PNE-300 P

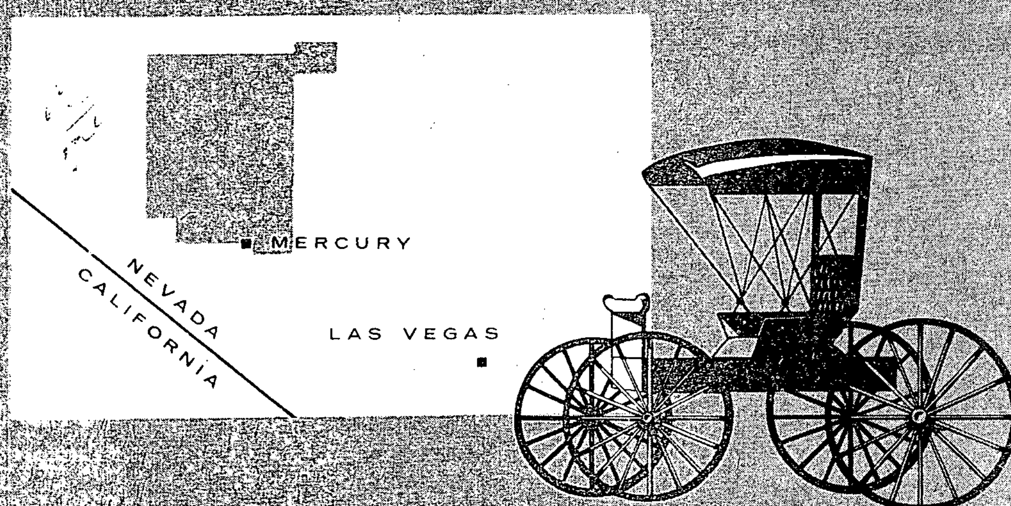
PRELIMINARY REPORT

Plowshare civil, industrial and scientific uses for nuclear explosives

UNITED STATES ARMY CORPS OF ENGINEERS

project pre-BUGGY

NEVADA TEST SITE ▪ NOV. 1962 – FEB. 1963



Scope of Chemical Explosive Cratering Experiment

E. Graves / W. R. Wray / R. B. Pierce

NUCLEAR CRATERING GROUP ▪ ISSUED: AUG., 1963

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PROJECT PRE-BUGGY

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SCOPE OF CHEMICAL EXPLOSIVE CRATERING EXPERIMENT

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May 15, 1963

ABSTRACT

This report provides a general description of the PRE-BUGGY CHEMICAL EXPLOSIVE EXPERIMENTS. These experiments consisted of a series of single- and multiple-charge detonations designed to refine our knowledge of channel size as a function of charge spacing, and to obtain data on venting of explosion products from a row of spherical charges detonated in alluvium.

A basic series of six single-charge ~~detonations~~s and four multiple-charge detonations of five charges in a row was executed in Area 5 of the Nevada Test Site from November 1962 through February 1963. Each charge contained 1,000 pounds of nitromethane with a La^{140} tracer.

Preliminary examination of the results indicates that:

(1) When charges were spaced at 1.0 single-charge crater radius, the channel depth and width were larger than the diameter and depth of a single-charge crater.

(2) Small increases in spacing resulted in considerable reduction of channel depth and a smaller reduction in width.

(3) The channel shape at spacings of 1.5 single-charge crater radii was very uneven.

(4) When the ratio of the depth-of-burst to depth-of-crater was about two, the venting of explosion products from a row-charge detonation was less than from single-charge detonations.

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

In the development of nuclear excavation technology, one of the most important questions to be answered concerns the effects of detonating a row of buried nuclear explosives to produce a linear excavation. Several nuclear cratering experiments have been proposed as part of the Atomic Energy Commission's Plowshare Program to investigate these effects. The first of these experiments, called Buggy, is planned to study crater dimensions and safety problems resulting from the detonation of row charges in desert alluvium.

The design of the Buggy experiment is to be based on information derived from nuclear and chemical explosive cratering work done in desert alluvium. Previous nuclear cratering experiments have been confined to single-charge shots. A number of experiments have been executed using chemical explosives to produce linear excavations, including one by the Sandia Corporation called Toboggan and one by the Lawrence Radiation Laboratory called Rowboat. Of these two, Rowboat, which involved 256-pound charges, is more nearly applicable to Buggy. This experiment showed that a row of charges placed at slightly greater than optimum depth and spaced at 1.0 single-charge crater radius will produce a channel with approximately the same apparent width and depth as a single-charge crater. As the spacing is increased to 1.5 single-charge crater radii, the channel width decreases only 10 percent, but the depth is reduced by as much as a factor of 2. No prior experiments have provided data on the release of radioactivity from row-charge detonations.

Although the previous row-charge work furnished much valuable data, additional information is needed to optimize the design of the Buggy experiment and to improve our knowledge of the interaction of row charges. In particular, more information is needed on the effect of varying charge spacing and on the venting of radioactivity from row-charge detonations.

1.2 OBJECTIVES OF PRE-BUGGY

The objective of the Pre-Buggy chemical explosives experiments was to extend current knowledge by obtaining data on crater dimensions and the venting of explosion products from a row of spherical charges detonated in alluvium.

In the case of the crater dimensions, emphasis was placed on learning the effect of varying the spacing of charges for a depth of burst slightly greater than optimum.

In the case of the venting studies, emphasis was placed on comparing the amount of radioactive tracer which escaped as local fallout for single-charge and multiple-charge detonations.

1.3 PURPOSE AND SCOPE OF REPORT

The purpose of this report is to describe the Pre-Buggy experiment, present the general results available at this time, and direct the reader to sources of additional detailed information.

Chapter 2 includes information on the site, a description of the detonation program, and a brief discussion of the technical programs which were executed. Chapter 3 presents a summary of results available at this time and the status of data analysis. A list of reports that will be published on the Pre-Buggy experiment is presented in Appendix A.

CHAPTER 2

GENERAL DESCRIPTION OF EXPERIMENT

2.1 ORGANIZATION

The Pre-Buggy chemical explosives cratering experiment was conducted in Area 5 of the Nevada Test Site (NTS) from November 1962 to February 1963. The project was administered by the NTS organization as prescribed by the SOP for NTS.

E. Graves of the U. S. Army Engineer Nuclear Cratering Group (NCG) was Technical Director for the project. Figure 2.1 gives the Technical Director's organization for the conduct of the experiment.

2.2 DESCRIPTION OF SITE

The site location was in the Triple Point, Kay (Ranger) Bunker, Sugar Bunker area of Area 5. The cratering detonations were located on an east-west line between the following coordinates on the Holmes & Narver NTS Grid System:

N 759,330	N 759,330
E 703,170	E 704,680.

Figure 2.2 shows the site and the layout of the experiment.

Most of the prior chemical explosives cratering experiments in alluvium had been conducted in Area 10. The Pre-Buggy series was executed in Area 5 because other activities in Area 10 at the time did not leave a suitable area for the Pre-Buggy shots.

The site selected in Area 5 met the following technical criteria for the experiment:

1. The alluvium was similar to that in Area 10. The material was predominantly a gravelly sand, containing some boulders and a small amount of silt. The primary difference from the material in Area 10 was the lesser amount of cementing agent in Area 5.
2. The alluvium was a relatively uniform medium with a thickness of at least 45 feet.
3. The relatively flat area over a mile square provided sufficient space for the experimental layout.
4. The background radiation level was low enough that it would not interfere with the venting measurements.

2.3 DESCRIPTION OF DETONATIONS

The basic detonation series consisted of six single-charge events and four multiple-charge events of five charges in each row. A test shot was detonated prior to this series as a check on the general cratering properties of the alluvium in this area. The series of six single-charge events was used to normalize the results of this experiment to the results of past experiments using TNT and to determine the depth of burst and spacing to be used for the row charges. Tables 2.1 and 2.2 present the emplacement data for the basic series of

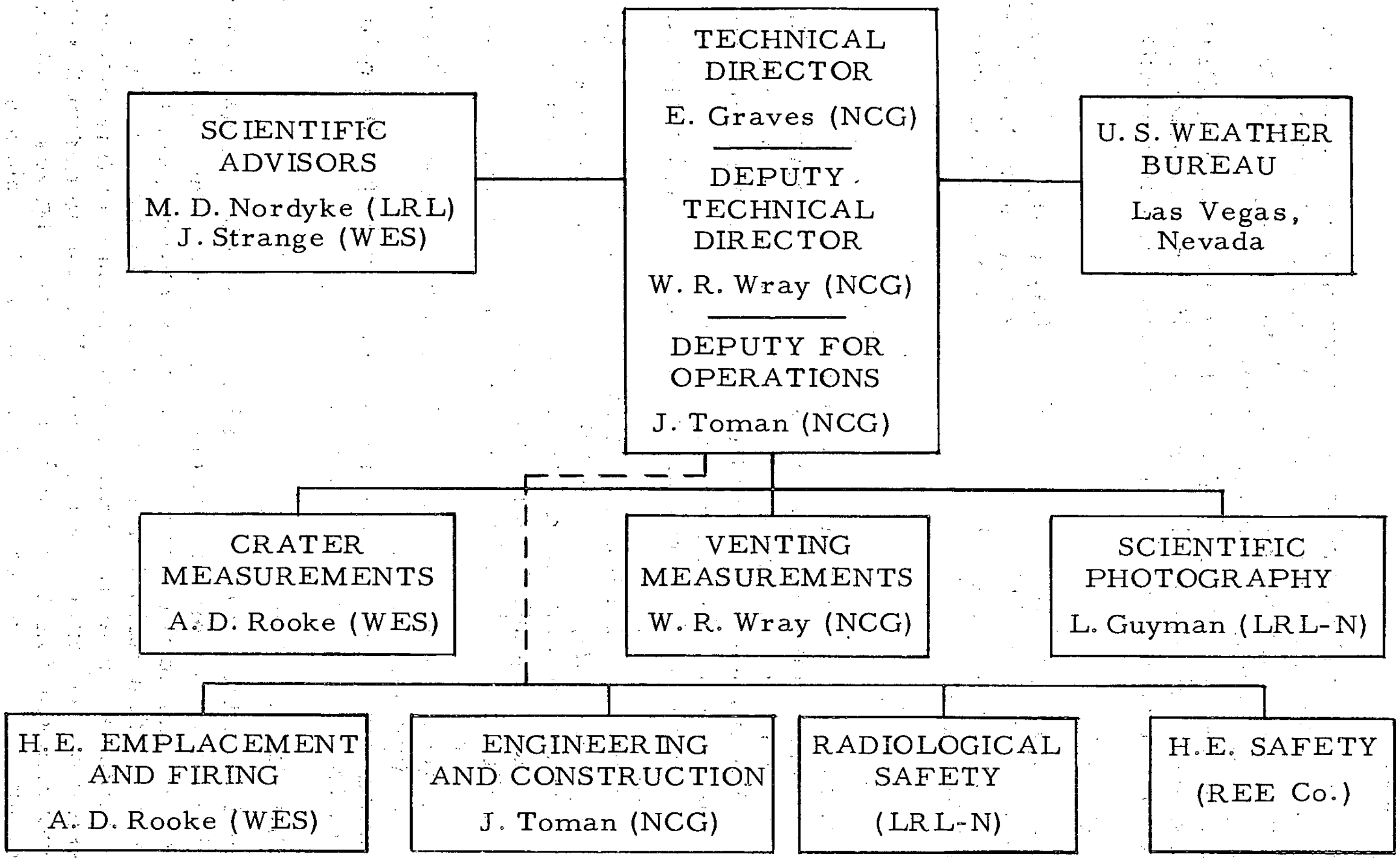

Figure 2.1 Technical organization of Pre-Buggy experiment.

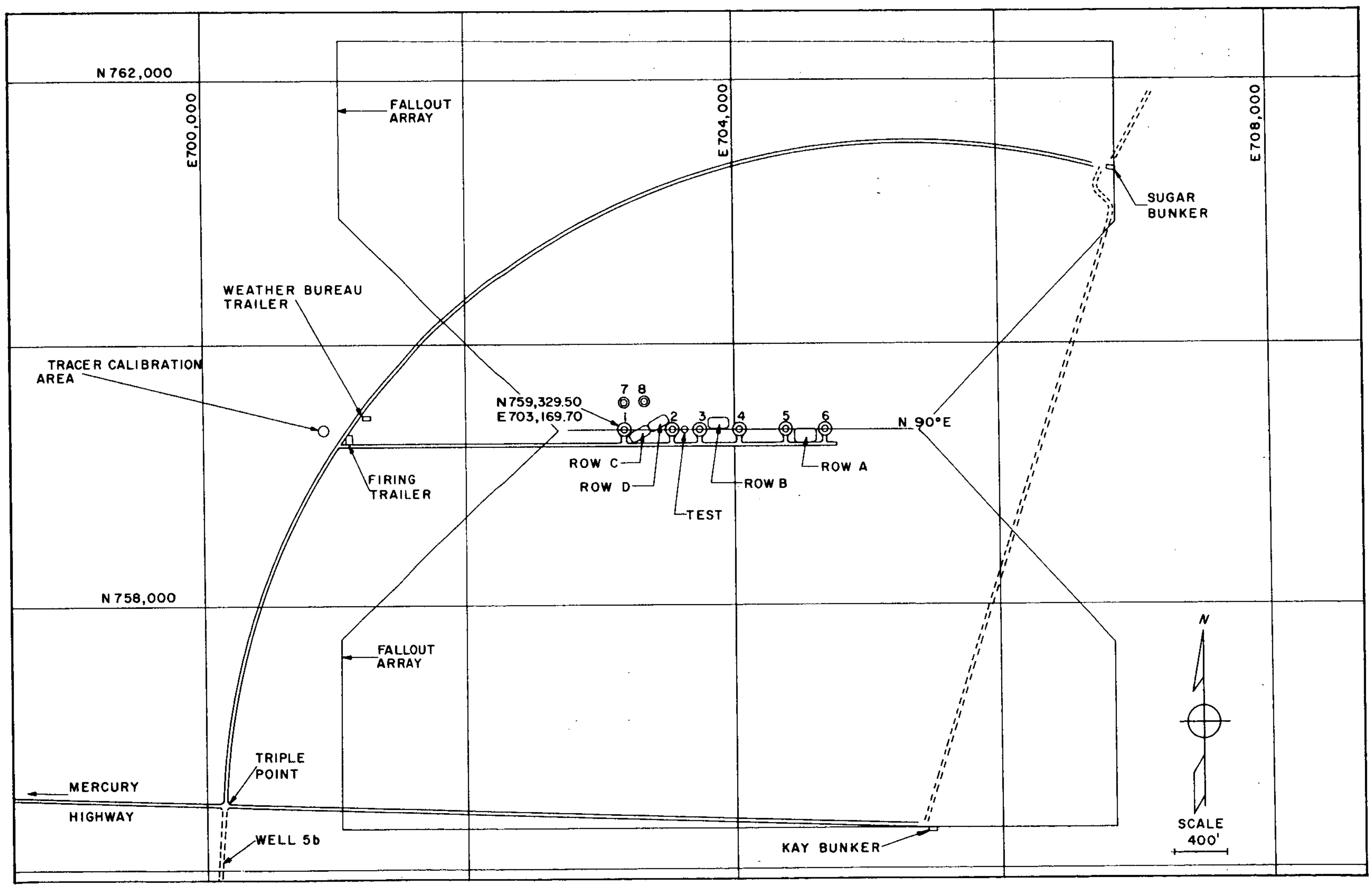

Figure 2.2 Site location.

TABLE 2.1 SINGLE-CHARGE DETONATIONS, BASIC SERIES

Event No.	Hole No.	DoB[a]	Charge Weight
		feet	pounds
Test	-	15.0	1,017
1	5	15.0	1,006
2	3	16.6	1,005
3	1	18.2	1,009
4	4	19.8	1,009
5	2	21.4	1,014
6	6	19.6	1,016

[a]Depth of burst measured from ground surface to center of charge

TABLE 2.2 MULTIPLE-CHARGE DETONATIONS, BASIC SERIES

Depth of burst of all charges was 19.8 feet.

	Spacing		Charge Weights	
Row	Feet	Single-Charge Crater-radii	Individual	Average
			pounds	pounds
A	20.6	R	1 - 1,018	1,016
			2 - 1,022	
			3 - 1,010	
			4 - 1,017	
			5 - 1,013	
B	30.9	1-1/2R	1 - 1,012	1,023
			2 - 1,017	
			3 - 1,019	
			4 - 1,019	
			5 - 1,047	
C	25.8	1-1/4R	1 - 1,008	1,007
			2 - 1,000	
			3 - 1,005	
			4 - 1,012	
			5 - 1,009	
D	23.2	1-1/8R	1 - 994	1,004
			2 - 1,005	
			3 - 995	
			4 - 1,013	
			5 - 1,013	

detonations. Appendix B gives the date and time of each event and the meteorological data for each event.

Each charge consisted of approximately 1,000 pounds of the liquid explosive nitromethane (CH_3NO_2) contained in a spun-aluminum sphere 36 inches in diameter. The nitromethane was center detonated by a pair of SE-1 detonators symmetrically embedded in a booster assembly containing 4 pounds of Composition C-4. The charges were placed at the bottom of 42-inch-diameter holes and the holes were stemmed with sand. A capsule containing the radioactive tracer, LA^{140}, was placed in the center of each booster charge. See Figures 2.3 - 2.6.

Nitromethane was used in the experiments for the following reasons:

1. One-thousand-pound TNT spheres could not be produced in time to meet the experiment schedule. The aluminum spheres, boosters, and nitromethane could be produced and shipped in the relatively short time required.

2. Nitromethane was more economical than TNT. The aluminum spheres, boosters, and nitromethane could be produced and shipped to NTS for less cost than the preparation of the TNT spheres. There was also a considerable savings in handling and storage of the nitromethane.

3. Future experiments of the NCG with charge sizes up to 40,000 pounds were also considered. Initial estimates indicated that for these larger detonations nitromethane would entail about one-third the expense of TNT.

4. Initial comparison of the properties of nitromethane and TNT, the explosive used in prior cratering experiments, showed that the detonation velocities, pressures, temperatures, energy content, and other properties which affect cratering efficiency were quite similar. Thus, the nitromethane was expected to produce results which could be compared with previous TNT experiments.

Prior to the basic series of detonations, two 1,000-pound nitromethane charges were detonated in Areas 9-10 in the vicinity of the following coordinates on the Holmes & Narver NTS Grid System:

N 875,000
E 685,850.

The original plan for Pre-Buggy was to conduct all detonations at this site.

The alluvium in this area contained a thick layer of strongly cemented caliche several feet thick. The cratering results in this area were poor and could not be correlated with previous chemical explosive work in alluvium. The only other sectors of Area 9-10 available to the NCG for the experiment were unsatisfactory for technical reasons. Therefore, the experiment was moved to the site in Area 5, where the cratering characteristics appeared to be suitable.

After the basic series of detonations, two 1,000-pound TNT spheres were detonated in Areas 9-10 and two in Area 5 to compare the cratering characteristics of the two explosives. A separate report is being prepared on the results of this comparison. Table 2.3 presents the basic description of these detonations.

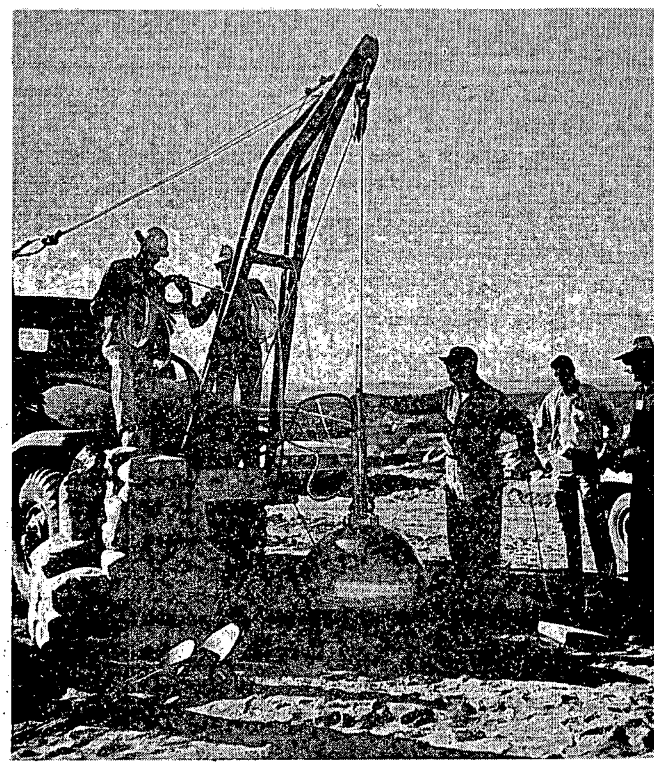

Figure 2.3 H. E. sphere and emplacement hole.

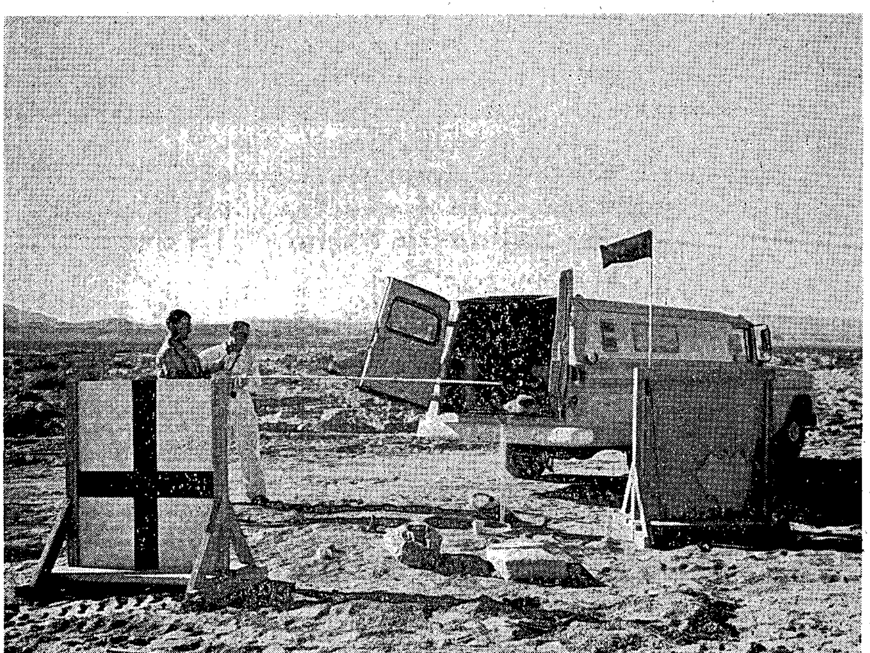

Figure 2.4 Tracer capsule insertion.

Figure 2.5 Single-charge detonation.

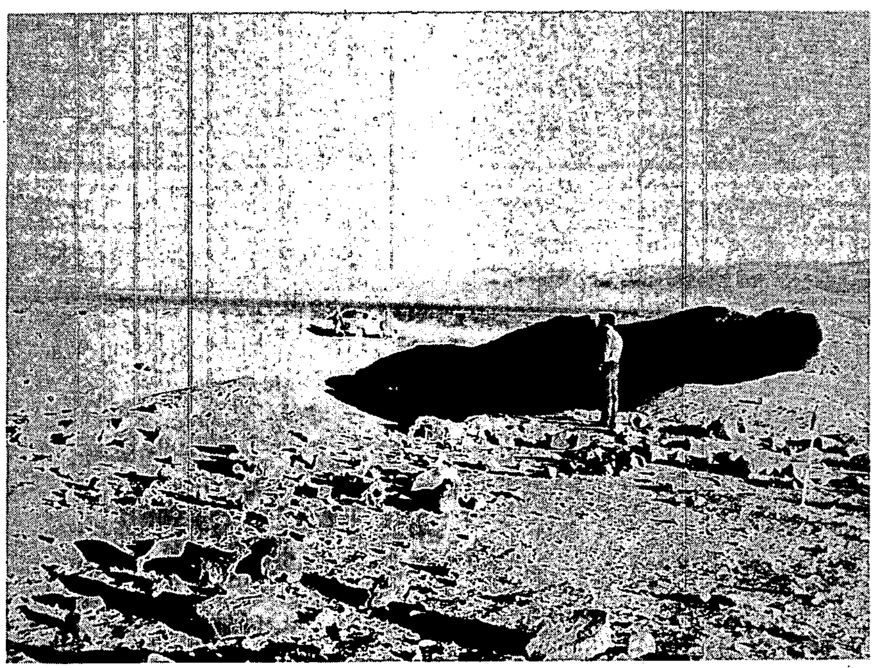

Figure 2.6 Row A channel.

TABLE 2.3 ADDITIONAL SINGLE-CHARGE DETONATIONS

Location	Event No.	DoB	Types of Explosives	Charge Weight
		feet		pounds
Area 5	7	19.8	TNT	968
	8	19.8	TNT	950
Area 9-10	1	16.6	NM[a]	983
	2	15.0	NM	1,008
	3	15.0	TNT	963
	4	16.6	TNT	958

[a]NM – nitromethane

2.4 TECHNICAL PROGRAMS

Three technical programs were established to fulfill the objectives of the Pre-Buggy experiment. These were: Crater Measurements, Venting Measurements, and Scientific Photography. Two additional studies, Instant Rock, and Ejecta Studies Using Magnets, were conducted during the experiment.

2.4.1 Crater Measurements. This was a program to determine the apparent crater dimensions and the extent of the true crater, rupture zone, and other underground effects. The U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi, was responsible for the execution of this program.

Apparent crater dimensions were determined by pre- and postshot aerial photography, from which topographic drawings, scale 1 inch equals 10 feet and 1-foot contour interval, were prepared by stereophotogrammetric methods. Field surveys were used for preliminary determination of apparent crater width and depth as soon after each shot as the H. E. and radiological safety situation permitted.

The extent of the true crater, rupture zone, and other underground effects was determined by using colored sand columns on the single-charge events 1, 3, and 4, and on the two multiple-charge events Row A and C. The sand columns were from 5 to 45 feet deep and were placed radially from ground zero to a distance of 50 feet. Three lines of sand columns were used to study each row event. Detonation effects were determined by postshot excavation of the sand columns.

2.4.2 Venting Measurements. This was a program to study the venting of explosion products from single-charge and multiple-charge detonations using a radioactive tracer. The Nuclear Cratering Group was responsible for the execution of this program.

The fraction of the explosion products vented to the surface and deposited as local fallout was investigated by placing a La^{140} tracer in the center of each charge of the basic series of detonations and sampling the resulting fallout field. For each detonation an array of approximately

200 fallout trays was placed to collect fallout samples to a distance of 3,000 feet downwind. The fallout sample collectors were 2-foot-square aluminum trays equipped with louvers. The trays were collected and counted with a scintillation counter. Information from field surveys and cloud samples was used to supplement the data obtained by fallout collection means.

Supplementary experiments were performed to compare efficiencies of several types of fallout collectors.

2.4.3 Scientific Photography. This was a program designed to study base surge and cloud development. Lawrence Radiation Laboratory, Mercury, Nevada (LRL-N), was responsible for shooting and preparing the films and Plowshare Division of Lawrence Radiation Laboratory, Livermore, California (LRL), is responsible for analysis of the films. During the course of the experiment, surface motion studies were added to this program and executed by LRL.

Cloud development was recorded by motion picture photography from two photo stations 90 degrees apart and from a helicopter flying in a circular orbit over the detonations. Several different film types, film speeds, and focal lengths were used to provide a more complete coverage. All the events of the basic series of detonations were documented.

The surface motion studies of the scientific photography program were added after the six single charges had been detonated. The purpose of these studies was to obtain useful surface motion data and to test, refine, and demonstrate the utility of a system whereby automatic data processing techniques could be used to read the film and record and analyze the data. Surface motion was recorded by high-speed motion picture photography of each of the first three row events and the two TNT shots in Area 5. Flares or long-burning flash bulbs were used as the camera targets.

2.4.4 Miscellaneous Studies. Two additional studies, both executed by LRL, were started during the Pre-Buggy experiments to investigate miscellaneous phenomena. The first, called Instant Rocks, was initiated to study the effect of shock on unconsolidated material. The second, called Ejecta Studies Using Magnets, was initiated to test the feasibility of a new method for studying the distribution of crater ejecta.

In the Instant Rocks study, various disaggregated materials such as Ottawa quartz sand and ground-up fragments of feldspar, gypsum, magnetite, and rock salt were placed adjacent to several of the explosive spheres. After these spheres were detonated, samples of the materials were to be recovered and analyzed to determine the effect of the shock waves in compacting and consolidating the loose grains.

The ejecta studies were conducted on Row D and the TNT shots Nos. 7 and 8. Small Alnico V magnets were marked and placed in groups of three or four at various depths in the emplacement holes as they were stemmed. A magnetometer was to be used to locate the magnets after the detonations.

CHAPTER 3

RESULTS

The results presented in this chapter are intended to provide only a general survey of the more important data available at this time. Detailed results from the individual programs will be given in the reports listed in Appendix A. A brief statement is given on the status of data analysis for each program at the time of this report

3.1 CRATER MEASUREMENTS

The preliminary crater dimensions of the basic series of detonations have been determined from the results of the field surveys and are presented in Tables 3.1 and 3.2. Figure 3.1 shows how these results compare with crater dimensions obtained in previous experiments using 256-pound TNT charges. The Pre-Buggy crater dimensions and depth of burst were normalized to the 256-pound results using 1/3.4 power scaling. Figure 3.2 shows several of the craters and channels resulting from this experiment.

TABLE 3.1 SINGLE-CHARGE CRATER DIMENSIONS

Event No.	DoB	Radius	Depth
	feet	feet	feet
Test	15.0	22.7	10.9
1	15.0	21.0	9.7
2	16.6	21.8	9.1
3	18.2	20.9	7.8
4	19.8	20.5	9.5
5	21.4	19.7[a]	4.1[a]
6	19.6	20.7	8.3

[a] Photography of Event No. 5 indicates that a partial stemming failure probably occurred.

All field work has been completed, including excavation of the sand columns, and the analysis of the remaining data has been started. The topographic drawings, Appendix C, are being analyzed to refine crater dimensions, prepare profiles, determine volumes, and study other crater parameters.

Preliminary examination of the data indicates the following:

1. Small changes in charge spacing caused significant changes in channel size.

2. A spacing of one single-charge crater radius gave channel dimensions significantly larger than the dimensions of a single-charge crater of the same depth of burst.

3. A spacing of 1.5 single-charge crater radii gave a very uneven channel with the minimum depth apparently unpredictable.

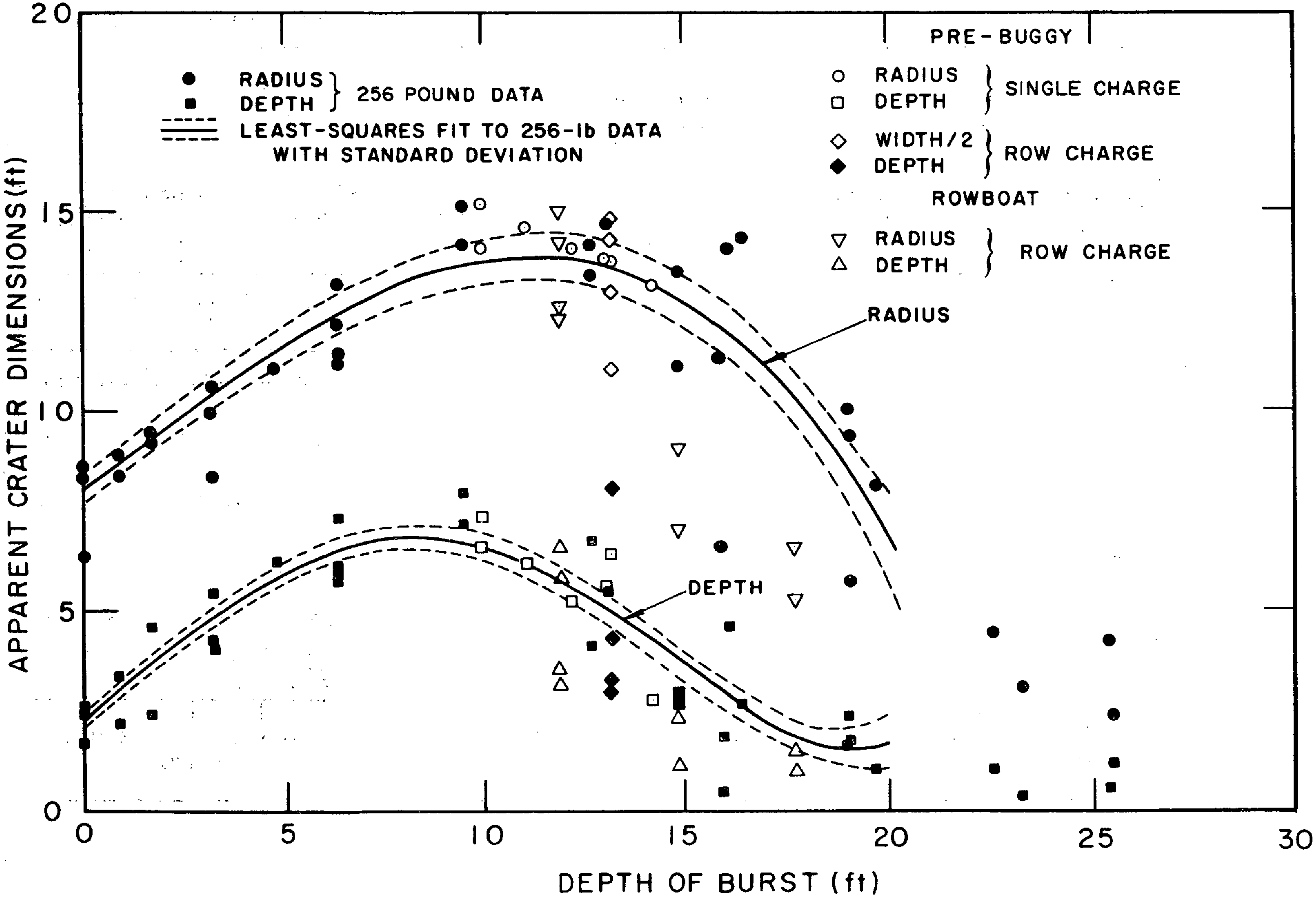

Figure 3.1 Comparison of cratering results from 256-pound TNT and Pre-Buggy series.

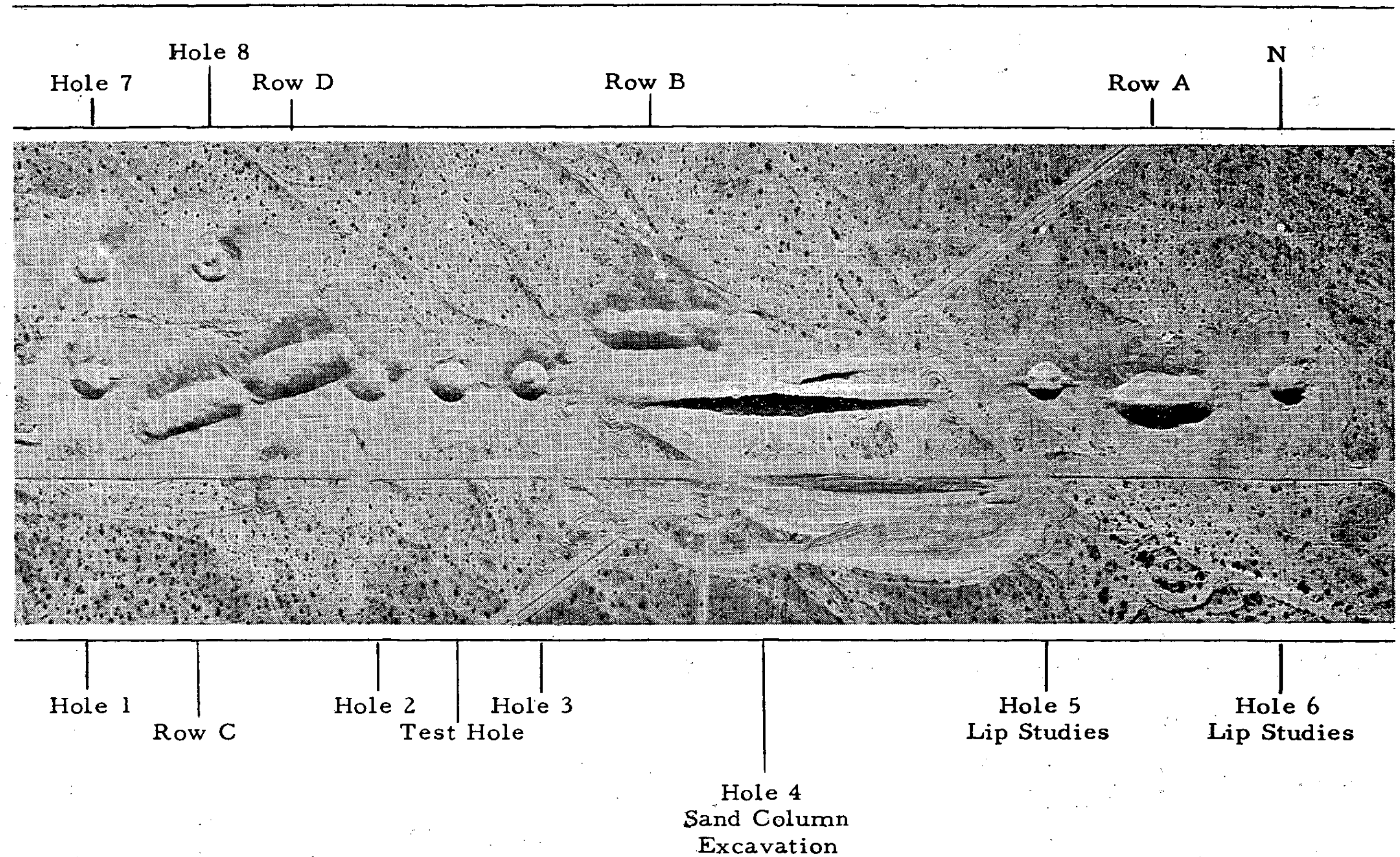

Figure 3.2 Pre-Buggy craters and channels.

TABLE 3.2 MULTIPLE-CHARGE CHANNEL DIMENSIONS

W – width D – depth

Charge Spacing	Row A 20.6 feet		Row B 30.9 feet		Row C 25.8 feet		Row D 23.2 feet	
Station	W	D	W	D	W	D	W	D
	feet	feet	feet	feet	feet	feet	feet	feet
1.0	44.6	12.3	35.1	5.1	39.5	4.6	42.5	5.9
1.5	44.8	13.3	33.1	5.5	34.5	4.5	41.0	5.9
2.0	45.3	13.8	37.1	7.7	37.6	4.5	43.5	6.1
2.5	47.1	13.3	33.6	6.2	39.5	5.0	45.0	6.3
3.0	45.5	12.9	35.4	6.9	42.0	4.3	46.3	6.8
3.5	47.0	12.3	33.8	3.7	40.0	4.2	45.5	6.7
4.0	43.2	11.2	32.6	2.5	36.0	4.2	43.0	6.7
4.5	43.1	10.1	28.2	1.8	37.0	4.0	38.5	6.6
5.0	39.9	9.5	29.0	4.3	39.0	4.1	40.2	6.6
Average	44.5	12.1	33.1	4.9	38.6	4.4	42.8	6.4

Notes:

1. All row-charge shots resulted in channels with massive lips on either side, but with very little throwout on the ends.
2. All excavations except Row A were roughly parabolic in section. The Row A channel was V-shaped, with a flat bottom only a few feet wide.
3. The Row B channel was quite irregular, particularly in depth. The other channels were fairly uniform, with Row D, at 1.125 radius spacing, the most uniform of all row-charge excavations.

3.2 VENTING MEASUREMENTS

A preliminary analysis of the data has been completed. Fallout patterns have been prepared and integrated and the percent of radioactivity that escaped as fallout has been determined. Each fallout pattern was integrated to determine the total fraction of tracer that fell to the ground (including the surface of the crater walls and bottom), the fraction which fell outside the crater, and the fraction which fell outside the area covered by direct throwout. The results are presented in Table 3.3.

The vented activity given in Table 3.3 includes only the activity which was deposited as local fallout out to 3,000 feet downwind. Preliminary evaluation of cloud samples taken at the limit of the fallout collection array indicated that, even in the worst case, the activity remaining in the cloud probably did not exceed about 2 percent of the tracer activity.

Figure 3.3 shows the radioactivity escape, excluding crater and throwout area, as a function of the ratio of depth of burst to depth of crater and compares it with results from previous nuclear detonations.

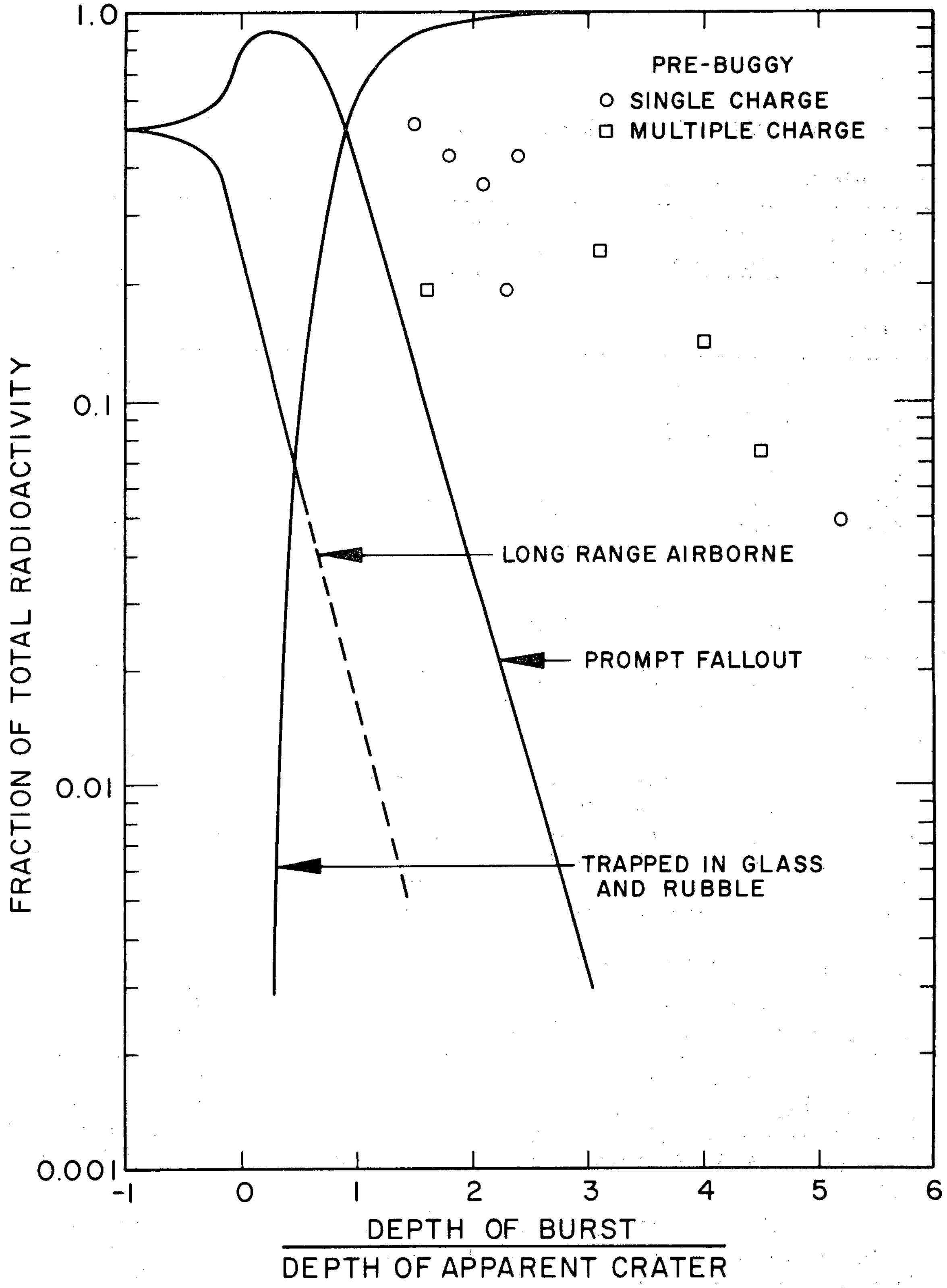

Figure 3.3 Comparison of radioactivity escape from nuclear and Pre-Buggy detonations.

TABLE 3.3 RADIOACTIVITY ESCAPE

(1) Excluding crater and throwout areas.
(2) Excluding crater area.
(3) Including all areas.

Event No.	DoB	Spacing	DoB/D	Percent Vented (1)	Percent Vented (2)	Percent Vented (3)
	feet	feet				
1	15.0	-	1.5	51	54	56
2	16.6	-	1.8	42	54	59
3	18.2	-	2.3	19	21	23
4	19.8	-	2.1	36	43	47
5	21.4	-	5.2	4.9	6.5	7.5
6	19.6	-	2.4	42	50	54
Row A	19.8	20.6	1.6	19	23	28
Row B	19.8	30.9	4.0	14	18	22
Row C	19.8	25.8	4.5	7.4	10	14
Row D	19.8	23.2	3.1	24	28	30

A preliminary examination of the data indicates that where the ratio of the depth of burst to the depth of the apparent crater was approximately two, the venting of explosion products from the multiple-charge detonation was no greater than from single charges.

3.3 SCIENTIFIC PHOTOGRAPHY

A description of photographic coverage of the experiment is presented in Appendix D.

3.3.1 Base Surge and Cloud Development. Analyses of the photography and atmospheric conditions are being conducted to obtain the time history of cloud and base surge development and growth, the ultimate dimensions of the cloud and surge, and the effect of the atmospheric conditions on these phenomena. At the time of this report only the base surge radial growth for the single-charge and row shots has been studied.

The maximum base surge radii varied from about 200 to 750 feet on four of the single-charge shots, and from 350 to 500 feet on the row events. The radii were measured in the crosswind direction. Wind speed and atmospheric stability appear to have had a major effect on the variation in radii.

Figure 3.4 shows the development of the base surge after the detonation of Event No. 2. The photographic targets, small white dots, were placed 250 feet apart, three in each direction north, south, east, and west.

3.3.2 Surface Motion. Due to problems in igniting the flares, only the Row C photography was satisfactory on the row events. On the TNT shots, only the Event 7 photography was satisfactory.

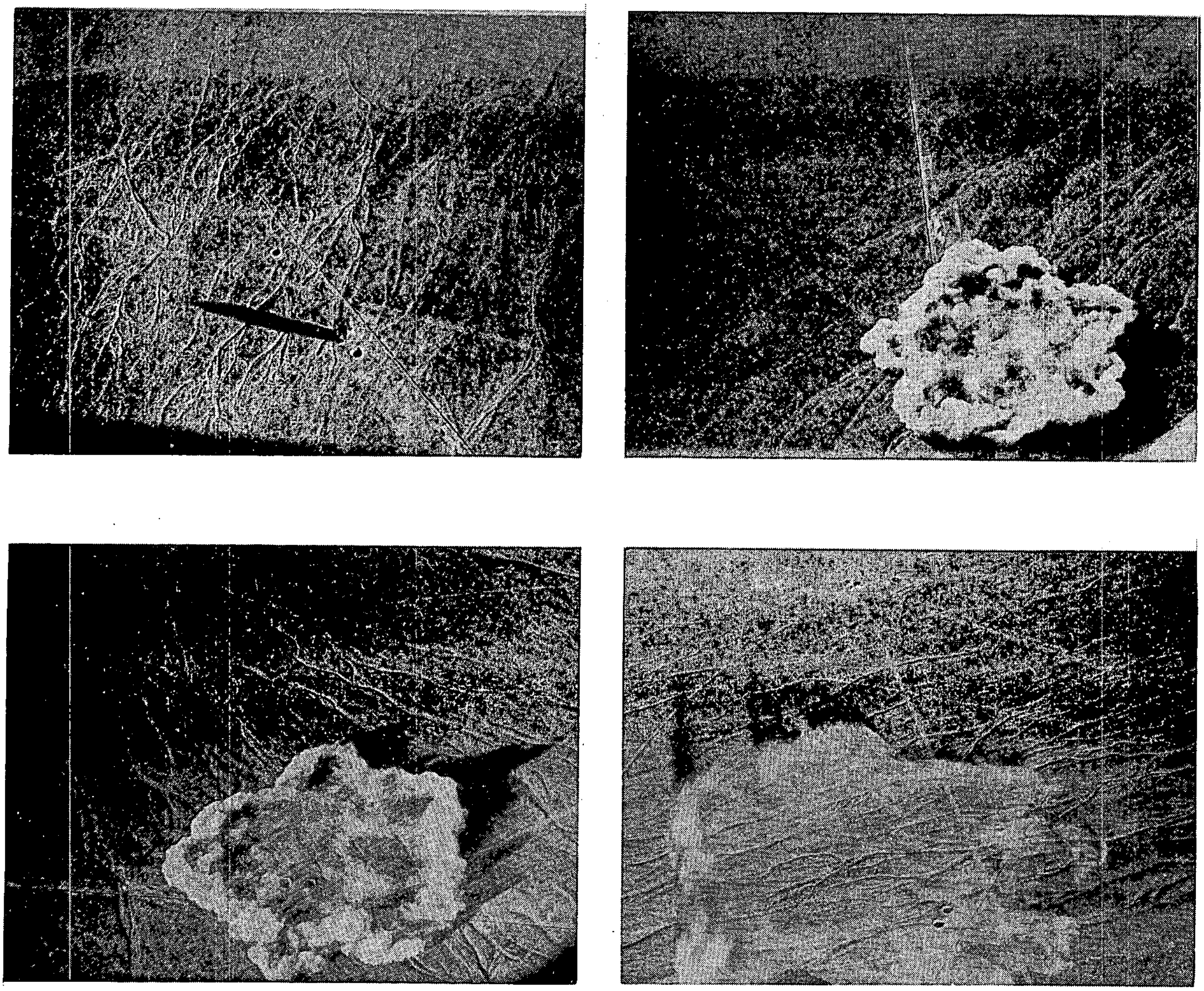

Figure 3.4 Base surge formation, event No. 2.

The photography is being analyzed at this time. The preliminary work done with the film shows considerable promise for the use of automatic data processing to read the film and provide data for studying surface motion.

3.4 MISCELLANEOUS STUDIES

3.4.1 Instant Rocks. On all shots some changes were noted in the physical properties of the fine silica sand used for stemming around the explosive sphere. Samples recovered from the crater debris showed that the sand immediately adjacent to the explosive was cemented together in chunks due to a welding action of the shock wave. Material slightly farther away from the explosive was transformed to a finer grained, almost powdery, material. The observation of this phenomenon prompted experiments using other types of materials. Some samples of consolidated quartz and magnetite and highly compacted alluvium have been recovered and are being analyzed. No other materials were found in the cursory postshot search. Further efforts will be made to recover additional samples.

3.4.2 Ejecta Studies Using Magnets. Of the 80 magnets emplaced on Events 7 and 8 and Row D, 15 have been located and their positions surveyed and plotted. The area around Shot No. 7 has not been surveyed. Recovery was made by surveying the area with a Varian Associates Model M-49A portable magnetometer. Studies of the ejecta distribution will not be started until recovery efforts are made for the remainder of the magnets.

APPENDIX A

REPORTS TO BE PUBLISHED

TABLE A.1 RESPONSIBILITY FOR REPORTS TO BE PUBLISHED

Title of Report	Responsible Agency	Responsible Person	Report Number
Scope of Chemical Explosive Cratering Experiment	U. S. Army Engineer Nuclear Cratering Group (NCG) Lawrence Radiation Laboratory P. O. Box 808 Livermore, California	Ernest Graves, Jr.	PNE 300
Venting Measurements	NCG	William R. Wray	PNE 301
Crater Measurements	U. S. Army Engineer Waterways Experiment Station (WES) P. O. Box 631 Vicksburg, Mississippi	Allen D. Rooke, Jr.	PNE 302
Comparison of TNT and Nitromethane as Cratering Explosives	NCG	John Toman, Jr.	PNE 303
Base Surge and Cloud Formation	Plowshare (K) Division Lawrence Radiation Laboratory P. O. Box 808 Livermore, California	Joseph B. Knox	PNE 304
Surface Motion	Plowshare Division, LRL	Joseph B. Knox	PNE 305
Instant Rocks	Plowshare Division, LRL	Nicholas M. Short	PNE 306
Ejecta Studies Using Magnets	Plowshare Division, LRL	Raymond S. Guido	PNE 307

APPENDIX B

METEOROLOGICAL DATA

The information in Tables B.1 and B.2 was furnished by the U. S. Weather Bureau, Las Vegas, Nevada.

TABLE B.1 SHOT-TIME RECONSTRUCTED TEMPERATURE SOUNDINGS

Event	Shot Time	Surface Temperature	850-millibar Temp.[a]
		°C	°C
1	1602	18.0	09.3
2	1525	22.0	10.6
3	1338	20.5	10.5
4	1351	15.2	08.8
5	1250	10.2	06.4
6	1342	15.2	03.6
Row A	1432	12.0	01.2
Row B	1422	22.3	07.5
Row C	1317	15.2	08.2
Row D	1459	24.8	15.5

[a]The 850-millibar level is approximately 1800 feet above the surface in Frenchman Flat.

Notes on the above reconstructed soundings:

Only the 0400 PST temperature sounding (RAOB) from Yucca Flat and the Frenchman Flat surface temperatures were available for the reconstruction of the soundings. However, it is thought that a linear interpolation between the shot-time surface temperature and the 850-mb level temperature would be fairly representative of the actual shot-time temperature sounding.

All cases were unstable (lapse rates greater than dry adiabatic) except for the case of Event No. 5, which was only slightly stable.

TABLE B.2 SHOT-TIME METEOROLOGICAL CONDITIONS

Event	Date	Shot Time	Winds Direction(Degrees)/Speed(Knots)			General Atmospheric Condition
			Sfc	250 feet	500 feet	
1	5 Dec 62	1602	010/08	012/07	015/07	Clear
2	10 Dec 62	1525	160/02	Unk	Unk	Clear, winds variable
3	11 Dec 62	1338	175/04	179/03	182/03	Clear
4	13 Dec 62	1351	150/03	150/06	150/05	Clear
5	18 Dec 62	1250	102/05	102/05	098/05	Overcast, light precipitation before and after shot
6	19 Dec 62	1342	040/07	033/10	028/14	Clear
Row A	16 Jan 63	1432	140/03	148/03	156/03	Clear
Row B	23 Jan 63	1422	150/04	170/05	183/05	Clear
Row C	31 Jan 63	1317	235/13	230/15	220/19	Overcast, light precipitation before shot time
Row D	7 Feb 63	1459	140/04[a]	151/04[a]	162/04[a]	Clear, winds variable

[a]Winds changed immediately after the shot and the weather observations do not reflect this change. The wind shifted to a direction of approximately 110° and decreased in speed to less than 4 knots.

APPENDIX C

TOPOGRAPHIC DRAWINGS

The topographic drawings were prepared by the American Aerial Surveys, Inc., Covina, California. The contour interval is 1 foot with datum based on sea level 1929.

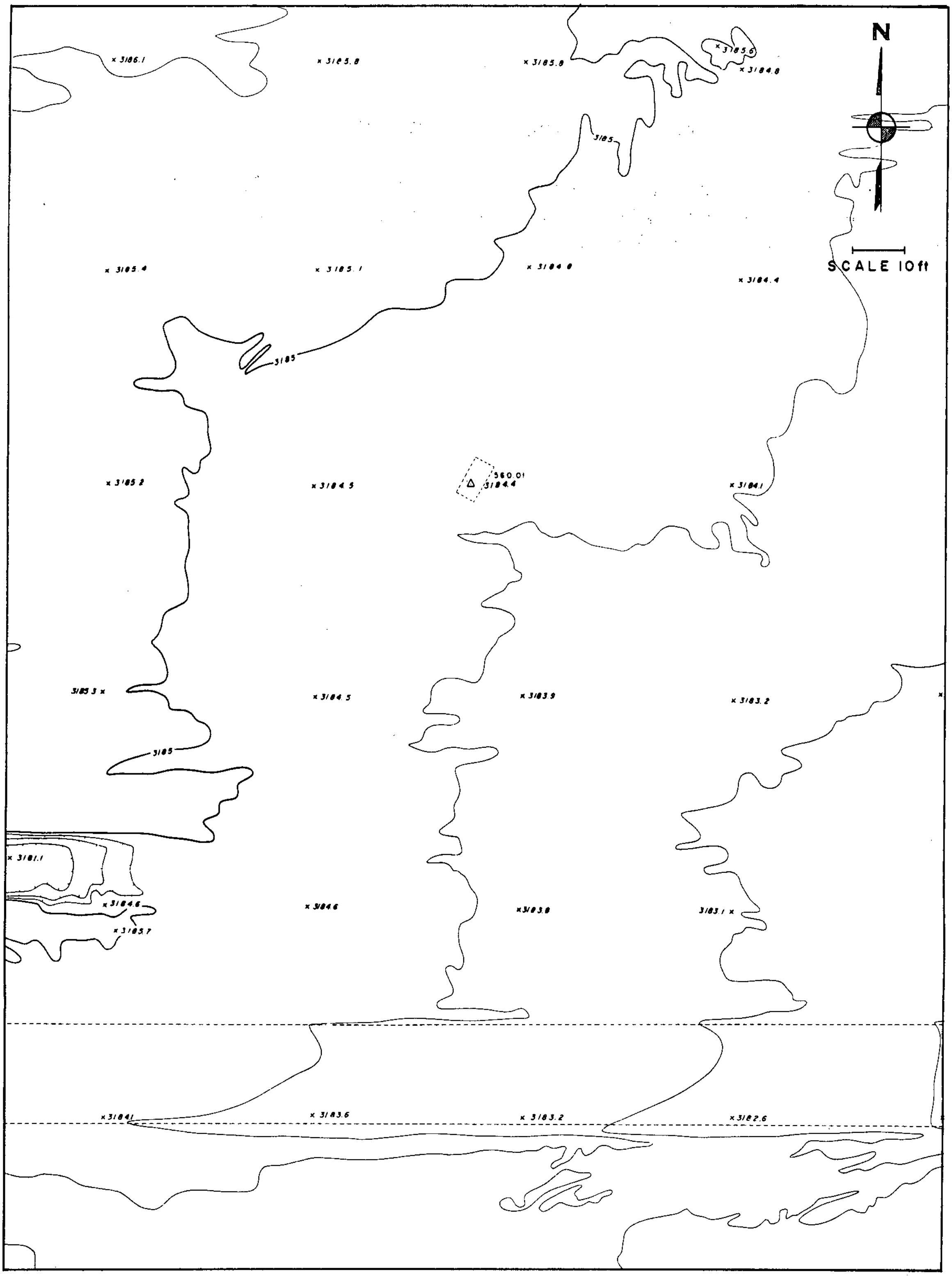

Figure C.1 Preshot topography, Event No. 1.

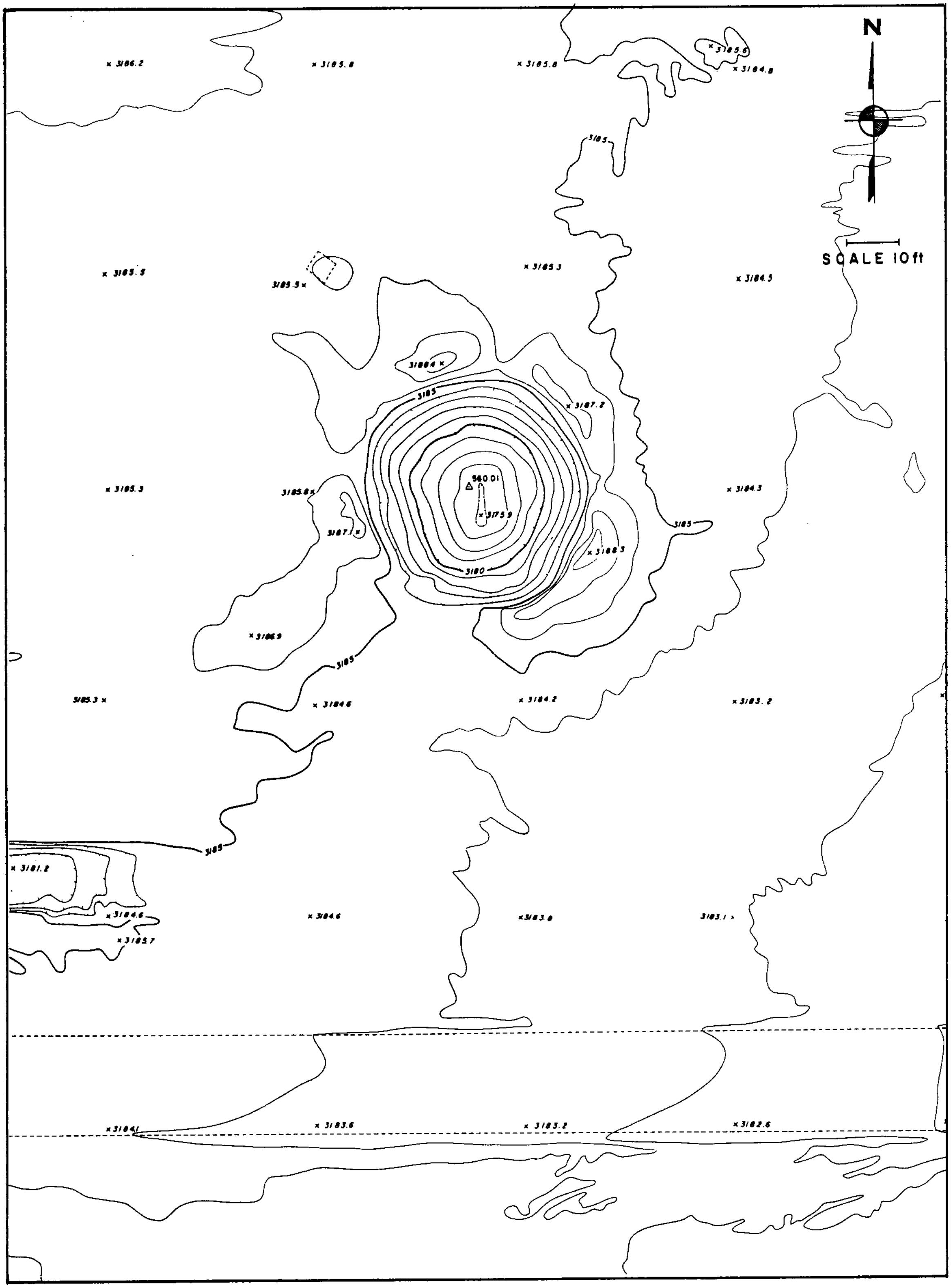

Figure C.2 Postshot topography, Event No. 1.

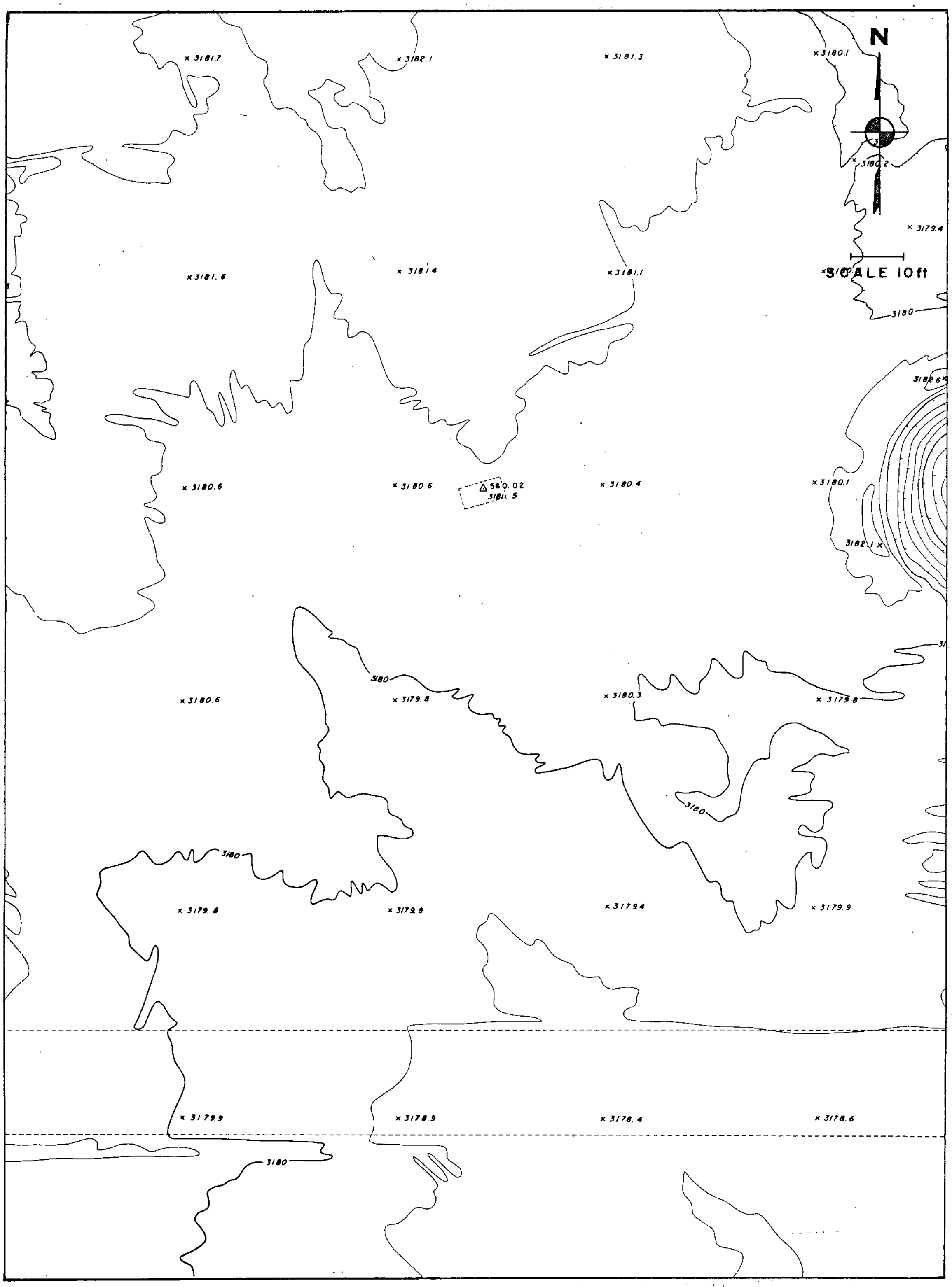

Figure C.3 Preshot topography, Event No. 2.

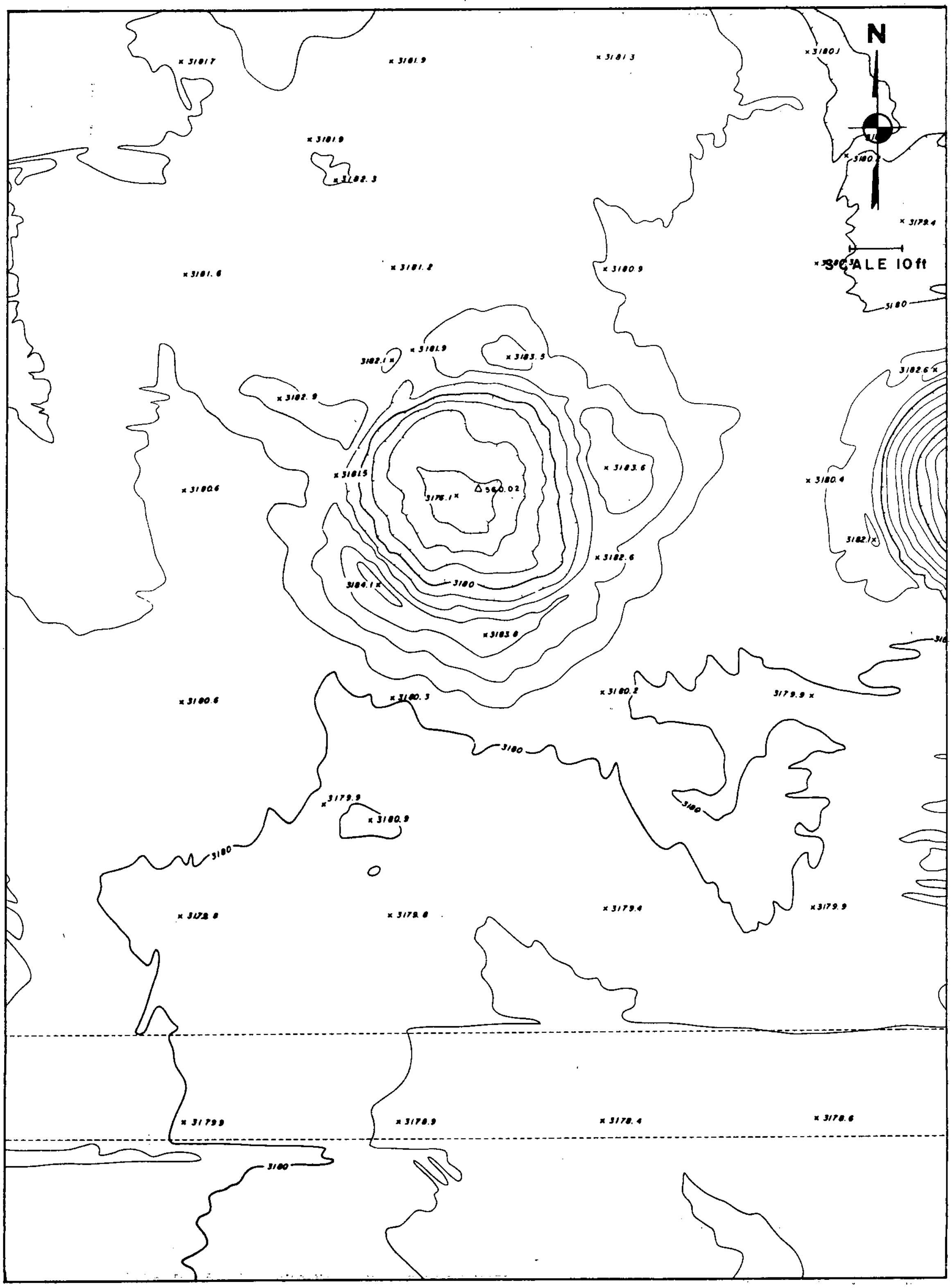

Figure C.4 Postshot topography, Event No. 2.

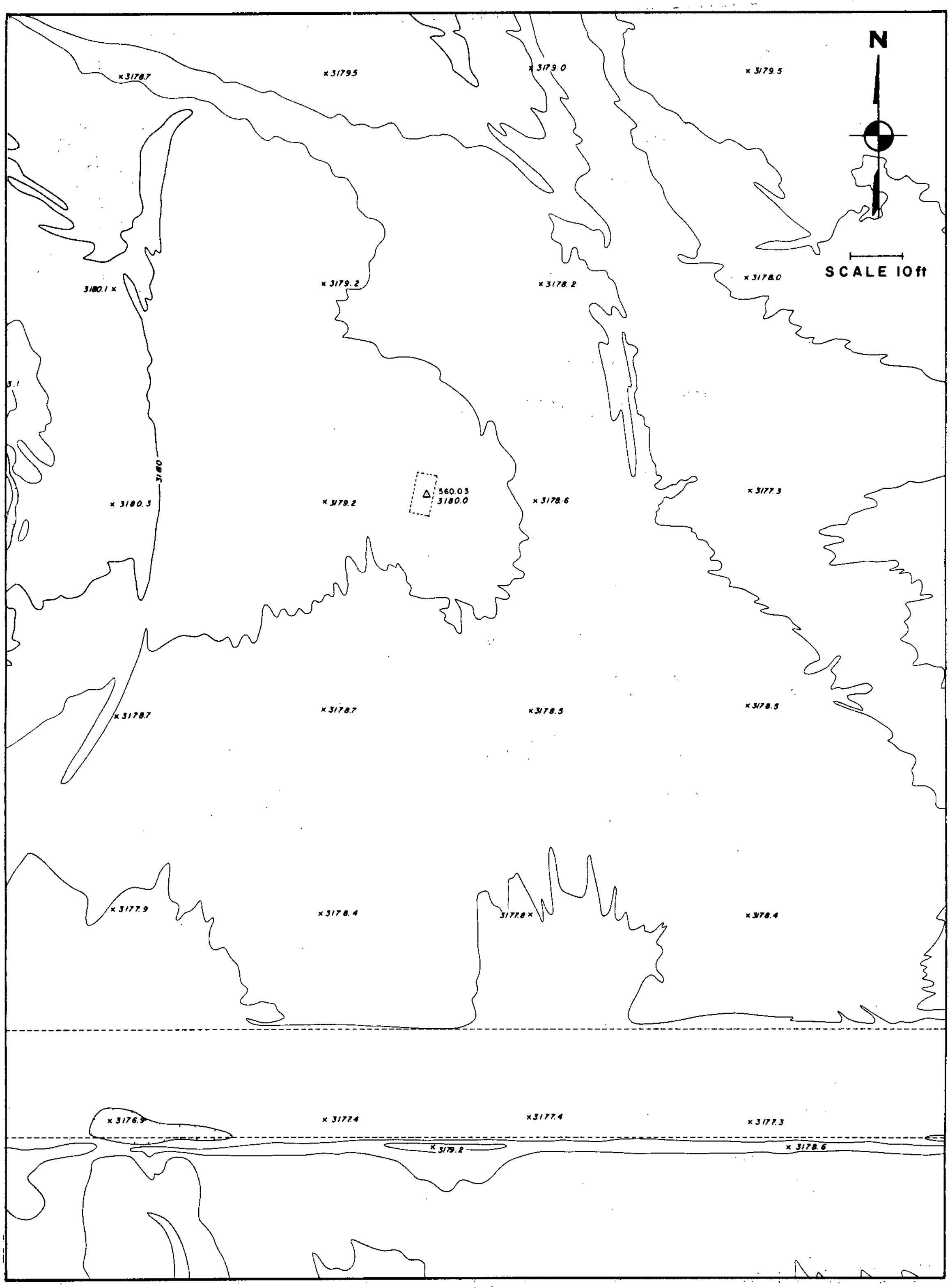

Figure C.5 Preshot topography, Event No. 3.

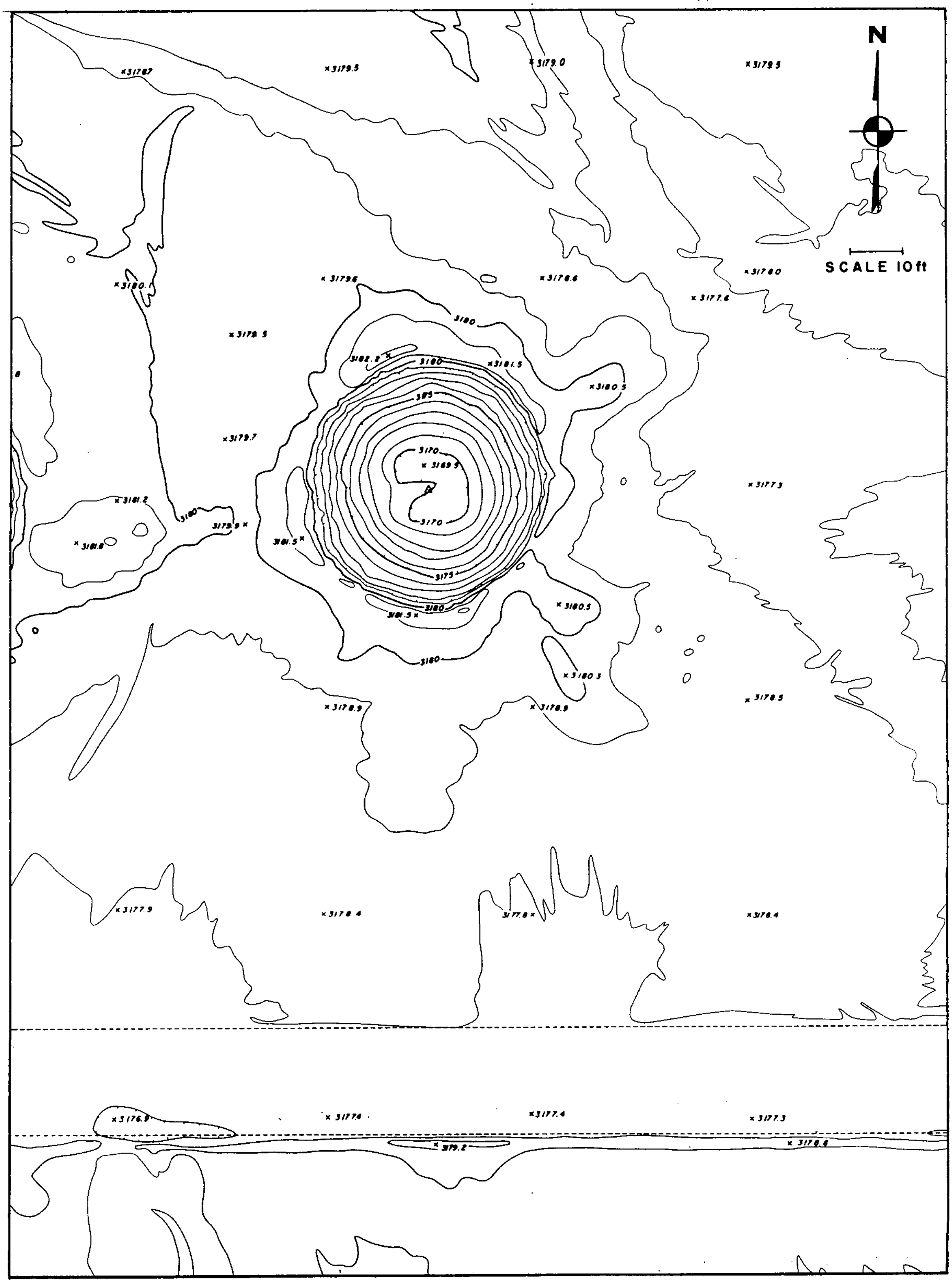

Figure C.6 Postshot topography, Event No. 3.

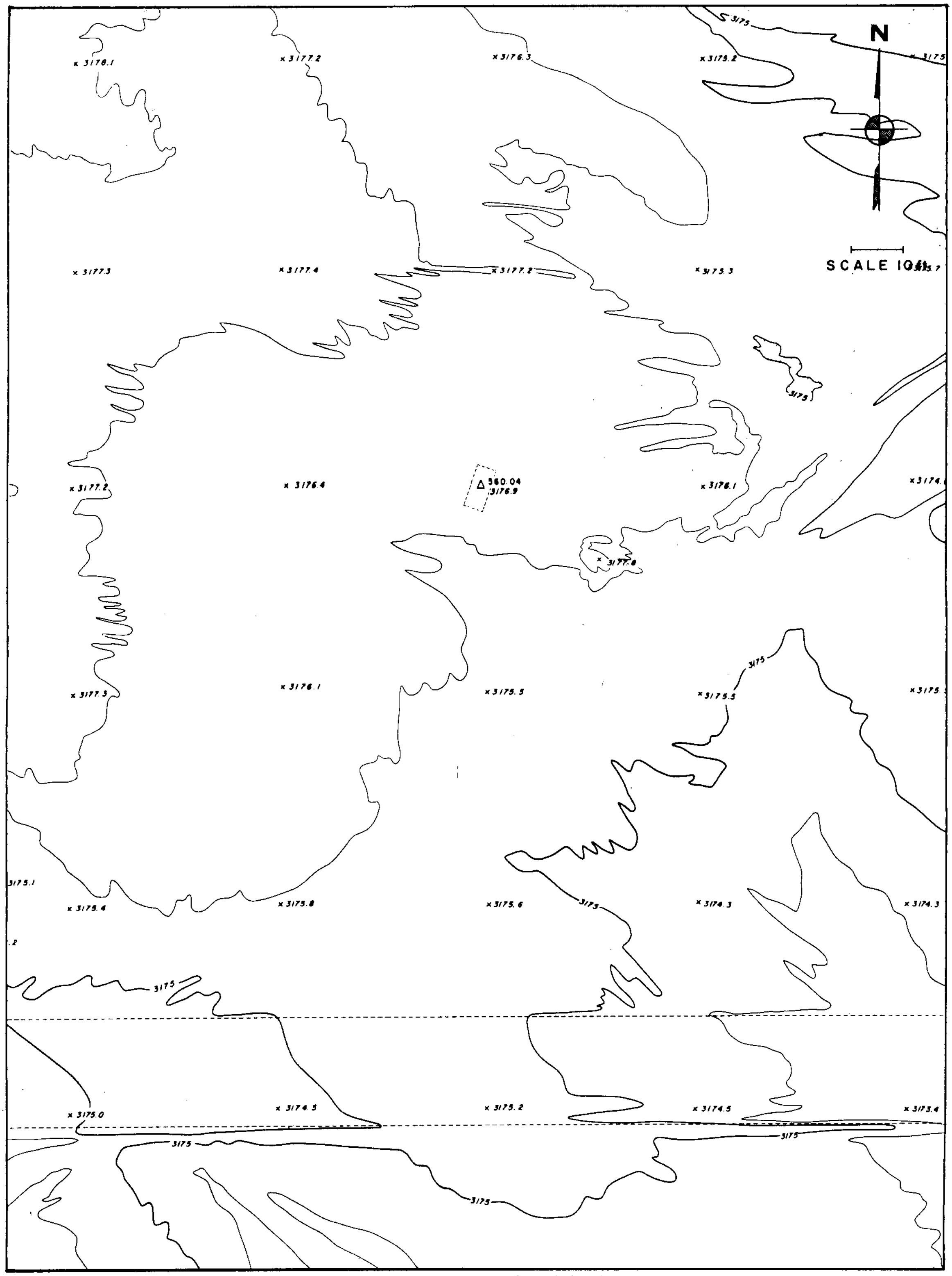

Figure C.7 Preshot topography, Event No. 4.

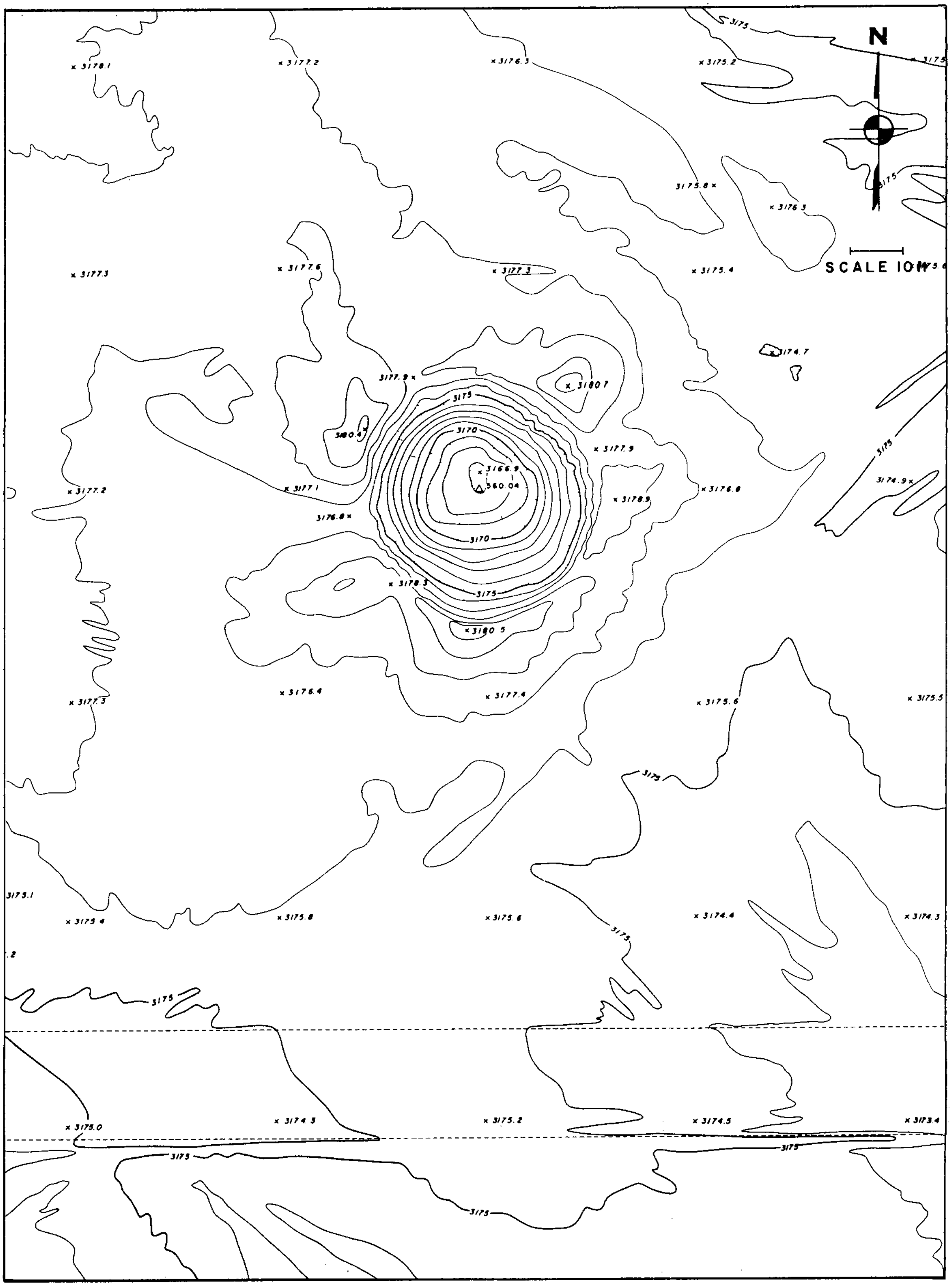

Figure C.8 Postshot topography, Event No. 4.

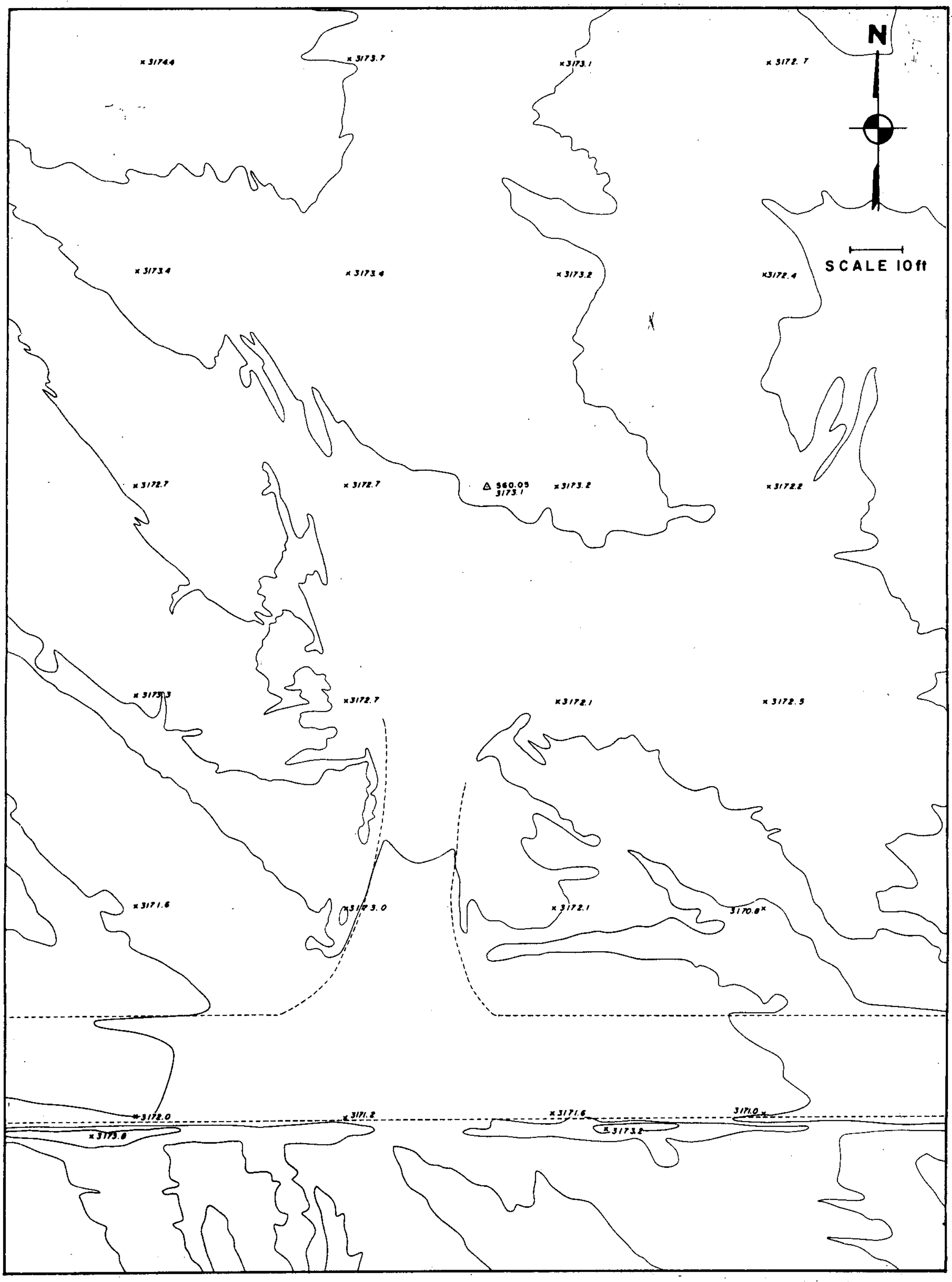

Figure C.9 Preshot topography, Event No. 5.

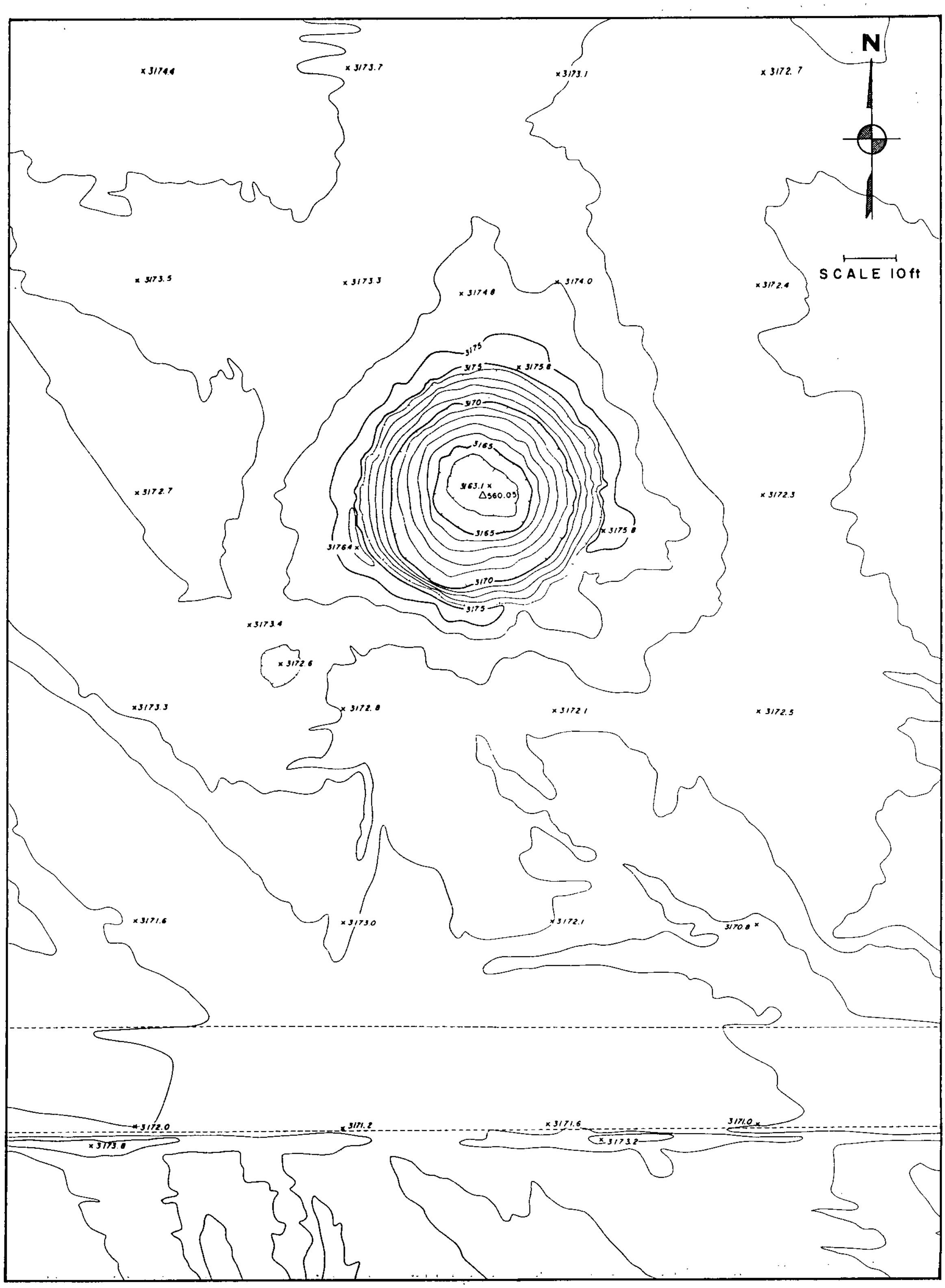

Figure C.10 Postshot topography, Event No. 5.

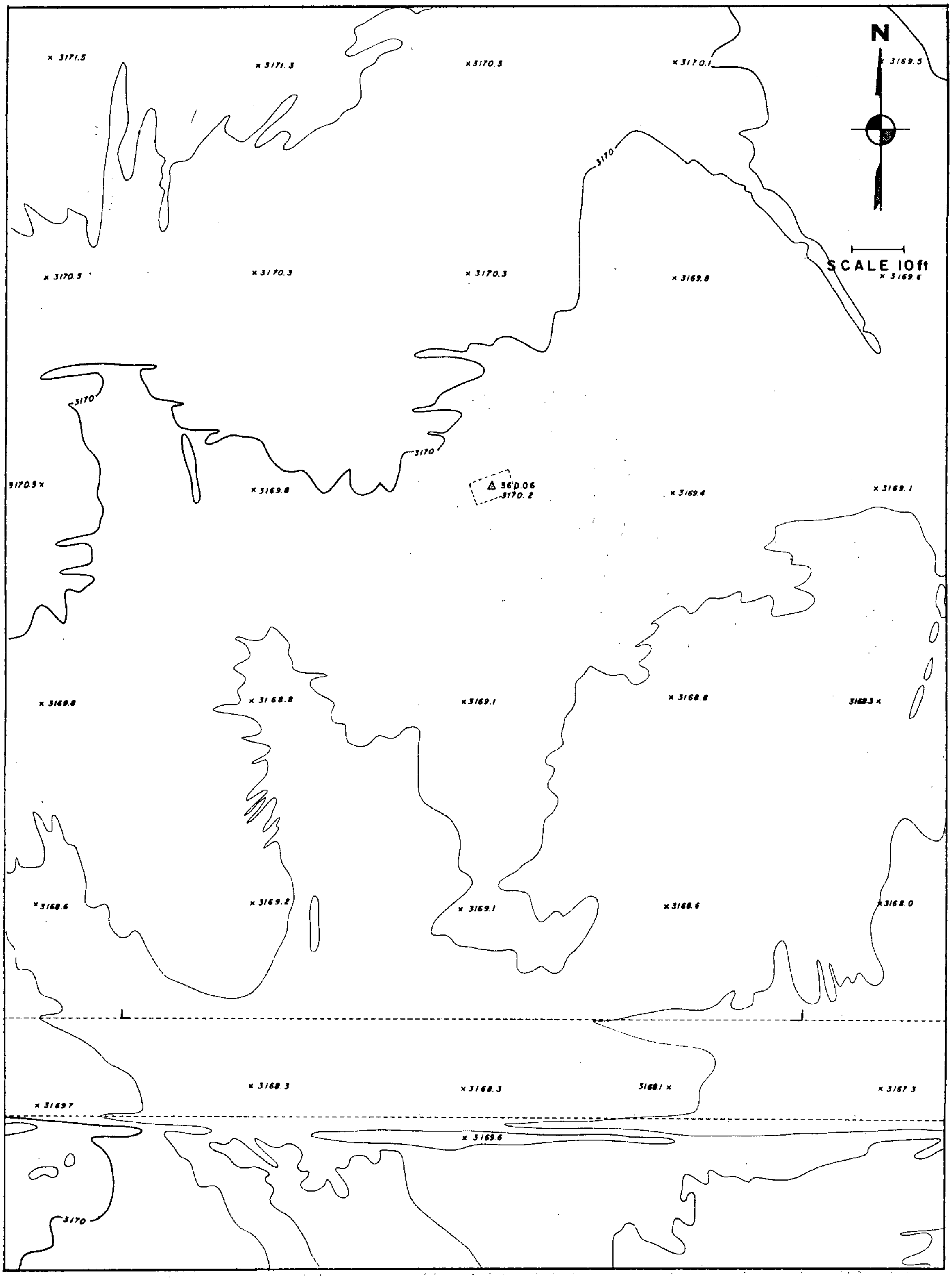

Figure C.11 Preshot topography, Event No. 6.

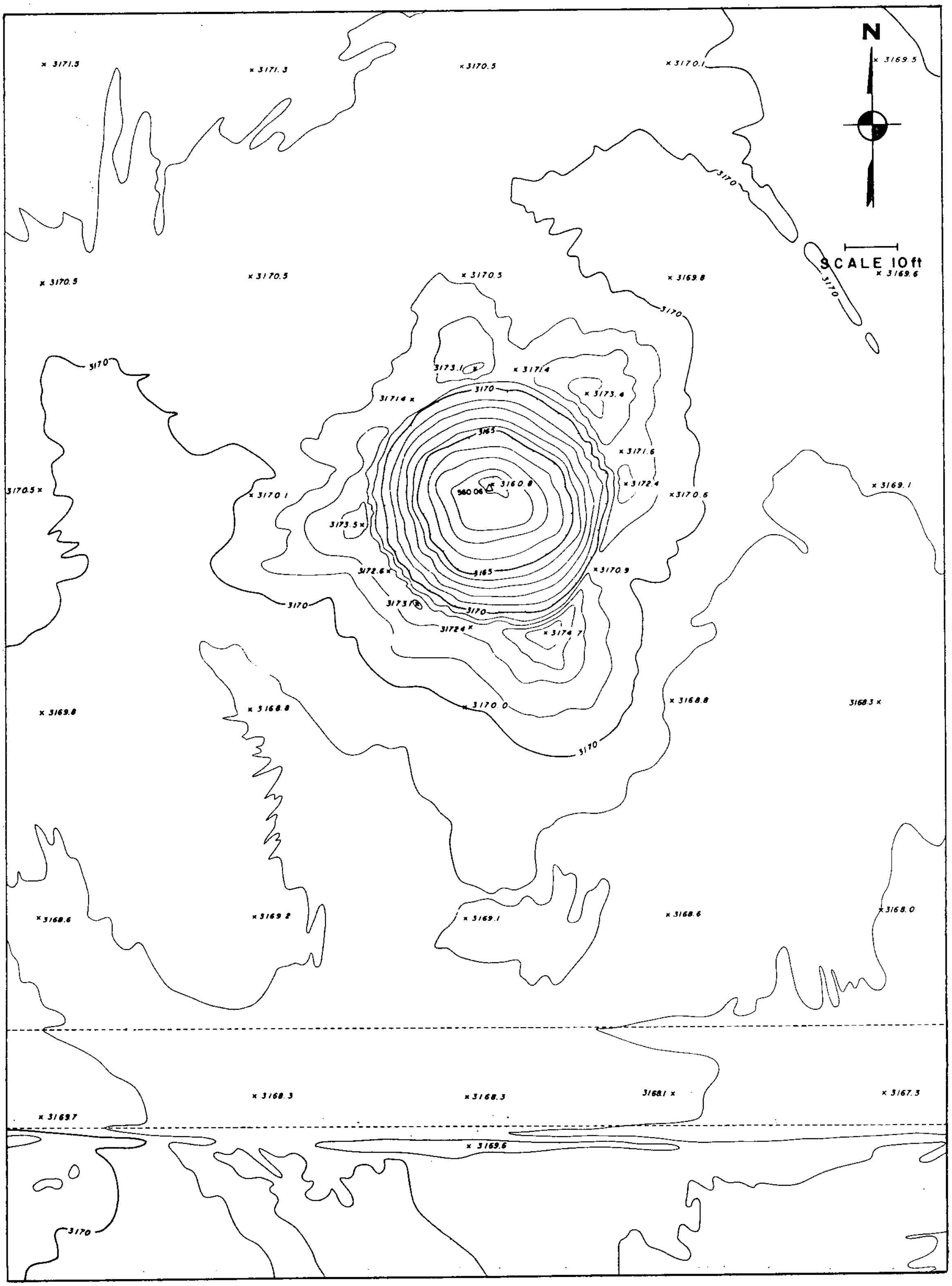

Figure C.12 Postshot topography, Event No. 6.

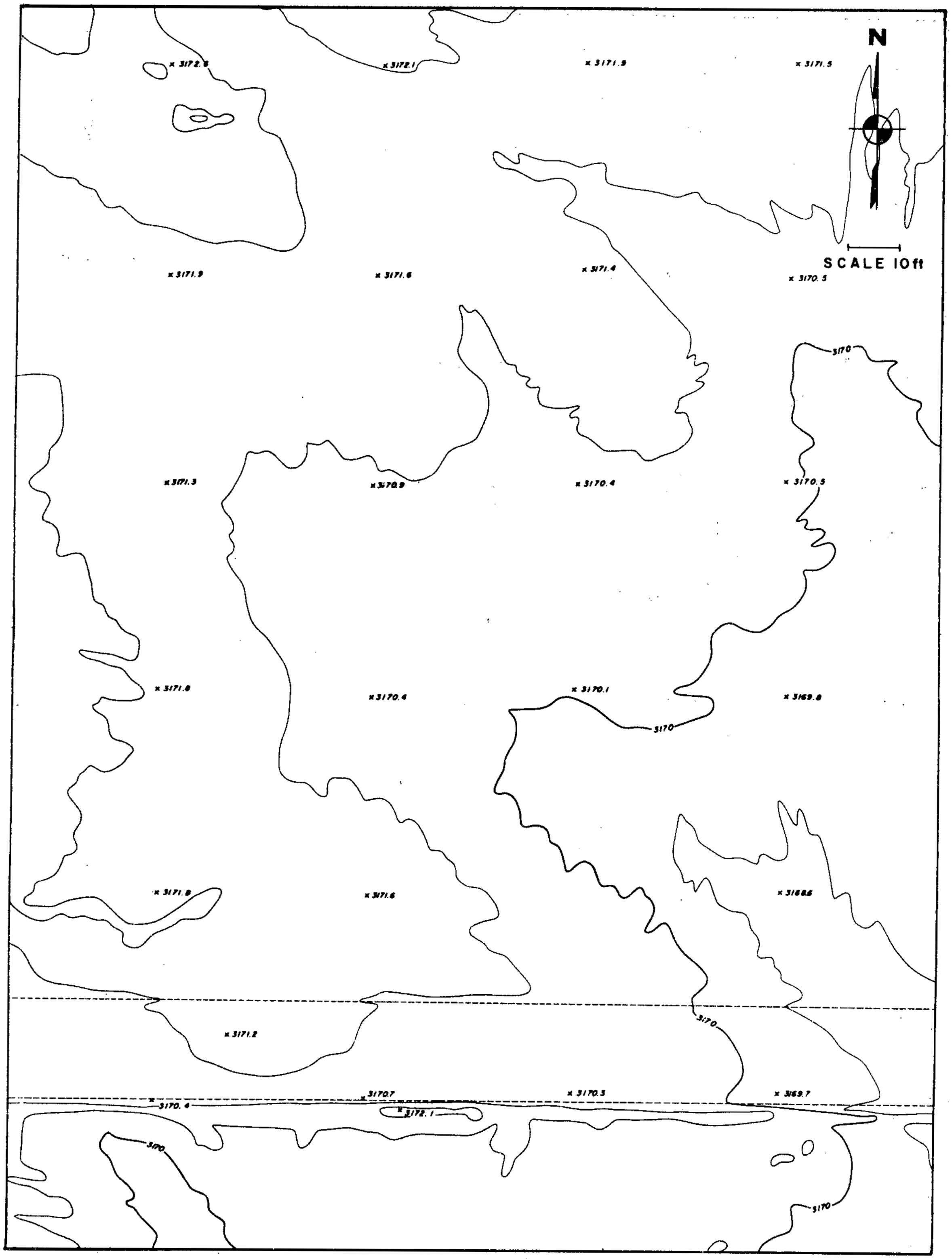

Figure C.13 Preshot topography, Row A.

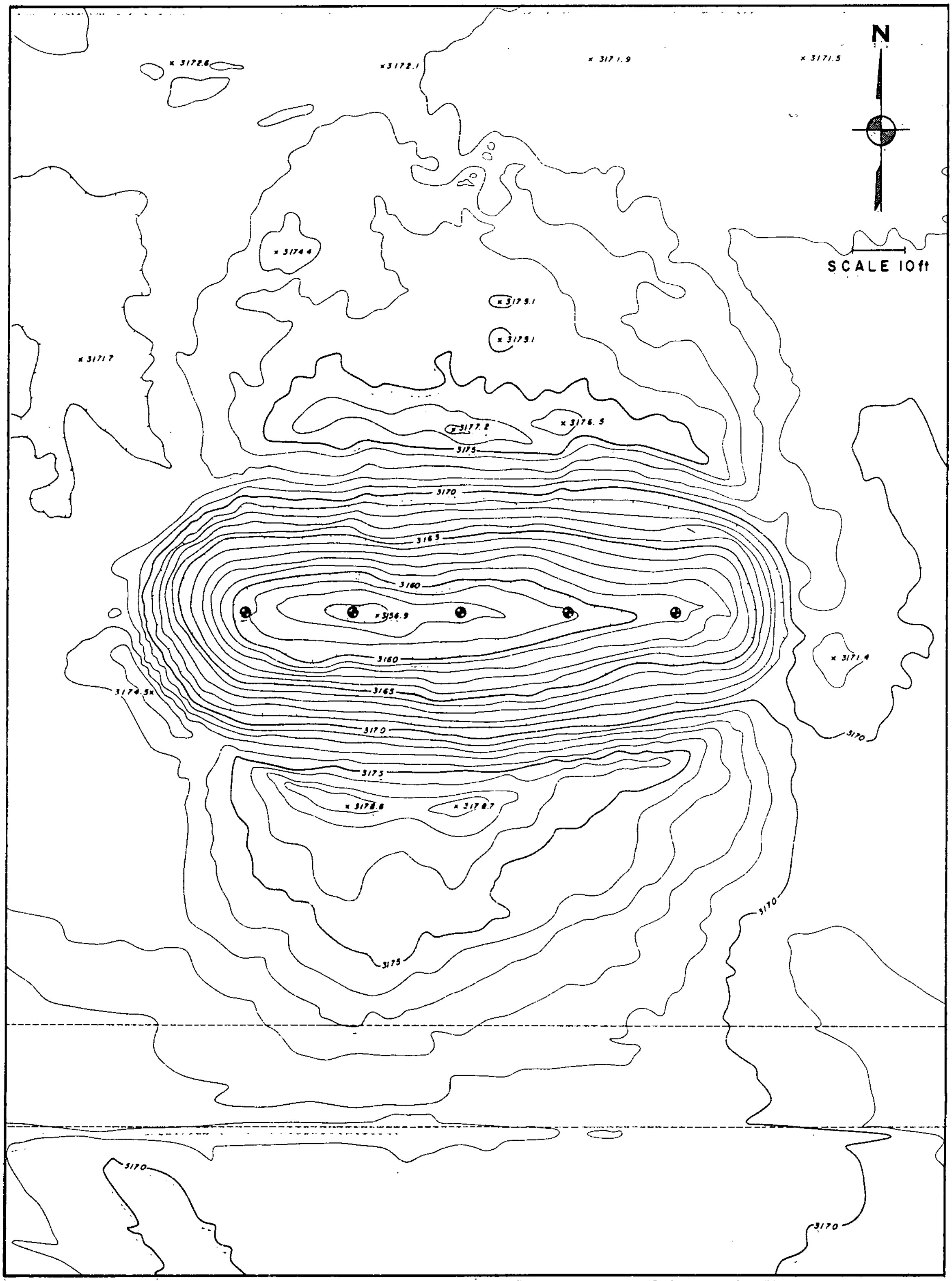

Figure C.14 Postshot topography, Row A.

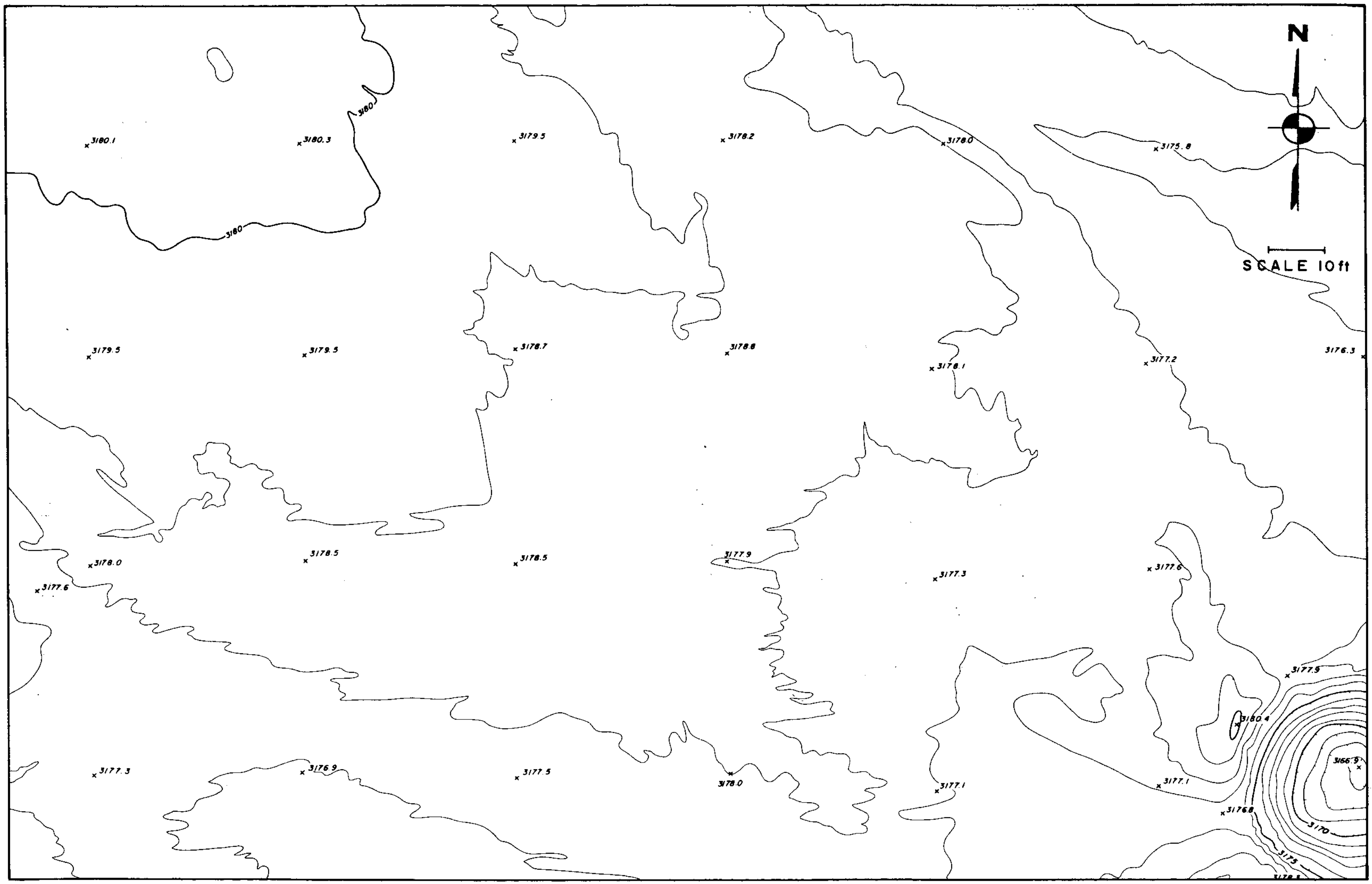

Figure C.15 Preshot topography, Row B.

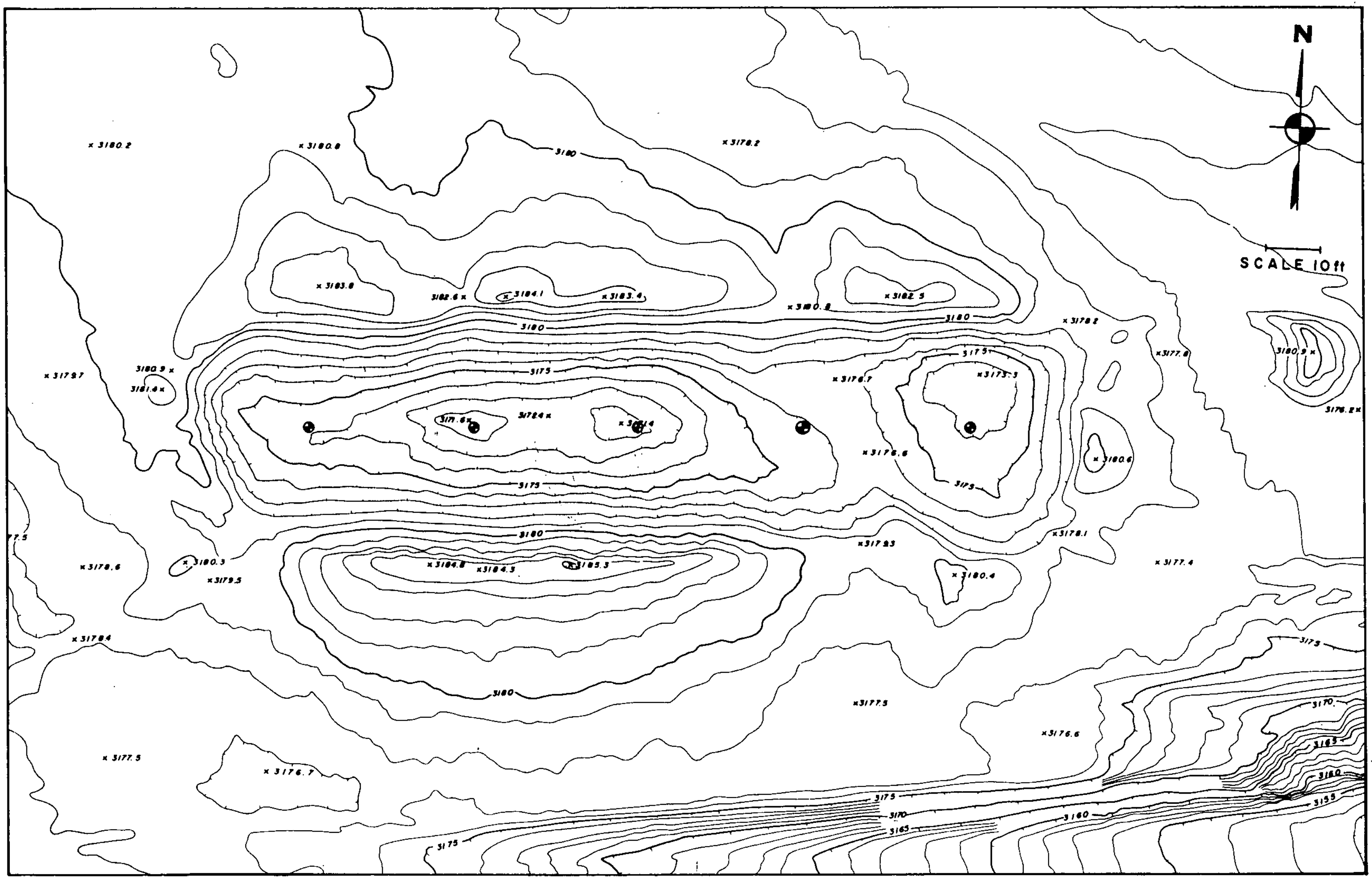

Figure C.16 Postshot topography, Row B.

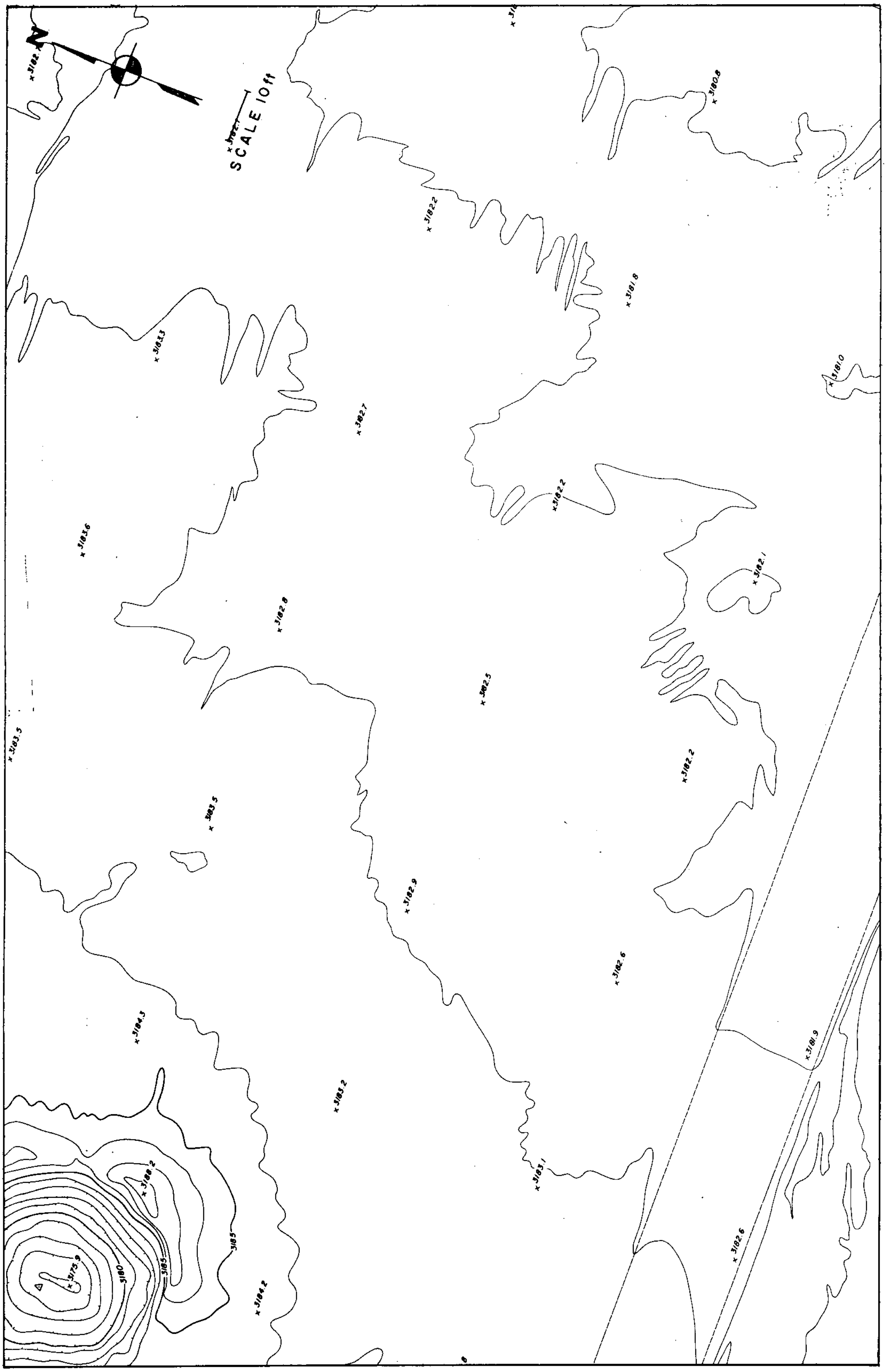

Figure C.17 Preshot topography, Row C.

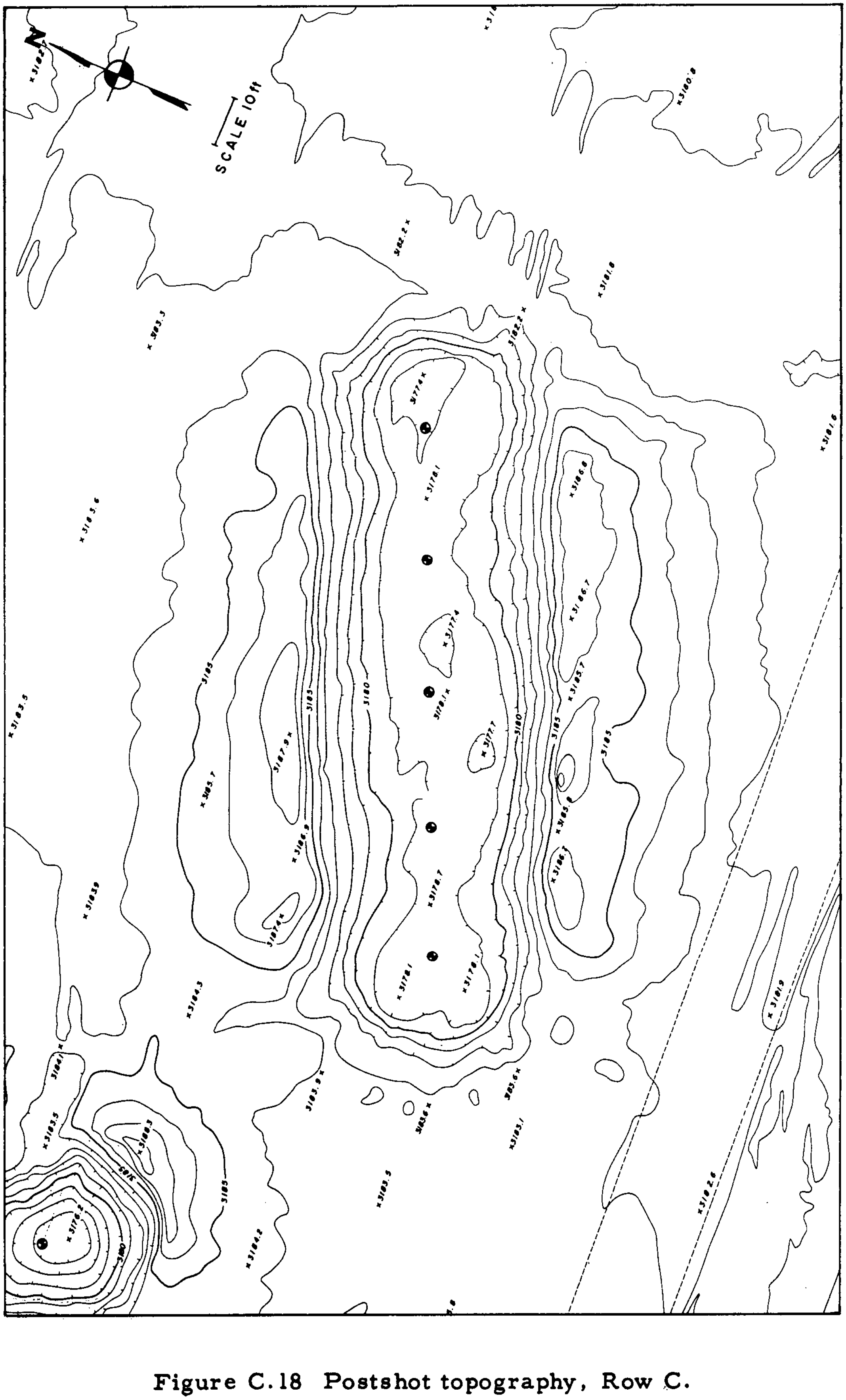

Figure C.18 Postshot topography, Row C.

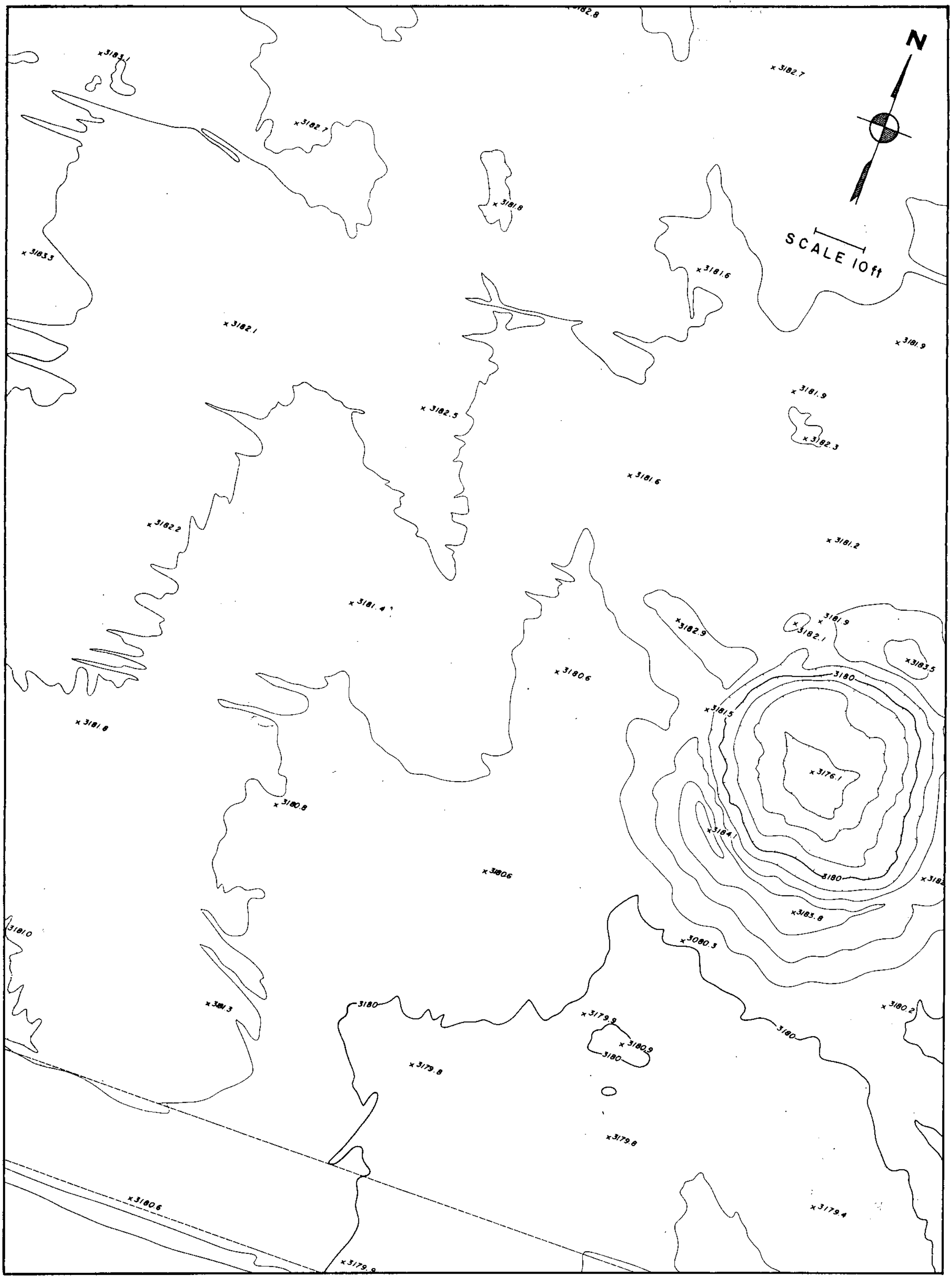

Figure C.19 Preshot topography, Row D.

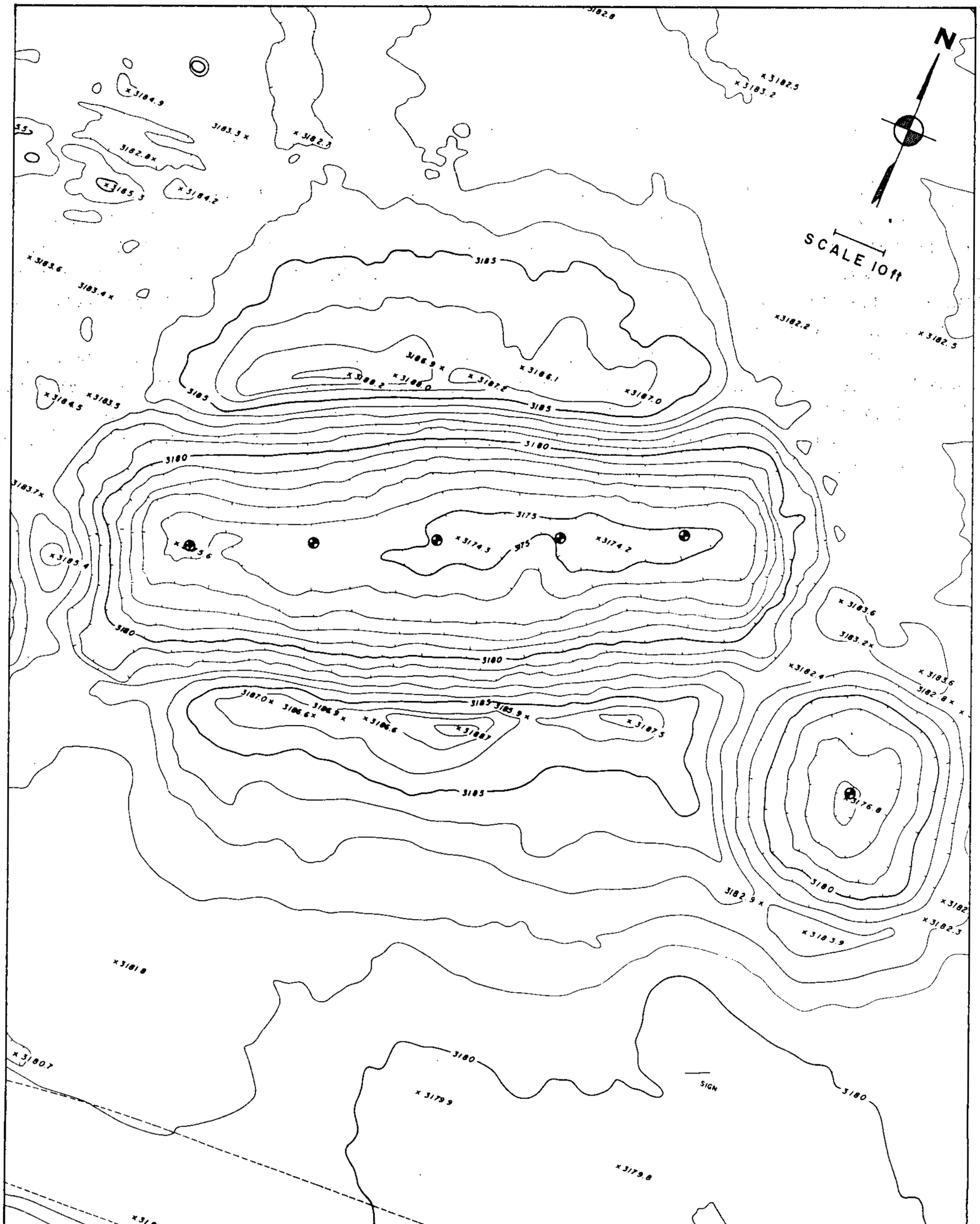

Figure C.20 Postshot topography, Row D.

APPENDIX D

SCIENTIFIC PHOTOGRAPHY COVERAGE

Table D.1 presents the coverage of the single-charge events. The CP camera station was located on an east-west line through the center of the six emplacement holes. The other ground stations were located on a north-south line through the particular emplacement hole. The aerial shots were taken from a helicopter circling slowly over the area approximately 2,000 feet above the surface.

Table D.2 presents the coverage of the row events. The CP camera station was located on a line running through the five emplacement holes. The other stations were located on a line perpendicular to that line and running through the center hole. Aerial coverage was the same as above.

All the films were 16 mm.

TABLE D.1 PHOTOGRAPHIC DATA FOR SINGLE-CHARGE EVENTS NOS. 1-7

(1) Tri-x Neg. (3) Plus-x Neg.
(2) Plus-x Rev. (4) Tri-x Rev.

Event No.	Camera Station	Type of Camera	Camera Speed	Lens	Film	Distance to G. Z.
			ft/sec	mm		feet
1	CP	B&H	64	50	KII	3100
	CP	ARRI	24	ZOOM	KII	3100
	N	P/S	100	25	KII	3200
	N	ARRI	16	ZOOM	KII	3200
2	CP	P/S	1000	50	(1)	2450
	CP	B&H	24	10	(2)	2450
	S	ARRI	48	ZOOM	KII	2000
	S	P/S	80	13	KII	2000
	Aerial	ARRI	48	ZOOM	KII	2000
3	CP	B&H	10	25	(2)	1900
	CP	B&H	24	10	(2)	1900
	S	ARRI	24	ZOOM	KII	3200
	S	B&H	16	17	KII	3200
	S	Hulcher	5	162	(3)	3200
	Aerial	ARRI	48	ZOOM	KII	2000
4	CP	B&H	48	10	(2)	2700
	CP	B&H	48	25	(2)	2700
	CP	P/S	850	25	(1)	2700
	S	ARRI	48	25	KII	3200
	S	ARRI	48	25	(2)	3200
	S	B&H	16	25	KII	3200
	S	Hulcher	5	162	(3)	3200
	Aerial	ARRI	48	ZOOM	KII	2000
5	CP	B&H	48	10	(4)	2250
	CP	P/S	100	25	(4)	2250
	N	P/S	50	25	(4)	2100
	N	B&H	48	25	(1)	2100
	Aerial	ARRI	48	ZOOM	KII	2000
6	CP	B&H	48	10	KII	3400
	N	B&H	24	25	KII	2136
	N	P/S	100	25	KII	2136
	Aerial	ARRI	48	ZOOM	KII	2000
7[a]		P/S	480	25	(4)	1800

[a]Surface motion study.

TABLE D.2 PHOTOGRAPHIC DATA FOR ROWS A-D

(1) Tri-x Neg.
(2) Tri-x Rev.
BS - Base surge and cloud studies.
SM - Surface motion studies.
NR - Not recorded.
NTM - No time marks camera speed unknown.

Event	Purpose	Camera Station	Type of Camera	Camera Speed	Lens	Film	Distance to G. Z.
				ft/sec	mm		feet
Row A	BS	CP	P/S	50	25	KII	3200
	BS	CP	P/S	200	25	KII	3200
	BS	S	P/S	100	13	KII	2000
	BS	S	ARRI	48	ZOOM	KII	2000
	SM	S	P/S	1000	NR	KII	2000
	SM	S	FASTAX	2200	NR	(2)	2000
	SM	S	P/S	1000	50	(2)	2000
	SM	S	P/S	1000	50	(2)	2000
	SM	S	P/S	1000	50	(2)	2000
	BS	Aerial	ARRI	48	ZOOM	KII	2000
Row B	BS	CP	P/S	50	25	KII	2000
	BS	CP	B&H	48	10	KII	2000
	BS	S	P/S	100	13	KII	2000
	SM	S	P/S	1000	50	(1)	2000
	SM	S	FASTAX	2200	100	(2)	2000
	BS	Aerial	ARRI	48	ZOOM	KII	2000
Row C	BS	CP	B&H	48	25	KII	2000
	BS	CP	B&H	48	10	KII	2000
	BS	S	ARRI	48	13	KII	2000
	BS	S	B&H	48	10	KII	2000
	SM	S	P/S	NTM	50	(2)	1300
	SM	S	P/S	750	50	(1)	1300
	SM	S	P/S	NTM	100	(2)	2000
	SM	S	P/S	NTM	50	(1)	2000
	SM	S	FASTAX	6000	252	(2)	2000
	SM	S	P/S	900	100	(2)	1300
	BS	Aerial	ARRI	48	ZOOM	KII	2000
Row D	BS	CP	B&H	48	10	KII	2000
	BS	CP	B&H	48	25	KII	2000
	BS	S	ARRI	48	ZOOM	KII	2000
	SM	S	FASTAX	6000	75	KII	2000
	BS	S	ARRI	48	30	KII	2000
	SM	S	P/S	1000	50	(2)	2000
	BS	Aerial	ARRI	48	ZOOM	KII	2000

/rd

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