MISCELLANEOUS PAPER N-73-4

OPERATION MINE SHAFT

DISTRIBUTION OF NATURAL AND ARTIFICIAL EJECTA RESULTING FROM DETONATION OF 100-TON TNT CHARGE ON GRANITE: MINERAL ROCK EVENT

by

J. W. Meyer, A. D. Rooke, Jr.

September 1973

Sponsored by Defense Nuclear Agency

Conducted by U. S. Army Engineer Waterways Experiment Station
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ARMY-MRC VICKSBURG, MISS.

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ABSTRACT

Event Mineral Rock, the detonation of a 100-ton spherically shaped charge of TNT on granite, was the last event of the Mine Shaft Series, a program of high-explosive tests primarily concerned with ground shock and cratering effects from explosions at or near the surface of a competent rock medium. The series, conducted in 1968 and 1969, was intended as a follow-on to previously conducted similar experiments in soil.

Mineral Rock (1969) duplicated the geometry and yield of Event Mine Ore (1968). Studies of crater ejecta were conducted to determine debris density and distribution, to examine the role of the ejection mechanism in crater formation, and to obtain additional information on the hazards associated with natural missiles. Mineral Rock, with a maximum observed ejecta range of approximately 2,800 feet for a 1-pound particle, produced a larger crater and a more extensive ejecta field than its predecessor, Mine Ore.

In addition to established methods of ejecta measurement, aerial photography was introduced to obtain spoil volume and distribution parameters. A comprehensive artificial missile experiment was included, and limited impact measurements were obtained from the terminal trajectories of small natural particles. As with other events in rock that preceded the Mine Shaft Series, the influence of rock jointing on ejecta distribution was evident. Volumetric analysis indicated that 230 yd^3 of in situ material was ejected from the crater, about 90 yd^3 of which was deposited in the crater lip. A factor of $W^{0.3}$ (W = charge weight) was confirmed for empirical scaling of ejecta ranges common to the Mine Ore/Mineral Rock test geometry. Size distribution as a function of range for discrete particles was also established, confirming that smaller particles (4 to 8 inches in diameter) tend to dominate the ejecta field at distances greater than 25 to 30 crater radii from the detonation.

Throwout regions common to the Mine Ore/Mineral Rock test geometry were satisfactorily defined, with good agreement being noted between the two events. In general, the ejecta mechanics resembled those associated with a surface burst in soil.

PREFACE

The Mine Shaft Series of high-explosive tests, sponsored by the Defense Nuclear Agency, included participation by a number of agencies under the technical direction and support of the U. S. Army Engineer Waterways Experiment Station (WES). Mr. L. F. Ingram of the Weapons Effects Laboratory (WEL), WES, served as Technical Director for the Mine Shaft Series. Mr. J. N. Strange, also of WEL, was Director of Program 1 (Cratering and Ejecta Studies).

Subtask SX30311, "Ejecta Studies," was prepared and executed during the period August through October 1969 as a part of Program 1 by Messrs. A. D. Rooke, Jr., Project Officer, and J. W. Meyer, the authors of this report. Fragment simulation tests intended to develop rock missile terminal trajectory data were performed by Mr. W. G. Dykes of WES; Dr. B. Rohani of WES made computer calculations for the same purpose. Assistance in the field was provided by Messrs. C. A. Miller and S. B. Price of WES. Mr. Price also assisted in data reduction, as did SP5 H. L. Knudson, and the report draft was prepared by Miss Virginia Mason of WEL. Finally, acknowledgment is made of the field personnel of all projects, especially Boeing Company personnel, who were helpful in locating, marking, and reporting artificial missiles and colored-grout fragments used in this study.

Mr. G. L. Arbuthnot, Jr. (retired), and Mr. W. J. Flathau were Chiefs of WEL during the conduct of this study and preparation of this report. COL Levi A. Brown, CE, BG Ernest D. Peixotto, CE, and COL G. H. Hilt, CE, were Directors of WES, and Mr. F. R. Brown was Technical Director.

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NOTATIONS AND ABBREVIATIONS

Notations

A Presented area

c Sonic velocity

C Constant representing effects of air drag in ballistic range equation

d Missile height

E_w Weight of ejected material

g Acceleration due to gravity

K Constant in ejecta areal density equation

ℓ Missile length

n Exponent of range R in ejecta areal density equation

p Shock-front pressure

R Range (distance from ground zero)

v Particle velocity

V_o Initial velocity of ejected particle

w Missile width

W Charge weight

W_c Calculated missile weight

W_m Measured missile weight

W_t Missile weight based upon presented area

α Particle exit angle

γ Specific (unit) weight

δ Ejecta areal density

π Pi, a constant, ≈ 3.142

ρ Mass density

σ Standard deviation from the mean

Crater notations are given in Figure 1.1.

Abbreviations

GZ Ground zero, the hypocenter or epicenter of detonation

HOB Height of burst

msl	Mean sea level, a reference plane
NX	Standard core size used in exploratory drilling, ≈3 inches in diameter
TNT	Trinitrotoluene, a chemical (high) explosive
WEL	Weapons Effects Laboratory
WES	U. S. Army Engineer Waterways Experiment Station

CONVERSION FACTORS, BRITISH TO METRIC UNITS OF MEASUREMENT

British units of measurement used in this report can be converted to metric units as follows:

Multiply	By	To Obtain
inches	2.54	centimeters
feet	0.3048	meters
miles (U. S. statute)	1.609344	kilometers
feet per second	0.3048	meters per second
miles per hour	1.609344	kilometers per hour
square inches	6.4516	square centimeters
square feet	0.092903	square meters
cubic feet	0.0283168	cubic meters
cubic yards	0.764555	cubic meters
pounds	0.45359237	kilograms
tons (2,000 pounds)	0.907185	metric tons
pounds per square inch	0.070307	kilograms per square centimeter
pounds per square foot	4.88243	kilograms per square meter
pounds per cubic foot	16.02	kilograms per cubic meter
Fahrenheit degrees	a	Celsius or Kelvin degrees

[a] To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use the following formula: C = (5/9)(F - 32). To obtain Kelvin (K) readings, use: K = (5/9)(F - 32) + 273.15.

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Events Mineral Lode and Mineral Rock were continuations of the Mine Shaft Series begun in 1968 (Reference 1). The primary objective of this test series was to study the effects of explosion-induced ground shock and cratering on or beneath the surface of a rock medium. A secondary objective was to observe the response of structures and structural components within the blast environment. Major effects measured were ground shock for the Mineral Lode Event (buried charge) and cratering, ejecta, ground shock, and airblast for the Mineral Rock Event (near-surface charge).

Mine Shaft was specifically designed to provide information on explosion effects in a rock medium, for which there is a paucity of data. Most large-scale explosive testing has been conducted in desert alluvium of the western United States and sandy clay of Canada. However, the interest in recent years in hardened military facilities in rock has required additional data to determine survivability of such facilities from hits or near misses of nuclear weapons. Since cratering and crater ejecta are among the prime destructive agents of an explosion, quantitative measurements of these phenomena are important. Of particular interest are the long-range ejecta strike probabilities on exposed structural elements of a facility.

1.2 OBJECTIVES

The primary objective of this study was to determine the ejecta areal density (in terms of weight per unit area, i.e., pounds per square foot[1]), range, and azimuthal distribution associated with the Mineral Rock Event. Secondary objectives were: (1) to obtain

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[1] A table of factors for converting British units of measurement to metric units is presented on page 11.

information on the mechanics of crater formation by surveying the origins and final positions of ejected material, and (2) to obtain information from which quantitative estimates of ejecta trajectory parameters and accompanying hazards could be made.

1.3 THEORY

The crater, its lip, and surrounding regions of deformation common to a surface or near-surface explosion are illustrated in Figure 1.1; the basic theory for an ejecta study is described in Reference 1. Briefly restated, predictions of ejecta parameters for any given explosion follow two general approaches: (1) a consideration of initial particle velocities based upon shock conditions, and (2) scaling of other experimental results to the yield under consideration.

The first approach is expressed by the fundamental ballistic equation for range

$$R = C \frac{V_o^2 \sin 2\alpha}{g} \tag{1.1}$$

Where: R = range (distance from ground zero)

C = a constant that is dependent on the effects of air drag

V_o = initial velocity (speed) of a given ejecta particle

α = starting or exit angle (with respect to the horizontal plane) of the particle

g = acceleration due to gravity

Reference 2, which includes some observations of ejecta particles, expresses C as a ratio of the observed range to the range in a vacuum.

The exit angle α is generally dependent upon shot geometry, and C must be selected to best represent the environmental conditions to which the particle will be subjected. Estimation of initial particle velocity depends upon conditions just behind the shock front according to the equation

$$v = \frac{p}{\rho c} \tag{1.2}$$

Where: v = particle velocity

p = shock-front pressure

ρ = the medium's mass density

c = sonic velocity in the medium

The quantities ρ and c can be readily determined experimentally; however, assigning a value to p requires use of a basic assumption concerning the origin of the ejected material. Material in direct contact with the charge is probably pulverized; therefore, ejected particles of practical interest are assumed to originate in areas slightly removed from the charge. Experience has shown that, for test geometries between that of a true surface burst and that of an above-surface tangent burst, the long-range ejecta generally originate near the ground surface at a distance approximately equal to one charge radius from the charge-medium interface (Reference 3). Thus, to determine maximum ejecta range, the value selected for p should represent the shock-front pressure at about this point. The resulting particle velocity can then be substituted into Equation 1.1 to calculate missile range. The major limitations of this method are (1) Equation 1.2 does not consider energy and velocity losses due to comminution, interparticle collisions, etc; and (2) the equation expresses a particle velocity in the direction of the spherically diverging ground-shock wave rather than toward ground surface, where ejection actually occurs. For these reasons, values of initial velocity and accompanying ranges are generally higher than those observed.

The second approach to predicting ejecta parameters involves empirical scaling procedures relating other experimental results to the current test. Considerable effort in cratering and ejecta research has been made toward developing the proper scaling relationships for various phenomena, both theoretically (through dimensional analysis methods) and experimentally. As yet, there has been little agreement between theory and experiment. For example, scaling factors for ejecta velocities and ranges have varied from as low as $W^{1/6}$ where W is charge weight (Reference 4, which presents results of a dimensional analysis using mass-gravity relations) to as high as $W^{0.4}$ (Reference 5, in which scaling factors are determined empirically from surface bursts in rock). The discrepancy seems to result from the fact that the effects of certain parameters such as charge geometry have not been evaluated completely and are not included in dimensional analysis procedures. Presently, empirically determined scaling factors provide the most reliable means of predicting cratering and ejecta effects.

1.4 PRESHOT PREDICTIONS

Since Mineral Rock duplicated the 1968 Event Mine Ore, the best predictions of ejecta ranges for Mineral Rock were the results of Mine Ore. These are given in Reference 6 and are: (1) maximum range = 2,500 feet, and (2) 90 percent missile range = 1,375 feet. The 90 percent missile range represents the radial distance within which 90 percent (by weight) of all ejecta is found.

However, as shown later, Mineral Rock results did not duplicate Mine Ore results; rather, they agreed more closely with original Mine Ore predictions, which are given in Reference 1 as: (1) maximum range = 3,000 feet, and (2) 90 percent missile range = 1,300 feet.

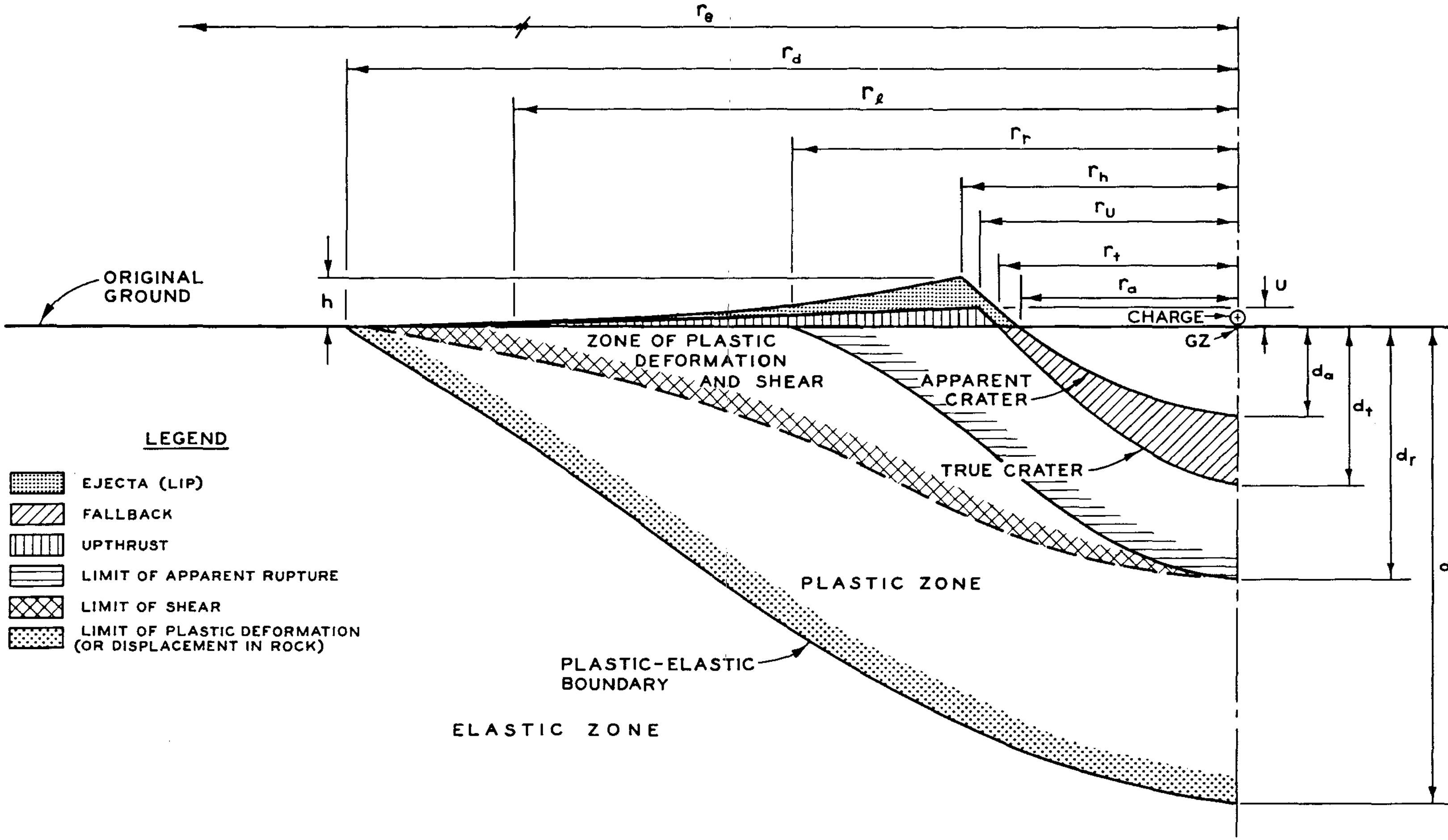


Figure 1.1 Typical half-crater profile and nomenclature for surface or near-surface burst. Profiles and dimensions are symmetrical about the centerline. Various radial and depth dimensions are indicated by r and d , respectively. Uplift is given by u , and h represents the crater lip crest height.

CHAPTER 2

EXPERIMENTAL PROCEDURES

2.1 TEST SITE

The Mine Shaft test site was located on a granite intrusion in the Iron Mountains of southwestern Utah, about 8 miles northwest of Cedar City, Utah. Figure 2.1 is a map of the test site area. The region has a semidesert environment with juniper trees, sage, and cactus as the predominant vegetation (Figure 2.2). The site is characterized by a thin layer of sandy silt soil (desert alluvium) with intermittent smoothly rounded rock outcrops. The site is approximately 5,900 feet above mean sea level (msl), and the area slopes gently toward the east at about 2 degrees. A steep 500-foot-high peak is located about 2,000 feet southwest of the site. Prior to testing, the area within approximately 100 feet of ground zero (GZ) was cleared of soil and weathered rock. The trees and brush were cleared as necessary to give an open area of 1,000-foot radius around GZ.

Results of a petrographic examination (Reference 7) showed the rock at the test site as tonalite (Shand's classification system), a light-colored, medium- to fine-grained igneous rock. The rock at the test site consisted of a fine-grained matrix of quartz, plagioclase feldspar, pyroxene, clay (montmorillonite and vermiculite), biotite, and magnetite grains. Examination of near-surface core samples showed the rock to be somewhat weathered, friable, and cracked. The basic physical properties of the tonalite, which is a granitoid rock, are listed below:

Specific gravity	2.6
Porosity	5 percent
Tensile strength	900 psi
Unconfined compressive strength	15,000 psi
Young's modulus of elasticity (unconfined)	3.0×10^6 psi
Initial angle of shearing	
intact samples	45 degrees
jointed samples	37 degrees

According to the classification system in Reference 8, the Cedar City tonalite would be classified as borderline between CA and CL (Figure 2.3), indicating medium strength and an average to low modulus-to-compressive strength ratio.

The rock mass in the vicinity of Mineral Rock GZ was moderately jointed, with the major joint zones trending in a north-south direction (Reference 9). Figure 2.4 is a map of the surface joints adjacent to GZ. Most joints were nearly vertical, and the wider joints tended to narrow rapidly below the surface. Some of the larger joints indicated slight downward faulting. One well-developed surface joint pattern involved the swirls of rock that occur in the Mineral Rock area. While not fully understood, these onionlike formations may be either stress relief features that formed after jointing or planes of parting that developed as the magma cooled geologic ages ago. Subsurface joint spacing averaged one joint about every 6 inches down to 10 feet below ground surface and decreased markedly with greater depth.

2.2 TEST GEOMETRY AND ENVIRONMENTAL CONDITIONS

This phase of the Mine Shaft Series consisted of two high-explosive (HE) charges: Mineral Lode, detonated on 5 September 1969, and Mineral Rock, detonated on 7 October 1969. Mineral Lode was a 16-ton, ammonium nitrate slurry charge buried 100 feet. This depth was chosen to approximate that of containment, where a camouflet would be formed but no explosion gases would be vented. Since Mineral Lode produced no significant ejecta field (Reference 10), it will not be considered further in this report.

Mineral Rock was a 100-ton near-surface burst. The charge was composed of 32.6-pound blocks of trinitrotoluene (TNT) stacked to approximate a 15.7-foot-diameter sphere (Figure 2.5). The height of burst (HOB) relative to charge center of gravity was 0.9 charge radius, or 7.07 feet.

As mentioned previously, Mineral Rock duplicated Event Mine Ore, which was detonated on 13 November 1968. The geographical coordinates for Mineral Rock were latitude $37^{\circ}46'10.033''$ N and longitude

$113^{o}10'52.037''$ W; this zero point was about 130 feet northeast of the old Mine Ore GZ. Part of the shot preparation for Mineral Rock included an effort to clear the area of ejecta from Mine Ore. This was accomplished mostly by grading. Just prior to shot day, a search of the area was made, and remaining ejecta of significant size were marked with spray paint so that they could be easily distinguished from ejecta resulting from the detonation of Mineral Rock.

Time of the Mineral Rock detonation was 1200 hours (to the nearest second). Shot day was partly cloudy and a stiff wind was blowing from the south (190 degrees) at 16.1 mph. The surface temperature was 68 F and the barometric pressure was 11.8 psi; relative humidity was 28 percent (Reference 11).

2.3 EJECTA MASS DENSITY AND DISTRIBUTION SAMPLING TECHNIQUES

To determine the areal mass density and distribution of ejecta resulting from the Mineral Rock Event, the ejecta field was divided into two regions: (1) the continuous ejecta region (within the crater lip), and (2) the discontinuous ejecta region (beyond the crater lip). Four techniques were used to collect data, one in the continuous ejecta region and three in the discontinuous ejecta region.

2.3.1. Ejecta Within and Adjacent to the Crater Lip. Following the shot, the crater lip was divided into 30-degree sectors (Figure 2.6) extending from 40 feet from GZ, the approximate edge of the apparent crater, to 100 feet from GZ, the outer limit of the continuous ejecta region. Each 30-degree sector was further divided into four areas by radial increments of 15 feet. The sectors for sampling (shaded sectors in Figure 2.6) were selected to provide continuous data points along four radial sectors and on two concentric rings circling GZ. Due to the irregularity of the lip extremity, some of the sampling areas lay slightly beyond the lip. These areas were recorded and the data were separated during analysis (Section 4.1). Ejecta collection was accomplished in coordination with Subtask SX30110, "Cratering Effects Investigations." The material from each sector was collected using a front-end loader and was placed in a dump truck. The material was then hauled to a local rock-crushing plant where the total sample was weighed and then sieved into four size classifications: >12 inches, >6 to 12 inches, >3 to 6 inches, and ≤3 inches. Figure 2.7 shows the sieving operation with the material passing through a series of screens on a rock-crushing machine, then onto conveyor belts where material of each size classification falls into a separate truck and is weighed. The data obtained were analyzed to determine areal mass density and size distribution of ejecta in the crater lip as a function of radial distance from GZ.

2.3.2. Ejecta Beyond the Crater Lip. Three techniques were used to sample ejecta falling beyond the crater lip: (1) hand collection of ejecta from predesignated collector areas, (2) aerial photography, and (3) peripheral plane-table survey.

The ejecta collector areas were used in the expected transition region between the continuous and discontinuous ejecta. Forty areas were laid out in an array extending from 75 to 200 feet from GZ, as shown in Figure 2.8. Each area covered 100 ft^2. In the areas that were bare rock, the rock surface was painted red. The areas that were composed of alluvium were marked with pins at the four corners and the center of the area. In the alluvium areas, recovery of sand-sized ejecta particles was impossible, since there was no practical means of separating the particles from the in situ material The entire ejecta sampling procedure in and adjacent to the lip was necessarily unrefined, but the procedure was adequate to gain an appreciation of the depostion in this area.

Figure 2.9 is an aerial photograph showing the Mineral Rock charge and the surrounding collector areas. After the shot, samples were collected from only 22 of these areas (shaded in Figure 2.8) because the inner areas fell in the continuous ejecta region that was sampled as part of the crater lip. All rock debris within each sampled area was gathered and weighed and then sized into groups with diameters <6 inches, 6 to 12 inches, and >12 inches. For each sampled area, all, or a representative sample, of the minus 6-inch material was retained for a more detailed laboratory sieve analysis.

The ejecta beyond the crater lip was sampled primarily by aerial photography. A mosaic of low-altitude photographs was planned to provide a complete picture of the debris field out to a radial distance of 1,000 feet from GZ. A contract was negotiated with a commercial firm to accomplish the aerial photography and to perform a sample count of ejected rock particles down to the 3- to 4-inch size from photograph enlargements. Due to various technical and fly-over difficulties, the photography did not effectively cover the designated 2,000-foot-diameter area. However, a sufficient number of photographs were obtained for sampling purposes and for establishing the methodology associated with this approach to an ejecta study. Eight pictures taken at various ranges from GZ (Figure 2.10) were selected for a detailed missile count. These pictures were enlarged, and the missiles were counted and sized into five classifications: 4 to 8 inches, >8 to 12 inches, >12 to 18 inches, >18 to 24 inches, and >24 inches. The coordinates of each missile were determined with respect to GZ, and all information was recorded on computer cards. The data were analyzed on a digital computer to determine ejecta areal density and size distribution relations as functions of radial distance.

The outer periphery of the ejecta field was mapped by a plane-table survey to determine the maximum range of natural missiles. Mapping was restricted to rock fragments weighing approximately 1 pound or more. Heavier pieces whose weights were difficult to estimate were weighed in a sling and spring-scale device. The area covered was an arc of about 170 degrees running clockwise from west to east-northeast. Broken terrain toward the east and southeast, a restricted Air Force test area toward the south, and a large hill toward the southwest restricted the mapping effort. However, a visual search was made of these areas, and extreme missile ranges were estimated.

2.4 TECHNIQUES FOR EVALUATING MISSILE TRAJECTORIES

Three experiments were designed to meet the secondary objective of evaluating missile trajectory parameters. These experiments involved the use of: (1) colored-grout ejecta, (2) artificial missiles, and (3) styrofoam missile traps.

2.4.1 Colored-Grout Ejects. An array of colored-grout columns (Figure 2.11) was emplaced during the conduct of Subtask SX30110, "Cratering Effects Investigations," to aid in defining the true crater and rupture envelope boundaries and in determining residual displacements surrounding the crater. The upper portions of the grout columns that were within the expected true crater were divided into 1-foot increments by the addition of colored beads to the grout mixture. For the purposes of the ejecta study, the beaded portions of the columns provided source material for tracing the ejecta origins. After the shot, those pieces of the grout columns found in the ejecta field were identified and their final positions were recorded.

2.4.2 Artificial Missiles. The artificial missile experiment served a purpose similar to that of the colored-grout experiment, with the addition that information on ballistic coefficients and drag characteristics for missiles of known shape and density was obtainable. Two basic missile shapes, cylinders and spheres, were used. The cylinders were made of aluminum and were 2.5 inches in diameter. The cylinders were emplaced in packages, each package consisting of one 4-, 2-, and 1-inch-long cylinder and one 1-inch-long cylinder divided into one half-cylinder and two quarter-cylinder wedges. The spheres were made of plastic, aluminum, steel, or lead, and were either 1 or 2 inches in diameter. The spheres were emplaced in packages that each contained two 1-inch and one 2-inch spheres of each of the four materials.

Table 2.1 gives the physical properties of the artificial missiles. One-hundred ninety-seven cylinder packages and 60 packages of spheres, making a total of 1,902 artificial missiles, were emplaced preshot in an array of NX-size (approximately 3 inches in diameter) holes extending along radials to the north, south, and west of GZ. Figure 2.12 shows the locations, relative to GZ, of all boreholes containing artificial missiles along with the positions of the missile packages in the holes. All holes were backfilled with strength-matching grout. Figure 2.13 shows missile packages and cylinders just prior to emplacement. Each missile was stamped with a three-digit number giving its initial position with respect to radial number, hole number, and depth. For example, a cylinder marked 154 was orginally emplaced on Radial 1 (south radial) in the fifth hole from GZ and was in the fourth cylinder package below ground surface. Preshot depths of all cylinder and sphere packages were recorded in the field. In addition, twenty-three 7.4-inch-diameter aluminum spheres were emplaced in four boreholes to the north of GZ at the request of the Aerospace Corporation, a participating agency. These spheres were number coded and their preshot positions were recorded. They served the same purpose as the other artificial missiles but were larger and brightly polished so that they could possibly be visible in the technical photography and thus provide data on initial missile trajectory parameters. Unfortunately, this was unsuccessful. Postshot, a search was made for all artificial missiles, which, when found, were identified and mapped by plane-table survey.

2.4.3 Styrofoam Missile Traps. The final missile trajectory experiment involved the use of styrofoam missile traps designed to obtain data on terminal trajectory parameters. The traps were made of 26-psi styrofoam, 4 feet by 8 feet by 6 inches thick, emplaced so that the top surface was flush with the ground surface. Five traps were placed along the west radial at distances of 249, 346, 509, 607, and 706 feet from GZ. A single trap was also placed 224 feet south of GZ. After the shot, those traps that survived were recovered and those portions containing embedded missiles were cut out. Impact angles and depths of penetration were later measured, and impact velocities were estimated on the basis of calibration tests conducted in a fragment simulator and on the basis of the results of a computer program on penetration parameters.

TABLE 2.1 PHYSICAL PROPERTIES OF ARTIFICIAL MISSILES

Spheres			Cylinders[a]	
Diameter	Material	Weight	Length	Weight
inches		pounds	inches	pounds
1	Aluminum	0.05	4	1.82
1	Lead	0.22	2	0.91
1	Plastic	0.02	1	0.46
1	Steel	0.15	1[b]	0.23
2	Aluminum	0.40	1[c]	0.12
2	Lead	1.72		
2	Plastic	0.20		
2	Steel	1.19		
7.4	Aluminum	20.30		

[a] All cylinders were made of aluminum and were 2.5 inches in diameter.

[b] One-half cylinder wedge of a 1-inch cylinder.

[c] One-quarter cylinder wedge of a 1-inch cylinder.

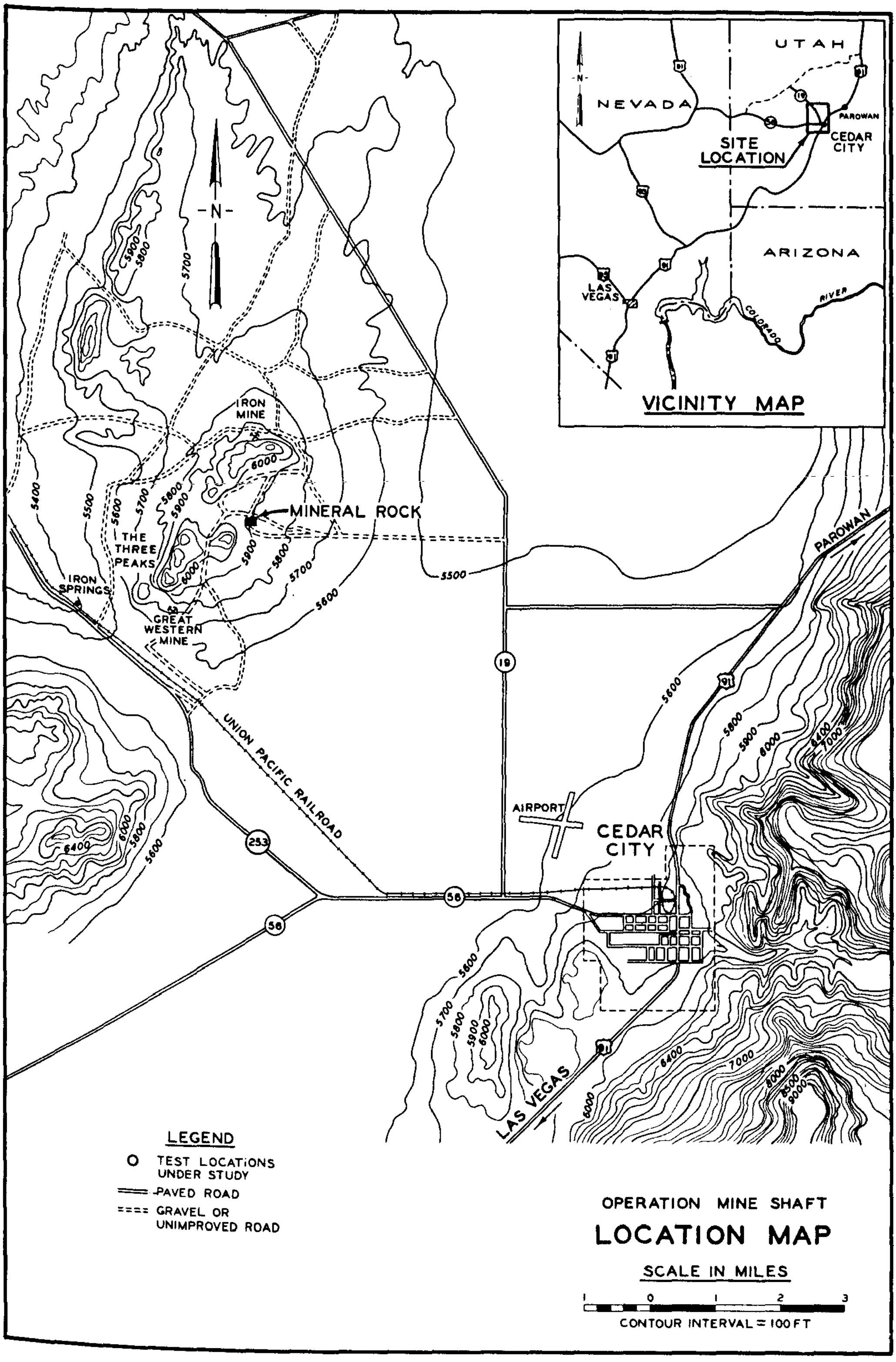


Figure 2.1 Location and vicinity maps for Mineral Rock. Contours are in feet above mean sea level.

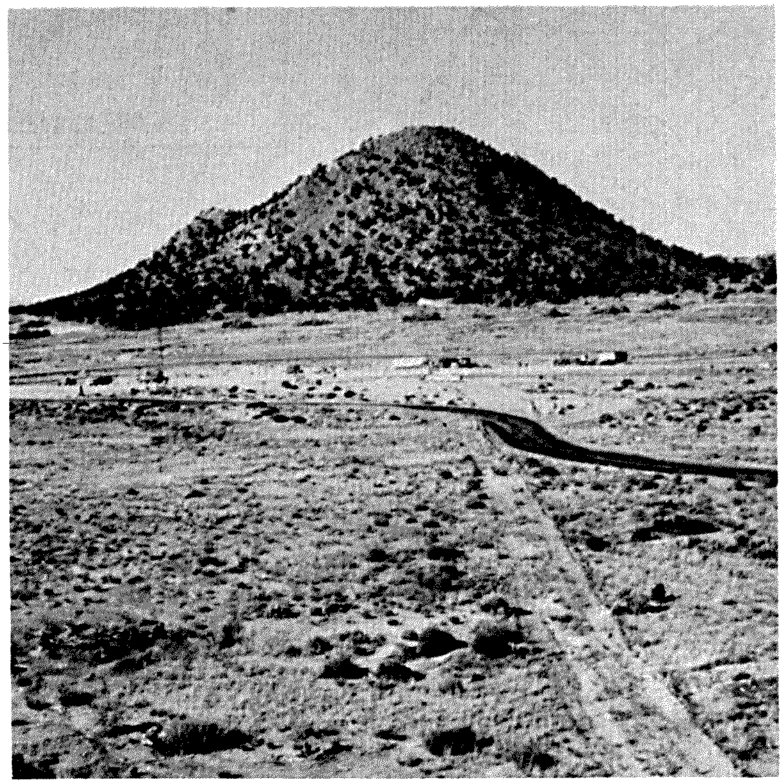


Figure 2.2 Preshot view of the Mineral Rock test site looking toward the southwest.

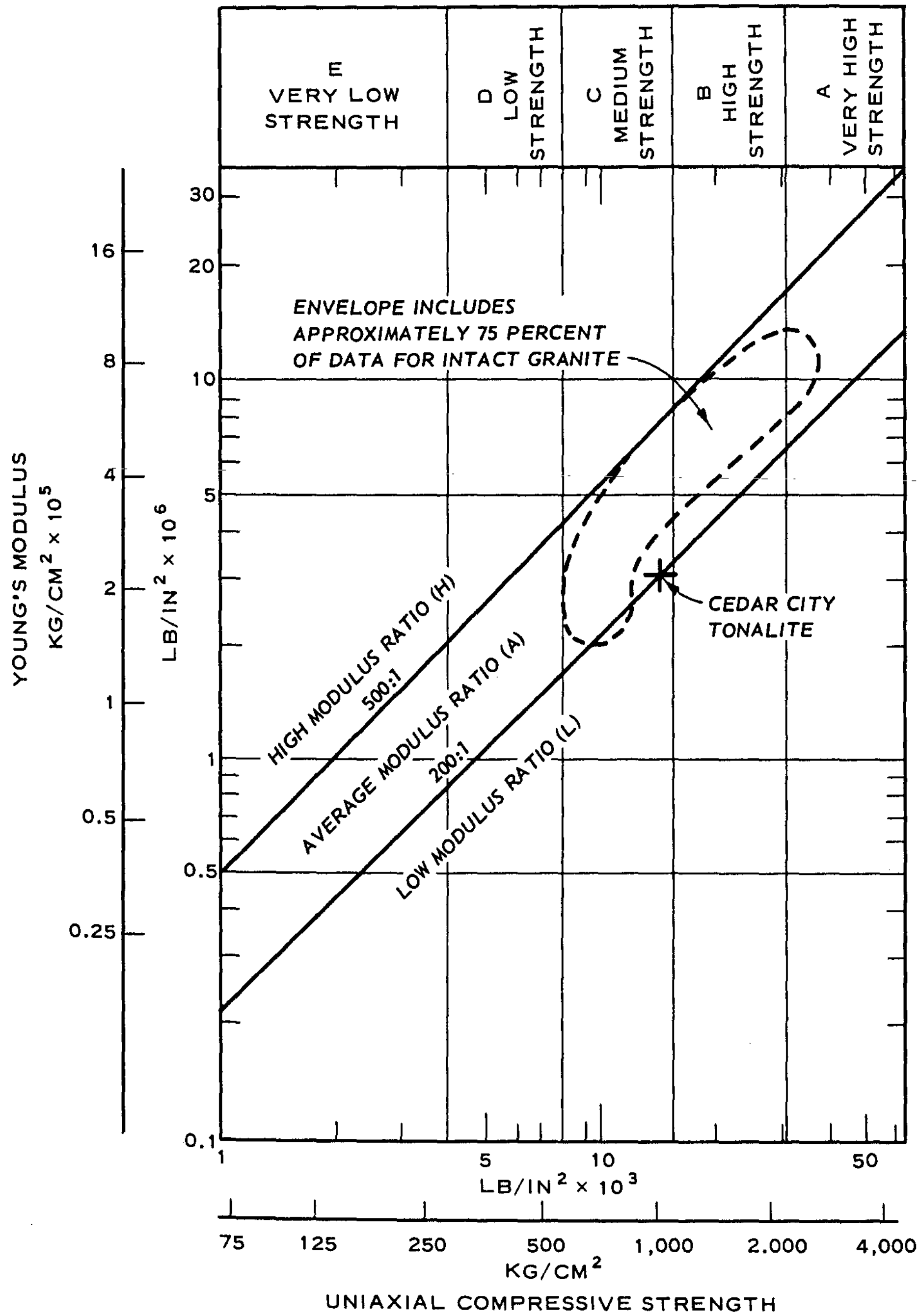
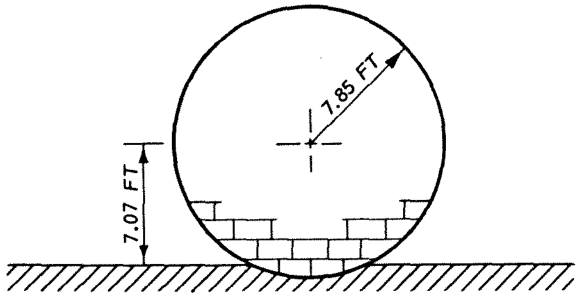
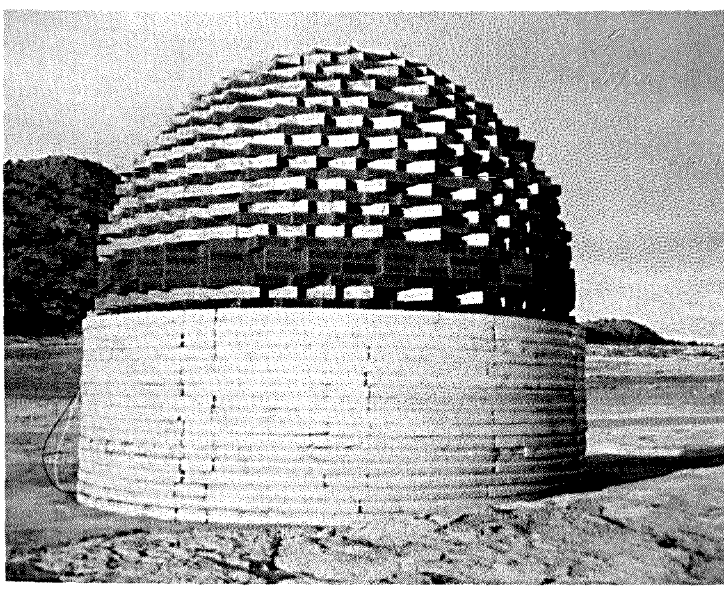


Figure 2.3 Engineering classification for Cedar City tonalite as compared with other intact granites.

Figure 2.4. Surface joint map for Event Mineral Rock. Major and minor joints are indicated by heavy and light lines. Note numerous swirls in rock, as discussed in Section 2.1.



a. Elevation view of charge;
HOB = 0.9 charge radius.



b. Stacked charge with styrofoam base.

Figure 2.5 Shot geometry for Event Mineral Rock, a 100-ton TNT detonation.

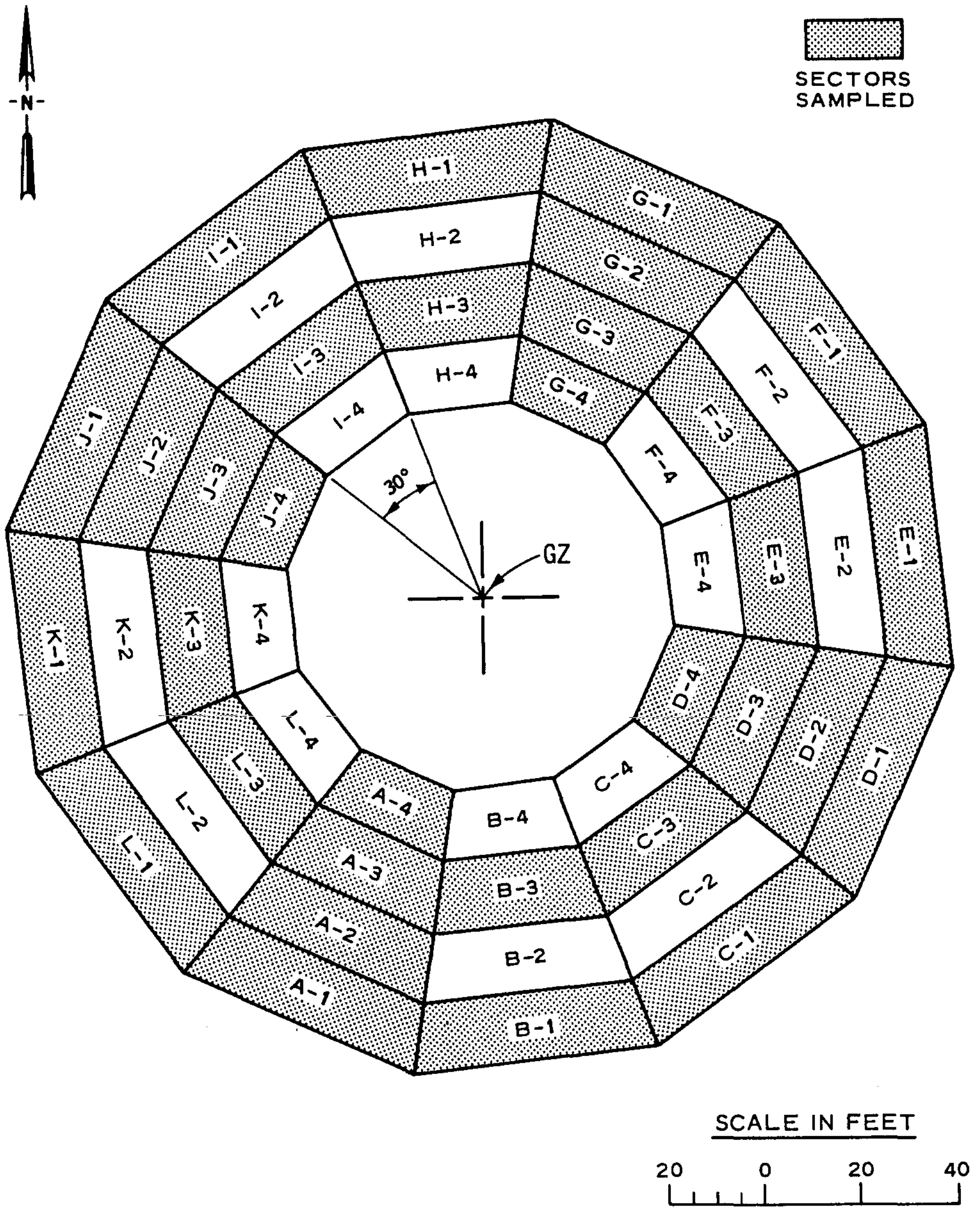


Figure 2.6 Sectors for collecting continuous ejecta in and immediately adjacent to the crater lip, Event Mineral Rock.

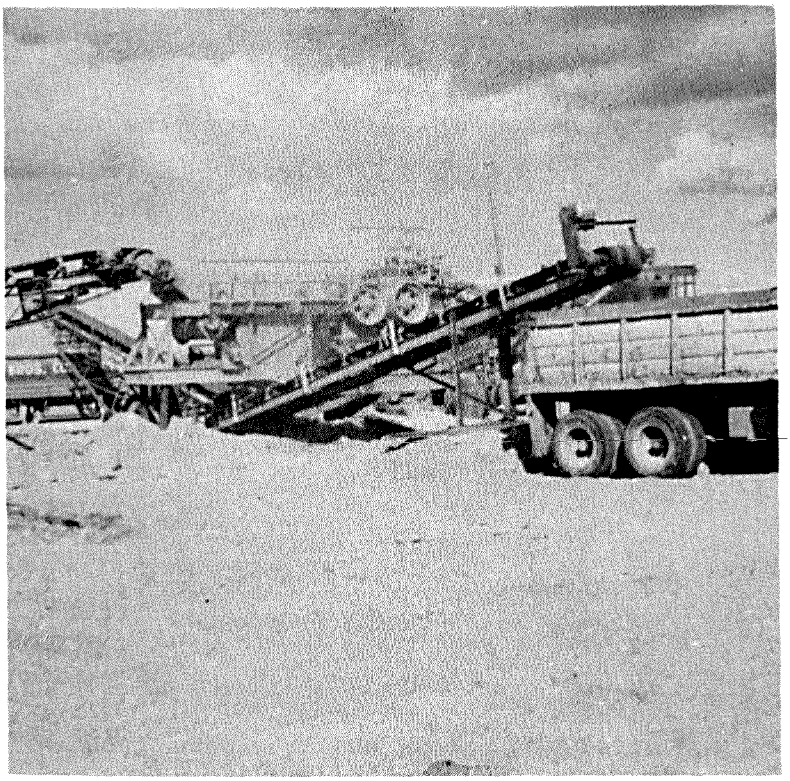


Figure 2.7 Sieving of ejecta from the Mineral Rock crater lip at a rock-crushing plant (Western Rock Products Corp., Cedar City, Utah).

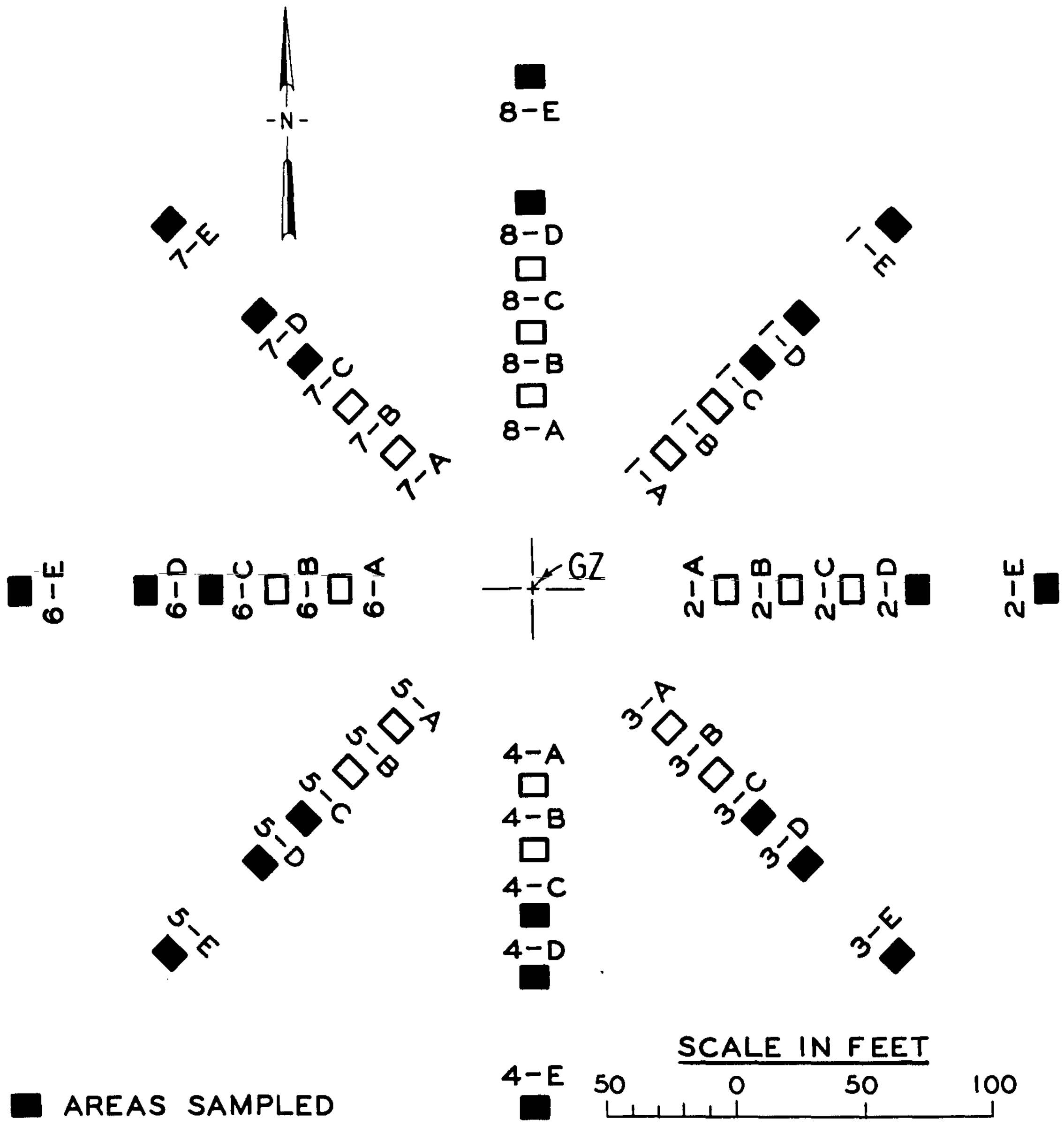


Figure 2.8 Array of ejecta collector areas, Event Mineral Rock.

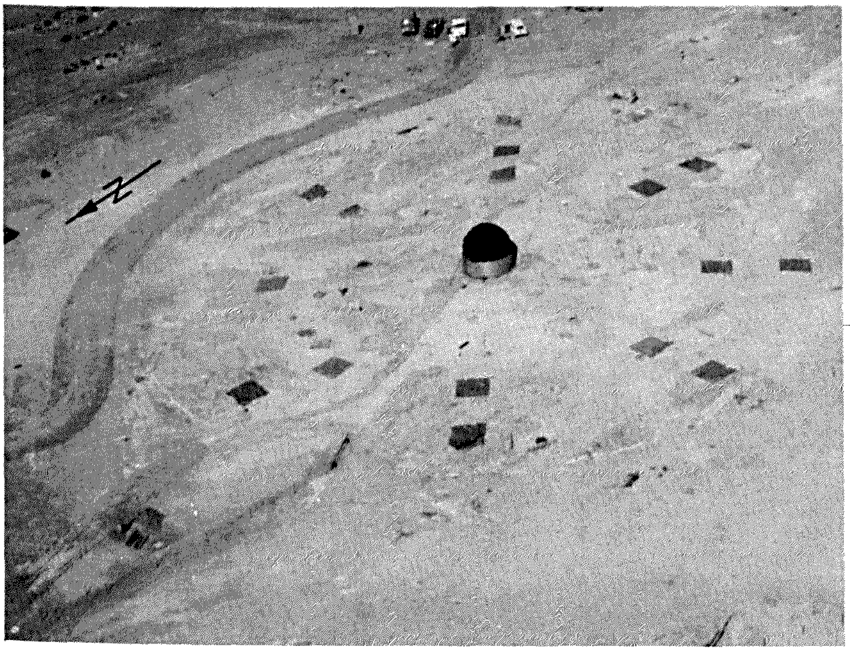


Figure 2.9 Mineral Rock charge and ejecta collector areas.

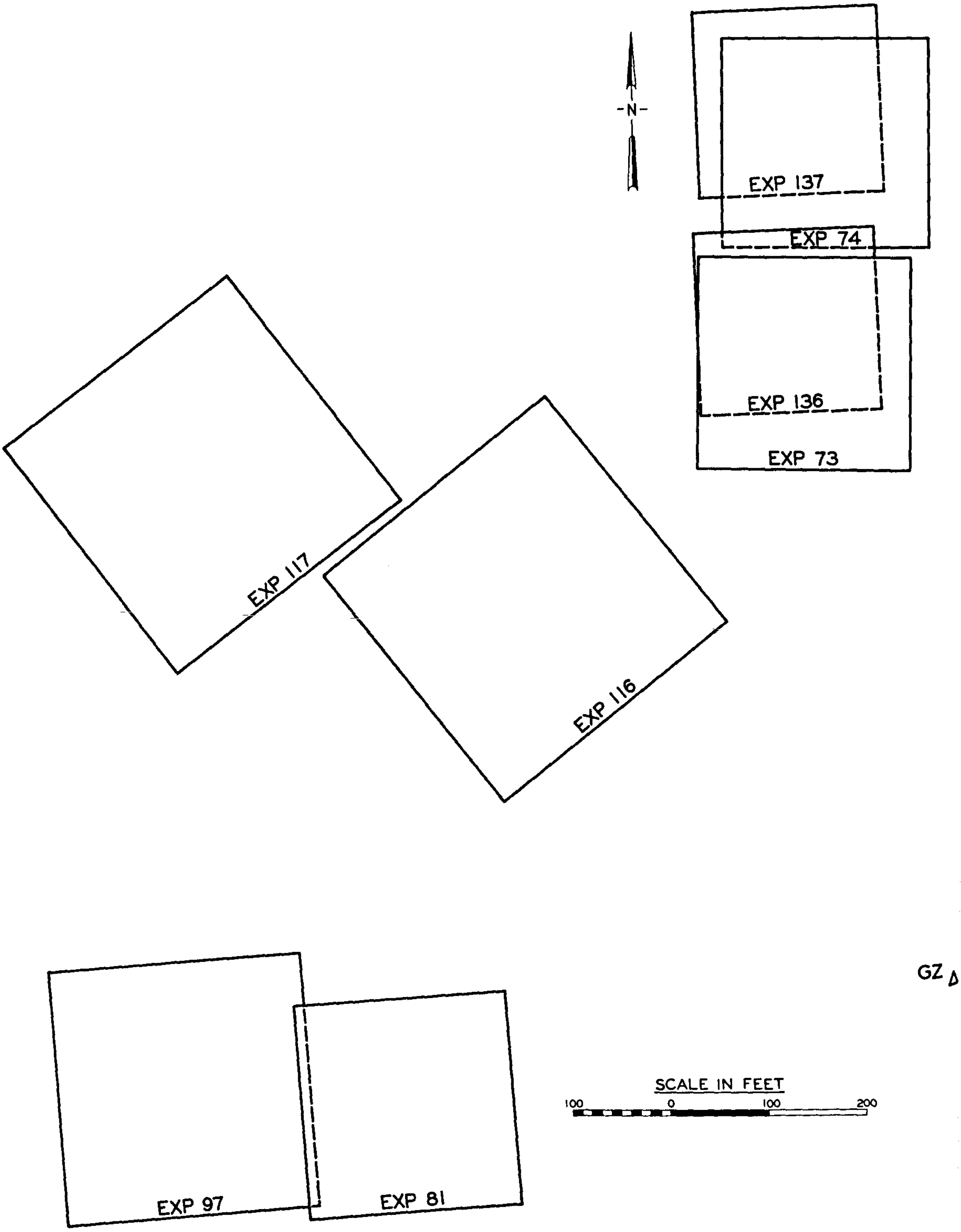


Figure 2.10 Areas selected for aerial photography ejecta count, by photograph exposure number.

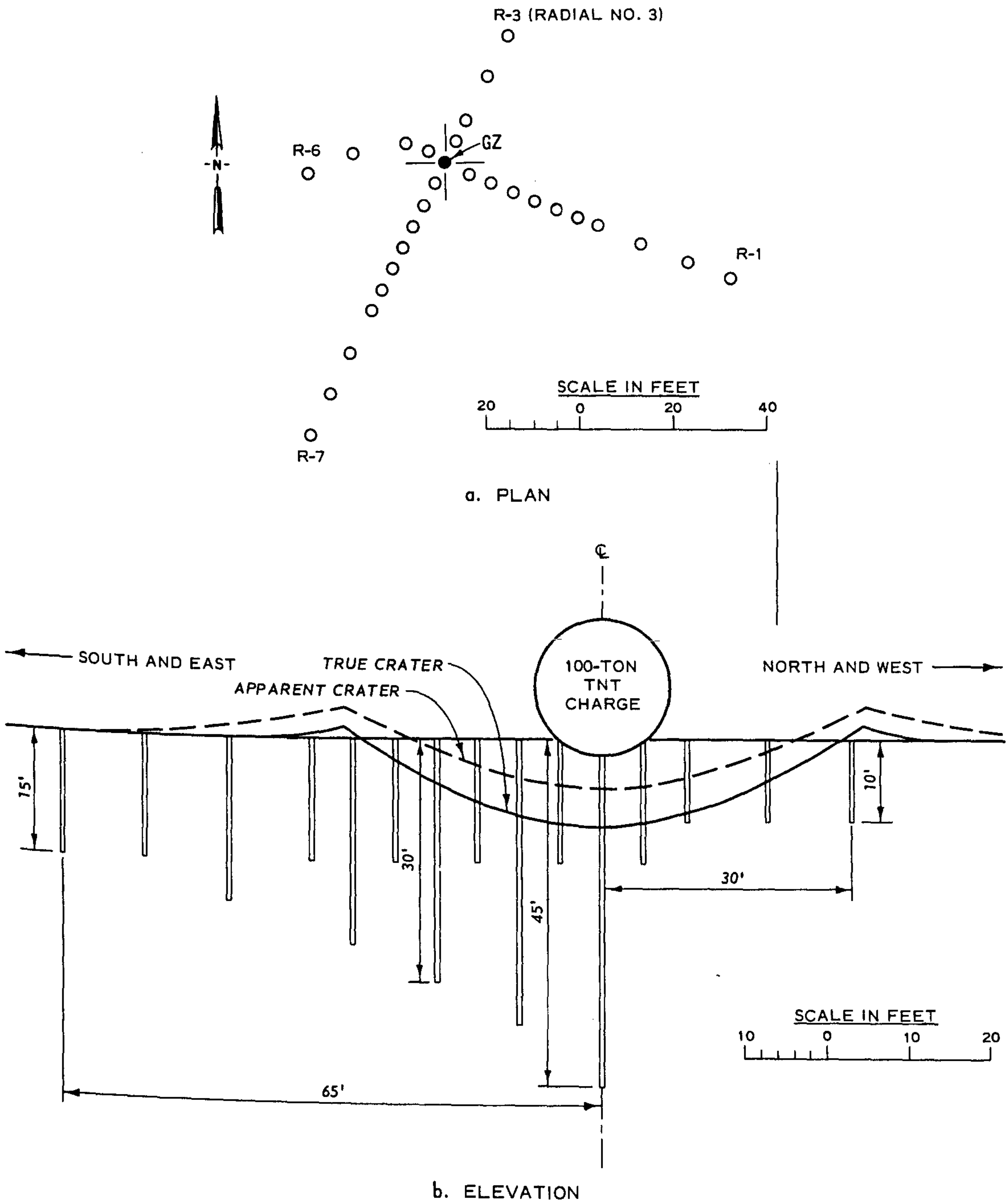
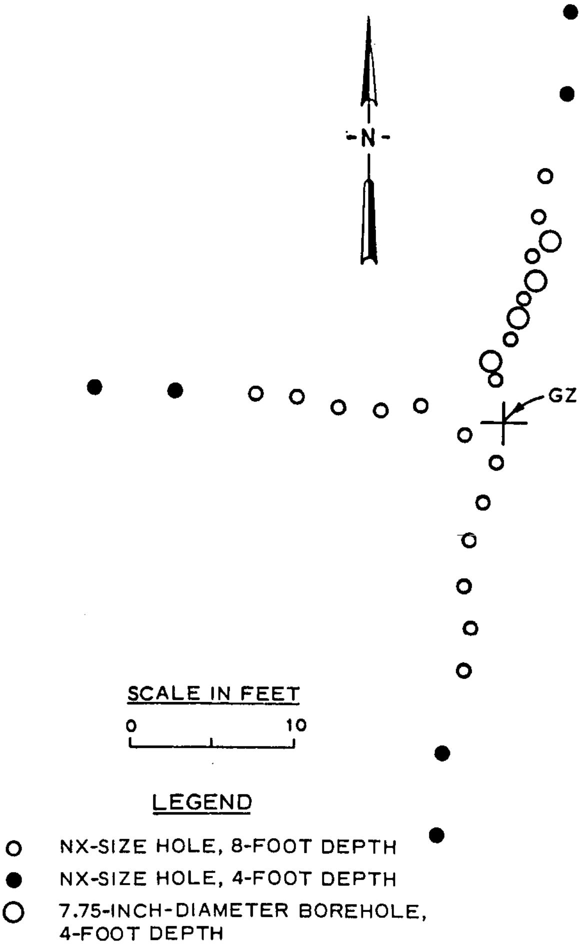
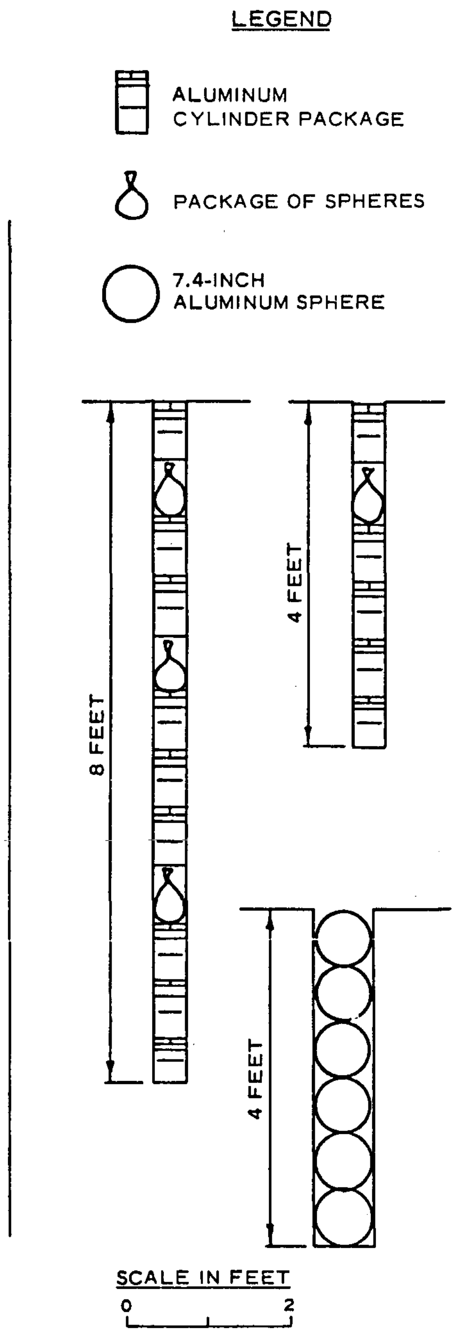


Figure 2.11 Bead- and color-coded grout columns of Subtask 30110.





a. Locations of artificial missile boreholes.

b. Positions of artificial missiles in boreholes.

Figure 2.12 Preshot locations and positions of the artificial missiles for Event Mineral Rock.

Figure 2.13 Artificial missiles (cylinder packages and sphere packages) prior to emplacement in NX-size boreholes.

CHAPTER 3

RESULTS

3.1 EJECTA DISTRIBUTION AND AREAL DENSITY

Figure 3.1 is an aerial photograph of the apparent crater and adjacent debris field for Event Mineral Rock. A more extensive ejecta field was obtained from Mineral Rock than from its predecessor, Mine Ore. However, as with Mine Ore, the ejecta distribution for Mineral Rock was distinctly rayed, with the principal rays running to the northwest and southeast. For the Mineral Rock Event, ejecta between the rays was less dense and was randomly distributed. Rock jointing again appeared to be the controlling factor in ejecta distribution, with topographical and vegetal features of the test site having only a slight effect. Wind and other weather factors apparently had no significant effect on the ejecta pattern.

Of interest in this test were the number of large missiles thrown for considerable distances. Several missiles weighing 100 pounds or more were hurled over 1,000 feet from GZ. Figure 3.2 shows a 400-pound fragment of a larger missile that was thrown about 1,200 feet northeast of GZ. Another missile landed about 200 feet east of GZ and broke in two, with the larger piece traveling another 100 feet. The larger piece weighed an estimated 10 to 12 tons, while the weight of the original missile was estimated at 18 tons. The two pieces are circled in Figure 3.1.

The maximum range for a natural missile was approximately 2,800 feet. This missile was a 1-pound fragment found north-northeast of GZ on a radial roughly parallel to the main jointing of the rock in the area covered by the peripheral plane-table survey. Maximum natural missile range south of GZ in the restricted Air Force area was estimated at 2,400 feet.

<u>3.1.1 Within the Crater Lip</u>. Table 3.1 gives the distribution and areal density of the ejecta collected from the crater lip and the area immediately adjacent. The lip itself was generally asymmetrical,

averaging 64 feet in its extremity, but with radii extending in some directions to 110 feet from GZ (Reference 12). The mass of lip material was unevenly distributed, with the heaviest depositions to the west, northeast, and southeast. Total ejecta mass in the crater lip was approximately 4×10^5 pounds.

3.1.2 Beyond the Crater Lip. Table 3.2 presents the distribution and areal density of the ejecta recovered from the ejecta collector areas that covered the transition zone along the periphery of the crater lip where deposition was heavy but not continuous. As in the lip, the ejecta distribution in the transition zone was asymmetrical, with the areas of heaviest distribution coinciding with those of the lip. The beginnings of the ejecta rays are also reflected in the collector area data. Table 3.3 presents the results of a sieve analysis performed on the small ejecta particles, i.e., those less than 6 inches in nominal diameter. These results are also shown graphically in Figure 3.3.

Results of the particle count and size classification performed on the discontinuous ejecta field by means of aerial photography are tabulated in Appendix A. Eight exposures were processed (see Figure 2.10), covering an area of 384,000 ft^2, in which 2,452 rock particles were located and classified into five size categories. Table 3.4 presents the ejecta areal densities as functions of range, as determined from the aerial photographs. Details of the computational techniques for obtaining these values are presented in Section 4.1.

Finally, the plane-table survey of missiles falling along the periphery of the debris field indicated a maximum ejecta range of roughly 2,800 feet. Maps of the portion of the periphery that was surveyed (slightly less than half of the ejecta field circumference) are presented in Figure 3.4. The missiles examined fell beyond 2,000 feet from GZ and ranged in weight from an arbitrarily selected lower limit of 1 pound to 100 pounds for a piece of grout. The largest natural missile found on the periphery weighed 40 pounds. To facilitate control, plane-table stations were established by highway-curve traverse on a 2,000-foot radius. Interstation distance (chord length) was 522 feet. Vegetation and terrain necessitated the establishment of additional stations during the course of the survey.

3.2 MISSILE TRAJECTORY EXPERIMENTS

Results of the three experiments designed to obtain information on the ballistic trajectories of ejecta missiles are presented below. Two of these experiments also provided information on the mechanics of crater formation by defining the origin of ejecta as a function of distance from the charge.

3.2.1 Colored-Grout Ejecta. Table 3.5 gives the postshot positions of particles recovered from the colored-grout columns as determined during the conduct of Subtask SX30110. Ejected grout was located as far as 1,450 feet to the east of GZ, 1,350 feet to the north, 540 feet to the west, and 1,300 feet to the south. Except for particles found in the fallback, the angular deviation of ejecta about radial lines extending from GZ through the grout columns was 10 degrees or less for all radials except Radial 6. The slightly greater spread on this radial was caused by the original nonlinear array of grout columns (see Figure 2.11). Identification of each piece of ejected grout by means of grout and bead colors permitted determination of its origin.

3.2.2 Artificial Missiles. A postshot plane-table survey was conducted to locate and map the artificial missiles that had been emplaced in the crater region. Table 3.6 lists the preshot and postshot positions of all WES missiles recovered in the search. Of the 1,925 missiles (both cylinders and spheres) originally emplaced, 547 (28.4 percent) were recovered, identified, and mapped during the survey. Four plane-table maps were drawn. The individual maps, shown in Figures 3.5 through 3.8, cover the crater area and the north, south, and west radials, respectively. Maximum artificial missile ranges were 2,165 feet to the west and 2,150 feet to the north, both for 4-inch-diameter cylinders. The search to the south was restricted to a distance of 900 feet because of the Air Force test area previously mentioned. Subsequent investigation of the true crater indicated that another 25 percent of the missiles were either buried in the fallback or had never been ejected. The number of missiles recovered, however, provided a sufficient sample to give a clear picture of ballistic ejecta origin versus range.

In recovering the artificial missiles, it was discovered that several groups of spheres and cylinders were still embedded in large blocks of ejected rock, as shown in Figure 3.9. Most such blocks were found in or near the edge of the crater lip, but one was found almost 960 feet north of GZ.

Nineteen of the twenty-three 7.4-inch-diameter aluminum spheres were recovered postshot, 18 of which were identifiable. Their ejected ranges are given in Table 3.7. Maximum range was 984 feet. Final positions can be seen in Figures 3.5 and 3.6. The unrecovered spheres, all from the hole nearest the charge, were believed to have been buried in the fallback.

3.2.3 Styrofoam Missile Traps. Only four small missiles were recovered in the styrofoam missile traps. Several of the close-in traps were blown away in the blast, and others were destroyed when struck by large rocks. Following the field work, tests were conducted in the WES Fragment Simulation Facility, and computer calculations were made[1] to determine impact velocities of the recovered rock fragments. Angles of penetration and calculated striking velocities of the missiles are listed in Table 3.8.

[1] By Dr. B. Rohani, using a time-sharing program developed within the Soil Dynamics Branch, Soils and Pavements Laboratory, WES.

TABLE 3.1 DISTRIBUTION AND AREAL DENSITY OF EJECTA WITHIN AND ADJACENT TO THE CRATER LIP

Note: The average lip extremity included Sectors -3 and -4.

Radial	Sector	Weight of Ejecta of Indicated Sizes				Total Weight of Ejecta	Areal Density
		>12 inches	>6 to 12 inches	>3 to 6 inches	≤3 inches		
		pounds	pounds	pounds	pounds	pounds	lb/ft^2
A	1	6,230	1,800	1,200	1,300	10,530	15.20
	2	1,200	1,800	1,000	1,100	5,100	8.75
	3	3,350	4,550	2,000	1,100	11,000	23.40
	4	850	1,600	850	500	3,800	10.64
B	1	2,690	5,100	2,400	1,600	11,790	17.00
	3	44,710	9,010	4,870	6,410	65,000	138.00
C	1	6,140	3,350	1,850	2,750	14,090	20.20
	3	13,130	2,850	1,750	1,900	19,630	41.70
D	1	1,100	1,450	1,120	1,500	5,170	7.44
	2	2,010	1,800	960	450	5,220	8.95
	3	10,590	5,000	2,400	2,400	20,390	43.40
	4[a]	--	--	--	--	17,080	47.80
E	1	2,625	2,900	1,400	1,750	8,675	12.50
	3[a]	--	--	--	--	40,840	87.00
F	1	2,475	3,400	2,750	9,250	17,875	25.70
	3	2,947	4,150	2,100	3,700	12,897	27.40
G	1	210	1,000	1,450	2,700	5,360	7.71
	2	650	1,500	1,150	2,750	6,050	10.40
	3	1,740	2,500	1,300	1,700	7,240	15.40
	4	9,080	2,050	1,200	1,200	13,530	38.00
H	1	1,450	2,000	1,300	2,500	7,250	10.40
	3	4,200	4,900	2,600	4,550	16,250	34.40
I	1	680	1,250	950	1,970	4,850	6.98
	3	28,550	3,100	1,900	4,500	38,050	81.00
J	1	3,400	2,600	1,400	1,800	9,200	13.20
	2	2,850	3,500	1,700	1,700	9,750	16.70
	3	2,885	1,950	1,200	1,000	7,035	15.00
	4[a]	--	--	--	--	9,140	25.60
K	1	7,560	2,800	3,400	5,100	18,860	27.10
	3	3,400	4,600	2,000	1,050	11,050	23.50
L	1	2,900	3,810	2,250	2,980	11,940	17.20
	3	1,580	2,550	1,900	2,500	8,530	18.10

[a] Sector consisted mostly of material too large for sieving.

TABLE 3.2 DISTRIBUTION AND AREAL DENSITY OF EJECTA FROM COLLECTOR AREAS

No data are given for material from A and B rings, as this material was collected along with that listed in Table 3.1.

Area No.	Distance from GZ	Weight of Ejecta of Indicated Sizes			Total Weight of Ejecta	Areal Density
		>12 inches	6 to 12 inches	<6[a] inches		
	feet	pounds	pounds	pounds	pounds	lb/ft^2
1-A	75	--	--	--	--	--
1-B	100	--	--	--	--	--
1-C	125	--	67.50	79.99	147.49	1.47
1-D	150	--	25.00	43.62	68.62	0.69
1-E	200	142.00	23.75	47.12	212.87	2.13
2-A	75	--	--	--	--	--
2-B	100	--	--	--	--	--
2-C	125	--	--	--	--	--
2-D	150	76.25	135.50	406.47	618.22	6.18
2-E	200	149.00	153.25	50.62	352.87	3.53
3-A	75	--	--	--	--	--
3-B	100	--	--	--	--	--
3-C	125	244.75	242.75	343.35	830.85	8.31
3-D	150	123.50	196.25	186.11	505.86	5.06
3-E	200	--	247.00	268.36	515.36	5.15
4-A	75	--	--	--	--	--
4-B	100	--	--	--	--	--
4-C	125	--	161.00	306.23	467.23	4.67
4-D	150	--	290.75	189.24	479.99	4.80
4-E	200	--	62.75	79.37	142.12	1.42
5-A	75	--	--	--	--	--
5-B	100	--	--	--	--	--
5-C	125	131.50	34.75	87.74	253.99	2.54
5-D	150	--	39.75	99.49	139.24	1.39
5-E	200	--	79.75	32.75	112.50	1.13
6-A	75	--	--	--	--	--
6-B	100	--	--	--	--	--
6-C	125	972.00	963.25	514.08	2,449.33	24.49
6-D	150	97.25	301.50	311.60	710.35	7.10
6-E	200	166.50	43.28	78.49	288.27	2.88
7-A	75	--	--	--	--	--
7-B	100	--	--	--	--	--
7-C	125	--	89.62	59.87	149.49	1.49
7-D	150	135.50	--	61.12	196.62	1.97
7-E	200	--	44.50	126.99	171.49	1.71
8-A	75	--	--	--	--	--
8-B	100	--	--	--	--	--
8-C	125	--	--	--	--	--
8-D	150	95.00	--	35.87	130.87	1.31
8-E	200	--	65.75	72.62	138.37	1.38

[a] For further sieve analysis of material in this size class, see Table 3.3.

TABLE 3.3 RESULTS OF SIEVE ANALYSIS OF SMALL MATERIAL FROM COLLECTOR AREAS

Area No.	Weight and Percentage Retained on Indicated Sieve Sizes																Total Weight of Sample
	5 inches		4 inches		3 inches		2 inches		1 inch		1/2 inch		No. 4		Pan		
	pounds	percent	pounds	percent	pounds	percent	pounds	percent	pounds	percent	pounds	percent	pounds	percent	pounds	percent	pounds
125 feet from GZ:																	
1-C	12.10	21.8	21.98	39.5	10.37	18.7	7.03	12.6	3.58	6.4	0.25	0.4	0.08	0.1	0.21	0.4	55.60
3-C	--	--	--	--	15.23	22.4	35.50	52.3	16.31	24.0	0.44	0.6	0.12	0.2	0.26	0.4	67.86
4-C	--	--	2.49	4.2	8.66	14.7	14.68	24.9	32.43	54.9	0.48	0.8	0.15	0.2	0.16	0.3	59.05
5-C	--	--	--	--	13.17	25.4	16.83	32.5	19.75	38.1	1.50	2.9	0.27	0.5	0.29	0.6	51.81
6-C	13.28	22.8	10.28	17.6	16.61	28.5	12.54	21.5	4.74	8.1	0.13	0.2	0.55	0.9	0.21	0.4	58.34
7-C	--	--	--	--	5.12	20.7	16.83	67.9	2.55	10.3	0.11	0.4	0.06	0.2	0.10	0.4	24.77
150 feet from GZ:																	
1-D	--	--	--	--	11.24	26.6	12.74	30.2	15.47	36.6	2.22	5.3	0.17	0.4	0.42	0.9	42.26
2-D	--	--	3.21	5.1	11.76	18.6	30.77	48.7	16.62	26.3	0.32	0.5	0.24	0.4	0.27	0.4	63.19
3-D	--	--	2.80	4.3	14.26	21.7	25.32	38.6	21.63	33.0	1.10	1.7	0.23	0.3	0.29	0.4	65.63
4-D	5.19	8.0	3.73	5.7	12.43	19.1	27.18	41.7	15.28	23.4	0.87	1.4	0.25	0.4	0.20	0.3	65.13
5-D	--	--	4.41	7.2	20.37	33.1	14.56	23.6	21.08	34.2	0.55	0.9	0.33	0.5	0.33	0.5	61.63
6-D	--	--	15.78	28.0	18.78	33.3	14.17	25.1	7.08	12.5	0.35	0.6	0.09	0.2	0.14	0.3	56.39
7-D	--	--	5.33	9.0	17.89	30.3	21.75	36.7	13.74	23.2	0.19	0.3	0.07	0.1	0.23	0.4	59.20
8-D	9.62	28.0	--	--	7.35	21.4	5.13	14.9	10.46	30.4	1.15	3.3	0.18	0.5	0.53	1.5	34.42
200 feet from GZ:																	
1-E	--	--	--	--	16.70	37.6	14.02	31.5	12.00	27.0	0.83	1.9	0.24	0.5	0.67	1.5	44.46
2-E	--	--	7.20	14.7	1.51	3.1	25.24	51.6	14.25	29.1	0.26	0.5	0.13	0.2	0.37	0.8	48.96
3-E	--	--	12.35	19.0	21.88	34.4	18.26	28.7	10.37	16.3	0.42	0.7	0.12	0.2	0.22	0.3	63.62
4-E	--	--	4.21	6.8	17.48	28.1	24.59	39.5	14.45	23.2	0.91	1.5	0.18	0.3	0.39	0.6	62.21
5-E	--	--	10.17	32.4	3.27	10.4	11.15	35.5	5.94	18.9	0.54	1.8	0.06	0.2	0.24	0.8	31.37
6-E	--	--	4.39	10.3	6.71	15.8	19.64	46.1	11.03	25.9	0.62	1.5	0.08	0.2	0.12	0.3	42.59
7-E	--	--	--	--	7.77	13.1	22.27	37.4	28.09	47.2	0.98	1.7	0.15	0.2	0.22	0.4	59.48
8-E	--	--	5.27	19.7	1.42	5.3	11.67	43.5	7.05	26.3	0.50	1.8	0.21	0.8	0.71	2.6	26.83

TABLE 3.4 EJECTA AREAL DENSITIES FROM AERIAL PHOTOGRAPHY

Azimuthal Bounds[a]	Radial Distance[b]	Ejecta Areal Density
degrees	feet	lb/ft^2
249-251	488	0.0083
	513	0.0957
	538	0.0151
	563	0.0510
	588	0.0069
	613	0.0266
	638	0.0000
251-253	488	0.0589
	513	0.0962
	538	0.0690
	563	0.0289
	588	0.0277
	613	0.0738
	638	0.0128
253-255	488	0.0339
	513	0.1182
	538	0.0151
	563	0.0438
	588	0.0489
	613	0.0734
	638	0.0383
255-257	488	0.2666
	513	0.0798
	538	0.0530
	563	0.0948
	588	0.0139
	613	0.0066
	638	0.0383
	713	0.0000
	738	0.0055
	763	0.0000
	788	0.0052
	813	0.0000
	838	0.0000
	863	0.0047
	888	0.0046
257-259	488	0.2258
	513	0.5793
	538	0.1443
	563	0.1378
	588	0.0485
	613	0.1794
	638	0.1092
	713	0.0114
	738	0.0389
	763	0.0213
	788	0.0626
	813	0.0454
	838	0.0049
	863	0.0427
	888	0.0275
259-261	488	0.5518
	513	0.3352
	538	0.2208
	563	0.2038
	588	0.0554
	613	0.0066
	638	0.1142
	713	0.0460
	738	0.0055
	763	0.0320
	788	0.0465
	813	0.0150
	838	0.0146
	863	0.0236
	888	0.0553
261-263	488	0.9137
	513	0.7265
	538	0.5692
	563	0.3307
	588	0.3867
	613	0.1137
	638	0.0323
261-263 (Continued)	713	0.0346
	738	0.0166
	763	0.0213
	788	0.0210
	813	0.0200
	838	0.0097
	863	0.0142
	888	0.0000
263-265	488	0.8966
	513	0.4217
	538	0.3419
	563	0.0579
	588	0.1462
	613	0.1458
	638	0.1543
	713	0.0114
	738	0.0389
	763	0.0053
	788	0.0103
	813	0.0050
	838	0.0097
	863	0.0094
	888	0.0046
265-267	488	0.3436
	513	0.1998
	538	0.6726
	563	0.2154
	588	0.0693
	613	0.0801
	638	0.0897
	713	0.0228
	738	0.0500
	763	0.0213
	788	0.0052
	813	0.0050
	838	0.0343
	863	0.0094
	888	0.0637
267-269	713	0.0346
	738	0.0000
	763	0.0107
	788	0.0052
	813	0.0100
	838	0.0000
	863	0.0655
	888	0.0046
269-271	713	0.0057
	738	0.0000
	763	0.0000
	788	0.0052
	813	0.0000
	838	0.0049
	863	0.0000
	888	0.0000
299-301	813	0.0050
	838	0.0246
	863	0.1357
	888	0.0509
	913	0.0089
	938	0.0393
	963	0.0552
	988	0.0330
	1,013	0.0685
301-303	813	0.0100
	838	0.0194
	863	0.0330
	888	0.0413
	913	0.0315
	938	0.0174
	963	0.0296
	988	0.0371
	1,013	0.1569
303-305	813	0.0050
	838	0.0440
	863	0.0522
	888	0.0736
	913	0.0713
	938	0.0694
	963	0.0763
	988	0.1440
	1,013	0.0846
305-307	463	0.1486
	488	0.0083
	513	0.0079
	538	0.0076
	563	0.0072
	588	0.0069
	613	0.0133
	638	0.0645
	663	0.0123
	688	0.0059
	713	0.0000
	813	0.0050
	838	0.0197
	863	0.0283
	888	0.0413
	913	0.0448
	938	0.0260
	963	0.0423
	988	0.1202
	1,013	0.0806
307-309	463	0.0352
	488	0.0167
	513	0.0000
	538	0.0000
	563	0.0000
	588	0.0000
	613	0.1543
	638	0.1347
	663	0.0246
	688	0.0536
	713	0.0000
	813	0.0253
	838	0.0049
	863	0.1549
	888	0.0415
	913	0.0451
	938	0.0217
	963	0.5100
	988	0.0288
	1,013	0.0482
309-311	463	0.0264
	488	0.0167
	513	0.0079
	538	0.0000
	563	0.0000
	588	0.0000
	613	0.1004
	638	0.1543
	663	0.0740
	688	0.0414
	713	0.0000
	813	0.0203
	838	0.0194
	863	0.0427
	888	0.0229
	913	0.0089
	938	0.0130
	963	0.0000
	988	0.0124
	1,013	0.1289
311-313	463	0.0264
	488	0.0923
	513	0.0723
	538	0.0000
	563	0.0072
	588	0.0281
311-313 (Continued)	613	0.0000
	638	0.0000
	663	0.1235
	688	0.1667
	713	0.0000
313-315	463	0.0176
	488	0.0083
	513	0.0000
	538	0.0076
	563	0.0072
	588	0.0962
	613	0.0399
	638	0.0833
	663	0.1423
	688	0.0237
	713	0.0000
315-317	463	0.0088
	488	0.0668
	513	0.0944
	538	0.0151
	563	0.0000
	588	0.0346
	613	0.0399
	638	0.0961
	663	0.0925
	688	0.0950
	713	0.0000
317-319	463	0.0000
	488	0.0000
	513	0.0000
	538	0.0000
	563	0.0145
	588	0.0277
	613	0.0399
	638	0.1021
	663	0.0491
	688	0.0595
	713	0.0000
319-321	463	0.0088
	488	0.0339
	513	0.0079
	538	0.0151
	563	0.0072
	588	0.0069
	613	0.0531
	638	0.0833
	663	0.0061
	688	0.0059
	713	0.0000
321-323	463	0.0357
	488	0.0083
	513	0.0159
	538	0.0076
	563	0.0072
	588	0.0069
	613	0.0000
	638	0.0255
	663	0.0061
	688	0.0358
	713	0.0000
323-325	463	0.0890
	488	0.0000
	513	0.0079
	538	0.0076
	563	0.0000
	588	0.0069
	613	0.0133
	638	0.2113
	663	0.0556
	688	0.0776
	713	0.0000

[a] Azimuths are relative to true north.

[b] Radial distances are relative to centers of sampled areas.

TABLE 3.5 COLORED-GROUT EJECTA/FALLBACK RECOVERY DATA

Data were taken from Reference 12.

Radial	Grout Deviation Angle[a]	Distance from GZ: Preshot	Distance from GZ: Postshot	Preshot Depth
	degrees	feet	feet	feet
1	0	10	11	5
	0	10	14	5
	30S	10	15	3
	0	15	18	8
	0	15	18	7
	0	20	30	6
	0	20	31	6
	0	20	31	6
	0	20	33	5
	0	30	36	4
	0	5	38	4
	0	10	63	6
	5S	30	64	2
	8S	25	67	5
	5S	30	68	3
	5N	10	70	6
	9S	20	72	3
	8S	30	75	1
	3S	30	90	2
	6S	20	95	5
	5N	30	100	1
	4S	20	105	6
	6S	10	105	4
	3N	30	110	1
	3N	25	110	5
	4N	25	110	5
	4S	20	115	5
	4S	20	125	5
	0	30	127	1
	6S	10	127	4
	4S	20	130	4
	5S	20	130	4
	3S	30	140	1
	5S	20	145	4
	0	20	150	5
	0	30	150	1
	2S	25	150	5
	4N	10	160	4
	0	20	175	4
	0	25	180	5
	0	25	200	5
	0	20	200	3
	4S	20	300	4
	4S	20	300	4
	3S	20	300	4
	1S	20	305	4
	7S	20	310	1
	10N	20	320	2
	3S	20	320	4
	3S	20	320	3
	4N	25	320	5
	3N	10	325	4
	0	20	330	4
	0	25	330	3
	4N	25	330	4
1 (Continued)	0	25	340	3
	0	25	350	4
	0	25	350	3
	0	10	350	3
	0	10	400	4
	0	15	450	4
	0	15	485	3
	0	15	490	4
	0	15	500	6
	0	15	580	3
	0	15	600	3
	5N	20	650	1
	6N	10	680	2
	3N	20	700	2
	3N	20	750	1
	0	15	800	5
	1S	10	1,000	1
	0	15	1,000	2
	0	15	1,000	5
	3N	20	1,000	1
	1S	10	1,050	4
	0	20	1,085	1
	0	20	1,100	2
	0	20	1,100	2
	3S	10	1,100	1
	0	20	1,120	2
	0	20	1,125	2
	0	20	1,125	1
	0	20	1,125	1
	0	20	1,125	3
	5N	20	1,150	1
	5N	20	1,300	2
	5S	15	1,450	2
	3N	15	1,450	2
	0	10	1,450	1
3	15E	0	10	4
	15E	0	13	5
	0	20	25	7
	0	30	40	1
	0	30	45	1
	0	20	240	6
	0	20	250	7
	1W	20	260	6
	1W	20	265	7
	1W	20	265	6
	2W	0	270	6
	0	0	330	6
	5W	0	380	6
	1W	20	550	4
	2W	20	600	5
	1W	20	600	4
	0	20	640	4
	2W	20	660	3
	0	20	660	4
	2W	20	670	4

(Continued)

[a] Angle of deviation of grout fragment location is relative to a line extending from GZ through the grout column location from which the fragment originated. North, east, west, and south are shown by appropriate abbreviations.

TABLE 3.5 (CONCLUDED)

Radial	Grout Deviation Angle	Distance from GZ		Preshot Depth
		Preshot	Postshot	
	degrees	feet	feet	feet
3 (Continued)	0	20	685	2
	2W	20	690	3
	0	20	700	4
	2W	20	700	3
	2W	20	700	3
	3W	20	790	1
	2W	20	800	2
	2W	20	810	3
	2W	20	840	2
	1W	20	850	2
	0	20	850	3
	0	20	850	3
	0	20	850	3
	0	20	850	3
	1W	20	860	2
	0	20	950	2
	4E	20	1,130	1
	4E	20	1,140	1
	4E	20	1,150	1
	5E	20	1,350	2
6	14N	5	8	5
	14N	5	10	4
	14N	5	11	6
	14N	5	11	5
	14N	5	11	6
	14N	5	11	7
	5N	20	28	6
	5N	20	30	5
	5N	30	98	3
	5N	30	98	2
	21S	10	102	1
	5N	30	103	3
	5S	30	125	2
	2N	30	135	1
	4N	30	170	1
	4N	30	185	1
	0	10	220	7
	0	10	230	6
	0	10	290	7
	12S	10	325	4
	12S	10	325	5
	12S	10	340	6
	3N	10	340	7
	10S	10	350	7
	9S	10	360	5
	3N	10	370	5
	14S	10	400	4
	3N	10	405	5
	8S	10	405	6
	12S	10	410	3
	1N	10	440	6
	12S	10	460	3
	0	10	490	6
	10S	10	540	4
7	20E	5	10	8
	25E	5	15	7
	15E	5	15	3
	10E	10	20	6
	3E	25	44	4
	0	15	45	6

Radial	Grout Deviation Angle	Distance from GZ		Preshot Depth
		Preshot	Postshot	
	degrees	feet	feet	feet
7 (Continued)	7E	5	48	5
	5E	25	50	5
	5E	25	50	3
	5E	30	50	1
	6E	5	72	6
	4E	5	95	6
	2E	5	100	10
	2E	5	100	1
	5E	30	127	4
	3E	30	130	2
	3E	15	130	2
	3E	15	130	5
	5W	5	135	5
	2W	30	139	2
	3E	30	140	3
	0	30	140	2
	0	15	145	4
	3E	5	150	5
	3W	30	154	2
	0	5	250	7
	2W	20	250	2
	2E	20	252	2
	2E	20	253	2
	2W	20	255	2
	2W	30	255	6
	3W	20	260	2
	2W	25	265	2
	3W	25	275	4
	3W	30	280	1
	0	20	285	3
	2W	5	290	5
	3W	5	295	6
	3W	5	298	6
	2W	5	325	7
	0	15	330	5
	5E	15	333	3
	10E	25	350	2
	2E	15	365	3
	5W	5	370	4
	3E	15	370	4
	2E	15	375	4
	10W	5	380	4
	0	15	380	3
	5E	15	380	4
	2W	25	436	1
	4E	15	460	4
	10E	15	550	3
	4E	15	580	2
	8E	15	700	2
	8E	15	750	2
	10E	15	780	2
	4E	20	794	2
	0	15	830	1
	0	10	830	1
	10E	20	900	1
	0	15	1,000	1
	10E	15	1,000	2
	3E	15	1,075	2
	5E	15	1,100	1
	10E	20	1,150	1
	5E	15	1,250	1
	5E	15	1,300	1

TABLE 3.6 WES ARTIFICIAL MISSILE DATA

Package No.	Missile Type[a]	Original Position: Distance from GZ	Original Position: Depth Below Surface	Distance Ejected
		feet	feet	feet
South Radial (205 missiles):				
112	C-1	2.47	1.72	30
112	C-2		1.84	28
112	C-4		2.09	25
113	C-1/2		2.31	17
113	C-2		2.51	16
113	S-2-S		3.28	11
114	C-1/2		3.63	12
114	C-2		3.83	10
114	C-4		4.08	12
115	C-1/2		4.30	11
115	C-4		4.75	10
121	C-4	4.97	1.29	24
121	S-2-A		1.80	18
122	C-1		2.24	20
122	C-2		2.36	20
122	C-4		2.61	18
123	C-1/4		2.84	17
123	C-4		3.29	21
123	S-2-S		3.81	14
123	S-1-S		3.81	15
124	C-1/4		4.16	8
124	C-1/4		4.16	8
124	C-1/2		4.16	8
124	C-1		4.24	8
124	C-2		4.36	8
131	S-2-A	7.47	2.02	808
132	C-1/4		2.29	540
132	C-1		2.37	524
132	C-2		2.49	524
132	C-4		2.74	803
133	C-1/2		2.96	608
133	C-2		3.16	422
133	C-4		3.41	458
133	S-2-A		3.60	474
134	C-1		4.33	139
134	C-2		4.45	139
134	C-4		4.70	134
135	C-1/4		4.92	133
135	C-1/2		4.92	120
135	C-1		5.00	130
135	C-2		5.12	130
135	C-4		5.37	122
136	C-1		5.67	124
136	C-2		5.79	124
136	C-4		5.94	118
136	S-2-S		6.53	82
137	C-1/2		6.88	99
137	C-1		6.96	65
137	C-2		7.08	65
141	C-2	10.00	1.38	973
141	S-2-S		2.13	926
142	C-1/2		2.49	463
142	C-1		2.58	636
142	C-2		2.69	636
142	C-4		2.94	633
143	C-1		3.25	481
143	C-2		3.37	481
143	C-4		3.62	454
143	S-2-A		4.15	354
143	S-1-S		4.15	228
144	C-1		4.60	157
144	C-2		4.72	157
144	C-4		4.97	163
145	C-4		5.65	64
146	C-1/4		5.88	76
146	C-1/4		5.88	78
146	C-1		5.96	58
146	C-2		6.08	58
146	C-4		6.33	80
146	S-1-S		6.81	65
146	S-2-P		6.81	85
146	S-2-A		6.81	78
146	S-1-S		6.81	78
146	S-1-A		6.81	78
146	S-1-P		6.81	78
147	C-1		7.24	56
147	C-2		7.36	54
147	C-4		7.61	54
149	C-1		8.51	30
149	C-4		8.96	19
151	C-1/2	12.50	0.83	629
151	C-2		1.03	920
South Radial (205 missiles): (Continued)				
152	C-1	12.50	2.25	597
152	C-2		2.37	645
152	C-4		2.62	643
153	C-1/2		2.84	487
153	C-1		2.92	513
153	C-2		3.04	157
153	C-4		3.29	160
153	S-1-A		3.80	151
153	S-1-P		3.80	160
154	C-1/4		4.15	156
154	C-1/2		4.15	167
154	C-4		4.60	150
155	C-1/4		4.82	163
155	C-1/2		4.82	150
155	C-1		4.90	163
155	C-2		5.02	163
156	C-1/4		5.49	150
156	C-1/2		5.49	140
156	C-4		5.94	51
156	S-2-S		6.40	38
156	S-1-S		6.40	40
161	C-4	15.00	1.29	977
161	S-1-S		1.78	947
161	S-1-A		1.78	860
161	S-1-A		1.78	834
162	C-1/4		2.14	700
162	C-1/2		2.14	516
162	C-1		2.22	580
162	C-2		2.34	165
163	C-1/4		2.82	160
163	C-1		2.94	160
163	C-2		3.02	169
163	C-4		3.27	165
163	S-1-S		3.77	155
163	S-1-P		3.77	160
163	S-2-A		3.77	156
163	S-2-P		3.77	157
163	S-1-A		3.77	167
163	S-1-A		3.77	160
164	C-1/4		4.13	161
164	C-1/2		4.13	160
164	C-1		4.21	161
164	C-2		4.33	160
164	C-4		4.58	160
165	C-1/4		4.80	155
165	C-1/4		4.80	157
165	C-1/2		4.80	156
165	C-1		4.88	155
165	C-2		5.00	152
165	C-4		5.25	147
166	C-1		5.56	150
166	C-2		5.68	142
166	C-4		5.93	142
166	11 1-inch spheres		6.41	142
167	C-1/4		6.76	142
167	C-1/4		6.76	142
167	C-1/2		6.76	142
167	C-1		6.84	142
167	C-2		6.96	142
167	C-4		7.21	137
168	C-1/4		7.43	145
168	C-1/4		7.43	142
168	C-1/2		7.43	142
168	C-1		7.51	78
171	C-1/4	20.00	0.44	618
171	C-4		0.99	975
171	S-2-S		1.41	523
171	S-1-S		1.41	340
172	C-1/4		1.72	240
172	C-1/2		1.72	237
172	C-1		1.80	256
172	C-2		1.92	244
172	C-4		2.17	263
173	C-1/4		2.39	264
173	C-1/4		2.39	262
173	C-1/2		2.39	251
173	C-1		2.47	262
173	C-2		2.59	262
173	C-4		2.84	266
174	C-1		3.15	215
South Radial (205 missiles): (Continued)				
174	C-2	20.00	3.27	224
174	C-4		3.52	165
175	C-1/4		3.74	151
175	C-1/4		3.74	151
175	C-1/2		3.74	151
175	C-1		3.82	151
175	C-2		3.94	151
175	C-4		4.19	155
181	C-1/2	25.00	0.62	459
181	C-1		0.70	447
181	C-2		0.82	498
181	C-4		1.07	355
181	S-2-A		1.63	367
181	S-2-L		1.63	335
181	S-2-P		1.63	213
181	S-2-S		1.63	413
181	S-1-A		1.63	395
181	S-1-L		1.63	248
181	S-1-L		1.63	365
181	S-1-P		1.63	382
181	S-1-S		1.63	365
181	S-1-S		1.63	375
182	C-1/4		2.03	257
182	C-1/2		2.03	255
182	C-1		2.11	258
182	C-2		2.23	247
182	C-4		2.48	165
183	C-1/4		2.70	104
183	C-1		2.78	117
183	C-4		3.15	96
184	C-1/2		3.37	61
184	C-1		3.45	61
184	C-2		3.57	47
West Radial (214 missiles):				
211	C-2	2.47	0.96	30
211	C-4		1.21	19
212	C-1		2.17	9
212	C-2		2.29	18
212	C-4		2.54	17
213	C-1/4		2.76	12
213	C-1/2		2.76	10
213	C-1		2.84	9
213	C-2		2.96	8
221	C-4	5.00	1.37	78
221	S-1-S		1.87	78
221	S-1-S		1.87	63
221	S-1-A		1.87	78
222	C-2		2.42	20
223	S-2-S		3.85	12
224	C-1/2		4.20	8
224	C-1		4.28	4
224	C-2		4.40	4
224	C-4		4.65	4
225	C-1		4.96	7
225	C-2		5.08	7
225	C-4		5.33	7
226	C-1/4		5.56	10
226	C-1/2		5.56	8
226	C-1		5.64	10
226	C-2		5.76	10
226	C-4		6.01	10
231	C-1/2	7.46	0.50	795
231	C-1		0.58	880
232	C-4		2.26	573
233	C-1		2.55	531
233	C-2		2.67	578
233	C-4		2.92	437
233	S-2-A		3.45	368
233	S-2-S		3.45	432
234	C-1		3.93	118
234	C-2		4.05	352
				317
235	C-1/2		4.51	68
235	C-1		4.59	38
235	C-2		4.71	71
235	C-4		4.96	84
236	C-2		5.26	75
236	C-4		5.63	58
236	S-2-S		6.13	63
236	S-1-A		6.13	78

(Continued)

[a] Key to missile types:

C-1/4	one-quarter wedge of 1-inch cylinder
C-1/2	one-half wedge of 1-inch cylinder
C-1	1-inch cylinder
C-2	2-inch cylinder
C-4	4-inch cylinder
S-1-A	1-inch aluminum sphere
S-2-A	2-inch aluminum sphere
S-1-L	1-inch lead sphere
S-2-L	2-inch lead sphere
S-1-P	1-inch plastic sphere
S-2-P	2-inch plastic sphere
S-1-S	1-inch steel sphere
S-2-S	2-inch steel sphere

TABLE 3.6 (CONCLUDED)

Package No.	Missile Type	Original Position: Distance from GZ	Original Position: Depth Below Surface	Distance Ejected
		feet	feet	feet
West Radial (214 missiles): (Continued)				
241	S-2-A	10.00	1.83	1,159
241	S-1-A		1.83	597
242	C-1/4		2.18	465
242	C-1/2		2.18	504
242	C-1		2.26	465
242	C-2		2.38	415
243	C-1/4		2.85	402
243	C-1/2		2.85	412
243	C-1		2.93	520
243	C-2		3.05	526
243	C-4		3.30	519
243	S-2-P		3.80	652
243	S-2-A		3.80	490
243	S-1-A		3.80	416
243	S-1-S		3.80	517
244	C-1/4		4.15	362
244	C-1/4		4.15	306
244	C-1/2		4.15	334
244	C-1		4.23	341
244	C-2		4.35	346
244	C-4		4.30	318
245	C-1/4		4.82	301
245	C-1/4		4.82	290
245	C-1		4.90	336
245	C-2		5.02	365
245	C-4		5.27	440
246	C-1/4		5.48	342
246	C-1/4		5.48	353
246	C-1/2		5.48	349
246	C-1		5.56	406
246	C-2		5.68	406
246	C-4		5.93	399
246	S-2-A		6.49	171
246	S-2-L		6.49	171
246	S-2-P		6.49	171
246	S-2-S		6.49	171
246	All small spheres (12)		6.49	171
247	C-1/4		6.86	171
247	C-1/4		6.86	171
247	C-1/2		6.86	171
247	C-1		6.94	177
247	C-2		7.06	177
247	C-4		7.31	115
248	C-1/4		7.54	110
248	C-1/2		7.54	82
248	C-1		7.62	80
248	C-4		7.99	13
249	C-1/4		8.21	12
249	C-1/2		8.21	12
249	C-1		8.29	12
249	C-2		8.41	12
249	C-4		8.66	12
250	C-1/2	12.49	0.53	1,240
251	C-2		1.28	1,323
252	C-1		2.49	867
252	C-2		2.61	748
252	C-4		2.98	674
				466
253	C-1/4		3.20	388
253	C-1		3.28	415
253	C-2		3.40	485
253	S-2-A		4.15	407
253	S-2-S		4.15	342
254	C-1/4		4.51	273
254	C-1		4.59	324
254	C-2		4.71	288
254	C-4		4.96	318
				221
255	C-1/4		5.18	231
255	C-1		5.26	172
255	C-2		5.38	219
255	C-4		5.63	228
256	C-1/4		5.85	221
256	C-1/2		5.85	204
256	C-1		5.93	182
256	C-2		6.05	225
256	S-2-A		6.78	84
256	S-2-S		6.78	93
256	S-1-S		6.78	63
257	C-1		7.22	102
257	C-2		7.34	93
257	C-4		7.59	60
258	C-4		8.26	21
260	C-4	15.00	0.67	2,165
262	C-2		2.39	1,281
262	C-4		2.64	1,314
263	C-1		2.95	999
263	C-2		3.07	1,037
263	S-1-A		3.88	171
263	S-1-S		3.88	155
263	S-1-S		3.88	155
263	S-1-A	15.00	3.88	159
263	S-2-S		3.88	161
264	C-1/4		4.24	155
264	C-1/2		4.24	142
264	C-2		4.44	162
264	C-4		4.69	162
265	C-1/4		4.91	164
265	C-1/4		4.91	164
265	C-1/2		4.91	164
266	C-1/4		5.58	168
266	C-1/4		5.58	171
266	C-1/2		5.58	163
266	C-1		5.66	188
266	C-2		5.78	181
266	C-4		6.03	74
266	S-2-A		6.53	75
266	S-2-S		6.53	38
266	S-1-A		6.53	59
267	C-1/4		6.90	35
267	C-1		6.98	35
267	C-4		7.35	42
268	C-2		7.74	35
269	C-1/4		8.24	17
269	C-1/4		8.24	17
269	C-1/2		8.24	17
269	C-1		8.32	17
269	C-2		8.44	17
269	C-4		8.69	16
271	S-2-S	19.95	1.36	932
272	C-1/4		1.72	461
272	C-1/4		1.72	420
272	C-1/2		1.72	540
272	C-1		1.80	455
272	C-4		2.17	245
273	C-1/4		2.40	183
273	C-1/4		2.40	179
273	C-1		2.48	156
273	C-2		2.60	172
273	C-4		2.85	139
274	C-1/2		3.10	93
274	C-1		3.18	93
274	C-2		3.30	93
274	C-4		3.55	93
275	C-1/4		3.76	93
275	C-1/4		3.76	93
275	C-1/2		3.76	93
275	C-1		3.84	93
275	C-2		3.96	93
281	C-1/4	24.98	1.25	341
281	C-1/2		1.25	344
281	C-1		1.33	333
281	C-2		1.45	368
281	C-4		1.70	285
281	S-2-A		2.24	180
281	S-2-S		2.24	151
281	S-1-S		2.24	178
282	C-1		2.61	145
282	C-2		2.83	142
282	C-4		3.08	110
283	C-1/4		3.30	120
283	C-1/2		3.30	119
283	C-1		3.38	119
283	C-4		3.75	116
284	C-2		4.18	107
284	C-4		4.43	107
285	C-1/2		4.66	134
285	C-1		4.74	93
285	C-2		4.86	93
285	C-4		5.11	61
North Radial (110 missiles):				
311	C-1	2.49	0.71	24
311	C-2		0.83	12
313	S-2-A		1.57	10
323	C-4	4.98	2.07	22
323	S-1-A		2.61	20
331	S-2-S	7.53	2.05	29
336	C-1/4		5.76	20
336	C-1/2		5.76	19
336	C-1		5.84	19
336	C-2		5.96	19
336	C-4		6.21	19
341	C-4	10.02	1.03	313
341	S-2-A		1.55	269
341	S-2-S		1.55	232
341	S-1-S		1.55	219
341	S-1-S		1.55	213
342	C-1/2		1.90	166
342	C-2		2.00	185
342	C-4		2.35	93
343	C-2		2.77	87
North Radial (110 missiles): (Continued)				
343	C-4	10.02	3.02	158
344	C-1		3.94	98
344	C-2		4.04	98
344	C-4		4.31	98
345	C-4		4.99	62
				34
351	C-1	12.48	1.54	392
351	C-4		1.91	529
351	S-2-A		2.41	472
351	S-2-S		2.41	436
351	S-1-A		2.41	360
352	C-1/2		2.76	330
352	C-1		2.84	331
352	C-2		2.96	316
352	C-4		3.21	356
353	C-1/4		3.43	284
353	C-2		3.63	52
353	S-2-S		4.39	22
355	C-4		5.80	15
356	C-2		6.27	14
356	C-4		6.52	14
356	S-2-P		7.00	14
356	S-2-L		7.00	10
356	S-1-S		7.00	10
356	S-1-S		7.00	10
356	S-1-P		7.00	10
356	S-1-A		7.00	10
361	C-1/2	15.02	0.49	2,070
361	C-4		0.94	2,150
361	S-1-A		1.49	956
362	C-1/4		1.87	137
362	C-1		1.95	118
362	C-2		2.07	123
362	C-4		2.32	155
363	C-1/4		2.55	130
363	C-1/4		2.55	135
363	C-1/2		2.55	144
363	C-1		2.63	146
363	C-2		2.75	145
363	S-2-A		3.54	60
363	S-2-P		3.54	51
364	C-4		4.36	22
365	C-1		4.66	21
365	C-2		4.78	14
365	C-4		5.03	14
366	C-1/4		5.26	14
366	C-1/4		5.26	14
366	C-1/2		5.26	14
366	C-1		5.34	14
366	C-2		5.46	14
366	C-4		5.71	14
366	S-2-S		6.24	16
366	S-1-S		6.24	17
371	C-1/2	20.00	0.14	712
371	C-2		0.34	957
371	C-4		0.59	957
371	S-2-S		1.11	964
371	S-2-A		1.11	963
371	S-1-A		1.11	796
372	C-1/2		1.46	771
372	C-1		1.54	758
372	C-2		1.66	751
372	C-4		1.91	618
373	C-1/2		2.14	416
373	C-2		2.34	444
373	C-4		2.59	445
374	C-1/4		2.82	85
374	C-1/2		2.82	195
375	C-1/2		3.73	200
375	C-1		3.81	122
375	C-2		3.93	123
381	C-4	25.00	1.15	122
381	S-1-S		1.66	138
381	S-2-S		1.66	105
381	S-2-L		1.66	109
381	S-2-A		1.66	152
382	C-1/4		2.01	100
382	C-1/4		2.01	100
382	C-1/2		2.01	104
382	C-1		2.09	104
382	C-2		2.21	94
382	C-4		2.46	98
383	C-1/4		2.68	74
383	C-1/2		2.68	74
383	C-1		4.17	68
383	C-2		2.88	82
383	C-4		3.13	57
384	C-1/4		3.36	58
384	C-1		3.44	59
385	C-2		4.29	49
385	C-4		4.54	52

TABLE 3.7 RANGES FOR EJECTED 7.4-INCH-DIAMETER ALUMINUM SPHERES

One unidentifiable sphere was found 16 feet from GZ.

Missile	Hole[a]	Depth of Burial	Range
		feet	feet
1	1	0.53	NR[b]
2	1	1.41	20
3	1	2.02	NR
4	1	2.63	NR
5	1	3.24	NR
6	1	3.83	NR
7	2	0.98	55
8	2	1.58	23
9	2	2.20	24
10	2	2.82	24
11	2	3.42	20
12	2	4.09	19
13	NE[c]	NE	NE
14	3	0.30	251
15	3	0.84	260
16	3	1.47	297
17	3	2.07	112
18	3	2.65	108
19	4	1.21	984
20	4	1.84	411
21	4	2.45	410
22	4	3.07	313
23	4	3.68	124
24	4	4.28	99

[a] Key to preshot locations:
Hole 1 - 3.79 feet from GZ, 345°10'20" azimuth;
Hole 2 - 6.25 feet from GZ, 6°42'00" azimuth;
Hole 3 - 8.78 feet from GZ, 12°12'00" azimuth;
Hole 4 - 11.28 feet from GZ, 14°00'40" azimuth.

[b] NR--not recovered.

[c] NE--not emplaced.

TABLE 3.8 IMPACT DATA FOR MISSILES CAUGHT IN STYROFOAM MISSILE TRAPS

Nominal Diameter[a]	Missile Weight	Range	Impact Angle Relative to Horizontal	Penetration Depth	Calculated Impact Velocity
inches	pounds	feet	degrees	feet	ft/sec
1.75	0.12	607	84	0.13	73
1.50	0.16	346	83	0.07	55
1.50	0.09	509	75	0.11	70
0.90	0.05	706	77	0.13	92

[a] Smallest sieve opening through which particle could pass.

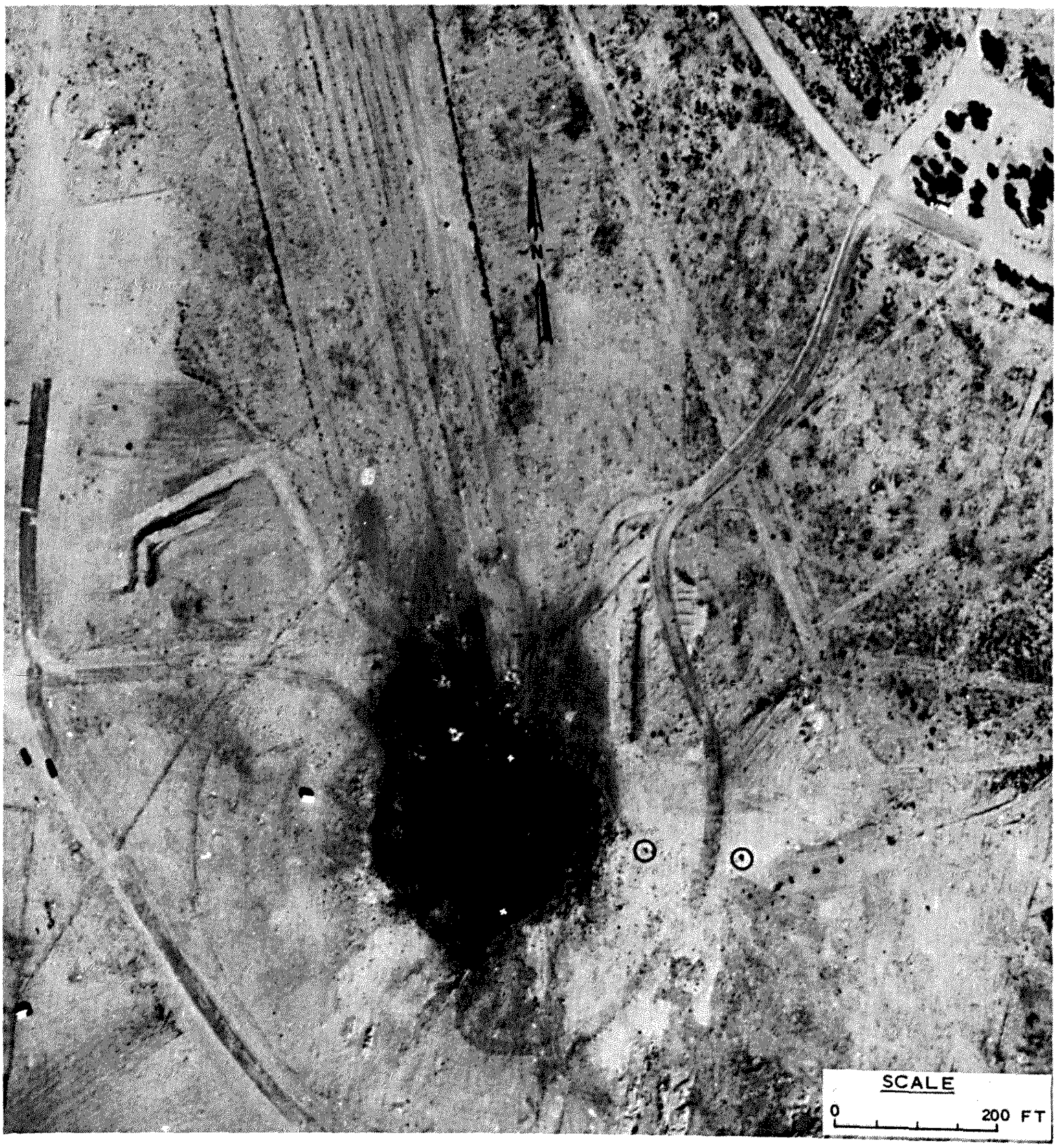


Figure 3.1 Mineral Rock apparent crater and adjacent debris field. Circles indicate large particles described in Section 3.1.

Figure 3.2 A 400-pound fragment of a larger missile that landed about 1,200 feet northeast of GZ. This fragment (circle) was part of a larger missile whose splash crater is visible in the foreground of the picture. Part of the large missile also struck one of the trees in the background; the broken branches are visible to the left (arrow).

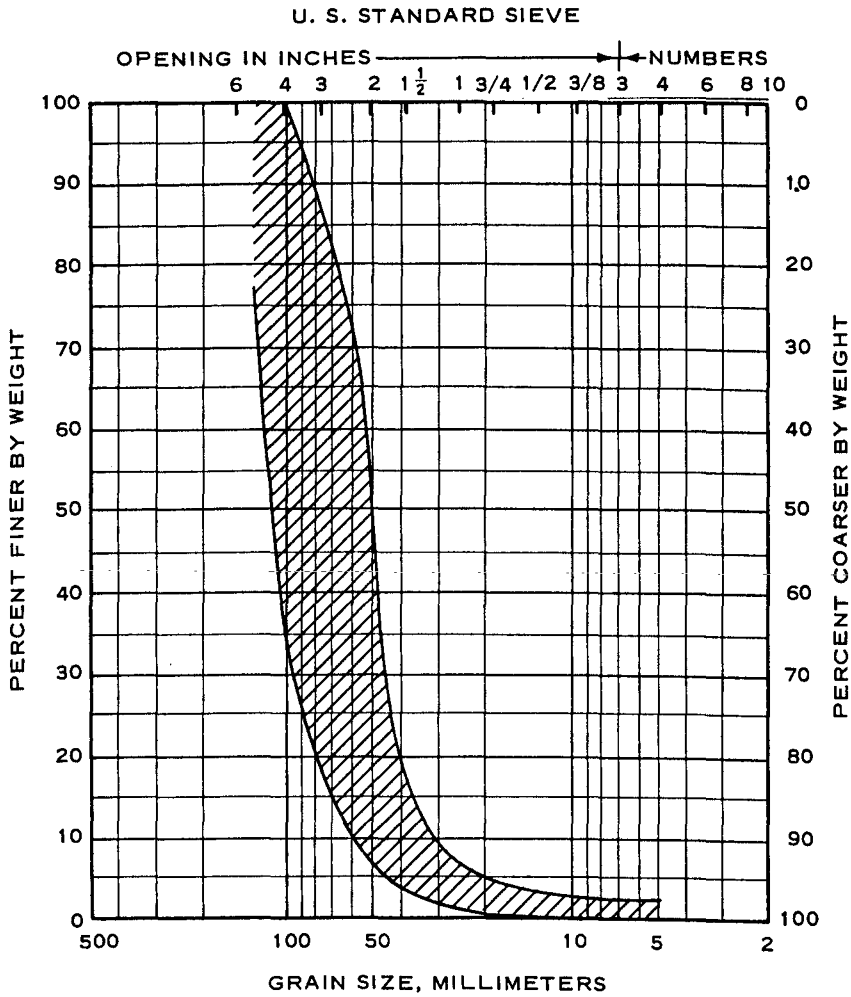


Figure 3.3 Range of particle-size distributions for <6-inch ejecta particles in collector areas (see Table 3.3).

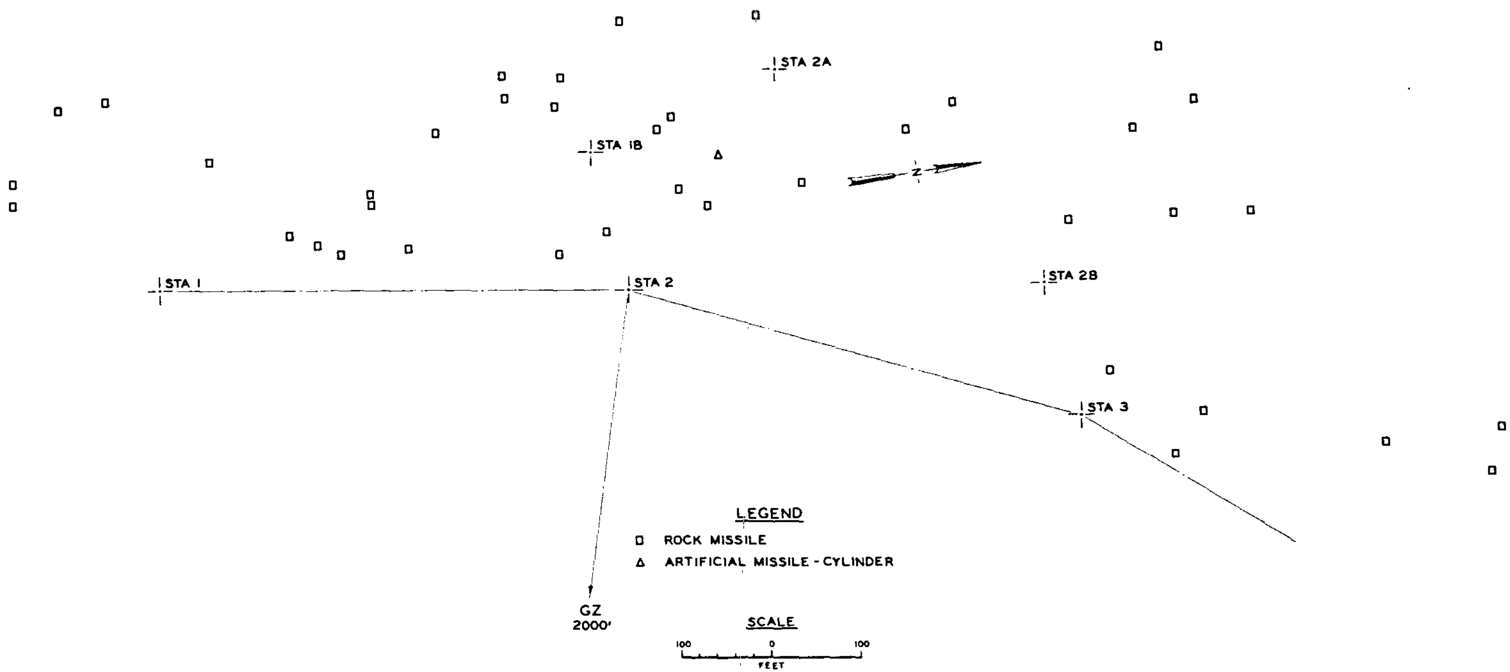


Figure 3.4 Plane-table survey of the ejecta field periphery, Stations 1 through 12. Terrain became quite broken near Station 12, and it was suspected that the graded area had been disturbed postshot (sheet 1 of 4).

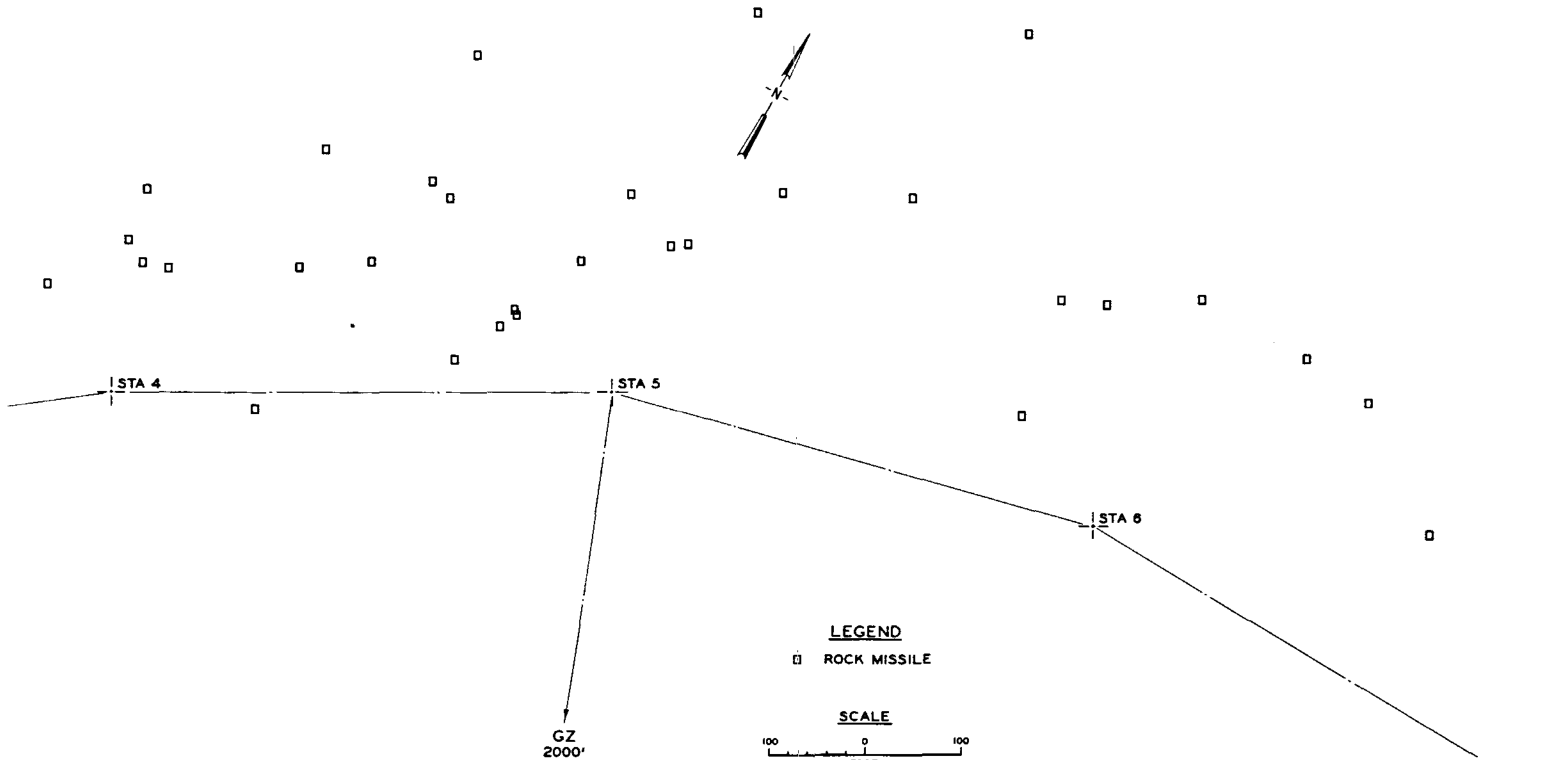


Figure 3.4 (sheet 2 of 4).

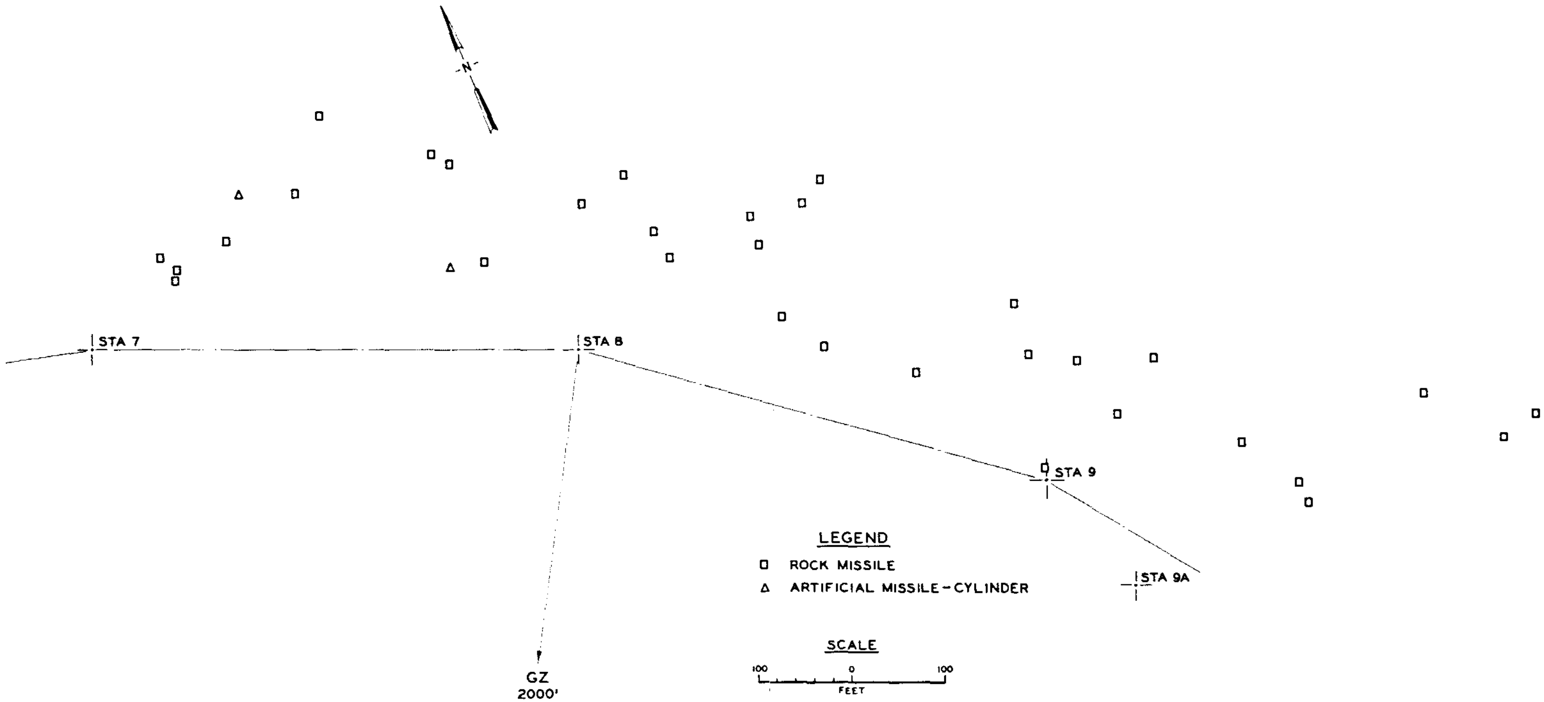


Figure 3.4 (sheet 3 of 4).

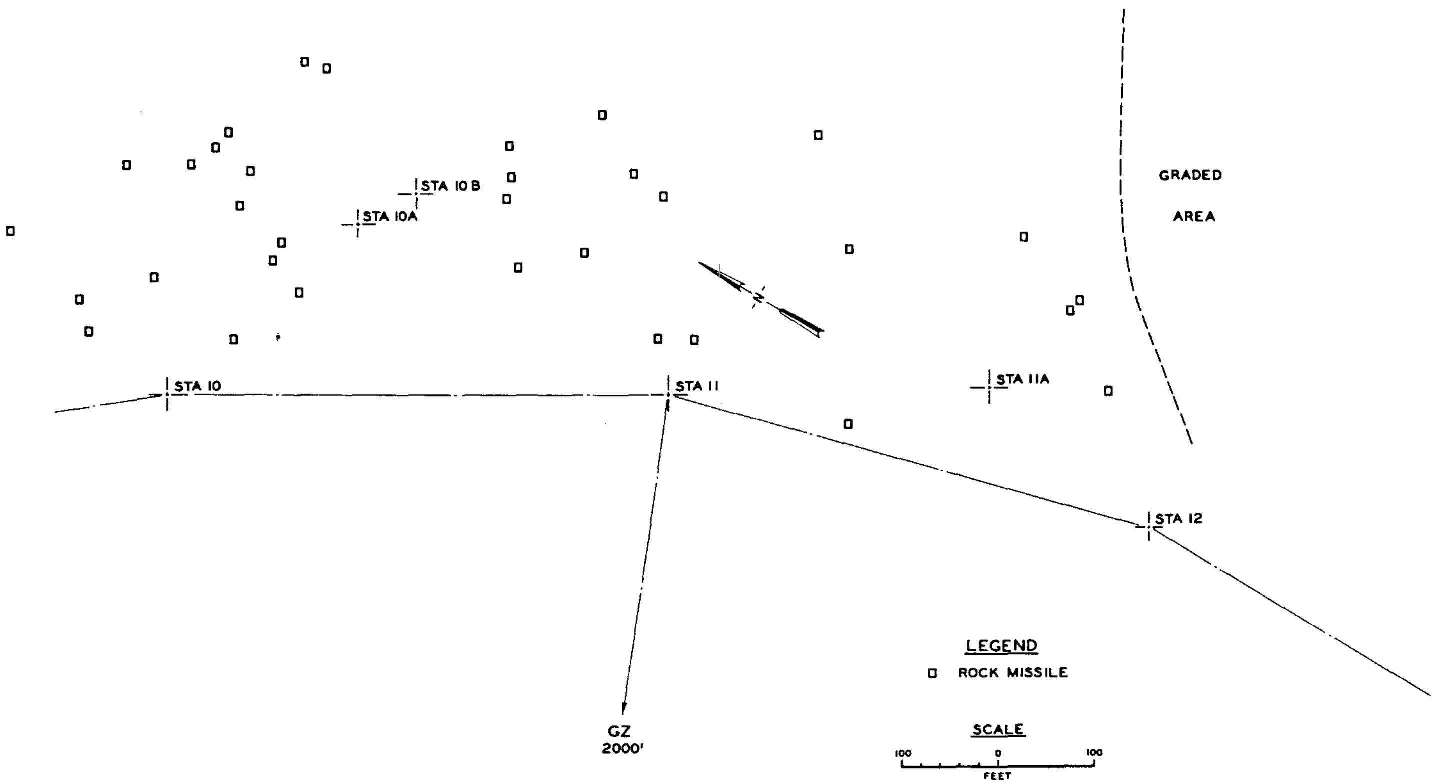


Figure 3.4 (sheet 4 of 4).

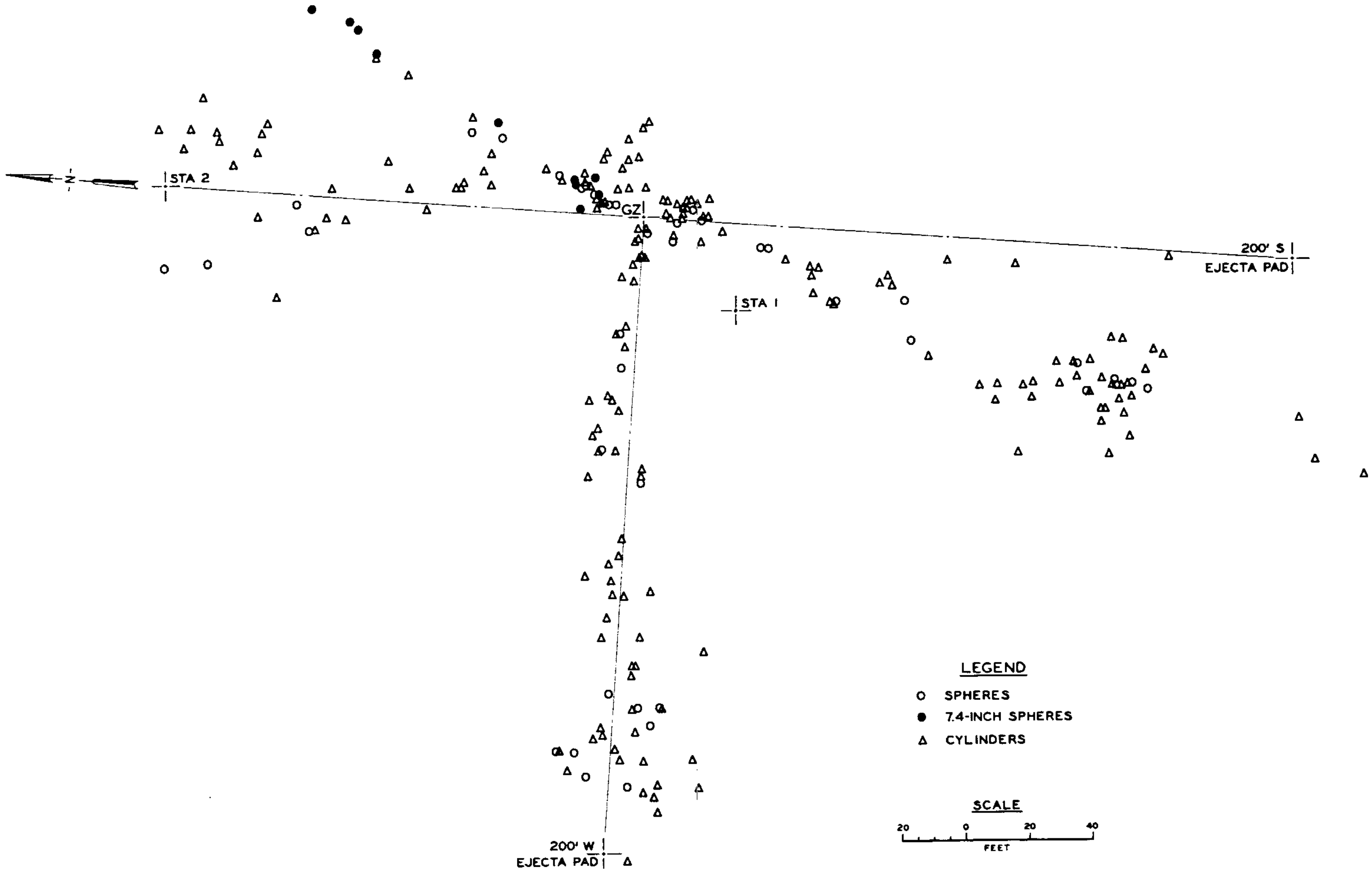


Figure 3.5 Final artificial missile positions in the crater area.

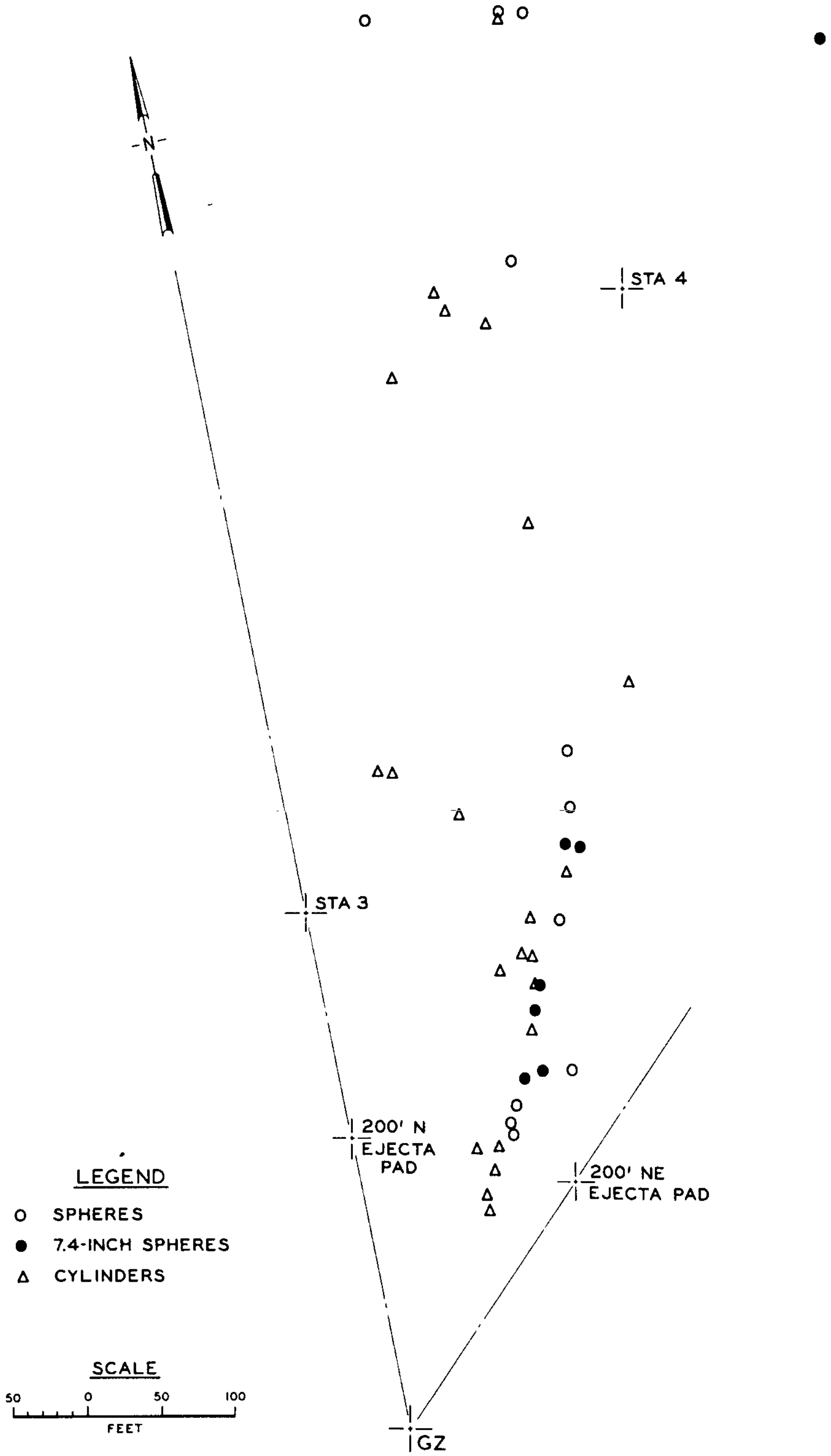


Figure 3.6 Final artificial missile positions along the north radial.

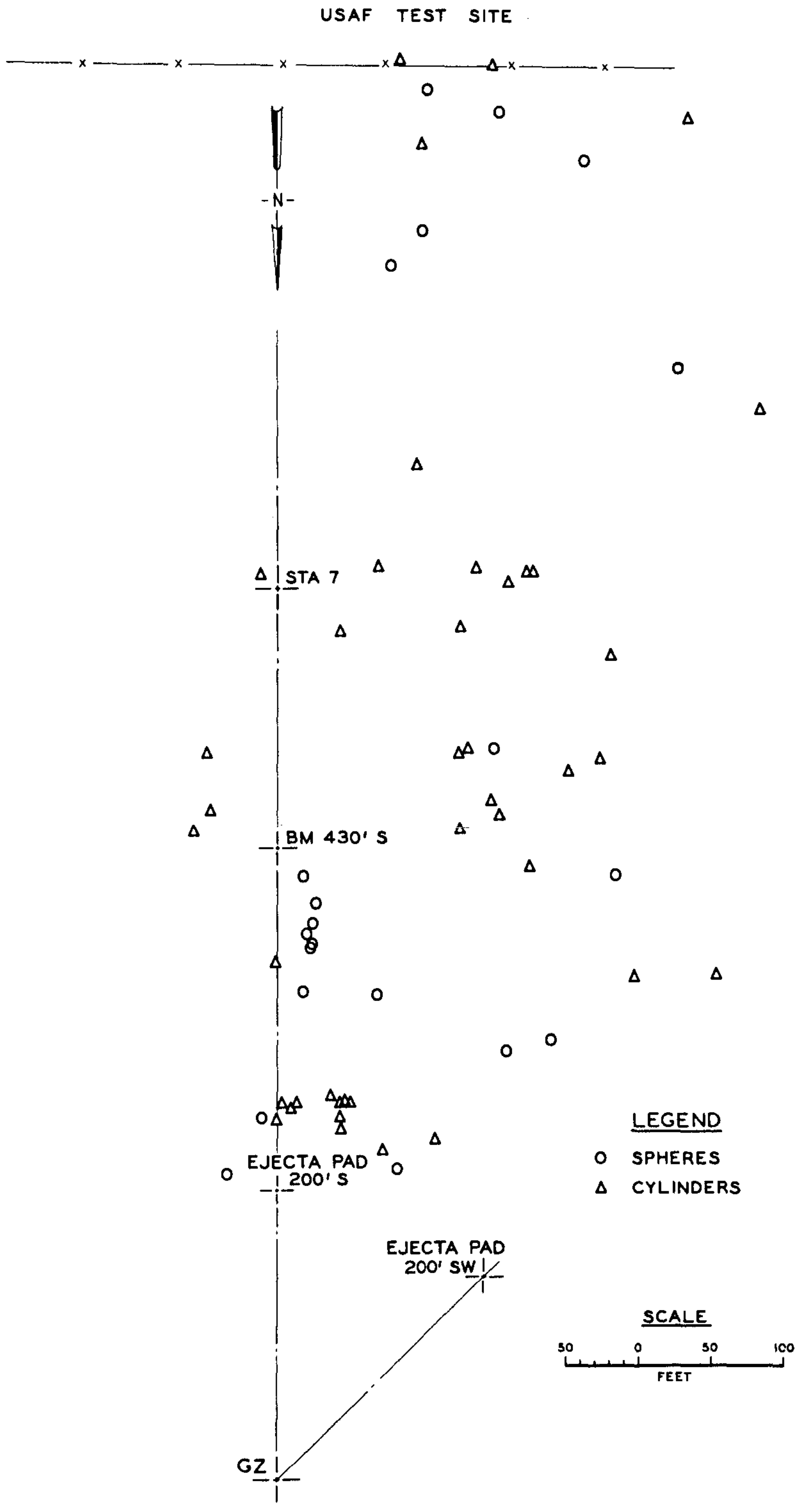


Figure 3.7 Final artificial missile positions along the south radial.

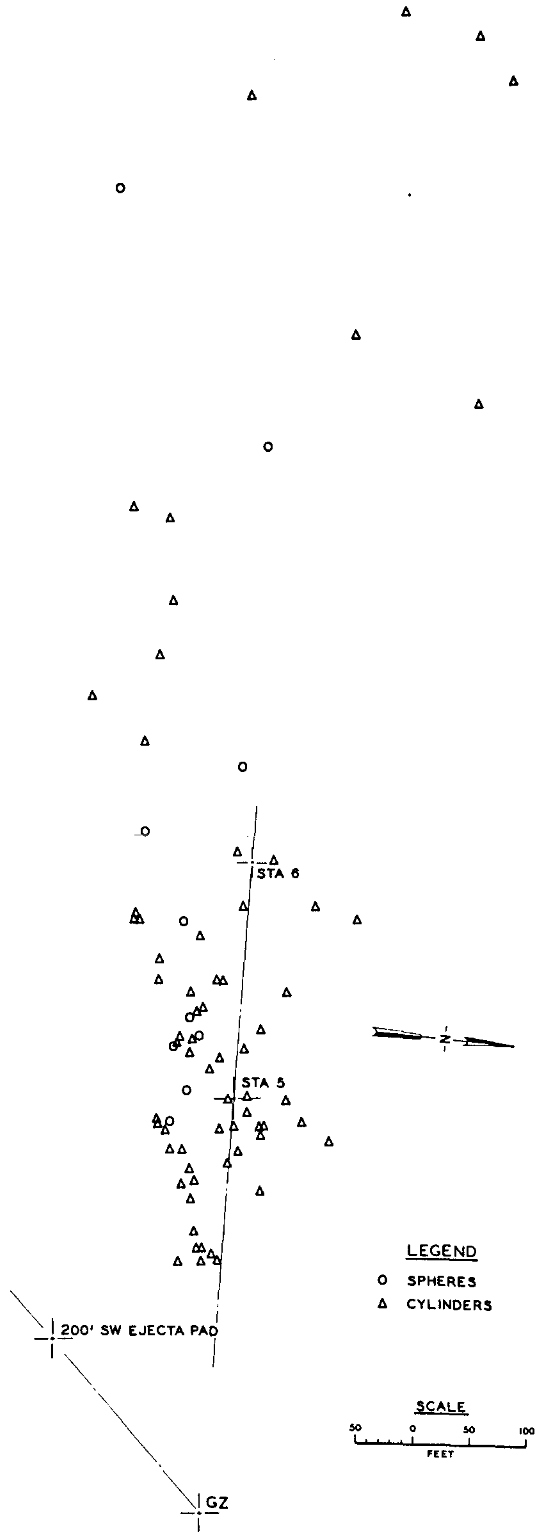


Figure 3.8 Final artificial missile positions along the west radial.

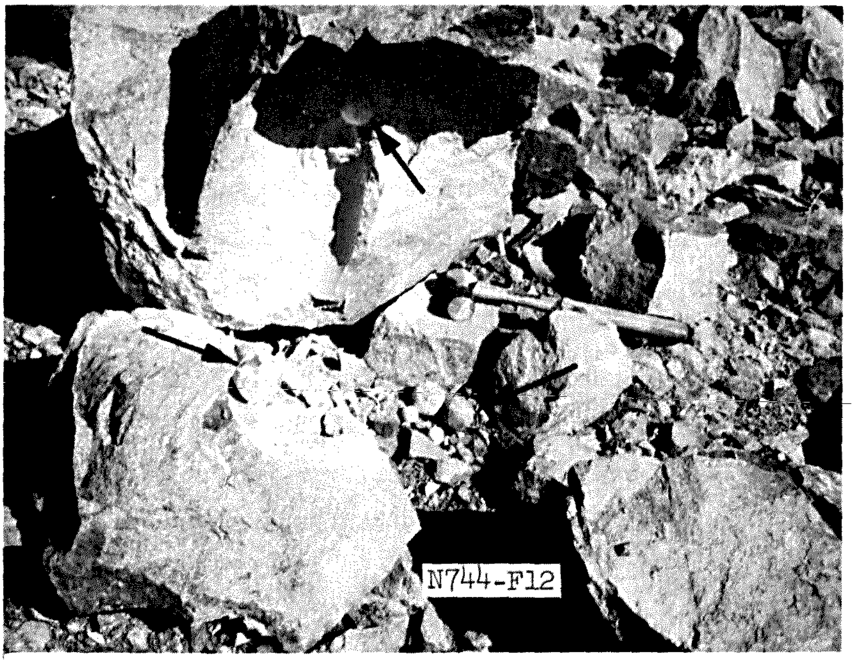


Figure 3.9 Recovered cylinder and spheres that were embedded in a block of rock ejected into the crater lip.

CHAPTER 4

DISCUSSION OF RESULTS

4.1 EJECTA AREAL DENSITY, VOLUME, AND DISTRIBUTION

Several techniques were used to determine ejecta areal density, volume, and azimuthal distribution in order to describe the Mineral Rock ejecta field. Some, such as excavation of the crater lip, use of collector areas, and plane-table surveys, were well-established testing techniques in ejecta work. However, the use of aerial photography for counting and sizing missiles was a new technique. The data obtained from the conventional techniques were generally good, particularly for the crater lip and adjacent areas. The data from the aerial photographs were less precise and were limited to particles that were 4 inches or greater in diameter. As mentioned in Section 2.3.2, area coverage was not as great as had been planned and was restricted to the areas north and northwest of GZ.

A digital computer was used extensively in reducing the data obtained from the aerial photographs. Appendix B is a listing of the computer program used. For input, data from computer cards concerning individual missiles (Appendix A) were fed into the computer. All rectangular coordinates were converted to polar coordinates, and a weight was assigned to each missile according to its size classification (the procedure for determining the weight-size class relationship is discussed in Section 4.2). Sampling areas, bounded by azimuthal radials and circumferential rings around GZ, were then delineated. The standard sampling area was 2 degrees in width and 25 feet in radial thickness. The program then searched the data and separated all missiles falling in a given sampling area, obtained the areal density of the missiles in the area by dividing total missile weight by area, and listed the missile size distribution in the area. Finally, a least-squares subroutine calculated the coefficient and power functions describing the relationship between range from GZ and both ejecta areal density and ejecta numerical density.

Using the lip excavation, collector area, and aerial photography data, a quantitative description of the ejecta field in terms of ejecta areal density was obtained. Figure 4.1 shows contours of ejecta areal density in and adjacent to the crater lip to a radial distance of 200 feet. The beginnings of the northwest and southeast rays are clearly visible. Figure 4.2 is the basic ejecta areal density curve

$$\delta = KR^{-n} \tag{4.1}$$

Where: δ = ejecta areal density

K = a constant

R = range from GZ

n = an exponent

In the following calculations, δ is in pounds per square foot and R is in feet. The debris field is divided into two regions, the crater lip and the area beyond the crater lip. The ejecta areal density equation for the crater lip is

$$\delta = 2.06 \times 10^{4} R^{-1.62} \tag{4.2}$$

This curve was calculated from the data obtained from the lip excavation. By combining the collector area and aerial photography data, the average curve for the ejecta beyond the crater lip was found to be

$$\delta = 6.96 \times 10^{5} R^{-2.58} \tag{4.3}$$

By combining all data, the average ejecta curve for the entire debris field became

$$\delta = 1.85 \times 10^{6} R^{-2.73} \tag{4.4}$$

The weight of the ejected material E_W can be estimated by integrating Equation 4.1 for the area under the average areal density curve and revolving it through 360 degrees. Thus,

$$E_W = 2\pi \int_{R_1}^{R_2} \delta \; R \; dR \tag{4.5}$$

where subscripts 1 and 2 refer to the selected limits of integration. In determining the ejecta weight in the crater lip, the limits of integration are the apparent crater radius r_a and crater lip radius r_ℓ. In determining the weight of the discontinuous ejecta, the limits of integration are r_ℓ and the maximum missile range r_e (see Figure 1.1). A lower limit of r_a appears permissible for a burst geometry such as that of Mineral Rock, where there is no definite lip crest. However, when a well-defined lip crest is formed (at r_h), the weight of the ejecta between r_a and r_h must be calculated separately. In most ejecta calculations, an upper limit of infinity for the discontinuous region yields a result little different from that yielded by the substitution of the maximum measured ejecta range. For Mineral Rock, r_e was used to obtain better agreement for ejecta missile ranges calculated in Section 4.3. For the crater lip (continuous ejecta)

$$\left(E_W\right)_{lip} = 2\pi \int_{32}^{64} \left(2.06 \times 10^4 R^{-1.62}\right) R \; dR$$

$$= 3.82 \times 10^5 \text{ pounds}$$

For the area beyond the crater lip (discontinuous ejecta)

$$\left(E_W\right)_{dis} = 2\pi \int_{64}^{2,800} \left(6.96 \times 10^5 R^{-2.58}\right) R \; dR$$

$$= 5.98 \times 10^5 \text{ pounds}$$

With the upper limit set equal to infinity,

$$\left(E_w\right)_{dis} = 6.73 \times 10^5 \text{ pounds}$$

Integration of the entire ejecta field (Equation 4.5) yields

$$E_w = 1.22 \times 10^6 \text{ pounds for limits } r_a \text{ to } r_e$$

and

$$E_w = 1.27 \times 10^6 \text{ pounds for limits } r_a \text{ to infinity}$$

For the ejecta in the crater lip, a good experimental check of the weight was possible. A total of 301,000 pounds of rock was excavated from the lip sectors that fell within the lip radius of 64 feet, as explained in Section 2.3.1. These sectors represented approximately 70 percent of the lip area; thus, the total weight in the lip can be roughly estimated as

$$\frac{100}{70} \times 301{,}400 = 430{,}000 \text{ pounds}$$

From the calculations above, it appears that over 1,000,000 pounds of rock were ejected from the crater, with about 40 percent of this amount falling within the crater lip and 60 percent beyond. Volumetrically, this amounts to about 230 yd^3 of in situ material, 90 yd^3 in the crater lip and 140 yd^3 beyond. Except for the lip measurements, these figures are probably too low. From the volumetric analysis in Reference 12, about 400 yd^3 were permanently ejected from the crater, of which about 190 yd^3 traveled beyond the lip. There are several possible reasons for this discrepancy of 50 yd^3 of ejecta beyond the lip. Although the photographic sample area was large, it was confined to the north and west, and may not have been truly representative. The large boulders in other parts of the debris field were not included; the addition of these would have added significantly to the total.

Then, too, the exclusion of particles less than 4 inches in diameter may have amplified the discrepancy; previous sampling techniques utilizing collector pads have included small particulate matter, even though its origin was suspect.

Regarding azimuthal distribution, the two main rays of ejecta deposition were at approximately 120 and 300 degrees in azimuth. Figure 2.4 shows that these rays roughly parallel the main northwest-southeast joint that passes about 4 feet southwest of GZ. It seems quite possible that material leaving the crater at low angles could have hit the joint face and been deflected along a path roughly parallel to the joint.

4.2 STATISTICS OF NATURAL MISSILE SIZES

In developing a technique for using aerial photographs in order to count, size, and determine mass density of ejecta missiles, the major problem encountered was that of assigning a weight to each missile according to its presented area A in the photograph. To accomplish this, a large number of missiles were carefully measured in the field and their dimensions and weights recorded, as listed in Table 4.1. Length ℓ , width w , and their product, the specimen area, are the planar dimensions that are visible in a photograph. For each specimen, a weight was calculated by assuming the volume of the missile to be a rectangular prism with the dimensions of ℓ , w , and height, d , and by then multiplying its volume by the unit weight γ of the granite. The ratio of the measured weight W_m to the calculated weight W_c was found to average about 0.5, with extremes of 0.275 to 0.831. The ratio tended to be lower than the average for smaller missiles (<8 inches nominal diameter) and higher than the average for larger missiles. With the three dimensions available through stereophotography, this method would provide a good means of estimating weight. However, since stereophotography was not available for Mineral Rock, it was necessary to assign missile weight on the basis of presented area. It was determined that the data were best treated in three area groupings and that a linear equation gave the best fit over each grouping. The ejecta area-to-weight relationships were calculated as follows:

$$W_t = 0.15A - 0.72 \quad \text{for} \quad A \leq 50 \; ; \quad \sigma = 0.95 \qquad (4.6a)$$

$$W_t = 0.30A - 8.94 \quad \text{for} \quad 50 < A < 120 \; ; \quad \sigma = 4.80 \qquad (4.6b)$$

$$W_t = 0.30A - 10.27 \quad \text{for} \quad A \geq 120 \; ; \quad \sigma = 21.94 \qquad (4.6c)$$

where W_t is missile weight (based on presented area) in pounds, A is the presented area in square inches, and σ is the standard deviation of the data points about the curves. Using these equations, the mean weights to be assigned to each size class of the aerial photography ejecta data were calculated. Area for each size class was assumed to be that of a circle whose diameter was the midpoint between the size class boundaries. For example, Size Class 2 was bounded by missiles of nominal diameters 8 and 12 inches. The midpoint diameter of 10 inches gives an area of 78.5 in^2, which, substituted into Equation 4.6b, gives a missile weight of 14.4 pounds. Size class weights calculated in this manner (with allowances for rounding off) were as follows:

Size Class	Weight
	pounds
1	3.55
2	14.4
3	42.2
4	92.6
5	200.0

These weights were used in the computer program analysis described in Section 4.1 and listed in Appendix B.

Of principal interest in the ejecta field are the distribution by size of the natural missiles and the changes in distribution by size as a function of range from GZ. Table 4.2 lists the distribution, according to size classes, for the sampling areas given in Table 3.4. For each area, the total number and total weight of the missiles are listed, along with the numbers and weights for each size class. Table 4.3 summarizes these data, giving the percentage by weight of each size class as a function of range from GZ. Figure 4.3 shows missile size distribution versus range. Because of the limited sampling area, distance from GZ, and the relatively large missile size of the smallest size class (4 to 8 inches), the data points show considerable scatter. However, trends are evident. The percentage of ejecta in Size Class 1 tends to increase steadily with increasing range. The percentage of ejecta in the largest size classes, Classes 3 and 4, drops off rapidly with increasing range. As shown in Figure 4.3, beyond 600 or 700 feet from GZ, these classes are represented by a small number of random missiles. The number of missiles in Size Class 2 rises as the number in the larger size classes decreases, then begins to decline at a distance equal to about 25 r_a. In general, the number of missiles in the larger size classes declines as range increases until finally the smallest size class predominates. It should be noted that the relative shapes and positions of curves on plots like Figure 4.3 are dependent on the boundaries and magnitudes of the missile size classes used. In the outer reaches of the debris field, where the total number of missiles becomes small, the continuity of the curves tends to break down as random large missiles comprise a disproportionate percentage of the ejecta weight. For Mineral Rock, this breakdown occurred beyond about 800 feet from GZ, as shown in Figure 4.3. The observed distribution probably cannot be completely explained until ballistic and drag coefficients for natural ejecta, as well as initial angles and velocities of ejection, are determined.

4.3 EJECTA MISSILE RANGES

<u>4.3.1 Scaling Considerations</u>. Empirical scaling of maximum

natural missile ranges for the Mineral Rock shot geometry is shown in Figure 4.4. In view of the sensitivity of ejecta distribution to charge geometry, only the calibration event with an HOB of 0.9 charge radius was considered along with Mine Ore and Mineral Rock. Thus, the indicated scaling factor $W^{0.31}$ is at present supported by only three data points and differs widely from the $W^{1/6}$ scaling used in Reference 5. The latter satisfactorily describes the upper limit of maximum-range data for buried explosions.

4.3.2 Deposition as a Function of Range. The percentage of ejected material deposited at any range can be determined using Equation 4.5 and solving for the upper limit of integration. The 90 percent limit is a frequently quoted figure, since it represents a range of comparative safety. Using the equation for ejecta beyond the crater lip,

$$\left(E_W\right)_{90} = 2\pi \int_{64}^{R_{90}} \left(6.96 \times 10^5 R^{-2.58}\right) R \, dR$$

where the subscript 90 refers to the radial limit within which 90 percent of the ejecta falls.

$$(0.90)(5.98 \times 10^5) = (4.37 \times 10^6) \left[\frac{R_{90}^{-0.58}}{-0.58} - \frac{(64)^{-0.58}}{-0.58}\right]$$

$$R_{90} = 1{,}012 \text{ feet}$$

Similar calculations can be made for various limits, both within and beyond the lip. Figure 4.5 illustrates ejecta deposition as a function of range for Mineral Rock.

4.3.3 Range as a Function of Origin. Ranges of ejected artificial missiles are shown in Figures 4.6 through 4.8 as contours (iso-range lines) drawn through their origins. Ranges of grout ejecta are similarly shown in Figure 4.9, taken from Reference 12. Figure 4.10, also from Reference 12, summarizes in general the experience of both artificial missile and colored-grout experiments. Extreme-range ejecta originated near the surface at a distance of about two charge radii from

GZ. Similar observations have been made for craters resulting from comparable shot geometries in soil (Reference 13).

4.4 ARTIFICIAL MISSILE DATA

Recovery of identifiable artificial missiles of all types was considered good. A detailed analysis of the data thus obtained is beyond the scope of this report; specifically, no attempt will be made to determine drag or ballistic coefficients. Certain general observations, however, do appear appropriate.

First, examination of the artificial missile data presented in Table 3.6 and of the illustrations of ejecta origins (Figures 4.6 through 4.9) clearly reveals the sensitivity of missile range to preshot position (depth and distance from GZ). For this reason, comparisons of missile performance must be made within a very narrow range of depths for a given borehole. Further, for the purpose of the initial assessment in this report, only those missiles that appeared to have achieved a ballistic trajectory were considered, and those that failed to clear the crater lip (~100 feet) were arbitrarily excluded. Many missiles apparently failed to break free from the surrounding rock or grout, and some of the cylinders, which had been held in a package by narrow annuli of a paperlike material with strong adhesive properties on both sides, failed to separate. When this occurrence was confirmed or strongly suspected, the missiles were excluded from consideration.

There were, of course, many missiles recovered that could not be identified and were of no value. Some missiles were badly deformed, as was common with the lead spheres. However, if the deformed missiles were identifiable, they were listed in Table 3.6, even though their ballistic properties may have been altered. In the case of the 4-inch-diameter cylinders, several identifiable missiles were sheared in two, and the two pieces traveled different distances. These missiles, too, were listed in Table 3.6, but they were not included in the brief analysis presented here. When all exclusions were made, there were far fewer data points than had originally appeared.

Using the data in Table 3.6, a rough comparison was made of extreme ejection distances for missiles from adjacent sphere and cylinder packages. Of the 41 comparisons considered valid, the spheres traveled farthest in 21 cases and the cylinders in 20, indicating similar maximum ranges for the two shapes. Next, comparisons were made of the effects of missile size and density on ejection ranges of missiles from individual sphere packages and of the effects of missile size and shape on ejection ranges of missiles from individual cylinder packages. For these comparisons, too, Table 3.6 was the data source. Only 16 packages of spheres were considered in the final analysis, and these are listed in Table 4.4, which ranks each spherical missile by distance traveled relative to distances traveled by other spheres in the same package. In addition to the criteria listed above, it was necessary to have two or more missiles in a package recovered and identified in order to make a comparison.

A size comparison between spheres of the same materials shows a slight (9 out of 15) tendency for the 2-inch spheres to outdistance the 1-inch spheres. The aluminum spheres (whose density closely matched that of the in situ tonalite) provided the range extremes most often, both in the 1- and 2-inch-diameter missiles. They were closely followed by the steel spheres. Only three comparisons could be made for lead spheres, and all showed poor range performance. As mentioned previously, the lead missiles deformed badly, although whether the deformation occurred during the ejection process or upon impact could not be ascertained. Relatively few plastic missiles were recovered, but the performance of the 1-inch plastic spheres was surprisingly good, and use of a greater number of these might have enhanced the results considerably.

In order to compare the performances of the cylinders and cylindrical sections, Table 4.5 was arranged to show the number of times that missiles of each size/shape category fell within a given range ranking compared with the number of possibilities for a poorer performance. This approach creates four range ranks (for five size/shape categories--the last missile in each category had no opportunity for a poorer performance, hence nothing with which to be compared). The results indicate that the maximum range is achieved by a 2-inch-long cylinder; however, within the first two range rankings, little difference is noted between this missile, the 1-inch-long cylinder, and the 1-inch-long, half-cylindrical wedge.

Finally, a comparison was attempted between the WES 1- and 2-inch spheres and the 7.4-inch aluminum spheres emplaced for Aerospace Corporation (Table 3.7), using the same criteria as before. This time it was necessary, however, to make the comparison between adjacent boreholes on the north radial, thus necessitating a very informal interpolation between observed ranges and between boreholes at comparable depths. Obviously, only a rough comparison is possible. The ranges associated with the larger spheres were similar to those associated with the smaller spheres with only one exception: 7.4-inch Sphere 19 traveled a much greater distance than would have been expected from the missile data for the adjacent boreholes.

4.5 COMPARISON WITH MINE ORE

Volumetric analyses of the Mine Ore and Mineral Rock craters (References 3 and 11) indicate that there was nearly 40 percent more ejected material for Mineral Rock than for Mine Ore. However, analysis of the ejecta field areal density indicates (incorrectly) more throwout in the Mine Ore Event. Two reasons are suspected: (1) the inability of aerial photography used in Mineral Rock to discern particles less than 4 inches in diameter, and (2) the fact that the only areas sampled by aerial photography in the Mineral Rock Event lay generally in the northwest quadrant of the test area.

Areal distribution curves for the two experiments, while different, were sufficiently close to establish a reasonable value for this parameter. The maximum ejecta range was definitely greater in Mineral Rock, for which the distribution curve shows a generally thinner deposition throughout the ejecta field. Unfortunately, the limited sampling prevented construction of an envelope containing maximum and minimum deposition, as was done in Mine Ore. Figure 4.11 shows a comparison of average ejecta distribution as a function of range for these two events.

Also shown in Figure 4.11 for comparison purposes is an envelope of data from explosions of buried charges.

The Mine Ore artificial missile experiment provided only a fraction of the data provided by Mineral Rock. The number of missiles emplaced in Mine Ore was only about 22 percent of the number emplaced in Mineral Rock, and recovery was poorer (about 19 percent compared with 28 percent). By the time the Mine Ore data were subjected to the same selection process employed in this study, only 39 data points were available. All except one of these points were on the south radial. There were insufficient data on cylinders and cylindrical sections (five identifiable missiles) to support any conclusions. The data concerning spheres were confined to relatively short-range trajectories (209 feet was the maximum) for aluminum missiles (only two data points for 2.5-inch lead spheres). The same dependence on origin was noted, but beyond the crater lip no performance trends were evident for the 1- and 2.5-inch-diameter aluminum spheres employed in the Mine Ore experiment. The larger missiles, however, did appear to clear the lip area more often than the smaller ones. The very limited data available suggested a slight trend toward better-than-average ballistic performance for 5.5- and 6-inch aluminum spheres, and poorer performance for 2.5-inch lead spheres.

TABLE 4.1 EJECTA FRAGMENTATION STATISTICS

Sample	Specimen Dimensions, feet			Presented Specimen Area	Calculated Specimen Volume	Measured Weight of Specimen	Calculated Specimen Weight W_c	W_m/W_c
	Length ℓ	Width w	Height d	ℓw	(ℓwd)	W_m	$(\ell wd)\gamma^a$	
				in^2	ft^3	pounds	pounds	
2-Inch Grouping:								
1	0.22	0.16	0.09	5.07	0.0032	0.15	0.513	0.292
2	0.20	0.16	0.10	4.61	0.0032	0.18	0.518	0.347
3	0.20	0.10	0.06	2.88	0.0012	0.06	0.194	0.309
4	0.23	0.18	0.15	5.96	0.0062	0.34	1.006	0.338
5	0.20	0.17	0.07	4.90	0.0024	0.12	0.386	0.311
6	0.20	0.15	0.12	4.32	0.0036	0.15	0.583	0.257
7	0.24	0.12	0.08	4.15	0.0023	0.11	0.373	0.295
8	0.22	0.15	0.10	4.75	0.0033	0.20	0.535	0.374
9	0.20	0.18	0.08	5.18	0.0029	0.13	0.467	0.279
10	0.23	0.11	0.08	3.64	0.0020	0.13	0.328	0.396
11	0.18	0.13	0.07	3.37	0.0016	0.08	0.265	0.301
12	0.24	0.15	0.11	5.18	0.0040	0.29	0.642	0.452
13	0.23	0.13	0.07	4.31	0.0021	0.11	0.339	0.324
14	0.20	0.16	0.10	4.61	0.0032	0.20	0.518	0.386
15	0.21	0.11	0.10	3.33	0.0023	0.19	0.374	0.508
16	0.20	0.12	0.11	3.46	0.0026	0.13	0.428	0.304
17	0.20	0.14	0.12	4.03	0.0034	0.19	0.544	0.349
18	0.25	0.11	0.08	4.00	0.0022	0.21	0.356	0.589
19	0.23	0.14	0.09	4.64	0.0029	0.19	0.469	0.405
20	0.23	0.17	0.07	5.63	0.0027	0.18	0.443	0.406
21	0.20	0.12	0.04	3.46	0.0010	0.08	0.156	0.514
22	0.18	0.14	0.09	3.63	0.0023	0.12	0.367	0.327
23	0.20	0.16	0.09	4.61	0.0029	0.14	0.467	0.300
24	0.25	0.10	0.08	3.60	0.0020	0.13	0.324	0.401
25	0.19	0.14	0.08	3.83	0.0021	0.14	0.345	0.406
4-Inch Grouping:								
1	0.30	0.15	0.12	6.48	0.0054	0.51	0.875	0.583
2	0.30	0.16	0.11	6.91	0.0053	0.44	0.855	0.514
3	0.30	0.20	0.13	8.64	0.0078	0.54	1.264	0.427
4	0.27	0.22	0.13	8.55	0.0077	0.52	1.251	0.416
5	0.28	0.21	0.14	8.48	0.0082	0.59	1.334	0.442
6	0.27	0.20	0.17	7.78	0.0092	0.76	1.487	0.511
7	0.30	0.20	0.10	8.64	0.0060	0.34	0.972	0.350
8	0.34	0.20	0.12	9.79	0.0082	0.49	1.322	0.371
9	0.30	0.18	0.10	7.78	0.0054	0.37	0.875	0.423
10	0.33	0.19	0.08	9.03	0.0050	0.36	0.813	0.443
11	0.30	0.17	0.12	7.34	0.0061	0.46	0.991	0.464
12	0.31	0.21	0.15	9.37	0.0098	0.70	1.582	0.442
13	0.27	0.21	0.14	8.16	0.0079	0.72	1.296	0.560
14	0.34	0.18	0.10	8.81	0.0061	0.47	0.991	0.474
15	0.30	0.25	0.07	10.80	0.0053	0.47	0.851	0.553
16	0.25	0.23	0.07	8.28	0.0040	0.22	0.652	0.337
17	0.29	0.12	0.14	5.01	0.0049	0.27	0.789	0.342
18	0.30	0.17	0.08	7.34	0.0041	0.44	0.661	0.666
19	0.32	0.18	0.13	8.29	0.0075	0.52	1.213	0.429
20	0.35	0.18	0.12	9.07	0.0076	0.52	1.225	0.425
21	0.32	0.16	0.09	7.37	0.0046	0.31	0.746	0.415
22	0.33	0.20	0.15	9.50	0.0099	0.52	1.604	0.324
23	0.33	0.19	0.15	9.03	0.0094	0.51	1.524	0.335
24	0.31	0.12	0.12	5.36	0.0045	0.32	0.723	0.442
6-Inch Grouping:								
1	0.48	0.23	0.15	15.90	0.0166	1.56	2.683	0.581
2	0.55	0.38	0.20	30.01	0.0418	2.85	6.772	0.421
3	0.40	0.24	0.18	13.82	0.0173	1.43	2.799	0.511
4	0.53	0.36	0.20	27.48	0.0382	2.30	6.182	0.372
5	0.42	0.35	0.15	21.17	0.0221	1.23	3.572	0.344

(Continued)

a Unit weight $\gamma = 162\ lb/ft^3$.

(1 of 3 sheets)

TABLE 4.1 (CONTINUED)

Sample	Specimen Dimensions, feet: Length ℓ	Width w	Height d	Presented Specimen Area ℓw	Calculated Specimen Volume (ℓwd)	Measured Weight of Specimen W_m	Calculated Specimen Weight W_c (ℓwd)γ	W_m/W_c
				in^2	ft^3	pounds	pounds	
6-Inch Grouping: (Cont'd)								
6	0.45	0.25	0.15	16.20	0.0169	1.36	2.734	0.497
7	0.39	0.24	0.14	13.48	0.0131	1.08	2.123	0.509
8	0.45	0.35	0.24	22.68	0.0378	3.38	6.124	0.552
9	0.50	0.43	0.19	30.96	0.0409	2.93	6.618	0.443
10	0.44	0.27	0.21	17.11	0.0249	1.84	4.042	0.455
11	0.46	0.26	0.27	17.22	0.0323	1.89	5.231	0.361
12	0.40	0.33	0.15	19.01	0.0198	1.57	3.208	0.489
13	0.43	0.15	0.12	9.29	0.0077	0.63	1.254	0.502
14	0.36	0.35	0.14	18.14	0.0176	1.00	2.858	0.350
15	0.38	0.19	0.17	10.40	0.0123	1.05	1.988	0.528
16	0.45	0.21	0.14	13.61	0.0132	0.99	2.143	0.462
17	0.44	0.26	0.11	16.47	0.0126	0.99	2.039	0.486
18	0.41	0.24	0.17	14.17	0.0167	1.39	2.710	0.513
19	0.46	0.21	0.12	13.91	0.0116	1.30	1.878	0.693
20	0.50	0.22	0.12	15.84	0.0132	0.91	2.138	0.426
21	0.42	0.30	0.19	18.14	0.0239	1.78	3.878	0.459
22	0.50	0.21	0.17	15.12	0.0179	1.17	2.892	0.405
23	0.50	0.25	0.14	18.00	0.0175	1.45	2.835	0.511
24	0.43	0.24	0.15	14.86	0.0155	1.20	2.508	0.479
25	0.47	0.17	0.10	11.51	0.0080	0.73	1.294	0.564
8-Inch Grouping:								
1	0.67	0.40	0.21	38.59	0.0563	5.33	9.117	0.585
2	0.57	0.29	0.20	23.80	0.0331	3.45	5.356	0.644
3	0.70	0.28	0.20	28.22	0.0392	3.12	6.350	0.491
4	0.65	0.48	0.20	44.93	0.0624	3.98	10.109	0.394
5	0.65	0.40	0.22	37.44	0.0572	4.32	9.266	0.466
6	0.60	0.30	0.13	25.92	0.0234	2.05	3.791	0.541
7	0.60	0.35	0.15	30.24	0.0315	2.80	5.103	0.549
8	0.70	0.35	0.25	35.28	0.0613	5.10	9.923	0.514
9	0.70	0.30	0.25	30.24	0.0525	3.48	8.505	0.409
10	0.65	0.43	0.23	40.25	0.0623	4.45	10.414	0.427
11	0.58	0.28	0.20	23.39	0.0325	2.54	5.262	0.483
12	0.60	0.35	0.19	30.24	0.0400	3.38	6.464	0.523
13	0.58	0.19	0.10	15.87	0.0110	0.88	1.785	0.493
14	0.65	0.27	0.20	25.27	0.0351	3.04	5.686	0.535
15	0.68	0.47	0.14	46.02	0.0447	3.40	7.249	0.469
16	0.70	0.24	0.13	24.19	0.0218	2.06	3.538	0.582
17	0.64	0.40	0.23	36.86	0.0589	4.17	9.539	0.437
18	0.60	0.33	0.25	28.51	0.0495	4.83	8.019	0.602
19	0.60	0.27	0.19	23.33	0.0308	3.28	4.986	0.658
20	0.58	0.35	0.27	29.23	0.0548	4.37	8.879	0.492
21	0.60	0.24	0.20	20.74	0.0288	3.29	4.666	0.705
22	0.64	0.48	0.20	44.24	0.0614	4.31	9.953	0.433
23	0.63	0.40	0.23	36.29	0.0580	5.13	9.390	0.546
24	0.63	0.34	0.23	30.84	0.0493	3.13	7.981	0.392
10-Inch Grouping:								
1	0.85	0.43	0.37	52.62	0.1352	12.05	21.908	0.550
2	0.90	0.45	0.27	58.32	0.1094	9.11	17.715	0.514
3	0.90	0.34	0.27	44.06	0.0826	9.49	13.384	0.709
4	0.85	0.35	0.34	42.84	0.1012	10.31	16.386	0.629
5	0.80	0.59	0.18	67.97	0.0850	9.02	13.764	0.655
6	0.75	0.58	0.30	62.64	0.1305	10.31	21.141	0.488
7	0.77	0.43	0.27	47.68	0.0894	11.10	14.482	0.766
8	0.90	0.36	0.25	46.66	0.0810	7.22	13.122	0.550
9	0.82	0.34	0.17	40.15	0.0474	4.44	7.678	0.578
10	0.96	0.47	0.25	64.97	0.1128	11.65	18.274	0.638

(Continued)

TABLE 4.1 (CONCLUDED)

Sample	Specimen Dimensions, feet			Presented Specimen Area	Calculated Specimen Volume	Measured Weight of Specimen	Calculated Specimen Weight W_c	W_m/W_c
	Length ℓ	Width w	Height d	ℓw	(ℓwd)	W_m	(ℓwd)γ	
				in^2	ft^3	pounds	pounds	
10-Inch Grouping (Cont'd):								
11	0.98	0.35	0.29	49.39	0.0994	7.72	16.114	0.479
12	0.90	0.38	0.35	49.25	0.1197	7.98	19.391	0.412
13	0.75	0.65	0.21	70.20	0.1024	10.33	16.585	0.623
14	0.80	0.50	0.25	57.60	0.1000	11.28	16.200	0.696
15	0.98	0.55	0.21	77.62	0.1132	9.67	18.337	0.527
12-Inch Grouping:								
1	1.00	0.63	0.32	90.72	0.2016	15.53	32.659	0.476
2	1.03	0.55	0.19	81.58	0.1076	12.24	17.437	0.702
3	0.90	0.50	0.32	64.80	0.1440	10.41	23.328	0.446
4	1.08	0.55	0.26	85.54	0.1544	14.66	25.019	0.586
5	1.08	0.62	0.28	96.42	0.1875	14.32	30.373	0.471
6	1.00	0.40	0.20	57.60	0.0800	7.00	12.960	0.540
7	0.92	0.55	0.35	72.86	0.1771	19.86	26.690	0.692
8	1.07	0.52	0.28	80.12	0.1558	15.95	25.238	0.632
9	1.04	0.50	0.44	74.88	0.2288	20.00	37.066	0.540
10	1.09	0.85	0.30	133.42	0.2780	21.00	45.028	0.466
11	1.00	0.60	0.34	86.40	0.2040	16.74	33.048	0.507
12	0.98	0.53	0.40	74.79	0.2078	15.74	33.657	0.468
13	0.90	0.70	0.23	90.72	0.1449	12.70	23.474	0.541
14	1.05	0.75	0.45	113.40	0.3544	31.00	57.409	0.540
15	1.03	0.50	0.30	74.16	0.1545	12.14	25.029	0.485
14-Inch Grouping:								
1	1.16	0.67	0.30	111.92	0.2332	16.92	37.772	0.448
2	1.20	0.73	0.45	126.14	0.3942	30.11	63.860	0.471
3	1.20	0.80	0.27	138.24	0.2592	22.09	41.990	0.526
4	1.20	0.86	0.47	148.61	0.4850	42.50	78.576	0.541
5	1.25	0.70	0.32	126.00	0.2800	20.50	45.360	0.452
6	1.20	0.90	0.42	155.52	0.4536	37.75	73.483	0.514
7	1.18	0.52	0.34	88.36	0.2086	17.50	33.797	0.518
8	1.23	0.60	0.32	106.27	0.2362	23.50	38.258	0.614
9	1.23	0.48	0.28	85.02	0.1653	18.25	26.781	0.681
10	1.15	0.70	0.28	115.92	0.2254	23.75	36.515	0.650
11	1.15	0.70	0.50	115.92	0.4025	42.00	65.205	0.644
12	1.23	0.70	0.30	123.98	0.2583	18.50	41.845	0.442
13	1.20	1.00	0.45	172.80	0.5400	35.00	87.480	0.400
14	1.20	1.05	0.55	181.44	0.6930	53.75	112.266	0.479
15	1.30	1.05	0.32	196.56	0.4368	30.00	70.762	0.424
16-Inch Grouping:								
1	1.52	1.00	0.32	218.88	0.4864	38.25	78.797	0.485
2	1.32	0.60	0.38	114.05	0.3010	33.00	48.756	0.677
3	1.40	1.30	0.62	262.08	1.1284	70.50	182.801	0.386
4	1.50	0.98	0.60	211.68	0.8820	50.00	142.884	0.350
5	1.50	1.20	0.47	259.20	0.8460	64.25	137.052	0.469
6	1.40	0.55	0.40	110.88	0.3080	26.00	49.896	0.521
7	1.35	0.80	0.40	155.52	0.4320	44.50	69.984	0.636
8	1.42	0.60	0.40	122.69	0.3408	41.00	55.210	0.743
9	1.32	0.93	0.50	176.77	0.6138	48.00	99.436	0.483
10	1.51	0.90	0.47	195.70	0.6387	59.00	103.474	0.570
18-Inch Grouping:								
1	1.50	1.10	0.55	237.60	0.9075	95.00	147.015	0.646
2	1.70	1.35	0.63	330.48	1.4459	96.75	234.228	0.413
3	1.90	1.05	0.42	287.28	0.8379	112.75	135.740	0.831
4	2.15	1.15	0.65	356.04	1.6071	167.00	260.354	0.641
5	1.80	1.23	0.55	318.82	1.2177	110.75	197.267	0.561

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TABLE 4.2 NATURAL MISSILE DISTRIBUTION BY SIZE

No Class 5 missiles appeared in the sample areas.

Collector Area				Numbers and Weights of Missiles in Indicated Size Classes							
Azimuthal Bounds[a]	Radial Distance[b]	Total Number of Missiles	Total Weight	Class 1		Class 2		Class 3		Class 4	
				Number	Weight	Number	Weight	Number	Weight	Number	Weight
degrees	feet		pounds		pounds		pounds		pounds		pounds
249-251	488	1	3.6	1	3.6	0	0	0	0	0	0
	513	9	43.0	8	28.6	1	14.4	0	0	0	0
	538	2	7.1	2	7.1	0	0	0	0	0	0
	563	4	25.0	3	10.6	1	14.4	0	0	0	0
	588	1	3.6	1	3.6	0	0	0	0	0	0
	613	4	14.2	4	14.2	0	0	0	0	0	0
	638	0	0	0	0	0	0	0	0	0	0
251-253	488	4	25.0	3	10.6	1	14.4	0	0	0	0
	513	6	43.0	4	14.2	2	28.8	0	0	0	0
	538	3	32.4	1	3.6	2	28.8	0	0	0	0
	563	4	14.2	4	14.2	0	0	0	0	0	0
	588	4	14.2	4	14.2	0	0	0	0	0	0
	613	5	39.4	3	10.6	2	28.8	0	0	0	0
	638	2	7.1	2	7.1	0	0	0	0	0	0
253-255	488	1	14.4	0	0	1	14.4	0	0	0	0
	513	4	52.8	3	10.6	0	0	1	42.2	0	0
	538	2	7.1	2	7.1	0	0	0	0	0	0
	563	3	21.5	2	7.1	1	14.4	0	0	0	0
	588	4	25.0	3	10.6	1	14.4	0	0	0	0
	613	8	39.3	7	24.9	1	14.4	0	0	0	0
	638	6	21.3	6	21.3	0	0	0	0	0	0
255-257	488	18	113.0	16	56.8	1	14.4	1	42.2	0	0
	513	7	35.7	6	21.3	1	14.4	0	0	0	0
	538	7	24.9	7	24.9	0	0	0	0	0	0
	563	7	46.6	5	17.8	2	28.8	0	0	0	0
	588	2	7.1	2	7.1	0	0	0	0	0	0
	613	1	3.6	1	3.6	0	0	0	0	0	0
	638	6	21.3	6	21.3	0	0	0	0	0	0
	713	0	0	0	0	0	0	0	0	0	0
	738	1	3.6	1	3.6	0	0	0	0	0	0
	763	0	0	0	0	0	0	0	0	0	0
	788	1	3.6	1	3.6	0	0	0	0	0	0
	813	0	0	0	0	0	0	0	0	0	0
	838	0	0	0	0	0	0	0	0	0	0
	863	1	3.6	1	3.6	0	0	0	0	0	0
	888	1	3.6	1	3.6	0	0	0	0	0	0
257-259	488	24	96.0	23	81.6	1	14.4	0	0	0	0
	513	20	259.0	15	53.2	2	28.8	2	84.4	1	92.6
	538	16	67.6	15	53.2	1	14.4	0	0	0	0
	563	16	67.6	15	53.2	1	14.4	0	0	0	0
	588	7	24.9	7	24.9	0	0	0	0	0	0
	613	10	95.9	7	24.9	2	28.8	1	42.2	0	0
	638	11	60.8	9	32.0	2	28.8	0	0	0	0
	713	2	7.1	2	7.1	0	0	0	0	0	0
	738	4	25.0	3	10.6	1	14.4	0	0	0	0
	763	4	14.2	4	14.2	0	0	0	0	0	0
	788	6	43.0	4	14.2	2	28.8	0	0	0	0
	813	6	32.2	5	17.8	1	14.4	0	0	0	0
	838	1	3.6	1	3.6	0	0	0	0	0	0
	863	6	32.2	5	17.8	1	14.4	0	0	0	0
	888	6	21.3	6	21.3	0	0	0	0	0	0

(Continued)

[a] Azimuths are relative to true north.

(1 of 6 sheets)

[b] Radial distances are relative to centers of sampled areas.

TABLE 4.2 (CONTINUED)

Collector Area				Numbers and Weights of Missiles in Indicated Size Classes							
Azimuthal Bounds	Radial Distance	Total Number of Missiles	Total Weight	Class 1		Class 2		Class 3		Class 4	
				Number	Weight	Number	Weight	Number	Weight	Number	Weight
degrees	feet		pounds		pounds		pounds		pounds		pounds
259-261	488	26	234.7	18	63.9	6	86.4	2	84.4	0	0
	513	30	149.9	26	92.3	4	57.6	0	0	0	0
	538	20	103.6	17	60.4	3	43.2	0	0	0	0
	563	19	100.0	16	56.8	3	43.2	0	0	0	0
	588	8	28.6	8	28.6	0	0	0	0	0	0
	613	1	3.6	1	3.6	0	0	0	0	0	0
	638	7	63.5	6	21.3	0	0	1	42.2	0	0
	713	5	28.6	4	14.2	1	14.4	0	0	0	0
	738	1	3.6	1	3.6	0	0	0	0	0	0
	763	6	21.3	6	21.3	0	0	0	0	0	0
	788	9	32.0	9	32.0	0	0	0	0	0	0
	813	3	10.6	3	10.6	0	0	0	0	0	0
	838	3	10.6	3	10.6	0	0	0	0	0	0
	863	5	17.8	5	17.8	0	0	0	0	0	0
	888	9	43.0	8	28.6	1	14.4	0	0	0	0
261-263	488	46	390.0	35	124.0	9	130.0	1	42.2	1	92.6
	513	47	324.0	35	124.0	11	158.0	1	42.2	0	0
	538	27	267.0	21	74.6	4	57.6	1	42.2	1	92.6
	563	10	163.0	6	21.3	1	14.4	3	127.0	0	0
	588	14	199.0	8	28.6	3	43.2	3	127.0	0	0
	613	11	60.8	9	32.0	2	28.8	0	0	0	0
	638	2	18.0	1	3.6	1	14.4	0	0	0	0
	713	3	21.5	2	7.1	1	14.4	0	0	0	0
	738	3	10.6	3	10.6	0	0	0	0	0	0
	763	4	14.2	4	14.2	0	0	0	0	0	0
	788	1	14.4	0	0	1	14.4	0	0	0	0
	813	4	14.2	4	14.2	0	0	0	0	0	0
	838	2	7.1	2	7.1	0	0	0	0	0	0
	863	3	10.6	3	10.6	0	0	0	0	0	0
	888	0	0	0	0	0	0	0	0	0	0
263-265	488	47	381.0	37	131.0	8	115.0	1	42.2	1	92.6
	513	30	189.0	25	88.8	4	57.6	1	42.2	0	0
	538	36	160.0	33	117.0	3	43.2	0	0	0	0
	563	8	28.6	8	28.6	0	0	0	0	0	0
	588	15	75.0	13	46.2	2	28.8	0	0	0	0
	613	8	77.9	6	21.3	1	14.4	1	42.2	0	0
	638	15	85.8	12	42.6	3	43.2	0	0	0	0
	713	2	7.1	2	7.1	0	0	0	0	0	0
	738	4	25.0	3	10.6	1	14.4	0	0	0	0
	763	1	3.6	1	3.6	0	0	0	0	0	0
	788	2	7.1	2	7.1	0	0	0	0	0	0
	813	1	3.6	1	3.6	0	0	0	0	0	0
	838	2	7.1	2	7.1	0	0	0	0	0	0
	863	2	7.1	2	7.1	0	0	0	0	0	0
	888	1	3.6	1	3.6	0	0	0	0	0	0
265-267	488	32	146.0	29	103.0	3	43.2	0	0	0	0
	513	16	89.4	13	46.2	3	43.2	0	0	0	0
	538	25	316.0	19	67.4	2	28.8	3	127.0	1	92.6
	563	8	105.0	6	21.3	0	0	2	84.4	0	0
	588	10	36.0	10	36.0	0	0	0	0	0	0
	613	9	43.0	8	28.6	1	14.4	0	0	0	0
	638	11	50.0	10	36.0	1	14.4	0	0	0	0
	713	4	14.2	4	14.2	0	0	0	0	0	0
	738	6	32.2	5	17.8	1	14.4	0	0	0	0
	763	4	14.2	4	14.2	0	0	0	0	0	0
	788	1	3.6	1	3.6	0	0	0	0	0	0

(Continued)

(2 of 6 sheets)

TABLE 4.2 (CONTINUED)

Collector Area				Numbers and Weights of Missiles in Indicated Size Classes							
Azimuthal Bounds	Radial Distance	Total Number of Missiles	Total Weight	Class 1		Class 2		Class 3		Class 4	
				Number	Weight	Number	Weight	Number	Weight	Number	Weight
degrees	feet		pounds		pounds		pounds		pounds		pounds
265-267	813	1	3.6	1	3.6	0	0	0	0	0	0
(Cont'd)	838	4	25.0	3	10.6	1	14.4	0	0	0	0
	863	2	7.1	2	7.1	0	0	0	0	0	0
	888	3	49.3	2	7.1	0	0	1	42.2	0	0
267-269	713	3	21.5	2	7.1	1	14.4	0	0	0	0
	738	0	0	0	0	0	0	0	0	0	0
	763	2	7.1	2	7.1	0	0	0	0	0	0
	788	1	3.6	1	3.6	0	0	0	0	0	0
	813	2	7.1	2	7.1	0	0	0	0	0	0
	838	0	0	0	0	0	0	0	0	0	0
	863	3	49.3	2	7.1	0	0	1	42.2	0	0
	888	1	3.6	1	3.6	0	0	0	0	0	0
269-271	713	1	3.6	1	3.6	0	0	0	0	0	0
	738	0	0	0	0	0	0	0	0	0	0
	763	0	0	0	0	0	0	0	0	0	0
	788	1	3.6	1	3.6	0	0	0	0	0	0
	813	0	0	0	0	0	0	0	0	0	0
	838	1	3.6	1	3.6	0	0	0	0	0	0
	863	0	0	0	0	0	0	0	0	0	0
	888	0	0	0	0	0	0	0	0	0	0
299-301	813	1	3.6	1	3.6	0	0	0	0	0	0
	838	2	18.0	1	3.6	1	14.4	0	0	0	0
	863	7	102.0	5	17.8	0	0	2	84.4	0	0
	888	5	39.4	3	10.6	2	28.8	0	0	0	0
	913	2	7.1	2	7.1	0	0	0	0	0	0
	938	6	32.2	5	17.8	1	14.4	0	0	0	0
	963	10	46.4	9	32.0	1	14.4	0	0	0	0
	988	8	28.6	8	28.6	0	0	0	0	0	0
	1,013	14	60.6	13	46.2	1	14.4	0	0	0	0
301-303	813	2	7.1	2	7.1	0	0	0	0	0	0
	838	4	14.2	4	14.2	0	0	0	0	0	0
	863	7	24.9	7	24.9	0	0	0	0	0	0
	888	9	32.0	9	32.0	0	0	0	0	0	0
	913	4	25.0	3	10.6	1	14.4	0	0	0	0
	938	4	14.2	4	14.2	0	0	0	0	0	0
	963	7	24.9	7	24.9	0	0	0	0	0	0
	988	9	32.0	9	32.0	0	0	0	0	0	0
	1,013	19	139.0	15	53.2	3	43.2	1	42.2	0	0
303-305	813	1	3.6	1	3.6	0	0	0	0	0	0
	838	6	32.2	5	17.8	1	14.4	0	0	0	0
	863	8	39.3	7	24.9	1	14.4	0	0	0	0
	888	13	57.0	12	42.6	1	14.4	0	0	0	0
	913	16	56.8	16	56.8	0	0	0	0	0	0
	938	16	56.8	16	56.8	0	0	0	0	0	0
	963	15	64.1	14	49.7	1	14.4	0	0	0	0
	988	21	124.0	10	67.4	1	14.4	1	42.2	0	0
	1,013	18	74.8	17	60.4	1	14.4	0	0	0	0
305-307	463	6	60.0	5	17.8	0	0	1	42.2	0	0
	488	1	3.6	1	3.6	0	0	0	0	0	0
	513	1	3.6	1	3.6	0	0	0	0	0	0
	538	1	3.6	1	3.6	0	0	0	0	0	0

(Continued)

TABLE 4.2 (CONTINUED)

Collector Area				Numbers and Weights of Missiles in Indicated Size Classes							
Azimuthal Bounds	Radial Distance	Total Number of Missiles	Total Weight	Class 1		Class 2		Class 3		Class 4	
				Number	Weight	Number	Weight	Number	Weight	Number	Weight
degrees	feet		pounds		pounds		pounds		pounds		pounds
305-307 (Cont'd)	563	1	3.6	1	3.6	0	0	0	0	0	0
	588	1	3.6	1	3.6	0	0	0	0	0	0
	613	2	7.1	2	7.1	0	0	0	0	0	0
	638	4	35.9	2	7.1	2	28.8	0	0	0	0
	663	2	7.1	3	7.1	0	0	0	0	0	0
	688	1	3.6	1	3.6	0	0	0	0	0	0
	713	0	0	0	0	0	0	0	0	0	0
	813	1	3.6	1	3.6	0	0	0	0	0	0
	838	1	14.4	0	0	1	14.4	0	0	0	0
	863	6	21.3	6	21.3	0	0	0	0	0	0
	888	9	32.0	9	32.0	0	0	0	0	0	0
	913	7	35.7	6	21.3	1	14.4	0	0	0	0
	938	6	21.3	6	21.3	0	0	0	0	0	0
	963	10	36.0	10	36.0	0	0	0	0	0	0
	988	20	104.0	17	60.4	3	43.2	0	0	0	0
	1,013	17	71.2	16	56.8	1	14.4	0	0	0	0
307-309	463	4	14.2	4	14.2	0	0	0	0	0	0
	488	2	7.1	2	7.1	0	0	0	0	0	0
	513	0	0	0	0	0	0	0	0	0	0
	538	0	0	0	0	0	0	0	0	0	0
	563	0	0	0	0	0	0	0	0	0	0
	588	0	0	0	0	0	0	0	0	0	0
	613	11	82.5	7	24.9	4	57.6	0	0	0	0
	638	15	75.0	13	46.2	2	28.8	0	0	0	0
	663	4	14.2	4	14.2	0	0	0	0	0	0
	688	6	32.2	5	17.8	1	14.4	0	0	0	0
	713	0	0	0	0	0	0	0	0	0	0
	813	2	18.0	1	3.6	1	14.4	0	0	0	0
	838	1	3.6	1	3.6	0	0	0	0	0	0
	863	8	117.0	5	17.8	1	14.4	2	84.4	0	0
	888	6	32.2	5	17.8	1	14.4	0	0	0	0
	913	4	35.9	2	7.1	2	28.8	0	0	0	0
	938	5	17.8	5	17.8	0	0	0	0	0	0
	963	9	43.0	8	28.6	1	14.4	0	0	0	0
	988	7	24.9	7	24.9	0	0	0	0	0	0
	1,013	12	42.6	12	42.6	0	0	0	0	0	0
309-311	463	3	10.6	3	10.6	0	0	0	0	0	0
	488	2	7.1	2	7.1	0	0	0	0	0	0
	513	1	3.6	1	3.6	0	0	0	0	0	0
	538	0	0	0	0	0	0	0	0	0	0
	563	0	0	0	0	0	0	0	0	0	0
	588	0	0	0	0	0	0	0	0	0	0
	613	9	53.7	7	24.9	2	28.8	0	0	0	0
	638	15	85.8	12	42.6	3	43.2	0	0	0	0
	663	9	43.0	8	28.6	1	14.4	0	0	0	0
	688	7	24.9	7	24.9	0	0	0	0	0	0
	713	0	0	0	0	0	0	0	0	0	0
	813	1	14.4	0	0	1	14.4	0	0	0	0
	838	4	14.2	4	14.2	0	0	0	0	0	0
	863	6	32.2	5	17.8	1	14.4	0	0	0	0
	888	5	17.8	5	17.8	0	0	0	0	0	0
	913	2	7.1	2	7.1	0	0	0	0	0	0
	938	3	10.6	3	10.6	0	0	0	0	0	0
	963	0	0	0	0	0	0	0	0	0	0
	988	3	10.6	3	10.6	0	0	0	0	0	0
	1,013	7	114.0	6	21.3	0	0	0	0	1	92.6

(Continued)

(4 of 6 sheets)

TABLE 4.2 (CONTINUED)

Collector Area				Numbers and Weights of Missiles in Indicated Size Classes							
Azimuthal Bounds	Radial Distance	Total Number of Missiles	Total Weight	Class 1		Class 2		Class 3		Class 4	
				Number	Weight	Number	Weight	Number	Weight	Number	Weight
degrees	feet		pounds		pounds		pounds		pounds		pounds
311-313	463	3	10.6	3	10.6	0	0	0	0	0	0
	488	8	39.3	7	24.9	1	14.4	0	0	0	0
	513	3	32.4	1	3.6	2	28.8	0	0	0	0
	538	0	0	0	0	0	0	0	0	0	0
	563	1	3.6	1	3.6	0	0	0	0	0	0
	588	1	14.4	0	0	1	14.4	0	0	0	0
	613	0	0	0	0	0	0	0	0	0	0
	638	0	0	0	0	0	0	0	0	0	0
	663	14	71.4	12	42.6	2	28.8	0	0	0	0
	688	19	100.0	16	56.8	3	43.2	0	0	0	0
	713	0	0	0	0	0	0	0	0	0	0
									0		
313-315	463	2	7.1	2	7.1	0	0	0	0	0	0
	488	1	3.6	1	3.6	0	0	0	0	0	0
	513	0	0	0	0	0	0	0	0	0	0
	538	1	3.6	1	3.6	0	0	0	0	0	0
	563	1	3.6	1	3.6	0	0	0	0	0	0
	588	3	49.3	2	7.1	0	0	1	42.2	0	0
	613	6	21.3	6	21.3	0	0	0	0	0	0
	638	10	46.4	9	32.0	1	14.4	0	0	0	0
	663	14	82.3	11	39.1	3	43.2	0	0	0	0
	688	4	14.2	4	14.2	0	0	0	0	0	0
	713	0	0	0	0	0	0	0	0	0	0
315-317	463	1	3.6	1	3.6	0	0	0	0	0	0
	488	8	28.6	8	28.6	0	0	0	0	0	0
	513	1	42.2	0	0	0	0	1	42.2	0	0
	538	2	7.1	2	7.1	0	0	0	0	0	0
	563	0	0	0	0	0	0	0	0	0	0
	588	5	17.8	5	17.8	0	0	0	0	0	0
	613	6	21.3	6	21.3	0	0	0	0	0	0
	638	12	53.5	11	39.1	1	14.4	0	0	0	0
	663	12	53.5	11	39.1	1	14.4	0	0	0	0
	688	13	57.0	12	42.6	1	14.4	0	0	0	0
	713	0	0	0	0	0	0	0	0	0	0
317-319	463	0	0	0	0	0	0	0	0	0	0
	488	0	0	0	0	0	0	0	0	0	0
	513	0	0	0	0	0	0	0	0	0	0
	538	0	0	0	0	0	0	0	0	0	0
	563	2	7.1	2	7.1	0	0	0	0	0	0
	588	4	14.2	4	14.2	0	0	0	0	0	0
	613	6	21.3	6	21.3	0	0	0	0	0	0
	638	16	56.8	16	56.8	0	0	0	0	0	0
	663	8	28.6	8	28.6	0	0	0	0	0	0
	688	7	35.7	6	21.3	1	14.4	0	0	0	0
	713	0	0	0	0	0	0	0	0	0	0
319-321	463	1	3.6	1	3.6	0	0	0	0	0	0
	488	1	14.4	0	0	1	14.4	0	0	0	0
	513	1	3.6	1	3.6	0	0	0	0	0	0
	538	2	7.1	2	7.1	0	0	0	0	0	0
	563	1	3.6	1	3.6	0	0	0	0	0	0
	588	1	3.6	1	3.6	0	0	0	0	0	0
	613	8	28.6	8	28.6	0	0	0	0	0	0

(Continued)

(5 of 6 sheets)

TABLE 4.2 (CONCLUDED)

Collector Area				Numbers and Weights of Missiles in Indicated Size Classes							
Azimuthal Bounds	Radial Distance	Total Number of Missiles	Total Weight	Class 1		Class 2		Class 3		Class 4	
				Number	Weight	Number	Weight	Number	Weight	Number	Weight
degrees	feet		pounds		pounds		pounds		pounds		pounds
319-321 (Cont'd)	638	10	46.4	9	32.0	1	14.4	0	0	0	0
	663	1	3.6	1	3.6	0	0	0	0	0	0
	688	1	3.6	1	3.6	0	0	0	0	0	0
	713	0	0	0	0	0	0	0	0	0	0
321-323	463	1	14.4	0	0	1	14.4	0	0	0	0
	488	1	3.6	1	3.6	0	0	0	0	0	0
	513	2	7.1	2	7.1	0	0	0	0	0	0
	538	1	3.6	1	3.6	0	0	0	0	0	0
	563	1	3.6	1	3.6	0	0	0	0	0	0
	588	1	3.6	1	3.6	0	0	0	0	0	0
	613	0	0	0	0	0	0	0	0	0	0
	638	4	14.2	4	14.2	0	0	0	0	0	0
	663	1	3.6	1	3.6	0	0	0	0	0	0
	688	3	21.5	2	7.1	1	14.4	0	0	0	0
	713	0	0	0	0	0	0	0	0	0	0
323-325	463	4	35.9	2	7.1	2	28.8	0	0	0	0
	488	0	0	0	0	0	0	0	0	0	0
	513	1	3.6	1	3.6	0	0	0	0	0	0
	538	1	3.6	1	3.6	0	0	0	0	0	0
	563	0	0	0	0	0	0	0	0	0	0
	588	1	3.6	1	3.6	0	0	0	0	0	0
	613	2	7.1	2	7.1	0	0	0	0	0	0
	638	10	118.0	5	17.8	4	57.6	1	42.2	0	0
	663	6	32.2	5	17.8	1	14.4	0	0	0	0
	688	7	46.6	5	17.8	2	28.8	0	0	0	0
	713	0	0	0	0	0	0	0	0	0	0

(6 of 6 sheets)

TABLE 4.3 EJECTA DISTRIBUTION BY SIZE AS A FUNCTION OF RANGE

Range[a]	Total Ejecta Weight	Weight and Percentage of Missiles in Indicated Size Classes							
		Class 1		Class 2		Class 3		Class 4	
		Weight	Percent	Weight	Percent	Weight	Percent	Weight	Percent
feet	pounds	pounds		pounds		pounds		pounds	
463	160.0	74.6	46.6	43.2	27.0	42.2	26.4	0	0
488	1,510.2	653.0	43.2	461.0	30.5	211.0	14.0	185.2	12.3
513	1,281.7	504.3	39.3	431.6	33.7	253.2	19.8	92.6	7.2
538	1,014.3	443.9	43.8	216.0	21.3	169.2	16.7	185.2	18.2
563	597.0	256.0	42.9	129.6	21.7	211.4	35.4	0	0
588	523.3	253.3	48.4	100.8	19.3	169.2	32.3	0	0
613	620.6	320.2	51.6	216.0	34.8	84.4	13.6	0	0
638	859.8	473.0	55.0	302.4	35.2	84.4	9.8	0	0
663	339.5	224.3	66.1	115.2	33.9	0	0	0	0
688	339.3	209.7	61.8	129.6	38.2	0	0	0	0
713	103.6	60.4	58.3	43.2	41.7	0	0	0	0
738	100.0	56.8	56.8	43.2	43.2	0	0	0	0
763	74.6	74.6	100.0	0	0	0	0	0	0
788	110.9	67.7	61.0	43.2	39.0	0	0	0	0
813	121.6	78.4	64.5	43.2	35.5	0	0	0	0
838	153.6	96.0	62.5	57.6	37.5	0	0	0	0
863	464.2	195.6	42.1	57.6	12.4	211.0	45.5	0	0
888	334.8	220.6	65.9	72.0	21.5	42.2	12.6	0	0
913	167.6	110.0	65.6	57.6	34.4	0	0	0	0
938	152.9	138.5	90.6	14.4	9.4	0	0	0	0
963	214.4	171.2	79.9	43.2	20.1	0	0	0	0
988	323.7	223.9	69.2	57.6	17.8	42.2	13.0	0	0
1,013	501.7	280.5	55.9	86.4	17.2	42.2	8.4	92.6	18.5

[a] Distance from ground zero.

TABLE 4.4 SPHERICAL MISSILE PERFORMANCE

Each sphere is ranked by distance traveled relative to distance traveled by other spheres in the same package. The missile that traveled farthest is ranked 1.

Missile Package No.	Range Rank/Number of Missiles Recovered Per Package							
	1-Inch Spheres				2-Inch Spheres			
	P[a]	A	S	L	P	A	S	L
143	--	--	2/2	--	--	1/2	--	--
153	1/2	2/2	--	--	--	--	--	--
161	2/3	3/3	1/3	--	--	--	--	--
163	2/5	1/5	5/5	--	3/5	4/5	--	--
171	--	--	2/2	--	--	--	1/2	--
181	3/8	2/8	4/8	7/8	8/8	5/8	1/8	6/8
233	--	--	--	--	--	2/2	1/2	--
241	--	2/2	--	--	--	1/2	--	--
243	--	4/4	2/4	--	1/4	3/4	--	--
253	--	--	--	--	--	1/2	2/2	--
263	--	1/3	3/3	--	--	--	2/3	--
281	--	--	2/3	--	--	1/3	3/3	--
341	--	--	3/3	--	--	1/3	2/3	--
351	--	3/3	--	--	--	1/3	2/3	--
371	--	3/3	--	--	--	2/3	1/3	--
381	--	--	2/4	--	--	1/4	4/4	3/4

[a] Key: P-plastic, A-aluminum, S-steel, L-lead.

TABLE 4.5 CYLINDRICAL MISSILE PERFORMANCE

Range Rank[a]	No. Times in Rank/No. Possibilities for Poorer Performance[b]				
	1/4-Wedge Section	1/2-Wedge Section	1-Inch Cylinder	2-Inch Cylinder	4-Inch Cylinder
1	8/27	5/26	8/29	12/28	11/32
2	8/22	12/19	13/24	7/24	5/25
3	8/15	6/13	4/18	6/17	8/15
4	2/6	1/6	4/6	3/6	5/6

[a] Each cylinder or cylindrical section was ranked by the distance traveled relative to the distance traveled by the other cylinders or cylindrical sections from the same package. The two 1/4-wedge sections in each cylinder package were both ranked, if both were recovered.

[b] Number of times any missile of indicated size/shape category was ranked in indicated position divided by the number of possibilities for poorer performance for all the missiles recovered of indicated size/shape category.

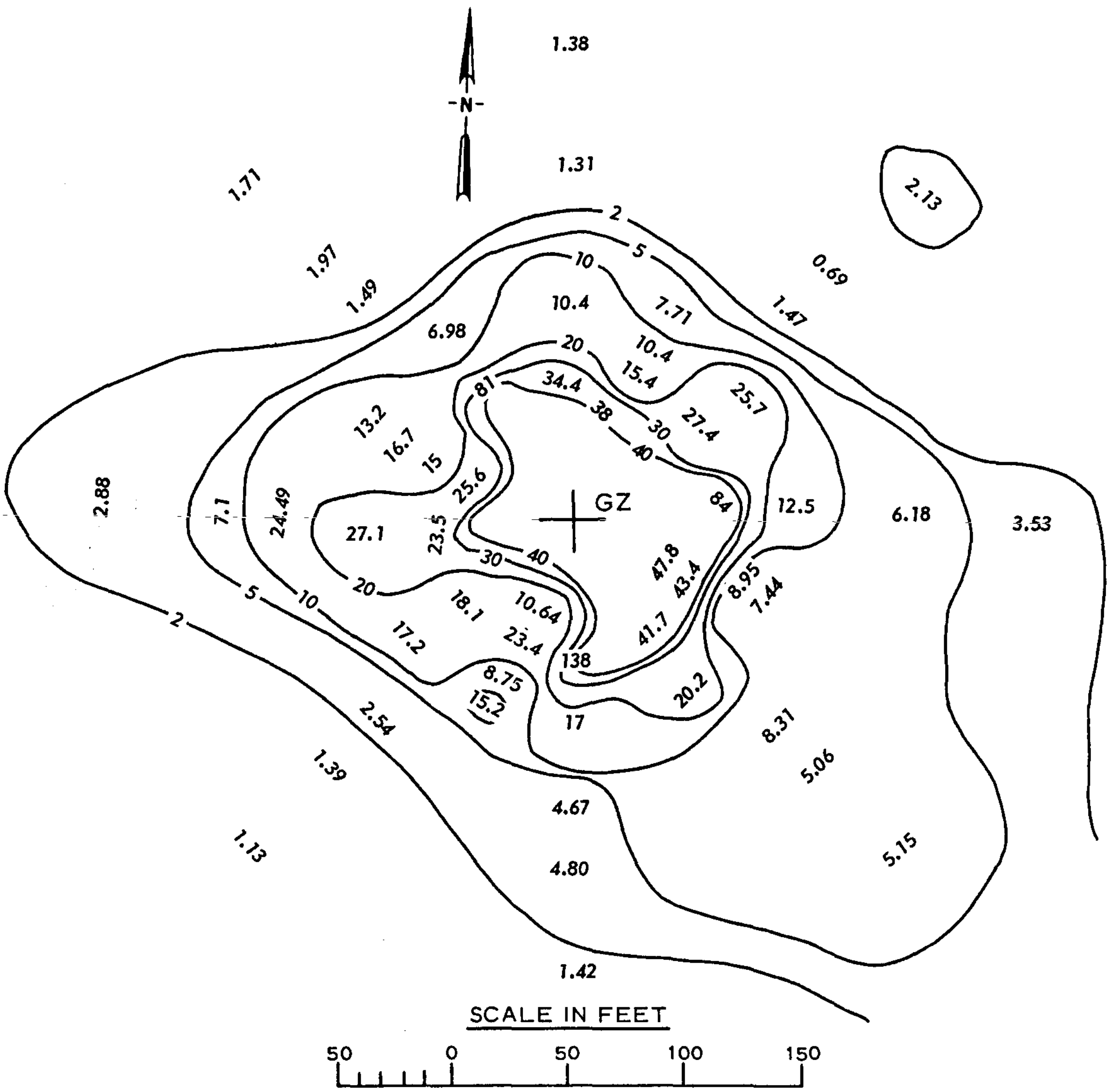


Figure 4.1 Ejecta areal mass density contours in and adjacent to the crater lip. Spot densities and contours are in pounds per square foot.

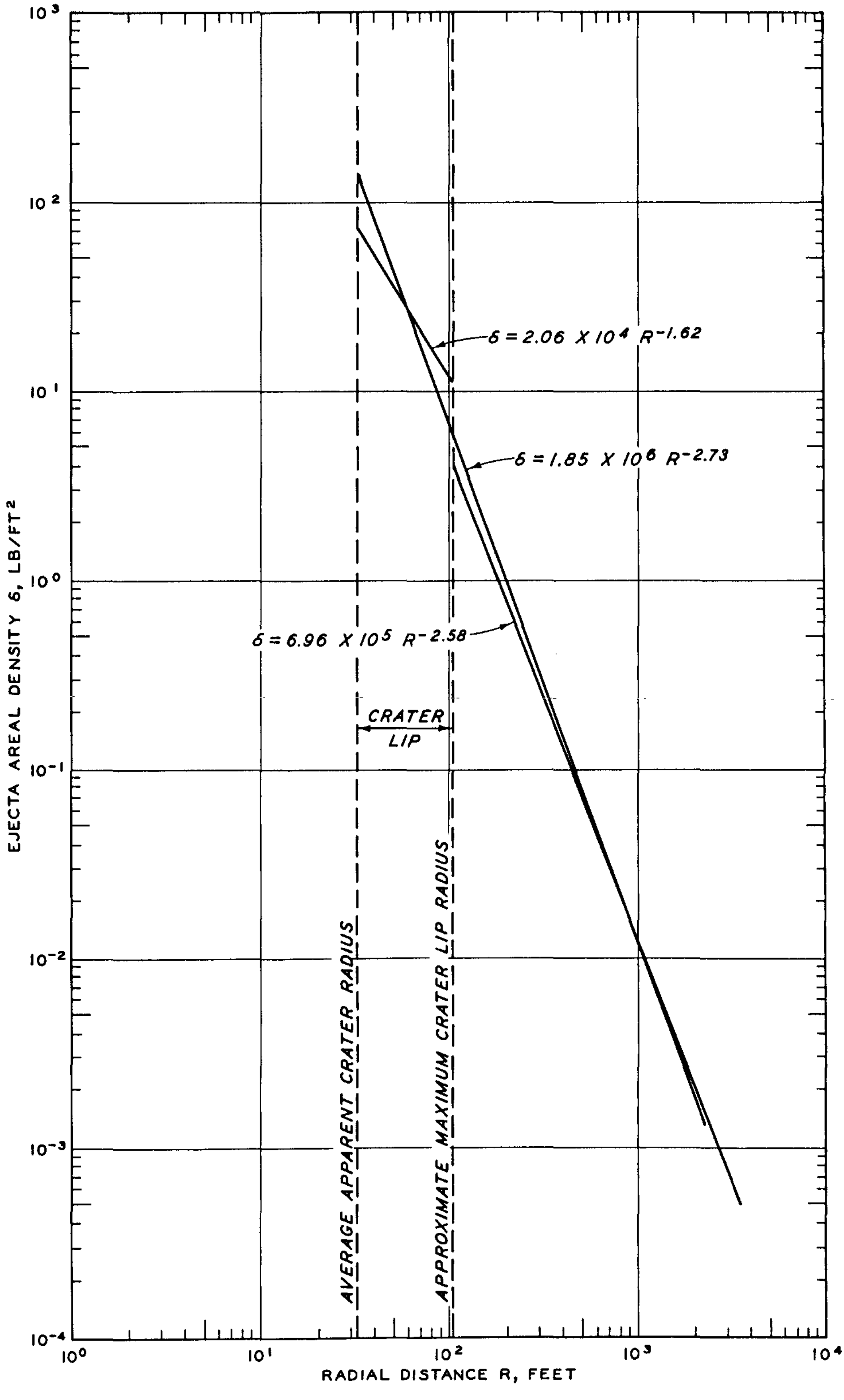


Figure 4.2 Ejecta mass density versus range.

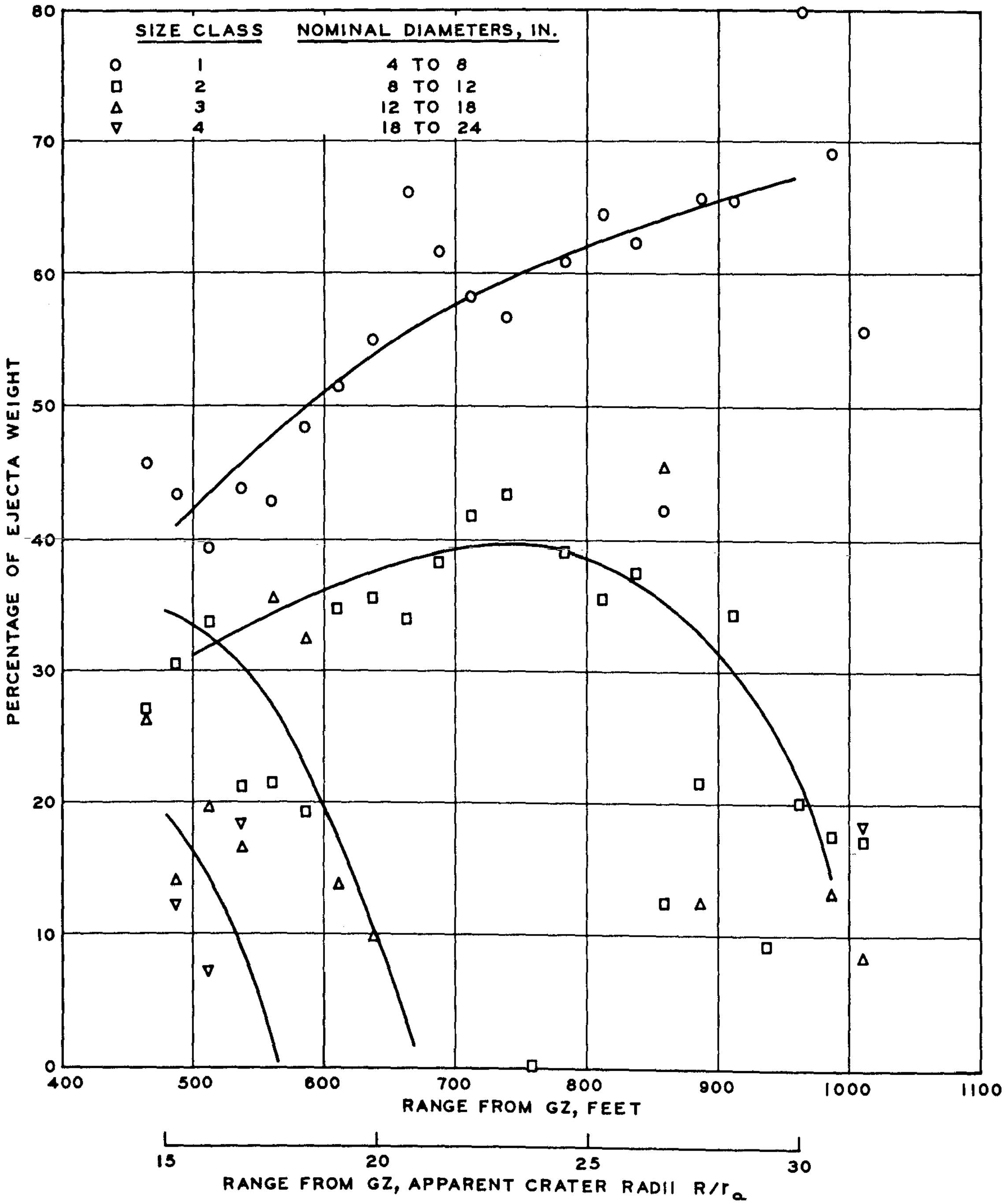


Figure 4.3 Distribution of missiles by size as a function of range from GZ.

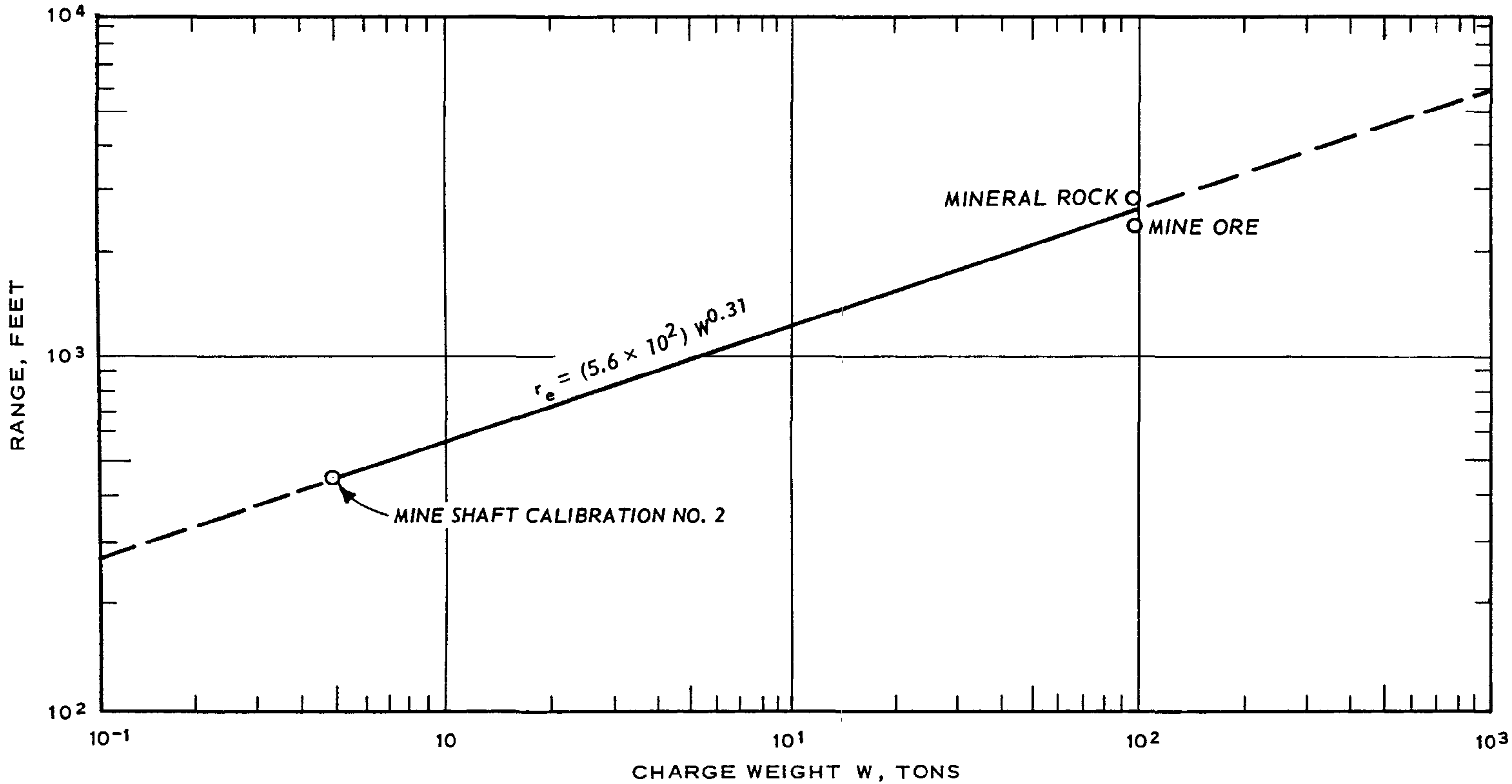


Figure 4.4 Maximum missile ranges r_e for Mine Shaft Events (HOB = 0.9 charge radius).

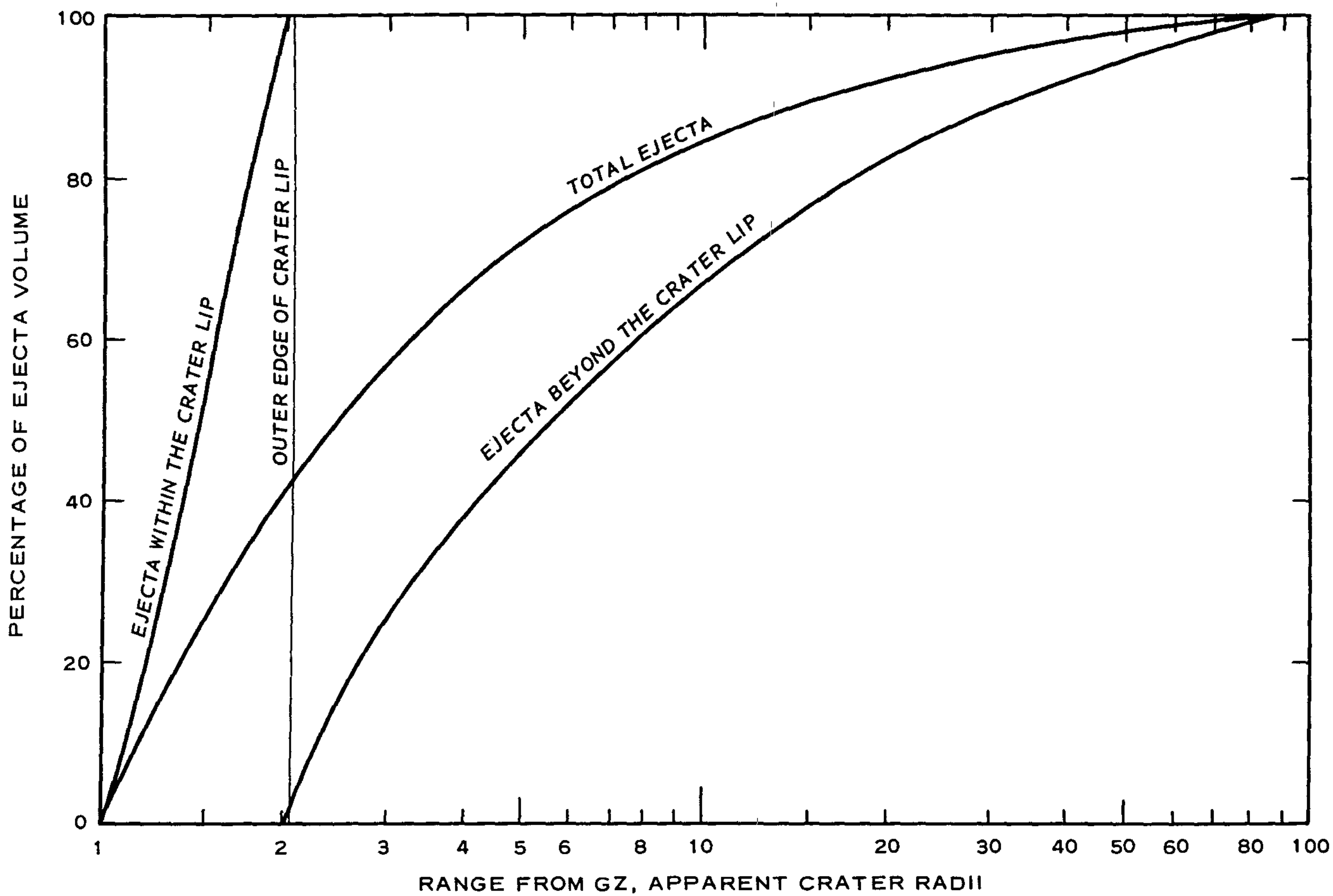


Figure 4.5 Percentage of ejecta volume (or weight) as a function of range from GZ.

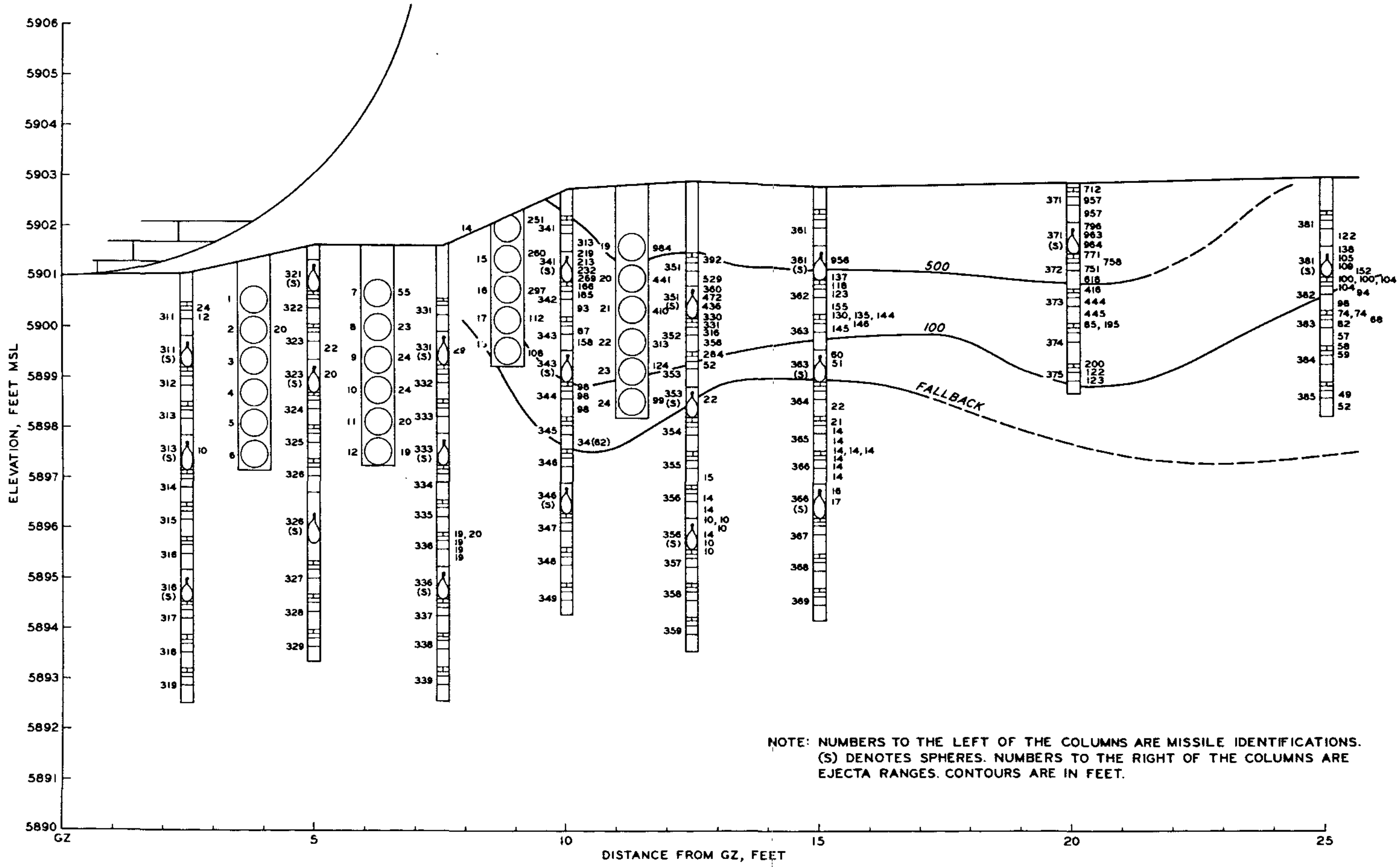


Figure 4.6 Range contours for artificial missiles on north radial. Topography shown is prior to grouting around charge.

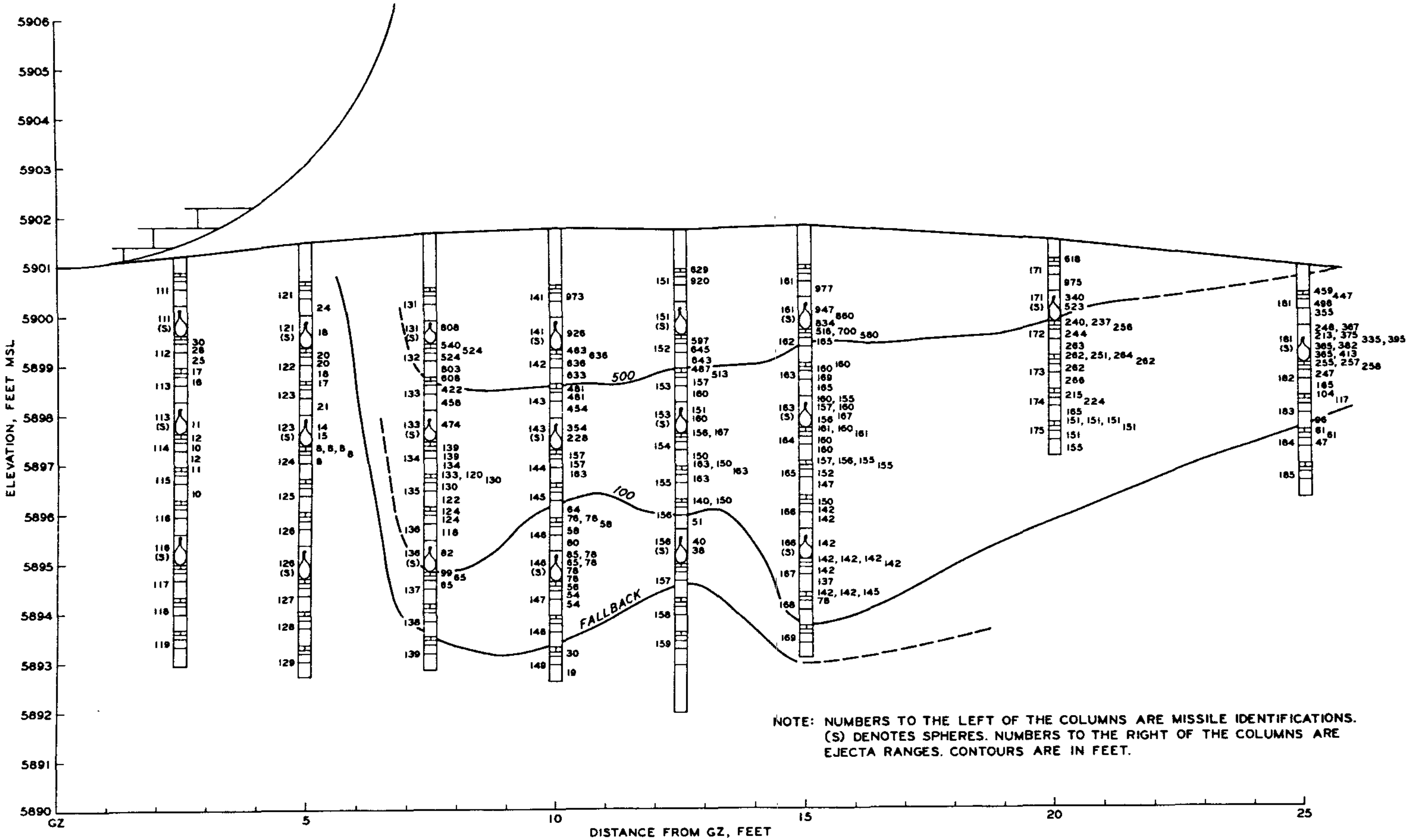


Figure 4.7 Range contours for artificial missiles on south radial. Topography shown is prior to grouting around charge.

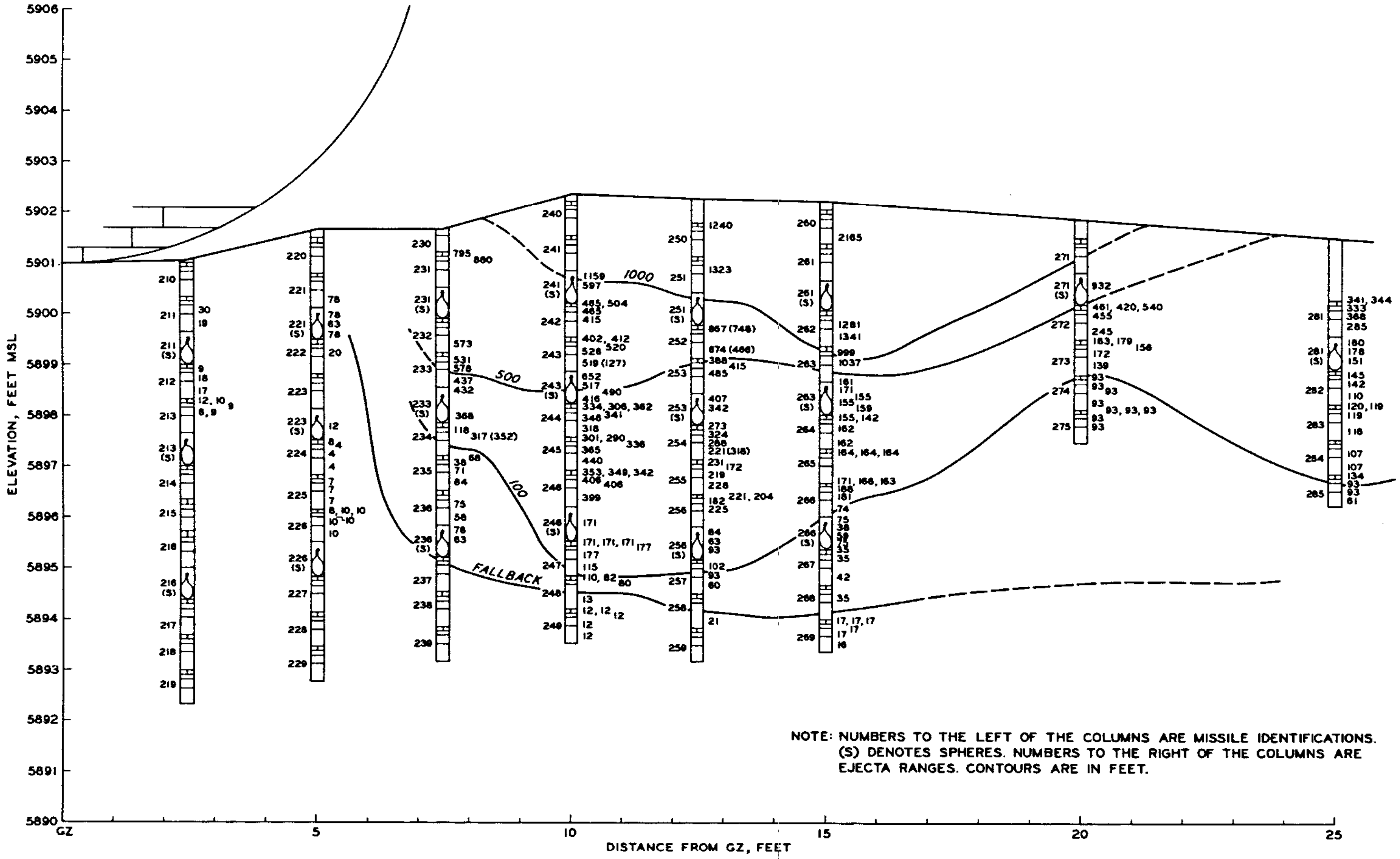
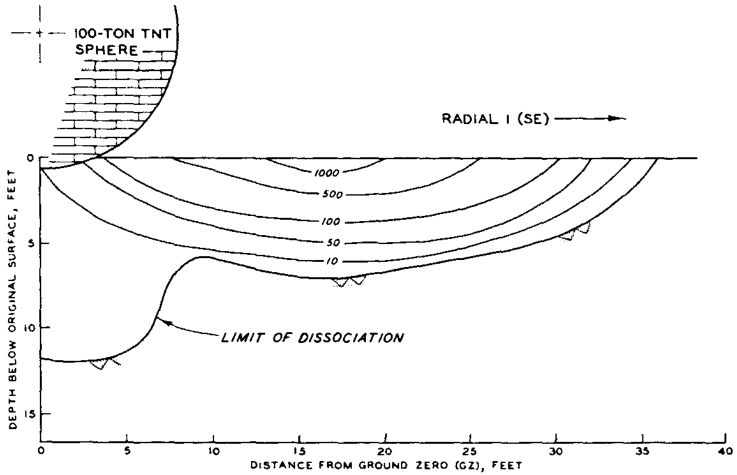
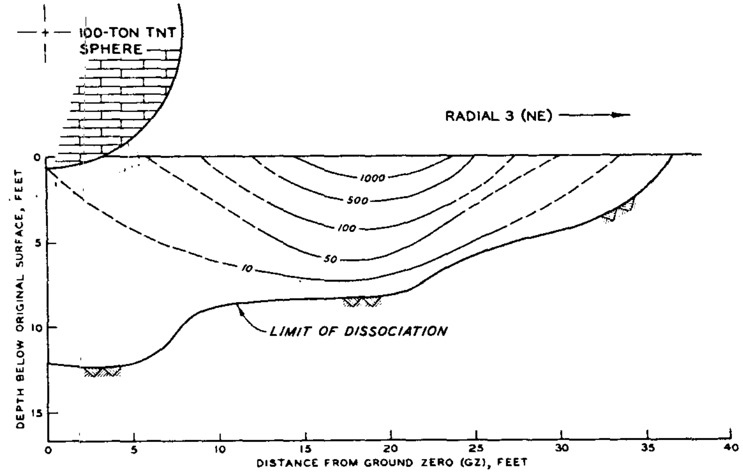


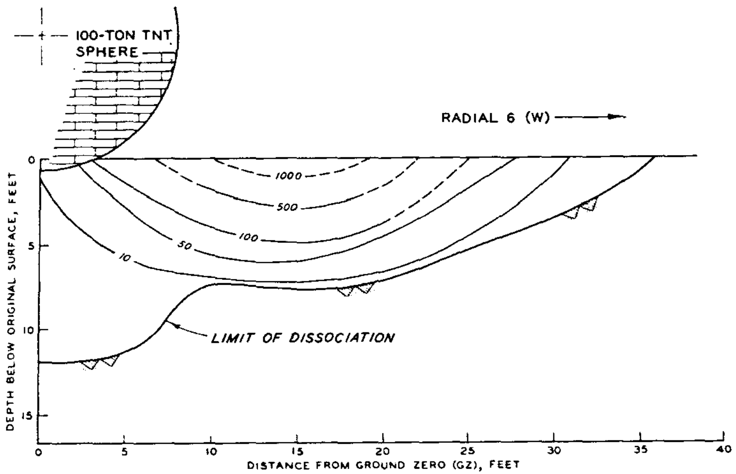
Figure 4.8 Range contours for artificial missiles on west radial. Topography shown is prior to grouting around charge.



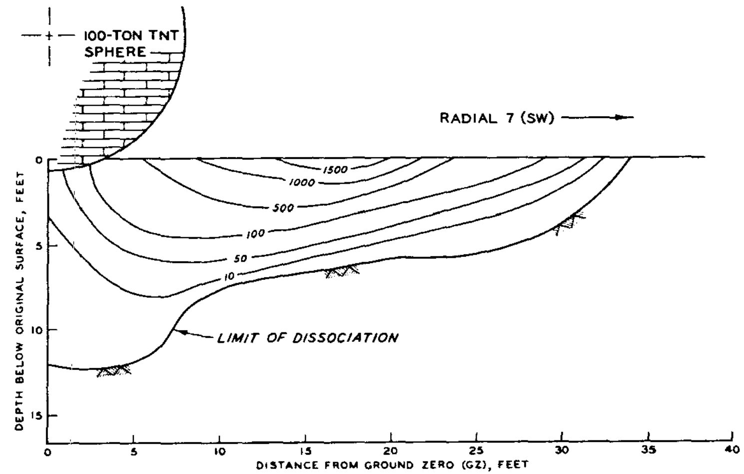
a. Radial 1.



b. Radial 3.



c. Radial 6.



d. Radial 7.

Figure 4.9 Contours of mean horizontal displacement of rock dissociated along radials of grout columns. Contour intervals indicated ranges (in feet) at which fragments were deposited, measured from their points of origin.

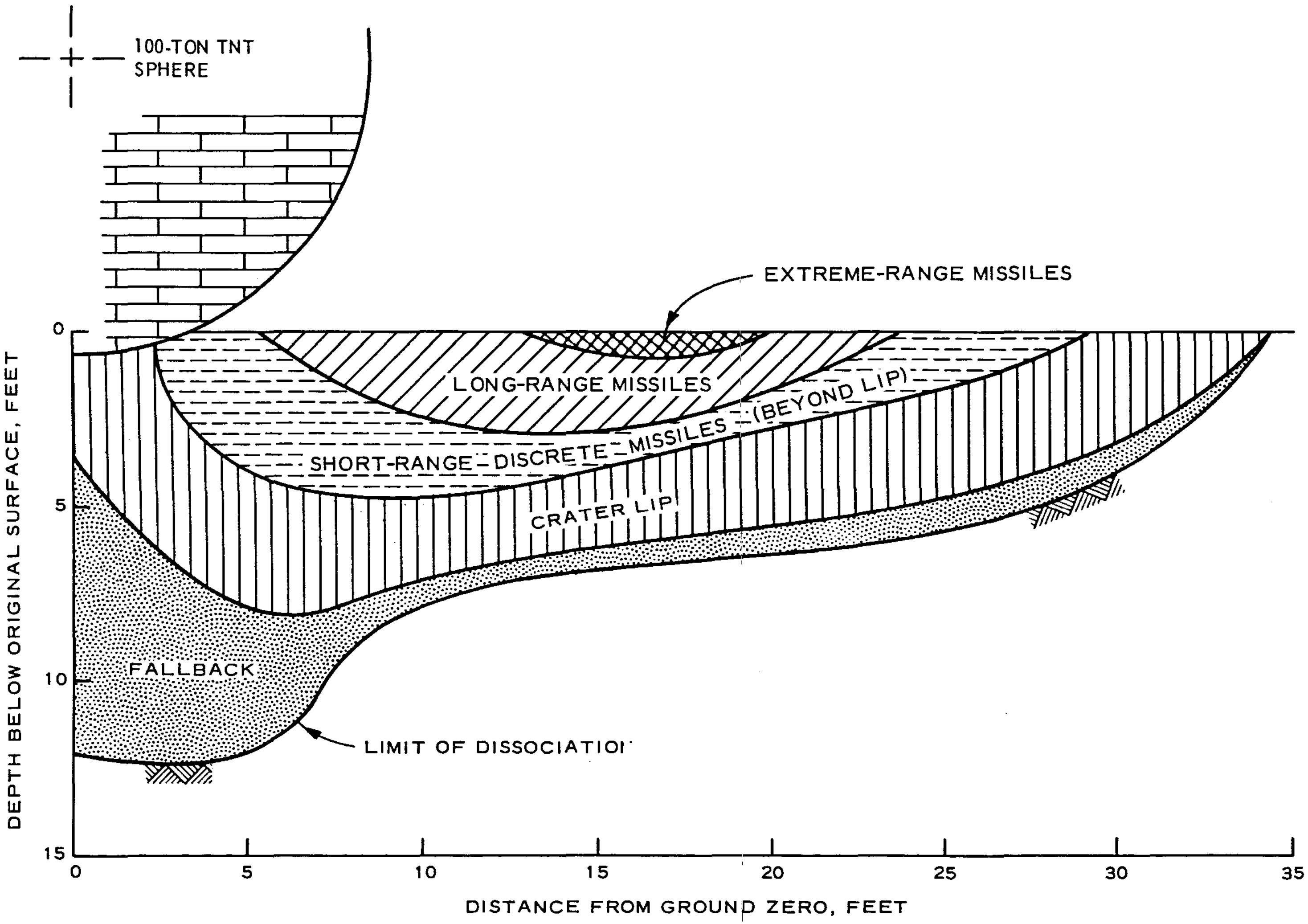


Figure 4.10 Zones of origin of crater and ejecta debris.

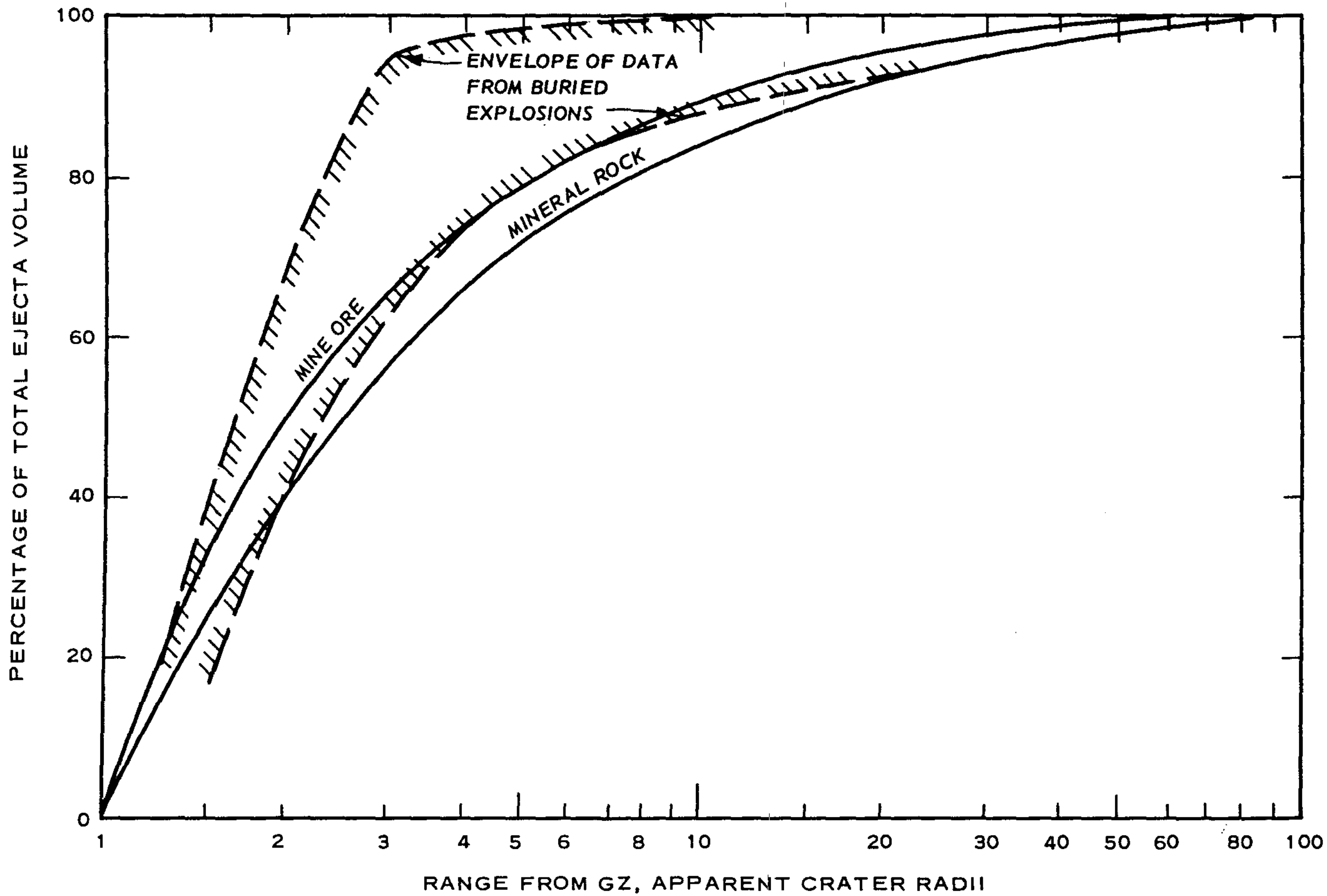


Figure 4.11 Comparison of ejecta distribution with range for Mineral Rock, Mine Ore, and buried explosions.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

The Mine Ore and Mineral Rock Events provided good information on ejecta areal density and distribution for this medium and shot geometry, but left some basic questions unanswered regarding reproducibility of crater ejecta data. The volume of ejected material in Mineral Rock was much greater than was predicted based on Mine Ore data. Proximity of the two GZ's and possible disturbance of the rock mass in the region of the Mineral Rock crater caused by the Mine Ore blast should be considered as a reason for the discrepancy. The failure of the ejecta sampling procedure to indicate the increase in ejecta determined by the crater volumetric analysis reflects the inadequate circumferential coverage of the aerial photography and its inability to account for particles smaller than 4 inches in diameter. In spite of this, the concept of the Mineral Rock experiment and the methodology developed for the event were sound.

The crater regions contributing to various ejecta volumes and distances were satisfactorily defined for the Mine Ore/Mineral Rock shot geometry, and good agreement was noted between the two events. These regions were also relatively the same as those observed for surface bursts in soil.

By using artificial missile experiments, ejecta photography (Reference 14), and impact data obtained for natural missiles, it would be possible to reconstruct the major portion of the ejecta terminal trajectories for Mineral Rock and to include tentative values for ballistic and drag coefficients. Although such a study is beyond the scope of this report, if this terminal trajectory data were to be considered with the size distribution data already developed for Mineral Rock, the hazards to personnel and structures associated with the Mineral Rock shot geometry could probably be quantified. Smaller particles (in this case, 4 to 8 inches) would tend to dominate the ejecta field beyond distances of 25 to 30 crater radii from GZ, as has been observed on surveys of the ejecta field periphery.

Volumetric analysis pointed up some discrepancies between the crater and ejecta studies. Analysis of the ejecta sampling indicated that 230 yd^3 of in situ material was ejected, a figure that appears too low when compared with the crater volume. About 90 yd^3 (in situ) was deposited in the crater lip.

In future experiments, a factor of $W^{0.3}$ should suffice for scaling maximum ejecta range r_e between charge weights for this and closely similar shot geometries in rock. Thus,

$$\frac{r_{e_1}}{r_{e_2}} = \left(\frac{W_1}{W_2}\right)^{0.3}$$

where the subscripts 1 and 2 denote different experiments. Presumably, the 0.3 exponent will decrease with increasing burial depth.

5.2 RECOMMENDATIONS

Aerial photography should be continued as a means of obtaining ejecta measurements in rock, and efforts should be made toward its refinement. Specifically, improvements in identification and resolution of ejecta particles and in determination of the height dimension should be sought in addition to improvements in film and camera quality, flight techniques, and survey control. Color, infrared, and stereophotography should be considered in future experiments. Due to economic considerations and due also to the uncertainty of the results, the use of such photography was not justified for Mineral Rock, but improved technology may change this. If aerial photography cannot be refined so as to permit counting of smaller particles (e.g., 1- or 2-inch-diameter samples), it will become necessary to supplement the photography with ground sampling to obtain an estimate of total ejecta. Count-and-weigh sectors have been successfully employed for such sampling. However, the use of small collector trays for this purpose is not recommended, since the effort associated with the technique is disproportinate to the results that can be obtained.

In future ejecta measurement experiments, the entire debris field should be photographically documented. Once this has been done, an adequate sample can probably be obtained through careful selection of counting areas, thus minimizing the cost associated with the time-consuming task of counting individual particles. Here again, the experimenter should be ever alert to technological advances such as optical scanning techniques. As with other crater measurements, it would be prudent to obtain good photographic records of ejecta fields for all large detonations, regardless of whether any immediate use of the data is anticipated.

Use of collector areas in and adjacent to the crater lip should be continued for explosions in cohesive material, where it is necessary to obtain quantitative data. For this particular shot geometry in rock, however, future sampling could be reduced, since good agreement was obtained for the weight of ejecta deposited in the Mine Ore and Mineral Rock crater lips.

Future sampling of ejecta fields, especially in the discontinuous region, must also include data on the statistics of particle fragmentation. This aspect of the Mineral Rock experiment provided some of the most useful information. Additional data are needed on an expanded range of rock sizes and for additional locations in the ejecta field.

Analysis of the artificial missile data should be undertaken at an early date to determine what was learned about the ballistics of ejected material. Additionally, comparison of the Mine Shaft ejecta data with results of theoretically oriented approaches appears promising. Some progress has been made on mathematical modeling of ejecta resulting from buried explosions (Reference 15), and it is recommended that correlation of theoretical and experimental observations be considered a priority item in cratering research.

APPENDIX A

AERIAL PHOTOGRAPHY EJECTA COUNT

The aerial photography of the Mineral Rock ejecta field was accomplished by Teledyne Geotronics, Inc., 725 East Third Street, Long Beach, California, under contract to the WES. This contract called for preshot and postshot photography of the test area and analysis of the results. Tables A.1 through A.8 are computer printouts showing the ejecta particle count for the eight useable photographs that were obtained, including size classifications and locations of natural missiles. The smallest identifiable particle was 4 inches in diameter. Coordinates (in feet) were based upon an assumed set of GZ coordinates. The size classifications applicable to all tables are given below.

Classification Code	Size Range (Diameter)
	inches
1	4 to 8
2	>8 to 12
3	>12 to 18
4	>18 to 24
5	>24 to 36

TABLE A.1 EJECTA DATA FROM PHOTOGRAPH NO. 73

TOTAL NUMBER OF PARTICLES COUNTED - 25.

COORDINATES ARE IN FEET RELATIVE TO GZ. NEGATIVE COORDINATES ARE SOUTH AND/OR WEST OF GZ.

SIZE	COORDINATES		SIZE	COORDINATES	
CLASS	NORTHING	EASTING	CLASS	NORTHING	EASTING
1	562.365	-254.587	1	575.914	-226.032
1	529.419	-208.551	1	526.523	-209.387
1	544.917	-192.661	1	534.156	-144.298
1	608.688	-148.811	1	717.629	-93.469
1	716.580	-91.629	1	677.970	-99.231
1	655.008	-103.963	1	651.816	-104.592
1	619.686	-101.784	1	611.335	-96.550
1	544.868	-97.370	1	605.613	-64.704
1	719.314	-72.888	2	560.377	-246.064
2	569.968	-257.631	2	602.150	-225.165
2	~~590.957~~	~~-212.727~~	2	~~563.792~~	~~-100.879~~
2	616.638	-176.121	3	644.204	-147.830
5	557.454	-151.076			

TABLE A.2 EJECTA DATA FROM PHOTOGRAPH NO. 74

TOTAL NUMBER OF PARTICLES COUNTED - 6.

COORDINATES ARE IN FEET RELATIVE TO GZ. NEGATIVE COORDINATES ARE SOUTH AND/OR WEST OF GZ.

SIZE CLASS	COORDINATES NORTHING	EASTING	SIZE CLASS	COORDINATES NORTHING	EASTING
1	839.385	-161.830	1	810.078	-141.740
1	782.137	-166.135	1	812.137	-116.079
1	817.261	-116.260	1	875.314	-62.330

TABLE A.3 EJECTA DATA FROM PHOTOGRAPH NO. 81

TOTAL NUMBER OF PARTICLES COUNTED - 1050.

COORDINATES ARE IN FEET RELATIVE TO GZ. NEGATIVE COORDINATES ARE SOUTH AND/OR WEST OF GZ.

SIZE	COORDINATES		SIZE	COORDINATES	
CLASS	NORTHING	EASTING	CLASS	NORTHING	EASTING
1	-12.312	-466.480	1	-13.505	-474.062
1	-18.610	-480.061	1	-30.599	-486.327
1	-29.293	-484.897	1	-25.895	-483.062
1	-28.130	-479.855	1	-27.775	-480.333
1	-26.490	-480.293	1	-25.490	-477.982
1	-26.872	-475.598	1	-23.861	-467.469
1	-31.397	-471.455	1	-31.053	-475.282
1	-33.178	-477.896	1	-32.960	-482.319
1	-33.638	-483.422	1	-34.755	-483.113
1	-36.625	-484.381	1	-39.030	-484.151
1	-40.927	-483.650	1	-41.050	-484.035
1	-47.662	-484.572	1	-48.217	-479.783
1	-47.152	-480.697	1	-45.150	-478.910
1	-45.193	-476.165	1	-44.392	-479.131
1	-40.788	-478.246	1	-40.841	-478.703
1	-36.997	-478.102	1	-39.680	-475.508
1	-37.743	-474.396	1	-37.419	-470.317
1	-37.681	-470.361	1	-35.161	-465.578
1	-38.605	-465.196	1	-42.418	-463.152
1	-45.096	-464.632	1	-37.768	-449.618
1	-49.806	-451.981	1	-47.516	-458.464
1	-48.934	-457.944	1	-49.559	-459.526
1	-47.511	-461.309	1	-53.119	-463.603
1	-50.443	-465.979	1	-47.565	-467.564
1	-51.397	-472.203	1	-50.299	-472.709
1	-47.304	-471.780	1	-44.713	-472.855
1	-42.365	-475.057	1	-44.266	-475.814
1	-48.044	-476.221	1	-52.255	-475.227
1	-54.267	-475.033	1	-55.261	-477.945
1	-61.[illegible]6	-482.608	1	-65.441	-482.685
1	-67.4[illegible]4	-482.846	1	-67.747	-479.513
1	-65.525	-479.798	1	-60.665	-478.119
1	-57.062	-476.341	1	-58.233	-474.137
1	-59.594	-475.241	1	-64.438	-472.999

TABLE A.3 EJECTA DATA FROM PHOTOGRAPH NO. 81 (CONTINUED)

SIZE CLASS	COORDINATES NORTHING	COORDINATES EASTING	SIZE CLASS	COORDINATES NORTHING	COORDINATES EASTING
1	-72,451	-470.987	1	-70.586	-471,539
1	-68,356	-471.539	1	-66.634	-468,289
1	-60,425	-468.726	1	-59.705	-469,944
1	-58,774	-471.446	1	-54.645	-469,349
1	-56,205	-467.898	1	-56.561	-466,232
1	-55,414	-465.640	1	-56.045	-465,003
1	-58,441	-463.476	1	-56.341	-463.355
1	-55,064	-463.312	1	-54,059	-462,060
1	-54,473	-461.939	1	-55,089	-461,854
1	-57,626	-461.025	1	-60.381	-460.953
1	-54,061	-456.163	1	-55.532	-455,900
1	-55,662	-455,059	1	-58.323	-453.041
1	-60,671	-454.895	1	-62.414	-451.546
1	-65,219	-449,774	1	-65.525	-448.501
1	-67,043	-454.131	1	-74.657	-456.586
1	-72,181	-457.996	1	-71.515	-456.246
1	-70,397	-457.169	1	-69.604	-456.396
1	-68,134	-458.142	1	-66.224	-464.206
1	-67,102	-464.402	1	-72,198	-465.193
1	-75,576	-462.113	1	-77.311	-458.232
1	-70,698	-445.895	1	-73.416	-445.010
1	-75,522	-445.781	1	-78.691	-444,057
1	-81,402	-447.103	1	-81.369	-449.141
1	-85,113	-447.435	1	-86.803	-447,563
1	-88,327	-443.401	1	-97.311	-444.326
1	-94,918	-446.050	1	-100.379	-448,866
1	-91,639	-449.207	1	-94.691	-452.046
1	-100,365	-454.823	1	-97.156	-456,478
1	-96,228	-457.513	1	-90.124	-455.377
1	-90,937	-452,980	1	-89.076	-452.181
1	-87,282	-453.307	1	-84.599	-455.582
1	-83,616	-455.953	1	-80.791	-458.106
1	-83,213	-466,094	1	-83.353	-469.642
1	-82,197	-471.047	1	-73.379	-478.140
1	-73,863	-478.330	1	-76.555	-481.801
1	-77,607	-482.053	1	-79.046	-482.012
1	-79,465	-480.573	1	-77.361	-479.695
1	-83,150	-482,603	1	-87.183	-475,087
1	-91,157	-480.972	1	-94.498	-477.760
1	-95,498	-477.999	1	-102.535	-480.017
1	-101,541	-476.192	1	-100.468	-472.182

TABLE A.3 EJECTA DATA FROM PHOTOGRAPH NO. 81 (CONTINUED)

SIZE CLASS	COORDINATES NORTHING	EASTING	SIZE CLASS	COORDINATES NORTHING	EASTING
1	-98,656	-475.304	1	-98.106	-474,054
1	-97,490	-473.535	1	-97.473	-473,203
1	-97,418	-472,667	1	-91.038	-472.388
1	-92,654	-469.493	1	-92.641	-465,893
1	-97,851	-462.384	1	-96.461	-465.425
1	-95,852	-469.183	1	-98.073	-468,076
1	-101,941	-468.220	1	-103.665	-462.936
1	-112,683	-467.605	1	-114.803	-464,011
1	-115,086	-471,649	1	-112.836	-472,975
1	-110,573	-472.269	1	-109.125	-472,854
1	-109,560	-473.452	1	-110.345	-475,655
1	-109,747	-476.565	1	-110.321	-478,014
1	-110,886	-476.258	1	-111,779	-476,468
1	-117,129	-474.470	1	-119.733	-471,543
1	-125,942	-471.569	1	-121.143	-468.145
1	-121,922	-463.718	1	-123,361	-456,886
1	-117,081	-456.725	1	-115.345	-454,375
1	-111.129	-450.897	1	-105.113	-448,330
1	-108,769	-443.601	1	-117,065	-446.990
1	-127,893	-444.951	1	-139.980	-448,395
1	-143,065	-452,354	1	-143,635	-453,437
1	-151,428	-464.913	1	-157,299	-466,351
1	-160,040	-442,101	1	-171,981	-461,153
1	-179,196	-472.860	1	-181.746	-471,392
1	-183,426	-472,057	1	-208.474	-462,627
1	-195,614	-477.152	1	-202.063	-482,099
1	-195,871	-485.263	1	-196.193	-488.194
1	-191,091	-486,587	1	-191,994	-482,779
1	-190,641	-483.520	1	-188.427	-482,990
1	-183,475	-484,024	1	-182,772	-484,024
1	-182,907	-483.509	1	-177.733	-481,769
1	-182,165	-488.920	1	-172,744	-483,393
1	-167,883	-485.776	1	-156.416	-489,548
1	-163,098	-497.298	1	-162.449	-495.307
1	-167,077	-493.338	1	-182,363	-510.805
1	-188,543	-506,852	1	-197,493	-499,332
1	-207,944	-497,661	1	-198.260	-519,309
1	-196,802	-521.091	1	-190,967	-520,305
1	-164,898	-518,472	1	-155,357	-509,448
1	-153,813	-508.667	1	-146.865	-502,094
1	-145,813	-500.958	1	-138.530	-490,615

TABLE A.3 EJECTA DATA FROM PHOTOGRAPH NO. 81 (CONTINUED)

SIZE	COORDINATES		SIZE	COORDINATES	
CLASS	NORTHING	EASTING	CLASS	NORTHING	EASTING
1	-129,924	-488.502	1	-125.233	-484,972
1	-108,862	-482.514	1	-104.769	-482.231
1	-110,136	-491.755	1	-115.006	-491,045
1	-115,272	-492.896	1	-117.275	-490.897
1	-126,782	-493,990	1	-136.222	-522,531
1	-132,576	-522.271	1	-129.782	-525,212
1	-124,855	-526.725	1	-119.113	-528,210
1	-118,813	-523.944	1	-113.500	-529,073
1	-112,334	-524.338	1	-108.016	-513,974
1	-106,541	-501.742	1	-106.443	-506,742
1	-104,466	-510.679	1	-101.593	-511,257
1	-95,121	-517.813	1	-103.362	-524,370
1	-104,993	-529.360	1	-90.240	-530,708
1	-89,893	-530.887	1	-88.920	-530,057
1	-89,751	-528.675	1	-90.475	-526,529
1	-88,251	-526.161	1	-86.809	-529,356
1	-85,517	-528.991	1	-83.161	-527,110
1	-80,423	-529.609	1	-80.272	-530.155
1	-76,173	-530.136	1	-75.614	-529,481
1	-69,255	-530.705	1	-67.970	-531,689
1	-62,036	-531.739	1	-59.284	-531,866
1	-66,677	-527.379	1	-60.439	-518,860
1	-64,280	-517.892	1	-63.804	-520.109
1	-69,458	-519.238	1	-71.255	-518.774
1	-73,417	-519.823	1	-73.589	-520,232
1	-74,285	-520.598	1	-85.063	-521.731
1	-82,428	-518.785	1	-80.323	-516,480
1	-77,191	-516.041	1	-79.640	-514,226
1	-88,315	-515.783	1	-90.957	-510,600
1	-92,046	-507.812	1	-91.710	-507.261
1	-91,761	-505.227	1	-92.293	-506,045
1	-93,202	-507.782	1	-93.920	-509,095
1	-95,314	-507.322	1	-94.393	-505,877
1	-59,898	-501.673	1	-99.749	-506,769
1	-100,500	-505.913	1	-102.000	-502.022
1	-99,131	-503.169	1	-98.277	-501,781
1	-97,669	-500.237	1	-98.239	-497,613
1	-97,736	-498.072	1	-95.244	-501.155
1	-94,096	-501.313	1	-92.358	-503,189
1	-86,609	-505.669	1	-86.509	-504,232
1	-85,059	-503.726	1	-81.266	-503,830

TABLE A.3 EJECTA DATA FROM PHOTOGRAPH NO. 81 (CONTINUED)

SIZE CLASS	COORDINATES NORTHING	COORDINATES EASTING	SIZE CLASS	COORDINATES NORTHING	COORDINATES EASTING
1	-80,239	-503,850	1	-80.383	-506,824
1	-69,007	-512.520	1	-66.520	-512,822
1	-67,110	-514.129	1	-65,955	-514.553
1	-65,330	-515.255	1	-63,941	-516,555
1	-62,005	-514.745	1	-60.018	-515,505
1	-58,539	-516.615	1	-60.500	-513,297
1	-57,532	-512.666	1	-60.632	-509,188
1	-56,466	-498,505	1	-58.095	-498,521
1	-59,882	-501.686	1	-63.223	-505,769
1	-65,438	-506.966	1	-67.370	-507,890
1	-69,925	-508.546	1	-71.694	-505,737
1	-72,943	-504.312	1	-71.822	-504,221
1	-68,630	-503.081	1	-63.507	-500,470
1	-66,195	-501.383	1	-66.384	-499,671
1	-66,492	-498.101	1	-71.610	-500,062
1	-73,542	-501.570	1	-73.669	-501.312
1	-74,721	-500.539	1	-76.521	-500.811
1	-77,488	-499.075	1	-79.077	-497,715
1	-80,549	-496.494	1	-83.065	-500,560
1	-85,070	-500.104	1	-86.287	-495,934
1	-87,906	-495.170	1	-91.491	-494.450
1	-101,207	-490.411	1	-102.809	-490.500
1	-102,707	-487.678	1	-104.771	-486.973
1	-95,218	-484.879	1	-94.944	-483,702
1	-75,367	-487.356	1	-77.695	-486,939
1	-78,476	-487.562	1	-80.834	-487,399
1	-80,925	-488,549	1	-78,923	-490,387
1	-78,736	-491.053	1	-78.386	-490,617
1	-77,334	-490.567	1	-75.921	-493.743
1	-74,796	-491.288	1	-73.917	-492.612
1	-72,586	-493.417	1	-71.174	-495.030
1	-70,078	-495.673	1	-69.167	-496,792
1	-72,657	-489.303	1	-69.538	-486,428
1	-66,526	-487.538	1	-64.373	-487,257
1	-62,971	-489,688	1	-62.463	-491.500
1	-62,718	-494.350	1	-60.184	-490,701
1	-60,302	-487.488	1	-61.157	-486.776
1	-61,825	-485.616	1	-62.236	-485,476
1	-62,008	-485.031	1	-61.401	-484,807
1	-53,996	-487.490	1	-52.968	-489.169

TABLE A.3 EJECTA DATA FROM PHOTOGRAPH NO. 81 (CONTINUED)

SIZE CLASS	COORDINATES NORTHING	COORDINATES EASTING	SIZE CLASS	COORDINATES NORTHING	COORDINATES EASTING
1	-53,957	-489,782	1	-54,616	-489,384
1	-55,450	-491,118	1	-53,713	-491,592
1	-51,713	-491,757	1	-50,284	-492,889
1	-50,605	-493,699	1	-53,305	-493,452
1	-55,766	-495,676	1	-49,499	-496,029
1	-48,566	-496,753	1	-47,897	-496,205
1	-47,479	-495,881	1	-48,311	-494,438
1	-46,733	-494,244	1	-49,745	-490,813
1	-48,616	-489,759	1	-46,659	-485,983
1	-46,563	-490,379	1	-44,592	-491,079
1	-42,579	-489,797	1	-43,355	-492,862
1	-40,805	-495,119	1	-34,353	-490,769
1	-34,222	-487,449	1	-30,038	-487,125
1	-28,421	-496,254	1	-26,848	-493,343
1	-24,903	-495,831	1	-20,151	-489,662
1	-18,140	-488,341	1	-15,293	-491,062
1	-17,806	-493,306	1	-19,081	-496,134
1	-13,167	-494,579	1	-15,128	-499,915
1	-11,866	-501,133	1	-15,408	-507,340
1	-15,150	-507,904	1	-21,387	-509,854
1	-25,512	-510,345	1	-25,175	-507,528
1	-35,242	-508,781	1	-36,733	-504,485
1	-37,902	-503,539	1	-39,197	-504,020
1	-42,974	-507,411	1	-46,087	-501,959
1	-50,282	-502,381	1	-50,997	-499,753
1	-54,381	-500,044	1	-55,229	-498,082
1	-56,008	-503,181	1	-56,158	-511,983
1	-52,557	-511,989	1	-51,044	-510,361
1	-49,435	-510,674	1	-49,148	-512,931
1	-43,452	-514,143	1	-39,919	-514,354
1	-35,754	-514,501	1	-26,573	-515,420
1	-25,268	-514,524	1	-20,094	-516,617
1	-18,002	-519,622	1	-17,363	-524,208
1	-18,113	-533,182	1	-17,611	-527,116
1	-17,776	-528,164	1	-19,805	-529,030
1	-26,251	-522,728	1	-25,416	-530,685
1	-26,300	-529,511	1	-28,909	-527,175
1	-31,914	-523,367	1	-33,661	-522,848
1	-34,625	-521,819	1	-37,454	-520,871
1	-40,645	-520,418	1	-48,443	-519,411
1	-47,553	-522,787	1	-48,288	-524,707

TABLE A.3 EJECTA DATA FROM PHOTOGRAPH NO. 81 (CONTINUED)

SIZE CLASS	COORDINATES NORTHING	EASTING	SIZE CLASS	COORDINATES NORTHING	EASTING
1	-49,430	-525.211	1	-49.813	-525.901
1	-52,284	-522.873	1	-53.337	-517,773
1	-55,868	-522.938	1	-55.873	-526.123
1	-54,188	-529.246	1	-55.053	-529.116
1	-56,622	-532.254	1	-57.483	-533,534
1	-54,767	-532.460	1	-53.641	-533.733
1	-50,797	-534.457	1	-50.025	-533.428
1	-49,057	-531.734	1	-48.111	-531,296
1	-48,710	-530.137	1	-42,877	-530,614
1	-38,804	-524.913	1	-35.768	-527.655
1	-34,766	-531.793	1	-33.122	-532,413
1	-26,064	-538.183	1	-28.943	-538.373
1	-38,660	-536.572	1	-41.555	-536,200
1	-41,801	-538.056	1	-42.586	-538,265
1	-44,841	-537,732	1	-45.323	-537,434
1	-49,663	-535.302	1	-51.547	-537,172
1	-54,257	-536.639	1	-56.170	-538.403
1	-57,783	-541.641	1	-57.788	-546,011
1	-55,634	-554.427	1	-45.200	-552,986
1	-52,600	-548.276	1	-51.808	-546,818
1	-52,862	-543.198	1	-50.432	-539,692
1	-48,086	-539,771	1	-34.722	-543,250
1	-34,294	-544.044	1	-33.371	-544,382
1	-32,613	-545.106	1	-34.981	-548,674
1	-34,157	-549.116	1	-29.057	-547,283
1	-27,912	-543.728	1	-25.109	-546.056
1	-22,308	-546.428	1	-13.172	-546.458
1	-21,250	-551,964	1	-19,866	-551,617
1	-17,836	-552.252	1	-18.356	-554,364
1	-18,473	-556.730	1	-27,974	-559,518
1	-27,960	-554.588	1	-35.733	-555.099
1	-49,068	-562.962	1	-32.623	-565,344
1	-31,560	-566.313	1	-26.504	-565,657
1	-23,652	-567,916	1	-21,163	-567,812
1	-20,062	-581.202	1	-23.530	-580,984
1	-21,420	-577.152	1	-22.918	-574.613
1	-25,220	-574.547	1	-25.689	-574,988
1	-30,499	-575,208	1	-26.130	-578,118
1	-26,697	-578.298	1	-28.522	-581.393
1	-29,205	-581.344	1	-28.980	-582.150
1	-40,319	-581.922	1	-43.299	-582,631

TABLE A.3 EJECTA DATA FROM PHOTOGRAPH NO. 81 (CONTINUED)

SIZE CLASS	COORDINATES NORTHING	COORDINATES EASTING	SIZE CLASS	COORDINATES NORTHING	COORDINATES EASTING
1	-45,583	-584,396	1	-49,626	-580,924
1	-51,191	-576,800	1	-51,303	-577,431
1	-52,644	-579,356	1	-55,630	-575,662
1	-62,682	-575,930	1	-64,261	-576,771
1	-62,261	-571,075	1	-63,879	-569,182
1	-62,430	-568,250	1	-66,564	-563,710
1	-69,666	-563,155	1	-70,173	-571,572
1	-78,097	-570,306	1	-75,065	-582,430
1	-85,215	-580,232	1	-86,225	-578,529
1	-88,182	-567,087	1	-92,237	-569,816
1	-92,967	-572,368	1	-99,504	-569,840
1	-107,098	-574,123	1	-107,762	-572,852
1	-107,204	-567,913	1	-109,977	-561,158
1	-108,951	-551,854	1	-102,784	-551,732
1	-99,473	-553,956	1	-96,798	-561,620
1	-96,128	-556,087	1	-96,078	-555,454
1	-93,400	-552,906	1	-92,912	-553,818
1	-92,958	-555,417	1	-91,491	-554,175
1	-90,378	-555,003	1	-86,582	-553,671
1	-68,074	-554,641	1	-63,518	-554,740
1	-64,103	-549,586	1	-62,455	-543,711
1	-60,439	-542,237	1	-63,605	-536,773
1	-65,360	-538,221	1	-67,121	-537,995
1	-72,374	-536,844	1	-73,738	-536,605
1	-77,897	-535,924	1	-70,481	-541,877
1	-71,784	-541,645	1	-73,178	-541,394
1	-76,941	-540,874	1	-78,968	-541,915
1	-79,737	-545,350	1	-82,199	-545,269
1	-82,766	-537,885	1	-83,437	-536,356
1	-87,229	-535,257	1	-87,874	-538,674
1	-92,107	-536,771	1	-94,091	-537,425
1	-97,404	-536,356	1	-93,793	-544,086
1	-99,085	-545,069	1	-98,418	-542,162
1	-99,643	-542,546	1	-102,290	-542,262
1	-101,602	-540,267	1	-104,455	-540,431
1	-106,957	-542,394	1	-106,372	-539,230
1	-108,027	-533,025	1	-111,416	-534,178
1	-111,146	-534,932	1	-114,872	-536,186
1	-120,485	-530,199	1	-121,141	-531,829
1	-121,855	-534,823	1	-123,920	-532,503
1	-125,698	-529,334	1	-128,577	-529,074

TABLE A.3 EJECTA DATA FROM PHOTOGRAPH NO. 81 (CONTINUED)

SIZE CLASS	COORDINATES NORTHING	COORDINATES EASTING	SIZE CLASS	COORDINATES NORTHING	COORDINATES EASTING
1	-122,968	-542.044	1	-124,532	-550,506
1	-120,381	-549.434	1	-121.653	-547,930
1	-121,852	-547,231	1	-121.359	-544,391
1	-119,889	-544.192	1	-117.697	-545,419
1	-115,818	-545,801	1	-114.417	-551,075
1	-111,807	-556,380	1	-111.613	-567,033
1	-114,779	-566,697	1	-112.930	-569,100
1	-122,565	-577.782	1	-130,261	-574,264
1	-132,400	-575,977	1	-144.890	-576,804
1	-143,730	-573.811	1	-128.065	-556,235
1	-130,318	-554.141	1	-129.922	-552,362
1	-135,303	-551.568	1	-139,688	-554.470
1	-146,075	-553.811	1	-149.914	-551,701
1	-157,498	-556.361	1	-160.243	-549,973
1	-170,321	-553.841	1	-172,500	-542,285
1	-173,157	-537.210	1	-170.128	-526,495
1	-181,370	-540.522	1	-206,352	-532,564
1	-206,821	-544.451	1	-186.305	-550,040
1	-186,207	-551.856	1	-181,557	-555,336
1	-164,421	-572,114	1	-198,684	-569,277
1	-210,397	-575.826	1	-215.374	-582,721
1	-206,319	-582,347	1	-198.477	-586,884
1	-191,186	-583,157	1	-182.117	-583,009
1	-168,206	-582,839	1	-168,232	-582,825
1	-167,897	-587,069	1	-170,585	-593,208
1	-167,932	-600.963	1	-172.408	-609,114
1	-176,534	-604,159	1	-181.917	-602,667
1	-185,303	-604,618	1	-187.806	-604.822
1	-184,487	-623.018	1	-183.192	-619.221
1	-170,188	-614.068	1	-160.992	-611,212
1	-159,966	-620.899	1	-147.750	-625,938
1	-148,314	-623.128	1	-151,898	-615,732
1	-156,795	-605.720	1	-161.616	-596,520
1	-154,847	-594,378	1	-159,821	-591,838
1	-155,081	-578,686	1	-128.672	-582,086
1	-129,009	-599,287	1	-131,082	-605,203
1	-123,806	-608,017	1	-124,938	-610,939
1	-131,459	-617,617	1	-135,797	-619,994
1	-128,065	-625,517	1	-117,797	-620,979
1	-116,699	-619,193	1	-121.484	-619,079

TABLE A.3 EJECTA DATA FROM PHOTOGRAPH NO. 81 (CONTINUED)

SIZE CLASS	COORDINATES NORTHING	COORDINATES EASTING	SIZE CLASS	COORDINATES NORTHING	COORDINATES EASTING
1	-120.839	-618.187	1	-120.504	-615.286
1	-119.654	-612.152	1	-120.126	-607.149
1	-114.939	-602.519	1	-116.068	-596.637
1	-106.792	-588.470	1	-102.551	-588.069
1	-81.593	-587.225	1	-81.945	-586.598
1	-77.071	-585.630	1	-67.924	-586.358
1	-69.589	-587.241	1	-72.308	-595.778
1	-79.352	-596.725	1	-79.713	-601.319
1	-73.066	-602.864	1	-78.004	-607.679
1	-89.295	-616.103	1	-92.000	-615.397
1	-94.209	-613.325	1	-95.423	-612.368
1	-94.867	-611.227	1	-95.959	-610.630
1	-103.763	-618.790	1	-114.664	-624.302
1	-75.146	-628.471	1	-76.185	-624.278
1	-72.348	-623.000	1	-72.347	-618.749
1	-66.950	-622.710	1	-66.167	-622.518
1	-65.292	-621.973	1	-64.960	-622.281
1	-64.571	-623.063	1	-54.146	-610.718
1	-59.412	-607.429	1	-60.340	-599.990
1	-48.935	-602.853	1	-51.642	-599.502
1	-47.896	-599.714	1	-46.509	-596.593
1	-54.604	-594.509	1	-51.048	-591.314
1	-51.999	-590.558	1	-53.729	-587.253
1	-55.531	-584.298	1	-52.856	-585.750
1	-50.821	-586.961	1	-50.467	-584.894
1	-29.584	-586.157	1	-27.274	-589.570
1	-27.430	-590.854	1	-22.424	-588.925
1	-19.108	-596.355	1	-27.048	-596.499
1	-33.814	-594.948	1	-20.130	-603.174
1	-19.105	-605.660	1	-25.730	-606.488
1	-26.988	-608.027	1	-27.741	-605.613
1	-32.207	-605.584	1	-36.556	-606.409
1	-38.517	-612.454	1	-33.544	-613.803
1	-29.796	-613.609	1	-26.704	-612.826
1	-21.520	-614.883	1	-19.314	-619.588
1	-19.726	-620.631	1	-20.246	-626.112
1	-31.914	-618.772	1	-35.873	-620.714
1	-37.164	-625.147	1	-39.385	-626.221
1	-42.150	-629.346	1	-45.675	-630.068
1	-50.516	-627.136	1	-55.035	-626.032
1	-55.822	-630.452	1	-54.398	-629.541

TABLE A.3 EJECTA DATA FROM PHOTOGRAPH NO. 81 (CONTINUED)

SIZE CLASS	COORDINATES NORTHING	COORDINATES EASTING	SIZE CLASS	COORDINATES NORTHING	COORDINATES EASTING
1	-37,661	-633.694	1	-25.364	-660,962
1	-24,575	-664.703	1	-41.070	-659,407
1	-42,228	-662.636	1	-47,679	-674,992
1	-53,020	-678.293	1	-60.461	-662,277
1	-62,304	-654.229	1	-60.694	-651,710
1	-53,403	-643.379	1	-45.899	-642,994
1	-50,086	-639.407	1	-62.799	-635,355
1	-71,842	-643.460	1	-81.884	-652,433
1	-86,407	-661.204	1	-78.018	-667.551
1	-83,117	-673.635	1	-102.481	-676.213
1	-102,956	-675.283	1	-104.095	-666,323
1	-111,629	-664.040	1	-117.409	-668,193
1	-114,570	-654.267	1	-115.834	-649,135
1	-98,181	-632.078	1	-101.215	-632,927
1	-116,627	-634.678	1	-117.187	-642,210
1	-126,134	-635.913	1	-135,350	-631,288
1	-144,915	-628.673	1	-154.566	-644,430
1	-139,668	-646.936	1	-140.915	-651,516
1	-135,692	-654.381	1	-131.342	-645,201
1	-141,424	-662.073	1	-146.197	-673,942
1	-153,958	-665.150	1	-167.184	-657,093
1	-177,737	-666.533	1	-197.730	-669,067
1	-209,650	-670,398	1	-212.376	-654,918
1	-211,410	-637.588	1	-203.924	-630,761
1	-177,341	-632.331	1	-169.120	-629,672
1	-166,821	-632,697	1	-168.143	-636,421
1	-170,120	-649.378	1	-180.102	-647,192
1	-186,735	-644.190	2	-18,884	-485,083
2	-35,495	-484.508	2	-43.880	-483,940
2	-54,709	-481.683	2	-45.774	-479,950
2	-42,480	-479,042	2	-43.181	-465,289
2	-55,398	-481.075	2	-59.317	-484.473
2	-64,422	-478.603	2	-58.631	-477,611
2	-60,720	-474,449	2	-62.992	-474,039
2	-69,046	-475.781	2	-63.961	-467,880
2	-56,223	-455.961	2	-67.071	-455.380
2	-68,215	-454.468	2	-76.969	-460,625
2	-77,884	-450.315	2	-81.825	-445,298
2	-97,951	-443.900	2	-94.168	-453,517
2	-94,575	-458.417	2	-82.972	-456.343
2	-82,449	-455.222	2	-72.981	-483,100

TABLE A.3 EJECTA DATA FROM PHOTOGRAPH NO. 81 (CONTINUED)

SIZE CLASS	COORDINATES NORTHING	COORDINATES EASTING	SIZE CLASS	COORDINATES NORTHING	COORDINATES EASTING
2	-83.744	-480.883	2	-89.589	-467.473
2	-107.943	-460.107	2	-106.827	-464.775
2	-109.014	-466.057	2	-126.497	-467.516
2	-128.036	-457.136	2	-107.778	-452.355
2	-114.992	-445.984	2	-142.722	-465.228
2	-170.135	-473.611	2	-160.065	-495.732
2	-160.776	-496.464	2	-168.985	-500.577
2	-174.257	-515.429	2	-101.562	-524.638
2	-123.114	-495.784	2	-118.816	-528.083
2	-109.462	-508.121	2	-90.715	-528.277
2	-80.500	-527.567	2	-61.886	-527.301
2	-76.763	-524.117	2	-77.614	-515.620
2	-90.424	-509.517	2	-97.468	-501.115
2	-81.668	-503.343	2	-78.522	-512.781
2	-74.797	-510.001	2	-71.815	-512.538
2	-63.541	-513.549	2	-61.129	-511.944
2	-62.356	-505.167	2	-67.642	-503.341
2	-65.963	-503.951	2	-69.677	-498.698
2	-73.726	-497.582	2	-75.474	-496.715
2	-84.543	-494.132	2	-93.013	-496.560
2	-93.459	-483.208	2	-92.421	-485.372
2	-86.839	-487.190	2	-87.673	-482.988
2	-69.589	-487.319	2	-63.514	-489.307
2	-61.456	-488.972	2	-58.878	-487.637
2	-57.973	-485.007	2	-40.476	-492.888
2	-37.734	-495.220	2	-13.456	-497.645
2	-10.747	-500.255	2	-37.962	-501.266
2	-39.754	-504.241	2	-48.653	-503.547
2	-55.032	-507.738	2	-49.961	-507.156
2	-34.413	-515.236	2	-17.186	-518.134
2	-22.534	-524.856	2	-53.663	-528.754
2	-29.870	-535.500	2	-25.072	-538.738
2	-46.792	-541.224	2	-17.941	-566.428
2	-14.948	-580.946	2	-20.162	-580.037
2	-19.049	-579.312	2	-27.233	-576.838
2	-27.257	-583.240	2	-51.944	-576.178
2	-52.357	-578.532	2	-99.434	-555.735
2	-68.052	-550.060	2	-61.955	-541.971
2	-79.541	-535.386	2	-77.640	-539.939
2	-93.339	-535.242	2	-95.465	-545.494
2	-95.446	-543.857	2	-150.082	-538.712

TABLE A.3 EJECTA DATA FROM PHOTOGRAPH NO. 81 (CONCLUDED)

SIZE CLASS	COORDINATES NORTHING	COORDINATES EASTING	SIZE CLASS	COORDINATES NORTHING	COORDINATES EASTING
2	-135,669	-538.255	2	-131.607	-541,585
2	-121,852	-549.765	2	-152.471	-563,407
2	-189,010	-541,653	2	-181.343	-579,615
2	-178,817	-576,649	2	-174.504	-591.187
2	-126,048	-607,443	2	-127.633	-614.705
2	-137,584	-624.361	2	-119.615	-608,089
2	-90,959	-589,256	2	-87.492	-586,326
2	-80,230	-588,665	2	-65.708	-598,300
2	-84,151	-612,285	2	-85.787	-609,841
2	-89,439	-621.878	2	-19.889	-591,813
2	-37,395	-621.243	2	-24.884	-638,626
2	-49,532	-658.588	2	-57.540	-666,736
2	-59,442	-656.824	2	-67.435	-651,878
2	-60,119	-644.002	2	-46.053	-636,117
2	-64,632	-637,108	2	-66.526	-633,500
2	-70,354	-653,800	2	-109.765	-675,243
2	-116,962	-665.505	2	-92.759	-646,120
2	-158,116	-632.869	2	-120.116	-671,146
2	-128,313	-674.632	2	-212.724	-671,382
2	-168,694	-648.670	2	-182.836	-656,114
2	-188,816	-645,154	3	-60.019	-473,072
3	-64,639	-455,505	3	-75.236	-449,922
3	-88,715	-466,654	3	-117.246	-466,420
3	-111,941	-451.571	3	-180.186	-456,415
3	-142,593	-480,118	3	-107.263	-490,393
3	-109,084	-489.836	3	-63.333	-502,125
3	-88,659	-487.422	3	-45.687	-485,689
3	-8,313	-501.495	3	-45.242	-508,643
3	-11,118	-529.970	3	-35.101	-538,575
3	-41,316	-542.712	3	-33.049	-548,610
3	-30,201	-555.238	3	-37,909	-564,262
3	-76,572	-578.710	3	-81.273	-555,180
3	-65,891	-535,459	3	-77,688	-544,980
3	-78,789	-545,927	3	-134.629	-600,896
3	-88,055	-589.596	3	-82.679	-592,840
3	-115,349	-626,847	3	-68.502	-615,309
3	-25,312	-614,469	3	-31.043	-617,995
3	-30,557	-636.006	3	-26,718	-668,755
4	-50,029	-479,985	4	-104,799	-503.135
4	-71,341	-522,361	4	-75.722	-485,106
4	-21,592	-530.495	4	-30.058	-525,368
5	-66,724	-461.330	5	-96.869	-506.271

TABLE A.4 EJECTA DATA FROM PHOTOGRAPH NO. 97

TOTAL NUMBER OF PARTICLES COUNTED - 190.

COORDINATES ARE IN FEET RELATIVE TO GZ. NEGATIVE COORDINATES ARE SOUTH AND/OR WEST OF GZ.

SIZE CLASS	COORDINATES NORTHING	COORDINATES EASTING	SIZE CLASS	COORDINATES NORTHING	COORDINATES EASTING
1	-210,786	-905.211	1	-199.543	-898,261
1	-189,287	-898.750	1	-193.868	-883,431
1	-198,267	-876.484	1	-211.386	-883,241
1	-217,990	-880.037	1	-219.803	-879,782
1	-217,446	-848.947	1	-203.427	-848,445
1	-193,497	-856.511	1	-196.808	-869,727
1	-186,779	-875.625	1	-174.476	-875,674
1	-173,077	-876.025	1	-167.540	-873,869
1	-168,287	-853.766	1	-164.946	-851,820
1	-161,215	-858.657	1	-158.372	-858,186
1	-159,309	-867.550	1	-160.222	-868,432
1	-140,834	-868.454	1	-139.309	-874,341
1	-140,706	-882.419	1	-142.052	-894,827
1	-146,309	-894.860	1	-148.477	-889,505
1	-153,483	-878.139	1	-162.371	-884,108
1	-167,159	-885.065	1	-165.336	-891,113
1	-164,526	-891.296	1	-160.272	-888,860
1	-156,810	-888.862	1	-167.257	-911,311
1	-162,648	-908.661	1	-160.448	-905,961
1	-152,938	-908.226	1	-148.678	-904,536
1	-131,597	-912.552	1	-123.924	-861,936
1	-109,497	-856.268	1	-102.072	-864,859
1	-102,046	-876.915	1	-104.321	-901,486
1	-72,058	-911.026	1	-79.360	-902,847
1	-65,114	-885.974	1	-69.803	-873,424
1	-36,631	-871.996	1	-25.479	-882,118
1	-7,519	-834.999	1	-16.693	-824,609
1	-49,512	-835.544	1	-55.185	-831,261
1	-50,990	-845.727	1	-44.581	-852,164
1	-42,167	-858.188	1	-73.844	-850,960
1	-92,825	-849.859	1	-122.749	-843,951
1	-117,448	-835.675	1	-100.865	-829,187
1	-83,433	-821.101	1	-98.524	-814,031
1	-110,498	-806.189	1	-118.747	-815,724
1	-118,287	-822.949	1	-142.788	-816,819

SIZE CLASS	COORDINATES NORTHING	COORDINATES EASTING	SIZE CLASS	COORDINATES NORTHING	COORDINATES EASTING
1	-161,425	-802.698	1	-174.950	-815,711
1	-154,024	-824,461	1	-157.194	-827,080
1	-146,839	-838.740	1	-152,969	-848,020
1	-168,753	-841,845	1	-176.236	-845,052
1	-176,807	-841.053	1	-177,497	-838,178
1	-217,602	-802.852	1	-195.744	-754,782
1	-178,469	-783.301	1	-175.394	-795,542
1	-172,128	-800.091	1	-159.261	-792,021
1	-151,834	-791.031	1	-150,121	-781,584
1	-172,744	-775,447	1	-170,452	-776,342
1	-165,298	-767,870	1	-154,239	-765,051
1	-143,644	-752,738	1	-137,849	-756,951
1	-136,837	-761,166	1	-139,366	-762,754
1	-127,261	-765,083	1	-142,019	-769,424
1	-135,877	-772,610	1	-140,133	-778,677
1	-141,051	-779,086	1	-126,193	-786,947
1	-136,591	-788,122	1	-141,583	-793,624
1	-129,119	-797,972	1	-122,510	-794,426
1	-109,364	-795,509	1	-89,130	-779,742
1	-76,158	-778,590	1	-63,883	-772,030
1	-50,682	-762,100	1	-50,599	-764,922
1	-57,426	-776,675	1	-51,669	-804,488
1	-40,787	-806,574	1	-22,224	-794,869
1	-3,445	-791,599	1	-19,397	-764,939
1	-19,379	-752,485	1	-,990	-721,229
1	-36,943	-711,215	1	-52,240	-718,299
1	-58,937	-725,602	1	-58,764	-727,854
1	-43,576	-742,838	1	-50,475	-742,043
1	-52,976	-743,243	1	-50,203	-751,794
1	-86,876	-736,838	1	-87,704	-739,311
1	-89,537	-739,804	1	-88,859	-746,448
1	-106,422	-745,922	1	-108,454	-748,599
1	-113,389	-752,108	1	-119,663	-753,421
1	-113,865	-741,323	1	-95,607	-731,294
1	-99,522	-722,004	1	-93,525	-723,290
1	-86,541	-711,800	1	-85,601	-709,625
1	-109,528	-707,849	1	-119,543	-723,936
1	-131,588	-740,677	1	-131,721	-746,596
1	-146,410	-747,408	1	-147,174	-747,518
1	-156,480	-743,301	1	-168,343	-745,036
1	-160,712	-723,653	1	-150,243	-723,151

TABLE A.4. EJECTA DATA FROM PHOTOGRAPH NO. 97 (CONCLUDED)

SIZE CLASS	COORDINATES NORTHING	EASTING	SIZE CLASS	COORDINATES NORTHING	EASTING
1	-141.142	-711.349	1	-149.938	-705.879
1	-183.730	-726.587	1	-134.500	-689.560
1	-131.702	-689.707	1	-131.797	-701.584
1	-131.813	-703.753	1	-127.828	-703.177
1	-87.090	-701.156	1	-81.662	-689.876
1	-82.245	-686.334	1	-59.069	-687.374
1	-60.527	-690.978	1	-58.290	-696.615
1	-51.995	-701.744	1	-49.083	-709.056
1	-43.765	-709.656	1	-34.916	-699.798
1	-31.182	-695.471	2	-225.772	-874.766
2	-144.003	-895.299	2	-161.251	-883.364
2	-59.647	-832.990	2	-167.289	-845.783
2	-180.731	-786.042	2	-158.758	-773.967
2	-157.327	-769.782	2	-99.698	-782.330
2	-65.836	-724.350	2	-49.903	-728.109
2	-90.438	-712.533	2	-162.431	-730.004
2	-128.986	-710.573	2	-136.071	-686.318
2	-21.511	-701.831	3	-172.229	-893.469
3	-74.299	-888.470	3	-34.677	-872.944

TABLE A.5 EJECTA DATA FROM PHOTOGRAPH NO. 116.

TOTAL NUMBER OF PARTICLES COUNTED - 455.

COORDINATES ARE IN FEET RELATIVE TO GZ. NEGATIVE COORDINATES ARE SOUTH AND/OR WEST OF GZ.

SIZE CLASS	COORDINATES NORTHING	COORDINATES EASTING	SIZE CLASS	COORDINATES NORTHING	COORDINATES EASTING
1	194,544	-451.527	1	203.822	-440,063
1	210,382	-440.436	1	226.254	-448,494
1	237,654	-457.513	1	223.722	-467,498
1	232,276	-476.936	1	243.401	-482,376
1	246,569	-464.445	1	269.642	-490,105
1	280,736	-484,250	1	307.220	-498,427
1	308,217	-519.996	1	332,041	-560,513
1	349,651	-567.011	1	345.070	-549,657
1	349,355	-553.175	1	356.471	-551,894
1	437,722	-543.992	1	416.879	-549,288
1	409,669	-554.555	1	390.775	-547,095
1	403,260	-537.711	1	412.666	-535,888
1	413,263	-535.512	1	414.773	-530,524
1	419.177	-534.863	1	408.086	-520,397
1	398,246	-517.301	1	394.010	-503,179
1	382,424	-505.878	1	401.266	-475,232
1	401,480	-477.158	1	407.830	-481,879
1	370,558	-504.176	1	363.542	-497,457
1	379,425	-520.480	1	368.820	-527,792
1	344,098	-496.852	1	350.597	-499,497
1	357,357	-481.825	1	333.567	-490,336
1	333.124	-458,052	1	304.223	-462,747
1	264,846	-444.905	1	275.791	-438,984
1	275,251	-434.369	1	258.215	-442,016
1	252,155	-423.415	1	252.125	-422.792
1	259,819	-412.279	1	265.404	-409,360
1	256,307	-408.296	1	256.879	-407,285
1	253,924	-405.072	1	252.628	-405,341
1	252,914	-404.337	1	254.481	-403,632
1	261.457	-400.100	1	251.247	-400,658
1	247,912	-399.288	1	247.645	-398,306
1	241.139	-397.190	1	236.118	-392,601
1	252,716	-394.469	1	272.391	-398,784
1	273,618	-388.060	1	275.418	-384,813

TABLE A.5 EJECTA DATA FROM PHOTOGRAPH NO. 116 (CONTINUED)

SIZE CLASS	COORDINATES NORTHING	COORDINATES EASTING	SIZE CLASS	COORDINATES NORTHING	COORDINATES EASTING
1	270,735	-382.944	1	265.052	-377,971
1	260,729	-379,057	1	255.803	-380,016
1	268,207	-372,183	1	267,070	-353,287
1	267,763	-353.416	1	278.862	-363,758
1	282,775	-359,245	1	278,433	-354,648
1	282,433	-351.994	1	291.665	-356,461
1	293,042	-358,307	1	299.936	-373,941
1	311,108	-373.011	1	293.124	-395,375
1	288,840	-410,239	1	311.454	-390,522
1	312,322	-422,815	1	372,883	-484,859
1	373,541	-484,755	1	376,773	-479,347
1	382,180	-479,837	1	384.475	-482,589
1	386,895	-480,469	1	388,344	-485,067
1	392,007	-487,942	1	387.475	-494,623
1	391,280	-496.919	1	394.417	-491,138
1	398,364	-495,009	1	397,970	-497,617
1	396,855	-499,113	1	394,195	-501,190
1	400,074	-504,429	1	404,201	-497,890
1	392,331	-480,654	1	394,192	-479,498
1	392,317	-471.452	1	399,115	-472,364
1	403,619	-473,409	1	414,410	-476,316
1	414,028	-482.764	1	415.177	-487,099
1	420,777	-487,724	1	421,371	-488,015
1	416,703	-492,500	1	416,780	-494,594
1	417,750	-495,879	1	409,909	-495,345
1	409,075	-494.627	1	402,416	-503,968
1	403,040	-504,030	1	407,421	-510,313
1	421,927	-505,159	1	423,935	-506,579
1	423,322	-507,654	1	421,366	-511,310
1	420,999	-512.066	1	425,654	-515,952
1	425,470	-520,510	1	423,492	-522,074
1	432,923	-530.615	1	441,050	-530,048
1	441,216	-486,693	1	441,084	-480,484
1	445,093	-488,614	1	449,571	-491,630
1	451,709	-492,591	1	453,621	-488,177
1	457,520	-491.567	1	457,945	-492,301
1	460,687	-495,405	1	462,687	-495,492
1	459,311	-499.029	1	457,197	-498,587
1	454,076	-497,312	1	451,889	-497,194
1	447,560	-502,124	1	449.637	-505,845
1	451,798	-505,469	1	452,116	-501,936

TABLE A.5 EJECTA DATA FROM PHOTOGRAPH NO. 116 (CONTINUED)

SIZE CLASS	COORDINATES NORTHING	COORDINATES EASTING	SIZE CLASS	COORDINATES NORTHING	COORDINATES EASTING
1	452,847	-502.445	1	452.792	-503.178
1	454,509	-503.215	1	457.643	-504.893
1	460.137	-506.056	1	454.931	-507.923
1	457,017	-512.250	1	441.142	-535.975
1	445.701	-530.319	1	446.943	-531.662
1	447.835	-531.336	1	447.110	-533.147
1	461.115	-512.164	1	461.988	-509.097
1	469.236	-514.736	1	486.539	-483.253
1	487.434	-478.064	1	490.946	-472.490
1	494.319	-471.912	1	496.980	-466.485
1	500.216	-465.549	1	496.708	-463.308
1	496.087	-457.943	1	493.152	-457.901
1	490.996	-456.931	1	490.508	-464.855
1	487.773	-468.842	1	487.984	-470.462
1	488.298	-471.205	1	486.329	-476.935
1	485.288	-470.548	1	481.854	-467.516
1	480.037	-464.885	1	480.578	-463.396
1	485.779	-457.903	1	482.958	-456.404
1	477.573	-452.646	1	473.499	-441.542
1	462.206	-430.039	1	457.817	-442.497
1	466.119	-449.976	1	471.413	-453.148
1	472.823	-459.238	1	468.179	-457.378
1	464.993	-462.531	1	477.369	-473.021
1	478.597	-478.781	1	474.108	-475.656
1	469.352	-476.453	1	463.782	-474.126
1	461.997	-474.904	1	466.973	-483.195
1	466.374	-492.749	1	464.312	-491.800
1	460.399	-489.520	1	460.493	-483.485
1	455.264	-477.792	1	453.943	-476.990
1	449.187	-477.203	1	442.328	-476.647
1	439.370	-469.201	1	445.971	-470.334
1	449.183	-472.598	1	444.831	-457.146
1	447.331	-455.084	1	450.634	-457.962
1	459.181	-456.934	1	460.885	-457.131
1	457.625	-450.441	1	454.016	-452.193
1	453.588	-451.591	1	452.865	-451.740
1	450.971	-450.234	1	449.064	-449.291
1	439.202	-456.756	1	437.648	-457.494
1	431.263	-453.192	1	440.544	-441.120
1	437.913	-438.732	1	450.171	-436.123
1	447.342	-424.521	1	452.591	-422.140

TABLE A.5 EJECTA DATA FROM PHOTOGRAPH NO. 116 (CONTINUED)

SIZE	COORDINATES		SIZE	COORDINATES	
CLASS	NORTHING	EASTING	CLASS	NORTHING	EASTING
1	435,303	-408.072	1	433.458	-412,694
1	431,733	-412.272	1	423.464	-407,891
1	429,927	-420.990	1	436.139	-422,471
1	434,262	-429.458	1	425.399	-426,791
1	417,663	-427.525	1	413.559	-427,648
1	412,518	-436.777	1	416.191	-440,538
1	412,795	-440.396	1	376.858	-408,369
1	385,882	-409.033	1	386.440	-389,079
1	355,070	-347.573	1	345.437	-356,589
1	334,434	-384.278	1	333.654	-383,805
1	329,176	-368.807	1	330.017	-361,221
1	326,022	-360.168	1	323.254	-360,209
1	321,722	-358.915	1	319.751	-355,633
1	319,764	-356.343	1	312.989	-361,099
1	305,200	-358.824	1	319.917	-345,178
1	326,114	-341.176	1	317.308	-341,013
1	317,513	-339.531	1	313.744	-340,602
1	289,204	-339.893	1	283.516	-337,596
1	301,338	-322.176	1	309.324	-317,152
1	312,631	-319.451	1	313.591	-318,006
1	320,505	-314.624	1	330.216	-313,035
1	337,511	-294.812	1	345.599	-276,188
1	355,218	-300.476	1	342.724	-329,452
1	346,256	-329.980	1	355.036	-340,575
1	354,032	-342.100	1	355.404	-343,425
1	356,337	-342.975	1	359.665	-345,049
1	392,230	-314.586	1	404.398	-321,079
1	398,708	-335.135	1	382.926	-364.511
1	395,883	-370.414	1	414.979	-340,667
1	414,858	-340.044	1	420.474	-335,830
1	413,743	-372.052	1	431.712	-359,737
1	422,840	-381.723	1	428.487	-388,983
1	431,281	-395.446	1	429.538	-397,882
1	431,800	-399.166	1	436.759	-408,383
1	445,283	-414.881	1	454.449	-421.198
1	455,697	-413.230	1	450.146	-401,412
1	452,391	-400.443	1	454.229	-401.116
1	452,726	-390.923	1	461.463	-396,724
1	462,024	-399.765	1	463.711	-399,192
1	476,248	-392.622	1	487.998	-391,064
1	469,270	-400.870	1	473.351	-401.618

TABLE A.5 EJECTA DATA FROM PHOTOGRAPH NO. 116 (CONTINUED)

SIZE CLASS	COORDINATES NORTHING	EASTING	SIZE CLASS	COORDINATES NORTHING	EASTING
1	474,141	-401.937	1	475.886	-403,721
1	476,727	-405.068	1	464.565	-413,024
1	467,792	-417.082	1	468.723	-417,119
1	464,979	-420.081	1	463.433	-425,439
1	470,091	-424.412	1	469.944	-423,026
1	473,343	-421.374	1	476.001	-419,445
1	477,011	-410.175	1	484.972	-408,407
1	488,811	-406.632	1	487.696	-411,051
1	493,344	-417.173	1	491.093	-418.641
1	486,478	-415.603	1	482.934	-413,798
1	478,791	-424.452	1	482.172	-426,897
1	478,449	-429.328	1	476.149	-429,055
1	468,267	-431.673	1	471.763	-434,098
1	476,086	-433.844	1	478.927	-440,153
1	481,836	-437.374	1	484.367	-443,255
1	489,283	-450.711	1	490.671	-428,845
1	492,906	-433.211	1	524.233	-428,018
1	508,528	-439.923	1	503.324	-455,585
1	502,553	-456.809	1	507.838	-451,228
1	511,777	-446.436	1	543.819	-432,484
1	544,052	-429.132	1	544.807	-408,032
1	561,325	-406.807	1	561.563	-405,990
1	567,939	-389.748	1	562.638	-383,471
1	560,586	-392.252	1	553.333	-394,271
1	542,745	-395.748	1	535.091	-408,597
1	532,003	-395.684	1	525.885	-391,787
1	514,170	-388.477	1	498.907	-389,736
1	505,764	-383.980	1	518.187	-369,881
1	521,450	-367.691	1	519.258	-372,298
1	524,736	-383.590	1	527.466	-382,871
1	534,085	-374.573	1	525.686	-358,069
1	512,750	-360.119	1	495.129	-362,012
1	493,869	-352.847	1	500.784	-336,527
1	489,664	-337.976	1	487.307	-333,198
1	486,964	-332.465	1	479.225	-327,747
1	471,970	-337.333	1	469.347	-354,909
1	442,899	-342.950	1	431.982	-318,948
1	437,864	-285.073	1	429.790	-282,676
1	407,514	-304.267	1	381.240	-292,813
1	378,549	-267.708	1	391.005	-265,370
1	393,111	-255.664	1	366.837	-268,242
2	227,972	-484.109	2	246.353	-473,100

TABLE A.5 EJECTA DATA FROM PHOTOGRAPH NO. 116 (CONCLUDED)

SIZE CLASS	COORDINATES NORTHING	COORDINATES EASTING	SIZE CLASS	COORDINATES NORTHING	COORDINATES EASTING
2	424,639	-528.460	2	374.699	-505,466
2	375,951	-529,522	2	367,614	-531,345
2	283,153	-474,144	2	243,547	-398,406
2	371,894	-483,422	2	383,493	-477,363
2	383,849	-480,096	2	391,506	-489,502
2	395,716	-492,293	2	390,990	-483,002
2	393,351	-475,560	2	394,685	-473,798
2	405,863	-478,510	2	415,617	-494,608
2	414,149	-498,955	2	420.110	-512,294
2	446,518	-481,150	2	458,252	-493,334
2	464,456	-503,282	2	458,899	-508,574
2	455,104	-507,151	2	485,477	-484,515
2	488,051	-465,592	2	472,745	-443,010
2	474,965	-477,220	2	459,478	-485,582
2	451,716	-477,053	2	446,127	-465,989
2	392,166	-436,340	2	334,833	-382,013
2	332,954	-380,089	2	320,629	-355,975
2	361,163	-289,617	2	361,133	-309,535
2	492,790	-413,393	2	505,020	-451,184
2	543,294	-416,287	2	562,962	-404,908
2	566,724	-396,882	2	528,575	-390,816
2	516,977	-386,650	2	510,187	-375,292
2	522,684	-375,167	2	507,367	-366,604
2	464,835	-331,608	2	445,076	-289,953
2	372,372	-279,428	2	378,036	-274,623
2	391,990	-265,492	2	374,318	-258,393
3	229,274	-454,741	3	269,069	-380,843
3	410,789	-431,105	3	357,837	-350,661
3	509.210	-363.451			

TABLE A.6 EJECTA DATA FROM PHOTOGRAPH NO. 117.

TOTAL NUMBER OF PARTICLES COUNTED - 693.

COORDINATES ARE IN FEET RELATIVE TO GZ. NEGATIVE COORDINATES ARE SOUTH AND/OR WEST OF GZ.

SIZE CLASS	COORDINATES NORTHING	EASTING	SIZE CLASS	COORDINATES NORTHING	EASTING
1	680,182	-765.005	1	676.507	-749,321
1	663,334	-746,094	1	658.343	-734,774
1	661,030	-730.980	1	661.054	-727.714
1	651,885	-728.820	1	651.909	-717,050
1	655,850	-713.846	1	656.708	-709,982
1	642,545	-702,377	1	629.899	-700,472
1	608,799	-712,180	1	608.536	-687.513
1	626,718	-681.698	1	625.979	-664,267
1	590,248	-683.406	1	587.421	-665.287
1	578,481	-667.406	1	577.965	-666,390
1	566,613	-669.767	1	569.088	-665.576
1	569,647	-664.468	1	584.625	-651,479
1	593,970	-643.532	1	584.837	-645.461
1	573,618	-647,063	1	552.052	-654.749
1	554,796	-650.106	1	549.811	-650,479
1	549,122	-650.155	1	551.099	-647,635
1	539,020	-656.867	1	534.889	-644,049
1	533,386	-644,397	1	537.349	-627,404
1	546,645	-619.684	1	486.689	-614,047
1	492,500	-661.722	1	508.578	-667,622
1	511,239	-640.646	1	536.012	-663,123
1	537,043	-673,027	1	527.621	-676.906
1	536,364	-682.748	1	541.301	-688,444
1	542.612	-688.734	1	540.677	-694.774
1	524,669	-691.002	1	515.593	-697.621
1	526,549	-705.199	1	532.046	-712,695
1	537,873	-707.418	1	544.902	-707,251
1	542.151	-719.577	1	563.174	-703,281
1	570,165	-702.001	1	581.473	-717,623
1	582,173	-721.608	1	574.286	-726,352
1	574,758	-729.077	1	578.106	-746,792
1	602,165	-724.435	1	597.428	-734,550
1	596,166	-750.653	1	594.245	-759.836
1	600,958	-759.059	1	606.580	-753,101
1	614,620	-763.108	1	610.881	-766,437

TABLE A.6 EJECTA DATA FROM PHOTOGRAPH NO. 117 (CONTINUED)

SIZE CLASS	COORDINATES NORTHING	EASTING	SIZE CLASS	COORDINATES NORTHING	EASTING
1	619,564	-774.745	1	629.369	-769,240
1	636,907	-765.999	1	638.781	-760,237
1	648,308	-762,896	1	650.584	-761,667
1	651,123	-762.076	1	673.997	-763,690
1	674,313	-763.236	1	678.983	-777,490
1	661,569	-774.323	1	664.553	-780,696
1	644,906	-776,273	1	643.951	-786,534
1	632,158	-791.469	1	661.196	-803,191
1	659,192	-807.213	1	658.931	-809,489
1	661,926	-812.220	1	656.961	-813,281
1	649,197	-812.099	1	640.556	-805,717
1	637,432	-809.168	1	648.146	-817,525
1	644,740	-818.499	1	644.730	-819,331
1	633,176	-822.618	1	626.391	-825.078
1	620,442	-829,482	1	630.345	-842,272
1	632,812	-845.389	1	630.666	-848,227
1	621,427	-843.042	1	606.091	-834,957
1	606,658	-830.051	1	606.019	-829,315
1	598,998	-827,286	1	616.477	-820,795
1	617,063	-821.369	1	618.767	-819,694
1	618,576	-818,268	1	624.328	-818.198
1	628,440	-812,716	1	626.845	-810,532
1	623,171	-812.417	1	613.561	-808,595
1	613,149	-809.181	1	613.479	-810,987
1	610,610	-812.091	1	610.404	-814,707
1	610,469	-809,865	1	606.509	-810,332
1	601,168	-807,027	1	609.776	-804,016
1	615,185	-799,682	1	614.794	-797,854
1	617,332	-790.304	1	607.730	-790,384
1	608,643	-795,092	1	605.510	-797,111
1	602,823	-796,870	1	599.351	-790,072
1	593,986	-795,307	1	591.018	-779,875
1	587,550	-779,943	1	586.580	-775,861
1	586,409	-763,512	1	578.670	-780,372
1	587,742	-800.919	1	586.593	-802,085
1	585,818	-805.472	1	598.208	-819,849
1	596,012	-827,081	1	590.280	-821,504
1	584,548	-816,843	1	582.268	-816,847
1	578,793	-807.184	1	577.667	-801,047
1	578,148	-798,492	1	576.262	-795,397

TABLE A.6 EJECTA DATA FROM PHOTOGRAPH NO. 117 (CONTINUED)

SIZE CLASS	COORDINATES NORTHING	COORDINATES EASTING	SIZE CLASS	COORDINATES NORTHING	COORDINATES EASTING
1	575,426	-795.532	1	574.351	-799,146
1	571,631	-798.575	1	572.424	-803,203
1	566,625	-805.272	1	565.075	-803,162
1	562,732	-795.194	1	566.569	-794,672
1	563,433	-791.861	1	569.139	-786,081
1	561,881	-784.085	1	564.283	-782,355
1	563,291	-777.338	1	571.760	-779,529
1	564,082	-762.159	1	575.193	-761,093
1	573,687	-759.518	1	570.418	-751,567
1	553,363	-735.052	1	546.097	-734,775
1	546,651	-750.241	1	541.179	-746,677
1	540,939	-753.410	1	548.298	-765,751
1	544,525	-766.894	1	550.018	-774,817
1	551,242	-784.704	1	544.833	-781,023
1	544,972	-776.302	1	542.073	-776,943
1	540,341	-780.125	1	535.176	-779,858
1	538,168	-777.830	1	538.300	-776,800
1	533,776	-769.021	1	532.682	-766,125
1	534,874	-763.275	1	527.654	-757,087
1	529,956	-770.242	1	525.454	-767,290
1	520,291	-768.466	1	520.568	-766,716
1	519,844	-759.303	1	517.394	-761,103
1	515,916	-758.845	1	513.591	-760,357
1	513,086	-761.810	1	512.377	-762,073
1	511,104	-753.787	1	508.812	-748,745
1	500,616	-748.873	1	491.685	-748,636
1	493,010	-742.521	1	480.967	-739,875
1	483,041	-734.396	1	488.480	-732,411
1	491,241	-731.188	1	493.886	-728,847
1	506,893	-729.514	1	507.854	-729,713
1	509,424	-726.178	1	511.826	-723,936
1	512,070	-722.919	1	511.773	-731,014
1	510,880	-735.814	1	507.806	-741,323
1	512,341	-745.085	1	521.912	-749,343
1	524,513	-734.580	1	520.237	-733,597
1	522,648	-727.653	1	523.242	-726,201
1	537,774	-726.941	1	525.792	-712,932
1	509,581	-709.508	1	507.998	-711,061
1	501,854	-710.430	1	500.411	-708,880
1	496,117	-710.014	1	488.160	-710,030

TABLE A.6 EJECTA DATA FROM PHOTOGRAPH NO. 117 (CONTINUED)

SIZE CLASS	COORDINATES NORTHING	COORDINATES EASTING	SIZE CLASS	COORDINATES NORTHING	COORDINATES EASTING
1	484,702	-703,879	1	489,032	-696,970
1	480,751	-692,116	1	477,769	-692,571
1	468,032	-690,884	1	473,226	-695,482
1	472,459	-714,667	1	478,114	-713,540
1	486,056	-719,367	1	485,902	-727,484
1	472,528	-727,737	1	471,355	-727,679
1	454,312	-690,493	1	444,210	-674,290
1	436,928	-670,041	1	444,666	-661,149
1	426,711	-691,950	1	433,133	-699,250
1	436,346	-703,938	1	433,794	-705,094
1	433,269	-704,972	1	431,545	-711,352
1	395,353	-689,639	1	391,323	-697,608
1	381,660	-709,338	1	381,202	-712,695
1	400,456	-712,512	1	421,952	-736,099
1	418,958	-743,663	1	414,508	-745,848
1	428,023	-746,796	1	429,254	-742,977
1	436,812	-730,333	1	448,125	-723,604
1	455,213	-724,169	1	456,291	-725,620
1	451,453	-739,336	1	461,955	-742,669
1	469,323	-744,533	1	474,145	-742,914
1	440,999	-765,334	1	460,317	-780,362
1	462,161	-771,952	1	462,372	-764,791
1	476,217	-754,384	1	470,537	-752,928
1	470,681	-748,869	1	479,751	-749,858
1	481,851	-747,344	1	486,800	-746,447
1	494,695	-756,032	1	493,282	-757,052
1	507,293	-761,375	1	501,799	-769,174
1	499,874	-777,785	1	488,881	-780,320
1	487,362	-784,385	1	494,187	-807,445
1	501,107	-812,109	1	498,437	-801,657
1	502,195	-799,917	1	514,019	-800,973
1	511,912	-785,910	1	509,825	-784,715
1	512,182	-776,853	1	518,515	-775,774
1	523,378	-782,461	1	539,128	-791,748
1	539,363	-797,220	1	536,949	-798,558
1	533,366	-800,379	1	532,770	-800,858
1	540,499	-805,729	1	545,859	-806,975
1	540,295	-807,084	1	540,310	-807,820
1	538,693	-809,879	1	534,433	-806,713

TABLE A.6 EJECTA DATA FROM PHOTOGRAPH NO. 117 (CONTINUED)

SIZE CLASS	COORDINATES NORTHING	COORDINATES EASTING	SIZE CLASS	COORDINATES NORTHING	COORDINATES EASTING
1	533,288	-812,545	1	530.659	-815,338
1	525,620	-819.592	1	522.081	-816,101
1	517,648	-813.919	1	513.925	-819,002
1	514,173	-822.295	1	521.878	-824,664
1	522,494	-824,241	1	526.488	-835,402
1	531,415	-827.074	1	535.714	-817,812
1	543,059	-816.415	1	542.068	-818,314
1	549,136	-823.531	1	549.388	-821,538
1	554,308	-822.014	1	556.756	-822,126
1	563,092	-814.445	1	559.226	-815,522
1	557,362	-815.971	1	555.023	-813,616
1	553,938	-811.874	1	551.998	-811,561
1	553,894	-806.198	1	559.252	-809,841
1	560,658	-809.442	1	566.456	-808,002
1	569,390	-825.932	1	567.109	-824,991
1	565,627	-824.397	1	566.909	-829,601
1	569,124	-828.974	1	576,011	-823,843
1	579,248	-820.737	1	591.015	-825,169
1	592,711	-828.459	1	586.961	-832,637
1	584,140	-827.769	1	579.821	-832,403
1	579,003	-830.908	1	576.867	-828,436
1	577,361	-839.659	1	572.802	-839,547
1	560,320	-834.359	1	546.639	-832,044
1	541,797	-833.212	1	547.961	-838,047
1	539,467	-845.070	1	546.395	-846,375
1	552,465	-856.347	1	557.672	-851,793
1	560,861	-855.517	1	564.447	-860,345
1	568,494	-860.860	1	568.966	-862,943
1	571,931	-858.889	1	572.666	-858,192
1	568,895	-856.788	1	569.642	-855,887
1	569,279	-854.636	1	571.449	-854,563
1	572,568	-854.495	1	572.869	-855,581
1	573,813	-850.155	1	574.330	-847,440
1	574,409	-846.500	1	575.281	-846,081
1	589,230	-848.107	1	590.397	-848,888
1	594,673	-853.755	1	591.029	-860,765
1	601,477	-862.538	1	602.199	-849,762
1	604,495	-839.730	1	610.139	-840,929
1	611,024	-843.962	1	608.186	-844,695
1	606,907	-844.427	1	607.304	-849,792

TABLE A.6 EJECTA DATA FROM PHOTOGRAPH NO. 117, (CONTINUED)

SIZE CLASS	COORDINATES NORTHING	EASTING	SIZE CLASS	COORDINATES NORTHING	EASTING
1	609,898	-848,089	1	610.273	-847,415
1	613,348	-845.935	1	615.522	-847,159
1	614,905	-848,188	1	615.907	-851,080
1	611,108	-851,677	1	608.703	-856,546
1	613,590	-854.060	1	615.336	-856,368
1	619,313	-855.805	1	619.728	-857,641
1	620,485	-859.011	1	622.929	-861,033
1	624,671	-862.283	1	620.823	-863,794
1	620,286	-863.093	1	619.625	-861,992
1	613,014	-875.965	1	604.134	-881,018
1	601,439	-875.104	1	598.764	-877,661
1	596,418	-871.272	1	594.406	-869,794
1	593,341	-871.040	1	593.181	-875,386
1	591,860	-877.403	1	590.707	-874,493
1	589,284	-873,909	1	588,991	-869,729
1	586,319	-868.722	1	584.987	-867,801
1	583,893	-872,698	1	580.772	-860,381
1	578,245	-858.486	1	568.808	-866,853
1	576,423	-869,341	1	576.198	-876,045
1	581,725	-875.436	1	584.524	-877,844
1	583,575	-879,453	1	588.561	-883,314
1	595,588	-883.835	1	596.967	-881,094
1	603,933	-887,035	1	604.745	-890,160
1	601,749	-887,732	1	601.399	-889,577
1	593,862	-889,490	1	597.775	-892,668
1	597,842	-894,188	1	587.745	-902,806
1	564,273	-902,653	1	583.442	-910,486
1	583,019	-917,419	1	567.982	-919.627
1	562,195	-911.180	1	556.580	-911,020
1	548,524	-912.585	1	553.442	-903,507
1	548,355	-904.148	1	546.489	-899,883
1	563,470	-896.741	1	567.284	-893,249
1	572,862	-896.553	1	578.513	-897,979
1	579,872	-894.747	1	584.874	-894,334
1	584,696	-892.674	1	581.505	-887,697
1	581,143	-884.076	1	574.841	-876.514
1	572,013	-876.261	1	566.245	-873,038
1	564,348	-878.073	1	565.182	-878,988
1	562,403	-881.610	1	568.318	-882,817

TABLE A.6 EJECTA DATA FROM PHOTOGRAPH NO. 117 (CONTINUED)

SIZE CLASS	COORDINATES NORTHING	COORDINATES EASTING	SIZE CLASS	COORDINATES NORTHING	COORDINATES EASTING
1	567,759	-884.964	1	569.498	-886,960
1	567,099	-888.616	1	563.150	-889,163
1	562.114	-886.764	1	553.687	-887,687
1	557,697	-880.443	1	556.566	-880,477
1	551,200	-881.042	1	547.405	-878,284
1	549,737	-877.466	1	556.852	-876,010
1	556,584	-874.178	1	557.803	-871,867
1	555,722	-868.627	1	553.854	-864,167
1	549,038	-867.896	1	550.196	-858,177
1	546,279	-854.357	1	537.357	-853.730
1	524,865	-845.887	1	524.437	-854,967
1	519,796	-858.194	1	523.650	-862,825
1	530,558	-861.114	1	533,016	-860,177
1	534,688	-860.122	1	540.602	-868,405
1	533,704	-869.986	1	529.444	-870.472
1	538,567	-876.592	1	537.388	-891,283
1	535,770	-891.891	1	535.867	-892,640
1	534,071	-891.789	1	533.701	-900,037
1	531,109	-903.375	1	529,049	-900,871
1	522,424	-897.430	1	522,986	-896,101
1	530,203	-882.463	1	524.400	-880,387
1	517,472	-877.005	1	512.252	-872,822
1	509,396	-873.223	1	501,586	-873,265
1	510,891	-869.845	1	522.213	-873,453
1	522,293	-872.420	1	519,884	-869,550
1	513,404	-861.624	1	513.993	-855,301
1	513.164	-855.451	1	504.815	-858,525
1	500,907	-854.968	1	504,709	-851,634
1	498,981	-848.561	1	494.220	-841,494
1	508,781	-847.644	1	509,524	-839,447
1	508,162	-837.635	1	505.006	-837,077
1	508,928	-832.381	1	496.864	-826,744
1	494,718	-832.438	1	492.061	-831,874
1	489,510	-830.584	1	479.017	-827,384
1	475,657	-825.911	1	472.282	-832,739
1	470,007	-828.596	1	463.100	-831,041
1	466,281	-817.551	1	466.675	-804,119
1	456,353	-815.504	1	454,790	-815,071
1	454,886	-814.475	1	425.303	-820,845

TABLE A.6 EJECTA DATA FROM PHOTOGRAPH NO. 117 (CONTINUED)

SIZE CLASS	COORDINATES NORTHING	COORDINATES EASTING	SIZE CLASS	COORDINATES NORTHING	COORDINATES EASTING
1	454,770	-784.461	1	448.059	-779,256
1	435,750	-792.124	1	432.968	-791,326
1	417,213	-773.090	1	416.161	-774,372
1	411,207	-809.362	1	403.868	-789,187
1	401,032	-787.483	1	399.304	-783,590
1	392,652	-781.735	1	386.838	-774,461
1	358,286	-736.850	1	353.254	-743,752
1	346,714	-753.386	1	348.234	-755,475
1	359,523	-781.858	1	367.036	-783,091
1	364,946	-785.551	1	362.321	-787,542
1	359,557	-791.460	1	359.805	-794,488
1	357,718	-815.387	1	394.490	-809,132
1	392,742	-813.963	1	394.685	-817,977
1	393,356	-818.635	1	376.760	-825,243
1	373,000	-833.059	1	385.980	-843,761
1	391,321	-846.351	1	400.328	-858,125
1	415,702	-853.668	1	424.005	-843,262
1	424,727	-827.932	1	434.202	-859,999
1	437,410	-863.595	1	438.747	-872,466
1	442,391	-873.007	1	438.696	-875,327
1	437,266	-881.635	1	443.936	-884,744
1	448,904	-887.228	1	446.739	-880,474
1	445,060	-866.614	1	449.767	-863,118
1	463,833	-860.912	1	464.491	-861,444
1	463,199	-864.988	1	476.691	-867,110
1	480,666	-880.574	1	472.681	-882,937
1	471,622	-877.680	1	464.322	-878,799
1	463,026	-881.105	1	461.564	-881,268
1	463,686	-900.451	1	470.038	-892,896
1	472,502	-895.191	1	482.405	-892,438
1	486,008	-899.032	1	493.816	-883,698
1	507,374	-887.435	1	501.983	-892,779
1	499,200	-902.621	1	508.365	-903,102
1	516,857	-902.694	1	519.574	-905,236
1	527,538	-906.640	1	534.145	-907,961
1	534,295	-908.883	1	504.763	-928,445
1	503,491	-927.958	1	498.846	-934,698
1	499,110	-933.164	1	527.416	-946,799

TABLE A.6 EJECTA DATA FROM PHOTOGRAPH NO. 117 (CONCLUDED)

SIZE CLASS	COORDINATES NORTHING	COORDINATES EASTING	SIZE CLASS	COORDINATES NORTHING	COORDINATES EASTING
1	523,366	-942.036	1	525.098	-940,188
1	528,987	-934,548	1	531.461	-927,203
1	538,770	-919,119	1	545.513	-915,973
1	555,742	-925.317	2	561,465	-651,218
2	538,073	-602,443	2	523.025	-628,254
2	510,286	-641.424	2	531.662	-680.448
2	548,841	-694,110	2	557,250	-715,408
2	559,128	-733,708	2	604,804	-754,971
2	659,703	-807,737	2	658,753	-807,757
2	657,802	-812,777	2	609,538	-836,188
2	577,868	-797,542	2	580,191	-795,991
2	574,017	-797,869	2	533.473	-728,960
2	486,635	-696,728	2	486,885	-694,029
2	477,073	-704.814	2	482,916	-730,264
2	422,876	-648,447	2	421.729	-730,907
2	449,468	-773,888	2	479,739	-766,559
2	541,988	-795,461	2	569,494	-818,884
2	588,860	-831.436	2	575,929	-830,255
2	591,231	-847,722	2	612,521	-846,871
2	623,041	-851.538	2	621,035	-860,117
2	609,656	-881,527	2	597,702	-875,339
2	584,608	-870.939	2	581,811	-868,227
2	575,376	-859,223	2	575,136	-861,688
2	543,781	-855,047	2	529,252	-849,185
2	523,902	-853,259	2	505,866	-870,195
2	484,263	-820.897	2	471,928	-820,562
2	444,988	-779,208	2	364,940	-778,475
2	328,007	-794.981	2	507.640	-928,201
2	507,098	-929,254	2	503.799	-931,069
3	443,288	-645.454	3	543,487	-676,594
3	536,940	-676.726	3	635,938	-839,826
3	432,923	-740,428	3	436,302	-741,658
3	541.793	-813.416	3	551,145	-850,613
3	563,627	-868.683	3	581,449	-871,178
3	508,103	-929.734	3	501,273	-934,106
4	662,514	-767,038	4	494,937	-929,426
5	676.737	-766.902			

TABLE A.7 EJECTA DATA FROM PHOTOGRAPH NO. 136

TOTAL NUMBER OF PARTICLES COUNTED - 18.

COORDINATES ARE IN FEET RELATIVE TO GZ. NEGATIVE COORDINATES ARE SOUTH AND/OR WEST OF GZ.

SIZE CLASS	COORDINATES NORTHING	EASTING	SIZE CLASS	COORDINATES NORTHING	EASTING
1	625.948	-233.658	1	750.238	-232.579
1	735.059	-180.231	1	733.840	-180.288
1	733.609	-180.649	1	683.298	-159.988
1	674.498	-144.985	1	679.078	-146.240
1	743.008	-83.028	2	694.529	-231.907
2	734.518	-183.413	2	655.264	-199.094
2	679.764	-158.843	3	635.488	-245.700
3	739.218	-183.582	3	713.145	-166.777
3	680.572	-157.802	4	592.080	-243.459

TABLE A.8 EJECTA DATA FROM PHOTOGRAPH NO. 137

TOTAL NUMBER OF PARTICLES COUNTED - 15.

COORDINATES ARE IN FEET RELATIVE TO GZ. NEGATIVE COORDINATES ARE SOUTH AND/OR WEST OF GZ.

SIZE	COORDINATES		SIZE	COORDINATES	
CLASS	NORTHING	EASTING	CLASS	NORTHING	EASTING
1	900.742	-229.921	1	979.052	-253.645
1	847.988	-185.914	1	922.232	-149.167
1	932.315	-151.030	1	952.843	-155.405
1	978.071	-157.806	1	930.963	-157.990
1	957.794	-144.924	1	955.541	-144.709
1	961.775	-135.728	1	967.294	-114.360
2	978.348	-252.676	2	942.350	-153.678
2	975.086	-76.147			

APPENDIX B

COMPUTER PROGRAM FOR ANALYSIS OF AERIAL PHOTOGRAPHY EJECTA COUNT

The computer program shown in Table B.1 was used to reduce the data from the aerial photographs. Basically, the program established a sampling area based on radial lines and circumferential rings, then searched the data for all missiles falling in the sample area. Weights were assigned to each missile according to its size class, and the ejecta mass density and size class distribution for the sample area were determined. The subroutine in the program calculated the coefficients of a power function relating the ejecta mass density to range from GZ.

TABLE B.1 GE-400 SERIES, FORTRAN IV COMPUTER PROGRAM FOR ANALYSIS OF AERIAL PHOTOGRAPHY DATA

Explanation	Statement Number	Statement
	1000	$NDM
	1010	DIMENSION X(550),Y(550),NSC(550),DEG(550),WT(550),RA(550)
	1020	DIMENSION R(15),AR(15),NOMIS(15),TOTWT(15),RM(15)
	1030	DIMENSION DENMAS(15),NOMIS1(15),NOMIS2(15),NOMIS3(15)
	1040	DIMENSION NOMIS4(15),NOMIS5(15),XNOMIS(15),XND(15)
	1050	DIMENSION NCODE(550),NEX(550)
Data Input	1060	CALL OPENF(1,"DAT34")
	1070	PRINT,""
	1080	PRINT,""
	1090	PRINT," EXPOSURE NUMBER"
	1100	READ,NEXPO
	1110	PRINT,""
	1120	PRINT,"NUMBER OF MISSILES ON EXPOSURE"
	1130	READ,N
	1140	PRINT,""
	1150	PRINT," NO. OF SAMPLE SUBAREAS"
	1160	READ,M
	1170	XM=M
	1180	PRINT,""
	1190	DO 10 I=1,N
	1200	READ(1;707),NSC(I),Y(I),X(I),NCODE(I),NEX(I)
	1230	10 CONTINUE
	1240	707 FORMAT(20X,I1,6X,2F12.4,21X,I1,4X,I3)
Polar Coordinate Conversion	1250	DO 1 I=1,N
	1280	RA(I)=SQRT((X(I)**2.)+(Y(I)**2.))
	1290	A=ABS(Y(I)/X(I))
	1300	AX=ABS(X(I)/Y(I))
	1310	IF(X(I).GT.0.AND.Y(I).GT.0)GO TO 70
	1320	IF(X(I).GT.0.AND.Y(I).LT.0)GO TO 71
	1330	IF(X(I).LT.0.AND.Y(I).LT.0)GO TO 72
	1340	IF(X(I).LT.0.AND.Y(I).GT.0)GO TO 73
	1350	70 AN=ATAN(AX)
	1360	GO TO 75
	1370	71 AN=ATAN(A)+1.5705
	1380	GO TO 75
	1390	72 AN=ATAN(AX)+3.141
	1400	GO TO 75
	1410	73 AN=ATAN(A)+4.7115
	1420	75 DEG(I)=AN*57.3
Assignment of weight according to missile size classification	1430	IF(NSC(I).EQ.1)GO TO 80
	1440	IF(NSC(I).EQ.2)GO TO 81
	1450	IF(NSC(I).EQ.3)GO TO 82
	1460	IF(NSC(I).EQ.4)GO TO 83
	1470	IF(NSC(I).EQ.5)GO TO 84
	1480	80 WT(I)=3.55
	1490	GO TO 1
	1500	81 WT(I)=14.4

TABLE B.1 (CONTINUED)

Explanation	Statement Number	Statement
	1510	GO TO 1
	1520	32 WT(I)=42.2
	1530	GO TO 1
	1540	33 WT(I)=92.6
	1550	GO TO 1
	1560	34 WT(I)=200.
Definition of Sample Area	1570	1 CONTINUE
	1700	PRINT,"STARTING RADIUS, RADIAL INTERVAL, ANGULAR BOUNDS"
	1710	READ,RA1,XINVAL,AB1,AB2
	1720	PRINT,
	1730	R(1)=RA1
	1740	M1=M+1
	1750	DO 2 J=2,M1
	1760	2 R(J)=R(J-1)+XINVAL
	1770	DO 3 L=1,M
	1780	AP=3.141*((R(L+1)**2.)-(R(L)**2.))
	1790	AR(L)=AP*((AB2-AB1)/360.)
	1800	3 CONTINUE
Missile search to find missiles falling in sample area and calculation of ejecta mass density and numerical density	1810	DO 4 K=1,M
	1820	NCOUNT=0
	1830	NC01=0
	1840	NC02=0
	1850	NC03=0
	1860	NC04=0
	1870	NC05=0
	1880	WTSUM=0.
	1890	DO 5 KI=1,N
	1900	IF(DEG(KI).LT.AB1.OR.DEG(KI).GT.AB2) GO TO 5
	1910	IF(RA(KI).GT.R(K).AND.RA(KI).LT.R(K+1))GO TO 6
	1920	GO TO 5
	1930	6 NCOUNT=NCOUNT+1
	1940	IF(NSC(KI).EQ.1)NC01=NC01+1
	1950	IF(NSC(KI).EQ.2)NC02=NC02+1
	1960	IF(NSC(KI).EQ.3)NC03=NC03+1
	1970	IF(NSC(KI).EQ.4)NC04=NC04+1
	1980	IF(NSC(KI).EQ.5)NC05=NC05+1
	1990	WTSUM=WTSUM+WT(KI)
	2000	5 CONTINUE
	2010	NOMIS(K)=NCOUNT
	2020	NOMIS1(K)=NC01
	2030	NOMIS2(K)=NC02
	2040	NOMIS3(K)=NC03
	2050	NOMIS4(K)=NC04
	2060	NOMIS5(K)=NC05
	2070	TOTWT(K)=WTSUM
	2080	DENMAS(K)=TOTWT(K)/AR(K)
	2084	XNOMIS(K)=NOMIS(K)
	2085	XND(K)=XNOMIS(K)/AR(K)
	2090	4 CONTINUE
	2100	DO 7 I=1,M

TABLE B.1 (CONCLUDED)

Explanation	Statement Number	Statement
	2110	7 RM(I)=(R(I)+R(I+1))/2.
	2120	PRINT,""
Printout of Output	2130	PRINT,""
	2140	PRINT," SAMPLE SUBAREAS"
	2150	PRINT,""
	2160	PRINT," NO. RADIUS AREA WEIGHT MASS DENSITY"
	2170	DO 8 I=1,M
	2180	PRINT 103,I,RM(I),AR(I),TOTWT(I),DENMAS(I)
	2190	8 CONTINUE
	2200	103 FORMAT(I4,F9.3,1X,E10.4,4X,E8.2,1X,F10.4)
	2210	PRINT,""
	2220	PRINT," NO. NOMIS NOMIS1 NOMIS2 NOMIS3 NOMIS4 NOMIS5"
	2230	DO 9 I=1,M
	2240	9 PRINT 104,I,NOMIS(I),NOMIS1(I),NOMIS2(I),NOMIS3(I),NOMIS4(I
	2250	&),NOMIS5(I)
	2260	104 FORMAT(I4,I6,I7,4I8)
	2290	PRINT,""
	2300	PRINT,""
	2310	CALL POWFLS(M,RM,DENMAS,A1,B1)
	2320	PRINT," EJECTA MASS DENSITY VERSUS RANGE"
	2330	PRINT,""
	2340	PRINT 105,B1
	2350	105 FORMAT(37X,F7.3)
	2360	PRINT 106,A1
	2370	106 FORMAT(2X,21HEJECTA MASS DENSITY =,E10.4,4H * R,//)
	2380	CALL POWFLS(M,RM,XND,A2,B2)
	2390	PRINT," MISSILE NUMERICAL DENSITY VERSUS RANGE"
	2400	PRINT,""
	2410	PRINT 107,B2
	2420	107 FORMAT(33X,F7.3)
	2430	PRINT 108,A2
	2440	108 FORMAT(2X,17HNO. OF MISSILES =,E10.4,4H * R,//)
	2450	END
Least-square-root subroutine determining a power function relationship between range and either ejecta mass density or ejecta numerical density	2460	SUBROUTINE POWFLS(NN,XX,YY,A,B)
	2470	DIMENSION XX(15),YY(15)
	2480	SUMLX=0.
	2490	SUMLY=0.
	2500	SUMLX2=0.
	2510	SUMLXY=0.
	2520	MCOUNT=0
	2530	DO 90 I=1,NN
	2540	IF(XX(I).LT.0.00001.OR.YY(I).LT.0.00001)GO TO 89
	2550	SUMLX=SUMLX+ALOG(XX(I))
	2560	SUMLY=SUMLY+ALOG(YY(I))
	2570	SUMLX2=SUMLX2+(ALOG(XX(I))**2.)
	2580	SUMLXY=SUMLXY+(ALOG(XX(I))*ALOG(YY(I)))
	2590	GO TO 90
	2600	89 MCOUNT=MCOUNT+1
	2610	90 CONTINUE
	2620	NN=NN-MCOUNT
	2630	XNN=NN
	2640	D=(SUMLY*SUMLX2)-(SUMLX*SUMLXY)
	2650	E=(XNN*SUMLX2)-(SUMLX**2.)
	2660	XLOGA=D/E
	2670	F=(XNN*SUMLXY)-(SUMLY*SUMLX)
	2680	B=F/E
	2690	A=EXP(XLOGA)
	2700	RETURN
	2710	END

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13. ABSTRACT Event Mineral Rock, the detonation of a 100-ton spherically shaped charge of TNT on granite, was the last event of the Mine Shaft Series, a program of high-explosive tests primarily concerned with ground shock and cratering effects from explosions at or near the surface of a competent rock medium. The series, conducted in 1968 and 1969, was intended as a follow-on to previously conducted similar experiments in soil. Mineral Rock (1969) duplicated the geometry and yield of Event Mine Ore (1968). Studies of crater ejecta were conducted to determine debris density and distribution, to examine the role of the ejection mechanism in crater formation, and to obtain additional information on the hazards associated with natural missiles. Mineral Rock, with a maximum observed ejecta range of approximately 2,800 feet for a 1-pound particle, produced a larger crater and a more extensive ejecta field than its predecessor, Mine Ore. In addition to established methods of ejecta measurement, aerial photography was introduced to obtain spoil volume and distribution parameters. A comprehensive artificial missile experiment was included, and limited impact measurements were obtained from the terminal trajectories of small natural particles. As with other events in rock that preceded the Mine Shaft Series, the influence of rock jointing on ejecta distribution was evident. Volumetric analysis indicated that 230 yd^3 of in situ material was ejected from the crater, about 90 yd^3 of which was deposited in the crater lip. A factor of $W^{0.3}$ (W = charge weight) was confirmed for empirical scaling of ejecta ranges common to the Mine Ore/Mineral Rock test geometry. Size distribution as a function of range for discrete particles was also established, confirming that smaller particles (4 to 8 inches in diameter) tend to dominate the ejecta field at distances greater than 25 to 30 crater radii from the detonation. Throwout regions common to the Mine Ore/Mineral Rock test geometry were satisfactorily defined, with good agreement being noted between the two events. In general, the ejecta mechanics resembled those associated with a surface burst in soil.

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