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PNE-529
FINAL REPORT

Plowshare civil, industrial and scientific uses for nuclear explosives

PROJECT SCHOONER

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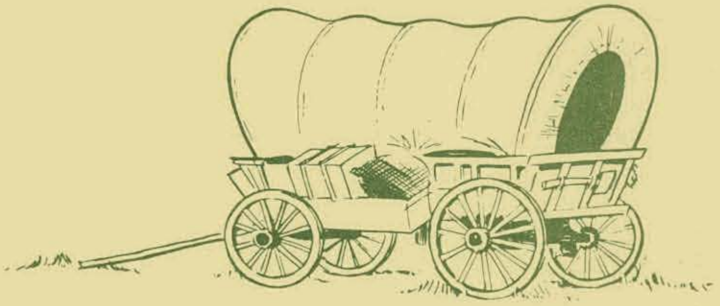

Ecological and Environmental Effects from Local Fallout from Schooner

2. The Beta and Gamma Radiation Effects from Close-in Fallout

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EG and G, Inc.
Goleta, California

ISSUED: JUNE 30, 1972

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PROJECT SCHOONER
PROJECT CEP-68.5

ECOLOGICAL AND ENVIRONMENTAL EFFECTS FROM LOCAL FALLOUT FROM SCHOONER

2. THE BETA AND GAMMA RADIATION EFFECTS FROM CLOSE-IN FALLOUT

by

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ABSTRACT

Project SCHOONER, a nuclear cratering event with approximately eight to ten times the yield of two previous Nevada Test Site cratering events, PALANQUIN and CABRIOLET, offered the opportunity to further investigate radiation doses and short-term effects to vegetation and the environment, where a larger affected area was anticipated and where topography might be expected to further influence the results of close-in fallout.

Specially constructed dosimeters were placed at 92 locations, forming an arc with a radius of approximately 1.7 to 2.0 km, beginning about 12 degrees west of north with respect to GZ. This arc was about 3.35 km long with a mean distance between dosimeter stations of 36 meters. Dosimeters were positioned in vertical arrays at 25 cm, 1 meter, and 3 meters above the surface away from shrubs, as well as on the soil surface, and on shrubs. To determine whether preventing direct fallout from reaching the shrubs would protect them, polyethylene sheets were placed over shrubs at alternate stations.

Twelve days after detonation the dosimeters were removed from the field and the protective sheets were removed. No effects were observed on the vegetation except a dusty covering on the unprotected shrubs. In April (D plus 4 months) the first effects attributable to radiation were noted. During the following months at the center of the fallout pattern all *Artemisia* shrubs lost their leaves and died except those which had been covered with plastic sheets. Elsewhere along the arc there was a "skirting effect" in which the lower parts of larger shrubs were defoliated while the tops remained near normal. Small shrubs were completely killed. Increasingly larger shrubs were killed with higher doses. Beyond the dosimetry arc, a helicopter survey allowed an assessment of the extent of vegetation damage. South of the crater, study sites were established in the most diverse environments resulting from the crater formation. Vegetation analysis at these sites showed successional changes which might be expected to return the area to conditions approximating undisturbed conditions.

ACKNOWLEDGEMENTS

Drs. Evan Romney, Hideo Nishita, Arthur Wallace, Verle Hales, Messrs. Harold Mork, James Childress, Thomas Ackerman, and Paul Wieland assisted jointly or individually in various phases of the field work and in planning. All are from the Laboratory of Nuclear Medicine and Radiation Biology, UCLA.

Mr. Thomas DeVore, EG&G, Inc., built the dosimeters and assisted in field placement. After return of the dosimeters from the field, he completed readout of the exposed dosimeters.

Radiological safety monitoring personnel from the Reynolds Electrical and Engineering Company accompanied work parties into the SCHOONER fallout pattern for radiation detection and contributed as well to other field tasks. Mr. Vernon Bostick was especially helpful.

Dr. Benjamin Mason, Environmental Protection Agency, Dr. Robert Mullen, EG&G, Inc., and Professor Robert Harvey, San Bernardino Valley College, California, assisted in vegetation analysis.

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To all these individuals and organizations, the authors express their grateful appreciation.

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1. INTRODUCTION

Project SCHOONER, a nuclear excavation experiment in a layered tuffaceous medium, offered an opportunity to investigate radiation doses to the local environment from a device approximately eight to ten times as large as those used in PALANQUIN and CABRIOLET, two previous nuclear cratering projects in the PLOWSHARE program. SCHOONER was detonated on 8 December 1968 in the northwest corner of Nevada Test Site (NTS) in Area 20 and a few miles north of the PALANQUIN and CABRIOLET sites. The yield was 31 ± 4 kt, and the resulting crater had the following dimensions:

1.	Radius of apparent crater	129.8 meters
2.	Maximum depth of apparent crater	63.4 meters
3.	Average apparent crater lip crest height	13.4 meters
4.	Radius of apparent lip crest	147.2 meters
5.	Radius of outer boundary of continuous ejecta	539.0 meters

1.1 TOPOGRAPHY AND VEGETATION

The area immediately around the SCHOONER GZ is flat, but at distances of 1500 to 1800 meters to the north and somewhat farther to the northeast there is a canyon with a bottom some 60 meters lower in elevation. The canyon width varies from 250 to 370 meters, and the canyon bottom is flat, allowing access with four-wheel-drive trucks for the placement of dosimetry stations. Outside the canyon there is very little soil, and the surfaces are mostly outcroppings of nearly flat-lying welded tuff. In the canyon bottom are alluvial layers in generally dry stream beds. Above the canyon the vegetation is dominated by *Artemisia tridentata* and *A. arbuscula* subsp. *nova*. In the canyon, dominance is shared with *Atriplex canescens*. These *Artemisia* species were important to this study because they also occurred at PALANQUIN and CABRIOLET and were the subject of investigation of radiation effects from those events. Approximately some 16 perennial shrub species are also found in the SCHOONER fallout pattern. These are listed in Appendix A. *Juniperus osteosperma* which was of interest at PALANQUIN and CABRIOLET did not, unfortunately, occur at SCHOONER, which was at a somewhat lower elevation.

It should be pointed out that the topography in the immediate downwind area of SCHOONER was quite different from that at either PALANQUIN or CABRIOLET. At those two experiments the direction of the fallout distribution was parallel with the directions of canyons, and the fallout occurred mainly along ridges. At SCHOONER, however, at the distances at which the dosimeters were placed, the canyon roughly encircled the GZ across the north and northeast, which was necessarily transverse to fallout originating at GZ. As will be discussed later, these conditions were of signficance in interpreting differences noted between SCHOONER and earlier close-in fallout studies of areas downwind to nuclear cratering experiments.

1.2 HISTORY AND BACKGROUND

The two earlier events in the PLOWSHARE program, PALANQUIN and CABRIOLET, both provided evidence of radiation damage to the vegetation in the close-in fallout patterns. Project PALANQUIN, which was detonated 14 April 1965, used a small device of about 4 kilotons that produced a crater approximately 350 feet in diameter. Vegetation in the immediate downwind vicinity was estimated to have received high (kiloroentgen) doses of radiation[1]. On the margins and downwind extremities of the radiation pattern and in other parts as well, however, the nature of the damage to the vegetation and the low estimates for the gamma doses indicated the damage was in a large measure due to beta radiation. At Station K-5 (Reynolds Electrical and Engineering Company radiological safety monitor station) 2.05 miles downwind from GZ, the estimated infinite gamma dose was 370 R*. At that location all *Artemisia* shrubs were dead in July 1967, 27 months after D-day.

Although gamma radiation doses to the vegetation could be calculated from the radiological safety monitoring which accompanied the experiment, these dose estimates were necessarily based on decay rates which were known to vary from place to place. Beta dose estimates would be much less reliable since they would have to be made by multiplying the estimated gamma doses by factors derived from a theoretical ratio of the beta dose to the gamma dose. The estimated values for these ratios have been large[2].

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*Estimated by Thomas A. Gibson, Jr., K. Division, Lawrence Radiation Laboratory.

As a consequnce of the PALANQUIN study, the CABRIOLET event, 26 January 1968, was also investigated. CABRIOLET was a cratering experiment using a device of 2.3 ± 0.5 kt. It occurred about 800 meters east of PALANQUIN. For CABRIOLET, dosimeters especially designed to distinguish between beta doses and gamma radiation doses were placed at 58 locations on D minus 1 day in order to assure better information on doses to the vegetation. These dosimeters were recovered from the fallout pattern on D plus 11 days. The total doses were very low compared to the doses estimated for areas at similar locations relative to PALANQUIN GZ, but damage to the vegetation was again detected, although it was restricted to a small area. On the basis of the dosimetry, the doses in the part of the fallout pattern where damage was noted were also attributed largely to beta radiation, since the ratios of beta doses to gamma doses ranged from 6.0 to 12.5.

This appears to have been the first extensive measurement of beta doses in a fallout field, particularly under conditions which would permit attributing such doses to exposed vegetation.

1.3 OBJECTIVES

The objectives of the SCHOONER study were similar to, and in large measure influenced by, the study of radiation doses and short-term effects on vegetation conducted at CABRIOLET. The four primary objectives were:

1. To measure with precision the radiation doses to the vegetation from both beta and gamma radiation from fallout close-in to GZ, and to obtain some indication of the beta fluxes, often referred to as the "beta bath", from the ground surface to 3.0 meters above it.
2. To detect plant damage and correlate it with doses which could be attributed to the vegetation, and to report the short-term (few months) and long-term (years) radiation effects.
3. To assess vegetation damage in terms of radiation levels encountered and compare the results with those from the two preceding events, PALANQUIN and CABRIOLET.

4. To investigate the use of shielding to prevent radiation damage to shrubs from direct fallout deposition. Since beta doses at CABRIOLET were postulated to be an important cause of damage to the vegetation, it appeared that any protective material which would prevent fallout particles from reaching the surfaces of shrubs might also prevent some beta radiation damage.

2. PROCEDURE

2.1 DOSIMETRY TECHNIQUES

Most of the objectives of this study required the same type of intensive dosimetry program undertaken in the CABRIOLET study, plus certain refinements in measurements and the design and deployment of dosimeters. The SCHOONER dosimetry program is documented in detail in Appendix B. This section summarizes the design, fielding, and recovery of dosimeters.

Special thermoluminescent dosimeters, slightly modified from those used at CABRIOLET[3] and capable of distinguishing between doses from beta radiation and gamma radiation, were used to determine doses to vegetation. The dosimeters were covered with black opaque Mylar light shields to prevent the degradation of recorded dose by fading in sunlight, a process that handicapped the CABRIOLET dosimetry. In addition, lead shields placed above or below the dosimeter ships were used to more precisely delineate the origins of the beta doses.

Experience at CABRIOLET suggested that dosimeters positioned 3 to 4 meters above the surface would be above the beta "bath". In a further attempt to distingush the beta energies encountered and the sources of beta doses to plants, dosimeters were placed 3 meters above the surface, as well as at the surface and at 25 cm and 1 meter above the surface. The dosimeters were held on a vertical wire between upper and lower side arms on steel fence posts bolted together to provide sufficient height, as shown in Fig. 1. The wire stringer held the dosimeters between side arms away from the posts, thereby reducing the shielding masses near the dosimeters and limiting the surfaces on which fallout particles could be retained to essentially the surfaces of the dosimeters themselves, the soil surface, or the surrounding vegetation.

Although tests in the laboratory and in open sunlight at Santa Barbara indicated there was no loss of dose from dosimeters left unread for extended times, one further test was made for loss of dose before readout. In this test, strings of dosimeters were placed outside the Civil Effect Test Operations (CETO) Laboratory at Mercury, Nevada, concurrently with the fielding of SCHOONER dosimeters. These dosimeters, which had been given standard doses of 500 rads in

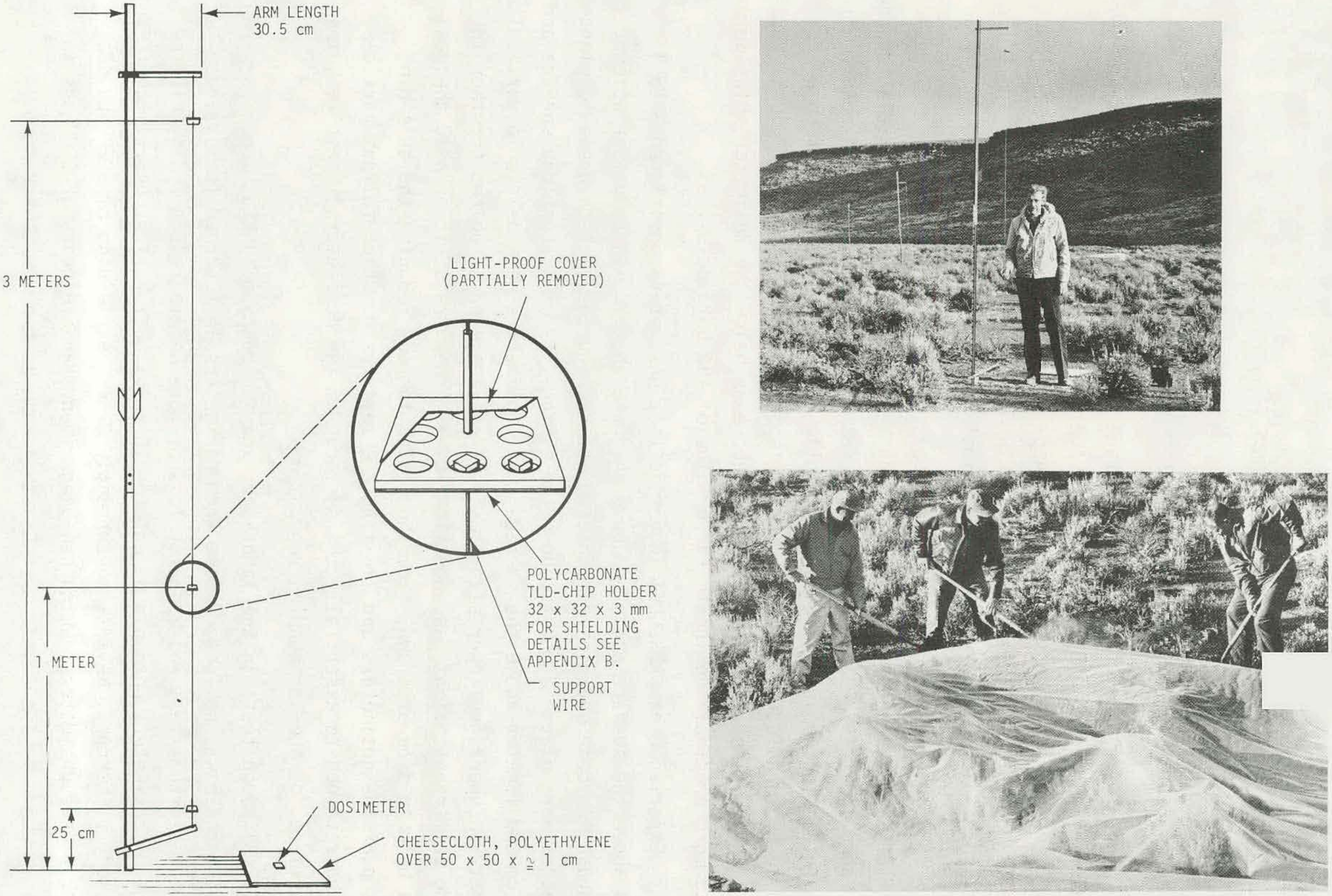


Fig. 1 Details of dosimeter placement and polyethylene shrub cover along the station arc north and east of GZ.

the laboratory at Santa Barbara, were collected for readout at the same time as the SCHOONER dosimeters.

2.1.1 Location and Placement of Dosimeter Stations

An attempt was made to locate the dosimeters where the highest doses would be observed, but beyond the larger masses of material from throwout and base surge. For this purpose, it was feasible to use the canyon described previously, located north and northeast of GZ, and which forms an irregular semicircle from west to east (see Fig. 2). This location was calculated to be about the same relative distance as that at which dosimetry had been placed at CABRIOLET, based on the cube root of the kilotonnages[4] of the two events.

Dosimeters were placed at 92 locations, forming an arc with a radius of approximately 1.7 to 2.0 km, beginning about 12 degrees west of north with respect to GZ. This arc was about 3.35 km long with a mean distance between dosimeter stations of 36 meters. All dosimeters except those on shrubs covered with polyethylene (Section 2.3) were placed in the field November 12-14, 1968, in anticipation of an earlier D-day. The locations of the dosimetry stations are shown in Fig. 2, which also indicates the crater, the plateau around the crater, and the canyon on the north and east of the plateau.

2.1.2 Recovery of Dosimeters

Dosimeters were removed from the field 20 December 1968, on D plus 12 days, and returned to the laboratory at Santa Barbara for reading by the same methods used previously (see Appendix B).

At the time the dosimeters were collected, radiation dose rate readings were made at each dosimeter station by Reynolds Electrical and Engineering Company (REECO) radiological safety monitoring personnel in the conventional manner, i.e., with an instrument probe held about 1 meter above the ground surface. The purpose was to allow evaluation of the usefulness of such methods as an indication of the total dose compared to the doses integrated by the dosimeters.

2.2 FALLOUT COLLECTION

For the purpose of estimating the total amount of material deposited

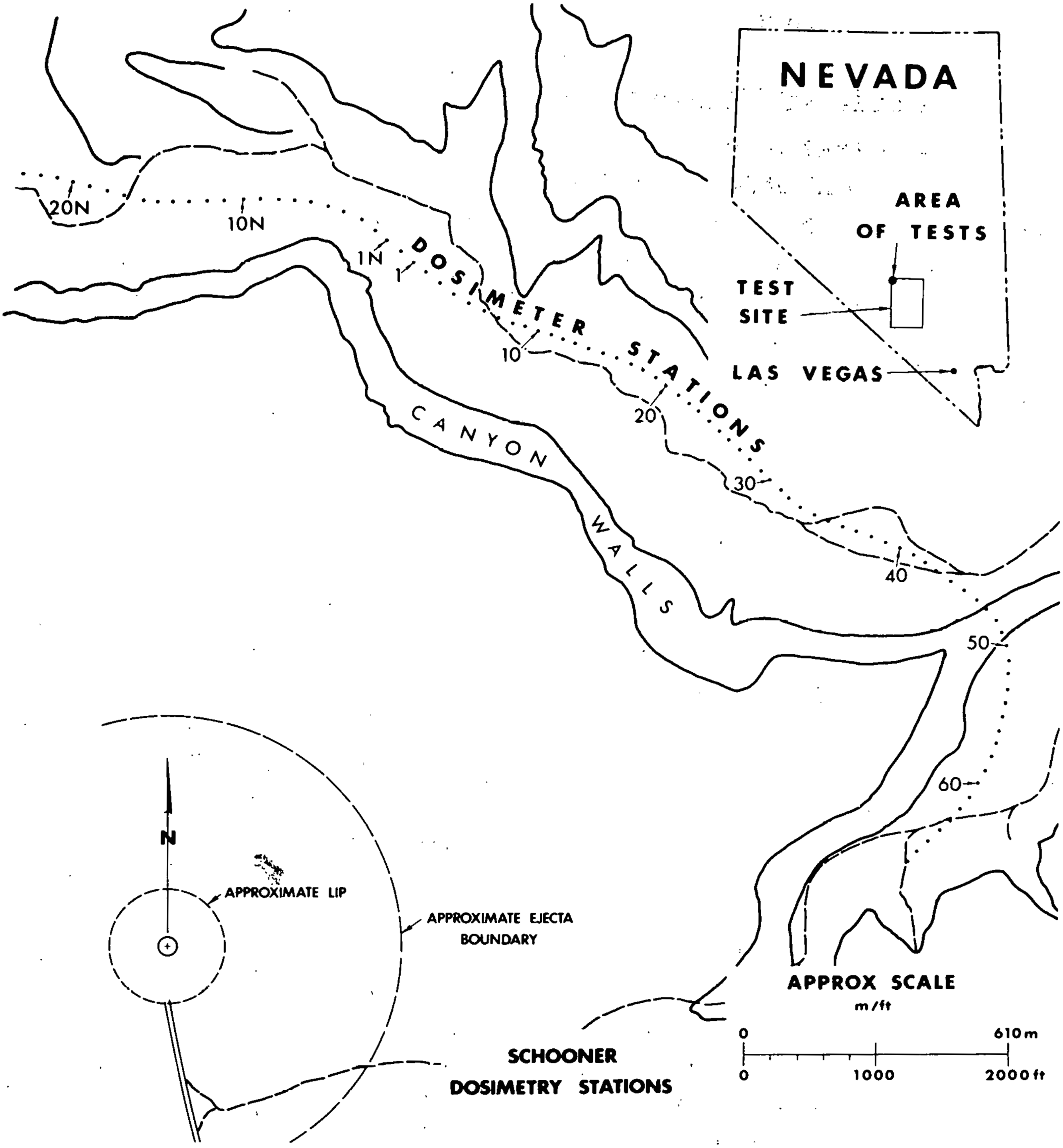


Fig. 2. SCHOONER crater and the location of the dosimetery stations to the north and east of it.

at each dosimeter station, collectors were placed at each location. The collectors consisted of 1/4-meter-square plywood sheets covered with a layer of polyethylene sheet topped with a double layer of cheesecloth. The board was covered in such a way as to allow the plastic sheet to be loosened from the back of the board and drawn with the edges together into a "bag" with the cheesecloth inside.

Dosimeters for recording "surface doses" were fastened to the center of each fallout collector.

2.3 PROTECTION OF VEGETATION FROM PARTICULATE FALLOUT MATERIAL

At each even-numbered dosimetry station, a polyethylene sheet 0.15 mm thick and approximately 6 meters square was placed over as many *Artemisia* shrubs as could be conveniently covered. The sheets were held down by soil shoveled on their margins. At the same time, four dosimeters were placed on the shrubs under the plastic covers as well as on nearby shrubs which were not covered. This was completed November 30, 1968 (D minus 8 days). The covers were removed from the vegetation on D plus 12 days, at the same time the dosimeters were removed from the field.

2.4 ASSESSMENT OF EFFECTS ON VEGETATION ALONG THE DOSIMETRY ARC

Examination of the vegetation began at the time of removal of dosimeters from the field. Evaluation of effects was done in a number of ways.

From Appendix A it will be noted that a relatively large number of perennial shrubs grow in the area. However, *Artemisia* was the only species which occurred with sufficient frequency to provide an adequate analysis, that is, to provide sufficient numbers for any statistical treatment. For this reason the vegetation study was primarily concerned with *Artemisia*. Outside the area along the arc of dosimeter stations, other shrubs were utilized where purely descriptive analyses could provide a more general picture in the relatively large area affected by SCHOONER.

The first examination was a simple visual comparison of vegetation in and out of the fallout pattern. Thereafter, these comparisons continued at monthly intervals, as weather conditions permitted, until manifestations of damage were noted.

With the first evidence of changes in the vegetation near the center of the fallout pattern — changes which could be attributed to fallout radiation — several more detailed methods were employed.

In August 1969, the dosimeter support stake at each station was used as the center point for a five-meter-radius circle in which all *Artemisia* shrubs were classified according to five categories of damage by means of visual estimates. From earlier experience at CABRIOLET[3] it was shown, for example, that the absence of inflorescence development (the growth of branches on these shrubs which in succeeding months, usually September, carries the flowers) was a characteristic sign of radiation damage. A second characteristic evidence of damage was the loss of leaves. Shrubs could therefore be categorized as follows:

1. 0% - No visual damage, shrub with normal inflorescence development.
2. 25% - Approximately 25% of the shrub showing damage viz., loss of leaves approximating that amount and showing suppressed inflorescence development or absence of inflorescence development.
3. 50% - Approximately 50% of the shrub showing damage as in Category 2.
4. 75% - Approximately 75% of the shrub showing damage as in Category 2.
5. 100% - Dead, i.e., completely defoliated, or remaining foliage dry and gray-brown and subject to fall when disturbed.

This same damage survey method was repeated later at each dosimeter station over an area with a 10-meter radius in order to increase the sample size.

In the part of the fallout pattern with significant effects, a further analysis of conditions in *Artemisia* was made. At each station about 100 shrubs were measured for size using meter sticks. The height was taken and two diameters at right angles were measured. With these measurements and the assumption the shrub was a cylinder, the volume was calculated using the mean of the two diameters as the diameter of a shrub. This last evaluation was made in April

1970, at which time there was no longer any uncertainty as to whether plants were alive or dead (Categories 1 and 5, respectively). The examination therefore involved primarily three estimates, that is, the placement into the categories of 25%, 50%, or 75% defoliation.

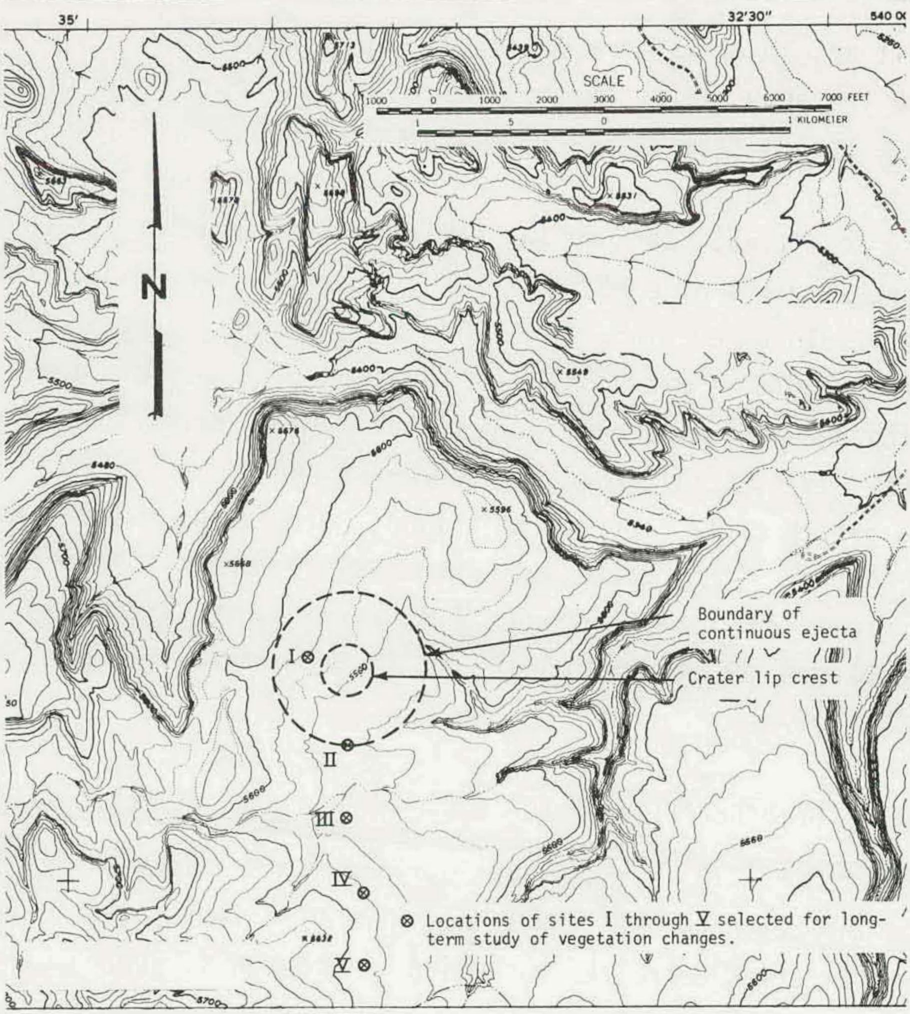
2.5 ASSESSMENT OF DAMAGE AT LOCALITIES OTHER THAN DOSIMETRY STATIONS

In an attempt to assess the extent of damage beyond the arc of dosimeter stations to which the above investigation had been restricted, most of the area outside the 1-mile radius from GZ was surveyed in two ways. The area immediately downwind of the fallout pattern was covered extensively on foot, or by truck where the terrain permitted. Because the damage zones extended into some very rough terrain, the services of a helicopter and pilot were secured. From a helicopter vegetation could be examined from relatively short distances with great mobility, and a map could be drawn which in a general way outlined the areas around GZ in which vegetation damage was detected. The examination by helicopter was made in January 1970, 13 1/2 months after D-Day, which was sufficient time for one complete growth cycle. During this time, defoliation became nearly complete on killed shrubs. Among those which were only damaged, some recovery in the form of new growth could be observed. This was not sufficient time, however, for regrowth to obscure the damaged conditions to the extent of complicating damage estimates unduly.

2.6 ASSESSMENT OF VEGETATION DAMAGE SOUTH (UPWIND) OF SCHOONER CRATER

During October 1970 an assessment was begun of conditions in the vegetation upwind to the GZ in the regions affected by base surge material. The survey extended into areas where the radiation background was normal and where the vegetation was unaffected.

Five sites were selected to represent the broadest spectrum of post-detonation environments which might result from a nuclear cratering experiment (see Fig. 3). The first site chosen was about 50 meters west of the crater lip itself, a new and obviously sterile environment with a very heavy overburden of crater ejecta, and a relatively high radiation area. The second site chosen was at the approximate boundary of continuous overburden, an area with a few centimeters of fine dusty material and scattered large boulders. The area was one



⊗ Locations of sites I through V selected for long-term study of vegetation changes.

Fig. 3 Approximate location of sites used for investigation of effects on vegetation from nuclear cratering upwind (south) of GZ.

which had been subject to shock, blast, and bombardment sufficient to destroy most of the above-ground parts of perennial shrubs. The third site was principally beyond the crater-ejected material, without blast or overburden but within the base surge where large radiation doses had killed all *Artemisia*. The fourth site chosen was essentially at the periphery of the base surge at a point where approximately 50% of all *Artemisia* shrubs were defoliated and dead in October 1970. The fifth site chosen was farther south and beyond the area visibly affected by SCHOONER. This site served as a nonirradiated, nondisturbed control area.

At each site triplicate 5-meter-radius circles were established within which each living perennial and annual plant was identified and the approximate surface area it covered was measured. From these data the frequency of occurrence of a particular species could be calculated as well as the proportionate part of the area covered by each individual species within the 78.5 square meters encompassed within each circle.

Details of density and cover calculations, with a complete list of species, are given in Appendix C.

3. RESULTS

3.1 POST-SHOT CONDITIONS ALONG THE DOSIMETRY ARC

When the dosimeters were removed from the field on D plus 12 days, the ground was covered intermittently with a thin layer of snow (see Fig. 4). However, since the snow apparently did not fall until December 15 or 16 (D plus 7 or 8 days), it could not have had the large effects on the total dose which might have been expected had a mantle of snow covered the area at the time the fallout was deposited. (ESSA* reported only 0.25 inches total precipitation for Pahute Mesa for the entire month of December 1968.)

Both the soil surface and vegetation along the northeastern segment of the arc of dosimeter stations were covered with a light gray dust. Because of the snow, the high winds after shot time, and the diurnal freeze-thaw cycles, snow and fallout material were often intermixed at the soil surface. For this reason it was not practical to use the surface fallout collectors which had been placed in the field for the purpose of estimating total fallout. Some had been swept clear of fallout by the winds and some contained small drifts of fallout-snow mixtures, often frozen into icy cakes. Similarly, the polyethylene sheets covering the shrubs often had mixtures of snow and fallout on their outer surface, sometimes frozen into large heavy cakes. The margins of the polyethylene sheets were frequently frozen to the soil surface by ice formed from melting snow.

Because of these conditions the plastic sheets were pulled off the shrubs with the ice and fallout material still on them and left in loose rolls at one side of the area they had previously covered. Despite evidence of high winds in the area, essentially all the polyethylene sheets were intact. Only on the eastern portion of the arc, at the mouth of the canyon, was there damage to the shrub covers, and this, fortunately, was in an area with very low doses — too low to be of interest to this study.

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*Environmental Sciences Service Administration

Fig. 4 Recovery team collecting dosimeters from field on D plus 12 days. The splotches of snow in the foreground are remnants of the snowfall which blanketed the area on 15 and 16 December (D plus 7 or 8 days).

3.2 COMPARISON OF THE INTEGRATED GAMMA DOSES WITH THE DOSE RATE AT D PLUS 12 DAYS

Readout of the gamma dosimeters positioned at the surface and at 25 cm, 1 meter, and 3 meters above the surface indicated there was little difference among the doses occurring at these levels. Figure 5 shows the mean gamma doses. (More complete dosimeter readings are shown in Appendix B.)

The highest dose measured (950 rads) occurred at two stations located about 10 degrees east of north relative to GZ. To the west the doses fell off to less than 200 rads within a distance of 0.6 km. There was also a secondary peak of activity between 1.3 and 1.4 km to the east, where the gamma doses reached 750 rads.

Because of the height of the vegetation in the area, doses at 25 cm above the soil surface, and at the soil surface were of particular interest. As noted previously, however, there was little difference between these gamma radiation doses. The doses at the soil surface had a mean that was 99.9% ± 5.8% of the doses measured at 25 cm above the surface*.

Figure 5 also shows the dose rates at the time the dosimeters were collected from the field. Such dose rates are often used in estimating doses to an environment from fallout at times from a few days to a few weeks or longer after fallout has occurred. Since integrated doses are derived by multiplying the dose rates by some systematic value, if the curves produced are parallel, this is evidence that dose-rate extrapolations are justified. If they are not, as is the case here, then other factors must be considered.

The opportunity to compare measured integrated doses and extrapolated doses from dose-rate data is infrequent. Such a comparison should, however, provide evidence of certain other phenomena. It is apparent here that there is considerable discrepancy — the ratios of dose rate to dose are not a constant. Possible reasons for this will be discussed subsequently.

3.3 BETA RADIATION DOSES

Beta doses in fallout patterns are not readily assessed. Certain

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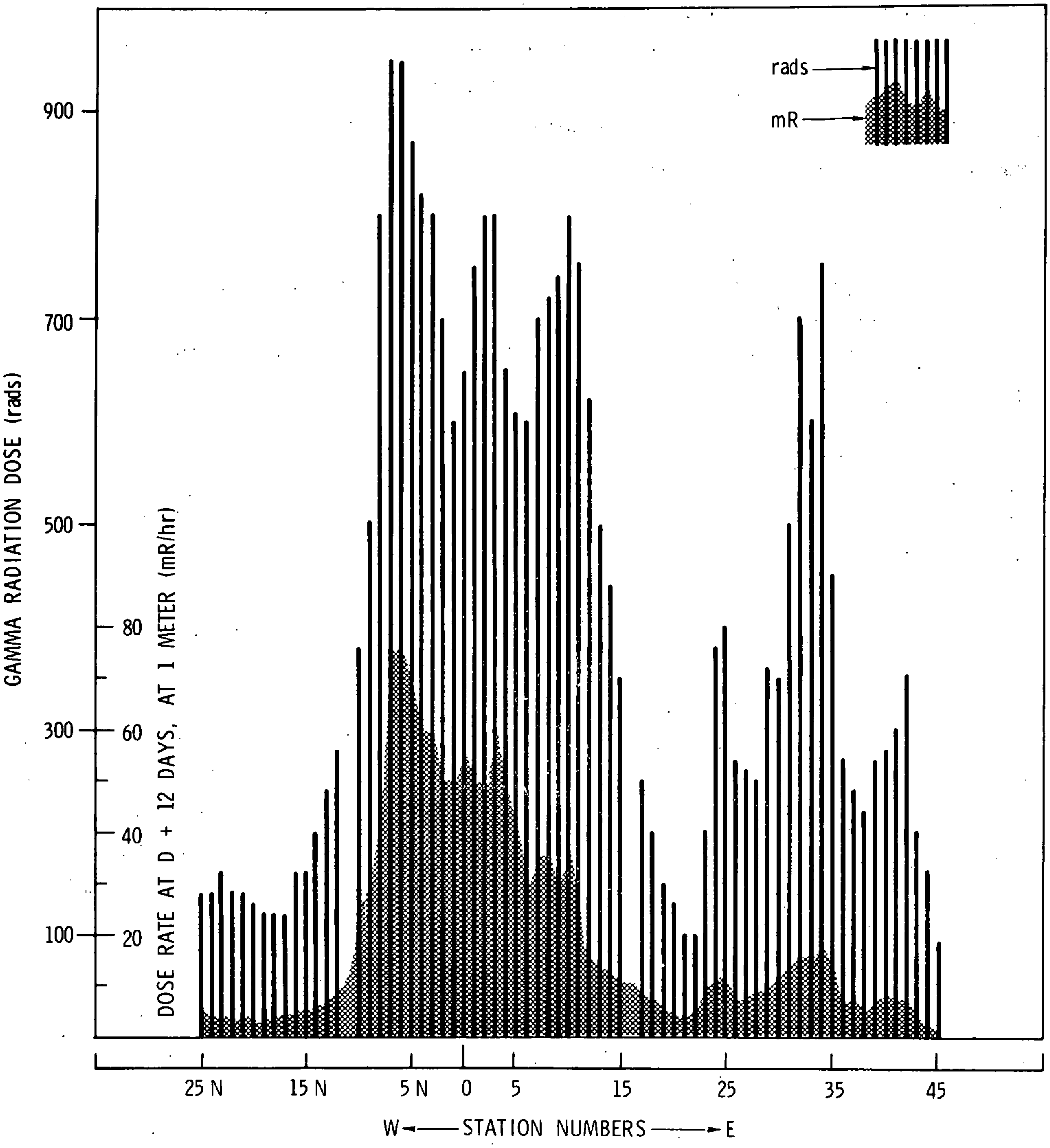
*Station 3 was omitted from the means calculations. At that station the surface dose was 150% of the 25-cm dose.



A comparison of the mean gamma-ray doses from dosimeters and the dose rates taken by conventional radiological safety monitoring on D plus 12 days.

assumptions must be made and terms defined. The doses attributed to various objects in the environment are the doses measured by dosimeters at or on the various objects and at various places in the environment. The dosimeters used here were designed to emulate the dose-receptive capacity of vegetation. The doses reported are extrapolated as theoretical surface doses, on the assumption that vegetation has the same beta dose absorptive capacity as water.

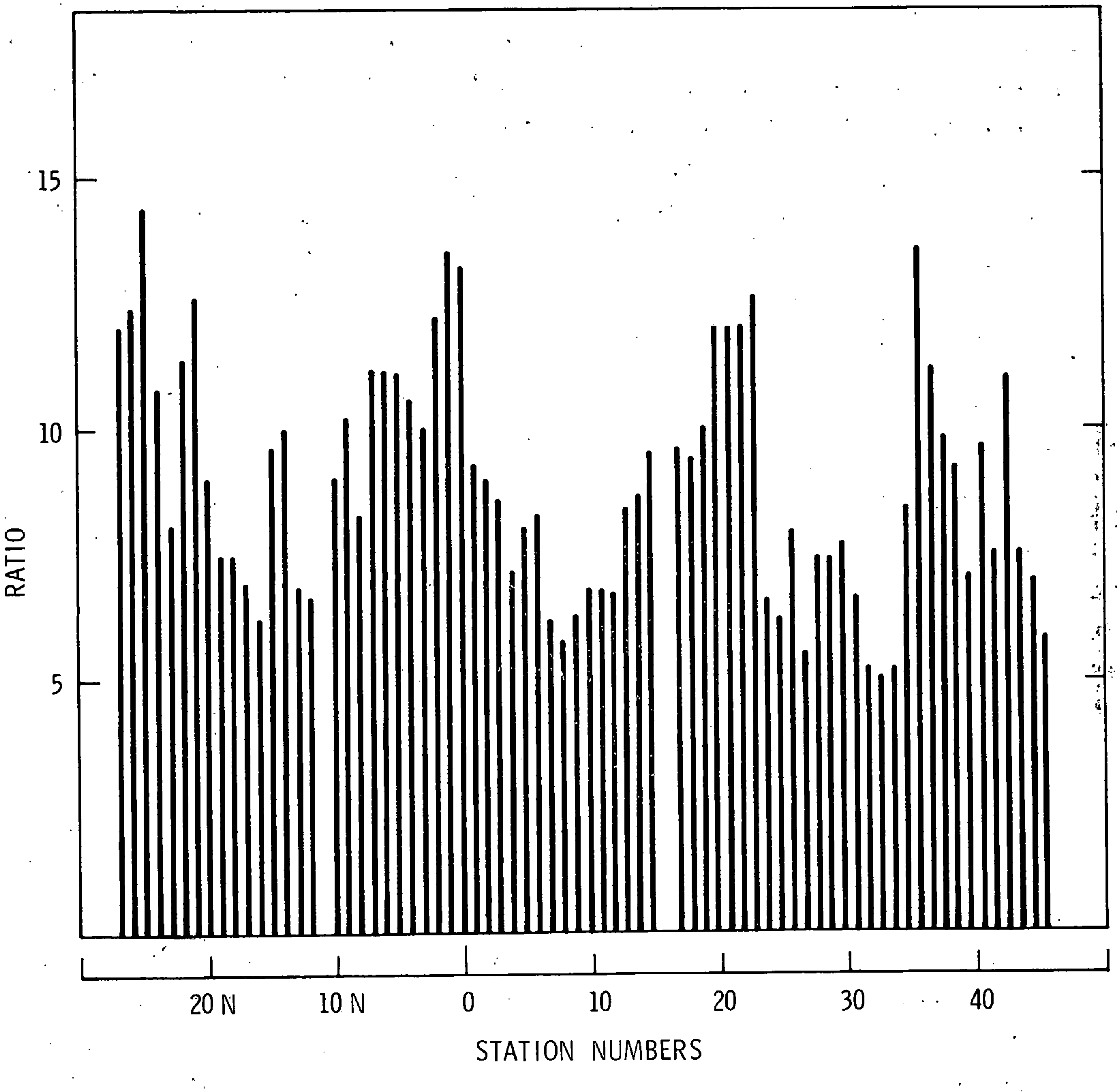
3.3.1 Beta Doses at the Soil Surface Compared to the Dose at 25 cm Above the Surface

For all dosimeter stations, the beta dose at the soil surface was 78% ± 19% of the dose at 25 cm. For stations 9N through 13 the surface dose was 66% ± 24% of the dose at 25 cm. These values were quite variable as can be seen from the standard deviation. The ratio of surface doses to 25-cm doses calculated independently for stations 20 through 26 was 81.1% ± 31%, which provides a curious contrast to the large variabilities on the whole.

3.3.2 Beta Doses at 25 cm Above the Surface Compared to Beta Doses at 3 Meters

These dose comparisons may also be of interest since they provide some basis for prediction of the beta doses to taller vegetation (than NTS vegetation) from their contaminated environment, that is the doses derived from particulate materials deposited around the shrubs as compared to the doses derived from the material deposited directly on the shrubs. Again, for the center of the main fallout pattern, stations 9N through 10, the dosimeters at 3 meters received only 34.1% ± 3.3% of the dose at 25 cm above the ground.

Figure 6 shows a plot of the ratios of the surface beta doses compared to the gamma doses for all stations with significant doses. A systematic variation of the ratio, which is apparent here, was also noted for a similar plot of data for the CABRIOLET event[4]. The values ranged from 5 to more than 14 here, which is somewhat higher than the ratios noted at CABRIOLET where they ranged from 4 to 12.5. These variations may be due to differences in the material from the two craters or an overestimate of the gamma-ray doses at CABRIOLET, which would, of course, lower the ratios.



The ratios of the beta radiation doses to the gamma radiation doses (both in rads) in the SCHOONER fallout pattern.

3.4 DOSES TO THE VEGETATION

3.4.1 Gamma Radiation Doses

Across the main fallout pattern, stations 12N through station 20 inclusive, the dosimeters on the shrubs that were not covered by the plastic sheets had essentially the same gamma-ray doses as the dosimeters in the vertical array at each station. (The difference was only +0.5% ± 5.7%.)

For those shrubs which had been covered with the plastic sheets, there was a reduction in the gamma radiation doses. The doses to covered shrubs had a mean value that was 84.5% ± 10.8% of the gamma doses recorded in the open, away from shrubs. This reduction is probably attributable to shielding by the air and the plastic sheets against the low-energy components of the fallout radiation.

3.4.2 Beta Radiation Doses

At stations 12N through 20 there was a reduction of 52.6% ± 10.9% for the beta doses recorded by the dosimeters on the shrubs, compared with the dosimeters in the open (on the array) away from the shrubs.

For those shrubs under the plastic sheets, there was still a further beta dose reduction. The covered shrubs indicated only 31.2% ± 6.9% of the beta radiation doses recorded by the dosimeters in the open. These data as well as the gamma dose data are summarized in Table 1.

3.4.3 Evaluation of Sources of Beta Doses to the Vegetation

The construction of the dosimeters provided some delineation between beta doses derived from fallout material contaminating the surfaces of plants and doses derived from material on the surface around the plants. These data were read from the dosimeters at 25 cm above the surface. The data for stations 21N through 44 are shown in Fig. 7. From this it would appear that beta doses were, in a large measure, different in their origin in the two parts of the pattern. In the main part of the fallout pattern, a relatively large portion of the total dose appears to have come from below the dosimeter, whereas in the eastern part of the pattern, where the secondary peak of activity occurred, dosimeters

Table 1. Doses across the main fallout patterns at 25 cm above the soil surface away from shrubs, to the shrubs protected by plastic sheets, and to shrubs not protected.

	GAMMA RAY DOSES (RADS)					BETA RAY DOSES (RADS)				
Station	25 cm	Shrub		Percent of 25 cm Dose		25 cm	Shrub		Percent of 25 cm Dose	
Number	Dose	Open*	Covered	Open**	Covered	Dose	Open	Covered	Open	Covered
12N	280		255		91	2100	1110	630	52	30
10N	380	420	350	+11	92	3420	2160	1590	63	46
8N	800	810	770	+ 2	96	7800	3000	2190	39	28
6N	950	1060	800	+11	84	10650	5250	3000	49	28
4N	820		710		86	8640	4140	3270	48	38
2N	700	640	610	- 9	87	8100	3900	2100	48	26
0	650	680	470	+ 5	72	7050	3000	2340	43	33
2	800	750	660	- 6	83	7500	2910	1770	39	24
4	650	660	480	+ 2	74	5550	2250	1650	41	30
6	600	590	600	- 2	100	4650	2340	1650	51	36
8	720	700	600	- 3	83	5040	3240	2040	64	40
10	800	850	530	+ 6	66	5400	3600	1560	67	29
12	620	580	550	- 6	89	4450	2190	900	49	20
14	440		370		84	3480	1620	900	47	26
16	300	⊕	260	⊕	87		1650	570		
18	200	210	200	+ 5	100	2100	1500	540	71	26
20	130	120	80	- 8	62	1410	990	570	70	39
Means				+0.5	84.5				52.6	31.2
Standard Deviation				±5.7	±10.8				±10.9	±6.9

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* Only doses which differed from the 25 cm doses are shown.

** Percent differences from the 25 cm doses are given.

⊕ Dosimeter not recovered.

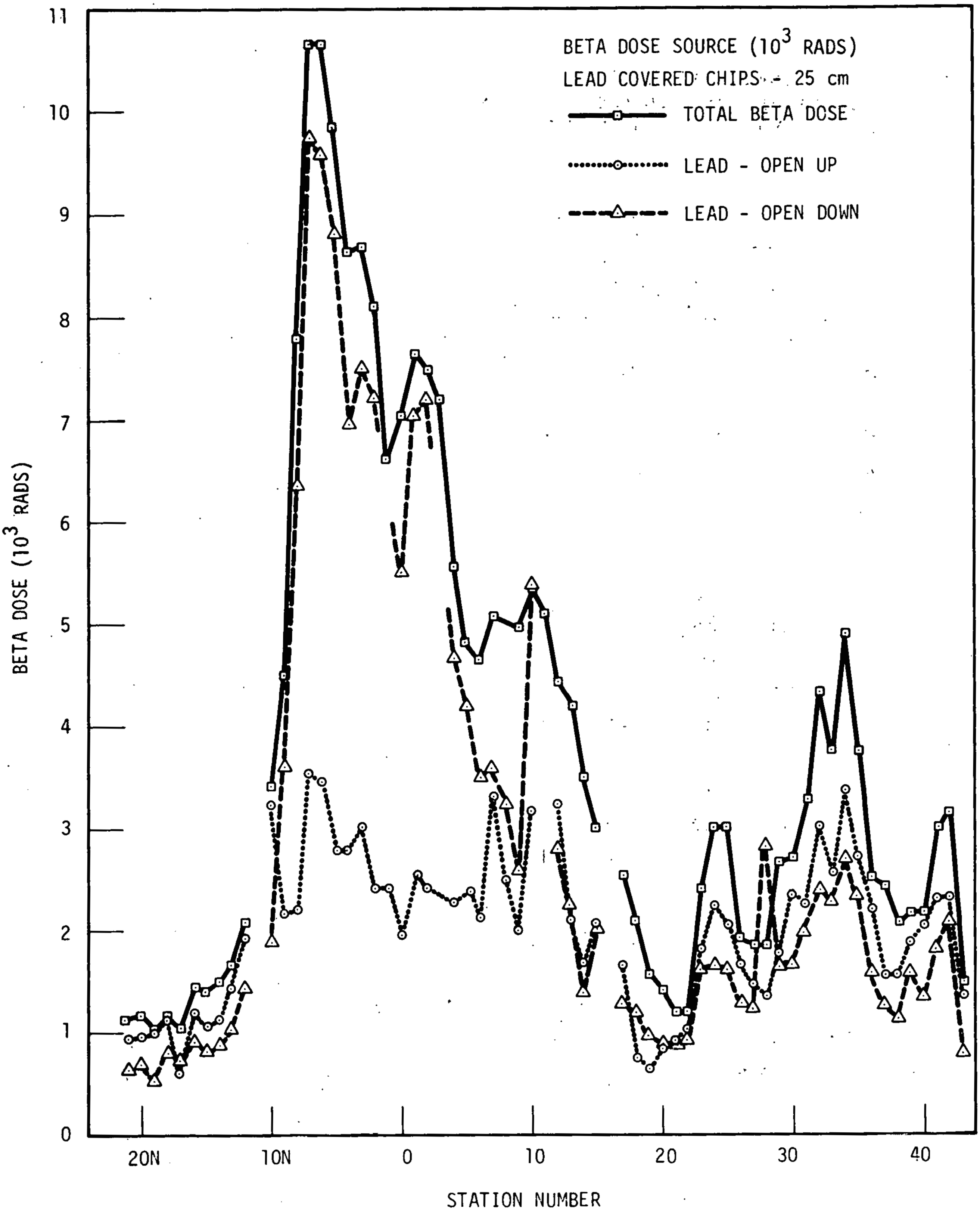


Fig. 7 Distribution of beta dose source at SCHOONER.

(with shields open upward) received a slightly larger portion of the total dose.

This dose distribution is probably the result of a larger amount of base surge material being distributed northward, where the dosimeter stations were somewhat closer to GZ than they were at the secondary peak of activity farther to the east. Base surge material is generally heavier than fallout material is conventionally thought to be be. Thus, in addition to the larger amounts of material in the main part of the fallout pattern, the lighter material going to the east would be more likely to remain suspended on the vegetation.

3.5 EFFECTS ON VEGETATION

At the time the dosimeters were removed from the field there were no observable changes in the vegetation in the fallout pattern compared to vegetation elsewhere, except that in the parts of the pattern with the higher dose rates the vegetation was very dusty.

In February 1969 (D plus 2 months), it was noted that much of the vegetation had lost its dust covering and that there were no differences in the appearance of shrubs which had been covered with the polyethylene sheets and those which had not been covered. By this time most of the snow had melted, with only small patches remaining in the shade of shrubs and rocks.

The normal appearance continued through most of April. In the last week of that month, the first evidence of any effects was noted. This could only be observed by comparing shrubs outside the irradiated areas with those within. Normally, the development of new growth in *Artemisia* begins during this period, but the beginning of new growth was absent in the parts of the pattern with the larger doses. The same phenology was observed at CABRIOLET[3].

By the end of June it was possible to begin a systematic analysis of the effects. From the outset it was clear that the characteristics of individual shrub damage along the arc were different from the damage noted at both PALANQUIN[1] and CABRIOLET[3].

On 4 July 1969, it was noted that most *Artemisia* shrubs within 10 meters radius of the support stakes for Stations 4N, 5N, 6N, and 7N were dead and the remainder 75% or more defoliated.

3.5.1 August 1969 (D Plus 8 Months) Damage Survey

In August a survey was made of the *Artemisia* shrubs within a 10 meter radius of each stake at all stations. Table 2 show the results of this survey.

Table 2. Condition of *Artemisia* within 10 meters of each dosimeter station stake, 7 August 1969

NUMBERS OF SHRUBS AND PERCENT DEFOLIATION

Station Number	0*	25	% 50	75	100	Station Number	0	25	% 50	75	100
67-43	All					13	No shrubs				
42	9	1				12	1				
41	3					11	10	5	2	4	3
40	7					10	8	3	3	2	4
39	4					9	3	3	2	3	4
38	4					8	2	2		2	3
37	19					7	15	11	9	3	11
36	17	1		1		6	3	5	5	5	3
35	11	3	3	3	1	5	2	4		2	2
34			1	1	7	4	1	3	1	2	7
33	4			1		3		2	1	3	9
32	2	2	3	2	6	2		2			2
31	3	3			1	1	No shrubs				
30	9	2				0		1	3	5	5
29	1					1N		3	2	2	4
28	5					2N				10	13
27	2					3N				4	25
26	No shrubs					4N					23
25	No shrubs					5N				4	24
24	4					6N					15
23	3	1				7N					15
22	1					8N		1	1	1	5
21	9					9N	8	1	1		
20	12					10N	21				
19	8	1				11N	20				
18	1					12N-24N	All				
17	1										
16	No shrubs										
15	No shrubs										
14	1										

*"0" indicates no damage, or more nearly to zero damage than to 25% defoliation. 100 indicates complete defoliation and death.

By autumn of 1969, damage had nearly reached its fullest expression, and there was little further change during the winter except for the continued loss of dead leaves from weathering.

3.5.2 April 1970 (D Plus 16 Months) Damage Survey

In April 1970, before new annual growth began, measurements were made on shrubs at most of the stations with shrub damage. The complete survey is given in Appendix D. An attempt was made to measure the sizes of 100 shrubs at each dosimeter station in the center part of the fallout pattern except as noted in Appendix D. The areas covered were approximately 30 meters wide and up to 60 meters long, along axes radiating from GZ to the dosimeter stations. Shrubs were classed into the five categories of damage previously mentioned. It should be noted that *Artemisia* does not survive when completely defoliated under these conditions. Unlike most other shrubs in the area, it does not redevelop from the lower trunk or roots.

3.5.3 Shrub Damage, Shrub Size, and Doses

The shrub measurements (called the "shrub volumes") for Stations 10N, 6, and 7, from the west and east sides of the pattern, are shown in Fig. 8. Shrubs with volumes of 0-1 cubic meters, and 1-2 cubic meters show a distinct shift in damage distribution with increasing dose. In the shrub volume class of 0-1 cubic meters, the damage distribution at 3420 rads is the reverse image of that at 5100 rads. The same shift, but less apparent, also occurred for shrubs of 2-3 cubic meters volume. Shrubs with volumes of 3 cubic meters or more have only a slightly shifted distribution with increasing dose. Contingency tests of the independence of defoliation classes from dose levels were conducted, with chi-square evaluated at the 0.05 level. Percent defoliation was dependent on dose level when three dose levels were considered. Percent defoliation classes were independent of dose level when only the largest shrubs were considered. It seems clear that with an increase in dose there was a corresponding increase in shrub damage. However, the extent of shrub damage appears to be moderated by shrub volume, the larger shrubs being less damaged than smaller shrubs.

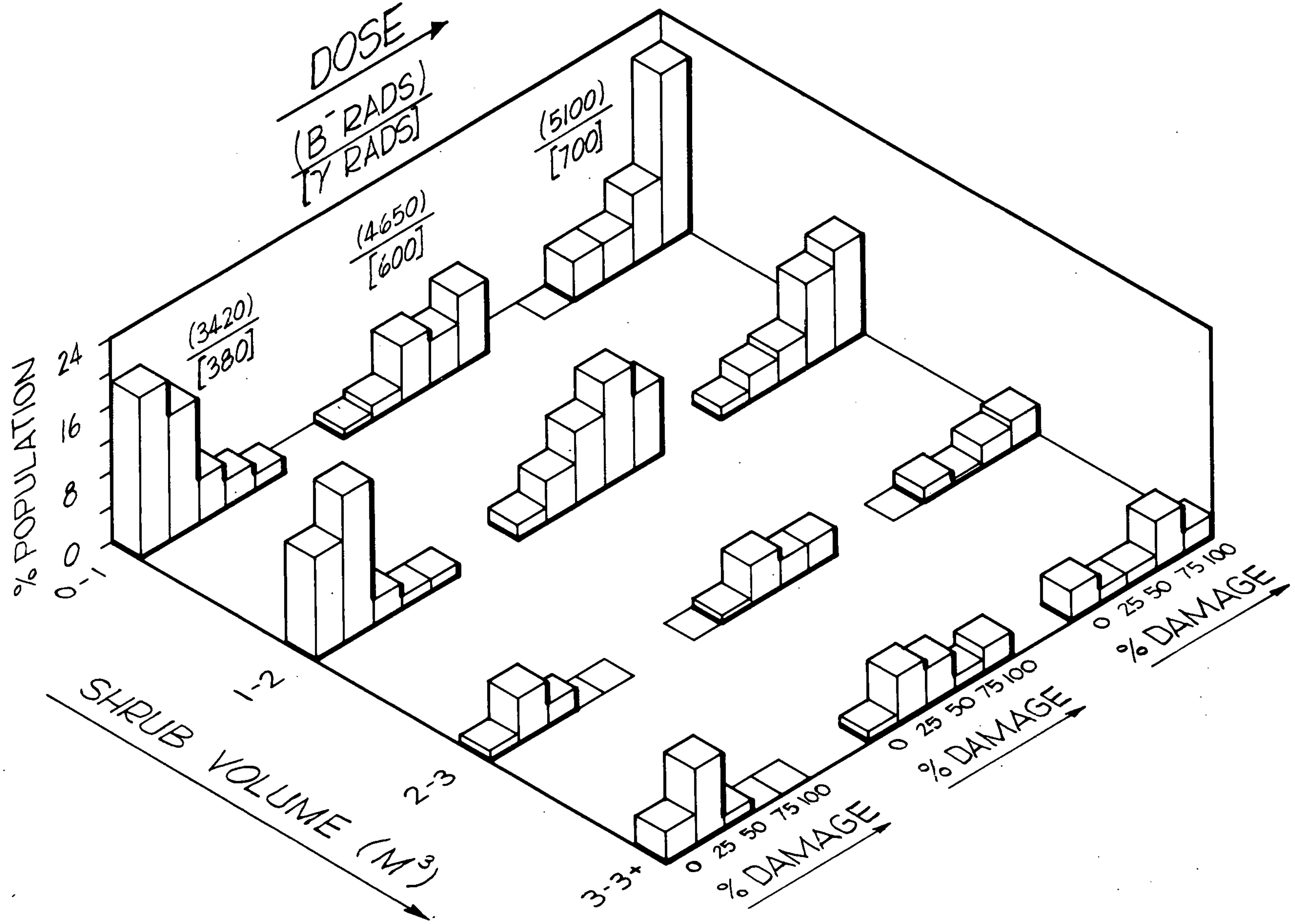


Fig. 8 Relationship of dose to population distribution for damage classes in areas around three dosimeter stations.

3.5.4 Shrub Size (Volume) and Extent of Defoliation at 5250-5850 Rads

In order to examine the relationship between shrub volume and percent defoliation, shrubs from Stations 5, 6, 7, 8, and 11, where doses ranged from 5250 to 5850 rads (beta-gamma) were considered as a single population of 495 shrubs. Figure 9 shows the percent shrub population distribution for the defoliation and shrub-volume classes. Class-volume intervals were adjusted to provide a minimum of 60 shrubs for any volume class. The greatest number of shrubs (133) occurred in the 0.5 to 1 cubic meter class. The volume class of 1 to 1.5 cubic meters contained 80 shrubs while the other classes had 60 to 77.

The data from Fig. 9 were transformed to present each shrub-volume class as an individual population distributed among damage classes, as shown in Fig. 10. The three shrub-volume classes occurring within 0 to 1.5 cubic meters have similar distributions, with few shrubs appearing in the 0% defoliation class and the greatest percentages appearing in the 100% defoliation class.

Despite the similarity of the distributions, however, there is a shift in the percentages toward the 75% defoliation class as shrub volume increases. The distribution of percentages of shrubs in the 1.5 to 2.0 cubic meter class differs from those having smaller volumes in that the mode occurs in the 75% defoliation class. Shrub-volume population percentages for shrubs with volumes greater than 2 cubic meters show a further modal shift down to 25% defoliation.

A contingency test (P = 0.05) of the independence of percent-defoliation classes from shrub-volume classes showed percent defoliation to be dependent upon shrub volume. Further chi-square calculations were made within each defoliation class. It was assumed that the percentage of each shrub-volume population occurring within a given defoliation class was similar among all shrub-volume classes. In the 100% defoliation class, shrub-volume population percentages were found to be dependent on shrub volume. Shrub-volume classes of 0 to 1.5 cubic meters formed one volume-independent set while shrub-volume populations of 1.5 cubic meters and greater formed another. Shrub-volume population percentages within either the 75% or 50% defoliation categories were found to be independent of volume classes. Shrub-volume population percentages within the 25% defoliation class were found to be dependent on shrub volume. Additional calculations for this latter class showed shrub-volume populations between 0 and 2 cubic meters formed a volume-independent group that was different from shrub-volume populations

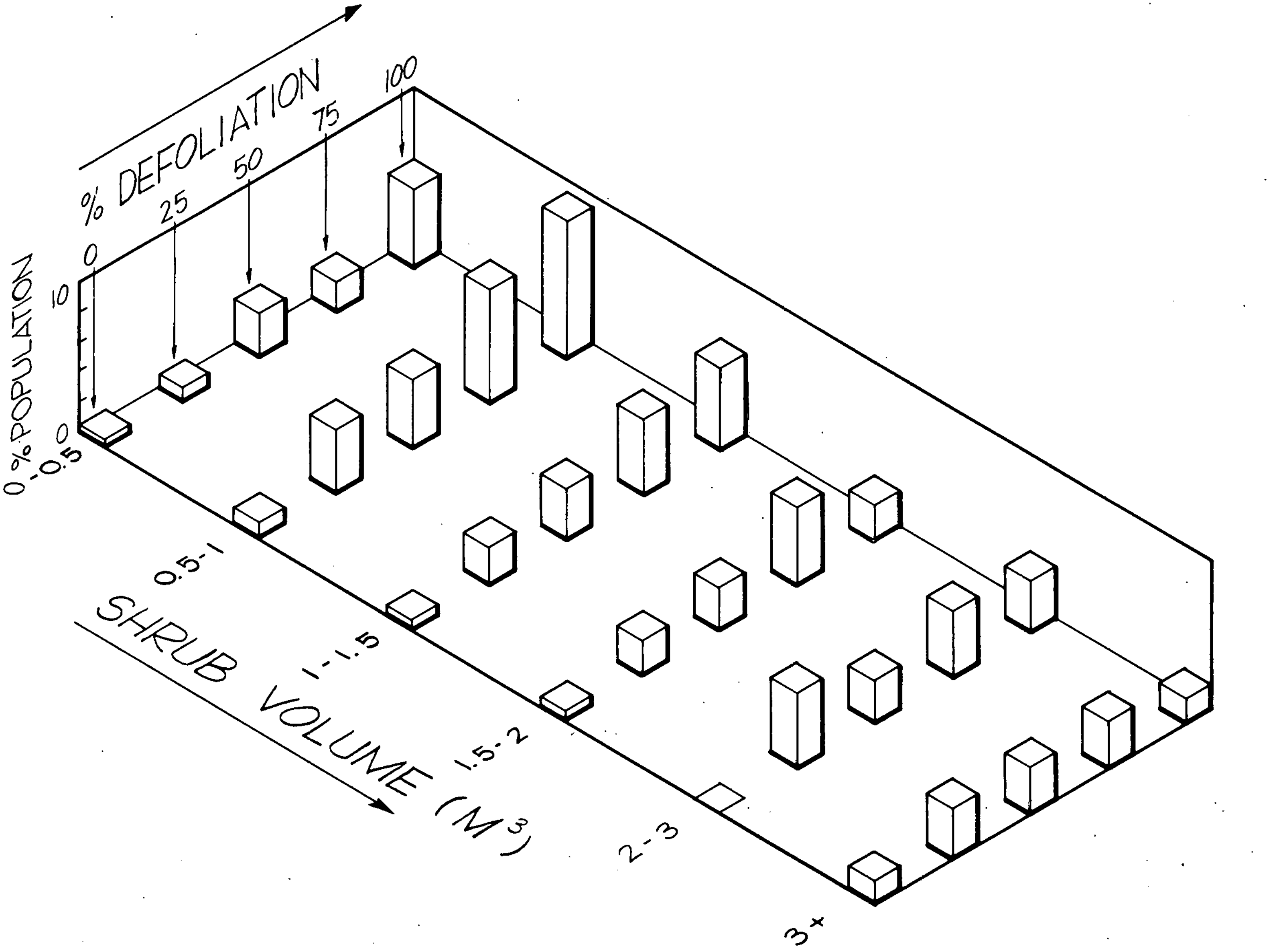
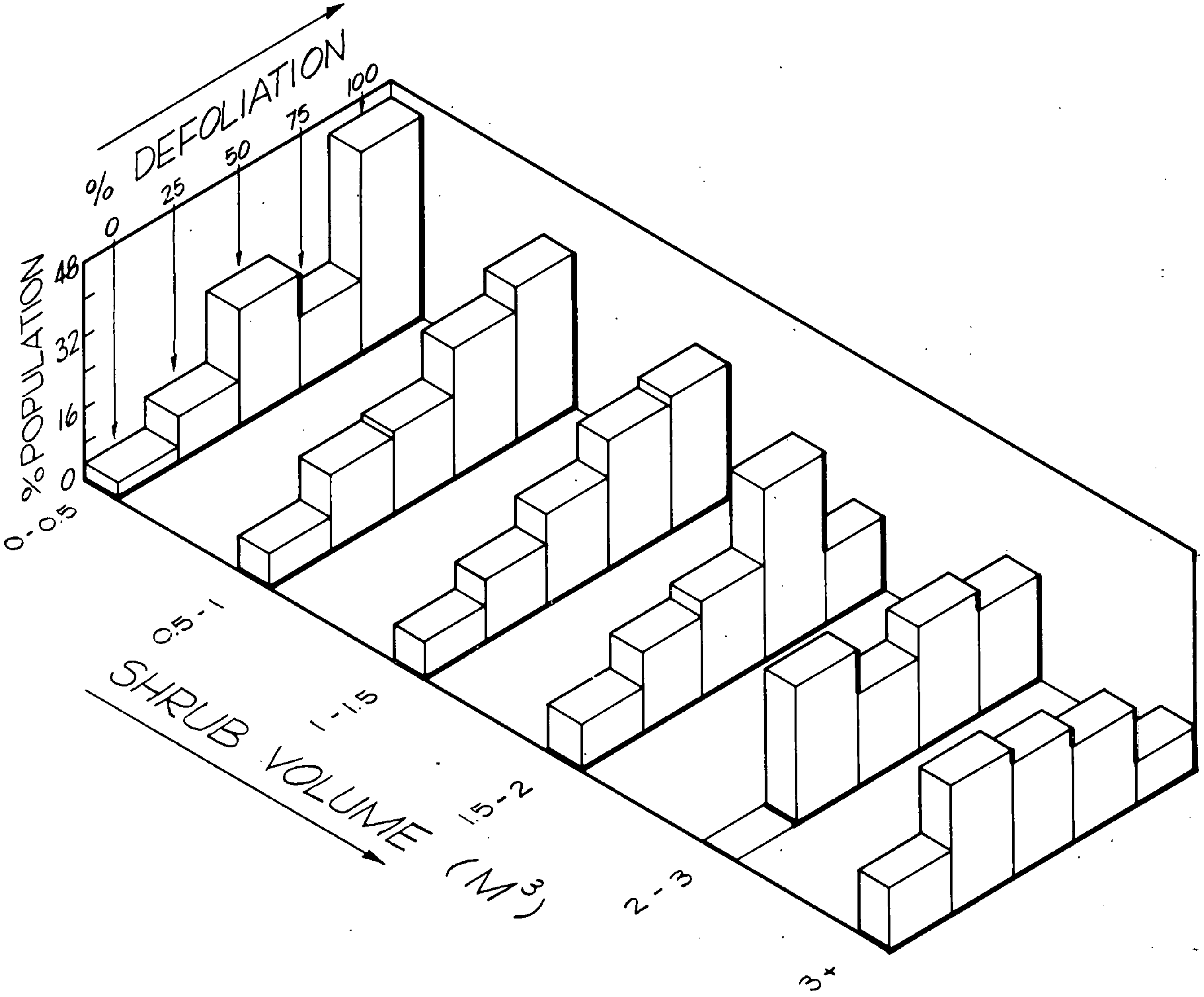


Fig. 9 A shrub population of 495 distributed over defoliation and volume classes at five dosimetry stations having beta-gamma doses between 5250 and 5850 rads.



Relationship of percent defoliation and shrub volume on the basis of each shrub-volume class being considered a single population based on 495 shrubs from dosimeter stations having beta-gamma doses between 5250 and 5850 rads.

of 2 or more cubic meters. These latter populations formed a second volume-independent group.

Both graphical interpretation and statistical considerations confirm the increased severity of damage among the smaller shrubs. The mode of damage is clearly shifted from killed shrubs among the smaller sizes to the categories of less damage among the larger sizes.

Figure 11 illustrates the frequent appearance of shrubs severely damaged but not killed. There is a single living branch at the apex, which is flowering at the end of the second growing season after irradiation. Figure 12 is a diagramatic illustration of *Artemisia* damage conditions frequently observed.

3.5.5 Effect on Shrub Species Other than *Artemisia*

No systematic analysis of other shrub species was attempted because of their sporadic distribution. It has been noted previously that *Artemisia* is one of the most sensitive plants in this area of the test site, and assessment of other species is difficult for many reasons. For example, many shrubs normally develop new growth from their bases or from underground under normal conditions. This also occurs very frequently with top damage of any kind. Thus, even if a shrub is not damaged, it may have a development pattern which is similar to that of another shrub which has been damaged. *Atriplex canescens*, one of the salt bushes, occurred with relatively high frequency at a few dosimetry stations. It was particularly outstanding for the absence of any apparent damage; in fact, its subsequent growth appeared more luxuriant than normal in areas where all *Artemisia tridentata* were killed — a logical outcome of reduced competition with *Artemisia*. On the other hand, another *Artemisia* species, *spinescens*, a deciduous *Artemisia*, appeared to have a sensitivity about as great as that of *tridentata*.

3.5.6 Vegetation Damage Away from the Dosimetry Arc

The more detailed studies of fallout effects on vegetation were confined to the immediate vicinity around the dosimeter stations. From conditions there, it seemed apparent there should have been considerable damage elsewhere. However, because of the large area in which damage could be expected, it would have been difficult to provide detailed assessments. Furthermore, much of the area is very

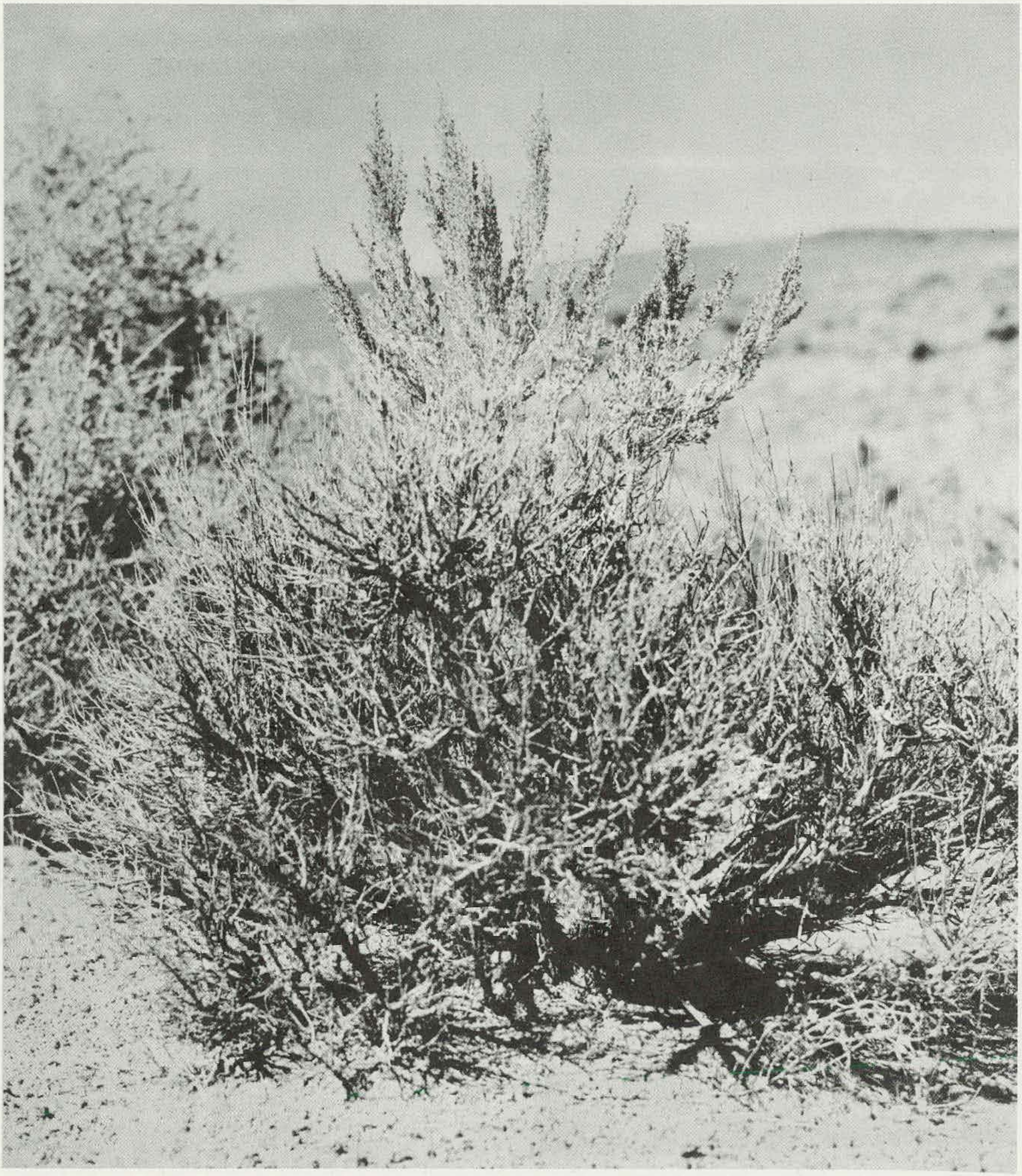


Fig. 11 An example of a severely damaged shrub after two years of growth from the very small amount of tissue which was not killed at the apex of the shrub. This is a more extreme condition than that diagrammed as Shrub B in Fig. 12. The inflorescence development appeared to be normal.

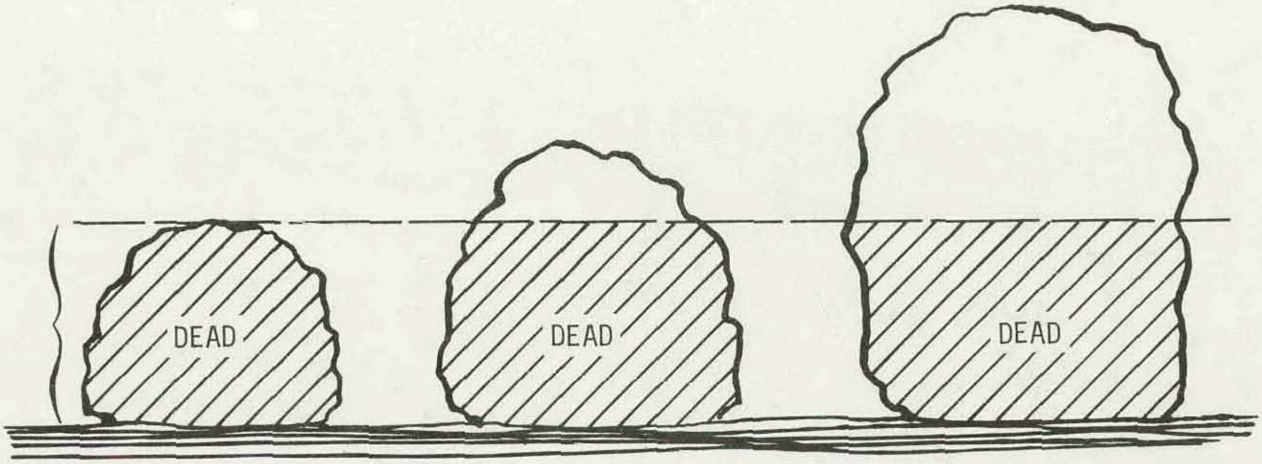


Fig. 12 Diagram of *Artemisia* shrub conditions noted frequently along the arc of dosimeter stations. The height to which a shrub was damaged (or killed) was to some extent dose dependent. Height was not the only factor, however, for the larger shrubs, in terms of volume, were also less likely to be killed even though they were sometimes not as tall as others which were entirely defoliated and killed.

rough, or impassable, even with four-wheel-drive vehicles. For these reasons an evaluation of fallout effects was undertaken by helicopter. The evaluation was made on 24 January 1970, one growing season after SCHOONER detonation. With enlarged aerial photographs of the area as a guide, the helicopter travelled slowly at altitudes of 10 to 50 feet above the surface while shrub damage was evaluated by gross visual inspection and notes were dictated into a tape recorder. Damage was assessed on the basis of whether more than half the shrubs appeared more than 50% defoliated, or less than 50% defoliated. Estimates were restricted to the genus *Artemisia*, as in the previous assessments.

From this aerial survey, the map shown in Fig. 13 was drawn. The boundaries of damaged vegetation to the west of SCHOONER GZ were not determined because of adverse winds on the day of flight. The area is very rough, making low-altitude flying hazardous. In addition, detailed aerial photographs of the area

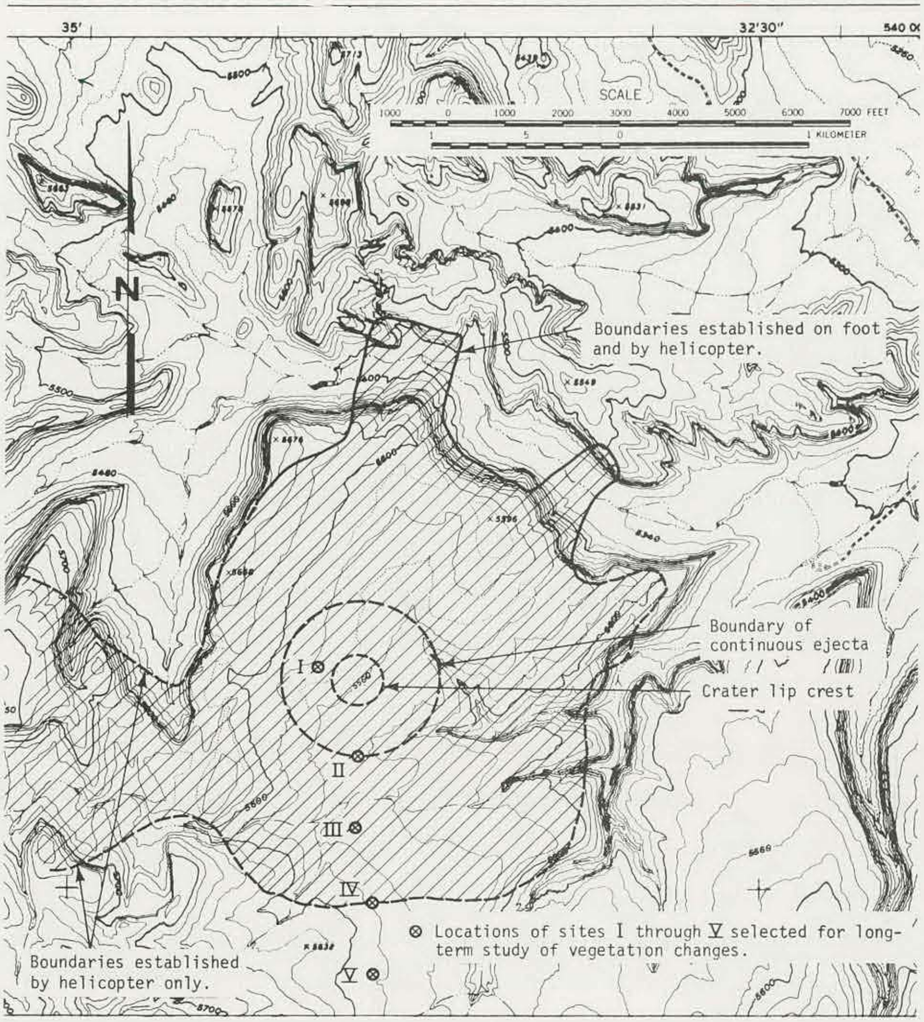


Fig. 13. Estimate of the boundaries within which 50% or more of *Artemisia* was 50% or more defoliated in January 1970. Visual estimates were made from a low-flying helicopter about boundaries in dashed lines; boundaries in solid lines were covered both on foot and by helicopter. (All boundaries including crater boundaries are approximate.)

were not available. It was estimated, however, that damage extended beyond 3 km west of GZ.

3.5.7 Preliminary Estimates of Damage and Recovery of the Ecosystem on the South Side of SCHOONER - October 1970

Data on cover for three of the 21 species of shrubs, grasses, and annuals found south of GZ are graphed in Fig. 14. (A complete list of species is provided in Appendix C.) The approximate location for the five sites (see Section 2.6) are indicated in Fig. 13.

In Fig. 14A, the mean cover percentage for each of the five sites from near GZ to beyond the effects of fallout are plotted. Site V provides a control value for comparison with the disturbed and irradiated areas. The value given for Site V is thus the expected norm for the area. There is an increase in the vegetation cover in both Sites II and III. The species responsible for this are in evidence in Figs. 14E and 14F. In Site II, as shown in Fig. 14E, there is a large increase in *Salsola* (Russian thistle) in a manner frequently noted at NTS for seriously distrubed areas. For Site III, from Fig. 14F, there is a large increase in the grass *Sitanion hystrix*. Both *Sitanion* and *Salsola* occur with relatively low frequency in undisturbed areas, with *Salsola* sometimes completely absent.

The total numbers of species for each site is plotted in Fig. 14B. There are increases for total numbers of species with the disturbances and radiation damage at all sites except directly on the crater itself. Figure 14C shows little differences in total numbers of plants except for the reduction in Sites I and II, both of which were regions of heavy overburden not yet covered by the large numbers of Russian thistle traditionally encroaching strongly disturbed areas of NTS.

3.6 LATE-POST-DETONATION DISTRIBUTION OR REDISTRIBUTION OF RADIOACTIVE MATERIAL

In July 1969, a survey was made which allowed a limited estimate of the radioactive material that had continued to be dispersed from the crater between D plus 12 days and the time of the survey, or had been redistributed after initial throw-out or dispersal from the crater.

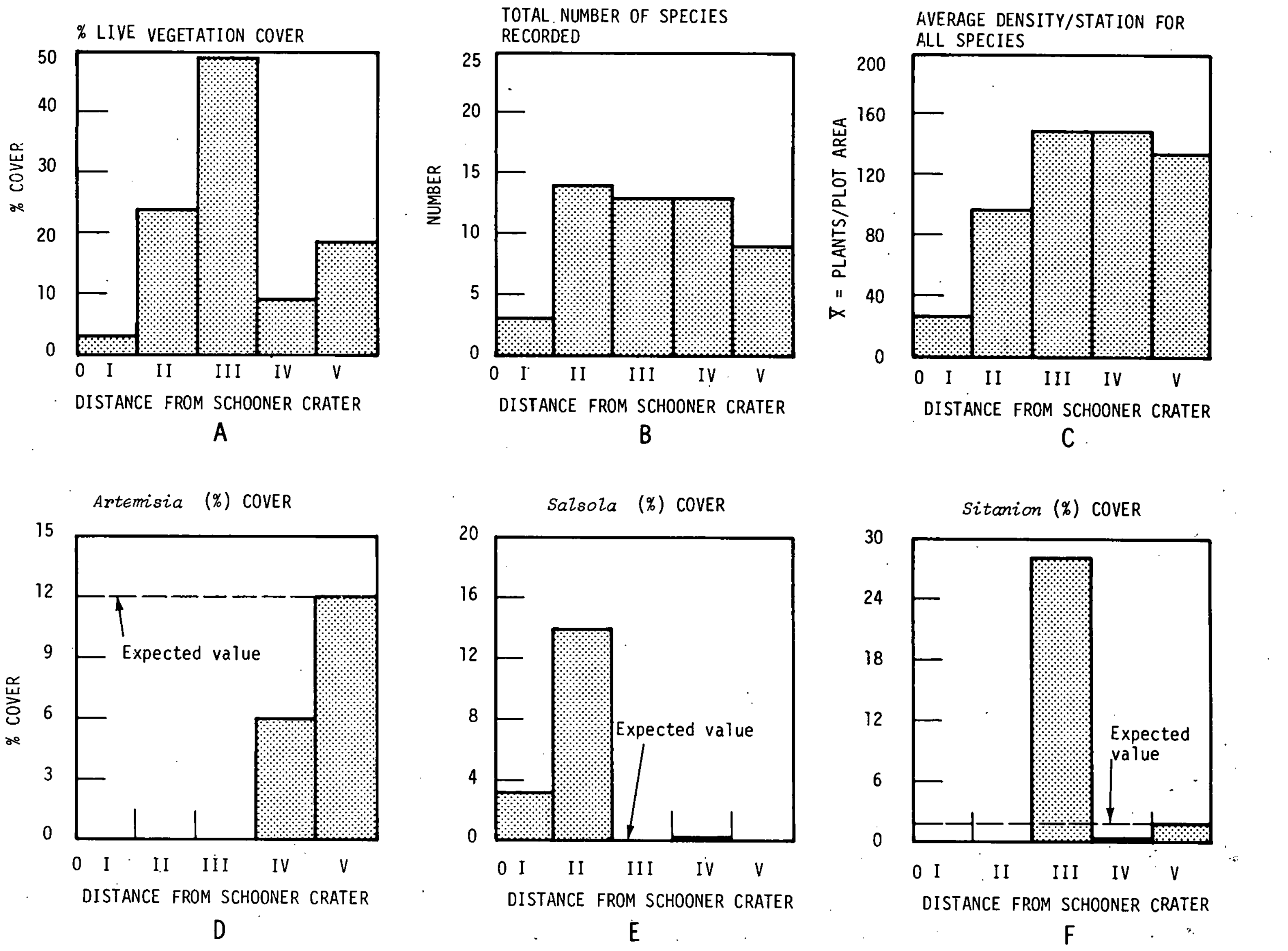


Fig. 14 Plant species distribution and cover percentages for five sites south of GZ. The sites were chosen to represent the broadest spectrum of cratering and fallout effects on the vegetation.

It would appear most likely that, because of proximity of the dosimeter stations to the large crater-lip deposits of loose fluffy material, the largest amount of material to reach to dosimetery arc would have come from the crater itself, that is, from the initial source.

As a part of the routine radiological survey, readings were made with the portable beta-gamma meter used conventionally at NTS. Readings were made with the probe both open and closed at the ground surface close to the dosimeter stations, but away from shrubs. The difference in dose rates between open-probe and closed-probe readings was called the "beta dose rate". Similar readings were made in the centers of the areas which had been covered with plastic sheets until D plus 12 days, and which could not have received fallout material until after that time. Beta radiation readings made in these areas should therefore reflect radioactivity which reached the area after D plus 12 days, and before D plus 7 months, i.e., 4 July 1969. Since beta rays are rapidly attenuated by air, the beta sources from outside these areas should not contribute significantly to the beta doses.

The dose rates and their ratios obtained from the July survey are presented in Table 3. The beta dose rates were estimated by subtracting the closed-probe dose rate readings from the open-probe readings. On the assumption that similar amounts of material would be deposited or redistributed into both areas, the beta dose rates from the covered areas were also subtracted from the dose rates from the not-covered areas before the ratios were calculated.

The data in Table 3 are from dosimeter stations north and eastward of GZ. From these data it appears there was an increase of nearly 2% in the material deposited on D-day at the most northerly point, and an increase of about 9% in the material deposited in a more easterly direction. Giving these values as percentages of the total beta activity may be misleading, since unequal amounts of material were deposited between D-day and D plus 12 days. Perhaps a better expression of the conditions would be that two to three times as much material was redeposited eastwardly compared to northerly and these amounts constituted from about 2% to 9% of the material deposited at individual locations before D plus 12 days. The prevailing winds in the area are from the southwest. Considering the dustiness of the general crater area, these values would not appear too high.

Table 3. Ratios between instrument readings in dosimetry arc areas contaminated continually and contaminated after D plus 12 days.

Stations	Not Covered (mr/hr)	Covered D-Day To D + 12 (mr/hr)	Not Covered minus Covered (mr/hr)	$\frac{\text{Covered}}{\text{Not Covered minus Covered}}$ (Ratio)
6N	53	1.0	52	0.019
4N	44	1.0	43	0.023
2N	50	1.5	48.5	0.031
0	30	1.0	29	0.034
2	21.5	1.5	20	0.075
4	43	1.0	42	0.024
6	46	3.5	42.5	0.082
8	35	2.2	32.8	0.067
10	28	2.3	25.7	0.089

4. SUMMARY AND DISCUSSION

At distances of 1.7 km to more than 2.0 km to the north and northeast, distances which were for the most part beyond the base surge from the SCHOONER detonation, radiation doses were measured and radiation effects on the vegetation in the area were evaluated. The dosimeter stations were positioned on an arc that extended approximately 3.35 km along the bottom of a canyon which was approximately 100 meters lower in elevation than the plateau on which GZ was located. Despite the irregularity of the topography, however, the dosimeter stations were located approximately the same relative distances from GZ as those at CABRIOLET.

As noted previously at CABRIOLET, the beta doses in the open, away from shrubs, were much greater than the gamma doses which were relatively constant throughout the environment of any particular location. A comparison of the potential doses showed that the beta-gamma dose ratios varied from 5 to 15. Dosimeters placed on shrubs indicated beta doses were considerably less (47%) than those indicated by dosimeters positioned at 25 cm above the soil surface, away from shrubs. This was interpreted as being the result of self shielding by the shrubs themselves, on the hypothesis that the doses to dosimeters were reduced by shrub shielding just as doses to parts of the shrubs must have been. Unlike CABRIOLET, differences in doses to fronts and backs of shrubs were not observed.

Dosimeters on shrubs covered with 0.15-mm-thick polyethylene received gamma radiation doses 15% less than those received by shrubs that were not covered. The beta doses to dosimeters in the same location were, however, 69% less than those indicated by dosimeters at 25 cm above the ground surface, away from shrubs. This 22% net reduction in beta dose was attribued to the polyethylene cover. This cover was sufficient to reduce the radiation doses below lethal levels. There was apparently no damage to the covered shrubs, except at Station 6N where 2 of the 6 shrubs covered had a small amount of defoliation. This was one of the areas where all *Artemisia* shrubs were otherwise killed.

Damage to the vegetation from radiation was not apparent until late April, almost four months after the shot. The first evidence was manifested by an absence of development of new growth on *Artemisia* — growth that produces flowers in September and October under normal conditions.

The condition of shrubs by D plus 15 months varied from no detectable damage at the lower doses to complete defoliation and killing at the higher doses. Shrubs with damage all the way around them, from the ground to varying heights, were commonplace. This condition was not observed at two earlier cratering experiments, PALANQUIN and CABRIOLET, where sublethal damage was primarily distributed across the fronts and tops of shrubs. At SCHOONER, however, along the arc of dosimetry stations, extremes of this "skirting" sometimes left only small branches alive in the tops of larger shrubs.

As might be expected in view of this "skirting" effect, small shrubs were more severely affected than larger ones. Extent of damage was shown to be a function of shrub "volume", defined as a volume calculated from the means of two measured shrub diameters and a height measurement, with the shrubs being treated as if they were cylinders.

The differences in damage noted along the dosimeter arc at SCHOONER compared to either PALANQUIN or CABRIOLET are probably attributable to a different pattern of particle deposition on shrubs and around them. This may, in turn, be attributed to differences between terrain at SCHOONER and the earlier events. The detailed investigations of shrub radiation effects *per se* were all done in the vicinity of the dosimeter stations.

In addition to the detailed surveys, an informal survey performed on foot, by truck, and by helicopter determined approximate boundaries of damaged areas all the way around the crater. During the summer of 1970, study plots on the south side of SCHOONER showed that revegetation was beginning to occur in damaged areas. In parts of the pattern where all *Artemisia* was killed but with significant overburden from the crater, Russian thistle occurred. Peripheral to that region was one characterized by a large increase in the *Sitanion hystrix*, a species which normally occurs with low frequency.

This study has provided further evidence of the importance of beta radiation as a hazard to vegetation in fallout fields, and has indicated something of the nature of self-shielding by vegetation itself. These findings provide a basis for understanding the relationship of doses and dose rates (measured for conventional radiological safety purposes) to the beta doses to which vegetation in fallout is subject. The shielding experiment in which 0.15-mm-thick polyethylene was used showed that even this small amount of protection may be of great importance in preventing vegetation damage.

A comparison of differences in terrain and topography at PALANQUIN and CABRIOLET versus SCHOONER has indicated these parameters may be important in determining the nature of damage manifestation where radiation levels may be high enough to cause damage.

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APPENDIX A

PERENNIAL SHRUBS ENCOUNTERED IN THE VICINITY OF DOSIMETER STATIONS

The shrubs listed below were collected and identified by Mr. Thomas Ackerman, Laboratory of Nuclear Medicine, UCLA. The shrubs may occur with widely varying frequency in any particular locality. They may be absent from some areas or share dominance in others. A few are essentially restricted to the sides of canyons and some are found only along the drainage pattern of the canyon bottoms. None occurred with sufficient abundance to permit an extensive investigation of reaction to readioactive fallout material. The list may be incomplete, however, since there was no intensive effort made to cover the entire length of the dosimeter arc.

- *Chrysothamnus nauseosus*
  - subsp. *hololeucus*
  - subsp. *leiospermus*
- *Chrysothamnus greenei*
- *Haplopappus nanus*
- *Tetradymia glabrata*
- *Tetradymia axillaris*
- *Artemisia spinescens*
- *Artemisia tridentata*
- *Gutierrezia sarothrae*
- *Lycium andersonii*
- *Grayia spinosa*
- *Symphoricarpos parishii*
- *Elymus cinereus**
- *Atriplex canescens*
- *Atriplex confertifolia*
- *Machaeranthera leucanthemifolia*

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*A large clump-forming grass which may reach 1.5 meters height.

APPENDIX B

DOSIMETRY

The general characteristics of fallout radiation expected from a cratering event would include a 1-MeV gamma-ray component, an associated beta component with energies in the 1-MeV region, and a possible low-energy photon characteristic. Two approaches for measuring this mixed field are equally valid: 1) measurement of fluence and interpretation of dose deposition; or 2) direct measurement of absorbed dose in some material and correlation with another material through known absorbtion coefficients. The more straightforward of the two methods, that of measuring fluence by determination of depth dose profiles, was chosen for the SCHOONER event.

B-1 DOSIMETER DESIGN

The dosimeters used at SCHOONER were patterned closely after the thermoluminescent dosimeters (TLD's) used in the CABRIOLET event. However, certain modifications were incorporated based on the CABRIOLET results.

The dosimeters, which were designed to simulate energy deposition from ionizing radiation in plant tissue, were made up of hot-pressed chips of CaF_2:Mn of a standard size, measuring 3 by 3 by 1.5 mm. The dosimeters were of two basic configurations — one designed to accommodate 3 chips (Type A) and the other 8 chips (Type B). Both types were constructed of 3-mm-thick polycarbonate, with 7-mm-diameter holes drilled through them to hold the TLD chips. The CaF_2:Mn chips with individual shields were placed in the holes, and the entire dosimeter was covered by a thin light-tight black Mylar film, as shown in Fig. B-1.

For SCHOONER, six shield thicknesses were employed to define the depth dose. Minimum shielding was provided by a double layer of 0.05-mm-thick black Mylar tape which also served to protect the chips from loss of dose due to fading in sunlight. This minimum shielding was the equivalent of 8 mg/cm^2. Additional shielding was provided as follows: 0.25 mm polyethylene, 1.27 mm polyethylene, 0.51 mm aluminum, 1.01 mm aluminum, and 0.79 mm lead. These shields were chosen as a result of the CABRIOLET experiment where penetration of beta particles was measured with a range of 325 mg/cm^2.

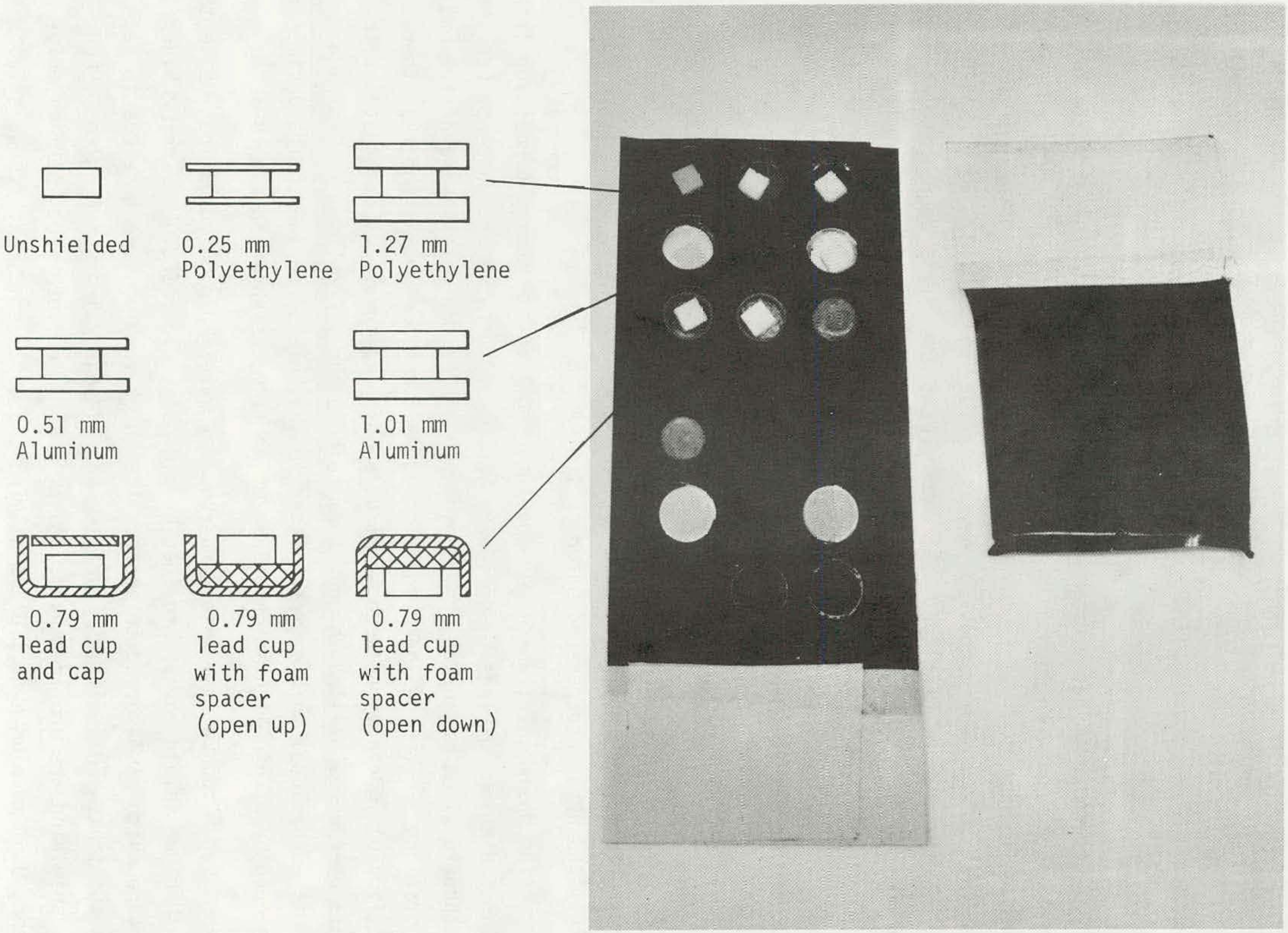


Fig. B-1. Thermoluminescent dosimeters (TLD's) constructed for SCHOONER.

Since the thickness of the TLD chips was sufficient to completely stop electrons with energies up to 1.0 MeV, readings on individual chips were proportional to energy fluence incident on the chip. The change in fluence (erg/cm^2) as mass was added in front of the TLD was used to infer the dose (erg/g).

Shielding was selected to produce a gradual decrease in beta contribution, with the thickest shield capable of stopping the most energetic beta particles. This thickness, however, did not require significant correction for the absorption of 1-MeV gamma rays. The presence of a low-energy photon component could be inferred by differences in the stopping power of polycarbonate and aluminum. These materials present equal absorption of electrons, but have a Z dependence for absorbtion of low-energy photons. Thus, a high reading for the polycarbonate-shielded chips signified a low-energy photon component whose magnitude could be estimated.

Lead was used for maximum shielding against beta fluence. Although it successfully shielded the TLD from the beta radiation, it resulted in an over-response for the gamma-ray background. To evaluate the over-response, calibrations were made with lead in front, in back, and on both sides of the chip. From this a correction factor of 0.7 was derived and used to correct gamma doses.

B-2 DOSIMETER READOUT AND ANALYSIS

The dosimeter packages from the field were individually read out in a standard EG&G Model TL-3 reader. Since the chips were calibrated against a standard Co^{60} source, the scale readings were a direct measure of the exposure in roentgens.

The energy deposited in a CaF_2:Mn chip when it is exposed to a calibrating Co^{60} source is

$$E_1 = 86\ R\ (\rho\ A\ t)\ \text{ergs} \tag{1}$$

where

R = exposure in roentgens
ρ = density of the dosimeter
A = area of the dosimeter
t = thickness of the dosimeter

The light emitted when the dosimeter is read is proportional to that energy,

$$L_1 = c\,E_1 \tag{2}$$

When the dosimeter is exposed to low-energy beta rays and subsequently read out, the energy deposited per unit area is

$$\Phi = \frac{E_2}{A} = \frac{L_2}{cA} = \frac{L_2}{A} \cdot \frac{86\ R\ \rho\ A\ t}{L_1}\ \text{ergs/cm}^2 \tag{3}$$

If the read-out instrument is adjusted to read in roentgens ($R - L_1$), the final calibrating formula is

$$\Phi = 86\ \rho\ t \cdot L_2\ \text{ergs/cm}^2 \tag{4}$$

For a typical chip, $\rho\ t$ is 0.550 gm/cm^2. The calibrating relationship is then

$$\Phi = 47.3\ L_2\ \text{ergs/cm}^2 \tag{5}$$

where L_2 is the scale reading on the dosimeter.

Dose may be inferred from the readings Φ_1 and Φ_2 on two dosimeters covered by absorbers having masses m_1 and m_2:

$$D = \frac{\Phi_1 - \Phi_2}{m_1 - m_2} \tag{6}$$

In this case, dose is determined for the absorbing material.

Data taken with the use of Mylar may be used to infer dose in water by multiplying by the stopping power for water and dividing by the stopping power for Mylar:

$$D_{H_2O} = D_{\text{Mylar}} \cdot \frac{(dE/dx)_{H_2O}}{(dE/dx)_{\text{Mylar}}} \tag{7}$$

Dosimeter readings along the dosimeter arc for all stations having significant dose are shown in Table B-1.

Table B-1. Summary of radiation doses (rads H_2O) along the arc of dosimeter stations, 1.7 to 2.0 km north and northeast of GZ. Beta doses are theoretical surface doses.

STATION	DOSES AT GROUND LEVEL		DOSES AT 25 CENTIMETERS				DOSE AT 1 METER			DOSES AT 3 METERS			DOSE AT SHRUBS***		
			Total		Pb Shielded		Total	Pb Shielded		Total	Pb Shielded		Uncovered	Polyethylene Covered	
					Above	Below		Above	Below		Above	Below			
	γ	β	γ	β	β	β	β	β	β	β	β	β	β	γ	β
27 N	---	---	140	---	---	---	---	---	---	---	---	---			
26 N	---	---	140	---	---	---	---	---	---	---	---	---	---	---	---
25 N	---	---	140	---	---	---	---	---	---	---	---	---			
24 N	---	---	140	---	---	---	---	---	---	---	---	---	720	120	630
23 N	---	---	160	---	---	---	---	---	---	---	---	---			
22 N	---	---	140	---	---	---	---	---	---	---	---	---	600	120	560
21 N	---	---	140	---	630	930	---	---	---	---	---	---			
20 N	130	1,200	130	1,170	660	960	850	750	700	540	30	330	480	120	450
19 N	120	1,000	120	1,020	510	990	---	---	---	---	30	360			
18 N	120	1,000	120	1,140	810	1,140	950	450	950	690	270	870	630	105	615
17 N	130	1,000	120	1,050	720	600	---	---	---	---	180	1,050			
16 N	160	1,500	160	1,470	900	1,200	800	330	850	600	150	480	630	150	540
15 N	180	1,200	160	1,410	810	1,050	---	---	---	---	150	1,080			
14 N	200	1,200	200	1,500	870	1,120	1,080	360	1,080	430	120	390	540	190	420
13 N	240	1,600	240	1,680	1,020	1,440	---	---	---	---	120	900			
12 N	280	1,500	280	2,100	1,440	1,920	1,440	850	1,200	900	120	1,360	1,110	125	630
11 N	**	---	**	**	**	**	---	---	---		150	1,080			
10 N	350	3,000	380	3,420	1,860	3,210	2,650	1,500	1,780	1,640	660	1,140	2,160	350	1,590
9 N	500	5,400	500	4,500	3,600	2,160	3,300	2,250	1,650	1,830	900	1,500			
8 N	800	5,600	800	7,800	6,360	2,220	4,700	3,400	1,980	2,570	1,500	1,800	3,000	770	2,190
7 N	950	10,000	950	10,650	9,750	3,510	6,750	6,250	2,800	3,480	1,650	1,350			
6 N	950	5,400	950	10,650	9,600	3,450	7,200	6,600	2,550	3,770	2,550	2,100	5,250	800	3,000
5 N	870	6,000	870	9,800	8,790	2,790	6,450	6,700	2,350	3,560	2,040	1,890			
4 N	800	6,500	820	8,640	6,940	2,790	5,400	5,100	2,000	2,610	1,740	1,740	4,140	710	3,270
3 N	800	6,000	800	8,700	7,500	3,000	5,700	5,700	2,400	2,820	2,400	2,100			
2 N	700	2,700	700	8,100	7,200	2,400	4,200	4,100	2,050	2,700	1,800	1,500	3,900	610	2,100
1 N	650	3,300	600	6,600	**	2,400	4,950	2,140	2,020	2,460	2,100	1,200			
0	650	3,150	650	7,050	5,550	1,950	4,800	3,300	1,420	2,200	1,350	1,050	3,000	470	2,340
1	800	8,500	750	7,650	7,050	2,550	4,650	4,650	1,950	2,350	1,650	1,650			
2	800	7,500	800	7,500	7,200	2,400	5,100	4,050	1,800	2,500	1,200	1,200	2,910	660	1,770
3	1,200	4,000	000	7,200	**	**	4,500	3,600	1,800	2,350	1,500	1,200			
4	650	2,000	650	5,550	4,650	2,250	3,400	2,950	1,750	1,580	1,050	450	2,250	480	1,650
5	600	3,600	610	4,830	4,170	2,370	3,300	2,400	1,500	1,630	870	570			
6	600	2,400	600	4,650	3,450	2,100	3,050	1,800	1,850	1,670	450	450	2,340	600	1,650
7	800	3,000	700	5,100	3,600	3,300	3,300	2,300	2,050	2,030	900	1,500			
8	900	3,000	720	5,040	3,240	2,490	2,850	1,950	2,030	1,890	900	1,740	3,240	600	2,040
9	700	2,100	740	4,980	2,580	1,980	2,280	2,450	---	1,600	2,580	780			
10	750	3,600	800	5,400	5,400	3,150	3,900	1,920	2,470	2,050	1,800	1,500	3,600	530	1,560
11	---	---	750	---	---	---	---	---	---	---	---	---			
12	600	3,000	620	4,450	2,790	3,240	3,100	1,520	2,340	2,140	660	2,100	2,190	550	900
13	500	2,700	500	4,200	2,250	2,100	2,850	1,300	1,950	2,030	600	1,800			
14	400	1,500	440	3,480	1,380	1,680	2,510	1,530	1,800	1,900	930	1,210	1,620	370	900
15	350	2,000	350	3,000	2,070	2,070	2,400	1,180	1,120	1,620	600	1,050			
16	**	**	**	**	**	**	---	---	---	**	**	**	1,650	260	570
17	250	2,100	250	2,550	1,290	1,650	1,500	810	1,050	900	300	1,050			
18	220	2,000	200	2,100	1,200	750	1,040	580	320	520	300	300	1,500	200	540
19	150	1,400	150	1,590	930	630	1,120	580	870	630	300	300			
20	140	1,200	130	1,410	870	840	780	480	220	510	270	330	990	80	570
21	110	1,000	100	1,200	840	900	900	480	570	450	0	0			
22	100	1,000	100	1,200	900	1,030	830	400	700	430	300	300	720	170	570
23	220	2,000	200	2,400	1,650	1,800	1,860	960	1,500	1,200	540	990			
24	350	2,500	380	3,000	1,650	2,240	2,250	1,050	2,100	1,800	360	1,980	1,260	260	870
25	400	2,200	400	3,000	1,620	2,040	1,800	1,020	1,500	1,200	60	90			
26	300	1,500	270	1,920	1,290	1,650	900	540	570	270	150	120	1,320	150	690
27	275	1,800	260	1,860	1,230	1,470	1,020	600	380	520	180	180			
28	260	1,600	260	1,860	2,850	1,350	1,200	2,050	720	540	240	180	1,650	190	1,110
29	360	2,500	360	2,670	1,620	1,770	1,590	510	1,160	570	180	60			
30	350	2,700	350	2,700	1,650	2,340	1,650	770	1,480	750	360	120	2,010	310	1,170
31	500	3,000	500	3,300	1,950	2,250	2,670	1,020	2,340	1,950	450	1,950			
32	---	---	700	4,050	2,400	3,000	2,850	1,250	2,250	1,980	360	2,250	3,150	550	2,010
33	---	---	600	3,600	2,250	2,550	2,760	1,200	2,340	1,650	450	1,200			
34	---	---	750	4,800	2,700	3,360	3,750	1,710	3,210	2,640	900	2,850	3,150	550	2,100
35	---	---	450	4,050	2,310	2,700	3,340	---	---	2,160	600	2,310			
36	---	---	270	2,490	1,590	2,190	1,780	840	1,600	1,290	390	1,140	1,740	250	900
37	---	---	240	2,130	1,230	1,530	1,890	---	---	860	180	1,020			
38	---	---	220	2,100	1,140	1,590	1,620	580	1,530	1,050	240	1,140	990	190	720
39	---	---	270	---	1,590	1,830	--	---	---	---	120	360			
40	---	---	280	2,050	1,320	2,040	1,860	780	2,080	800	210	1,460	1,560	250	750

--- Dosimeters not read out
** Dosimeters not recovered
*** Dosimeters at even-numbered stations only
( ) Doses below confidence level

Table B-1 (Continued)

STATION	DOSES AT GROUND LEVEL		DOSES AT 25 CENTIMETERS				DOSE AT 1 METER			DOSES AT 3 METERS			DOSE AT SHRUBS***		
			Total		Pb Shielded		Total	Pb Shielded		Total	Pb Shielded		Uncovered	Polyethylene Covered	
					Above	Below		Above	Below		Above	Below			
	γ	β	γ	β	β	β	β	β	β	β	β	β	β	γ	β
41	---	---	300	---	1,800	2,550	---	---	---	---	450	2,550			
42	---	---	350	3,300	2,100	2,550	2,550	1,250	2,370	2,400	510	2,550	---	---	---
43	---	---	200	---	780	1,350	---	---	---	---	120	840			
44	---	---	160	---	---	---	950	---	---	600	---	---	450	150	100
45	---	---	90	---	---	---	---	---	---	---	---	---			
46	---	---	40	---	---	---	---	---	---	---	---	----	---	---	---
48	---	---	(5)	---	---	---	---	---	---	---	---	---	30	(4.5)	(25)
50	---	---	(4)	---	---	---	---	---	---	---	---	---	30	(3.5)	27
52	---	---	(5)	---	---	---		--	---		--		27	(5.0)	(21)
54	---	---	(5)	---	---	---	---	---	---	---	---	---	30	(5.0)	(24)
56	---	---	(6)	---	---	---	---	---	---	---	---	---	27	(5.0)	27
58	---	---	(8)	---	---	---	---	---	---	---	---	---	30	(7.0)	27
60	---	---	(15)	---	---	---	---	---	---	---	---	---	33	(15.0)	(24)
62	---	---	(15)	---	---	---	---	---	---	---	---	---	33	(15.0)	(21)
64	---	---	(20)	---	---	---	---	---	---	---	---	---	60	(20.0)	54
66	---	---	(25)	---	---	---	---	---	---	---	---	---	45	(25.0)	27

--- Dosimeters not read out
** Dosimeters not recovered
*** *Dosimeters at even-numbered stations only*
( ) Doses below confidence level

B-3 DIRECT DOSE MEASUREMENT FOR FUTURE EVENTS

To supplement the method of determining the energy fluence and the interpretation in terms of absorbed dose, a dosimeter material may be used directly to measure absorbed dose if it absorbs only a negligible portion of the incident radiation. That is, if considering an absorbtion of the form $E_0e^{-\mu t}$, the material is "thin" under the condition that $\mu t = 0$.

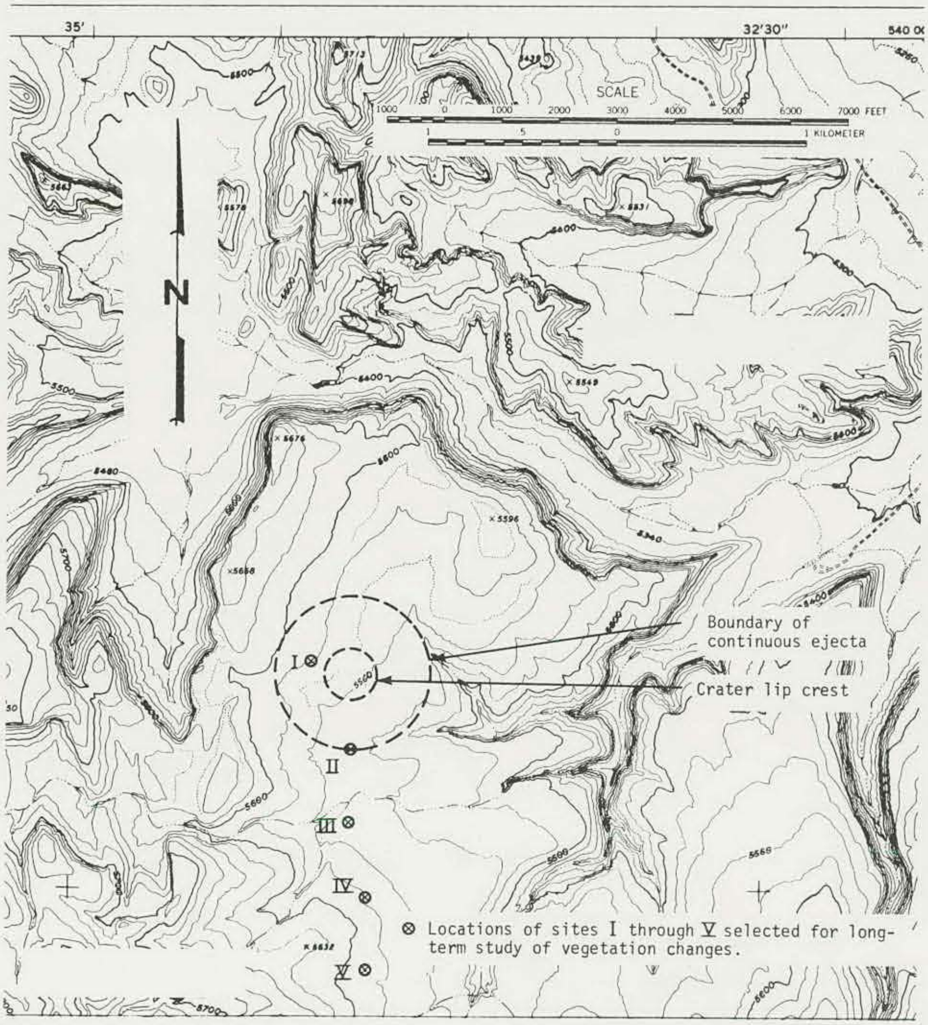
From the experience gained in measuring depth dose in the CABRIOLET and SCHOONER cratering fallout fields, it was determined that a direct-reading dosimeter could be made with a thickness small compared to the beta range of 325 mg/cm^2. This dosimeter, which consists of a 0.30-inch cube of hot-pressed CaF_2:Mn, has been found to have a stable geometery, and measurements made with it in radiation fields were consistent within a probable error of ± 3 R.

This small cube may be placed directly alongside of a stem, leaf, branch, or at a meristem, thus placing dosimeteric measurements at the vital points of interest to ecological studies. The gamma-ray contributions may be evaluated in a manner similar to that of the fluence measurements, by shielding with sufficient material to entirely absorb electrons while producing a negligible effect on the gamma-ray component.

APPENDIX C

VEGETATION, DENSITY, AND COVER CALCULATIONS FOR THE AREA SOUTH OF SCHOONER

Five sites, located west and south of GZ were selected as being representative of the most diverse environments which may have resulted from creation of the SCHOONER crater (see Fig. C-1). At each of the sites, three 5-meter-radius plots were randomly chosen. Site I, the most proximate to GZ, was located about 50 meters west of GZ crater lip in an area characterized by massive overburdens of material thrown from the crater and a relatively high radiation background. The most distant site was located to the south in an undisturbed area beyond the base surge deposits where radiation readings were essentially background.



Approximate location of sites used for investigation of effects on vegetation from nuclear cratering upwind from GZ.

Separate determinations of the numbers within a species in each circular plot were made, and the area occupied by each species was estimated. These data are listed in Table C-1.

Table C-1. Species of plants found from the SCHOONER crater southward with estimates of their density and cover.

SPECIES	SITE NO.	$\bar{X}$ DENSITY $\frac{\text{NUMBER OF INDIVIDUALS}}{\text{PLOT}}$	FREQUENCY $\frac{\text{NUMBER OF PLOTS WITH A SPECIES PRESENT}}{3}$	$\bar{X}$ INDIVIDUAL COVER $\frac{\bar{X}\ \text{\% COVER}}{\text{INDIVIDUAL}}$	$\bar{X}$ % COVER $\bar{X}$ DENSITY TIMES $\bar{X}$ INDIVIDUAL COVER
Artemisia	I	--	--	--	--
	II	--	--	--	--
	III	0.33	0.33	0.0173	0.0057
	IV	63.0	1.0	0.0971	6.117
	V	63.0	1.0	0.19135	12.055
Artemisia seedlings	I	--	--	--	--
	II	--	--	--	--
	III	--	--	--	--
	IV	10.6	1.0	0.01360	0.144
	V	--	--	--	--
Astragalus lentigenosus	I	0.33	0.33	NV	--
	II	0.67	0.66	NV	--
	III	2.0	0.66	1.047	2.094
	IV	7.0	0.66	0.0629	0.440
	V	--	--	--	--
Atriplex canescens	I	--	--	--	--
	II	2.67	0.66	1.1360	3.033
	III	1.0	0.33	0.200*	0.800
	IV	0.33	0.33	0.624	0.206
	V	0.67	0.33	0.0815	0.0546
Atriplex confertifolia	I	--	--	--	--
	II	0.67	0.33	1.215	0.814
	III	--	--	--	--
	IV	0.33	0.33	--	--
	V	1.0	0.33	0.713	0.713
Chrysothamnus viscidiflorus	I	--	--	--	--
	II	4.33	--	0.262	1.134
	III	0.67	0.33	0.188	0.1259
	IV	--	--	--	--
	V	--	--	--	--
Ephedra nevadensis	I	--	--	--	--
	II	--	--	--	--
	III	1.0	0.33	0.2204	0.2204
	IV	1.33	0.66	0.0359	0.0477
	V	0.67	0.33	NV	NV
Eriogonum deflexum	I	0.33	0.33	NV	--
	II	0.67	0.33	0.163	0.109
	III	--	--	--	--
	IV	--	--	--	--
	V	--	--	--	--
Eurotia lanata	I	--	--	--	--
	II	--	--	--	--
	III	9.67	1.0	0.0799	0.7243
	IV	3.0	1.0	0.0473	0.142
	V	--	--	--	--
Grayia spinosa	I	--	--	--	--
	II	0.33	0.33	0.1527	0.050
	III	12.3	1.0	0.4871	5.991
	IV	5.0	0.66	0.2907	1.454
	V	6.0	1.0	0.5172	3.103

Table C-1 (Cont'd.)

SPECIES	SITE NO.	$\bar{X}$ DENSITY NUMBER OF $\frac{\text{INDIVIDUALS}}{\text{PLOT}}$	FREQUENCY NUMBER OF $\frac{\text{PLOTS WITH A SPECIES PRESENT}}{3}$	$\bar{X}$ INDIVIDUAL COVER $\frac{\bar{X}\ \text{\% COVER}}{\text{INDIVIDUAL}}$	$\bar{X}$ % COVER $\bar{X}$ DENSITY TIMES $\bar{X}$ INDIVIDUAL COVER
Halogeton glomeratus	I	--	--	--	--
	II	2.0	0.33	0.255	0.66
	III	--	--	--	--
	IV	.33	0.33	0.0735	0.024
	V	--	--	--	--
Hilaria jamesii	I	--	--	--	--
	II	6.67	0.33	0.250	1.668
	III	7.67	1.0	1.1850	9.089
	IV	--	--		--
	V	3.33	0.33	NV	NV
Machaeranthera leucanthemifolia	I	--	--	--	--
	II	0.67	0.33	0.253	0.170
	III	7.0	1.0	0.0916	0.641
	IV	0.67	1.0	0.0256	0.0172
	V	0.33	0.33	0.115	0.383
Opuntia erinacea	I	--	--	--	--
	II	--	--	--	--
	III	0.33	0.33	0.023	0.008
	IV	--	--	--	--
	V	--	--	--	--
Oryzopsis hymenoides	I	--	--	--	--
	II	3.67	1.0	0.0386	0.142
	III	7.0	0.66	0.0804	0.563
	IV	19.0	0.66	0.0290	0.551
	V	4.67		0.0928	0.433
Salsola pestifera	I	26.0	1.9	0.11475	2.98
	II	6.9	1.0	0.2065	14.249
	III	--	0.33	--	--
	IV	.67	--	0.0837	0.056
	V	--		--	--
Sitanion hystrix	I	--	--	--	--
	II	--	--	--	--
	III	92.6	1.0	0.307	28.428
	IV	38.3	1.0	(0.00869)	0.333
	V	53.0		0.0310	1.643
Spheralcea ambigua	I	--	--	--	--
	II	1.0	0.66	0.2337	0.234
	III	8.0	0.33	0.0482	0.386
	IV	0.33	--	0.00815	0.0027
	V	--		--	--
Stanlea elata	I	--	1.0	--	--
	II	3.33	0.33	0.238	0.793
	III	--	--	--	--
	IV	--	--	--	--
	V	--		--	--
Tetradomia glabrata	I	--	--	--	--
	II	0.33	0.33	0.0407	0.013
	III	--	--	--	--
	IV	--	--	--	--
	V	--		--	--
Psathyrotes annua	I	--	--	--	--
	II	--	--	--	--
	III	--	--	--	--
	IV	--	--	--	--
	V	--		--	--

Density data in Table C-1 is based on a separate determination of the "number of individuals" per circular plot. Fifteen circular-plot determinations were made for each species. Next, Plots (1, 2, 3), (4, 5, 6), (7, 8, 9), (10, 11, 12), and (13, 14, 15) were each summed for each species. If a species was absent from one of the three plots at a site, a zero was added. These sums were then divided by 3 (for 3 plots) and the *mean density* ($\overline{X}$ density) was recorded. Hence, mean density is the number of individuals per plot (1 plot = 78.54 M^2).

Frequency data provides information as to what fraction of the three plots at each site contain a given species. That is

$$\text{Frequency} = \frac{\text{Number of plots with a species present}}{3}$$

Mean percent cover was calculated as follows: Each individual plant was assigned an area or "cover value" according to a calculated area assuming a rectangle or circle, as was more appropriate for the species concerned. These areas were summed and divided by the average area (cm^2) for each species for each of the 15 plots (three at each of five sites). This value was added to similar values for the other two plots at a site and the sum divided by the number of plots having such estimates (1, 2, or 3). The resulting value ($\overline{X}$ % cover/individual) was then multiplied by the $\overline{X}$ density to give the $\overline{X}$ % species cover. Following is an example of the calculation for *Salsola* at Plot C, Site I:

The total area covered by the 25 individual *Salsola* at Plot C was 23,405 cm^2. Thus, the cover/individual was

$$\frac{23{,}405}{25} \text{ cm}^2 = 936.2 \text{ cm}^2$$

Since the area of each of the three plots at each site was 78.54 m^2, the percent of the total area at Plot C covered by a mean-size *Salsola* was

$$\frac{936.2 \text{ cm}^2}{78.54 \text{ cm}^2} = 0.1192\ \%$$

The mean percent cover ($\overline{X}$ % cover) for Site I *Salsola* becomes the sums of Plots A (0.1148%), B (0.1104%), and C (0.1192%) divided by the number of plots:

$$\frac{0.1148\% + 0.1104\% + 0.1192\%}{3} = 0.1148\%$$

This value multiplied by the mean number of individuals at the three plots, (that is, 26) gives the mean percent cover for the species:

$$\overline{X}\ \%\ \text{cover} = 26 \times 0.1148\% = 2.98\%$$

APPENDIX D

SHRUB VOLUMES AND ESTIMATES OF EXTENT OF DAMAGE AT SELECTED DOSIMETER STATIONS

In April 1970 (D plus 16 months), an attempt was made to measure the sizes of 100 shrubs and estimate the extent of their damage in the main part (northern sector) of the fallout pattern along the dosimeter arc at each station from 10N to 11.

Stations 4 through 8N were, however, subsequently omitted from the survey. At some of these stations all *Artemisia* was killed, and at others such a large proportion was killed that the determination of the shrubs damaged and their sizes would have had little significance. Station 9 was not analyzed because the number of shrubs available was too few.

Shrub volumes were calculated as if the shrubs were cylinders, using a mean of two measured diameters and the heights as dimensions of the cylinders. Shrub damage was estimated according to the following percent-damage categories:

1. 0% - No visual damage, shrub with normal inflorescence development.
2. 25% - Approximately 25% of the shrub showing damage vis., loss of leaves approximating that amount and showing suppressed inflorescence development or absence of inflorescence development.
3. 50% - Approximately 50% of the shrub showing damage as in Category 2.
4. 75% - Approximately 75% of the shrub showing damage as in Category 2.
5. 100% - Dead, i.e., completely defoliated, or remaining foliage dry and gray-brown and subject to fall when disturbed.

Complete tabulations of the data obtained from this survey are presented in Tables D-1 through D-8.

Table D-1. Station 10N shrub volumes and estimated extent of damage.

Calculated shrub volume (M³)	ESTIMATED EXTENT OF DAMAGE (%) 0	25	50	75	100	Total sample
	NUMBERS OF SHRUBS IN EACH CATEGORY					
0.5	1	4	1	1	1	8
1.0	13	7	3	1	0	24
1.5	6	6	2	0	0	14
2.0	3	7	0	1	1	12
2.5	1	2	1	0	0	4
3.0	0	2	1	0	0	3
3.5	1	0	1	0	0	2
4.0	1	4	0	0	0	5
4.5	0	0	0	0	0	0
5.0	0	0	0	0	0	0
5.5	0	0	0	0	0	0
6.0	0	2	0	0	0	2
						74
	DOSE (RADS) AT DOSIMETER STATION					
		Gamma	380			
		Beta	3420			
		total	3800			

Table D-2. Station 9N shrub volumes and estimated extent of damage.

Calculated shrub volume (M³)	ESTIMATED EXTENT OF DAMAGE (%) 0	25	50	75	100	Total sample
	NUMBERS OF SHRUBS IN EACH CATEGORY					
0.5	3	3	5	3	2	16
1.0	1	4	2	2	3	12
1.5	4	2	4	5	1	16
2.0	0	5	2	3	0	10
2.5	4	7	1	1	0	13
3.0	2	9	3	1	0	15
3.5	1	1	2	1	0	5
4.0	1	5	1	0	0	7
4.5	0	0	2	0	0	2
5.0	0	1	0	0	0	1
5.5	0	0	0	0	0	0
6.0	0	2	0	2	0	4
						101
	DOSE (RADS) AT DOSIMETER STATION					
		Gamma	500			
		Beta	4500			
		Total	5000			

Table D-3. Station 5 shrub volumes and estimated extent of damage.

Calculated shrub volume (M^3)	ESTIMATED EXTENT OF DAMAGE (%) 0	25	50	75	100	Total sample
	NUMBERS OF SHRUBS IN EACH CATEGORY					
0.5	0	1	1	2	4	8
1.0	2	5	3	2	5	17
1.5	2	3	2	3	5	15
2.0	1	2	1	6	1	11
2.5	0	6	3	4	1	14
3.0	0	2	1	2	4	9
3.5	0	0	1	0	1	2
4.0	0	0	0	1	0	1
4.5	0	0	1	0	0	1
5.0	0	0	0	2	0	2
5.5	0	0	0	0	0	0
6.0	0	1	1	0	0	2
						82

DOSE (RADS) AT DOSIMETER STATION

Gamma	610
Beta	4830
Total	5440

Calculated shrub volume (M^3)	ESTIMATED EXTENT OF DAMAGE (%) 0	25	50	75	100	Total sample
	NUMBERS OF SHRUBS IN EACH CATEGORY					
0.5	0	0	3	0	12	15
1.0	1	2	5	7	6	21
1.5	0	1	6	8	7	22
2.0	2	4	3	5	2	16
2.5	0	1	2	1	1	5
3.0	0	1	3	3	3	10
3.5	0	5	1	1	1	8
4.0	1	0	1	0	1	3
4.5	0	1	0	0	0	1
5.0	0	0	0	1	0	1
5.5	0	0	1	0	1	2
6.0	0	0	2	0	0	2
						106

DOSE (RADS) AT DOSIMETER STATION

Gamma	600
Beta	4650
Total	5250

Table D-5. Station 7 shrub volumes and estimated extent of damage.

Calculated shrub volume (M³)	ESTIMATED EXTENT OF DAMAGE (%)					Total sample
	0	25	50	75	100	
	NUMBERS OF SHRUBS IN EACH CATEGORY					
0.5	0	2	1	2	4	9
1.0	0	3	4	11	19	37
1.5	1	1	0	3	10	15
2.0	1	2	4	8	3	18
2.5	0	2	1	1	2	6
3.0	0	0	0	2	2	4
3.5	1	1	1	2	1	6
4.0	1	0	0	1	2	4
4.5	0	1	0	0	0	1
5.0	1	0	0	2	0	3
5.5	0	0	1	1	0	2
6.0	1	0	0	0	0	1
						106
	DOSE (RADS) AT DOSIMETER STATION					
	Gamma 700					
	Beta 5100					
	Total 5800					

Table D-6. Station 8 shrub volumes and estimated extent of damage.

Calculated shrub volume (M³)	ESTIMATED EXTENT OF DAMAGE (%)					Total sample
	0	25	50	75	100	
	NUMBERS OF SHRUBS IN EACH CATEGORY					
0.5	1	0	3	3	5	12
1.0	0	5	2	11	11	29
1.5	0	1	3	8	4	16
2.0	1	0	3	6	4	14
2.5	0	5	2	3	1	11
3.0	0	1	1	3	0	5
3.5	1	0	1	1	0	3
4.0	0	1	1	0	1	3
4.5	0	0	0	1	0	1
5.0	0	1	0	0	0	1
5.5	0	0	0	0	0	0
6.0	2	2	0	0	1	5
						100
	DOSE (RADS) AT DOSIMETER STATION					
	Gamma 720					
	Beta 5040					
	Total 5760					

Table D-7. Station 10 shrub volumes and estimated extent of damage.

Calculated shrub volume (M^3)	ESTIMATED EXTENT OF DAMAGE (%)					Total sample
	0	25	50	75	100	
	NUMBERS OF SHRUBS IN EACH CATEGORY					
0.5	5	2	1	6	5	19
1.0	4	5	8	11	4	32
1.5	0	4	5	8	2	19
2.0	0	6	5	2	5	18
2.5	1	1	5	6	2	15
3.0	2	5	2	2	2	13
3.5	0	2	0	0	0	2
4.0	1	0	0	1	0	2
4.5	0	1	0	1	0	2
5.0	0	0	0	1	0	1
5.5	0	0	0	0	0	0
6.0	1	0	0	0	0	1
						124

DOSE (RADS) AT DOSIMETER STATION

Gamma	800
Beta	5400
Total	6200

Table D-8. Station 11 shrub volumes and estimated extent of damage.

Calculated shrub volume (M^3)	ESTIMATED EXTENT OF DAMAGE (%)					Total sample
	0	25	50	75	100	
	NUMBERS OF SHRUBS IN EACH CATEGORY					
0.5	1	3	7	3	2	16
1.0	4	6	9	6	4	29
1.5	3	7	7	3	1	21
2.0	1	4	3	2	1	11
2.5	0	0	1	1	2	4
3.0	0	5	1	1	2	9
3.5	0	1	0	1	0	2
4.0	0	1	2	0	0	3
4.5	0	1	1	0	0	2
5.0	0	1	0	0	0	1
5.5	0	1	0	0	0	1
6.0	0	0	1	1	0	2
						101

DOSE (RADS) AT DOSIMETER STATION

Gamma	750
Beta	5100
Total	5850

PROJECT SCHOONER REPORTS

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PNE-520	LRL	H. A. Tewes	Schooner Summary
PNE-521	Sandia	L. Vortman	Close-In Air Blast
PNE-522	ERC	W. W. Hays R. A. Mueller C. T. Spiker, Jr.	A Contribution to the Analysis of Seismic Data from Cratering and Contained Events
PNE-523	ESSA/ARL		Weather and Radiation Predictions, Schooner Event
PNE-524	EPA		Off-Site Surveillance, Schooner Event
PNE-525	REECo		On-Site Radiological Safety, Schooner Event
PNE-526	EG&G	H. Nishita W. A. Rhoads	Ecological and Environmental Effects from Local Fallout from Schooner. 1. Soil Thermoluminescence in Relation to Radiation Exposure Under Field Conditions
PNE-529	EG&G	W. A. Rhoads A. D. Kantz H. L. Ragsdale	Ecological and Environmental Effects from Local Fallout from Schooner. 2. The Beta and Gamma Radiation Effects From Close-In Fallout
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