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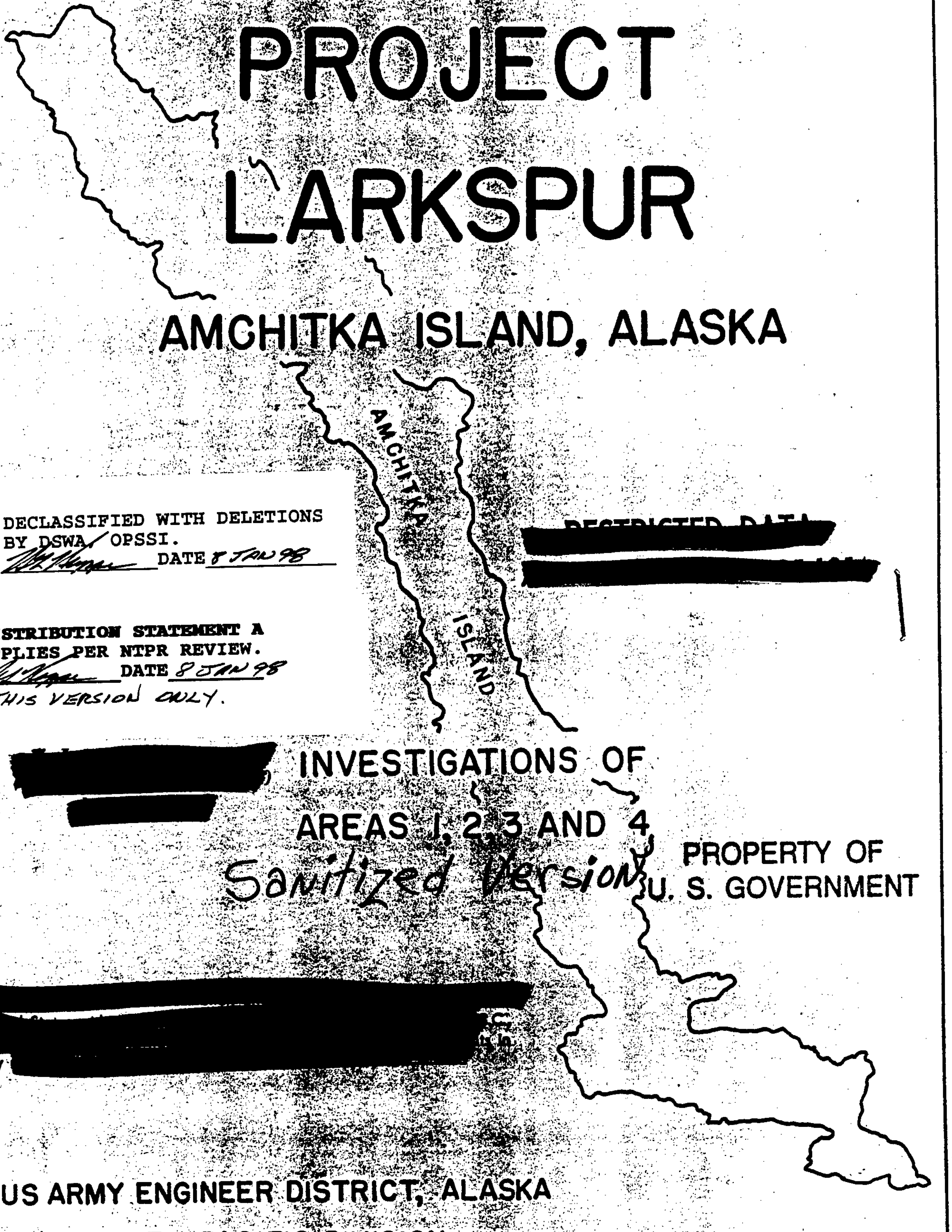
PROJECT LARKSPUR

AMCHITKA ISLAND, ALASKA



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AREAS 1, 2, 3 AND 4

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PROJECT LARKSPUR
AMCHITKA ISLAND, ALASKA
INVESTIGATIONS OF AREAS 1, 2, 3 AND 4, (U)

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U. S. Army Engineer District, Alaska
North Pacific Division
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PROJECT LARKSPUR

INVESTIGATIONS OF AMCHITKA ISLAND

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PART I

RESUMÉ

RESUME'

1.1 Project "Rufus" was initiated on 8 July 1962 for the purpose of selecting a suitable site for field testing the response of a typical Minuteman missile installation to the detonation of a nuclear device of one megaton or greater yield. The Project "Rufus" study eliminated several sites in different parts of the world and selected three sites, all in Alaska, for further study. These were: (1) Amchitka Island, (2) North Slope of the Brooks Range, and (3) Chirikof Island, which is to be held in reserve. Project "Larkspur" was initiated in April 1963 to further study the three Alaska sites. One of the conclusions of the "Rufus" study was that Amchitka Island is the only site where a nuclear detonation of 10 megatons or larger yield can be tested safely. It was also concluded that safe yield limits on the North Slope of the Brooks Range were 2 to 10 megatons, and for Chirikof Island, 2 megatons.

This report summarizes results of field and office studies to date, and makes a partial evaluation of the Amchitka Island portion of the "Larkspur" project. Four specific areas were studied over the length of the island, and each was evaluated insofar as possible with respect to design criteria set forth in the "Rufus" report. Except for Area 2 which was inaccessible to drilling equipment, each site was investigated with a 120-foot deep core boring, which approximates the depth of a Minuteman missile silo. Sample cores from each drilled site have been subjected to comprehensive testing procedures by both USGS and Corps of Engineers. A complete discussion on results of the Corps of Engineers' testing program is included as an appendix to this report.

TENTATIVE CONCLUSIONS AND RECOMMENDATIONS

1.2.1 Of the four Areas investigated, Area 3 appears to be the least desirable from the standpoint of relatively weak rock formations, related landslide conditions, and associated construction problems. Some portions of Area 2 may have similar limitations but not to the same degree as exist in Area 3.

1.2.2 The following tentative conclusions have been evaluated with respect to specific design criteria as set forth in the "Rufus" project: (See page 11).

(a) Topography. Areas 3 and 4 have the most favorable topographic features with respect to design slope criteria.

(b) Overburden. Overburden in all Areas is generally less than ten feet deep. The soils in Area 1 and probably Area 2 are unsaturated, however, they are believed to be saturated in Areas 3 and 4.

(c) Bedrock Properties. The USGS has conducted field and laboratory tests to determine the following pertinent bedrock (and soil) parameters at each Area: sonic velocities, dynamic elastic constants, resistivity, dielectric constants, and magnetic permeabilities. Two comprehensive reports on the results of these tests are being compiled by USGS. The Corps of Engineers has conducted tests on core samples from Areas 1, 3 and 4 for determinations of moisture, density, compressibility and elastic constants. The complete results and discussion of these tests are included in the appendix. While the rock tests conducted by the Corps of Engineers were not performed on a scale that would permit positive identification of elastic constants for the various materials at the sites, they indicate certain values for some materials. More importantly, they indicate a range of deformations in which elastic properties exist, and they indicate that elastic properties are probably variables rather than constants. This being the case, selected design values would have to consider the conditions of loading.

(d) Groundwater. From the standpoint of shallow surface lakes and probable high perched water tables, Areas 3 and 4 are the least favorable. Although these lakes could be drained, the impervious soil materials would continue to exist in or near a state of saturation.

1.2.3 Other Considerations

The following conclusions have been evaluated with respect to important considerations other than the criteria set forth in the "Rufus" project.

(a) Logistics. Area 4 has the most favorable logistics situation because of its proximity to the main island airfield and to existing harbor facilities along some 10 miles of relatively good road. (This latter advantage could also be a major disadvantage due to probable blast damage to these same facilities during a test).

(b) Access. With respect to ease of access, the 4 sites rank in the following order of preference; Area 4, Area 3, Area 1 and Area 2. A large scale major road building program will be required to effectively negotiate the mountainous northern terrain of Amchitka Island in which Area 1 and Area 2 are located. Both Area 1 and Area 2 do have passable beach approaches which could probably be employed as supplementary access by landing craft vessels both during and after road building operations.

(c) Blast Damage. Areas 1 and 2 have the most favorable location with respect to minimum blast damage to supply installations near the south end of the island. Area 2 could have an additional advantage in this regard due to its 600 foot deep bowl shaped topography.

(d) Concrete Aggregate. To adequately simulate a missile complex comparable to installations at Malmstrom and Warren Air Force Bases, a high quality structural concrete will be required. It is almost certain that the only satisfactory source of high quality concrete aggregates on Amchitka Island will be from crushed ledge rock. Suitable sources of this material are not always conveniently situated with respect to need. Areas 2 and 4 appear to be most favorably situated with regard to nearby sources of satisfactory ledge rock for concrete aggregate.

1.2.4 Tentative Ranking of Sites

On the basis of all Corps of Engineer studies concluded to date, the order of site preference would tentatively be Area 4, Area 1, Area 2 and Area 3. It is to be noted that this listing must be considered tentative until all USGS testing and evaluation has been completed, and until a definite ranking of all controlling criteria has been established by higher authority.

1.2.5 Recommendations

(a) It is recommended that a field reconnaissance be conducted by Corps of Engineer personnel to establish definite sources of suitable concrete aggregate for each area considered as soon as weather permits. This could be particularly important to the development of possible missile complexes at either Areas 1 or 3.

(b) It is also recommended that a study of beach landing sites for Areas 1 and 2 be made by a qualified expert as a possible means of supplementary access to these sites during (and after) new road construction.

HISTORICAL BACKGROUND OF PROJECT

1.2 A letter dated 8 October 1962 from Defense Atomic Support Agency (DASA) to the Nevada Operations Office of the Atomic Energy Commission, was the first of a series of actions which led to the inauguration of Project "Rufus". This project was to be a world wide search for a site or sites where nuclear devices of approximately one megaton yield [redacted] could be safely detonated on or near ground surface. The primary purpose for the planned nuclear event or events was a full scale response test of a typical Minuteman missile system to induced electromagnetic and seismic impulses. A secondary purpose was to find a site that would be suitable for effects tests of nuclear explosions, device testing, and Plowshare experiments.

The Project "Rufus" search included only the conterminous United States, Alaska, Carribbean area, and the Pacific Islands under United States control. The main site criteria looked for besides safety, was that the areas considered should be as similar as possible to the Minuteman missile sites at Malmstrom and Warren Air Force Bases. The Project "Rufus" study eliminated all but three areas because of political ramifications or population considerations. Further evaluation studies were therefore recommended to be carried out only at Amchitka Island and the North Slope of the Brooks Range. A third choice, Chirikof

Island, was to be held in reserve. Field site evaluation studies on Amchitka and on the North Slope of the Brooks Range were to be conducted under the project code name "Larkspur".

Planning for Larkspur was completed and field investigations were about to begin in the summer of 1963 when the test ban treaty was signed on 26 July 1963. All impending field operations were therefore cancelled.

During the summer of 1964, field investigations were started on Amchitka Island for a project unrelated to Larkspur. This project was being conducted under the code name "Long Shot" and provided a convenient screen for contemporaneous completion of the Amchitka portion of Project Larkspur. Exploration on the North Slope of the Brooks Range has been deferred until some later date.

PART 2

INTRODUCTION
AND
SCOPE

INTRODUCTION

2.1.1 Geography. Amchitka Island in the Rat Islands group of the Aleutian Islands, is located between 178°37' and 179°29' East longitudes and 51°21' and 51°39' North latitudes. (See Figure 1). The island is elongate towards the northwest which is the trend of this segment of the Aleutian arc. It is approximately 35 miles long and from 3 to 5 miles wide.

The island contains landforms of varied aspect, ranging from rugged mountains over 1,100 feet high in the northwest, to a low tundra plateau in the southeast covered with shallow ponds and small lakes. These ponds do not necessarily occupy bedrock depressions, but are usually confined only by impervious organic soil and turf.

2.1.2 Ecology. Tundra growth covers the entire island except on the steepest cliff faces, exposed ridges and on the wave swept rock benches above mean tide level. There are no trees anywhere on the island.

Large numbers of water fowl, sea birds, rats, sea otters, and seals inhabit Amchitka and its environs. The surrounding waters are the maturing ground for salmon who spawn in Asia and North America. Ecology will be the subject of a following report by another agency.

2.1.3 Climate. Amchitka Island lies along the North Pacific belt of storms and therefore its maritime climate is characterized by abundant wind, rain and fog. Climatological records from 1942 to 1948 at the airfield showed summer winds to average 20 MPH and seldom exceed 70 MPH while winter winds averaged 25 MPH and have frequently exceeded 100 MPH. Precipitation averaged 35 inches annually, including 70 inches of snowfall.

2.1.4 <u>Former Habitation</u>. Although it once supported a large Aleut population, Amchitka is now deserted. The nearest populated areas are about 200 miles away on Shemya Island in the Near Island group and on Adak Island in the Andreanof Islands with the exception of occasional trappers on several of the neighboring islands. Between 1943 and 1950, the island was occupied by the military. A usable paved airfield and a docking facility which has been damaged by storms are among the remnant structures of this military occupancy. A former military road traverses the entire length of the island, but is impassable to conventional vehicles on the northern half of the island. This road connects with a beach at the northern extremity of the island which is believed to have been used for landing craft access.

GENERAL GEOLOGY OF AMCHITKA ISLAND

2.2 Amchitka Island, one of the islands of the Aleutian Chain is composed almost entirely of Tertiary volcanic strata. The regional geologic structure of Amchitka is closely related to the block faulting of this segment of the Aleutian Submarine Ridge which is tilted toward the Aleutian Trench. The island itself has been locally disturbed by further faulting, differential uplift, and has been dissected by marine, stream, and glacial erosion. Rock strata generally dip gently to the south and southeast over most of the island.

Except for several small bodies of quartz diorite near the southeast end of the island, the exposed primary rocks are of andesitic and basaltic composition, principally in the form of well indurated explosion breccias and tuffs with minor extrusives and intrusives. There are also minor amounts of volcanic conglomerate, sandstone, siltstone, and shale formed during Tertiary time by mechanical breakdown of the primary volcanic rocks.

The most prominent structural features of the island geology are faults and well-developed joint systems which are easily discernible as lineations on aerial photographs. Topographic and physiographic features are usually well developed along many of these joint and fault systems.

GENERAL DESIGN CRITERIA

2.3 Design criteria were outlined in the earlier Rufus and Larkspur reports. The site selected is to possess qualities similar to the Minuteman Installations at Malmstrom and Warren Air Force Bases including specifically:

2.3.1 Topography. A relatively flat area two miles in diameter is desired in which the average slope is less than 1 vertical to 30 horizontal. Topographic features within this two mile circle should be noncentral and of limited extent. The minimum requirement is that at least one radius of the circle have a slope of 1 vertical to 30 horizontal or less.

2.3.2 Overburden Properties.

a. Thirty feet deep or less

b. Unsaturated and relatively dry

c. Seismic velocity 2,000 to 4,000 ft/sec.

2.3.3 Bedrock Properties.

a. Strata relatively flat lying

b. Water content less than 25 percent by weight

c. Seismic velocity 4,000 to 10,000 ft/sec.

d. Resistivity average 8 to 84 ohm-meters with a minimum of 5 and a maximum of 500 ohm-meters.

e. Non-crystalline

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2.3.4 Water Table. Eighty feet or greater depth from ground surface.

The foregoing site characteristics are not necessarily listed in the order of their importance to the project.

PART 3

SITE EVALUATION

AREA 1

3.1.1 Location. Area 1 is the most northerly of the four areas under study. It is approximately 30 miles from the airfield at the south end of Amchitka. (See Figures 2 and 4).

3.1.2 Access. Access to Area 1 is a difficult problem. The existing road which passes through Area 1 has a poor road bed and grades which approach 60 percent. Four wheel drive vehicles with winches were able to traverse the present road to Area 1 from the south, but only with great difficulty. This road leads to a beach at Bird Cape Camp some 3½ miles northwest of Area 1. This beach could probably be utilized by landing craft as a means of supplementary access. A short, rough airstrip 1000 feet long and 25 feet wide lies 2½ miles northwest of core hole 64-D-4. Supplementary access by helicopter to Area 1 is also possible but would be very sharply limited by frequent fog and high winds.

3.1.3 Site Evaluation as to Design Criteria.

(a) Topography. Area 1 satisfies the minimum requirements for topography. (See Figure 4, Plates 1 and 12, and Photo 22).

(b) Overburden Properties. The overburden as shown in core hole 64-D-4 is approximately 4 feet deep, coarse grained with small quantities of fines. All the soil is residually derived from the underlying bedrock and probably is not saturated. Seismic velocities will be reported soon by the U. S. Geological Survey.

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(c) Bedrock Properties. Bedrock at core hole 64-D-4 consists of approximately 60 feet of volcanic breccia overlying a welded tuff which extends at least to the bottom of the 120 foot deep core hole. (See Core Photos 25 to 28 and Plates 5 and 8). Welded tuff is similar to a flow rock and as such, may not be as desirable for a pragmatic test which involves a planned comparison with sedimentary rock types at Malmstrom and Warren Air Force Bases. Average water content of the rock is approximately 6 percent by weight. Seismic velocities, electrical properties, and other pertinent physical characteristics of the bedrock at Area 1 will be forthcoming in a U. S. Geological Survey report. Moisture contents, densities, and static elastic constants are included in an appendix to this report.

(d) Water Table. Drilling mud level 24 hours after completion of core hole 64-D-4 was at 42 feet, and not down to the true water table. There are no perched water tables in the immediate vicinity of the core hole.

3.1.4 Additional Considerations.

(a) Blast damage to the facilities at the south end of the island by an air burst at Area 1 will be less than at Areas 3, 4 and possibly 2.

(b) A suitable quarry for high quality manufactured concrete aggregate is believed to exist 4½ miles east of the site, but will have to be located by field reconnaissance.

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(c) Supplemental access by landing craft may be possible at the beach at Bird Cape Camp some 3½ miles from Area 1, but additional studies should be performed by a qualified expert to determine adequacy for landing craft type vessels.

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AREA 2

3.2 Because of the difficulty of present access to Area 2, no borings or systematic surface examinations were performed at this site. Evaluation studies on Area 2 must therefore be limited to interperative studies of maps and to general geologic features which can be relatively safely extrapolated from other investigated areas of the island. The following site evaluation is offered with these limitations in mind.

3.2.1 Location. Area 2 is situated in the mountainous northern end of Amchitka Island near the eastern coast, and approximately 25 air miles northwest of the airfield. (See Figures 2 and 5).

3.2.2 Access. Access to Area 2 is at present extremely difficult for conventional vehicles. Not only is the existing road bed in a poor state of repair, but it has grades up to 60 percent and can be traversed only by four wheel drive vehicles with winches. In addition, this existing road passes no nearer than three quarters of a mile to the center of Area 2.

A natural harbor, three quarters of a mile northwest of the center of Area 2, is probably suitable for handling landing craft for supplemental access. Maximum natural grades from the beach to the center of the area approach 23 percent but reasonable access grades could be established. Cargo helicopters would probably have to be ruled out as a form of transport due to extreme winds and frequent heavy fog.

3.2.3 Site Evaluation as to Design Criteria.

(a) Topography. Area 2 meets the minimum requirements for topography. (See Figure 5 and Plate 2). This Area is shaped like a large tilted bowl open to the northwest. Hills rise to over 1100 feet less than a mile away to the north, east and south.

(b) Overburden Properties. Overburden is expected to be 5 feet or less and not saturated.

(c) Bedrock Properties. Bedrock is a well indurated, hydrothermally altered volcanic breccia. Seismic velocities and electrical properties of these formations will be forthcoming in a U. S. Geological Survey report and are based upon a geophysical field survey of the area performed by the USGS.

(d) Water Table. Water table is expected to be 40 feet deep or less.

3.2.4 Additional Considerations.

(a) Shielding by the hills to the south of the Area may reduce blast damage to the south end of the island provided the event takes place below 1000 feet elevation.

(b) Some evidence exists that portions of Area 2 may be in a zone of potential landslide activity. This possibility will have to have further investigation by field reconnaissance.

(c) A suitable quarry for high quality concrete aggregate is believed to exist within one mile of Area 2 but will have to be definitely located by field reconnaissance.

(d) A field examination of the beach at the natural harbor immediately adjacent to Area 2 should be performed by a qualified expert to determine adequacy for landing craft type vessels as a possible supplementary access during and after road building activity.

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AREA 3

3.3.1 Location. Area 3 lies approximately 18 air miles northwest of the airfield on a tundra plateau in the central portion of Amchitka Island. (See Figures 2 and 6). The site is just inland from Chitka Point.

3.3.2 Access. Access to Area 3 is almost as good as to Area 4. The existing road between Areas 3 and 4 is now passable to two wheel drive vehicles but would have to be reinforced to carry heavy construction equipment. The maximum grade on this road is approximately 7 percent.

3.3.3 Site Evaluation as to Design Criteria.

(a) Topography. Area 3 more than meets the minimum requirements for topography, but has steep slopes to the northeast where a large landslide has interrupted the landscape. (See Figure 6 and Plate 3, Photos C1 to C6 of Area 3 and Photos 8 to 16, 23, 24). There are indications this slide is working its way towards core hole 64-D-2 and the stability of this slope would be in question if it were suddenly loaded, such as by an air burst of high yield.

(b) Overburden Properties. Overburden in core hole 64-D-2 is a residual soil formed from the underlying volcanic conglomerate. The soil of peat and bouldery silt is saturated and approximately 3 feet thick. Seismic velocities of the overburden are to be included in a forthcoming report by the U. S. Geological Survey.

(c) Bedrock Properties. Bedrock encountered to 120 feet in core hole 64-D-2 is a poorly consolidated volcanic conglomerate. This conglomerate is exposed over most of the surface within a mile radius of the core hole, and extends 1½ miles north, where it overlies an andesite breccia. (See Plates 6, 9 and Core Photos 29 to 31). The core hole had drilling problems due to running gravel, soft sand, and water loss. Excavations, particularly to depths of 120 feet, will require shoring or resloping. Two core samples showed an average of 16 percent moisture by weight, but this value may be low, as some drying may have taken place prior to testing. Seismic velocities, electrical properties and other pertinent physical characteristics of the bedrock in Area 3 will be shown in a forthcoming U. S. Geological Survey report. Moisture contents, densities, and some static elastic constants are included in an appendix to this report.

(d) Water Table. Core hole 64-D-2 was drilled with mud. Fluid levels at the completion of drilling and 2 months later were 1 and 2 feet deep respectively. This probably is the reflection of a perched water table or of a hole sealed by mud and is not a true gravity water table. The following lines of evidence strongly suggest that the true water table is at a minimum of 91 feet depth: (1) loss of all drilling fluid at 91 feet, and (2) pronounced iron oxide staining to a depth of 60 feet suggesting percolation of surface waters down to a static water table at or below this point.

3.3.4 Additional Considerations. A quarry of definitely known suitability for the manufacture of high quality concrete aggregate is located approximately 12½ miles to the southeast. Further reconnaissance may disclose suitable aggregate sources much closer.

3.3.5 General Comments. Area 3 is not considered to be an adequate site because a portion of it includes a large slide-susceptible area, and because of the widespread occurrence of lesser quality rock materials. The present slide area would expand by high loading from an air burst, to the point where it could influence any structures built in Area 3.

AREA 4

3.4.1 Location. Area 4 lies approximately 10 miles northwest of the airfield on a tundra plateau in the central portion of Amchitka Island. (See Figures 2 and 7). The site is the most southerly of the 4 areas under study.

3.4.2 Access. Area 4 is the most accessible of the Areas with a very serviceable road passing through it from the docking area and main airfield. The maximum grade on this road is approximately 7 percent and is presently passable by all conventional type vehicles but will need reinforcing for heavy construction vehicles.

3.4.3 Site Evaluation as to Design Criteria.

(a) Topography. Area 4 is the flattest of the four areas under study and meets more than the minimum requirements for topography. (See Figure 7, Plate 4, Photos 17 to 21 and C1 to C4 of Area 4).

(b) Overburden Properties. The overburden at core hole 64-D-3, in the center of Area 4, is approximately 4 feet deep, thoroughly saturated, and residually derived from the underlying bedrock. Overburden seismic velocities will be reported in a soon to be released report by the U. S. Geological Survey.

(c) Bedrock Properties. Bedrock at core hole 64-D-3 is a volcanic breccia as described and shown on Plates 7, 10 and Core Photos 32 to 35. Bedding appears to dip between 10 and 20 degrees to the East. Water content from a core sample was 12.2

percent by weight, but some drying may have taken place before testing. Seismic velocities, electrical properties, and other pertinent bedrock characteristics at Area 4 will be forthcoming in a U. S. Geological Survey report. Moisture contents, densities and some static elastic constants are included in an appendix to this report.

(d) <u>Water Table</u>. True water table depth appears to be around 75 feet deep as suggested by staining on the rock cores. A perched water table is encountered within 2 feet of the ground surface. The water table as measured in core hole 64-D-3 was 1 foot below the surface at the completion of drilling, and 2 months later was at 4 feet. It must be pointed out that the hole was drilled with mud and the four foot level is probably not the true level of the water table.

3.4.4 Additional Considerations.

(a) The closeness of Area 4 to the main airbase, docking facilities and living facilities could also be a detriment, because the supply installations may suffer considerable damage from an air burst at Area 4.

(b) Area 4 is the closest to a quarry of definitely known suitability for the manufacture of high quality concrete aggregate. Access to the quarry from Area 4 is along four miles of good roads with no unusually steep grades. Further reconnaissance may disclose suitable aggregate sources even closer to the Area.

(c) No unusual construction problems for a missile complex are anticipated in this area.

PART 4

REFERENCES

REFERENCES

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2. William S. Twenhofel, editor; "Project Rufus Site Selection"; May 1963; U. S. Atomic Energy Commission, Nevada Operations Office, Las Vegas, Nevada; Secret.

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5. Arthur M. Piper; "Operations Windstorm and Jangle. Geologic, Hydrologic and Thermal Features of the Sites"; May 1952; U. S. Geological Survey, Portland, Oregon; Unclassified.

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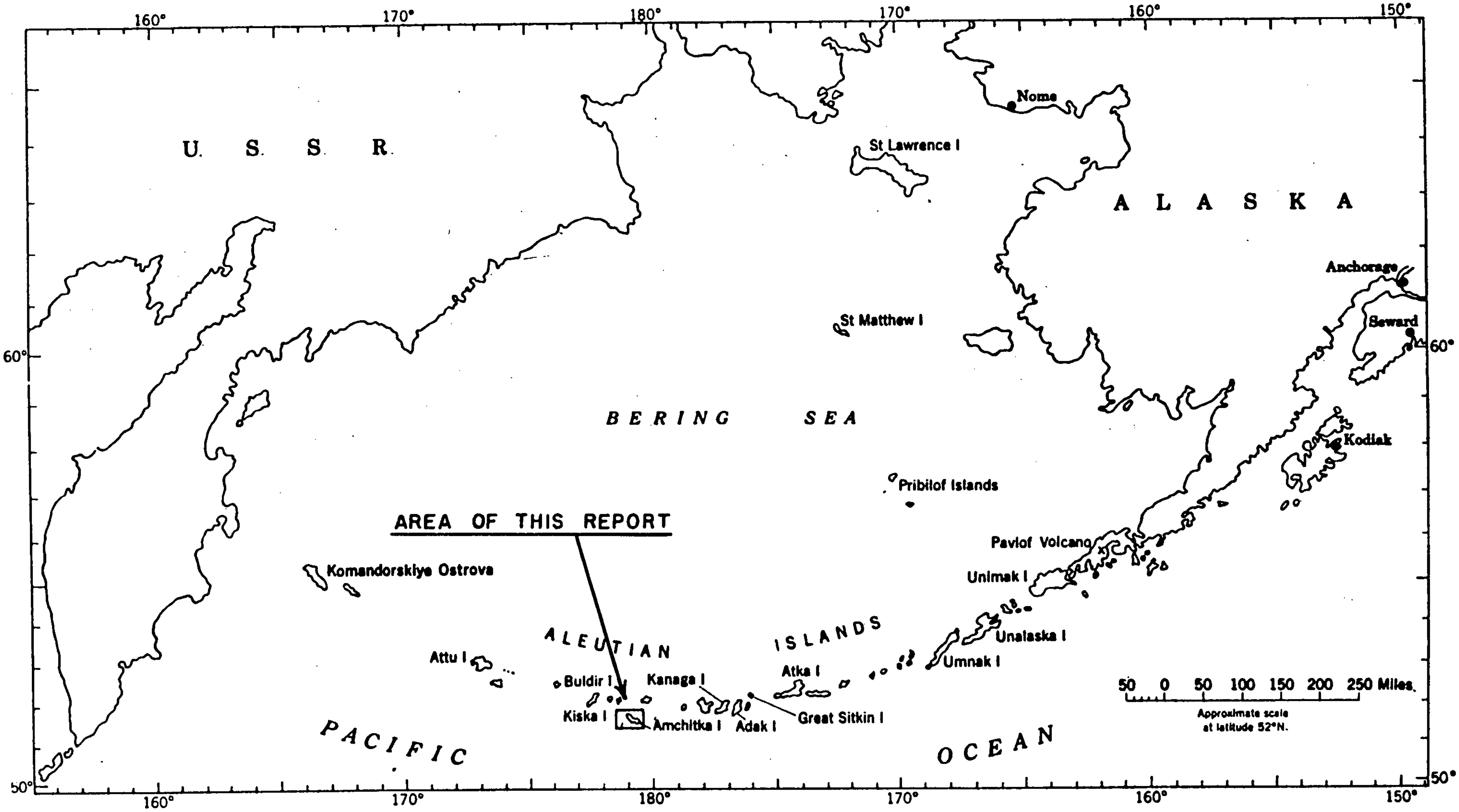
PART 5

ILLUSTRATIONS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170°
180°
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U. S. S. R.
ALASKA
Nome
St Lawrence I
Anchorage
Seward
St Matthew I
Kodiak
BERING SEA
Pribilof Islands
AREA OF THIS REPORT
Komandorskiye Ostrova
Pavlof Volcano
Unimak I
Unalaska I
Umnak I
ALEUTIAN ISLANDS
Attu I
Buldir I
Kanaga I
Atka I
Kiska I
Amchitka I
Adak I
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PACIFIC OCEAN
50 0 50 100 150 200 250 Miles
Approximate scale at latitude 52°N.

Fig. 1

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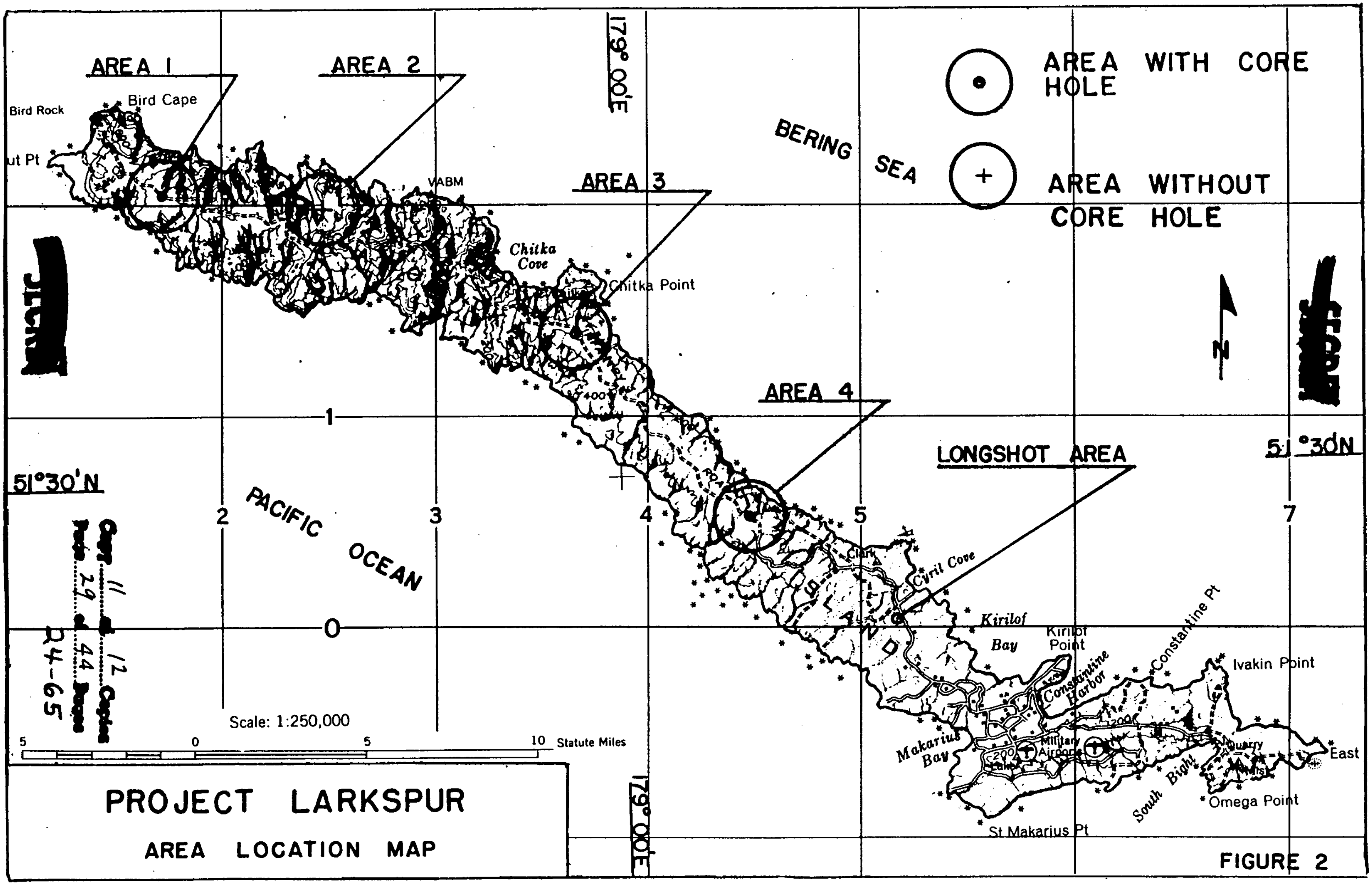

PROJECT LARKSPUR

AREA LOCATION MAP

FIGURE 2

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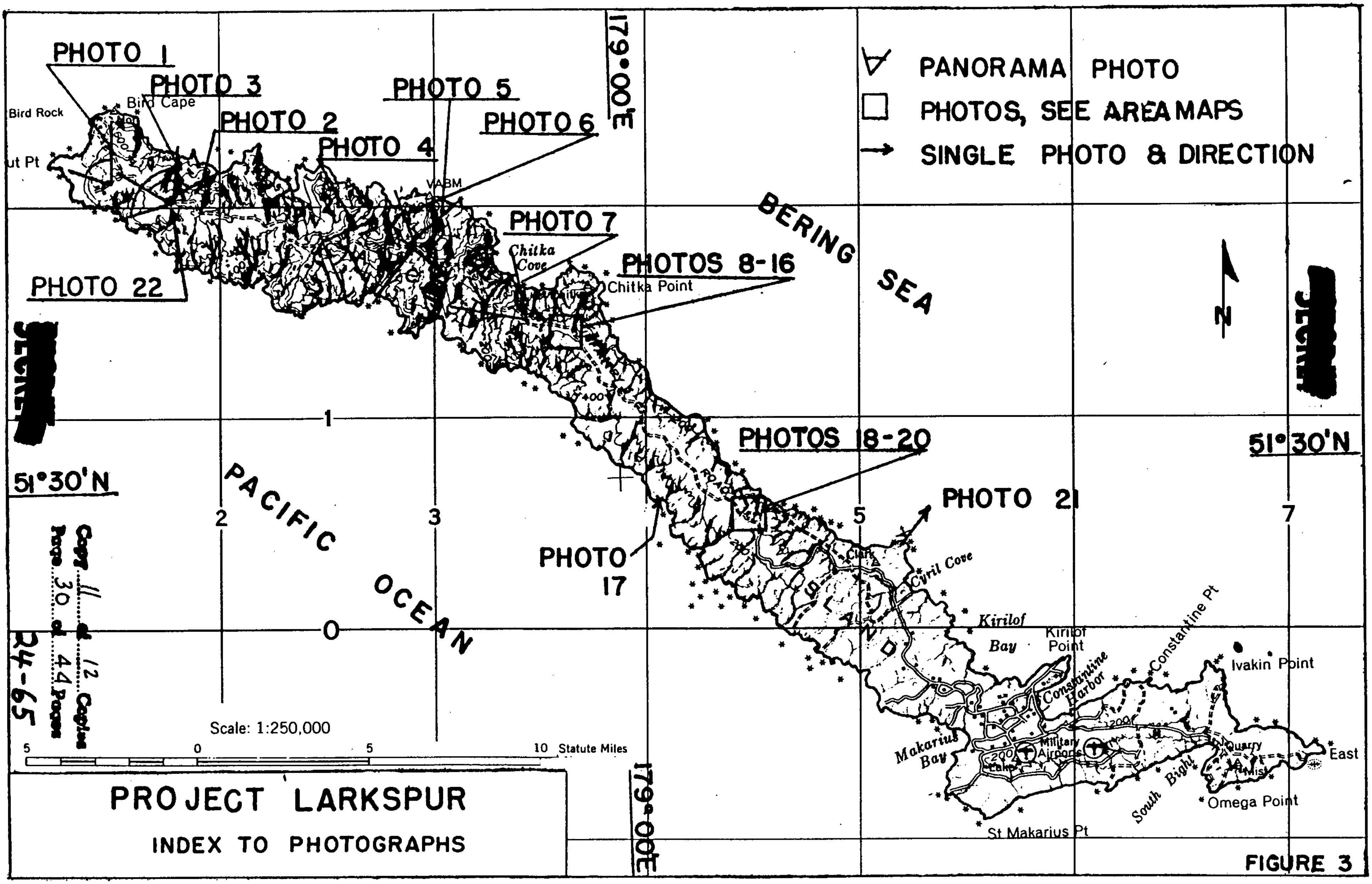

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PROJECT LARKSPUR

INDEX TO PHOTOGRAPHS

FIGURE 3

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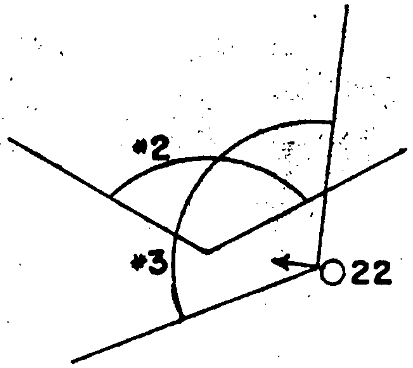
2 B & W PHOTO-PANORAMA DIRECTION

22 B & W PHOTO-NUMBER & DIRECTION



AREA 1

PHOTO LOCATION OVERLAY

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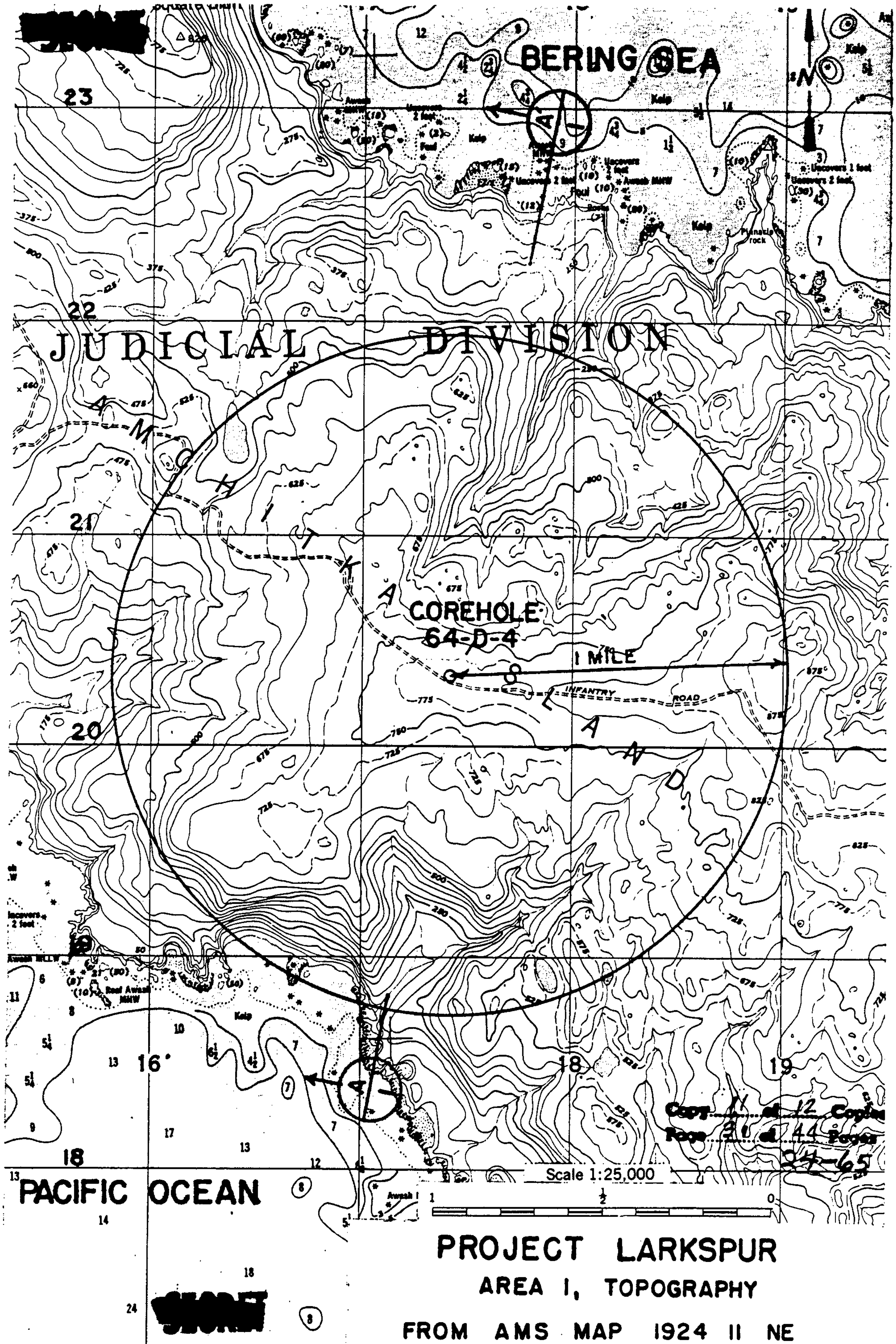

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PROJECT LARKSPUR

AREA I, TOPOGRAPHY

FROM AMS MAP 1924 II NE

FIGURE 4

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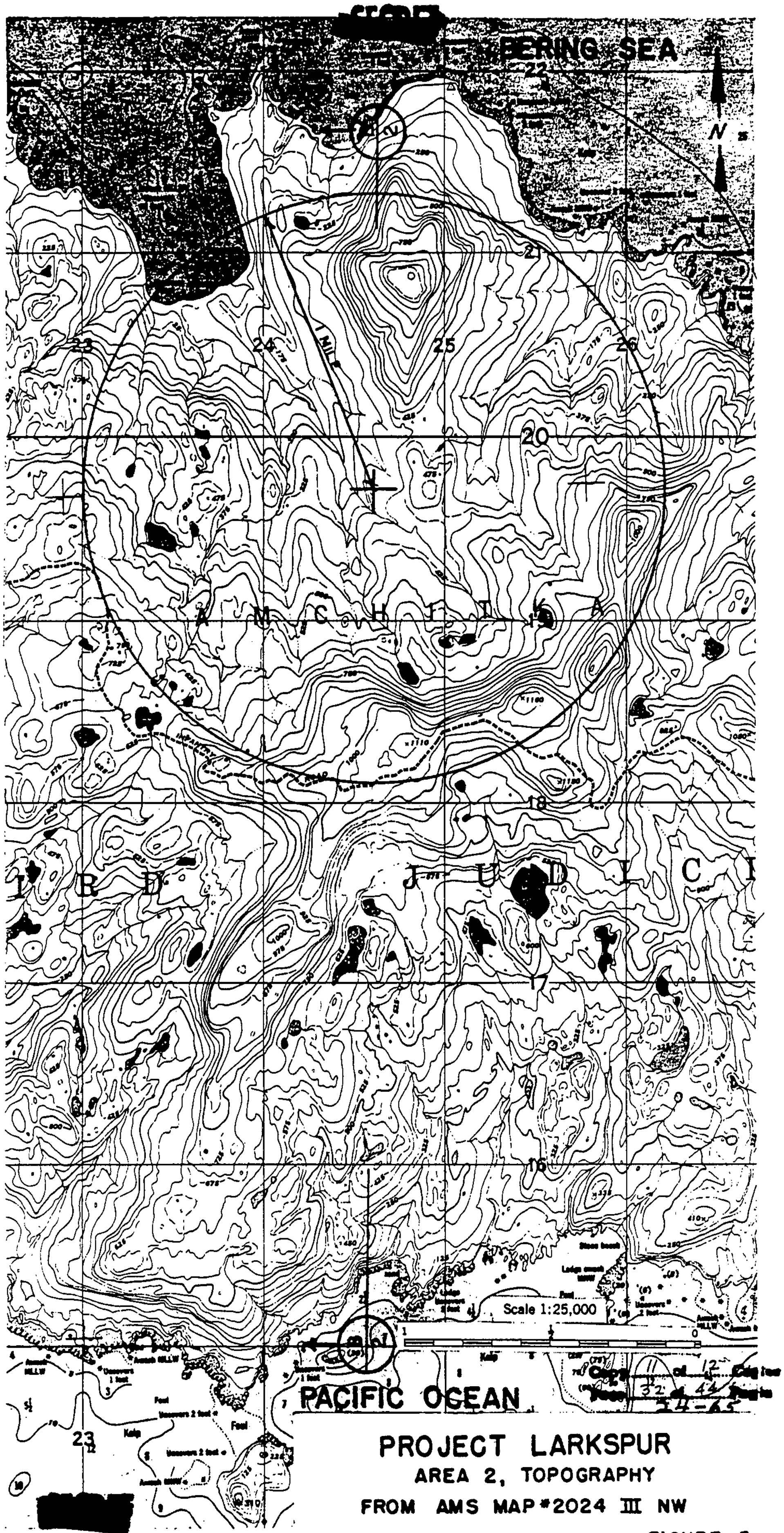

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PROJECT LARKSPUR
AREA 2, TOPOGRAPHY
FROM AMS MAP #2024 III NW

FIGURE 5

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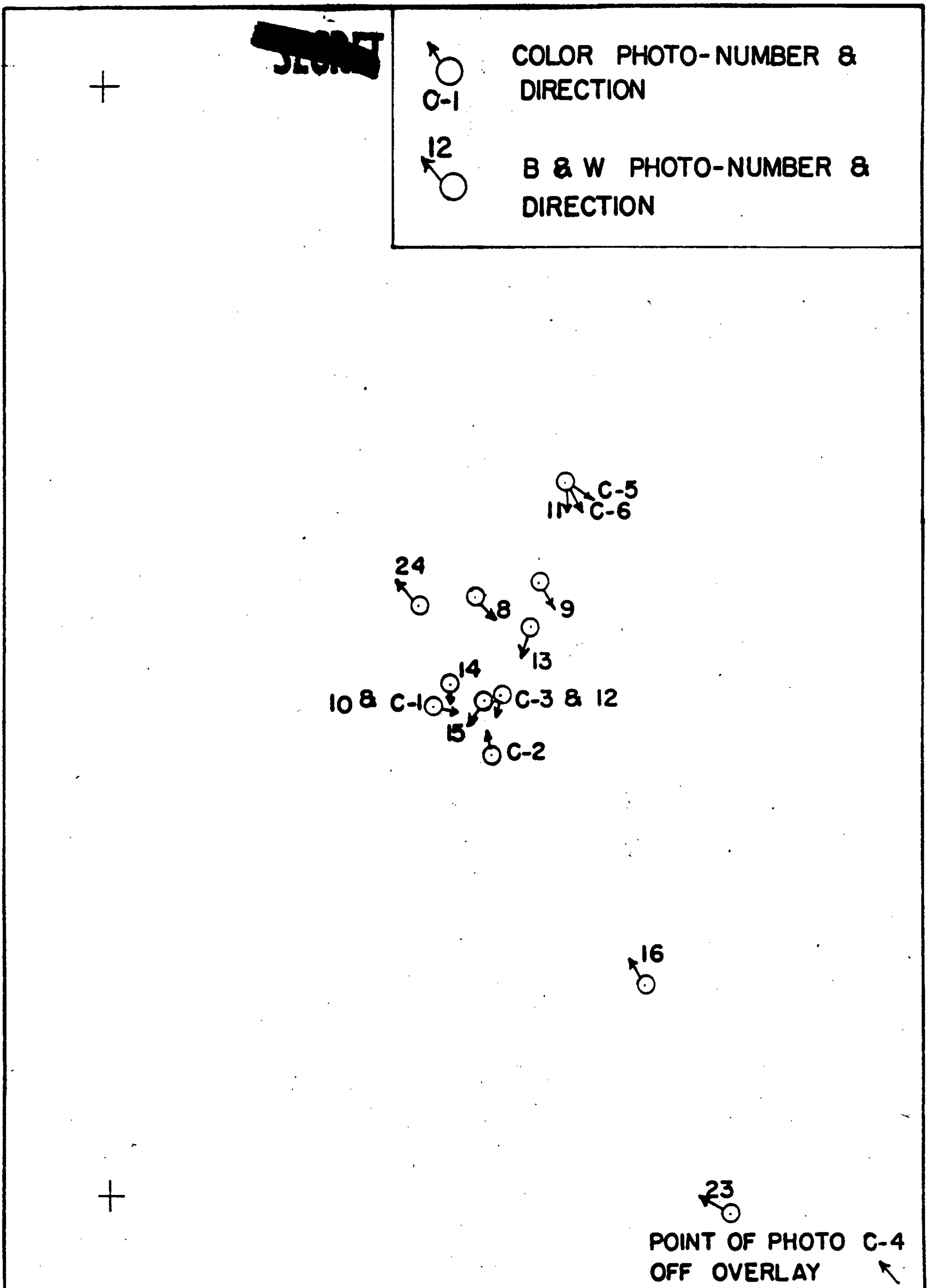

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PHOTO LOCATION OVERLAY

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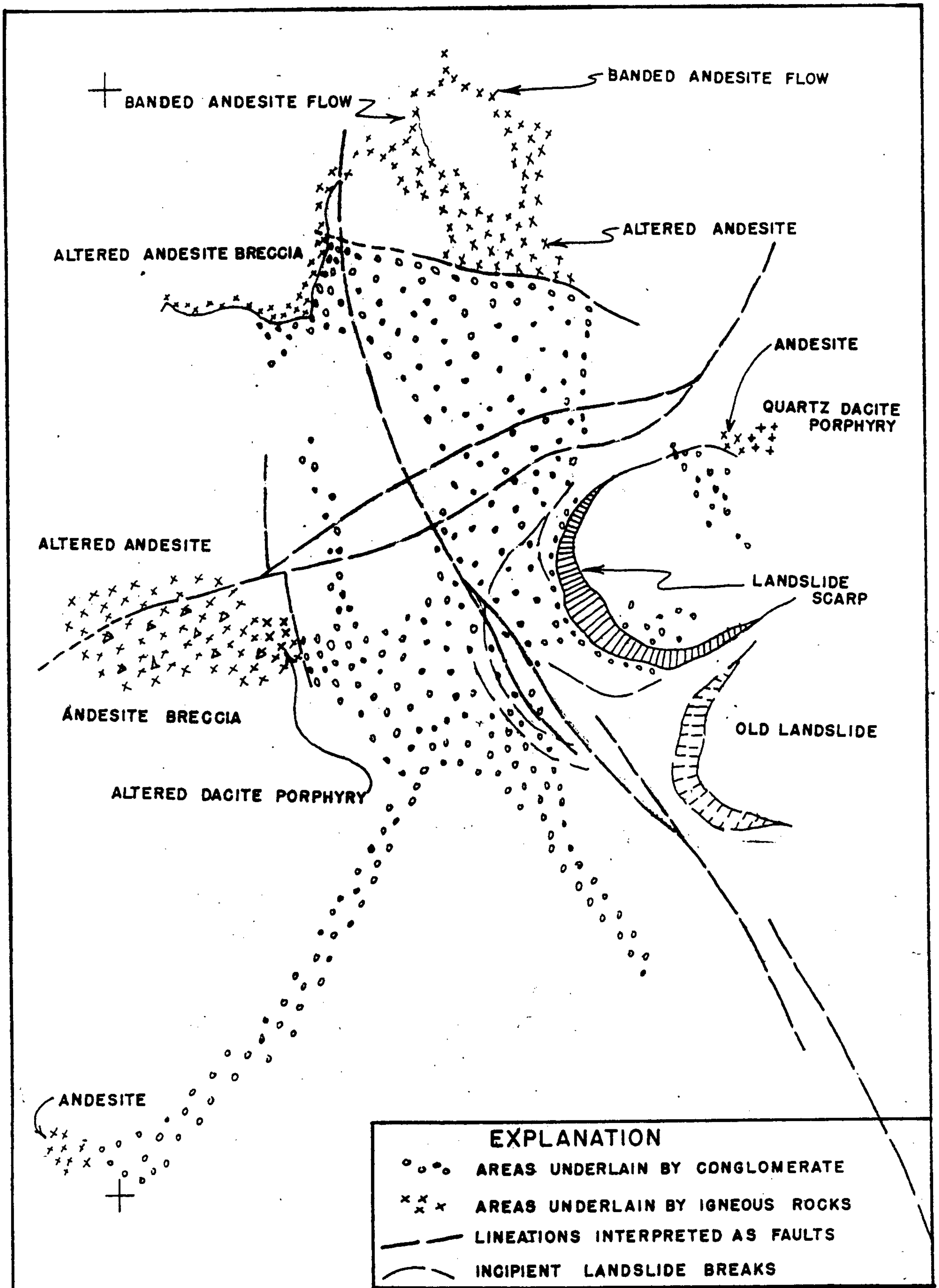
FIG. 6

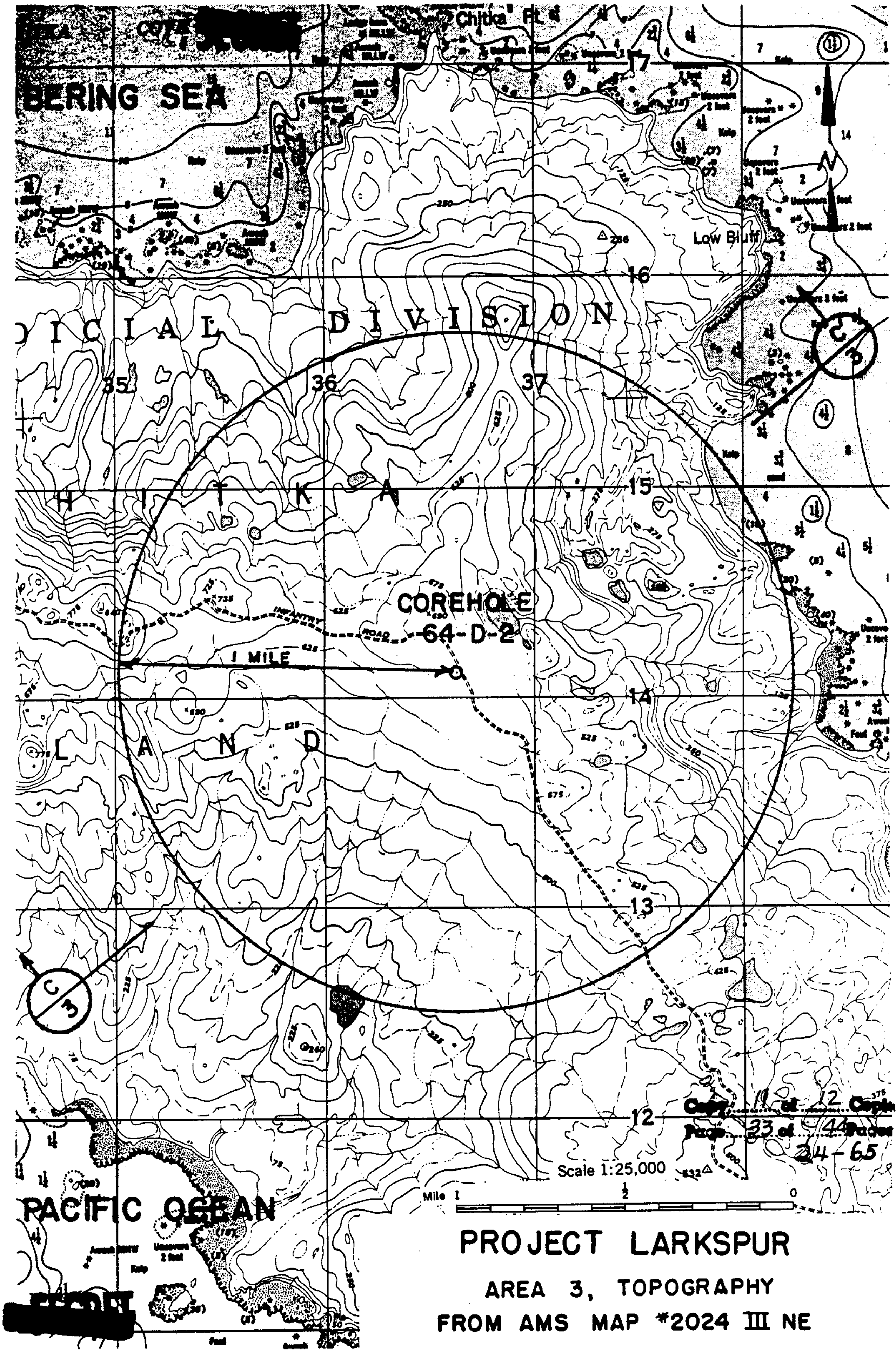


AREA 3

SURFACE GEOLOGY OVERLAY

FIG. 6

[redacted]



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[redacted]

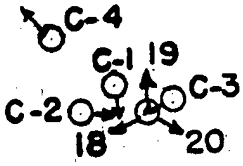
PROJECT LARKSPUR

AREA 3, TOPOGRAPHY
FROM AMS MAP *2024 III NE

FIGURE 6

C-1 COLOR PHOTO-NUMBER & DIRECTION

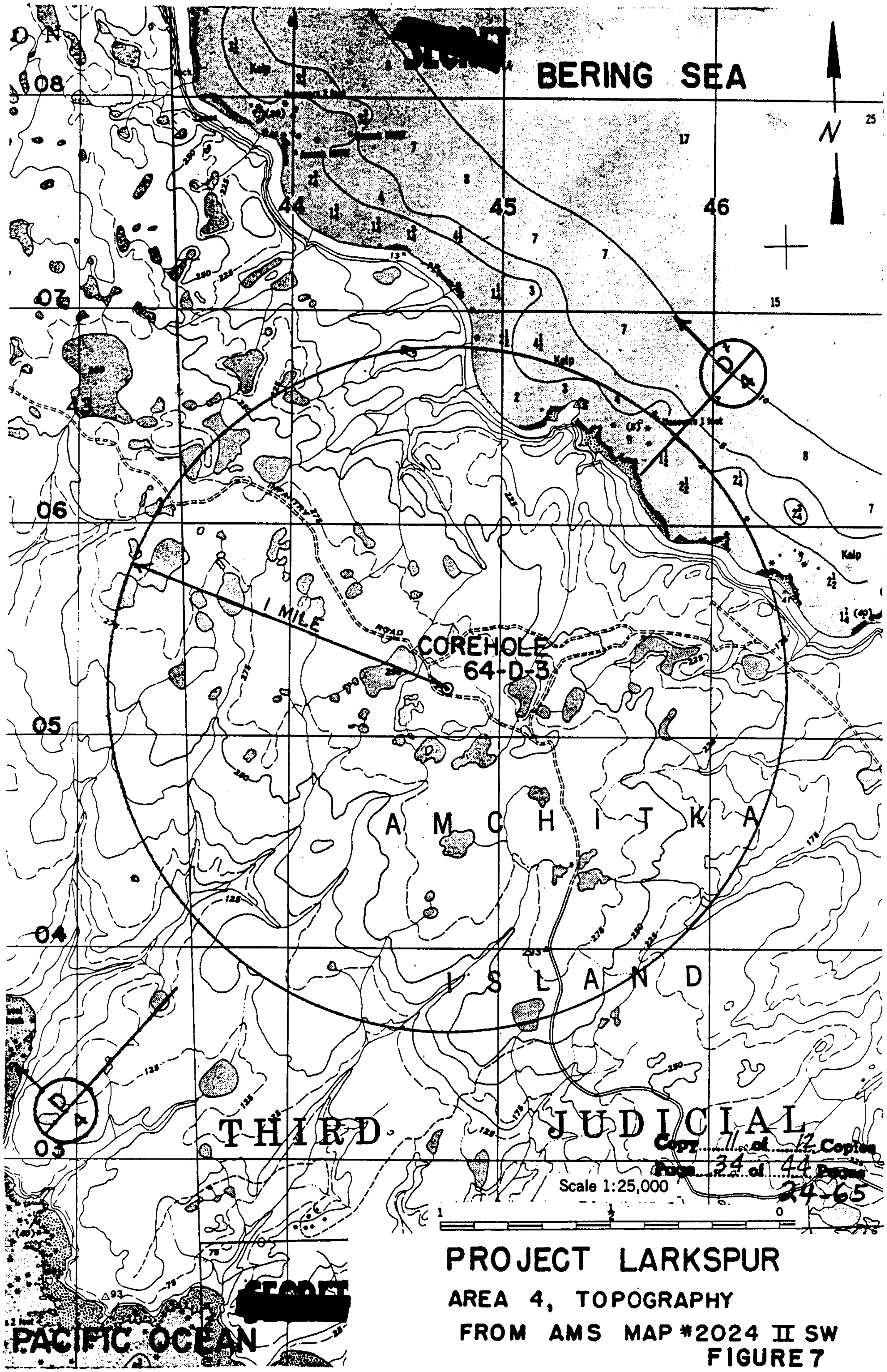
B & W PHOTO-NUMBER & DIRECTION



AREA 4

PHOTO LOCATION OVERLAY

[redacted]



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[redacted]

PROJECT LARKSPUR

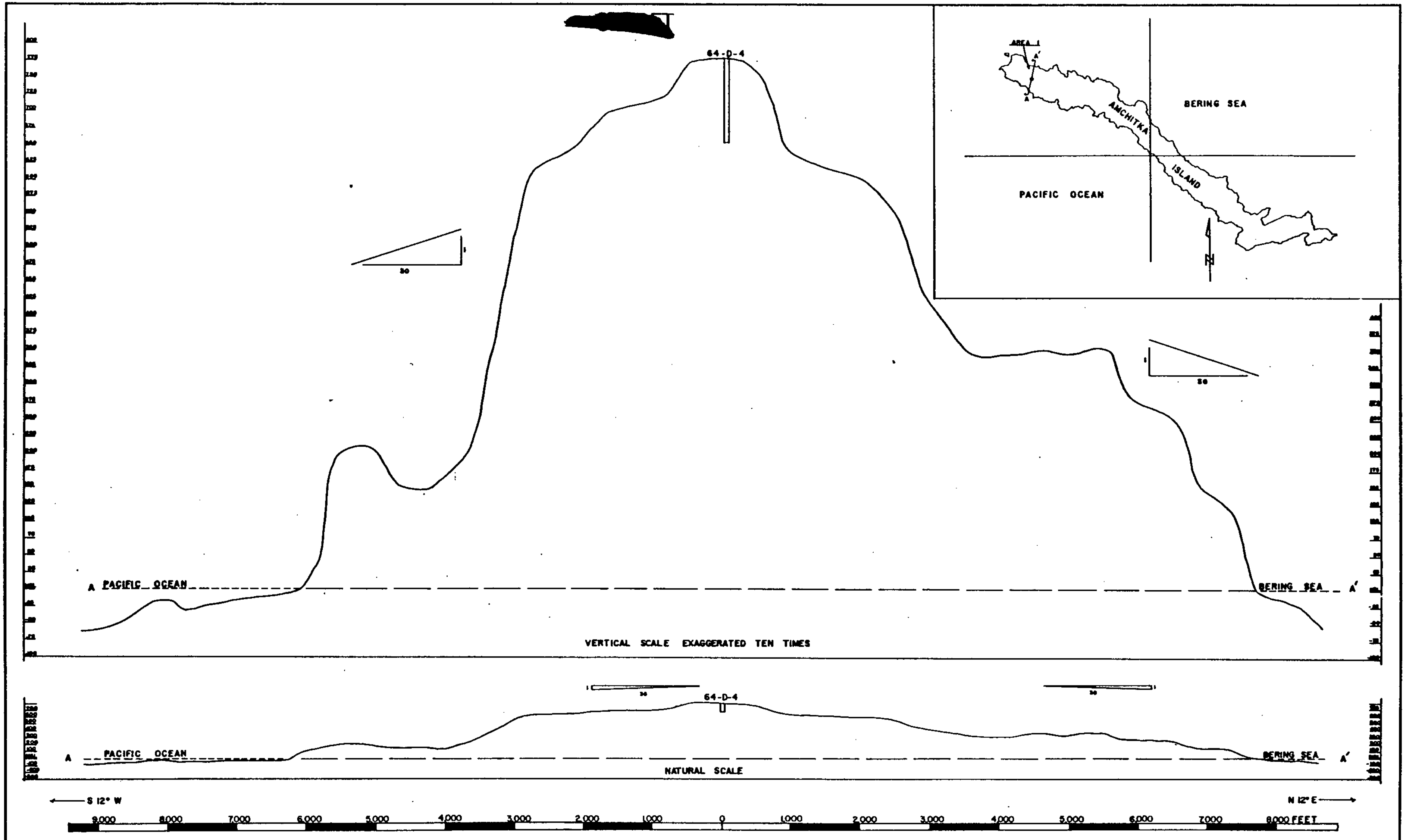
AREA 4, TOPOGRAPHY

FROM AMS MAP #2024 II SW

FIGURE 7

FIGURE 7

[redacted]



SECTION A-A'

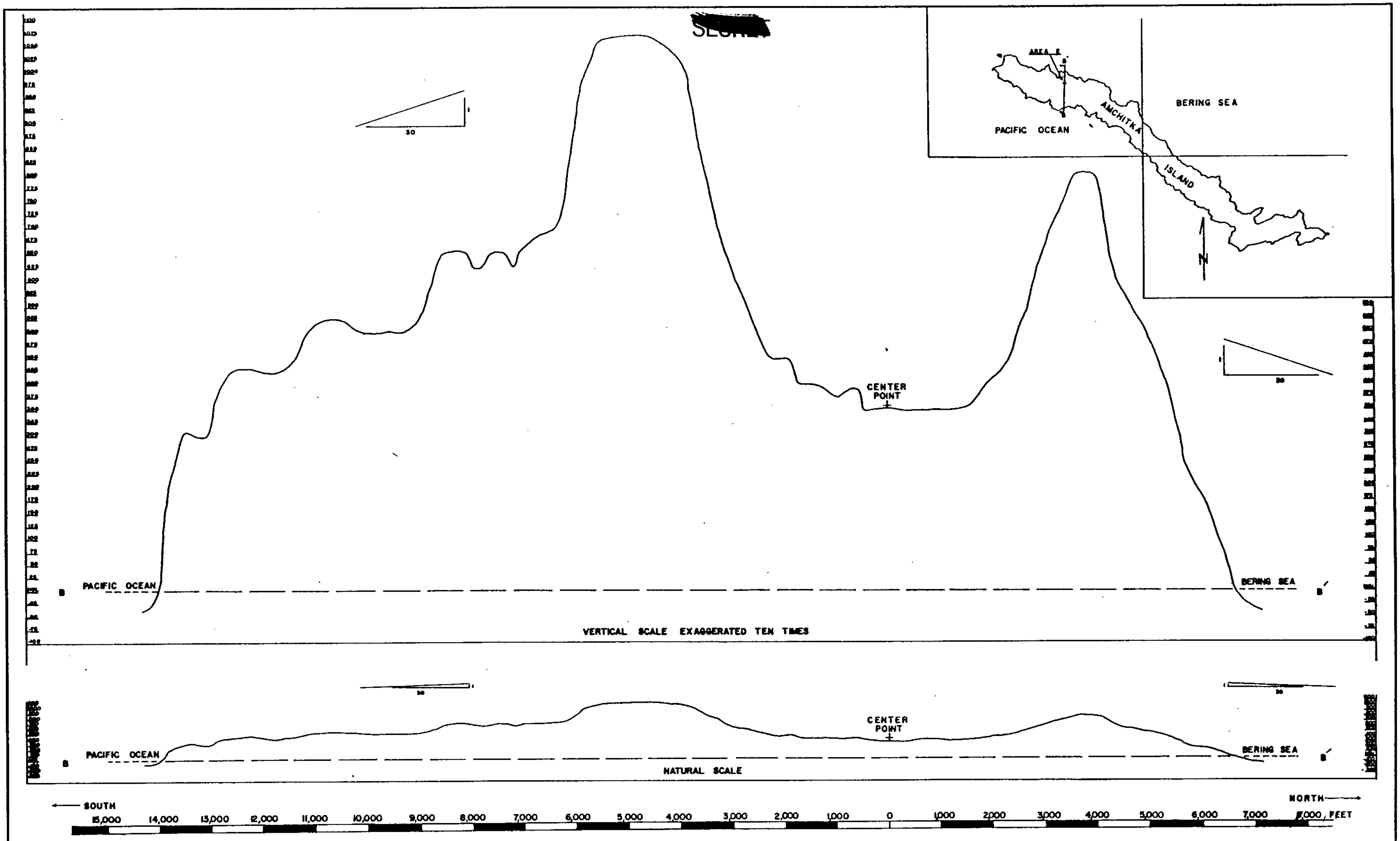
[redacted]

PROJECT LARKSPUR
AMCHITKA ISLAND, ALASKA
TOPOGRAPHIC SECTION
AREA I

11 12
35 44
2-4-65

PLATE I

[redacted]



SECTION B-B´

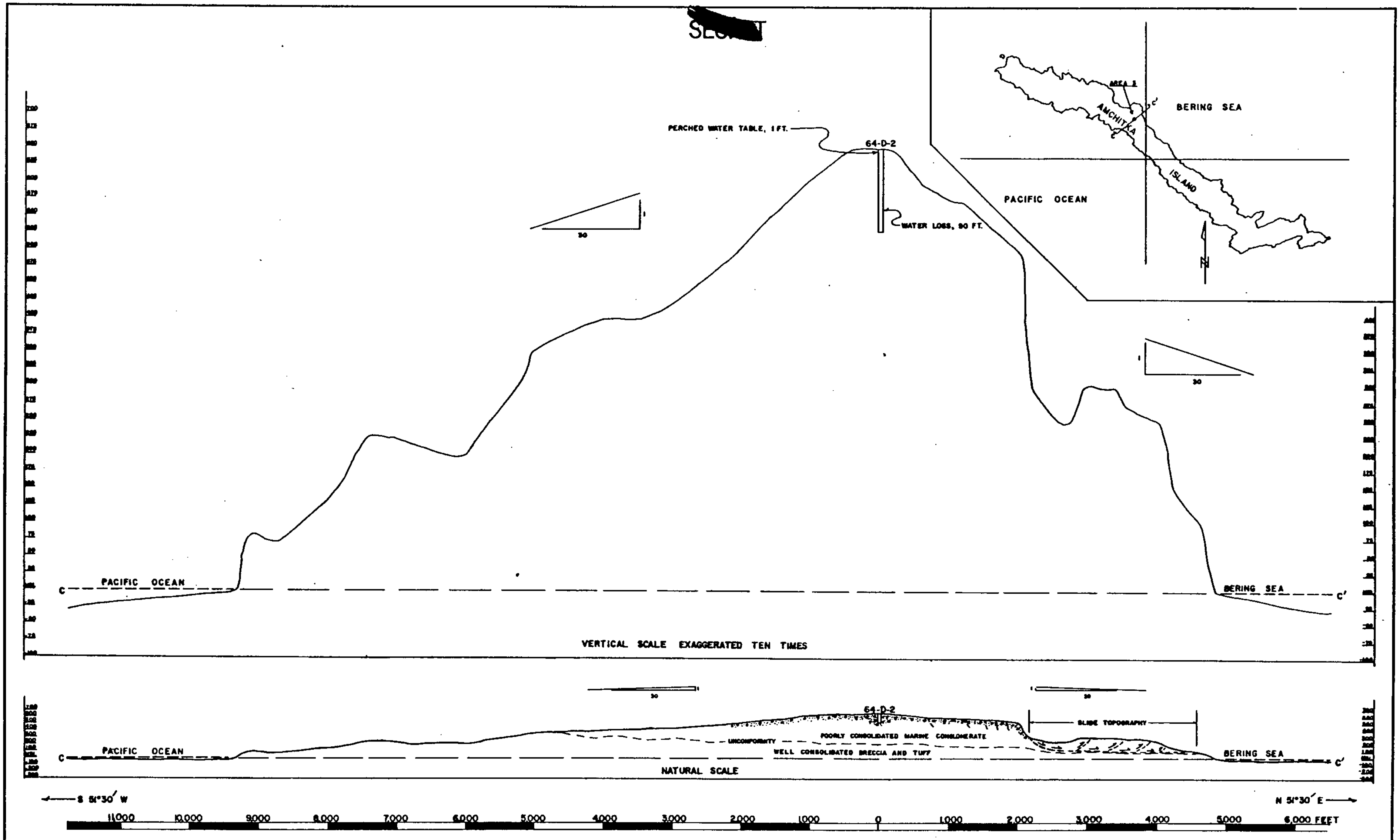
PROJECT LARKSPUR
AMCHITKA ISLAND, ALASKA
TOPOGRAPHIC SECTION
AREA 2

11 12
36 44
24-65

PLATE 2

[redacted]

SEC[redacted]



SECTION C-C'

[redacted]

PROJECT LARKSPUR
AMCHITKA ISLAND, ALASKA
TOPOGRAPHIC SECTION
AREA 3

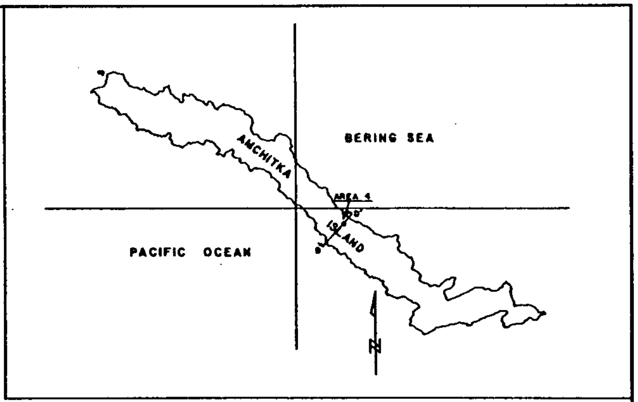
11 12
37 47
24-65

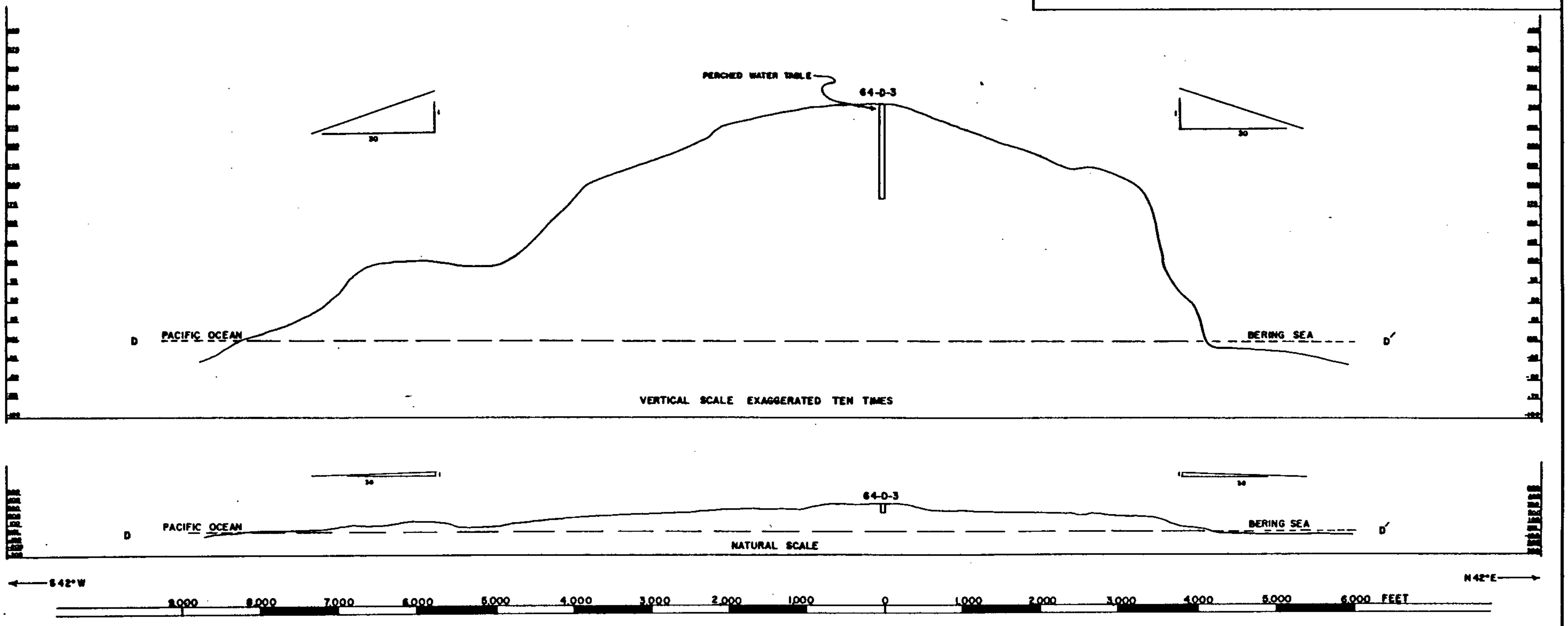
PLATE 3

CORPS OF ENGINEERS

U. S. ARMY

[redacted]





SECTION D-D′

[redacted]

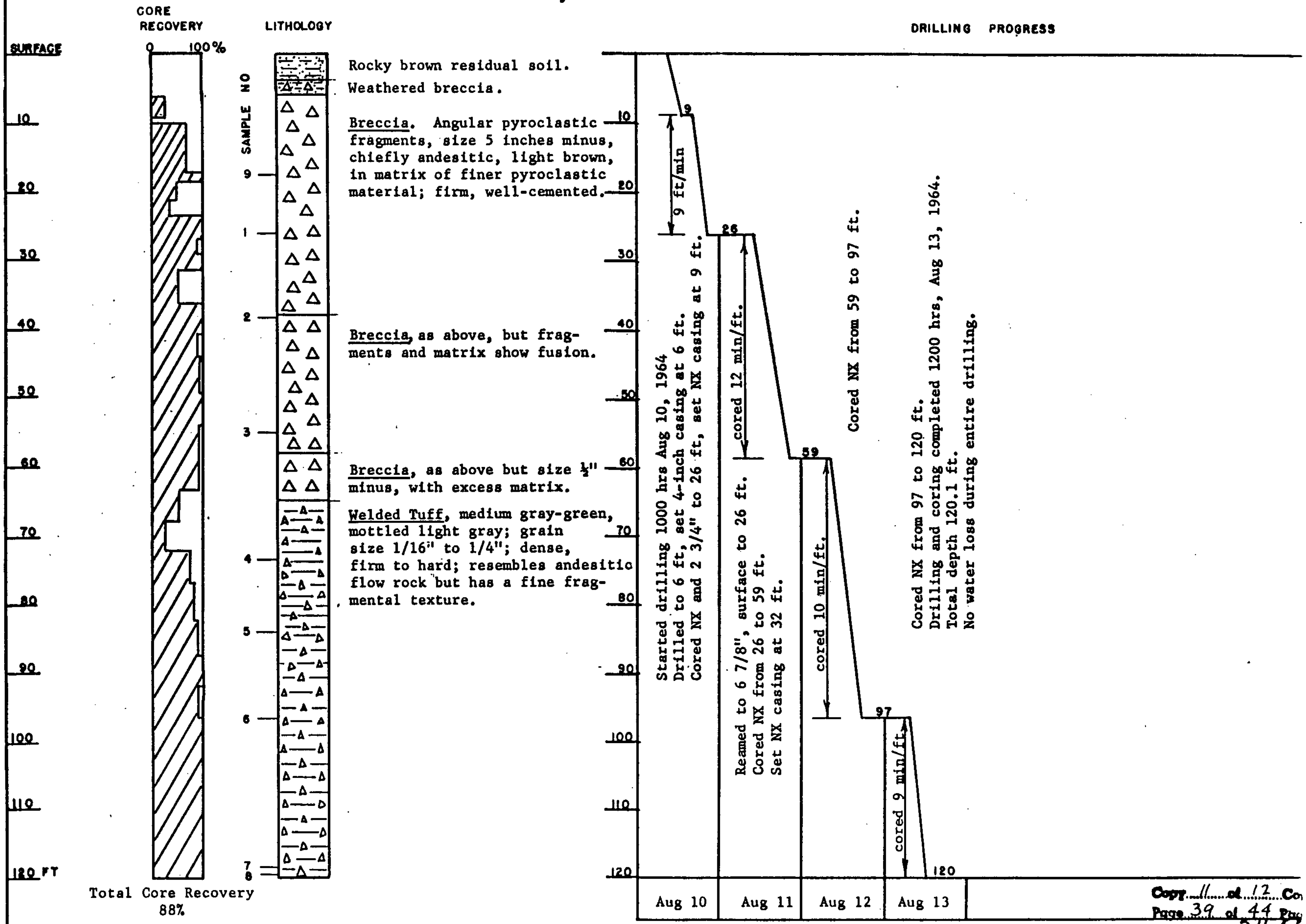
PROJECT LARKSPUR
AMCHITKA ISLAND, ALASKA
TOPOGRAPHIC SECTION
AREA 4

11 12
~~38 44~~
24-65

PLATE 4

[redacted]

AREA I, COREHOLE 64-D-4



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PROJECT LARKSPUR
PLATE 5

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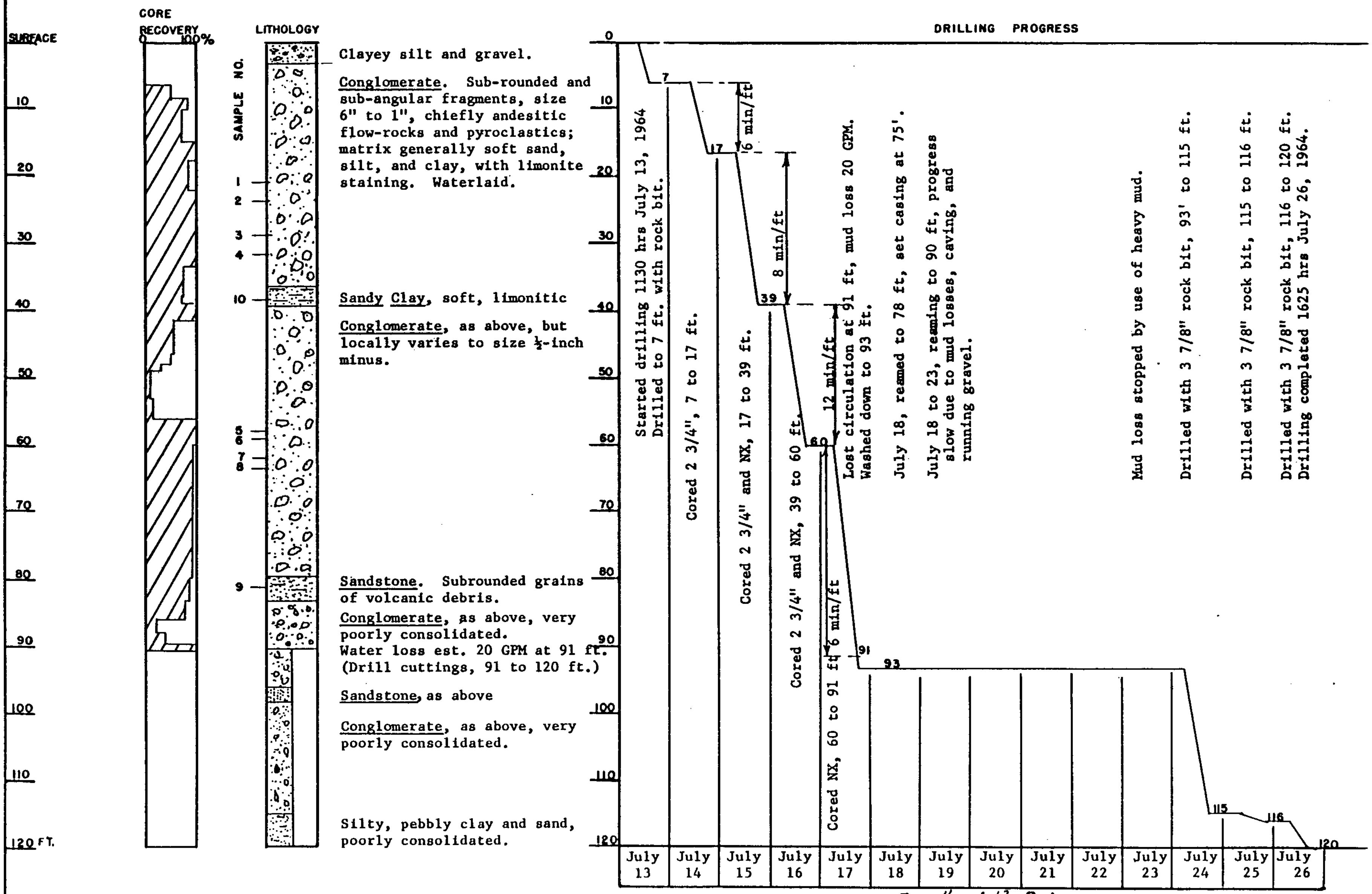
AREA 3, COREHOLE 64-D-2



Clayey silt and gravel.

Conglomerate. Sub-rounded and sub-angular fragments, size 6" to 1", chiefly andesitic flow-rocks and pyroclastics; matrix generally soft sand, silt, and clay, with limonite staining. Waterlaid.

Sandy Clay, soft, limonitic

Conglomerate, as above, but locally varies to size ½-inch minus.

Sandstone. Subrounded grains of volcanic debris.

Conglomerate, as above, very poorly consolidated.
Water loss est. 20 GPM at 91 ft.
(Drill cuttings, 91 to 120 ft.)

Sandstone, as above

Conglomerate, as above, very poorly consolidated.

Silty, pebbly clay and sand, poorly consolidated.

Started drilling 1130 hrs July 13, 1964
Drilled to 7 ft. with rock bit.

Cored 2 3/4", 7 to 17 ft.

Cored 2 3/4" and NX, 17 to 39 ft.

Cored 2 3/4" and NX, 39 to 60 ft.

Cored NX, 60 to 91 ft

Lost circulation at 91 ft, mud loss 20 GPM.
Washed down to 93 ft.

July 18, reamed to 78 ft, set casing at 75'.

July 18 to 23, reaming to 90 ft, progress slow due to mud losses, caving, and running gravel.

Mud loss stopped by use of heavy mud.

Drilled with 3 7/8" rock bit, 93' to 115 ft.

Drilled with 3 7/8" rock bit, 115 to 116 ft.

Drilled with 3 7/8" rock bit, 116 to 120 ft.
Drilling completed 1625 hrs July 26, 1964.

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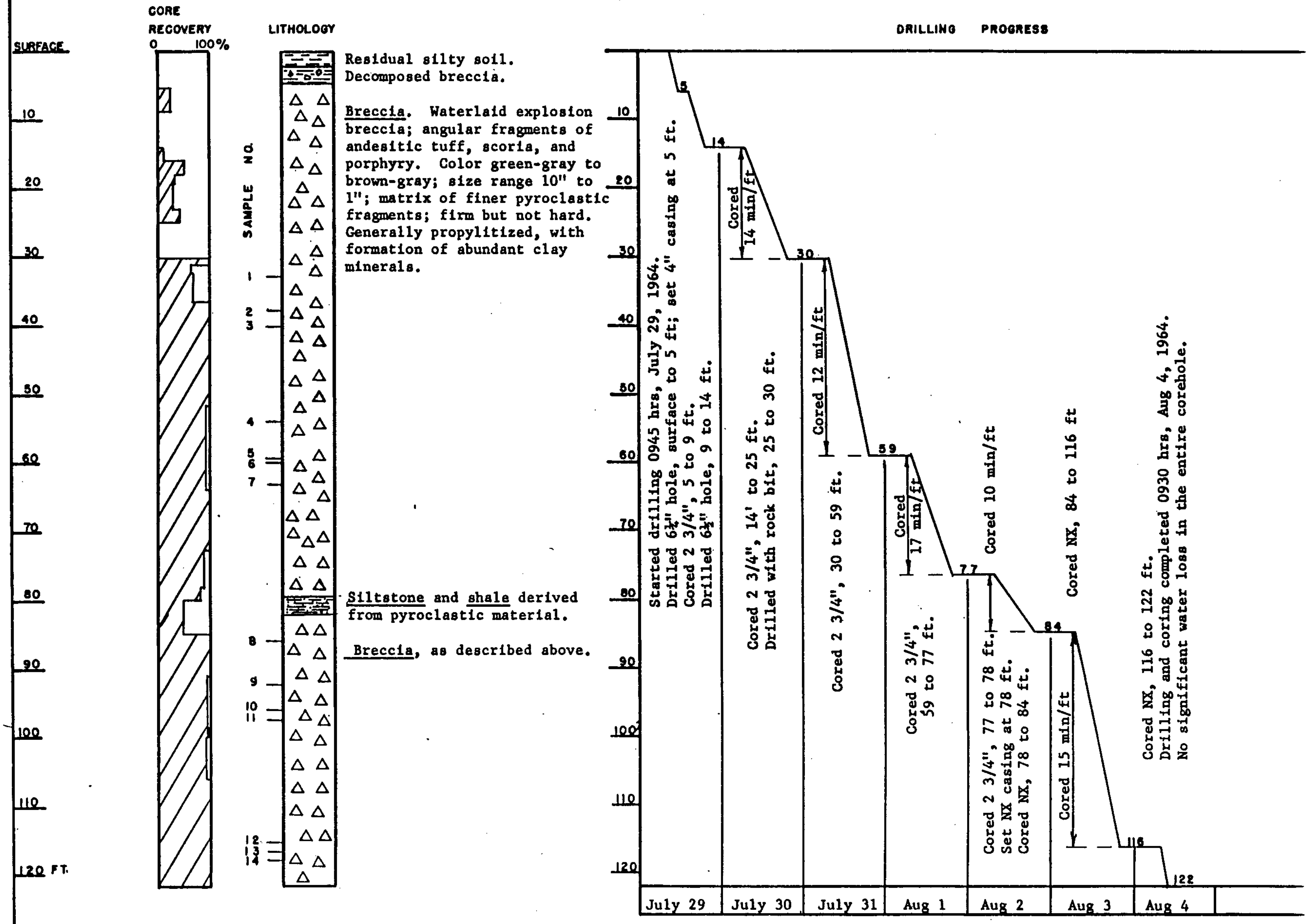
[redacted]

PROJECT LARKSPUR
PLATE 6

AREA 4, COREHOLE 64-D-3



Residual silty soil.
Decomposed breccia.

Breccia. Waterlaid explosion breccia; angular fragments of andesitic tuff, scoria, and porphyry. Color green-gray to brown-gray; size range 10" to 1"; matrix of finer pyroclastic fragments; firm but not hard. Generally propylitized, with formation of abundant clay minerals.

Siltstone and shale derived from pyroclastic material.

Breccia, as described above.

Started drilling 0945 hrs, July 29, 1964.
Drilled 6¼" hole, surface to 5 ft; set 4" casing at 5 ft.
Cored 2 3/4", 5 to 9 ft.
Drilled 6¼" hole, 9 to 14 ft.

Cored 2 3/4", 14' to 25 ft.
Drilled with rock bit, 25 to 30 ft.

Cored 2 3/4", 30 to 59 ft.

Cored 2 3/4", 59 to 77 ft.

Cored 2 3/4", 77 to 78 ft.
Set NX casing at 78 ft.
Cored NX, 78 to 84 ft.

Cored NX, 84 to 116 ft

Cored NX, 116 to 122 ft.
Drilling and coring completed 0930 hrs, Aug 4, 1964.
No significant water loss in the entire corehole.

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PROJECT LARKSPUR
PLATE 7

~~SECRET~~

AREA I, Hole No. 64-D-4

DRILLING LOG

DIVISION: North Pacific
INSTALLATION: Alaska District
SHEET 1 OF 2 SHEETS
1. PROJECT: LARKSPUR
2. LOCATION (Coordinates or Station):
3. DRILLING AGENCY: Corps of Engineers
4. HOLE NO. (As shown on drawing title and file number): 64-D-4, Area 1
5. NAME OF DRILLER: Roy Risley
6. DIRECTION OF HOLE: ☒ VERTICAL ☐ INCLINED ______ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN: 4 ft.
8. DEPTH DRILLED INTO ROCK: 115.1
9. TOTAL DEPTH OF HOLE: 120.1
10. SIZE AND TYPE OF BIT:
11. DATUM FOR ELEVATION SHOWN (TBM or MSL):
12. MANUFACTURER'S DESIGNATION OF DRILL: Failing 43-SA
13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: DISTURBED 1 UNDISTURBED
14. TOTAL NUMBER CORE BOXES: 4
15. ELEVATION GROUND WATER: 42 ft.
16. DATE HOLE: STARTED 10 Aug COMPLETED 13 Aug
17. ELEVATION TOP OF HOLE: Approximately 775
18. TOTAL CORE RECOVERY FOR BORING: 88.5% %
19. SIGNATURE OF INSPECTOR: R. W. Griffith

ELEVATION a	DEPTH b	JOINT ANGLE c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
			Overburden, silty sandy gravel		#1	Soil sample #1 0.0 ft. to 4.0 ft.
			BRECCIA, weathered			
			BRECCIA	26		
	10	60°	Tricone 3 7/8"			
		45° 90°	BRECCIA; 5" minus, excess 1" minus, light brn or buff, matrix easily scratched by penny, matrix very coarse grained and very deficient, rock tends to break easily around fragments, most all fragments andesite, alteration very extensive, no CO_3 Small seams of silty clay between 17' & 31'	66	#9	Core sample #9 16.8 - 17.4
		90°		100		
	20			50		
		90° 45°		38		
				100	#1	Core sample #1 (25.2 to 26.0)
		90° 65°		92		
	30			100		
		50° 40°		57		
		90° 30°			#2	Core sample #2 (37.8 - 38.8 ft.)
	40	45° 50°	BRECCIA, 5" minus, excess 1" minus, light brn or buff and some red, very mottled, difficult to distinguish between matrix and fragments, fusion between fragments and between fragments and matrix	100		
		30°		92		
		90°		98		
	50	80° 60°				
		90°		100		
		55° 80°		98	#3	Core sample #3 (54.0 - 54.8 ft.)
	60	60°	BRECCIA, 1/2" minus, excess matrix, matrix medium fine grained	98		
		20°	1/8" minus. Looks like an andesitic flow rock, however, possibility that it is highly altered tuff completely reconstituted by alteration so that it appears like an igneous rock. Upper part 65.5 - 79 ft. fragmental	57		
	70			23	#4	Core sample #4 (72.7 - 73.6 ft.)
		65°		79		
	80			85	#5	Core sample #5 (83.3 - 84.3 ft.)
				92		
	90	65° 45° 45° 45° 30°		100		
		90°		100	#6	Core sample #6 (95.5 - 96.5 ft.)
	100			100		

ENG FORM 1 APR 63 1836 PREVIOUS EDITIONS MAY BE USED (EM 1110-1-1801)
PROJECT: LARKSPUR
HOLE NO.: 64-D-4

AREA I, Hole No. 64-D-4

DRILLING LOG

DIVISION: North Pacific
INSTALLATION: Alaska District
SHEET 2 OF 2 SHEETS
1. PROJECT: ... LARKSPUR
2. LOCATION (Coordinates or Station):
3. DRILLING AGENCY: Corps of Engineers
4. HOLE NO. (As shown on drawing title and file number): 64-D-4, Area 1
5. NAME OF DRILLER: Roy Risley
6. DIRECTION OF HOLE: ☒ VERTICAL ☐ INCLINED ______ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN: 4 ft.
8. DEPTH DRILLED INTO ROCK: 115.1
9. TOTAL DEPTH OF HOLE: 120.1
10. SIZE AND TYPE OF BIT:
11. DATUM FOR ELEVATION SHOWN (TBM or MSL):
12. MANUFACTURER'S DESIGNATION OF DRILL: Failing 43-SA
13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: DISTURBED 1 UNDISTURBED
14. TOTAL NUMBER CORE BOXES: 4
15. ELEVATION GROUND WATER: 42 ft.
16. DATE HOLE: STARTED 10 Aug COMPLETED 13 Aug
17. ELEVATION TOP OF HOLE: Approximately 775
18. TOTAL CORE RECOVERY FOR BORING: 88.5% %
19. SIGNATURE OF INSPECTOR: R. W. Griffith

ELEVATION a	DEPTH b	JOINT ANGLE c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
		65°	See above rock description	100		
		45°		100		
	110			100		
				100	#7	Core sample #7 (118.6 - 119.4 ft.)
	120				#8	Core sample #8 (119.4 - 120.1 ft.)
			End boring 120.1 ft.			

[redacted]

ENG FORM 1 APR 63 1836 PREVIOUS EDITIONS MAY BE USED (EM 1110-1-1801)
PROJECT: LARKSPUR
HOLE NO.: 64-D-4

I. LIST OF SAMPLES TESTED

SAMPLE NO.	DEPTH	TESTING AGENCY	TESTS
1	25.2- 26.0	USGS CE(NPA)	A,B,C,D, E,F,G,H
2	37.8- 38.8	USGS CE(NPA)	A,B,G,H
3	54.0- 54.8	USGS CE(NPA)	A,B,C,D
4	72.7- 73.6	USGS CE(NPA)	A,B,C,D, E,F,G,H
5	83.3- 84.3	USGS CE(NPA)	A,B
6	95.5- 96.5	USGS CE(NPA)	A,B,C,D, E,F,G,H
7	118.6- 119.5	USGS CE(NPA)	A,B
8	119.5- 120.1	USGS CE(NPA)	A,B,C,D
9	16.8- 17.4	USGS CE(NPA)	A,B,C,D

II. TYPES OF TESTS

USGS TESTS

A. RESISTIVITY
B. SEISMIC

CE(NPA) TESTS

C. MOISTURE
D. SPECIFIC GRAVITY
E. ABSORPTION
F. COMPRESSIBILITY
G. YOUNG'S MODULUS
H. POISSON'S RATIO
X. SAMPLE DETERIORATED BEFORE TESTS COULD BE RUN

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PROJECT LARKSPUR

AREA I

COREHOLE 64-D-4

DRILLING LOG

PLATE 8

[redacted]

AREA 3, Hole No. 64-D-2

DRILLING LOG

DIVISION: North Pacific
INSTALLATION: Alaska District
SHEET ___ OF ___ SHEETS
1. PROJECT: LARKSPUR
2. LOCATION (Coordinates or Station):
3. DRILLING AGENCY: Corps of Engineers
4. HOLE NO. (As shown on drawing title and file number): (area 3) 64-D-2
5. NAME OF DRILLER: Gallaher
6. DIRECTION OF HOLE: ☒ VERTICAL ☐ INCLINED ______ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN: 3.5
8. DEPTH DRILLED INTO ROCK: 116.5
9. TOTAL DEPTH OF HOLE: 120.0
10. SIZE AND TYPE OF BIT:
11. DATUM FOR ELEVATION SHOWN (TBM or MSL): MSL
12. MANUFACTURER'S DESIGNATION OF DRILL: Failing 750 - 43 - SA
13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: 5 DISTURBED: 5 UNDISTURBED: 0
14. TOTAL NUMBER CORE BOXES: 3
15. ELEVATION GROUND WATER: 0-2' below surface
16. DATE HOLE STARTED: 7-13-64 COMPLETED: 7-27-64
17. ELEVATION TOP OF HOLE: approximately 660'
18. TOTAL CORE RECOVERY FOR BORING: 74% of cored interval*
19. SIGNATURE OF INSPECTOR: Lutton

ELEVATION a	DEPTH b	JOINT ANGLE c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
+660	0		Overburden; organic soil and rocky detrital soil.	not cored		Drilled, tricone bit.
			VOLCANIC CONGLOMERATE, andesite material; 60%, cobbles and pebbles, rounded to sub-rounded. 20%, ½" to silt size, subangular. 20%, intergranular silt and clay; tan, yellow and ochre; oxidized.	48		Cored, 2 3/4 x 3 7/8" diamond bit.
				80		
	10	30°		70		Core losses due to washing out of soft matrix.
				100		
	20			81	Spls. #1	Cored, NX diamond bit.
				100	#2	Core losses as above.
	30	80°		100	#3 #4	
			Strong oxidation from surface to 36'.	76		
			SANDY CLAY; yellow-gray and tan; silty; limonitic.	72		
	40		VOLCANIC CONGLOMERATE, as described above; moderate oxidation; few wood fragments. Conglomerate, ½" minus, 40.6-41.6'.	95		Cored, 2 3/4x3 7/8" Dia.
		35° 50° 50°		51		Cored, NX diamond bit.
				47		Core losses due to washing out of soft matrix.
				27		
	50			10		
				13	Spls.	
			VOLCANIC CONGLOMERATE, andesite material: 25%, cobbles and pebbles. 15%, ¼" fragments. 60%, sand-clay matrix. Oxidation decrease below 61.0'. Conglomerate ½" minus, 56.2'-58.5'. Woody debris, 60.0-66.0'.	100	#5 #6	
	60			95	#7 #8	
	70	85° 60° 40° 75° 55° 90° 80		96		
				97		
	80	70° 60°	VOLCANIC GRAYWACKE, tan sand-size volcanic fragments; waterlaid; carbonaceous.	86	Spl. #9	
		90°	VOLCANIC CONGLOMERATE, as above, but better rounded and less consolidated; matrix lost in drilling mud.	75		
				17		
				37		Drilling-mud loss approx. 20 gal/min at 90.8'.
	90			100		
			VOLCANIC CONGLOMERATE, very loose; soft matrix.	not cored		Drilled 3 7/8" tricone bit. Mud loss stopped by pumping in heavy mud.
+560	100		(cuttings) GRAYWACKE. VOLCANIC CONGLOMERATE.			

ENG FORM 1 APR 63 1836 PREVIOUS EDITIONS MAY BE USED (EM 1110-1-1801)
PROJECT: LARKSPUR
HOLE NO. 64-D-2

AREA 3, Hole No. 64-D-2

DRILLING LOG

DIVISION: North Pacific
INSTALLATION: Alaska District
SHEET ___ OF ___ SHEETS
1. PROJECT: LARKSPUR
2. LOCATION (Coordinates or Station):
3. DRILLING AGENCY: Corps of Engineers
4. HOLE NO. (As shown on drawing title and file number): (area 3) 64-D-2
5. NAME OF DRILLER:
6. DIRECTION OF HOLE: ☒ VERTICAL ☐ INCLINED ______ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN: 3.5
8. DEPTH DRILLED INTO ROCK: 116.5
9. TOTAL DEPTH OF HOLE: 120.0
10. SIZE AND TYPE OF BIT:
11. DATUM FOR ELEVATION SHOWN (TBM or MSL): MSL
12. MANUFACTURER'S DESIGNATION OF DRILL: Failing 750 - 43 - SA
13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: DISTURBED: UNDISTURBED:
14. TOTAL NUMBER CORE BOXES:
15. ELEVATION GROUND WATER:
16. DATE HOLE STARTED: 7-13-64 COMPLETED: 7-27-64
17. ELEVATION TOP OF HOLE: approximately 660'
18. TOTAL CORE RECOVERY FOR BORING: 74% of cored interval*
19. SIGNATURE OF INSPECTOR: Lutton

ELEVATION a	DEPTH b	JOINT ANGLE c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
560	100		VOLCANIC CONGLOMERATE (not cored). Drill action indicates conglomerate with soft matrix; few interbeds of siltstone and graywacke.	not cored		Drilled, 3 7/8" tricone bit. Slow progress due to running gravel and caving hole.
	110					
						NX Diamond core-bit.
540	120					Drilled, 3 7/8" Tricone bit.
			120' total depth.			

[redacted]

ENG FORM 1 APR 63 1836 PREVIOUS EDITIONS MAY BE USED (EM 1110-1-1801)
PROJECT: LARKSPUR
HOLE NO. 64-D-2

I. LIST OF SAMPLES TESTED

SAMPLE NO.	DEPTH	TESTING AGENCY	TESTS
1	20.-20.9	USGS	A,B
2	22.9-23.9	USGS	A,B
3	28.1-29.0	USGS	A,B
4	30.7-31.8	CE(NPA)	G,H
5	57.0-57.9	USGS	A,B
6	58.5-59.3	CE(NPA)	C
7	61.0-62.4	USGS	A,B
8	62.4-63.7	CE(NPA)	C,D,F,G,H
9	80.2-81.1	USGS	A,B

II. TYPES OF TESTS

USGS TESTS

A. RESISTIVITY
B. SEISMIC

CE(NPA) TESTS

C. MOISTURE
D. SPECIFIC GRAVITY
E. ABSORPTION
F. COMPRESSIBILITY
G. YOUNG'S MODULUS
H. POISSON'S RATIO
X. SAMPLE DETERIORATED BEFORE TESTS COULD BE RUN

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PROJECT LARKSPUR

AREA 3

COREHOLE 64-D-2

DRILLING LOG

PLATE 9

S[redacted]

AREA 4, Hole No. 64-D-3

DRILLING LOG

DIVISION: North Pacific
INSTALLATION: Alaska District
SHEET OF SHEETS
1. PROJECT: LARKSPUR
2. LOCATION (Coordinates or Station)
3. DRILLING AGENCY: Corps of Engineers
4. HOLE NO. (As shown on drawing title and file number) (area 4) 64-D-3
5. NAME OF DRILLER: Gallaher and Risley
6. DIRECTION OF HOLE: ☒ VERTICAL ☐ INCLINED ______ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN: 3.3
8. DEPTH DRILLED INTO ROCK: 118.7
9. TOTAL DEPTH OF HOLE: 122.0
10. SIZE AND TYPE OF BIT
11. DATUM FOR ELEVATION SHOWN (TBM or MSL): MSL
12. MANUFACTURER'S DESIGNATION OF DRILL: Failing 750 - 43 - SA
13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: DISTURBED 6 UNDISTURBED 0
14. TOTAL NUMBER CORE BOXES: 4
15. ELEVATION GROUND WATER
16. DATE HOLE: STARTED 7-29-64 COMPLETED 8-4-64
17. ELEVATION TOP OF HOLE: approximately 305'
18. TOTAL CORE RECOVERY FOR BORING: 85% of cored interval %
19. SIGNATURE OF INSPECTOR: Lutton

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
+305	0		Rocky soil	not cored		Drilled 0'-5.5' with 6¾" tricone bit. Set casing 5.5'.
			BRECCIA, angular to subround fragments of andesitic pyroclastic material, limonitic.	27		Cored 5.5'-8.8' with 2 3/4 x 3 7/8" diamond bit.
	10			not cored		Drilled 8.8'-14.0' with 6¾" tricone bit.
			BRECCIA, as above, poorly cemented, subround pebbles and cobbles in gritty clay matrix.	14 55 37 33 41		Cored 14.0'-24.9' with 2 3/4" x 3 7/8" dia. bit. Core losses due to grinding incompetent matrix.
	20			not cored		Drilled 24.9'-30.3' with 6¼" tricone bit.
	30		BRECCIA, as above, poorly sorted; andesite, andesite porphyry and basalt; pumice and scoria; subround to angular; limonite stained. 25% over 2½" diam. 20% 1-2½" diam. 45% ¼-1" diam. 10% less than ¼".	65 67 100 100 97	Spls. #1 #2 #3 #4	Cored 30.3'-77.7' with 2 3/4 x 3 7/8". No significant mud loss.
	40					
	50					
	60		BRECCIA, as above, but chloritic dark greenish gray (not limonitic); nontronite and montmorillonite alteration products of tuffaceous material.	98 100 100 93	#6 #5 #7	Set casing 77.7'.
	70			90		Cored 77.7'-122.0' with NX bit.
	80		SILTSTONE and GRAYWACKE	48		
			BRECCIA, as above.	100	#8	
	90		BRECCIA, ½" minus, otherwise as above.	100 99	#9 #10 #11	
+205	100					

ENG FORM 1836 1 APR 63 PREVIOUS EDITIONS MAY BE USED (EM 1110-1-1801) PROJECT LARKSPUR HOLE NO. 64-D-3

AREA 4, Hole No. 64-D-3

DRILLING LOG

DIVISION: North Pacific
INSTALLATION: Alaska District
SHEET OF SHEETS
1. PROJECT: LARKSPUR
2. LOCATION (Coordinates or Station)
3. DRILLING AGENCY: Corps of Engineers
4. HOLE NO. (As shown on drawing title and file number) 64-D-3
5. NAME OF DRILLER: Gallaher and Risley
6. DIRECTION OF HOLE: ☒ VERTICAL ☐ INCLINED ______ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN: 3.3
8. DEPTH DRILLED INTO ROCK: 118.7
9. TOTAL DEPTH OF HOLE: 122.0
10. SIZE AND TYPE OF BIT
11. DATUM FOR ELEVATION SHOWN (TBM or MSL): MSL
12. MANUFACTURER'S DESIGNATION OF DRILL: Failing 750 - 43 - SA
13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: DISTURBED 6 UNDISTURBED 0
14. TOTAL NUMBER CORE BOXES: 4
15. ELEVATION GROUND WATER
16. DATE HOLE: STARTED 7-29-64 COMPLETED 8-4-64
17. ELEVATION TOP OF HOLE: approximately 305'
18. TOTAL CORE RECOVERY FOR BORING: 85% of cored interval %
19. SIGNATURE OF INSPECTOR: Lutton

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
+205	100		BRECCIA, greenish gray, chloritic, poorly sorted; 30% over 2½" diam. 55% 1/8"-2½" 15% sand size matrix	94 100		
	110			100 100	Spls. #12 #13 #14	No significant mud loss in the entire core-hole.
	120		122.0' total depth, Aug. 4, 1964.			

[redacted]

ENG FORM 1836 1 APR 63 PREVIOUS EDITIONS MAY BE USED (EM 1110-1-1801) PROJECT LARKSPUR HOLE NO. 64-D-3

I. LIST OF SAMPLES TESTED

SAMPLE NO.	DEPTH	TESTING AGENCY	TESTS
1	32.6-33.5	USGS	A,B
2	37.0-38.1	USGS	A,B
3	39.2-40.3	CE(NPA)	X
4	53.1-54.5	CE(NPA)	X
5	60.1-60.8	USGS	A,B
6	59.4-60.1	USGS	A,B
7	63.0-63.7	CE(NPA)	X
8	86.0-87.2	CE(NPA)	X
9	92.0-93.0	CE(NPA)	C,D
10	95.8-96.9	USGS	A,B
11	96.9-98.1	USGS	A,B
12	115.7-116.7	USGS	A,B
13	116.7-117.7	CE(NPA)	G,H
14	117.7-118.7	CE(NPA)	G,H

II. TYPES OF TESTS

USGS TESTS

A. RESISTIVITY
B. SEISMIC

CE(NPA) TESTS

C. MOISTURE
D. SPECIFIC GRAVITY
E. ABSORPTION
F. COMPRESSIBILITY
G. YOUNG'S MODULUS
H. POISSON'S RATIO
X. SAMPLE DETERIORATED BEFORE TESTS COULD BE RUN

Copy 11 of 12 Copies
Page 44 of 44 Pages
24-65

PROJECT LARKSPUR

AREA 4

COREHOLE 64-D-3

DRILLING LOG

PLATE 10

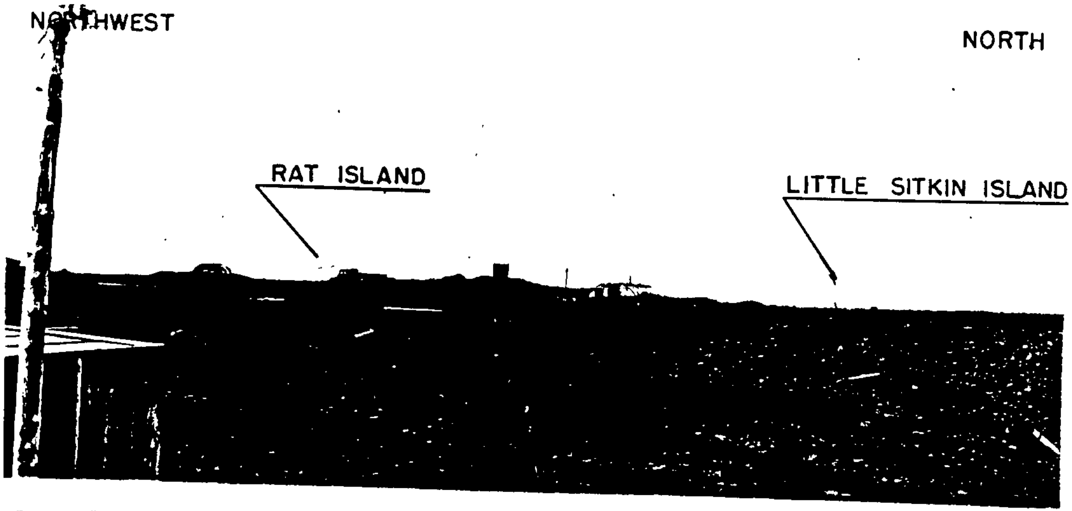

PHOTO # 1. PANORAMIC VIEW NW, FROM MAP COORDINATES 145208. ABANDONED MILITARY CAMP NEAR NW END OF ISLAND.

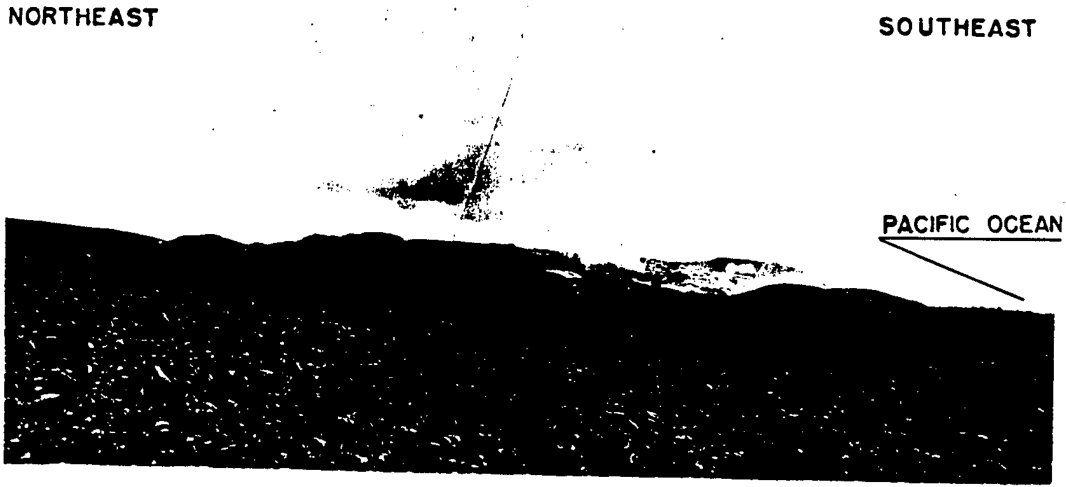

PHOTO # 4. PANORAMIC VIEW SOUTHEAST FROM MAP COORDINATES 248182. UPLAND TERRAIN TRAVERSED BY OLD MILITARY ROAD.

PHOTO # 5. PANORAMIC VIEW EAST FROM MAP COORDINATES 289182. HILLY TERRAIN TRAVERSED BY OLD MILITARY ROAD.

PANORAMIC VIEWS, NORTHERN AMCHITKA ISLAND PLATE #11

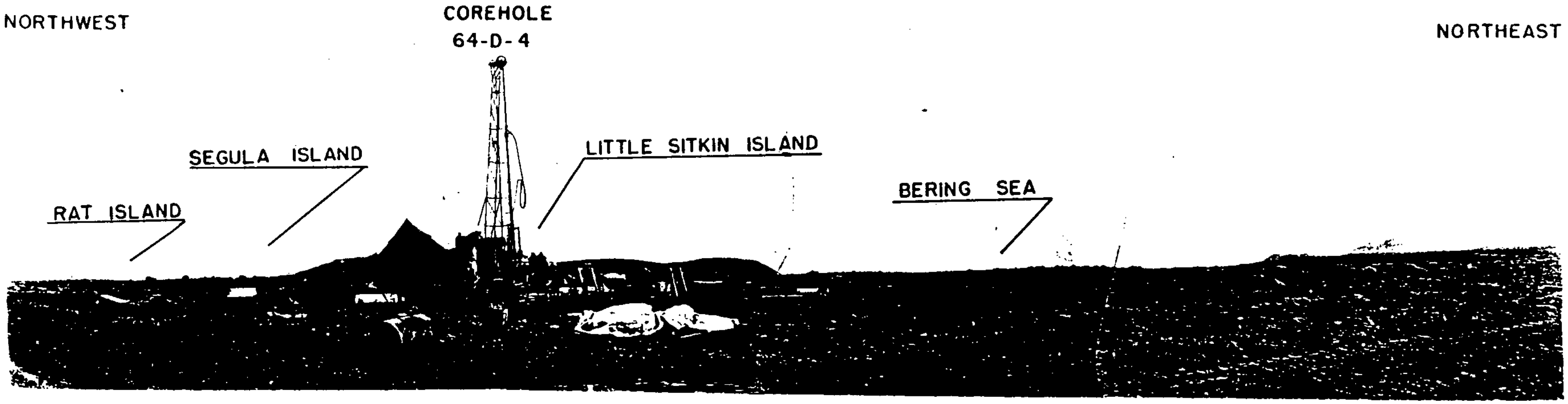

PHOTO # 2. PANORAMIC VIEW NORTH FROM MAP COORDINATES 174203
AREA 1, CORE DRILL RIG AND SURROUNDING TERRAIN.

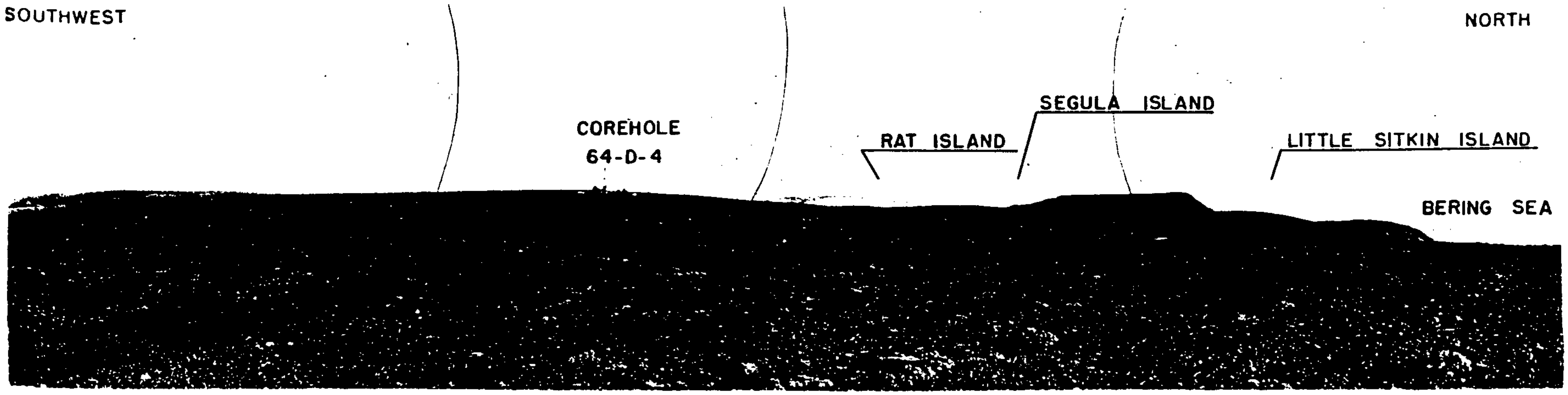

PHOTO # 3. PANORAMIC VIEW NORTHWEST FROM MAP COORDINATES 178202.
FLAT UPLAND RIDGE IN AREA 1.

PANORAMIC VIEWS, NORTHERN AMCHITKA ISLAND

PLATE #12

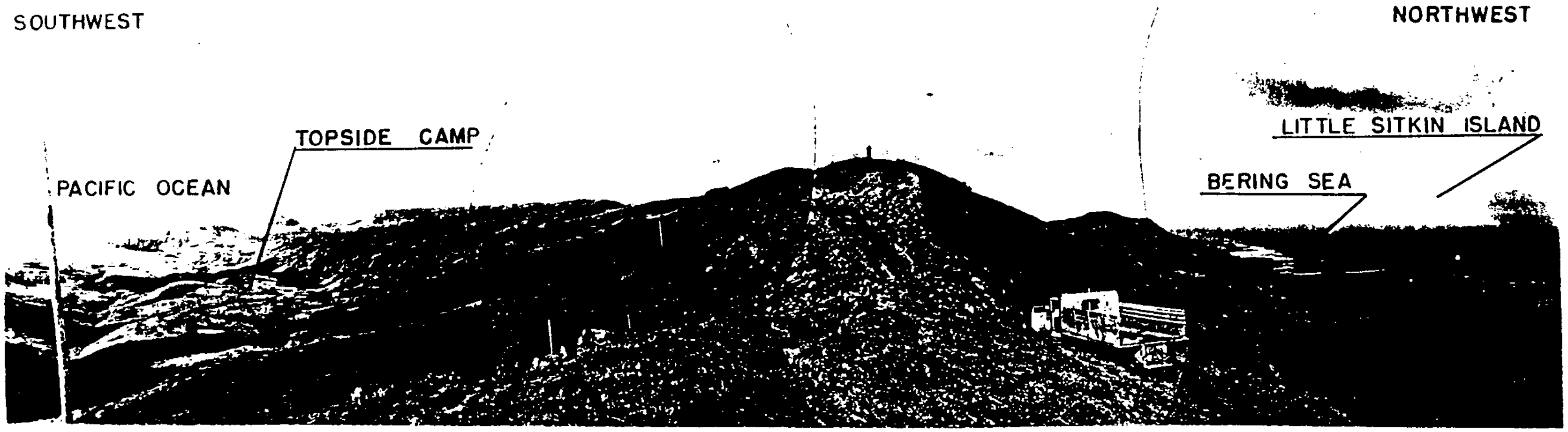

PHOTO # 6. PANORAMIC VIEW FROM MAP COORDINATES 291182.
HILLY TERRAIN ALONG OLD MILITARY ROAD.

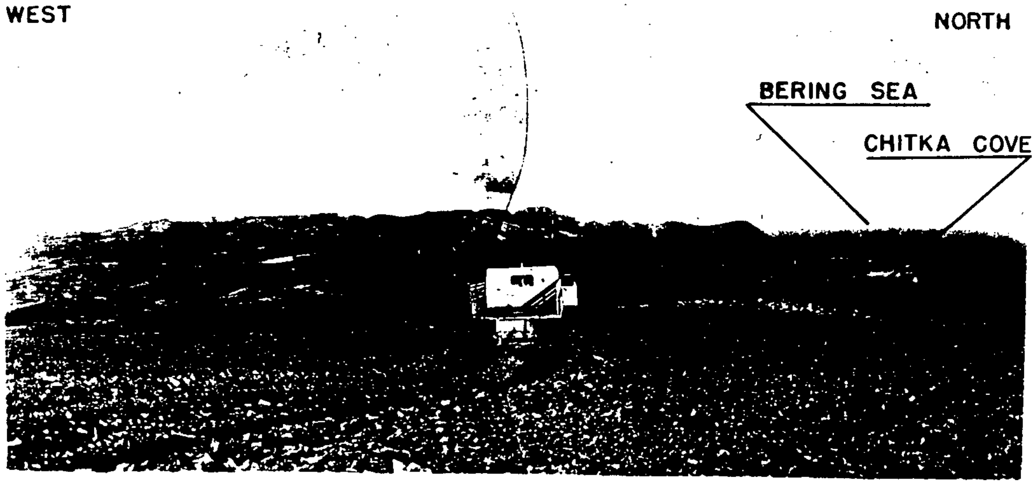

PHOTO # 7. PANORAMIC VIEW FROM MAP COORDINATES 342149.
DISTANT VIEW OF HILLY TERRAIN WHICH FORMS NORTH END OF ISLAND.

PANORAMIC VIEWS, NORTHERN AMCHITKA ISLAND

PLATE #13

PHOTO INDEX

BLACK-AND-WHITE PHOTOS

PHOTO 1 - (Plate #11) North of Area 1, panorama to the northwest
PHOTO 2 - (Plate #12) Area 1, panorama to the north
PHOTO 3 - (Plate #12) Area 1, panorama to the northwest
PHOTO 4 - (Plate #11) South of Area 2, panorama to the southeast
PHOTO 5 - (Plate #11) Between Areas 2 and 3, panorama to the east
PHOTO 6 - (Plate #13) Between Areas 2 and 3, panorama to the west
PHOTO 7 - (Plate #13) Between Areas 2 and 3, panorama to the northwest
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PHOTO 10 - Area 3; detail of surface near 64-D-2
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PHOTO 12 - Area 3; terraced slope
PHOTO 13 - Area 3; northeast of 64-D-2
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PHOTO 16 - Area 3; one mile southeast of 64-D-2
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PHOTO 19 - Area 4; view east from 250 feet east of 64-D-3
PHOTO 20 - Area 4; view north from 64-D-3
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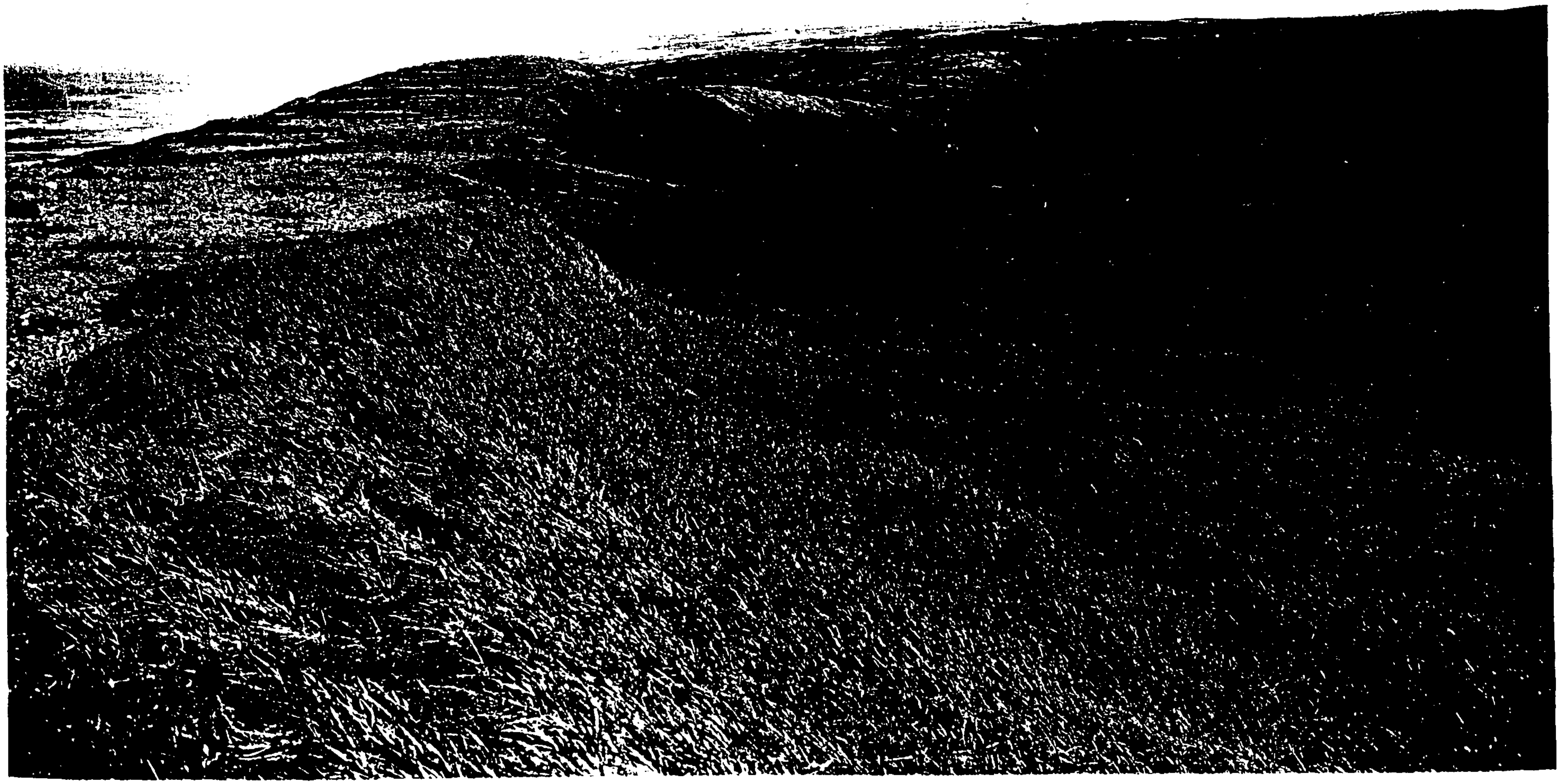
PHOTO 24 - Area 3; Chitka Cove from north of 64-D-2
PHOTO 25 - Area 1; cores from core hole 64-D-4
PHOTO 26 - Area 1; cores from core hole 64-D-4
PHOTO 27 - Area 1; cores from core hole 64-D-4
PHOTO 28 - Area 1; cores from core hole 64-D-4
PHOTO 29 - Area 3; cores from core hole 64-D-2
PHOTO 30 - Area 3; cores from core hole 64-D-2
PHOTO 31 - Area 3; cores from core hole 64-D-2
PHOTO 32 - Area 4; cores from core hole 64-D-3
PHOTO 33 - Area 4; cores from core hole 64-D-3
PHOTO 34 - Area 4; cores from core hole 64-D-3
PHOTO 35 - Area 4; cores from core hole 64-D-3

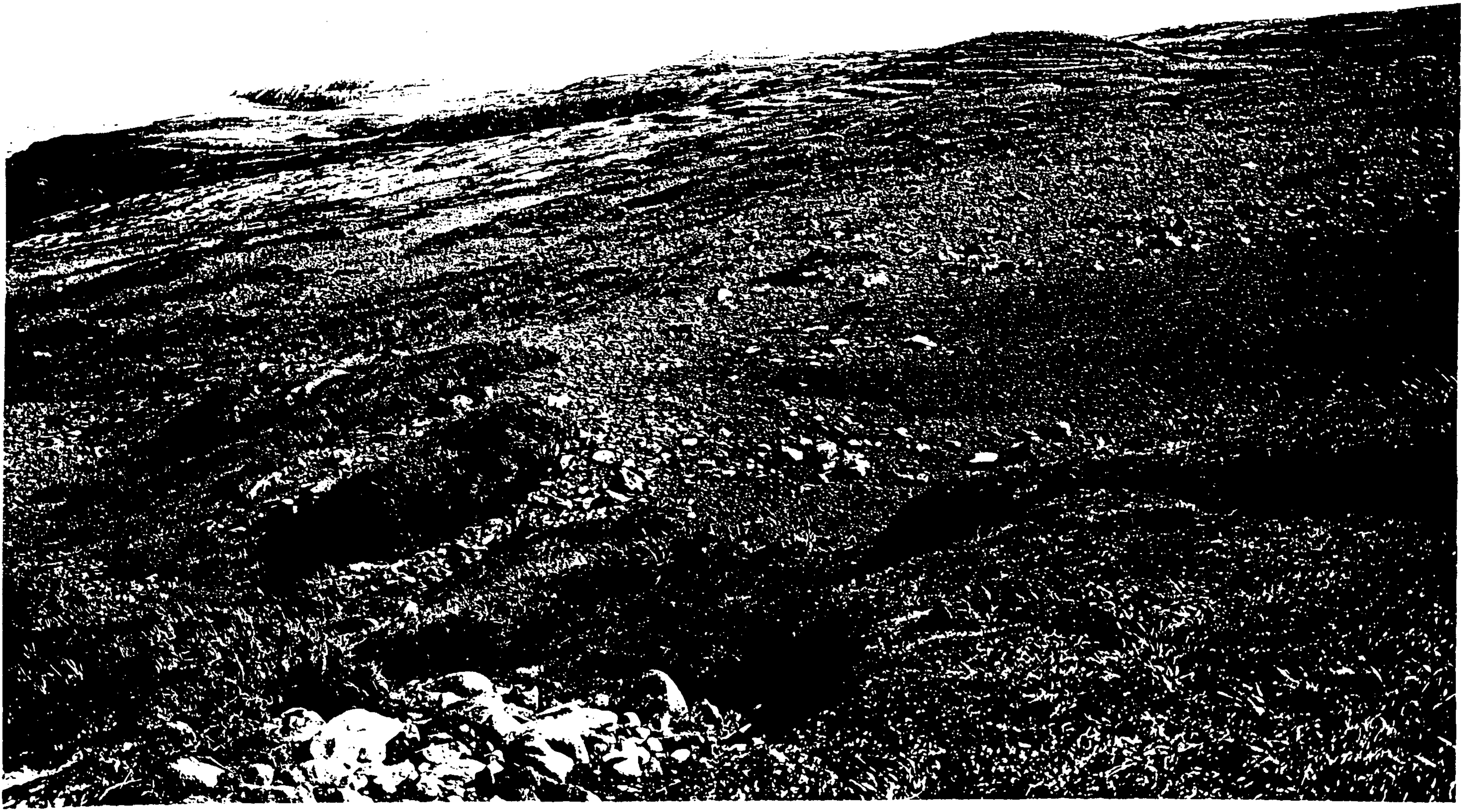


AREA 3

LOOKING SOUTHEAST FROM POINT 2000' NORTH OF 64-D-2 ALONG PROBABLE FAULT TRACE. LAKE LIES 1500' FROM HOLE. NOTE SHARP BOUNDARY BETWEEN GRASSY LAND AND TERRACED LAND.

AUG 1964

PHOTO 8



AREA 3

LOOKING SOUTH FROM POINT 3000' NORTHEAST OF HOLE 64-D-2. TERRACED GROUND SHOWING A TYPICAL GRAVELLY PATCH IN FOREGROUND.

AUG 1964

PHOTO 9

AREA 3

DETAILS OF SURFACE 100' FROM 64-D-2. NOTEBOOK IS 7" LONG.

AUG 1964

PHOTO 10

AREA 3

LOOKING SOUTHEAST ALONG SCARP OF LANDSLIDE THAT PASSES 3000' FROM HOLE 64-D-2.

AREA 3

TERRACED SLOPE SHOWING MOSS-COVERED BOUNDING DIKE. TRENCH REVEALED THE FOLLOWING PROFILE: BACK EDGE OF TERRACE, 7" SAND; MIDDLE OF TERRACE, 2" PEA GRAVEL ON THIN SILT OVER 10" SAND; OUTER EDGE OF TERRACE, 15" COBBLES IN SILT, ON 5" SILT AND SAND; MIDDLE OF DIKE, 15" SILT; AND FOOT OF DIKE, 7" SILT. BEDROCK IS POORLY CONSOLIDATED CONGLOMERATIC SANDSTONE.

AUG 1964

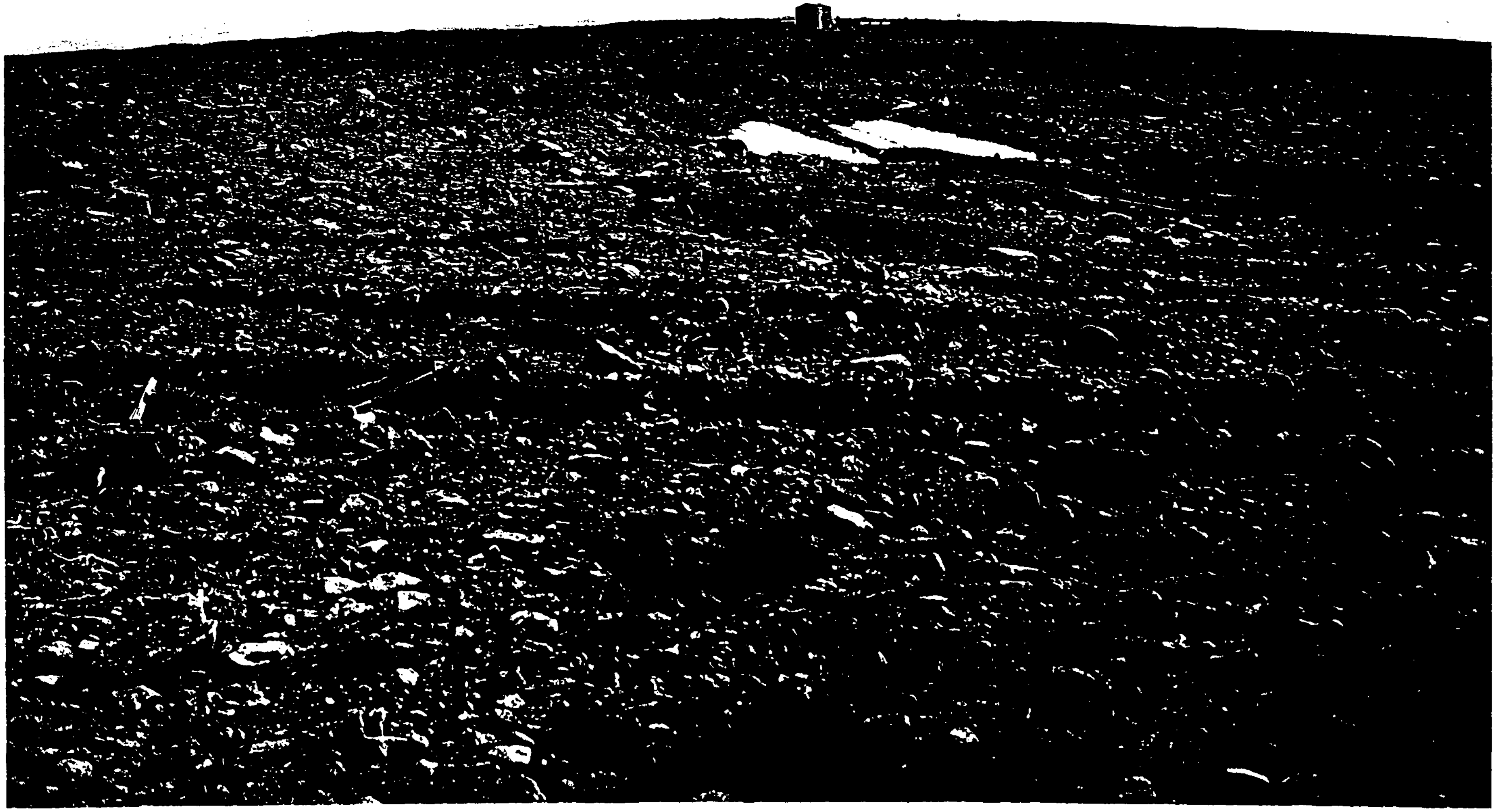
PHOTO 12

AREA 3

LOOKING SOUTHWEST TOWARD 64-D-2 SHACK ON MIDDLE HORIZON 2000'. TERRACED GROUND ON UPPER SLOPE.

AUG 1964

PHOTO 13



AREA 3

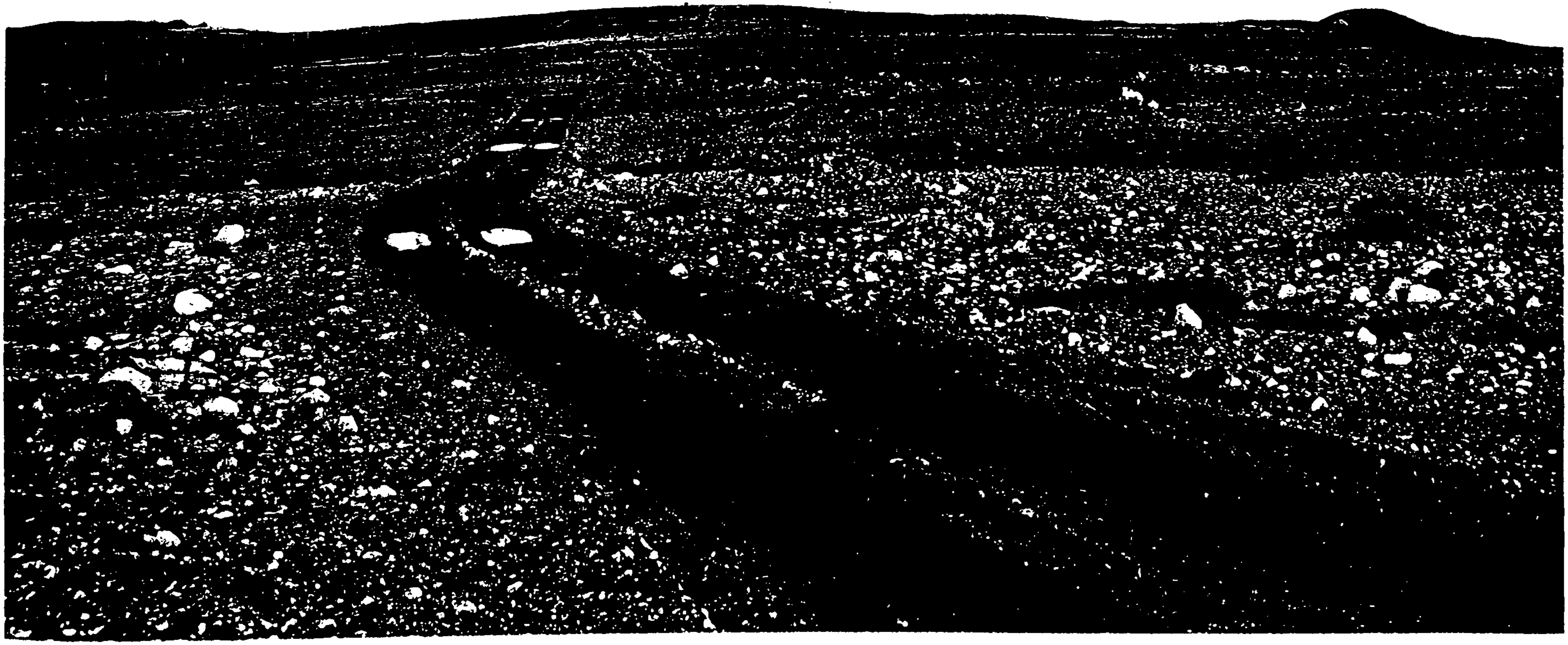
LOOKING SOUTH FROM BEND IN ROAD TOWARD SHACK AT 64-D-2. HOLE IS RIGHT OF SHACK.

AREA 3

LOOKING SOUTHWEST AT SHACK AT 64-D-2.

AUG 1964

PHOTO 15



AREA 3

LOOKING NORTHWEST ALONG ROAD. SHACK ON HORIZON IS AT HOLE, A DISTANCE OF 1 MILE.

AUG 1964

PHOTO 16

AREA 4

VOLCANIC BRECCIA IN CLIFF ON PACIFIC COAST 3 MILES N 80 W OF HOLE 64-D-3. ROCK HAMMER INDICATES SCALE.

AUG 1964

PHOTO 17

AREA 4

VIEW WEST FROM ABOUT 250' EAST OF HOLE 64-D-3. GRASS-COVERED MOUNDS ARE FROM PREVIOUS CLEARING OPERATIONS. HOLE 64-D-3 LIES JUST TO THE RIGHT OF THE LARGE HUT. MAIN ROAD FROM AIRFIELD PASSES TO THE LEFT AND THENCE ACROSS THE HORIZON TO THE RIGHT.

AUG 1964

PHOTO 18

AREA 4

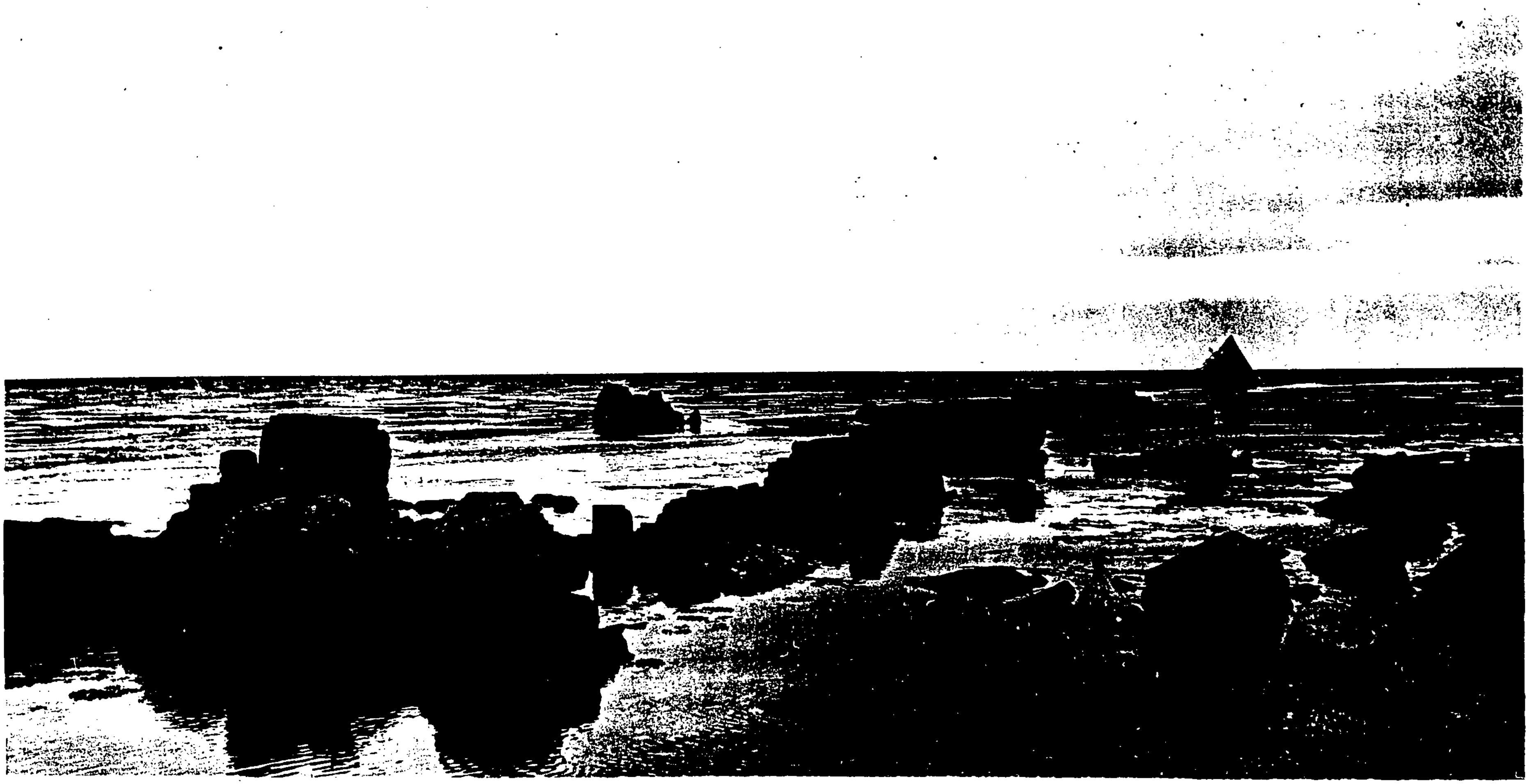
LOOKING EAST FROM 250' EAST OF 64-D-3. GRASS AND MOSS TUNDRA IN LEFT FOREGROUND EXHIBITS WAFFLE-LIKE MICROGEOMETRY PASSING ON THE RIGHT TO WIDELY SPACED CLUMPS OF GRASS (NIGGERHEADS) RAISED ABOVE THE DOMINANT LEVEL OF MOSS. TUNDRA IS INTERRUPTED IN THE MIDDLE DISTANCE BY GRAVELLY PATCHES WHICH APPEAR TO RESULT FROM EROSION OF MOSSY SURFACE AND REMOVAL OF SILT BELOW. WOODEN FOUNDATION IN CLEARED AREA IN CENTER HORIZON.

AUG 1964

PHOTO 1

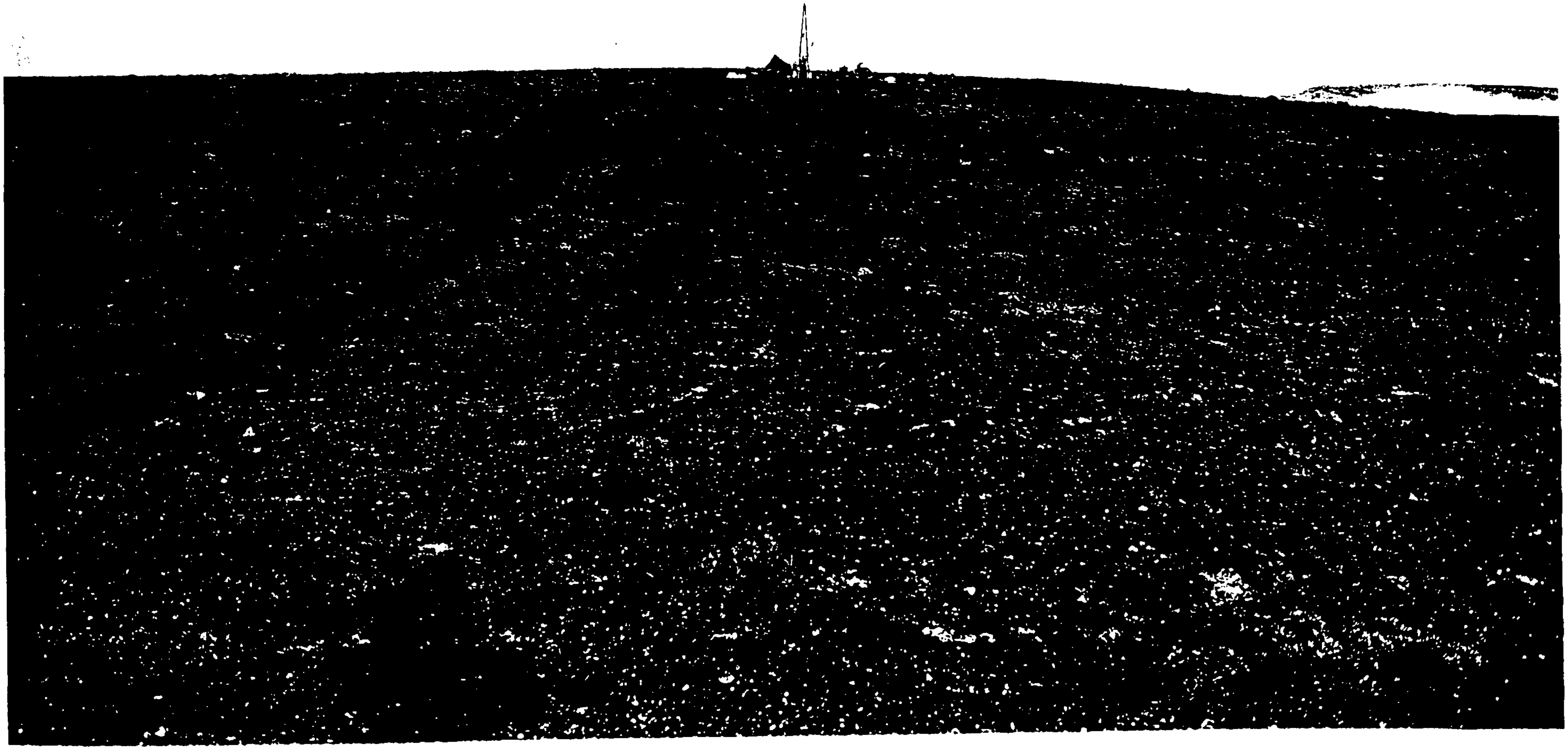
AREA 4

VIEW NORTH FROM 300 FEET EAST OF 64-D-3. EDGE OF GRAVELLY PATCH IN FOREGROUND REVEALS NORMAL SOIL PROFILE OF TUNDRA, I.E., ABOUT 1 FOOT OF MOSS AND GRASS ON 1-2' SILT OVERLYING STONY, DECOMPOSED BEDROCK. POLYGONAL PATTERN IS POORLY DEVELOPED IN PEA GRAVEL TO LEFT AND COARSE GRAVEL AT LOWER RIGHT. SURFACE DRAINAGE AS SHOWN HERE IS UNUSUAL. TYPICAL TERRAIN IN MIDDLE BACKGROUND EXTENDS ABOUT 4000' TO THE SEA CLIFFS ON THE NORTH COAST.



AREA 4

FLOW-BANDED ANDESITE ON NORTH COAST, BETWEEN AREA 4 AND MAIN CAMP. PART OF UNIT REGARDED AS AMCHITKA FORMATION IN USGS BUL. 1028-P; BUT HAS APPEARANCE OF LAVA INTERBEDDED IN BANJO POINT FORMATION. LOOKING NE TOWARD SHIPWRECK, 1½ MILES N OF CYRIL COVE.



AREA 1, CORE HOLE 64-D-4, AND SURROUNDING TERRAIN. VIEW TO NW.

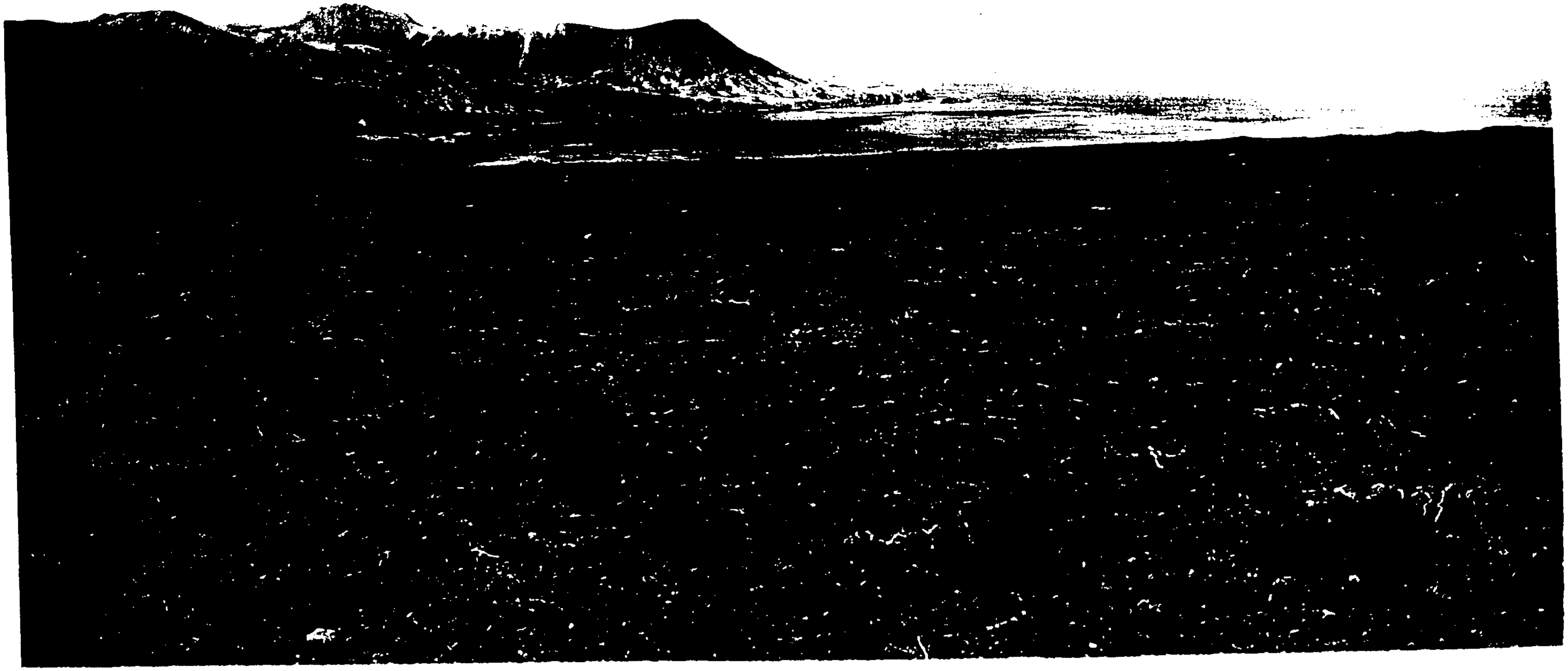
AUG 1964

PHOTO 22

PACIFIC SLOPE FROM 2 MILES SOUTHEAST OF AREA 3

AUG 1964

PHOTO 23



AREA 3

CHITKA COVE FROM NEAR HILL NORTH OF HOLE 64-D-2.

CORE SAMPLES, CORE HOLE 64-D-4, (AREA 1).

CORE SAMPLES, CORE HOLE 64-D-4, (AREA 1).

AUG 1964

PHOTO 26

CORE SAMPLES, CORE HOLE 64-D-4, (AREA 1).

AUG 1964

PHOTO 27

CORE SAMPLES, CORE HOLE 64-D-4, (AREA 1).

AUG 1964

PHOTO 28

CORE SAMPLES, CORE HOLE 64-D-2, (AREA 3).

AUG 1964

PHOTO 29

CORE SAMPLES, CORE HOLE 64-D-2, (AREA 3).

AUG 1964

PHOTO 30

CORE SAMPLES, CORE HOLE 64-D-2, (AREA 3).

AUG 1964

PHOTO 31

CORE SAMPLES, CORE HOLE 64-D-3, (AREA 4).

AUG 1964

PHOTO 32

CORE SAMPLES, CORE HOLE 64-D-3, (AREA 4).

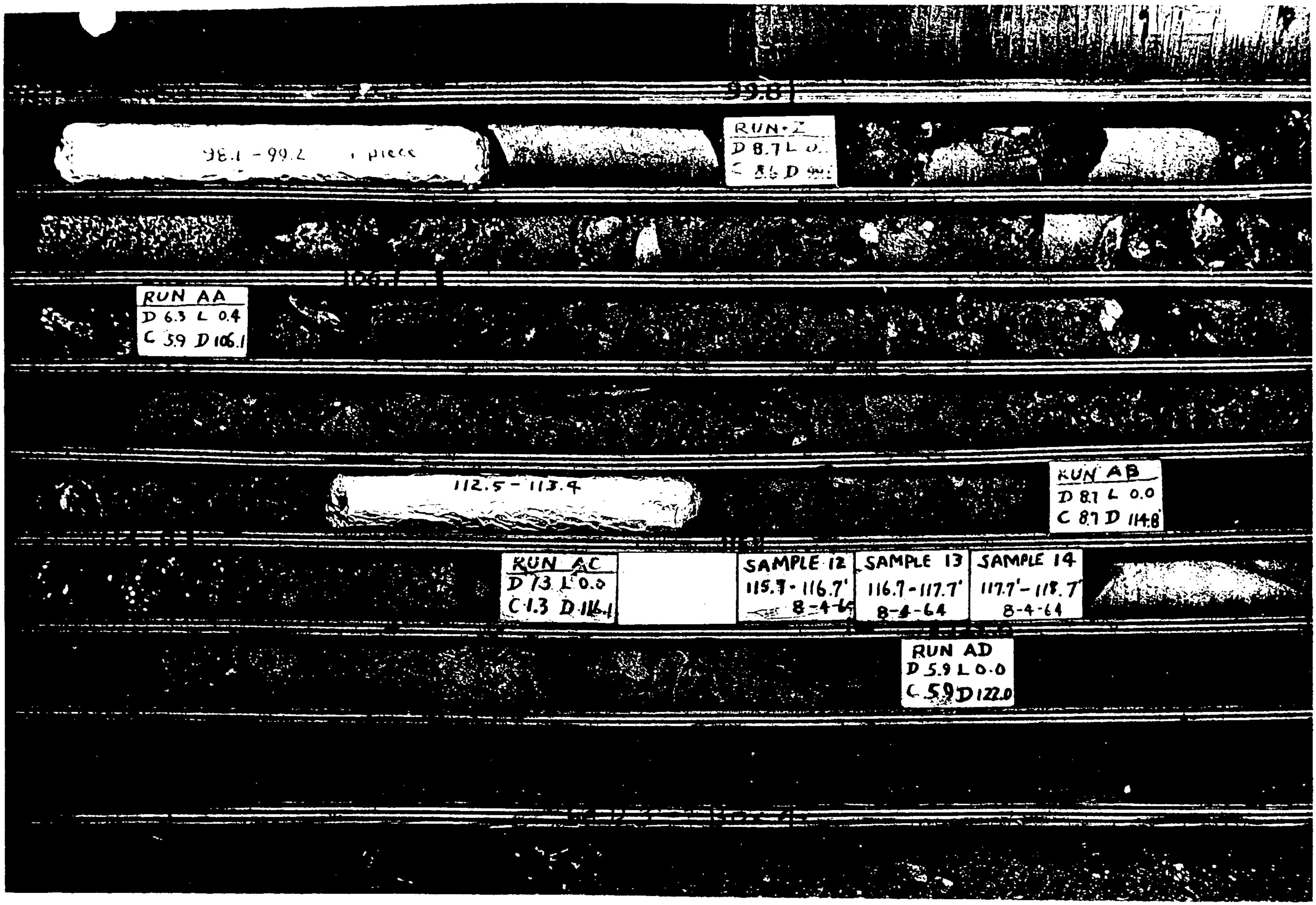
AUG 1964

PHOTO 33

CORE SAMPLES, CORE HOLE 64-D-3, (AREA 4).

AUG 1964

PHOTO 34



CORE SAMPLES, CORE HOLE 64-D-3, (AREA 4).

AUG 1964

PHOTO 35

PHOTO INDEX

COLOR PHOTOS

AREA 3 - See Figure 6

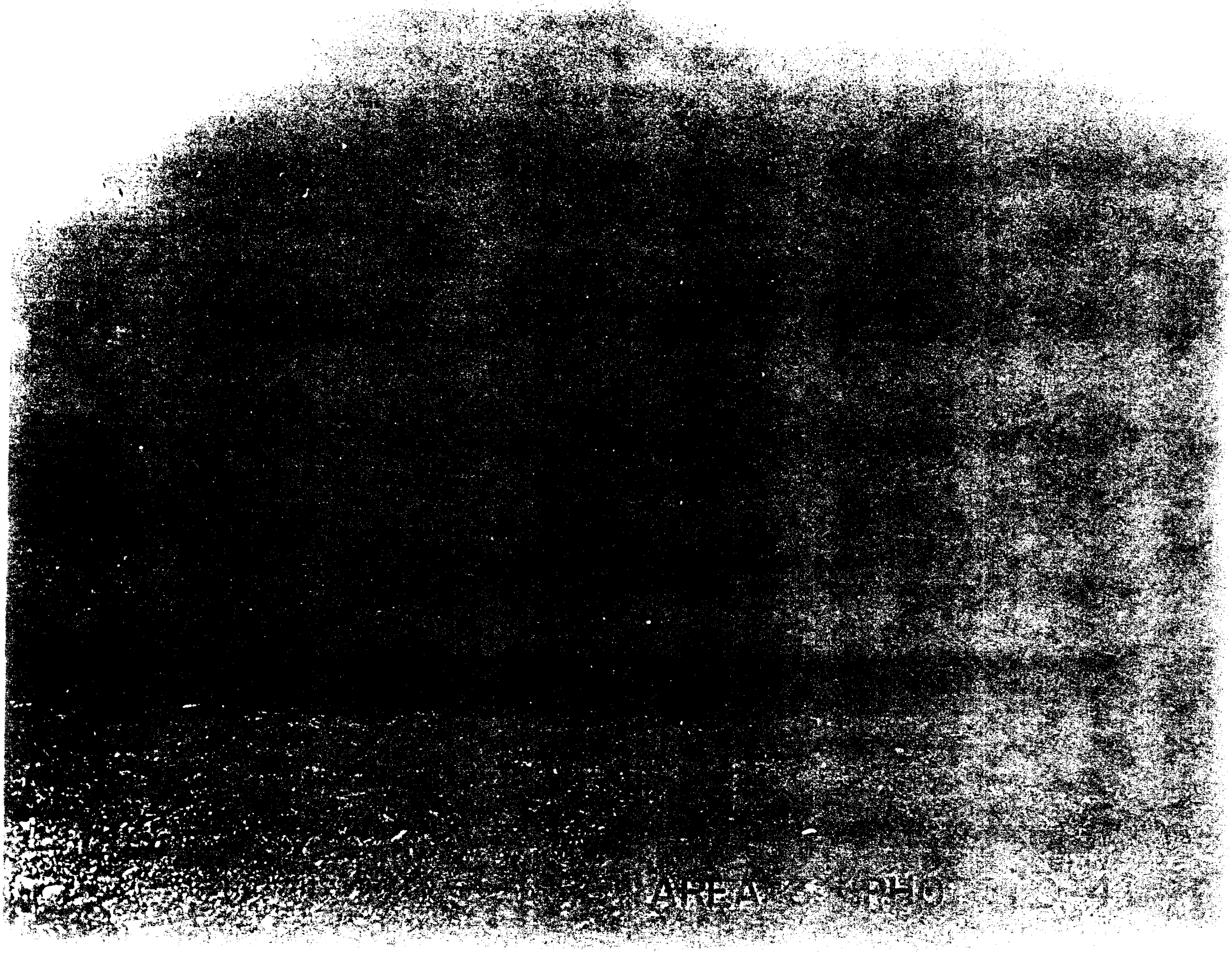
PHOTO C-1	Drill site, core hole 64-D-2, view to east
PHOTO C-2	Drill site, core hole 64-D-2, view to north
PHOTO C-3	Drill site, core hole 64-D-2, view to south
PHOTO C-4	Three miles southeast of 64-D-2, view to northwest
PHOTO C-5	Slide northeast of 64-D-2, view to southeast
PHOTO C-6	Slide northeast of 64-D-2, view to southeast

AREA 4 - See Figure 7

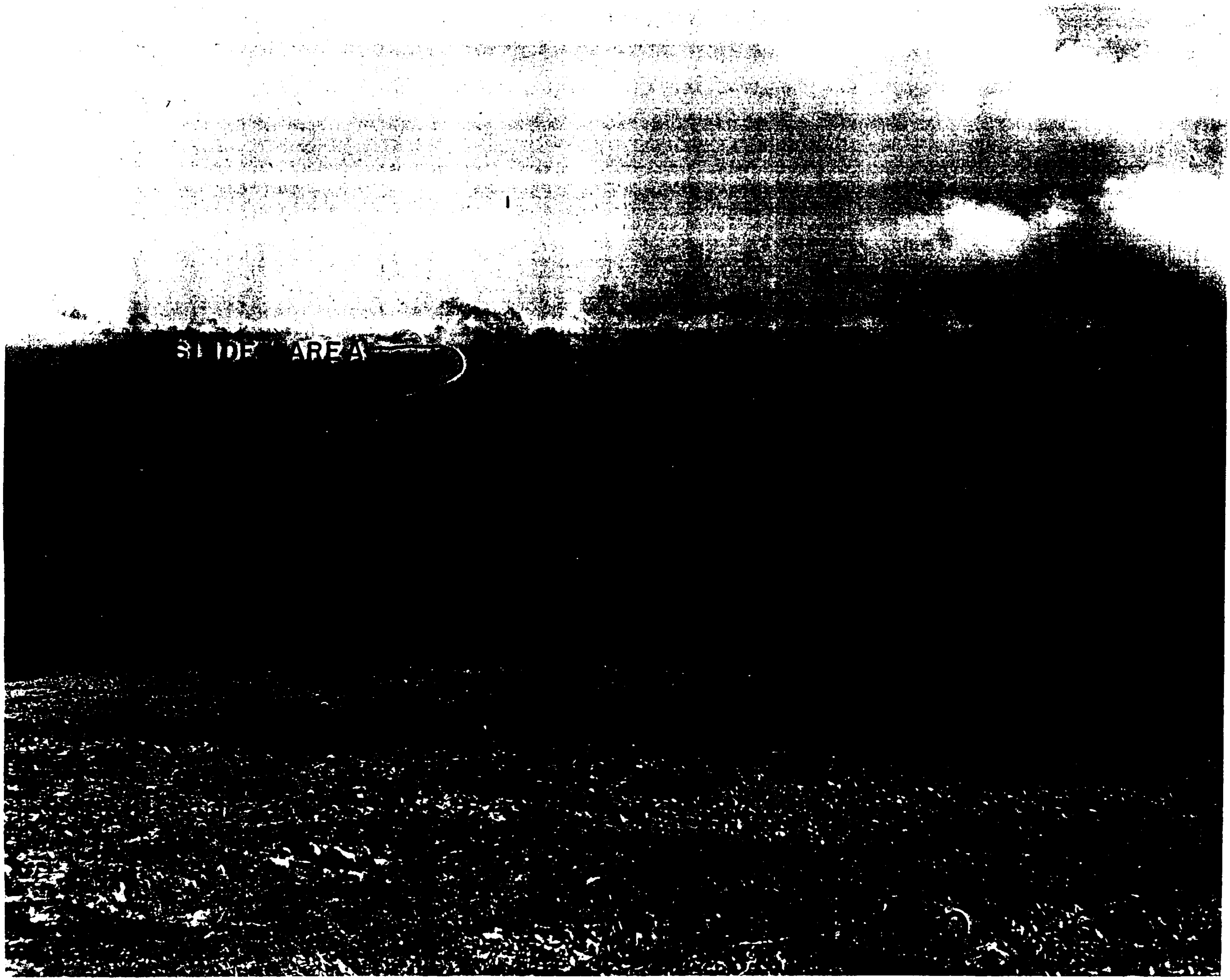
PHOTO C-1	Drill-site, core hole 64-D-3, view south
PHOTO C-2	Drill-site, core hole 64-D-3, view east
PHOTO C-3	Drill-site, core hole 64-D-3, view west
PHOTO C-4	One-half mile northwest of core hole 64-D-3, view northwest

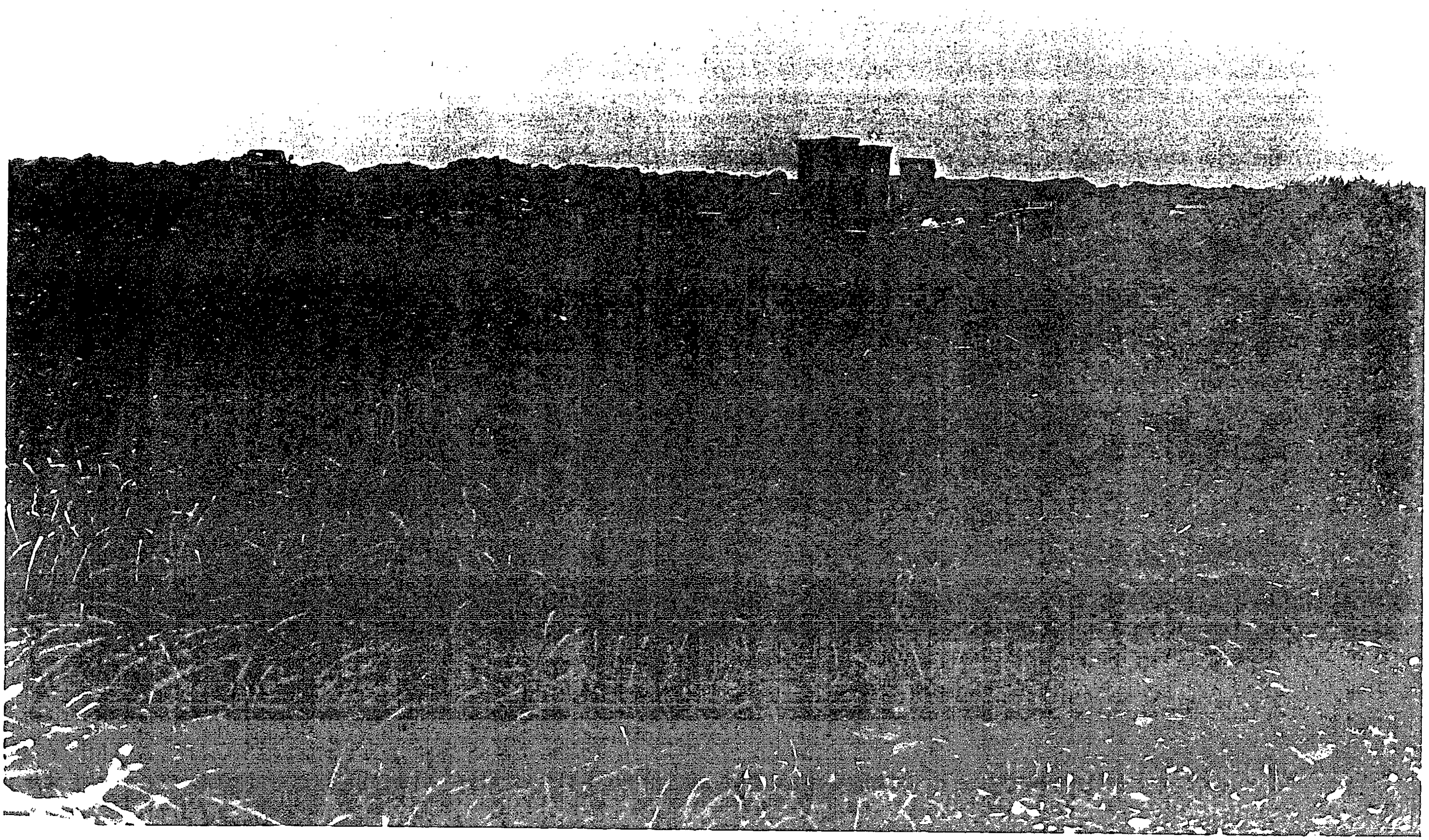
GA-D-2, Phot

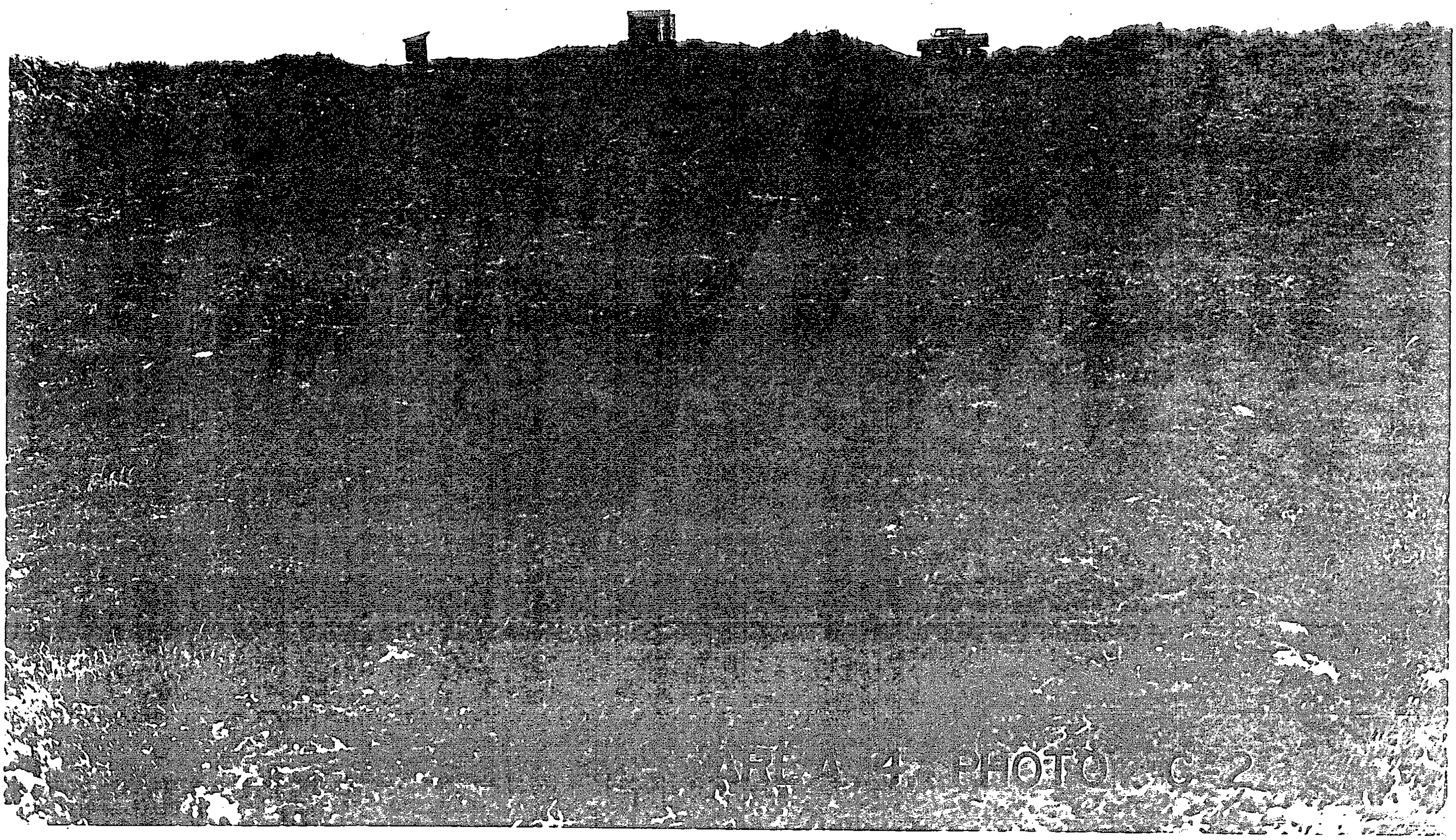

AREA 5 PHOTO C-2



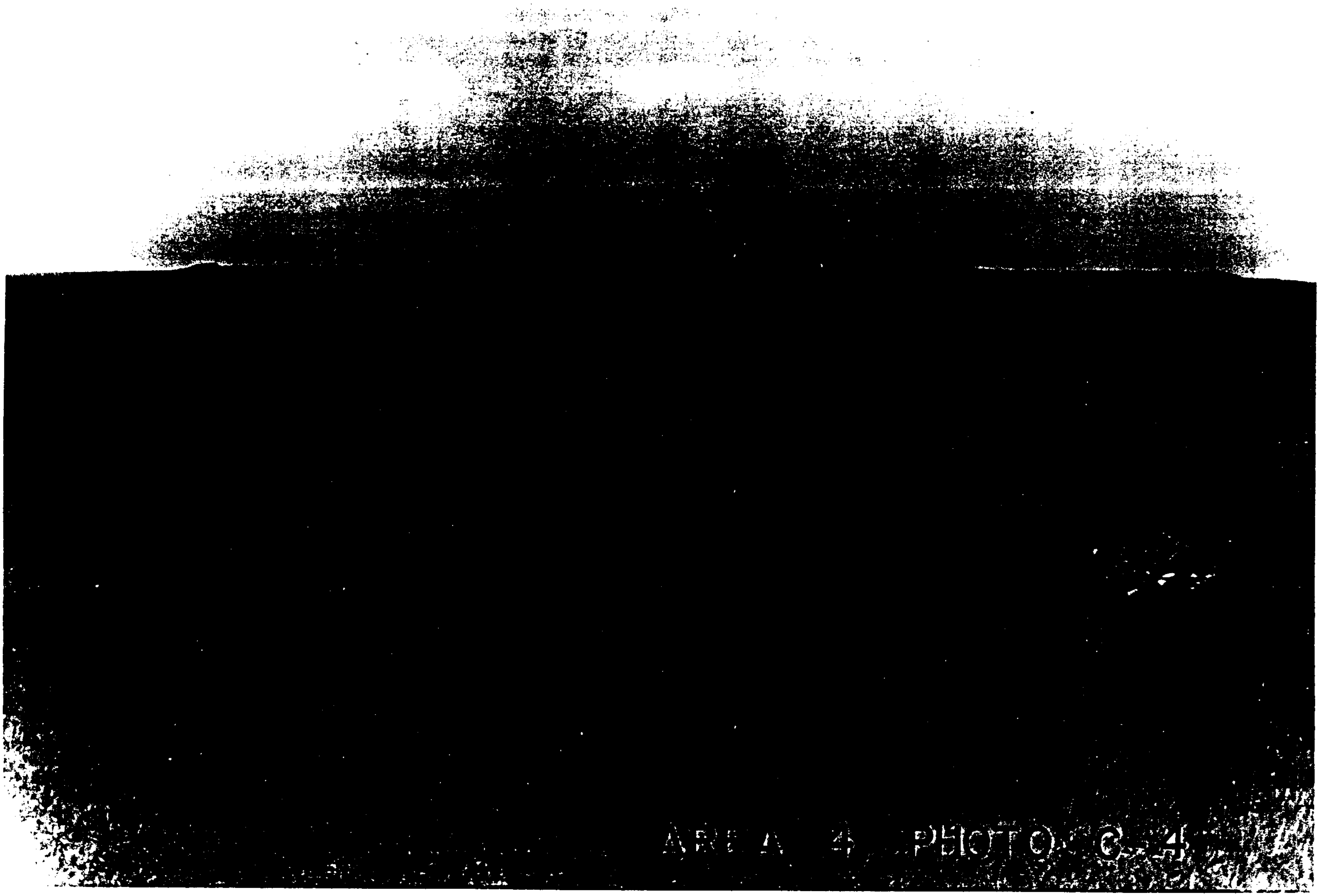
AREA
PHO


SLIDE AREA





AREA 4 PHOTO C-2


AREA 4 PHOTO G-4

PART 6

APPENDIX

Missing

APPENDIX

REPORT OF HIGH PRESSURE TRIAXIAL ROCK TESTS ON CORES FROM EXPLORATION DRILLING, AMCHITKA ISLAND, PHASE III

U. S. Army Engineer District, Alaska
North Pacific Division
U. S. Corps of Engineers

1 April 1965

INDEX TO FIGURES

APPENDIX

REPORT OF HIGH PRESSURE TRIAXIAL ROCK TESTS

1. Introduction

This appendix presents the results of a series of high pressure triaxial tests on rock core samples from exploration drilling on Amchitka Island. The purpose of these tests was twofold, first, to determine elastic constants, water contents, and specific gravities of the rock samples; and second, to develop and test a method for reliable determination of elastic constants by means of high pressure triaxial equipment and precise volumetric control. This work was performed by Alaska District, Corps of Engineers during the period from October 1964 to March 1965.

2. Materials

a. The rocks tested are described and shown in photographs in the main report preceeding this appendix. A brief description for each sample from the geologic report is shown in Figure 1.

b. Formations varied from very weak conglomerates in Area 3 and somewhat firmer breccias in Area 4 to relatively hard and firm welded tuffs and breccias in Area 1. The harder materials in Area 1 furnished relatively good cores suitable for testing; whereas, the softer materials in the other areas furnished less suitable test specimens.

3. Testing Equipment

a. A schematic diagram of basic equipment is shown in Figure 2. Photographs of equipment are included in Figures 19 through 22.

b. Hydraulic System:

The basic unit for these tests is a triaxial chamber designed and built by the Corps of Engineers, Missouri River Division Laboratory for testing NX rock cores at lateral pressures of up to 10,000 psi. To this unit is attached a hydraulic volume measuring device consisting of a cylinder containing a piston on a threaded shaft. Volume measurement is accomplished by calibration of cylinder area and piston position as indicated by thread count. Also attached to the chamber is a dead weight gage for measurement of lateral pressure. The chamber, volume meter, and dead weight gage comprise the basic hydraulic system.

The triaxial chamber consists of a headblock with spherical seat to receive the specimen cap, to which is threaded a cylindrical chamber sleeve which encloses the specimen and confining fluid, and moves axially along the chamber base during the progress of a test. The inside surface of the chamber sleeve, in contact with the base, is a honed cylinder of 3.000 inch I.D.

The chamber base supports the specimen and guides the chamber sleeve during axial motion. Teflon chevron seals on the base serve as a seal for the hydraulic fluid. The base is tapped for connection of hydraulic systems.

During calibration runs and early tests the chamber base and volume meter were rigidly connected by a short steel nipple. Because of possibility of fatigue of this nipple due to repeated torque produced by volume meter adjustments at high pressure, the volume meter was removed from rigid contact with the chamber base and a support for the meter was attached to the loading machine. The meter was then connected to the base with a high pressure hydraulic hose. The dead weight gage is connected by steel tubing to the volume meter base.

Sealing of connections within the hydraulic system is accomplished with "O" rings, teflon tape on threaded connections, and teflon chevron seals on piston assemblies of volume meter and chamber base.

c. Measuring System:

Axial motion is measured as the average of the readings of 2 Ames dials, reading to 0.0001 inch, which are mounted on opposite sides of the chamber sleeve and are referenced to the lower platen of the loading machine. Axial loading is measured by the helicoid dials of the 400,000 pound capacity loading machine. Lateral pressure and volume change are measured by the dead weight gage and the volume meter respectively.

d. Hydraulic Fluid:

Three fluids were used in preliminary calibration runs. These were glycerine, hydraulic oil and mercury. Glycerine was rejected because it fouled the equipment. Hydraulic oil was rejected because of difficulty in de-airing. All tests on rock samples were run using mercury as hydraulic fluid.

e. Environmental System:

The test apparatus is set up in a controlled temperature room. Temperature control is effected by means of thermostatically regulated cold water flow in a coil system across a fan-fed warm air intake. A perforated false ceiling serves as a plenum for air intake and perforated low wall sections expel air. Variation of temperature during tests was generally less than 1 degree fahrenheit. The system can be altered to provide controlled temperatures below freezing. Further refinement of temperature control is possible but was felt to be unwarrented.

4. Testing Methods

This equipment is adaptable to several possible test methods. The initial concept of testing envisioned multi-stage triaxial testing. Six of the 13 tests were run in this manner. The remainder of the tests were run as single stage triaxial tests at constant lateral pressure. Review and analyses of test data indicate the possibility that the Bulk Modulus may be determined by means of lateral pressure alone.

a. Multistage

Tests were carried out in accordance with the following procedures:

(1) Prepare specimen as described hereafter and place in test chamber.

(2) Fill chamber with hydraulic fluid by means of vacuum pump.

(3) Close connection valves and bring head of loading machine down on chamber until dead weight gage indicates desired lateral pressure for first stage of test.

(4) Continue loading until load dials on loading machine indicate an increase in load upon contact with specimen, meanwhile maintaining constant lateral pressure by adjusting volume meter. Record constant load dial reading prior to contact.

(5) Zero Ames dials and read initial volume meter reading, initial load dial reading, and time.

(6) Increase axial load, maintaining constant lateral pressure by adjustment of volume meter. At selected strain increments read axial load, volume meter, Ames dials, and time.

(7) Upon completion of a series of readings at one lateral pressure, increase lateral pressure to next selected level by simultaneous increase of axial load and adjustment of volume meter, as required to hold constant Ames dial readings. When desired lateral pressure is reached read axial load, volume meter, Ames dials, and time.

(8) Repeat steps 6 and 7 for each level of lateral pressure.

b. Single stage test procedure conforms basically to steps 1 through 6 of multistage test.

c. Lateral pressure test for Bulk Modulus determination: Calibration of volume change of hydraulic system versus fluid pressure was attempted. Resulting curves (figure 17) show significant effect of air compression up to 3,000 psi. Above 3,000 psi the curves were parallel, indicating that entrapped air was reduced to insignificant volume. Bulk Moduli determined by single stage and multistage tests are in the range of 0.3 to 1.0 x 10^6 psi.

Comparison of Bulk Moduli and calibration curves indicates that the specimen volume changes which would result from pressure variations above 3,000 psi would be large enough to be measurable within the potential accuracy of calibration.

d. Preparation of Specimens:

Specimens for testing were selected to provide a minimum finished length of 4.3 inches, a limitation dictated by chamber configuration. Samples were considered suitable for testing if they were in one piece, or if they exhibited a clean sharp fracture along a nearly horizontal plane. The specimens selected for testing were cut to provide square and smooth ends, measured and weighed, and surface voids and chips were patched with plaster of Paris. The specimens were then wrapped in a protective cover of heavy sheet plastic (one or two layers), and inserted in a membrane consisting of a section of motorbicycle innertube. For the first 7 tests the specimens were saturated by submergence in a vacuum chamber for several hours. The specimen cap and pedestal were installed under water. Early test results seemed to indicate unusually high Poisson's ratios and it was suspected that supersaturation was taking place upon specimen consolidation under load. This would produce high pore pressures which could not be measured, and would also result in indication of zero volume change (i.e., Poisson's ratio of approximately 0.50) during strain with constant lateral pressure. These characteristics might represent a reasonable facsimile of in-situ rock behavior under high rate loading; however, in order to obtain results which would correlate with Elastic Modulus determinations by other methods, and which might be more representative of rock behavior under shock loading or slow rate loading, specimens for test numbers 8 through 13 were allowed to dry to a saturated surface dry condition prior to testing. The saturated surface dry moisture content is near the as-received moisture content for most specimens. Dry weights and specific gravities were not obtained for specimens from test numbers 2 through 8.

5. Computations and Derivations of Formulas

a. Basis of computations

Determination of elastic constants is predicted upon the assumption that these rocks are homogenous isotropic substances which act in accordance with Hooke's law. The linear stress-strain curves obtained in tests of the stronger specimens indicate that, for these specimens, this assumption is reasonable. However, this assumption of elastic behavior for the weaker specimens is disproved as evidenced by Poisson's ratios in excess of 0.5.

b. Symbols and Notations

P = Axial Load on Chamber	kips
P_1 = Axial Load on Chamber prior to solid contact with specimen	kips

A_s	= Cross Section Area of Specimen	sq in
A_c	= Cross Section Area of Chamber Sleeve	sq in
σ_1	= Axial Stress on Specimen	psi
σ_3	= Lateral Stress on Specimen	psi
V	= Volume of Specimen	cu in
H	= Height of Specimen	in
D	= Diameter of Specimen	in
R	= Radius of Specimen	in
E	= Young's Modulus	psi
μ	= Poisson's Ratio	
K	= Bulk Modulus	psi
ε	= Axial Strain	
M	= Volume Meter Reading Converted to	cu in

c. Stress

Net unbalanced axial stress (deviator stress) = $\sigma_1 - \sigma_3$

$P = \sigma_3 A_c + (\sigma_1 - \sigma_3) A_s + \text{friction}$

but: $\sigma_3 A_c + \text{friction} = P_1$

therefore: $\sigma_1 - \sigma_3 = \frac{P - P_1}{A_s}$ (1)

d. Axial Strain,

$$\varepsilon = \frac{\Delta H}{H} \quad (2)$$

ΔH is measured by Ames dials but readings must be corrected by subtracting calibrated axial deformation of chamber assembly (figure 16).

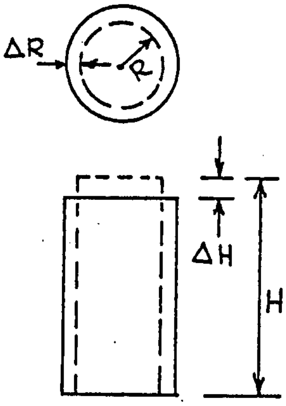
e. Young's Modulus, E

$$E = \frac{(\sigma_1 - \sigma_3)_B - (\sigma_1 - \sigma_3)_A}{\varepsilon_B - \varepsilon_A} \quad (3)$$

where points A and B are any selected points on a plotted stress-strain curve. E was determined graphically from curves fitted to plotted points.

f. Radial Strain and Volumetric Strain

Skin approximation was used to simplify computations as the error would be very small.



Assuming volume decrease is positive:

$$\Delta V \approx \pi R^2 \Delta H - 2\pi \Delta R H R \qquad (4)$$

The Hydraulic volume meter measured total change taking place within the chamber, including (at any constant σ_3) decrease in chamber volume due to chamber shortening with specimen strain, and increase in chamber volume with volume decrease of specimen:

$$-\Delta M = -\Delta H A_c - 2\pi \Delta R H R + \pi R^2 \Delta H \qquad (5)$$

$-\Delta M$	$-\Delta H A_c$	$-2\pi \Delta R H R$	$+\pi R^2 \Delta H$
Volume Meter Change (increased reading	Volume decrease in chamber with strain	Volume decrease in chamber due to increased radius of specimen	Volume increase in chamber due to axial shortening of specimen

but $\Delta V = \pi R^2 \Delta H - 2\pi \Delta R H$, so that

$-\Delta M = -\Delta H A_c + \Delta V$ and $\Delta V = \Delta H A_c - \Delta M$ (6)

rearranging terms, equation (4) and substituting equation (2) we get,

$$\Delta R = \frac{R}{2}\varepsilon - \frac{\Delta V}{2\pi H R}$$

ΔM and ΔH were determined between end points selected for determination of Young's Modulus (E). In multistage tests the calibrated chamber volume change with change of lateral pressure (σ_3) was a factor also included for determinations of volume change.

g. Poisson's Ratio

$$\mu = \frac{\Delta R}{\varepsilon R}$$ by definition.

h. Bulk Modulus

$$K = \frac{E}{3(1-2\mu)} = \frac{1}{\text{compressibility}}$$ by elastic theory.

i. Accuracy of Measurements:

Indicated limits of accuracy for the various measurements are as follows:

Axial Load "P" (lbs.)	$\pm 200 \pm .005$ P
Lateral Pressure "σ_3" (psi)	$\pm .001 \sigma_3$
Axial deformation "ΔH" (inch)	$\pm .0002$
Volume Meter Change "ΔM" (cu. in.)	$\pm .001$

Using these values in combination to provide maximum possible error, and applying them to the stress-strain curve and volume data of test No. 11, results in a possible error of measurement of ± 3% for Young's Modulus and ± 1% for Poisson's ratio.

Loading of specimens was quite rapid, with load, volume, and strain readings being taken at approximately 1 minute intervals. It was found in one test; that, after an increment of axial load was applied, volume meter adjustments were required at a uniform rate of about 0.003 cubic inches per minute in order to maintain constant axial strain, constant lateral pressure, and constant axial load. This rate is considered representative for all tests. The direction of this required adjustment indicated hydraulic fluid leakage, or specimen consolidation. Leakage of this magnitude was not observed during the progress of the tests, and it is concluded that this effect is largely the result of specimen consolidation or creep. There was no tendency for axial creep upon application of load, as evidenced by constant Ames dial readings, thus any consolidation or creep which occurred would have been radial; i.e., at right angles to principal stress.

In any case, adjustment of volume change readings to an instantaneous value on the basis of the observed rate of creep or consolidation would result in tabulated Poisson's ratios approximately 50% greater than shown, and would result in an increase in Bulk Modulus. Thus it appears that, for these rocks, the time rate of loading has a significant effect on the determination of elastic constants; and that the results obtained in these tests are applicable to rapid but not instantaneous loading.

6. Test Results

a. Summary sheet is shown on Figure No. 1 and individual test results on Figures 3 through 11.

b. Multistage tests.

The intent of this procedure was to obtain values of elastic moduli at several lateral pressures. The samples that were selected at random for these tests were some of the least uniform and weaker specimens. Test No.'s 1 and 2 were lost, as far as data is concerned, because of membrane failure upon application of lateral pressure. This problem was eliminated in subsequent tests by the use of a layer of protective plastic sheeting under the membrane. Test No.'s 3, 5, 6 and 7 followed this procedure. At low pressures these samples developed a relatively low Modulus of elasticity. In making strain-controlled transitions from one lateral pressure to another, internal stress reversals take place within the specimen. These stress reversals, together with the high lateral pressure used and prolonged strain at each pressure, tended to break down the sample structure causing remolding and reconsolidation. Multistage testing was discontinued after test No. 7.

c. Single stage tests.

The first single stage test was test No. 4. This test was run with 1000 psi lateral pressure on half of sample No. 14 from Hole No. 64-D-3 (Area 4). The other half of sample No. 14 was used in test No. 3, a multistage test. Poisson's ratio resulting from this test was in excess of 0.5, indicating nonelastic performance. Failure was by shear failure on a steep plane. Dilation during shear would account for the high Poisson's ratio. Test No. 10, a single stage test run at 10,000 psi lateral on sample No. 8 from Hole No. 64-D-2 (Area 3), exhibited a similar failure without developing appreciable strength. Poisson's ratio determined over on 5 minute interval of this test was 0.4.

Specimen performance more nearly conforming to elastic theory was exhibited by samples from Hole No. 64-D-4, in test No.'s 8, 9, 11, 12 and 13. These exhibited characteristics conforming to the elastic theory within lower limits of deformation and gave the following values:

Poisson's Ratio	0.19 to 0.39
Young's Modulus	0.60 to 0.90 x 10^6 psi
Bulk Modulus	0.34 to 0.91 x 10^6 psi

Values obtained from sample 1 (Breccia) are doubtful because the sample was variable in composition, and the elastic limit was probably exceeded early in the test.

7. Discussion

a. Laboratory tests to be of great value must simulate field conditions. This may be very difficult if not impossible to do when bedrock is highly variable, faulted, and fractured. At least for such conditions, acceptable values would require a statistical study using a large number of test specimens having similar properties. Because of the very small number of acceptable test specimens the greatest value of the test results will be to provide interpreted comparisons with the field seismic determinations. Test values are indicative of properties of certain materials under certain load conditions, but they do not represent acceptable values for all rocks at the sites.

b. Some tentative conclusions can be drawn that may influence future test programs. Elastic limit determinations are dependent upon certain characteristics of the testing procedures as well as upon the variable properties of the test specimen. Sample variations such as degree of saturation, differences in moisture content between specimens, preconsolidation or other residual locked in rock stresses, are examples of variations possible in different test specimens. Rate of loading, recycling techniques, allowable axial strain and the use of lateral loading versus vertical loading will also affect the elastic limit determinations. Equipment of the type used in these tests is adaptable for testing these variables as well as performing the lateral pressure test for Bulk Modulus determination, as described above.

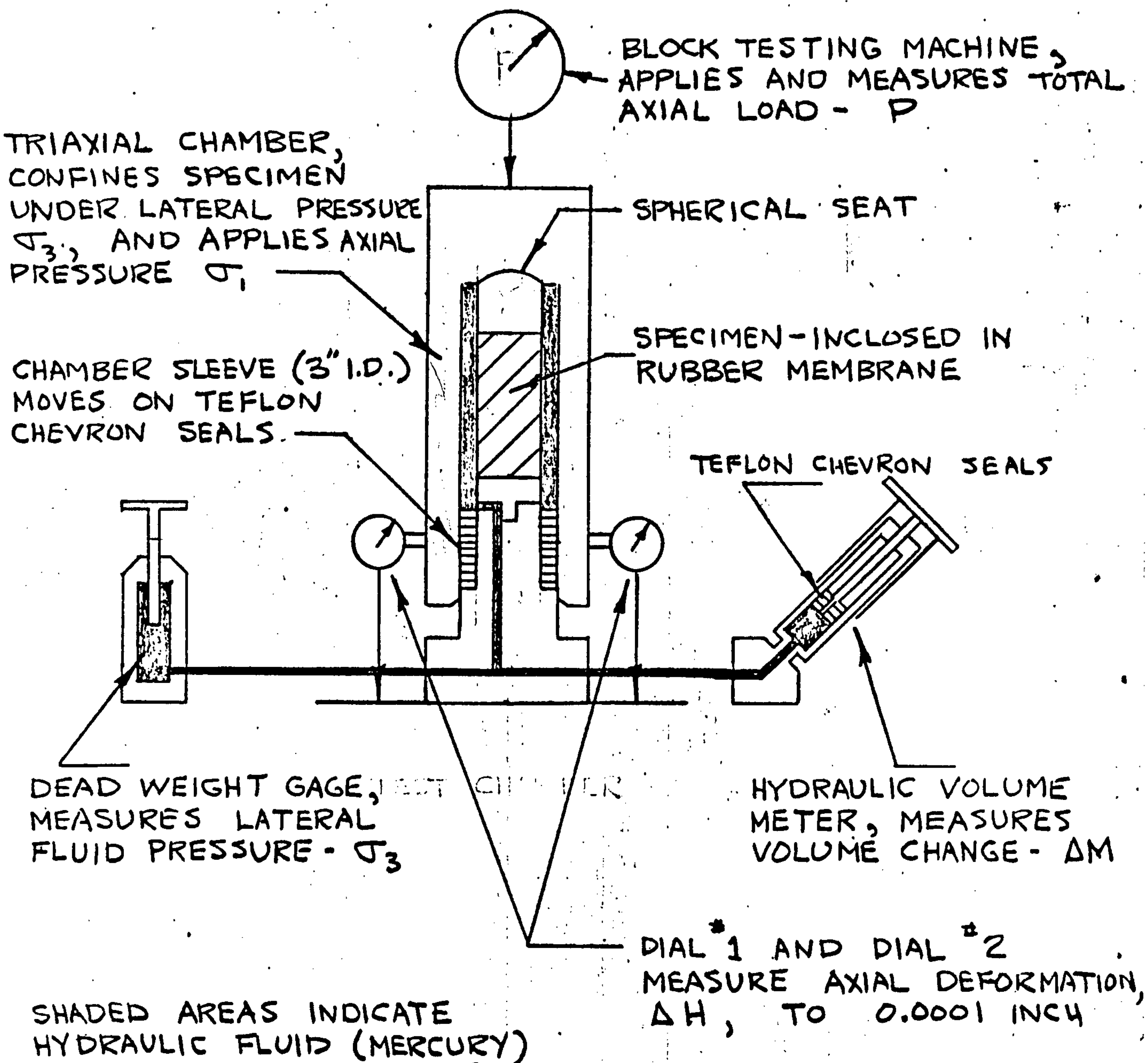
c. A curve (Figure 18) is included which indicates an apparent variation of Poisson's Ratio and Young's Modulus with recycled loading on test number 8, and with 2 different proportional stress-strain relationships obtained in test number 13. A series of recycled load tests might indicate a significant relationship to exist between these constants.

d. Regardless of confining pressures the elastic properties need to be determined within relatively limited ranges of axial strain. In these tests, even though the test specimen showed no evident signs of failure following the test, the elastic limit had been exceeded with axial strains in the order of 0.5 percent. If this relationship is true for all confining pressures, as it appears to be, then the elastic properties of the rocks may not be constant. Instead they might vary with the confining pressure. This could be a very worthwhile subject for additional investigations, and the available equipment could be utilized for tests of this nature.

SUMMARY OF SPECIMENS AND TESTS

	HOLE NUMBER	SAMPLE NUMBER	DEPTH OF SAMPLE FEET	ROCK TYPE (SEE GEOLOGIC REPORT)	TEST NUMBER	APPARENT SPECIFIC GRAVITY	MOISTURE CONTENT %	YOUNGS MODULUS 10^6 PSI	POISSION'S RATIO	BULK MODULUS 10^6 PSI	COMMENTS
AREA-3	64-D-2	4	30.7 TO 31.8	VOLCANIC CONGLOMERATE	5	-	-	-	-	-	MULTISTAGE TEST SPECIMEN BROKEN PRIOR TO TEST - WOULD NOT DEVELOP SIGNIFICANT STRENGTH - DEAD WEIGHT GAGE LEAKING DURING TEST
	64-D-2	6	58.5 TO 59.3	VOLCANIC CONGLOMERATE	NONE	-	15.6	-	-	-	UNSUITABLE FOR TESTING
	64-D-2	8	62.4 TO 63.7	VOLCANIC CONGLOMERATE	10	2.68	16.3	-	0.40	-	SINGLE STAGE TEST AT 10,000 PSI - SPECIMEN FAILED ALONG STEEP SHEAR PLANE WITHOUT DEVELOPING SIGNIFICANT STRENGTH
AREA-4	64-D-3	8	86.0 TO 87.2	BRECCIA	1	2.61	12.2	-	-	-	MULTISTAGE TEST LEAK AT VOLUME METER AT 10,000 PSI - MEMBRANE FAILURE CAUSED MERCURY SATURATION OF SPECIMEN AND LOSS OF EFFECTIVE LATERAL PRESSURE
	64-D-3	9	92.0 TO 93.0	BRECCIA	2	-	-	-	-	-	MULTISTAGE TEST MEMBRANE FAILURE CAUSED MERCURY SATURATION OF SPECIMEN AND LOSS OF EFFECTIVE LATERAL PRESSURE
	64-D-3	13	116.7 TO 117.7	BRECCIA	6	-	-	1.00	-	-	MULTISTAGE TEST - YOUNGS MODULUS SHOWN FOR 10,000 PSI STAGE ALSO DETERMINED AT 100 PSI - SPECIMEN BROKEN PRIOR TO TEST LEAKING CHAMBER VALVE AT 10,000 PSI
					7	-	-	.93	.48 ~~.34~~	7.75 ~~.97~~	MULTISTAGE TEST - ELASTIC CONSTANTS SHOWN FOR 10,000 PSI STAGE - SPECIMEN FAILED BY BULGING
	64-D-3	14	117.7 TO 118.7	BRECCIA	3	-	-	.56.	.46 ~~.49~~	2.34 ~~9.33~~	MULTISTAGE TEST - ELASTIC CONSTANTS SHOWN FOR 10,000 PSI STAGE - SPECIMEN FAILED BY BULGING
AREA-1					4	-	-	.35	.52 ~~.55~~	-	SINGLE STAGE TEST AT 1,000 PSI - SPECIMEN FAILED ALONG STEEP SHEAR PLANE
	64-D-4	1	25.2 TO 26.0	BRECCIA	9	2.59	7.5	.50	.23 ~~.25~~	.31 ~~.33~~	SINGLE STAGE TEST AT 10,000 PSI - FAILURE BY BULGING AND NEARLY HORIZONTAL SHEAR
	64-D-4	2	37.8 TO 38.8	BRECCIA	8	-	-	.60	.37 ~~.39~~	.77 ~~.91~~	TWO SINGLE STAGE TESTS AT 10,000 PSI, BOTH ENDING IN HYDRAULIC LEAKS - ELASTIC CONSTANTS SHOWN FOR 1st TEST - NO APPARENT FAILURE
	64-D-4	3	54.0 TO 54.8	BRECCIA	NONE	2.59	6.9	-	-	-	UNSUITABLE FOR TESTING
	64-D-4	4	72.7 TO 73.6	ANDESITE OR ALTERED TUFF	12	2.59	9.9	.60	.39 ~~.40~~	.91 ~~1.00~~	SINGLE STAGE TEST AT 10,000 PSI - NO APPARENT FAILURE
	64-D-4	5	83.3 TO 84.3	ANDESITE OR ALTERED TUFF	13	2.69	7.2	.63	.19 ~~.20~~	.34 ~~.38~~	SINGLE STAGE TEST AT 10,000 PSI - NO APPARENT FAILURE
	64-D-4	6	95.5 TO 96.5	ANDESITE OR ALTERED TUFF	11	2.68	6.3	.91	.23 ~~.25~~	.56 ~~.81~~	SINGLE STAGE TEST AT 10,000 PSI - NO APPARENT FAILURE
	64-D-4	8	118.6 TO 119.5	ANDESITE OR ALTERED TUFF	NONE	2.64	1.9	-	-	-	UNSUITABLE FOR TESTING
	64-D-4	9	16.8 TO 17.4	ANDESITE OR ALTERED TUFF	NONE	-	2.0	-	-	-	UNSUITABLE FOR TESTING

SCHEMATIC DIAGRAM OF TEST APPARATUS

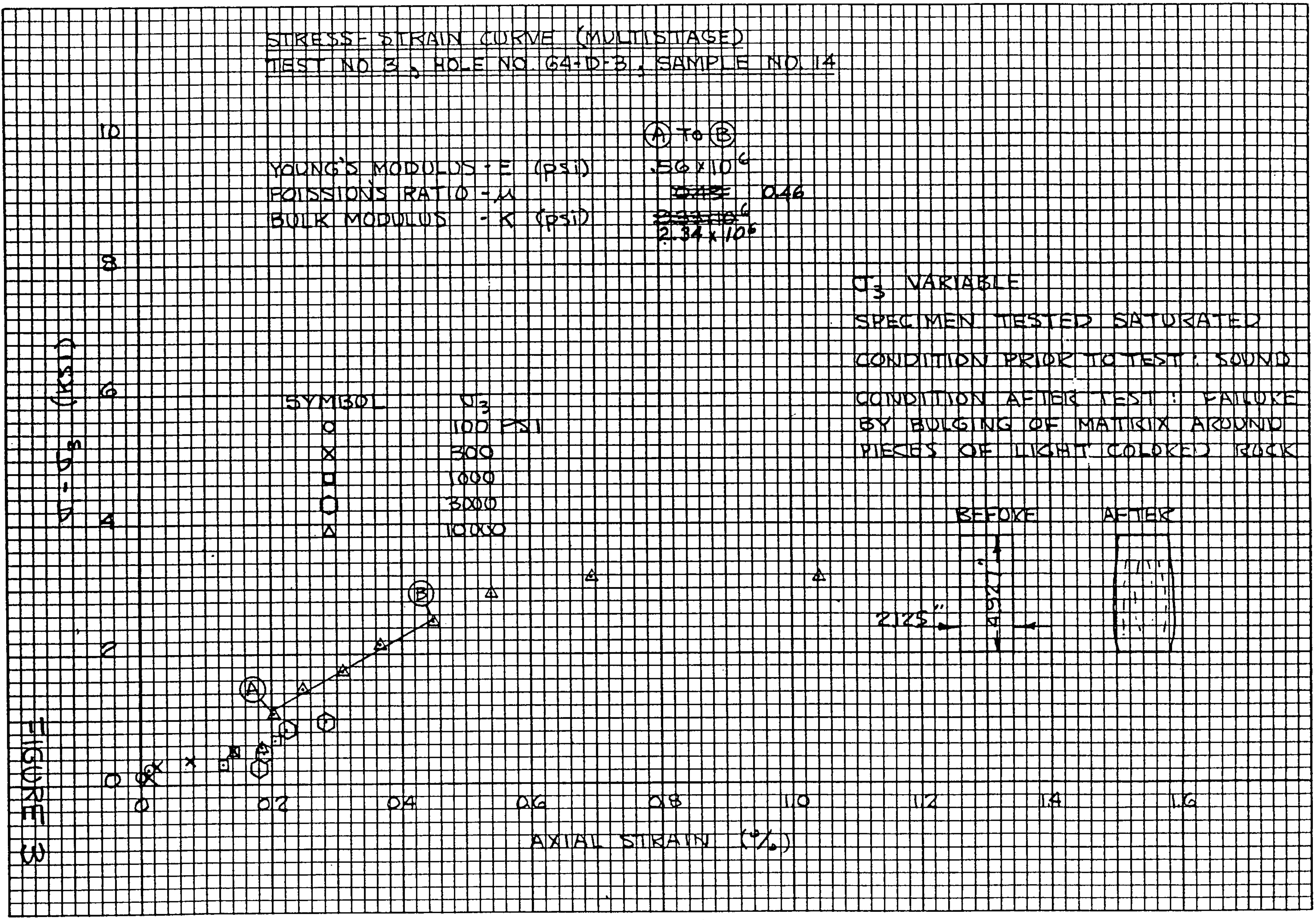


SHADED AREAS INDICATE HYDRAULIC FLUID (MERCURY) UNDER LATERAL PRESSURE - σ_3

FIGURE 2

NO. 340R-10 DIETZGEN GRAPH PAPER
10 X 10 PER INCH

EUGENE DIETZGEN CO.
MADE IN U.S.A.



STRESS-STRAIN CURVE (MULTISTAGE)
TEST NO 3, HOLE NO 64-D-3, SAMPLE NO. 14

	Ⓐ To Ⓑ
YOUNG'S MODULUS - E (psi)	.56 x 10^6
POISSIONS RATIO - μ	~~[illegible]~~ 0.46
BULK MODULUS - K (psi)	~~[illegible]~~ 2.34 x 10^6

SYMBOL	σ_3
○	100 PSI
×	300
□	1000
⬡	3000
△	10000

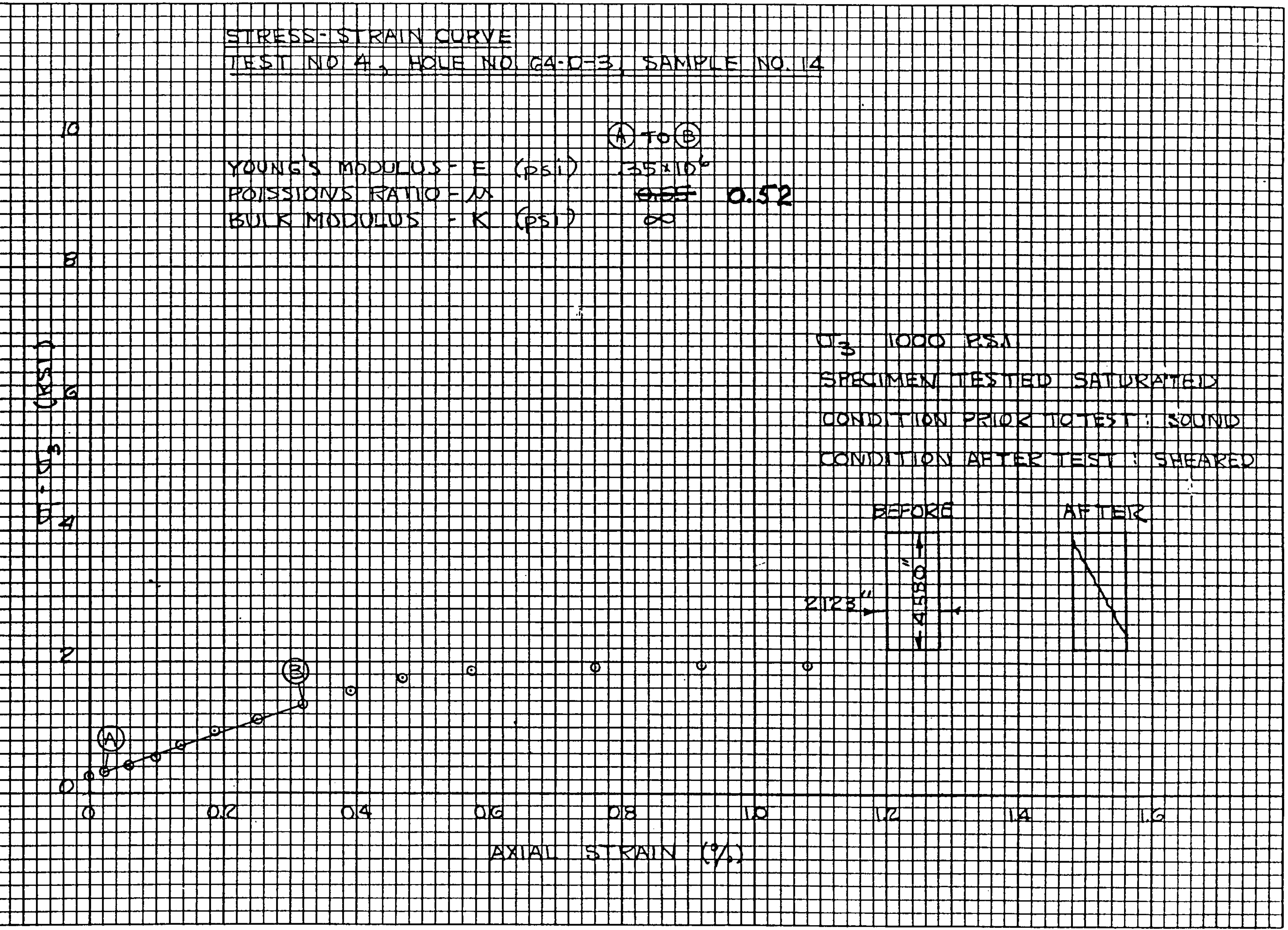
σ_3 VARIABLE

SPECIMEN TESTED SATURATED

CONDITION PRIOR TO TEST: SOUND

CONDITION AFTER TEST: FAILURE BY BULGING OF MATRIX AROUND PIECES OF LIGHT COLORED ROCK

FIGURE 3



STRESS-STRAIN CURVE
TEST NO 4, HOLE NO 64-D-3, SAMPLE NO. 14

	Ⓐ TO Ⓑ	
YOUNG'S MODULUS - E (psi)	.35×10⁶	
POISSIONS RATIO - μ	~~0.55~~	0.52
BULK MODULUS - K (psi)	∞	

σ_3 1000 PSI

SPECIMEN TESTED SATURATED

CONDITION PRIOR TO TEST : SOUND

CONDITION AFTER TEST : SHEARED

FIGURE 4

NO. 340R-10 DIETZGEN GRAPH PAPER
10 X 10 PER INCH

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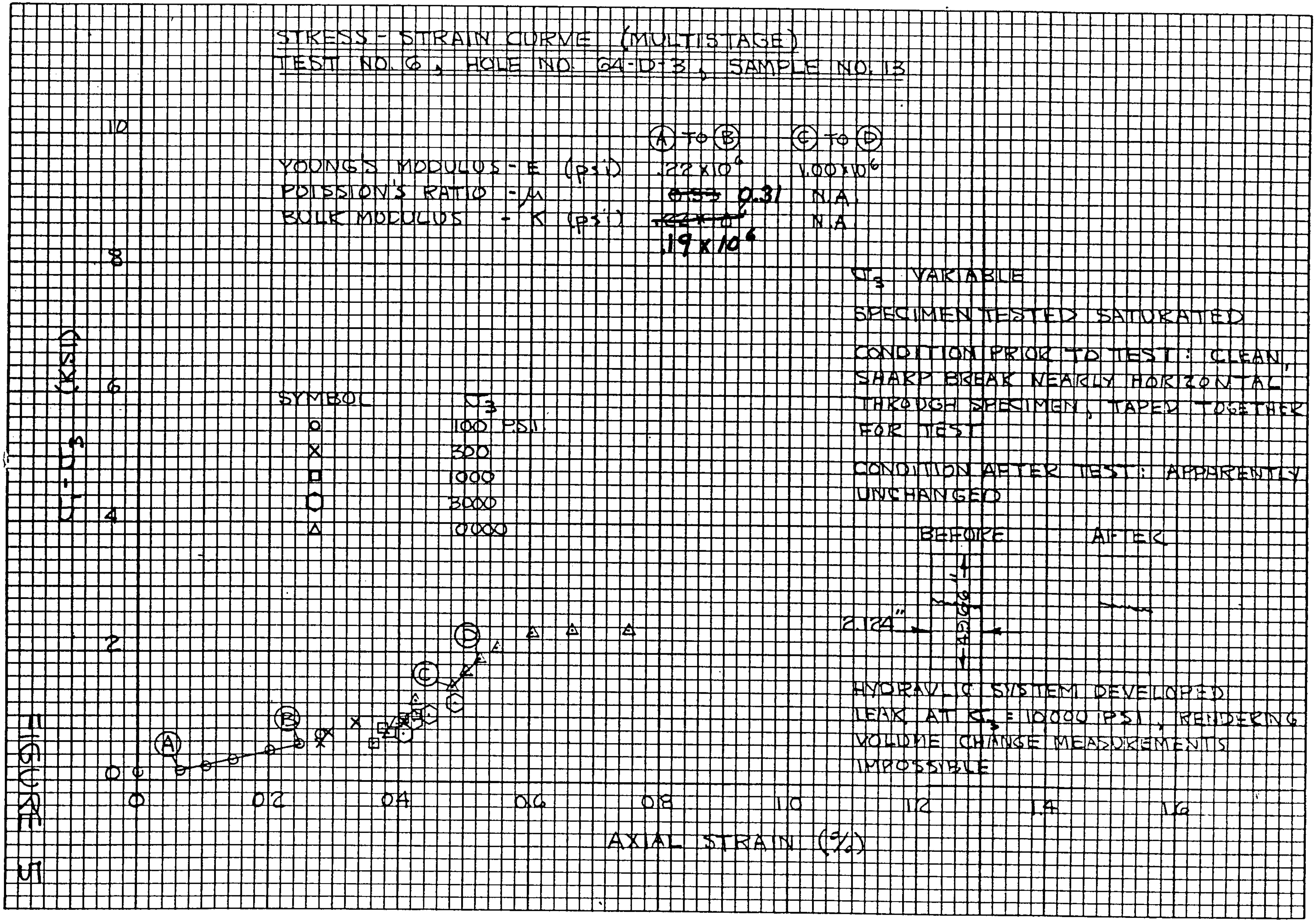

STRESS - STRAIN CURVE (MULTISTAGE)
TEST NO. 6, HOLE NO. 64-D-3, SAMPLE NO. 13

	Ⓐ TO Ⓑ	Ⓒ TO Ⓓ
YOUNG'S MODULUS - E (psi)	$.22 \times 10^6$	1.00×10^6
POISSON'S RATIO - μ	~~0.35~~ 0.31	N.A.
BULK MODULUS - K (psi)	~~[illegible]~~ $.19 \times 10^6$	N.A.

SYMBOL	σ_3
○	100 PSI
X	300
□	1000
⬡	3000
△	10000

σ_3 VARIABLE

SPECIMEN TESTED SATURATED

CONDITION PRIOR TO TEST: CLEAN, SHARP BREAK NEARLY HORIZONTAL THROUGH SPECIMEN, TAPED TOGETHER FOR TEST

CONDITION AFTER TEST: APPARENTLY UNCHANGED

HYDRAULIC SYSTEM DEVELOPED LEAK AT σ_3 = 10,000 PSI, RENDERING VOLUME CHANGE MEASUREMENTS IMPOSSIBLE

FIGURE 11

10 X 10 PER INCH

EUGENE DIETZGEN CO.
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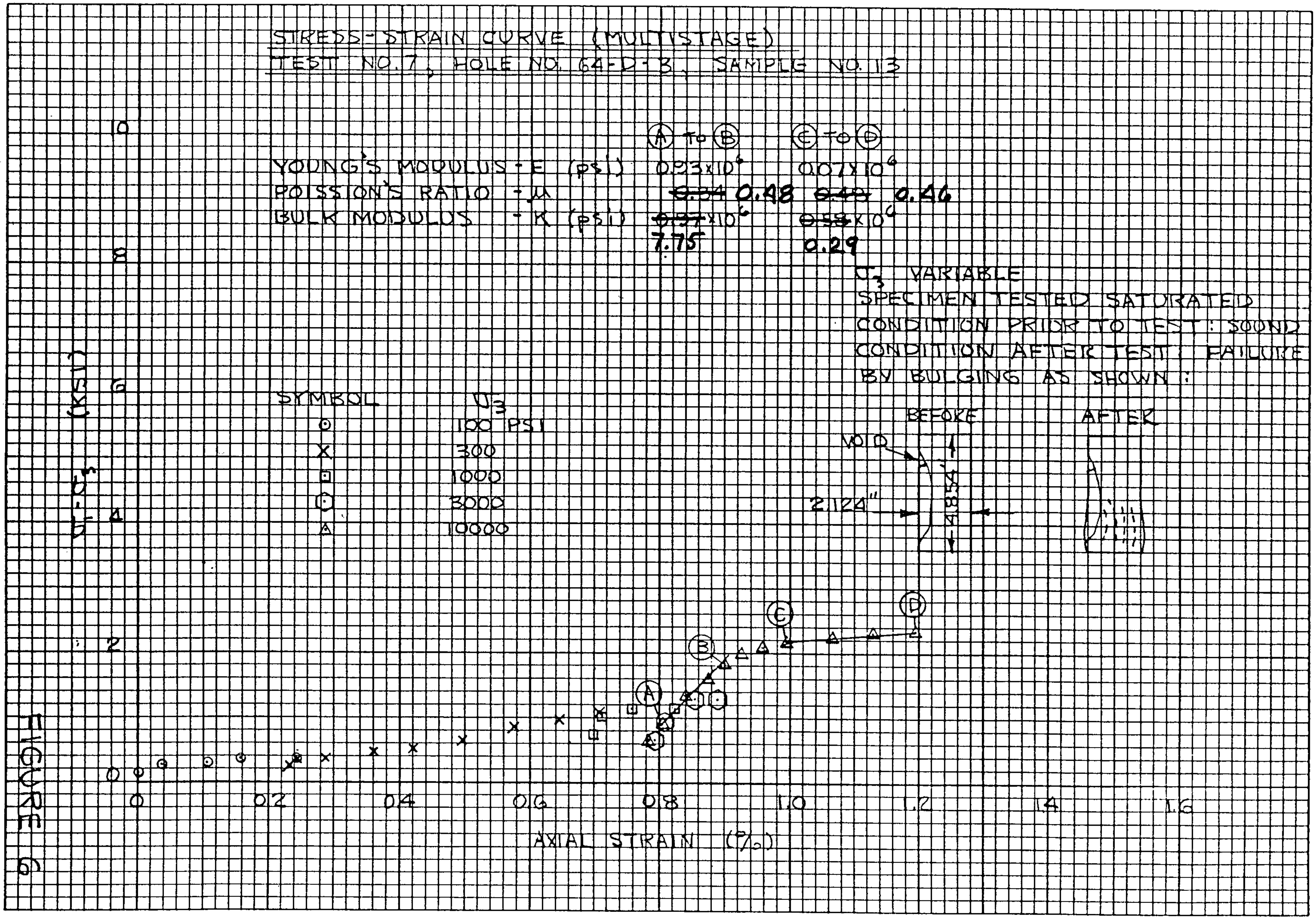


STRESS-STRAIN CURVE (MULTISTAGE)

TEST NO. 7, HOLE NO. 64-D-3, SAMPLE NO. 13

	Ⓐ To Ⓑ	Ⓒ To Ⓓ
YOUNG'S MODULUS - E (psi)	0.93×10^6	0.07×10^6
POISSON'S RATIO - μ	~~0.34~~ 0.48	~~0.49~~ 0.46
BULK MODULUS - K (psi)	~~0.97~~ $\times 10^6$ 7.75	~~0.58~~ $\times 10^6$ 0.29

σ_3 VARIABLE

SPECIMEN TESTED SATURATED

CONDITION PRIOR TO TEST: SOUND

CONDITION AFTER TEST: FAILURE BY BULGING AS SHOWN:

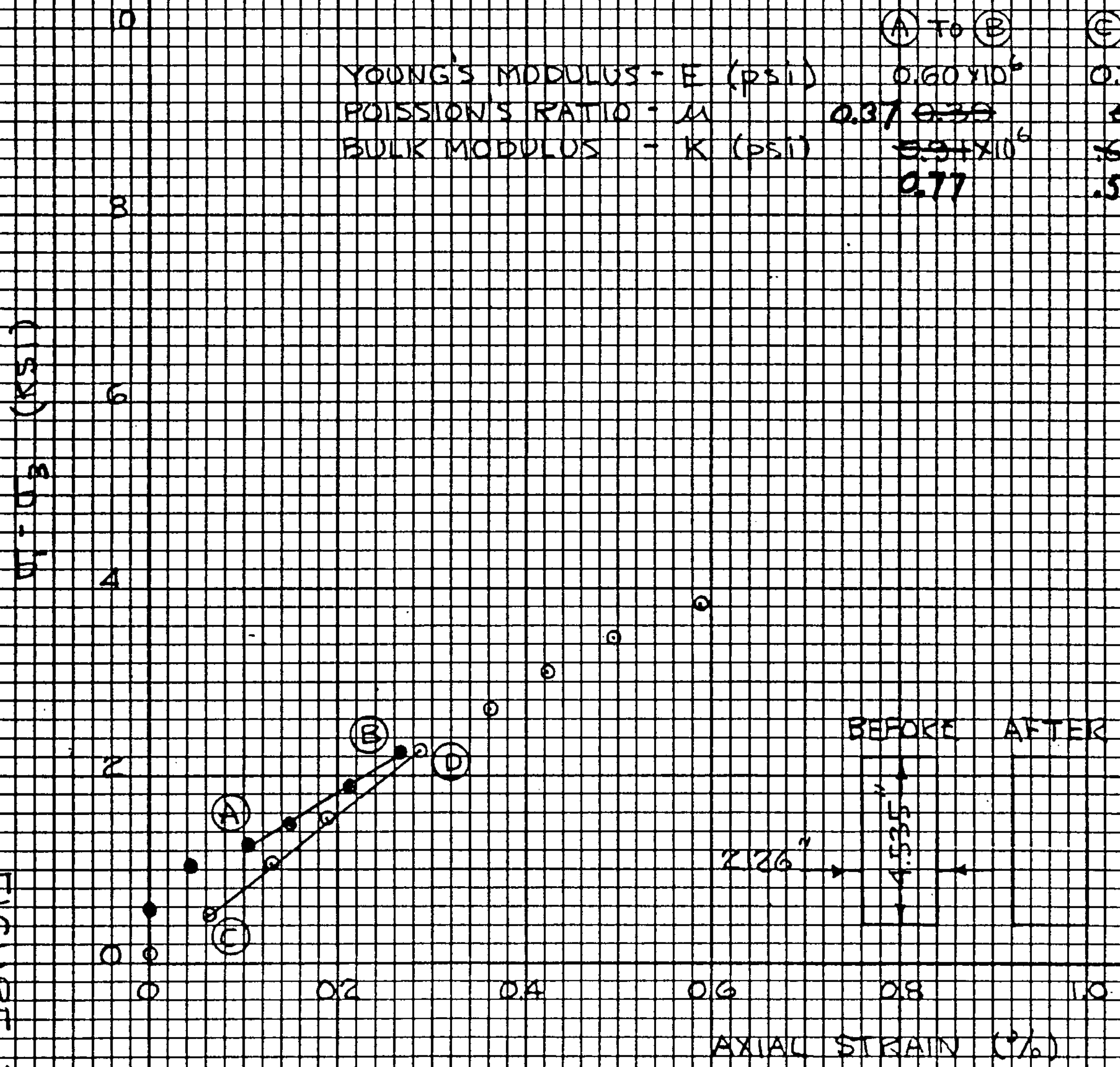
SYMBOL	σ_3
⊙	100 PSI
×	300
⊡	1000
⬡	3000
△	10000

FIGURE 6

STRESS-STRAIN CURVE

TEST NO. 8, HOLE NO. 64-D-4, SAMPLE NO. 2

	Ⓐ To Ⓑ	Ⓒ To Ⓓ
YOUNG'S MODULUS - E (psi)	0.60 x 10^6	0.78 x 10^6
POISSION'S RATIO - μ	0.37 ~~0.30~~	~~0.30~~ 0.28
BULK MODULUS - K (psi)	~~5.94~~ x 10^6 0.77	~~.65~~ x 10^6 .59



σ_3 = 10,000 P.S.I.

SPECIMEN TESTED S.S.D.

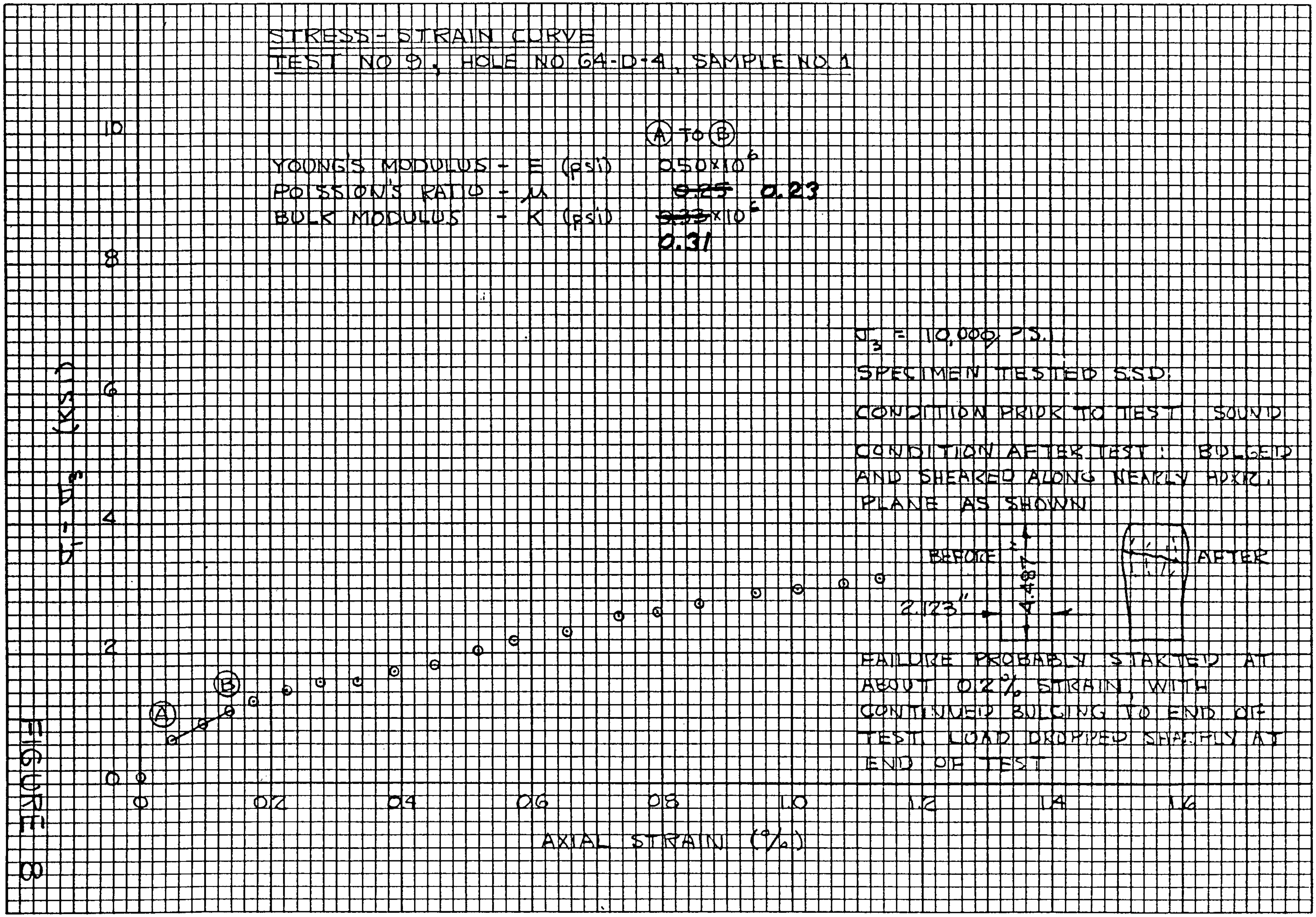
CONDITION PRIOR TO TEST: SOUND

CONDITION AFTER TEST: APPARENTLY UNCHANGED

TEST WAS RUN TO POINT Ⓑ, A LEAK DEVELOPED IN THE HYDRAULIC SYSTEM, THE SYSTEM WAS DISASSEMBLED AND REPAIRED, AND THE TEST RE-RUN. ON THE SECOND RUN A LEAK DEVELOPED IN THE HYDRAULIC SYSTEM WHEN SAMPLE STRAIN REACHED 0.59% AND THE TEST WAS TERMINATED.

FIGURE 7

10 X 10 PER INCH
EUGENE DIETZGEN CO.
MADE IN U. S. A.



STRESS-STRAIN CURVE
TEST NO 9, HOLE NO 64-D-4, SAMPLE NO 1

	Ⓐ TO Ⓑ
YOUNG'S MODULUS - E (psi)	0.50 × 10^6
POISSON'S RATIO - μ	~~0.25~~ 0.23
BULK MODULUS - K (psi)	~~0.33~~ × 10^6 0.31

σ_3 = 10,000 P.S.I.

SPECIMEN TESTED S.S.D.

CONDITION PRIOR TO TEST: SOUND

CONDITION AFTER TEST: BULGED AND SHEARED ALONG NEARLY HORIZ. PLANE AS SHOWN

FAILURE PROBABLY STARTED AT ABOUT 0.2% STRAIN, WITH CONTINUED BULGING TO END OF TEST. LOAD DROPPED SHARPLY AT END OF TEST

FIGURE 8

NO. 340R-10 DIETZGEN GRAPH PAPER
10 X 10 PER INCH

EUGENE DIETZGEN CO.
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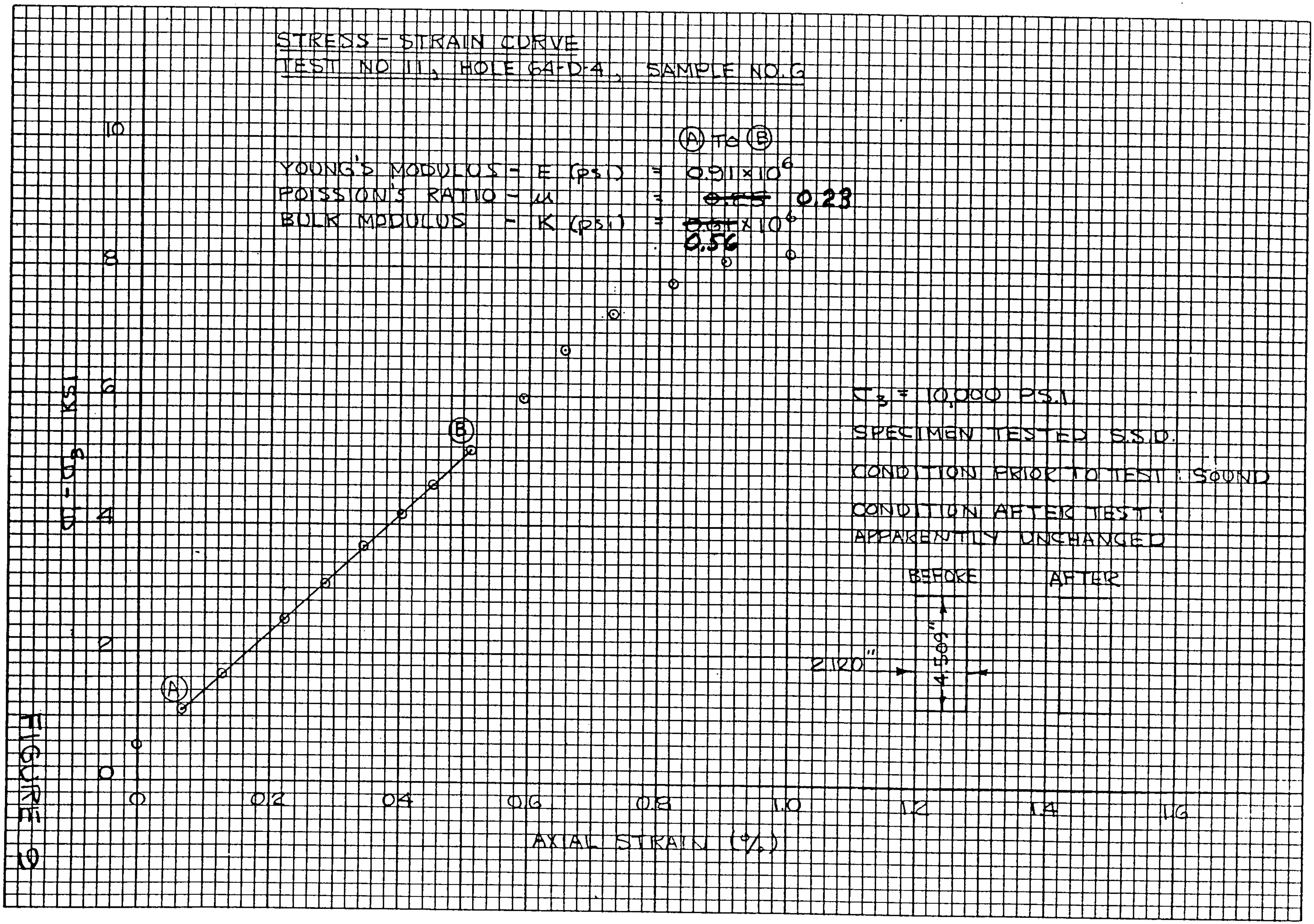


STRESS - STRAIN CURVE

TEST NO 11, HOLE 64-D-4, SAMPLE NO. G

Ⓐ To Ⓑ

YOUNG'S MODULUS - E (psi) = 0.91×10^6

POISSON'S RATIO - μ = ~~0.65~~ 0.23

BULK MODULUS - K (psi) = ~~0.61~~ 0.56 $\times 10^6$

σ_3 = 10,000 PSI

SPECIMEN TESTED S.S.D.

CONDITION PRIOR TO TEST: SOUND

CONDITION AFTER TEST: APPARENTLY UNCHANGED

FIGURE 9

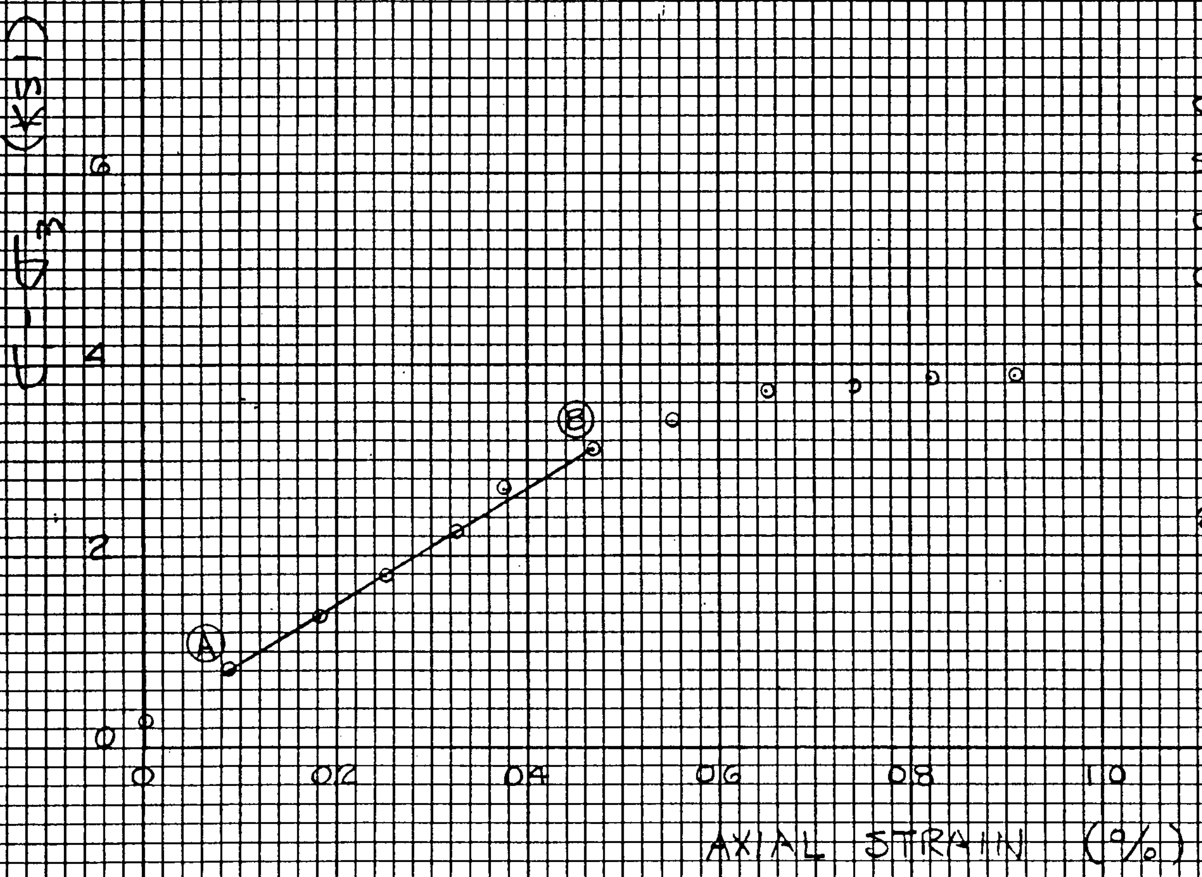
NO. 340R-10 DIETZGEN GRAPH PAPER
10 X 10 PER INCH

EUGENE DIETZGEN CO.
MADE IN U. S. A.

STRESS - STRAIN CURVE
TEST NO 12, HOLE G4 D4 SAMPLE NO 4

Ⓐ TO Ⓑ

YOUNG'S MODULUS - E (psi) = .60 X 10^6
POISSION'S RATIO - μ = ~~0.40~~ 0.39
BULK MODULUS - K (psi) = ~~10~~ X 10^6 0.91



σ_3 = 10,000 P.S.I.
SPECIMEN TESTED AS RECEIVED
CONDITION PRIOR TO TEST: SOUND
CONDITION AFTER TEST: APPARENTLY UNCHANGED

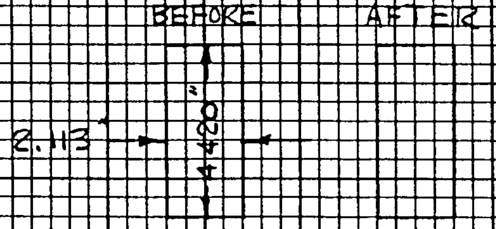


FIGURE 10

NO. 340R-10 DIETZGEN GRAPH PAPER
10 X 10 PER INCH

EUGENE DIETZGEN CO.
MADE IN U. S. A.

STRESS-STRAIN CURVE

TEST NO. 13, HOLE G4D4, SAMPLE NO. 5

	Ⓐ TO Ⓑ	Ⓒ TO Ⓓ
YOUNG'S MODULUS - E (psi)	.45 x 10^6	.63 x 10^6
POISSION'S RATIO - μ	~~0.30~~ 0.28	~~0.20~~ 0.19
BULK MODULUS - K (psi)	~~.37~~ x 10^6 .34	~~.35~~ x 10^6 .34

σ_3 = 10,000 PSI.

SPECIMEN TESTED S.S.D.

CONDITION PRIOR TO TEST: SOUND EXCEPT FOR CHIPPED CORNER WHICH WAS PATCHED WITH PLASTER-OF-PARIS

CONDITION AFTER TEST: APPARENTLY UNCHANGED EXCEPT FOR MEASURED 0.043 INCH SHORTENING

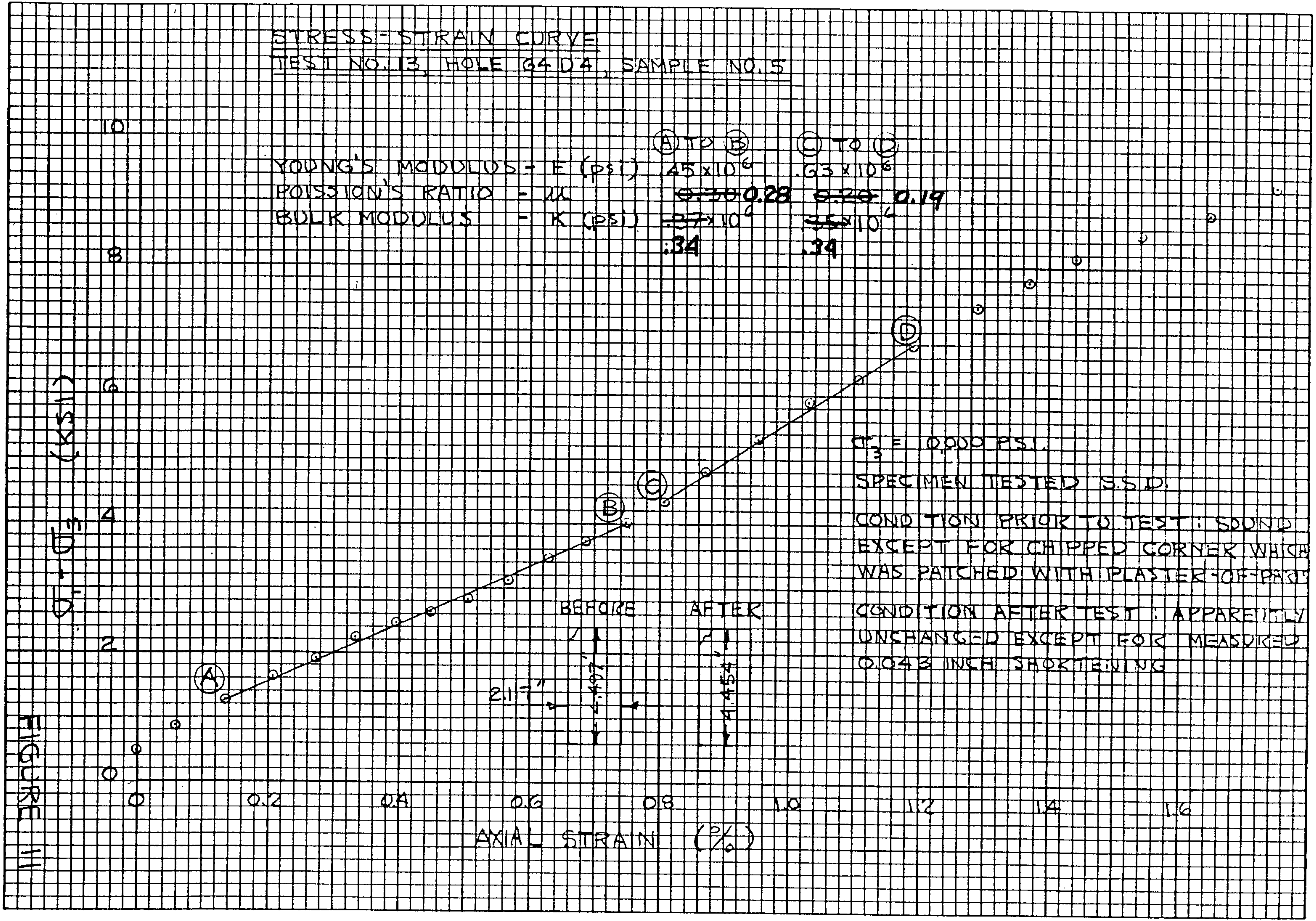


FIGURE 11

TESTED 9 FEB., 1965
BY S.P. AND L.S.

COMP. L.S.
CHKD. ______

CORPS OF ENGINEERS
ALASKA DISTRICT
ANCHORAGE, ALASKA

SHEET NO. 1-2
FILE ______

SUBJECT HIGH PRESSURE TRIAXIAL TEST - DATA SHEET

TEST NO. 11, HOLE NO. 64-D-4, SAMPLE NO. 6, σ_3 = 10,000 PSI

TIME, HR-MIN.	AXIAL LOAD READING, $\sigma_1 A_s$, KIPS	DEVIATOR LOAD, $(\sigma_1-\sigma_3)A_s$, KIPS	DEVIATOR STRESS, $\sigma_1-\sigma_3$, P.S.I.	STRAIN DIAL NO 1, .0001"	STRAIN DIAL NO 2, .0001"	AVERAGE OF DIALS 1 & 2, .0001"	APPARATUS HT. DEFORMATION, .0001"	SPECIMEN HEIGHT, H AND ΔH, INCHES	AXIAL STRAIN, ΔH÷H, %	VOLUME METER READING, THREADS	
10:30	72.0	0	0	(NO HEAD CONTACT, IE. $\sigma_1 = \sigma_3$)							
10:32	74.0	2.0	567	0	0	0	78	4.5090	0	35.83	
								30	.067		
10:33	75.9	3.9	1104	27	36	31	79	4.5060	.067	36.08	Ⓐ
								27	.060		
10:34	77.8	5.8	1643	51	69	60	81	4.5033	.127	36.39	
								43	.096		
10:35	80.9	8.9	2520	88	123	105	83	4.4990	.223	36.92	
								28	.062		
10:36	82.8	10.8	3060	110	160	135	85	4.4962	.285	37.24	ELASTIC RANGE
								27	.060		
10:37	84.9	12.9	3655	133	196	164	87	4.4935	.345	37.55	
								25	.056		
10:38	86.7	14.7	4170	154	227	190	88	4.4910	.401	37.83	
								24	.053		
10:39	88.3	16.3	4620	176	257	216	90	4.4886	.454	38.10	
								26	.058		
10:40	90.2	18.2	5160	201	290	244	92	4.4860	.512	38.44	Ⓑ
								37	.082		
10:42	93.1	21.1	5980	237	330	283	94	4.4823	.594	38.88	
								29	.064		
10:43	95.8	23.8	6740	268	363	315	97	4.4794	.658	39.26	
								33	.073		
10:44	97.7	25.7	7280	300	398	349	98	4.4761	.731	39.65	
								40	.089		
10:45	99.5	27.5	7790	338	435	391	100	4.4721	.820	40.12	
								37	.082		
10:46	100.8	28.8	8160	382	478	430	102	4.4684	.902	40.70	
								44	.098		
10:47	101.0	29.0	8220	428	520	474	102	4.4640	1.000	41.29	

NPA FORM
NOV. 1961 168a (Rev.) Previous editions obsolete.

FIGURE 12

COMP. L.S.
CHKD.

CORPS OF ENGINEERS
ALASKA DISTRICT
ANCHORAGE, ALASKA

SHEET NO. 2-2
FILE

SUBJECT HIGH PRESSURE TRIAXIAL TEST - DATA SHEET

TEST NO. 11, HOLE NO 64-D-4, SAMPLE NO. 6

SAMPLE DATA

AVERAGE HEIGHT - 4.509"
AVERAGE DIAMETER - 2.120"
WEIGHT AS RECEIVED - 632.2 GM.
WEIGHT AS TESTED (S.S.D.) - 632.5 GM
WEIGHT SUBMERGED - 373.1 GM
CONDITION OF SAMPLE: SOUND, NO APPARENT CHANGE AFTER TEST

POISSION'S RATIO DETERMINATION

$\Delta H = 4.5060'' - 4.4860'' = .0200''$

DECREASE IN CHAMBER VOLUME $= .0200 \times 7.07 = .1414 \text{ IN}^3$

$\Delta M = (38.44 - 36.08)\,.0439 = .1037$

$\Delta V = C = .0377$

$\Delta H/H = .0200 \div 4.5060 = .00443$

$\frac{1}{2} \cdot r \cdot \Delta H/H = \frac{(1.06)}{2} \cdot .00443 = \cancel{.00249}\ .00235$

$\Delta V / 2\pi HR = \frac{.0377}{6.28 \times 4.506 \times 1.06} = \cancel{.00133}\ .00126$

$\Delta r = \cancel{.00116}''\ .00109$

$\Delta r/r = \frac{\overset{.00109}{\cancel{.00116}}}{1.06} = \overset{.001028}{\cancel{.001094}}$

$\mu = \frac{\Delta r \cdot H}{\Delta H \cdot r} = \frac{\overset{.001028}{\cancel{.001094}}}{.00443} = \cancel{0.25}\ 0.23$

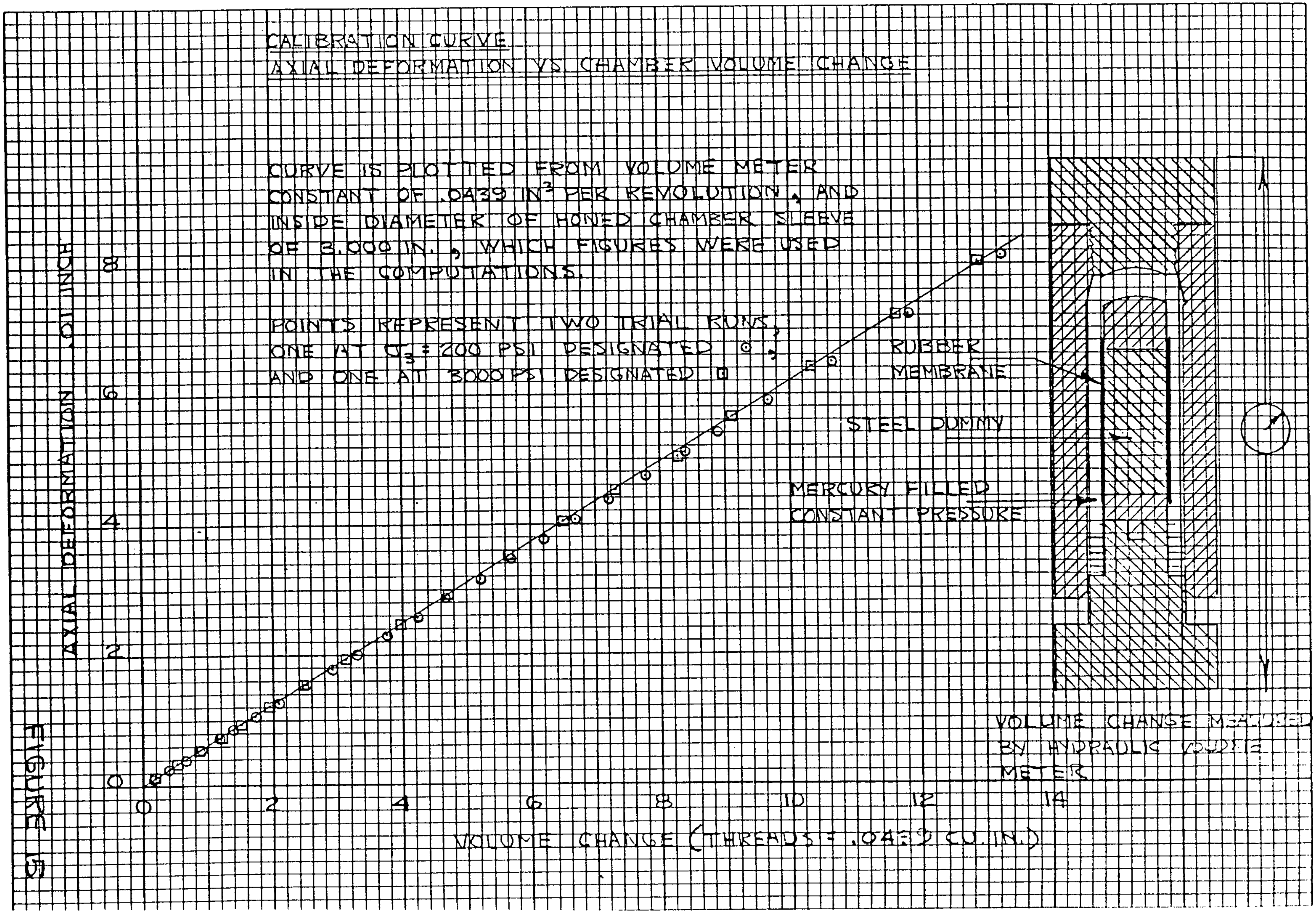
$K = \frac{E}{3(1-2\mu)} = \frac{.91 \times 10^6}{3(1 - 2 \times \underset{0.23}{\cancel{0.25}})} = \overset{0.56}{\cancel{0.61}} \times 10^6$ P.S.I.

NPA FORM NOV. 1961 168a (Rev.) Previous editions obsolete.

FIGURE 13

NO. 340R-10 DIETZGEN GRAPH PAPER
10 X 10 PER INCH

EUGENE DIETZGEN CO.
MADE IN U. S. A.



CALIBRATION CURVE
AXIAL DEFORMATION VS CHAMBER VOLUME CHANGE

CURVE IS PLOTTED FROM VOLUME METER CONSTANT OF .0439 IN^3 PER REVOLUTION, AND INSIDE DIAMETER OF HONED CHAMBER SLEEVE OF 3.000 IN., WHICH FIGURES WERE USED IN THE COMPUTATIONS.

POINTS REPRESENT TWO TRIAL RUNS, ONE AT σ_3 = 200 PSI DESIGNATED ⊙, AND ONE AT 3000 PSI DESIGNATED ⊡

FIGURE 15

NO. 340R-10 DIETZGEN GRAPH PAPER
10 X 10 PER INCH

EUGENE DIETZGEN CO.
MADE IN U. S. A.

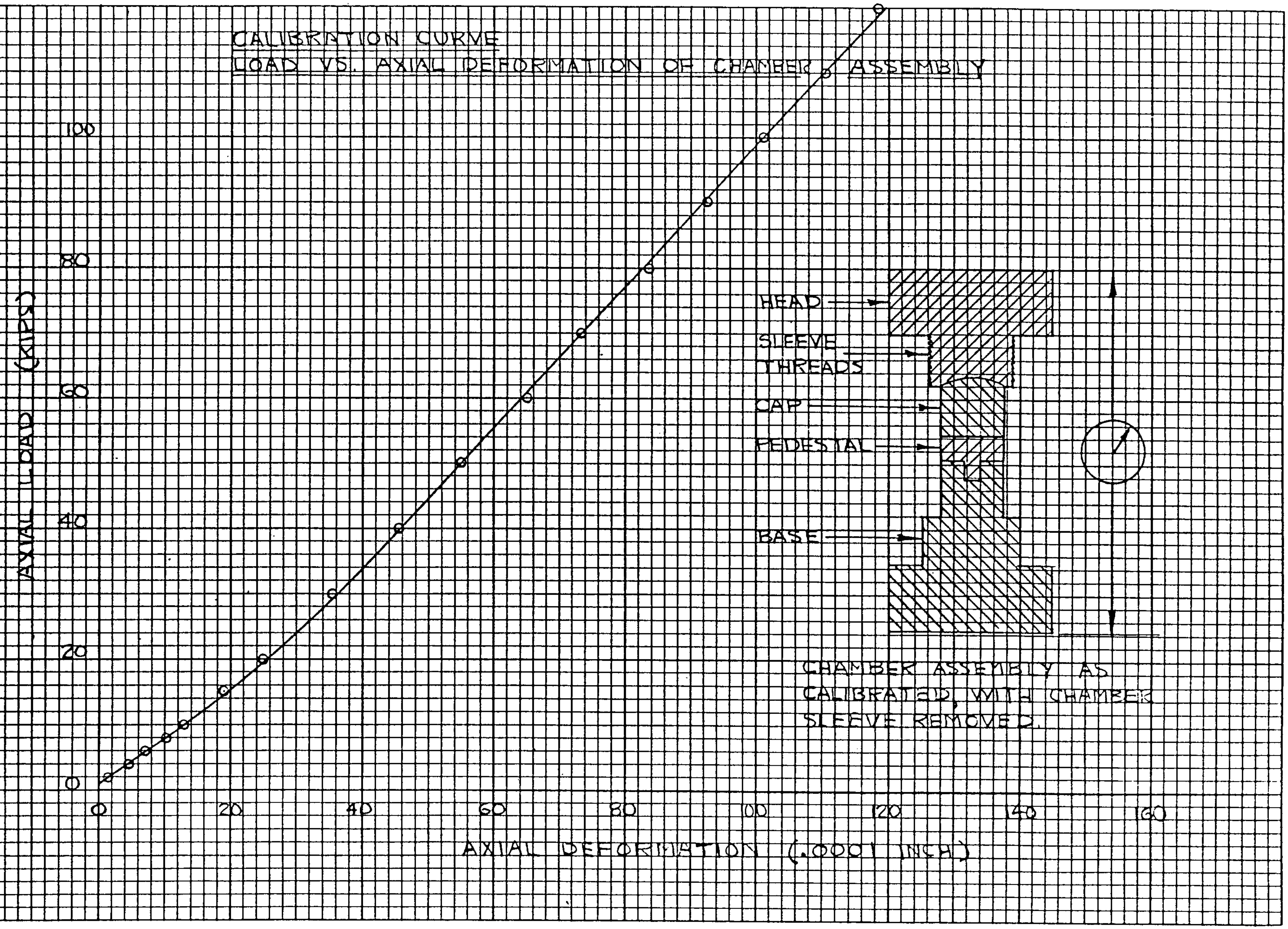
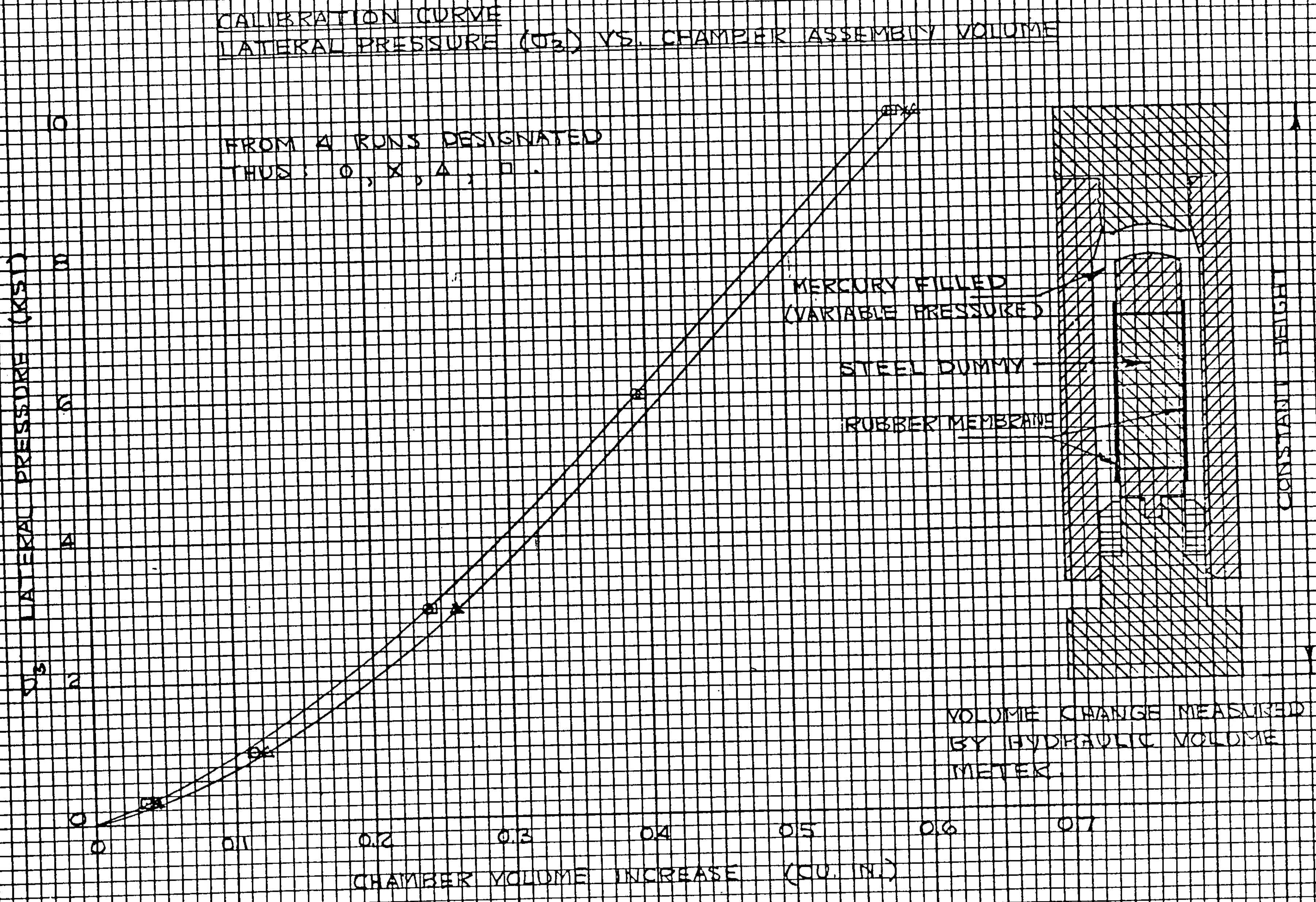


FIGURE 16

NO. 340R-10 DIETZGEN GRAPH PAPER
10 X 10 PER INCH

EUGENE DIETZGEN CO.
MADE IN U. S. A.



CALIBRATION CURVE
LATERAL PRESSURE (σ_3) VS. CHAMBER ASSEMBLY VOLUME

FIGURE 17

NO. 340R-10 DIETZGEN GRAPH PAPER
10 X 10 PER INCH

EUGENE DIETZGEN CO.
MADE IN U. S. A.

VARIATION OF POISSON'S RATIO AND YOUNG'S MODULUS

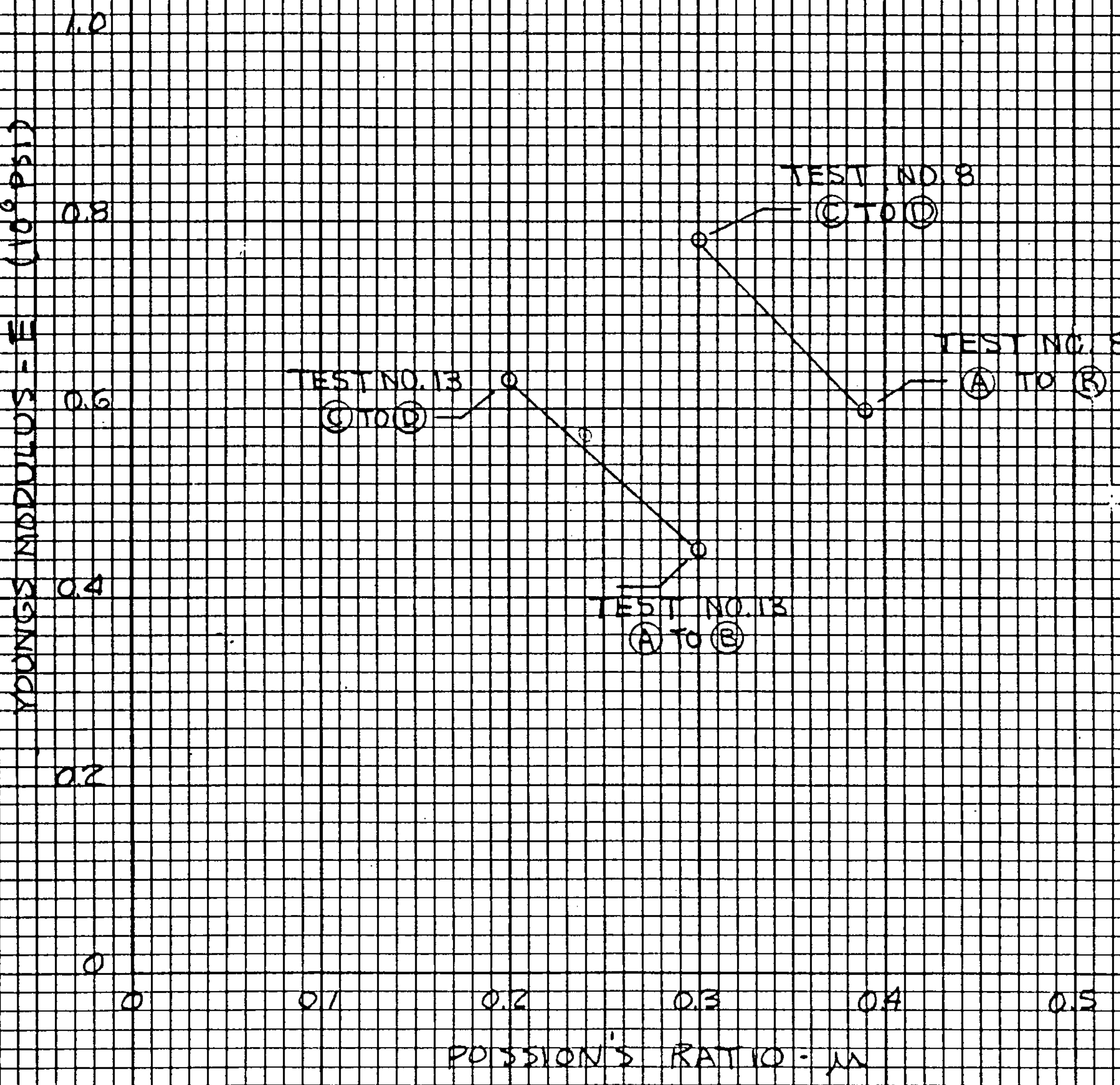
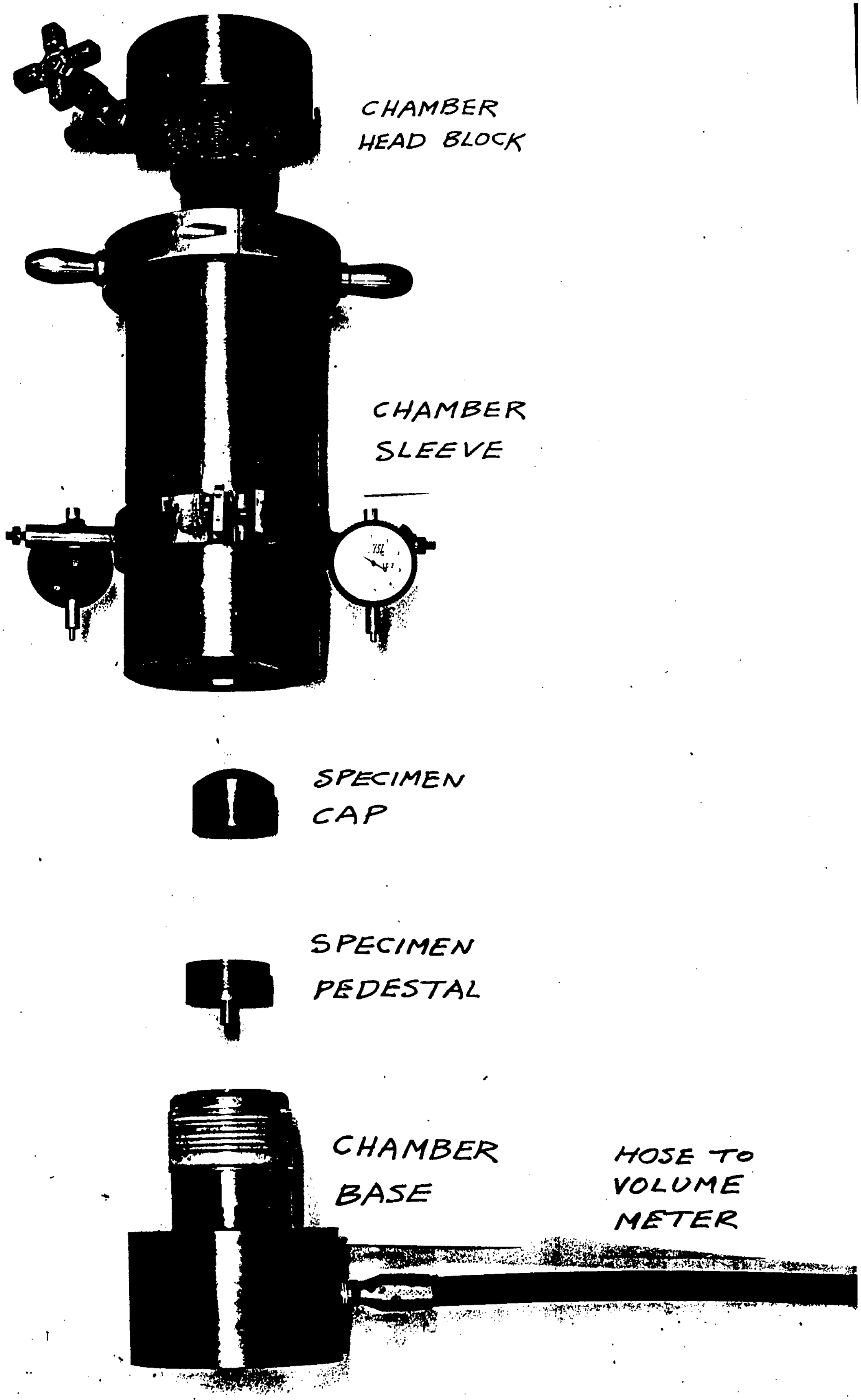
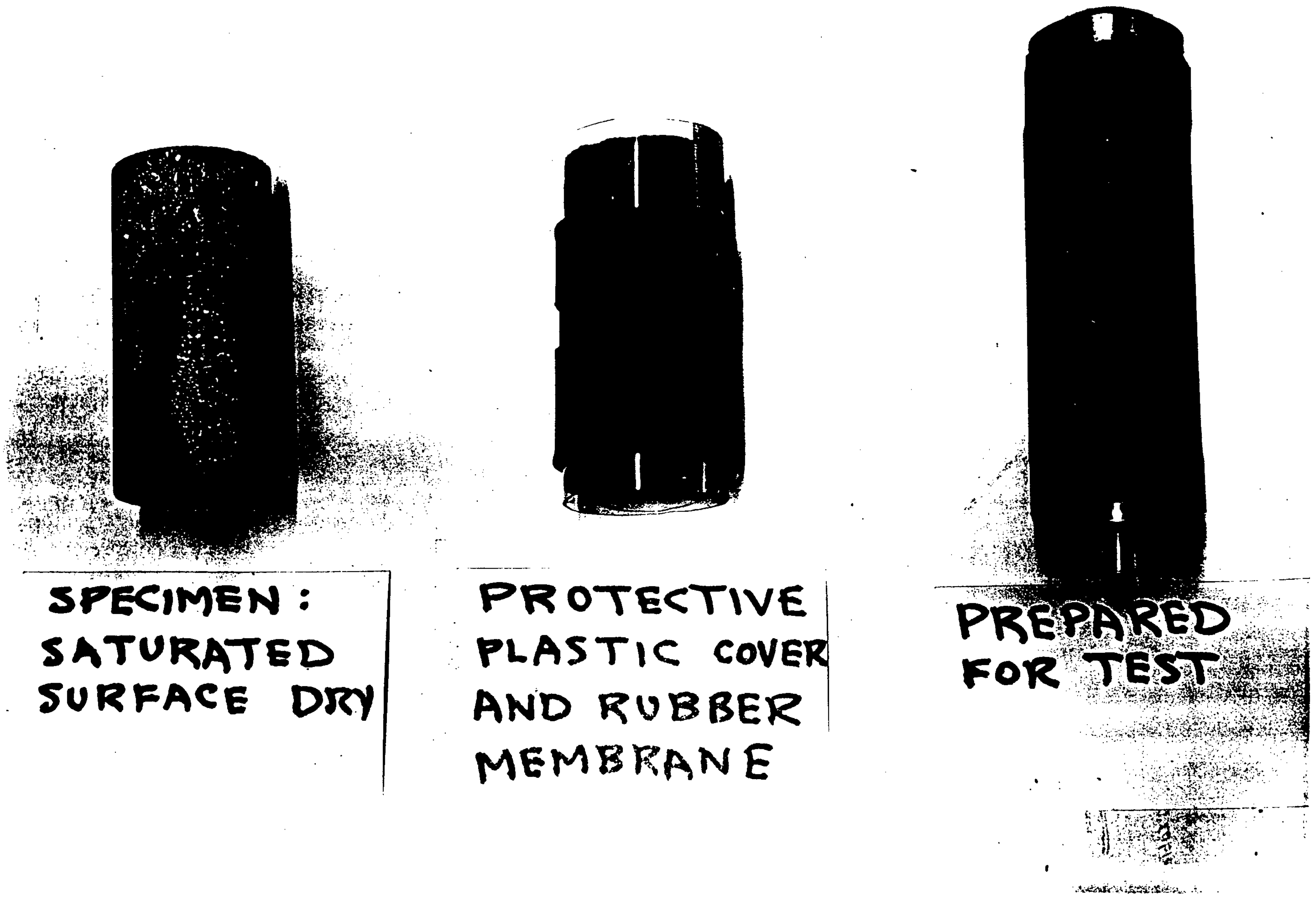


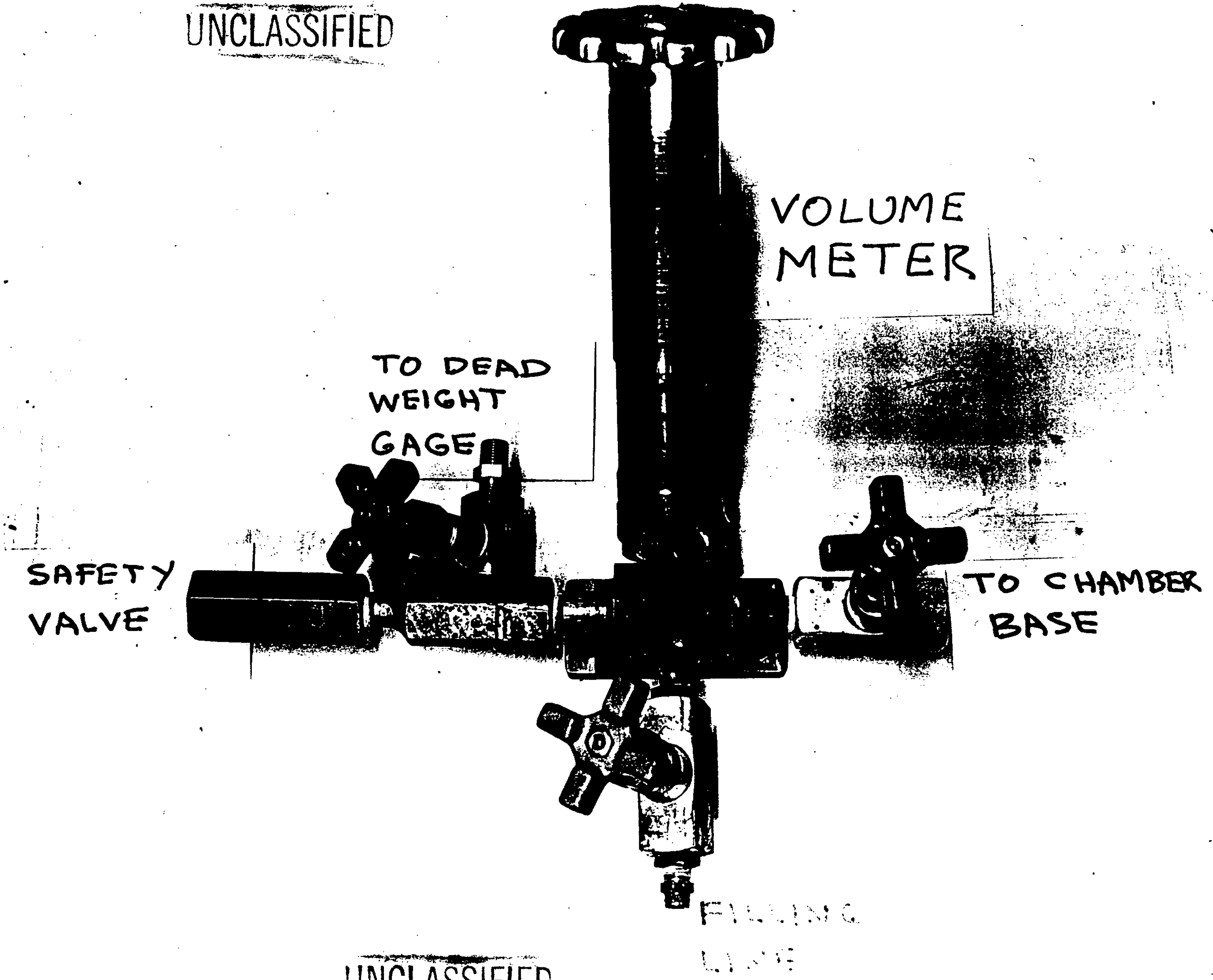
FIGURE 18



CHAMBER HEAD BLOCK
CHAMBER SLEEVE
SPECIMEN CAP
SPECIMEN PEDESTAL
CHAMBER BASE
HOSE TO VOLUME METER

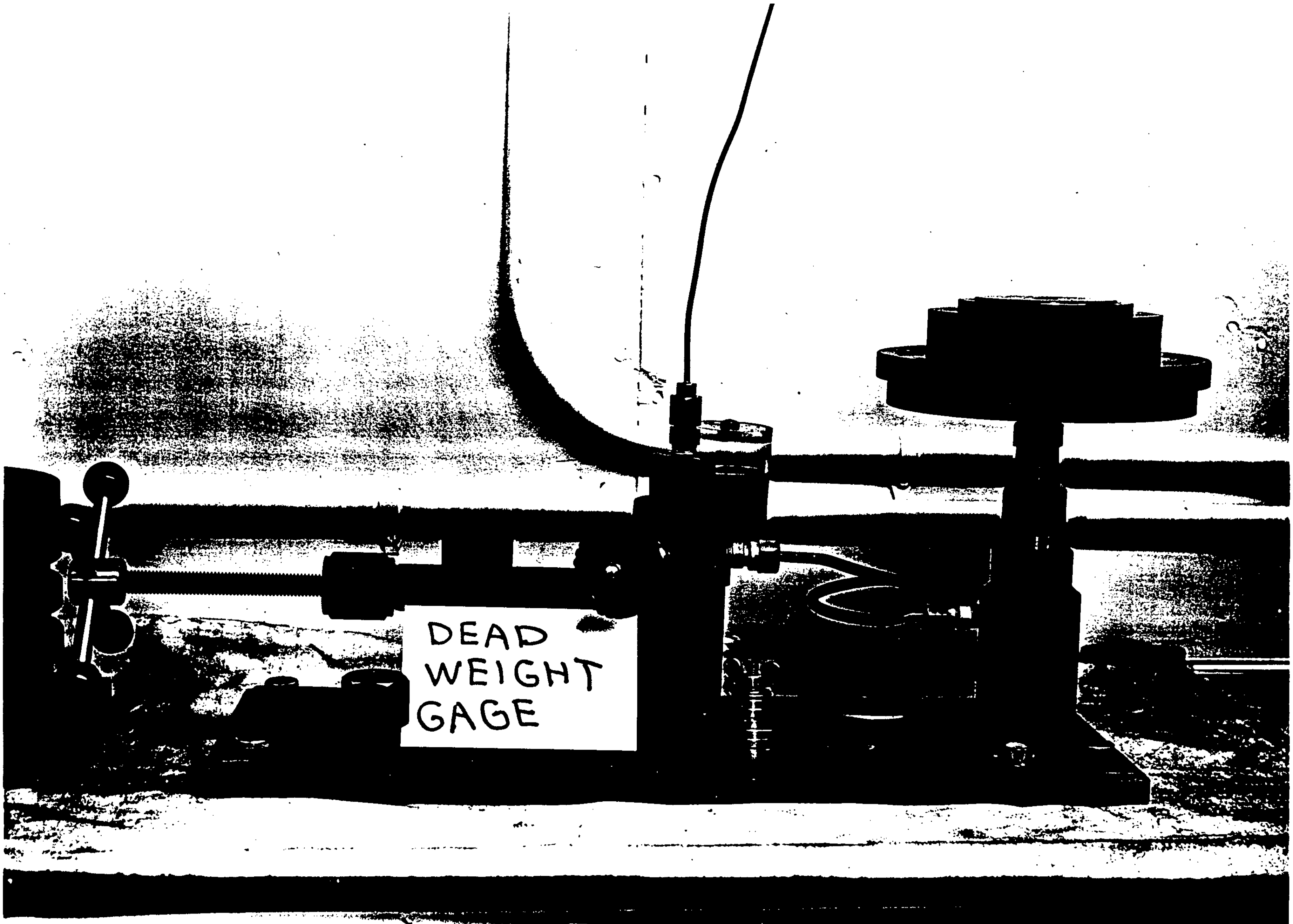

SPECIMEN :
SATURATED
SURFACE DRY
PROTECTIVE
PLASTIC COVER
AND RUBBER
MEMBRANE
PREPARED
FOR TEST

UNCLASSIFIED



UNCLASSIFIED

UNCLASSIFIED



UNCLASSIFIED