APPENDIX 2C

GEOLOGIC INVESTIGATIONS OF THE SCOTLAND ROAD FAULT (CLINTON - NEWBURY FAULT), NEWBURY, MASSACHUSETTS, AND PORTSMOUTH FAULT INVESTIGATIONS

The information contained in this appendix was not revised, but has been extracted from the original FSAR and is provided for historical information.

SCOTLAND ROAD FAULT INVESTIGATIONS

CONTENTS

PUBLIC SERVICE COMPANY OF NEW HAMPSHIRE

SEABROOK STATION

SCOTLAND ROAD FAULT INVESTIGATIONS

Investigations have been conducted over a portion of the Scotland Road fault in Newbury, Massachusetts, to determine the presence, location, orientation and physical characteristics of the fault, and to examine the nature and structure of the unconsolidated Pleistocene deposits which overlie the fault trace. The investigations have indicated that the fault structure is of Permian age, and that Pleistocene deposits overlying the fault zone show no evidence of movement on the fault subsequent to their deposition.

I. LOCATION OF FAULT INVESTIGATIONS

The Scotland Road fault was inferred by A. F. Shride of the U. S. Geological Survey (Shride; 1971) to trend easterly through the towns of West Newbury, Newbury and Newburyport, Massachusetts, about 7 miles to the south of the proposed Seabrook Station (see Figure 1). Shride has interpreted the Scotland Road fault to represent the eastern portion of the Clinton-Newbury fault, which is inferred to trend northeasterly for about 60 miles from the area of Worcester, Massachusetts, to project offshore at Plum Island, Newbury.

Detailed investigations to locate and examine the fault and its overlying Pleistocene deposits have been carried out just to the north of Scotland Road near the north corner of Newbury, Massachusetts, in an open field owned by the Marion H. Marshall Estate (see Figure 2). In this area, the fault forms the boundary between Newburyport granodiorite of presumed Devonian age on the north, and an unnamed complex of diorite and schist of unknown geologic age on the south. Diabase dikes of probable Triassic age intrude both the Newburyport and the unnamed diorite/schist on both sides of the fault.

II. INVESTIGATION PROCEDURES

A. Preliminary - General Area

As preliminary investigation of the Scotland Road fault zone, J. R. Rand walked portions of the fault trace, and inquired of A. F. Shride by telephone as to his studies of the fault zone in the area. R. J. Holt of Weston Geophysical Research, Inc., and J. R. Rand together viewed the inferred trace of the fault zone between Plum Island and Groveland, Massachusetts, by helicopter flying at various altitudes. Diorite ridges aligned parallel to, and about 1000 feet to the south of the trace of the Scotland Road fault in West Newbury are readily seen from the air, but no anomalous physiographic features were noted along the trace of the fault itself. Backhoe trenching investigations over the inferred trace of the fault were attempted on the farm of Miss Alice Elwell, adjacent to Holman Lane,

West Newbury. This exploration, ultimately involving a 232-foot trench excavation in boulder till, sand-cobble till and clay till, was terminated because these glacial materials did not appear suitable for demonstrating the presence or absence of tectonic fault deformation.

B. Final - Property of Marion H. Marshall Estate

As geographic control for all investigations at the final study area on property owned by the Marion H. Marshall Estate in Newbury, a stadia survey of the area and a base map showing all pertinent features were provided by McKenna Associates, Engineers, Portsmouth, New Hampshire (see Plate 1). Technical investigations in the study area have included a seismic refraction survey; the excavation of four backhoe trenches; and the drilling of nine core borings. Laboratory investigations conducted on drill core samples from the study area have included petrographic examinations and radiometric age dating.

III. TECHNICAL INVESTIGATIONS

A. Seismic Refraction Survey

A seismic refraction survey was conducted across the study area during the period November 5-19, 1973, by Weston Geophysical Engineers, Inc., Weston, Massachusetts, to determine thicknesses of unconsolidated overburden and weathered rock materials, as well as velocities of the various geologic materials in the study area. Technical details of this survey are presented in a report by Weston Geophysical Engineers, Inc., attached herewith.

This seismic survey report concludes:

"The bedrock surface, as interpreted from seismic data, does not have any sharp breaks indicating faulting. The seismic velocities of the bedrock do not change sufficiently along the 1000-foot line of investigation to indicate the presence of any significant bedrock anomaly. The fault zone does not exhibit significant velocity differences from adjacent bedrock."

B. Borings Investigations

During the period December 4, 1973, to February 13, 1974, nine borings were put down along the centerline of the seismic refraction survey (Seismic Line "A") to locate, define and sample the Scotland Road fault zone (see Plates 2 and 3). These borings, designated SRF-1 through SRF-9, were drilled by American Drilling and Boring Co., Inc., East Providence, Rhode Island, under the supervision of Geotechnical Engineers, Inc., Winchester, Massachusetts. Geotechnical Engineers' personnel logged the unconsolidated soils materials in these borings, and J. R. Rand logged the bedrock cores. Detailed logs of these borings are attached herewith.

1. Soils

The unconsolidated soils materials encountered in 7 of the study area borings include a blanket of silty clay ranging to 40 feet in thickness,

overlying sandy deposits of varying grain sizes which range to 55 feet in thickness. Locally, a basal section of boulders of a few feet in thickness underlies the sand deposits immediately upon the bedrock surface. Soils materials were not sampled in the two angle borings, SRF-5 and SRF-7.

Plates 3 and 4 describe J. R. Rand's interpretation of the stratigraphy of the soils materials along the line of borings. The geologic interpretation is that of a blanket of glacial-marine clay of late Pleistocene age overlying glacial outwash and marine sands, all underlain by a smooth bedrock surface on which were deposited discontinuous thin sheets of glacial till or ground moraine. The sands in borings SRF-1 and SRF-4, on the southeastern end of the line of borings, are largely yellow-brown, medium- to coarse-grained, and resemble glacial outwash. The sands in SRF-6, SRF-9, SRF-2, SRF-8 and SRF-3 are commonly finer-grained and gray in color, and contain occasional thin interbeds of gray clay. These sands underlying the northern part of the line of borings are interpreted as having been derived from erosion of the outwash, with redeposition in the near-shore marine environment prior to, but historically essentially contemporaneously with deposition of the marine clays. The boundary between the two types of sandy deposits is in the area of SRF-6, where the elevation of the top of the sandy material is low, and the overlying clay blanket is thick.

2. Bedrock

The bedrock in the study area has been defined by outcrops of Newburyport granodiorite at the north end of Seismic Line "S", and by the nine borings which extend intermittently from the outcrop area on the north to Scotland Road on the south. The Newburyport outcrops at the north end of the line consist of massive, mottled pink and green, medium-grained granodiorite which exhibits saussurite alteration of feldspars and chloritization of biotite. The rock does not show evidence of shearing on the outcrop surfaces.

Proceeding southeasterly along the line of borings, the bedrock is seen in cores from SRF-5, SRF-7 and SRF-3 to become progressively more altered chemically and more deformed mechanically, becoming light tannish-green in color, and medium-fine grained and foliated in texture and fabric. With continued distance to the southeast, the bedrock in the hangingwall of the fault is seen in SRF-7, -8, -2, -9 and -6 to be an intensely deformed, light yellow-green welded breccia or cataclastic rock. All of the rock in the fault zone is compact and well consolidated, and no zones of clay gouge or other unconsolidated crushed or sheared materials were encountered in borings in the study area.

Borings SRF-7, SRF-8 and SRF-9 all progressed through the intensely deformed portion of the Scotland Road fault zone into unaltered, dark gray diorite and schist of the unnamed complex which lies to the south of the fault.

In each of these borings, a thin (1" to 2"), tan aphanitic rock layer was cored about 5 feet stratigraphically above the horizon where alteration and cataclastic deformation ceased, and this thin marker has been termed "mylonite" on Plates 3 and 4. Borings SRF-4 and SRF-2 drilled only unaltered bedrock of the diorite/schist complex.

Core in borings SRF-2, -3, -7, -8 and -9 was taken with an orienting barrel. Orientation measurements made by Geotechnical Engineers consistently show schistosity or foliation fabric of cores of the fault zone in these borings to dip in the range 35° to 60° toward the north or N10°W. On Plate 2, the subcrop of the footwall of the fault is interpreted to strike N80°E and to dip to the north at an average of about 44°. The trace of the footwall lies within only about 150 feet of the location inferred by A. F. Shride from his regional mapping studies. The true thickness of the rock section subject to mechanical deformation in the fault zone approaches 300 feet, indicating that the Scotland Road fault is a regional tectonic feature of major geologic significance.

C. Trenching Investigations

At various times during the period November 20, 1973, to March 4, 1974, four backhoe trenches were excavated in the study area to expose and examine the glacial-marine clay which overlies the Scotland Road fault zone (see Plate 2). In all trenches, the organic topsoil zone was about 6 inches to 8 inches thick overlying weathered clay, and was continuous and lay parallel with the nearly planar surface of the study area field.

1. Trench 1

Trench 1, near the north edge of the fault zone, was excavated on November 20, 1973, in massive olive-gray clay to a depth of about 12 feet at the north end of the trench, and was carried for about 150 feet toward the southeast with a depth of 4 feet to 5 feet. A 2-inch to 3-inch layer of fine laminated silty sand occurred in the clay at a depth of 3 feet to 3½ feet below ground surface, sloping gradually to the south. This laminated sand-silt layer was continuous and not disrupted in the southern 100 feet of the trench. At the northern end of the trench, the sand-silt layer merged upward into the weathered portion of the soil zone and became unidentifiable.

2. Trench 2

Trench 2, to the south of the fault trace, was excavated on December 12, 1973, to a depth of 7 feet to 8 feet in clay, and was carried northwesterly for about 50 feet until collapse of the trench walls terminated the work. This trench exposed a thin, flat-lying laminated sand-silt layer in the clay at a depth of about 6 feet. This sand-silt layer generally resembled that found in Trench 1, although the layer was saturated in Trench 2, and small springs issued from it locally when cut by the backhoe bucket.

3. Trench 3

Trench 3 was excavated across the fault zone from south to north on February 26-27, 1974, for a total length of 435 feet and to an average depth of about 7 feet. The trench was cut in olive-gray clay which was internally

massive, but which had a thick-bedded characteristic which permitted measuring the gentle undulating layering structure in the clay. Strike-and-dip plots of these layering features are shown in plan on Plate 2, and the projected layering of the clay is shown schematically in profile on Plate 4.

In addition to gross layering structure seen in the clay throughout the length of the trench, a 2-inch to 4-inch laminated fine sand and silt layer was identified within the clay overlying the footwall trace of the underlying fault zone. This sand-silt marker layer dipped northerly out of the weathered soil zone at about 100 feet north of the south end of the trench, and sloped northerly into a synclinal sag at 135 feet north of the south end of the trench, to rise back into the weathered soil zone and be lost about 170 feet north of the south end of the trench.

The structure of layering in the clay throughout Trench 2 forms gently undulating, open folds which appear generally to parallel the upper surface of the underlying outwash and marine sand deposits. No tight or abrupt folds were seen to disrupt the continuity of layering in the clay, and close examination throughout the length of the trench failed to detect any drag folding within the clay beds. The clay is jointed throughout the trench area, with joints tending to change orientations to conform to changing attitudes of the broad undulations in clay layering. No slickensides or other evidence of displacement were detected on any joints in the trench. No

sand dikes cutting across clay layering or filling joints were found. No offsets were found in the thin, sagged sand-silt marker horizon which was interbedded in the clay between Stations 100 and 170 in Trench 3.

Between 55 feet to 65 feet north of the south end of Trench 3, the backhoe excavated a pocket into the floor of the trench to a depth of about 14 feet, to determine whether there were any stratigraphic changes to that depth which might be useful to examine while proceeding northerly with the excavation across the fault zone. To the 14-foot depth tested, no sand layers were seen in the clay, and the pocket was backfilled to restore the trench floor to the normal 7-foot depth. Within a few moments of completing and tamping the backfill, several springs erupted from the trench floor within the backfill area, with artesian flows rising 1 inch to 2 inches above the floor of the trench. Fine gray sand suspended in the flowing waters of the several springs rapidly built sand cones several inches thick around the springs. A dam was built across the trench to the north of the springs, to protect the proposed excavation to the north from flooding, and thereafter the southern 80 feet of the trench filled to within 2 feet of ground surface, with the highly mobile fine gray sand continuing to be deposited from the springs onto the floor of the flooding trench.

4. Trench 4

Trench 4 was excavated on March 4, 1974, in an attempt to locate the westerly projection of the laminated sand-silt marker horizon found between

Stations 100 and 170 in Trench 3. A similar layer was found in Trench 4, taking the form of an open synclinal sag which plunged gently to the northeast toward Trench 3. Spoon sampling of the soils in Boring SRF-6, between the two trenches, also had detected a sand-silt layer in the clay at an elevation corresponding with that which projected between the two trenches.

Various points on the sand-silt horizon in each of the two trenches were then surveyed in by McKenna Associates in order to provide locations and elevations with which to define the structure of the horizon as it passed over the footwall and portions of the intensely deformed base of the Scotland Road fault. These surveyed points are designated points "A" through "J" on Plate 2. The structure of the horizon is defined in plan in an insert on Plate 2, and in profiles showing the east wall of Trench 3 and the east and west walls of Trench 4 on Plate 4.

As shown on Plate 2, the structure of the sand-silt marker horizon takes the form of an open, doubly-plunging syncline which strikes southwesterly across the footwall of the fault. No offsets of the sand-silt layer were detected in either trench, and no abrupt folding or drag folds were detected in this layer or in the clay beds in either trench. The sand-silt layer in both trenches does not apparently thicken or show increased grain sizes toward the trough of the syncline. No sand dikes were found in Trench 4, nor were joints slickensided.

No evidence was found to suggest that the synclinal structure of the sand-silt layer crossing the fault in the area of Trenches 3 and 4 was formed by other than passive deformation due to differential settlement of the underlying clay. The relatively non-compressible outwash and marine sands underlying the clay in the study area are at a low elevation beneath the area of this synclinal sag, and the relatively compressible clay section is thick. Conversely, the sand elevation is high and the clay is thin as seen in borings put down to the north and south of the sag. With the gradual post-depositional compaction of the clay materials through time, the thicker clay sections settled more deeply than the thin clay sections, passively producing sags in the originally horizontal layering of the fine-grained clay deposits.

There is no detectable sag in the topsoil zone which overlies the synclinal sag in the sand-silt marker horizon in Trenches 3 and 4, and there is no noticeable variation in thickness of the topsoil zone in these trenches. Since the sand-silt layer does not thicken or show coarser grain sizes toward the trough of the synclinal sag, the sand-silt layer appears to have been deposited on an originally horizontal surface which lay stratigraphically above the present ground surface. Differential settlement and sagging of the sand-silt horizon must have been completed prior to the last erosional beveling of the present ground surface, presumably upon retreat of the last post-glacial marine transgression, since the topsoil zone built

upon this beveled horizon shows no evidence of having sagged over the sand-silt sag or over any other of the gently undulations seen in the clay layering throughout the length of Trench 3. There is no evidence of disruption of any of the sedimentary layers overlying the fault zone in any of the trenches, to suggest movement on the Scotland Road fault subsequent to deposition of the overlying Pleistocene deposits.

D. Age of Pleistocene Deposits

No shells or other organic materials were found in the clay in the study area with which to establish an age of deposition of the clay. The clay deposit is, however, considered correlative with similar glacial-marine clays which blanket portions of the seaboard lowland throughout eastern New England.

Borns (1973) reports that "a major amelioration of climate began prior to 14,200 years ago which resulted in a rapid dissipation of the ice sheet in New England at least by 12,500 years ago". The recession of the ice sheet was accompanied by a marine invasion of the seaboard lowland, with deposition of glacial-marine clay sediments. Borns brackets the time of deposition of the glacial-marine clay in the region between 13,500 and 12,500 years ago.

Schafer and Hartshorn (1965) report that radiocarbon dates of shells from glacial-marine sediments on the seaboard lowland in Maine range from 11,800 to 12,800 years old. Kaye and Barghoorn (1964) have constructed

a curve of sea-level fluctuations for the Boston, Massachusetts, area which describes the last marine submergence as having ended about 12,500 years ago in that area.

It appears, therefore, that the glacial-marine clays of the Newbury study area are at least older than 11,800 years, and are probably in the range of 12,500 to 13,500 years old.

E. Petrographic Examinations

The petrography of eight samples of drill core from borings in and adjacent to the Scotland Road fault has been described by Professor Gene Simmons and Dorothy Richter of Massachusetts Institute of Technology.

Sample	Boring	Depth (feet)	Description
SRF-1A	SRF-1	74.0 to 74.4	Amphibolite breccia
SRF-2A	SRF-2	60.0 to 60.4	Mylonized quartz-muscovite schist
SRF-2B	SRF-2	72.9 to 73.4	Brecciated quartz-muscovite schist
SRF-3A	SRF-3	67.0 to 67.5	Muscovite mylonite
SRF-4A	SRF-4	92.9 to 93.3	Chlorite augen gneiss
SRF-5A	SRF-5	42.1 to 42.6	Sheared granodiortie
SRF-5B	SRF-5	175.1 to 175.6	Altered olivine basalt
SRF-7A	SRF-7	115.9 to 116.4	Ultramylonite

Simmons and Richter conclude from their studies that "the samples (with the exception of sample SRF-5B) all show evidence of dynamic deformation; that is, cataclasis, brecciation and intense crushing--all probably due to motion along the fault. The deformation clearly took place after the regional metamorphism of the rocks (which was probably associated with the Devonian Acadian orogeny). The microcracks produced in the deformational

events appear in thin section to have either annealed, or have been filled by secondary minerals. There is no firm petrographic evidence of recent deformation of these samples". The complete text of the Simmons and Richter report is attached herewith.

A further indication of the old age of deformation of the fault zone is evidenced by sample SRF-5B, from a diabase dike which is enclosed within deformed rocks of the fault zone. Petrographically the dike is seen to be completely undeformed. The dike has been dated radiometrically (K-Ar) at $199^{\pm}9$ million years.

F. Radiometric Age Dating

K-Ar age determination have been obtained on six samples of drill core from borings in and adjacent to the Scotland Road fault by Geochron Laboratories, Division of Krueger Enterprises, Inc., Cambridge, Massachusetts.

Sample	Boring	Depth (feet)	Material	Age
SRF-5A	SRF-5	42.1 to 42.6	whole rock	272 10 M.Y.
SRF-3A	SRF-3	67.0 to 67.5	whole rock	269 10 M.Y.
SRF-2A	SRF-2	60.0 to 60.4	whole rock	256 10 M.Y.
SRF-8A	SRF-8	155.6 to 156.0	sericite/ feldspar	248 9 M.Y.
SRF-1A	SRF-1	74.0 to 74.4	amphibole	324 14 M.Y.
SRF-5B	SRF-5	175.1 to 175.6	whole rock	199 9 M.Y.

Samples SRF-5A, -3A, -2A, and -8A are from within the fault zone; SRF-1A is from the diorite/schist complex which lies to the south of the fault zone; SRF-5B is from an undeformed diabase dike which is enclosed within deformed rocks of the fault zone (see Plate 3). Of apparent geologic

interest is the fact that radiometric ages increase progressively with distance from the footwall of the fault zone. SRF-8A is from about 5 feet above the mylonite band near the footwall of the fault, whole SRF-5A is in relatively undeformed granodiorite about 250 feet stratigraphically above the footwall. Radiometric dating of rocks within the Scotland Road fault zone indicates that the fault is of Permian age, and suggests that deformation in the zone may have been active through a period of as much as 20 million years. The dike (SRF-5B) which intruded the fault zone is completely undeformed, indicating that movement on the fault had ceased by Triassic time.

IV. CONCLUSIONS

The Scotland Road fault has been located within 150 feet of the location inferred by A. F. Shride on the basis of his regional field studies. Nine core borings have defined the fault zone as being about 300 feet thick and dipping at about 44^{o} to the north adjacent to Scotland Road in Newbury, Massachusetts. Chemical alteration and mechanical deformation in the fault zone increases progressively from north to south across the fault zone, and alteration effects of faulting terminate abruptly at the footwall of the fault zone, about 5 feet stratigraphically below a thin mylonite band. The fault is a feature of major geological significance in the region.

The fault is geologically very old, of early to middle Permian age, and the altered and deformed bedrock materials in the fault zone are annealed and compact. No unconsolidated gouge, shear zones or polished joint surfaces

were detected in cores from borings drilled across the width of the fault zone. The bedrock surface overlying the fault zone slopes gradually up to undeformed bedrock outcrops at the north edge of the fault zone, and appears from refraction seismic surveys and borings data to be smooth and sub-planar, with no detectable topographic anomalies.

Surficial materials overlying the fault zone include glacial till, glacial outwash and marine sands, and glacial-marine clays, all of Pleistocene age. The youngest of these Pleistocene deposits are the glacial-marine clays, estimated from regional studies to be older than 11,800 years. A thin, essentially horizontal layer of post-Pleistocene topsoil covers the glacial-marine clay in the area.

Examination of the glacial-marine clay in four trenches excavated over the area of the fault zone failed to detect any evidence of tectonic fault displacement in the clay and its interbedded sand-silt layers. Bedding in the clay displayed no abrupt monoclinal or drag folds. Joints were not slickensided. The thin laminated sand-silt horizons interbedded in the clay were not offset. No sand dikes were found in the clay, which directly overlies deposits of highly mobile fine sand.

All evidence observed in the current investigations indicate that Pleistocene deposits overlying the Scotland Road fault have not been subjected to disruption by tectonic faulting.

John R. Rand
Consulting Geologist

References:

Borns, H. W., Jr. (1973) Late Wisconsin Fluctuations of the Laurentide Ice Sheet in Southern and Eastern New England. in The Wisconsinan Stage; Geological Society of America, Memoir 136; Boulder, Colorado.

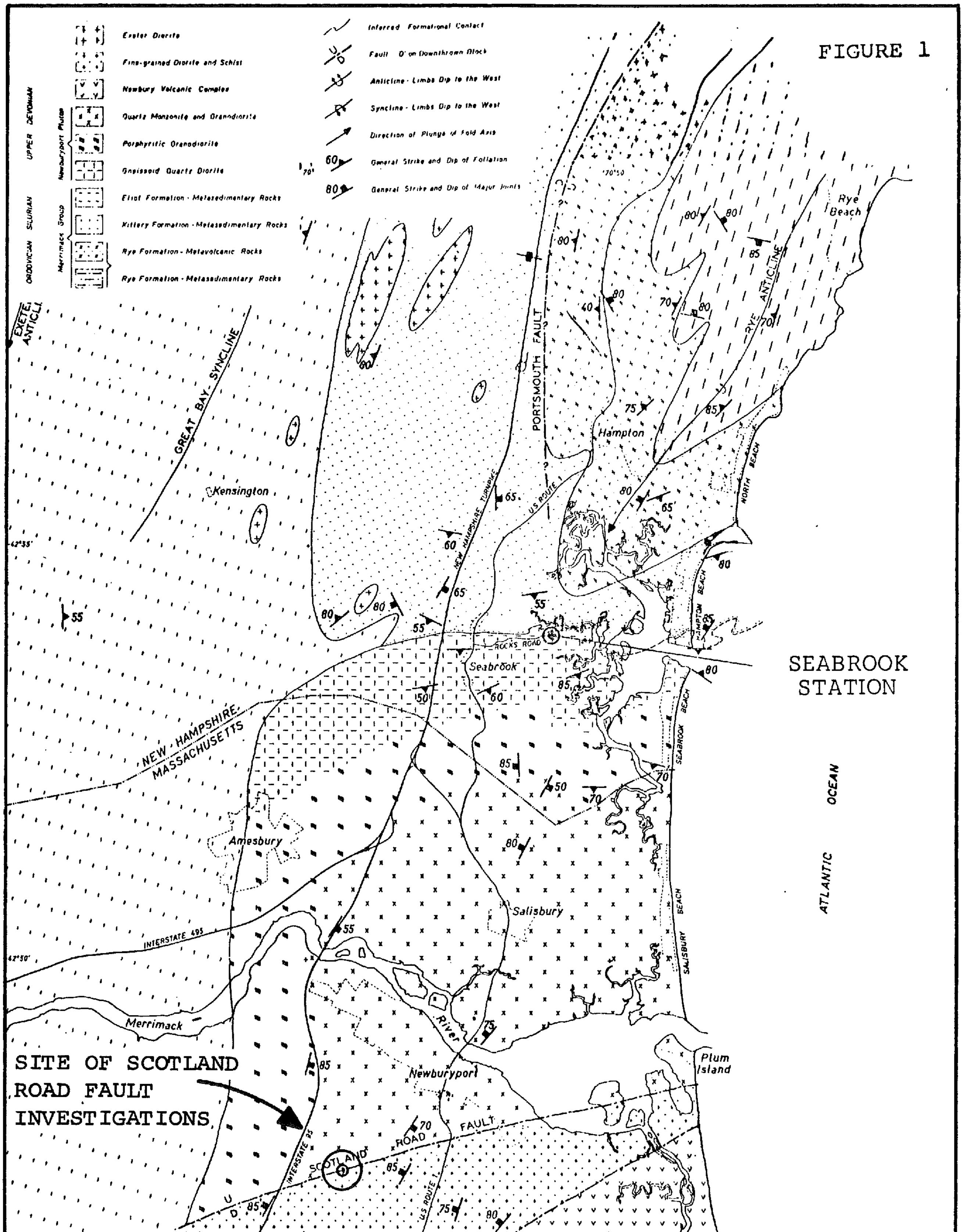
Kaye, C. A. and E. S. Barghoorn (1964) Late Quarternary Sea-Level Change and Crustal Rise at Boston, Massachusetts, with Notes on the Autocompaction of Peat. Geological Society of America, Bulletin Vol. 75, 63-80.

Schafer, J. P. and J. H. Hartshorn (1965) The Quaternary of New England. in The Quaternary of the United States; Princeton University Press; Princeton, New Jersey.

Shride, A. F. (1971) Igneous Rocks of the Seabrook, New Hampshire-Newbury, Massachusetts, Area. in Guidebook for Field Trips in Central New Hampshire and Contiguous Areas. New England Intercollegiate Geological Conference - 1971.

NOTE: The study area was visited on March 13, 1974, by M. H. Pease, Jr. and P. J. Barosh, U. S. Geological Survey, Boston. Trenches 3 and 4 were inspected. The trenches were thereupon filled in.

FIGURE 1



BEDROCK GEOLOGY OF THE SEABROOK REGION, NEW HAMPSHIRE - MASSACHUSETTS

0 1 2 3 4
SCALE OF MILES

LOCATION MAP
REGIONAL FAULT INVESTIGATIONS
PUBLIC SERVICE CO. of NEW HAMPSHIRE
SEABROOK STATION
J. R. Rand, Consulting Geologist

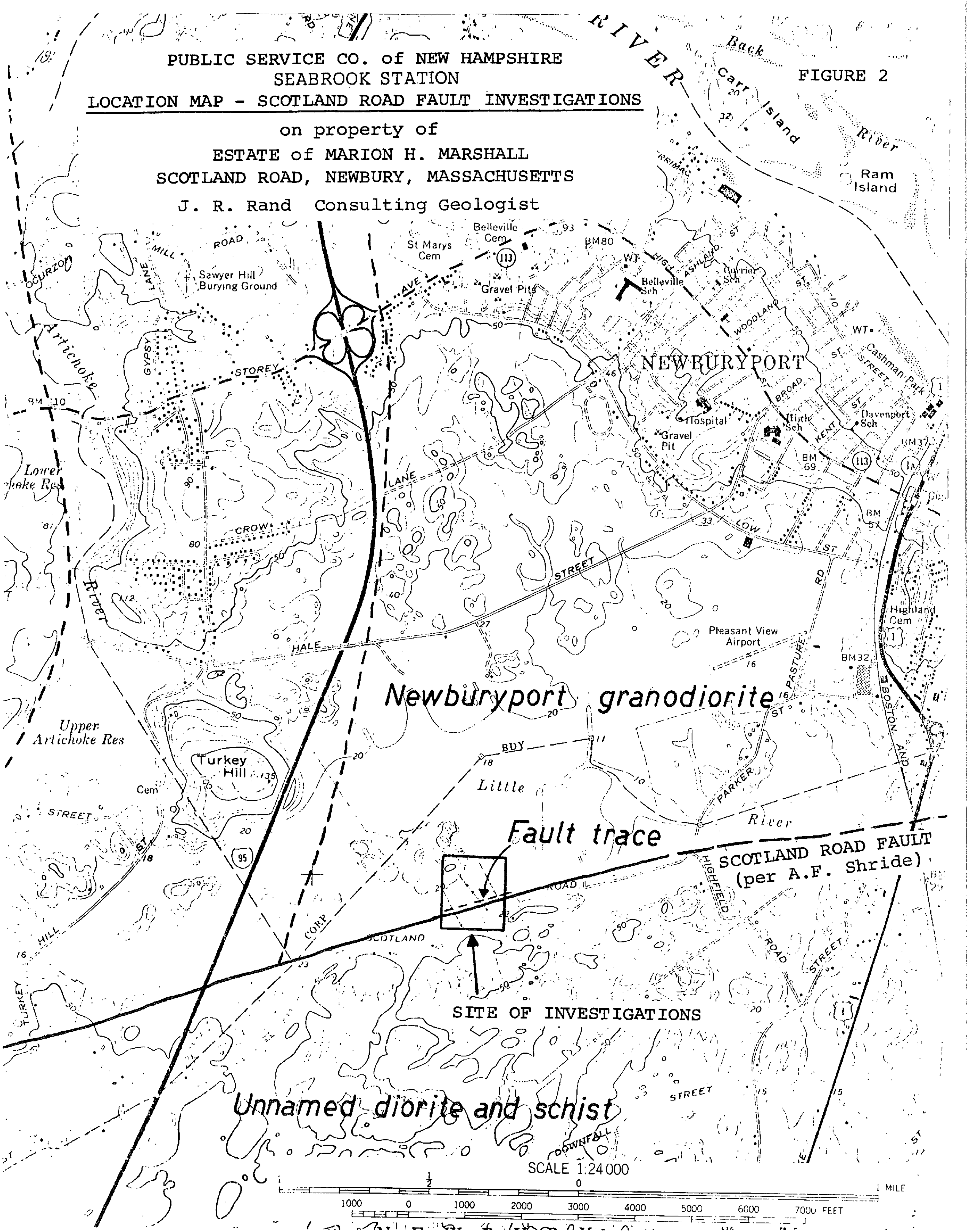
FIGURE 2

PUBLIC SERVICE CO. of NEW HAMPSHIRE
SEABROOK STATION

LOCATION MAP - SCOTLAND ROAD FAULT INVESTIGATIONS

on property of
ESTATE of MARION H. MARSHALL
SCOTLAND ROAD, NEWBURY, MASSACHUSETTS

J. R. Rand Consulting Geologist



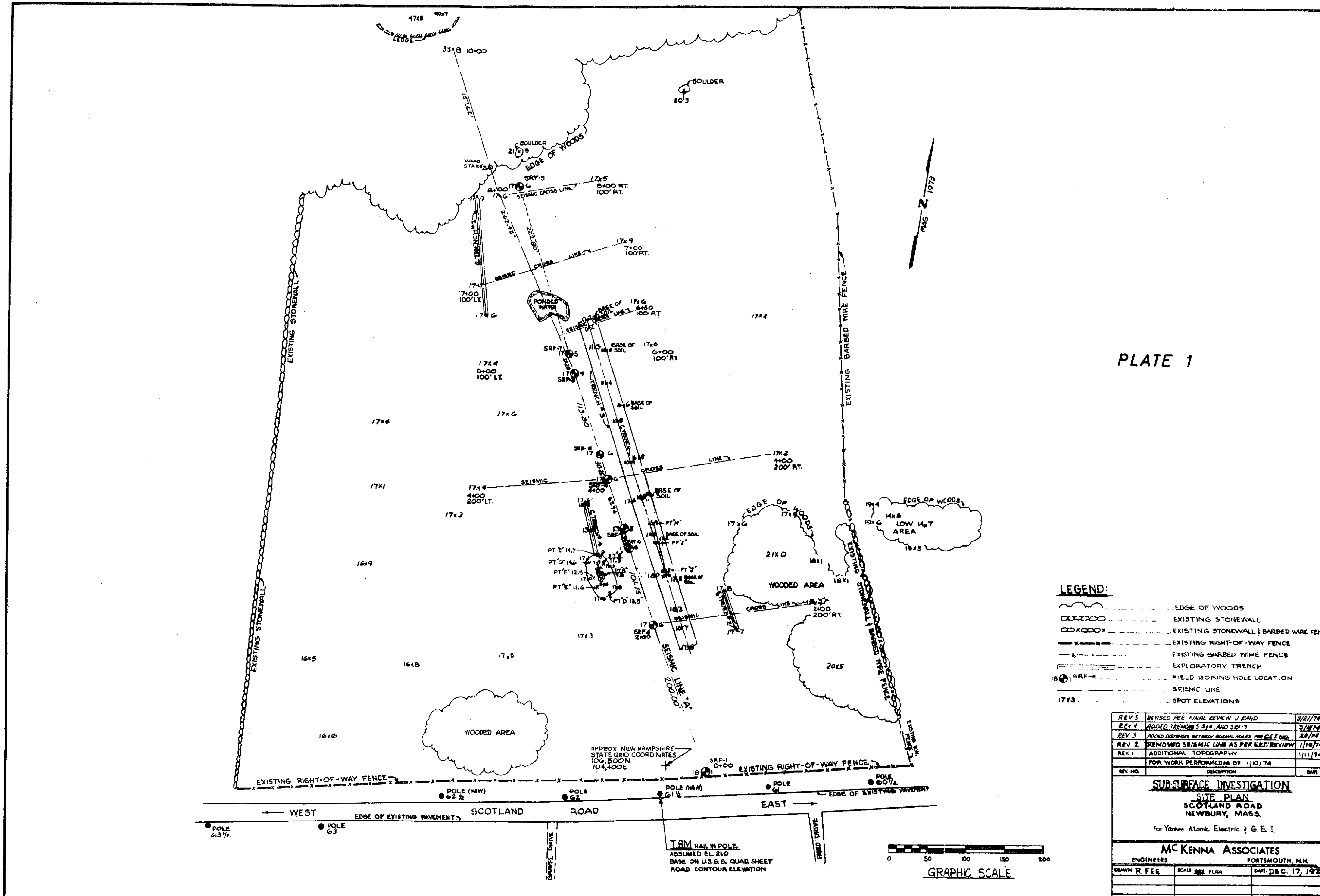
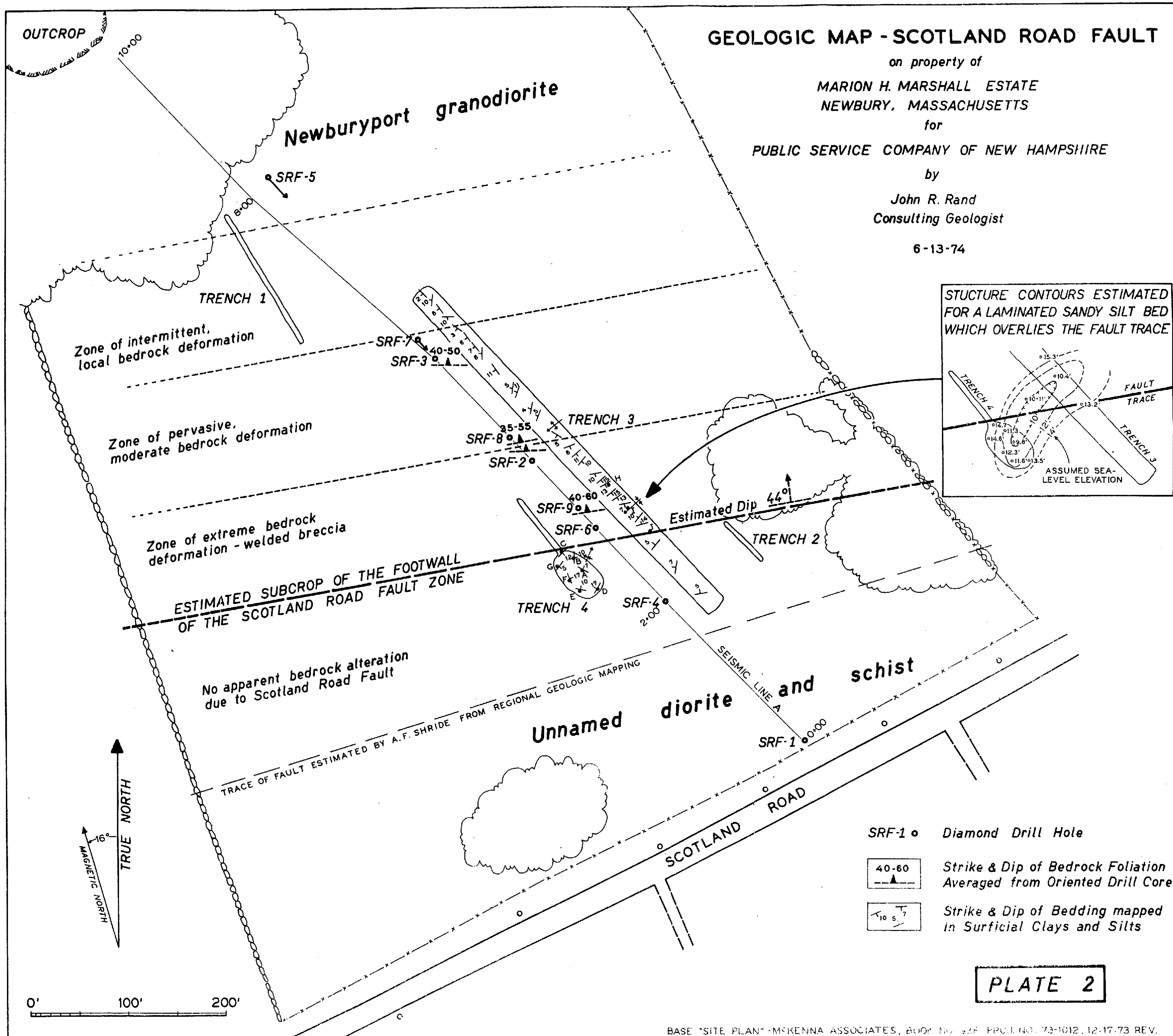
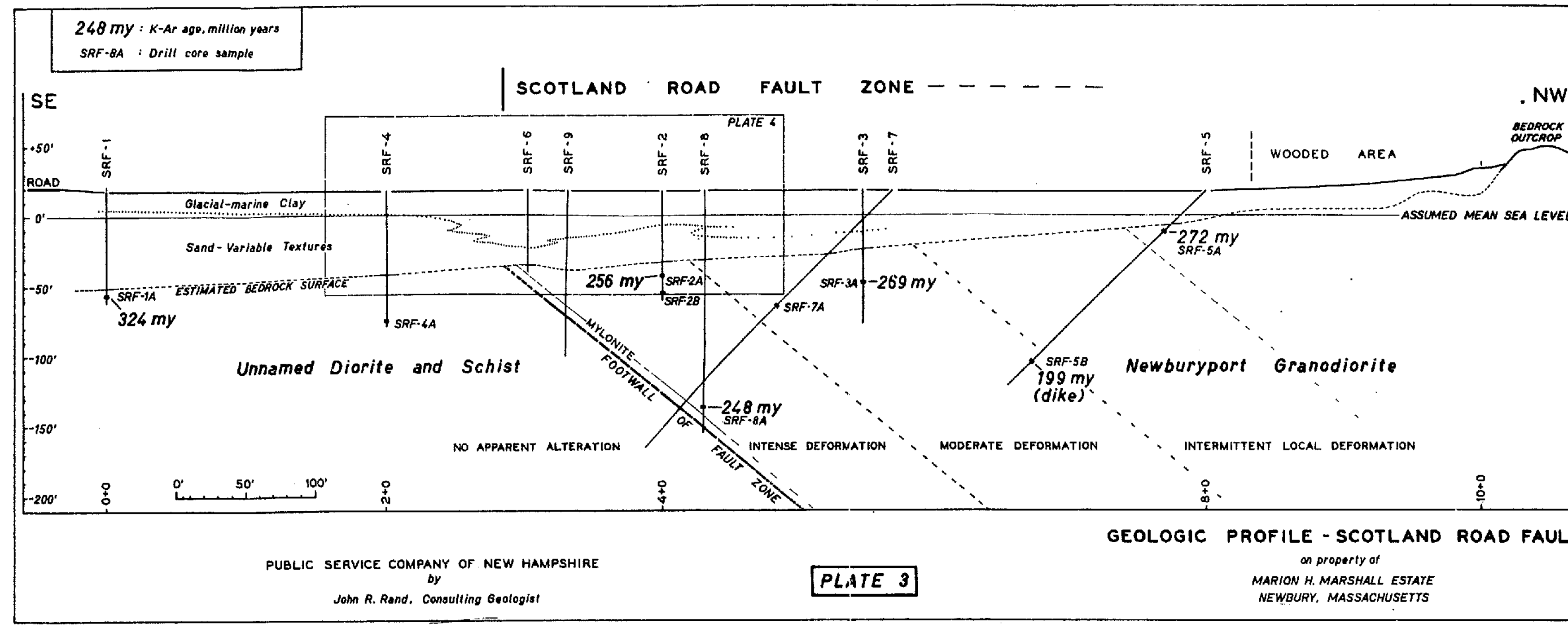
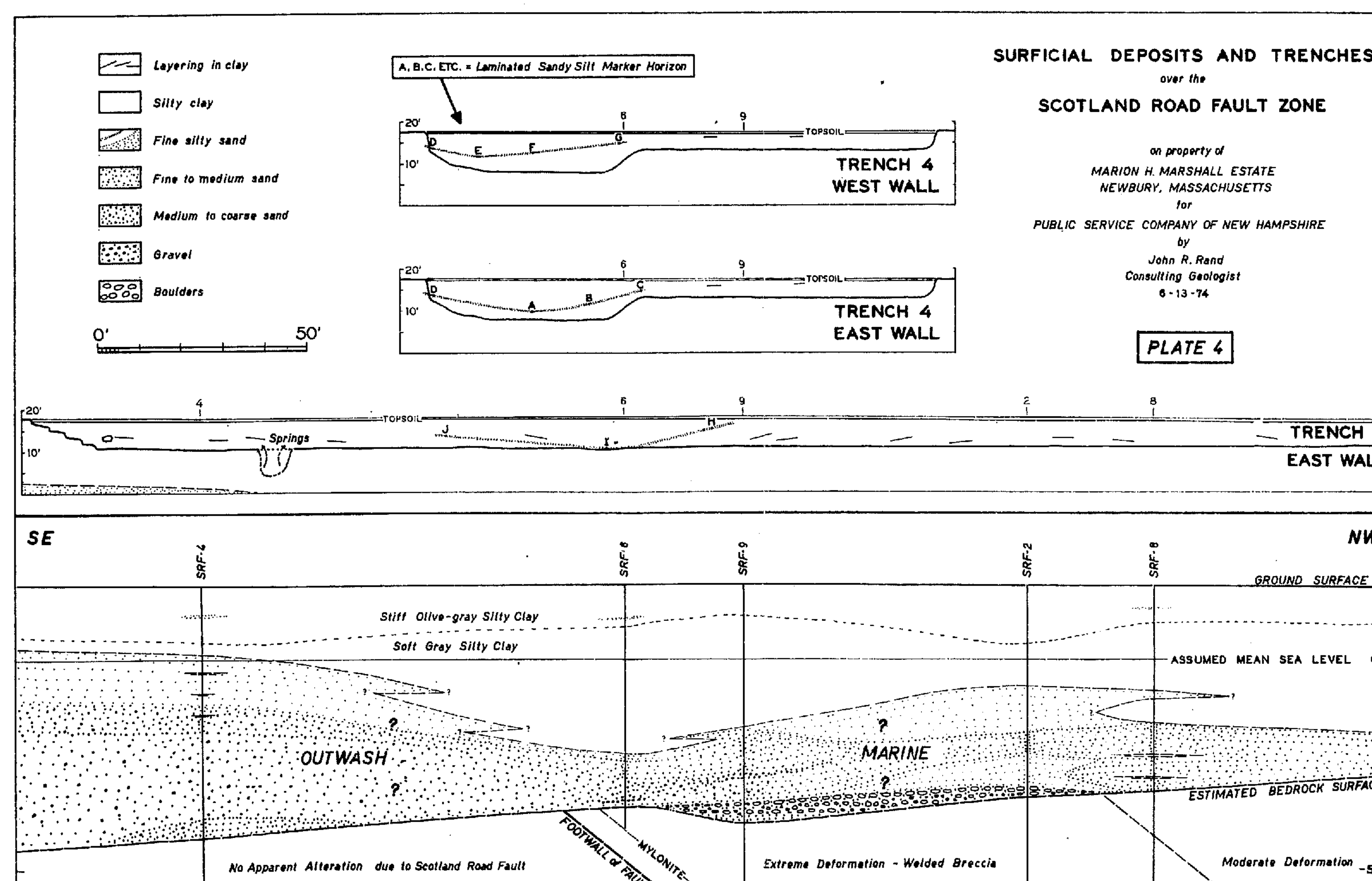


PLATE 1
LEDGE
BOULDER
EDGE OF WOODS
EXISTING STONEWALL
EXISTING BARBED WIRE FENCE
EXISTING STONEWALL
PONDED WATER
SEISMIC CROSS LINE
SEISMIC LINE "A" 200.00'
WOODED AREA
LOW 14±7 AREA
APPROX NEW HAMPSHIRE STATE GRID COORDINATES 106,500N 704,400E
EXISTING RIGHT-OF-WAY FENCE
EDGE OF EXISTING PAVEMENT
WEST
SCOTLAND ROAD
EAST
GRAVEL DRIVE
TBM NAIL IN POLE
ASSUMED EL. 21.0
BASE ON U.S.G.S. QUAD SHEET
ROAD CONTOUR ELEVATION
GRAPHIC SCALE
0 50 100 150 200
LEGEND:
EDGE OF WOODS
EXISTING STONEWALL
EXISTING STONEWALL & BARBED WIRE FENCE
EXISTING RIGHT-OF-WAY FENCE
EXISTING BARBED WIRE FENCE
EXPLORATORY TRENCH
FIELD BORING HOLE LOCATION
SEISMIC LINE
SPOT ELEVATIONS
REV 5 REVISED PER FINAL REVIEW J. RAND 3/21/74
REV 4 ADDED TRENCHES 3 & 4, AND SRF-7 3/4/74
REV 3 ADDED DISTANCES BETWEEN BORING HOLES PER G.E.I. 2/8/74
REV 2 REMOVED SEISMIC LINE AS PER G.E.I. REVIEW 1/18/74
REV. 1 ADDITIONAL TOPOGRAPHY 1/11/74
FOR WORK PERFORMED AS OF 1/10/74
REV. NO. DESCRIPTION DATE
SUB-SURFACE INVESTIGATION
SITE PLAN
SCOTLAND ROAD
NEWBURY, MASS.
for Yankee Atomic Electric & G. E. I.
McKENNA ASSOCIATES
ENGINEERS PORTSMOUTH, N.H.
DRAWN R. FEE
DATE DEC. 17, 1973
BOOK NO 93 F
PROJ NO. 73-1012
SHEET 1 OF 1


GEOLOGIC MAP - SCOTLAND ROAD FAULT
on property of
MARION H. MARSHALL ESTATE
NEWBURY, MASSACHUSETTS
for
PUBLIC SERVICE COMPANY OF NEW HAMPSHIRE
by
John R. Rand
Consulting Geologist
6-13-74
OUTCROP
Newburyport granodiorite
SRF-5
TRENCH 1
Zone of intermittent, local bedrock deformation
SRF-7
SRF-3
40-50
Zone of pervasive, moderate bedrock deformation
TRENCH 3
SRF-8
35-55
SRF-2
SRF-9
40-60
SRF-6
Zone of extreme bedrock deformation - welded breccia
Estimated Dip 44°
TRENCH 2
ESTIMATED SUBCROP OF THE FOOTWALL OF THE SCOTLAND ROAD FAULT ZONE
TRENCH 4
SRF-4
No apparent bedrock alteration due to Scotland Road Fault
SEISMIC LINE A
Unnamed diorite and schist
TRACE OF FAULT ESTIMATED BY A.F. SHRIDE FROM REGIONAL GEOLOGIC MAPPING
SRF-1
SCOTLAND ROAD
STUCTURE CONTOURS ESTIMATED FOR A LAMINATED SANDY SILT BED WHICH OVERLIES THE FAULT TRACE
FAULT TRACE
ASSUMED SEA-LEVEL ELEVATION
TRUE NORTH
MAGNETIC NORTH
16°
0' 100' 200'
SRF-1 Diamond Drill Hole
40-60 Strike & Dip of Bedrock Foliation Averaged from Oriented Drill Core
Strike & Dip of Bedding mapped in Surficial Clays and Silts
PLATE 2
BASE "SITE PLAN" McKENNA ASSOCIATES, BOOK NO. 92F PROJ. NO. 73-1012, 12-17-73 REV.


248 my : K-Ar age, million years
SRF-8A : Drill core sample
SCOTLAND ROAD FAULT ZONE
SE
NW
BEDROCK OUTCROP
WOODED AREA
PLATE 4
ROAD
Glacial-marine Clay
Sand - Variable Textures
ESTIMATED BEDROCK SURFACE
ASSUMED MEAN SEA LEVEL
324 my
256 my
-269 my
272 my
-248 my
199 my (dike)
Unnamed Diorite and Schist
Newburyport Granodiorite
MYLONITE - FOOTWALL OF FAULT ZONE
NO APPARENT ALTERATION
INTENSE DEFORMATION
MODERATE DEFORMATION
INTERMITTENT LOCAL DEFORMATION
GEOLOGIC PROFILE - SCOTLAND ROAD FAULT
on property of
MARION H. MARSHALL ESTATE
NEWBURY, MASSACHUSETTS
PUBLIC SERVICE COMPANY OF NEW HAMPSHIRE
by
John R. Rand, Consulting Geologist
PLATE 3


Layering in clay
Silty clay
Fine silty sand
Fine to medium sand
Medium to coarse sand
Gravel
Boulders
A, B, C, ETC. = Laminated Sandy Silt Marker Horizon
TRENCH 4 WEST WALL
TRENCH 4 EAST WALL
TRENCH 3 EAST WALL
SURFICIAL DEPOSITS AND TRENCHES
over the
SCOTLAND ROAD FAULT ZONE
on property of
MARION H. MARSHALL ESTATE
NEWBURY, MASSACHUSETTS
for
PUBLIC SERVICE COMPANY OF NEW HAMPSHIRE
by
John R. Rand
Consulting Geologist
6-13-74
PLATE 4
SE
NW
GROUND SURFACE
Stiff Olive-gray Silty Clay
Soft Gray Silty Clay
ASSUMED MEAN SEA LEVEL
OUTWASH
MARINE
ESTIMATED BEDROCK SURFACE
FOOTWALL of FAULT
MYLONITE
No Apparent Alteration due to Scotland Road Fault
Extreme Deformation - Welded Breccia
Moderate Deformation

ATTACHMENT No. 1

SEISMIC REFRACTION SURVEY
SCOTLAND ROAD FAULT ZONE
NEWBURY, MASSACHUSETTS

WESTON GEOPHYSICAL ENGINEERS, INC.
for
PUBLIC SERVICE COMPANY OF NEW HAMPSHIRE

SEISMIC REFRACTION SURVEY

SCOTLAND ROAD FAULT ZONE

NEWBURY, MASSACHUSETTS

for

PUBLIC SERVICE COMPANY

OF NEW HAMPSHIRE

WESTON GEOPHYSICAL ENGINEERS, INC.
WESTON, MASSACHUSETTS

SEISMIC REFRACTION SURVEY

SCOTLAND ROAD FAULT ZONE

NEWBURY, MASSACHUSETTS

INTRODUCTION

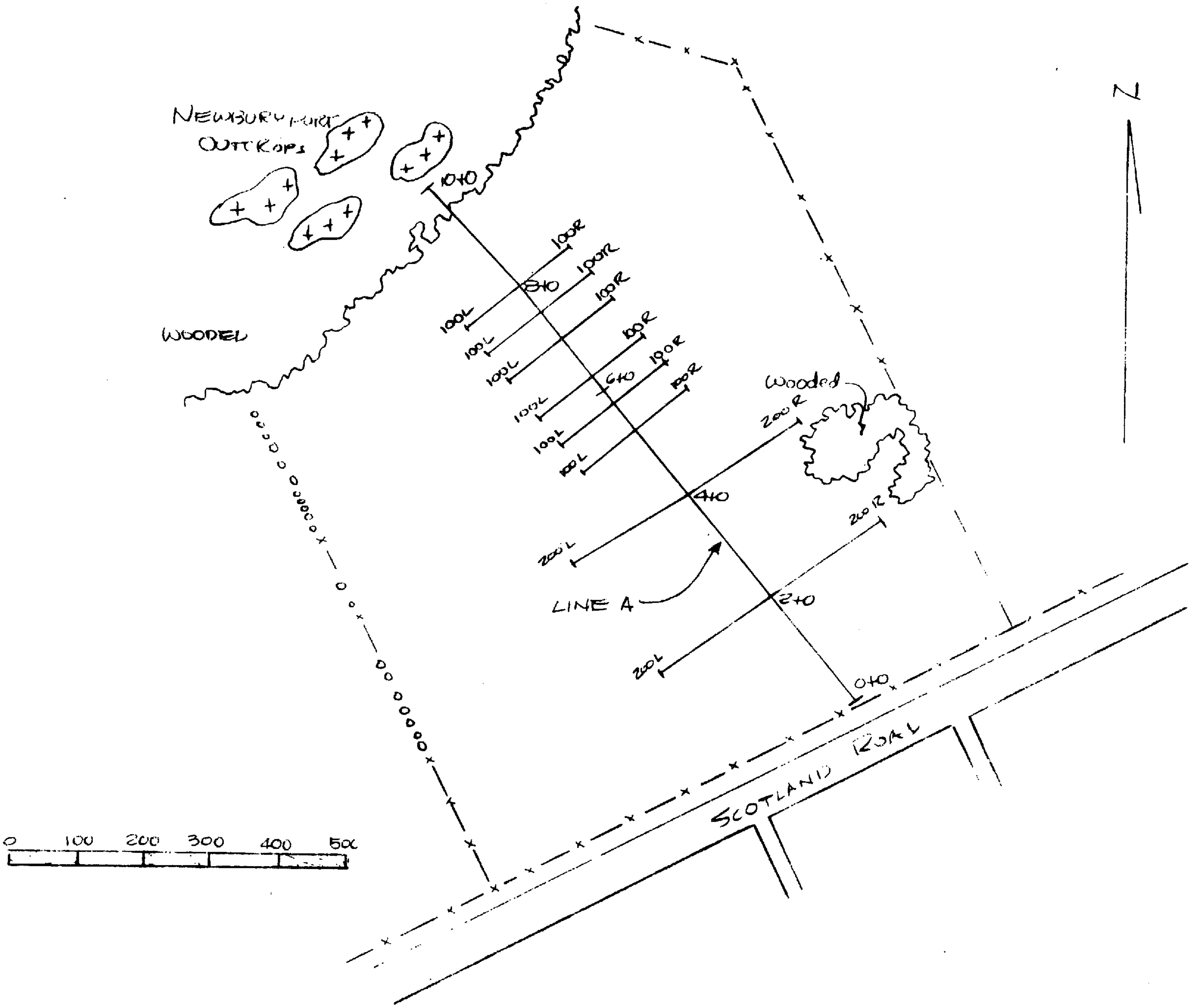
A seismic refraction survey was conducted across the mapped location of the Scotland Road fault, as originally mapped by A. F. Shride (1971) and shown on Figure 1 and Plate 2 of the report. Seismic field work took place during the period of November 5 through 19, 1973. The location of this survey is shown on Figure 1 of this attachment.

The general purpose of this work was to determine thicknesses of overburden and weathered rock materials as well as the velocities of the verious geologic materials existing at this location.

RESULTS

The results of this refraction survey are shown on a profile of the bedrock surface (Figure 2). Also shown on this profile are overburden and bedrock seismic velocities, boring locations, and bedrock depths as found from borings as well as the fault zone, as indicated by J. R. Rand.

The bedrock surface, as interpreted from seismic data, does not have any sharp breaks indicating faulting. The seismic velocities of the bedrock do not change sufficiently along the 1,000-foot line of investigation to indicate the presence of any significant bedrock anomaly. The fault zone does not exhibit significant velocity differences from the adjacent bedrock.



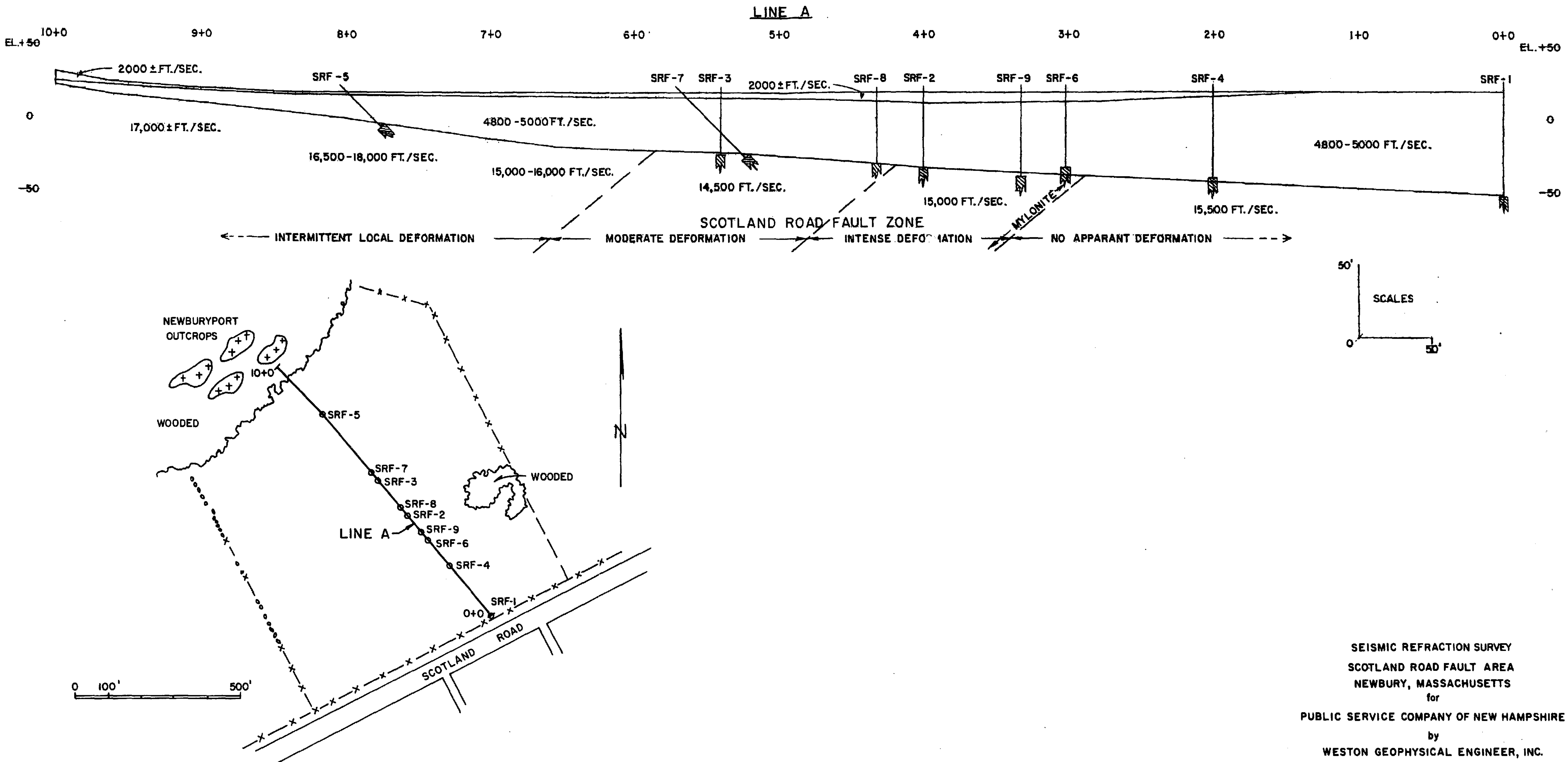
SEISMIC LINE LOCATIONS

SCOTLAND ROAD FAULT

PUBLIC SERVICE CO. of NEW HAMPSHIRE

SEABROOK NUCLEAR STATION

Figure 1



SEISMIC REFRACTION SURVEY
SCOTLAND ROAD FAULT AREA
NEWBURY, MASSACHUSETTS
for
PUBLIC SERVICE COMPANY OF NEW HAMPSHIRE
by
WESTON GEOPHYSICAL ENGINEER, INC.
Figure 2

ATTACHMENT No. 2

GEOLOGIC AND SOILS LOGS OF BORINGS
SRF-1 THROUGH SRF-9

BORING LOCATION See Scotland Rd. site plan INCLINATION Vertical BEARING ______ DATE START/FINISH Dec. 4, 1973 / Dec. 6, 1973

CASING ID 3 in. CORE SIZE 1-7/8 in. TOTAL DEPTH 69.0 ft DRILLED BY American Drilling & Boring Co.; W. Manco

GROUND EL (MSL) 18.1 ft DEPTH TO WATER/DATE 0.5 ft / Dec. 28, 1973 LOGGED BY Soil - K. Polk; Rock - J. R. Rand

EL. MSL ft	SAMPLE Depth ft	SAMPLE Type and No.	SAMPLE N or Rec.	RATE OF ADV. min/ft	WATER CONTENT % or RQD	Graphic (0–100)	PRESSURE TEST gpm psi	PRESSURE TEST Computed k 10^{-4} cm/sec	STRIKE, DIP (F = Foliation, J = Joint, C = Contact, B = Bedding, S = Slickenside)	CORE BREAKS	SOIL AND ROCK DESCRIPTIONS (Weathering, defects, etc.) (Type, texture, mineralogy, color, hardness, etc.)
18.1		S1	7		33.5			TOP	OF CLAY		Mottled gray, olive-gray, and brown silty clay. Low plasticity; w > P. L.; s_u(tor)=60 tsf
		S2	7		29.4						Slightly mottled gray & olive brown silty clay. Low to med. plasticity. s_u(tor) > 1.0 tsf
		S3	21		32.3						Olive-brown silty clay. Low to medium plasticity; w > P. L. s_u(tor) > 1.0 tsf [1]
		S4	29		31.9						Similar to Sample S3. s_u(tor) > 1.0 tsf
		S5	30		32.4						Similar to S3, but somewhat softer; contains few gray spots to 8 mm. s_u(tor) = 0.95 tsf
		S6	31		34.9						Similar to S3, but softer; some gray spots. s_u(tor) = 0.65 tsf
	10	S7	5		37.8						Similar to Sample S3, but medium stiff; contains a gray silt layer < 0.5 mm thick; color varies slightly olive-brown to olive-gray. s_u(tor) = 0.34 tsf
	13.0							TOP	OF SAND		
0		S8	0								Gray layered silty clay and clayey fine sand. Silty clay is soft; medium to high plasticity; slightly sticky; very soft when remolded. Layers vary 0.5-10 mm. s_u(tor) = 0.22tsf
	20	S9	9								Gray silty fine sand. Uniform; fines are nonplastic; very fast reaction to shaking test.
		S10	10								Similar to Sample S9, but also contains a few gray clay layers 1-2 mm thick.
	30	S11	9/6"								Similar to Sample S9, but also contains some gray clay layers.
		S11A	19								Brown silty fine sand. Uniform; fines are nonplastic; contains a few rusty-brown fine sand layers.
		S12	24								Brown slightly silty fine to medium sand. Uniform; fines are nonplastic; contains a layer of gray clayey gravelly sand with subrounded gravel up to 20 mm in size.
-20	40	S13	26								Brown very slightly silty uniform fine to medium sand.
		S14	31								Light brown silty fine sand. Uniform; fines are nonplastic; contains a few subrounded coarse sand grains and some rusty-brown medium sand layers.
	50	S15	17								Similar to Sample S14.
		S16A	59								Similar to Sample S14.
	56.0							TOP	OF TILL		
-40		S16B	15/6"								Gray-brown silty sandy gravel. Widely graded; angular grains; contains gravel pieces up to 30 mm in size; fines are nonplastic.
	60	S17A	79								Light gray fine to medium sand. Uniform; angular to subrounded grains; clean.
		S17B	28/6"								Light gray silty sandy gravel. Angular grains; appears to decomposed rock and rock fragments up to 30 mm in size.
		S18	92/6"								Gray silty gravelly fine sand. Uniform; fines are nonplastic; contains angular gravel pieces up to 15 mm in size.
		NX-1	41								
		NX-2	100	3.0							Cored boulders.
	69.0							TOP	OF ROCK		
	70	NX-3	93	4.2	43						75° Joint Clean — Fresh and hard. Drills well. Only very slight surface wx effects on joints and partings. — Diorite. Dark gray with large (?)hornblend cyrstals (1/2") in fine-grained quartz diorite matrix.
-60		NX-4	98	3.6	83						75° Joint Minor wx — 76.3' Gradational contact - fused. Diorite. Massive, fine-grained, dk. gray
	79.0							BOTTOM	OF BORING		

LEGEND

- N - Standard penetration resistance, blows/ft
- Rec - Length recovered/length cored, %
- RQD - Length of sound core 4 in. and longer/length cored, %
- S - Split spoon sample ∇ Groundwater
- U - Undisturbed samples
  - S - Shelby tube N - Denison
  - F - Fixed piston P - Pitcher
  - O - Osterberg G - GEI
- D - Drilling break k - Coefficient of permeability
- wx - Weathered, weathering

NOTES

1) - s_u(tor) = Shear strength measured with Torvane.

SEABROOK STATION

PUBLIC SERVICE COMPANY OF NEW HAMPSHIRE

YANKEE ATOMIC ELECTRIC COMPANY

united engineers & constructors inc. a subsidiary of Raytheon Company

Date: January 10, 1974 Project 7286

PAGE 1 of 1 LOG OF BORING SRF 1

GEOTECHNICAL ENGINEERS INC.

BORING LOCATION See Scotland Rd. site plan INCLINATION Vertical BEARING ________ DATE START/FINISH Dec. 7, 1973 / Dec. 10, 1973

CASING ID 3 in. CORE SIZE 2-1/8 to 1-5/8 TOTAL DEPTH 77.5 ft DRILLED BY American Drill. & Boring Co.; W. Mann, R. Lamouraux

GROUND EL (MSL) 17.6 ft DEPTH TO WATER/DATE 0.0 ft / Dec. 31, 1973 LOGGED BY Soil - K. Polk; Rock J. R. Rand

EL. MSL ft	SAMPLE Depth ft	SAMPLE Type and No.	SAMPLE N or Rec.	RATE OF ADV. min/ft	WATER CONTENT or RQD %	Graphic (0–100)	PRESSURE TEST gpm psi	Computed k 10^{-4} cm/sec	STRIKE, DIP (F = Foliation, J = Joint, C = Contact, B = Bedding, S = Slickenside)	CORE BREAKS	SOIL AND ROCK DESCRIPTIONS (Weathering, defects, etc.) (Type, texture, mineralogy, color, hardness, etc.)
17.6	1	S1A S1B	2.4 6"		3)			TOP	OF CLAY		S1A - Dark brown soft fibrous peat. S1B - Mottled gray and olive-brown silty clay.
		S2	16		29.0						Similar to Sample S1B, contains some rusty brown layers to 3 mm thick. s_u(tor) > 1.0 tsf
		S3	26		30.1						Olive brown silty clay. Low to medium plasticity; w > P. L.; s_u(tor) >1.0 tsf 2)
		S4	24		33.8						Similar to Sample S3, but fewer brown spots; gray streaks to 5 mm. s_u(tor) > 1.0 tsf
		S5	13		35.6						Similar to S3, but fewer brown spots; more gray streaks; somewhat softer. s_u(tor) = .90 tsf
		S6	5		35.5						Olive-brown silty clay. Low to medium plasticity. s_u(tor) = 0.50 tsf
	10	S7	5		49.5						Similar to S6, but no dark brown spots; soft to medium stiff; slightly sticky. s_u(tor) = 0.23-0.30 tsf
0		S8	2		52.5						Gray to olive-gray silty clay. Very soft to soft; medium to high plasticity; slightly sticky. s_u(tor) = 0.15 tsf
	20	S9	0		37.8						Similar to Sample S8. s_u(tor) = 0.18 tsf
	24.0							TOP	OF SAND		
		S10	7								Gray very silty fine sand. Uniform; fines are generally nonplastic, but contains a few gray clay pockets up to 8 mm in size.
	30	S11	10								Similar to Sample S10.
-20		S12	13								Gray-brown fine to medium sand. Uniform; subrounded grains; clean.
	40	S13	4								Light gray fine sand. Uniform; clean; contains one 8 mm size subrounded piece gravel.
		S14	8								Similar to Sample S13.
	50	NX-1	93		1) 22			TOP	OF ROCK		
	50.5			4)					52°		No slickensides. Not notably wx. Altered by metamorphic process to light yellow green color. Not slickensided.
		NX-2	100		32				49°		
-40									53° 45°		
	60	NX-3	100		23				55° 46°		50° Joint. Minor rusty. Fresh. Drills well. Partings and some high-angle joints show crusty surface wx effects. No slickensides or other recent movements.
		BX-4	100	4.7	67						85° Joint. Irregular
	70	BX-5	100	2.6	55				47° 40°		60° Joint, striated. Cross-stringers
		BX-6	100	2.0	100				42°		Not slickensided. Clean joints
-60	77.5							BOTTOM	OF BORING		

Cataclastic rock. Mottled light yellowish green, fine-grained matrix. Foliated with rounded pebble-like breccia, and sworled feldspathic and chloritic foliations. Thin feldspathic stringers and irregular veinlets dip 35° to 40° opposite to dip of foliation. Cross-stringers.

LEGEND

N - Standard penetration resistance, blows/ft
Rec - Length recovered/length cored, %
RQD - Length of sound core 4 in. and longer/length cored, %
S - Split spoon sample
U - Undisturbed samples
Groundwater (symbol)

S - Shelby tube N - Denison
F - Fixed piston P - Pitcher
O - Osterberg G - GEI

D - Drilling break
wx - Weathered, weathering
k - Coefficient of permeability

NOTES

1) Cored two boulders from 47.5 ft to 50.5 ft.
2) s_u(tor) = Shear strength measured with Torvane
3) S1A = 146.2, S1B = 31.7
4) Rate of advance not available for NX-1 through 3.

SEABROOK STATION

PUBLIC SERVICE COMPANY OF NEW HAMPSHIRE
YANKEE ATOMIC ELECTRIC COMPANY
united engineers & constructors inc. a subsidiary of Raytheon Company

Date: January 10, 1974 Project 7286

PAGE 1 of 1 LOG OF BORING SRF 2

GEOTECHNICAL ENGINEERS INC.

BORING LOCATION See Scotland Rd. site plan INCLINATION Vertical BEARING ______ DATE START/FINISH Dec. 11, 1973 / Dec. 19, 1973

CASING ID 3 in. CORE SIZE 2-1/8 to 1-7/8 in. TOTAL DEPTH 95.0 ft DRILLED BY American Drilling & Boring Co.; Manco

GROUND EL (MSL) 17.9 ft DEPTH TO WATER/DATE 0.0 ft / Dec. 31, 1973 LOGGED BY Soil - K. Polk; Rock - J. R. Rand

EL. MSL ft	SAMPLE Depth ft	SAMPLE Type and No.	SAMPLE N or Rec.	RATE OF ADV. min/ft	WATER CONTENT or RQD %	Graphic (0–100)	PRESSURE TEST gpm psi	Computed k 10^{-4} cm/sec	STRIKE, DIP F = Foliation J = Joint C = Contact B = Bedding S = Slickenside	CORE BREAKS	SOIL AND ROCK DESCRIPTIONS (Weathering, defects, etc.) (Type, texture, mineralogy, color, hardness, etc.)
17.9		S1	4		40.0						Slightly mottled brown and gray peaty silty clay. Low plasticity. s_u(tor) = 0.60 tsf 1)
		S2	19		29.1						Mottled olive-gray and rusty brown silty clay. Low plasticity; w > P. L. s_u(tor)=0.90tsf
		S3	33		27.8						Similar to Sample S2. s_u(tor) > 1.0 tsf
		S4	9		36.3						Olive-brown silty clay. Medium plasticity; w > P. L.; s_u (tor) = 0.80 tsf
		S5	7		37.7						Similar to Sample S4, but contains several silt laters < 0.5mm thick. s_u (tor) = 0.48 tsf
		S6	4		45.0						Similar to S4, but medium stiff; contains several very thin silt layers. s_u (tor) = 0.45 tsf
		S7	2		43.5						Olive-brown to gray silty clay. Slightly sticky; s_u(tor) = 0.12-0.17 tsf
	10	S7A	2/6"		51.9						Gray silty clay. Very soft to soft; medium plasticity; sticky. s_u (tor) = 0.10 tsf
0		S8	2		55.4						Similar to Sample S7A. s_u(tor) = 0.12 tsf.
	20	S9	3		50.94						Similar to Sample S7A. s_u(tor) = 0.15-0.19 tsf
		S10	2		36.3		TOP		OF SAND		Similar to Sample S7A, but also contains a few silt layers < 0.5 mm thick; color varies slightly lighter and darker. s_u(tor) = 0.18 tsf
	30	S11	16								Gray layered soft silty clay and silty fine sand. Layers are 1-5 mm thick.
-20	38.0	S12	8				TOP		OF TILL		Gray silty fine sand. Uniform; fines are nonplastic; very fast reaction to shaking test; contains a few gray clay layers up to 5 mm thick.
	40	S13	57								Gray-green silty angular rock fragments up to 30 mm in size.
		S14	75/6" *				TOP		OF ROCK		Similar to Sample S13, but larger pieces. Appears to be decomposed rock.
	42	NX-1	97	3.0	43						45° joint-rusty; 50° joint minor wx. Fairly fresh (as for wx) but is altered, presumably hydrothermally, to a light gray-green to tan green color. Joints show slight rusty wx effects. Altered diorite (?). Fine-grained, light gray-green matrix with medium-grained feldspar phenocrysts. Sense of vague foliation throughout.
	50	NX-2	97	3.2	47						Vuggy; 40° joint. Tan diabase
		NX-3	100	4.0	77						
-40	60	NX-4	100	3.8	87						Fresh, but altered hydrothermally to light greenish (epidote) gray. Joints and partings are not slickensided, not polished. Quartz-Pink feldspar 61.5'
		NX-5	100	4.2	75						Epidote, Claystone, Gouge, Epidote. Fault block (?) Fused, tight contacts-notable epidotization strong foliation. Fine-grained to very fine-grained, locally feldspathized light gray to light green
	70	NX-6	100	4.0	82				2) N50E, 38NW F		Rough
		NQ-7	100		68				N83W, 46NE J; N89E, 51NW F		Driller ground. Altered diorite (?). Moderately foliated, saussuritized feldspar phenocrysts in fine-grained matrix. Appears to be moderately foliated Newburyport Diorite.
-60	80	NQ-8	100	3)	52						Fresh, but altered hydrothermally. Quartz/pyrite mineralization conforms to foliation. Joints are not slickensided. Pyrite
		NQ-9	95		67				N56W, 27SW F; N80W, 64NE J		61° joint; Rough surface
		NQ-10	100		72				N69E, 39NW F; N65W, 46NE J		Fairly fresh, but altered. Joints not slickensided or polished.
	90	NQ-11	100		63				N52W, 58NE S; N56W, 27NE J; N 9W, 24NE J; N86W, 52NE F		
	95						BOTTOM		OF BORING		

LEGEND

N - Standard penetration resistance, blows/ft
Rec - Length recovered/length cored, %
RQD - Length of sound core 4 in. and longer/length cored, %
S - Split spoon sample ▽ Groundwater
U - Undisturbed samples
S - Shelby tube N - Denison
F - Fixed piston P - Pitcher
O - Osterberg G - GEI
D - Drilling break k - Coefficient of permeability
wx - Weathered, weathering

NOTES

1) s_u(tor) = Shear strength measured with Torvane.

2) This is only a partial list of dip and strike data.

3) Rate of advance not available for NQ-8 through NQ-11.

* Used 300 lb hammer.

SEABROOK STATION

PUBLIC SERVICE COMPANY OF NEW HAMPSHIRE

YANKEE ATOMIC ELECTRIC COMPANY

united engineers & constructors inc. A Subsidiary of Raytheon Company

Date: February 13, 1974 Project 7286

PAGE 1 of 1 LOG OF BORING SRF 3

GEOTECHNICAL ENGINEERS INC.

BORING LOCATION See Scotland Rd. site plan INCLINATION Vertical BEARING ______ DATE START/FINISH Dec. 20, 1973 / Jan. 3, 1974

CASING ID 3 in. CORE SIZE 2-1/8 to 1-7/8 in. TOTAL DEPTH 96.0 ft DRILLED BY American Drilling & Boring Co.; W. Manco

GROUND EL (MSL) 17.6 ft DEPTH TO WATER/DATE 0.0 ft / Jan. 2, 1974 LOGGED BY Soil - K. Polk; Rock - J. R. Rand

EL. MSL ft	SAMPLE Depth ft	SAMPLE Type and No.	SAMPLE N or Rec.	RATE OF ADV. min/ft	WATER CONTENT or RQD %	PRESSURE TEST	STRIKE, DIP (F = Foliation, J = Joint, C = Contact, B = Bedding, S = Slickenside)	SOIL AND ROCK DESCRIPTIONS (Weathering, defects, etc.) (Type, texture, mineralogy, color, hardness, etc.)
17.6		S1, S1A	1, 6		27.5			S1-Dark brown peaty topsoil. S1A-Mottled brown, olive-brown, and gray silty clay. Med. stiff to stiff; low plasticity; contains roots < 0.5mm in dia.; w above PL. s_u(tor) = 0.75 tsf. S2-Similar to S1A, but very stiff; somewhat blocky, some layering; w slightly above PL. s_u(tor) > 1.0 tsf S3-Olive-brown silty clay. Very stiff; low to medium plasticity; somewhat blocky. s_u(tor) > 1.0 tsf S4-Similar to Sample S3, with some dark brown spots up to 1mm thick. s_u(tor) > 1.0 tsf S5-Olive-brown silty clay. Medium stiff to stiff; medium plasticity; contains several dark brown spots. s_u(tor) = 0.52 tsf S6-Similar to Sample S5. s_u(tor) = 0.45 tsf S7-Similar to Sample S5. s_u(tor) = 0.35 tsf
		S2	19		28.0			
		S3	17		30.7			
		S4	31		33.7			
		S5	6		40.8			
		S6	9		38.5			
	10	S7	11		41.3			
	16.5	S8	13		33.0	TOP	OF SAND	Gray silty clay. Medium stiff; medium to high plasticity; contains some silty fine sand layers up to 20 mm thick near bottom. s_u(tor) = 0.30 tsf
0	20	S9	10					Light gray silty fine sand. Uniform; fines are nonplastic; very fast reaction to shaking test; contains a few clay layers up to 1 mm thick.
		S10	30					Similar to Sample S9, but contains clay layers up to 5 mm thick.
	30	S11	34					Brown medium to coarse sand. Uniform; subrounded grains; contains a few olive-brown clay layers up to 8 mm thick and a few gravel pieces up to 15 mm in size.
	34.0					TOP	OF TILL	
-20		S12	15					Gray-brown silty gravelly sand. Widely graded; subangular to subrounded grains; fines are nonplastic; contains a few gravel pieces up to 20 mm in size.
	40	S13	17					Brown gravelly silty sand. Widely graded; subrounded grains; fines are nonplastic; contains a few gravel pieces up to 20 mm in size.
		S14	18					Similar to Sample S13, but also contains subangular grains.
	50	S15	9					Similar to Sample S13, but clean.
-40		S16	15*					Brown medium sand. Uniform; subrounded grains; clean.
	60					TOP	OF ROCK	
		NX-1	100	3.6	0			Rusty / Soft-fissile — Fresh internally. Locally is subject to severe wx, softening. Parts on foliation. Not slickensided. — Schist. Feldspathic, fine-grained medium dark gray foliation matrix with disseminated medium-grained feldspars. Not altered. May be foliated diorite.
		NX-2	77	5.7	0			
	70	NX-3	100	3.1	14			Striated Chlorite — Apparent narrow fault zones or shears at 77', 82.5-85' and 88.5' Have feldspar stringers, and micaceous "gouge".
		NX-4	83	4.0	0			Fault-narrow — Fresh. Closely broken on high-angle joints or on partings on high-angle foliation. Fresh, not wx.
-60		NX-5	100	3.0	0			
	80	NX-6	100	2.8	33			82.5 Faulted 85.0
		NQ-7 (x)	100	2)	7			
	90	NQ-8 (x)	95		45		N20W, 44NW J; N 2E, 44SE J; N80W, 60NE J	Feldspar veining apparent faulted zone 82.5-85' — Sense of drag-folding at 90.6 ft is up.
	96	NQ-9 (x)	100		0		N66W, 55NE J	
						BOTTOM	OF BORING	

LEGEND

N - Standard penetration resistance, blows/ft
Rec - Length recovered/length cored, %
RQD - Length of sound core 4 in. and longer/length cored, %
S - Split spoon sample
U - Undisturbed samples
Groundwater
S - Shelby tube N - Denison
F - Fixed piston P - Pitcher
O - Osterberg G - GEI
D - Drilling break k - Coefficient of permeability
wx - Weathered, weathering

NOTES

1) s_u (tor) = Shear strength measured with Torvane
2) Rate of advance not available for NQ-7 to 9.
* - Used 300 lb hammer
x - Oriented core

SEABROOK STATION

PUBLIC SERVICE COMPANY OF NEW HAMPSHIRE

YANKEE ATOMIC ELECTRIC COMPANY

united engineers & constructors inc

Date: January 10, 1974 Project 7286

PAGE 1 of 1 LOG OF BORING SBF 4

GEOTECHNICAL ENGINEERS INC.

BORING LOCATION See Scotland Road site plan INCLINATION 45 - 46° BEARING S30E DATE START/FINISH December 26, 1973 / January 8, 1974

CASING ID 3 in. CORE SIZE 1-7/8 in. TOTAL DEPTH 197.7 [1)] ft DRILLED BY American Drilling & Boring Co., T. Canning.

GROUND EL (MSL) 17.6 ft DEPTH TO WATER/DATE 0.0 ft / Dec. 26, 1973 LOGGED BY Soil - K. Polk; Rock - J. R. Rand

EL. MSL ft	Depth ft	Type and No.	N or Rec.	RATE OF ADV. min/ft	WATER CONTENT % or RQD	PRESSURE TEST gpm psi	Computed k 10^{-4} cm/sec	STRIKE, DIP (F = Foliation, J = Joint, C = Contact, B = Bedding, S = Slickenside)
17.6	0				3) None			
	10							
	20		2)					
0	30						TOP	OF ROCK
	34.0			4)				
		NQ-1	88	1.6	71			40°
	40	NQ-2	100	1.5	58			
		NQ-3	92	1.6	62			
-20	50	NQ-4	100	1.7	50			
		NQ-5	88	1.9	70			
	60	NQ-6	95	2.0	77			30°
		NQ-7	75	2.0	75			40°
	70	NQ-8	100	2.5	52			35°
		NQ-9	93	2.5	48			
-40	80	NQ-10	95	2.8	28			40°
		NQ-11	98	3.5	27			
	90	NQ-12	97	3.8	0			40°
		NQ-13	97	4.8	35			30°
	100	NQ-14	100	1.7	35			35°
		NQ-15	100	1.6	72			
-60	110	NQ-16	100	1.6	72			23°
		NQ-17	98	1.7	85			
	120	NQ-18	102	1.7	67			47°
		NQ-19	100	1.7	68			50°
	130	NQ-20	100	1.8	78			
-80		NQ-21	100	1.9	42			
	140	NQ-22	100	2.0	32			
	148	NQ-23	98	2.2	63			

SOIL AND ROCK DESCRIPTIONS (Weathering, defects, etc.) (Type, texture, mineralogy, color, hardness, etc.)

Core breaks / defects: Most partings are joints; Chlorite; Rusty joint - Strikes ± NW; Rusty joint; Minor rusty; Minor rusty; Minor rusty; Minor rusty; Minor rusty; Minor rusty; Minor rusty, Bleached; Bleached; Joints striated. Rough not slickensided; Minor wx; Minor bleached

Fresh with minor powdery wx effects on joint surface. Joint surfaces are not slickensided.

Granodiorite. Typical Newburyport, medium-grained, medium gray, with greenish gray hue, and pink feldspar spotting. Generally massive. Locally shows foliated zones. Cut by fused feldspar quartz stringers. Biotite speckling. Becomes medium-fine grained at 56', foliation develops locally vague. First mechanical effects of fault zone apparently at around 56-58'. (Med. Grained; Finer Grained; Pyrrhotite)

Fresh. Drills well. Joint and partings show minor surface wx effects. Not slickensided.

Fused fault material

Diorite. Medium-fine grained. Medium greenish gray. Locally foliated. Foliation is sometimes drag-folded. Rock is mechanically deformed, approaching fault-carbonate veinlets.

Fresh. Partings locally show minor wx effects, but not slickensided.

Fresh. Not wx, but is altered hydrothermally to light greenish gray color. Partings are not slickensided.

Fine-grained rock, with chlorite (?) speckling. Locally foliated, cut throughout by feldspar veinlets. (Cherty Vein)

103' Contact(open) dips 43°

Granodiorite. Medium grained, medium greenish gray, massive, chlorite specks. (not fully altered)

109' Contact dips 20°

110.1' Fine-grained rock fused contact dips 50°

Fresh and hard. Drills well. Relatively minor hydrothermal alteration.

Granodiorite. Medium-grained. Locally shows tendency to foliation. Medium greenish gray.

Foliated-fused Cataclastic

Fresh and hard. Local minor bleaching. Partings show minor wx effects, but are not slickensided.

Granodiorite. Medium-grained, medium greenish gray. Fairly massive. Dark chlorite speckling. (Chlorites not altered appreciably) (Fine inclusion)

LEGEND

N - Standard penetration resistance, blows/ft
Rec - Length recovered/length cored, %
RQD - Length of sound core 4 in. and longer/length cored, %
S - Split spoon sample; ▽ Groundwater
U - Undisturbed samples
S - Shelby tube; N - Denison
F - Fixed piston; P - Pitcher
O - Osterberg; G - GEI
D - Drilling break; k - Coefficient of permeability
wx - Weathered, weathering

NOTES

1) Depths noted were measured "along the boring", not vertically
2) Washed through clay to 34.0' - no samples taken
* - Roller bitted to 36.0'
3) No clays present; therefore no water contents were determined.
4) Roller bitted to 52.0 ft.

SEABROOK STATION
PUBLIC SERVICE COMPANY OF NEW HAMPSHIRE
YANKEE ATOMIC ELECTRIC COMPANY
united engineers & constructors inc — A Subsidiary of Raytheon Company

Date: January 11, 1974 Project 7286

PAGE 1 of 2 LOG OF BORING SRF 5

GEOTECHNICAL ENGINEERS INC.

BORING LOCATION	See Scotland Road site plan	INCLINATION	45 - 46°	BEARING		DATE START/FINISH	December 26, 1973 / January 8, 1974
CASING ID	3 in.	CORE SIZE	1-7/8 in.	TOTAL DEPTH	197.7 [1] ft	DRILLED BY	American Drilling & Boring Co., T. Canning.
GROUND EL (MSL)	17.6 ft	DEPTH TO WATER/DATE	0.0 ft / Dec. 26, 1973			LOGGED BY	Soil - K. Polk; Rock - J. R. Rand

CONTINUED FROM PREVIOUS PAGE

EL. MSL ft	SAMPLE Depth ft	Type and No.	N or Rec.	RATE OF ADV. min/ft	WATER CONTENT or RQD %	Graphic (0–100)	PRESSURE TEST gpm / psi	Computed k 10^{-1} cm/sec	STRIKE, DIP (F = Foliation, J = Joint, C = Contact, B = Bedding, S = Slickenside)
	148								
	150	NQ-24	97	2.5	70				
		NQ-25	100	2.7	60				
	160	NQ-26	97	3.1	68				
-100		NQ-27	98	3.4	47				27°
	170	NQ-28	102	3.2	47				
		NQ-29	92	3.5	35				30°
	180	NQ-30	93	3.1	57				
		NQ-31	97	3.1	62				40°
	190	NQ-32	100	3.2	63				30°
-120		NQ-33	100	2.5	55				30°
	197.7								

BOTTOM OF BORING

SOIL AND ROCK DESCRIPTIONS

(Weathering, defects, etc.)

- Fresh and hard. Partings are not slickensided.
- Slight wx
- Fresh and hard. Partings are not slickensided.
- Slight wx
- Note: At 171.2' - Fresh diabase butts against light green fine-grained cataclasite (calcite) stringer in diabase does not extend across into cataclasite.

(Type, texture, mineralogy, color, hardness, etc.)

- Chlorites are still dark green.
- Becomes vaguely foliated. Apparently cataclastic. Light greenish gray.
- 174.2 Open contact dips 0°
- Diabase. Dark gray, not altered.
- 176.4 Open contact dips 50°. Not slickensided. Cataclastic. Lt. greenish gray, fine-grained, foliated.
- 181.7 Fused, brecciated contact. Diabase, dark gray, unaltered.
- Note: At 181.7', contact of diabase is brecciated, and re-cemented by calcite. Diabase is not appreciably altered.

LEGEND

N - Standard penetration resistance, blows/ft
Rec - Length recovered/length cored, %
RQD - Length of sound core 4 in. and longer/length cored, %
S - Split spoon sample
Groundwater
U - Undisturbed samples
S - Shelby tube, N - Denison
F - Fixed piston, P - Pitcher
O - Osterberg, G - GEI
D - Drilling break
k - Coefficient of permeability
wx - Weathered, weathering

NOTES

SEABROOK STATION

PUBLIC SERVICE COMPANY OF NEW HAMPSHIRE

YANKEE ATOMIC ELECTRIC COMPANY

united engineers & constructors inc

Date: January 11, 1974

Project 7286

LOG OF BORING SRF 5

BORING LOCATION	See Scotland Rd. site plan	INCLINATION	Vertical	BEARING		DATE START/FINISH	Jan. 4, 1974 / Jan. 8, 1974
CASING ID	3 in.	CORE SIZE	1-5/8 in. BX	TOTAL DEPTH	58.0 ft	DRILLED BY	American Drilling & Boring; Manco
GROUND EL (MSL)	17.8 ft	DEPTH TO WATER/DATE	0.0 ft / Jan. 30, 1974			LOGGED BY	Soil - K. L. Polk; Rock - J. R. Rand

EL. MSL ft	SAMPLE Depth ft	SAMPLE Type and No.	SAMPLE N or Rec.	RATE OF ADV. min/ft	WATER CONTENT or RQD %	Graphic (0–100)	PRESSURE TEST gpm psi	PRESSURE TEST Computed k 10^{-4} cm/sec	STRIKE, DIP F = Foliation J = Joint C = Contact B = Bedding S = Slickenside	CORE BREAKS	SOIL AND ROCK DESCRIPTIONS (Weathering, defects, etc.) (Type, texture, mineralogy, color, hardness, etc.)
17.8		S1, S1A	1/6", 3								S1-Brown organic silt. S1A - Mottled gray and brown silty clay; low plasticity.
		S2	15								Olive-brown silty clay. Stiff to very stiff; low plasticity; somewhat blocky structure.
		S3	15								Similar to Sample S2, but fewer brown spots. s_u(tor) > 1.0 tsf 1)
		S4	18								Olive-brown silty clay. V. stiff; low to med. plasticity; w above PL; somewhat blocky.
		S5	13								Similar to Sample S4. s_u(tor) > 1.0 tsf
		S6	8								Similar to Sample S4, but also contains some gray streaks up to 3 mm thick.
	10	S7	5								Similar to Sample S4, but medium stiff. s_u(tor) = 0.45 tsf.
		S8	3								Gray silty clay. Soft; medium plasticity; slightly sticky. s_u(tor) = 0.26 tsf
0	20	S9	4								Similar to Sample S8, but more sticky. s_u(tor) = 0.15 tsf
		S10	5								Similar to Sample S8, but more sticky. s_u(tor) = 0.14 tsf
	30	S11	5								Similar to Sample S8, but more sticky. s_u(tor) = 0.20 tsf
-20		S12	5								Similar to Sample S8. s_u(tor) = 0.25-0.30 tsf
	40	S13	4					TOP	OF SAND		Similar to Sample S8, few silty fine sand layers to 1 mm thick. s_u(tor) = 0.30 tsf
	41.0	S14	13/6"								Layered gray silty clay and silty fine sand. Clay is soft; low to medium plasticity; in layers up to 30 mm thick. Sand is uniform; in layers up to 10 mm thick.
		S15	12								
		S16	9/6"					TOP	OF TILL		
	46.5										Gray-brown silty medium to coarse sand. Widely graded; fines are nonplastic; subangular to subrounded grains; contains a few gravel pieces up to 8 mm in size.
	50	S17	70								
		S18	85/6"					TOP	OF ROCK		
	53	BX-1	92	3.0	57						Minor rusty. Minor rusty. Not wx. Altered by hydrothermal bleaching. Cataclastic, foliated. Fused breccia, medium-light greenish gray.
-40	58							BOTTOM	OF BORING		

Note: Casing bent at ± 14 ft while driving and hole cound not accept N-barrel for 5 ft only. Could not risk a second run due to caving potential at base of casing.

Note: Rock is medium-fine grained, groundmass contains subrounded fragments and micro-faulted piece. All fused. Joints show minor rusty surface wx effects. Not slickensided.

LEGEND

- N - Standard penetration resistance, blows/ft
- Rec - Length recovered/length cored, %
- RQD - Length of sound core 4 in. and longer/length cored, %
- S - Split spoon sample
- Groundwater
- U - Undisturbed samples
  - S - Shelby tube
  - N - Denison
  - F - Fixed piston
  - P - Pitcher
  - O - Osterberg
  - G - GEI
- D - Drilling break
- k - Coefficient of permeability
- wx - Weathered, weathering

NOTES

1) S_u(tor) = Shear strength measured with Torvane

SEABROOK STATION

PUBLIC SERVICE COMPANY OF NEW HAMPSHIRE

YANKEE ATOMIC ELECTRIC COMPANY

united engineers & constructors inc.
a subsidiary of Raytheon Company

Date: March 9, 1974

Project 7286

PAGE 1 of 1

LOG OF BORING SRF 6

GEOTECHNICAL ENGINEERS INC.

BORING LOCATION See Scotland Road site plan INCLINATION 45° BEARING S44E or 136° T DATE START/FINISH Jan. 8, 1974 / Jan. 18, 1974

CASING ID 3 in. CORE SIZE 1-7/8 in. TOTAL DEPTH 255.0 ft DRILLED BY American Drilling & Boring; T. Canning,

GROUND EL (MSL) 17.5 ft DEPTH TO WATER/DATE 6.3 ft / Jan. 18, 1974 LOGGED BY Soil - K. Polk; Rock - J. R. Rand

EL. MSL ft	Sample Depth ft	Sample Type and No.	N or Rec.	Rate of Adv. min/ft	Water Content % or RQD	Pressure Test gpm / psi	Computed k 10^{-4} cm/sec	Strike, Dip (F = Foliation, J = Joint, C = Contact, B = Bedding, S = Slickenside)
17.5	0	2)			4) None			
	65.5					TOP	OF ROCK	
		NQ-1 3)	92	1.5	42			
	70	NQ-2	83	1.3	47			
		NQ-3	100	1.3	13			
-40	80	NQ-4	77	1.3	23			
		NQ-5	100	1.4	8			
	90	NQ-6	100	1.4	0			
		NQ-7	93	2.0	25			
	100	NQ-8	100	2.1	55			
		NQ-9	97	1.9	47			
-60	110	NQ-10	85	2.1	12			
		NQ-11	80	2.1	7			
	120	NQ-12	100	2.2	55			5)
		NQ-13	98	2.1	73			N48E, 83NW J; N68W, 38NE J; N46E, 38NW J
	130	NQ-14	93	1.6	43			N41E, 68NW J; N46E, 81SE J; N20W, 58NE F
-80		NQ-15	97	2.6	63			
	140	NQ-16	83	2.3	33			
	148	NQ-17	92	2.0	23			

SOIL AND ROCK DESCRIPTIONS

(Weathering, defects, etc.)			(Type, texture, mineralogy, color, hardness, etc.)
Minor rusty Minor rusty 1' core lost Minor rusty	Fairly fresh and hard throughout but altered by bleaching. Partings are not slickensided.		Cataclastic. Foliated, saussuritized, deformed diorite. Fine to medium grained, light greenish to tannish gray.
		Aphanitic-yellow-green	
Driller broken at close intervals	Not wx. Core broken throughout into 1' to 4' pieces by poor drilling.		Cataclastic. Fairly fine-grained, light greenish gray. Foliated. Apparent dark (chlorite ?) minerals scattered locally.
Discontinuous vertical joint strikes NW		95.2	Fused intrusive contact, NE strike
		Calcite vein	Diabase. Dark gray fine grained. Younger than alteration in country rock. Calcite veinlets.
		99.2	
Striated	Not ws. Bleached by hydrothermal alteration to greenish-gray.		Cataclastic. Medium grained foliated diorite to 103'. Fine-grained, foliated with small quartz eyes below. Becomes very fine-grained.
2' core lost Soft, some talc	112' to 114' core lost in soft zone. Minor rough slickensides.		
		114.9'	Greenish tan (?)Diabase (?)-Bleached to greenish tan, aphanitic. May be mylonite. Hairline foliation.
Slickensided-minor polish Internal slickensides parallel to foliation Fused	Not wx. Hydrothermally altered throughout. Fairly hard. Drills well. Partings tend to parallel foliation.	Welded breccia Welded breccia	Cataclastic. Fine-grained, medium light greenish gray. Does not resemble diabase. Irreg. veining (feldspar) throughout.
		Light greenish tan 133'	
Mislatch 1' core lost Somewhat softened by alteration	Not wx. Hydrothermally altered. Light tan bleach. Joints and partings are not slickensided.		Diorite-granodiorite. Medium grained, light greenish gray. Locally foliated. Granodiorite. Light tannish gray (extensive bleaching), foliated, medium grained.

LEGEND

- N - Standard penetration resistance, blows/ft
- Rec - Length recovered/length cored, %
- RQD - Length of sound core 4 in. and longer/length cored, %
- S - Split spoon sample — Groundwater
- U - Undisturbed samples
- S - Shelby tube, N - Denison
- F - Fixed piston, P - Pitcher
- O - Osterberg, G - GEI
- D - Drilling break, k - Coefficient of permeability
- wx - Weathered, weathering

NOTES

1) Angle hole
2) Washed through soil from 0-65.5' - no sample taken.
3) Roller bitted to 66.0'
4) No clays present; therefore, no water contents were determined.
5) This is only a partial list of dip and strike data.

SEABROOK STATION

PUBLIC SERVICE COMPANY OF NEW HAMPSHIRE.

YANKEE ATOMIC ELECTRIC COMPANY

united engineers & constructors inc. A subsidiary of Raytheon Company

Date: February 13, 1974 Project 7286

PAGE 1 of 2 LOG OF BORING SRF 7

GEOTECHNICAL ENGINEERS INC.

BORING LOCATION See Scotland Road site plan INCLINATION 45° BEARING S44E or 136° DATE START/FINISH Jan. 8, 1974 / Jan. 18, 1974

CASING ID 3 in. CORE SIZE 1-7/8 in. TOTAL DEPTH 255.0 ft DRILLED BY American Drilling & Boring; T. Canning,

GROUND EL (MSL) 17.5 ft DEPTH TO WATER/DATE 0.3 ft / Jan. 18, 1974 LOGGED BY Soil - K. L. Polk; Rock - J. R. Rand

CONTINUED FROM PREVIOUS PAGE

EL. MSL ft	Depth ft	Type and No.	N or Rec.	RATE OF ADV. min/ft	WATER CONTENT or RQD %	PRESSURE TEST gpm psi	Computed k 10^{-4} cm/sec	STRIKE, DIP (F = Foliation, J = Joint, C = Contact, B = Bedding, S = Slickenside)
	150	NQ-18	92	2.0	35			
		NQ-19	100	2.4	48			
	160	NQ-20	100	2.2	32			
-100		NQ-21	100	1.9	45			
	170	NQ-22	97	1.9	28			
		NQ-23	100	2.0	51			
	180	NQ-24	100	2.1	55			
		NQ-25	100	1.7	28			
	190	NQ-26	100	1.6	72			
-120		NQ-27	100	1.7	25			
		x NQ-28	100	1.8	40			N53E, 24NW J
	200	x NQ-29	100	1.9	87			N78E, 38NW J; N70E, 82NW J; N80E, 44SE F
		x NQ-30	100	1.7	80			N86W, 42NE F; N84W, 90 J; N80E, 70NE S
	210	x NQ-31	100	1.9	52			N66E, 17NW S; Horizontal F
		x NQ-32	100	2.3	55			N80E, 73NW J; N75E, 59NW S
-140	220	NQ-33	100	2.1	53			
		x NQ-34	100	2.1	90			N59E, 52NW S
	230	x NQ-35	100	2.5	54			N52E, 78NW J; N76E, 80NW S; N61E, 77SE J
		x NQ-36	100	2.6	65			N67W, 81NE S; N81E, 44NW S; N35W, 33SW S
	240	x NQ-37	100	2.3	50			N35W, 72NE J; N60W, 59NE J; N64W, 43NE J; N72E, 58NW J
		x NQ-38	100	2.6	43			N61E, 60NW J; N30E, 16NW S
-160	250	x NQ-39	100	2.6	46			N70E, 61NW J; N85E, 69NW F; N72E, 56NW S
	255	x NQ-40	64	2.5	18			N52E, 44NW J

BOTTOM OF BORING

SOIL AND ROCK DESCRIPTIONS (Weathering, defects, etc.) / (Type, texture, mineralogy, color, hardness, etc.)

149.7 Broken contact. No visible attitude.

Weathering, defects, etc.			Type, texture, mineralogy, color, hardness, etc.
Breccia-fused Driller ground	Not wx. Minor surface wx effects on partings. Partings generally parallel to foliation. Not so bleached as above. Not slickensided.	Less bleached Epidote	Cataclastic. Fine-grained, medium gray fused breccia. Hairline veinlets. Medium dark green (epidote) beginning 155'
		Offset veinlets Fused	Cataclastic. Fine-grained, locally foliated and brecciated (fused). Medium-dark greenish gray. Epidotized.
Slight wx Not extensively bleached, moderate alteration only	Not wx. Some minor wx effects locally on joints. Tends to part parallel to foliation. Not slickensided. Competent fairly hard. Drills fairly well.	Fused breccia throughout	Cataclastic. Fine-grained becoming prominently foliated, brecciated. Not cut by cross-cutting veinlets. Hard, breccia is fused (annealed). Not fissile or slickensided. Medium greenish gray.
Moderate bleaching alteration	Not wx. Minor surface wx effects on joints and partings. Not slickensided.	mylonite	Cataclastic. Fine-grained matrix, epidote banding. Extensive fused breccia fabric. Light yellow-green mylonite (aphanitic) at 210.6-211.6'. Fused throughout. Not slickensided.
Smooth. Moderate wx, minor striated Slickensided on foliation Pyrite xtals Smooth, soft Moderate wx Smooth, chlorite	Not wx internally. Joints and partings not polished. Some slickensides. Some slickensides and softened rock at 222.4'.	213.7	Clinton-Newbury fault. Contact fused. Moderate wx at 213.2' Diorite. Slight alteration and foliation to about 218'. Medium grained, medium gray. Veined below 218'.
	Fresh and hard. Drills well. Joints and partings show minor surface wx. Not slickensided.		Diorite. Medium grained, medium dark to dark gray. Not altered hydrothermally. Irregularly calcite-veined throughout. Fused.
Hematite Moderate wx Minor slickensided Moderate wx 9' left in hole	Fresh and hard. Local zones of slight to moderate wx. Not hydrothermally altered.		Diorite. Mixed medium-grained dark gray diorite enclosing fine-grained, dark gray diorite inclusions. Extensively irregularly veined.

LEGEND

N - Standard penetration resistance, blows/ft
Rec - Length recovered/length cored, %
RQD - Length of sound core 4 in. and longer/length cored, %
S - Split spoon sample ⊻ Groundwater
U - Undisturbed samples
S - Shelby tube N - Denison
F - Fixed piston P - Pitcher
O - Osterberg G - GEI
D - Drilling break k - Coefficient of permeability
wx - Weathered, weathering

NOTES
x - Oriented core

SEABROOK STATION
PUBLIC SERVICE COMPANY OF NEW HAMPSHIRE
YANKEE ATOMIC ELECTRIC COMPANY
United Engineers & Constructors Inc.
A subsidiary of Raytheon Company

Date: April 18, 1974 Project 7286

 LOG OF BORING SRF 7

BORING LOCATION See Scotland Rd. site plan — INCLINATION Vertical — BEARING ____ — DATE START/FINISH Jan. 25, 1974 / Feb. 19, 1974

CASING ID 3 in. — CORE SIZE 1-7/8 in. — TOTAL DEPTH 172.0 ft — DRILLED BY American Drilling & Boring; T. Canning

GROUND EL (MSL) 17.6 ft — DEPTH TO WATER/DATE Tidal ft / - — LOGGED BY Soil - K. L. Polk; Rock - J. R. Rand

EL. MSL ft	Depth ft	Sample Type and No.	N or Rec.	Rate of Adv. min/ft	Water Content or RQD %	Pressure Test gpm psi	Computed k 10^{-4} cm/sec	Strike, Dip (F = Foliation, J = Joint, C = Contact, B = Bedding, S = Slickensides)	Soil and Rock Descriptions (Weathering, defects, etc.) (Type, texture, mineralogy, color, hardness, etc.)
17.6		S1,S1A	0,5		3)				
		S2	24		29.4				Similar to Sample S1A, but very stiff. s_u(tor) > 1.0 tsf 2)
		S3	29		27.4				Similar to Sample S1A, but very stiff. s_u(tor) > 1.0 tsf
		S4	14		33.8				
		S5	7		40.4				Similar to Sample S4, but fewer brown spots; softer. s_u(tor) = 0.58 tsf
		S6	4		41.9				Similar
	10	S7	2/18"		48.9				Gray silty clay. Soft; medium plasticity; slightly sticky; contains one brown spot 10 mm in size. s_u(tor) = 0.15 tsf
0		S8	0		51.1				Similar to Sample S7, but contains some slightly darker and lighter colored layering. s_u(tor) = 0.15 tsf
	20	S9	3		33.1				Similar to Sample S7, but contains some darker and lighter colored layers dipping ~10°. s_u(tor) = 0.18 tsf
		S10	8		43.3				Similar to Sample S7, but contains a silty fine sand layer; sticky (very disturbed).
	30	S11	2		44.3				Similar to Sample S7, but very soft and sticky (very disturbed).
	33.0						TOP	OF SAND	
-20		S12	5						Gray-brown slightly silty fine to medium sand. Uniform; fines are nonplastic.
	40	S13	0						Similar to Sample S12, but contains a clay layer and few gravel pieces up to 5 mm in size.
		S14	39						Similar to Sample S12, but contains a clay layer and a few gravel pieces up to 15 mm in size.
	49.0						TOP	OF ROCK	
	50	1)							
		NQ-1	52	1.5	0				Slight wx
-40		NQ-2	95	1.3	25				Slight wx on partings; D
	60	NQ-3	98	1.4	83				Slight wx
		NQ-4	100	1.4	74			3)	
	70	NQ-5	93	1.5	82			N78W, 57NE F	Slight wx; D
		x NQ-6	100	1.0	95			N88E, 50NW F	
-60		x NQ-7	100	1.0	86			N81E, 36NW J; N36W, 40NE F; N49W, 27NE J	
	80	x NQ-8	100	1.0	63			N10E, 25SE S; N79W, 54NE J; N36W, 29NE J	Foliation
		x NQ-9	100	1.1	82				
	90	x NQ-10	100	1.1	87			N87W, 75NE J	Soft-striated; Powdery surface
-80		x NQ-11	100	1.2	31			N50W, 27NE S; N35W, 36NE J; N87E, 64NW S	Chips
	100	x NQ-12	83	1.2	75			N 7E, 35SE J	
		x NQ-13	100	1.2	78			N72E, 47NW F; N57W, 29NE J; N54W, 47NE F	
		x NQ-14	98	1.2	93			N82E, 37NW J; N70E, 36NW J; N58E, 54NW F	
	110	x NQ-15	100	1.0	80			N71W, 76NE J; N40W, 12NE J	
-100		NQ-16	92	1.0	23				Chips
	120	NQ-17	100	1.0	83				
		NQ-18	100	0.8	58				
		NQ-19	100	1.0	100				
	130	NQ-20	100	1.1	82				
-120		NQ-21	100	1.1	70				Minor rusty
	140	NQ-22	100	1.0	62				Chlorite
	145								

Rock descriptions (approx. 50–145 ft):

- Generally not wx internally. Breaks on foliation with slight powdery wx effects on partings surfaces. Medium greenish-gray hydrothermal alteration. — Cataclastic. Fine-grained, bleached to light tan-green gray.
- Highly deformed welded breccia.
- Not wx. Minor wx effects on some partings as well as some striated but not polished surfaces. — Welded breccia throughout. Less bleached.
- 80.0' Fused contact, deformed dips 60°.
- Cataclastic. Medium dark greenish gray. Deformed veins. 83.6'
- Not wx. Drills well. Light green-gray hydrothermal alteration. Soft, powdery zone at 96 ft probably wx associated with joint. Local striated joints or partings usually parts on foliation. — Fused breccia; Epidote; Diorite — Cataclastic. Fine-grained, medium greenish gray. Foliated. Local fused breccia zones.
- Not wx. Joints show minor slippery chlorite-talc coatings. Not polished. Subject to hydrothermal alteration, epidotization. — Welded breccia; Welded breccia throughout — Cataclastic. Fine-grained, medium greenish gray. Zones of welded breccia, hairline epidote stringers.
- Not wx. Minor surface wx effects on partings. Partings also show some striated, not polished surfaces. — Light tan — Cataclastic. Fine-grained, medium light greenish-gray. Local welded breccias. Fairly well foliated.
- Not wx. Medium-gray green bleaching due to hydrothermal alteration. Minor surface wx effects on partings. Some partings striated. — Medium grained — Cataclastic. Fine-grained, fused breccia throughout. Medium greenish-gray.

LEGEND

- N - Standard penetration resistance, blows/ft
- Rec - Length recovered/length cored, %
- RQD - Length of sound core 4 in. and longer/length cored, %
- S - Split spoon sample; ▽ Groundwater
- U - Undisturbed samples
  - S - Shelby tube; N - Denison
  - F - Fixed piston; P - Pitcher
  - O - Osterberg; G - GEI
- D - Drilling break; k - Coefficient of permeability
- wx - Weathered, weathering

NOTES

1) Roller bitted to 53 ft.
2) s_u (tor) = Shear strength measured with Torvane
3) This is only a partial list of dip and strike data.

x - Oriented core

SEABROOK STATION

PUBLIC SERVICE COMPANY OF NEW HAMPSHIRE

YANKEE ATOMIC ELECTRIC COMPANY

United Engineers & Constructors Inc — A subsidiary of Raytheon Company

Date: March 9, 1974 — Project 7286

PAGE 1 of 2 — LOG OF BORING SRF 8

Geotechnical Engineers Inc.

BORING LOCATION See Scotland Rd. site plan INCLINATION Vertical BEARING ______ DATE START/FINISH Jan. 25, 1974 / Feb. 19, 1974

CASING ID 3 in. CORE SIZE 1-7/8 in. TOTAL DEPTH 172.0 ft DRILLED BY American Drilling & Boring; T. Canning

GROUND EL (MSL) 17.6 ft DEPTH TO WATER/DATE Tidal ft / - LOGGED BY Soil - K. L. Polk; Rock - J. R. Rand

EL. MSL ft	SAMPLE Depth ft	SAMPLE Type and No.	SAMPLE N or Rec.	RATE OF ADV. min/ft	WATER CONTENT or RQD %	Graphic (0–100)	PRESSURE TEST gpm psi	Computed k 10^{-4} cm/sec	STRIKE, DIP (F = Foliation, J = Joint, C = Contact, B = Bedding, S = Slickenside)	CORE BREAKS	SOIL AND ROCK DESCRIPTIONS (Weathering, defects, etc.) (Type, texture, mineralogy, color, hardness, etc.)
											CONTINUED FROM PREVIOUS PAGE
	145										
		NQ-23	100	1.1	57				N72E, 68NW J,F N85W, 81SW J N85W, 20NE S		Not polished. Intensely deformed, re-welded. Not cut by cross-cutting veinlets. No observable calcite.
	150	NQ-24	100	1.2	78				N86W, 60NE F N82E, 28NW J		
-140		NQ-25	100	1.2	77				N59W, 40SW J N85E, 56NW F N34W, 19NE J N75E, 51NW F		Chips. Not wx. hydrothermally altered to 163.6'. Fresh, essentially unaltered below partings generally parallel foliation. A few striated surfaces, not polished. Cataclastic. Fine-grained fused breccia, hairline epidote. Medium greenish gray-tan at 159-160.6 ft. 160.2' to 160.4' Mylonite
	160	NQ-26	98	1.2	47						Chips. Fault zone-transitional-not slick.
		NQ-27	98	1.5	57				N63W, 56NE F N21W, 34SW S		Not slickensided. Diorite. Slight alteration and foliated to about 168 ft. Medium-fine grained, medium gray.
	170	NQ-28	100	1.2	71				N27E, 70NW F N89E, 46NW F		Smooth joint
	172							BOTTOM	OF BORING		

LEGEND

N - Standard penetration resistance, blows/ft
Rec - Length recovered/length cored, %
RQD - Length of sound core 4 in. and longer/length cored, %
S - Split spoon sample
U - Undisturbed samples
Groundwater

S - Shelby tube
F - Fixed piston
O - Osterberg
N - Denison
P - Pitcher
G - GEI

D - Drilling break
wx - Weathered, weathering
k - Coefficient of permeability

NOTES

SEABROOK STATION

PUBLIC SERVICE COMPANY OF NEW HAMPSHIRE

YANKEE ATOMIC ELECTRIC COMPANY

united engineers & constructors inc. A subsidiary of Raytheon Company

Date: March 9, 1974 Project 7286

 LOG OF BORING SRF 8

GEOTECHNICAL ENGINEERS INC.

BORING LOCATION See Scotland Rd. site plan INCLINATION Vertical BEARING ______ DATE START/FINISH Dec. 20, 1973 / Jan. 3, 1974

CASING ID 3 in. CORE SIZE 1-7/8 in. TOTAL DEPTH 118.3 ft DRILLED BY American Drilling & Boring; T. Canning, T. Paquette

GROUND EL (MSL) 17.8 ft DEPTH TO WATER/DATE 0.2 ft / Dec. 20, 1973 LOGGED BY Soil - K. L. Polk; Rock J. R. Rand

EL. MSL ft	Depth ft	Sample Type and No.	N or Rec.	Rate of Adv. min/ft	Water Content or RQD %	Strike, Dip (F = Foliation, J = Joint, C = Contact, B = Bedding, S = Slickenside)
17.8		S1, S1A			*	
		S2			27.4	
		S3			28.2	
		S4			33.0	
		S5			37.9	
		S6			40.3	
	10	S7			40.0	
0		S8	0		45.8	
	20	S9	3		41.9	
		S10	3		44.1	
	30	S11	8		29.5	
-20	37.0	S12	9		29.6	TOP OF SAND
	40	S13	11			
		S14	0			
	50	S15	24			
	55.0					TOP OF TILL
-40	57.0					TOP OF ROCK
	60	NQ-1	90			
		NQ-2	100	1.0	33	
		NQ-3	100	1.2	26	
	70	NQ-4	100	1.2	7	
-60		x NQ-5	97	1.2	43	
	80	x NQ-6	100	1.5	28	N81E, 58NW F; N42E, 34NW F; N83E, 39NW J; N74E, 45NW F; N74W, 55NE J; N38W, 46SW F
		x NQ-7	100	1.9	53	N76E, 48NW F; N15E, 51SE J
	90	x NQ-8	96	2.0	65	North, 78E J; N75W, 30NE J; East, 55N F
-80		x NQ-9	98	2.0	98	
	100	x NQ-10	100	2.0	100	N34W, 56NE F
		NQ-11	64	1.9	7	
		NQ-12	100	1.8	48	
	110	NQ-13	100	2.0	83	
-100	118.3	NQ-14	100	2.0	62	BOTTOM OF BORING

SOIL AND ROCK DESCRIPTIONS

(Weathering, defects, etc.) (Type, texture, mineralogy, color, hardness, etc.)

Dark brown clayey topsoil; some small roots; organic odor. S1A-Mottled gray, brown, and rusty-brown silty clay. Low plasticity. s_u(tor) > 1.0 tsf. S2-Similar to Sample S1A, with blocky structure. s_u(tor) > 1.0 tsf. S3-Olive-brown silty clay. Low to medium plasticity; w above PL; nonsticky; somewhat blocky structure. s_u(tor) > 1.0 tsf. S4-Similar to Sample S3. s_u(tor) > 1.0 tsf. S5-Similar to Sample S3, but stiff; spots. s_u(tor) = 0.5-0.6 tsf. S6-Olive-brown to olive-gray silty clay. Medium plasticity; nonsticky; contains a few silt layers < 0.5 mm thick. s_u(tor) = 0.36-0.42 tsf. S7-Similar to Sample S6, but slightly sticky. s_u(tor) = 0.32 tsf.

Gray silty clay. Soft; medium to high plasticity; sticky. s_u(tor) = 0.15 tsf

Similar to Sample S8, but has a blocky structure; appears disturbed. s_u(tor) = 0.23 tsf

Similar to Sample S8, but has a blocky structure; appears very disturbed. s_u(tor) = 0.10 tsf

Similar to Sample S8, but medium stiff; blocky structure; appears very disturbed. s_u(tor) = 0.43 tsf

Similar to Sample S8, but has a blocky structure; contains layers of silty fine sand up to 20 mm thick.

Gray fine sand. Uniform; clean; very fast reaction to shaking test.

Similar to Sample S13, but also contains a layer of coarse sand.

Light gray fine to coarse sand. Widely graded; very slightly silty; subangular grains; contains a few gravel pieces up to 15 mm in size.

Core breaks	Weathering, defects	Rock	Type, texture, mineralogy
Chips; Chips 72.5'; Ground chips 74.5'; Chlorite	Not wx internally, but is bleached by hydrothermal alteration. Minor wx effects on partings. Parts on foliation. No polished slickensides. Some partings striated. Moderate wx 72.5' to 74.5'.	Welded breccia throughout	Cataclastic. Generally fine-grained, medium greenish gray (epidotized). Predominantly welded breccia throughout quartz veinlets x-cut foliation.
Chips; Chips-slight wx	Not wx internal. Joints and partings are not polished. Some striated surfaces.	Tan mylonite	Light yellow-green alteration 80' to 81.7'.
Chlorite-striated			Diorite. Medium-grained, medium gray. Unaltered rock - feldspar veinlets. Foliated to about 89' depth.
D Driller mislatch	Fresh and hard. Drills well. Joints and partings not slickensided. Not affected by hydrothermal alteration or mechanical deformation.		Diorite - amphibolite. Medium-grained, dark gray, irregular feldspathic veinlets.
Slight wx	Fresh and hard. Not deformed or altered by faulting effects.	Pink quartzite (?)	Diorite - amphibolite. Medium-grained, dark gray, not foliated.

LEGEND

N - Standard penetration resistance, blows/ft
Rec - Length recovered/length cored, %
RQD - Length of sound core 4 in. and longer/length cored, %
S - Split spoon sample; Groundwater
U - Undisturbed samples
S - Shelby tube; N - Denison
F - Fixed piston; P - Pitcher
O - Osterberg; G - GEI
D - Drilling break; k - Coefficient of permeability
wx - Weathered, weathering

NOTES

1) s_u(tor) = Shear strength measured with Torvane.

* 1 - 103.4, 1A - 30.6

x - Oriented core

SEABROOK STATION

PUBLIC SERVICE COMPANY OF NEW HAMPSHIRE

YANKEE ATOMIC ELECTRIC COMPANY

United Engineers & Constructors Inc. A subsidiary of Raytheon Company

Date: May 8, 1974 Project 7286

PAGE 1 of 1 LOG OF BORING SRF 9

GEOTECHNICAL ENGINEERS INC.

ATTACHMENT No. 3

PETROLOGY AND PRELIMINARY INTERPRETATION OF EIGHT SAMPLES OF DRILL CORE FROM THE SCOTLANT ROAD FAULT NEWBURY, MASSACHUSETTS

GENE SIMMONS
DOROTHY RICHTER
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
CAMBRIDGE, MASSACHUSETTS 02134
for
WESTON GEOPHYSICAL RESEARCH, INC.
WESTBORO, MASSACHUSETTS 01581

PETROGRAPHY AND PRELIMINARY INTERPRETATION OF EIGHT SAMPLES OF DRILL CORE FROM THE SCOTLAND ROAD FAULT, NEWBURYPORT, MASSACHUSETTS

Weston Geophysical Research, Inc.
Post Office Box 306
Weston, Massachusetts 02193

Gene Simmons
Dorothy Richter
15 June 1974

SUMMARY

The petrography of eight samples of drill core from the vicinity of the Scotland Road fault, Newburyport, Massachusetts is described in this report. The samples (with the important exception of sample SRF-5B) all show evidence of dynamic deformation; That is, cataclasis, brecciation, and intense crushing--all probably due to motion along the fault. The deformation clearly took place after the regional metamorphism of the rocks (which was probably associated with the Devonian Acadian orogeny). The microcracks produced in the deformational events appear in thin section to have either annealed, or have been filled by secondary minerals. There is no firm petrographic evidence of recent deformation of these samples.

Sample SRF-5B may be a very important clue to the history of movement on the Scotland Road Fault. It is an altered olivine basalt that seems to be completely free of deformation. If the thin section is representative of a significant volume of this rock, then it may show that no deformation has occurred on the Scotland Road Fault since this rock last cooled below about 500°C. An even stronger statement can be made with respect to movement on the fault after the alteration of the rock was completed: Because the strength of diabase decreases with alteration and because of the absence of deformational features in Sample SRF-5B, we are quite sure that no movement occurred on the fault after the alteration was completed.

Table 1 is a summary of the rock types in the Scotland Road fault suite. Detailed petrographic descriptions and photomicrographs of textural features are given on the following pages.

Table 1. Summary of Samples

Sample #	Rock Type
SRF-1A	Amphibolite breccia
SRF-2A	Mylonized quartz-muscovite schist
SRF-2B	Brecciated quartz-muscovite schist
SRF-3A 67'	Muscovite mylonite
SRF-4A 43'	Chlorite augen gneiss
SRF-5A 42'	Sheared granodiorite
SRF-5B 175'	Altered olivine basalt
SRF-7A 116'	Ultramylonite
SRF-8A 155'	Brecciated quartz-muscovite schist
SRF-8B 146.5'	Brecciated quartz-muscovite schist
SRF-9A 80'	Brecciated quartz-muscovite schist

PETROGRAPHY OF SAMPLE SRF-1A

Name: Amphibolite breccia

Macroscopic Description

This sample is a coarse-grained dark green breccia. Large (to 1.5cm) angular fragments of dark green amphibole appear set in a finer matrix of crushed amphibole and finer-grained white minerals. Zones of continuous mylonized and sheared materials cut across the sample.

Microscopic Description

Texture

The texture of the thin section is very complex. Large single crystals can be seen to be split, sheared, rotated, and crushed. The original foliation of the schist is totally disrupted and the crystals are now randomly oriented. Multiple sets of fine parallel cracks and/or inclusion trains can be traced from an amphibole crystal into an adjacent feldspar grain. Coherent fragments of crystals can be "fitted" back together by eye, but they are separated by fibrous chlorite. Large cystals have cataclastic material along grain edges. Calcite viens which crosscut the breccia are themselves deformed, and crosscut by thin veins of undeformed plagioclase.

Mineralogy

Hornblende is the dominant constituent of the rock. It is optically negative with a large axial angle, and pleochroic from pale green to dark greenish brown.

Crystal fragments range in size from 0.01mm- 1.5cm. The crystals contain abundant inclusion trains and cataclastic material occurs within crystals and bevels grain boundaries. The hornblende appears to be unaltered except for a few overgrowths of blue-green amphibole.

Plagioclase is the second most abundant mineral in the rock. It occurs as untwinned crystals which were probably a part of the original amphibolite schist. Plagioclase forms large (0.5 - 1.0mm) crystals which are completely covered with linear sets of dusty inclusions. Most crystals appear strained and broken; healed fractures are marked by strings of quartz, calcite, and fresh plagioclase.

Chlorite forms pale green, fibrous, slightly pleochroic aggregates. All crystals display a consistent anomalous "tiger eye" brown interference color. Some of the chlorite seems to be post-brecciation recrystallized mylonitic material which appears to be stretched between cystals. A lesser amount of chlorite appears to be retrograded biotite which is recognized by small amounts of relict biotite and remnant pleochroic haloes.

Calcite appears in veins and fills interstices in the matrix of the rock. Most of the calcite in the veins

is highly distorted and elongated; but there are also minor amounts of undistorted calcite in thin younger veins.

Sphene occurs in accessory amounts as small nodular crystals associated with fuzzy aggregates of leucoxene.

Opaque minerals form stringy aggregates in the mica flakes and more rarely occur as roundish single crystals in the matrix of the rock.

Apatite and Cordierite occur as small euhedral crystals in the matrix of the sample.

Estimated modal composition

amphibole	45%
plagioclase	30%
calcite	15%
opaque	5%
accessories	5%

PETROGRAPHY OF SAMPLE SRF-2A

Name: Mylonized quartz muscovite schist

Macroscopic Description

Sample SRF-2A is a light greenish-grey rock. It appears in hand specimen to be a brecciated cataclasite; in other words, it has a very complex texture which may be the result of multiple deformations. The sample can be separated into different domains of fragments of coarser and finer grained material. The fragments are separated by fine-grained, lighter colored material.

Microscopic Description

Texture

The domains mentioned above appear in thin section as very fine mosaics of granular quartz grains and scaly muscovite. The average grain size is about 0.0mm.

The coherent fragments are separated by shear zones of chlorite, calcite, sphene and ultrafine material which is unresolvable with high magnification.

Mineralogy

Quartz is abundant in the rock fragments and occurs as small (0.2mm) roundish grains. Many grains appear to be crushed and granulated. Most grains have undulose extinction. The quartz crystals are almost always separated from each other by a film of minute mica flakes, except in the coarser grained fragments where they are in direct contact along sutured grain boundaries.

Muscovite occurs as small scaly clusters of crystals. Muscovite is a major constituent of the rock and has three modes of occurrence -- 1) as minute aggregates completely replacing what was probably feldspar, 2) as thin films around individual quartz crystals, and 3) as part of the shear zones between the rock fragments.

Calcite forms small aggregates in the shear zones and small veins which cut the rock.

Chlorite occurs in the shear zones between the fragments as irregular stringers.

Estimated modal composition

quartz	40%
muscovite	35%
calcite	15%
chlorite	5%
unresolvable material	5%

PETROGRAPHY OF SAMPLE SRF-2B

Name: Brecciated quartz-muscovite schist

Macroscopic Description

This sample is a medium greyish green brecciated rock which is very similar to sample SRF-2A in hand specimen. It is slightly coarser grained than the latter sample but is has a similar texture of sheared and brecciated metamorphic rock fragments up to 2cm in size.

Microscopic Description

Texture

The thin section shows a complex texture of brecciated quartz-muscovite rock. The fragments are of various sizes but have an internal uniform grain size of 0.1mm or less. The fragments are separated by zones of unresolvably fine minerals mixed with calcite.

Mineralogy

Quartz is one of the most abundant minerals in this rock. It occurs as irregular but generally ovoid grains which appear to be highly strained and are 0.1mm in size. Most of the quartz grains are not in contact with other quartz grains, and contain relatively few inclusions and bubble trains.

Muscovite forms small scaly masses which thinly separate quartz grains. The muscovite contains many small inclusions of opaques. Muscovite is a common mineral in the shear zones where it has a weblike pattern.

Chlorite is not very abundant in the main body of the rock but it is quite common in the sheared zones between the rock fragments. It is generally very pale green, only slightly pleochroic, and very weakly birefringent.

Biotite occurs as a few relict grains associated with some of the chlorite.

Calcite, clouded with fluid inclusions, fills the shear zones and younger veins. It is also present in the matrix of the fragments as small subhedral crystals.

Opaque grains are widely dispersed throughout the thin sections as minute single crystals and aggregates.

Garnet crystals are present in the sample but are very rare. Crystals <0.1mm in size appear brownish at the core because of tiny opaque inclusions.

Estimated Modal Composition

quartz	35%
muscovite	40%
calcite	15%
chlorite	5%
opaques & accessories	5%

PETROGRAPHY OF SAMPLE SRF-3A 67'

Name: Muscovite Mylonite

Macroscopic Description

This sample is a massive rock, mottled light and dark grey, and almost gneissic in texture. Most grains are too fine-grained to be recognized although enough larger quartz grains are visible to give the sample its banded appearance.

Microscopic Description

Texture

The sample is very fine-grained (∽0.01mm) and vaguely schistose in thin section. Very faint outlines of lenticular shapes seem to mark former brecciated fragments. These fragments are obscured by a fine network of stringy mica which have a preferred orientation in another direction. The complex texture of this sample suggests multiple periods of deformation.

Mineralogy

Muscovite is abundant in this sample as ultrafine crystals which are often optically aligned to give a weblike appearance of the mineral. Muscovite is very finely mixed with quartz in the matrix of the rock. It is the major mineral in the sample, although one cannot see it in hand specimen.

Quartz occurs as isolated fragmental crystals in the sample. It generally has indistinct grain boundaries.

Quartz also appears to be mixed with the muscovite at a very fine scale.

Calcite occurs commonly as 0.5mm roundish crystals in the matrix and as thin aggregates following the schistosity.

Opaque grains occur in small knots with streamlined outlines, and small crystals following schistosity.

Estimated Modal Composition

muscovite	70%
quartz	15%
calcite	10%
opaques	5%

Note: Another thin section from this core exhibits similar textures but contains small domains which are calcite rich.

PETROGRAPHY OF SAMPLE SRF-4A 43'

Name: Chlorite augen gneiss

Macroscopic Description

This sample is a fine-grained augen gneiss. It has a dark green matrix of indistinguishable minerals and 0.5mm "eyes" of white crystals. The sample shows strong directional foliation which is crosscut by younger veins of light colored minerals.

Microscopic Description

Texture

In thin section, the sample shows a complex, almost chaotic texture. It is basically a mosaic of fragmental quartz and feldspar crystals and aggregates with lenticular shapes sandwiched by shear zones of chlorite, calcite, and opaques. Thin veins of calcite cut the foliation.

Mineralogy

Chlorite is the most abundant mineral in the rock. It is pale green, pleochroic, and exhibits anomalous brown interference colors. Very fine, scaly aggregates of chlorite are commonly finely mixed with quartz and opaque grains. Larger crystals of chlorite show small amounts of relict biotite.

Plagioclase occurs as intensely sericitized, poorly twinned, fragmented crystals in the augen.

Quartz has three modes of occurrence in this sample: 1) large broken crystals in the augen, 2) very finely

mixed in the matrix, and 3) fresh crystals in thin veinlets.

Calcite is a very common mineral in the matrix, shear zones, and in veins. It commonly has deformed twin planes.

Orthoclase occurs in accessory amounts as anomalously fresh appearing fragmental crystals in the augen.

Opaque grains are widely dispersed throughout the thin section as minute crystals.

Estimated Modal Composition

chlorite	35%
plagioclase	20%
quartz	15%
calcite	20%
orthoclase	5%
opaque	5%

Note -- the bulk mineral composition of this sample suggests that its protolith was a mafic igneous rock.

PETROGRAPHY OF SAMPLE SRF-5A 42'

Name: Sheared granodiorite

Macroscopic Description

This sample appears in hand specimen to be a massive, coarse-grained igneous rock with no evidence of deformation. The average grain size is approximately 1mm. Visible in hand specimen are pink feldspar, white quartz, and an unknown green mineral.

Microscopic Description

Texture

The thin section has the hypidiomorphic granular texture typical of plutonic rocks. Equidimensional crystals showing varying degrees of alteration are crosscut by thin veinlets. The major deformational features in the thin section are: healed cracks, undulose extinction of the minerals, and a narrow shear zone.

Mineralogy

"Plagioclase", once a major component of this sample, has been completely kaolinized with only a few rare traces of the original twinning or textures left. The kaoinization reaction produces excess SiO_2 which can be seen in the thin section as a thin rim around each kaolinized grain. These peculiar rims are optically uniform around each crystal. The rims only occur along feldspar-feldspar contacts but do not occur along feldspar-quartz contacts.

Quartz occurs as 1 mm blocky crystals with undulose extinction and numerous inclusion trains. Quartz-feldspar boundaries are generally smooth whereas quartz-quartz boundaries are sutured, a sign of partial recrystallization. Quartz also occurs in the rims around kaolinized feldspar grains as mentioned above.

Microcline occurs as slightly altered crystals with a microperthitic texture.

Chlorite forms pseudomorphs after biotite and amphibole. It is medium green, weakly pleochroic, and contains abundant needles of opaques.

Calcite occurs as small clusters of crystals finely mixed with kaolinite alteration products, as thin veinlets, and as aggregates in the matrix. Calcite also fills the one shear zone in the thin section.

Accessory minerals in this rock are opaques, apatite, and sphene.

<u>Estimated Modal Composition</u>

"plagioclase"	40%
microcline	20%
quartz	25%
chlorite	12%
opaque & accessories	3%

PETROGRAPHY OF SAMPLE SRF-5B 175'

Name: Altered olivine basalt

Macroscopic Description

This is a massive, dark greenish grey aphanitic rock. Small dark phenocrysts (0.5 - 1.0mm) and 0.5mm white amygdules are visible in the black groundmass. There are no signs of deformation such as shear zones or even veins.

Microscopic Description

Texture

The sample has a very fine-grained (<0.1mm) intersertal texture. The matrix texture is somewhat obscured by partial alteration of the minerals. The vesicles are rimmed with fibrous minerals. The phenocrysts are completely replaced by alteration minerals.

Mineralogy

Plagioclase occurs as small (0.1mm or less) laths in the matrix of the rock. It does not form any phenocrysts. The plagioclase is generally poorly twinned and partially altered to a sericitic product.

Pyroxene crystals occur as small roundish grains with small scale intergrowths with opaque rods. It is pinkish brown in color and is probably augite.

Serpentine completely replaces roundish 1.0mm phenocrysts of olivine. Serpentine also occurs as fibers in the matrix of the rock, and as the lining of the amygdules.

Calcite forms twinned single crystals in the amygdules and is otherwise rare in the matrix.

Estimated Modal Composition

plagioclase	35%
pyroxene	35%
serpentine	10%
calcite	10%
sericitic alteration	10%

Note -- This sample is probably from a dike which post-dates movement along the Scotland Road fault since it is completely undeformed.

PETROGRAPHY OF SAMPLE SRF-7A 116'

Name: Ultramylonite

Macroscopic Description

This is a compact, extremely fine-grained, mustard colored rock. A few small whitish augen (0.5 - 1.0mm) are visible in the hand specimen. The matrix is buff colored, highly sheared looking material.

Microscopic Description

Texture

This is an ultrafine-grained crush breccia. The original texture of the rock is totally obliterated. The apparent mineral layering is due to 'smearing' of the grain in local shear zones.

Mineralogy

The rock is so fine-grained that individual crystals are difficult to discriminate, except in the few augen of quartz, calcite, and opaque minerals. The matrix is extremely finely-ground quartz, mica, calcite, sphene, apatite, and opaque minerals. Calcite occurs in small nodules which show some signs of recrystallization.

Note -- the fine-grained nature of this rock precludes any further discussion of its mineralogy or texture.

PETROGRAPHY OF SAMPLE SRF-8A 155'

Name: Brecciated quartz-muscovite schist

Macroscopic Description

This sample is a dark greenish grey rock. On a fresh surface it appears to be a fine grained quartzite cut by narrow black shear zones and mottled tan zones. The wet sawed surface shows the texture of a breccia with distinct fragments ranging in size from 1mm to 1cm. The fragments are separated by the tan material; both are cut by the black shear zone.

Microscopic Description

Texture

The texture in thin section is similar to other samples in the suite. Lenticular fragments of various sizes of quartz muscovite rock are separated by ultrafine-grained shear zones. Average grain size is 0.1mm. The relative proportions of quartz and muscovite varies from fragment to fragment.

Mineralogy

Quartz occurs as roundish grains which are almost always isolated from each other by varying amounts of muscovite. Some of the crystals appear to be broken.

Muscovite forms scaly masses which are vaguely schistose. Muscovite is a major component of the rock, filling interstices, between quartz grains, shear zones. It forms the bulk of several lithic fragments.

Chlorite is a major constituent of the sheared zones between lithic fragments although it is not abundant in the fragments themselves. It is pale green, slightly pleochoic, and exhibits anomalous blue interference colors.

Opaque grains, finely mixed with leucoxene, form intricate integrowths pseudomorphous after tabular biotite plates and occur as euhedral crystals in the lithic fragments.

Calcite is common in the shear zones as elongate crystals. It also occurs as minute single crystals in the lithic fragments, and in a few thin, undeformed veins.

Sphene forms fine granular aggregates in the matrix of the fragments and occurs as stringers in the shear zones.

<u>Estimated modal composition</u>

Quartz	45%
Muscovite	30%
Chlorite	10%
Opaque	5%
Calcite	5%
Sphene	5%

PETROGRAPHY OF SAMPLE SRF-8B 146.5'

Name: Brecciated quartz-muscovite schist

Macroscopic Description

This sample is strikingly similar to SRF-8A in hand specimen. It is dark greenish-grey in color. On a fresh broken surface, it appears fine grained and structureless. On the sawed surface, one can see lenticular fragments of various sizes, thinly outlined by lighter colored material. The core is broken along a major fracture surface.

Microscopic Description

Texture

The texture of the sample is variable and complex. The rock fragments consist of roundish quartz grains and scaly mica; the grain size and composition of the fragments vary. The lithic fragments are separated by mylonite which consists of ground quartz, mica, chlorite, and calcite.

Mineralogy

Quartz is the most abundant and most coarsely grained mineral in the rock. It occurs as roundish grains which vary in size (0.1-0.3mm) and abundance (60%-40%) in the different lithic fragments. The crystals commonly contain inclusions. Quartz crystals are rare in contact with each other. A minor amount of quartz occurs in thin veins which cut the rock and probably post-date the brecciation.

Muscovite occurs as scaly aggregates whose crystals are

much less than 0.1mm in size. The aggregates form most of the matrix of the lithic fragments. Submicroscopic muscovite appears to occur in the mylonized zones.

Chlorite forms pale green 0.1mm crystals in the shear zones. Chlorite less commonly occurs in the matrix of the lithic fragments.

Opaque grains occur in the shear zones, in the matrix and in a few rare veins.

Carbonate forms irregular clusters of crystals in the shear zones but does not occur in the lithic fragments.

Sphene occurs in minor amounts as grainy aggregates in the matrix of fragments and in the mylonized zones.

Estimated modal composition

Quartz	40%
Muscovite	40%
Chlorite	10%
Calcite	5%
Opaques	5%

PETROGRAPHY OF SAMPLE SRF-9A 80'

Name: Brecciated quartz-muscovite schist

Macroscopic Description

The texture of this sample is similar to that of samples 8A and 8B, although the rock is light tannish-grey in color. Lenticular and irregularly shaped fragments 0.1-1cm in size are recognizable in a highly sheared matrix. Individual minerals are too fine-grained to recognize in hand specimen. Thin veins of light-colored minerals and, more rarely, opaques are present.

Microscopic Description

Texture

The thin section exhibits the chaotic texture of the rock. Lenticular quartz-muscovite lithic fragments are elongate parallel to foliation. Mylonized zones appear to be structureless. Irregular semi-parallel veinlets cut the foliation.

Mineralogy

Quartz occurs as roundish grains in the lithic fragments. The grains appear to be highly strained and in places broken. They commonly contain linear arrays of inclusions. Very finely ground quartz is apparently a constituent in the mylonite zones. Several thin veins of quartz cut the rock. The margins of the veins are commonly sutured and show signs of recrystallization; in some places the vein quartz is optically continuous with quartz grains which it cuts.

Muscovite forms scaly masses between quartz grains in the lithic fragments. The individual crystals are minute but seem to show a general preferred orientation parallel to the foliation. Muscovite appears to be relatively more abundant in the finer-grained lithic fragments than in the coarser-grained fragments.

Calcite is prominant in the mylonized zones and in a few veins. It occurs less commonly in the matrix of the rock fragments.

Sphene aggregates are also common in the shear zones but sparsely distributed in the rest of the rock.

Opaques seem to be concentrated in the shear zones between lithic fragments in clusters of 0.1mm crystals. They also occur in a few veins and as euhedral crystals in the fragments.

Estimated modal composition

Quartz	35%
Muscovite	30%
Calcite	20%
Sphene	5%
Opaques	10%

Note: The light color of this sample is apparently due to the virtual absence of chlorite in the shear-zones coupled with the relative abundance of calcite.

Photo 1. Sample SRF-1A. Amphibolite breccia. Plane polarized light. Width of field 1.5mm. This photomicrograph shows a typical field of view of this sample. Note that the large darkish hornblende crystals are sheared. The lighter grey crystals are plagioclase. See also Photo 2.

Photo 2. Sample SRF-1A. Amphibolite breccia. Crossed polarized light. Width of field 1.5mm. This photomicrograph shows a major shear zone in the rock. The elongate crystals are deformed calcite. See also Photo 1.

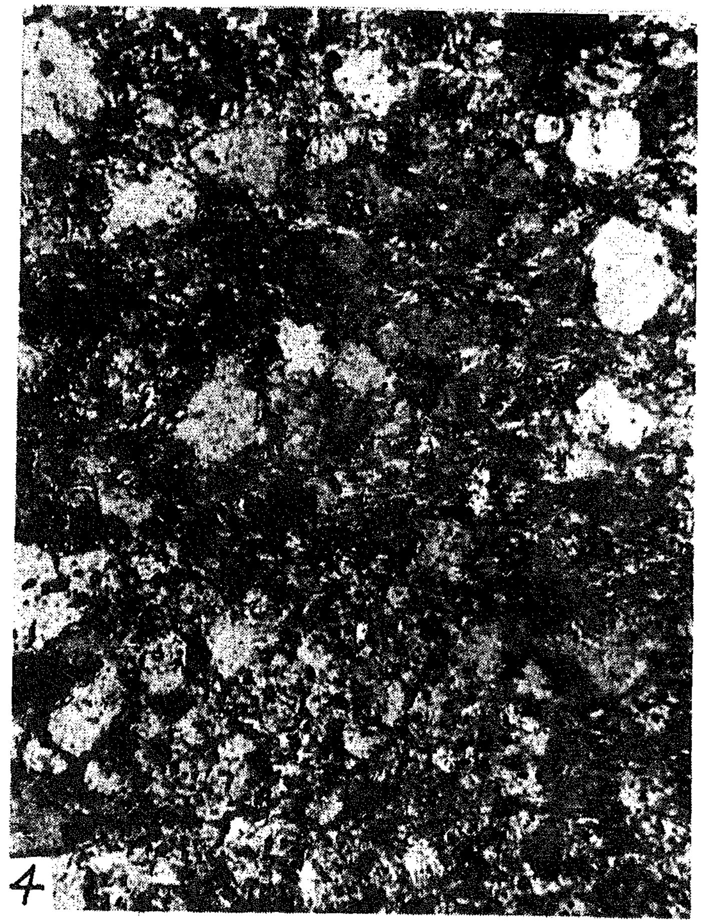
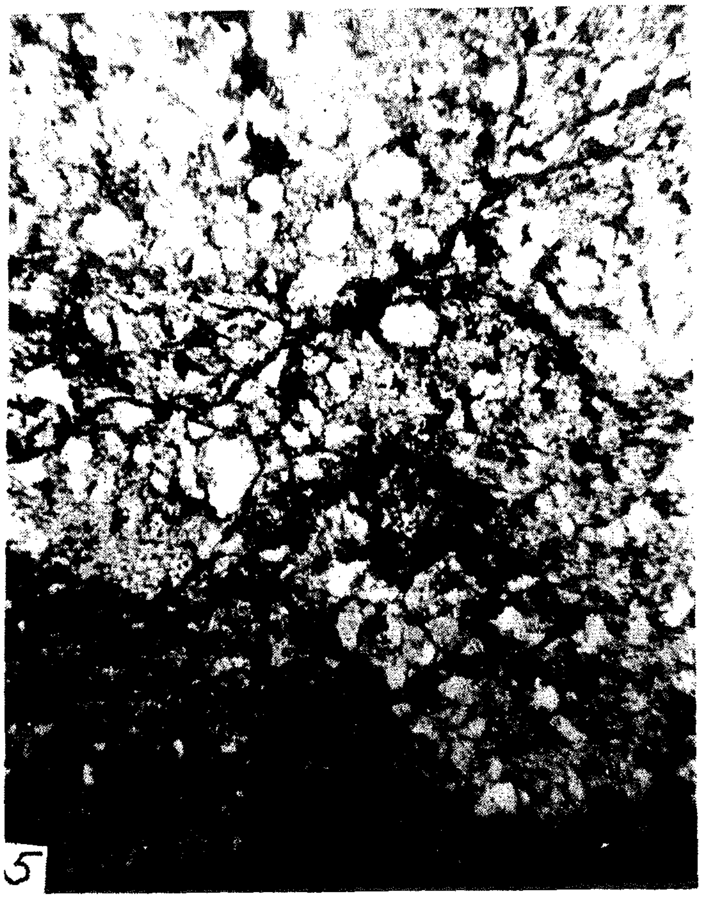


Photo 3. Sample SRF-2A. Mylonized quartz-muscovite schist. Cross polarized light. Width of field 1.5mm. This photomicrograph shows one large lithic fragment covering 3/4 of the photograph and consisting of roundish quartz grains and fuzzy muscovite. The dark zones around the fragment are shear zones of chlorite and other unresolvable minerals. See Photo 4 for an enlargement of the lithic fragment.

Photo 4. Sample SRF-2A. Mylonized quartz-muscovite schist. Plane polarized light. Width of field 0.5mm. This photo is an enlargement of the large lithic fragment shown in Photo 3. The roundish grains are quartz, and the matrix is scaly muscovite, opaques, sphene, and tiny euhedral crystals of calcite as in the left center of the photo.



5

6

Photo 5. Sample SRF-2B. Brecciated quartz-muscovite schist. Plane polarized light. Width of field 1.5mm. This photomicrograph shows the chaotic texture typical of this rock. Note the lenticular fragments of varying grain sizes. The round white crystals are quartz; the darker minerals are scaly muscovite, sphene, calcite and opaques. See also Photo 6, an enlargement of a part of this field magnified. Note the similarity of this sample with SRF-2A.

Photo 6. An enlargement of a portion of Photo 5. Sample SRF-2B. Brecciated quartz-muscovite schist. Plane polarized light. Width of field 0.5mm. This photomicrograph shows the chaotic texture typical of this rock. The round white crystals are quartz; the darker minerals are scaly muscovite, sphene, calcite and opaques. Note the similarity of this sample with SRF-2A.

Photo 7. Sample SRF-3A 67'. Muscovite mylonite. Crossed polarized light. Width of field 1.5mm. This photomicrograph shows the typical texture of this very fine-grained sample. The few larger grains are fragmented quartz crystals. They are set in a finely ground matrix of quartz, muscovite and lesser amounts of calcite, sphene, and opaques.

Photo 8. Sample SRF-4A 43'. Chlorite augen gneiss. Plane polarized light. Width of field 1.5mm. This photomicrograph shows a polycrystalline 'eye' (lower half of photo) in a crushed and sheared matrix. The light grains in the photo are mostly plagioclase and quartz. The large darker grey crystals are chlorite. Note the concentration of opaques in the shear zone in the upper right corner.

Photo 9. Sample SRF-5A 42'. Sheared granodiorite. Crossed polarized light. This photomicrograph shows a typical field of view of this sample. Note the large fuzzy grains. They are kaolinized plagioclase crystals which have narrow rims of optically continuous quartz. These rims were probably produced as a result of the kaolinization. Note that the rims do not continue along a quartz-plagioclase grain boundary at the left. The medium grey grains are microperthite, and the light grey grains are quartz.

Photo 10. Sample SRF-5B 175'. Altered olivine basalt. Plane polarized light. Width of field 1.5mm. This photomicrograph is a good example of the texture of this sample. In the upper left is an amygdule filled with twinned calcite and lined with fibrous serpentine. At the right is a phenocryst of olivine which has been completely replaced by serpentine. The matrix consists of laths of plagioclase (white) and darker crystals of pyroxene and black opaques. See also photo 11, an enlargement of the matrix.

Photo 11, an enlargement of a portion of photo 10. Sample SRF-5B 175'. Altered olivine basalt. Plane polarized light. Width of field 0.5mm. This photomicrograph is an enlargement of the matrix.

Photo 12. Sample SRF-7A 116'. Ultramylonite. Plane polarized light. Width of field 1.5mm. This photomicrograph shows typical texture of this rock. Dark shear zones can be distinguished against the background of highly crushed minerals. See also photo 13.

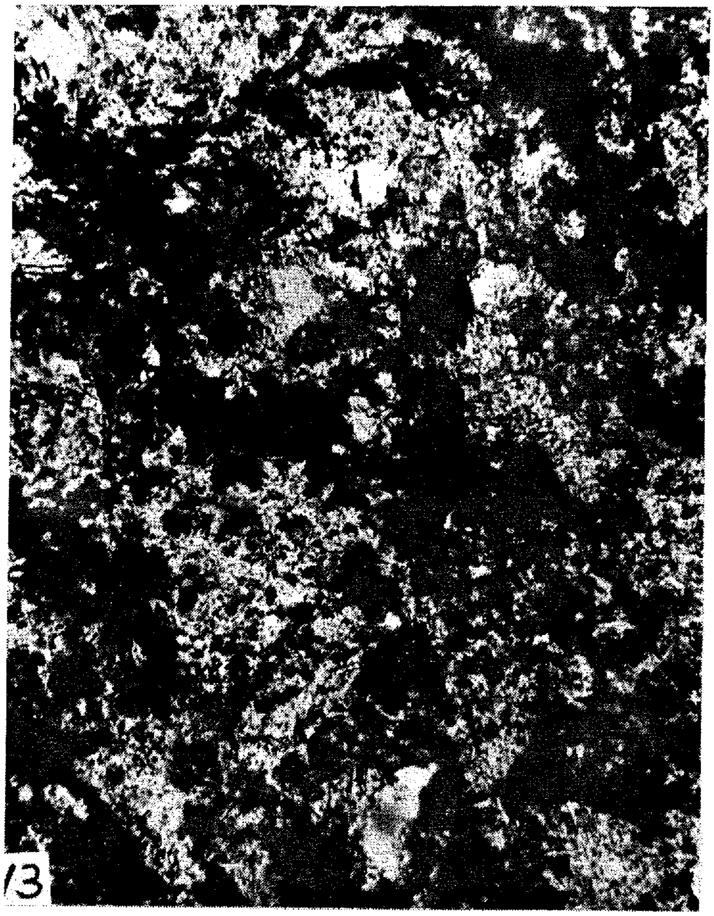


Photo 13. an enlargement of a portion of photo 12. Sample SRF-7A 116'. Ultramylonite. Plane polarized light. Width of field 0.5mm. The rock is so pulverized that only a few grains can be identified with certainty--some dark nodular sphene, a few quartz grains and a few aggregates of calcite.

Photo 14. Sample SRF-8A 155'. Brecciated quartz-muscovite schist. Plane polarized light. Width of field 1.5mm. This photomicrograph shows a typical field of view. Two large lithic fragments are separated by a dark grey shear zone consisting of chlorite, calcite, and finely ground quartz and muscovite. The white grains in the rock fragments are quartz which are surrounded by darker muscovite, calcite, sphene, and opaque grains.

Photo 15. Sample SRF-8B 146.5'. Brecciated quartz muscovite schist. Cross polarized light. Width of field 1.5mm. This photomicrograph shows parts of three lithic fragments. Two of the fragments are coarser-grained than the fragment in the lower right. The larger roundish grains are quartz and the fuzzy material is fine grained masses of muscovite. A thin black line of chlorite and opaques separate the three fragments. Note the similarity of this sample to SRF-8A.

Photo 16. Sample SRF-9A 80'. Brecciated quartz-muscovite schist. Cross polarized light. Width of field 1.5mm. The left hand side of the photomicrograph shows a lithic fragment of roundish quartz grains surrounded by scaly masses of muscovite. At the right is a stringy mylonite zone consisting of pulverized quartz and muscovite with carbonate and opaques. This sample is similar to samples SRF-8A and 8B except for the absence of chlorite.

ATTACHMENT No. 4

K-Ar AGE DETERMINATIONS OF SIX SAMPLES FROM THE SCOTLAND ROAD FAULT ZONE

GEOCHRON LABORATORIES DIVISION,
KRUEGER ENTERPRISES, INC.
CAMBRIDGE, MASSACHUSETTS 02139
for
WESTON GEOPHYSICAL RESEARCH, INC.
WESTBORO, MASSACHUSETTS 01581

KRUEGER ENTERPRISES, INC.
GEOCHRON LABORATORIES DIVISION
24 BLACKSTONE STREET • CAMBRIDGE, MASSACHUSETTS 02139 • (617) 876-3691

16 May 1974

Richard J. Holt
Weston Geophysical
P.O. Box 364
Weston, MA 02193

Dear Mr. Holt:

Enclosed are the analytical reports of the K-Ar age determinations on two (2) of the six (6) samples sent to us by Gene Simmons at M.I.T. I have already given these results to you by telephone.

We analyzed sample 5B as a whole rock and obtained an age of about 199 m.y., and we analyzed a sericite concentrate from 8A and obtained an age of about 248 m.y. This latter concentrate contained a significant amount of feldspar, but with a sample of this sort it is often not possible to obtain a high quality mica concentrate. The measured age of sample 8A should be a reasonably good metamorphic age for the rock.

If you have any questions, please do not hesitate to contact me. In the meantime, I am enclosing our invoice for this work. I will contact you as soon as the remaining samples have been analyzed.

Sincerely,

Richard H. Reesman

Richard H. Reesman
General Manager

RHR/dm
encl: 2 reports & invoice #4401

KRUEGER ENTERPRISES, INC.
GEOCHRON LABORATORIES DIVISION

24 BLACKSTONE STREET • CAMBRIDGE, MA. 02139 • (617)-876-3691

POTASSIUM-ARGON AGE DETERMINATION | **REPORT OF ANALYTICAL WORK**

Our Sample No. R-2813

Date Received: 22 April 1974

Your Reference: SRF 5B (175.1')

Date Reported: 14 May 1974

Submitted by:

Richard Holt
Weston Geophysical Res. Inc.
P.O. Box 364
Weston, MA 02193

Sample Description & Locality: Dark basalt drill core, SRF 5B (175.1')

Material Analyzed: Whole rock, crushed to -40/+100 mesh.

Ar^{40*}/K^{40} = .01230 **AGE =** 199 ± 9 **M.Y.**

Argon Analyses:

Ar^{40*}, ppm.	Ar^{40*}/ Total Ar^{40}	Ave. Ar^{40*}, ppm.
.01647	.686	.01638
.01628	.645	

Potassium Analyses:

% K	Ave. %K	K^{40}, ppm
1.095	1.091	1.331
1.087		

Constants Used:

$\lambda_\beta = 4.72 \times 10^{-10}$/ year

$\lambda_e = 0.585 \times 10^{-10}$/ year

$K^{40}/K = 1.22 \times 10^{-4}$ g./g.

$$AGE = \frac{1}{\lambda_e + \lambda_\beta} \ln\left[\frac{\lambda_\beta + \lambda_e}{\lambda_e} \times \frac{Ar^{40*}}{K^{40}} + 1\right]$$

Note: Ar^{40*} refers to radiogenic Ar^{40}.
M.Y. refers to millions of years.

KRUEGER ENTERPRISES, INC.
GEOCHRON LABORATORIES DIVISION

24 BLACKSTONE STREET • CAMBRIDGE, MA. 02139 • (617)-876-3691

POTASSIUM-ARGON AGE DETERMINATION — **REPORT OF ANALYTICAL WORK**

Our Sample No. M-2820

Date Received: 26 April 1974

Your Reference: SRF 8A

Date Reported: 15 May 1974

Submitted by: Richard J. Holt
Weston Geophysical
P.O. Box 364
Weston, MA 02193

Sample Description & Locality: Sericitized meta-sediment, drill core #SRF 8A.

Material Analyzed: Sericite concentrate with substantial feldspar remaining.

Ar^{40*}/K^{40} = .01550

AGE = 248 ± 9 M.Y.

Argon Analyses:

Ar^{40*}, ppm.	Ar^{40*}/ Total Ar^{40}	Ave. Ar^{40*}, ppm.
.09410	.891	.09629
.09848	.791	

Potassium Analyses:

% K	Ave. %K	K^{40}, ppm
5.086	5.092	6.212
5.099		

Constants Used:

$\lambda_\beta = 4.72 \times 10^{-10}$/ year

$\lambda_e = 0.585 \times 10^{-10}$/ year

$K^{40}/K = 1.22 \times 10^{-4}$ g./g.

$$AGE = \frac{1}{\lambda_e + \lambda_\beta} \ln\left[\frac{\lambda_\beta + \lambda_e}{\lambda_e} \times \frac{Ar^{40*}}{K^{40}} + 1\right]$$

Note: Ar^{40*} refers to radiogenic Ar^{40}.
M.Y. refers to millions of years.

KRUEGER ENTERPRISES, INC.
GEOCHRON LABORATORIES DIVISION
24 BLACKSTONE STREET • CAMBRIDGE, MASSACHUSETTS 02139 • (617) 876-3691

31 May 1974

Richard Holt
Weston Geophysical Research Inc.
P.O. Box 364
Weston, MA 02193

Dear Mr. Holt:

Enclosed are the analytical reports of the K-Ar age determinations on the remaining four (4) samples of the six (6) we received from Gene Simmions last month.

The amphibole in SRF 1A gave an age of 324 m.y. Samples SRF 2A, SRF 3A, and SRF 5A 42' were analyzed as whole rocks and gave indistinguishable ages of 256 m.y., 269 m.y., and 272 m.y. respectively.

Judging from past analyses we have done for you I suspect these numbers are about what you expected.

If you have any questions, please do not hesitate to contact me. In the meantime, I am enclosing our invoice for this work. We look forward to serving you again in the near future.

Sincerely,

Richard H. Reesman
General Manager

RHR/dm
encl: 4 reports & invoice # 4414

KRUEGER ENTERPRISES, INC.
GEOCHRON LABORATORIES DIVISION

24 BLACKSTONE STREET • CAMBRIDGE, MA. 02139 • (617)-876-3691

POTASSIUM-ARGON AGE DETERMINATION | **REPORT OF ANALYTICAL WORK**

Our Sample No. A-2814

Date Received: 22 April 1974

Your Reference: SRF 1A up

Date Reported: 31 May 1974

Submitted by:

Richard Holt
Weston Geophysical Res. Inc.
P.O. Box 364
Weston, MA 02193

Sample Description & Locality: Coarse-grained amphibolite

Material Analyzed: Amphibole concentrate, -40/+100 mesh.

Ar^{40*}/K^{40} = .02069

AGE = 324 ± 14 M.Y.

Argon Analyses:

Ar^{40*}, ppm.	Ar^{40*}/ Total Ar^{40}	Ave. Ar^{40*}, ppm.
.01967	.679	.01974
.01981	.704	

Potassium Analyses:

% K	Ave. %K	K^{40}, ppm
.786	.782	.954
.778		

Constants Used:

$\lambda_\beta = 4.72 \times 10^{-10}$/ year

$\lambda_e = 0.585 \times 10^{-10}$/ year

$K^{40}/K = 1.22 \times 10^{-4}$ g./g.

$$AGE = \frac{1}{\lambda_e + \lambda_\beta} \ln\left[\frac{\lambda_\beta + \lambda_e}{\lambda_e} \times \frac{Ar^{40*}}{K^{40}} + 1\right]$$

Note: Ar^{40*} refers to radiogenic Ar^{40}.
M.Y. refers to millions of years.

KRUEGER ENTERPRISES, INC.
GEOCHRON LABORATORIES DIVISION

24 BLACKSTONE STREET • CAMBRIDGE, MA. 02139 • (617)-876-3691

POTASSIUM–ARGON AGE DETERMINATION | **REPORT OF ANALYTICAL WORK**

Our Sample No. R-2817

Date Received: 26 April 1974

Your Reference: SRF 2A

Date Reported: 31 May 1974

Submitted by:
Richard J. Holt
Weston Geophysical
P.O. Box 364
Weston, MA 02193

Sample Description & Locality: Sericite schist

Material Analyzed: Whole rock, crushed to -60/+100 mesh.

Ar^{40*}/K^{40} = .01604 AGE = 256 ± 10 M.Y.

Argon Analyses:

Ar^{40*}, ppm.	Ar^{40*}/ Total Ar^{40}	Ave. Ar^{40*}, ppm.
.03235	.676	.03307
.03378	.807	

Potassium Analyses:

% K	Ave. %K	K^{40}, ppm
1.699	1.689	2.061
1.680		

Constants Used:

$\lambda_\beta = 4.72 \times 10^{-10}$/ year

$\lambda_e = 0.585 \times 10^{-10}$/ year

$K^{40}/K = 1.22 \times 10^{-4}$ g./g.

$$AGE = \frac{1}{\lambda_e + \lambda_\beta} \ln\left[\frac{\lambda_\beta + \lambda_e}{\lambda_e} \times \frac{Ar^{40*}}{K^{40}} + 1\right]$$

Note: Ar^{40*} refers to radiogenic Ar^{40}.
M.Y. refers to millions of years.

KRUEGER ENTERPRISES, INC.
GEOCHRON LABORATORIES DIVISION

24 BLACKSTONE STREET • CAMBRIDGE, MA. 02139 • (617)-876-3691

POTASSIUM-ARGON AGE DETERMINATION **REPORT OF ANALYTICAL WORK**

Our Sample No. R-2818 **Date Received:** 26 April 1974

Your Reference: SRF 3A **Date Reported:** 31 May 1974

Submitted by: Richard J. Holt
Weston Geophysical
P.O. Box 364
Weston, MA 02193

Sample Description & Locality: Sericite schist

Material Analyzed: Whole rock, crushed to -60/+100 mesh.

Ar^{40*}/K^{40} = .01690 AGE = 269 ± 10 M.Y.

Argon Analyses:

Ar^{40*}, ppm.	Ar^{40*}/ Total Ar^{40}	Ave. Ar^{40*}, ppm.
.07748	.913	.07756
.07763	.787	

Potassium Analyses:

% K	Ave. %K	K^{40}, ppm
3.782	3.761	4.589
3.741		

Constants Used:

$\lambda_\beta = 4.72 \times 10^{-10}$/ year

$\lambda_e = 0.585 \times 10^{-10}$/ year

$K^{40}/K = 1.22 \times 10^{-4}$ g./g.

$$AGE = \frac{1}{\lambda_e + \lambda_\beta} \ln \left[\frac{\lambda_\beta + \lambda_e}{\lambda_e} \times \frac{Ar^{40*}}{K^{40}} + 1 \right]$$

Note: Ar^{40*} refers to radiogenic Ar^{40}.
M.Y. refers to millions of years.

KRUEGER ENTERPRISES, INC.
GEOCHRON LABORATORIES DIVISION

24 BLACKSTONE STREET • CAMBRIDGE, MA. 02139 • (617)-876-3691

POTASSIUM–ARGON AGE DETERMINATION — **REPORT OF ANALYTICAL WORK**

Our Sample No. R-2819

Date Received: 26 April 1974

Your Reference: SRF 5A 42'

Date Reported: 31 May 1974

Submitted by: Richard J. Holt
Weston Geophysical
P.O. Box 364
Weston, MA 02193

Sample Description & Locality: Altered granodiorite

Material Analyzed: Whole rock, crushed to -60/+100 mesh.

Ar^{40*}/K^{40} = .01710 **AGE =** 272 ± 10 **M.Y.**

Argon Analyses:

Ar^{40*}, ppm.	Ar^{40*}/ Total Ar^{40}	Ave. Ar^{40*}, ppm.
.06782	.879	.06893
.07003	.872	

Potassium Analyses:

% K	Ave. %K	K^{40}, ppm
3.341	3.304	4.030
3.267		

Constants Used:

$\lambda_\beta = 4.72 \times 10^{-10}$/ year

$\lambda_e = 0.585 \times 10^{-10}$/ year

$K^{40}/K = 1.22 \times 10^{-4}$ g./g.

$$AGE = \frac{1}{\lambda_e + \lambda_\beta} \ln\left[\frac{\lambda_\beta + \lambda_e}{\lambda_e} \times \frac{Ar^{40*}}{K^{40}} + 1\right]$$

Note: Ar^{40*} refers to radiogenic Ar^{40}.
M.Y. refers to millions of years.

GEOLOGICAL INVESTIGATIONS

of the

PORTSMOUTH FAULT
(Novotny - 1963)

PORTSMOUTH-HAMPTON, NEW HAMPSHIRE

PUBLIC SERVICE COMPANY OF NEW HAMPSHIRE

SEABROOK STATION

SEPTEMBER 1974

PORTSMOUTH FAULT INVESTIGATIONS

CONTENTS

CONTENTS (CON'T.)

PUBLIC SERVICE COMPANY OF NEW HAMPSHIRE

SEABROOK STATION

PORTSMOUTH FAULT INVESTIGATIONS

Investigations have been conducted along the general path of the inferred Portsmouth fault between Portsmouth and Hampton, New Hampshire, in an attempt to locate and define the inferred feature, and to examine the nature and structure of unconsolidated Pleistocene deposits which overlie bedrock in the area. (Figure 1)

All investigations have failed to locate or to suggest the existence of the Portsmouth fault. Well-stratified outwash sand deposits of Pleistocene age, as exposed in the walls of a number of gravel pits at scattered localities along the general trend of the inferred fault, show no evidence of tectonic faulting subsequent to their deposition.

Consideration of all available facts leads to the conclusion that the Portsmouth fault does not exist.

I. DEFINITION OF THE PORTSMOUTH FAULT

The Portsmouth fault was originally postulated by R. F. Novotny to trend southerly in an arcuate path for a total length of 12½ miles from Pierce's Island, Portsmouth, to the Taylor River, Hampton, New Hampshire (Novotny; 1963). Novotny's bases for postulating the fault include: 1) brecciated and faulted rocks in the Kittery formation in an exposure on Route 1 By-pass, Portsmouth; 2) brecciated and partly silicified Kittery formation rocks exposed on the southeastern shore of Goat Island, New Castle; 3) brecciated and partly silicified Kittery formation rocks exposed near the east end of Brumley Hill, North Hampton; 4) the presence of granitic intrusives in the Rye formation near the Kittery contact; 5) an apparently unconformable stratigraphic relationship between the Rye and Kittery formations along the trend of their contact zone.

Novotny further interpreted the Portsmouth fault to form the steeply west-dipping contact between the Rye and Kittery formations. Displacement was inferred to be down on the west, suggesting a normal fault. Outcrops were reported to be too few and too poor to attempt calculation of fault displacement.

II. INVESTIGATION PROCEDURES

A. Preliminary - General Area

As a preliminary investigation of the Portsmouth fault, J. R. Rand walked portions of the fault trace as it was defined by Novotny, and examined gravel pits and highway road cuts and construction excavations in a strip about 2 miles wide overlapping the postulated trace of the fault from Portsmouth to Hampton. Each specific outcrop cited by Novotny as proof of faulting was also examined. R. J. Holt of Weston Geophysical Research, Inc. and J. R. Rand together viewed by helicopter the inferred trace of the fault between the Seabrook site and Gerrish Island, Maine. J. R. Rand also studied commercial aerial photographs covering the zone from the site to North Hampton, and his own color photographs taken along the path of the zone during the helicopter inspection. Backhoe trenching and ground magnetometer surveys have also been conducted in Greenland, New Hampshire, 8 to 9 miles north of the Seabrook site, in an effort to locate the fault (Point "A" on Figures 1 and 2). Several bedrock samples were taken along the zone for radiometric age dating.

B. Detailed - Breakfast Hill Road, Greenland

Just to the northeast of the intersection of the New Hampshire Turnpike and Breakfast Hill Road, Greenland, a wide area of outwash sands, ice-contact gravels and cobble till deposits was excavated for Turnpike construction subsequent to Novotny's field studies in the area (Point "A" on Figures 1 and 2; Figure 3; Figure 4). Within this large area, numerous low, glacially striated surfaces of Rye formation bedrock are now exposed in the floor of the reclaimed borrow area, in contradiction to Novotny's interpretation of Kittery formation terrane in this area. Survey control for investigations was provided by McKenna Associates, Portsmouth (map attached).

1. Coakley Sand Pit

As shown on Figure 3, backhoe trenching in an operating sand pit at the northwest corner of the area exposed additional outcrop of the Rye formation bedrock. Boring PF-1 was drilled on a N50W (True) bearing at an inclination of about 43° to a depth of 276', taking oriented core samples, in a search for a possible Rye/Kittery contact in an apparent folded structure which underlay well-stratified and undisturbed outwash sands exposed in the north wall of the pit.

Boring PF-1 encountered only interbedded gneiss, fine-grained schist and thin interbedded quartzites of the Rye formation, and was terminated as it passed to the west of the edge of the sand pit. The structure of the Rye formation in the boring, as indicated by orientation measurements of bedrock foliation, is that of a tight syncline which dips steeply to the west. Five zones of welded breccia were encountered in the boring, the thickest of which included 7.5' of welded quartzite breccia at 249.5' to 257' depths in the hole. The brecciated rock in PF-1 was fresh, compact, thoroughly welded or annealed, and did not show polished or slickensided surfaces on partings.

No mineralization, hydrothermal alteration, shear zones, or other evidence of major faulting was encountered in the boring. The welded brecciation is of the type found frequently in borings in metamorphic rocks in the region, and is interpreted to be associated with strains developed at the time of folding and metamorphism of the region during the Acadian orogeny. Two diabase dikes encountered in the boring were fresh, unaltered, and showed normal intrusive contacts.

2. Loch-Coombs Reclaimed Borrow Area

As shown on Figure 4, three core borings (PF-2, PF-3, PF-3A) were drilled across the property line between lands of Anthony Loch and Richard Coombs, at the north edge of a reclaimed borrow area to the north of Breakfast Hill Road, to investigate the western boundary of a local magnetic anomaly.

a. Ground Magnetometer Survey

Because the bedrock exposed throughout the Breakfast Hill study area is represented only by Rye formation metavolcanic rocks for as much as one-half mile to the west of Novotny's fault trace, and comprises no outcrops of Kittery formation quartzites as had been interpreted by Novotny, the presence of a fault contact between these two formations in this area cannot, by definition, exist. Having no formational contact to investigate for these current studies, Weston Geophysical Engineers, Inc. undertook a ground magnetometer survey to determine whether any anomalous magnetic features might occur which could suggest faulting within the Rye formation itself. Technical details of this survey are presented in a report by Weston Geophysical Engineers, Inc., attached herewith.

The magnetometer surveys show no anomalous magnetic intensities in the zone of Novotny's fault trace in five profiles which were conducted across the inferred trace at intervals influencing a zone of almost 4,000' along the trace from north to south. In the area of Coombs Pond (Figure 4), a local magnetic anomaly high was detected on 3 survey lines (Lines 6, 2NR and 2R). The apparent alignment of this anomaly is about N10E, parallel to the strike of bedrock foliation in the area. Novotny's inferred fault trace in the same general area strikes about N40E, transverse to foliation.

b. Borings Investigations

Two borings, PF-2 and PF-3A, were drilled at approximately 40^{o} inclination to the southeast to investigate bedrock conditions at the western boundary of the local magnetic anomaly. A third boring, PF-3, was drilled vertically to determine bedrock depth prior to drilling PF-3A. The results of these borings are generalized in cross section on Figure 4, on which also is projected the magnetic profile of Mag. Line 6.

Overburden, which was not specifically sampled in these three borings, is comprised of outwash sands overlying a sandy boulder till. Boring PF-2 was drilled to a depth of 271' (about 201' in bedrock), in light gray banded gneiss and dark green amphibolite, intruded locally by weakly magnetic diabase dikes. PF-3 was drilled to a depth of 50' (10' in bedrock) in gray and greenish gneiss. PF-3A was drilled to a depth of 204.3' (124' in bedrock) in gray banded gneiss, dark green amphibolite and, at the bottom 5' of the boring, notably magnetic, salmon-feldspar gneiss, with a single diabase dike. The location of the basal magnetic gneiss in PF-3A conforms reasonably with the downward projection on the local bedrock structure of the magnetic anomaly found by surface surveys. The weakly magnetic dikes in the borings conform with a slight increase in magnetic intensity found by surface surveys.

The condition of bedrock in PF-2, PF-3 and PF-3A was weakened by weathering effects on moderately closely-spaced jointing to about -70' Elevation. In no boring, however, were there slickensided or polished joint surfaces, gouge zones, hydrothermal alteration or any other visible evidence of bedrock faulting.

C. Petrographic Examinations

The petrography of three samples of drill core from Boring PF-2 has been described by Professor Gene Simmons and Dorothy A. Richter of Massachusetts Institute of Technology.

Sample	Depth	Field Description	Petrographic Description
PF-2A	99.5 - 99.9'	Gneiss	Felsic Metatuff
PF-2B	136.0 - 136.5'	Diabase	Metabasalt
PF-2C	262.0 - 262.4'	Amphibolite	Fine Grained Amphibolite

Simmons and Richter conclude from their studies that "Evidence for dynamic structural deformation, either recent or ancient, is entirely absent. In summary, we find no petrographic evidence that these three samples are associated with a fault. If a fault does exist in the region from which these samples were obtained, then either its deformation was not so pervasive as to effect these three samples, or else the deformation occurred before metamorphism and all petrographic evidence has been erased by the last metamorphic event".

The full report by Simmons and Richter is attached herewith.

III. RESULTS OF INVESTIGATIONS ALONG THE INFERRED FAULT

None of the current investigations along the path of the inferred Portsmouth fault has detected or suggested the presence of a through-going fault structure along the zone of the Rye/Kittery contact between Portsmouth and Hampton. No exposure of Pleistocene deposits seen along this zone has shown internal structures suggestive of tectonic fault displacement.

A. Novotny's "Faulted" Outcrop Exposures

1. Route 1 By-pass, Portsmouth (Point "B" on Figures 1 and 2)

Novotny cites a road cut on the north side of the Route 1 By-pass in Portsmouth as suggesting the presence of the Portsmouth fault nearby, but not within, the road cut exposure. This exposure shows two steeply west-dipping zones of weathered and rusty rock material interlayered in gneiss and quartzite. In one of these weathered zones, an open drag fold was interpreted by Novotny to represent differential movement, down on the west. This folding could also represent simple folding of the beds, signifying an anticline to the west.

The rock materials within these two weathered zones are not slickensided or mineralized, and the rock adjacent to the weathered zones shows no hydrothermal alteration. Very similar open folding can be seen in an unweathered exposure of quartzitic rock near the Rye/Kittery contact, 3.54 miles S52W of this locality, on the west right-of-way of the New Hampshire Turnpike, where there is no evidence of fracturing. Fold structures of the type

seen at the Route 1 By-pass and on the New Hampshire Turnpike right-of-way are most logically explained as simple small-scale drag folding formed during the regional folding of the Rye anticline. The exposure on the Route 1 By-pass is suggestive of faulting only because it is weathered. Rye formation rocks occur on both sides of the weathered zone at the Route 1 exposure.

2. <u>Goat Island, New Castle</u> (Point "C" on Figures 1 and 2)

Bedrock structure on the southeast shore of Goat Island is a complex jumble of brecciated Rye formation metavolcanics and quartzite. The breccia is welded, and is intruded by diabase dikes. No "trend" of faulting is apparent at this locality to suggest a through-going fault plane which might connect this exposure with the exposure cited on the Route 1 By-pass, 2.1 miles to the southwest. The apparently random distribution of metavolcanics and quartzite breccia blocks suggests that fault structure in this area may represent explosion breccia, which Hussey (1962) has also found as discontinuous masses 3 miles to the east on Gerrish Island, Maine. Hussey suggests that the breccia at Gerrish Island may relate to volcanic activity associated with the Cape Neddick and Tatnic volcanic complexes, southwestern Maine.

3. <u>Brumley Hill, North Hampton</u> (Point "F" on Figure 1)

The brecciated quartzite cited by Novotny for the east end of Brumley Hill showed some healed fracturing and rusty staining in a dark, fine-grained quartzite. Billings (1956) interpreted this area to lie in a broad fold zone in the Rye formation. No through-going shears were apparent in the exposure to suggest the presence of faulting. The exposure no longer exists, having been removed during construction of a new north-bound lane of the New Hampshire Tunrpike.

B. <u>Granite in the Rye Formation</u>

Novotny states (1963; p. 147): "Although metamorphic zones are apparently not displaced because of the fault, the presence of concordant foliated and granulated Breakfast Hill granite only in the Rye formation and near the Kittery formation contact supports the hypothesis of a fault developed during the Acadian period of orogeny, along which deeply buried and intruded portions of the Rye formation were elevated". (Point "D" on Figures 1 and 2)

Foliated granite, seen in a number of places in the Rye formation, appears to be a primary metamorphic constituent of that formation, having formed by recrystallization ("granitization") of the inherently feldspathic Rye formation rocks. These granitic masses appear genetically related to a process of metamorphism within the Rye, rather than to plutonic intrusions from a separate deep-seated source. Because of the fundamental lack of feldspar in the Kittery formation, furthermore, no comparable granitization of the Kittery could have occurred at the time the Rye was being recrystallized and granitized.

Whereas the granites of the Rye formation to the east of the Rye/Kittery contact do not in themselves offer any proof that the Rye has been elevated relative to the Kittery, plutonic intrusives of the Exeter diorite are found in the Kittery formation to the west of the Rye/Kittery contact, tending to negate an hypothesis of fault displacement based on the presence or absence of igneous rocks in the metamorphic terrane. (Point "E" on Figures 1 and 2)

C. Unconformable Rye/Kittery Stratigraphy

Whereas Novotny interpreted an unconformable stratigraphic relationship between the Rye and Kittery formations in the area between Portsmouth and Hampton, outcrops of the two formations are widely scattered, and the contact between these formations is nowhere exposed along the 12½ mile path of the inferred Portsmouth fault. On Gerrish Island, Maine, about 5 miles east of Portsmouth, Hussey (1962) interprets the Rye/Kittery contact to be conformable, grading upward through progressively less feldspathic gneisses of the Rye formation into biotite quartzites typical of the Kittery.

Novotny, Hussey and Billings (1956) all define the Rye formation as metavolcanic and the Kittery as metasedimentary, predominantly quartzite. Novotny interprets the contact between these two formations to be defined by a major fault structure, while Hussey and Billings do not. Novotny, furthermore, defines the geographic location of the Rye/Kittery contact as much as three-quarters of a mile to the east of the contact trace defined by Hussey and Billings. Figure 1 shows by a dotted line the contact between the Rye metavolcanic member and the Kittery formation as defined by Billings to the southwest and by Hussey to the northeast.

Current investigations have indicated that Novotny's contact trace trends from Portsmouth to North Hampton through a terrane characterized only by bedrock exposures of the Rye formation metavolcanic member. Since the metavolcanic member of the Rye is made up of an original sequence of different types of volcanic rocks and interbedded sedimentary units, unconformable stratigraphic relationships might be expected in the zone where Novotny has defined the Rye/Kittery contact. Such relationships would not, however, signify the presence of a major fault zone. Furthermore, foliation structure symbols shown on Figure 1 (after Novotny and Hussey; and J. R. Rand reconnaissance) indicate a reasonable parallelism of bedrock structure along Novotny's inferred fault trace in this area, with no suggestion of the alledged formational unconformity.

D. Radiometric Age Dating

Four outcrop samples (PF-S1, -S2, -S3, -S4) were taken at intervals along the path of the inferred fault for radiometric age dating (K-Ar). The locations and K-Ar ages of these samples, along with three other samples taken from Borings B2, B4 and B9 at the site area in 1969, are defined on Figure 1. Age determinations were obtained by Geochron Laboratories, Division of Krueger Enterprises, Inc., Cambridge, Massachusetts.

Sample	Location	Rock Type	Material	K-Ar Age
PF-S1	Towle Road, Hampton	Quartzite	Biotite	268±10 M.Y.
PF-S2	Rte. 151, North Hampton	Quartzite	Amphibole	308±14 M.Y.
PF-S3	Rte. 1, Portsmouth	Gneiss	Muscovite	294±10 M.Y.
PF-S4	Rte. 1, Portsmouth	Quartzite	Mica-Quartz	262±11 M.Y.
B2	129.5' - Boring B2	Qtz. Diorite	Biotite	294± 9 M.Y.
B4	93.0' - Boring B4	Schist	Biotite	254± 9 M.Y.
B9	12.3' - Boring B9	Bio. Diorite	Biotite	284± 9 M.Y.

No anomalously young ages were found in this dating program. All ages found conform to previously reported regional data which indicates a Permian thermal event for the area (Zartman et al, 1970). The lower ages obtained in this investigation (PF-S1, PF-S4 and B4) are mineral dependent, with argon loss associated with the fine-grained materials analyzed.

IV. CONCLUSIONS

Field investigations have shown that

1. The graphic trace of the alleged Portsmouth fault bears no meaningful spatial relationship to the contact between the Rye and Kittery formations, along which the fault was postulated by Novotny to trend.

2. There is no evidence of the alleged unconformable relationship between the Rye and Kittery formations.

3. There is no evidence of anomalous magnetic intensities on the inferred fault trace in Greenland, New Hampshire.

4. Examination of drill cores in the area of the alleged fault trace in Greenland, complimented by petrographic studies of core samples, indicate no evidence of faulting in that area.

5. There is no evidence of a through-going fault structure associated with the specific bedrock exposures cited by Novotny as indicating the presence of the Portsmouth fault.

6. There is no justification for ascribing the presence of granitic rocks at ground surface in the Rye formation terrane to the differential uplift of these rocks along a nearby fault.

7. There are no meaningful variations in radiometric ages of rocks along the alleged fault trace.

8. Ground and aerial examinations have failed to detect any anomalous landforms or stream patterns along the trace of the alleged fault.

9. Pleistocene deposits exposed in road cuts and gravel pits along the alleged fault trace show no features which might imply tectonic faulting in the area.

The current investigations have concluded that the Portsmouth fault does not exist.

John R. Rand
Consulting Geologist

September 1974

References:

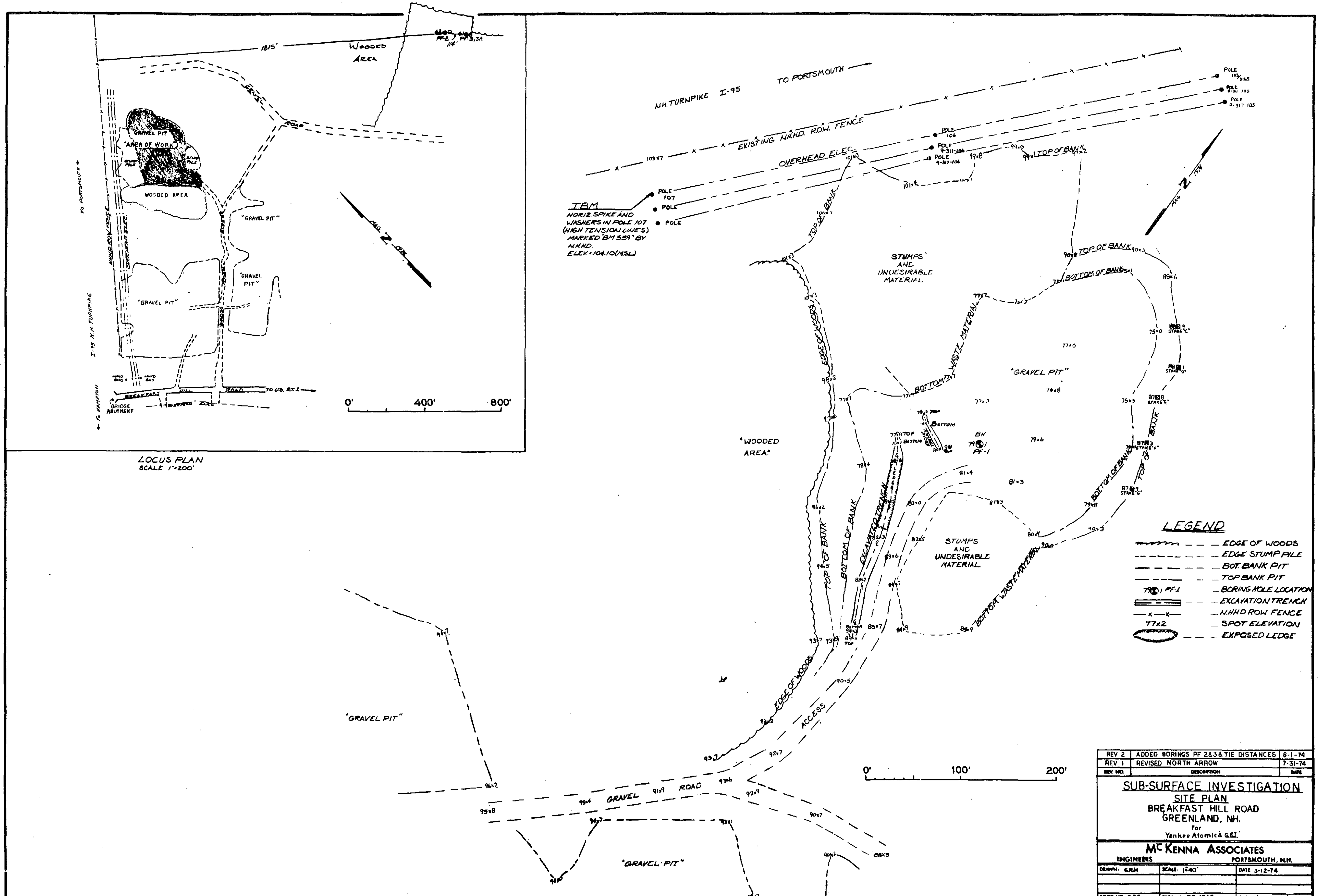
Billings, M. P. (1956) The Geology of New Hampshire - Part II: Bedrock Geology. Department of Resources and Economic Development; Concord, New Hampshire.

Hussey, A. J. II (1962) The Geology of Southern York County, Maine. Special Geologic Studies, No. 4, Maine Geological Survey; Augusta, Maine.

Novotny, R. F. (1963) Bedrock Geology of the Dover-Exeter-Portsmouth Region, New Hampshire. Doctral Thesis, Department of Geology, The Ohio State University; Columbus, Ohio.

Novotny, R. F. (1969) The Geology of the Seacoast Region, New Hampshire. Ed. T. R. Meyers. Department of Resources and Economic Development; Concord, New Hampshire.

Zartman, R. E., P. M. Hurley, H. W. Krueger and B. J. Gilletti (1970) A Permian Disturbance of K-Ar Radiometric Ages in New England: Its Occurrence and Cause, Geological Society of America Bulletin, Vol. 81, 3359-3374.



WOODED AREA
1815'
"GRAVEL PIT"
"AREA OF WORK"
WOODED AREA
"GRAVEL PIT"
TO PORTSMOUTH
I-95 N.H. TURNPIKE
BREAKFAST HILL ROAD
TO US. RT. 1
BRIDGE ABUTMENT
TO HAMPTON
0' 400' 800'
LOCUS PLAN
SCALE 1"=200'
N.H. TURNPIKE I-95
TO PORTSMOUTH
EXISTING N.H.H.D. R.O.W. FENCE
OVERHEAD ELEC.
POLE 107
POLE
POLE
TBM
HORIZ. SPIKE AND WASHERS IN POLE 107 (HIGH TENSION LINES) MARKED 'BM 559' BY N.H.H.D.
ELEV.=104.10(MSL)
TOP OF BANK
STUMPS AND UNDESIRABLE MATERIAL
BOTTOM OF BANK
BOTTOM WASTE MATERIAL
"GRAVEL PIT"
"WOODED AREA"
EDGE OF WOODS
TOP OF BANK
BOTTOM OF BANK
EXCAVATION TRENCH
BH PF-1
STUMPS AND UNDESIRABLE MATERIAL
BOTTOM WASTE MATERIAL
ACCESS
GRAVEL ROAD
"GRAVEL PIT"
"GRAVEL PIT"
0' 100' 200'
LEGEND
EDGE OF WOODS
EDGE STUMP PILE
BOT. BANK PIT
TOP BANK PIT
BORING HOLE LOCATION
EXCAVATION TRENCH
N.H.H.D. ROW FENCE
SPOT ELEVATION
EXPOSED LEDGE
REV 2 | ADDED BORINGS PF 2&3 & TIE DISTANCES | 8-1-74
REV 1 | REVISED NORTH ARROW | 7-31-74
REV. NO. | DESCRIPTION | DATE
SUB-SURFACE INVESTIGATION
SITE PLAN
BREAKFAST HILL ROAD
GREENLAND, N.H.
for
Yankee Atomic & G.E.I.
McKENNA ASSOCIATES
ENGINEERS
PORTSMOUTH, N.H.
DRAWN: G.R.M.
SCALE: 1"=40'
DATE: 3-12-74
BOOK NO. 936
PROJ. NO. 73-1012
SHEET 1 OF 1

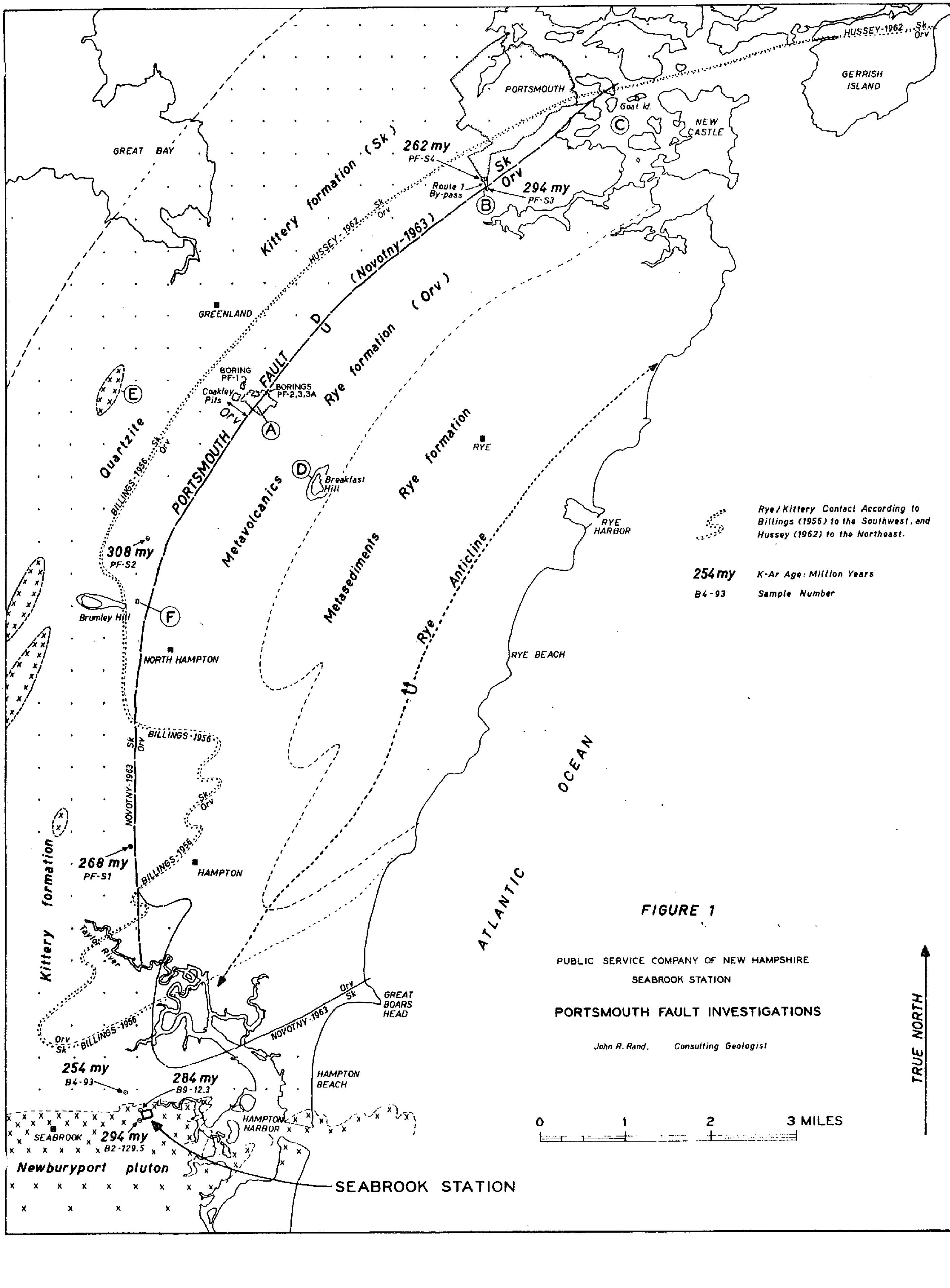
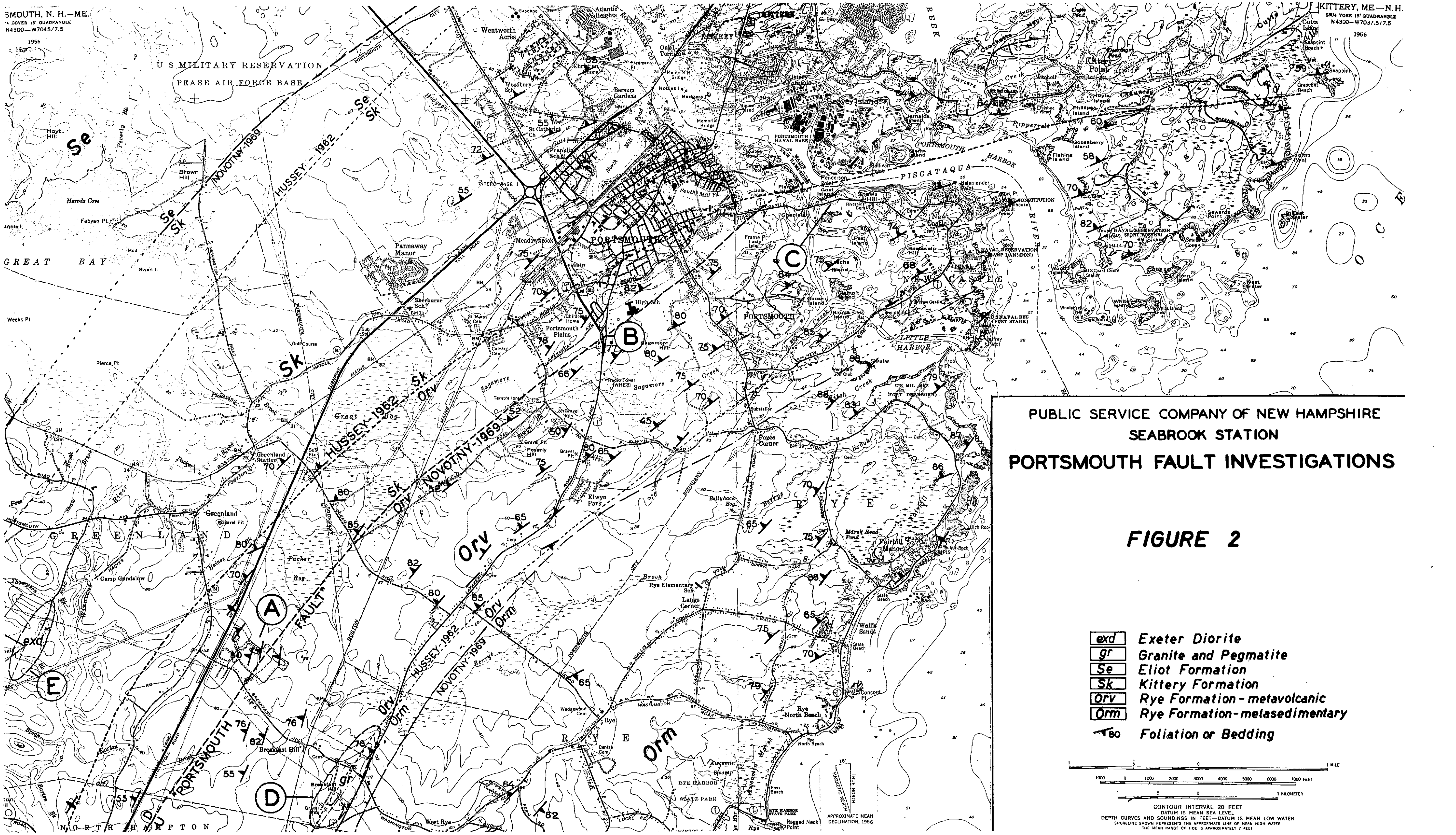


FIGURE 1

PUBLIC SERVICE COMPANY OF NEW HAMPSHIRE
SEABROOK STATION

PORTSMOUTH FAULT INVESTIGATIONS

John R. Rand, Consulting Geologist



PUBLIC SERVICE COMPANY OF NEW HAMPSHIRE
SEABROOK STATION

PORTSMOUTH FAULT INVESTIGATIONS

FIGURE 2

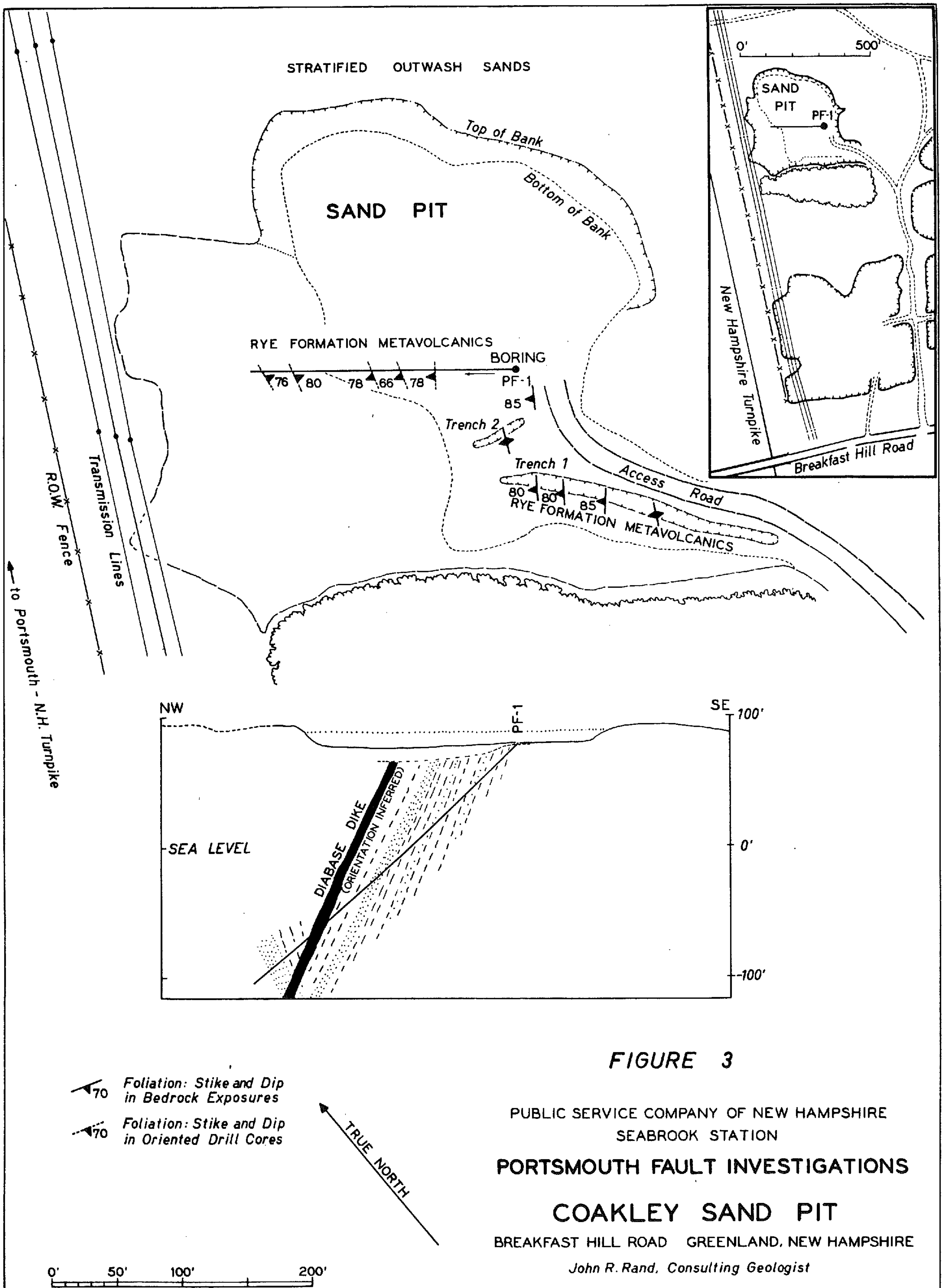


FIGURE 3

PUBLIC SERVICE COMPANY OF NEW HAMPSHIRE
SEABROOK STATION

PORTSMOUTH FAULT INVESTIGATIONS

COAKLEY SAND PIT

BREAKFAST HILL ROAD GREENLAND, NEW HAMPSHIRE

John R. Rand, Consulting Geologist

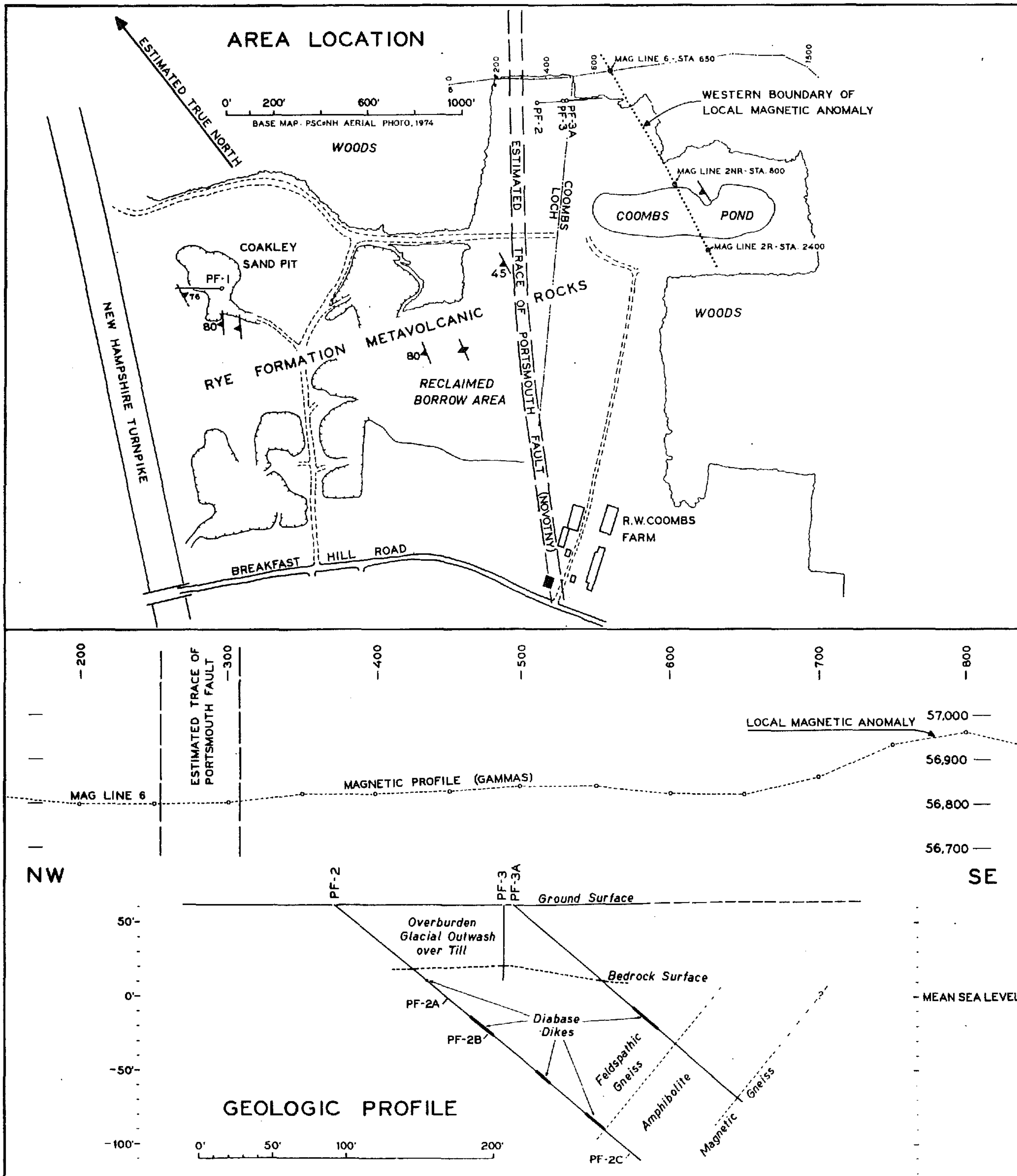


FIGURE 4

PUBLIC SERVICE COMPANY OF NEW HAMPSHIRE
SEABROOK STATION

PORTSMOUTH FAULT INVESTIGATIONS

COOMBS POND AREA

BREAKFAST HILL ROAD - GREENLAND, NEW HAMPSHIRE

John R. Rand, Consulting Geologist

ATTACHMENT NO. 1

GROUND MAGNETOMETER SURVEY

BREAKFAST HILL ROAD AREA

GREENLAND, NEW HAMPSHIRE

WESTON GEOPHYSICAL RESEARCH, INC.

WESTBORO, MASSACHUSETTS

GROUND MAGNETOMETER SURVEY
BREAKFAST HILL ROAD AREA
GREENLAND, NEW HAMPSHIRE

SUMMARY

This report details a ground magnetometer survey conducted by Weston Geophysical Research, Inc. in the vicinity of Breakfast Hill Road, Greenland, New Hampshire. This study was completed in conjunction with a general geologic investigation of the inferred Portsmouth fault, as proposed by Novotny (1963).

Five separate magnetic lines were run across the trace of the inferred fault. No magnetic evidence for faulting was found on any of the profiles.

INSTRUMENTATION

The survey was begun with a vertical field, torsion magnetometer (Askania, Model Gfz), which is tripod mounted and must be leveled prior to each reading. Because this procedure is difficult in soft or swampy ground, which is extensive in the investigation area, the vertical field magnetometer was replaced with a total field, proton precession magnetometer (Geometrics, Model G-816), which requires neither tripod nor leveling.

METHOD

The survey method consisted of making total magnetic field intensity measurements at paced intervals along a predetermined line. The interval used varied from 50 to 100 feet. The magnetic sensor was oriented north (magnetic) for each reading, and readings were repeated to insure precision. A base station was established, and base station readings were taken regularly to determine the diurnal variation of the earth's magnetic field during a given portion of the survey. The diurnal variation has been removed from the final profiles. Careful notes were taken during the survey so that the presence of magnetic interference sources (i. e., power lines, buried metal, houses, parked vehicles, etc.) could be considered in the final analysis.

RESULTS

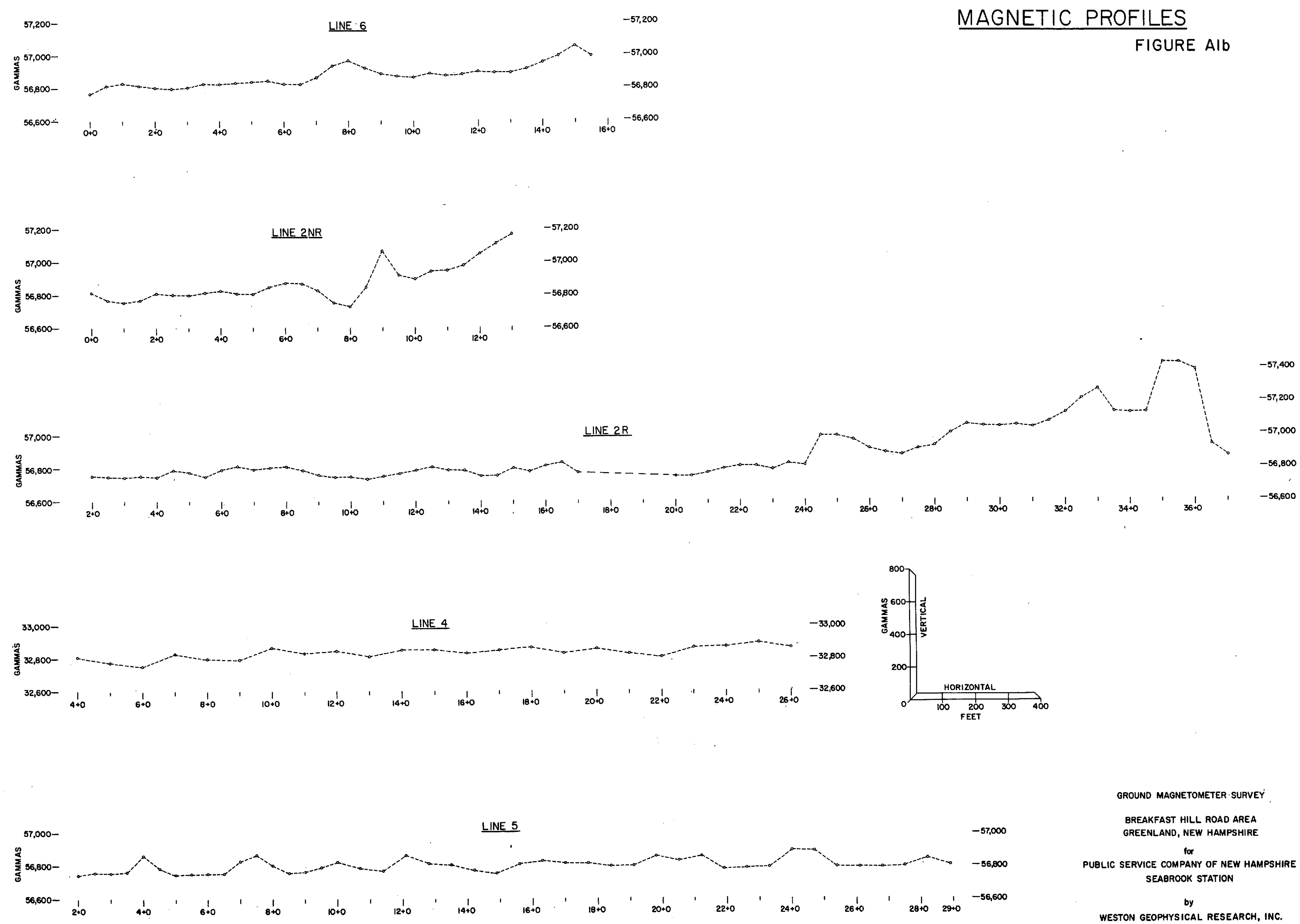
Total field intensity magnetic profiles were made from data for five traverses in the area of investigation. As shown in Figure A1a, Profiles 2R, 2NR and 6 are located at distances extending up to approximately 2,500 feet northeast of Breakfast Hill Road, near Coombs Pond. Profiles 4 and 5 are located at distances extending up to approximately 1,500 feet southwest of Breakfast Hill Road. All five magnetic profiles crossed Novotny's inferred fault trace at nearly perpendicular angles. Any magnetic expression of Novotny's inferred fault (within the Rye formation) should, therefore, have been readily apparent.

Figure A1a locates the inferred fault trace relative to magnetic profiles reported in Figure A1b at or near the following profile points: 3+0 on Line 6, 1+5 on Line 2NR, 16+0 on Line 2R, 15+0 on Line 4, and 13+0 on Line 5.

No evidence of the postulated fault was found. Further examination of the profiles indicates that localized anomalies, probably due to local variations in magnetic mineral concentrations known to be present in the Rye formation, appear on each of the traverses near Coombs Pond. Profiles 6, 2NR and 2R show such an anomalous condition, which appears to trend N10E in the vicinity of the three lines. It should be noted that this strike is parallel to the bedrock foliation of the area.

MAGNETIC PROFILES

FIGURE AIb



GROUND MAGNETOMETER SURVEY

BREAKFAST HILL ROAD AREA
GREENLAND, NEW HAMPSHIRE

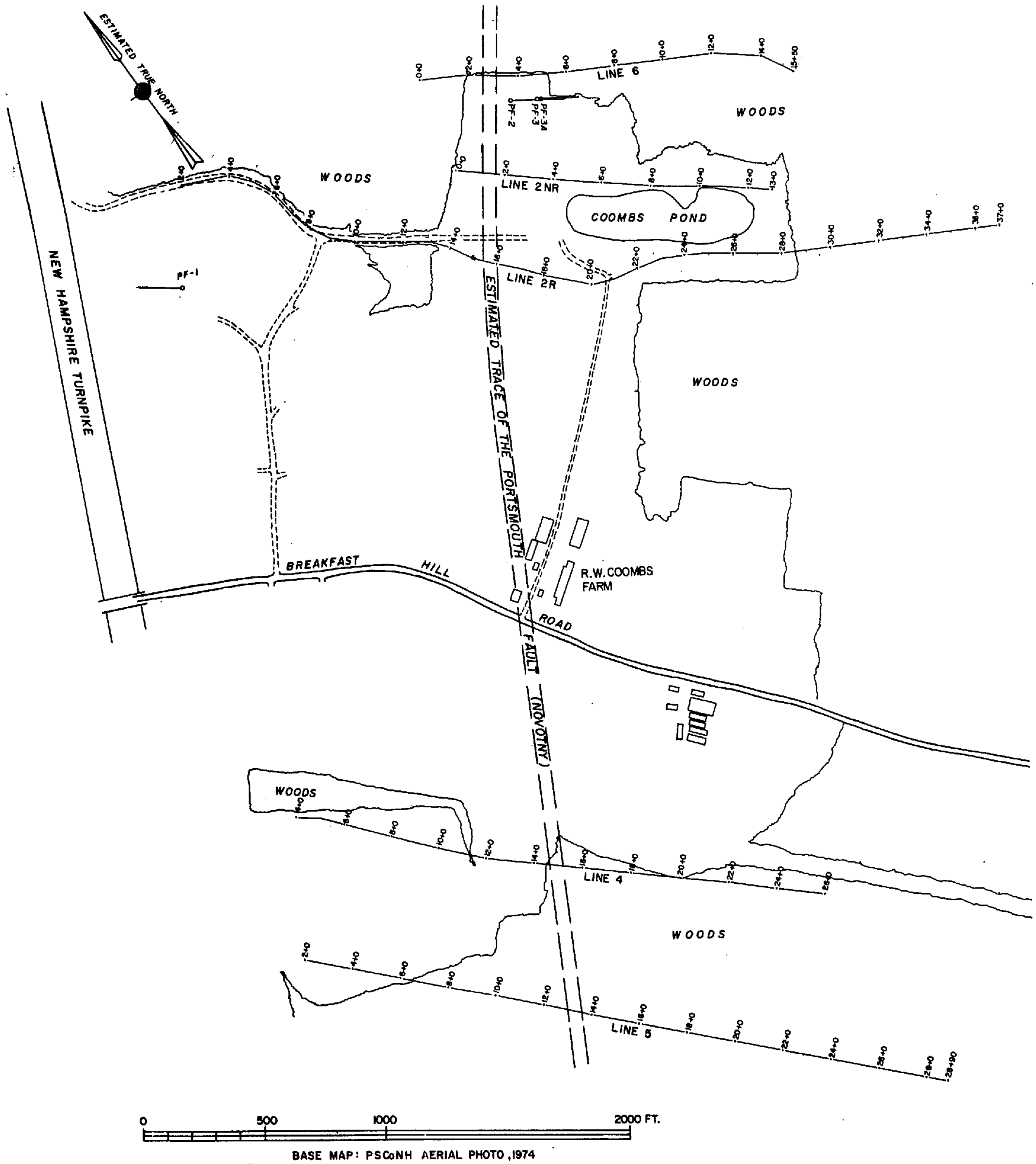
for

PUBLIC SERVICE COMPANY OF NEW HAMPSHIRE
SEABROOK STATION

by

WESTON GEOPHYSICAL RESEARCH, INC.

FIGURE AI



AREA LOCATION

FIGURE A1a

ATTACHMENT NO. 2

GEOLOGIC BORINGS LOGS

BORINGS PF-1, PF-2, PF-3, PF-3A

BORING LOCATION See Breakfast Hill Rd. site plan INCLINATION 48.5° BEARING N 50 W DATE START/FINISH Feb. 19, 1974 / March 21, 1974

CASING ID 3 in. CORE SIZE 2-1/8 to 1-7/8 in. TOTAL DEPTH 276.0 ft DRILLED BY American Drilling & Boring Co.; K. Allen

GROUND EL (MSL) 79.1 ft DEPTH TO WATER/DATE 13.7 ft / - LOGGED BY Soil - K. Polk; Rock - J. R. Rand

Sample Type and No.	N or Rec.	Rate of Adv. min/ft	RQD %	Strike, Dip (F = Foliation, J = Joint, C = Contact, B = Bedding, S = Slickenside)
NX-1	100	4.0	0	TOP OF ROCK
NX-2	100	4.7	21	
NX-3	100	6.4	25	
NX-4	100	4.1	74	
NX-5	100	6.8	50	
NX-6	100	9.0	56	
NX-7	100	5.0	89	
NX-8	100	2.7	35	
NX-9	100	5.1	62	
NX-10	96	5.6	62	
NX-11	100	5.5	12	
NX-12	100	5.0	0	
NX-13	100	6.0	43	
NX-14	92	15.5	42	
NX-15	96	13.1	22	
NX-16	100	7.3	64	
NX-17	94	6.8	70	
NX-18	100	7.9	95	
NX-19	100	10.0	100	
NX-20	100	6.0	100	
NX-21	100	11.2	92	
NX-22	100	12.8	88	
NX-23	97	18.4	73	N37E, 74NW F; N60E, 32SE S
NX-24	100	8.0	65	N45W, 42NE J; N33E, 28SE J
NX-25	100	6.6	83	N50W, 4NE J; N75E, 8NW J; N33W, 18NE J
NX-26	96	17.4	86	N52E, 78NW F
NX-27	100	7.2	73	Horizontal S; N45E, 8SE J
NX-28	100	5.6	95	N83E, 32SE J
NX-29	100	7.4	93	
NX-30	100	24.4	75	N 6W, 10NE J; N43E, 62SE J; N60E, 67SE J; N15E, 73NW F
NX-31	99	5.6	92	N20E, 62NW F
NX-32	97	4.0	95	N10W, 77SW F; N41W, 66NE S; N66E, 63NW F
NX-33	100	6.2	90	N66E, 74NW F; N33E, 69NW
NX-34	100	5.6	100	
NX-35	100	12.8	58	N47E, 35SE J

SOIL AND ROCK DESCRIPTIONS

(Weathering, defects, etc.) / (Type, texture, mineralogy, color, hardness, etc.)

Minor rusty. Slight wx on foliation and joints. Slight wx. D. Minor rust. Slight wx.

Fresh and hard. Local minor rusty and surface wx effects on joints and some partings. Partings not slickensided.

Drag folds - sense of movement west side up to the east - syncline to west. Welded breccia. Welded diabase.

Rye formation. Fine to very fine-grained, medium dark gray. Thinly and evenly foliated, metavolcanic. Fine feldspathic quartzite. Brecciated fractures welded with calcite.

Moderate wx. Moderate wx. D. D. Minor rusty.

Fresh and hard. Minor rusty, vuggy zones associated with joints and partings not slickensided.

Gneiss. Gneiss. Gneiss. Gneiss. Gneiss. Gneiss.

Fine-very fine feldspathic quartzite with interbeds of light gray feldspathic gneiss. Medium-grained.

Slight wx. Minor rusty. Moderate wx.

Fresh and hard. Local zones of slight to moderate wx on joint surfaces. Not slickensided.

40.5' Broken contact-minor rusty. Diabase. Fine, dark gray. 43.7' Fused transitional contact.

Sense of drag folds suggests syncline to west.

Quartzite. Quartzite. Quartzite. Quartzite. Medium grained.

Rye metavolcanics. Fine, evenly laminated feldspathic quartzite. Discrete fairly pure quartzite beds.

85° joint. Calcite coating. D.

Fresh and hard. Joints and partings are clean, not slickensided. Hard, dense.

Gneiss. Quartz-feldspar gneiss. Garnets (?). Dark fine feldspathic hornfels.

Rye formation. Predominantly fine-grained, dark gray hornfelsic schist. Very dense texture. Interlayered with zones of quartzose. Feldspathic gneiss, medium to coarse grained, light gray. All contacts are tight, fused. Somewhat transitional.

Fresh and hard. Joints and partings are clean except in narrow rusty-stained zone at 80.5-80.8'. Not slickensided.

Moderate wx. Rusty stain.

Quartzite. Gneiss.

Interlayered fine-grained feldspathic gneiss. Light gray, and fine-grained, dark gray hornfelsic schist.

Fresh and hard. Some thin calcite coatings on joints. Joints and partings not slickensided.

Welded micro-fault. Fold sense Syncline to west.

Sense of some open drag folding suggests that syncline is to the west. Rock fabric offset locally by welded micro faults.

Vuggy. D.

Micro fault-welded. Quartzite. Quartzite. Lime silicate. Quartzite.

Fresh and hard throughout. Joints and partings are generally clean. Not wx. Surfaces are not slickensided.

Rye formation. Predominantly fine-grained, dark gray (hornfelsic) feldspathic schist. Very hard. Almost massive texture. Interbedded locally as shown with fairly pure white quartzite beds.

Minor chlorite. Pyrite coated.

Fresh and hard throughout. Joints and partings are clean. Not slickensided. Has only very minor tendency to part on foliation.

Quartzite.

Rye formation, as above. Fairly evenly, thinly laminated throughout, although laminae locally are wavy, some complex folding.

D. On foliation. Minor vuggy.

Welded breccia gneiss.

LEGEND

N - Standard penetration resistance, blows/ft
Rec - Length recovered/length cored, %
RQD - Length of sound core 4 in. and longer/length cored, %
S - Split spoon sample
U - Undisturbed samples
Groundwater
S - Shelby tube, N - Denison, F - Fixed piston, P - Pitcher, O - Osterberg, G - GEI
D - Drilling break
wx - Weathered, weathering
k - Coefficient of permeability

NOTES

1) No clays present; therefore no water contents were determined.

x - Oriented core

SEABROOK STATION

PUBLIC SERVICE COMPANY OF NEW HAMPSHIRE

YANKEE ATOMIC ELECTRIC COMPANY

united engineers

Date: May 14, 1974 Project 7286

PAGE 1 of 2 LOG OF BORING PF 1

GEOTECHNICAL ENGINEERS INC.

BORING LOCATION See Breakfast Hill Rd. site plan INCLINATION 48.5° BEARING N 50 W DATE START/FINISH Feb. 19, 1974 / March 21, 1974

CASING ID 3in. CORE SIZE 2-1/8 to 1-7/9 in. TOTAL DEPTH 276.0 ft DRILLED BY American Drilling & Boring Co.; K. Allen

GROUND EL (MSL) 79.1 ft DEPTH TO WATER/DATE 13.7 ft / - LOGGED BY Soil - K. Polk; Rock - J. R. Rand

CONTINUED FROM PREVIOUS PAGE

EL. MSL ft	Depth ft	Sample Type and No.	N or Rec.	Rate of Adv. min/ft	RQD %	Pressure Test gpm psi	Computed k 10⁻ cm/sec	Strike, Dip (F = Foliation, J = Joint, C = Contact, B = Bedding, S = Slickenside)	Core Breaks
	144.0	NQ-36	100	9.2	100				Mislatch; D
-20	150	NQ-37	100	4.8	89			N23E, 78NW F; N82W, 42SW J; N32W, 28NE J	D
		NQ-38	100	5.0	87			N32E, 62SE J; N18E, 60SE J; N45W, 10NE J	
	160	NQ-39	100	5.2	100				D; D
		NQ-40	96	5.4	96			N18W, 23NE J; N65W, 61SW J	
	170	NQ-41	98	6.6	71			N40E, 61SE J	Minor rusty
		NQ-42	100	5.6	95			N35E, 16SE J; N88E, 34SE J; N80E, 57SE J	
-40	180	NQ-43	100	4.0	50				D
		NQ-44	93	9.8	93				D
	190	NQ-45	100	6.0	58			N62E, 60NW J; N73W, 35SW J; N82W, 59SW J	
		NQ-46	92	7.8	0				Chips-slight wx effects
	200	NQ-47	100	18.0	52				
		NQ-48	100	6.6	100				
-60	210	NQ-49	100	3.6	100				
		NQ-50	100	4.2	100				Slight wx
	220	NQ-51	100	6.6	65				
		NQ-52	100	8.0	100			N15E, 85SE F	D
	230	NQ-53	100	14.6	100			N80E, 11SE S; N66W, 65SW J	D; Pyrite xtals
		NQ-54	100	5.0	40				Chips-fresh
-80	240	NQ-55	100	4.0	98			N 5E, 86SE F; N60E, 16SE S	Slight wx
		NQ-56	98	5.0	97			N15E, 87SE F; N31E, 70SE S; N30W, 15NE S	Pyrite; Slight wx
	250	NQ-57	100	7.0	45			N24E, 38SE S	Not wx
		NQ-58	100	8.0	33			N20E, 75SE J	Vuggy
	260	NQ-59	100	6.6	43			N13E, Horiz. F	
		NQ-60	100	6.0	33			N75W, 5NE J; N25E, Vert F	Chips-slight surface wx
-100	270	NQ-61	100	6.0	58			N10E, 75SE F; N42W, 50NE S	
	276	NQ-62	100	6.8	100				

BOTTOM OF BORING

SOIL AND ROCK DESCRIPTIONS

Weathering, defects, etc.	Rock	Type, texture, mineralogy, color, hardness, etc.
Fresh and hard. Some minor powdery wx effects on some joints and partings. No polishing.	Gneiss; Gneiss	Predominantly quartzite. Very fine-grained, medium gray. Fairly massive. Local interbeds of feldspathic gneiss. Fused fault plane at 155.3'.
Fresh and hard. Joints and partings show only local minor wx effects. Partings are not polished.	Calcitic veining	Rye formation. Fine-grained dark gray feldspathic quartzite. Fairly evenly, but vaguely foliated.
Fresh and hard. Joints and partings show only local minor wx effects. Not slickensided or polished.	Quartzite; Gneiss; Medium coarse Diabase	Rye formation, as above with local zones of feldspathized quartzite and feldspathic gneiss.
	199.8'	Welded breccia at contact. Fused contact dips 60°
Fresh and hard. Excellent drilling. Partings in diabase break across core. Not jointed. Not wx or slickensided.	Chill	Diabase. Medium-grained dark gray with white phenocryst spotting. Notably calcitic. Diabase, as above.
	218.7'	Fused contact
Fresh and hard. Only minor surface wx effects on joints and partings. Not slickensided.		Rye formation. Fine-grained, medium to dark gray. Feldspathic, evenly foliated throughout.
Fresh and hard. Only minor surface wx effects on joints and partings. Not slickensided.		Rye formation. Fine-grained, dark gray. Evenly foliated feldspathic quartzite. Quartzite. Fine, medium gray.
	249.5'	Fused contact
		Welded breccia. Quartzite fragments, angular with some veining. Annealed rock throughout.
	257.0'	
Fresh and hard. Only minor surface wx effects.	Quartzite; Diabase; Diabase, Fused	Rye formation. Predominantly fine-grained, dark gray feldspathic quartzite.

LEGEND

N - Standard penetration resistance, blows/ft
Rec - Length recovered/length cored, %
RQD - Length of sound core 4 in. and longer/length cored, %
S - Split spoon sample ▽ Groundwater
U - Undisturbed samples
S - Shelby tube N - Denison
F - Fixed piston P - Pitcher
O - Osterberg G - GEI
D - Drilling break k - Coefficient of
wx - Weathered, weathering permeability

NOTES

SEABROOK STATION

PUBLIC SERVICE COMPANY OF NEW HAMPSHIRE

YANKEE ATOMIC ELECTRIC COMPANY

united engineers & constructors inc

Date: May 14, 1974 Project 7286

 LOG OF BORING PF 1

BORING LOCATION: Breakfast Hill Road, Greenland, New Hampshire | INCLINATION: 40° | BEARING: S50E | DATE START/FINISH: July 9, 1974 / July 24, 1974

CASING ID: 3 in. | CORE SIZE: 2-1/8 in. | TOTAL DEPTH: 271.0 ft | DRILLED BY: American Drilling & Boring Co.; K. Allen

GROUND EL (MSL): +62.0 ft | DEPTH TO WATER/DATE: -2.1 ft / July 19, 1974 | LOGGED BY: Soil - K. L. Polk; Rock - J. R. Rand

EL. MSL ft	SAMPLE Depth ft	SAMPLE Type and No.	SAMPLE N or Rec.	RATE OF ADV. min/ft	WATER CONTENT or RQD %	PRESSURE TEST gpm psi	Computed k 10^{-4} cm/sec	STRIKE, DIP (F = Foliation, J = Joint, C = Contact, B = Bedding, S = Slickenside)
+62.0	0							
	65					TOP OF	ROCK	
		NX-1	50	2.7	30			
		NX-2	95	3.0	0			
		NX-3	96	3.0	0			
		NX-4	100	3.0	0			5°
		NX-5	100	5.7	8			22°
		NX-6	100	3.4	32			15°, 18°
		NX-7	98	4.0	34			
		NX-8	100	3.9	63			
		NX-9	100	4.8	52			
		NX-10	100	5.7	40			
		NX-11	98	5.3	9			
		NX-12	97	5.1	30			
	135							

SOIL AND ROCK DESCRIPTIONS

(Weathering, defects, etc.)		(Type, texture, mineralogy, color, hardness, etc.)
Sand seam Moderate wx Slight to moderate wx throughout Minor vuggy	Subject to slight wx throughout and parts readily on foliation. Core characterized by disks 1/2" to 2" in length. Minor tan rusty staining on joints. Not slickensided or polished.	Diabase and gneiss boulders (?) 70' Top of rock (?) Drag folding — Gneiss. Banded light and medium gray. Fine-grained, thinly laminated. Fused diabase inclusion at 79'.
Slight wx Vuggy Moderate wx Slight wx		80.3' Contact broken. Not slickensided. Diabase. Fine, dark. 81.5' Contact broken. Not slickensided. Quartz Quartz
Small pervasive vugs throughout Core contains numerous small vugs Fresh pyrite xtals	Subject to slight wx throughout on foliation. Characterized by pervasive small vugs. Parts on foliation at 1/2" to 1" intervals. Fresh internally, but subject to vug development throughout. (May be wx calcite?) Joints and partings are not slickensided or polished.	Gneiss. Banded to thinly laminated light and medium gray. Fine to very fine grained, feldspathic with local quartzitic or cherty banding. Definitely not Kittery Quartzite. Probably metamorphosed acid volcanics. PF-2A Becomes more feldspathic at 110.5'.
Severe wx Vuggy Pyrite Epidote Minor vuggy Epidote Slight wx Chips	Fresh and hard. Only minor local solution effects. Closely jointed. Joints are not slickensided or polished.	119.7' Broken contact. Not slickensided. Diabase. Fine-medium grained, dark gray. Diabase. Medium-grained, dark gray. Massive. Some local porphyritic texture. Small phenocrysts. PF-2B Becomes finer-grained. Chill zone

LEGEND

N - Standard penetration resistance, blows/ft
Rec - Length recovered/length cored, %
RQD - Length of sound core 4 in. and longer/length cored, %
S - Split spoon sample
U - Undisturbed samples
Groundwater

S - Shelby tube | N - Denison
F - Fixed piston | P - Pitcher
O - Osterberg | G - GEI

D - Drilling break
k - Coefficient of permeability
wx - Weathered, weathering

NOTES

SEABROOK STATION

PUBLIC SERVICE COMPANY OF NEW HAMPSHIRE

YANKEE ATOMIC ELECTRIC COMPANY

united engineers

Date: August 15, 1974 | Project 7286

PAGE 1 of 2 | LOG OF BORING PF-2

BORING LOCATION: Breakfast Hill Road, Greenland, New Hampshire | INCLINATION: 40° | BEARING: S50E | DATE START/FINISH: July 9, 1974 / July 24, 1974

CASING ID: 3 in. | CORE SIZE: 2-1/8 in. | TOTAL DEPTH: 271.0 ft | DRILLED BY: American Drilling & Boring Co.; K. Allen

GROUND EL (MSL): 162.0 ft | DEPTH TO WATER/DATE: -2.1 ft / July 19, 1974 | LOGGED BY: Soil - K. L. Polk; Rock - J. R. Rand

CONTINUED FROM PREVIOUS PAGE

Depth ft	Type and No.	N or Rec.	Rate of Adv. min/ft	Water Content or RQD %	Strike, Dip
138.5–140	NX-13	90	4.8	0	
	NX-14	93	4.4	0	
	NX-15	100	5.0	31	
	NX-16	100	6.4	41	
160	NX-17	62	7.5	28	
	NX-18	98	7.5	51	20°
	NX-19	34	6.0	12	
180	NX-20	100	3.6	24	
	NX-21	99	2.6	13	20°
190	NX-22	100	9.0	0	30°
	NX-23	100	8.5	0	
	NX-24	100	5.0	32	30°
	NX-25	100	2.0	46	20°
	NX-26	100	2.6	32	15°
	NX-27	95	2.1	65	
	NX-28	100	2.0	77	
240	NX-29		2.5		
	NX-30	100	4.9	81	
	NX-31	98	6.9	90	15°
	NX-32	100	4.7	83	60°
270–271.0	BOTTOM OF BORING				

Soil and Rock Descriptions

Drilling remarks: Chips; Chips; Vuggy; Drilling better; Less wx; Chips; Chips; Vuggy; Striated joint; Not polished; Rods dropped; Wx zone 1'; Pyrite; Slight wx; Slight wx; Slight wx; Chlorite; Steep joint; Rough surface; Vuggy; Chips; Minor vuggy; Minor vuggy; Chips; Vuggy; Chlorite; Slight wx.

Weathering, defects:
- Slightly wx throughout. Not slickensided.
- Generally fresh internally.
- Some local minor vug development. Joints and partings are not slickensided.
- Fairly fresh internally. Some minor local vug development. Not slickensided.
- Fairly fresh internally. Some minor vuggy textures, and powdery wx effects on joints and partings. Joints are not polished.
- Quite fresh internally. Some minor local vug textures. Minor surface wx on joints. Joints not polished or slickensided.
- Fresh and hard. Some minor local vug development. Minor surface wx effects on joints. No polishing or slickensides on joints.
- Fresh and hard; drills very well. Only minor powdery wx effects on joints. No evidence of movement.
- Fresh and hard; drills well. Only very minor powdery surface wx effects on some joints and partings. Not slickensided.
- Fresh and hard; drills well. Not slickensided on joints.

Type, texture, mineralogy, color, hardness:
- About 139.5' contact broken
- Quartzitic / Quartzitic: Gneiss, feldspathic, locally quartzitic. Light to medium gray, irregular gneissosite. Locally schistose. Medium grained.
- Quartzose: Becomes darker gray, finer grained irregularly. Foliated schist, feldspathic.
- Drag Folds: Schist, gneissic-feldspathic as above.
- Approximately 177.5' presume wx contact. Not slickensided.
- Diabase. Dark gray, medium grained, gravelly to fine grained. (Chill) at top and bottom. Not calcitic.
- 190.4' Fused contact. Dips parallel to foliation.
- Metaquartzite to metasilt, feldspathic, fine-grained, cherty, medium gray. Locally gneissic. Banded texture of fine-medium light gray feldspathic quartzite with dark gray, very fine grained cherty rock. Drag Folds. Banding is commonly even to slightly wavy. Drag Folds.
- Becomes somewhat schistose, greenish tinge (lime silicates?)
- 221.9 Contact broken. Not slickensided.
- Chill: Diabase, calcitic, medium grained, dark gray, scattered phenocrysts.
- Diabase, calcitic, medium grained, dark gray, massive with occasional carbonate veinlets. Chill.
- 239.9 Fused contact. Dips ± 58°
- Feldspathic: Quartzite, fine, medium gray, somewhat feldspathic.
- 245.5: Gradational fused contact emphibolite(?), fine grained, dark green color. Light green hairline laminate are very irregular in texture. Some calcite veining. Hard rock. Breaks across grain. Feldspathic.
- PF-2C Quartzite: Local zones of fine grained, medium dark gray quartzite.

LEGEND

- N - Standard penetration resistance, blows/ft
- Rec - Length recovered/length cored, %
- RQD - Length of sound core 4 in. and longer/length cored, %
- S - Split spoon sample; ▽ Groundwater
- U - Undisturbed samples
  - S - Shelby tube; N - Denison
  - F - Fixed piston; P - Pitcher
  - O - Osterberg; G - GEI
- D - Drilling break; k - Coefficient of permeability
- wx - Weathered, weathering

NOTES

SEABROOK STATION

PUBLIC SERVICE COMPANY OF NEW HAMPSHIRE

YANKEE ATOMIC ELECTRIC COMPANY

United Engineers & Constructors Inc

Date: August 15, 1974 | Project 7286

PAGE 2 of 2 | LOG OF BORING PF-2

GEOTECHNICAL ENGINEERS INC

BORING LOCATION: Breakfast Hill Road, Greenland, New Hampshire | INCLINATION: Vertical | BEARING: ____ | DATE START/FINISH: July 29, 1974 / July 30, 1974

CASING ID: 3 in. | CORE SIZE: 2-1/8 in. | TOTAL DEPTH: 50.0 ft | DRILLED BY: American Drilling & Boring Co.; K. Allen

GROUND EL (MSL): +61.8 ft | DEPTH TO WATER/DATE: -2.4 ft / July 29, 1974 | LOGGED BY: Soil - K. L. Polk; Rock - J. R. Rand

EL. MSL ft	SAMPLE Depth ft	SAMPLE Type and No.	SAMPLE N or Rec.	RATE OF ADV. min/ft	WATER CONTENT or RQD %	Graphic (0–100)	PRESSURE TEST gpm / psi	Computed k 10^{-4} cm/sec	STRIKE, DIP (F = Foliation, J = Joint, C = Contact, B = Bedding, S = Slickenside)	CORE BREAKS	SOIL AND ROCK DESCRIPTIONS (Weathering, defects, etc.)		(Type, texture, mineralogy, color, hardness, etc.)
+61.8 ▽	0	1)											
	10												
+40	20												
	30												
								TOP	OF ROCK				
+20	40	NX-1	93	4.0	30				67°		Rusty Slight wx Minor rust	Fairly fresh internally. Joints and partings have minor rust and powder wx effects.	Gneiss, medium light gray, medium coarse grained.
												Contact	
		NX-2	100	4.1	0				70°		Slight wx	Broken	Gneiss or quartzite, medium dark green, fine-grained.
	50							BOTTOM	OF BORING			Note: Joints and partings not slickensided or polished.	Not magnetic.

LEGEND

N - Standard penetration resistance, blows/ft
Rec - Length recovered/length cored, %
RQD - Length of sound core 4 in. and longer/length cored, %
S - Split spoon sample ▽ Groundwater
U - Undisturbed samples

S - Shelby tube N - Denison
F - Fixed piston P - Pitcher
O - Osterberg G - GEI

D - Drilling break k - Coefficient of permeability
wx - Weathered, weathering

NOTES

1) Washed through soil 0-40 ft. No samples taken.

SEABROOK STATION

PUBLIC SERVICE COMPANY OF NEW HAMPSHIRE

YANKEE ATOMIC ELECTRIC COMPANY

united engineers

Date: August 11, 1974 Project 7286

PAGE 1 of 1 LOG OF BORING PF-3

GEOTECHNICAL ENGINEERS INC

BORING LOCATION Breakfast Hill Road, Greenland, New Hampshire — INCLINATION 41° — BEARING S50E — DATE START/FINISH July 30, 1974 / August 8, 1974

CASING ID 3 in. — CORE SIZE 2-1/8 in. — TOTAL DEPTH 204.3 ft — DRILLED BY American Drilling and Boring Co.; K. Allen

GROUND EL (MSL) +61.8 ft — DEPTH TO WATER/DATE -2.5 ft / July 30, 1974 — LOGGED BY Soil - K. L. Polk; Rock - J. R. Rand

EL. MSL ft	SAMPLE Depth ft	SAMPLE Type and No.	N or Rec.	RATE OF ADV. min/ft	WATER CONTENT or RQD %	Graphic (0–100)	PRESSURE TEST gpm psi	Computed k 10^{-4} cm/sec	STRIKE, DIP F = Foliation J = Joint C = Contact B = Bedding S = Slickenside	CORE BREAKS
+61.8		1)								
+40	20									
+20	40									
0	60									
							TOP	OF ROCK		
-20	80	NX-1	99	2)	11					
		NX-2	80		10					
		NX-3	69		0					
		NX-4	100		0					
		NX-5	100		0					
	90	NX-6	100		0					
		NX-7	100		26					
		NX-8	98		31					
-40	100									
		NX-9	100		0					
		NX-10	87		0					
		NX-11	100	5.6	26					
	110									
		NX-12	100	4.3	16					
		NX-13	100	3.2	63					
-60	120									
		NX-14	100	3.0	20					
	130	NX 15	100	7.0	0					
		NX 16	100	5.5	0					
		NX 17	100	9.0	0					
		NX-18	100	9.0	0					
-79.8	140									

SOIL AND ROCK DESCRIPTIONS (Weathering, defects, etc.) (Type, texture, mineralogy, color, hardness, etc.)

Weathering	Defects	Type	Description
Slight wx; Chips; Moderate wx; Minor vuggy; Chips; Slightly vuggy	Generally fresh internally. Subject to slight wx on closely-spaced joints. Joints and partings are not slickensided or polished. Core breaks at close intervals.	Diabase; Pegmatite; Diabase; Dark gray quartzite	Gneiss, quartzitic. Somewhat mottled light to medium gray, fine-grained rock. Locally greenish tinge (lime silicates).
Slight wx; Slight wx	Generally fresh. Slight powdery wx effects on joints and partings. No slickensides or polished joints		Gneiss, feldspathic, locally banded. Becomes somewhat schistose at base.
		106' Fused contact. Chill zone	Diabase, dark gray, fine to medium grained. Phenocrysts wx, vuggy; rock is not calcitic. Rock is magnetic.
Slight wx; Chlorite; Slight wx; Slight wx	Fresh, with slight wx effects locally on joints. Some small vugs in diabase where phenocrysts dissolved. Not slickensided or polished.	110.3' Fused contact. Chill zone.	Diabase (Gabbro?). Dark gray, medium - coarse grained, mottled texture. Magnetic, non-calcitic.
Vuggy; Chips; Vuggy; Chips to 135'; Slight wx; Vuggy	Fresh and hard internally. Parts easily on foliation, making for '0' RQD. Partings and joints are not slickensided or polished.	128.7' Fused contact. Chill zone. Thin quartz banding	Quartzitic gneiss, thinly banded, greenish tinge (calc-silicate rock). Fine-grained. Banding normal to hole 50° dip to N57W. Locally somewhat vuggy.

LEGEND

N - Standard penetration resistance, blows/ft
Rec - Length recovered/length cored, %
RQD - Length of sound core 4 in. and longer/length cored, %
S - Split spoon sample — Groundwater
U - Undisturbed samples
S - Shelby tube — N - Denison
F - Fixed piston — P - Pitcher
O - Osterberg — G - GEI
D - Drilling break — k - Coefficient of permeability
wx - Weathered, weathering

NOTES

1) Washed through soil 0-80 ft, no samples taken.
2) No drill times available.

SEABROOK STATION

PUBLIC SERVICE COMPANY OF NEW HAMPSHIRE

YANKEE ATOMIC ELECTRIC COMPANY

united engineers & constructors inc

Date: August 15, 1974 — Project 7286

PAGE 1 of 2 — LOG OF BORING PE-3A

GEOTECHNICAL ENGINEERS INC

BORING LOCATION Breakfast Hill Road, Greenland, New Hampshire — INCLINATION 41° — BEARING S50E — DATE START/FINISH July 30, 1974 / August 8, 1974

CASING ID 3 in. — CORE SIZE 2-1/8 in. — TOTAL DEPTH 204.3 ft — DRILLED BY American Drilling and Boring Co.; K. Allen

GROUND EL (MSL) +61.8 ft — DEPTH TO WATER/DATE -2.5 ft / July 30, 1974 — LOGGED BY Soil - K. L. Polk; Rock - J. R. Rand

CONTINUED FROM PREVIOUS PAGE

EL. MSL ft	SAMPLE Depth ft	Type and No.	N or Rec.	RATE OF ADV. min/ft	WATER CONTENT % or RQD	Graphic (0–100)	PRESSURE TEST gpm psi	Computed k 10^{-4} cm/sec	STRIKE, DIP (F = Foliation, J = Joint, C = Contact, B = Bedding, S = Slickenside)
80		NX-19	100	8.4	0				
		NX-20	100	5.8	20				
	150	NX-21	100	16.0	0				
		NX-22	100	3.0	0				
		NX-23	100	13.0	.0				
100	160								
		NX-24	100	4.8	29				
		NX-25	97	7.8	43				
	170	NX-26	100	5.4	22				
		NX-27	97	6.2	36				
120	180	NX-28	100	3.9	32				
		NX-29	100	6.0	0				
	190	NX-30	100	4.9	49				
140	200	NX-31	100	10.9	62				
	201.3						BOTTOM	OF BORING	

SOIL AND ROCK DESCRIPTIONS

Weathering, defects, etc.		Type	Type, texture, mineralogy, color, hardness, etc.
Slight wx effects			Contact broken
Moderate wx	Fairly fresh internally but subject locally to slight to moderate wx, vug development. Joints and partings not slickensided.	Feldspathic Feldspathic Feldspathic	Amphibolite (?). Dark green, similar to 215.5' in PF-2. Fine-grained, locally foliated or sanded rock. Local feldspathic gneiss. Bands are transitional with amphibolite. Rock is not magnetic.
Moderate wx Pyrite crystals		Feldspathic	
Slight wx effects	Fairly fresh. Subject to slight wx effects. Joints and partings are not slickensided or polished.	Quartzitic	Amphibolite, dark green, fine-grained. Locally fine light green veinlets or seams. Local zones of gray feldspathic or quartzitic gneiss.
Chips Vuggy Crystal growths	Fresh and hard. Local minor wx effects. Joints are planar and are not slickensided or polished.	Dark green quartzitic Dark green	Gneiss, alternating layers of greenish quartzitic gneiss and gray evenly layered quartzitic gneiss. Gradational contacts. Dark green rock, looks like amphibolite. Not magnetic.
Minor vuggy	Shows some internal folding.	Dark green Evenly foliated gneiss Amphibolite	Feldspathic gneiss, pink feldspars. Strongly magnetic.
Minor vuggy	Fresh. Joints and partings are not slickensided or polished.	quartzite 0.1' welded breccia	

Note: Contains magnetite concentrations 200.0' to 201.3'. Strongly magnetic, coarse feldspathic gneiss.

LEGEND

- N - Standard penetration resistance, blows/ft
- Rec - Length recovered/length cored, %
- RQD - Length of sound core 4 in. and longer/length cored, %
- S - Split spoon sample — Groundwater
- U - Undisturbed samples
  - S - Shelby tube — N - Denison
  - F - Fixed piston — P - Pitcher
  - O - Osterberg — G - GEI
- D - Drilling break — k - Coefficient of permeability
- wx - Weathered, weathering

NOTES

SEABROOK STATION

PUBLIC SERVICE COMPANY OF NEW HAMPSHIRE

YANKEE ATOMIC ELECTRIC COMPANY

United Engineers

Date: August 15, 1974 — Project 7286

PAGE 9 of 9 — LOG OF BORING PF-3A

GEOTECHNICAL ENGINEERS INC

ATTACHMENT NO. 3

PETROGRAPHY AND PRELIMINARY INTERPRETATION OF THREE SAMPLES OF DRILL CORE FROM THE PORTSMOUTH FAULT GREENLAND, NEW HAMPSHIRE

Gene Simmons
Dorothy A. Richter

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

CAMBRIDGE, MASSACHUSETTS

for

WESTON GEOPHYSICAL RESEARCH, INC.

WESTBORO, MASSACHUSETTS

PETROGRAPHY AND PRELIMINARY INTERPRETATION
OF THREE SAMPLES OF DRILL CORE
FROM THE PORTSMOUTH FAULT,
GREENLAND, NEW HAMPSHIRE

Weston Geophvsical Research, Inc.
Post Office Box 306
Weston, Massachusetts 02193

Gene Simmons
Dorothy Richter
26 August 1974

SUMMARY

In this report we describe three samples of drill core from the vicinity of the alleged Portsmouth fault near Greenland, New Hampshire. The three samples are metamorphic rocks. The pronounced laminations in sample PF-2A appear to be of primary depositional origin rather than of tectonic origin. The peculiar arcuate structures common to both samples PF-2A and PF-2C are reminiscent of glass shards, which suggests that the rocks are totally recrystallized meta-tuffs or reworked volcanic detritus of different compositions. Sample PF-2B is a partially recrystallized basalt which is probably younger than the other two samples. All three samples lack substantial preferred orientation of their minerals. Evidence for dynamic structural deformation, either recent or ancient, is entirely absent. In summary, we find no petrographic evidence that these three samples are associated with a fault. If a fault does exist in the region from which these samples were obtained, then either its deformation was not so pervasive as to affect these three samples, or else the deformation occurred before metamorphism and all petrographic evidence has been erased by the last metamorphic event.

PETROGRAPHY OF SAMPLE PF-2A 99.5-99.9'

Name: Felsic metatuff

Macroscopic Description

This sample is a finely laminated schist. It is light grey in color and fine grained. Layers of alternating light and dark colors are probably due to segregation of mineral phases. Euhedral crystals of pyrite (~ 1/2 mm) are abundant. The texture is punctuated by light colored augen and irregular 0.5 mm pores. This 5 inch core shows no veins, folds, and only a few large cracks.

Microscopic Description

Texture

The average grain size is less than 0.05 mm. Laminations are the product of the effect of variations in grain size, in the proportions of quartz to mica, and the abundance of opaques. Micas tend to show a preferred orientation of flakes at an angle of about 60° to the laminae. Most of the veinlet-like seams of quartz follow the foliation; although a few seams crosscut the foliation they are not common and their margins have recrystallized to blend with the rest of the rock. The augen are pods of fine grained quartz. Some of the pores have minor amounts of weathering products around the rims.

A few large microcracks that are now completely healed were observed in the thin section. They are marked by

chlorite, quartz, and trains of discrete grains of opaques (probably pyrite). However, there is no other textural evidence of penetrative deformation. The thin laminations and indications of flow structures imply that this sample is a recrystallized silicious tuff or reworked volcanic detritus.

Mineralogy

Quartz is the most abundant mineral in the thin section. It occurs in very fine (0.01-0.1 mm) anhedral aggregates. The individual crystals appear strained and have sutured grain boundaries. Coarser grained quartz occurs in thin seams and pods which are generally parallel to the layering.

Muscovite occurs as small flakes between quartz grains. It commonly shows a preferred orientation at about 60° to the layering. Muscovite rarely occurs in multigranular aggregates.

Chlorite occurs scattered through the matrix, in minor amounts in thin seams both with and without quartz, and in a few of the darker laminae in the sample. It is pale green, fibrous, and exhibits blue and brown interference colors.

Opaque grains occur in thin, discontinuous layers in the sample. Some seem to be dendrites parallel to the layers, and others are small nodules. Many crystals can be seen in hand specimens to occur as well formed

cubes.

Calcite and sphene occur in accessory amounts in some of the layers.

<u>Estimated Modal Composition</u>

quartz	60%
muscovite	15%
chlorite	15%
others	10%
	100%

PETROGRAPHY OF SAMPLE PF-2B 136-136.5'

Name: Metabasalt

Macroscopic Description

This massive dark grey sample has a fine grained, uniform, phaneritic texture. Felty plagioclase crystals (1-2 mm size) set in a dark groundmass are easily recognized with a hand lens. The plagioclase (Hardness 6) is evidently quite altered since it is readily pulverized by probing with a knife point (Hardness 5.5). In the black groundmass biotite flakes are large enough to be seen. Pyrite is present as widely dispersed anhedral grains. There are no veins or major cracks visible in the core. A few open pores are present.

Microscopic Description

Texture

The thin section displays a primary intersertal texture which is partially masked by secondary minerals. Plagioclase laths (0.5 mm) form a mat with ferromagnesian and secondary minerals filling the interstices. Cleavage cracks are not abundant. There is no evidence of healed cracks, no veinlets, and no other signs of structural disruption. Even the larger feldspar crystals are remarkably free of all types of microcracks.

The absence of deformation structures in this rock indicates that no significant non-hydrostatic stress has

existed after the last metamorphic event. Hence, if a fault is present in the vicinity of this rock, stresses, if any, have been small since the time of last metamorphism of the rock.

Mineralogy

Plagioclase originally composed about 40% of the rock. It is now very highly altered to sericitic products. Most of the lath-like crystals have a turbid appearance, and are uniform 0.5 mm. There are a very few larger crystals which are now sericitized.

Clinopyroxene (probably augite) occurs as abundant roundish grains 0.1 - 0.3 mm in diameter. The crystals have poor cleavage and weak zonation. The clinopyroxene is interpreted to be relict in this biotite grade metamorphic assemblage.

Opaque grains are relatively abundant in thin section. They commonly have square outlines, and occur in clumps with pyroxene and biotite.

Biotite occurs as subhedral crystals in the matrix. Basal sections are reddish brown while other orientations are pleochroic from yellowish brown to dark brown. The biotite is probably metamorphic in origin.

Chlorite is a common mineral in the matrix of this rock. It is pale green and fibrous. There are a few ovoid mats of chlorite about 1 mm in diameter which may represent replaced olivine crystals.

Apatite is an accessory mineral in this sample. Euhedral crystals are minute but common.

Actinolite needles are dispersed through the section. Incipient blue green actinolite also seems to be present in some chlorite mats.

Minor amounts of sphene and hematite are also present in the rock.

Estimated Modal Composition

plagioclase (plagioclase + sericite)	40%
clinopyroxene	15%
opaque	10%
biotite	15%
chlorite	15%
apatite and accessories	5%
	100%

PETROGRAPHY OF SAMPLE PF-2C 262.0-262.4'

Name: Fine Grained Amphibolite

Macroscopic Description

This specimen is a very fine grained dark green rock. The individual minerals are too small to identify with a hand lens. The rock is massive and non-foliated. It is cut by a weblike network of calcite and quartz veinlets. Small clots of pyrite are visible.

Microscopic Description

Texture

The sample displays a complex texture in thin section. The average grain size is about 50 microns. There is no preferred orientation or systematic foliation although the constituent minerals are metamorphic. There is a vague layering to the rock marked by arcuate clumps and thin layers of epidote and calcite. Calcite-quartz veins which randomly crosscut the rock are partially recrystallized.

Mineralogy

Amphibole (probably hornblende) and chlorite, in about equal proportions, are in the sample. The amphibole occurs as brownish green stubby, poorly formed crystals finely mixed with chlorite. The crystals are pleochroic from pale green to brownish green. There is no apparent preferred orientation of the grains.

Chlorite is also a major phase in the rock. It is generally

pale bluish green and forms both platy mats and stringy aggregates.

Epidote occurs as minute granular crystals clustered in veins, in arcuate clumps, and scattered through the matrix.

Quartz forms spongy crystals in the matrix barely resolvable at high magnification, and clear 0.1 mm crystals in veins.

Sphene is widely distributed as nodular aggregates and a few 0.1 mm subhedral crystals.

Apatite is present as accessory crystals.

Calcite is common in fine grained veins and in lesser amounts in the matrix.

Opaque grains are usually associated with veins and are not common in the matrix.

Estimated Modal Composition

amphibole	25%
chlorite	25%
epidote	20%
quartz	20%
calcite	5%
opaque, sphene & apatite	5%
	100%

Photo 1. Sample PF-2A 99.5-99.9'. Felsic metatuff. Plane polarized light. Width of field 1.5 mm. The photomicrograph shows the fine grained nature of the sample. Roundish white spots are quartz which are obscured by muscovite and chlorite. The thin discontinuous laminae are composed of sphene, calcite, iron oxides, and chlorite. (The black circles are bubbles in the epoxy.)

Photo 2. Sample PF-2A 99.5-99.9'. Felsic metatuff. Plane polarized light. Width of field 0.5 mm. This photomicrograph is an enlarged view of the matrix and shows one of the few quartz veinlets which crosscuts the laminae. The thin, discontinuous laminae are composed of sphene, calcite, iron oxides, and chlorite. In this view, the dark laminae are almost opaque because the individual grains are only about 1-2μ.

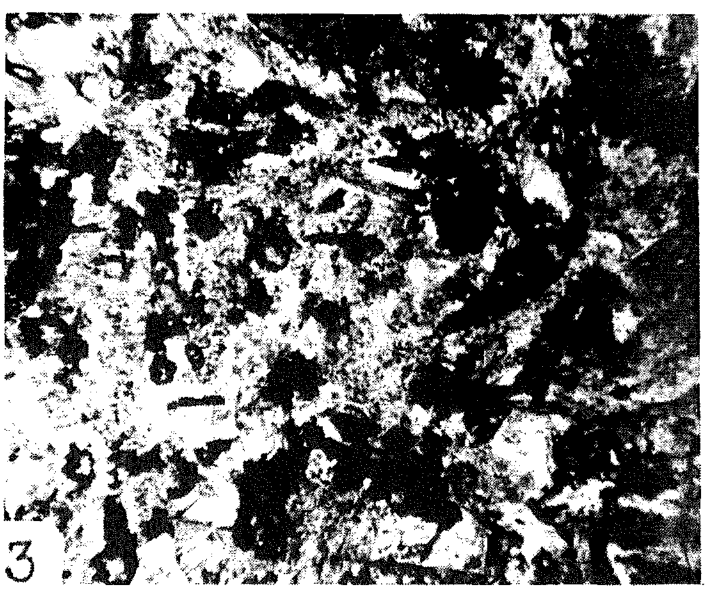


Photo 3. Sample PF-2B 136-136.5'. Metabasalt. Plane polarized light. Width of field 1.5 mm. This photomicrograph shows the typical textures observed in this sample. The light grey dusty looking background is altered plagioclase. Ovoid darker grains are relict clinopyroxene. Note the abundance of black grains; they are both opaque minerals and iron-rich biotite. See photo 4 for the details of the fabric.

Photo 4. Sample PF-2B 136-136.5'. Metabasalt. Plane polarized light. Width of field 0.5 mm. This photomicrograph shows the typical details of the fabric. Note how pervasively altered the plagioclase is. Note also the hexagonal biotite plates; the euhedral form implies that the biotite is metamorphic.

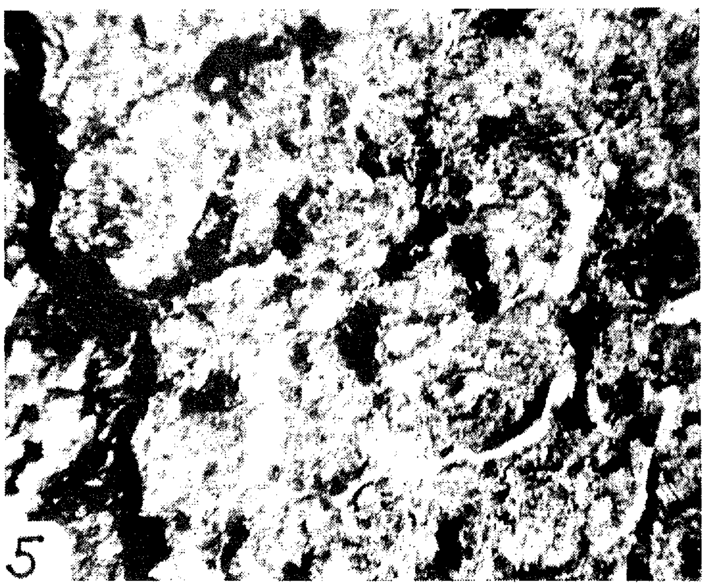


Photo 5. Sample PF-2C 262-262.4'. Fine grained amphibolite. Plane polarized light. Width of field 1.5 mm. This photomicrograph shows a typical view of this sample. The fine light and medium grey crystals are intergrown amphibole and chlorite; the white grains are quartz; and the darkest aggregates are clusters of epidote-calcite-sphene. Note the abundant arcuate quartz and epidote shapes; these are all polygranular.

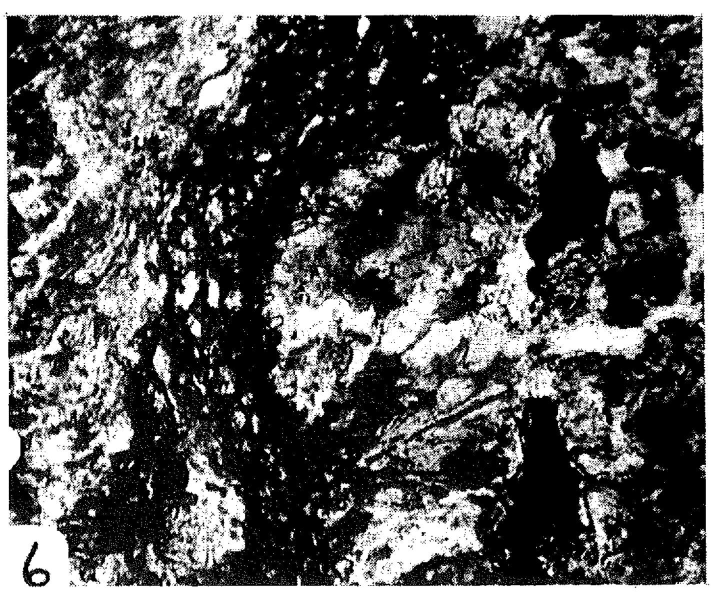


Photo 6. Sample PF-2C 262-262.4'. Fine grained amphibolite. Plane polarized light. Width of field 0.5 mm. This photomicrograph shows the intimate amphibole-chlorite intergrowths, and a granular epidote-sphene seam which arches across the field of view.

ATTACHMENT NO. 4

K-Ar AGE DETERMINATIONS OF SEVEN

SAMPLES RELATED TO THE INFERRED PORTSMOUTH FAULT

GEOCHRON LABORATORIES DIVISION

KRUEGER ENTERPRISES, INC.

CAMBRIDGE, MASSACHUSETTS

for

WESTON GEOPHYSICAL RESEARCH, INC.

WESTBORO, MASSACHUSETTS

KRUEGER ENTERPRISES, INC.
GEOCHRON LABORATORIES DIVISION

24 BLACKSTONE STREET • CAMBRIDGE, MASSACHUSETTS 02139 • (617) 876-3691

20 August 1974

Richard J. Holt
Weston Geophysical Res. Inc.
P.O. Box 550
Westboro, MA 01581

Dear Mr. Holt:

Enclosed are the analytical reports Mr. Rand requested. They are B-1236, B-1237 and B-1238 which were submitted for analyses on 20 January 1969.

Please forward these reports to Mr. Rand and if we can be of any further assistance, please do not hesitate to contact us.

Sincerely,

Derreth McStowe

Derreth McStowe
Office Manager

KRUEGER ENTERPRISES, INC.
GEOCHRON LABORATORIES DIVISION

24 BLACKSTONE STREET • CAMBRIDGE, MA 02139 • (617)-876-3691

POTASSIUM-ARGON AGE DETERMINATION | **REPORT OF ANALYTICAL WORK**

Our Sample No. B-1236 — **Date Received:** 20 January 1969

Your Reference: B2 129.5 — **Date Reported:** 31 January 1969

Submitted by:
Ed Levine
Weston Geophysical Research Inc.
P.O. Box 364
Weston, MA

Sample Description & Locality:

Newburyport quartz diorite, biotite-bearing phase, drill core B2, Seabrook, N.H.

Material Analyzed:
Biotite concentrate, -20/+100 mesh

Ar^{40*}/K^{40} = 0.0186 — AGE = 294 ($\pm$ 9) x 10^6 yrs.

Argon Analyses:

Ar^{40*}, ppm.	Ar^{40*}/ Total Ar^{40}	Ave. Ar^{40*}, ppm.
0.1431	0.950	0.1432
0.1432	0.953	

Potassium Analyses:

% K	Ave. %K	K^{40}, ppm
6.295	6.306	7.693
6.316		

Constants Used:

$\lambda_\beta = 4.72 \times 10^{-10}$/ year

$\lambda_e = 0.585 \times 10^{-10}$/ year

$K^{40}/K = 1.22 \times 10^{-4}$ g./g.

$$AGE = \frac{1}{\lambda_e + \lambda_\beta} \ln\left[\frac{\lambda_\beta + \lambda_e}{\lambda_e} \times \frac{Ar^{40*}}{K^{40}} + 1\right]$$

Note: Ar^{40*} refers to radiogenic Ar^{40}.
M.Y. refers to millions of years.

Geochron Laboratories, Inc.

24 Blackstone Street, Cambridge, Mass. 02139
Telephone Trowbridge 6-9691

REPORT OF ANALYTICAL WORK

POTASSIUM-ARGON AGE DETERMINATION

Our Sample No. B-1237

Your Reference: NH #4 93'

Submitted by:

Mr. M. Levine
Weston Geophysical Research, Inc.
P. O. Box 3[illegible]
Weston, Mass.

Date Received: 20 January 1969

Date Reported: 31 January 1969

Sample Description & Locality:

Biotite-rich metasediment of the Merrimack Group,
Drill Core NH #4, 93', Seabrook, N. H.

Material Analyzed:

Biotite concentrate, -60/+200 mesh. The biotite was too fine grained to be completely free grains, therefore, a concentrate of the most biotite-rich grains was used. Estimated 70-80% biotite.

Ar^{40*}/K^{40} = 0.0159 AGE = 254 (±9) x 10^6 years.

Argon Analyses:

Ar^{40*}, ppm.	Ar^{40*}/ Total Ar^{40}	Ave. Ar^{40*}, ppm.
0.0483	0.892	0.0483
0.0483	0.897	

Potassium Analyses:

% K	Ave. %K	K^{40}, ppm
2.430	2.486	3.033
2.542		

Constants Used:

$\lambda_\beta = 4.72 \times 10^{-10}$/ year

$\lambda_e = 0.585 \times 10^{-10}$/ year

$K^{40}/K = 1.22 \times 10^{-4}$ g./g.

$$AGE = \frac{1}{\lambda_e + \lambda_\beta} \ln\left[\frac{\lambda_\beta + \lambda_e}{\lambda_e} \times \frac{Ar^{40*}}{K^{40}} + 1\right]$$

Note: Ar^{40*} refers to radiogenic Ar^{40}

Geochron Laboratories, Inc.

24 Blackstone Street, Cambridge, Mass. 02139
Telephone TRowbridge 6-3691

REPORT OF ANALYTICAL WORK

POTASSIUM-ARGON AGE DETERMINATION

Our Sample No. B-1238

Your Reference: B9 12.3'

Submitted by:
Mr. Ed. Levine
Weston Geophysical Res., Lab.
P. O. Box 3[illegible]
Weston, Mass.

Date Received: 20 January 1969

Date Reported: 31 January 1969

Sample Description & Locality: Biotite phase of Newburyport Quartz diorite, Drill core B9, Seabrook, N.H. Coarse-grained diorite in igneous contact with dark, fine-grained rock.

Material Analyzed: Biotite concentrate. -40/+100 mesh, from coarse igneous phase. Fresh biotite, 75%, Chlorite, 15%; Amphibole, 10%.

Ar^{40*}/K^{40} = 0.0179

AGE = 284 (±9) x 10^6 years.

Argon Analyses:

Ar^{40*}, ppm.	Ar^{40*}/ Total Ar^{40}	Ave. Ar^{40*}, ppm.
0.0854	0.935	
0.0904*	0.917	0.0857
0.0860		

(*Poor gas sample - not used in age calculation).

Potassium Analyses:

% K	Ave. %K	K^{40}, ppm
3.998		
	3.933	4.798
3.868		

Constants Used:

$\lambda_\beta = 4.72 \times 10^{-10}$/ year

$\lambda_e = 0.585 \times 10^{-10}$/ year

$K^{40}/K = 1.22 \times 10^{-4}$ g./g.

$$AGE = \frac{1}{\lambda_e + \lambda_\beta} \ln\left[\frac{\lambda_\beta + \lambda_e}{\lambda_e} \times \frac{Ar^{40*}}{K^{40}} + 1\right]$$

Note: Ar^{40*} refers to radiogenic Ar^{40}.

KRUEGER ENTERPRISES, INC.
GEOCHRON LABORATORIES DIVISION
24 BLACKSTONE STREET • CAMBRIDGE, MASSACHUSETTS 02139 • (617) 876-3691

19 August 1974

Richard J. Holt
Weston Geophysical Res. Inc.
P.O. Box 550
Westboro, MA 01581

Dear Mr. Holt:

Enclosed are the analytical reports of the K-Ar age determinations on the seven (7) rock samples described in John Rand's letter of 18 July 1974.

These samples were a little difficult to work with because of the type of materials, however we did the best we could with them. The measured K-Ar ages are about what I would expect for these rocks.

I will be away for a few days, but Hal Krueger will be here. I have discussed these results with him, and he is quite familiar with the geology of the area in question and with the work we did for you in this area several years ago. He will be happy to discuss these results with you in greater detail if you care to give him a call.

In the meantime, I am enclosing our invoice for this work. We look forward to serving you again in the near future.

Sincerely,

Richard H. Reesman

Richard H. Reesman
General Manager D.M.

RHR/dm
nelc: 7 reports & invoice #4473
cc: J.R. Rand (letter)

KRUEGER ENTERPRISES, INC.
GEOCHRON LABORATORIES DIVISION

24 BLACKSTONE STREET • CAMBRIDGE, MA. 02139 • (617)-876-3691

POTASSIUM–ARGON AGE DETERMINATION | **REPORT OF ANALYTICAL WORK**

Our Sample No. B-2882

Date Received: 22 July 1974

Your Reference: PF - S1

Date Reported: 16 August 1974

Submitted by: Richard J. Holt
Weston Geophysical Res., Inc.
P.O. Box 550
Westboro, MA 01581

Sample Description & Locality: Kittery quartzite
Towle Road, Hampton-Exeter Expressway
Hampton, New Hampshire

Material Analyzed: Chloritized biotite concentrate, -80/+200 mesh.

Ar^{40*}/K^{40} = .01687

AGE = 268 ± 10 M.Y.

Argon Analyses:

Ar^{40*}, ppm.	Ar^{40*}/ Total Ar^{40}	Ave. Ar^{40*}, ppm.
.06717	.834	.06653
.06588	.862	

Potassium Analyses:

% K	Ave. %K	K^{40}, ppm
3.224	3.233	3.944
3.242		

Constants Used:

$\lambda_\beta = 4.72 \times 10^{-10}$/ year

$\lambda_e = 0.585 \times 10^{-10}$/ year

$K^{40}/K = 1.22 \times 10^{-4}$ g./g.

$$AGE = \frac{1}{\lambda_e + \lambda_\beta} \ln\left[\frac{\lambda_\beta + \lambda_e}{\lambda_e} \times \frac{Ar^{40*}}{K^{40}} + 1\right]$$

Note: Ar^{40*} refers to radiogenic Ar^{40}.
M.Y. refers to millions of years.

KRUEGER ENTERPRISES, INC.
GEOCHRON LABORATORIES DIVISION
24 BLACKSTONE STREET • CAMBRIDGE, MA. 02139 • (617)-876-3691

POTASSIUM-ARGON AGE DETERMINATION — REPORT OF ANALYTICAL WORK

Our Sample No. A-2883

Date Received: 22 July 1974

Your Reference: PF - S2

Date Reported: 16 August 1974

Submitted by: Richard J. Holt
Weston Geophysical Res., Inc.
P.O. Box 550
Westboro, MA 01581

Sample Description & Locality: Rye fm. feldspathic quartzite
Winnicut Road, Route 151
North Hampton, New Hampshire

Material Analyzed: Amphibole concentrate, -80/+200 mesh. Estimated composition: 95% gray-black amphibole, 5% adhering groundmass.

Ar^{40*}/K^{40} = .01960

AGE = 308 ± 14 M.Y.

Argon Analyses:

Ar^{40*}, ppm.	Ar^{40*}/ Total Ar^{40}	Ave. Ar^{40*}, ppm.
.01794	.674	.01773
.01752	.668	

Potassium Analyses:

% K	Ave. %K	K^{40}, ppm
.752	.741	.904
.731		

Constants Used:

$\lambda_\beta = 4.72 \times 10^{-10}$/ year

$\lambda_e = 0.585 \times 10^{-10}$/ year

$K^{40}/K = 1.22 \times 10^{-4}$ g./g.

$$AGE = \frac{1}{\lambda_e + \lambda_\beta} \ln\left[\frac{\lambda_\beta + \lambda_e}{\lambda_e} \times \frac{Ar^{40*}}{K^{40}} + 1\right]$$

Note: Ar^{40*} refers to radiogenic Ar^{40}.
M.Y. refers to millions of years.

KRUEGER ENTERPRISES, INC.
GEOCHRON LABORATORIES DIVISION

24 BLACKSTONE STREET • CAMBRIDGE, MA. 02139 • (617)-876-3691

POTASSIUM–ARGON AGE DETERMINATION — REPORT OF ANALYTICAL WORK

Our Sample No. M-2884 — **Date Received:** 22 July 1974

Your Reference: PF – S3 — **Date Reported:** 16 August 1974

Submitted by: Richard J. Holt
Weston Geophysical Research Inc.
P.O. Box 550
Westboro, MA 01581

Sample Description & Locality: Rye fm. feldspathic gneiss
Route 1 Bypass, Lafayette Road
Portsmouth, New Hampshire

Material Analyzed: Muscovite concentrate, -80/+200 mesh. Estimated composition: 90% msucovite, 5% biotite, 5% quartz and feldspar.

Ar^{40*}/K^{40} = .01864 — AGE = 294 ± 10 M.Y.

Argon Analyses:

Ar^{40*}, ppm.	Ar^{40*}/ Total Ar^{40}	Ave. Ar^{40*}, ppm.
.1522	.852	.1500
.1478	.782	

Potassium Analyses:

% K	Ave. %K	K^{40}, ppm
6.563	6.597	8.048
6.631		

Constants Used:

$\lambda_\beta = 4.72 \times 10^{-10}$/ year

$\lambda_e = 0.585 \times 10^{-10}$/ year

$K^{40}/K = 1.22 \times 10^{-4}$ g./g.

$$AGE = \frac{1}{\lambda_e + \lambda_\beta} \ln\left[\frac{\lambda_\beta + \lambda_e}{\lambda_e} \times \frac{Ar^{40*}}{K^{40}} + 1\right]$$

Note: Ar^{40*} refers to radiogenic Ar^{40}.
M.Y. refers to millions of years.

KRUEGER ENTERPRISES, INC.
GEOCHRON LABORATORIES DIVISION
24 BLACKSTONE STREET • CAMBRIDGE, MA. 02139 • (617)-876-3691

POTASSIUM–ARGON AGE DETERMINATION — REPORT OF ANALYTICAL WORK

Our Sample No. M-2885

Date Received: 22 July 1974

Your Reference: PF - S4

Date Reported: 16 August 1974

Submitted by: Richard J. Holt
Weston Geophysical Res., Inc.
P.O. Box 550
Westboro, MA 01581

Sample Description & Locality: Rye fm. feldspathic quartzite
Route 1 Bypass, Greenleaf Road
Portsmouth, New Hampshire

Material Analyzed: Concentrate of fine-grained mica-quartz aggregates, -80/+200 mesh.

Ar^{40*}/K^{40} = .01645 AGE = 262 ± 11 M.Y.

Argon Analyses:

Ar^{40*}, ppm.	Ar^{40*}/ Total Ar^{40}	Ave. Ar^{40*}, ppm.
.02042	.625	.02046
.02049	.645	

Potassium Analyses:

% K	Ave. %K	K^{40}, ppm
1.015	1.019	1.243
1.023		

Constants Used:

$\lambda_\beta = 4.72 \times 10^{-10}$/ year

$\lambda_e = 0.585 \times 10^{-10}$/ year

$K^{40}/K = 1.22 \times 10^{-4}$ g./g.

$$AGE = \frac{1}{\lambda_e + \lambda_\beta} \ln\left[\frac{\lambda_\beta + \lambda_e}{\lambda_e} \times \frac{Ar^{40*}}{K^{40}} + 1\right]$$

Note: Ar^{40*} refers to radiogenic Ar^{40}.
M.Y. refers to millions of years.

KRUEGER ENTERPRISES, INC.
GEOCHRON LABORATORIES DIVISION
24 BLACKSTONE STREET • CAMBRIDGE, MA. 02139 • (617)-876-3691

POTASSIUM-ARGON AGE DETERMINATION — REPORT OF ANALYTICAL WORK

Our Sample No. A-2886

Date Received: 22 July 1974

Your Reference: SRF - S1

Date Reported: 16 August 1974

Submitted by: Richard J. Holt
Weston Geophysical Res., Inc.
P.O. Box 550
Westboro, MA 01581

Sample Description & Locality: Diorite
Scotland Road, Interstate 95
Newbury, Massachusetts

Material Analyzed: Amphibole concentrate, -80/+200 mesh. Estimated composition: 85% amphibole, 10% biotite, 5% chlorite.

Ar^{40*}/K^{40} = .02764

AGE = 422 ± 17 M.Y.

Argon Analyses:

Ar^{40*}, ppm.	Ar^{40*}/ Total Ar^{40}	Ave. Ar^{40*}, ppm.
.03714	.807	.03892
.04070	.389	

Potassium Analyses:

% K	Ave. %K	K^{40}, ppm
1.154	1.154	1.407
1.154		

Constants Used:

$\lambda_\beta = 4.72 \times 10^{-10}$/ year

$\lambda_e = 0.585 \times 10^{-10}$/ year

$K^{40}/K = 1.22 \times 10^{-4}$ g./g.

$$AGE = \frac{1}{\lambda_e + \lambda_\beta} \ln\left[\frac{\lambda_\beta + \lambda_e}{\lambda_e} \times \frac{Ar^{40*}}{K^{40}} + 1\right]$$

Note: Ar^{40*} refers to radiogenic Ar^{40}.
M.Y. refers to millions of years.

KRUEGER ENTERPRISES, INC.
GEOCHRON LABORATORIES DIVISION

24 BLACKSTONE STREET • CAMBRIDGE, MA. 02139 • (617)-876-3691

POTASSIUM–ARGON AGE DETERMINATION — **REPORT OF ANALYTICAL WORK**

Our Sample No. A-2887 — **Date Received:** 22 July 1974

Your Reference: SRF - S2 — **Date Reported:** 16 August 1974

Submitted by:
Richard J. Holt
Weston Geophysical Res., Inc.
P.O. Box 550
Westboro, MA 01581

Sample Description & Locality: Schist
Highfield Road, Abandoned RR grade
Newbury, Massachusetts

Material Analyzed: Chlorite - amphibole concentrate, -80/+200 mesh. Estimated composition: 40% amphibole, 60% chlorite.

Ar^{40*}/K^{40} = .01932 — AGE = 304 ± 15 M.Y.

Argon Analyses:

Ar^{40*}, ppm.	Ar^{40*}/ Total Ar^{40}	Ave. Ar^{40*}, ppm.
.01162	.381	.01149
.01136	.548	

Potassium Analyses:

% K	Ave. %K	K^{40}, ppm
.492	.487	.594
.483		

Constants Used:

$\lambda_\beta = 4.72 \times 10^{-10}$/ year

$\lambda_e = 0.585 \times 10^{-10}$/ year

$K^{40}/K = 1.22 \times 10^{-4}$ g./g.

$$AGE = \frac{1}{\lambda_e + \lambda_\beta} \ln\left[\frac{\lambda_\beta + \lambda_e}{\lambda_e} \times \frac{Ar^{40*}}{K^{40}} + 1\right]$$

Note: Ar^{40*} refers to radiogenic Ar^{40}.
M.Y. refers to millions of years.

KRUEGER ENTERPRISES, INC.
GEOCHRON LABORATORIES DIVISION

24 BLACKSTONE STREET • CAMBRIDGE, MA. 02139 • (617)-876-3691

POTASSIUM–ARGON AGE DETERMINATION | **REPORT OF ANALYTICAL WORK**

Our Sample No. B-2888

Date Received: 22 July 1974

Your Reference: SRF - S3

Date Reported: 16 August 1974

Submitted by: Richard J. Holt
Weston Geophysical Res., Inc.
P.O. Box 550
Westboro, MA 01581

Sample Description & Locality: Newburyport granodiorite
Parker Street, Little River area
Newburyport, Massachusetts

Material Analyzed: Chlorite-biotite concentrate, -80/+200 mesh. Estimated composition: 70% chloritized biotite, 30% quartz.

Ar^{40*}/K^{40} = .01860

AGE = 294 ± 20 M.Y.

Argon Analyses:

Ar^{40*}, ppm.	Ar^{40*}/ Total Ar^{40}	Ave. Ar^{40*}, ppm.
.005765	.325	.005548
.005330	.370	

Potassium Analyses:

% K	Ave. %K	K^{40}, ppm
.245	.244	.298
.244		

Constants Used:

$\lambda_\beta = 4.72 \times 10^{-10}$/ year

$\lambda_e = 0.585 \times 10^{-10}$/ year

$K^{40}/K = 1.22 \times 10^{-4}$ g./g.

$$AGE = \frac{1}{\lambda_e + \lambda_\beta} \ln\left[\frac{\lambda_\beta + \lambda_e}{\lambda_e} \times \frac{Ar^{40*}}{K^{40}} + 1\right]$$

Note: Ar^{40*} refers to radiogenic Ar^{40}.
M.Y. refers to millions of years.