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MISCELLANEOUS PAPER C-70-11

TESTS OF ROCK CORES PEASE STUDY AREA, NEW HAMPSHIRE

by

R. W. Crisp

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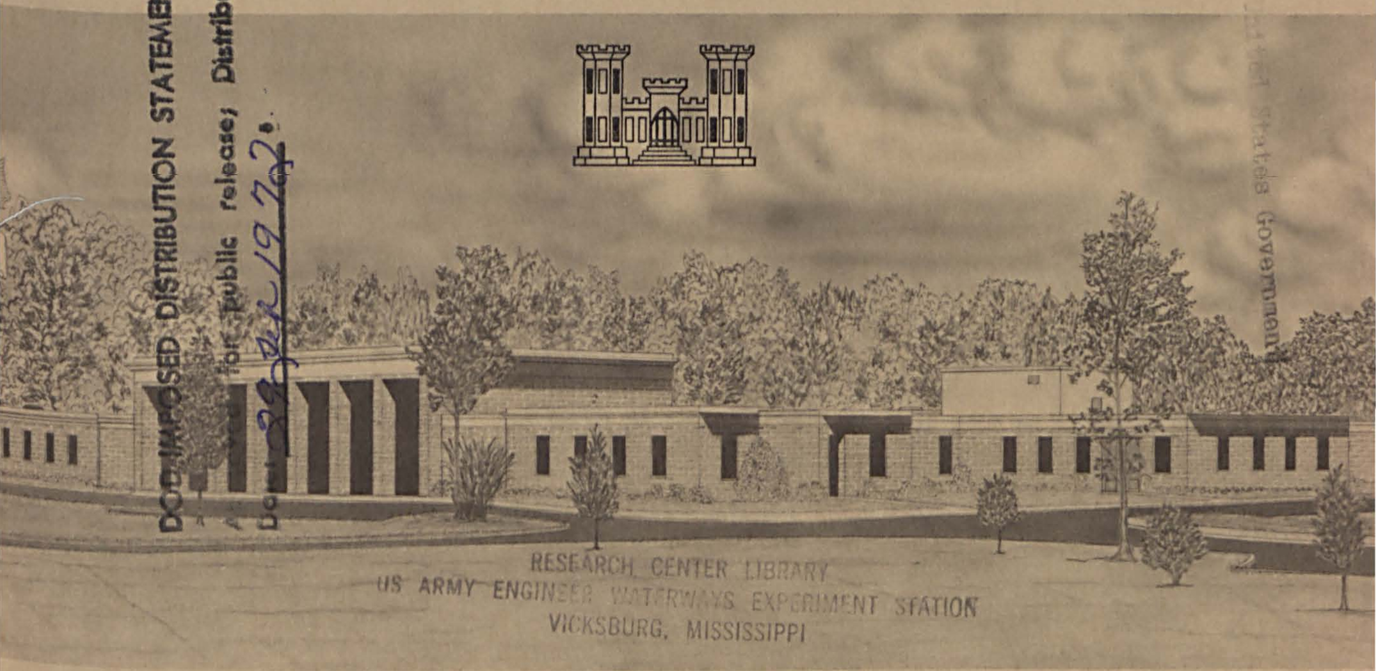

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July 1970

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Conducted by U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi

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ASSOCIATED REPORTS

Report No.	Title	Date
MP C-69-3	Tests of Rock Cores, Warren Area, Wyoming	March 1969
MP C-69-12	Tests of Rock Cores, Mountain Home, Idaho, and Fairchild, Washington, Areas	September 1969
MP C-69-16	Tests of Rock Cores, Castle Study Area, California	October 1969
MP C-70-4	Tests of Rock Cores, Bergstrom Study Area, Texas	February 1970
MP C-70-6	Tests of Rock Cores, Scott Study Area, Missouri	May 1970
MP C-70-7	Tests of Rock Cores, Plattsburgh Study Area, New York	June 1970
MP C-70-9	Tests of Rock Cores, Duluth-Vermillion Study Area, Minnesota	June 1970
MP C-70-10	Tests of Rock Cores, Michigamme Study Area, Michigan	June 1970

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29 February 1972

SUBJECT OF CONVERSATION

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Mr. James M. Polatty	Concrete Division	

PERSON CALLED	ADDRESS	PHONE NUMBER AND EXTENSION
Captain B. W. Bullard	Space & Missile Systems Organization	

SUMMARY OF CONVERSATION

I called SAMSO and talked to CPT Bullard. CPT Bullard was familiar with the WES reports covering rock tests for SAMSO. I explained the requirements of AR 70-31. He agreed that Statement A should be utilized on all of the SAMSO rock test reports.

James M. Polatty

JAMES M. POLATTY, Chief
Engineering Mechanics Branch
Concrete Division

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Laura Hanisee said following MP's/covering rock tests for SAMSO were to be changed to Statement A :

C-69-3
C-69-12
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C-70-6
C-70-7
C-70-9
C-70-10
C-70-11
C-70-14
C-70-16
C-70-17

DA FORM 751, 1 APR 66 REPLACES EDITION OF 1 FEB 50 WHICH WILL BE USED.

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MISCELLANEOUS PAPER C-70-11

TESTS OF ROCK CORES
PEASE STUDY AREA, NEW HAMPSHIRE

by

R. W. Crisp

July 1970

Sponsored by Space and Missile Systems Organization, U. S. Air Force Systems Command

Conducted by U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi

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ABSTRACT

Laboratory tests were conducted on rock core samples received from six core holes in the Pease study area of Belknap, Cheshire, Grafton, and Merrimack Counties in New Hampshire. Results were used to determine the quality and uniformity of the rock to depths of 200 feet below ground surface.

The rock core was petrographically identified as predominately mica gneiss, mica schist, dacite, granite gneiss, and muscovite granodiorite, with relatively minor quantities of tonalite, granodiorite gneiss, and basaltic material.

Evaluation of the Pease study area core on a hole-to-hole basis indicates the moderately fractured and intact dacite removed from Hole PZ-CR-36 to be very competent rock. The highly fractured core, removed at depths of 40 feet or less below ground surface, was marginal in quality. Generally, this hole yielded material representative of competent, hard rock media.

The remainder of the holes from this area, i.e., PZ-CR-2, -11, -23, -25, and -34, generally yielded rock core exhibiting physical properties characteristic of marginal to barely competent material. Holes PZ-CR-11, -23, and -34 yielded incompetent core from depths greater than 50 feet below ground surface, dictating classification of the core as unsuitable as competent media. Holes PZ-CR-2 and

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-25 yielded significant quantities of rock of marginal quality, but, dependent on results of possible further investigation, could offer some possibility as competent hard rock media.

The above evaluations and conclusions have been based on somewhat limited data; therefore, more extensive investigation will be required in order to accurately assess the individual areas under consideration.

PREFACE

This study was conducted in the Concrete Division of the U. S. Army Engineer Waterways Experiment Station (WES) under the sponsorship of the U. S. Air Force Space and Missile Systems Organization (SAMSO) of the Air Force Systems Command. The study was coordinated with CPT Rupert G. Tart, Jr., SAMSO Project Officer, Norton Air Force Base, San Bernardino, California. The work was accomplished during November 1969 through April 1970 under the general supervision of Mr. Bryant Mather, Chief, Concrete Division, and under the direct supervision of Messrs. J. M. Polatty, Chief, Engineering Mechanics Branch, W. O. Tynes, Chief, Concrete and Rock Properties Section, and K. L. Saucier, Project Officer. Mr. C. R. Hallford was responsible for the petrography work. Mr. R. W. Crisp performed the majority of the program analysis and prepared this report.

Directors of the WES during the investigation and the preparation and publication of this report were COL Levi A. Brown, CE, and COL Ernest D. Peixotto, CE. Technical Director was Mr. F. R. Brown.

CONTENTS

CONVERSION FACTORS, BRITISH TO METRIC UNITS OF MEASUREMENT

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

Multiply	By	To Obtain
inches	2.54	centimeters
feet	0.3048	meters
miles (U. S. statute)	1.609344	kilometers
feet per second	0.3048	meters per second
pounds	0.45359237	kilograms
pounds per square inch	0.070307	kilograms (force) per square centimeter
	6,894.757	newtons per square meter

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

The purpose of this study was to supplement the information being obtained for the area evaluation study by the U. S. Air Force Space and Missile Systems Organization (SAMSO). It was necessary to determine the individual properties of the specific materials for an analysis of the quality and uniformity of the rock. Results of tests on cores from the Pease study area of Belknap, Cheshire, Grafton, and Merrimack Counties in New Hampshire are reported herein.

1.2 OBJECTIVE

The objective of this investigation was to conduct laboratory tests on samples from areas containing hard, near-surface rock to determine the integrity and the mechanical behavior of the materials as completely as possible, analyze the data thus obtained, and report the results to appropriate parties.

1.3 SCOPE

Laboratory tests were conducted on samples received from the field as indicated in the following paragraph. Table 1.1 gives pertinent information on the various tests.

Tests were conducted to determine the general quality, uniformity, and integrity of the rock in the area. The following properties were determined: (1) relative hardness (Schmidt number), (2) specific gravity, (3) ultimate uniaxial compressive strength, and (4) dynamic elastic properties. Additional tests conducted (1) to evaluate the degree of anisotropy of the sampled rock and (2) to compare direct and indirect tensile strengths of the various types present were: (1) dynamic elastic properties along three mutually perpendicular axes and (2) direct and Brazilian tensile tests. A limited petrographic examination was also conducted.

1.4 SAMPLES

Samples were received from six holes in the Pease study area designated as PZ-CR-2, -11, -23, -25, -34, and -36. All samples were NX-size cores (nominal 2-1/8-inch[1] diameter). Test specimens of the required dimensions, as given in Table 1.1, were prepared for the individual tests. Quality and uniformity tests were conducted on selected specimens from all holes. Special tests were conducted on specimens selected from the various core holes to represent differences in rock type, weathering, etc.

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[1] A table of factors for converting British units of measurement to metric units is presented on page 8.

1.5 REPORT REQUIREMENTS

The immediate need for the test results required that data reports be compiled and forwarded to responsible parties as work was completed on each hole. The data reports of the individual test results are included herein as Appendixes A through F.

TABLE 1.1 SUMMARY OF TESTS

Test	Specimen Size	Test Equipment	Recording Equipment	Measured Properties	Computed Properties
Relative hardness	1 diameter by 2 diameters	Schmidt hammer	--	Relative hardness	--
Specific gravity	↓	Scales	--	Specific gravity	Density
Indirect tension	↓	440,000-pound test machine	--	Tensile strength	--
Direct tension	↓	30,000-pound test machine	--	Tensile strength	--
Unconfined compression	↓	440,000-pound test machine	X-Y recorder	Compressive strength	--
Cyclic compression	↓	440,000-pound test machine	X-Y recorder	Compressive strength	Young's, shear, and bulk moduli and Poisson's ratio
Dynamic elastic moduli	↓	Pulse generator, amplifiers	Oscilloscope	Compressional and shear velocity	Young's, shear, and bulk moduli and Poisson's ratio
Sonic velocity	↓	Pulse generator, amplifiers	Oscilloscope	Compressional and shear velocity	--
Petrographic examination	Variable	Microscopes, X-ray diffraction	--	Appearance, texture, and mineralogy	--
Anisotropy	1 diameter by 1 diameter	Pulse generator, amplifiers	Oscilloscope	Compressional and shear velocities in three-orthogonal directions	Young's, shear, and bulk moduli and Poisson's ratio

CHAPTER 2

TEST METHODS

2.1 SCHMIDT NUMBER

The Schmidt number is a measure of the relative degree of hardness as determined by the degree of rebound of a small mass propelled against a test surface. The test was conducted as suggested in Reference 1 (a Swiss-made hammer was used) except that 8 to 12 readings per specimen were made. The average of these readings is the Schmidt number or relative hardness. The hardness is often taken as an approximation of rock quality, and may be correlated with other physical characteristics such as strength, density, and modulus.

2.2 SPECIFIC GRAVITY

The specific gravity of the "as-received" samples was determined by the loss of weight method conducted according to method CRD-C 107 (Reference 2). A pycnometer is utilized to determine the loss of weight of the sample upon submergence. The specific gravity is equal to the weight in air divided by the loss of weight in water.

2.3 INDIRECT TENSION

The tensile strength was determined by the indirect method, commonly referred to as the tensile splitting or Brazilian method, in which a tensile failure stress is induced in a cylindrical test specimen by a compressive force applied on two diametrically opposite line elements of the cylindrical surface. The test was conducted according to method CRD-C 77 (Reference 2).

2.4 DIRECT TENSION

For purposes of comparison, specimens were prepared and tested for tensile strength according to the American Society for Testing and Materials (ASTM) proposed "Standard Method of Test for Direct Tensile Strength of Rock Core Specimens." Tensile splitting tests were conducted on specimens cut adjacent to the direct tensile test specimens.

For the direct tension tests, the specimens were right circular cylinders, the sides of which were straight to within 0.01 inch over the full length of the specimen and the ends of which were parallel and not departing from perpendicularity to the axis of the specimen by more than 0.25 degree. Cylindrical metal caps were cemented to the ends of the specimen and provided the means for applying the direct tensile load. The load was applied continuously by a 30,000-pound-capacity universal testing machine and at a constant rate such that failure occurred within 5 to 15 minutes.

2.5 COMPRESSIVE STRENGTH TESTS

The unconfined and cyclic compression test specimens were prepared according to ASTM and Corps of Engineers standard method of test for triaxial strength of undrained rock core specimens, CRD-C 147 (Reference 2). Essentially, the specimens were cut with a diamond blade saw, and the cut surfaces were ground to a tolerance of 0.001 inch across any diameter with a surface grinder prior to testing. Electrical resistance strain gages were utilized for strain measurements, two each in the axial (vertical) and horizontal (diametral) directions. Static Young's, bulk, shear, and constrained moduli were computed from strain measurements. Stress was applied with a 440,000-pound-capacity universal testing machine.

2.6 DYNAMIC ELASTIC PROPERTIES

Compressional and shear wave velocities, bulk, shear, and Young's moduli, and Poisson's ratio were determined by the ASTM proposed "Standard Method of Test for Laboratory Determination of Ultrasonic Pulse Velocities and Elastic Constants of Rock." The method consisted essentially of generating a wave in the specimen with a pulse generator unit and measuring, with an oscilloscope, the time required for the compression and shear waves to travel the length of the specimen, the resulting wave velocity being the distance traveled divided by the travel time. These compressive and shear velocities, along with the bulk density of the specimen, were used to compute the elastic properties.

In the case of the special tests used to determine the degree of anisotropy of the samples, compression and shear velocities were measured along two mutually perpendicular, diametrical (lateral) axes and along the longitudinal axis. This was facilitated by grinding four 1/2-inch-wide strips down the sides of the cylindrical surface at 90-degree angles and generating the compressive and shear waves perpendicular to these ground surfaces.

2.7 PETROGRAPHIC EXAMINATION

A limited petrographic examination was conducted on samples selected to be representative of the material from the several holes. The examination was limited to identifying the rock, determining general condition, identifying mineralogical constituents, and noting any unusual characteristics which may have influenced the test results.

CHAPTER 3

RESULTS OF QUALITY AND UNIFORMITY TESTS

3.1 TESTS UTILIZED

As with testing and data analysis of core from study areas previously evaluated,[1] the following physical properties were used in evaluating the quality and uniformity of the Pease core: Schmidt number, specific gravity, ultimate uniaxial compressive strength, and compressional wave velocity. Dynamic elastic constants were determined for selected representative specimens and results were compared with static elastic constants determined for these same specimens. Static moduli were based on a Poisson's ratio and tangent modulus of elasticity computed at 50 percent of ultimate uniaxial compressive strength.

The core received from the Pease study area was quite varied in composition, comprised of five principal rock types: (1) mica gneiss, (2) mica schist, (3) dacite, (4) granite gneiss, and (5) muscovite granodiorite. Relatively insignificant quantities of other rock types (tonalite, granodiorite gneiss, and basaltic material) were also received from the area. Differences in ultimate uniaxial

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[1] A list of associated reports is given on the inside front cover of this report.

compressive strength appear to have arisen from variation in rock type coupled with variation in nature, number, and inclination of fractures present in the individual specimens.

To facilitate analysis, data were generally grouped according to rock type, and, where applicable, these general groupings were subdivided according to physical conditions as defined below:

1. Intact rock core, which was macroscopically free of joints, seams, vesicles, and/or fractures.

2. Moderately fractured rock core containing horizontally or vertically oriented fractures.

3. Critically to highly fractured rock core containing well-developed systems of fracture, or critically oriented fractures, i.e., fractures inclined with respect to the horizontal at angles so as to result in the development of shearing stresses of failure magnitude when the specimen is subjected to relatively low axial stress.

4. Rock containing vesicles.

Detailed physical test results are presented in Appendixes A through F; summaries of the results are tabulated in the various sections of this chapter.

3.2 MICA GNEISS

All of the rock specimens received from Hole PZ-CR-2, and portions of those received from Holes PZ-CR-11 and -34, were petrographically identified as mica gneiss. Relatively few specimens contained fractures, the majority of the core being intact. One specimen tested contained a biotite inclusion.

A summary of the test results is given below. Detailed results are given in Appendixes A, B, and E.

Hole No.	Specimen No.	Specific Gravity	Schmidt No.	Ultimate Uniaxial Compressive Strength	Compressional Wave Velocity	Core Description
				psi	fps	
PZ-CR-2	5	2.72	44.2	10,710	10,840	Intact
	7	2.73	39.6	12,400	10,360	Intact
	8	2.72	43.5	13,460	11,220	Intact
	11	2.73	44.8	14,870	10,090	Intact
	15	2.71	35.8	14,480	9,910	Moderately fractured
	16	2.74	40.0	8,450	10,830	Intact
	17	2.72	--	10,450	10,100	Moderately fractured
	19	2.73	41.2	12,300	10,160	Intact
	22	2.73	39.6	9,760	9,660	Contained biotite inclusion
PZ-CR-11	3	2.83	44.2	11,970	16,500	Intact
	8	2.85	41.3	10,580	17,170	Critically oriented fracture
	12	2.81	40.7	10,230	15,680	Intact
	13	2.73	42.4	19,030	16,400	Intact
	15	2.89	44.4	17,330	18,480	Intact
	19	2.97	47.2	17,390	20,540	Intact
	21	2.90	44.9	23,030	19,520	Intact
PZ-CR-34	9	2.71	--	21,770	14,960	Intact
	21	2.82	43.6	11,640	15,880	Intact
	Average	2.78	42.3	13,880	13,790	

Physical properties exhibited by the fractured specimens appeared to be only slightly, if at all, affected by the presence of fractures, as these test results were generally comparable to those of the intact mica gneiss from the same core holes.

Ultimate uniaxial compressive strengths were somewhat variable, ranging from approximately 8,500 to 23,000 psi. The ultimate compressive strengths yielded by specimens from Hole PZ-CR-2 were generally lower than those exhibited by the mica gneisses from the other two holes. These lower strengths were probably due to the very well-developed foliation coupled with the high degree of mineral segregation (see Figure 4.5) characteristic of the PZ-CR-2 gneisses.

Compressional wave velocities were also rather variable, ranging from approximately 10,000 to 20,000 fps. Expectedly, the higher velocities were generally exhibited by the stronger specimens. The unusually low velocities exhibited by the core from Hole PZ-CR-2 probably resulted from the same physical characteristics discussed in the immediately preceding paragraph, the foliation and mineral segregation resulting in longer paths of travel and travel times.

Dynamic elastic constants determined for the well-foliated mica gneiss from Hole PZ-CR-2 were, due to the low compressional wave velocities measured, very low, but they were quite uniform.

Dynamic elastic constants determined for the poorly foliated mica gneisses from Holes PZ-CR-11 and -34 were considerably higher. Overall, the dynamic elastic constants correlated rather well with the variations in ultimate uniaxial compressive strength and compressional wave velocity previously discussed.

As indicated in the following tabulation, static elastic constants were generally somewhat lower than their corresponding dynamic values.

Hole No.	Specimen No.	Modulus			Shear Velocity	Poisson's Ratio
		Young's	Bulk	Shear		
		10^6 psi	10^6 psi	10^6 psi	fps	
Dynamic Tests:						
PZ-CR-2	5	4.2	1.8	1.8	7,105	0.12
	7	3.6	2.0	1.5	6,360	0.20
	8	4.4	2.1	1.9	7,170	0.15
	11	3.7	1.4	1.7	6,835	0.08
	15	3.6	1.4	1.6	6,710	0.08
	16	4.0	2.1	1.7	6,780	0.18
	17	3.0	2.2	1.2	5,625	0.27
	19	3.7	1.6	1.7	6,730	0.11
	22	2.7	2.0	1.0	5,340	0.28
PZ-CR-11	3	8.2	6.1	3.2	9,140	0.28
	8	8.1	7.2	3.1	8,980	0.31
	15	8.0	9.4	2.9	8,675	0.36
	19	13.5	9.8	5.3	11,515	0.27
	21	12.0	8.6	4.8	11,035	0.27
PZ-CR-34	9	7.0	4.4	2.9	8,815	0.23
	21	8.1	5.3	3.2	9,225	0.25
Static Tests:						
PZ-CR-2	5	3.8	1.9	1.7	--	0.16
	15	4.1	2.2	1.7	--	0.19
	16	2.6	2.2	1.1	--	0.15
PZ-CR-11	8	7.1	3.4	3.1	--	0.15
PZ-CR-34	21	5.3	2.2	2.4	--	0.09

Cyclic stress-strain curves determined for several specimens revealed the majority of the mica gneiss so tested to be somewhat inelastic, frequently exhibiting considerable hysteresis and residual strain.

3.3 MICA SCHIST

A portion of the core received from Holes PZ-CR-11 and -34 was petrographically identified as mica schist, this rock type being basically the same as the mica gneiss previously discussed with some differences in structure and texture. Three of the specimens tested contained pegmatite bands. Several specimens contained fractures. Two of the specimens tested from Hole PZ-CR-11 were vesicular.

A tabulation of physical test results is given below. Detailed results are given in Appendixes B and E.

Hole No.	Specimen No.	Specific Gravity	Schmidt No.	Ultimate Uniaxial Compressive Strength	Compressional Wave Velocity	Core Description
				psi	fps	
PZ-CR-11	4	2.95	45.6	15,000	19,090	Intact
	14	2.78[a]	--	6,120[a]	15,420[a]	Vesicular
	16	2.58[a]	--	4,240[a]	9,280[a]	Vesicular
PZ-CR-34	3	2.69	50.9	19,120	17,165	Moderately fractured, slightly weathered
	4	2.65	37.7	23,030	10,605	Contained pegmatite band
	7	2.64	48.1	18,450	13,290	Contained pegmatite band
	11	2.72	45.0	17,760	15,045	Intact
	14	2.68	44.8	13,090	13,045	Intact
	15	2.83	43.7	12,320	12,360	Intact
	18	2.72	39.7	14,550	14,500	Contained pegmatite band
	25	2.77	45.3	16,880	16,735	Intact
	Average	2.74	44.5	16,690	14,650	

[a] Results of physical tests on two vesicular specimens were not included in the average.

Ultimate uniaxial compressive strengths yielded by the mica schist from this area were, on the average, slightly higher than those determined for the mica gneisses previously discussed. This generality was not true of the two vesicular specimens from Hole PZ-CR-11, which were quite weak, probably due to a combination of vesicles and very strong (45-degree) foliation (see Figure 3.1).

Compressional wave velocities determined for the mica schist were rather low, similar to those exhibited by the mica gneiss.

As indicated in the tabulation below, elastic constants determined for this portion of the core were quite variable, the values of a particular constant ranging widely for the various specimens tested.

Hole No.	Specimen No.	Modulus			Shear Velocity	Poisson's Ratio
		Young's	Bulk	Shear		
		10^6 psi	10^6 psi	10^6 psi	fps	
Dynamic Tests:						
PZ-CR-11	4	11.1	8.7	4.3	10,455	0.29
	14	7.4	5.0	2.9	8,865	0.25
	16	3.0	1.1	1.4	6,330	0.06
PZ-CR-34	3	7.7	6.7	3.0	9,020	0.31
	4	3.7	2.0	1.6	6,585	0.19
	7	5.3	3.4	2.1	7,755	0.24
	11	7.3	4.3	3.0	9,080	0.21
	14	5.5	3.1	2.3	7,925	0.21
	15	5.0	2.6	2.1	7,755	0.18
	18	6.7	1.4	4.7	11,350	--[a]
	25	10.4	3.7	5.0	11,640	--[a]
Static Tests:						
PZ-CR-11	16	1.2	0.6	0.5	--	0.14
PZ-CR-34	25	7.4	5.7	3.0	--	0.28

[a] Due to the unusually high shear velocity to compressional wave velocity ratio, Poisson's ratio for these specimens could not be reliably determined.

The rather wide range in value of the various dynamic elastic constants determined was probably due to variation in extent of foliation and angle of inclination of this foliation with respect to the horizontal, coupled with variation in the garnet content of the specimens from Hole PZ-CR-11.

The mica schist specimens subjected to cyclic compression tests yielded stress-strain curves which were characteristic of relatively inelastic materials, exhibiting considerable hysteresis and residual strain.

3.4 MUSCOVITE GRANODIORITE

The entire core received from Hole PZ-CR-25 was petrographically identified as muscovite granodiorite. The core from the upper portion of the hole was slightly weathered. The majority of the core was intact.

A summary of the test results is given below. Detailed results are given in Appendix D.

Hole No.	Specimen No.	Specific Gravity	Schmidt No.	Ultimate Uniaxial Compressive Strength	Compressional Wave Velocity	Core Description
				psi	fps	
PZ-CR-25	1	2.65	--	9,440	11,100	Slightly weathered
	2	2.64	36.8	9,610	9,385	Slightly weathered
	5	2.64	40.1	15,260	8,140	Intact
	8	2.64	36.3	8,820	7,735	Intact
	11	2.65	51.8	9,760	8,425	Intact
	13	2.64	45.3	9,210	9,975	Moderately fractured
	15	2.64	47.2	15,240	10,725	Intact
	18	2.65	48.4	14,080	8,935	Intact
	21	2.65	46.7	15,450	8,950	Intact
	23	2.65	48.3	14,390	10,075	Intact
	Average	2.64	44.5	12,130	9,345	

The ultimate uniaxial compressive strengths exhibited by this material were relatively uniform, but rather low, ranging from 8,820 to 15,450 psi. Generally, the weaker specimens were either slightly weathered or contained fractures; two of the weaker specimens tested, however, were intact.

Compressional wave velocities determined for the muscovite granodiorite were also rather uniform, but very low. These exceptionally low velocities, originally determined by the ASTM proposed "Standard Method of Test for Determination of Ultrasonic Pulse Velocities and Elastic Constants of Rock" and then verified by the resonant frequency method, were probably due to the very high mica content indicated by the petrographic analysis.

Specific gravities yielded by the muscovite granodiorite specimens were unusually uniform and ranged only from 2.64 to 2.65 for the 10 specimens tested over the full 200-foot range in core hole depth.

As indicated in the tabulation below, elastic constants determined for this material were also very low, but uniform.

Hole No.	Specimen No.	Modulus			Shear Velocity	Poisson's Ratio
		Young's	Bulk	Shear		
		10^6 psi	10^6 psi	10^6 psi	fps	
Dynamic Tests:						
PZ-CR-25	1	3.8	2.4	1.5	6,525	0.24
	2	3.0	1.4	1.3	6,115	0.13

(Continued)

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Hole No.	Specimen No.	Modulus			Shear Velocity	Poisson's Ratio
		Young's	Bulk	Shear		
		10^6 psi	10^6 psi	10^6 psi	fps	
Dynamic Tests: (Continued)						
PZ-CR-25 (Continued)	5	2.2	1.1	0.9	5,115	0.16
	8	2.0	1.0	0.9	4,910	0.16
	11	2.5	0.8	1.3	5,985	--[a]
	13	3.2	1.8	1.3	6,140	0.20
	15	3.7	2.0	1.6	6,655	0.19
	18	2.8	1.2	1.2	5,900	0.11
	21	2.8	1.1	1.3	6,105	0.07
	23	3.5	1.5	1.6	6,670	0.11
	Average	3.0	1.4	1.3	6,010	0.15
Static Tests:						
PZ-CR-25	2	2.9	2.2	1.1	--	0.28
	13	3.4	1.5	1.5	--	0.12
	21	4.5	2.5	1.9	--	0.20
	Average	3.6	2.1	1.5	--	0.20

[a] Due to the unusually large shear velocity to compressional velocity ratio, the dynamic Poisson's ratio for this specimen could not be accurately determined.

For those specimens on which both tests were conducted, static elastic constants were of the same approximate magnitude as their corresponding dynamic values.

Stress-strain curves revealed the muscovite granodiorite to be a relatively inelastic material which exhibited substantial hysteresis and residual strain upon cycling.

3.5 DACITE PORPHYRY

The majority of the core received from Hole PZ-CR-36 was petrographically identified as dacite porphyry; Specimens 1, 2, and 3 were identified as black and white tonalite. Several specimens contained fractures; one was severely fractured.

A summary of the physical test results is given below. Detailed results are given in Appendix F.

Hole No.	Specimen No.	Specific Gravity	Schmidt No.	Ultimate Uniaxial Compressive Strength	Compressional Wave Velocity	Core Description
				psi	fps	
PZ-CR-36	4	2.67	56.0	34,700	16,660	Intact
	5	2.59[a]	49.6[a]	9,640[a]	14,810[a]	Severely fractured
	6	2.61	50.8	37,880	15,365	Intact
	9	2.61	57.8	25,000	14,200	Moderately fractured
	12	2.61	54.2	43,180	15,005	Intact
	15	2.61	58.1	40,910	12,370	Intact
	18	2.67	53.3	37,880	13,080	Moderately fractured
	20	2.65	52.9	39,090	14,265	Moderately fractured
	Average	2.63	54.7	36,950	14,420	

[a] Physical test results for this specimen not included in average.

Ultimate uniaxial compressive strengths yielded by the intact and moderately fractured dacite porphyry specimens were the greatest exhibited by any rock from the Pease study area. With the exception of the single severely fractured specimen, which failed at an ultimate strength of 9,640 psi, the dacite porphyry exhibited ultimate compressive strengths averaging approximately 37,000 psi, twice as strong in uniaxial compression as the next most competent rock from this area.

Compressional wave velocities, while generally not as low as those exhibited by some specimens from this area, were unusually low for a material of such high ultimate uniaxial compressive strength. Apparently, the many fine-grained inclusions scattered throughout the core resulted in longer than usual travel paths and travel times and, as a consequence, lower wave velocities. The absence of correlation of compressional wave velocity with nature and degree of fracturing would seem to indicate that fracturing had little, if any, effect on wave velocity.

Like the compressional wave velocities discussed above, elastic constants determined for the dacite porphyry were rather low for a material of such high ultimate uniaxial compressive strength. The constants, however, as indicated in the tabulation below, were particularly uniform.

Hole No.	Specimen No.	Modulus			Shear Velocity	Poisson's Ratio
		Young's	Bulk	Shear		
		10^6 psi	10^6 psi	10^6 psi	fps	
Dynamic Tests:						
PZ-CR-36	4	7.3	6.3	2.8	8,805	0.31
	5	6.8	4.0	2.8	8,935	0.21
	6	6.9	4.6	2.8	8,865	0.25
	9	6.0	3.8	2.4	8,315	0.24
	12	6.7	4.4	2.7	8,730	0.24
	15	5.2	2.2	2.4	8,225	0.10
	18	5.5	3.1	2.3	8,000	0.20
	20	6.4	3.8	2.6	8,535	0.22
	Average	6.4	4.0	2.6	8,550	0.22
Static Tests:						
PZ-CR-36	12	8.5	4.7	3.5	--	0.20
	18	9.4	5.7	3.9	--	0.22
	Average	9.0	5.2	3.7	--	0.21

For the two specimens on which comparisons could be made, static elastic constants were generally slightly higher than the corresponding dynamic values.

Stress-strain curves determined for two specimens of dacite porphyry revealed this material to be slightly inelastic. Upon being subjected to cyclic compressive tests, these specimens exhibited slight hysteresis and residual strain. The initial upward concavity of the stress-strain curves was probably due to crack closure during the initial stages of loading.

3.6 GRANITE GNEISS AND GRANODIORITE GNEISS

All of the cores from Hole PZ-CR-23 were petrographically identified as gneiss, the majority being granite and granodiorite gneiss. Several of the granodiorite gneiss specimens contained fractures. Most of the specimens were intact.

A summary of the physical test results is given below. Detailed results are given in Appendix C.

Hole No.	Specimen No.	Specific Gravity	Schmidt No.	Ultimate Uniaxial Compressive Strength	Compressional Wave Velocity	Core Description
				psi	fps	
PZ-CR-23	7	2.60	37.2	6,060	9,040	Moderately fractured granodiorite gneiss
	8	2.64	44.8	13,240	11,555	Moderately fractured granodiorite gneiss
	10	2.67	--	11,050	14,655	Intact granite gneiss
	11	2.63	52.8	13,530	12,340	Intact granite gneiss
	17	2.67	53.4	11,970	12,195	Intact granite gneiss
	19	2.78	49.8	7,760	14,510	Intact granite gneiss
	Average	2.66	47.6	10,600	12,380	

Ultimate uniaxial compressive strengths yielded by these materials were moderate to rather low in magnitude, similar to those exhibited by the mica gneiss and muscovite granodiorite from the Pease area (previously discussed). Nature and degree of fracturing had no immediately obvious effect on ultimate strength; intact specimens yielded both high and low (relatively speaking) strengths. As indicated in Figure 3.2, orientation of the plates of mica may have been responsible for the lower compressive strengths.

Compressional wave velocities were also comparable to those determined for much of the material previously discussed, rather low in magnitude and varying somewhat. These low velocities, and the low strengths mentioned above, were probably due to the presence of very large concentrations of mica throughout the core.

As indicated in the tabulation below, elastic constants determined for these gneisses were somewhat variable, but generally were in the same range as the constants determined for the various other rock types from this area.

Hole No.	Specimen No.	Modulus			Shear Velocity	Poisson's Ratio
		Young's	Bulk	Shear		
		10^6 psi	10^6 psi	10^6 psi	fps	
Dynamic Tests:						
PZ-CR-23	7	2.1	1.8	0.8	4,840	0.30
	8	4.3	2.4	1.8	7,095	0.20
	10	6.0	4.6	2.4	8,090	0.28
	11	5.2	2.3	2.3	8,070	0.13
	17	5.3	1.6	2.9	8,865	--[a]
	19	6.0	4.8	2.3	7,855	0.29
	Average	4.8	2.9	2.1	7,470	0.24

(Continued)

[a] Due to the unusually large shear velocity to compressional velocity ratio, the dynamic Poisson's ratio for this specimen could not be accurately determined.

Hole No.	Specimen No.	Modulus			Shear Velocity	Poisson's Ratio
		Young's	Bulk	Shear		
		10^6 psi	10^6 psi	10^6 psi	fps	
Static Tests:						
PZ-CR-23	8	4.8	2.0	2.1	--	0.11
	17	5.6	2.9	2.3	--	0.18
	Average	5.2	2.4	2.2	--	0.14

Cyclic stress-strain curves plotted during the static tests on representative specimens revealed these gneisses to be somewhat inelastic, not unlike the rock types previously discussed. Significant hysteresis and residual strain were detected upon cycling.

3.7 OTHER ROCK TYPES

Also tested, but not discussed in previous sections of this chapter, were two specimens representing gneissic inclusions in Hole PZ-CR-23, one specimen of basaltic material received from Hole PZ-CR-34, and one specimen of black and white tonalite from Hole PZ-CR-36.

Physical test results yielded by the tonalite specimen and the two specimens representing gneissic inclusive material were generally similar to the results exhibited by the more common materials received from Holes PZ-CR-23 and -36, and therefore, warrant no additional comment or evaluation. Test results are given in Appendixes C and F.

Physical characteristics exhibited by the basaltic specimen received from Hole PZ-CR-34 were, however, the least competent of any specimen from this hole and thus might require additional evaluation. This specimen was the only one from Hole PZ-CR-34 to yield an ultimate uniaxial compressive strength of less than 8,000 psi.

Figure 3.1 Core PZ-CR-11, Specimen 16. The plane of failure in this schist was parallel to the foliation, which was at 45 degrees. This section failed at 4,240 psi.

Figure 3.2 Core PZ-CR-23, Specimen 7. The top half of the photograph shows the planes along which the section failed during compressive tests. The lower half shows a mica layer inclined at about 40 degrees along which failure occurred.

CHAPTER 4

SPECIAL TESTS

4.1 ANISOTROPY TESTS

Eight rock specimens from the Pease area were selected and prepared for determination of compressional and shear velocities according to the ASTM proposed "Standard Method of Test for Laboratory Determination of Ultrasonic Pulse Velocities and Elastic Constants of Rock," as discussed in Section 2.6. The NX-diameter specimens were cut to lengths of 2 inches and ground on the ends to a tolerance of 0.001 inch. Four 1/2-inch-wide strips were also ground down the sides of the cylindrical surface at 90-degree angles. The velocities, densities, and dimensions were measured as specified in the proposed test method. Results of velocity determinations are given in Table 4.1.

Compressional and shear wave velocities exhibited by the specimens tested were rather variable, generally low to moderate in magnitude. The lowest velocities were exhibited by the well-foliated mica gneiss and the muscovite granodiorite which contained unusually large percentages of muscovite and biotite.

Deviations from the average compressional wave velocity were, in most instances, quite high--frequently exceeding 10 percent. In all cases, deviations from the average exceeded 5 percent. These high but varying degrees of anisotropy are apparently due to the well-foliated and porphyritic nature of much of the material from this area, the lesser degrees of anisotropy being characteristic of the slightly foliated and/or finer grained specimens.

A compilation of the elastic properties computed from the compressive and shear velocities and the specific gravity is given in Table 4.2. However, particular discretion must be used in utilizing the moduli results as experimental errors are introduced when the differences in velocities are significant. The proposed ASTM test method states that the equations for computation of elastic moduli should not be used if "any of the three compressional wave velocities varies by more than 2 percent from their average value. The error in E and G due to both anisotropy and experimental error then does not exceed 6 percent." Naturally, the error is compounded by greater differences in the three-directional velocity measurements, as are present here.

4.2 COMPARATIVE TENSILE TESTS

Eight NX-diameter rock specimens were selected in an attempt to represent the variation of rock type present in the core received from the drill holes in the Pease study area. The specimens were prepared and tested for tensile strength according to the ASTM proposed "Standard Method of Test for Direct Tensile Strength of Rock

Core Specimens." For comparative purposes, tensile splitting tests were conducted on specimens cut adjacent to the direct tensile test specimens. The test results are given in Table 4.3.

Direct tensile strengths were generally rather low, in most cases less than 400 psi. The specimens which exhibited direct tensile strengths greater than 400 psi (i.e., 600, 640, and 1,090 psi) were the three mica gneiss specimens tested. The specimen which yielded the lowest direct strength was the only fractured specimen tested.

Indirect tensile strengths were generally somewhat higher than the corresponding direct tensile strengths, probably due to the more restricted location of the failure plane in the indirect test, resulting in less probability of failure occurring at a point of minimum strength.

Of the two specimens exhibiting characteristics which did not follow this trend, one was a well-foliated mica gneiss with foliation perpendicular to the plane of direct tensile stress and parallel to the plane of indirect tensile stress. In this case, the foliation and orientation were probably responsible for the indirect strength being lower than the corresponding direct value.

In most cases, the direct tensile strength should better reflect the minimum tensile strength characteristic of a particular rock specimen, since a specimen subjected to direct tension should be more prone to failure at a point of minimum strength, i.e., along fractures, etc.

4.3 PETROGRAPHIC EXAMINATION

4.3.1 Samples. Six boxes of NX core from holes in Belknap, Cheshire, Grafton, and Merrimack Counties, New Hampshire, were received in October and November 1969. Each box contained about 15 feet of core which represented several depths to 200 feet.

The cores were inspected to select representative pieces from all significant rock types for petrographic examination. The cores are described below:

1. Hole PZ-CR-2. The entire core was black and white, coarse-grained granitic mica gneiss. Specimens 15 and 17 contained sealed fractures and the remaining specimens were intact. All of the specimens showed a well-developed steep foliation.

2. Hole PZ-CR-11. This core was dark green and white, coarse-grained garnet mica gneiss and schist. Most of the gneissic specimens showed a poorly developed foliation while the schistose specimens contained a well-developed steep foliation.

Specimens 4, 6, 9, 14, 16, and 17 were schist; Specimens 8 and 19 were contacts between the schist and gneiss; the remaining specimens were gneiss. Specimens 11 and 12 of the gneiss were severely altered. Sealed fractures were common in the gneissic specimens.

3. Hole PZ-CR-23. The core was white and black, coarse-grained porphyritic granite gneiss with several inclusions of white, fine- to

coarse-grained granodiorite gneiss.

Specimens 6 through 9 and 21 were white pegmatitic granodiorite gneiss, and Specimens 1 and 22 were a fine-grained gneiss that appeared to have been an inclusion. Most of the specimens of porphyritic granite gneiss were intact and only Specimens 2 and 14 contained fractures.

4. Hole PZ-CR-25. This core was gray and white, coarse-grained muscovite granodiorite. The rock contained a large amount of muscovite and biotite mica. Specimens 1 and 2 were slightly weathered; Specimen 13 contained a sealed high-angle fracture; the remaining specimens were intact.

5. Hole PZ-CR-34. The core was black and white, fine- to coarse-grained mica gneiss and schist. Pegmatites were common in the upper portions of the core.

Specimens 1, 2, and 3 were fractured and weathered, and Specimens 4, 5, 7, 8, 16, and 18 contained pegmatite bands. All of these specimens were coarse-grained schist. Specimens 6, 9, 20, and 21 were fine-grained gneiss and Specimens 11 through 15, 17, 19, and 22 through 25 were coarse-grained schist. The fine-grained specimens and Specimens 12, 15, and 19 were banded and contained a 45-degree foliation. Specimen 10 was a black, fine-grained basaltic rock logged as trap rock.

Healed fractures were common in most of the specimens;

weathering was evident in the upper segments of the core.

6. Hole PZ-CR-36. This core was salmon pink, fine-grained dacite that was logged as metaarkosic conglomerate; however, further study revealed that the majority of this core was volcanic rock.

Specimens 5 through 16 were porphyry; Specimens 4 and 17 through 21 contained black and white inclusions. Specimens 1, 2, and 3 were black and white tonalites similar to the inclusions in Specimens 4 and 17 through 21. Specimen 5 contained several high-angle fractures and was the most severely fractured specimen in the core. Specimen 1 was slightly weathered.

The specimens selected for petrographic examination were:

Hole No.	Concrete Division Serial No.	Specimen No.	Approximate Depth	Rock Description
			feet	
PZ-CR-2	SAMSO-12, DC-3	12	110	Black and white, coarse-grained granitic mica gneiss
PZ-CR-11	SAMSO-12, DC-6	17	124	Dark green and white, coarse-grained garnet mica schist with large quartz pod
PZ-CR-23	SAMSO-12, DC-4	14	127	White and black, coarse-grained porphyritic granite gneiss
		21	190	Inclusion of white, fine- to coarse-grained granodiorite gneiss

(Continued)

Hole No.	Concrete Division Serial No.	Specimen No.	Approximate Depth	Rock Description
			feet	
PZ-CR-25	SAMSO-12, DC-5	17	140	Gray and white, coarse-grained muscovite granodiorite
PZ-CR-34	SAMSO-12, DC-1	12	101	Black and white, coarse-grained garnet mica gneiss
		21	165	Gray and white, fine-grained gneiss
PZ-CR-36	SAMSO-12, DC-2	10	79	Salmon pink, fine-grained dacite porphyry
		17	148	Salmon pink and black, medium-grained diorite inclusion in salmon pink porphyry

4.3.2 Test Procedure. Each piece of core was sawed axially. One sawed surface of each piece was polished and photographed. Composite samples were obtained from the whole length or from selected portions from the remaining half of each piece. The composite samples were ground to pass a No. 325 sieve (44 μm). X-ray diffraction (XRD) patterns were made of each sample as a tightly packed powder. All XRD patterns were made using an XRD-5 diffractometer with nickel-filtered copper radiation. The samples X-rayed are listed below:

Hole No.	Section No.	Description of X-ray Sample
PZ-CR-2	12	Entire length of section
PZ-CR-11	17	Entire length of section except quartz pod was sampled
PZ-CR-23	14	Entire length of section
	21	Entire length of section
PZ-CR-25	17	Entire length of section
PZ-CR-34	12	Entire length of section
	21	Entire length of section
PZ-CR-36	10	Entire length of section
	17	Inclusion and porphyry both sampled

Small portions of the powdered samples were tested with dilute hydrochloric acid and with a magnet to determine whether carbonate minerals or magnetite were present.

The polished surface of each section was examined with a stereomicroscope. Thin sections were prepared from each section of core and examined with a polarizing microscope. A point-count modal analysis was made on each thin section in which 500 points were counted.

4.3.3 Results. The cores examined from the Pease area can be divided into four groups: mica schist and gneiss, muscovite granodiorite (Reference 3), dacite porphyry (Reference 3), and granitic gneiss. The cores were taken from the middle Paleozoic rocks in central New Hampshire. The granite gneisses came from the Cardigan pluton of metamorphosed Kinsman quartz monzonite and Bethlehem gneiss (Reference 4) in west-central New Hampshire. The mica schists and gneisses were taken from the Devonian Littleton formation, which was intruded by the rocks of the Cardigan pluton. The muscovite granodiorites were taken from post-Devonian intrusive rocks to the east of the Cardigan pluton and may represent an outlier of the Conway granite. The dacite porphyry was taken from Belknap Mountains and was part of the White Mountain magma series (Reference 5).

The majority of the rocks from the Pease area had undergone at least one major thermal metamorphism (Reference 6). The effects of the metamorphism varied from core to core and in some areas varied within a core. The relation of the cores examined to the geologic units in the Pease area is summarized in Table 4.4. The modal composition of each rock type is shown in Tables 4.5, 4.6, and 4.7, and the bulk composition by XRD is shown in Tables 4.8, 4.9, and 4.10. The rocks in each core are discussed below:

1. Mica schists and gneisses. The rocks in Cores PZ-CR-11 and -34 were foliated, garnet-rich mica schists and gneisses from metasediments mapped as the Littleton formation. Porphyroblasts of quartz and garnet were common in most of the sections. These rocks range in degree of metamorphism from chlorite schists to garnet gneisses.

Section 17, Core PZ-CR-11, was dark green and white, coarse-grained garnet-mica schist, showing steeply dipping foliation that bends around quartz and feldspar porphyroblasts (Figure 4.1). Biotite was partially altered to chlorite and plagioclase was severely altered to sericite. Garnet and chlorite were present (Tables 4.5 and 4.8). Quartz was severely strained and broken and biotite was often bent or broken.

Section 12, Core PZ-CR-34, was black and white, medium-grained garnet gneiss. Several porphyroblasts of garnet disrupted the foliation which paralleled the compositional banding (Figure 4.2). Two visible fractures appeared normal to the foliation and at a high angle to it, and several microfractures parallel to the larger fractures were detected. Biotite was severely altered to chlorite, and plagioclase was partially altered to sericite. Quartz had been recrystallized.

Section 21, Core PZ-CR-34, resembled Section 12 in composition, but it was much finer grained and contained little chlorite (Figure 4.2). The section was banded and foliated parallel to the banding. The rock appeared to have been recrystallized. Figure 4.2 shows what may be traces of original cross-bedding in the section. The compositional banding suggests original shaly layers, now high in biotite, mixed sandy-shale layers, and sandstone layers in the original sediment.

2. Muscovite granodiorite. Only granodiorite was present in Core PZ-CR-25, and Section 17 was representative. This section was gray and white, coarse-grained muscovite granodiorite with inconspicuous lineation or foliation dipping about 40 degrees. Though the section appeared intact (Figure 4.3), there were many randomly oriented microfractures cutting it. Quartz had been severely strained and fractured, but the remaining minerals appeared fresh. Plagioclase, with an anorthite content of 34 percent, was slightly altered to sericite along microfractures. The modal composition is given in Table 4.6.

3. Dacites. These rocks were salmon pink, fine-grained dacite porphyries with a few diorite inclusions (Figure 4.4). Section 10 of Core PZ-CR-36 was representative of the dacites. It contained many rectangular phenocrysts of antiperthitic plagioclase feldspar in a fine-grained groundmass of quartz and feldspar. Section 17 of Core PZ-CR-36 was representative of the partially assimilated diorite inclusion (Figure 4.4). The inclusions consisted predominantly of plagioclase with biotite, and minor hornblende (Tables 4.6 and 4.9).

The plagioclase of Section 10 was severely altered to sericite, and the groundmass was so fine that it was almost impossible to make optical identifications.

4. Granite gneisses. Cores PZ-CR-23 and -2 were drilled in areas mapped as the Kinsman quartz monzonite and the Bethlehem gneiss

of the Cardigan pluton (Table 4.4). In part, these rocks were massive, foliated, mica-rich granitic gneisses. Many of the specimens had a well-developed porphyritic texture that frequently disrupted the foliation (Figure 4.5). Muscovite mica was common in these gneisses, apparently as a product of retrograde metamorphism (Reference 4).

Section 12, Core PZ-CR-2, was black and white, coarse-grained granitic-mica gneiss. The section showed a steep foliation and a few poorly developed quartz and plagioclase phenocrysts (Figure 4.5). Most of the grains have been stretched or sheared parallel to plane of the foliation and apparently have undergone minor recrystallization. Quartz was usually slightly strained and elongated. Plagioclase, with an anorthite content of 24 percent, and microcline, were slightly altered. Biotite and muscovite flakes were often bent, and biotite was partially altered to chlorite.

Section 14, Core PZ-CR-23, was black and white, coarse-grained porphyritic granitic gneiss. The large phenocrysts of quartz and plagioclase mask any evidence of foliation or flow structure in this section (Figure 4.5). The feldspars showed minor alteration to sericite, and biotite was partially altered to chlorite. Plagioclase, with an anorthite content of 26 percent, and microcline were much more abundant than in Section 12 of PZ-CR-2. This section contained many horizontal microfractures.

Section 21, Core PZ-CR-23, was gray and white, fine- to coarse-grained pegmatitic rock, apparently an inclusion or segregation with a somewhat different composition and texture. The section contained more plagioclase and less microcline than Section 14 of PZ-CR-23 and would be a granodiorite using the Shand classification (Reference 3). The grain size ranged from coarse to fine (Figure 4.1). Garnet and muscovite were present as metamorphic products.

4.3.4 Summary. Petrographic examination of nine sections of core from six holes in the Pease area of central New Hampshire indicated that four major rock types were represented: granodiorite gneiss, mica schist and gneiss, muscovite granodiorite, and dacite porphyry. The mica gneisses and schists and the granite gneisses were slightly more abundant than the other rock types.

TABLE 4.1 VELOCITY DETERMINATIONS

		Velocity[a]	
		Compressional	Shear
		fps	fps
Hole PZ-CR-2, Specimen 21:			
Mica gneiss, well foliated		12,230	5,790
Depth: 178 feet		11,090	5,830
Specific gravity: 2.81		14,680	6,880
Compressional deviation:[b] 15.9 pct			
	Average	12,670	6,170
Hole PZ-CR-11, Specimen 11:			
Mica gneiss, slightly foliated		17,200	8,780
Depth: 124 feet		19,180	9,310
Specific gravity: 2.84		17,470	8,930
Compressional deviation: 6.8 pct			
	Average	17,950	9,010
Hole PZ-CR-23, Specimen 2:			
Granite gneiss, fractured		15,080	7,820
Depth: 11 feet		16,700	7,430
Specific gravity: 2.71		15,980	7,870
Compressional deviation: 5.3 pct			
	Average	15,920	7,710
Hole PZ-CR-23, Specimen 4:			
Granite gneiss		12,370	5,300
Depth: 30 feet		19,070	6,770
Specific gravity: 2.61		17,530	6,210
Compressional deviation: 24.2 pct			
	Average	16,320	6,090

(Continued)

[a] First velocity listed is in axial (longitudinal) direction; other two are on mutually perpendicular, diametral (lateral) axes.

[b] Maximum percent deviation from the average of the compressional wave velocity.

TABLE 4.1 (CONCLUDED)

		Velocity	
		Compressional	Shear
		fps	fps
Hole PZ-CR-25, Specimen 9:			
Muscovite granodiorite		9,300	4,700
Depth: 75 feet		13,620	5,830
Specific gravity: 2.63		14,510	5,870
Compressional deviation: 25.5 pct			
	Average	12,480	5,470
Hole PZ-CR-34, Specimen 6:			
Mica gneiss		16,790	8,740
Depth: 58 feet		18,160	9,080
Specific gravity: 2.67		18,060	8,980
Compressional deviation: 5.2 pct			
	Average	17,670	8,930
Hole PZ-CR-34, Specimen 24:			
Mica schist		14,710	7,690
Depth: 190 feet		16,970	8,180
Specific gravity: 2.72		15,410	7,630
Compressional deviation: 12.7 pct			
	Average	15,700	7,830
Hole PZ-CR-36, Specimen 21:			
Dacite porphyry with inclusions		14,110	7,950
Depth: 188 feet		17,570	8,370
Specific gravity: 2.63		18,150	8,590
Compressional deviation: 15.0 pct			
	Average	16,610	8,300

TABLE 4.2 DYNAMIC ELASTIC PROPERTIES

Hole No.	Specimen No.	Moduli Young's	Shear	Bulk	Poisson's Ratio
		10^6 psi	10^6 psi	10^6 psi	
2	21	3.4	1.3	4.0	0.36
		3.4	1.3	2.9	0.31
		4.9	1.8	5.8	0.36
	Average	3.9	1.5	4.2	0.34
11	11	7.8	3.0	7.4	0.32
		8.9	3.3	9.6	0.35
		8.1	3.0	7.6	0.32
	Average	8.3	3.1	8.2	0.33
23	2	5.9	2.2	5.3	0.32
		5.6	2.0	7.5	0.38
		6.1	2.3	6.3	0.34
	Average	5.9	2.2	6.4	0.35
23	4	2.7	1.0	4.1	0.39
		4.6	1.6	10.6	0.43
		3.9	1.4	9.0	0.43
	Average	3.7	1.3	7.9	0.42
25	9	2.1	0.8	2.0	0.33
		3.3	1.2	5.0	0.39
		3.4	1.2	5.8	0.40
	Average	2.9	1.1	4.3	0.37
34	6	7.2	2.8	6.5	0.31
		7.9	3.0	7.9	0.33
		7.8	2.9	7.9	0.34
	Average	7.6	2.9	7.4	0.33
34	24	5.7	2.2	5.0	0.31
		6.6	2.4	7.3	0.35
		5.7	2.1	5.8	0.34
	Average	6.0	2.2	6.0	0.33
36	21	5.7	2.2	4.1	0.27
		6.7	2.5	7.6	0.35
		7.1	2.6	8.2	0.36
	Average	6.5	2.4	6.6	0.33

TABLE 4.3 TENSILE STRENGTH DETERMINATIONS

Hole No.	Specimen No.	Depth	Tensile Strength		Direct/ Splitting Strength	Core Description
			Splitting	Direct		
		feet	psi	psi	pct	
PZ-CR-2	21	178	570	640	112	Mica gneiss, well foliated
PZ-CR-11	11	124	760	600	79	Mica gneiss, slightly foliated
PZ-CR-23	2	11	970	100	10	Granite gneiss, fractured
PZ-CR-23	4	30	680	210	31	Granite gneiss
PZ-CR-25	9	75	640	240	38	Muscovite granodiorite
PZ-CR-34	6	58	760	1,090	143	Mica gneiss
PZ-CR-34	24	190	1,330	300	23	Mica schist
PZ-CR-36	21	188	2,100	350	17	Dacite porphyry w/inclusions

TABLE 4.4 RELATION OF ROCK TYPES AND GEOLOGIC UNITS

Hole No.	Rock Type	Geologic Unit	
PZ-CR-2	Granite gneiss	Bethlehem gneiss	Intrusives of the Cardigan pluton, New Hampshire magma series
PZ-CR-11	Mica schist and gneiss	Devonian Littleton formation	
PZ-CR-23	Granite gneiss	Kinsman quartz monzonite	Intrusives of the Cardigan pluton, New Hampshire magma series
PZ-CR-25	Muscovite granodiorite	Outlier--may represent a stock of Conway granite	
PZ-CR-34	Mica schist and gneiss	Devonian Littleton formation	
PZ-CR-36	Dacite porphyry	Unassigned intrusives associated with the White Mountain magma series	

TABLE 4.5 MODAL COMPOSITION OF MICA SCHISTS AND GNEISSES

Based on count of 500 points per thin section. Tr = trace.

Constituent	Mica Schist, PZ-CR-11	Mica Gneiss, PZ-CR-34	
	Section 17	Section 12	Section 21
Quartz	39	40	39
Plagioclase	6	13	18
Biotite	40	21	35
Chlorite	3	14	2
Muscovite	--	1	--
Garnet	3	7	5
Zircon	Tr	Tr	Tr
Pyrite	Tr	3	Tr
Calcite	Tr	Tr	Tr
Sillimanite	8	--	--

TABLE 4.6 MODAL COMPOSITION OF GRANODIORITE, DACITE PORPHYRIES, AND DIORITE

Based on count of 500 points per thin section. Tr = trace.

Constituent	Granodiorite, PZ-CR-25	PZ-CR-36	
	Section 17	Dacite Section 10	Diorite Section 17[a]
Quartz	30	39	4
Plagioclase	28	58[b]	62
Microcline	15	58[b]	--
Biotite	4	1	20
Muscovite	23	--	--
Zircon	Tr	--	Tr
Apatite	Tr	--	Tr
Calcite	Tr	Tr	Tr
Hornblende	--	2	4

[a] Diorite inclusion.
[b] Antiperthitic plagioclase--approximately 75 percent plagioclase.

TABLE 4.7 MODAL COMPOSITION OF GRANITE GNEISSES AND GRANODIORITE

Based on count of 500 points per thin section. Tr = trace.

Constituent	Granite, PZ-CR-2	PZ-CR-23	
	Section 12	Granite Section 14	Granodiorite[a] Section 21
Quartz	47	36	20
Plagioclase	11	28	50
Microcline	10	24	15
Biotite	16	10	4
Muscovite	15	--	8
Chlorite	--	Tr	Tr
Garnet	--	2	3
Zircon	Tr	Tr	Tr
Apatite	Tr	Tr	Tr
Pyrite	Tr	--	--
Calcite	Tr	--	Tr

[a] Pegmatite-like rock of granodiorite composition associated with the granites.

TABLE 4.8 BULK COMPOSITION OF MICA SCHISTS AND GNEISSES

Based on X-ray diffraction results. A = abundant, M = minor, Tr = trace.

Constituent	Mica Schist, PZ-CR-11	Mica Gneiss, PZ-CR-34	
	Section 17	Section 12	Section 17
Quartz	A	A	A
Plagioclase	M	A	A
Biotite	A	A	A
Chlorite	--	A	Tr
Sillimanite	M	--	--
Calcite	Tr	Tr	--

TABLE 4.9 BULK COMPOSITION OF GRANODIORITE, DACITE PORPHYRIES, AND DIORITE

Based on X-ray diffraction results. A = abundant, M = minor, Tr = trace.

Constituent	Granodiorite, PZ-CR-25	PZ-CR-36	
	Section 17	Dacite Section 10	Diorite Section 17
Quartz	A	A	M
Plagioclase	A	A	A
Microcline	A	A	--
Biotite	M	Tr	A
Muscovite	A	--	--
Hornblende	--	Tr	M
Calcite	Tr	Tr	Tr

TABLE 4.10 BULK COMPOSITION OF GRANITE GNEISSES AND GRANODIORITE

Based on X-ray diffraction results. A = abundant, M = minor, Tr = trace.

Constituent	Granite, PZ-CR-2	PZ-CR-23	
	Section 12	Granite Section 14	Granodiorite[a] Section 21
Quartz	A	A	A
Plagioclase	M	A	A
Microcline	M	A	A
Biotite	A	M	M
Muscovite	A	--	M
Chlorite	--	Tr	Tr
Garnet	--	Tr	Tr

[a] Pegmatite-like rock of granodiorite composition associated with the granites.

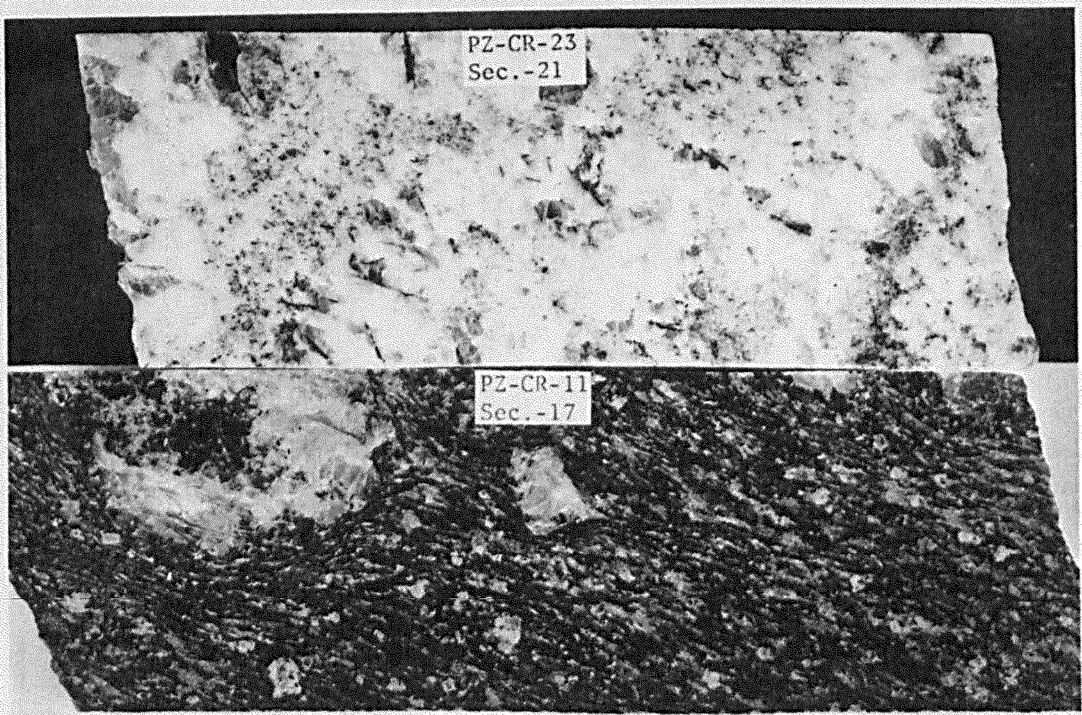


Figure 4.1 Granite gneiss, Core PZ-CR-23, Section 21, and mica schist, Core PZ-CR-11, Section 17. PZ-CR-23, Section 21, shows a range in grain size from coarse to fine. Black areas are biotite and gray areas are quartz. PZ-CR-11, Section 17, shows a well-developed high-angle foliation disrupted by quartz porphyroblasts. The small, white, rectangular or square grains are highly altered plagioclase.

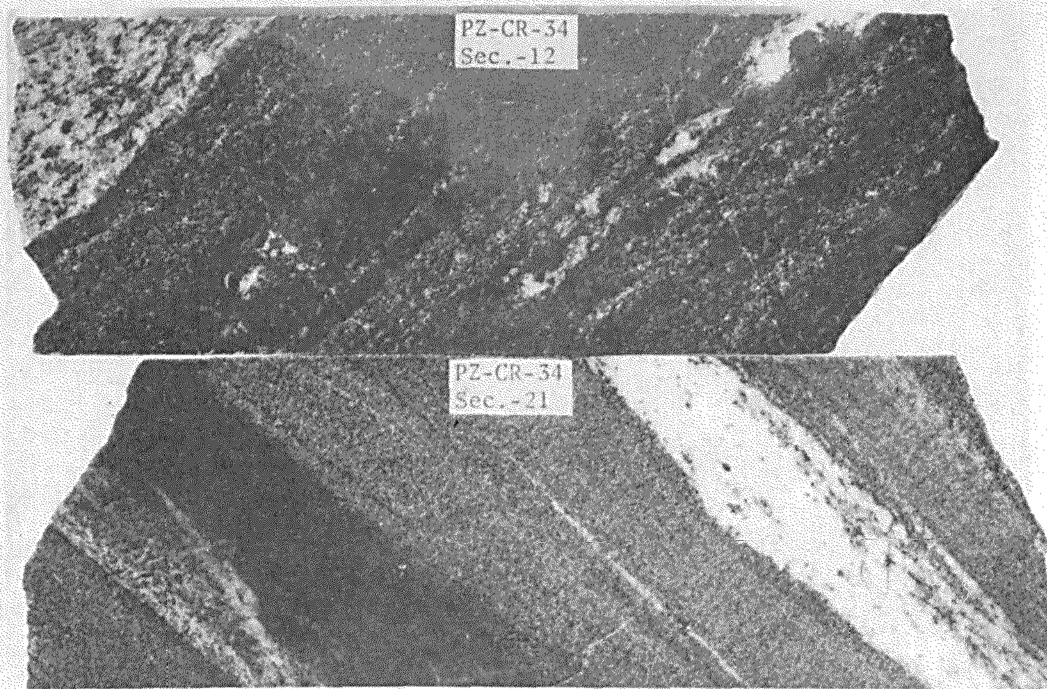


Figure 4.2 Mica gneiss, Core PZ-CR-34, Sections 12 and 21. Section 12 shows foliation parallel to banding, both dipping at 45 degrees. The banding is accented by quartz- or biotite-rich layers. Narrow white lines normal to the foliation are fractures. Section 21 shows finer grain size and foliation dipping at about 45 degrees. Compositional bands parallel to the foliation may represent original bedding. The variation in structure in the lower left corner may be relic cross-bedding.

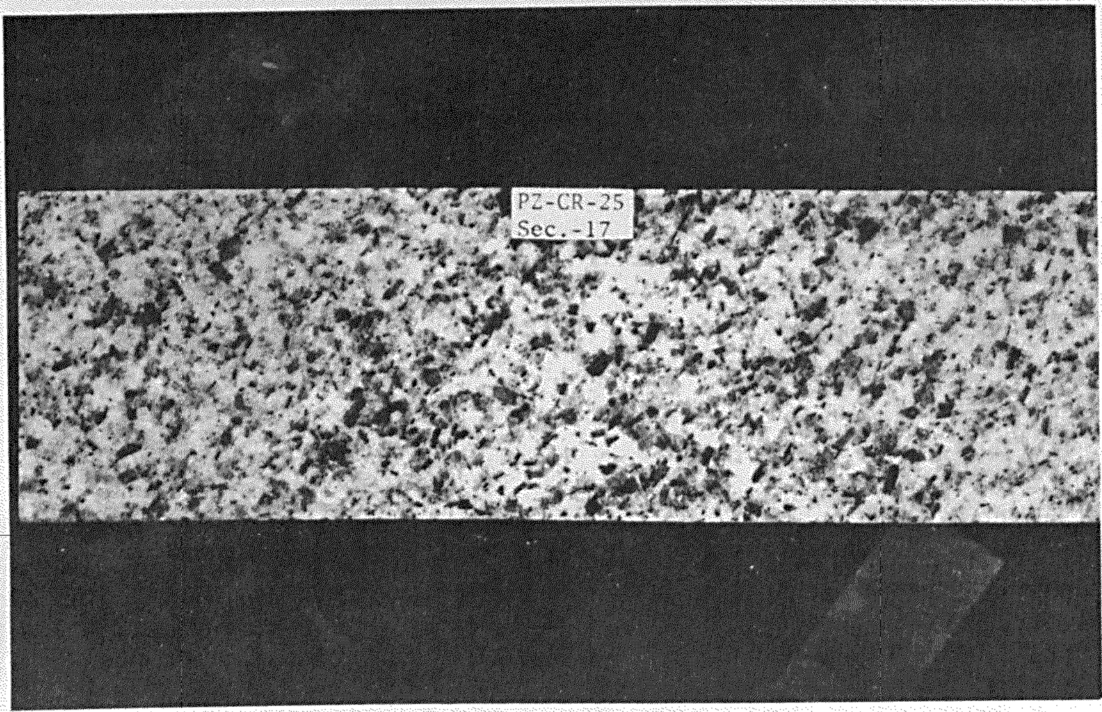


Figure 4.3 Muscovite granodiorite, Core PZ-CR-25, Section 17. Section shows uniform grain size and inconspicuous preferred orientation dipping at about 40 degrees. The black grains are biotite and the gray, clearly outlined grains are muscovite.

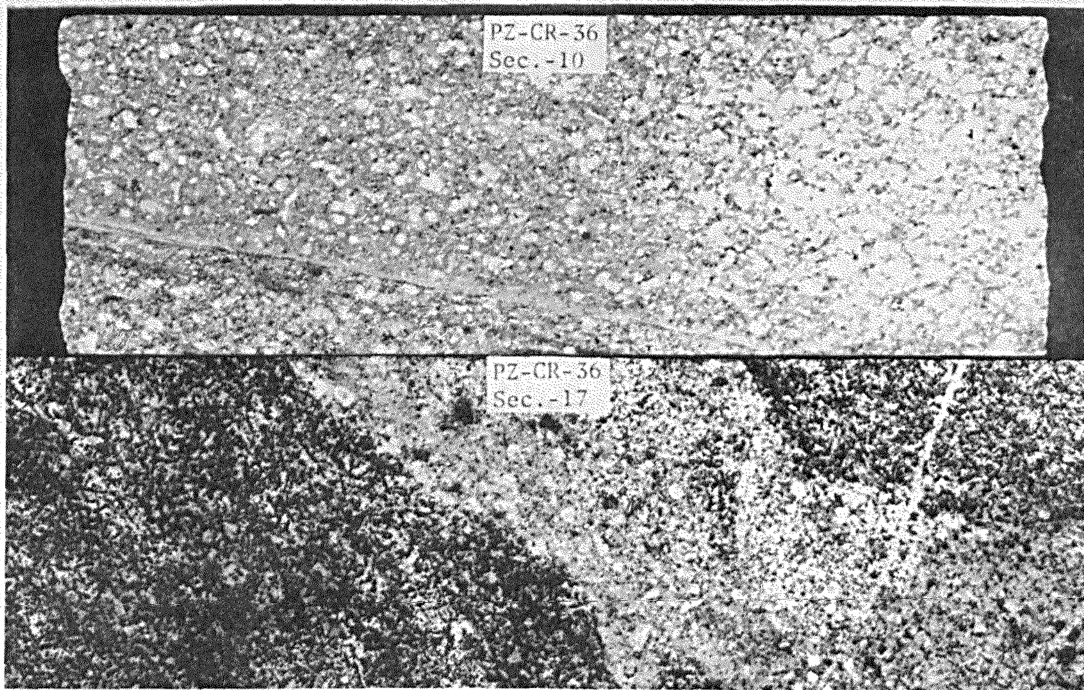


Figure 4.4 Dacite, Core PZ-CR-36, Sections 10 and 17. Section 10 shows porphyritic texture of the dacite. Most of the white phenocrysts are plagioclase. A pair of steeply dipping shear fractures are seen at the lower left and center. Section 17 shows a contact between the lighter dacite and the darker diorite inclusions. White lines at the right of the section are sealed low-angle shear fractures.

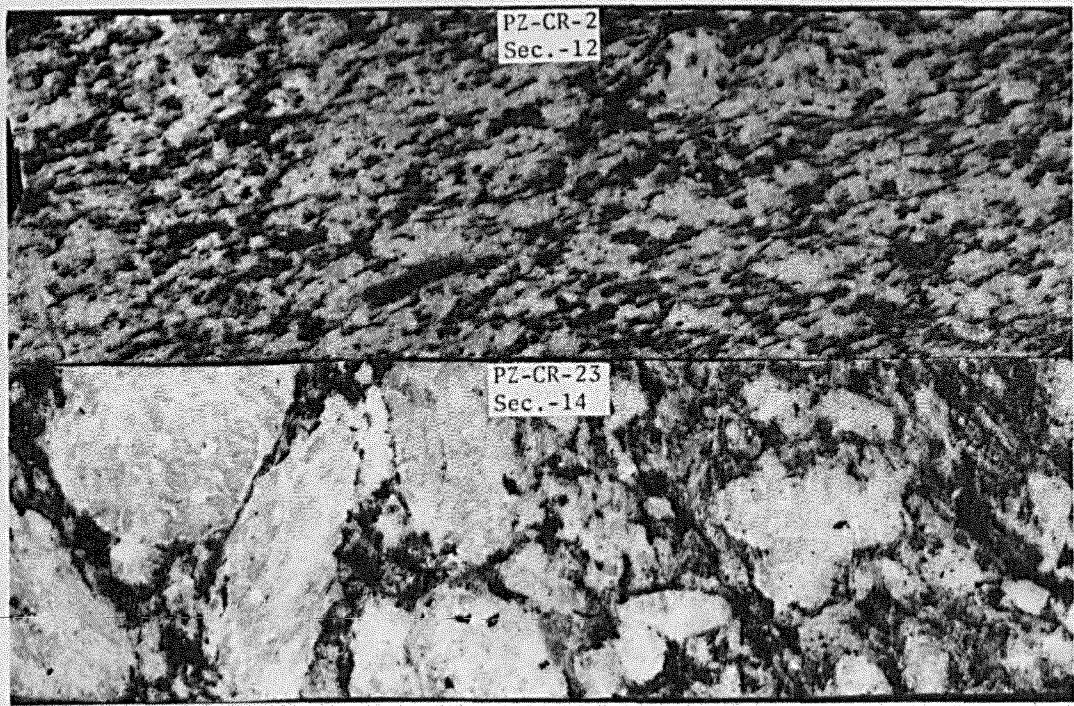


Figure 4.5 Granitic gneiss, Core PZ-CR-2, Section 12, and Core PZ-CR-23, Section 14. PZ-CR-2, Section 12, is granitic mica gneiss with steeply dipping foliation. To the right of the label there is a large quartz grain disrupting the foliation. PZ-CR-23, Section 14, shows several large phenocrysts of quartz and feldspar that completely disrupt the foliation. The narrow white lines in the right half of the section are horizontal fractures.

CHAPTER 5

DISCUSSION AND CONCLUSIONS

5.1 DISCUSSION

The nature of the objective of these rock quality tests dictates overall evaluation of the core on a hole-to-hole basis. In the instances where individual holes yielded core of only one rock type, the evaluation of the hole will, of course, be dictated by the characteristics of the particular rock type present. In those instances, however, where several rock types are represented in a single hole, the evaluation of the hole will necessarily reflect the quality of the least competent material tested.

To facilitate evaluation of the Pease study area in this manner, a rock quality chart (Figure 5.1) was prepared. Ultimate uniaxial compressive strengths depicted on this chart were expressed in one of three categories: good (above 12,000 psi), marginal (8,000 to 12,000 psi), and poor(less than 8,000 psi). Locations of the individual drill holes are shown in Figure 5.2.

5.2 CONCLUSIONS

On the basis of physical test results, the following conclusions appear to be justified:

1. The rock core received from the Pease study area was petrographically identified as predominately mica gneiss, mica schist,

dacite, granite gneiss, and muscovite granodiorite with relatively minor quantities of tonalite, granodiorite gneiss, and basaltic material.

2. Several specimens contained fractures which ranged in orientation from horizontal to vertical. Two mica schist specimens contained vesicles.

3. Physical test results exhibited by the rock core specimens tested from this area ranged considerably in magnitude. A large percentage of the specimens yielded ultimate uniaxial compressive strengths typical of marginal quality material (8,000- to 12,000-psi range). The majority of the remainder of the core was of slightly higher quality.

4. The mica gneiss and mica schist yielded similar physical characteristics, the mica schist generally being slightly stronger. With the exception of the two vesicular mica schist specimens, which were incompetent, this core was marginal to relatively competent in quality.

5. The muscovite granodiorites, granodiorite gneisses, and granite gneisses were slightly less competent than the mica gneisses and schists discussed above, generally marginal in quality. Compressional wave velocities determined for the muscovite granodiorite specimens were unusually low, probably due to the very high muscovite content of these specimens.

6. The dacite porphyry from this area was by far the most competent material tested, generally averaging approximately 37,000 psi in ultimate uniaxial compressive strength. One highly fractured specimen, however, was marginal in quality. Surprisingly, compressional wave velocities for this generally very competent rock were rather low, averaging approximately 14,000 fps.

7. Elastic constants determined for the core from the Pease study area were generally moderate to low in magnitude. The lowest static Young's modulus exhibited was 1.2×10^6 psi. Due to the low compressional wave velocities previously mentioned, dynamic elastic constants were frequently quite low.

8. Anisotropy tests on representative specimens revealed most of the core from this area to have physical properties with a high degree of directional dependence. This was probably due to the well-foliated and porphyritic nature of much of the core. As a result of the rather large degree of anisotropy typical of these specimens, particular discretion must be used in utilizing the dynamic moduli determined for the core from this area.

9. Evaluation of the Pease study area core on a hole-to-hole basis indicates the moderately fractured and intact dacite removed from Hole PZ-CR-36 to be very competent rock. The highly fractured core, removed at depths of 40 feet or less below ground surface, was marginal in quality. Generally, this hole yielded material

representative of competent, hard rock media.

10. The remainder of the holes from this area, i.e., PZ-CR-2, -11, -23, -25, and -34, generally yielded rock core exhibiting physical properties characteristic of marginal to barely competent material. Holes PZ-CR-11, -23, and -34 yielded incompetent core from depths greater than 50 feet below ground surface, dictating classification of the core as unsuitable as competent media. Holes PZ-CR-2 and -25 yielded significant quantities of rock of marginal quality, but, dependent on results of possible further investigation, could offer some possibility as competent hard rock media.

The above evaluations and conclusions have been based on somewhat limited data; therefore, more extensive investigation will be required in order to accurately assess the individual areas under consideration.

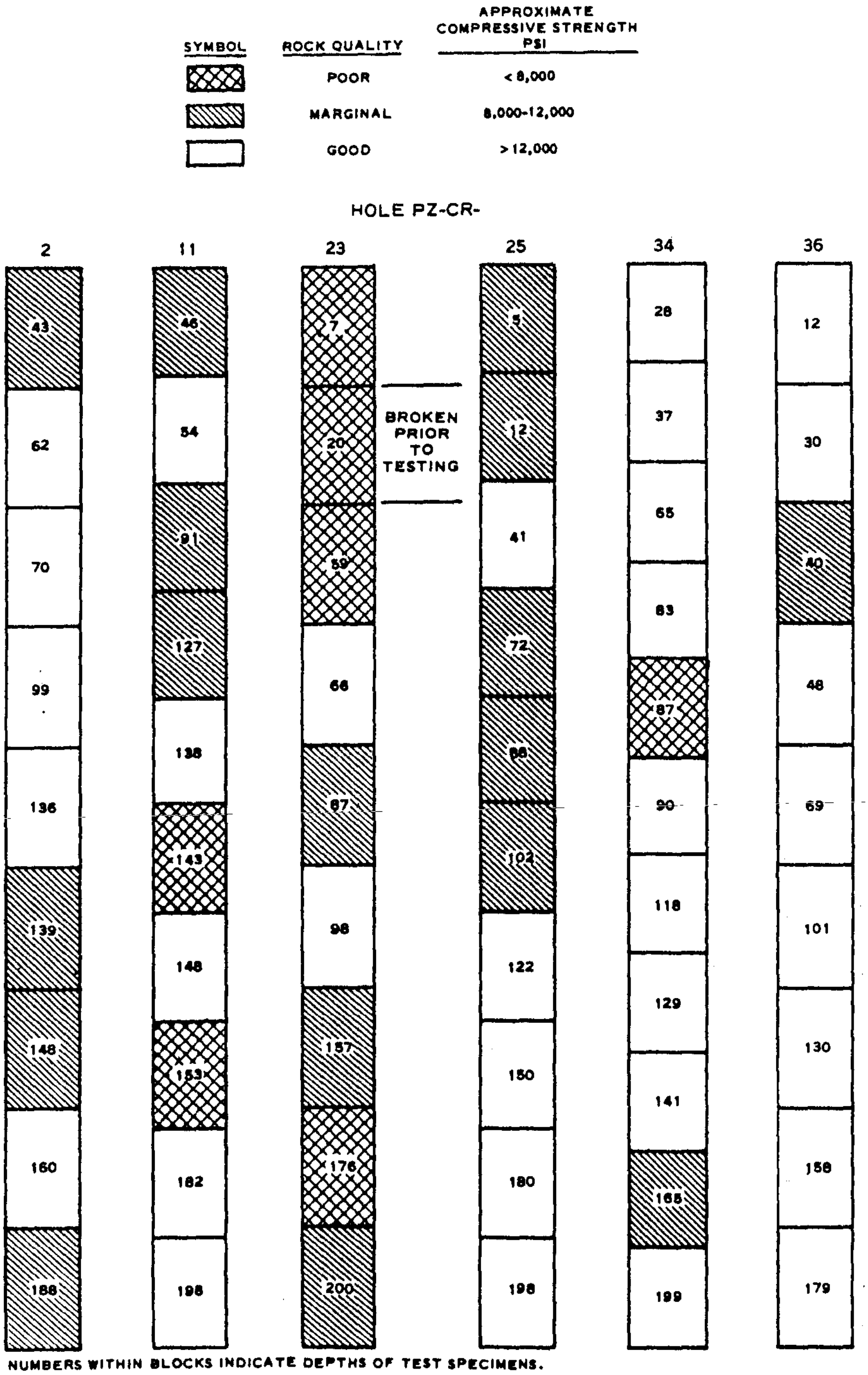


Figure 5.1 Depth versus quality as indicated by compressive strength for individual holes.

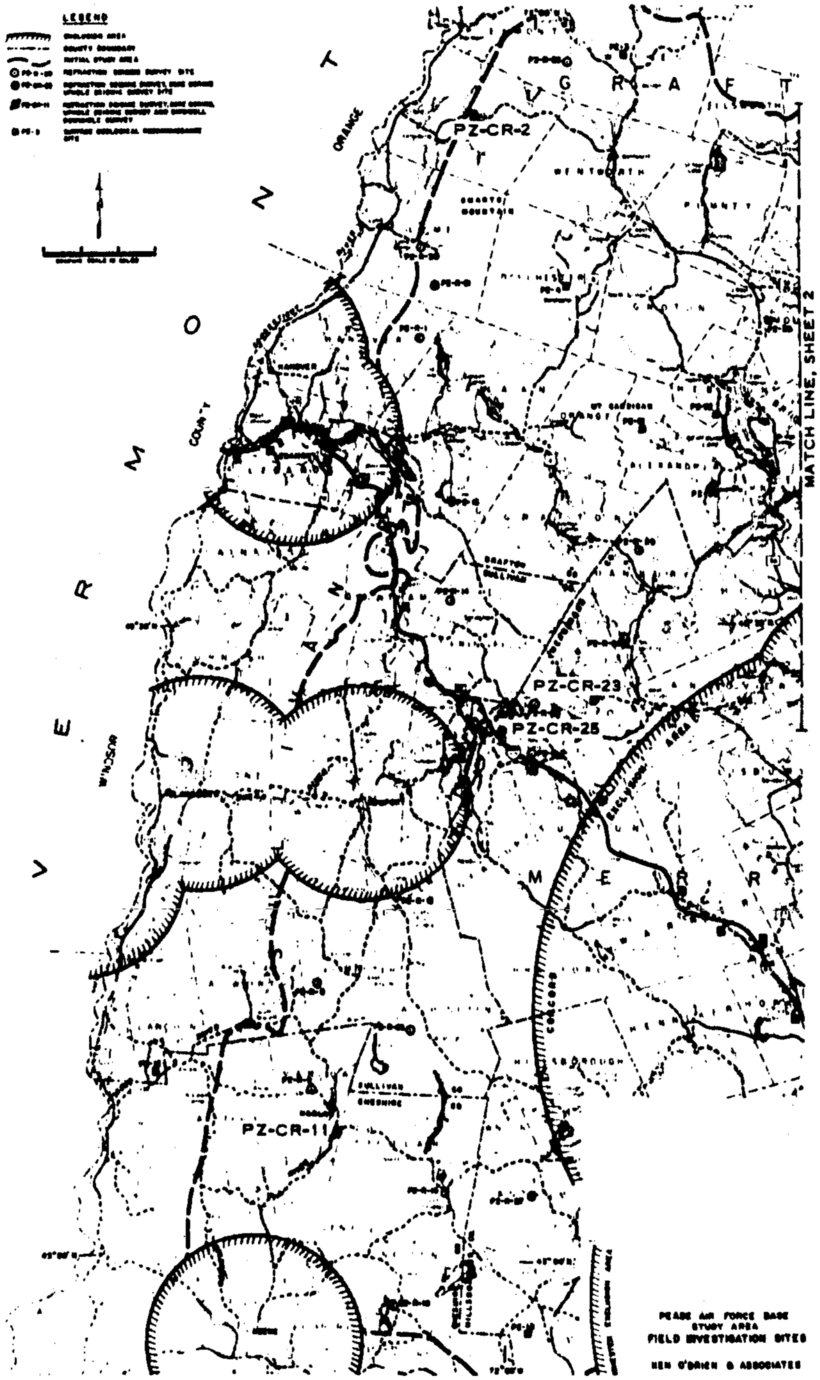


Figure 5.2 Field investigation sites (Sheet 1 of 2).

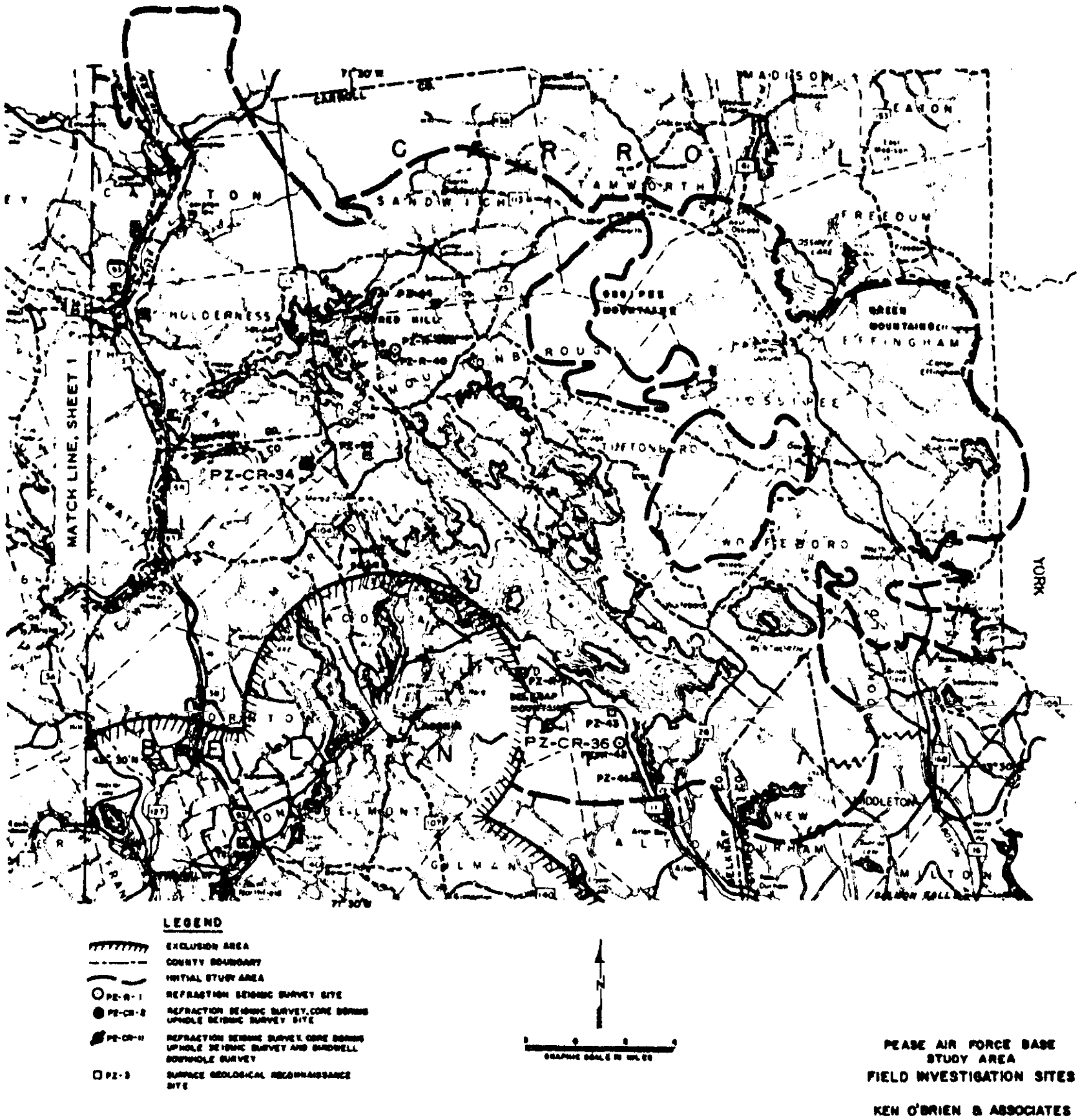


Figure 5.2 (Sheet 2 of 2).

APPENDIX A

DATA REPORT

Hole PZ-CR-2

21 November 1969

Hole Location: Grafton County, New Hampshire

Longitude: 72° 03' 39.5" West

Latitude: 43° 53' 53.4" North

Core

1. The following core was received on 31 October 1969 for testing:

Core Piece No.	Approximate Depth, ft
1	6
2	15
3	26
4	37
5	43
6	52
7	62
8	70
9	81
10	91
11	99
12	110
13	121
14	130
15	136
16	139
17	148
18	149
19	160
20	168
21	178
22	188
23	198

Description

2. The samples received were rather uniform in appearance. According to the field log received with the core, the rock was identified as a black and white coarsely crystalline gneiss. Specimen Nos. 15 and 17 contained tightly healed fractures; No. 22 contained a small biotite inclusion.

Quality and uniformity tests

3. To determine variations within the hole, specific gravity, Schmidt number, compressive strength, and compressional wave velocity were determined on specimens prepared from representative samples as given below:

	Sample No.	Description	Core Depth	Sp Gr	Schmidt No.	Comp Strg, psi	Comp Wave Vel, fps
Mica Gneiss	5	Intact	43	2.725	44.2	10,710	10,835
	7	Intact	62	2.731	39.6	12,400	10,360
	8	Intact	70	2.717	43.5	13,460	11,220
	11	Intact	99	2.728	44.8	14,870	10,090
	15	Contains Healed Fracture	136	2.714	35.8	14,480	9,910
	16	Intact	139	2.741	40.0	8,450	10,830
	17	Contains Healed Fracture	148	2.721	--	10,450	10,095
	19	Intact	160	2.726	41.2	12,300	10,165
	22	Contains Small Biotite Inclusion	188	2.734	39.6	9,760	9,660
Average of All Specimens Tested (9)				2.726	41.1	11,880	10,350

Moduli of deformation

4. Representative specimens were selected for dynamic and static moduli of deformation tests. The dynamic moduli were determined by the proposed ASTM method for determination of ultrasonic pulse velocities

and elastic constants of rock. The static moduli were computed from theory of elasticity by use of strain measurements taken from electrical resistance strain gages affixed to the specimens, Nos. 5, 15, and 16. Stress-strain curves are given in plates 1, 2, and 3. The three specimens were cycled at 5000 psi. Results are given below.

Specimen No.	Modulus, psi x 10^6			Shear Velocity, fps	Poisson's Ratio
	Young's	Bulk	Shear		
		Dynamic Tests			
5	4.2	1.8	1.8	7105	0.12
7	3.6	2.0	1.5	6360	0.20
8	4.4	2.1	1.9	7170	0.15
11	3.7	1.4	1.7	6835	0.08
15	3.6	1.4	1.6	6710	0.08
16	4.0	2.1	1.7	6780	0.18
17	3.0	2.2	1.2	5625	0.27
19	3.7	1.6	1.7	6730	0.11
22	2.7	2.0	1.0	5341	0.28
		Static Tests			
5	3.8	1.9	1.7	--	0.16
15	4.1	2.2	1.7	--	0.19
16	2.6	2.2	1.1	--	0.15

Conclusions

5. The core received for testing from hole PZ-CR-2 was rather uniform, identified by the field log received with the core as black and white coarsely crystalline gneiss. Specimen Nos. 15 and 17 contained tightly healed fractures which appeared to have no appreciable effect

on physical test results. Physical test results exhibited by this material were rather low but very uniform. Uniaxial compressive strengths were marginal, ranging from 9760 to 14,870 psi. Wave velocities were consistently low, possibly due to the strongly lineated nature of the black minerals.

Property	Average of All Specimens Tested
Specific Gravity	2.726
Schmidt Number	41.1
Compressive Strength, psi	11,880
Compressional Wave Velocity, fps	10,350
Static Young's Modulus, psi x 10^6	3.5

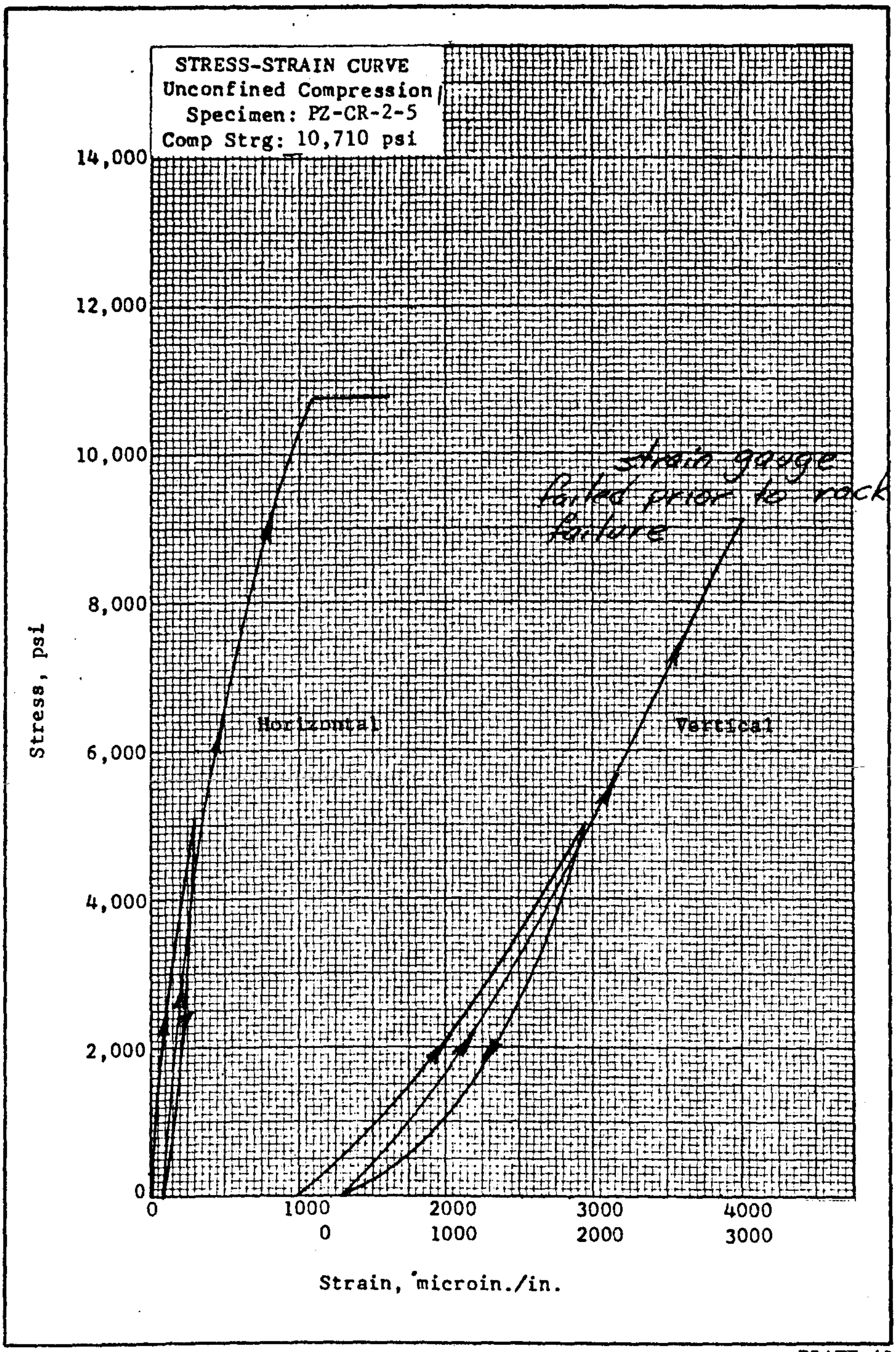

STRESS-STRAIN CURVE
Unconfined Compression
Specimen: PZ-CR-2-5
Comp Strg: 10,710 psi
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
Stress, psi
Horizontal
Vertical
strain gauge failed prior to rock failure
0
1000
2000
3000
4000
0
1000
2000
3000
Strain, microin./in.

PLATE A1

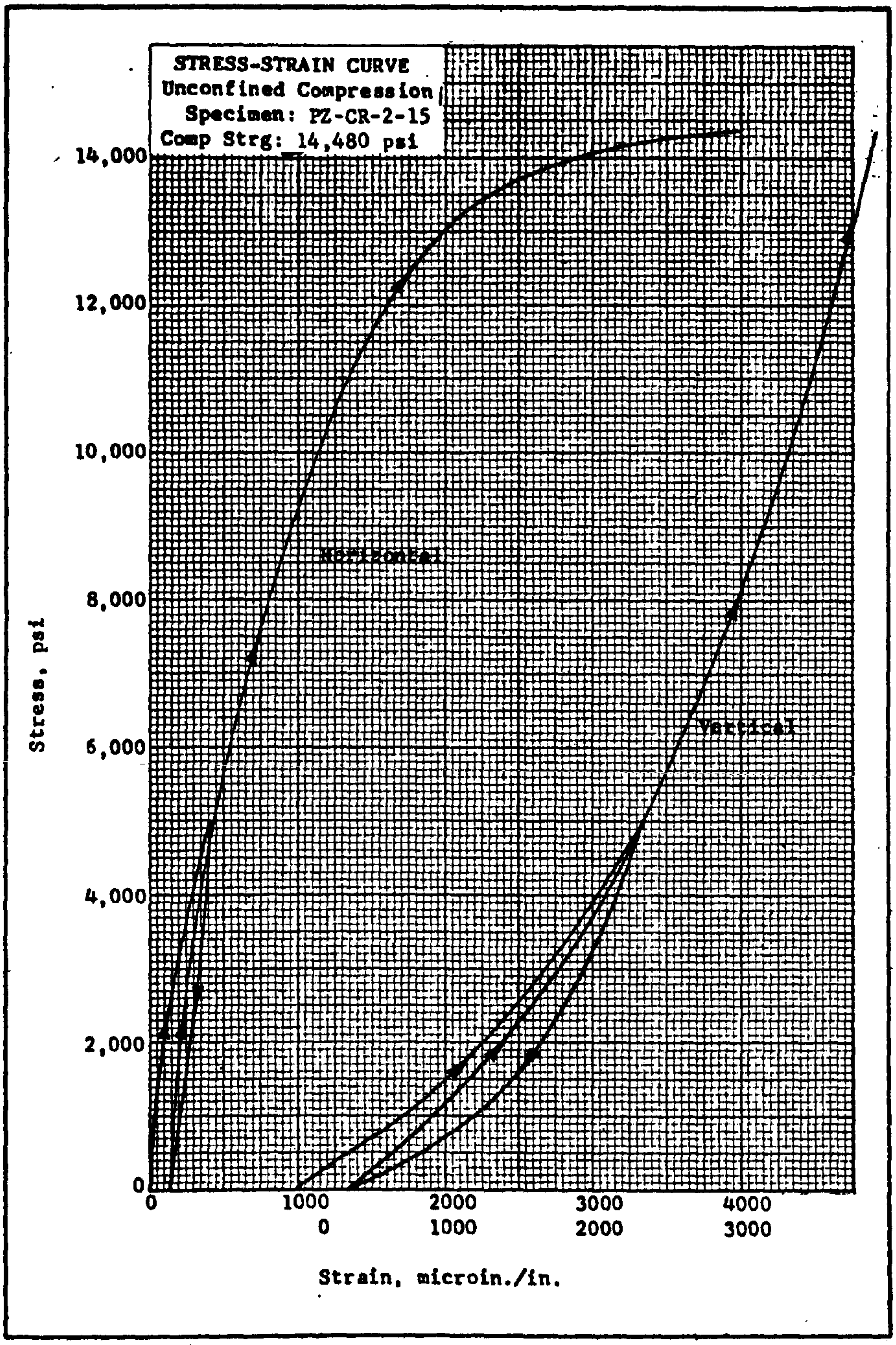

STRESS-STRAIN CURVE
Unconfined Compression
Specimen: PZ-CR-2-15
Comp Strg: 14,480 psi
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
Stress, psi
Horizontal
Vertical
0
1000
2000
3000
4000
0
1000
2000
3000
Strain, microin./in.

PLATE A2

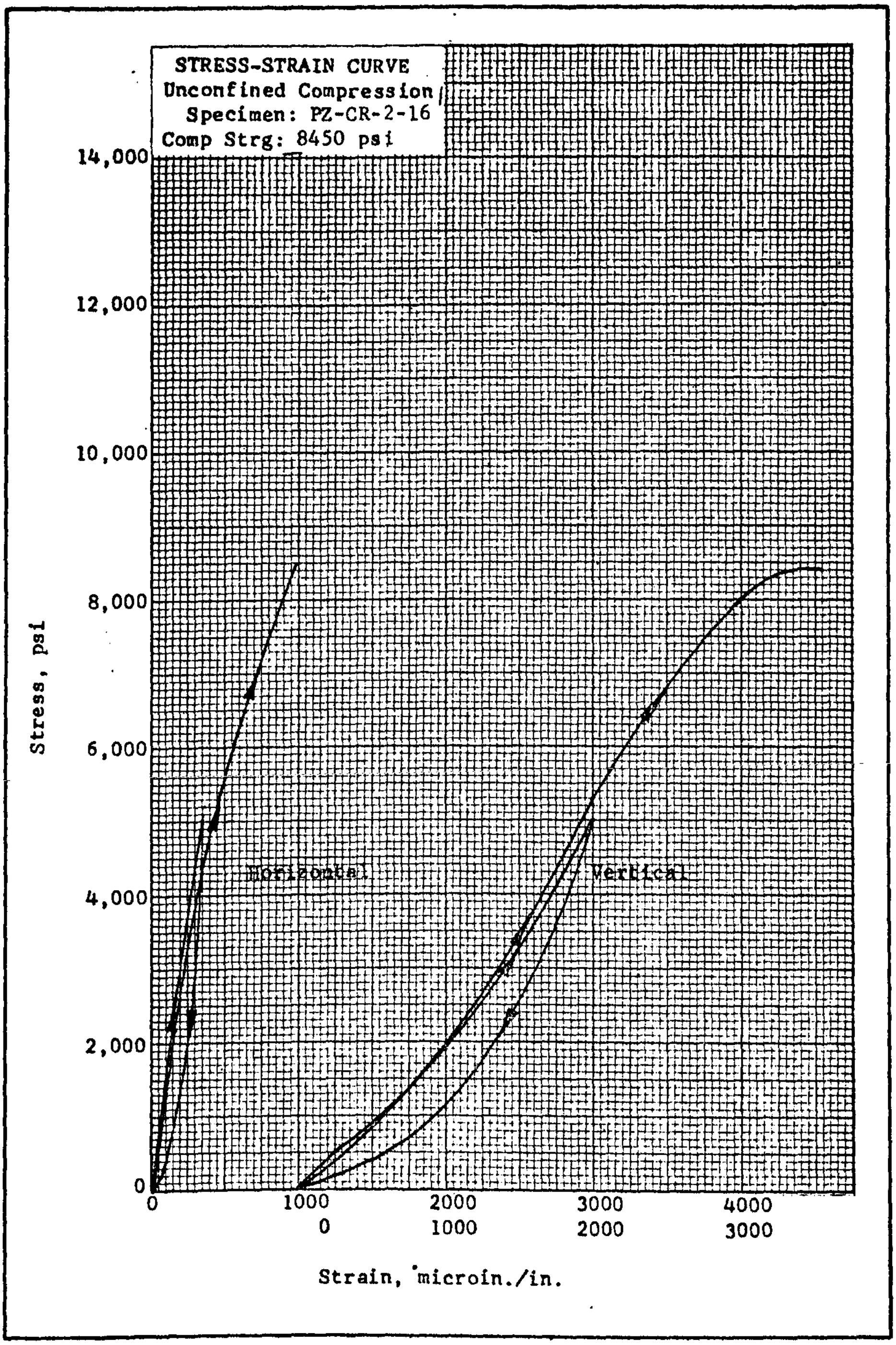

STRESS-STRAIN CURVE
Unconfined Compression
Specimen: PZ-CR-2-16
Comp Strg: 8450 psi
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
Stress, psi
Horizontal
Vertical
0
1000
2000
3000
4000
0
1000
2000
3000
Strain, microin./in.

PLATE A3

APPENDIX B

DATA REPORT

Hole PZ-CR-11

20 November 1969

Hole Location: Cheshire County, New Hampshire

Longitude: 72° 11' 46" West

Latitude: 43° 5' 56" North

Core

1. The following core was received on 6 November 1969 for testing:

Core Piece No.	Approximate Depth, ft
1	26
2	34
3	46
4	54
5	65
6	75
7	83
8	91
9	100
10	110
11	124
12	127
13	138
14	143
15	148
16	153
17	162
18	172
19	182
20	193
21	198

Description

2. The samples received were relatively uniform in appearance. According to the field log received with the core, the rock was identified as brownish-gray to gray gneiss. Specimen No. 8 contained a critically oriented fracture. Numbers 14 and 16 were vesicular and contained well-defined planes of lineation.

Quality and uniformity tests

3. To determine variations within the hole, specific gravity, Schmidt number, compressive strength, and compressional wave velocity were determined on specimens prepared from representative samples as given below:

	Sample No.	Description	Core Depth	Sp Gr	Schmidt No.	Comp Strg, psi	Comp Wave Vel, fps
Mica Gneiss	3	Intact	46	2.830	44.2	11,970	16,500
Mica Schist	4	Intact	54	2.948	45.6	15,000	19,090
Mica Gneiss	8	Contained Critically Oriented Fracture	91	2.853	41.3	10,580	17,170
Mica Gneiss	12	Intact	127	2.814	40.7	10,230	15,685
Mica Gneiss	13	Intact	138	2.733	42.4	19,030	16,400
Mica Schist	14	Vesicular, Well-Defined Lineation	143	2.776	--	6,120	15,420
Mica Gneiss	15	Intact	148	2.887	44.4	17,330	18,475
Mica Schist	16	Vesicular, Well-Defined Lineation	153	2.577	--	4,240	9,280
Mica Gneiss	19	Intact	182	2.969	47.2	17,390	20,540
Mica Gneiss	21	Intact	198	2.902	44.9	23,030	19,520
	Vesicular Material Containing Well-Defined Planes of Lineation (2)			2.676	--	5,180	12,350
	Remainder of Core (8)			2.867	43.8	15,570	17,925

4. Physical properties determined for this core were somewhat variable. The low physical test results exhibited by specimen Nos. 14 and 16 were apparently due to the vesicles and well-defined lineation. The somewhat higher wave velocities exhibited by specimen 14 were possibly due to the fact that the vesicles in this specimen were partially filled whereas the vesicles in specimen 16 were empty.

Moduli of deformation

5. Representative specimens were selected for dynamic and static moduli of deformation tests. The dynamic moduli were determined by the proposed ASTM method for determination of ultrasonic pulse velocities and elastic constants of rock. The static moduli were computed from theory of elasticity by use of strain measurements taken from electrical resistance strain gages affixed to the specimens, Nos. 8, 11, and 16. Stress-strain curves are given in plates 1, 2, and 3. Specimens 8 and 16 were cycled at 3000 psi. Specimen 11 was cycled at 5000 psi. Results are given below.

Specimen	Modulus, psi x 10^6			Shear	Poisson's
No.	Young's	Bulk	Shear	Velocity, fps	Ratio
		Dynamic Tests			
3	8.2	6.1	3.2	9,140	0.28
4	11.1	8.7	4.3	10,455	0.29
8	8.1	7.2	3.1	8,980	0.31
12	7.9	5.1	3.2	9,185	0.24
13	8.7	5.2	3.5	9,810	0.22
14	7.4	5.0	2.9	8,865	0.25
15	8.0	9.4	2.9	8,675	0.36
16	3.0	1.1	1.4	6,330	0.06
19	13.5	9.8	5.3	11,515	0.27
21	12.0	8.6	4.8	11,035	0.27
		Static Tests			
8	7.1	3.4	3.1	--	0.15
11	7.1	3.8	3.0	--	0.19
16	1.2	0.6	0.5	--	0.14

Of the three specimens cycled, the one containing open vesicles exhibited considerable hysteresis. Erratic behavior of the horizontal stress-strain curve for specimen 16 was possibly due to location of the strain gages over vesicles.

Conclusions

6. The core received for testing from hole PZ-CR-11 was relatively uniform, identified by the field log received with the core as brownish-gray to gray gneiss. Specimen Nos. 14 and 16 exhibited physical test results somewhat lower than those exhibited by the remainder of the core, possibly due to vesicles and well-defined lineation present in both specimens. The remainder of the material from this hole was found to be more competent, exhibiting compressive strengths ranging from 10,000 to 23,000 psi.

Property	Vesicular Material Containing Well-Defined Planes of Lineation (2)	Remainder of Core (8)
Specific Gravity	2.676	2.867
Schmidt Number	--	43.8
Compressive Strength, psi	5,180	15,570
Compressional Wave Velocity, fps	12,350	17,925
Static Young's Modulus, psi x 10^6	1.2	7.1

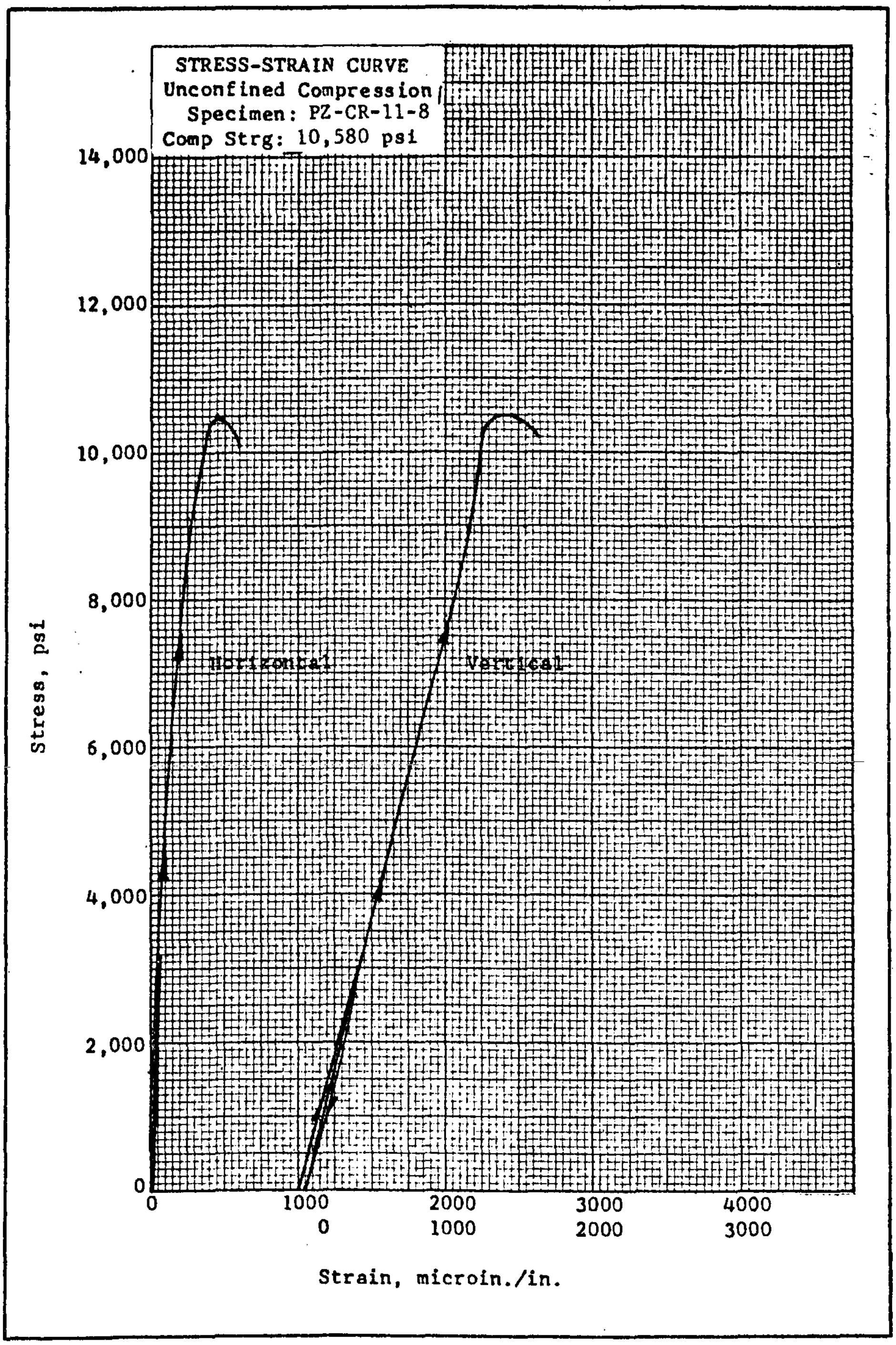
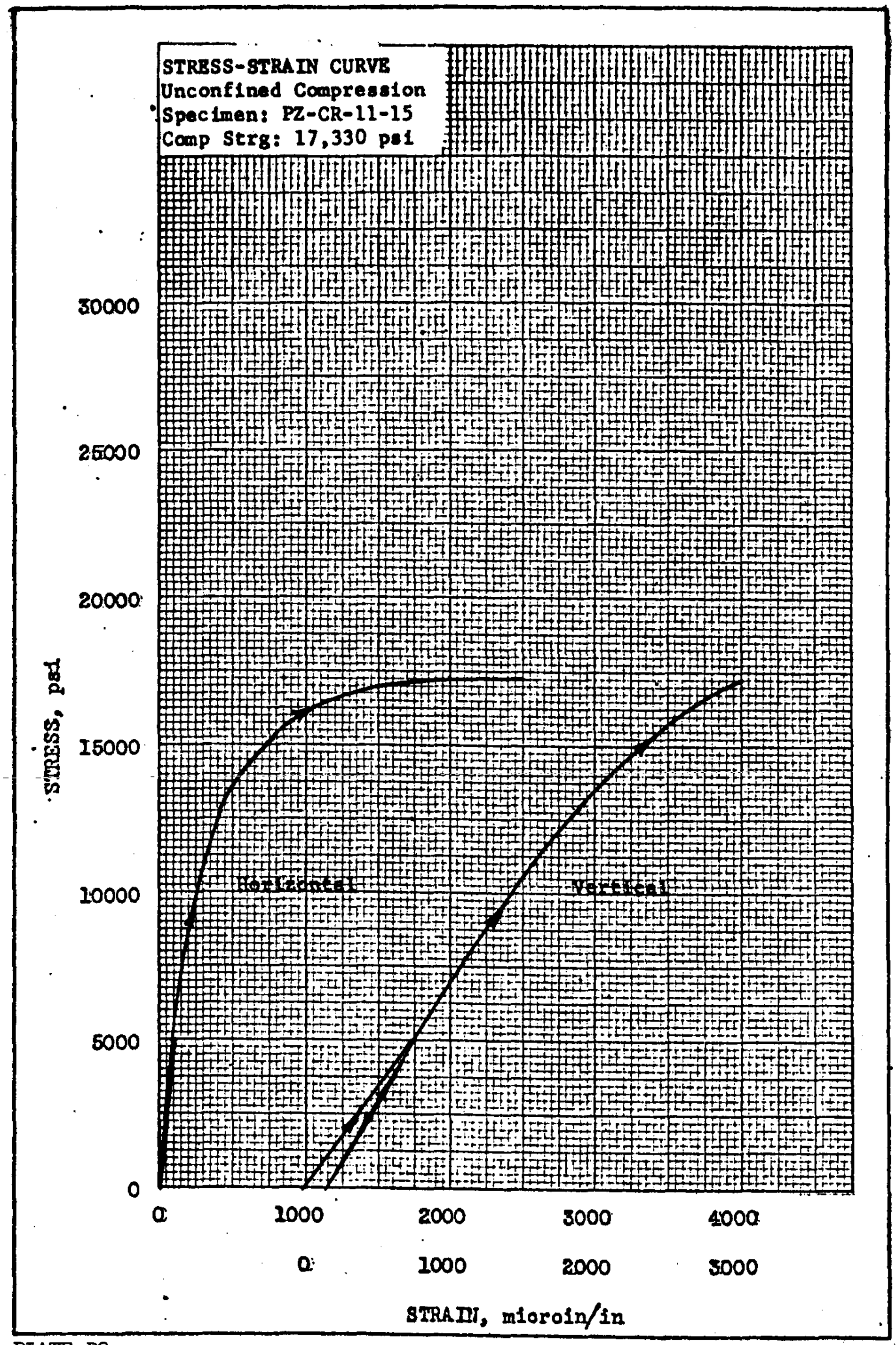
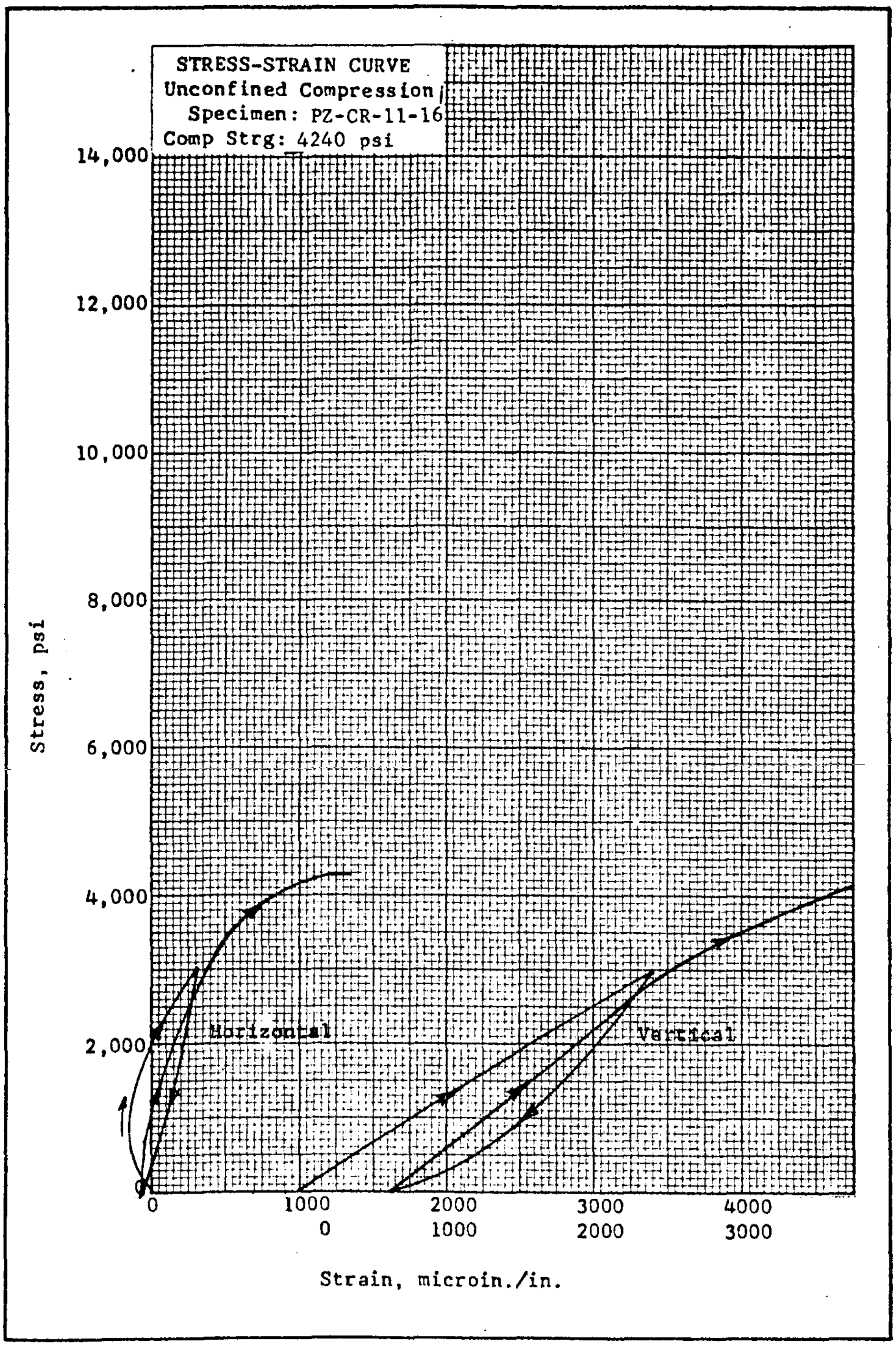

STRESS-STRAIN CURVE
Unconfined Compression
Specimen: PZ-CR-11-8
Comp Strg: 10,580 psi
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
Stress, psi
Horizontal
Vertical
0
1000
2000
3000
4000
0
1000
2000
3000
Strain, microin./in.

PLATE B1



STRESS-STRAIN CURVE
Unconfined Compression
Specimen: PZ-CR-11-15
Comp Strg: 17,330 psi
STRESS, psi
30000
25000
20000
15000
10000
5000
0
Horizontal
Vertical
0
1000
2000
3000
4000
0
1000
2000
3000
STRAIN, microin/in

PLATE B2



STRESS-STRAIN CURVE
Unconfined Compression
Specimen: PZ-CR-11-16
Comp Strg: 4240 psi
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
Stress, psi
Horizontal
Vertical
0
1000
2000
3000
4000
0
1000
2000
3000
Strain, microin./in.

PLATE B3

APPENDIX C

DATA REPORT

Hole PZ-CR-23

19 November 1969

Hole Location: Merrimack County, New Hampshire

Core

1. The following core was received on 31 October 1969 for testing:

Core Piece No.	Approximate Depth, ft
1	7
2	11
3	20
4	30
5	43
6	50
7	59
8	66
9	77
10	87
11	98
12	107
13	117
14	127
15	138
16	146
17	157
18	167
19	176
20	188
21	190
22	200

Description

2. The samples received were relatively uniform in appearance. According to the field log received with the core, the rock was identified as light- to dark-gray quartz monzonite. Specimen Nos. 6, 7, 8, 9, and 21 were identified as pegmatite; Nos. 1, 2, 7, 9, and 21 contained fractures.

Quality and uniformity tests

3. To determine variations within the hole, specific gravity, Schmidt number, compressive strength, and compressional wave velocity were determined on specimens prepared from representative samples as given below:

	Sample No.	Description	Core Depth	Sp Gr	Schmidt No.	Comp Strg, psi	Comp Wave Vel, fps
Gneissic Inclusion	1	Critically Oriented Fracture	7	2.681	49.7	6,000	12,875
Granite Gneiss	3	Intact	20	2.685	--	--	--
Pegmatitic Granodiorite Gneiss	7	Fractured Pegmatite	59	2.597	37.2	6,060	9,040
" "	8	Intact Pegmatite-	66	2.636	44.8	13,240	11,555
Granite Gneiss	10	Intact	87	2.672	--	11,050	14,655
Granite Gneiss	11	Intact	98	2.631	52.8	13,530	12,340
Granite Gneiss	17	Intact	157	2.667	53.4	11,970	12,195
Granite Gneiss	19	Intact	176	2.777	49.8	7,760	14,510
Gneissic Inclusion	22	Intact	200	2.666	--	10,500	16,340
	Fractured Specimens (2)			2.639	43.4	6,030	10,955
	Intact Specimens (7)			2.676	50.2	11,340	13,600

4. Schmidt hammer test was not conducted on several specimens due to possibility of breakage. Specimen No. 3 was accidentally broken before all tests could be conducted. The low compressive velocities and compressive strengths exhibited by this material were possibly due to the presence of very large concentrations of mica throughout the core. Petrographic work, to be conducted later, will examine this possibility.

Moduli of deformation

5. Representative specimens were selected for dynamic and static moduli of deformation tests. The dynamic moduli were determined by the proposed ASTM method for determination of ultrasonic pulse velocities and elastic constants of rock. The static moduli were computed from theory of elasticity by use of strain measurements taken from electrical resistance strain gages affixed to the specimens, Nos. 1, 8, and 17. Stress-strain curves are given in plates 1, 2, and 3. Specimens 1, 8, and 17 were cycled at 5000 psi. Results are given below.

Specimen No.	Modulus, psi x 10^6 Young's	Bulk	Shear	Shear Velocity, fps	Poisson's Ratio
		Dynamic Tests			
1	4.6	3.6	1.8	7040	0.29
7	2.1	1.8	0.8	4840	0.30
8	4.3	2.4	1.8	7095	0.20
10	6.0	4.6	2.4	8090	0.28
11	5.2	2.3	2.3	8070	0.13
17	5.3	1.6	2.9	8865	--*
19	6.0	4.8	2.3	7855	0.29
22	7.4	5.8	2.9	8925	0.29
		Static Tests			
1	3.5	2.7	1.4	--	0.29
8	4.8	2.0	2.1	--	0.11
17	5.6	2.9	2.3	--	0.18

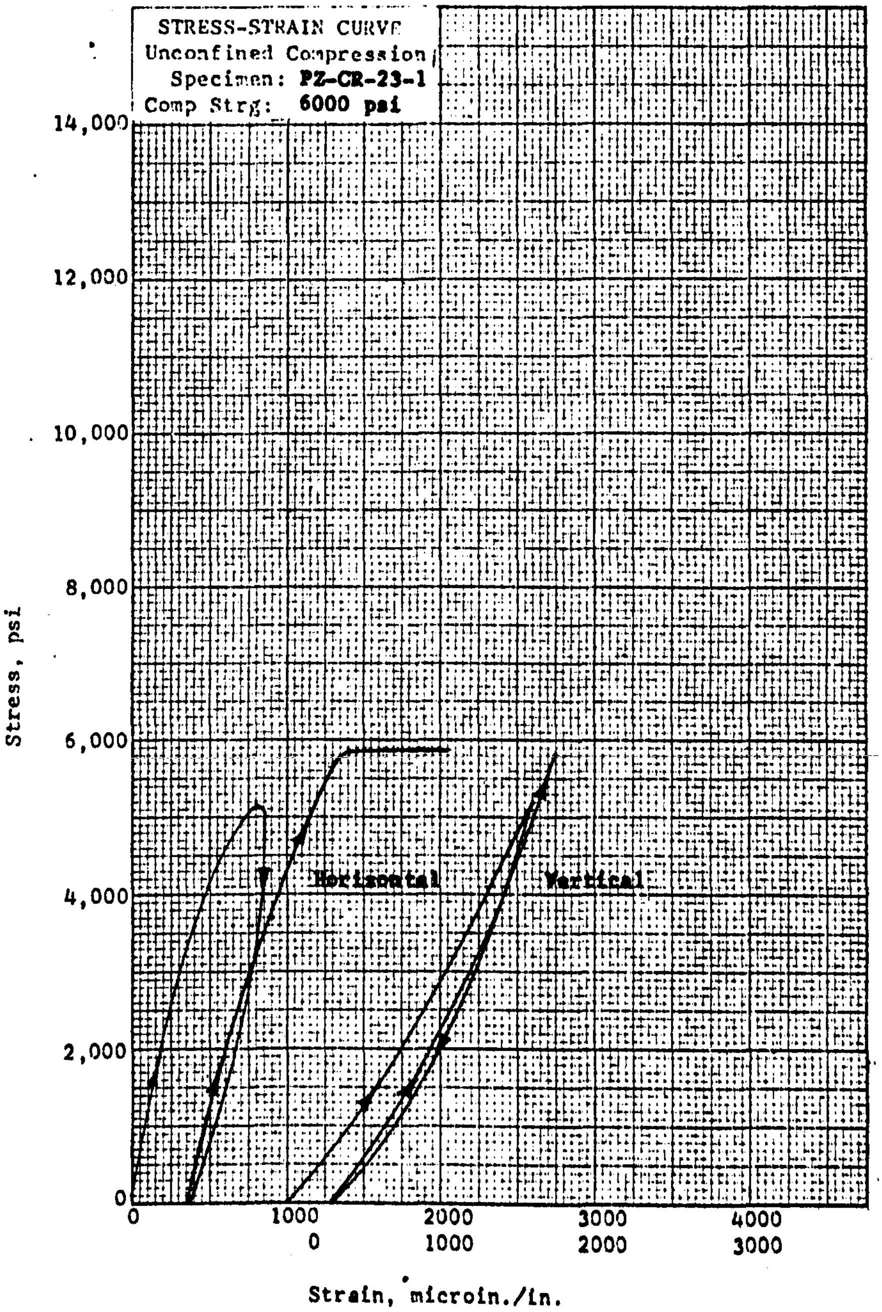
* Due to the unusually large shear velocity to compressive velocity ratio, the dynamic Poisson's ratio for this specimen could not be accurately determined.

All of the rock tested herein is apparently rather rigid material. The three specimens for which static moduli were determined exhibited some hysteresis and, upon cycling, residual strain.

Conclusions

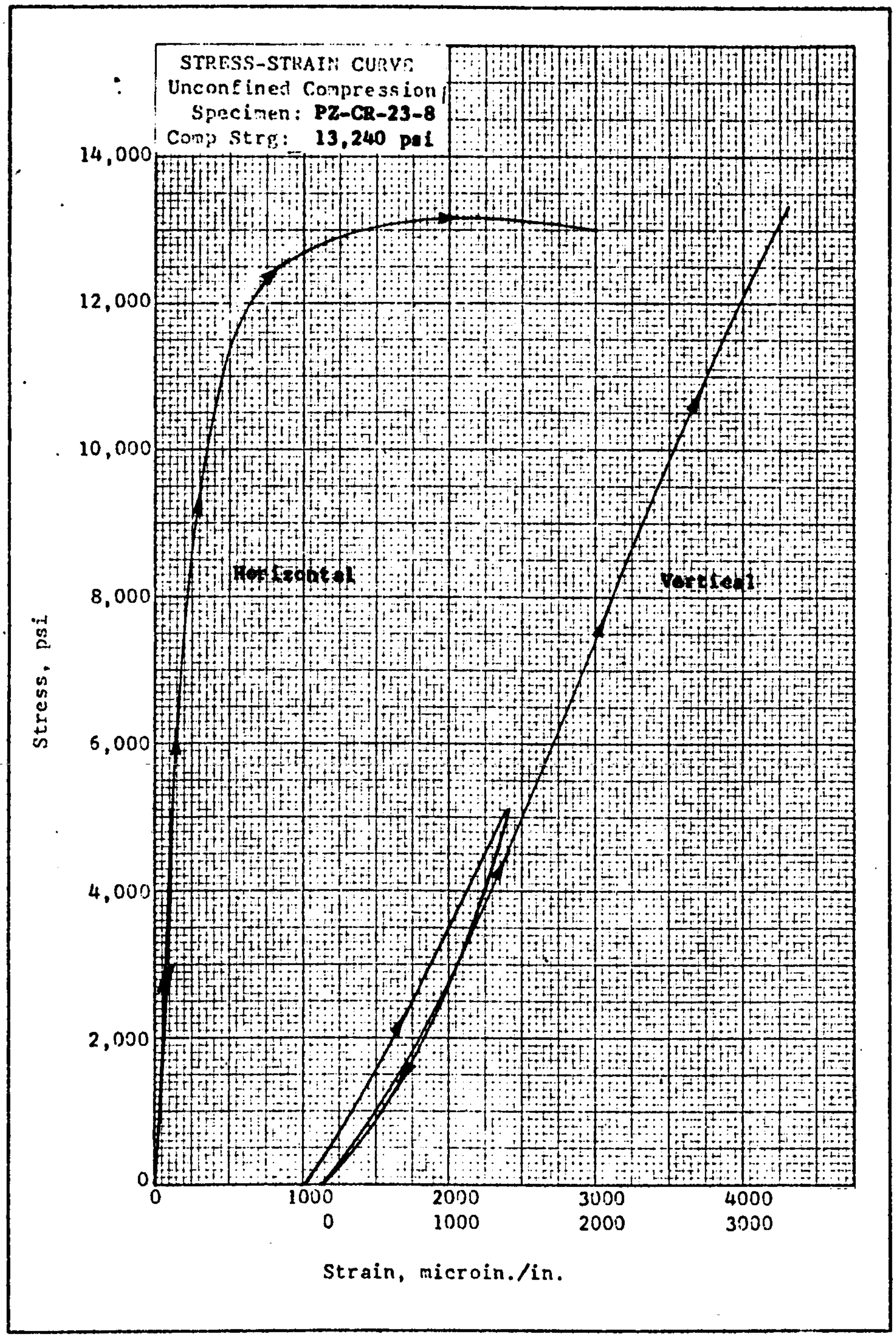
6. The core received for testing from hole PZ-CR-23 was relatively uniform in appearance, identified by the field log received with the core as light- to dark-gray quartz monzonite. Specimen Nos. 6, 7, 8, 9, and 21 were pegmatite; Nos. 1, 2, 7, 9, and 21 contained fractures. Physical test results were consistently low, possibly due to the large mica concentrations present in the core. The fractured material was very incompetent, exhibiting an average compressive strength of 6330 psi. The intact rock exhibited only marginal strength characteristics.

Property	Fractured Specimens	Intact Specimens
Specific Gravity	2.639	2.676
Schmidt Number	43.4	50.2
Compressive Strength, psi	6,330	11,340
Compressional Wave Velocity, fps	10,955	13,600
Static Young's Modulus, psi x 10^6	3.5	5.2



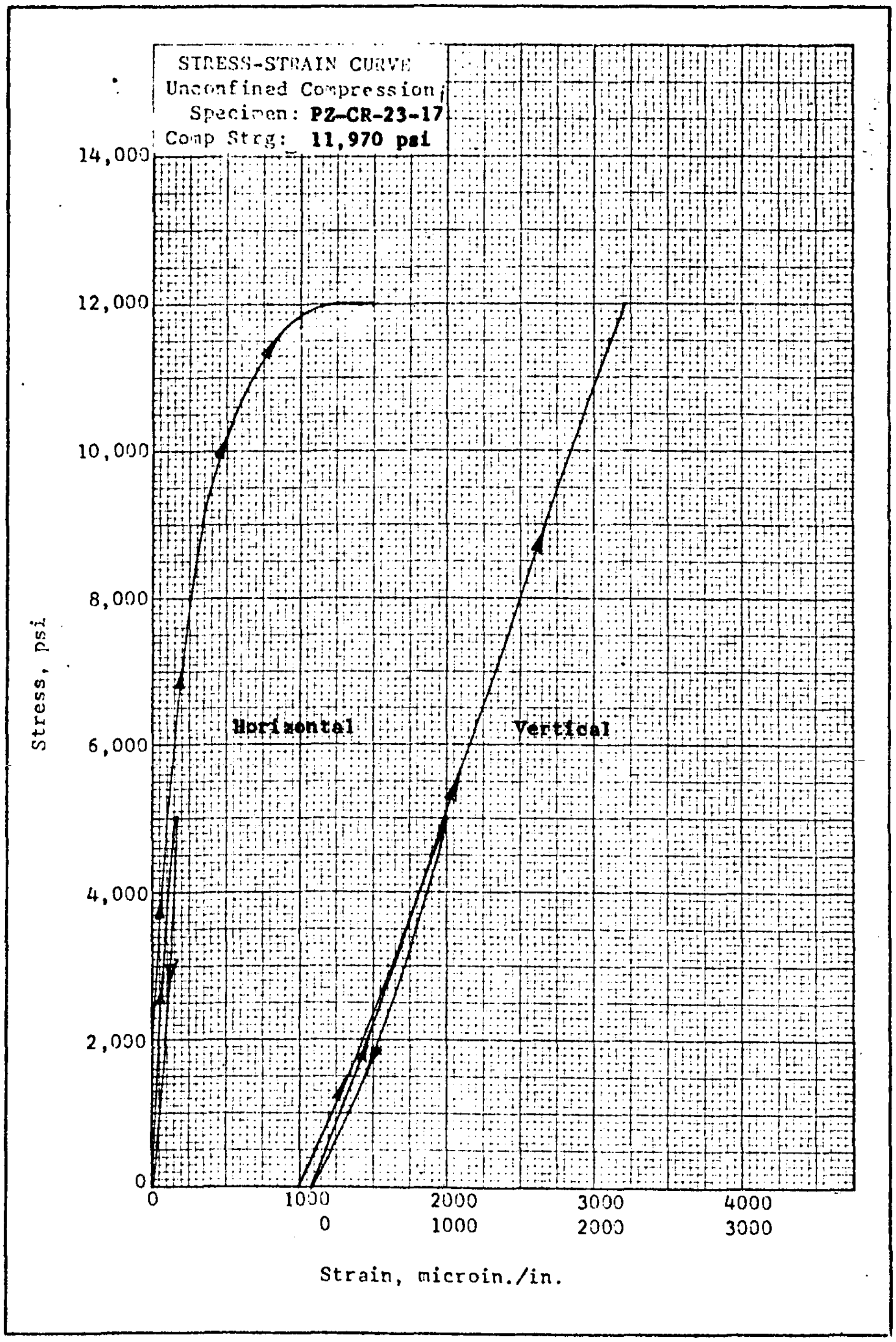
STRESS-STRAIN CURVE
Unconfined Compression
Specimen: PZ-CR-23-1
Comp Strg: 6000 psi
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
Stress, psi
Horizontal
Vertical
0
1000
2000
3000
4000
0
1000
2000
3000
Strain, microin./in.

PLATE C1



STRESS-STRAIN CURVE
Unconfined Compression
Specimen: PZ-CR-23-8
Comp Strg: 13,240 psi
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
Stress, psi
Horizontal
Vertical
0
1000
2000
3000
4000
0
1000
2000
3000
Strain, microin./in.

PLATE C2



STRESS-STRAIN CURVE
Unconfined Compression
Specimen: PZ-CR-23-17
Comp Strg: 11,970 psi
Stress, psi
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
Horizontal
Vertical
0
1000
2000
3000
4000
0
1000
2000
3000
Strain, microin./in.

PLATE C3

APPENDIX D

DATA REPORT

Hole PZ-CR-25

19 November 1969

Hole Location: Merrimack County, New Hampshire

Core

1. The following core was received on 3 November 1969 for testing:

Core Piece No.	Approximate Depth, ft
1	5
2	12
3	21
4	31
5	41
6	52
7	64
8	72
9	75
10	85
11	88
12	91
13	102
14	114
15	122
16	131
17	140
18	150
19	160
20	170
21	180
22	189
23	198

Description

2. The samples received were relatively uniform in appearance. According to the field log received with the core, the rock was identified as muscovite biotite granite. Specimen Nos. 1 and 2 were weathered; specimen 13 contained a high-angle fracture.

Quality and uniformity tests

3. To determine variations within the hole, specific gravity, Schmidt number, compressive strength, and compressional wave velocity were determined on specimens prepared from representative samples as given below:

	Sample No.	Description	Core Depth	Sp Gr	Schmidt No.	Comp Strg, psi	Comp Wave Vel, fps
Muscovite Granodiorite	1	Weathered	5	2.649	--	9,440	11,100
	2	Weathered	12	2.636	36.8	9,610	9,385
	5	Intact	41	2.636	40.1	15,260	8,140
	8	Intact	72	2.635	36.3	8,820	7,735
	11	Intact	88	2.648	51.8	9,760	8,425
	13	Contained High-Angle Fracture	102	2.636	45.3	9,210	9,975
	15	Intact	122	2.644	47.2	15,240	10,725
	18	Intact	150	2.650	48.4	14,080	8,935
	21	Intact	180	2.650	46.7	15,450	8,950
	23	Intact	198	2.654	48.3	14,390	10,075
	Average of all specimens tested (10)			2.644	44.5	12,130	9,345

4. The material from this hole exhibited comparatively low physical test results for a dense intact rock. To verify the velocity measurements, two pieces of test equipment were used on the samples tested herein.

5. Preliminary petrographic examination indicated that the muscovite biotite granite was composed of up to 50 percent mica. If confirmed by more extensive analysis, this could possibly explain the low velocities and uniaxial compressive strengths.

Moduli of deformation

6. Representative specimens were selected for dynamic and static moduli of deformation tests. The dynamic moduli were determined by the proposed ASTM method for determination of ultrasonic pulse velocities and elastic constants of rock. The static moduli were computed from theory of elasticity by use of strain measurements taken from electrical resistance strain gages affixed to the specimens, Nos. 2, 13, and 21. Stress-strain curves are given in plates 1, 2, and 3. Specimens 2 and 21 were cycled at 5000 psi. Specimen 13 was cycled at 6000 psi. Results are given below.

Specimen No.	Modulus, psi x 10^6			Shear Velocity, fps	Poisson's Ratio
	Young's	Bulk	Shear		
			Dynamic Tests		
1	3.8	2.4	1.5	6525	0.24
2	3.0	1.4	1.3	6115	0.13
5	2.2	1.1	0.9	5155	0.16
8	2.0	1.0	0.9	4910	0.16
11	2.5	0.8	1.3	5985	--*
13	3.2	1.8	1.3	6140	0.20
15	3.7	2.0	1.6	6655	0.19
18	2.8	1.2	1.2	5900	0.11
21	2.8	1.1	1.3	6105	0.07
23	3.5	1.5	1.6	6670	0.11

(Continued)

* Due to the unusually large shear velocity to compressive velocity ratio, the dynamic Poisson's ratio for this specimen could not be accurately determined.

(Continued)

Specimen No.	Modulus, psi x 10^6			Shear Velocity, fps	Poisson's Ratio
	Young's	Bulk	Shear		
			Static Tests		
2	2.9	2.2	1.1	--	0.28
13	3.4	1.5	1.5	--	0.12
21	4.5	2.5	1.9	--	0.20

All of the core tested herein is apparently rather brittle material, exhibiting some hysteresis and residual strain. The erratic behavior of the stress-strain curves for specimen 13 was possibly due to vertical strain relief caused by slippage along fractures.

Conclusions

7. The core received for testing from hole PZ-CR-25 was identified by the field log received with the core as muscovite biotite granite. Specimen Nos. 1 and 2 were weathered; No. 13 contained a high-angle fracture. Physical test results for this material were relatively uniform but low, possibly due to the unusually large mica content indicated by preliminary petrographic analysis. Uniaxial compressive strengths ranged from 9000 to 15,000 psi.

Property	Average of All Specimens
Specific Gravity	2.644
Schmidt Number	44.5
Compressive Strength, psi	12,130
Compressional Wave Velocity, fps	9,345
Static Young's Modulus, psi x 10^6	3.6

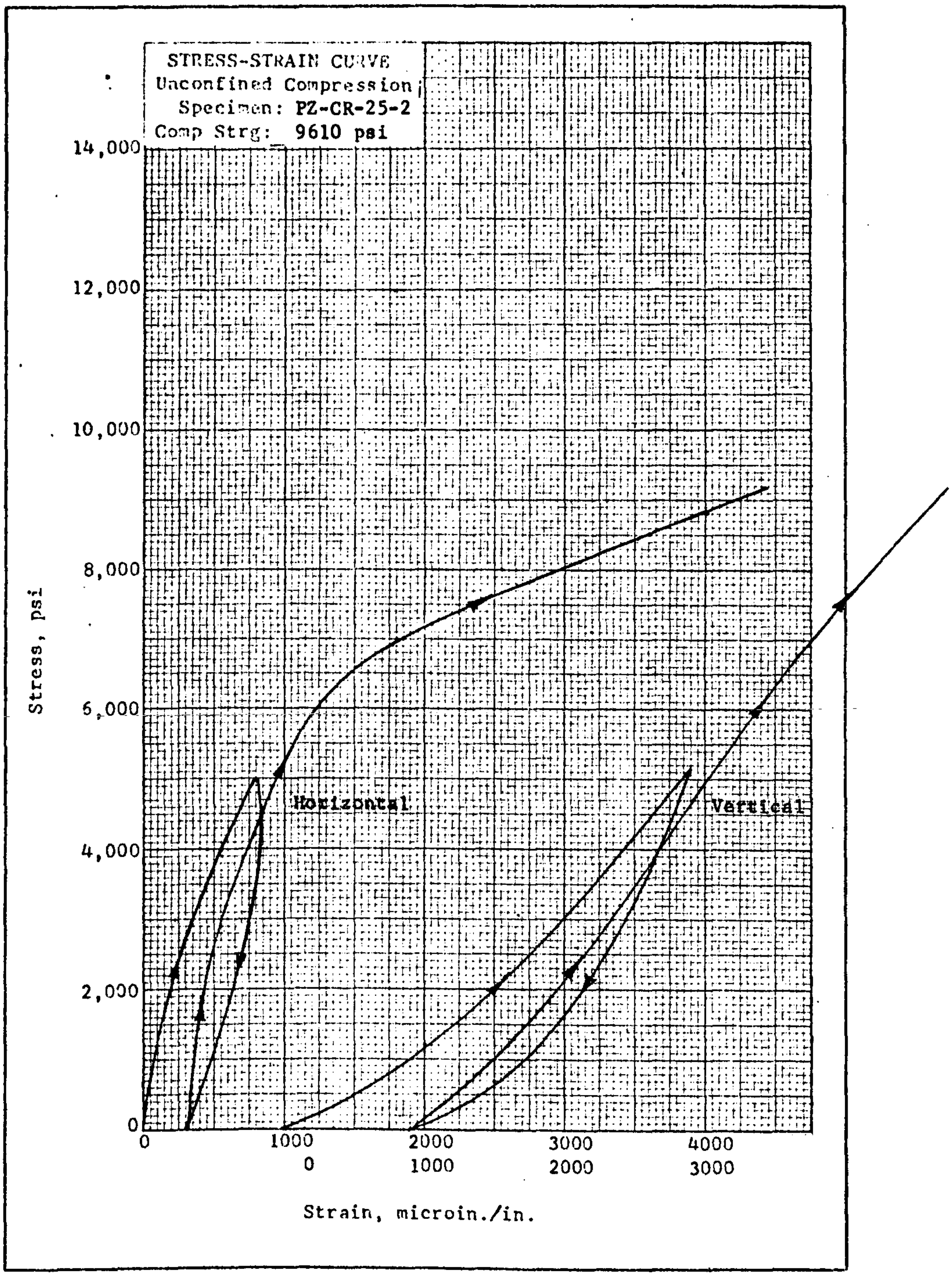

STRESS-STRAIN CURVE
Unconfined Compression
Specimen: PZ-CR-25-2
Comp Strg: 9610 psi
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
Stress, psi
Horizontal
Vertical
0
1000
2000
3000
4000
0
1000
2000
3000
Strain, microin./in.

PLATE D1

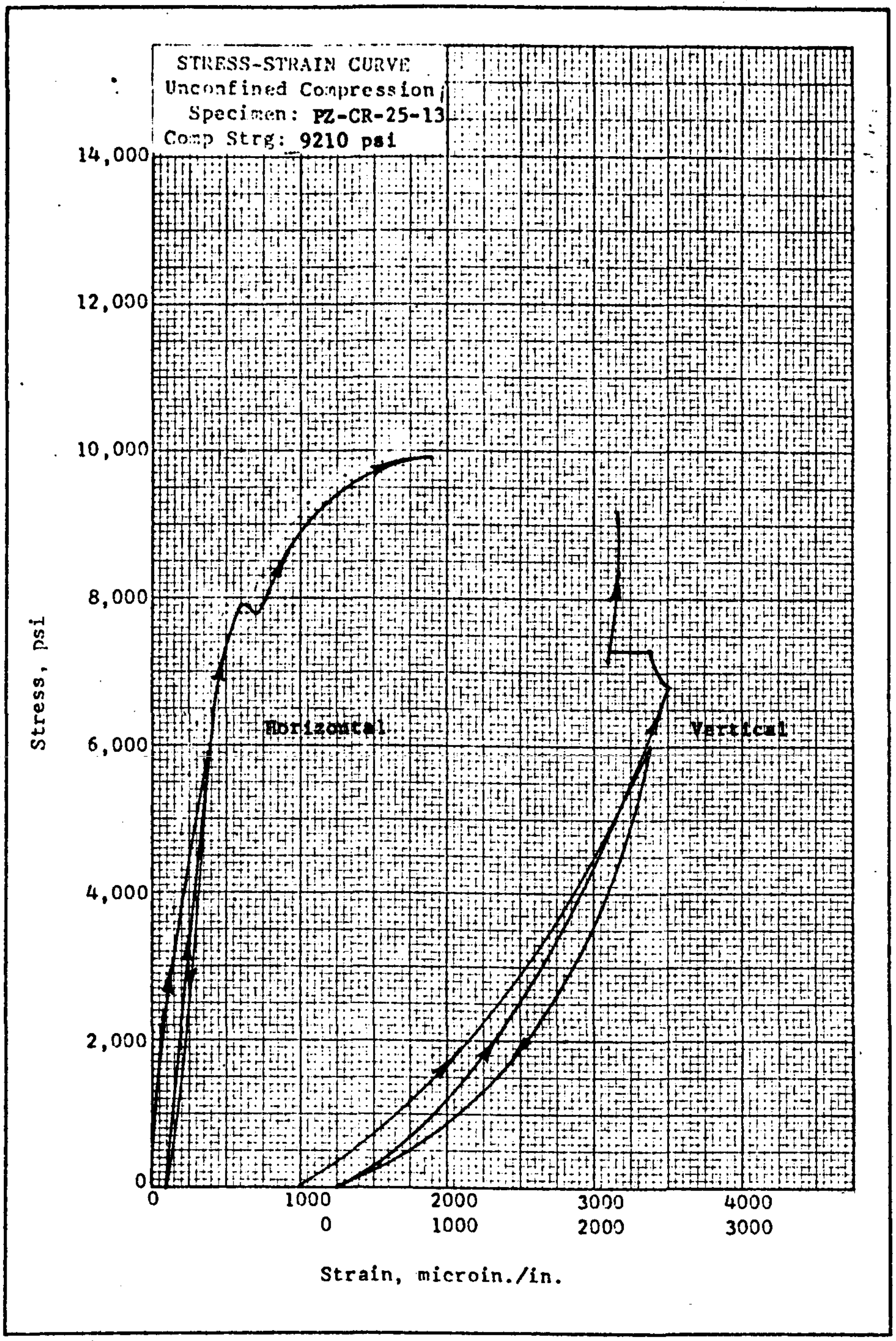
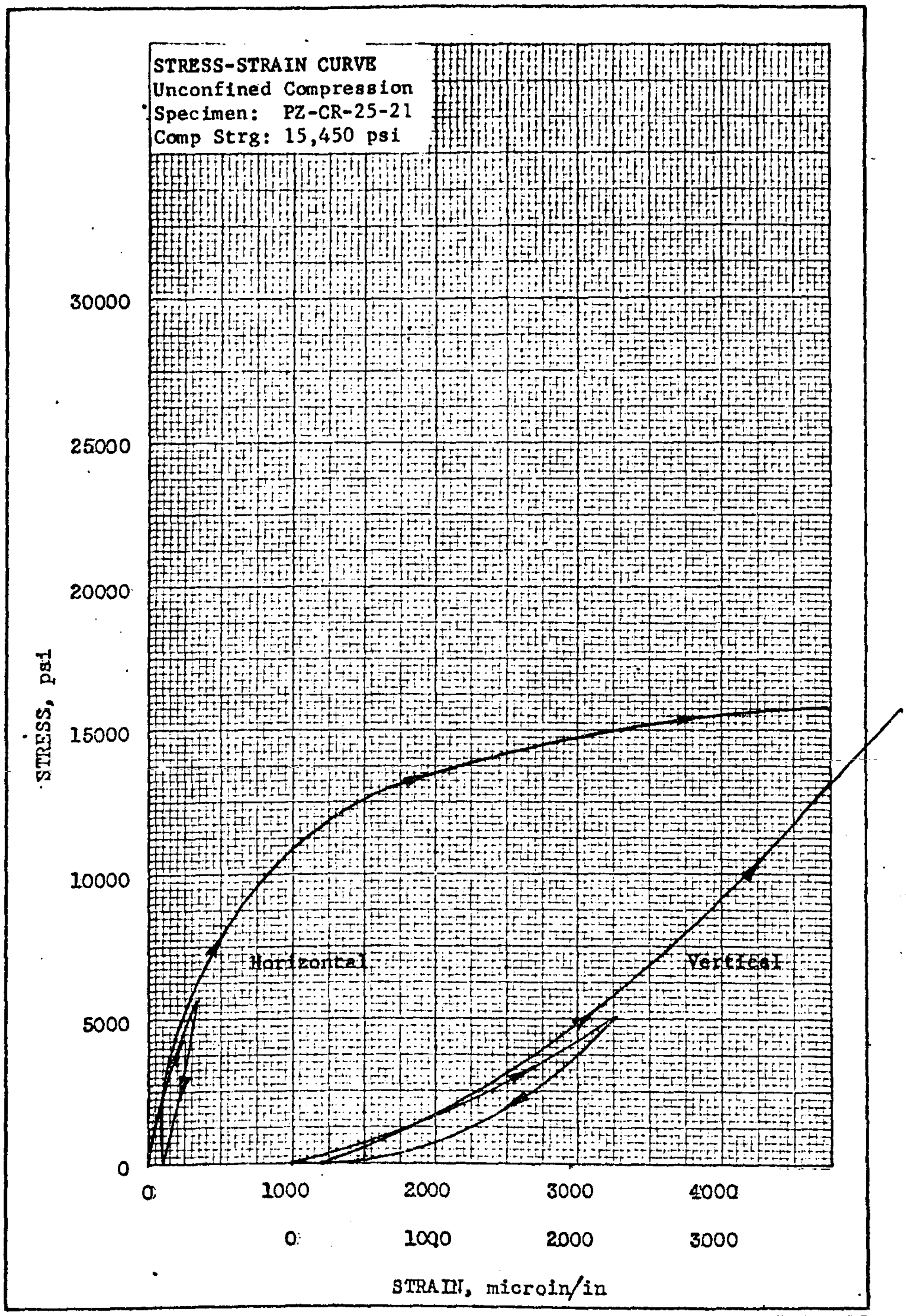

STRESS-STRAIN CURVE
Unconfined Compression
Specimen: PZ-CR-25-13
Comp Strg: 9210 psi
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
Stress, psi
Horizontal
Vertical
0
1000
2000
3000
4000
0
1000
2000
3000
Strain, microin./in.

PLATE D2



STRESS-STRAIN CURVE
Unconfined Compression
Specimen: PZ-CR-25-21
Comp Strg: 15,450 psi
30000
25000
20000
15000
10000
5000
0
STRESS, psi
Horizontal
Vertical
0
1000
2000
3000
4000
0
1000
2000
3000
STRAIN, microin/in

PLATE D3

APPENDIX E

DATA REPORT

Hole PZ-CR-34

14 November 1969

Hole Location: Belknap County, New Hampshire

Core

1. The following core was received on 20 October 1969 for testing:

Core Piece No.	Approximate Depth, ft
1	10
2	18
3	28
4	37
5	46
6	58
7	65
8	74
9	83
10	87
11	90
12	101
13	110
14	118
15	129
16	137
17	139
18	141
19	155
20	160
21	165
22	169
23	179
24	190
25	199

Description

2. The samples received were quite variable in appearance. According to the field log received with the core, the rock was identified as gray to light-gray quartz diorite. Specimen Nos. 1, 2, 3, 10, and 18 contained fractures. Specimen Nos. 4, 5, 7, 8, 16, and 18 contained pegmatite dike material. Three specimens were banded. Specimen Nos. 1, 2, and 3 appeared slightly weathered.

Quality and uniformity tests

3. To determine variations within the hole, specific gravity, Schmidt number, compressive strength, and compressional wave velocity were determined on specimens prepared from representative samples as given below:

	Sample No.	Description	Core Depth	Sp Gr	Schmidt No.	Comp Strg, psi	Comp Wave Vel, fps
Mica Schist	3	Slightly Weathered	28	2.687	50.9	19,120	17,165
Mica Schist	4	Contained Pegmatite ~~Dike~~ Band	37	2.650	37.7	23,030	10,605
Mica Schist	7	Contained ~~Pegmatite~~ Pegmatite Band	65	2.640	48.1	18,450	13,290
Mica Gneiss	9	Fine Grained	83	2.714	--	21,770	14,965
Basaltic Material	10	Contained Healed, Critical-Angle Fracture	87	2.898	47.5	7,360	19,660
Mica Schist	11	Coarse Grained	90	2.722	45.0	17,760	15,045
Mica Schist	14	Coarse Grained	118	2.683	44.8	13,090	13,045
Mica Schist	15	Banded	129	2.828	43.7	12,320	12,360
~~Mica Schist~~	~~18~~	~~Contained Pegmatite Dike~~ Band	~~141~~	~~2.725~~	39.7	14,550	14,500
Mica Gneiss	21	Fine Grained	165	2.824	43.6	11,640	15,885
Mica Schist	25	Coarse Grained	199	2.766	45.3	16,880	16,735
	Specimens Containing Pegmatite (3)			2.672	41.8	18,680	12,800
	Specimen Containing Healed, Critical-Angle Fracture (1)			2.898	47.5	7,360	19,660
	Remainder of Specimens (7)			2.746	45.6	16,080	15,030

The Schmidt hammer test was not conducted on one specimen due to possibility of breakage. Also, the above Schmidt values should be considered with caution since most core surfaces were very irregular, rendering test results somewhat questionable.

4. Physical test results exhibited by this material were quite variable, possibly due to the large variation in grain size, degree of weathering, and composition of the core.

Moduli of deformation

5. Representative specimens were selected for static moduli of deformation tests. At the request of Mr. Paul Kraft of Ken O'Brien and Associates, dynamic moduli were determined on all specimens tested. The dynamic moduli were determined by the proposed ASTM method for determination of ultrasonic pulse velocities and elastic constants of rock. The static moduli were computed from theory of elasticity by use of strain measurements taken from electrical resistance strain gages affixed to the specimens, Nos. 10, 21, and 25. Stress-strain curves are given in plates 1, 2, and 3. Specimen 25 was cycled at 10,000 psi; specimen 21 was cycled at 5000 psi. Results are given below.

Specimen No.	Modulus, psi x 10^6 Young's	Bulk	Shear	Shear Velocity, fps	Poisson's Ratio
		Dynamic Tests			
3	7.7	6.7	3.0	9,020	0.31
4	3.7	2.0	1.6	6,585	0.19
7	5.3	3.4	2.1	7,755	0.24
9	7.0	4.4	2.9	8,815	0.23
10	14.6	6.3	6.6	12,960	0.12
11	7.3	4.3	3.0	9,080	0.21
14	5.5	3.1	2.3	7,925	0.21
15	5.0	2.6	2.1	7,755	0.18
18	6.7	1.4	4.7	11,350	--*
21	8.1	5.3	3.2	9,225	0.25
25	10.4	3.7	5.0	11,640	--*

(Continued)

* Due to the unusually large shear velocity to compressive velocity ratio, Poisson's ratio for these specimens could not be determined.

(Continued)

Specimen No.	Modulus, psi x 10^6 Young's	Bulk	Shear	Shear Velocity, fps	Poisson's Ratio
		Static Tests			
10	8.9	5.3	3.6	--	0.22
21	5.3	2.2	2.4	--	0.09
25	7.4	5.7	3.0	--	0.28

All of the rock tested herein is apparently rather rigid material, exhibiting slight hysteresis. Upon cycling, some residual strain was detected.

Conclusions

6. The core received from hole PZ-CR-34 was quite variable, identified by the core log as gray to light-gray quartz diorite. The specimens tested exhibited a rather wide range of physical test results, possibly due to the large variation in grain size, degree of weathering, and composition of the core. One specimen containing a critically oriented fracture failed along this fracture at a stress of 7360 psi. The specimens containing pegmatite dike material were slightly different from the remainder of the core.

Property	Critically Fractured Specimen	Specimens Containing Pegmatite	Remainder of Specimens
Specific Gravity	2.898	2.672	2.746
Schmidt Number	47.5	41.8	45.6
Compressive Strength, psi	7,360	18,680	16,080
Compressional Wave Velocity, fps	19,660	12,800	15,030
Static Young's Modulus, psi x 10^{-6}	8.9	--	6.4

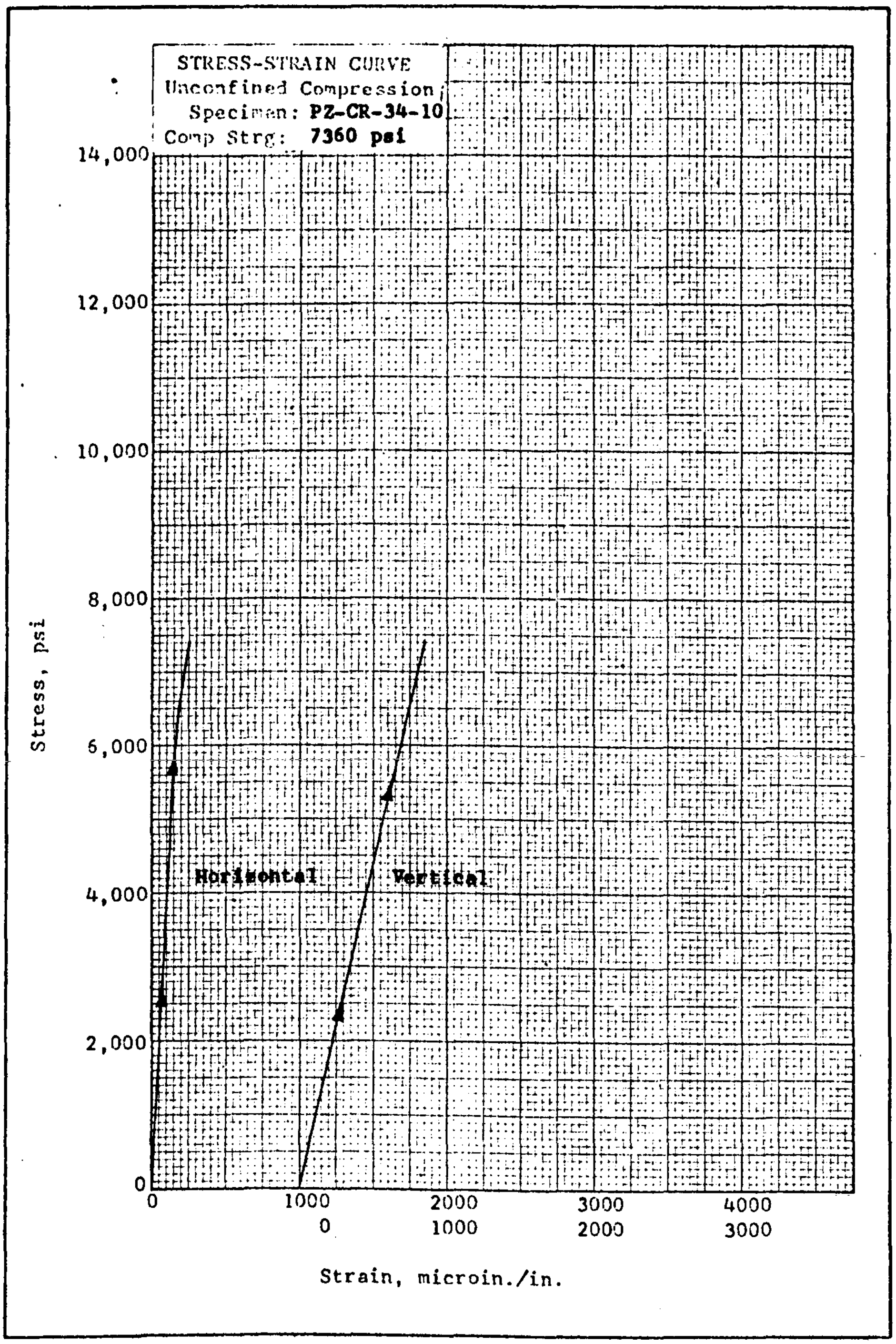

STRESS-STRAIN CURVE
Unconfined Compression
Specimen: PZ-CR-34-10
Comp Strg: 7360 psi
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
Stress, psi
Horizontal
Vertical
0
1000
2000
3000
4000
0
1000
2000
3000
Strain, microin./in.

PLATE E1

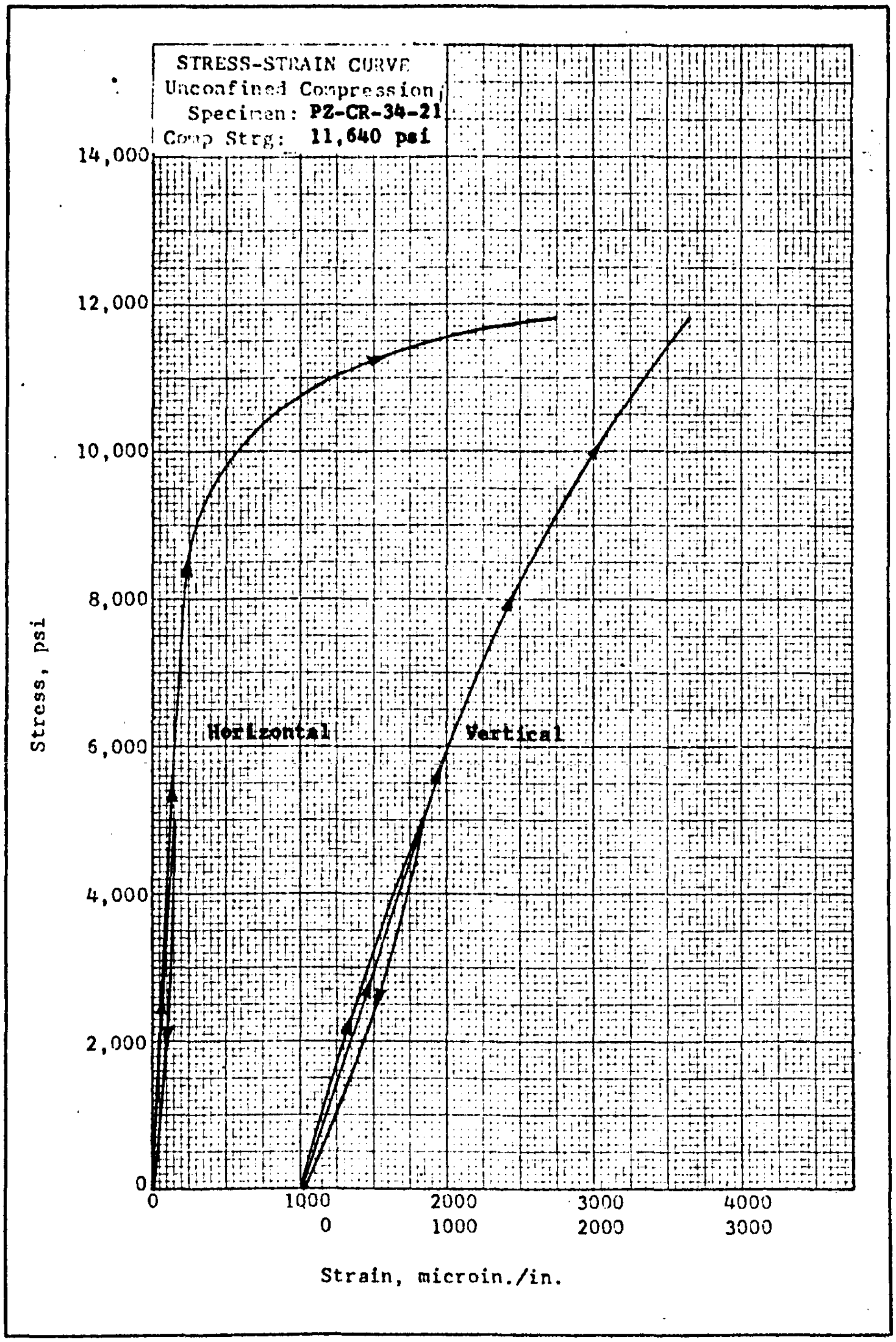

STRESS-STRAIN CURVE
Unconfined Compression
Specimen: PZ-CR-34-21
Comp Strg: 11,640 psi
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
Stress, psi
Horizontal
Vertical
0
1000
2000
3000
4000
0
1000
2000
3000
Strain, microin./in.

PLATE E2

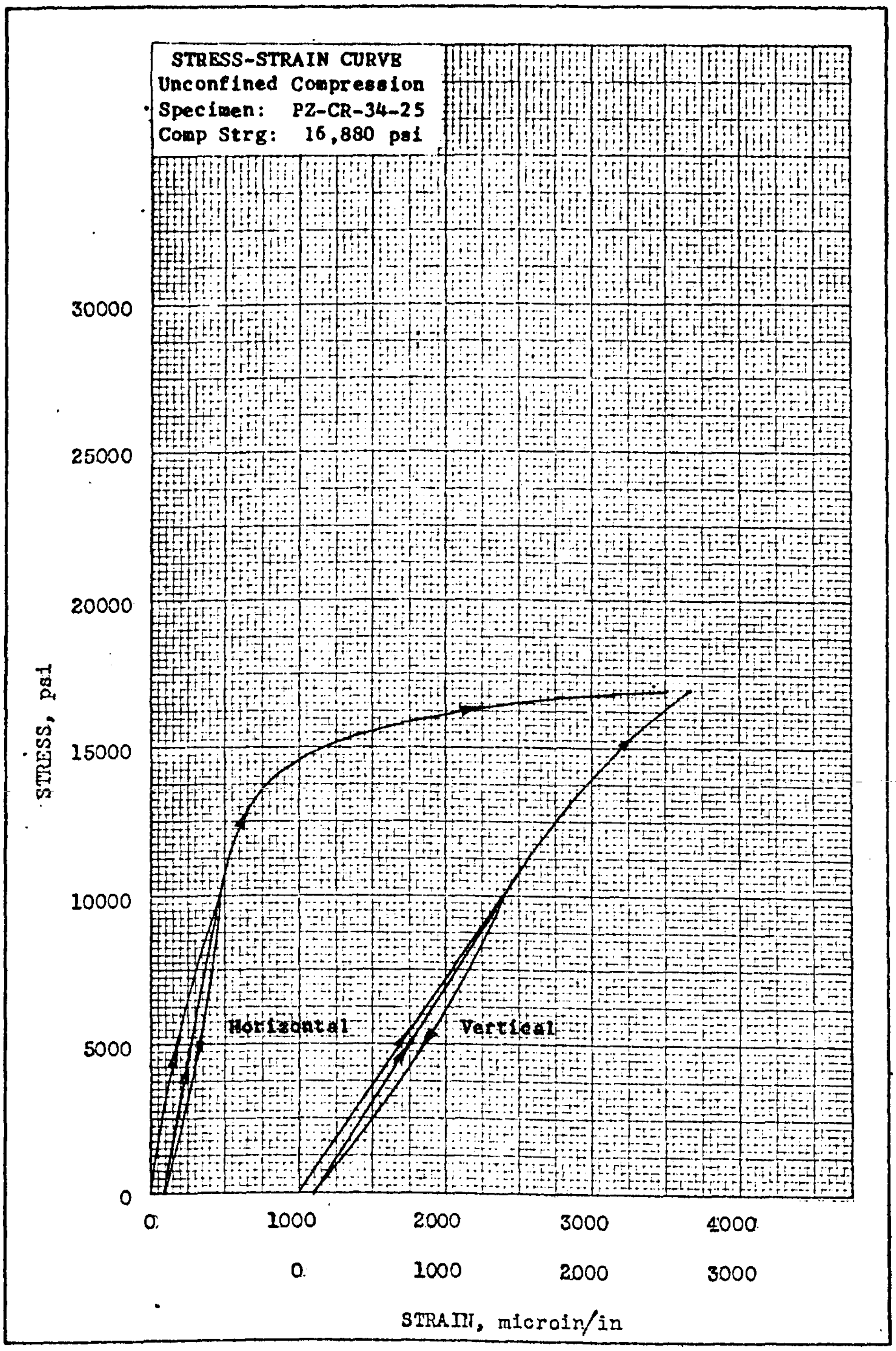

STRESS-STRAIN CURVE
Unconfined Compression
Specimen: PZ-CR-34-25
Comp Strg: 16,880 psi
STRESS, psi
30000
25000
20000
15000
10000
5000
0
Horizontal
Vertical
0
1000
2000
3000
4000
0
1000
2000
3000
STRAIN, microin/in

PLATE E3

APPENDIX F

DATA REPORT

Hole PZ-CR-36

21 November 1969

Hole Location: Belknap County, New Hampshire

Longitude: 71° 20' 14.3" West

Latitude: 43° 31' 37.0" North

Core

1. The following core was received on 20 October 1969 for testing:

Core Piece No.	Approximate Depth, ft
1	10
2	12
3	20
4	30
5	40
6	48
7	56
8	61
9	69
10	79
11	89
12	101
13	108
14	119
15	130
16	140
17	148
18	158
19	170
20	179
21	188

Description

2. The samples received were somewhat variable in appearance. According to the field log received with the core, the rock was identified as granite, and conglomerate-breccia mosaic in a granitic matrix. Specimen Nos. 3, 5, 7, 8, 9, 14, 18, 20, and 21 contained fractures; Nos. 1, 2, 3, 4, 17, 18, 19, 20, and 21 contained conglomerate-fragment material.

Quality and uniformity tests

3. To determine variations within the hole, specific gravity, Schmidt number, compressive strength, and compressional wave velocity were determined on specimens prepared from representative samples as given below:

	Sample No.	Description	Core Depth	Sp Gr	Schmidt No.	Comp Strg, psi	Comp Wave Vel, fps
Black and White Tonalite	2	Intact, Fragment Material-	12	2.768	--	26,210	15,865
Fine-Grained Dacite	4	Matrix-and-Fragments, Intact	30	2.673	56.0	34,700	16,660
	5	Matrix-Material, Severely Fractured	40	2.593	49.6	9,640	14,810
	6	Matrix-Material, Intact	48	2.606	50.8	37,880	15,365
	9	Matrix-Material, Fractured	69	2.609	57.8	25,000	14,200
	12	Matrix-Material, Intact	101	2.611	54.2	43,180	15,005
	15	Matrix-Material, Intact	130	2.609	58.1	40,910	12,370
	18	Matrix-and-Fragments, Fractured	158	2.672	53.3	37,880	13,080
	20	Matrix-and-Fragments; Fractured	179	2.652	52.9	39,090	14,265
Severely Fractured Specimen (1)				2.593	49.6	9,640	14,810
Fractured Specimens (3)				2.644	54.7	33,990	13,850
Intact Specimens (5)				2.653	54.8	36,580	15,055

Moduli of deformation

4. Representative specimens were selected for dynamic and static moduli of deformation tests. The dynamic moduli were determined by the proposed ASTM method for determination of ultrasonic pulse velocities and elastic constants of rock. The static moduli were computed from theory of elasticity by use of strain measurements taken from electrical resistance strain gages affixed to the specimens, Nos. 2, 10, and 17. Stress-strain curves are given in plates 1, 2, and 3. Specimens 10 and 17 were cycled at 10,000 psi. Results are given below.

Specimen No.	Modulus, psi x 10^6 Young's	Modulus, psi x 10^6 Bulk	Modulus, psi x 10^6 Shear	Shear Velocity, fps	Poisson's Ratio
		Dynamic Tests			
2	7.1	5.7	2.7	8565	0.29
4	7.3	6.3	2.8	8805	0.31
5	6.8	4.0	2.8	8935	0.21
6	6.9	4.6	2.8	8865	0.25
9	6.0	3.8	2.4	8315	0.24
12	6.7	4.4	2.7	8730	0.24
15	5.2	2.2	2.4	8225	0.10
18	5.5	3.1	2.3	8000	0.20
20	6.4	3.8	2.6	8535	0.22
		Static Tests			
2	8.1	4.5	3.3	--	0.20
12	8.5	4.7	3.5	--	0.20
18	9.4	5.7	3.9	--	0.22

The rock tested herein is apparently a rather brittle material, exhibiting some hysteresis and residual strain.

Conclusions

5. The core received for testing from hole PZ-CR-36 was rather variable in appearance, identified by the field log received with the core as granite and conglomerate-breccia mosaic in a granitic matrix. Specimen Nos. 3, 5, 7, 8, 9, 14, 18, 20, and 21 contained fractures, most of which were tightly closed. With the exception of specimen No. 5, the only severely fractured specimen, the material from this hole appeared to be very competent, ranging in uniaxial compressive strength from 25,000 to 43,000 psi. Generally, slight to moderate fracturing appeared to have little effect on physical test results. However, the previously mentioned severely fractured specimen was quite weak, exhibiting an ultimate strength of 9640 psi.

Property	Severely Fractured Specimen	Fractured Specimens	Intact Specimens
Specific Gravity	2.593	2.644	2.653
Schmidt Number	49.6	54.7	54.8
Compressive Strength, psi	9,640	33,990	36,580
Compressional Wave Velocity, fps	14,810	13,850	15,055
Static Young's Modulus, psi x 10^6	--	9.4	8.3

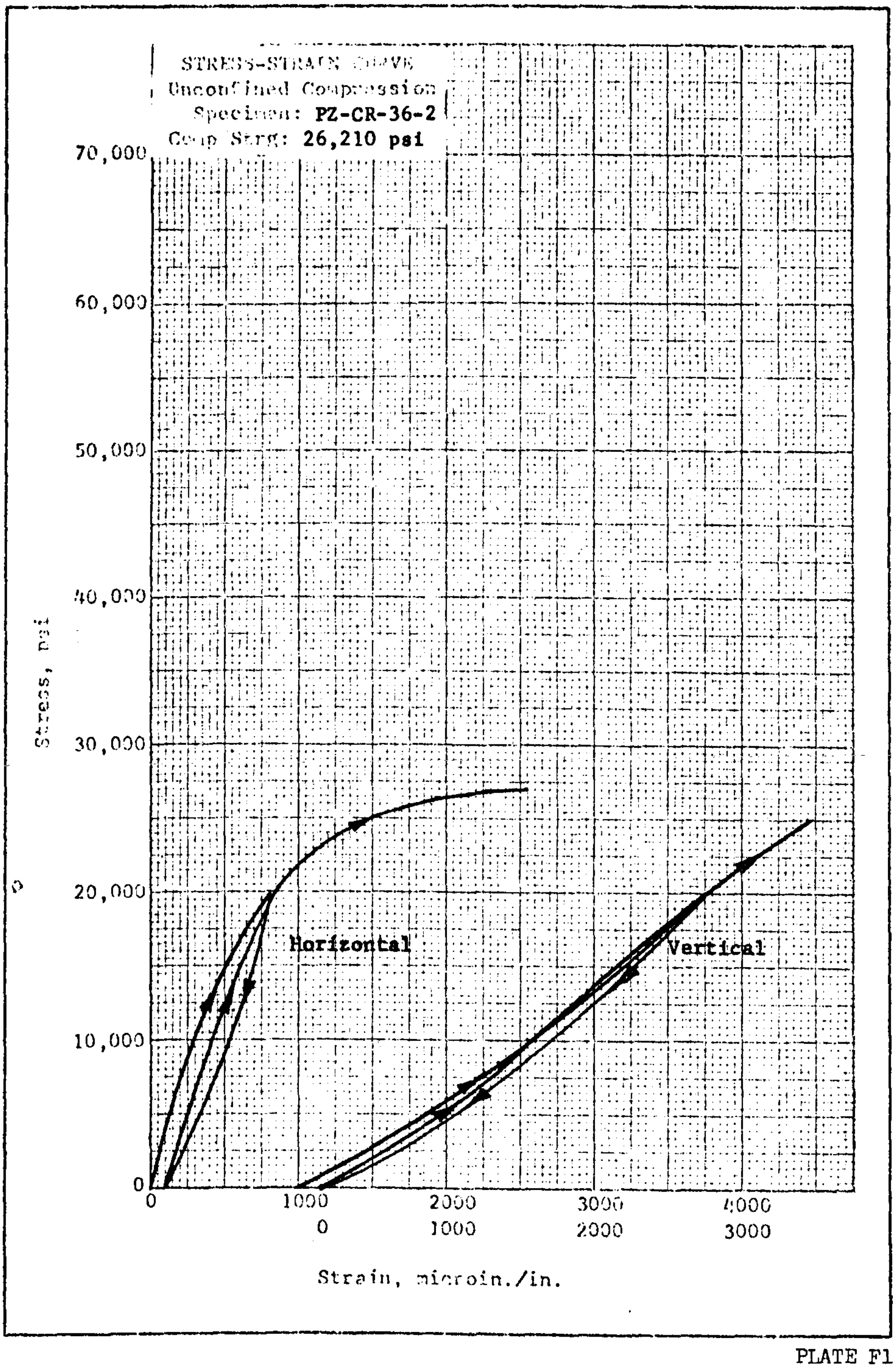

STRESS-STRAIN CURVE
Unconfined Compression
Specimen: PZ-CR-36-2
Comp Strg: 26,210 psi
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
Stress, psi
Horizontal
Vertical
0
1000
2000
3000
4000
0
1000
2000
3000
Strain, microin./in.

PLATE F1

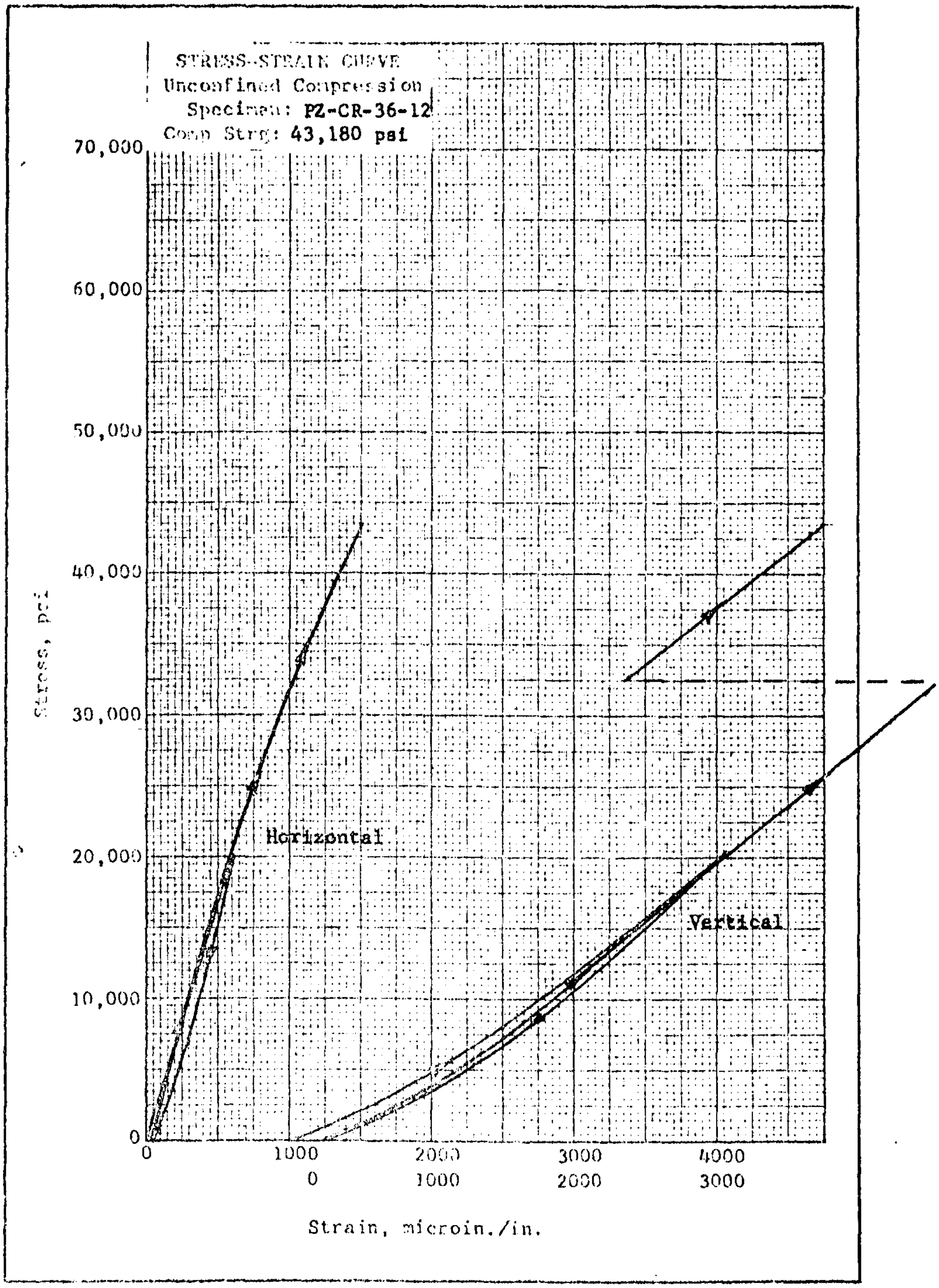

STRESS-STRAIN CURVE
Unconfined Compression
Specimen: PZ-CR-36-12
Comp Strg: 43,180 psi
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
Stress, psi
Horizontal
Vertical
0
1000
2000
3000
4000
0
1000
2000
3000
Strain, microin./in.

PLATE F2

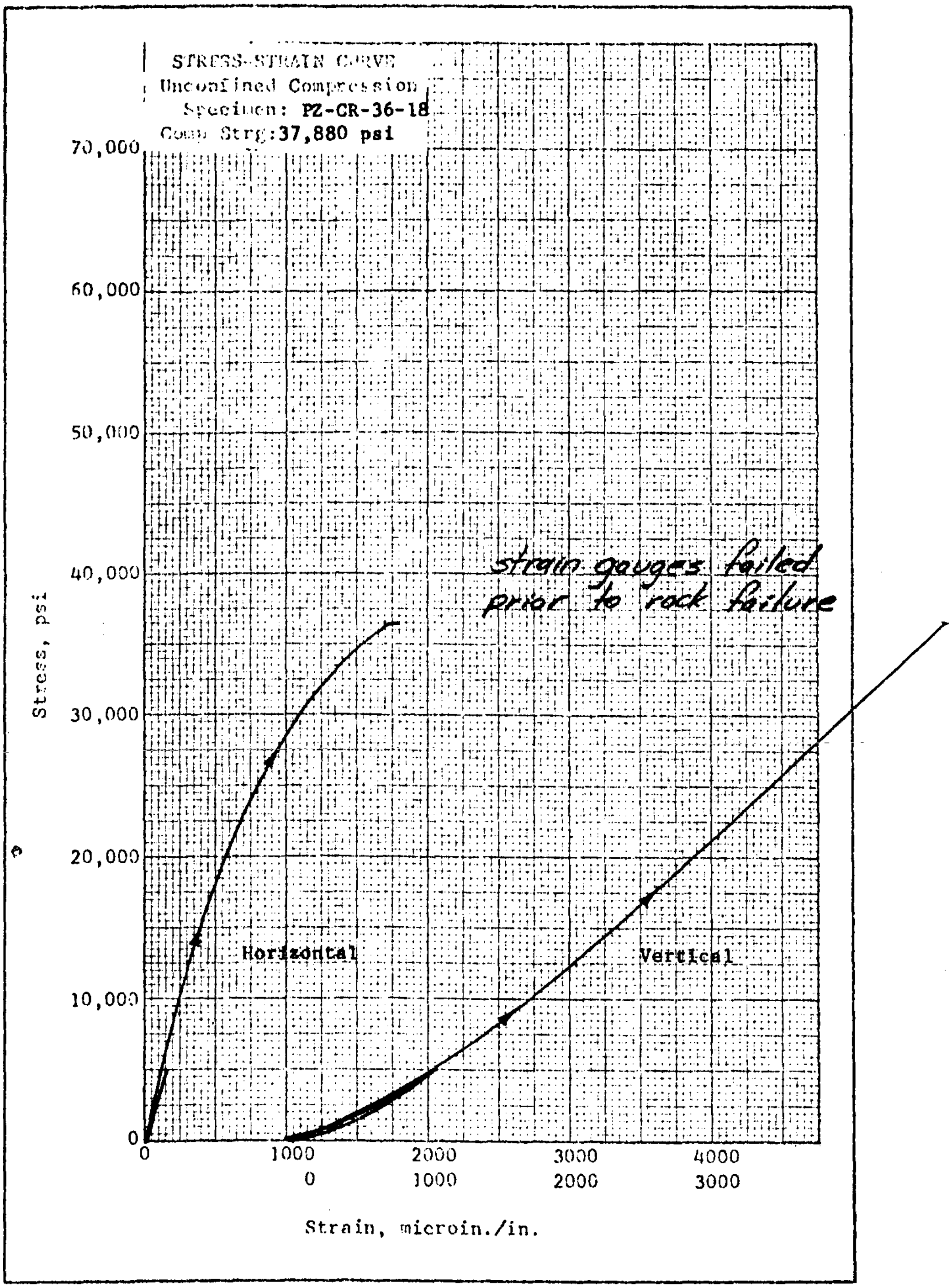

STRESS-STRAIN CURVE
Unconfined Compression
Specimen: PZ-CR-36-18
Comp Strg:37,880 psi
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
Stress, psi
strain gauges failed prior to rock failure
Horizontal
Vertical
0
1000
2000
3000
4000
0
1000
2000
3000
Strain, microin./in.

PLATE F3

REFERENCES

1. D. U. Deere and R. P. Miller; "Engineering Classification and Index Properties for Intact Rock"; Technical Report No. AFWL-TR-66-116, December 1966; Air Force Weapons Laboratory, Kirtland Air Force Base, N. Mex.; Unclassified.

2. U. S. Army Engineer Waterways Experiment Station, CE; "Handbook for Concrete and Cement"; August 1949 (with quarterly supplements); Vicksburg, Miss.; Unclassified.

3. S. J. Shand; "Eruptive Rocks"; Third Edition, 1947; John Wiley and Sons, New York, N. Y.; Unclassified.

4. F. Barker, "Phase Relations in Cordierite-Garnet-Bearing Kinsman Quartzmonzonite and the Enclosing Schist, Lovewell Mountain Quadrangle, New Hampshire"; American Mineralogist, 1961, Vol. 46, Pages 1166-1176; Unclassified.

5. A. Quinn; "Petrology of the Alkaline Rocks at Red Hill, New Hampshire"; Bulletin of the Geological Society of America, 1937, Vol. 48, Pages 373-402; Baltimore, Md.; Unclassified.

6. M. P. Billings; "Regional Metamorphism of the Littleton-Moosilauke Area, New Hampshire"; Bulletin of the Geological Society of America, 1937, Vol. 48, Pages 463-566; Baltimore, Md.; Unclassified.

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13. ABSTRACT

Laboratory tests were conducted on rock core samples received from six core holes in the Pease study area of Belknap, Cheshire, Grafton, and Merrimack Counties in New Hampshire. Results were used to determine the quality and uniformity of the rock to depths of 200 feet below ground surface. The rock core was petrographically identified as predominately mica gneiss, mica schist, dacite, granite gneiss, and muscovite granodiorite, with relatively minor quantities of tonalite, granodiorite gneiss, and basaltic material. Evaluation of the Pease study area core on a hole-to-hole basis indicates the moderately fractured and intact dacite removed from Hole PZ-CR-36 to be very competent rock. The highly fractured core, removed at depths of 40 feet or less below ground surface, was marginal in quality. Generally, this hole yielded material representative of competent, hard rock media. The remainder of the holes from this area, i.e., PZ-CR-2, -11, -23, -25, and -34, generally yielded rock core exhibiting physical properties characteristic of marginal to barely competent material. Holes PZ-CR-11, -23, and -34 yielded incompetent core from depths greater than 50 feet below ground surface, dictating classification of the core as unsuitable as competent media. Holes PZ-CR-2 and -25 yielded significant quantities of rock of marginal quality, but, dependent on results of possible further investigation, could offer some possibility as competent hard rock media. The above evaluations and conclusions have been based on somewhat limited data; therefore, more extensive investigation will be required in order to accurately assess the individual areas under consideration.

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