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OPERATION BUSTER-JANGLE

Radiological Safety

Los Alamos Scientific Laboratory
University of California

July 1953

Nevada Proving Grounds
October—November 1951

**Approved for public release;
distribution unlimited.**

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DEFENSE NUCLEAR AGENCY
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FOREWORD

This report has had classified material removed in order to make the information available on an unclassified, open publication basis, to any interested parties. This effort to declassify this report has been accomplished specifically to support the Department of Defense Nuclear Test Personnel Review (NTPR) Program. The objective is to facilitate studies of the low levels of radiation received by some individuals during the atmospheric nuclear test program by making as much information as possible available to all interested parties.

The material which has been deleted is all currently classified as Restricted Data or Formerly Restricted Data under the provision of the Atomic Energy Act of 1954, (as amended) or is National Security Information.

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ABSTRACT

A description of the responsibilities, organization, and activities of the Radiological Safety and Health Unit for Operation Buster-Jangle is given. Suggestions as to changes which should improve the operation of, and the service rendered to, the Test Director by such a unit are also included.

Data on radiation exposures of operation personnel, decontamination, residual radiation levels of shot sites, residual off-site radiation levels, and off-site fall-out intensities are included in Appendixes A to E.

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RADIOLOGICAL SAFETY

1 INTRODUCTION

For the purposes of this report Operation Buster-Jangle is regarded as a single operation since the activities of the Radiological Safety (Rad-Safe) and Health Unit were continuous from the beginning of Buster to the end of Jangle. The purpose of this report is to provide a bird's-eye view of the entire operation as seen by the Rad-Safe and Health Unit. Certain comments and criticisms of functions outside this organization will be given.

During Operation Buster-Jangle the radiological safety work was combined with first-aid and medical care, safety, and fall-out analysis for administrative purposes. The advisability of continuing this type of organization will be considered below.

2 RAD-SAFE ORGANIZATION AND PERSONNEL

Table 1 lists the entire personnel of the Rad-Safe and Health Unit in three categories: Los Alamos Scientific Laboratory (LASL), military, and all other civilian personnel. Those individuals who replaced someone else in the middle of the test are not listed, but military officers who were actually assigned to LASL for varying periods on work not specifically related to the test program are listed.

As can be seen from Table 1, H-Division contributed approximately one-third of the entire roster. Of the 30 civilian monitors, 5 were drawn from the Atomic Energy Security Service (AESS) at Los Alamos, 3 from the Federal Civil Defense Administration (FCDA), 1 from the Atomic Energy Commission (AEC) Division of Biology and Medicine in Washington, and the remainder from other AEC installations. Of the military monitors the majority were officers up to and including the rank of colonel. It is felt that in the future more dependence should be placed on enlisted men. Also, the number of H-Division personnel participating should be held very rigidly to a minimum. There was no aspect of the regular work in Los Alamos which did not suffer as a result of the extensive participation in the test. Over a third of H-Division was involved to a greater or lesser extent, a situation which is considered extremely questionable.

3 FUTURE ORGANIZATION

In considering the size and shape of a Rad-Safe organization for a future test, the following suggestions are made:

1. H-Division should furnish only personnel needed for supervision. The actual operational work should be placed entirely in the hands of the military.
2. As mentioned above, extensive use of enlisted men, with a limited group of officers to supervise them, is recommended.

Table 1—RAD-SAFE AND HEALTH UNIT PERSONNEL

	LASL H-Division	Military	Other	Total
Administration	8	2		10
Monitoring	9	52	20	81
Fall-out study	14	1	17	32
Dosimetry and records	10	3		13
Supply	3	2		5
First aid	5	1		6
Safety	1			1
Vehicle decontamination		18		18
Meteorology	3			3
Transportation	1			1
Instrument repair	5	4		9
Aerial-terrain survey	2			2
Pilots		4	2	6
Total	61	87	39	187

3. Air-sampling and fall-out studies as carried out during Operation Buster-Jangle by the H-5 Group, Industrial Hygiene, should be continued, at least for Operation Snapper. This work, however, can be combined with all the off-site monitoring.

4. It is felt that the provision of first-aid and medical care is a responsibility of AEC which should best be delegated to the military. An LASL physician should undoubtedly be at the site during the most active period.

5. Safety and sanitation should be a continuing and full-time responsibility of AEC.

6. The LASL supply organization was understaffed, and, in the future, it is strongly recommended that laundry equipment be installed at the test site, with adequate personnel to operate it on at least a two-shift, and preferably a three-shift, basis.

7. The dosimetry and exposure records group, in spite of being understaffed, did a fine job. However, there is room for improvement, which requires a slight increase in personnel.

8. In many instances, the vehicles provided were unsatisfactory for the work they were called on to perform. Dodge sedans proved inadequate for back roads, whereas jeeps and weapons carriers left much to be desired during a winter operation. The total number of vehicles available was insufficient, owing to the constantly increasing requirements of the operation.

9. Instrument repair was at times unsatisfactory because there was not always a qualified man in charge. This work was accomplished better at Operation Greenhouse.

10. The use of airplanes and helicopters appears to be increasingly vital; however, details on this subject will not be given in this report.

11. Telephone communications between the Control Point (CP) and Camp 3 were inferior and should be improved before the next operation. It is recommended that the Rad-Safe Unit have two radio channels assigned, one for site monitoring and the other for all off-site work, including direct communication with helicopters and planes assigned to this unit.

4 RADIATION EXPOSURES

In Appendix A certain tables are given which will give the essential facts of individual exposures. An exposure limit of 3 r was agreed on prior to the test; experience at Operations

Ranger, Greenhouse, Buster, and Jangle indicates that this is a reasonable goal. The Division of Biology and Medicine agreed to an unpublicized exposure of 3.9 r, which was used to give the 3-r limit added flexibility where absolutely necessary. Although there were overexposures, none were of such magnitude as to cause any concern. Of course, these overexposures will be kept in mind at any future test, and as a result certain individuals may be given lower permissible exposures. The average exposure in the monitoring group was kept as low as it was only by the most diligent conservation of man power. It might have been possible to use fewer monitors had it been known more definitely in advance what the monitoring requirements would be. So far as can be determined, no individual was injured by radiation, either within the test program or in the surrounding countryside.

5 ACCIDENTS

The motor vehicle proved to be the greatest hazard, as evidenced by one fatality and one near fatality. In addition, one jeep and two pickup trucks turned over, fortunately without injury to the occupants. There were no other accidents within the test program of any consequence, with the exception of one case of back strain. The need for improved first-aid facilities, with space for at least two beds at Camp 3, has been clearly demonstrated.

6 RESIDUAL CONTAMINATION

In Appendixes B and D maps are given which indicate the level and extent of residual activity at the shot sites, as well as in the surrounding territory. This test seems to have established the fact that airdrops provide little in the way of problems from the point of view of residual radiation. At Operation Jangle no significant activity was deposited in any populated localities. It was shown, however, that significant exposures at considerable distances could be acquired by individuals who actually were in the fall-out while it was in progress. Detonations at higher yield can drop active material at greater distances.

7 METEOROLOGY

Mention should be made of the very significant contribution of Lt Col Clifford A. Spohn and Maj Robert E. Heft in devising a method of forecasting the time and area of fall-out. These forecasts, of course, can be no more accurate than the weather predictions; however with this limitation the work was of enormous assistance in locating the fall-out study and mobile monitoring teams in strategic spots.

8 FALL-OUT STUDY

This program has added considerably to our knowledge of fall-out phenomenology. Thirty-two people, seventeen from the United States Public Health Service (USPHS) or other civilian organizations, were absorbed in this work; they had at their disposal a large number of dust-collecting and air-sampling instruments. Their operations were carried out under difficult conditions and in terrain which was unfavorable for such work. The members of this group regarded Operation Buster mainly as a training operation for the more important problems of Jangle. Of particular interest in both the Jangle shots was the large amount of extremely radioactive airborne dust which could pass a given point without leaving any significant deposition on the ground. It is well known that the dust cloud following the second shot went to the north with a low-velocity wind and seemed to hang in the valleys. However, it is not so generally known that in the late afternoon the wind reversed, and the dust returned and passed directly over the CP. By this time it had a mean particle size of approximately 0.1 μ but was sufficiently active in raising the background so that all counting activities had to be discontinued for the night. Filter papers on which some of this dust was collected were too hot to count even on the following day. Appendix E contains the results of the work.

9 COMMENTS ON ADMINISTRATION AND ENGINEERING

There were numerous factors which served to complicate the work of the Rad-Safe organization. A few of these factors will be briefly considered here.

9.1 Operations Schedule

The majority of the Rad-Safe people arrived at the test site during the last week of September and remained there for the most part until the first week of December. They arrived at a test site which was not in any condition to receive them. The necessity of adhering to the previously announced schedule subjected a large number of people to a period of intense discomfort. The entire area, which was still under construction, was extremely hazardous, and the relatively small number of injuries which resulted was fortunate. The risks which were incurred as a result of jamming people into a partly completed and grossly overcrowded camp were far more serious than any risks normally attendant on full-scale weapons tests.

The inclusion of a Rad-Safe representative at a majority of the meetings and conferences in the early planning phase of a test is recommended. In these early stages many problems with radiological safety aspects arise, and this group was given very little opportunity either to express an opinion or to inform itself as to what was in store for it.

9.2 Operations Plan

In the early part of 1951 Operation Buster seemed to be a reasonably simple operation. It grew with the inclusion of a Military Effects Program, and then the entire appearance of the operation was changed by the addition of Jangle. No firm facts were available on which the Rad-Safe organization could estimate its requirements; changes and additions appeared and reappeared up to and, in some cases, after the various detonations. Some way must be found to insist on an early cut-off date so that it will be possible to say "This is the operation, and these are the specific requirements; additions or amendments must wait for a future operation."

At the time of Operation Ranger the dangers and difficulties of having shots too close together were appreciated, and at that time it was agreed that future detonations would be spaced adequately far apart. At Operation Buster this lesson was forgotten or neglected; consequently, shots were crowded together with inadequate time for personnel to function efficiently.

9.3 Organization

The officers of the Rad-Safe and Health Unit were somewhat confused as to whom they were actually responsible. They did not know specifically whether they were assigned to the University, the AEC, or the Special Weapons Center. It is hoped that a clearer organization can be worked out in the future.

There was a very marked tendency for certain officials to operate more or less by remote control. On innumerable occasions a decision on some point was needed from some person in authority, and it would be found that the person had departed for Las Vegas or for Los Alamos without leaving a responsible alternate. This was particularly true during the pretest and roll-up periods. Many people seemed to forget that many operations, including the work of the Rad-Safe Unit, started early and continued well after the last shot was fired. The office handling travel reservations was dissolved when needed most. Establishing the post of duty officer helped considerably, but this post was abolished a day or two after the last shot.

9.4 Information Service

No machinery seemed to be available for wide dissemination of information to test personnel. The use of a daily newsletter, containing items of interest and importance to personnel, is recommended.

9.5 Drafting of Maps

In the future an improvement in map-making facilities is necessary.

9.6 Roads and Transportation

Attention should be given to the provision of adequate bypass roads so that all parts of the test area can be reached even when main highways become contaminated. This is regarded as of prime importance for Operation Snapper. The type of highway construction within the site, with the narrow shoulders and deep ditches, is hazardous. It should be obvious by this time that the motor vehicle is potentially our most dangerous instrument. The operation of the motor pool during Operation Buster-Jangle left much to be desired. More care should be exercised in providing vehicles suitable for the type of work to be performed; there should be an adequate number of vehicles for all organizations so that those which go to the contaminated area generally will not have to go south of the CP. Better transportation between Camp 3 and the CP should be provided as well as between Las Vegas and Camp 3. A schedule should be arranged so that military shuttle planes operating between Indian Springs and Albuquerque can return to Albuquerque in time to make connections with the last scheduled Carco plane to Los Alamos.

9.7 Meals

The system of feeding people whose work required that they remain at the CP was deplorable. There was nothing in the entire operation which produced as many complaints. Thought should also be given to the lunches provided to work parties obliged to remain at remote points in the Forward Area all day.

9.8 Sleeping Accommodations

It is necessary that sleeping quarters be provided at the CP to accommodate approximately 20 members of the Rad-Safe organization. It is impossible to predict how much of this space will have to be utilized only the night before a shot and how much will be needed almost consecutively.

10 SUMMARY

Personnel of the Rad-Safe and Health Unit feel that their mission was accomplished successfully at Operation Buster-Jangle. Success was achieved in spite of mistakes, many of them by the Unit itself and some beyond its control. It is felt that many of these mistakes could be avoided at a subsequent operation. The supply organization, the dosimetry and exposure records group, and the instruments repair group were somewhat undermanned, but in each instance the work was completed. For a subsequent operation smaller participation by LASL and a greater contribution from military personnel is recommended. It is felt that first-aid and medical care and safety should be excluded from the organization and that laundry facilities and a labor pool should be included. If the group responsible for the study of fall-out problems is included, the Rad-Safe and Health Unit, for a test of comparative size and complexity, will be approximately the same size, and the expenses would not be as great since so much of the equipment has already been purchased.

APPENDIX A

RADIATION-EXPOSURE SUMMARY

A.1 BADGE AND EXPOSURE DATA

Number of personnel badged:

Nevada Test Site	1523
Kirtland and Indian Springs	226
Total	1749

Number of badges:

	Issued	Processed
Nevada Test Site		
Buster	2,130	1,958
Jangle	7,008	6,600
Kirtland and Indian Springs		
Buster	1,036	866
Jangle	415	199
Experimental	510	510
Total	11,099	10,133

The maximum issue was on S + 8 day, i.e., 680 badges.

Personnel total exposures:

Range	Number
0 to 2 r	1555
2 to 3 r	132
3 to 4 r	50
4 to 5 r	9
5 to 6 r	3
Total	1749

Distribution of overexposures by magnitude and organization (permissible limit: Nevada Test Site, 3.0 r; cloud sampling, 3.9 r):

Organization	No. of persons exposed				
	3 to 3.1 r	3.1 to 4 r	3.9 to 4 r	4 to 5 r	5 to 6 r
Program 1	1	1		0	0
Program 2	2	3		0	1
Program 3	0	2		0	0
Program 4	1	0		0	0
Program 6	3	5		4	1
Program 10 (LASL)	2	1		0	0
Mixed programs and Experimental Test Group Headquarters	0	1		1	0
Rad-Safe	3	11		0	0
Haddock	0	1		0	0
Desert Rock	0	0		2	1
Cloud sampling			2	1	

A.2 REMARKS ON OVEREXPOSURES

Minimal overexposures [3 to 3.1 r at Nevada Test Site (NTS) or 3.9 to 4 r in cloud sampling] totaled 14, moderate overexposures (3.1 to 4 r at NTS or 4 to 5 r in cloud sampling) totaled 43, and large overexposures (4 to 6 r at NTS) totaled 10.

The contribution of Program 6 to the large overexposure group appears to be excessive in relation to the number of personnel and the nature of the projects.

A.3 RAD-SAFE EXPOSURES

Figure 1 shows the average dose and the accumulated dose for Rad-Safe personnel actuall engaged in monitoring operations on the days indicated. Entries made in the exposure record of an individual were accepted as sufficient evidence of monitoring activity on dates of such entries.

For Buster average daily doses were relatively low (0 to 0.23 r), and the total doses accumulated at a slow and approximately linear rate as the series progressed. During the period from 8 to 19 November, eight monitors were active, and the total exposure was only 0.04 r. This minor information was omitted in order to compress the time scale on the graph. The total exposure for Buster monitoring operations was about 36 r.

The Jangle average daily doses were relatively high (0.06 to 1.18 r), and the total doses accumulated exponentially. The total dose curves for the Sugar (surface shot) and Uncle (underground shot) shots are similar and may be typical for shot operations where residual contamination is large.

The large average dose on 10 December was due to close-in recovery operations for Program 3. This was anticipated, and only one exposure in excess of 3 r occurred on that dat

A total of 12 monitors received exposures in excess of 3 r, and they all exceeded that value after the last shot. Seventy-five per cent of the monitors exceeded the level on 4 December or later. Over 90 per cent received a dose greater than 0.5 r, and more than 50 per cent received a dose greater than 1 r on their final exposure. Perhaps the biggest factor causing these high exposures late in the series was the willingness of project personnel to accept high final doses in order to expedite recoveries and return to home stations. Other factors were inexperience, natural curiosity, and, perhaps, the desire to accumulate 3 r quickly so that early release from duty was probable.

Total exposure for Jangle monitoring operations was about 160 r, bringing the total for the entire operation to approximately 195 r. The average exposure per monitor was about 2 r

Peak personnel requirements were on shot days and, in the case of the Uncle shot, the da following shot day.

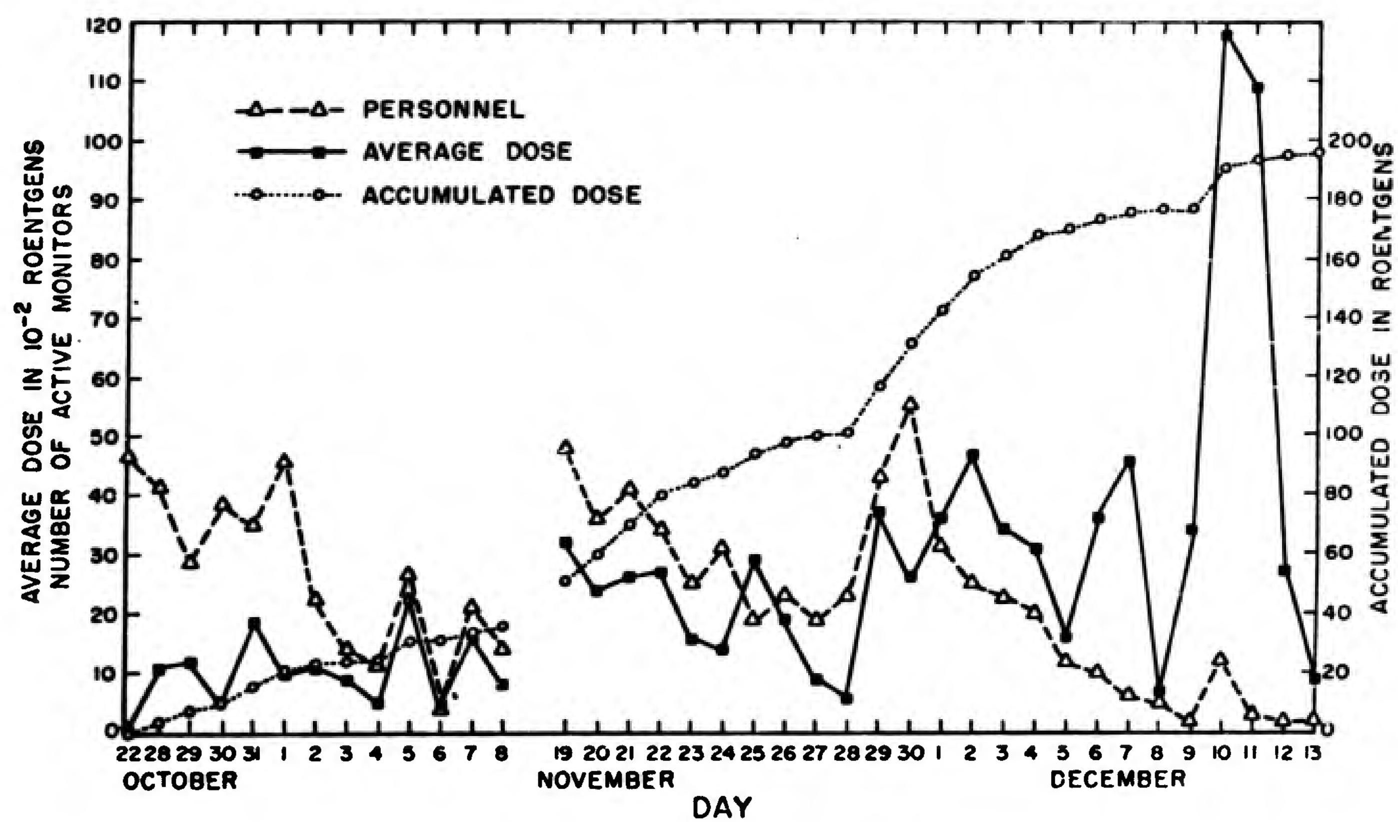


Fig. 1—Dose history of Rad-Safe monitors.

APPENDIX B

SHOT-SITE-AREA SURVEYS INDICATING RESIDUAL CONTAMINATION

The maps contained in this appendix (Figs. 2 to 8) indicate the extent of residual contamination in the immediate vicinity of the shot sites. Readings were obtained by area-survey parties at specific stations, and the isointensity lines approximated from this information. It should be noted that survey times were not the same for each shot. Survey times selected were those for which the most information was available.

For the Buster shots the activity was apparently neutron induced, with a half life of about 10 hr for the early stages. Figures 9 and 10 show the radioactivities, expressed as decay rates in milliroentgens per hour, at certain Project 2.5a stations for a period of time following the Sugar and Uncle test explosions. Stations selected were those for which the earliest and most complete data were available. Four or five readings were assumed sufficient for plotting purposes, and a negative slope of 1.2 was included in both graphs to compare station decay rates with those for normal fission products.

Readings were obtained by monitors on area surveys or recovery operations and were taken about 3 ft above ground with T1B or SU-10 ionization-chamber-type survey meters. Owing to inaccuracies associated with the exact geographical locations of readings, meter elevations above ground, meter precision (±10 per cent), and possible personnel factors, it is not surprising that measured activities for each station do not plot well. However, it is evident that, for operational purposes after shots of this type, predictions as to radiation levels may be based on fission-product decay laws with good results. Table 2 lists some of the stations and their bearings and distances from U0 and S0.

Table 2—STATIONS, BEARINGS, AND DISTANCES FROM U0 AND S0

Station	Bearing	Distance, ft	Station	Bearing	Distance, ft
	From U0			From S0	
101	WNW	2,000	4	E	2,000
103	NW	2,000	23	NNE	8,000
104	ENE	2,000	27	NNE	11,000
105	SE	2,000	33	NNE	20,000
107	WNW	3,000	104	N	14,500
108	N	3,000	108	N	17,000
124	NE	8,000			

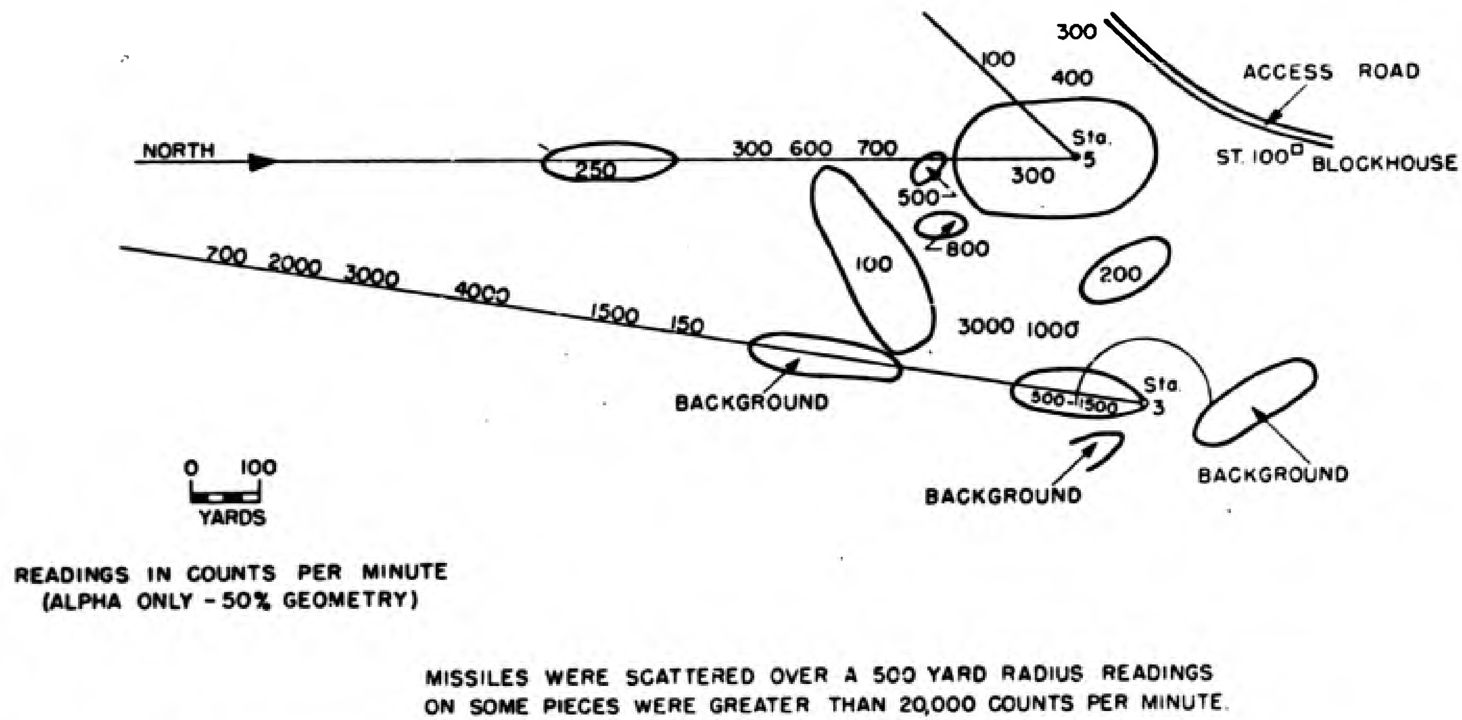


Fig. 2—Combined readings for Buster Able, 22 and 23 October. Weapon: [ ] burst height: 100 ft (tower); location: Area 7, Station 5; yield: $<2 \times 10^{-9}$ kt; firing time: 0600 PST; date: 22 October.

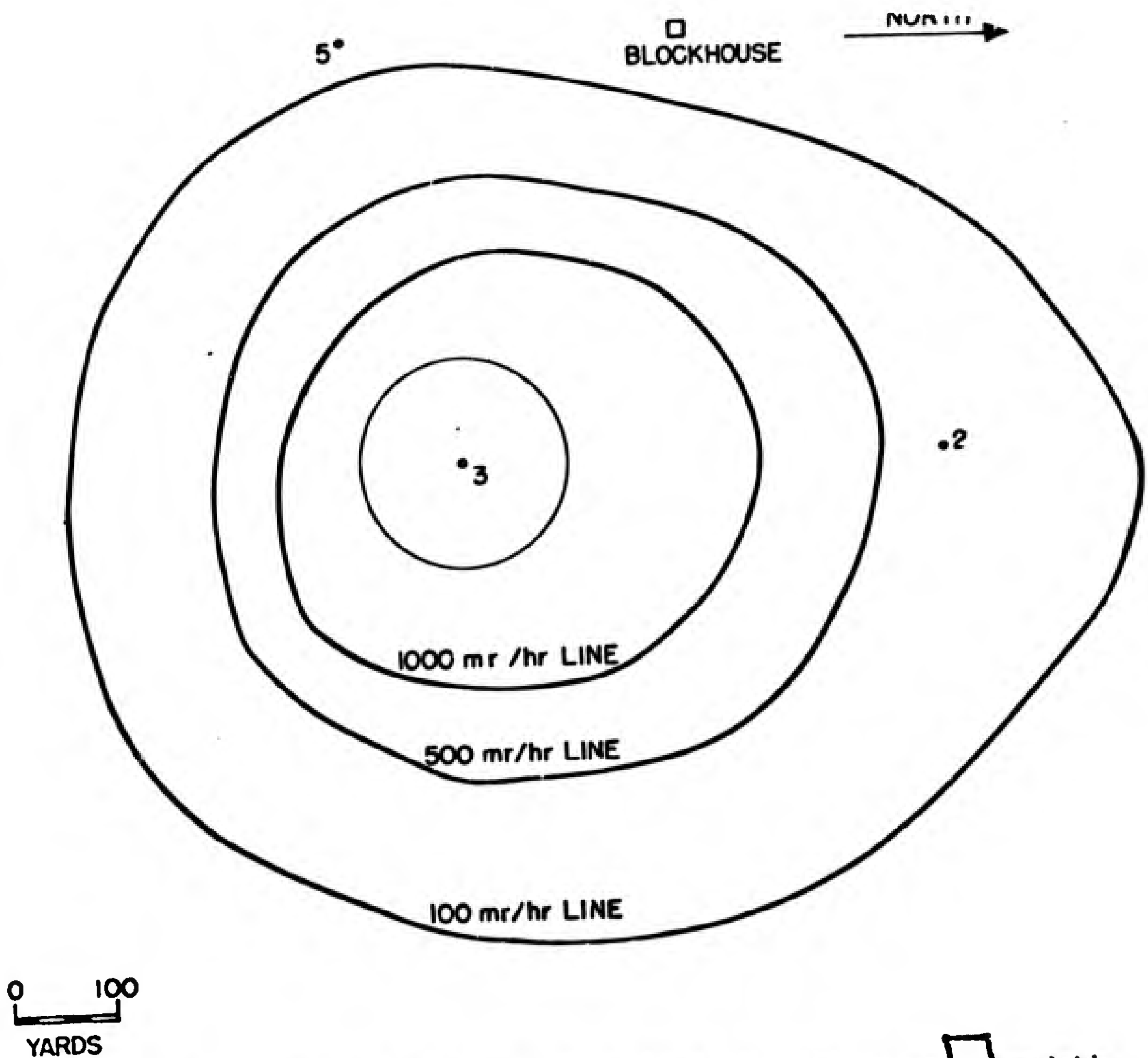


Fig. 3—Readings for Buster Baker, B + 11 hr, 1810 to 1850 PST, 28 October. Weapon: ; burst height: 1118 ft; location: Area 7, Station 3; yield: 3.49 kt; firing time: 0720 PST; date: 28 October.

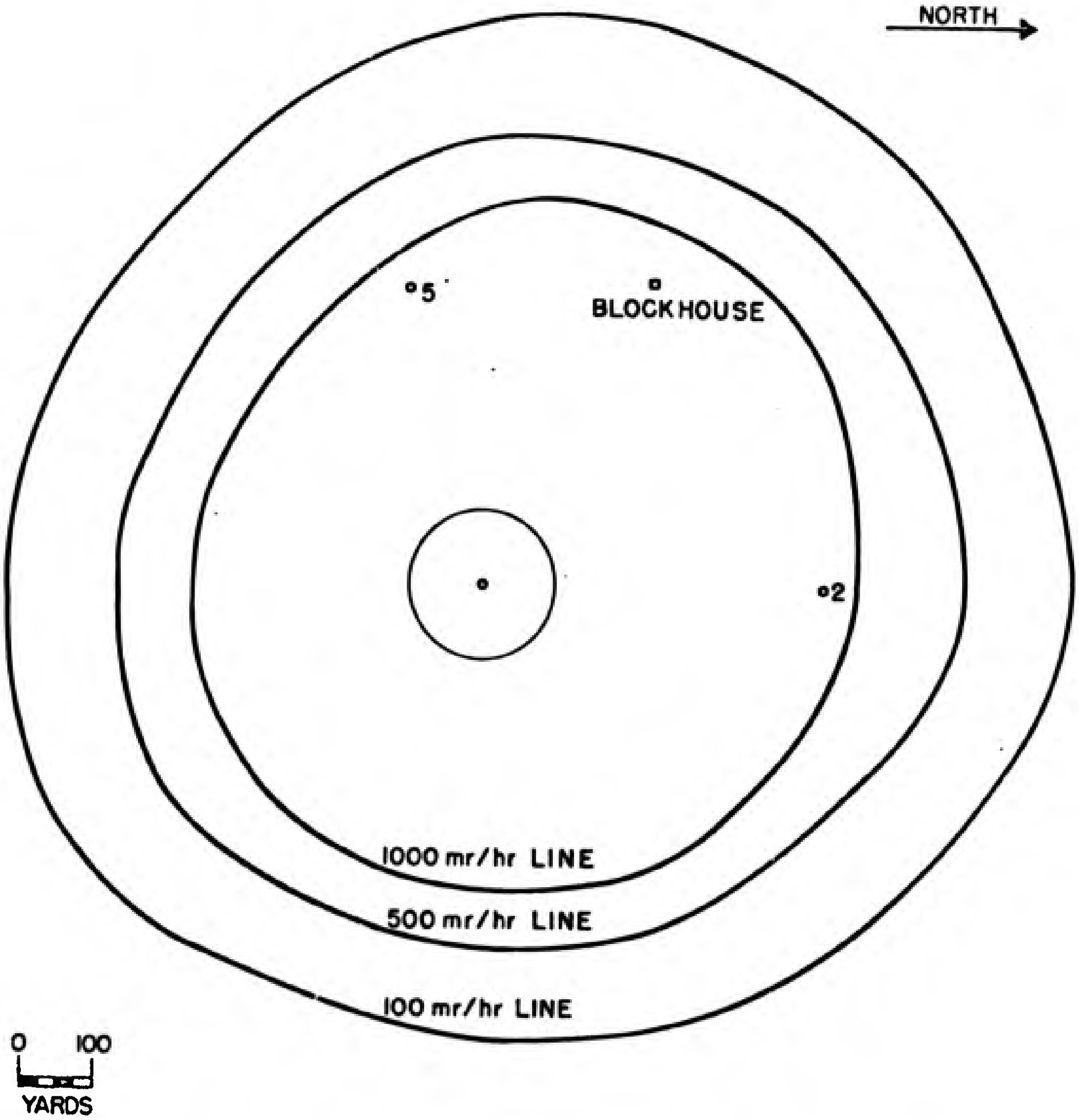


Fig. 4—Readings for Buster Charlie, C + 9 hr, 1530 to 1700 PST, 30 October. Weapon: [ ] burst height: 1132 ft; location: Area 7, Station 3; yield: 14.0 kt; firing time: 0700 PST, date: 30 October.

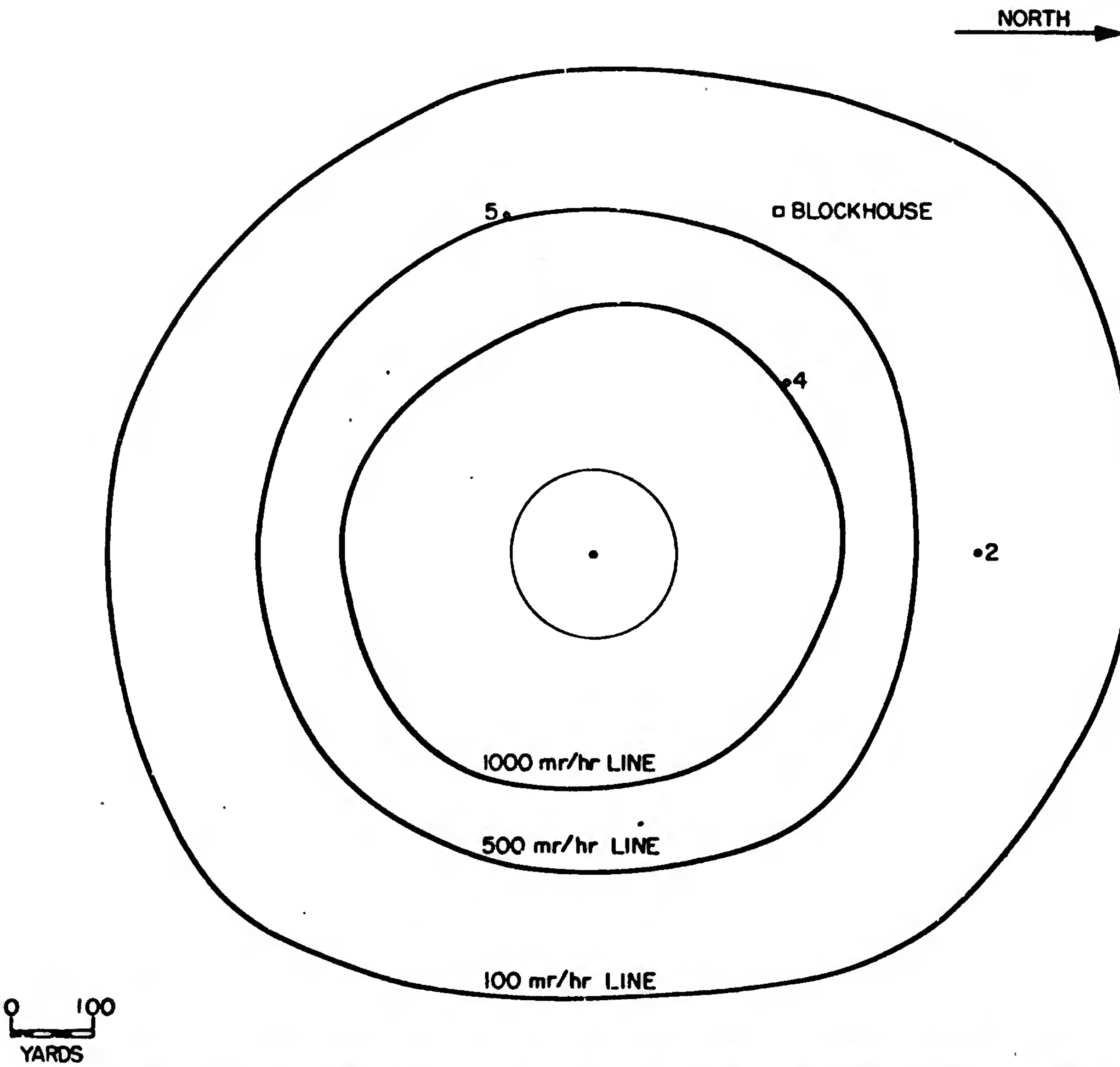


Fig. 5—Readings for Buster Dog, D + 1 day, D + $25\frac{1}{2}$ hr, 0900 PST, 2 November. Weapon: [ ] burst height: 1417 ft; location: Area 7, Station 3; yield: 21.0 kt; firing time: 0730; date: 1 November.

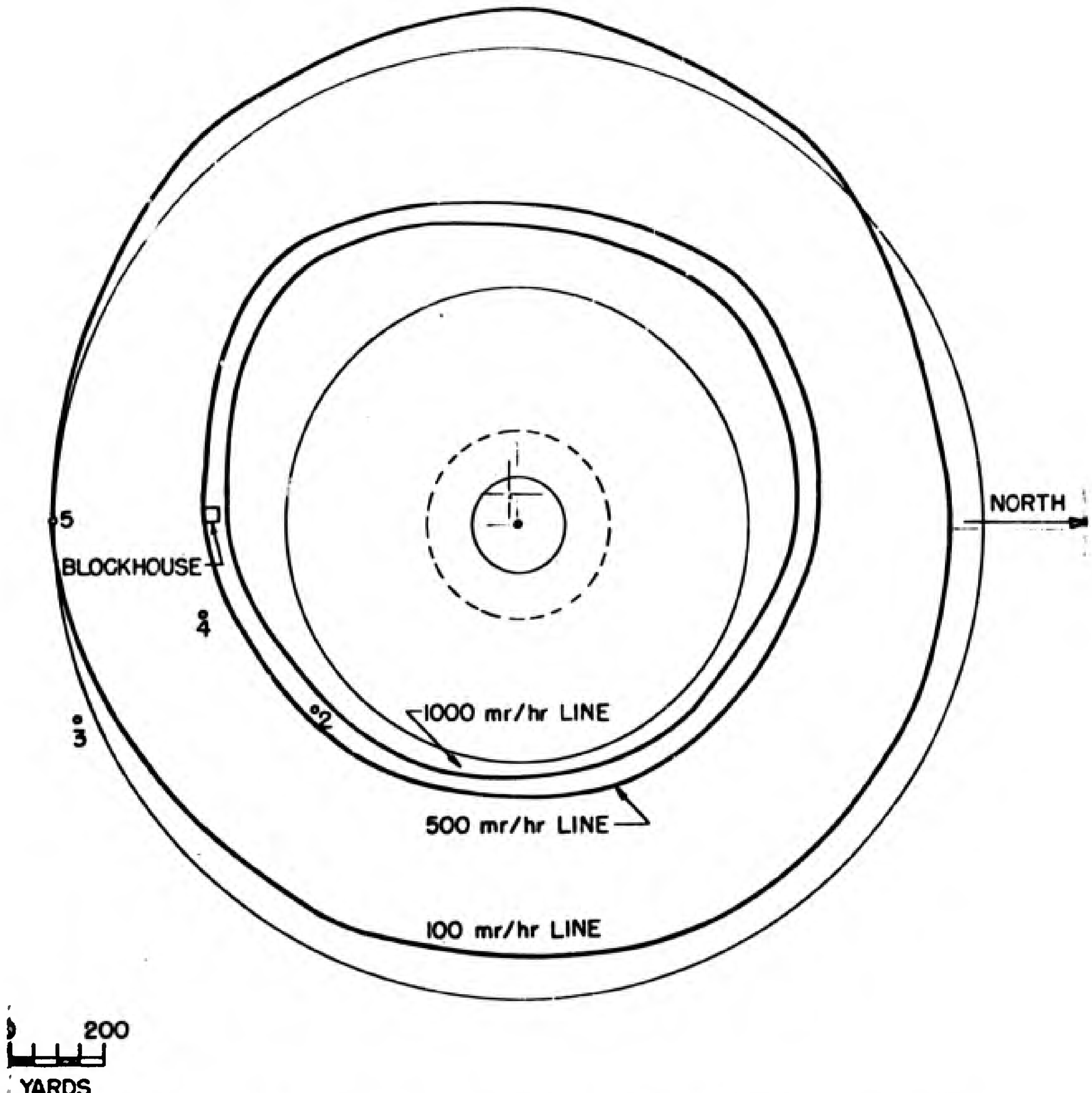


Fig. 6—Readings for Buster Easy, E + 1 day, E + 24 hr, 0800 to 0930 PST, 6 November. Weapon: burst height: 1314 ft; location: Area 7, Station 1; yield: 31.4 kt; firing time: 0830 PST; date: 5 November.

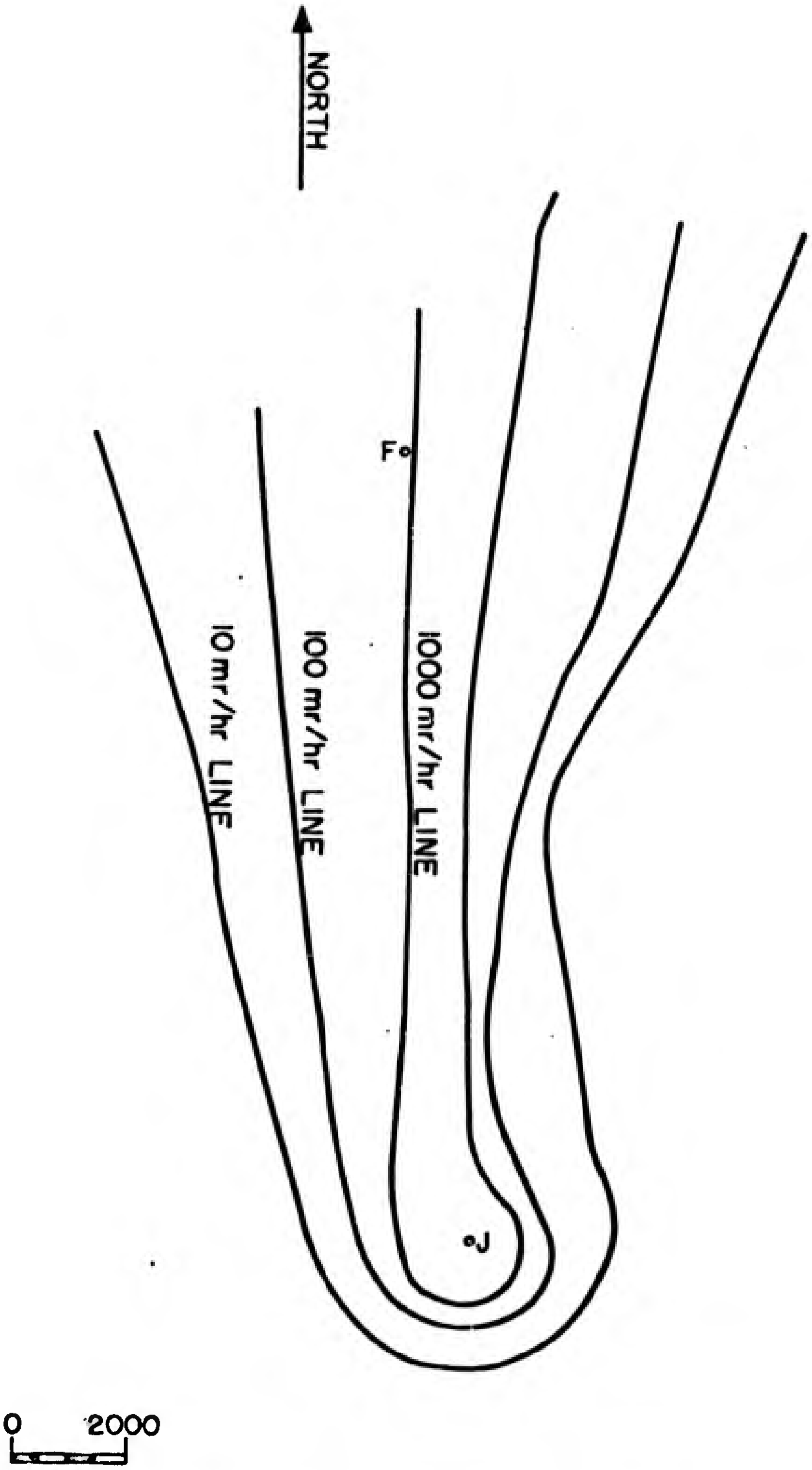


Fig. 7—Readings for Jangle Sugar, S + 22 hr, 0700 PST, 20 November. Weapon: burst height: surface; location: Area 7; yield: 1.19 kt; firing time: 0900 PST; date: 19 November.

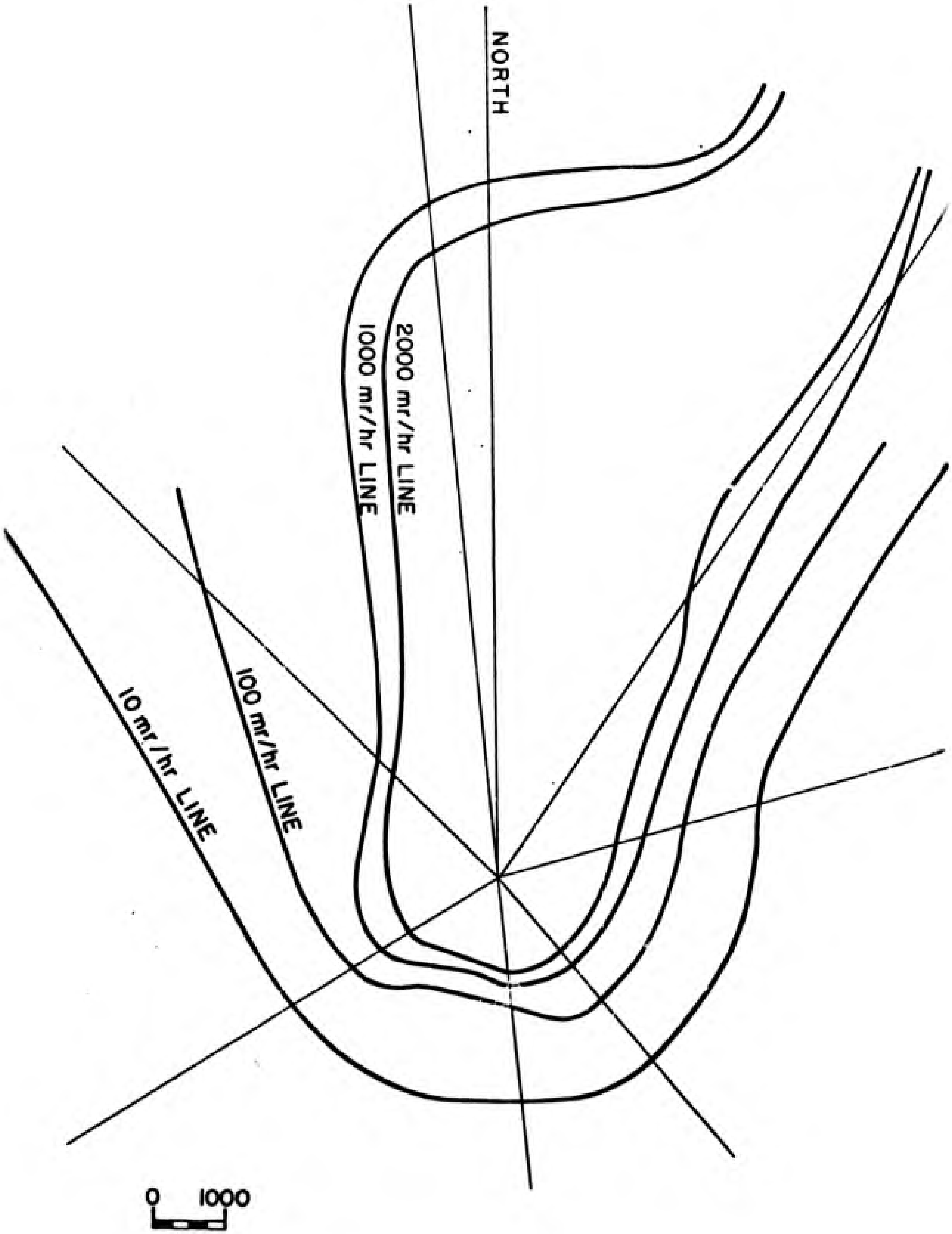


Fig. 8—Readings for Jangle Uncle, U + 19 hr, 0700 PST, 30 November. Weapon: burst height: underground (17 ft); location: Area 7; yield: 1.22 kt; firing time: 1200 PST; date: 29 November.

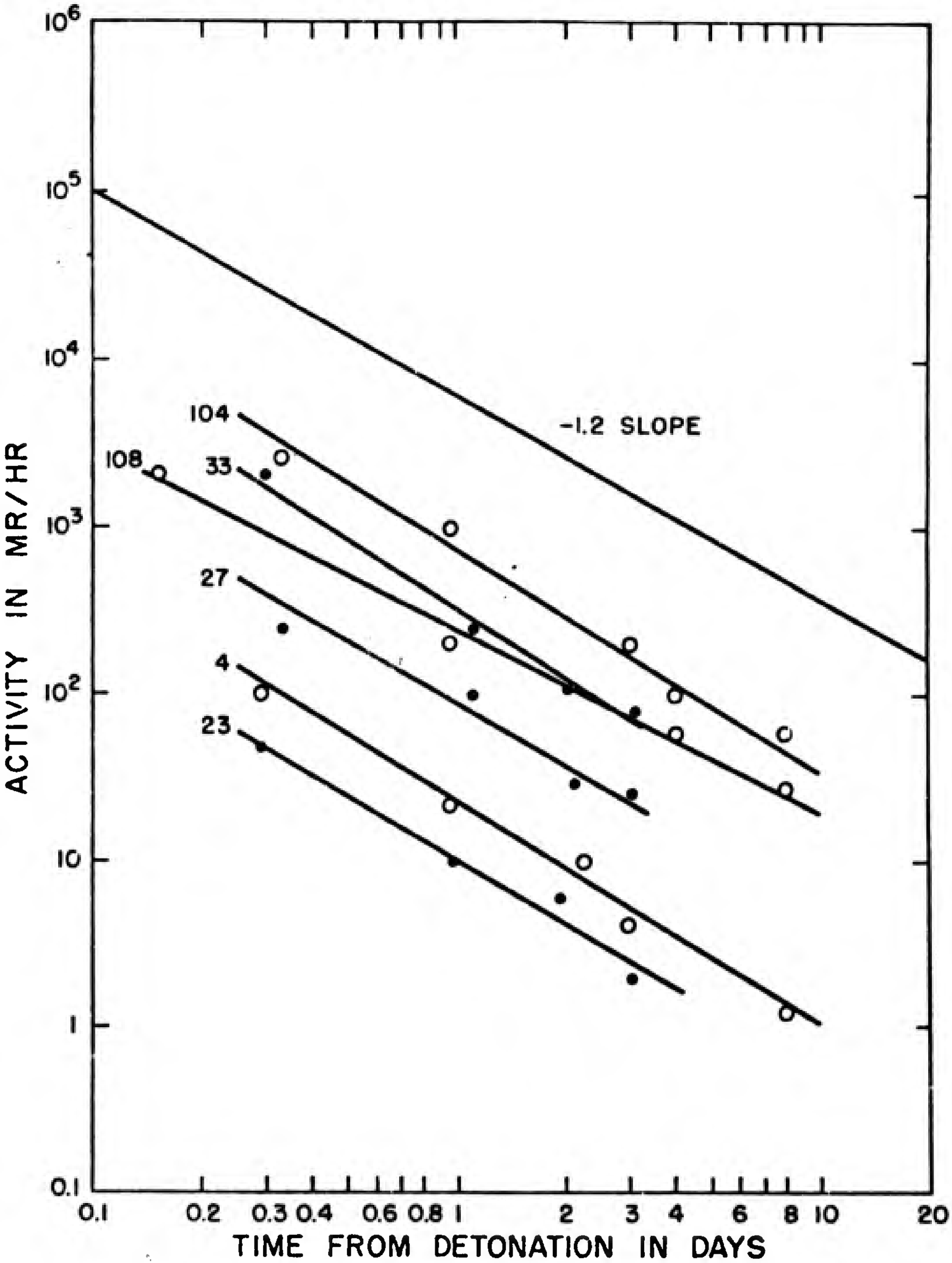


Fig. 9—Decay rates at certain stations following Sugar shot.

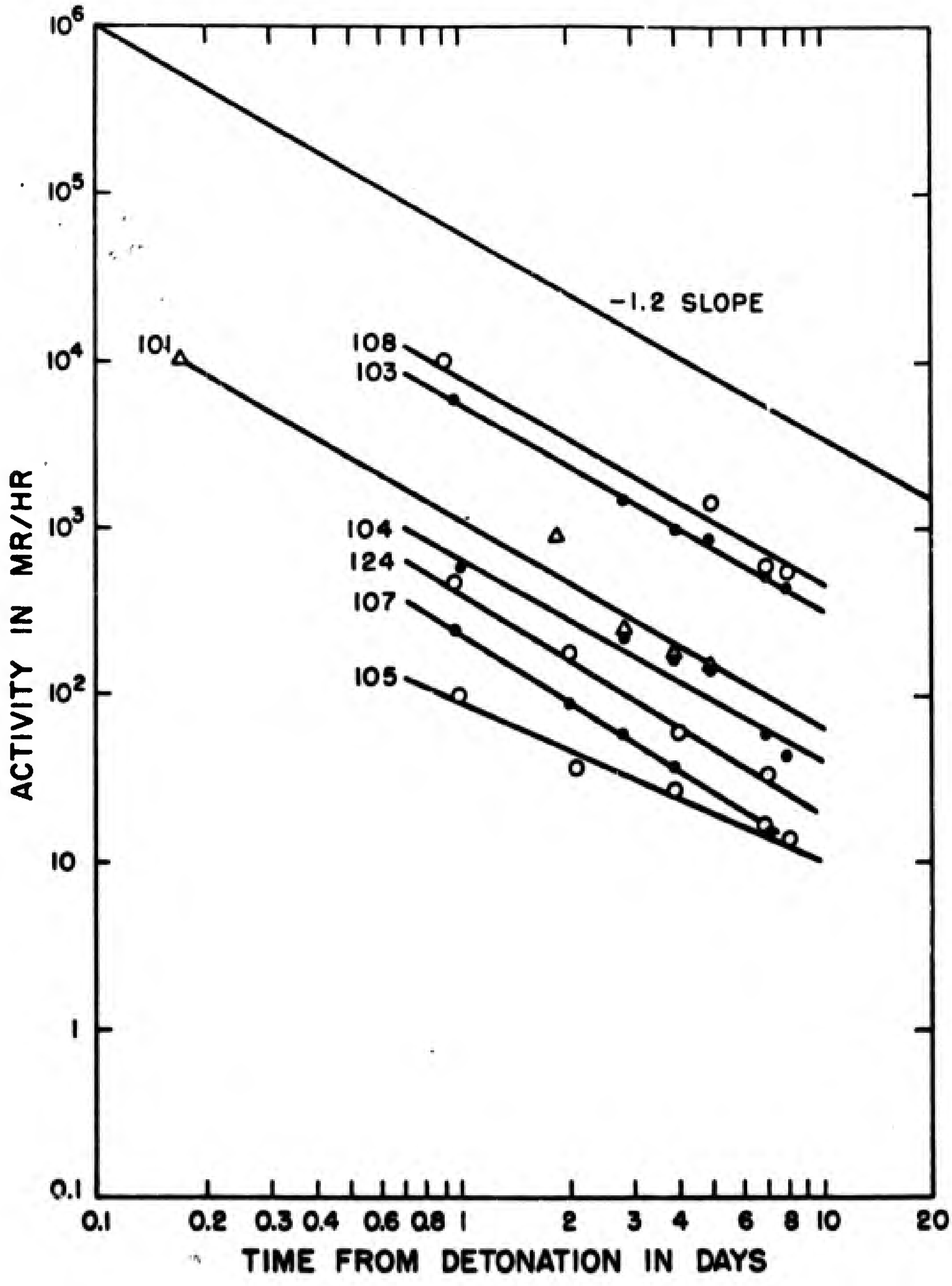


Fig. 10—Decay rates at certain stations following Uncle shot.

APPENDIX C

VEHICLE CONTAMINATION

The number of contaminated vehicles, expressed as a percentage of total daily vehicular entries for each day that such information was available, is shown in Fig. 11.

On 30 October (Charlie shot) 27 vehicles entered the area, and about half this number became contaminated. Wind conditions on this shot permitted a relatively high degree of fall-out in the target area. The following day 224 vehicles entered the same area (Station 3), and only [illegible] were contaminated. This illustrates the typically short half-life contamination encountered during the Buster series. Five per cent or less of vehicular entries on other days of this series became contaminated.

For the Jangle series the available data reveal contamination of much longer half life (fission products). For the underground shot about one-third of all vehicles entering the area became contaminated as late as nine days after detonation. The average percentage for this period was 36 per cent.

Although it apparently is not possible to determine the exact percentage of vehicular entries which will be contaminated under specified shot conditions, the foregoing information may serve as a guide for vehicle-decontamination logistics on future test operations. Table 3 gives the number of vehicles entering the contaminated area and the number which were contaminated.

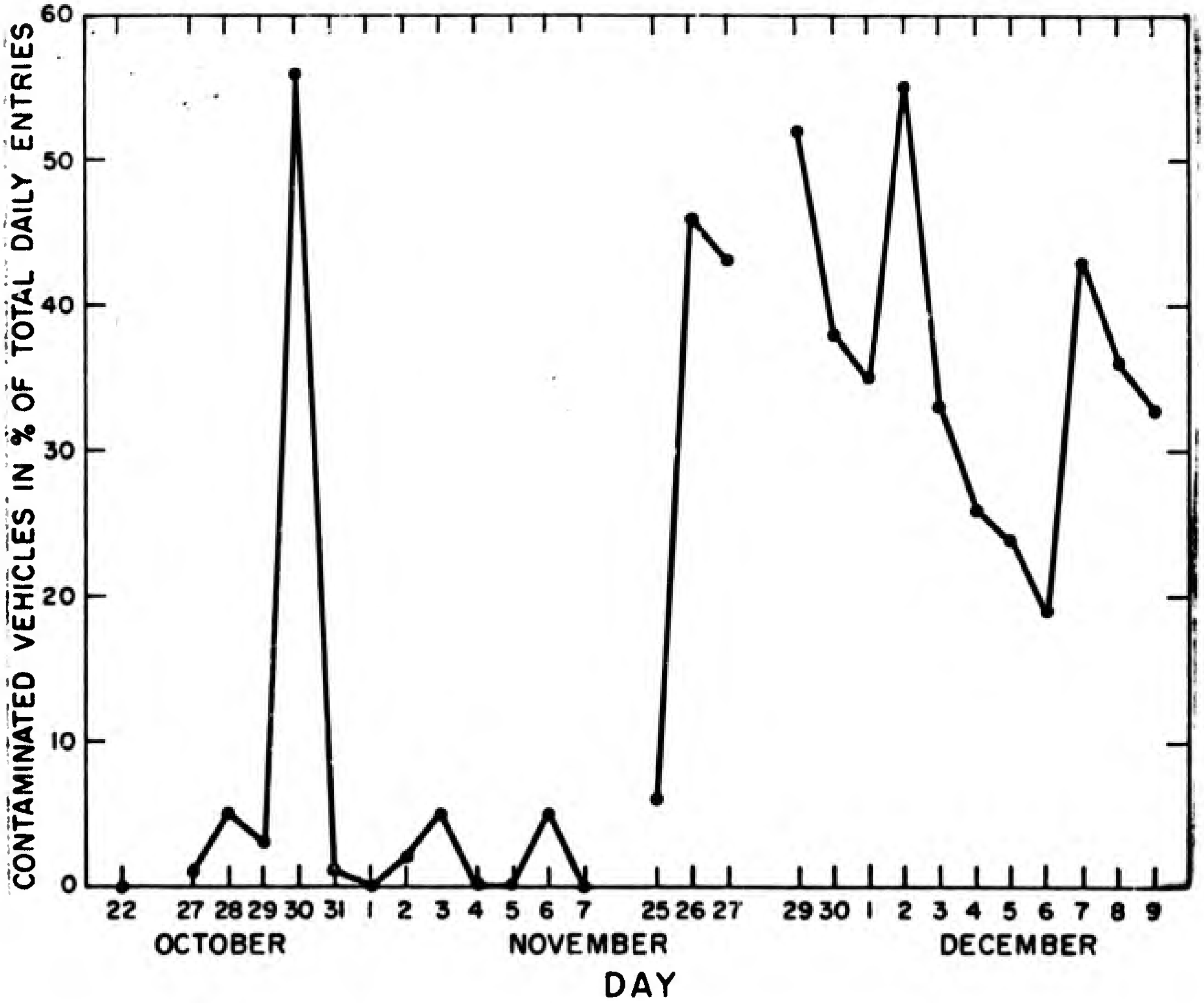


Fig. 11—Percentage of vehicles which became contaminated on entering shot sites.

Table 3—VEHICLES ENTERING CONTAMINATED AREAS

Date	Total number of vehicles	Number contaminated	Percentage of total
22 October	72	0	0
27 October	75	8	1
28 October	44	2	5
29 October	118	4	3
30 October	27	15	56
31 October	224	3	1
1 November	35	0	0
2 November	49	1	2
3 November	79	4	5
4 November	99	0	0
5 November	26	0	0
6 November	20	1	5
7 November	19	0	0
25 November	236	14	6
26 November	253	117	46
27 November	276	120	43
29 November	62	32	52
30 November	128	49	38
1 December	147	51	35
2 December	60	33	55
3 December	117	39	33
4 December	89	23	26
5 December	46	11	24
6 December	48	9	19
7 December	30	13	43
8 December	28	10	36
9 December	15	5	33

APPENDIX D

MOBILE MONITORING FOR FALL-OUT

A system of mobile monitoring teams was set up to determine the locations and intensities of radioactive particle fall-out following each test shot of the Buster-Jangle series. Each team consisted of two men in a two-way-radio-equipped sedan or truck; they were provided with two Geiger-Mueller type instruments and one ionization type instrument for measurement of radiation intensities after the fall-out. The area surveyed by these teams extended to a radius of 200 miles from the Nevada Test Site (NTS).

The day before each shot teams were dispatched to positions determined by a meteorological forecast of the fall-out pattern. After passage of the radioactive debris cloud and fall-out of the active particles, the teams attempted to traverse the fall-out path to determine boundaries of the fall-out and the maximum intensities. Only gamma radiation was recorded. The measurements were made about 3 ft above ground.

Usually it was not possible to determine at what time the fall-out first occurred in more than one location for each shot. This time and the distance to this location were used to estimate an effective velocity, which was then used to estimate the time of arrival at other locations. From these times, together with the intensities and times of measurement, the maximum dose that would be received at each location if the fall-out intensity remained unaltered by wind and weather was calculated.

In every case except the Jangle Sugar shot, sufficient sets of readings at the same locations, but with various time intervals, were obtained to indicate that the fall-out activity conformed sufficiently well with fission-product decay for purposes of calculating the integrated dose.

The results are summarized in Tables 4, 5, and 6 and Figs. 12 to 17. (The heavy lines on the maps show fall-out activity.)

In addition to the mobile team work previously described, it was possible to conduct a very limited amount of helicopter survey work outside the NTS after the Jangle shots. The objective of these surveys was to ascertain the limits of the hottest areas and the maximum intensities in regions not readily accessible to the ground teams. These hot spots are defined as areas having intensities greater than 2 r/hr calculated to 1 hr after shot time. There is some reason to suspect that the southern limits of the hot spots were influenced by the presence of an east-west ridge of mountains running across the north end of NTS. The information concerning the hot spots found after each Jangle shot is summarized in Table 6. The results are subject to fairly large errors because of navigational errors (there were few good landmarks) and the very limited amount of work that could be done. Intensities are calculated to 1 hr post shot. The time of fall-out was probably about 40 min after the surface shot and 1 hr after the underground shot.

Table 4—SUMMARY OF RESULTS, OPERATION BUSTER

Shot	Direction of cloud	Max. velocity, mph	No. of teams	Fall-out detected: Distance from NTS, miles	Fall-out detected: Length on highway, miles	Fall-out detected: Integrated dose, mr	Fall-out detected: Location	Remarks
Able	SE		6					Not detected
Baker	SE	15.5	5	45	15	15	Highway 95	
				65	55	12	Death Valley, Calif.	
				150		0	Johannesburg, Calif.	Passage of cloud detected
Charlie	SW	13	5	45	15	160	Highway 95	
				65	16	85	Death Valley, Calif.	
				185	10	5	Mojave, Calif., N	
Dog	SE	58	5	40	5	10	Indian Springs, Nev.	
				80	20	95	Las Vegas, Nev.	
				100	40	30	Henderson, Nev.	
				175	65	15	Kingman, Ariz., to Needles, Calif.	
Easy	SE	20	6	22	Spot	4	Camp 3, NTS	
				35	35	6	Highway 95	
				62	10	70	Charleston Peak, Nev.	
				72	12	7	Road 20 miles S of Charleston Peak, Nev.	

Table 5 — SUMMARY OF RESULTS, OPERATION JANGLE

Shot	Direction of cloud	Max. velocity, mph	No. of teams	Fall-out detected: Distance from NTS, miles	Length on highway, miles	Integrated dose, mr	Location	Remarks
Sugar*	NNE	46	7	40	25	2500	20 miles NW of Lincoln Mine	
				115	100	100	5 miles N of Currant, Nev.	
				160	72	280	36 miles E of Eureka, Nev.	
				235	100	20	15 miles N of Currie, Nev.	
Uncle	NNE	14.4	6	40	30	240	22 miles NW of Lincoln Mine	
				90	80	10	30 miles NE of Warm Springs	
				160			Ely, Nev.	Passage of cloud detected

* No sets of readings were made at the same points at different times on the Sugar shot. Fission-product decay is assumed in calculating the integrated dose.

Table 6—HOT SPOTS LOCATED FOLLOWING JANGLE SHOTS

	Shot	
	Sugar	Uncle
Dimensions, miles	5 × 10	5 × 8
Distance from Ground Zero to center of spot, miles	18	13
Distance from Ground Zero to maximum intensity, miles	15	9
Maximum intensity, r/hr	15	35
Average intensity, r/hr	5	3.5
Average dose, r	27	18

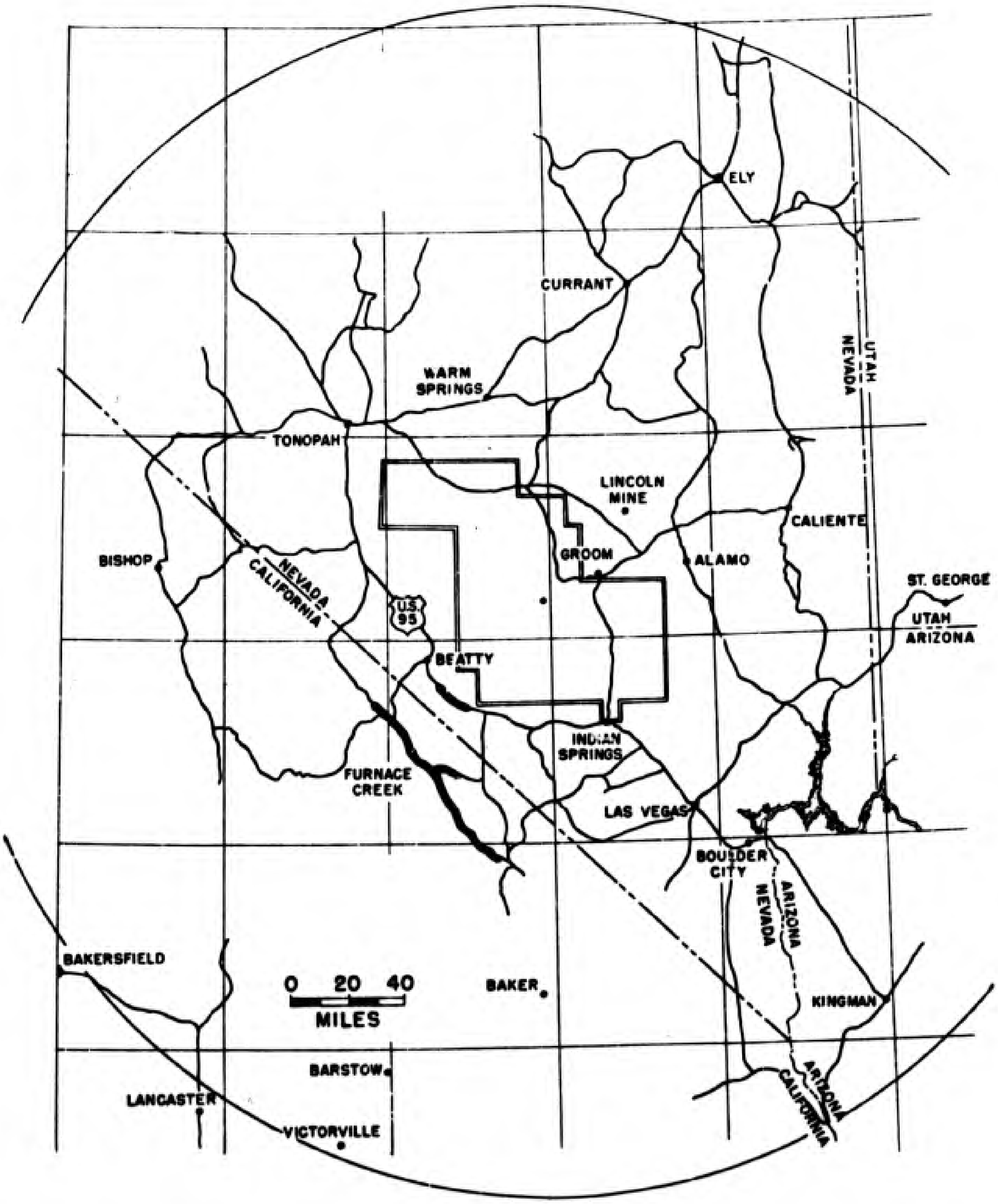


Fig. 12—Fall-out detected by mobile monitoring, Buster Baker, 0720 PST, 28 October.

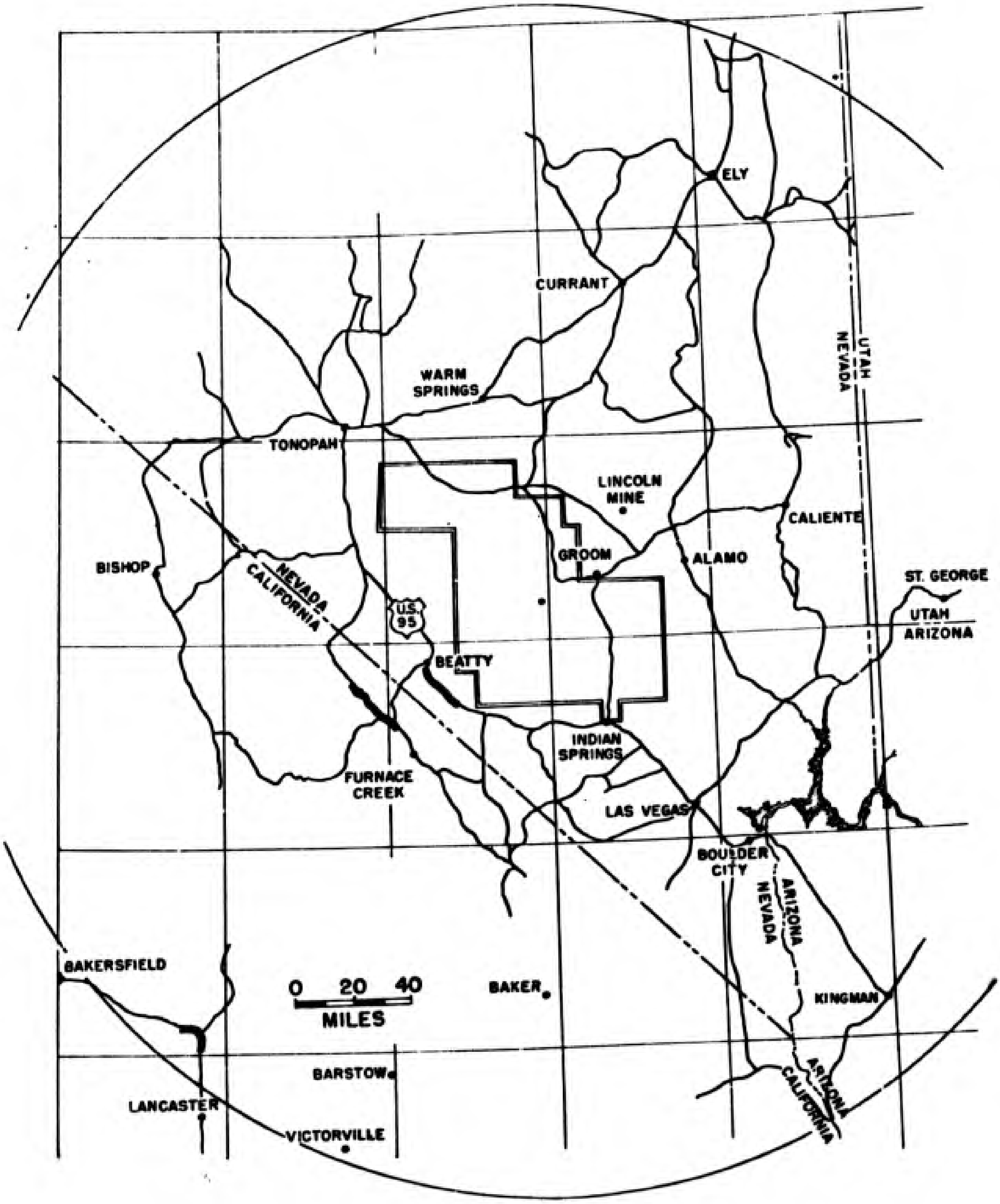


Fig. 13—Fall-out detected by mobile monitoring, Buster Charlie, 0700 PST, 30 October.

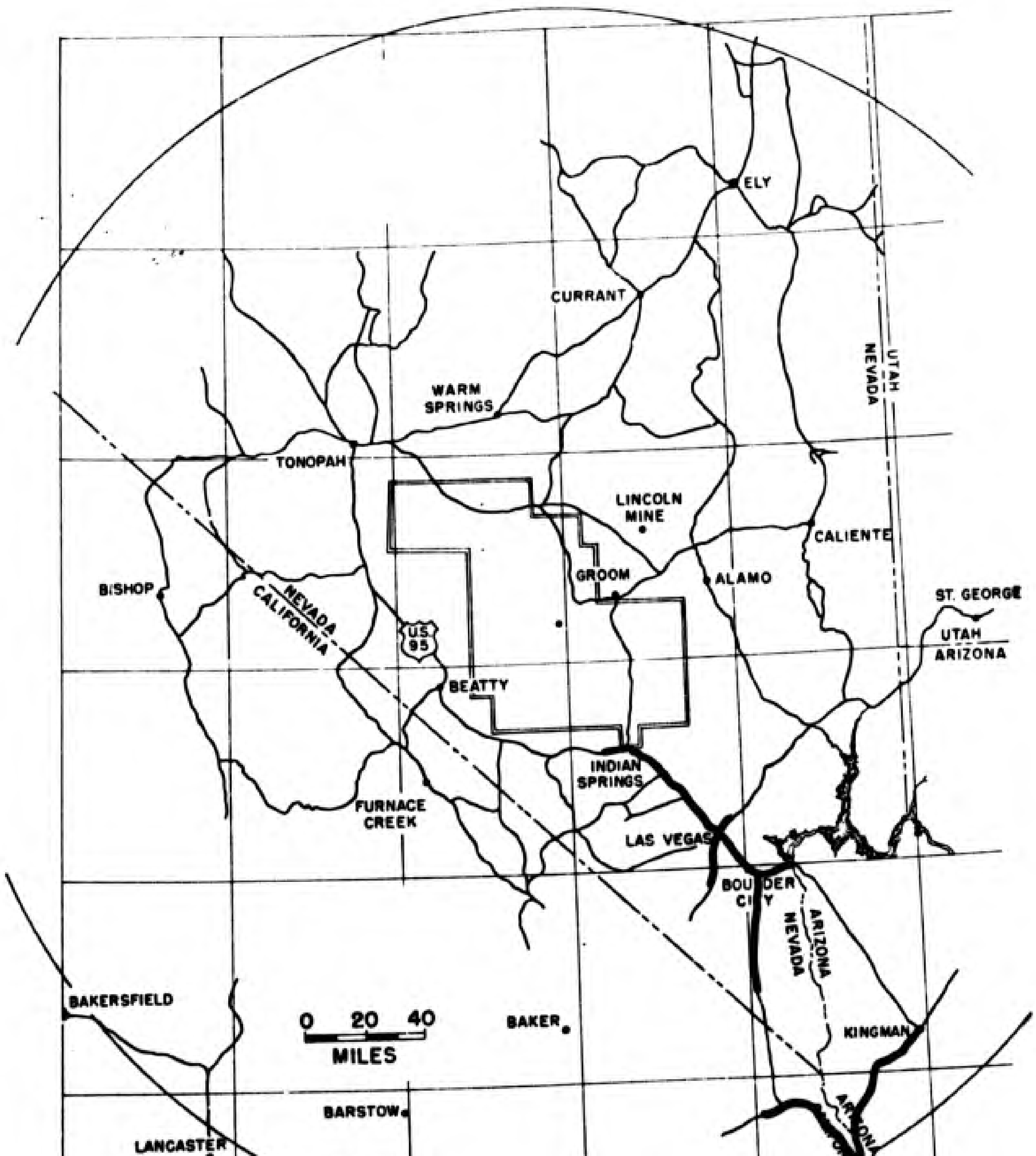


Fig. 14—Fall-out detected by mobile monitoring, Buster Dog, 0730 PST, 1 November.

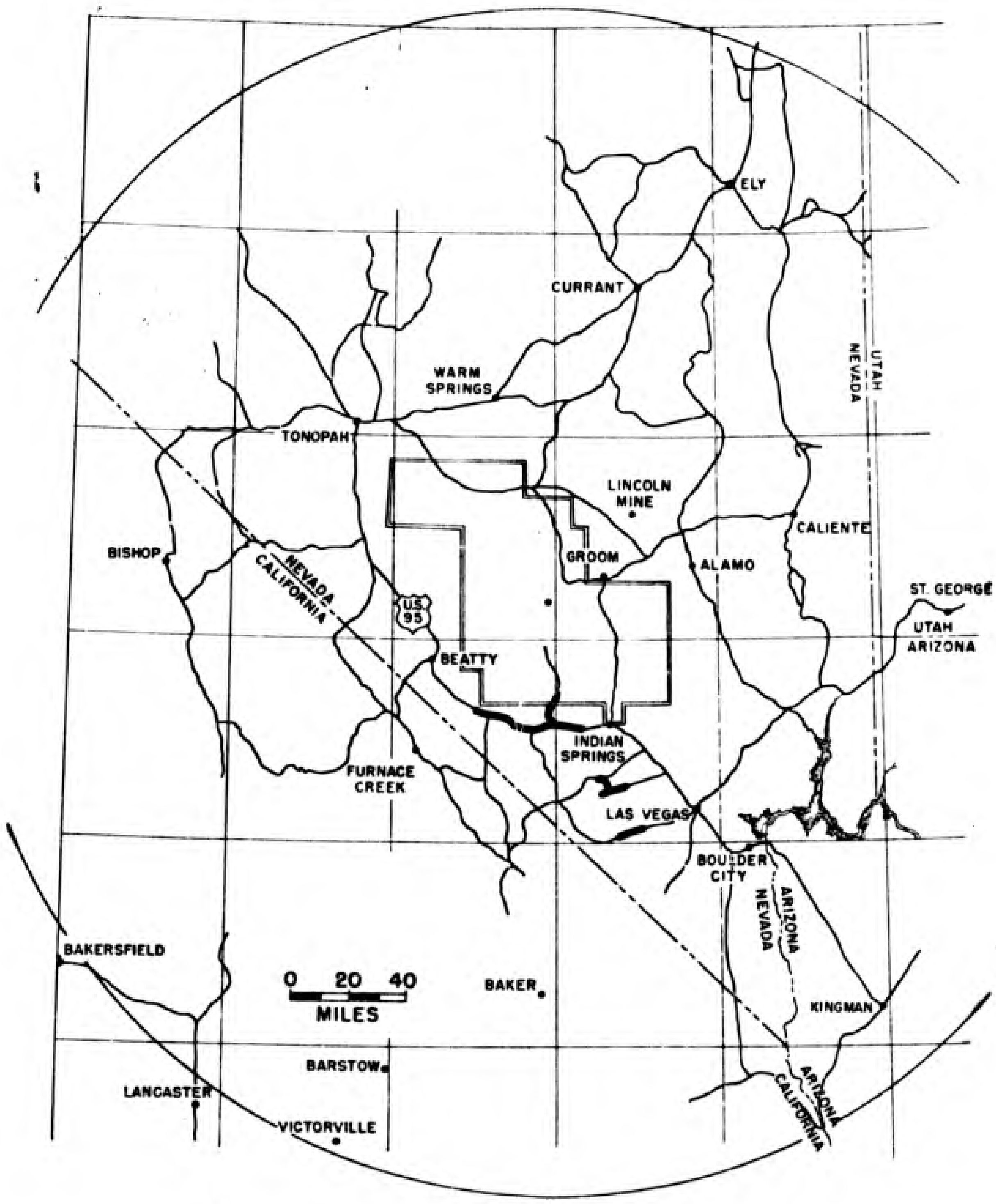


Fig. 15—Fall-out detected by mobile monitoring, Buster Easy, 0830 PST, 5 November.

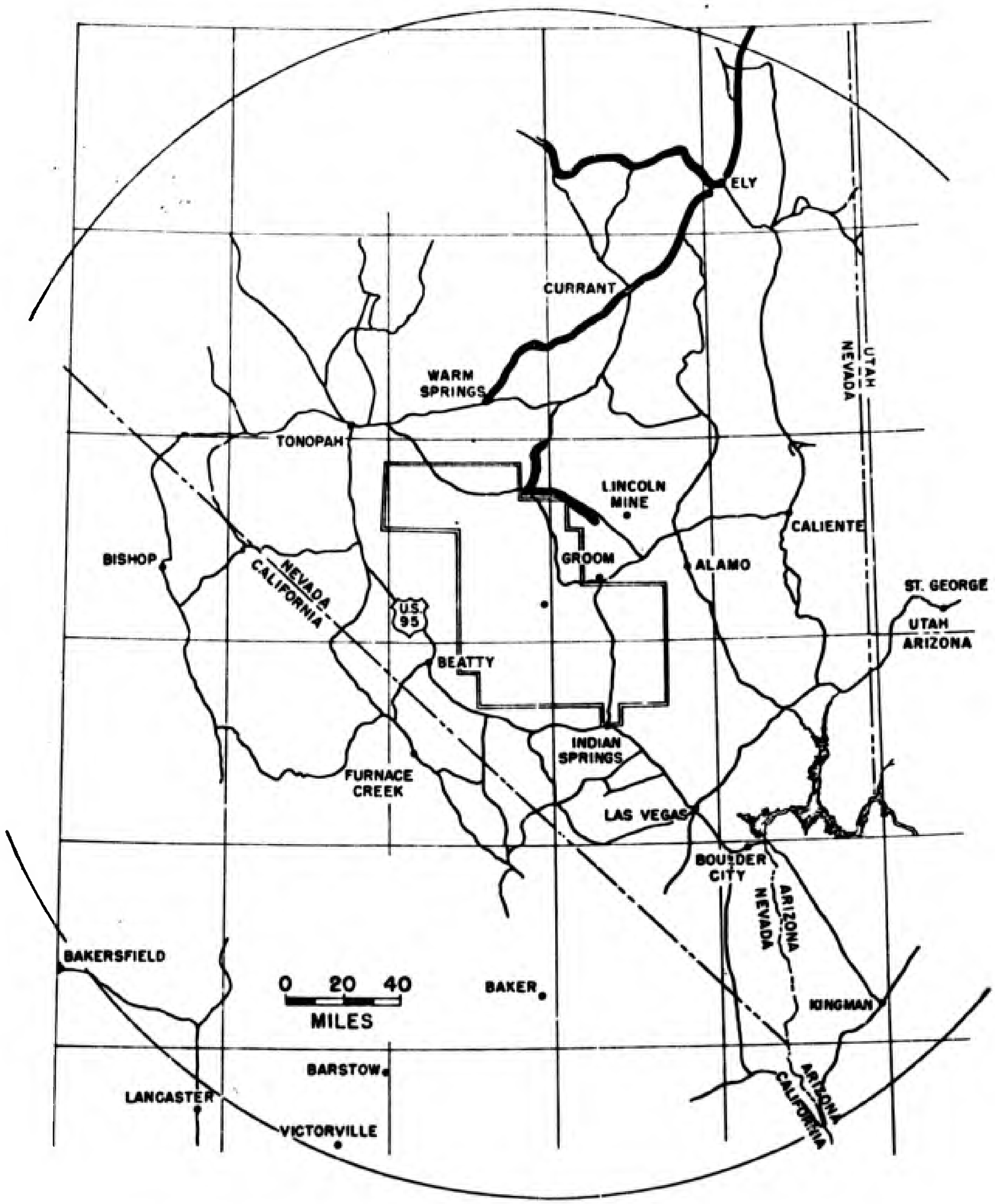


Fig. 16—Fall-out detected by mobile monitoring, Jangle Sugar, 0900 PST, 19 November.

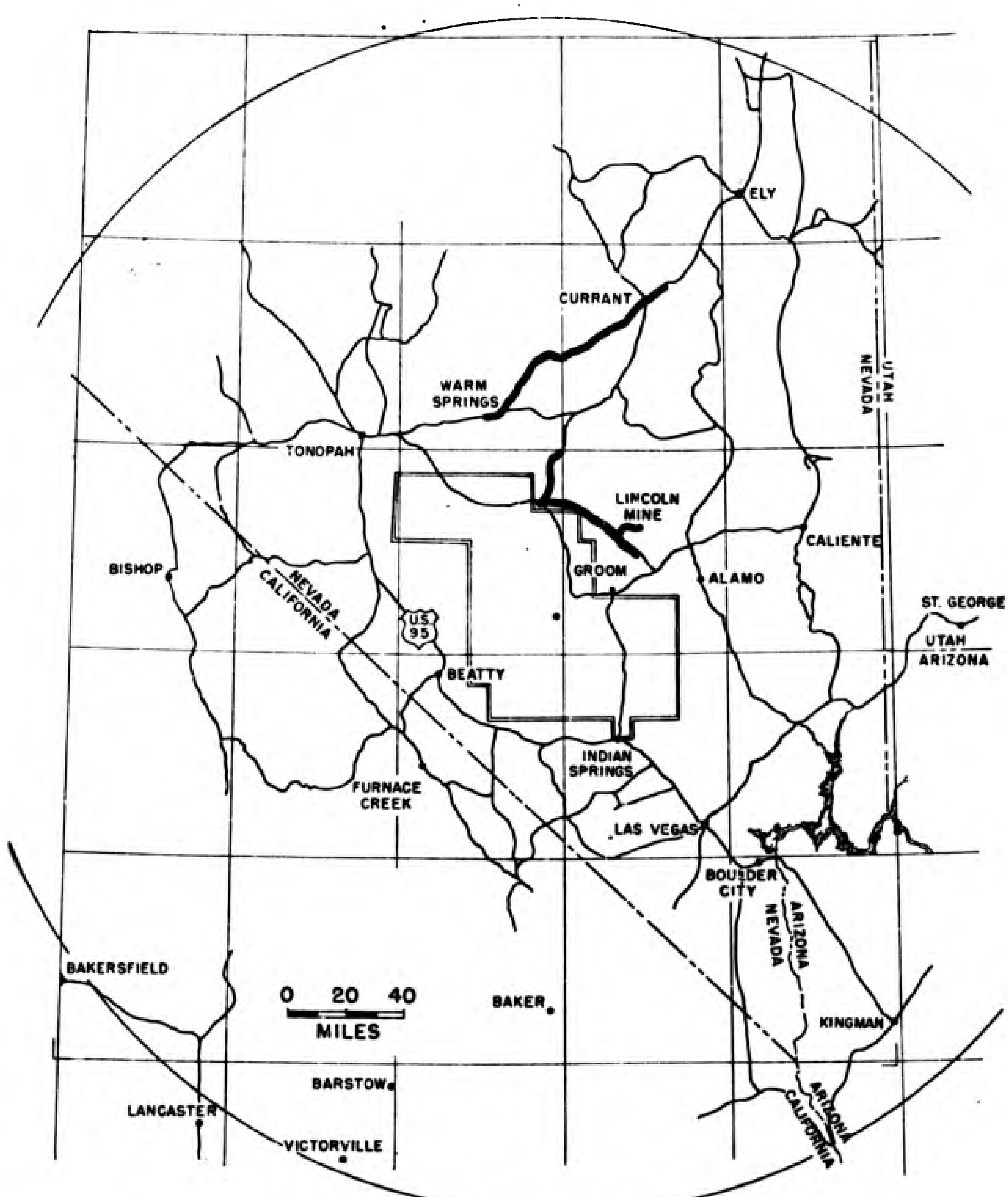


Fig. 17—Fall-out detected by mobile monitoring, Jangle Uncle, 1200 PST, 29 November.

APPENDIX E

FALL-OUT PROJECT

E.1 SCOPE

The fall-out project conducted by the Rad-Safe and Health Unit was confined to a zone 10 to 200 miles from Ground Zero. Fall-out at greater distances was covered by a project conducted by the AEC New York Operations Office. Fall-out at less than 10 miles was covered by Jangle Effects Test Program 2. During both Buster and Jangle incidental coverage within 10 miles was provided by the Rad-Safe and Health Unit but not as a formal part of the fall-out project. The primary objective of the fall-out project was to assess airborne contamination near the surface outside the NTS at the distances of the closer inhabited areas.

E.2 CRITERIA

The radiological safety requirements set forth by the Jangle Feasibility Committee were as follows:

1. The external dose of gamma radiation to nonparticipating inhabitants shall not exceed the accepted international permissible dose level of 300 mr/week, which may be integrated over a maximum of 10 weeks.
2. At a point of human habitation the activity of radioactive particles in the atmosphere, averaged over a 24-hr period, shall be limited to 100 μc per cubic meter of air (corresponding approximately to a ground-level gamma intensity of 30 mr/hr).
3. The 24-hr average radioactivity per cubic meter of air, due to suspended particles having diameters in the range 0 to 5.0 μ, shall not exceed 1/100 of the above, nor is it desirable for any individual particle in this size range to have an activity greater than 10^{-2} μc calculated 4 hr after the blast.

E.3 PERSONNEL AND EQUIPMENT

After preliminary surveys of the terrain to be covered and an estimation of the size of the program, it was apparent that Group H-5 could not supply the entire personnel for an undertaking of this magnitude. Assistance was requested, and given freely, from a number of agencies having personnel trained in air-sampling work. Personnel used were mainly those having experience in the field of industrial hygiene.

The equipment used was largely standard since there was not enough time for the development of specialized equipment. Electrolux vacuum cleaners, sampling through fluted filter paper (Mine Safety Appliances Co. type S), were used as the primary air-sampling instrument for the measurement of air concentrations of beta-active material. These fluted filter papers were ashed at the laboratory in CP Building 2, plated, and counted on end-window beta counters. In addition to the Electrolux units, Filter Queen vacuum cleaners, sampling through flat filter paper which was counted directly, were used at certain stations. The purpose of these was to provide a check on the Electrolux units with a sample that could be counted directly. Particle-size measurements were made using a cascade impactor with a Gast pump as a source of suction. Since no central sources of power were available at the locations to be sampled, individual gasoline-driven motor-generator sets were used as power sources.

In addition to these major items of sampling equipment, several other samplers were used in order to test their usefulness under field conditions. These included a spiral sampler developed by USPHS, several electrostatic precipitators, and two thermal precipitators. For the measurement of radiation background and time of arrival of fall-out, a number of recording Geiger-tube instruments were constructed and located at several points from the sampling area and in the surrounding communities. Aluminum sheets coated with adhesive and mounted on steel posts were placed at numerous points throughout the area to be studied. After exposure to fall-out these sheets were collected and radioautographed to give a graphic picture of the fall-out at each point. A 1000-cfm home precipitron unit was set up in an attempt to collect a large sample for additional chemical and microscopical work. In addition to this, a very large quantity of miscellaneous equipment was required to service the sampling stations.

The end-window counters used for counting filter papers and impactor slides were originally calibrated with uranium standards. After the conclusion of the operation a study of the counting problem was undertaken by using these same counters to measure the decay of fission products formed by exposure of a known amount of enriched uranium to a known neutron flux in the Los Alamos Water Boiler. Samples for this study were prepared by adding known volumes of solution of the irradiated material to filter papers and ashing them in exactly the same manner used in the field study. This study introduced certain corrections in the original data which have been incorporated into the results reported here.

E.4 OPERATION

A plan was prepared in advance whereby 10 teams were designated to set out 2 to 4 sampling stations each in the quadrant to the northeast of the firing site. Certain of these stations were located in fixed positions; other stations were to be located at the latest possible time, depending on the meteorological forecast. Because of the difficult terrain and the large distances encountered, this plan was found to be somewhat ineffective. Following the surface shot a number of changes were made because of these difficulties and because of the extreme contamination encountered in close-in areas. Most of the sampling stations were removed from the area within 30 miles of Ground Zero and were concentrated along an arc from 20 deg west of north to due east in a band 30 to 50 miles from the shot site.

It was planned to utilize Operation Buster primarily as a means of testing the sampling equipment under actual operating conditions, and only two sampling teams were utilized during this operation. Mainly it was found that the sampling equipment worked well and would be capable of obtaining the required information. For Buster each of the two teams utilized a radio-equipped panel truck for transporting the required equipment in setting up two sampling stations each. For Jangle there were 12 such teams using a variety of vehicles, including sedans, jeeps, pickup trucks, panel trucks, and a weapons carrier. All these were equipped with radios so that they could be directed to places where sampling would be most advantageous.

The sampling points are designated by numbers in Figs. 18 and 19. Some of the designated points were not used on any tests since experience in the field dictated the best sampling points.

E.5 RESULTS

On Operation Buster no significant air-concentration samples were collected on the Able shot. However, following the shot considerable air sampling was done in the shot area. Air sampling in the on-site region was attempted on several other Buster shots without obtaining very significant data. The remaining air-concentration data are given in Table 7.

Table 7—AIR CONCENTRATIONS, OPERATION BUSTER

Sampling location	Air concentrations, μc/m³			
	Baker	Charlie	Dog	Easy
Control Point	0.013		0.010	0.047
Beatty	0.0003	0.001		0.0002
15 miles W of Lathrop Wells		0.023		
10 miles W of Lathrop Wells		0.005		
Furnace Creek Ranch	0.0050	0.002		
12.5 miles NW of Furnace Creek		0.011		
Death Valley Junction	0.0005			
9 miles E of Lathrop Wells	0.0034			
Mercury				0.0032
5 miles E of NPG turnoff				0.0014
10 miles E of NPG turnoff			0.0013	
Cactus Springs			0.0064	
Indian Springs	0.0015		0.022	0.0008
Charleston Peak				0.0024
Charleston Peak Road and Deer Creek turnoff				0.0014
Highway 95 and Charleston Peak turnoff			0.0038	
Las Vegas	0.0005		0.028	0.0020
Water tank N of NPG		0.001		

It will be noted that most of the fall-out from the Buster shots occurred in the area south of the test site. This naturally caused considerable concern since the planned location of sampling points for Jangle were all to the north of the test site. It is to be noted that all air concentrations measured on Operation Buster were far below the permissible concentrations recommended by the Feasibility Committee. This is true even if it is assumed that all the material collected is within the size range capable of being inhaled into the lower respiratory tract.

The results obtained on the two Jangle shots are shown in Tables 8 and 9 and in approximate form in Figs. 20 and 21 which also show the distribution.

As a result of the unexpectedly high wind velocities encountered on the surface shot, several samplers were started after fall-out had begun. These results have been omitted or indicated as doubtful in the tables. The concentrations have been expressed in microcuries per cubic meter of beta activity averaged over the sampling period. Assuming the entire fall-out occurred during the sampling period and none occurred later, the 24-hr average concentration was calculated and is included in the tables. Because of the high wind velocities on the surface shot, all the fall-out occurred within the sampling period, except in the case of those samplers

Table 8—AIR CONCENTRATIONS FOR SUGAR SHOT, OPERATION JANGLE

Sampling station	Approximate location	Duration of sampling, hr	Air concentrations, $\mu c/m^3$ During sampling	24-hr av.
2	15 miles N of Ground Zero		Sampler started late	
40	15 miles N of Ground Zero		Sampler started late	
3	18 miles N of Ground Zero	1	0.079	0.002
3.5	19 miles N of Ground Zero	1¼	0.635	0.035
4	20 miles N of Ground Zero	3	0.406	0.048
5	18 miles NE of Ground Zero	4	0.0056	0.001
6	20 miles N of Ground Zero	6⅓	0.0079	0.002
7	25 miles NE of Ground Zero	4¼	0.0004	0.00008
8	25 miles N of Ground Zero	3	0.0256	0.0035
9	19 miles NE of Ground Zero (Groom Mine)	4¾	0.0005	0.0001
39	27 miles NW of Ground Zero	3	0.0040	0.0005
37	30 miles N of Ground Zero	5	0.0168	0.0037
41	30 miles N of Ground Zero	4¼	0.0206	0.0037
42	32 miles N of Ground Zero	4	0.0124	0.0022
36	34 miles NE of Ground Zero	4¾	0.0002	0.00004
15	44 miles NW of Ground Zero	4	0.0072	0.0011
14	43 miles N of Ground Zero	2¼	0.585	0.057
16	50 miles N of Ground Zero	4⅓	0.071*	0.011
17	43 miles N of Ground Zero	3¾	0.0147	0.0023
44	43 miles N of Ground Zero	4	0.261	0.046
32	41 miles N of Ground Zero	4	0.0047	0.0008
33	44 miles NE of Ground Zero	4⅓	0.0003	0.00004
31	39 miles NE of Ground Zero	4⅓	0.0001	0.00002
34	50 miles NE of Ground Zero	4¾	0.0013	0.0002
30	38 miles NE of Ground Zero	4¾	0.0008	0.0001
20	38 miles NE of Ground Zero	7	0.0002	0.00005
19	40 miles N of Ground Zero (Lincoln Mine)	1¾	0.0047	0.0003
Warm Springs	70 miles N of Ground Zero	5	0.0141	0.0031
Ely	150 miles NE of Ground Zero	24	0.0021	0.0021
Pioche	100 miles NE of Ground Zero	?		0.0027
Caliente	90 miles NE of Ground Zero	?	Background	
Hiko	55 miles NE of Ground Zero	8	0.0003	0.0001
Alamo	50 miles E of Ground Zero	11	0.0007	0.0003
Las Vegas	85 miles SE of Ground Zero	5	0.0002	0.00008
Indian Springs	45 miles SE of Ground Zero	7½	0.0001	0.00007
Beatty	45 miles W of Ground Zero	?		0.00008

*This sampler was started shortly after fall-out had begun; hence the result is undoubtedly low.

Table 9 — AIR CONCENTRATIONS FOR UNCLE SHOT, OPERATION JANGLE

Sampling station	Approximate location	Duration of sampling, hr	Air concentrations, $\mu c/m^3$ During sampling	Air concentrations, $\mu c/m^3$ 24-hr av.
9	19 miles NE of Ground Zero (Groom Mine)	4¾	0.00078	0.00016
43	44 miles NW of Ground Zero	~3½*	0.013	0.0020
15	44 miles NW of Ground Zero	3½	3.39	0.49
14	43 miles N of Ground Zero	5¼	0.971	0.0128
16	50 miles N of Ground Zero	3¼	0.072	0.010
17	43 miles N of Ground Zero	3½	0.448	0.067
44	43 miles N of Ground Zero	7¼	0.293	0.093
32	41 miles N of Ground Zero	7½	0.374	0.116
33	44 miles NE of Ground Zero	6¾†	0.666	0.186
33A	44 miles NE of Ground Zero	3½‡	0.103	0.0288
31	39 miles NE of Ground Zero	4⅓	0.684	0.118
34	50 miles NE of Ground Zero	5¾	0.722	0.174
36	34 miles NE of Ground Zero	3¾	1.17	0.192
30	38 miles NE of Ground Zero	4½	1.03	0.208
20	38 miles NE of Ground Zero	4¼	0.428	0.075
19	40 miles NE of Ground Zero (Lincoln Mine)	4½	0.541	0.102
21	36 miles NE of Ground Zero	4½	0.393	0.065
26	30 miles NE of Ground Zero	3¼	0.064	0.0093
22	36 miles NE of Ground Zero	3¾	0.216	0.034
23	36 miles NE of Ground Zero	4½	0.0004	0.00008
24	36 miles NE of Ground Zero	5½	0.0003	0.00008
28	45 miles NE of Ground Zero	5½	0.053	0.013
13	40 miles NE of Ground Zero	7	0.0163	0.0063
29	35 miles E of Ground Zero	5¾	0.0153	0.0037
45	35 miles E of Ground Zero	3⅔	0.0005	0.00008
Ely	150 miles NE of Ground Zero	20½	0.268	0.202
Pioche	80 miles NE of Ground Zero	19¾	0.00008	0.00005
Caliente	80 miles NE of Ground Zero	7	0.0005	0.00014
Hiko	55 miles NE of Ground Zero	6½	0.0010	0.00028
Alamo	50 miles E of Ground Zero	8½	0.0013	0.00049
Las Vegas	70 miles SE of Ground Zero	22	0.0002	0.00012
Indian Springs	45 miles SE of Ground Zero	25	0.0015	0.0016

* Filter torn at unknown time.
† Time: 1:30 to 8:15 p.m.
‡ Time: 8:15 to 11:45 p.m.

which were started too late. However, on the underground shot secondary fall-out occurred throughout the night, but, since these fall-outs were quite light as compared with the primary fall-out, the results probably are not more than 15 per cent in error from this cause.

Since the Feasibility Committee had not defined the method of calculating concentrations, all results were extrapolated to H+3 hr, which was representative of the fall-out time. This undoubtedly results in somewhat low values for the close-in samples on the surface shot and gives somewhat high values on distant samples for the underground shot. This error is not serious for the majority of the samples collected and does not affect the results of the study.

The danger of using one single shot to predict the results to be expected on another shot is well illustrated here. The magnitude of the directional wind shear was practically the same on both Jangle shots, but the velocities were considerably higher on the surface shot. The resulting pattern of distribution for the surface shot shows a narrow path of high air concentrations with the values falling off sharply at the edges. With the lower wind velocities for the underground shot, high air concentrations were found over a much broader sector. How much of this broad prevalence of fall-out is due to the presence of a greater quantity of active material in the air is difficult to say. Of considerable interest is the fact that external radiation levels from fall-out material on the ground were much higher on the surface shot than on the underground shot.

A limited number of cascade impactors were available for particle-size measurements, and these were placed in the anticipated fall-out path. Stage median diameters, assuming a density of 2.5 for the collected material, were calculated from the data of Laskin. The percentage of activity at each stage was plotted cumulatively against stage median diameter on logarithmic probability paper. The mass median diameter of particles containing activity can be taken from this plot, and the standard deviation, σ, can be taken from the slope. These data are given in Tables 10 and 11.

Table 10—PARTICLE-SIZE MEASUREMENTS, OPERATION BUSTER

Shot	Sampling location	Distance from Ground Zero, miles	Mass median diameter, μ	σ	Particles less than 5 μ, %
B	Furnace Creek Ranch	65	2.7	4.4	67
B	Control Point	10	1.4	11.7	74
C	On-site 10 min after shot	0	1.3	7.7	76
C	12.5 miles N of Furnace Creek	65	5.8	5.8	46
C	15 miles W of Lathrop Wells	45	2.8		76
D	Cactus Springs	40	8.8	6.8	38
D	Highway 95 and Charleston Peak turnoff	68	0.8	4.5	90
D	Indian Springs	42	1.5	2.1	95
E	Mercury	28	>10		~10
E	On-site 10 min after shot	0	4.5	7.5	50

No correlation of particle size with distance is apparent in these data. The range of distances studied is too narrow, the sampling points are not arranged along radii, and the various portions of the cloud do not travel in straight lines but are greatly affected by terrain factors. In general, particle sizes are appreciably larger on the underground shot than on the surface shot. A large fraction of all samples are smaller than 5 μ and hence are capable of being taken into the lower respiratory tract.

E.6 SPECIFIC ACTIVITY

Fall-out trays, adhesive-coated aluminum sheets, were used to collect particulate matter near the surface of the ground. These trays were radioautographed and washed with toluene, and the washings were ashed and counted. The number of exposed spots on the radioautographs were counted. From these data it is possible to calculate average values of activity per square foot, activity per particle, and number of particles per square foot. This complete type of analysis was possible on only a limited number of trays since the activity collected must be high enough for accurate counting and yet low enough for individual particles to be counted on the radioautograph. On the surface shot there were very few suitable trays; however three trays from stations lying approximately along a radius from Ground Zero gave values of 16.9×10^{-3}, 3.3×10^{-3}, and 2.1×10^{-3} μc/particle at distances of 18, 30, and 43 miles, respectively. On the underground shot the range of distances over which measurements were made was much smaller, and the variations in specific activity were small. However, close-in trays (approximately 18 miles) are high (approximately 20 μc/particle) as compared to more distant trays (1 to 3 μc/particle). The data are too limited to allow a determination of whether there is any significant difference between the specific activities of particles from these two shots. Certainly the difference is not large.

A number of filter papers were radioautographed and counted for particle number and activity. These gave specific activities much lower than the trays in the case of the surface shot but equal to, or higher than, the trays on the underground shot.

Table 11—PARTICLE-SIZE MEASUREMENTS, OPERATION JANGLE

Sampling station	Distance from Ground Zero, miles	Mass median diameter, μ	σ	Particles less than 5 μ, %
		Surface Shot		
40	15	1.1	5.0	83
41	30	3.0	4.3	64
37	30	0.6	7.7	85
42	32	3.1	8.6	60
14	43	0.6	5.4	90
44	43	1.4	13.5	70
		Underground Shot		
36	34	1.0	>15	55
22	36	5.0	3.1	50
31	39	10.0	9.5	36
19	40	1.2	5.8	80
14	43	27	10.5	23
34	50	18	7.2	26

E.7 GROUND CONTAMINATION

Data from monitoring runs in off-site areas are given in Appendix D of this report. However, radioautographs of fall-out trays give graphic pictures of the distribution of ground contamination. Figures 18 and 19 contain portions of prints from these radioautographs.

E.8 GENERAL PARTICLE DATA

A detailed study of individual particles was not carried out as planned because of the necessity of preparing for the next test operation. Some general observations were made, however. Following the surface shot the presence of small "beads" of active material was noted in the area immediately north of the test site. These appeared to be fused glassy material containing numerous inclusions. No such particles were found in the cloud path after the underground shot.

Radioautographs of fall-out trays from many stations after the surface shot contained numerous tracks, all oriented in the same general direction. Such tracks did not appear on radioautographs from the underground shot. The most reasonable explanation appears to be that particles traveling at high velocities in the high winds that prevailed on S-day continued to move across the adhesive-coated surface for short distances and detached active material as they moved. This indicates that at least some of the activity is only loosely attached to the surface of the fall-out particles. Prints from several typical radioautographs are given in Figs. 22 to 27.

The particle-size distributions plotted from cascade-impactor data are distinctly different in shape from those found on dust dispersed by industrial operations, such as grinding, sanding, and machining. This bomb-dispersed material seems to contain a relatively high percentage of very small material (less than 1 μ) and also a relatively high percentage of large material (greater than 10 μ) with very little in the intermediate ranges. The standard deviation or slope of the distribution curve is also much higher in this dust than in most industrial dusts.

E.9 DECAY RATES

Decay curves were plotted on numerous samples, and they showed the typical slope of −1.2 on log-log paper for times greater than 500 hr. Below 500 hr the points lie well above the curve except on the few measurements made earlier than 50 hr, where the points again seem to be on the same curve as those measured after 500 hr. This is in general agreement with the data of Maxwell[1] on Jangle crater samples. This hump in the curve is attributed by Maxwell to the presence of 2.3-day neptunium.

E.10 SOIL COMPOSITION

Before Operation Buster-Jangle soil samples were collected in the area where the shots were to be fired. A particle-size study of these samples indicated that the soil contained a relatively high proportion of fine particles, more than 50 per cent of it being smaller than 200 μ. Chemically the soil is chiefly silicates, iron oxide, and quartz; the fine material consists chiefly of cerussite, feldspar, clay, iron oxide, and calcite. A much more detailed soil analysis was made as part of a U. S. Department of Agriculture project, and the results will be found in their report.[2]

E.11 CONCLUSIONS

1. The particle-size distribution of airborne material varied greatly from point to point on all shots and did not vary in any consistent manner with distance over the area studied. Although the mass median particle size was somewhat greater on the underground shot than on the surface shot, all samples contained a very considerable percentage of particles of respirable size.

2. Measured average specific activities of particles in the fall-out path varied from 0.001 to 0.02 μc/particle. Activity per particle appeared to decrease with distance over this area.

3. Air concentrations of active material did not exceed the recommendations of the Jangle Feasibility Committee at any point, although they approached these figures at several points as much as 50 miles distant from the point of detonation.

REFERENCES

1. Charles R. Maxwell, Nature and Distribution of Residual Contamination, Buster-Jangle Project 2.6c-1 Report, WT-373, p 34, June 1952.
2. L. T. Alexander, J. M. Blume, and M. E. Jefferson, Analysis of Test Site and Fall-out Material, Buster-Jangle Project 2.8 Report, WT-371, March 1952.

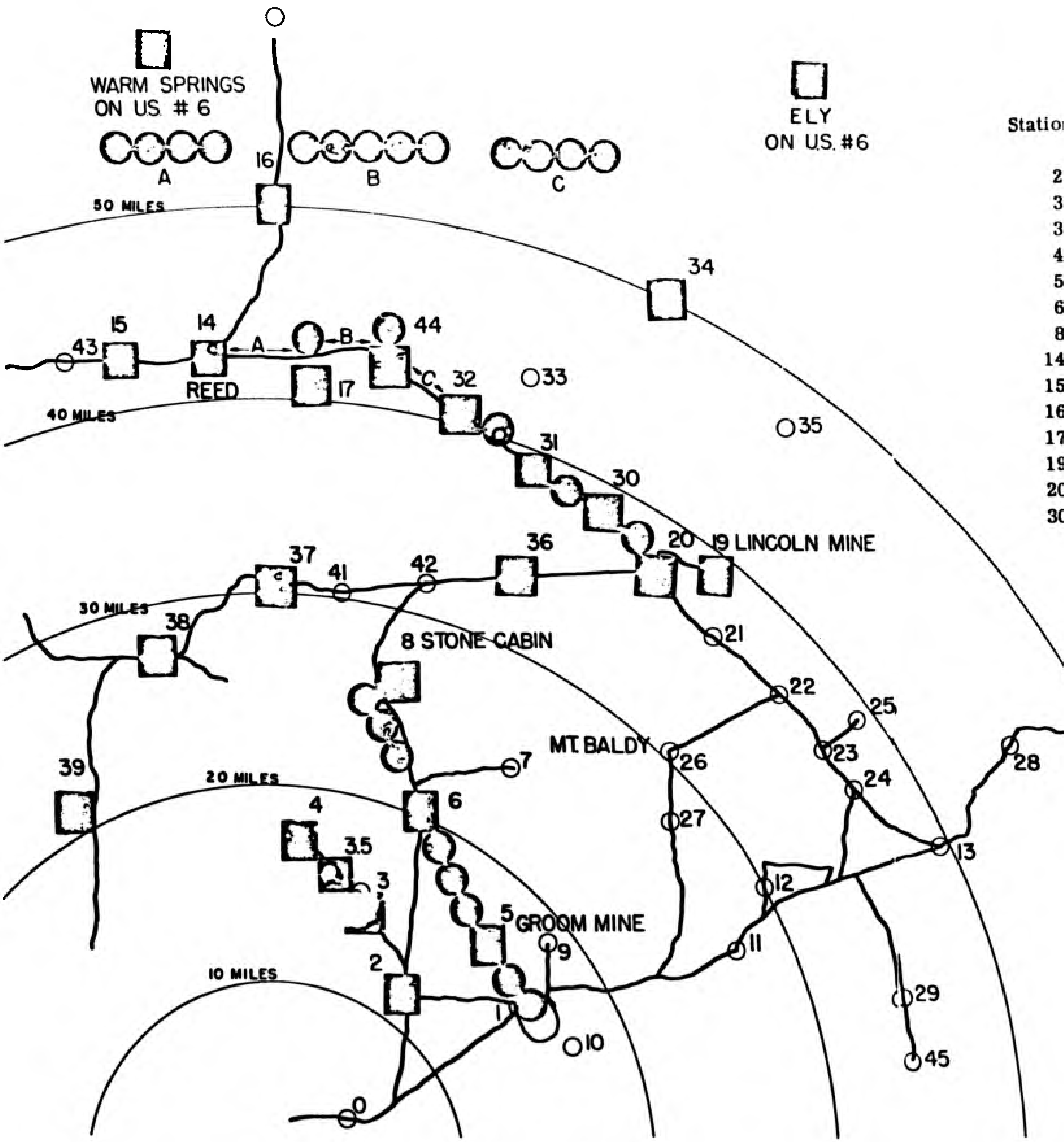
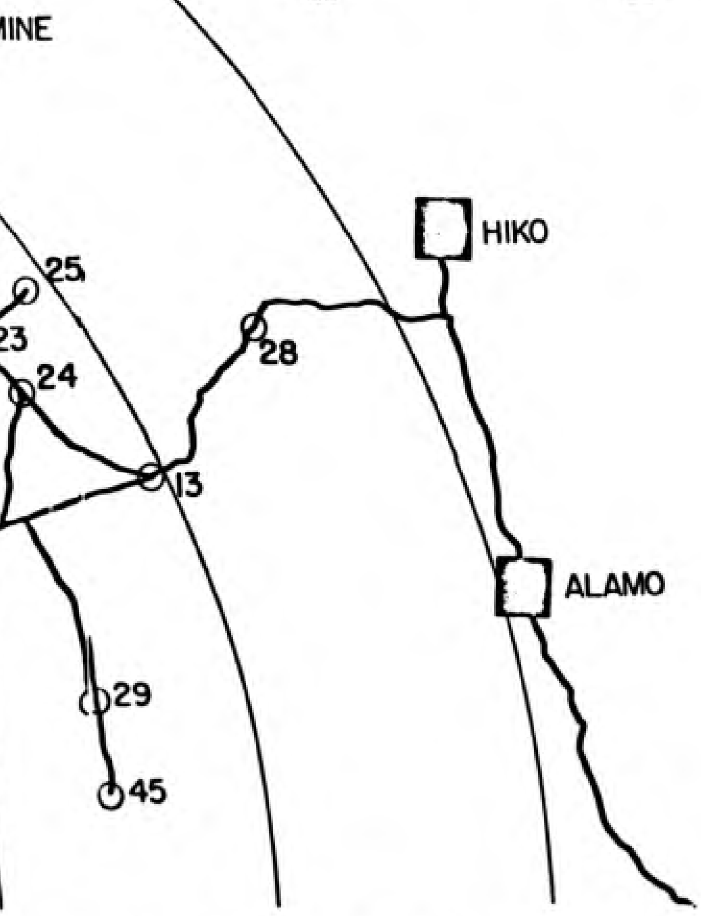


Fig. 18—Distribution of fall-out by radioautograph of collect'ion trays, Jangle Suga

■ Collection trays located at air sampling stations.
○ Collection trays located on post between stations.

#6

Station No.	No. of particles/sq ft	Station No.	No. of particles/sq ft
2	4,300	31	460
3	21,200	32	3,300
3.5	22,500	34	8,200
4	880	36	18
5	510	37	22,900
6	430	38	3,300
8	45,000	39	1,200
14	14,900	44	30,400
15	940	Alamo	200
16	4,600	Hiko	80
17	9,700	Ely	510
19	17	Warm Springs	600
20	175		
30	42		



f collect'ion trays, Jangle Sugar shot, 19 November.

2

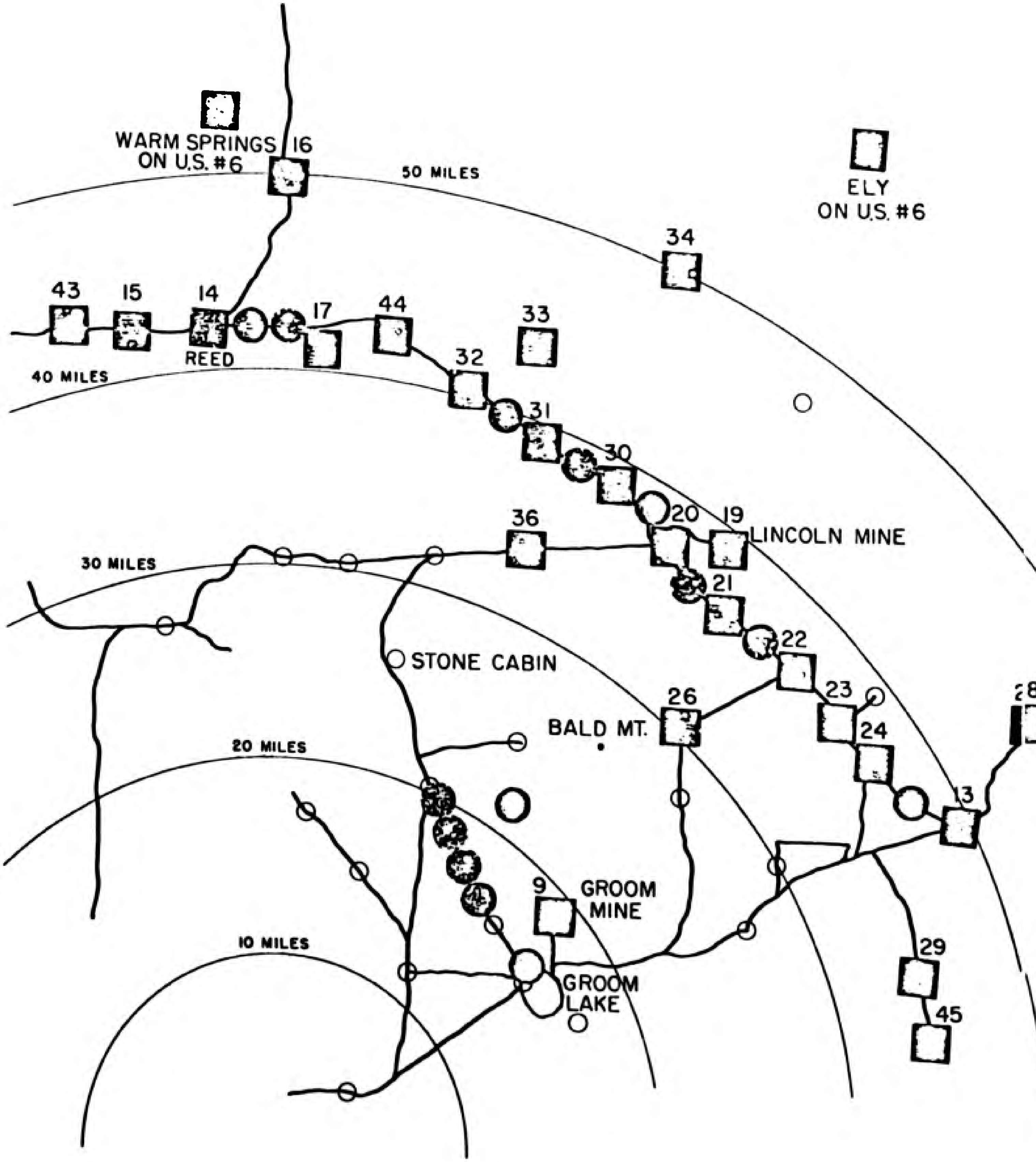
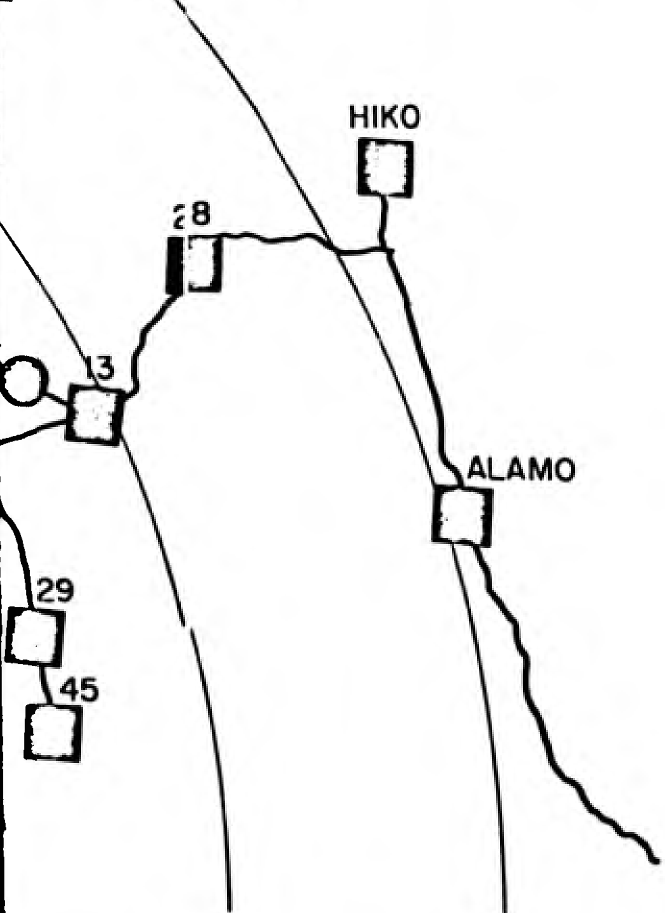


Fig. 19—Distribution of fall-out by radioautograph of coll e
November.

□ Collection trays located at air sampling stations.
○ Collection trays located on post between stations.

Station No.	No. of particles/sq ft	Station No.	No. of particles/sq ft
9	210	29	630
13	770	30	54,500
14	65,500	31	74,500
15	69,600	32	113,300
16	23,300	33	61,400
17	44,400	34	58,000
19	35,400	36	71,100
20	42,700	43	1,500
21	35,000	44	62,000
22	58,500	45	490
23	420	Ely	35,600
24	280	Hiko	105
26	18,800	Alamo	125
28	350	Warm Springs	56,500



utograph of coll ection trays, Jangle Uncle shot, 29

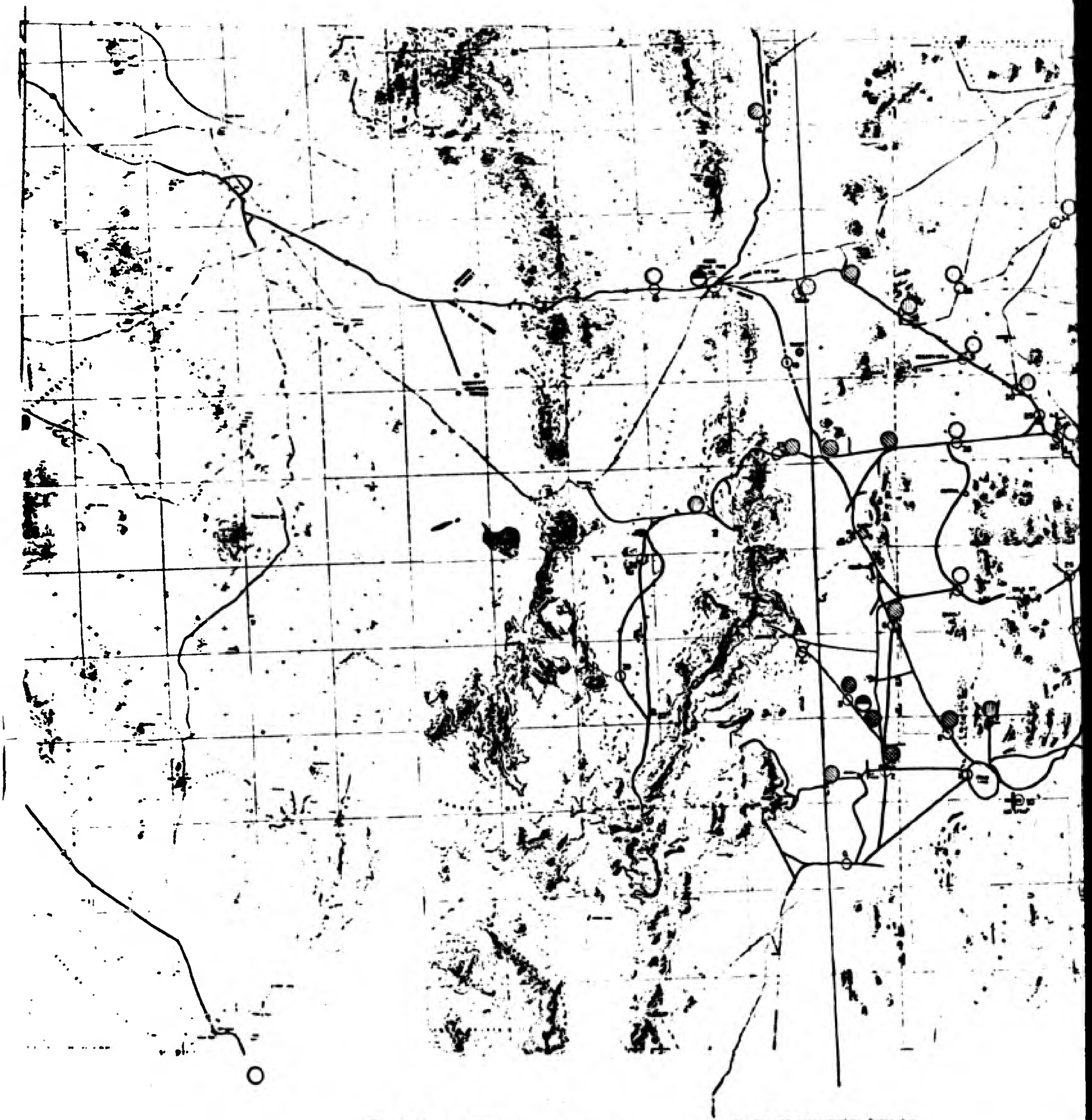
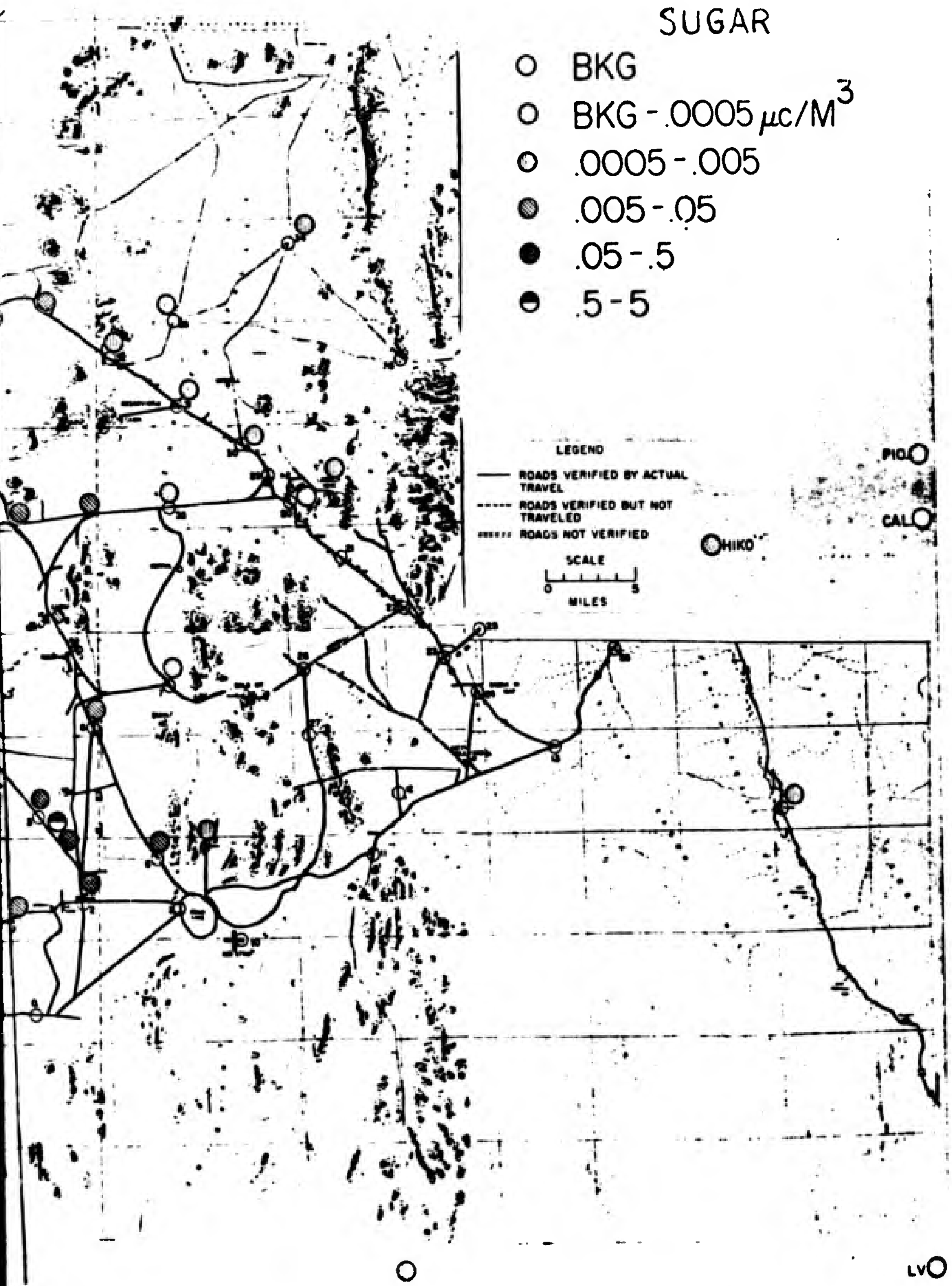


Fig. 20—Air concentrations, Sugar shot.



rations, Sugar shot.
3

2

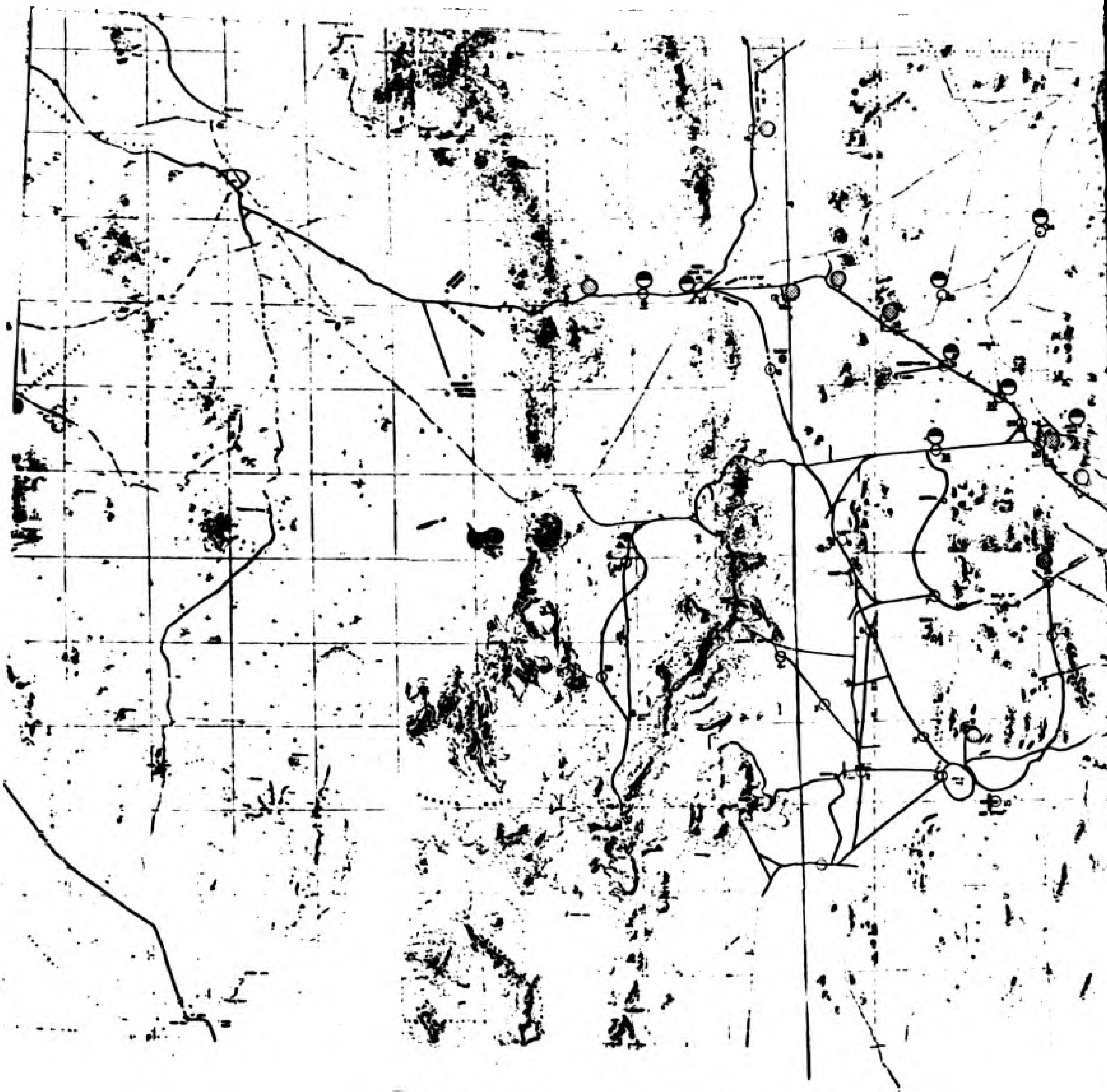
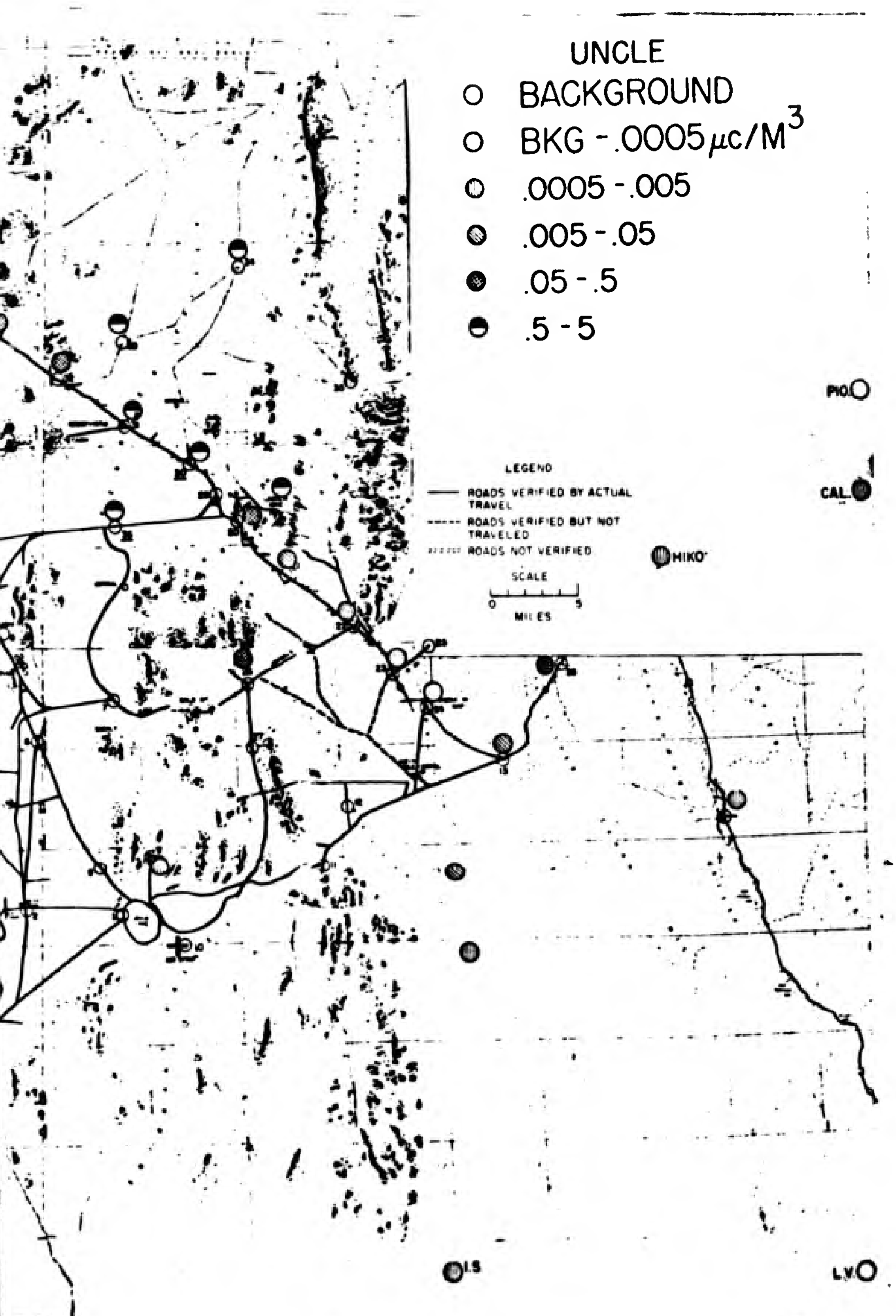


Fig. 21—Air concentrations, Uncle shot.



Uncle shot.

1

2

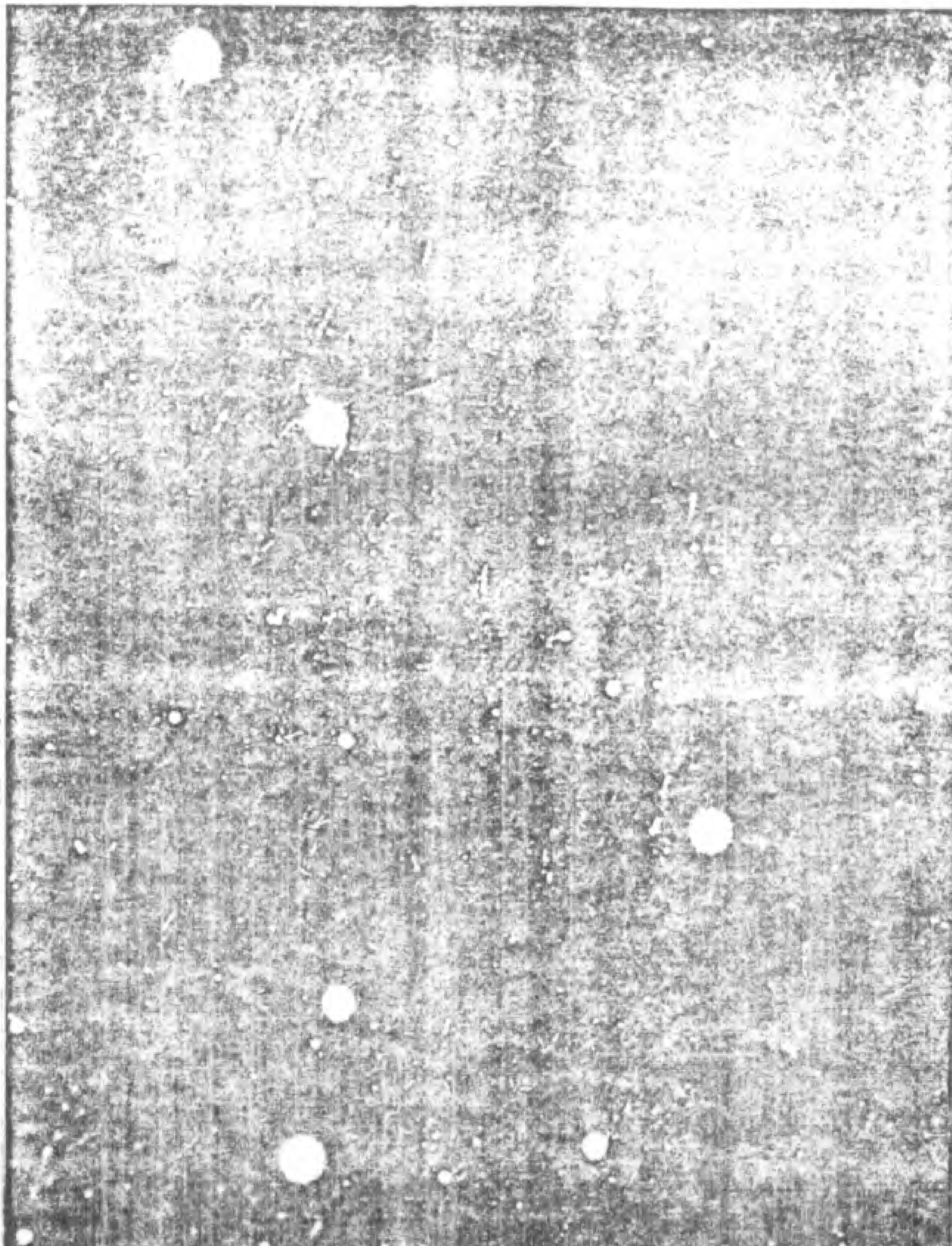


Fig. 22—Radioautograph of fall-out tray located four miles south of Station 8, Jangle Sugar shot.

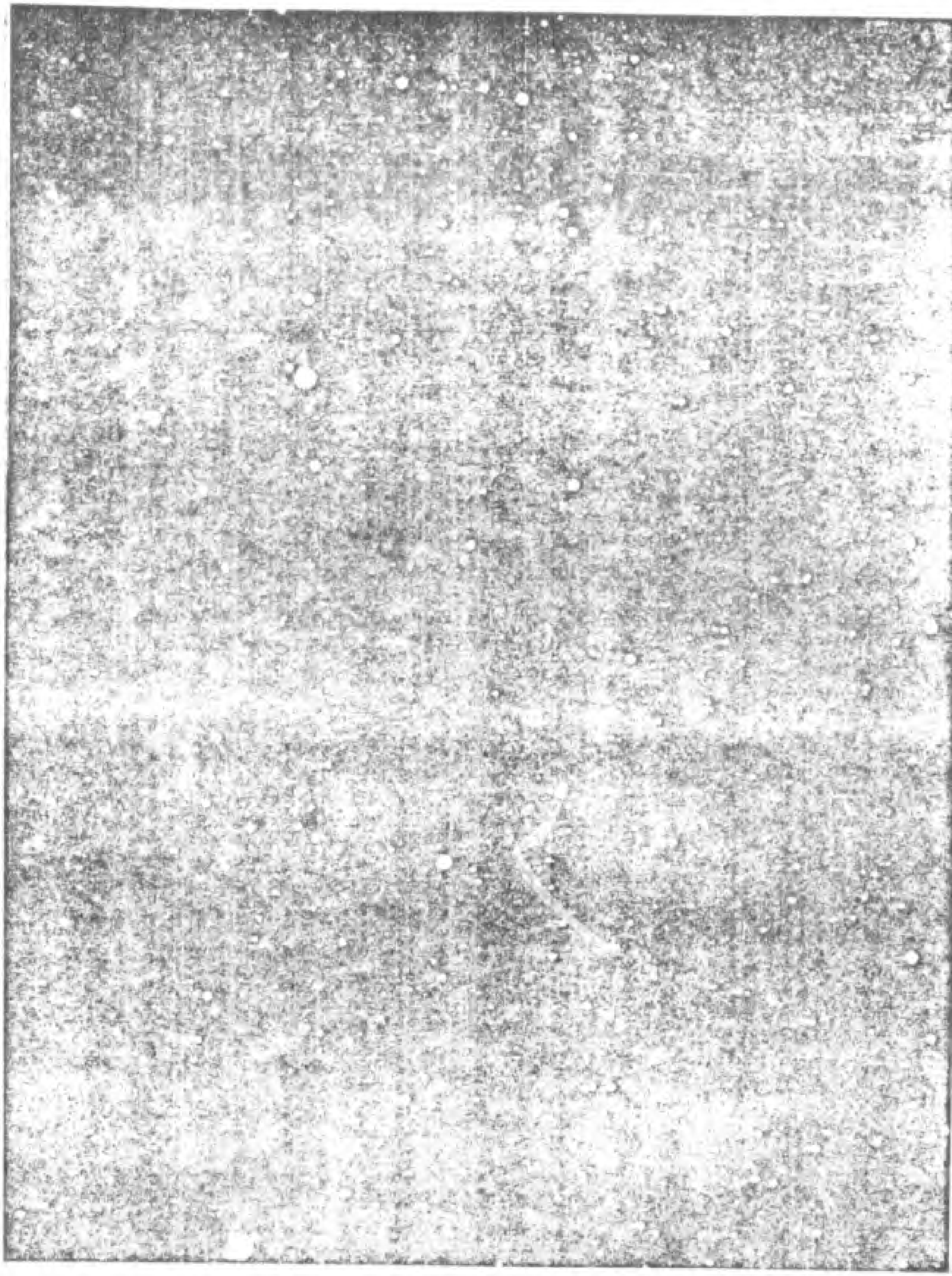


Fig. 23—Radioautograph of fall-out tray located at Station 14, Jangle Sugar shot.

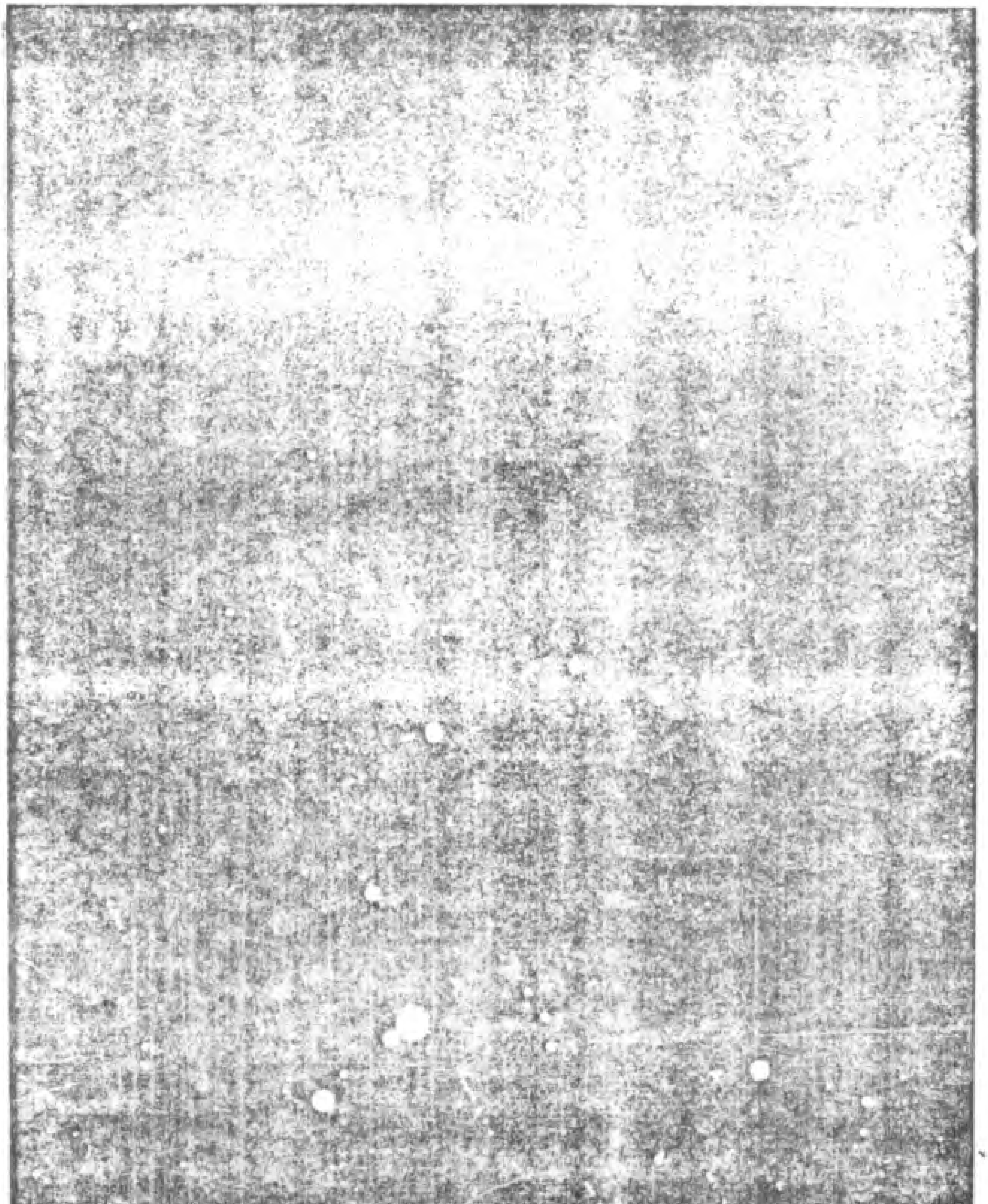


Fig. 24—Radioautograph of fall-out tray located at Station 32, Jangle Sugar shot.

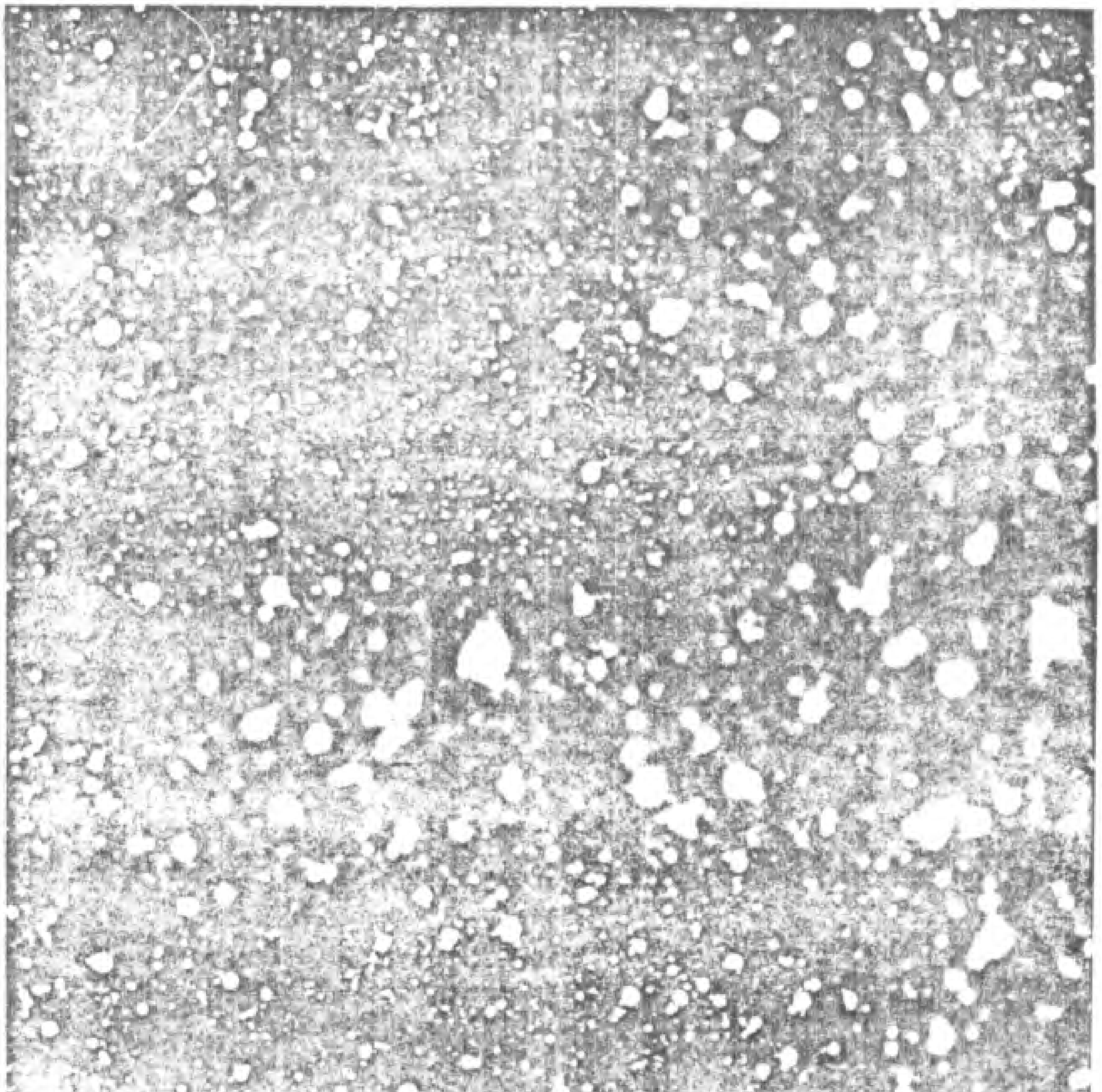


Fig. 25—Radioautograph of fall-out tray located midway between Stations 20 and 21, Jangle Uncle shot.

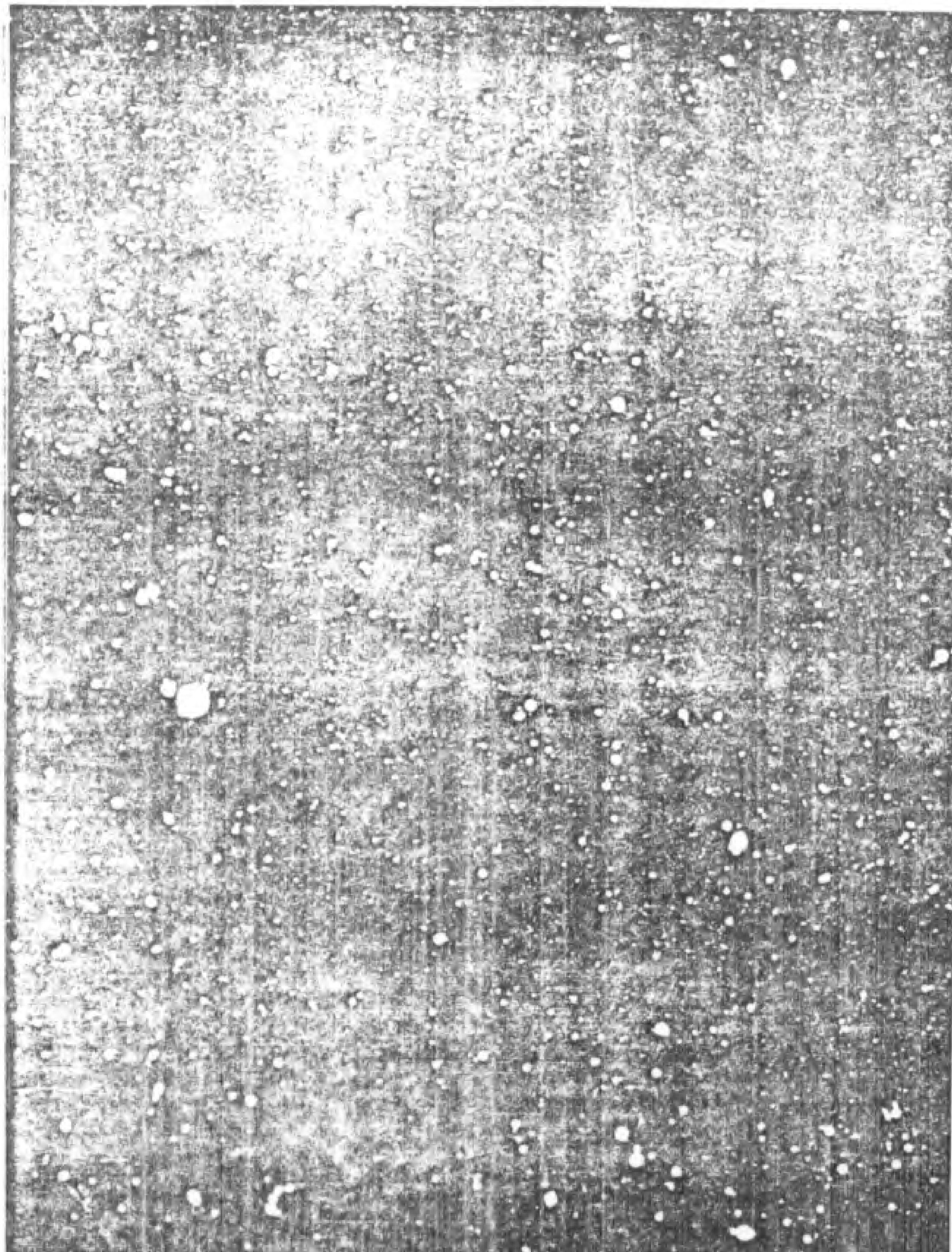


Fig. 26—Radioautograph of fall-out tray located midway between Stations 31 and 32, Jangle Uncle shot.

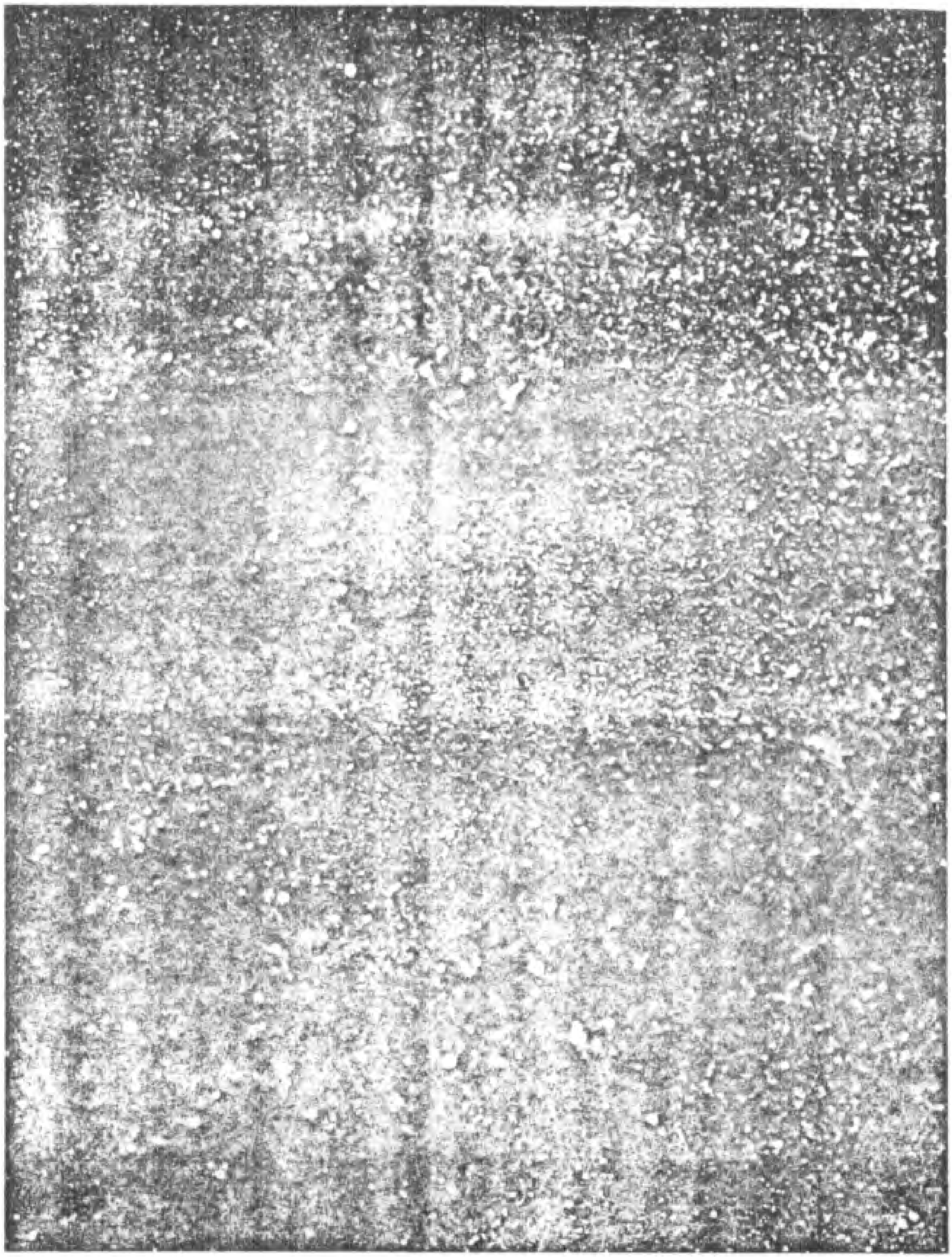


Fig. 27—Radioautograph of fall-out tray located 7.4 miles northwest of Groom Lake toward Stone Cabin, Jangle Uncle shot.