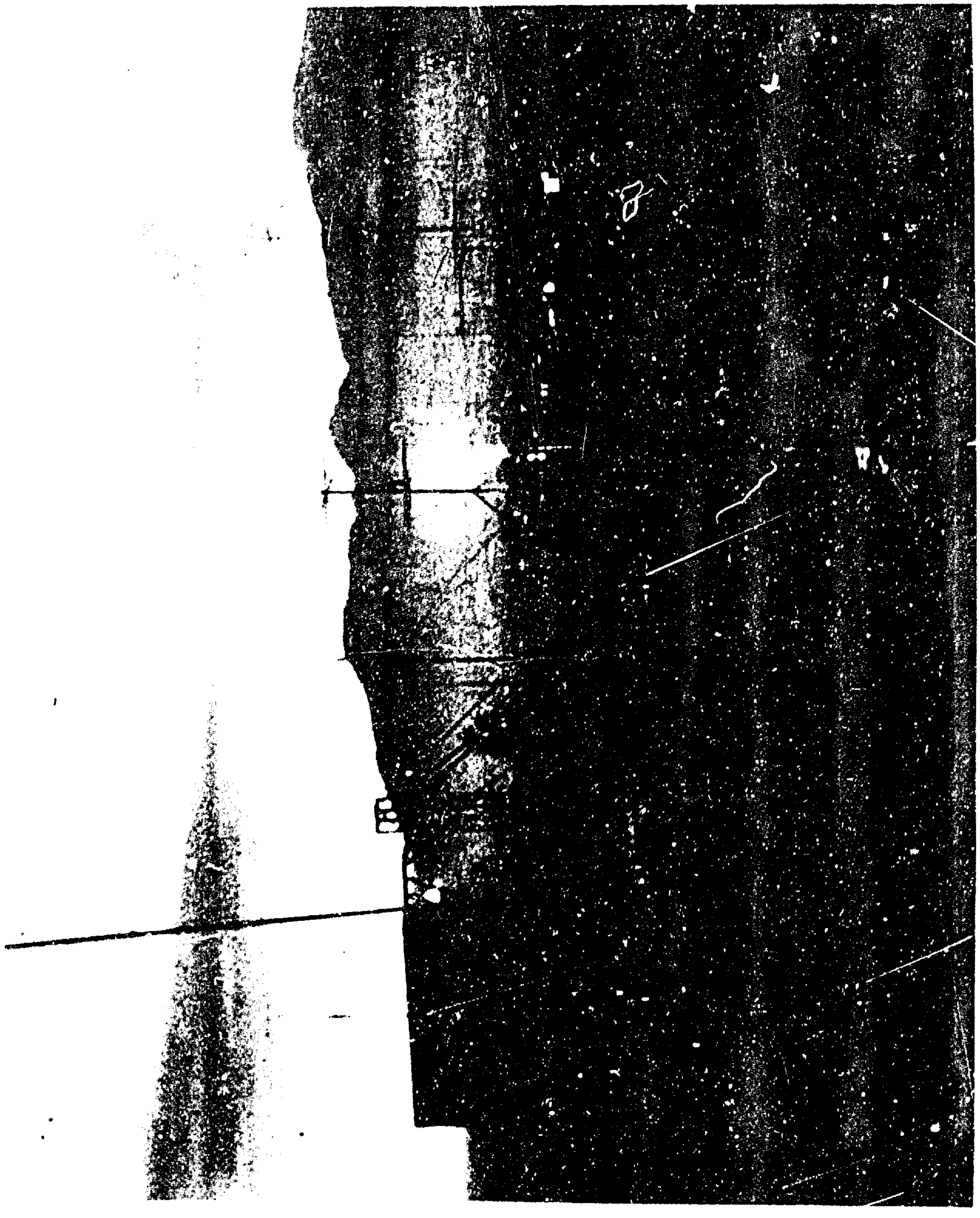


Figure 4

PARTICLE CLOUD

Figure 5

PARTICLE CLOUD

Figure 6

PARTICLE CLOUD

Figure 7

PARTICLE CLOUD

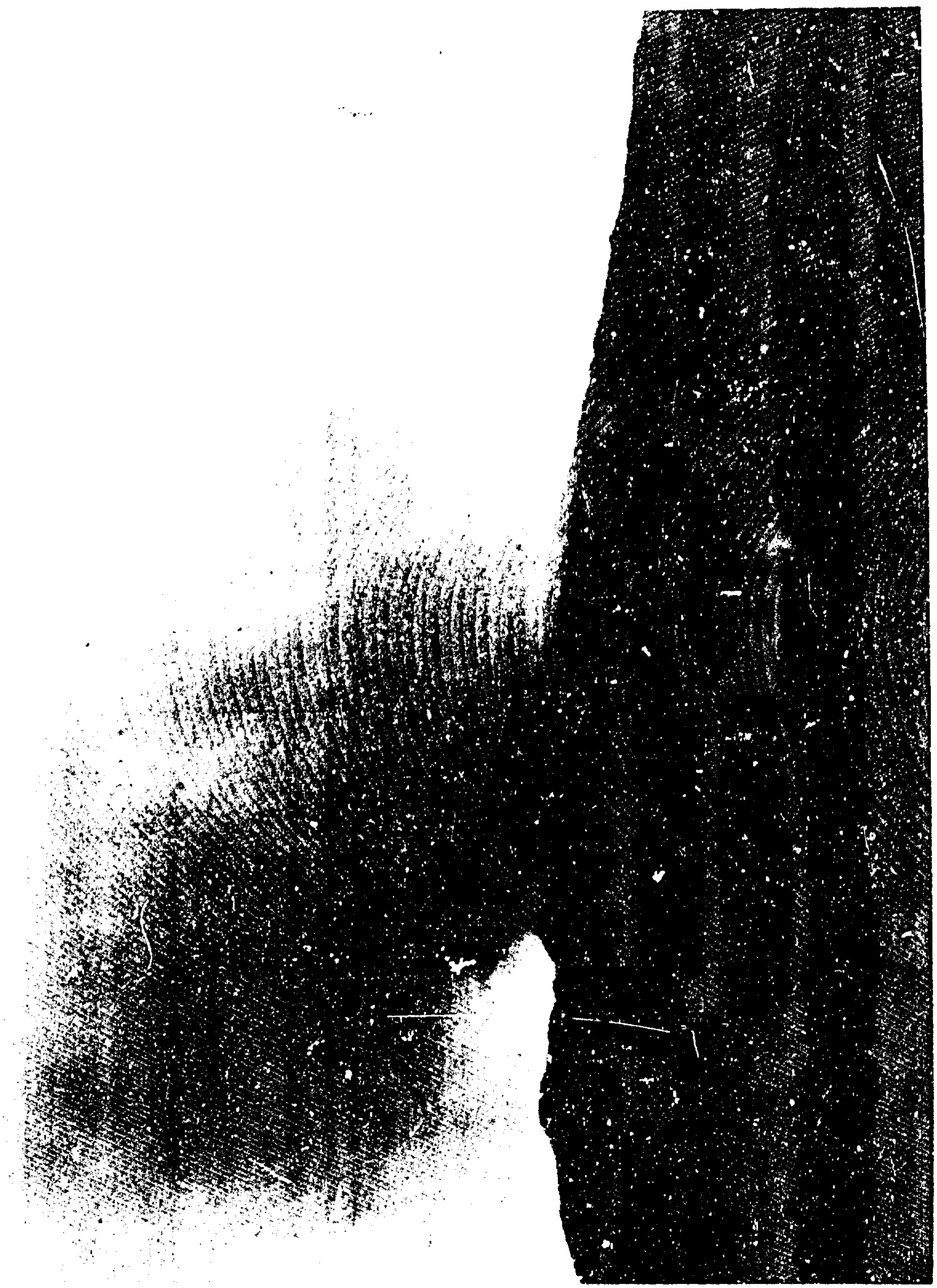


Figure 8

PARTICLE CLOUD

Figure 9

THE DEAD AREA

The dead area on the upper slopes of Irazú, where all the vegetation had been killed by heavy deposits of volcanic debris, corresponded to the image that many people have of the whole world after a large scale nuclear war. Technical studies, however, show that such conceptions are generally incorrect because of exaggerated views of the destructive power of nuclear explosions. The dead area shown here is probably a good representation of what the landscape might look like in the regions near the point of detonation of a nuclear weapon. It is not a good representation of the major portion of the regions on which the fallout would deposit; better representations of these regions are shown in the figures that follow.

Figure 10

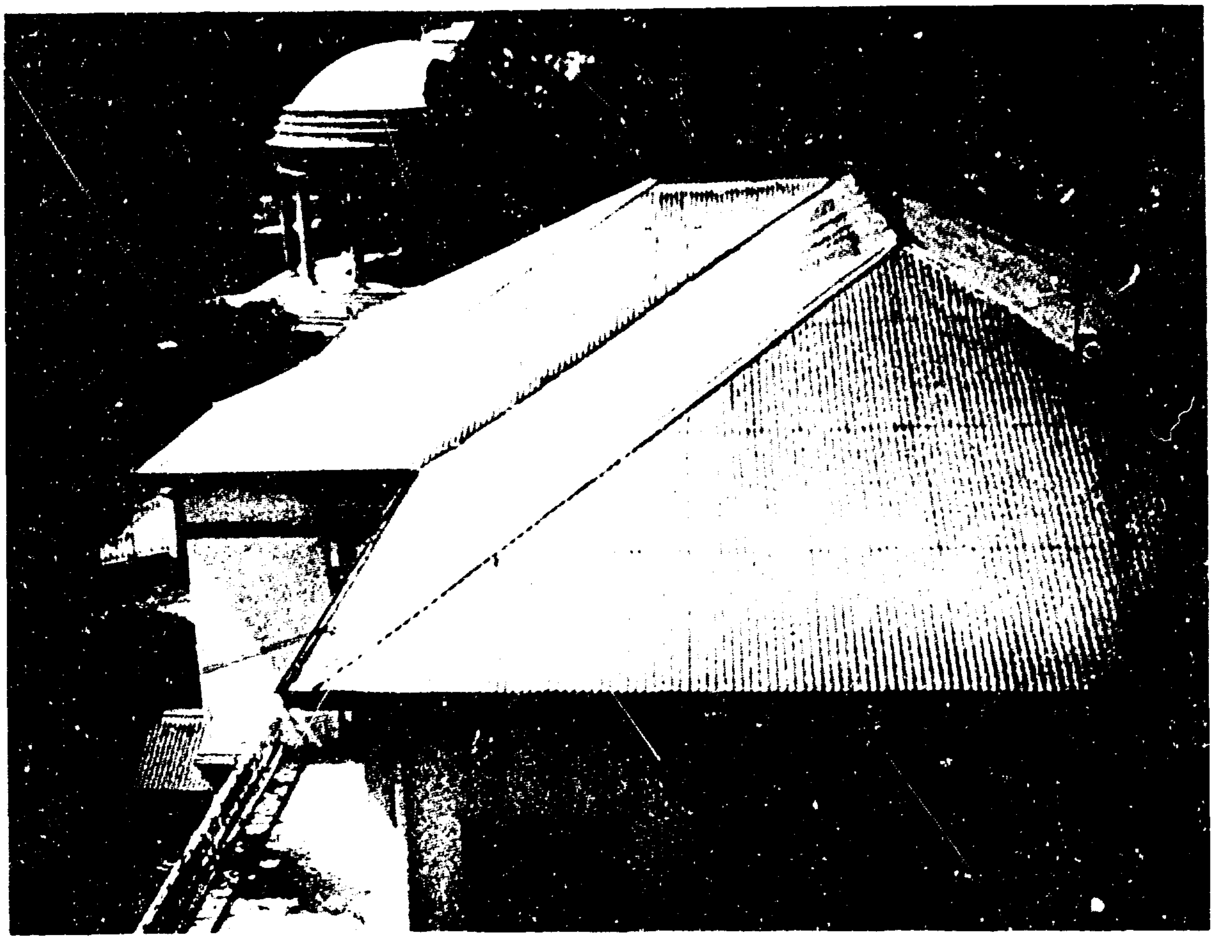
CONTAMINATION OF STRUCTURES

This is a view of an overnight deposit of particles on the lid of an instrument case located 6 miles from the volcano near the village of Rancho Redondo. Two members of the research team put their initials in the deposit to better show the depth of the deposit. Fallout from several nuclear weapons would be required to give such a depth of deposit.

After sundown, the relative humidity rapidly increased to 100 percent, and flat surfaces, such as the box cover, became damp. Also, the wind speed dropped and the surface air was generally calm until early morning. The particles deposited under such conditions adhered to smooth flat surfaces until they dried out in the morning sun. If only slightly damp, most of the particles would then gradually be blown from the surface by the midmorning winds.

Figure 11

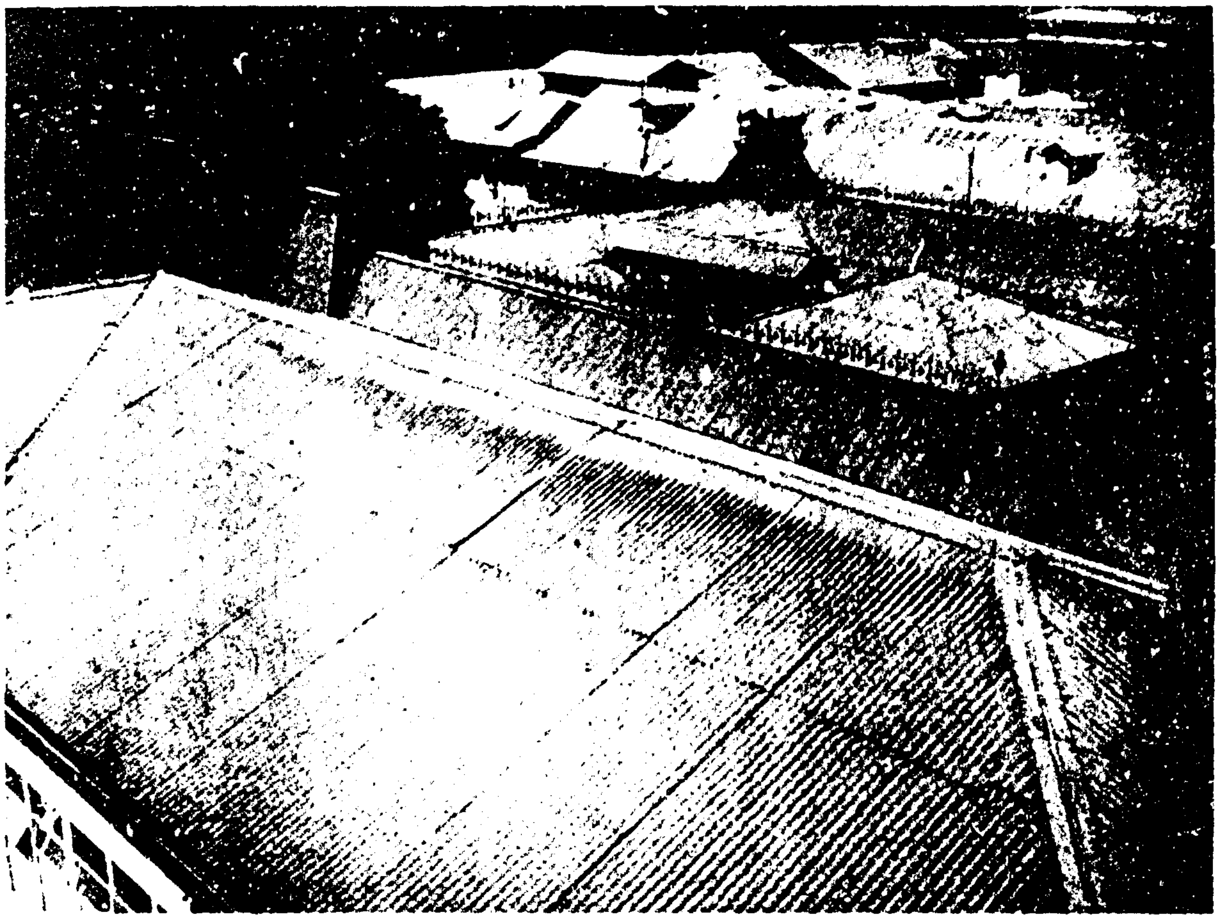
CONTAMINATION OF STRUCTURES



Most of the roofs in the capital city of San José are covered with corrugated iron. When the volcanic fallout particles arrived under dry conditions (relative humidity less than 90 percent) and with at least moderate surface wind speeds, the major accumulations appeared on the lee side of the roof just below the ridge, as shown. When the particles arrived under damp calm conditions during the night, they formed a uniform layer over the whole roof and generally remained in place until they were rapidly removed by the midmorning winds (which usually increased in velocity after sunrise because of terrain heating).

Figure 12

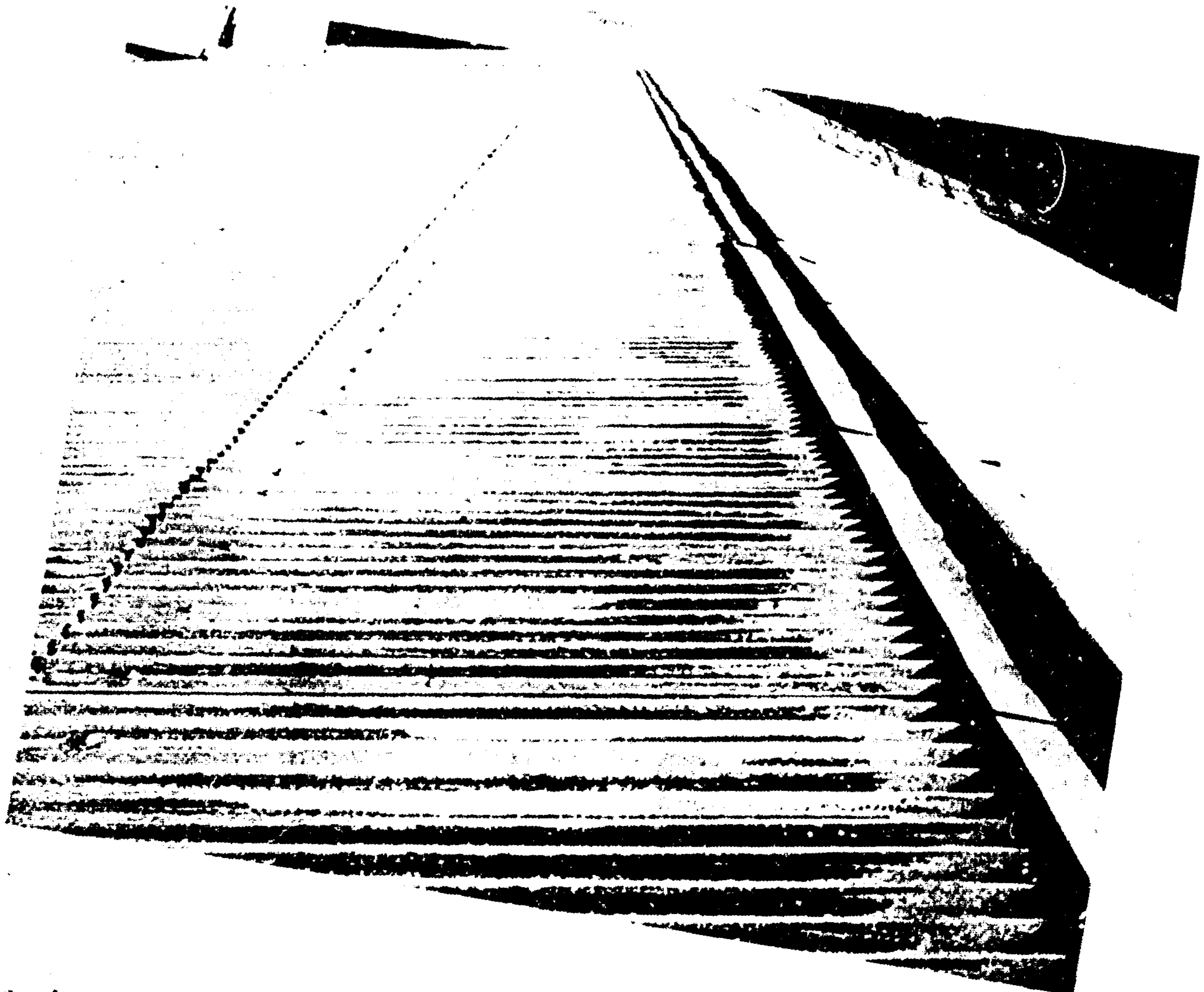
CONTAMINATION OF STRUCTURES



The particles drifted into roof gutters and into wind-protected places (see roof joins in Figure 11). After prolonged exposure, the weight of the material broke many roof gutters. It collected, to some degree, on windowsills and entered buildings through open windows (mostly during the wind weathering periods after a deposit under calm conditions at night). Most of the particles were deposited on the floor or on furniture near the open windows. Particles blown from the roofs were mainly deposited in the streets. Some fell on pedestrians and lodged in their hair, clothes, and eyes.

Figure 13

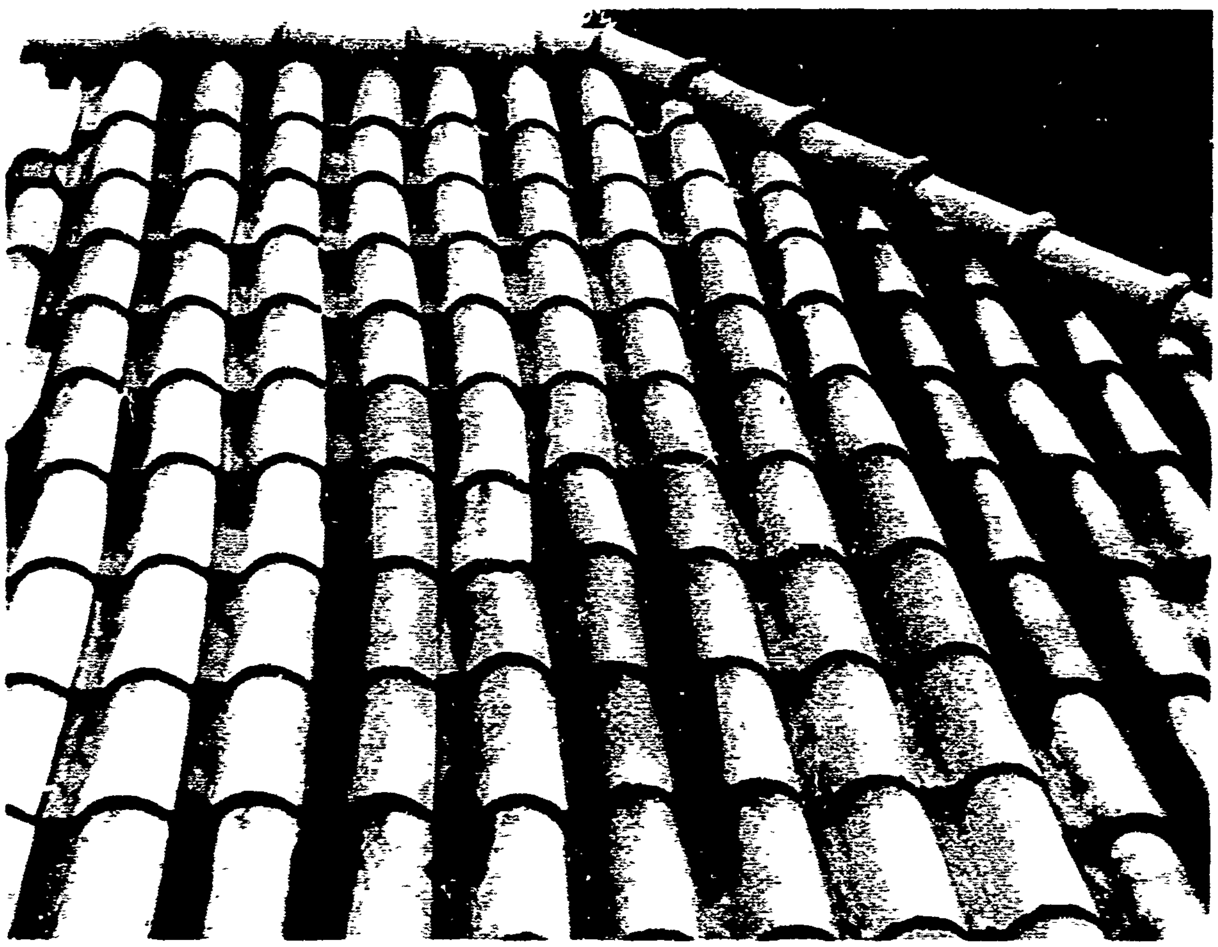
CONTAMINATION OF STRUCTURES



The wind did not erode the volcanic fallout particles from graveled areas to any great extent. Thus it may be concluded that wind would not remove very many nuclear weapon fallout particles from flat gravel-covered roofs. Nuclear radiation from the particles would emanate from the whole area of such roofs until either the radioactivity decayed or the gravel and fallout particles were removed from the roof by decontamination. However, on the smooth sloped roofs, such particles would form two line sources of radiation--one along the ridge of the roof and one along the edge of the roof (from the particles in the roof gutters).

Figure 14

CONTAMINATION OF STRUCTURES



Some houses in the residential districts of San José had tile roofs. The particles collected in the depressions between the tiles, as shown in the figure. The wind was not very effective in removing the particles from the depressions but most were washed off in a heavy rainfall. The deposits in the figure show evidence of being wetted by a light rain and have piled up between some of the tiles; the larger accumulations were still damp when the photograph was taken. Under dry and windy conditions, some of the particles sifted under the tiles; but, from the amounts of material left in the depression compared with the amounts deposited on the surrounding areas, it appeared that only a very small percentage of the deposits could have sifted under the tiles.

Figure 15

CONTAMINATION OF STREETS AND SIDEWALKS

This is a view of a fresh deposit on the streets of San José that fell during the early morning hours under calm surface wind conditions. The tracks of two cars are clearly visible, like tracks through a light fall of dark grey snow. Even very light deposits could be detected visually on streets after the passage of an automobile by the difference in sheen or reflected light between the track and the rest of the asphalt pavement. This sheen is not observed after wind weathering and is not seen on streets without an undisturbed thin layer of dust.

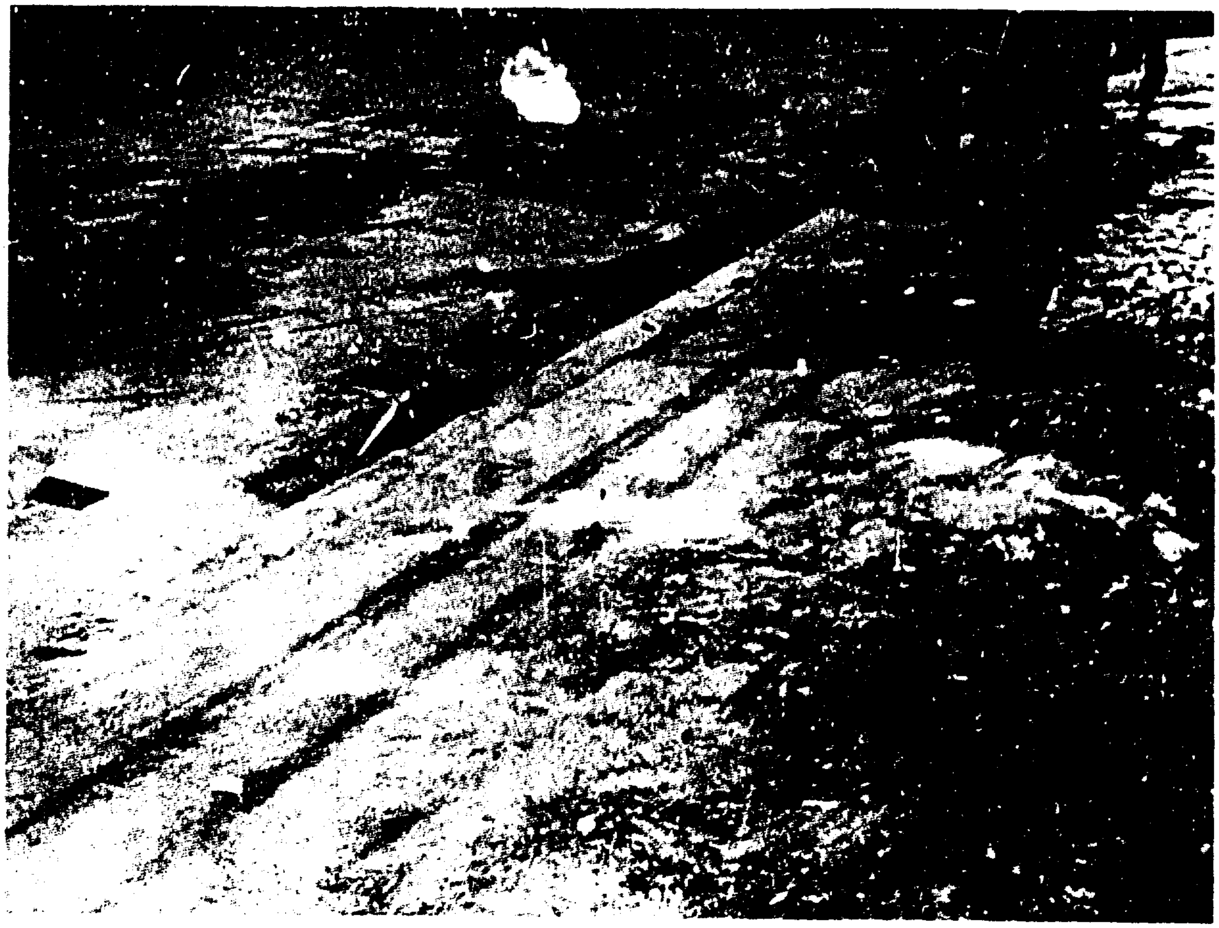
Figure 16

CONTAMINATION OF STREETS AND SIDEWALKS

This is a view of a contaminated street and sidewalk that was taken during the mid-morning hours. The center of the street has been cleaned by the combined action of wind and passing automobiles. The deposit, which was uniformly spread over the street at daybreak, has shifted toward the gutters. The deposit on the sidewalk, protected from the wind, has been only slightly disturbed by passing pedestrians. The particles that were redistributed by the wind drifted along the surface of the road much like dry snow over a clean macadam surface. Very strong winds were required to lift the particles higher than 3 or 4 inches above the pavement.

Figure 17

CONTAMINATION OF STREETS AND SIDEWALKS



This view of the volcanic fallout on the street and sidewalk was taken in the early afternoon. The street deposit had been moving since morning to the right and around the corner due to wind action. The center of the intersection has been cleaned by the passing automobiles and the wind. The wind also moved the deposit on the sidewalk toward the building. People walking over the dry deposit did not tend to move the particles very far. On the other hand, shoes did pick up wetted deposits and carried the particles into the shops and homes. The damp particles did not adhere to shoes strongly since they were more like sand than like clay or mud.

Figure 18

CONTAMINATION OF STREETS AND SIDEWALKS

This is another view of street and sidewalk contamination taken in the early afternoon after the volcanic fallout particles had been redistributed by wind and passing cars. The particles have accumulated near the curb and in cracks and small depressions in the concrete pavement. On many intersections, a triangular-shaped area at one of the wind-protected corners was observed to retain the particles that drifted in from other sections of the street. If the shown deposits were fresh nuclear weapon fallout, the pedestrians would most likely not be present in this picture.

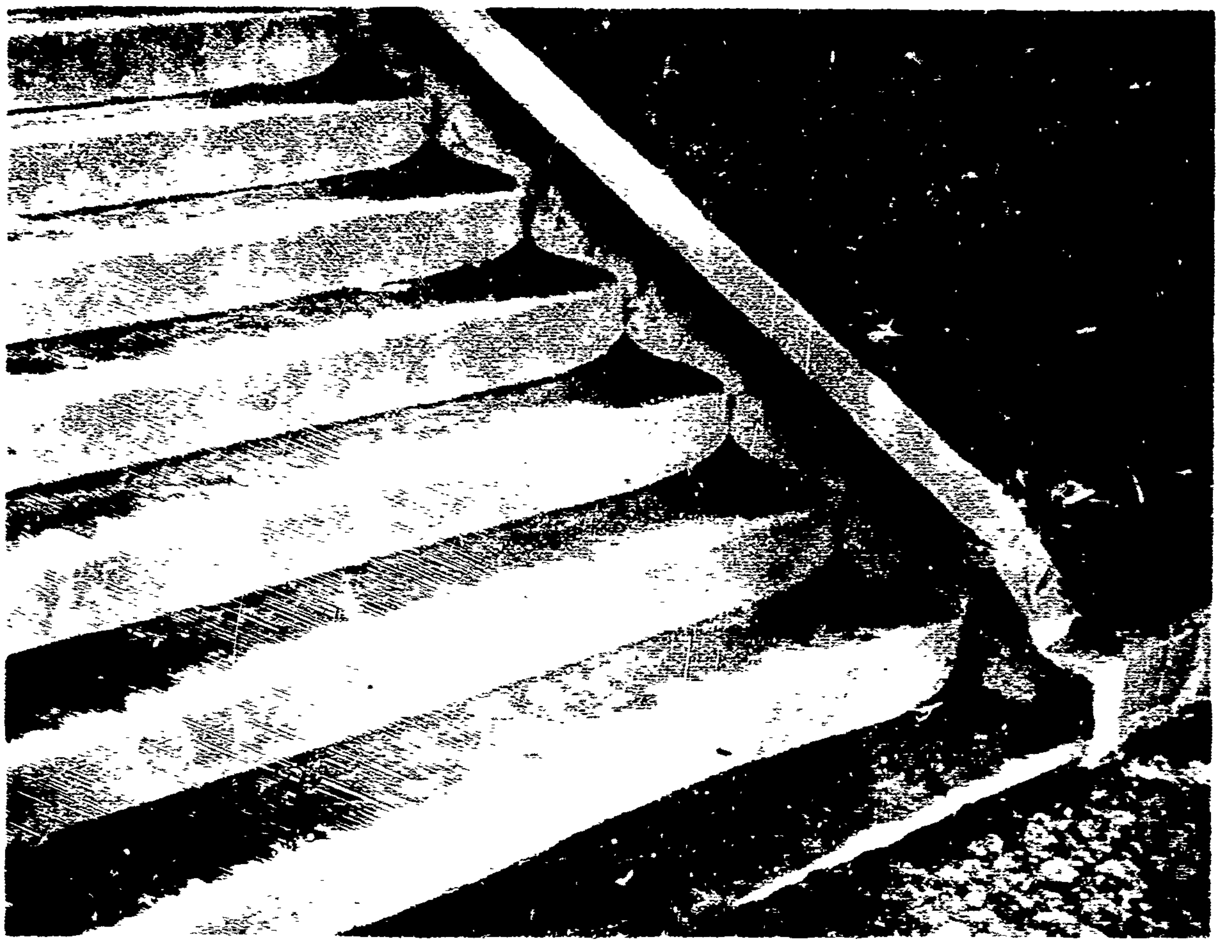
Figure 19

CONTAMINATION OF ROADS

This is a view of the deposits on the road up the slope of volcano Irazú in the dry season. The road was clean where the tires ran. Since the particles were fairly large, little dust was raised by the passing of vehicles over the road, and the disturbed particles did not travel very far before coming to rest in the center or on the edge of the road. Such a road would be washed clean by one good rain shower in the rainy season.

Figure 20

CONTAMINATION OF STEPS AND SIDEWALKS



This view was taken at the University of Costa Rica during the dry season. The wind and pedestrian traffic has, to some degree, moved the deposits from the higher to the lower steps and to the wind-protected corners of each step. The deposits apparently show the accumulation of particles for several weeks and, therefore, are somewhat thicker than would be expected in areas that might receive fallout from a nuclear explosion without receiving blast and heat effects.

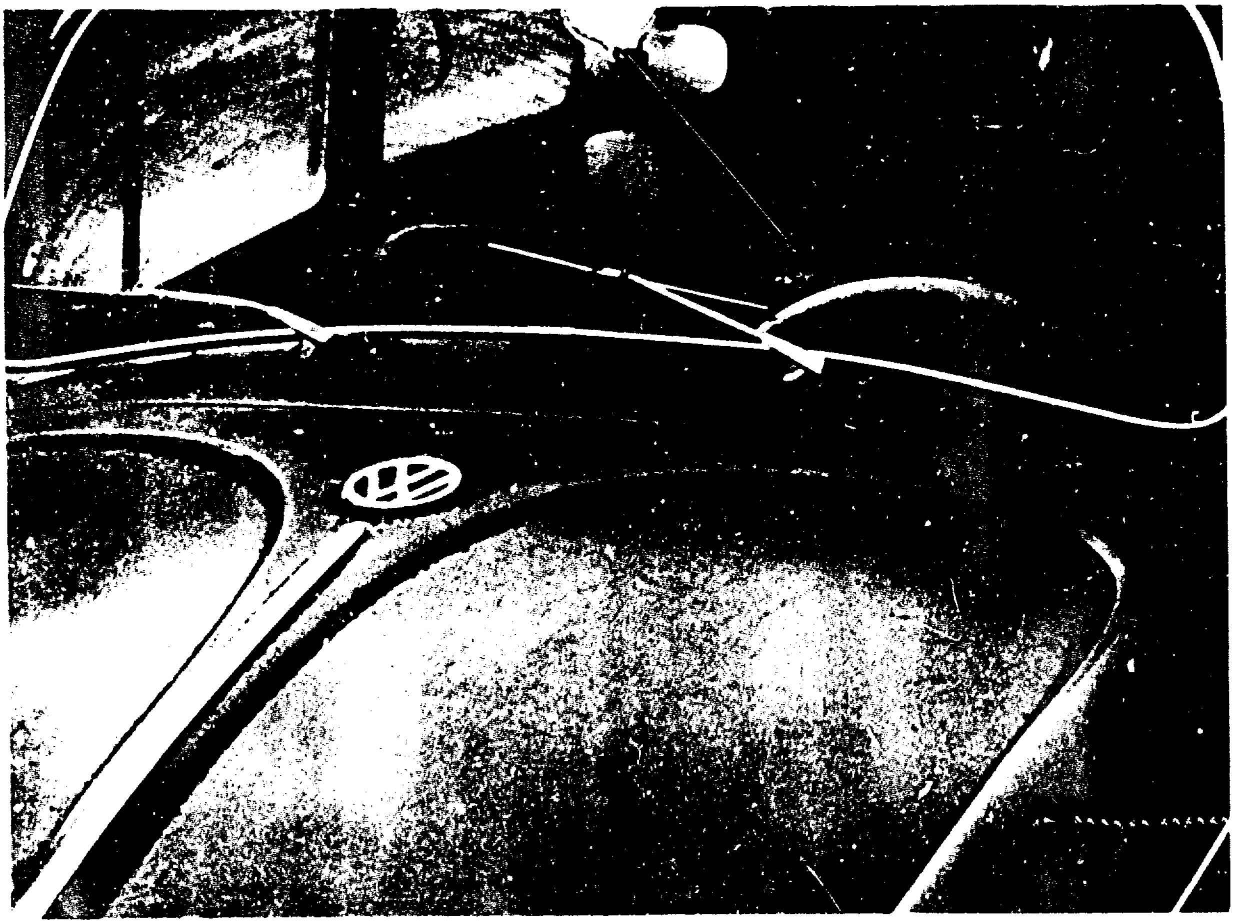
Figure 21

CONTAMINATION OF STEPS AND SIDEWALKS

The wind has moved the particles to the grass at the left edge of the sidewalk where it was piled in small drifts. The deposit on the right, protected from the wind by the building and step, has been disturbed only locally by pedestrian traffic. It is somewhat thicker than average because of drifting from the steps at the right. Deposits on the grass areas were not redistributed by the wind but generally stayed in place. Grass areas thus could receive and trap particles that drifted in from the paved areas but did not lose particles to other areas.

Figure 22

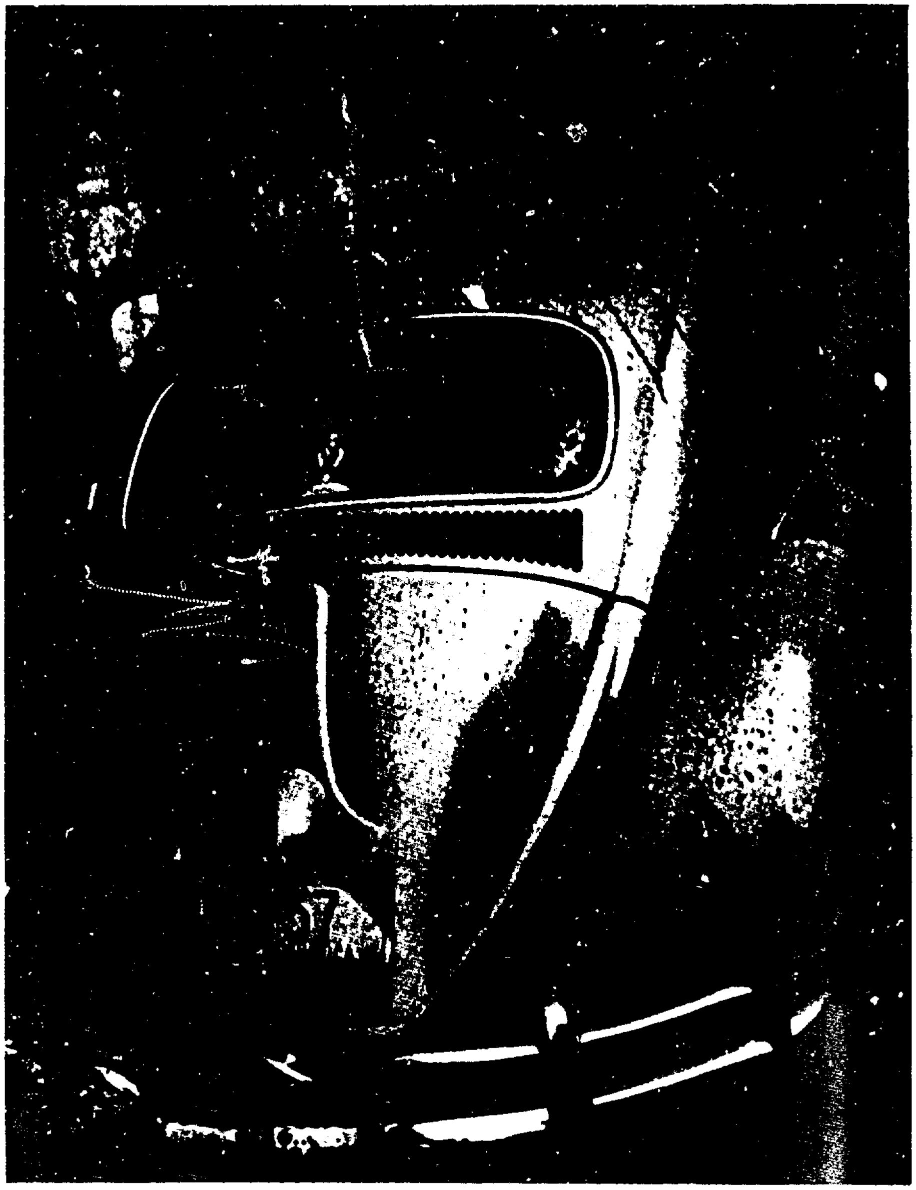
CONTAMINATION OF AUTOMOBILES



Figures 22 and 23 show the deposits on two different small cars at two times. When the particles were deposited under dry conditions and fairly low wind speeds on parked automobiles, the particles collected on the more flat horizontal surfaces (especially in wind-protected locations), along folds in the metal, on ledges, and on greasy surfaces. Under such conditions, most of the particles fell off the car when it was moved. Under damp conditions, especially when the car surface was wet with dew at the time of the deposit, the particles were retained on the wetted locations (see streamers of particles in Figure 23 where water drops had been draining from the top of the car). Particles deposited in the wet condition did not fall off

Figure 23

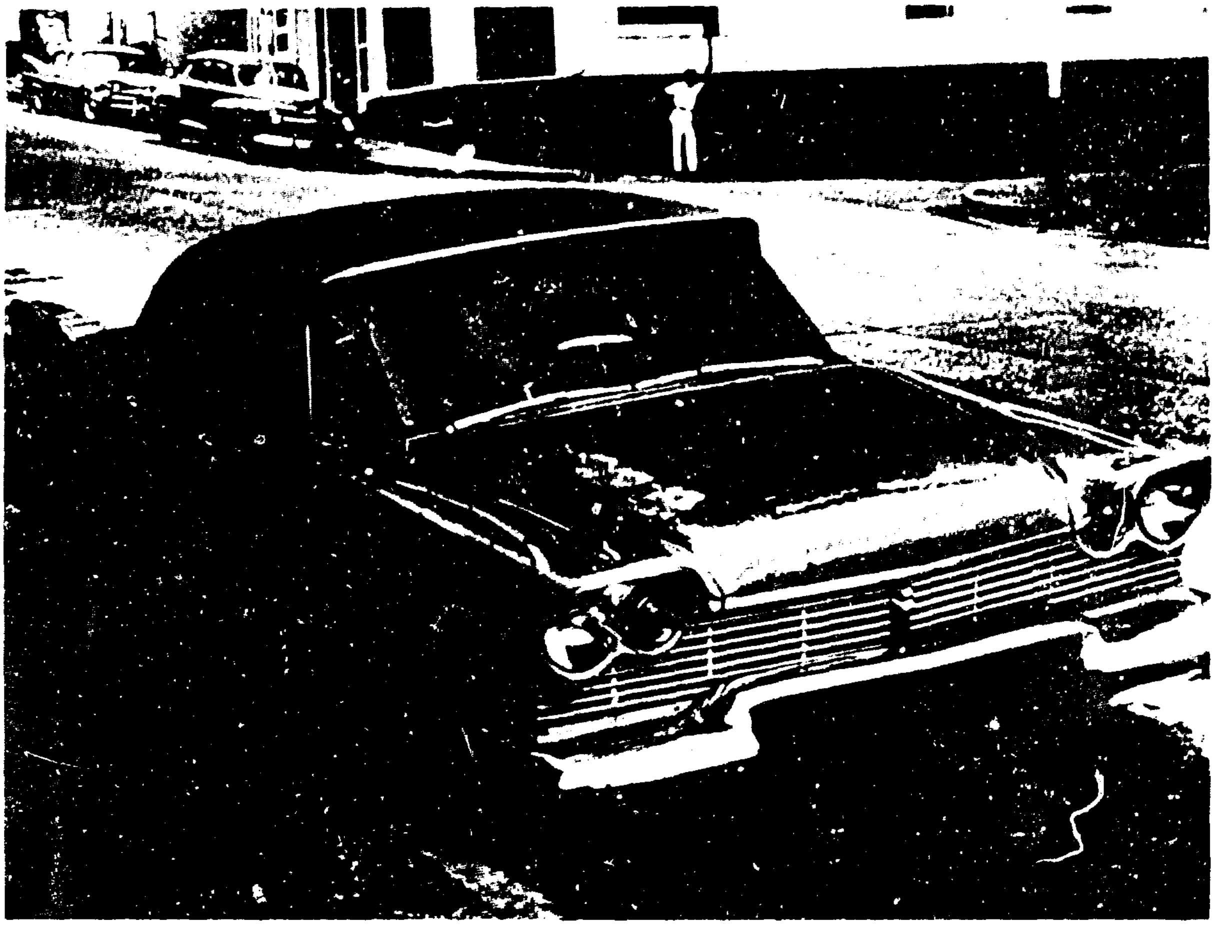
CONTAMINATION OF AUTOMOBILES



when the car was moved unless the deposit was very heavy. The same result occurred when the particles impacted on a moving car along with a light rain. In a heavy rain, they streamed down the windshield along with the water, similar to the way splashed-up soil or mud particles do when a car is driven in a rain on a dirt road with holes filled with water, the main difference being that the volcanic particles, like local fallout particles, were more like wet sand than like mud containing clay soil.

Figure 24

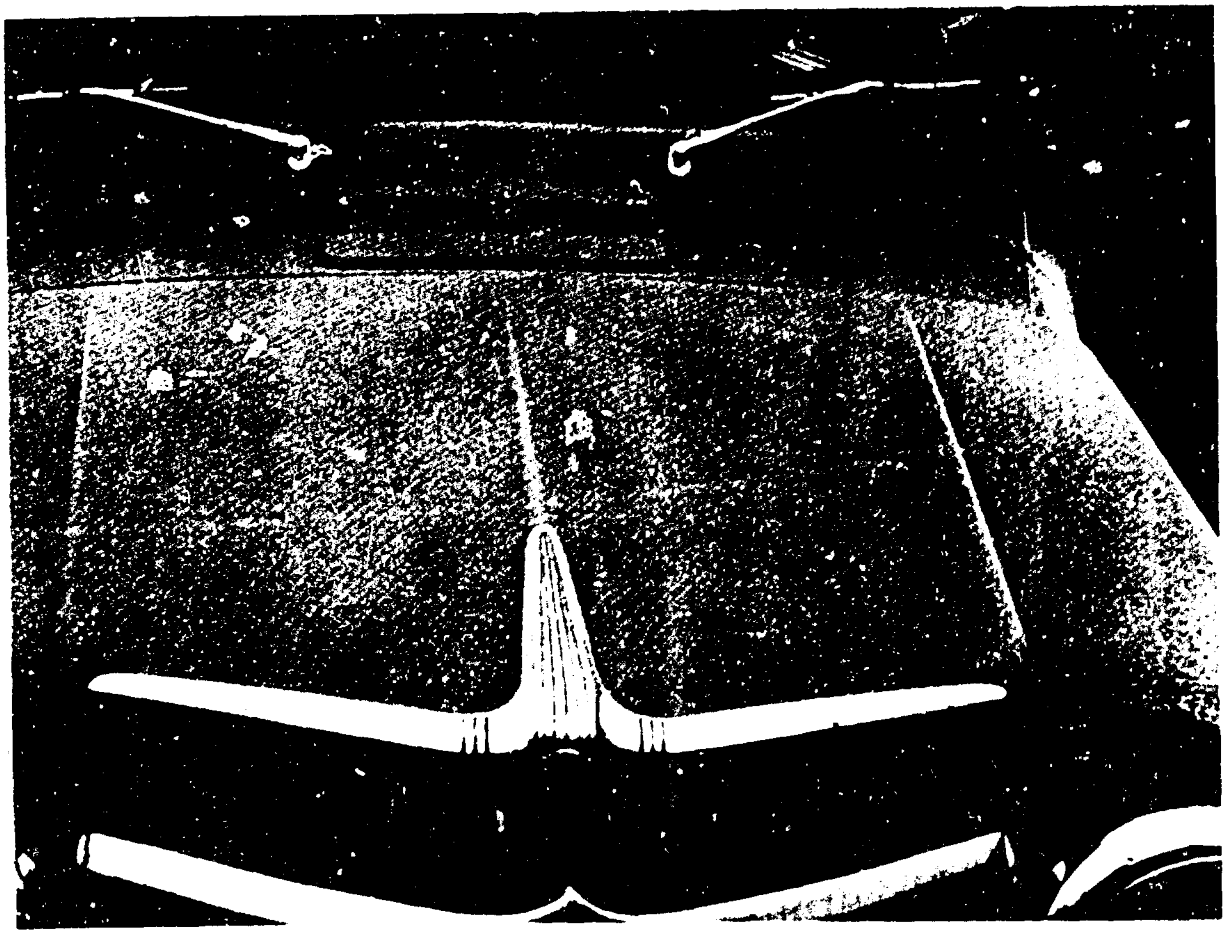
CONTAMINATION OF AUTOMOBILES



Many of the volcanic fallout particles, like those from near-surface nuclear detonations, arrived in the form of agglomerated particles (e.g., fairly large particles that were composed of many smaller particles weakly attached to each other). When these impacted on a dry hard surface,they tended to shatter into smaller particles which spattered onto the surface near the point of impact. A discrete hard particle of the same size as the agglomerated particle had more tendency to bounce and roll when it landed on a dry hard surface. This tendency to bounce was reduced when the surface was covered with a scattered layer of water drops.

Figure 25

CONTAMINATION OF AUTOMOBILES



Automobiles with deposits as thick as those shown in Figures 23, 24, and 25 were, to a large extent, cleaned by the winds during the midmorning hours after the particles dried out. However, washing was required to remove the final layer of particles from the surfaces.

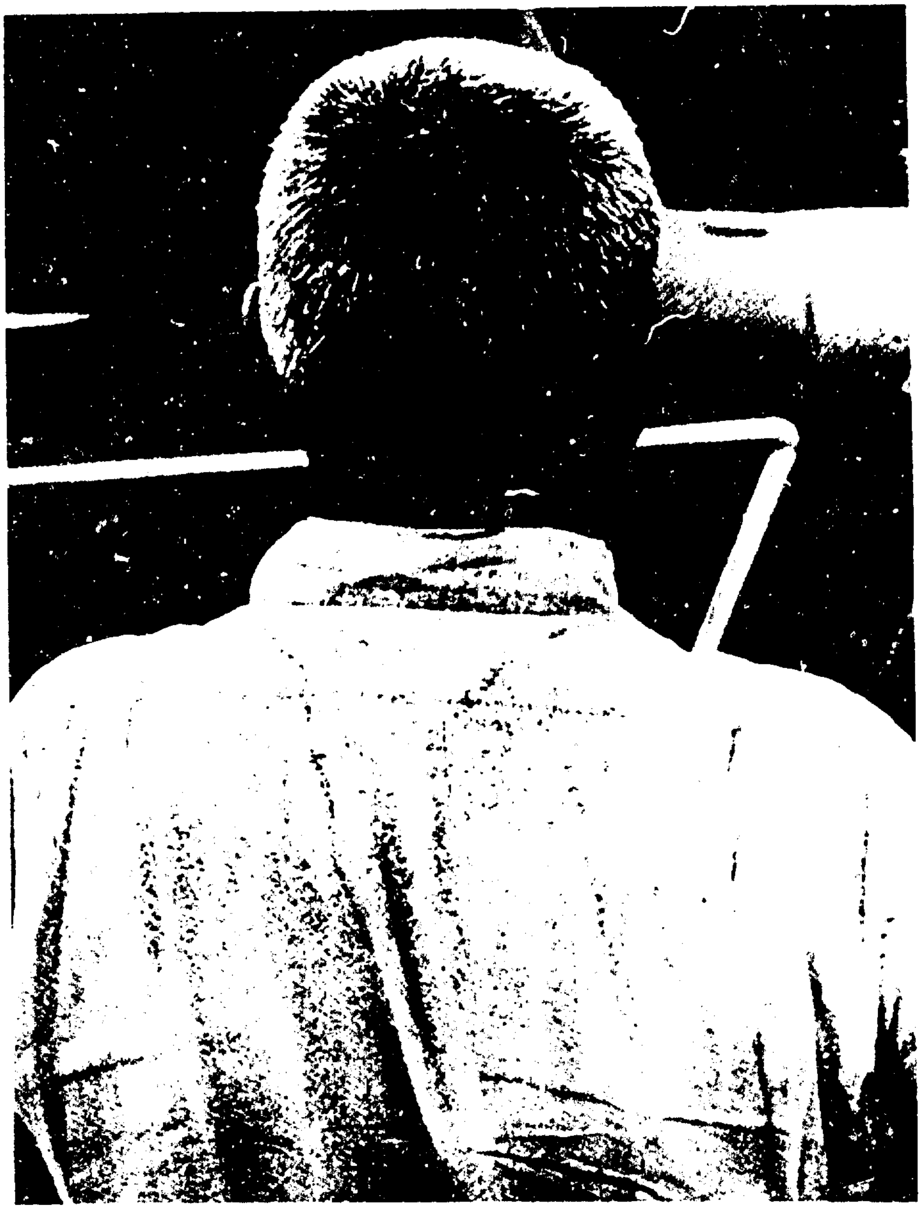
Figure 26

CONTAMINATION OF PEOPLE

The first sensation by humans in a particle shower was the impact of the particles on the nose and forehead. Local fallout particles from nuclear detonations are generally too large to enter the nose by normal breathing, and this was also true of the volcanic particles at distances up to about 30 miles from the volcano where the deposit levels were readily observed and measurable. After a few minutes of exposure, the second sensation was a gritty feeling on the lips and between the teeth. Next noticed was a disturbance in the scalp--especially for people with short haircuts.

Figure 27

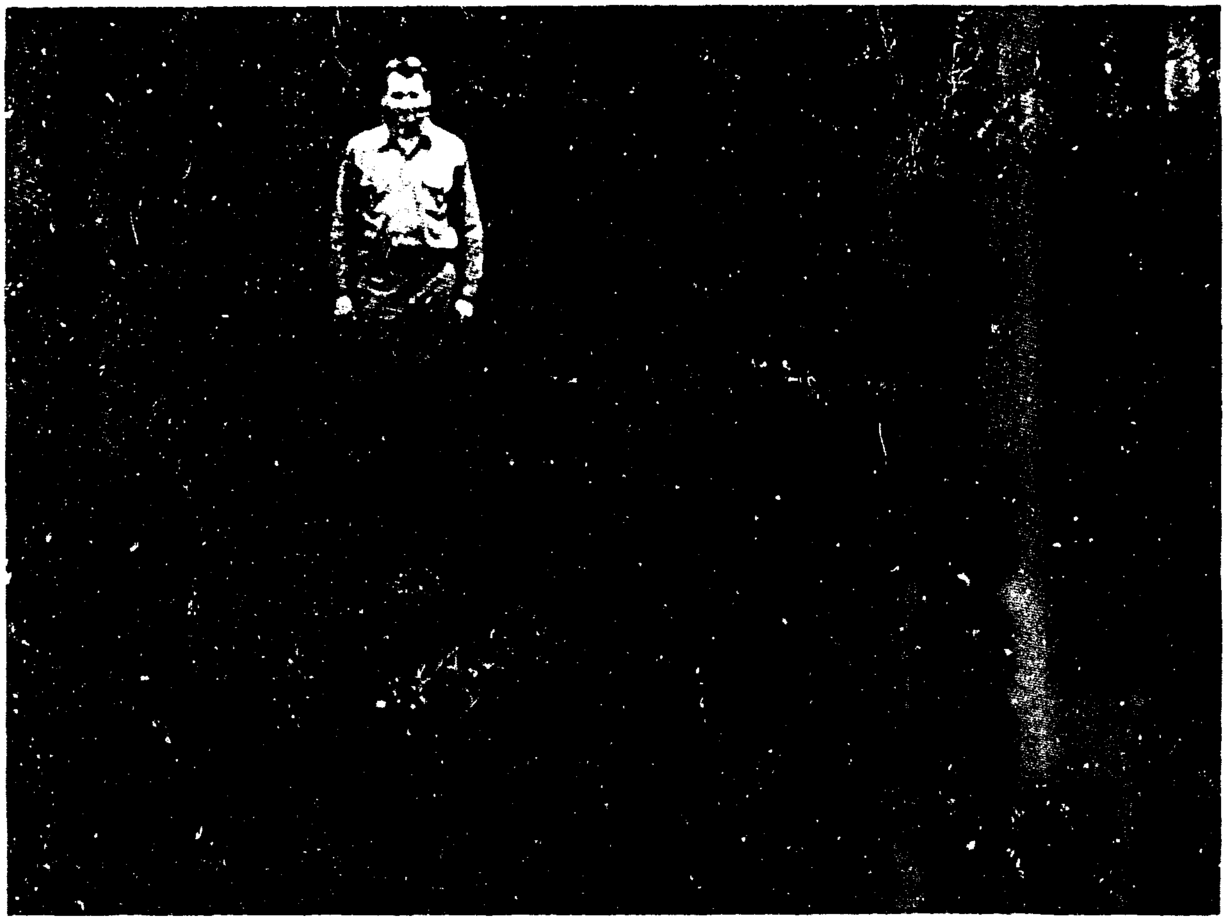
CONTAMINATION OF PEOPLE



On clothes, the particles collected in the folds, in pockets, in cuffs, and under belts. If the clothes and particles were dry, the particles could be readily removed by shaking. The particles were not so readily removed from damp cotton cloth and had some tendency to adhere to dry plastic fabrics, presumably because of static electric charge on the fabrics. On women wearing open-necked blouses, the particles landing on the collars and the neck sifted into brassiere cups and other underclothing.

Figure 28

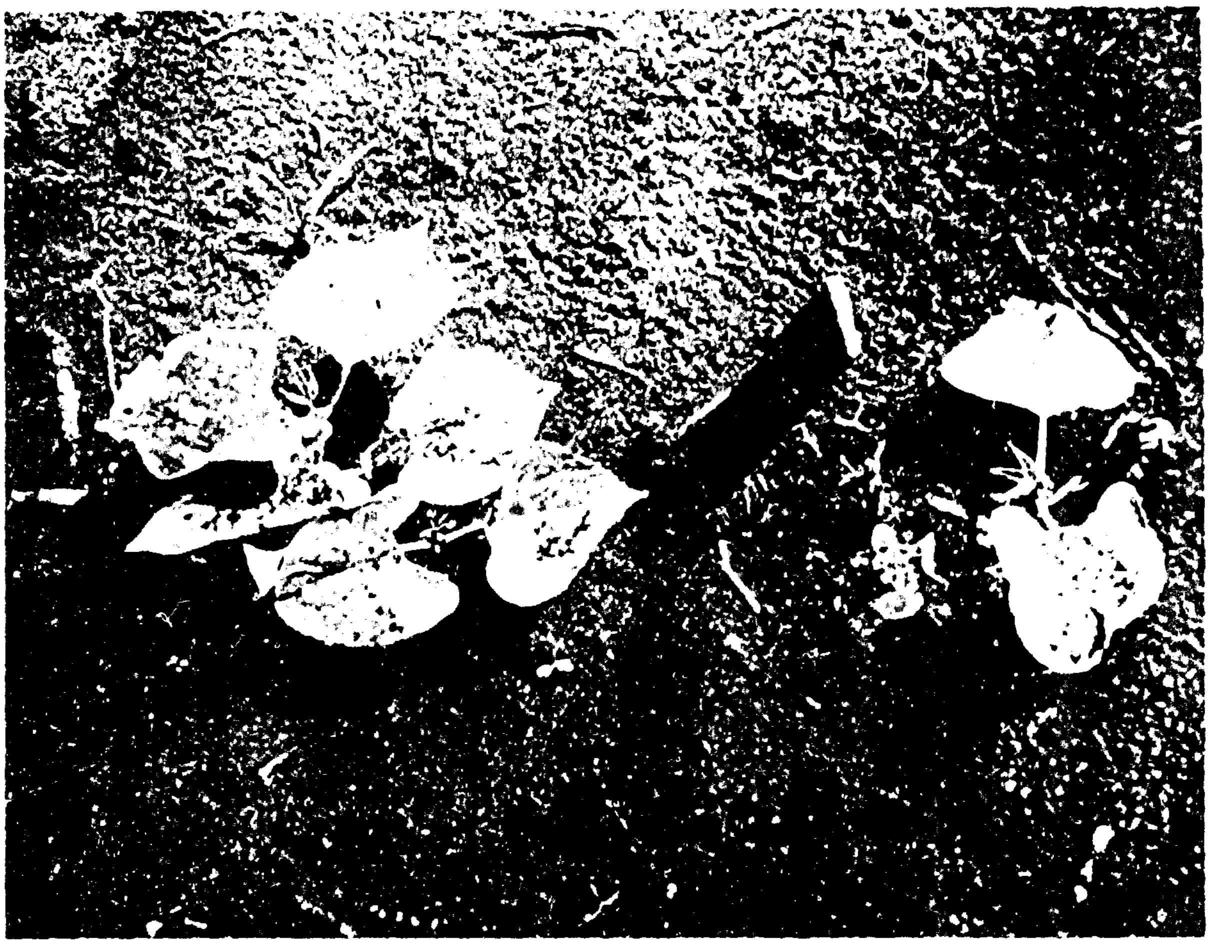
CONTAMINATION OF VEGETATION: LAWNS



Lawn grass was a good particle collector, and due to the low wind speed at the height of the grass and its tendency to dry relatively slowly after sunup, the particles tended to remain on the grass blades for long periods. However, when the grass was walked on, the particles were loosened and fell into the root mat; thus, as in the figure, the pathways of pedestrian travel can be seen readily.

Figure 29

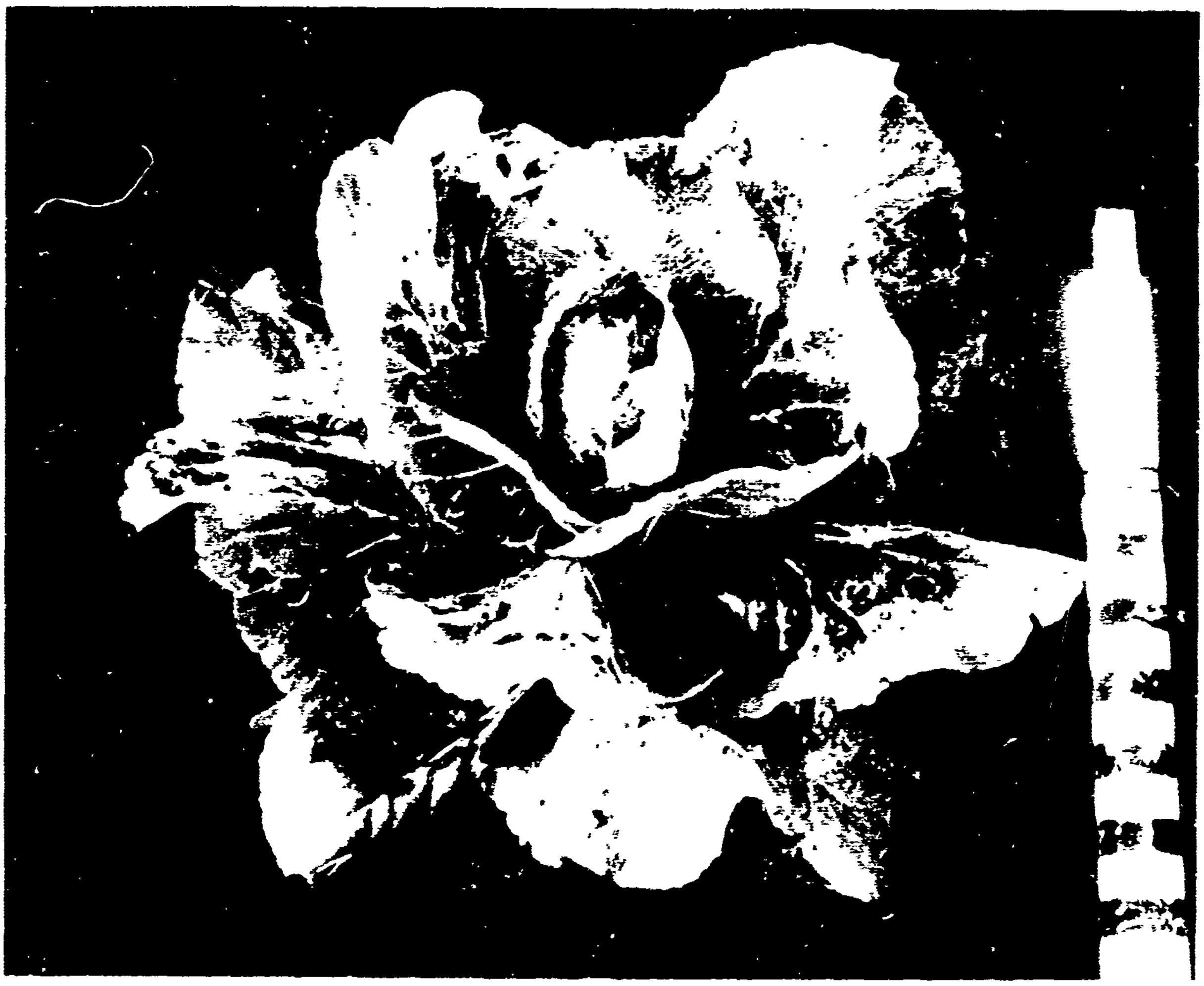
CONTAMINATION OF VEGETATION: BEANS



This is a view of small bean plants that were contaminated under dry conditions and, a few minutes later, received a few drops of rain. The particles can be seen concentrated in the folds of the small and larger leaves and on the portions of the leaves that are nearest to being horizontal. The leaf with rounded clean spots is flat and horizontal. The water drops displaced particles to the side when the drops landed on the leaf, and the water then spread through the particle layer and evaporated. On other leaves, the water drops wetted a few particles and drew them together to form small mud balls before the water evaporated.

Figure 30

CONTAMINATION OF VEGETATION: CABBAGE



At this stage of growth, cabbage plants were good particle collectors. When the leaves were wet with dew, the exposed portions of the leaves usually were fairly uniformly covered with particles. However, the surface of the cabbage leaves is fairly smooth, and when the particles dried they drifted down the sloped portions of the leaves to the ground, to the center of the plant, or to the lower center portion of a cup-shaped leaf.

Since the cabbage heads grow from the inside and the outer leaves form a good seal around the head, particles were never found below the outer leaves on matured cabbage heads. Thus, in fallout from nuclear detonations, the matured cabbage heads could be contaminated only by foliar absorption of the soluble radioactive elements. But even then, for elements such as Sr-90, which do not translocate within the plants very far from the point of absorption, it is expected that only the outer leaves, which retain the particles, would be contaminated in this manner. (The marked rule in the figure was used to determine the size of the plants from the photograph.)

Figure 31

CONTAMINATION OF VEGETATION: CORN

On young corn plants, the funnel shape of the new top leaf was the site in which many of the impacting particles were collected and retained. Once in the funnel, the particles were not dislodged, to any large degree, by wind or even rain. Particles also tended to collect in the leaf folds near the stem of the second, third, and even fourth leaf from the top. Also, small particles tended to be trapped in the fine hair on the top surface of the leaves on older corn plants. Otherwise, heavy deposits on the leaves that were retained under damp conditions and light surface winds during a particle shower eroded quite rapidly in the wind after drying.

Figure 32

CONTAMINATION OF VEGETATION: CORN

On older plants, the tassel was found to retain a fairly large amount of particles that shifted into the structure of the tassel head. (The corn plants in Figure 32 were stunted because of high rainfall, lack of sunshine, cool weather, and acid-burn from some of the particle showers.) Although particles did collect on the silk fibers, especially after they became soft, and in the outer leaf folds between the husk and stalk, particles were never found on the inside of the husk in contact with the ear. Like the cabbage head, the corn grain would not be expected to be directly contaminated by radioactive elements in fallout from nuclear weapons.

Figure 33

CONTAMINATION OF VEGETATION: TRANSVAAL DAISY AND GLADIOLA

With occasional very heavy deposits under damp conditions, low growing plants had almost the same color as the carpet of particles on the ground under the leaves. The particles even coated the leaf stems, and the flower heads, weighted with a heavy load of particles, are lying facedown on the soil. The back side of the young gladiola blade is relatively clean.

Figure 34

CONTAMINATION OF VEGETATION: GERANIUM

The geranium plant, with its flat fuzzy leaf surfaces, was found to collect and retain most of the particles that impacted on the foliage, especially if the deposit occurred at night. When damp with dew, the flower was an effective collector. The high degree of retention by the leaves on upper stems was probably more due to the fact that these leaves were horizontal and flat or cup-shaped than to the fuzzy nature of their surface.

Figure 35

CONTAMINATION OF VEGETATION: GRASSES

Grasses (broad-leafed barley and Imperial and narrow-leafed Quicuyo) retained the volcanic fallout particles along the length of their blades, except that the blades of the narrow-leafed grass had more of a tendency to retain the particles in the center of the V-shaped portion of the blade and on the hairlike fibers along the stem.

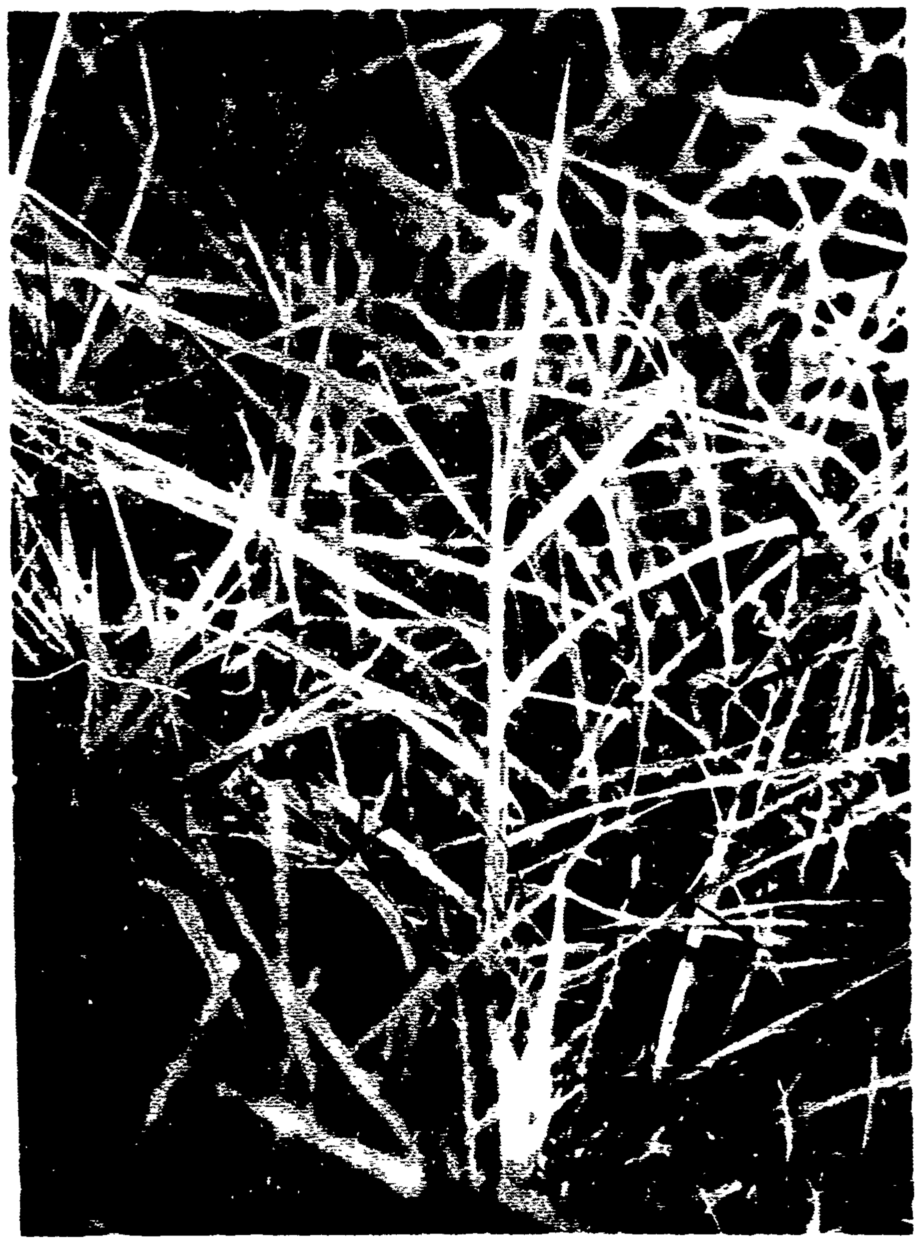
Figure 36

CONTAMINATION OF VEGETATION: GRASSES

The particles on the top of the young barley shoots tended to fall off in the wind after they became dry. However, the rate of removal by this process was rather small on the lower leaves and on the leaves that were lying down because the lower leaves dried slowly and the air moved rather slowly through the leaf mat near the ground. A large fraction of the particles, after drying, would fall off the grass blades onto the stem mats when the blades were touched. In a light rain, the particles collected in the water drops (appearing like small mud balls), and when large enough, they rolled down the blade and onto the ground.

Figure 37

CONTAMINATION OF VEGETATION: GRASSES



It is expected that cows, if permitted to graze on contaminated grasses, would disturb the grass sufficiently to knock off many of the particles before they consumed it. However, in Costa Rica the dairy cows on farms in the areas where the volcanic particles fell were not let out to graze on the grasslands. Rather, the grass was grown as fodder (except for the Imperial grass, which tended to be smothered by heavy deposits of the volcanic particles). The grass was cut, washed, and fed fresh-cut to the animals in barns along with chopped palm stems for roughage.

Figure 38

CONTAMINATION OF VEGETATION: SQUASH

The leaves on the young squash plant shown here are uniformly covered with particles. The deposit occurred under damp conditions; after drying in the early morning sun, the deposit was light grey. The fibers along the leaf stems also retained many particles. The weight of two or three successive deposits was sufficiently heavy to force the outer leaves down onto the ground.

Figure 39

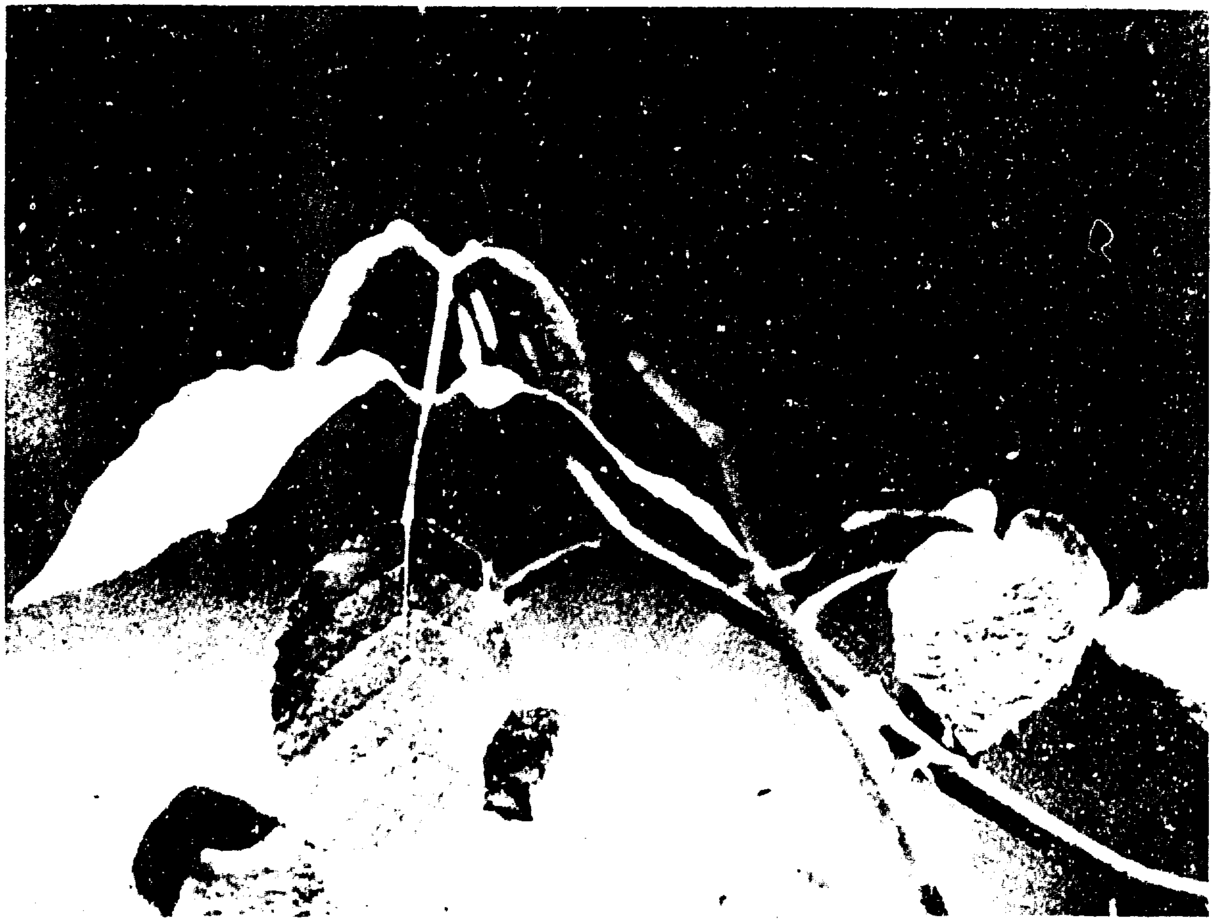
CONTAMINATION OF VEGETATION: SQUASH

The deposit on the leaves of this young squash plant, disturbed by a light rain (about 0.05 inch over a period of about 5 minutes), was still damp when the photograph was taken. Some of the particles were washed from the leaves that are hanging down. Very few particles were washed from the horizontal leaves. Vegetable plants were never thoroughly cleaned by heavier rains because both the volcanic particles and soil particles were spattered onto the leaves by the falling raindrops.

The flowers of the squash were very good fallout collectors when they were fully open in bell shape. When they closed at night, the particles were trapped in the folds of the petals. The fruits were better protected from the particles by the large leaves of the mature plant and were easily cleaned by washing.

Figure 40

CONTAMINATION OF VEGETATION: ROSE



This is a view of leaves on a tea rose bush and the particles retained by the leaves in a dry condition. The leaf in the vertical orientation has retained essentially no particles. The particles on the leaves of the rose bushes and other similar shrubs were not dislodged as rapidly as might be expected by the wind. The branches could be swinging in the breeze without any observable loss in particles from the leaves. However, if the branches were disturbed mechanically by touch, the particles showered from the leaves on the disturbed branch.

Figure 41

CONTAMINATION OF VEGETATION: NATIVE PHILODENDRON

In the dry season, the native vegetation on the slopes of Irazú and of other mountains toward the Caribbean Ocean retained heavy deposits of the volcanic particles for a long period of time. Deposits of particles as much as a quarter of an inch thick were seen on fern fronds in protected locations. The vegetation was damp most of the time because of the high humidity and persistent cloud cover. The philodendron leaves and those of other similar plants were cleaned to some extent by the water drops that formed from condensations on the leaf and then rolled off and by the water drops that fell from overhead leaves and landed on the leaf.

Surprisingly, some of the succulent-type ground cover plants appeared clean and green against the greyish color of the surrounding foliage on the larger plants.

Figure 42

CONTAMINATION OF VEGETATION: BEAN FRUITS AND CABBAGE LEAVES

Bean fruits collected particles on the sides of the pods facing the direction of fall of the depositing particles where the pod was not protected by the leaves. Contamination by nuclear weapon fallout particles would be expected to leave residues of translocated radionuclides in the pods of the green and string beans. Part of these residues would be leached out in cooking and canning. Very little, if any, of these residues would reach the bean seeds if the pods were left to ripen.

The mud balls on the cabbage leaves were formed by heavy dewdrops; they are in an early stage of drying in the morning sun. The leaf has been partially cleaned by the drainage of the dewdrops from the leaf. First, the dew wets the particles and the leaf, and after the particles are saturated, the excess water contracts to form drops with the particles in the bottom of the drops. When these become sufficiently large, they start moving down the sloped portions of the leaf and take the particles along with them.

Figure 43

CONTAMINATION OF VEGETATION: BARLEY HEADS

As soon as the barley and wheat heads were formed, particles collected on the beards and in the spaces between the seed grains, especially when the particles were deposited under damp conditions and low wind speeds during the night. After the particles sift into the heads, they are not removed by the wind. Rain washes the particles from the beards and outer surfaces of the grains but helps to p[illegible] the particles more firmly into the center of the head between the grains. The larger particles are readily removed from dry ripened heads by threshing.

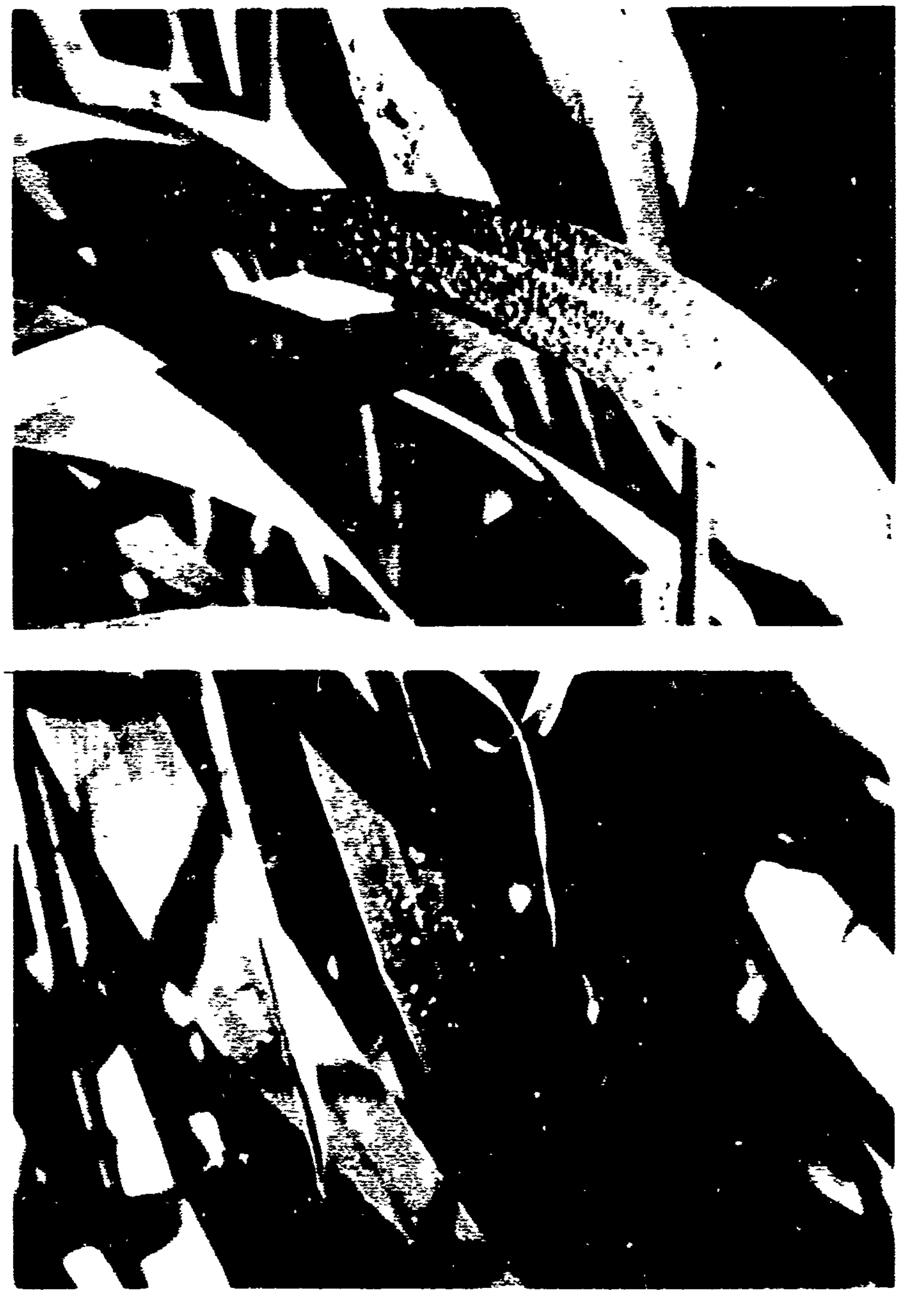
Figure 44

CONTAMINATION OF VEGETATION: OAT AND WHEAT HEADS

Translocation of radionuclides from nuclear weapon fallout particles to the seeds could occur at any stage before the seeds ripen, and in the flowering stage, beta radiation might inhibit pollinization. The wheat seeds are protected from contamination more than the barley seeds by the husks around the individual seed grains. Data from fallout tests show that the translocated radionuclides are not distributed uniformly in the wheat grains; of the small amount that penetrates through the husk, only a low fraction passes through the seed skin. After milling, most of the remaining radionuclides are separated from the flour along with the bran.

Figure 45

CONTAMINATION OF VEGETATION: BROADLEAF GRASSES



Broad-leafed oat grass was partially cleaned by heavy dew. On the bottom, mud balls and clean dewdrops are shown in an early stage of drying in the morning sun. On the top, the mud balls on the horizontal portion of the leaf were almost fully dried. The portion of the leaf with the steep slope was cleaned by the drainage of the dew-drops. The initial contamination of most vegetation under damp conditions (presence of dew) was about twice that under dry conditions, given the same wind conditions, despite the loss of particles when the dew was very heavy.

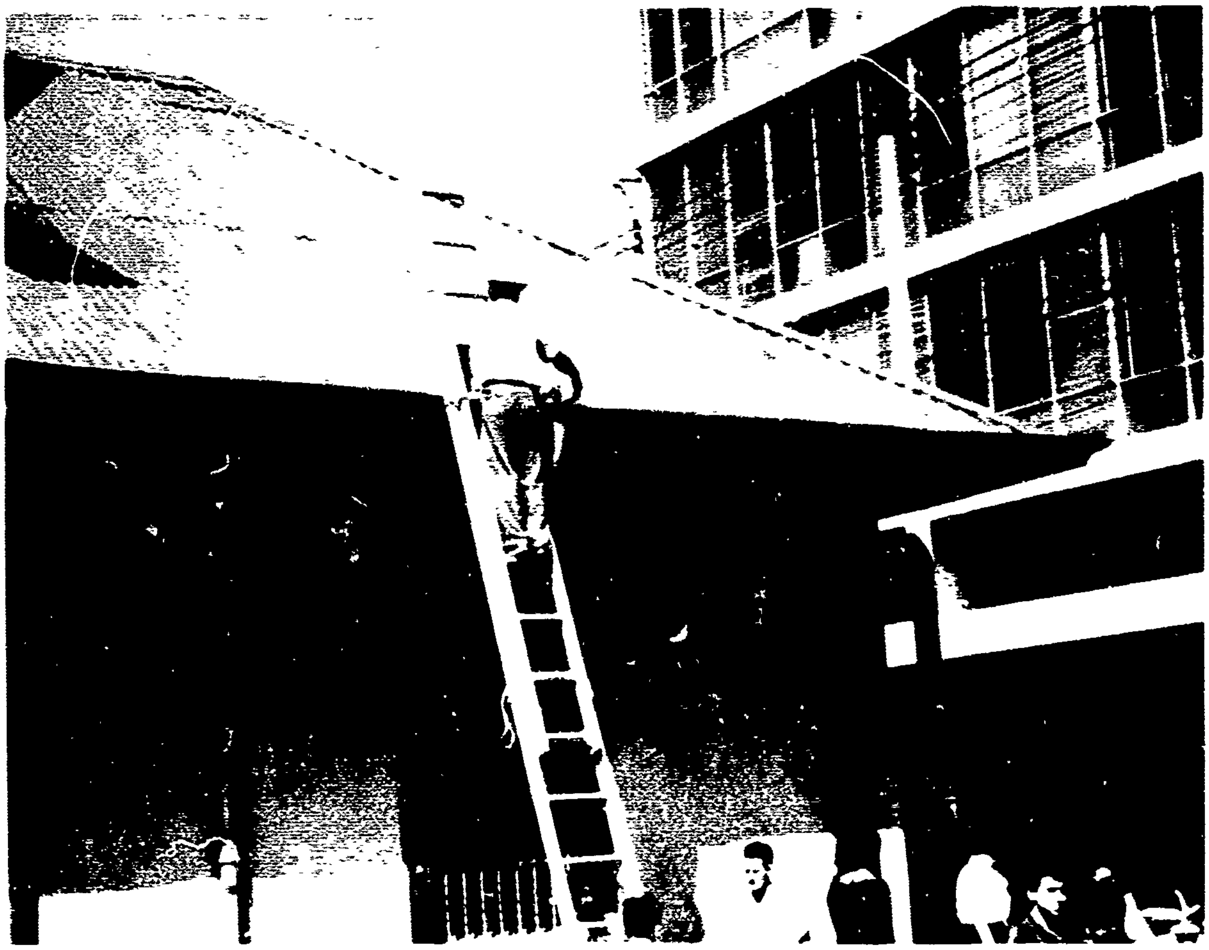
Figure 46

COSTA RICAN DECONTAMINATION METHODS: ROOFS

Although the wind and rain kept the exposed corrugated iron sheet roofs relatively clean, wind-protected roof areas collected a relatively large amount of the particles and were not cleaned by wind action. These areas were occasionally cleaned by sweeping. This cleaning job was left to the property owner to accomplish. The material was swept off the roof, as shown in this figure, and onto the street and sidewalk. After the roof was cleaned, the material on the sidewalk was generally swept into the gutter in a pile. Some of the house owners and shop owners collected the sweepings in large barrels and garbage cans for later pickup by municipal crews.

Figure 47

COSTA RICAN DECONTAMINATION METHODS: ROOFS



Most of the roof gutters were cleaned by hand, using a small can to scoop the particles from the gutter. They were then dumped into a large bucket which, when full, was lowered to the sidewalk with a rope. In some of the downtown areas, a vacuum cleaner attached to a large metal drum (as a collecting container) was used to clean the gutters.

Figure 48

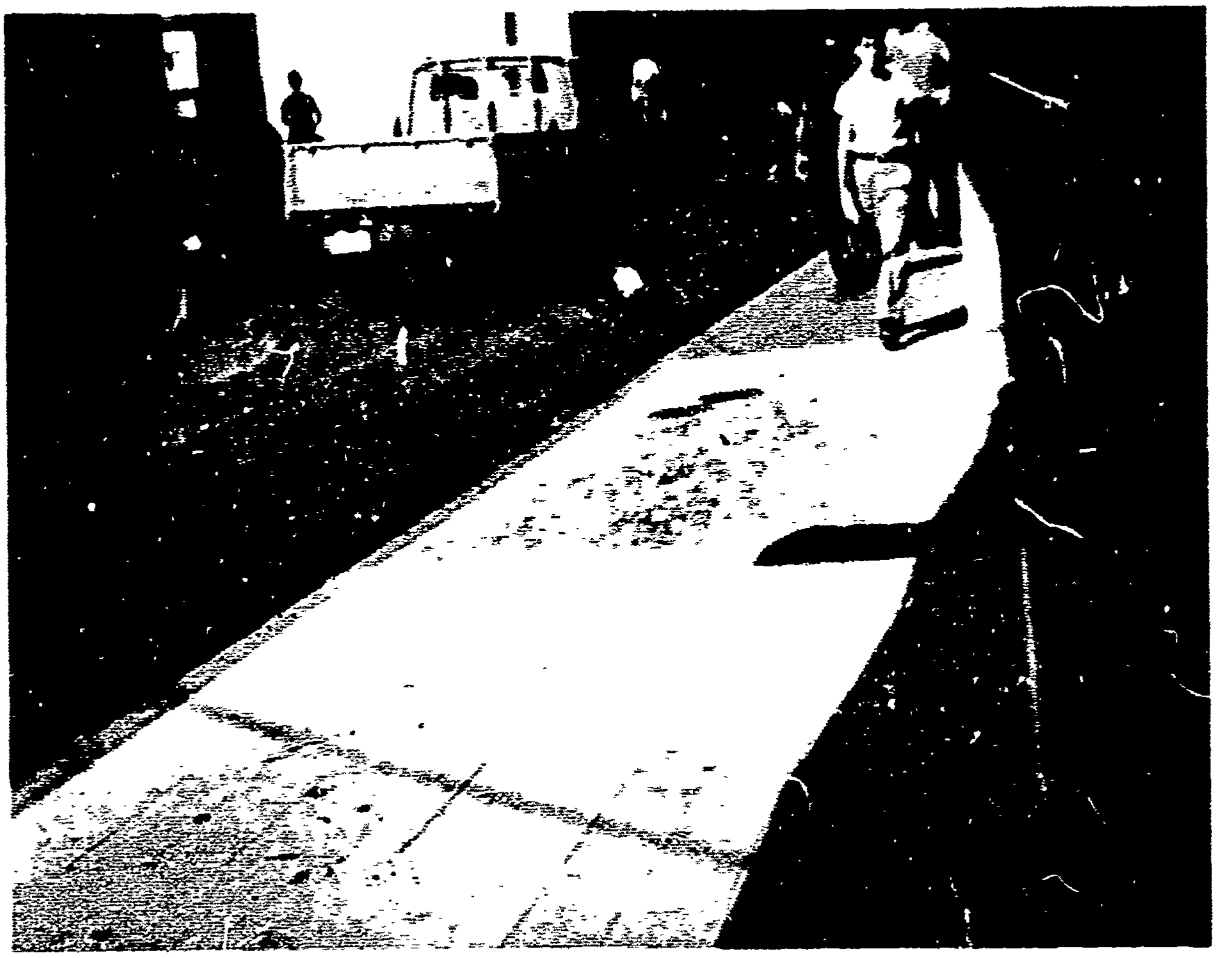
COSTA RICAN DECONTAMINATION METHODS: ROOFS

Broom, shovel, pail, and wheelbarrow were used to clean parapeted flat roofs. For small areas, such as shown in this figure, the material was put into the wheelbarrow, transported to the edge of the roof, and dumped onto the ground (or street) below.

With a limited water supply, some variation of the described techniques would be suitable for decontamination of roofs in the postattack period following a nuclear war. Where water is available, roofs would be more effectively cleaned by fire-hosing, using trained crews under controlled scheduling of the exposure of the crews to radiation.

Figure 49

COSTA RICAN DECONTAMINATION METHODS: SIDEWALKS



In Figure 49, the sidewalk has been cleaned in front of one store but not in front of an adjacent store. Although pedestrian traffic has disturbed the deposit on the uncleaned portion of the sidewalk, very little has been tracked onto the cleaned section. The downtown sidewalks were generally swept clean by the shopkeepers each morning.

Figure 50

COSTA RICAN DECONTAMINATION METHODS: SIDEWALKS

Figure 50 illustrates how cleaning of the sidewalks should not be done; water was first used, presumably to reduce the dust, making it impossible to sweep the sidewalks clean with a broom.

Figure 51

COSTA RICAN DECONTAMINATION METHODS: STREETS

The cleaning of the streets was carried out as a municipal function within a short time after the eruptions started; the technical aspects of these operations have been summarized in some detail in Reference 3. Initially, the streets were swept by hand; the swept particles were shoveled into wheelbarrows and dumped into large piles at street intersections (see Figures 52 and 53). Later, the piles were picked up by shoveling

Figure 52

COSTA RICAN DECONTAMINATION METHODS: STREETS

into trucks, and the material was then hauled to one of three dumping sites on the outskirts of the city. A water sprinkler (see Figure 54) was used on some of the downtown streets during the midmorning and midafternoon hours to minimize the movement of the particles by the wind (the particles were too large to be called dust). The particles drifted more or less like dry snow down the street.

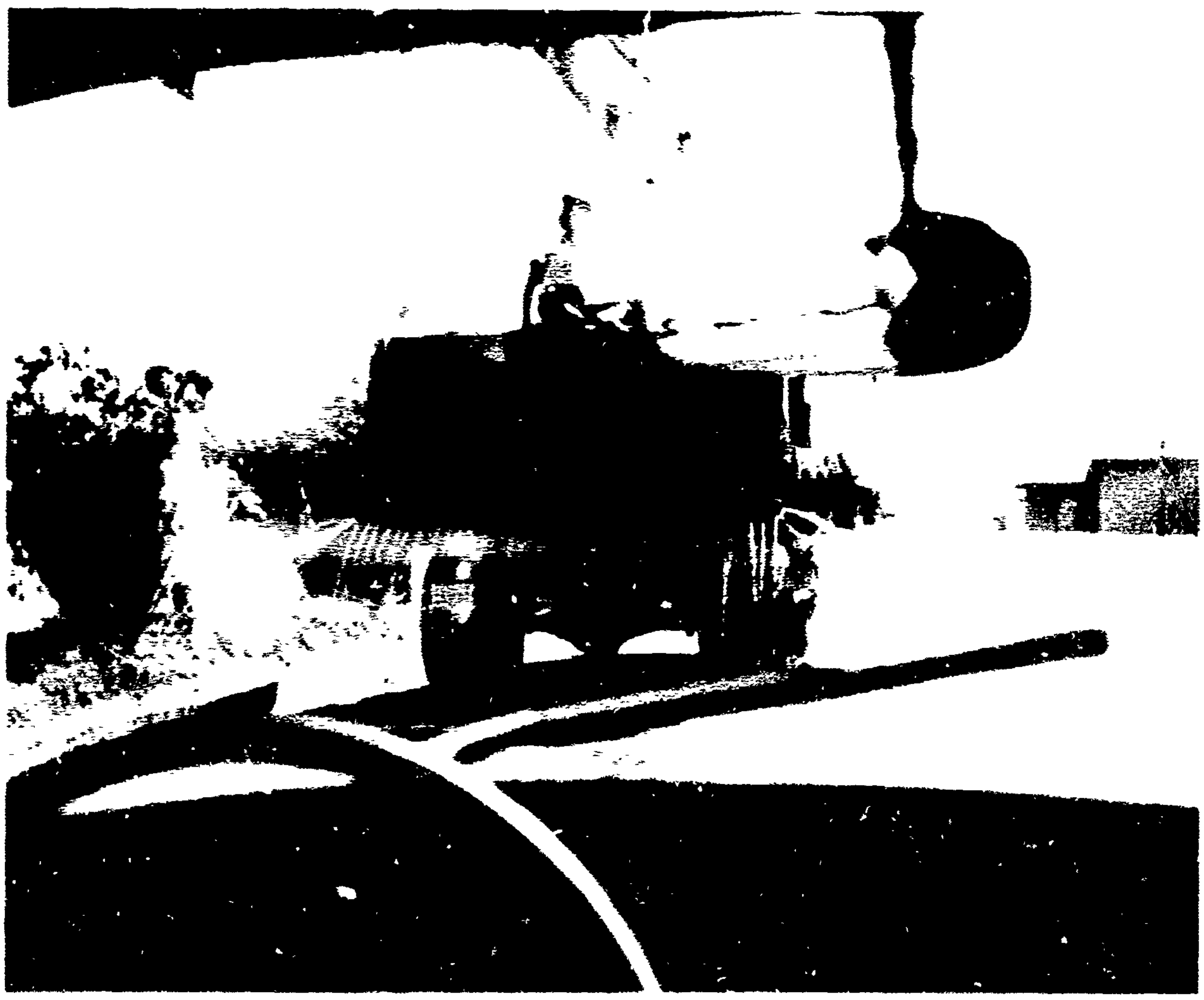
Figure 53

COSTA RICAN DECONTAMINATION METHODS: STREETS

Early in 1965 the municipal decontamination operations were improved with the delivery of street sweepers, loaders, and new dump trucks (see Figures 55, 56 and 57). The street sweepers were used in the downtown areas during the night (requiring cars to be moved out of that area) and in the paved residential areas during the daytime. When it rained in the afternoon, the sweeping operation ceased for the day.

Figure 54

COSTA RICAN DECONTAMINATION METHODS: STREETS



The particles collected by the sweepers were dumped at selected sites and then picked up during the morning work period with a front-end loader. The remains of the pile were cleaned up with brooms and shovels.

Figure 55

COSTA RICAN DECONTAMINATION METHODS: STREETS

Although these described techniques would generally be applicable to the decontamination of fallout from streets following a nuclear war, the scheduling of the operations would be different because the radiation exposure to the crews would have to be taken into account. In addition, more care would have to be exercised in the selection of dumping sites and disposal areas.

Figure 56

COSTA RICAN DECONTAMINATION METHODS: STREETS

In areas where water and pumping facilities were available, firehosing and motorized street flushers could be used to more effectively clean the sidewalks and paved streets.

Figure 57

COSTA RICAN DECONTAMINATION METHODS: STREETS

Lawn areas might, in some cases, be decontaminated by removing the sod. Agricultural land could be stripped using motorized scrapers but, in most cases, plowing the land would be satisfactory since crops do not assimilate the radionuclides in local fallout very efficiently.

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13 ABSTRACT

Photographs of objects contaminated with particles ejected from volcano Irazú in Costa Rica are presented to indicate the nature of particle behavior in various environmental situations. The similarity between the particles ejected by the volcano and the fallout particles produced by land-surface nuclear detonations suggests that the contamination behavior of the radioactive fallout particles would be similar to that observed for the volcanic particles. The peculiarities of the particle behavior are discussed in rather general terms in the figure captions for each situation depicted.

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