UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

GEOLOGIC DESCRIPTION OF SELECTED STRONG-MOTION ACCELEROGRAPH SITES

PART I

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OPEN FILE REPORT
No. 78-1005

This report is preliminary and has not been edited or reviewed for conformity with Geological Survey standards and nomenclature.

Prepared on behalf of the National Science Foundation

PREFACE

One of the major tasks of the U. S. Geological Survey as regards seismic engineering is the collection and dissemination of strong-motion accelerograph records. When analyzing these records certain information describing the instrument site is important: local geology; instrument housing (buildings, dams, bridges, instrument shelters, etc.); local topography; and proximity of an accelerograph to man-made structures that might influence the record. This report describes local geologic conditions of selected sites and it is intended to be the first in a series of continuing reports covering strong-motion accelerograph sites in the western hemisphere.

I would like to acknowledge the help of R. B. Matthiesen, R. P. Maley, C. Rojahn and A. G. Brady for their review of the manuscript.

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GEOLOGIC SITE DESCRIPTIONS OF STRONG-MOTION ACCELEROGRAPH SITES

For each site, the first page has a location map and a short verbal description of the local geology with references. The map is not designed to direct a visitor to the site, but to give a general location of the site. Other information includes station name, number and coordinates (a complete list of station names and numbers is given in Open File Report No. 77-374). The second page gives a graphic representation of the geology, seismic velocity and density. Lack of data indicates the need for further research; consequently updated and corrected versions may be part of future summaries. For the sake of brevity, only local site conditions are described.

The geologic code found on the bottom of the page has been developed for a computerized summary of strong-motion station characteristics. The symbols used in this code are defined in table 1. The first three characters are a class code that broadly describes the surface materials and is intended for those interested only in general geology.

Rock types are given by two letter abbreviations. A third letter describes the condition of the rock. For example, SH indicates shale, and SHF would indicate a fractured, sheared or jointed shale. Lack of a descriptive term generally implies that its condition is not known. The abbreviations are not standardized to a particular nomenclature.

A number following the rock type indicates the depth of the rock, i.e. AL914; CS1067 means there is alluvium to 914 meters and a combination of sedimentary rocks from 914 to 1067 meters.

The letter K following a number is a 1000 times multiplier, e.g. 4K equals 4000 meters. In some cases a number is not given. This indicates that the actual depth is not known but evidence suggests that a particular rock is present. The semicolon, not including the one

immediately after the three letter general description, may be translated literally as "overlying". A plus sign between two (or more) rock names means both (or all) are present.

Example:

ALV; AL84; SSU; SH+SC

ALV; = alluvium at surface. (General surface geology.)

AL84 = alluvium to 84m.

;SSU = overlying unconsolidated sandstone to unknown depth.

;SH+SC = overlying shale and schist to an unknown depth.

If under the depth column there is no depth given the actual depth of the rock type(s) shown is not known. Depths indicated do not necessarily follow a linear scale.

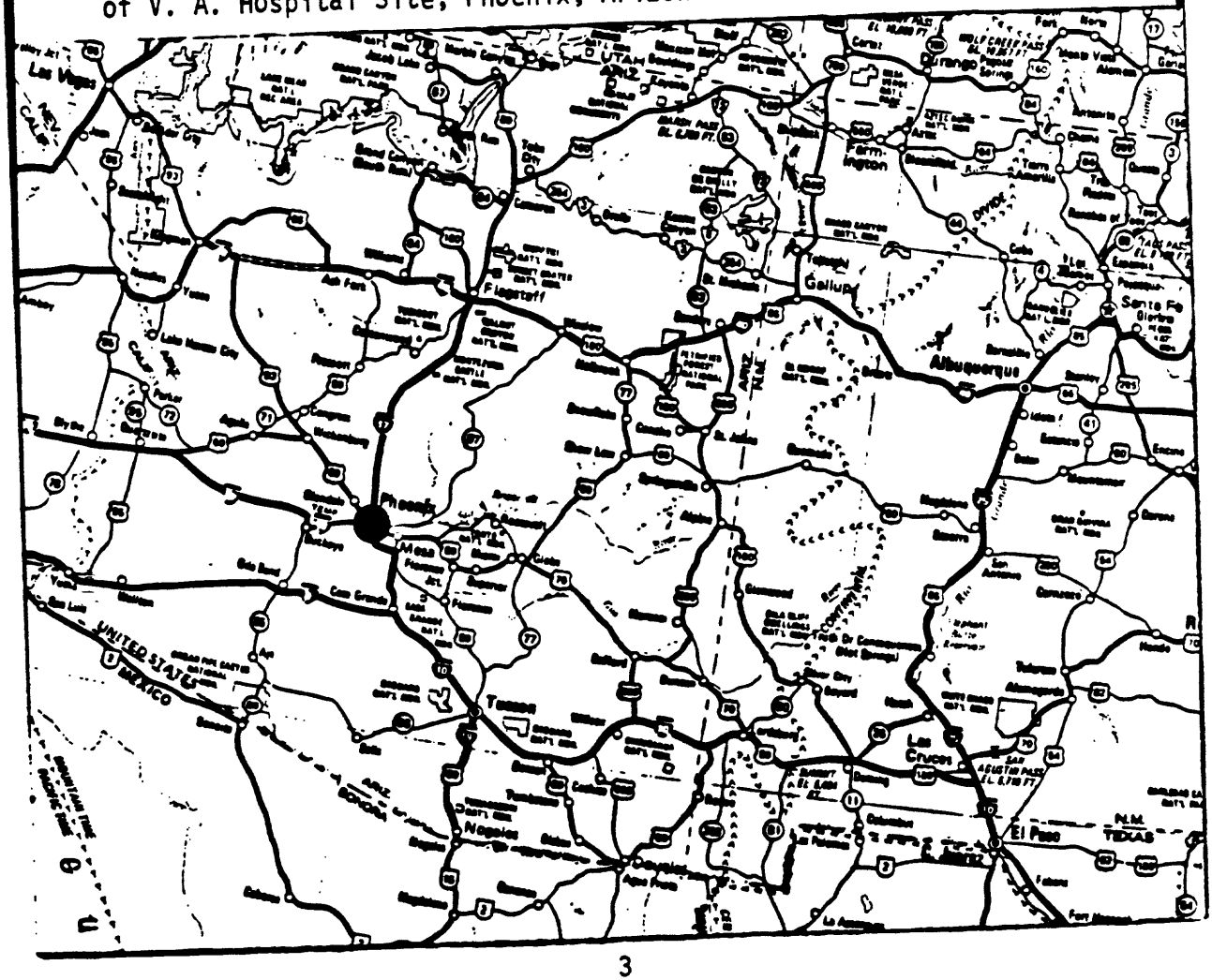
Station No. 2305 Station Phoenix VA Hospital

Coordinates 33.49 N, 112.07 W

The alluvium below the hospital site is predominantly clay with interbeds of silt, sand, and fine gravel. Well logs near the hospital indicate coarse-grained alluvial fans may interfinger with the sediments. These alluvial deposits are underlain by a granitic basement. A well north of the hospital site indicates the material overlying the granite as cemented gravel.

REFERENCE

John A. Blume & Associates., 1973; Geologic and Seismic Exposure Evaluation of V. A. Hospital Site, Phoenix, Arizona JABE-VA-009



GEOLOGIC SUMMARY OF STRONG-MOTION SITES

Date 4/78 Station No. 2305 Station PHOENIX VA HOSPITAL

Depth meters	P-Wave m/sec	S-Wave m/sec	Density g/cm³	Log	Site Geology
				18m	ALLUVIUM
122					GRANITE

ALV;AL122;GR

Station No. 1002 Station APEEL Array: Station 2 Redwood City

Coordinates 37.53 N, 122.26 W

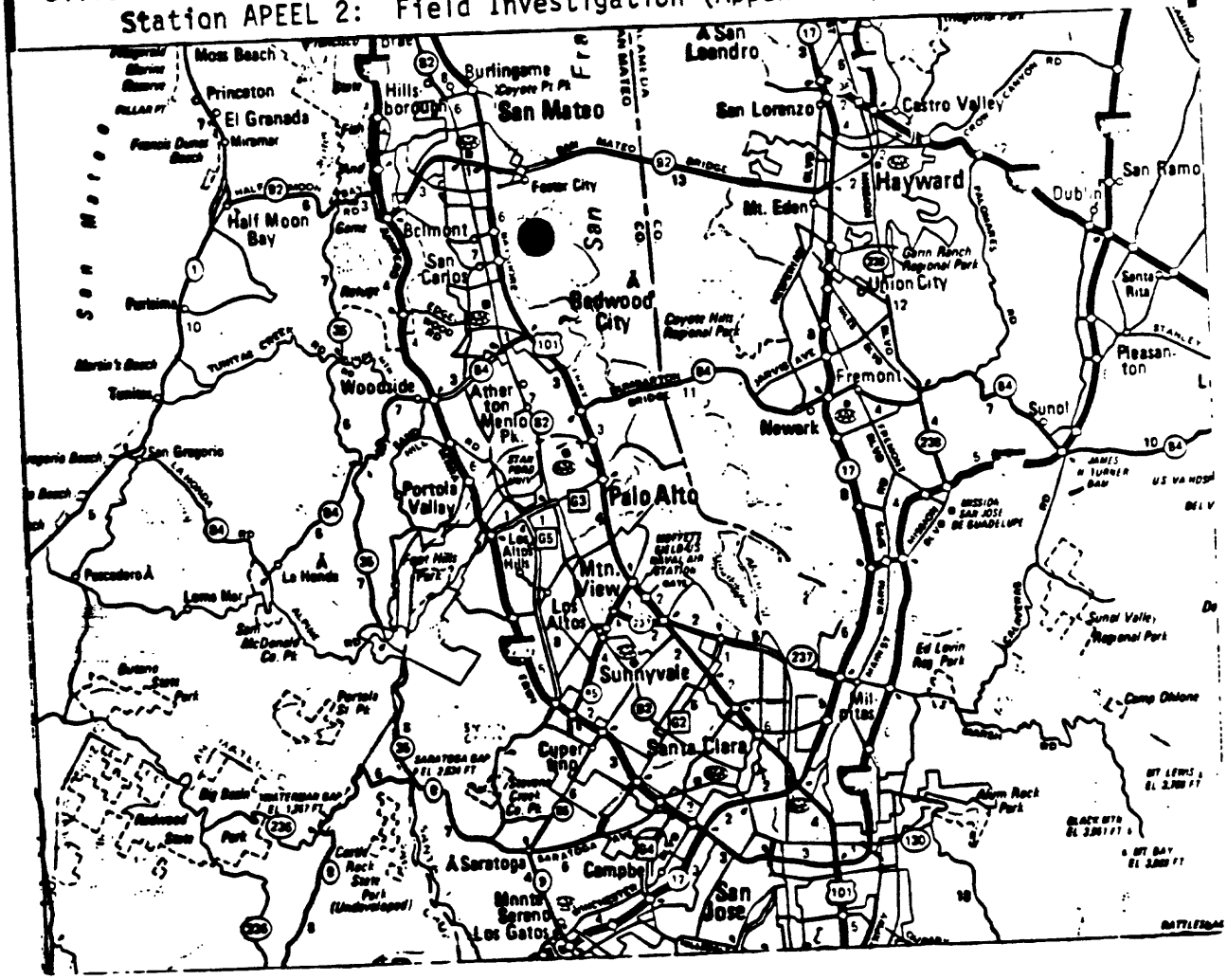
The instrument sits on appx. 7.5m of recent bay mud; 86m of stiff clay, silty sand, clayey sand and gravels over a basement of Franciscan graywacke sandstone.

The site is appx. 8km east of the San Andreas Fault zone and 32km west of the Hayward Fault zone.

REFERENCES

Morrill, B. J., 1972; The APEEL Array: A Site Study; NOAA Technical Report ERL 245-ESL 22

Silverstein, B. L., 1974; A Shallow Refraction Survey at Strong-Motion Station APEEL 2: Field Investigation (Appendix A)



GEOLOGIC SUMMARY OF STRONG-MOTION SITES

Date 3/78 Station No. 1002 Station APEEL Array:Sta. 2 Redwood City

Depth meters	P-Wave m/sec	S-Wave m/sec	Density g/cm³	Log	Site Geology
	408	158(est)	1.92		Alluvium
20					
40			1.92		
60					
			2.08		
80					
					Franciscan graywacke sandstone
100					

ALV;AL95;SS

Station No. 1023 Station Ferndale, Old City Hall, Brown Street

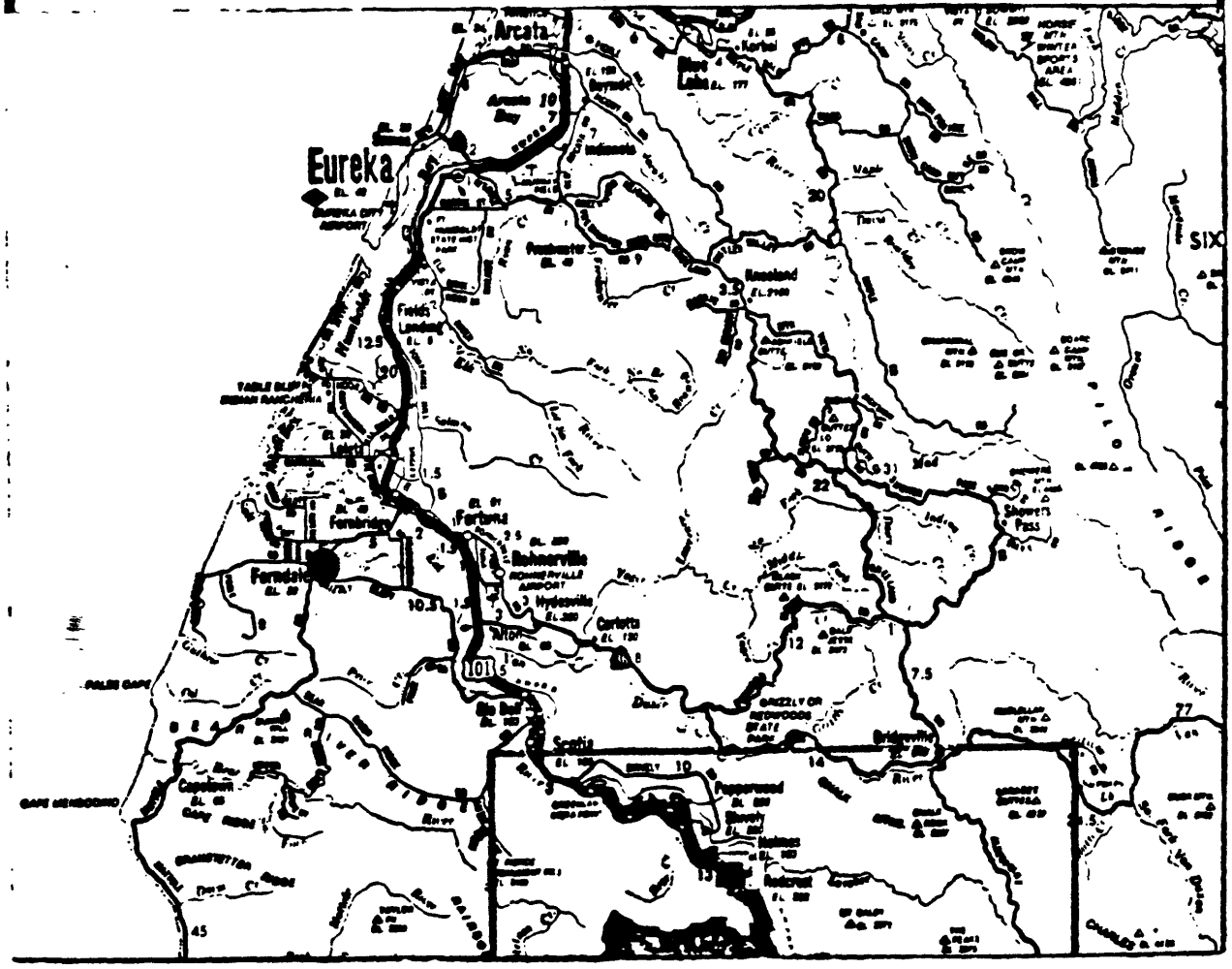
Coordinates 40.58 N, 124.26 W

From 0-7.6m the soils are a silty clay with a Standard Penetration Resistance (SPR)*of less than 10. From 7.6m to 12.8m the clay has an SPR of about 20. 20-46.6m are alternating layers of dense fine sandy silt and stiff to hard clays. 46.6-52.4m are dense fine to course sands and gravels which are underlain to a depth of 80m (bottom of the core); by dense silts and sands. The SPR for the latter material is greater than 100.

REFERENCE

Shannon and Wilson Inc. and Agbabian Assc., 1976; Geotechnical and Strong-Motion Earthquake Data from U. S. Accelerograph Stations; Nureg-0029, Vol.1

* See soil mechanics book for description of SPR tests.



GEOLOGIC SUMMARY OF STRONG-MOTION SITES

Date 3/78 Station No. 1023 Station FERNDALE, Old City Hall- Brown St.

Depth meters	P-Wave m/sec	S-Wave m/sec	Density g/cm³	Log	Site Geology
					Hookton Fm.- gravels, sands and clays
60					Sedimentary rocks including: 1)Carlotta-Scotia Bluffs Fm. conglomerate,sandstone, and claystone. 2)Rio Dell Fm.-Muds, silts, and sandstones. 3)Eel River Fm.-Mudstones and sandstones.
1800					Yager Fm.-Shale, mudstone and siltstone interbedded with graywacke sandstone and conglomerate; plus Franciscan Rocks.

ALV;AL60;CS1800;CS+FR

Station No. 638 **Station** Los Angeles VA Hospital, Brentwood Bldg. 259

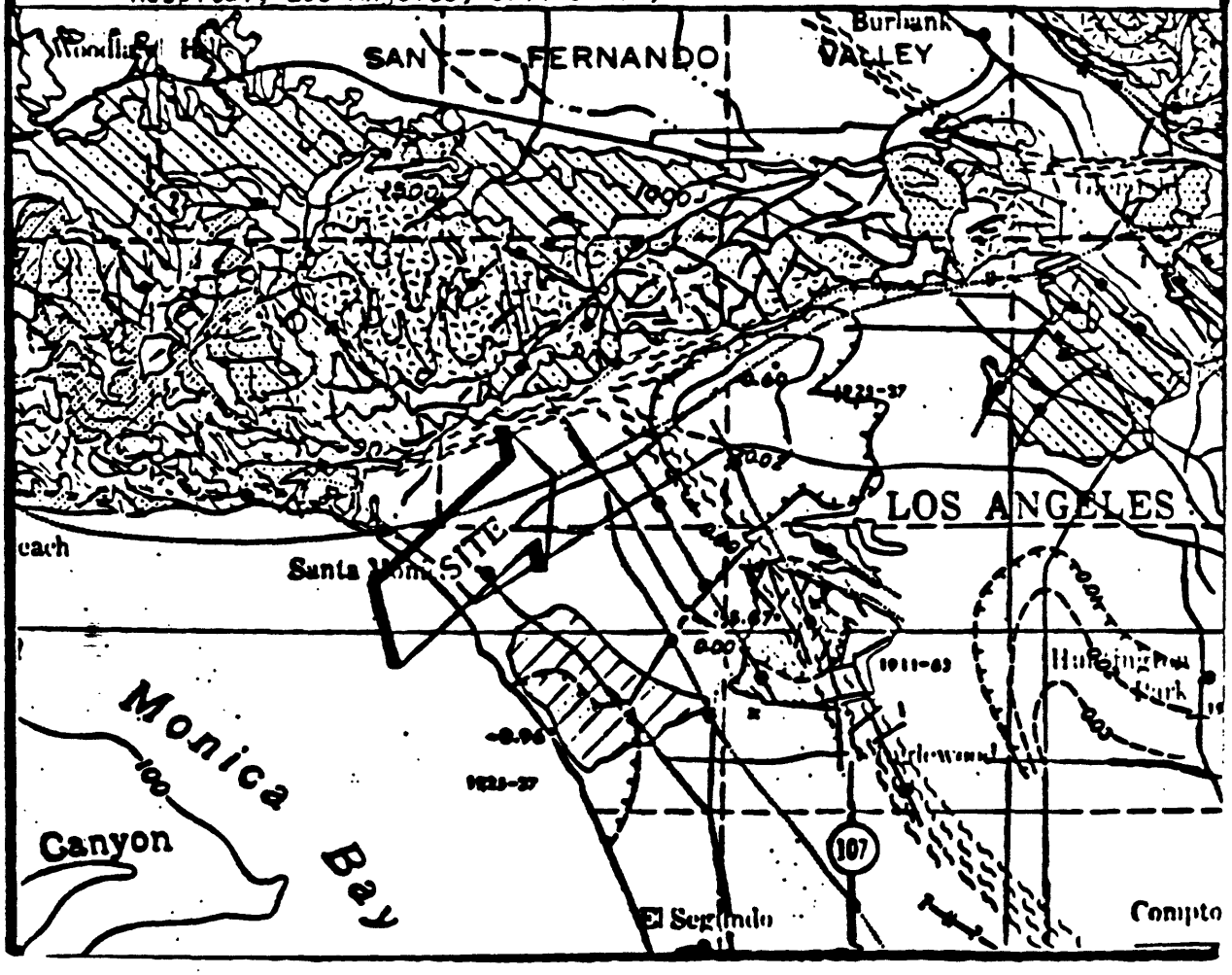
Coordinates 34.06 **N,** 118.46 **W**

The site is on the border of the Los Angeles Basin and within the Transverse Range Province. The nearest large faults are the Santa Monica fault postulated to be at or immediately south of the site, the Newport-Inglewood fault about 1.2km east of the site and the San Andreas fault which comes within 12km of the site.

The water table was not encountered within a 9m core.

REFERENCE

Dames and Moore., 1974; Earthquake Hazards, Veterans Administration Hospital, Los Angeles, California; 2712-006-10



GEOLOGIC SUMMARY OF STRONG-MOTION SITES

Date 3/78 Station No. 638 Station LA VA Hospital, Brentwood Bldg. 259

Depth meters	P-Wave m/sec	S-Wave m/sec	Density g/cm³	Log	Site Geology
					Borings to 10 meters indicate variable strata of clays, clayey sands, silty sands and well graded sands with gravel and fines.
50					
					Terrace sands
100					
1000					Siltstone and shale
					Shale and sandstone
					Slate basement
1500					

ALV;AL914;CS1067;SL

Station No. 1140 Station Oroville Dam

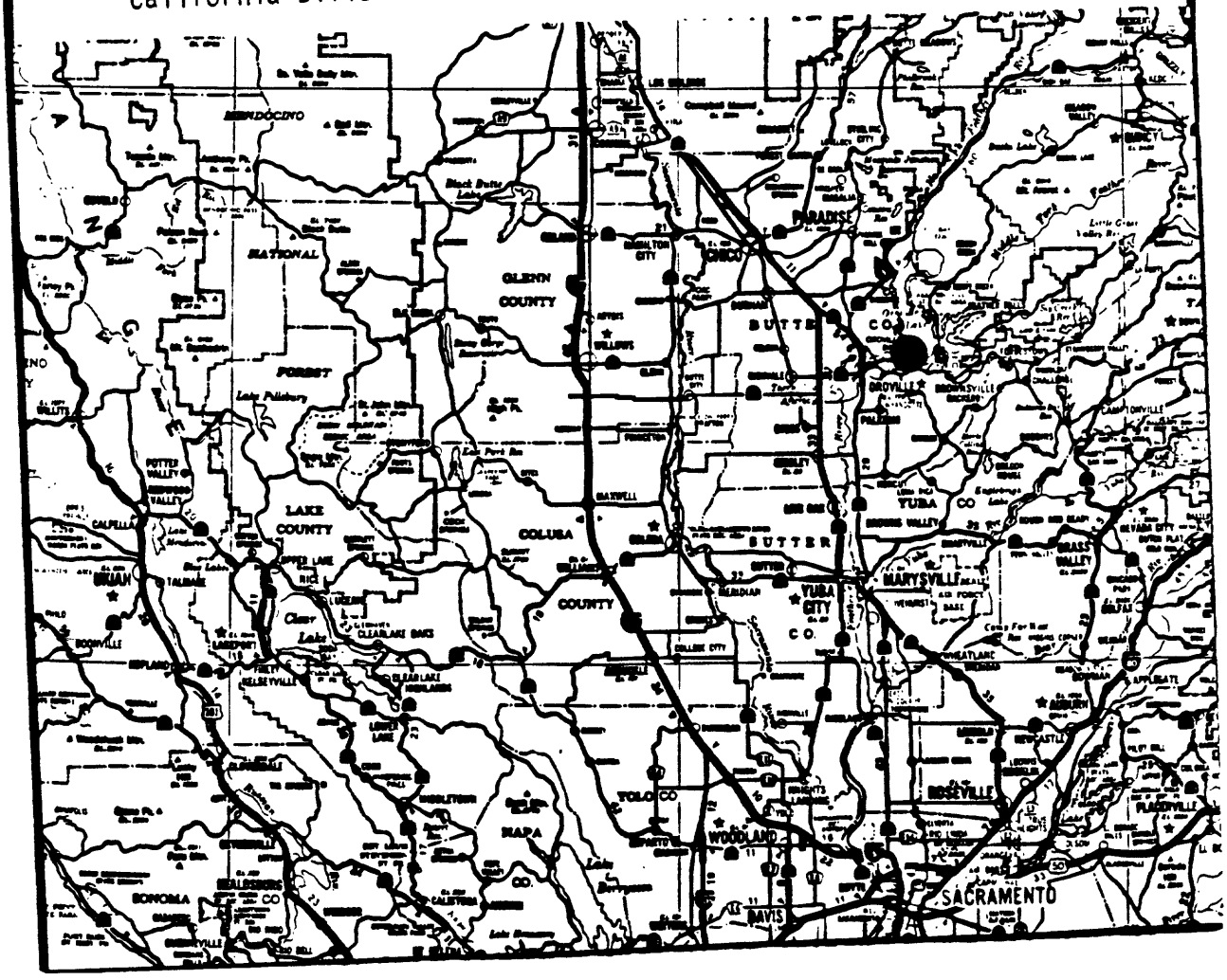
Coordinates 39.55 N, 121.48 W

The accelerographs are located on the dam, which is located on rocks of the upper Paleozoic 'Bedrock Series'; dense and usually massive metavolcanic schists. The maximum thickness for these rocks in this area is 1500m.

REFERENCES

Creely, R. S., 1965; Geology of the Oroville Quadrangle; California Division of Mines and Geology, Bulletin 184

Oroville Dam, Key Unit of the State Water Project., 1965, Oroville Project Tour, Pacific Southwest Inter-Agency Committee; California Division of Water Resources



GEOLOGIC SUMMARY OF STRONG-MOTION SITES

Date 3/78 Station No. 1140 Station OROVILLE DAM

Depth meters	P-Wave m/sec	S-Wave m/sec	Density g/cm³	Log	Site Geology
					Metavolcanic schist (Amphibole-albite-epidote chlorite schist)

MET;SC

Station No. 1051 Station Oroville - Seismograph Station

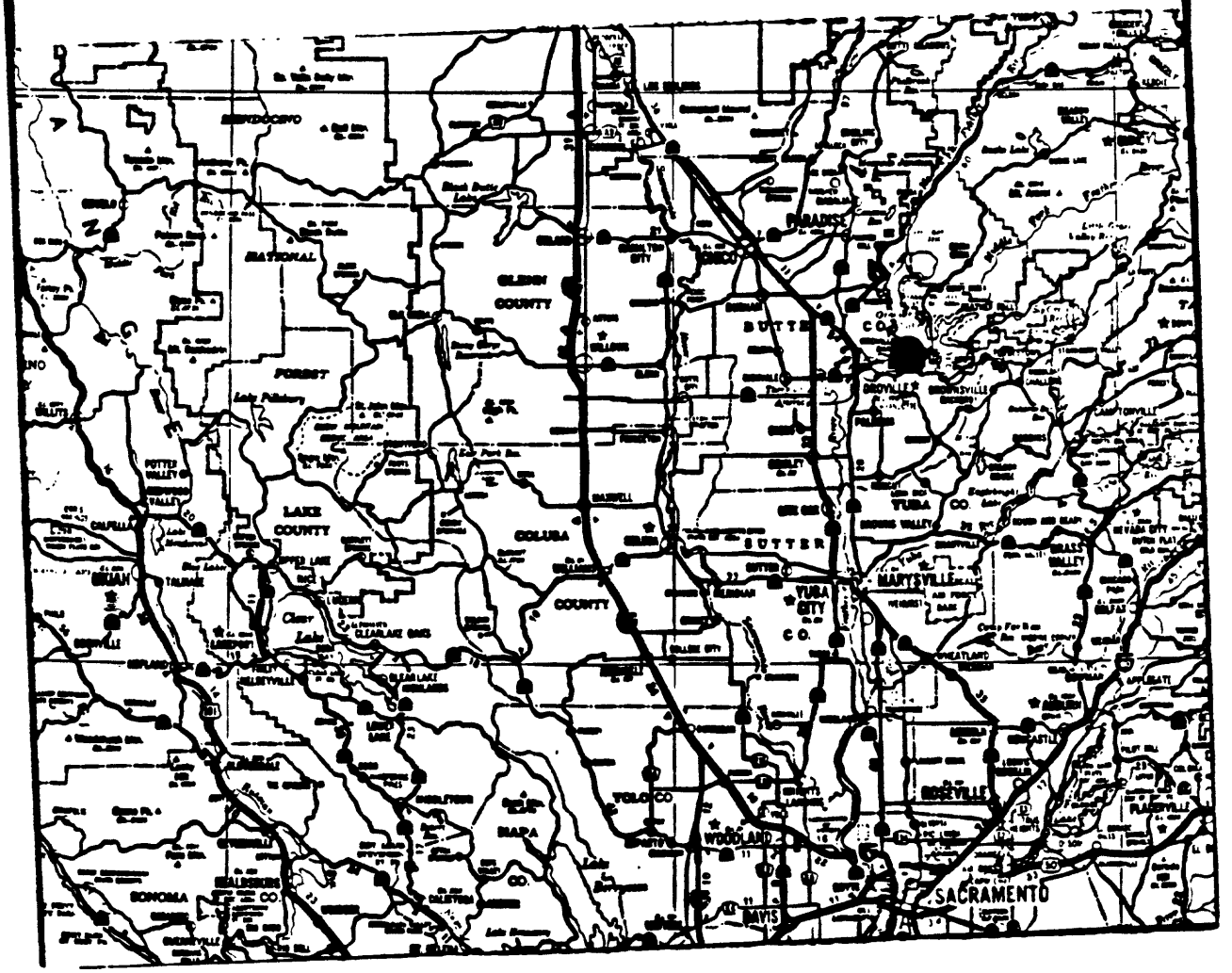
Coordinates 39.55 N, 121.50 W

The accelerograph is located on rocks of the upper Paleozoic 'Bedrock Series'; dense and usually massive metavolcanic schists. The maximum thickness for these rocks in this area is 1500m.

REFERENCES

Creely, R. S., 1965; Geology of the Oroville Quadrangle; California Division of Mines and Geology, Bulletin 184

Oroville Dam, Key Unit of the State Water Project., 1965, Oroville Project Tour, Pacific Southwest Inter-Agency Committee; California Division of Water Resources



GEOLOGIC SUMMARY OF STRONG-MOTION SITES

Date 3/78 Station No. 1051 Station OROVILLE SEISMOGRAPH STATION

Depth meters	P-Wave m/sec	S-Wave m/sec	Density g/cm³	Log	Site Geology
					Metavolcanic Schist-(Amphibole-albite-epidote-chlorite schist)

Station No. 1117 Station San Francisco, Golden Gate Park

Coordinates 37.77 N, 122.48 W

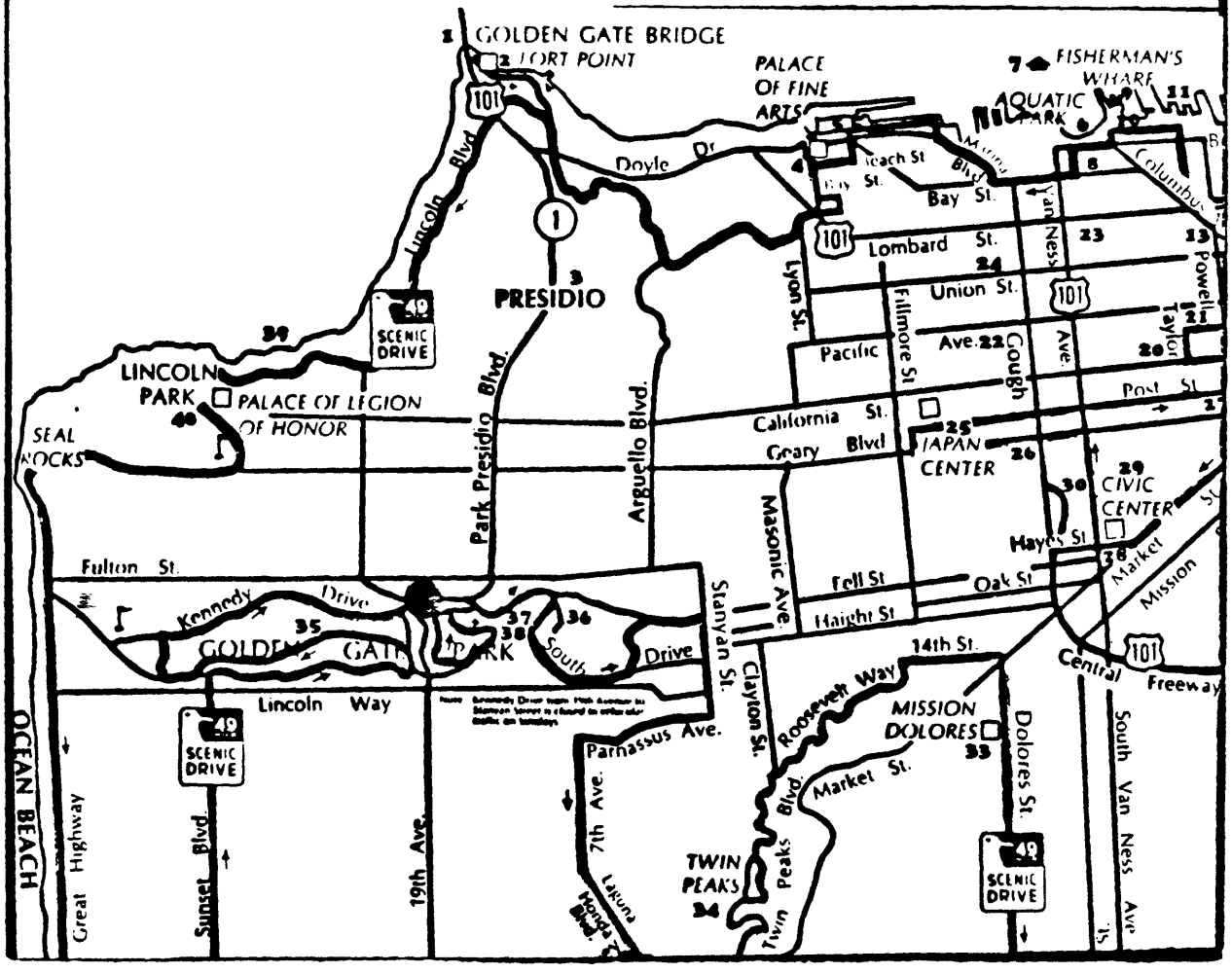
The accelerograph rests on alternating beds of Franciscan chert and shale at Prayerbook Cross. Hard brittle chert beds are one to five inches thick while the crumbly shales are in layers 1/8 to 1/2 inch thick. Locally the chert is massive. The instrument is approximately 8 km east of the San Andreas Fault zone and 30 km west of the Hayward Fault zone.

References

Gibbs, James F., Fumal, Thomas E., Borcherdt, Roger D., and Roth, Edward F. 1977; In-Situ Measurements of Seismic Velocities in the San Francisco Bay Region...Part 3, Open File Report 77-850

Schlocker, S., Bonilla, M.G., and Radbruch, D.H., 1958; Geology of the San Francisco North Quadrangle, California, USGS Misc. Geologic Investigations; Map I-272

Silverstein, Barry L., 1974; Field Investigation



GEOLOGIC SUMMARY OF STRONG-MOTION SITES

Date 4/78 Station No. 1117 Station SAN FRANCISCO - Golden Gate Park

Depth meters	P-Wave m/sec	S-Wave m/sec	Density g/cm³	Log	Site Geology
	390	200			Franciscan chert
5	583	316			
	634	364			
10					
	760	508			
	803	527			Franciscan shale
	899	582			
	1020	611	2.31		
20	1070	636			
					Franciscan chert
30				11/75	Bottom of core Franciscan chert and shale

SED;CH+SH

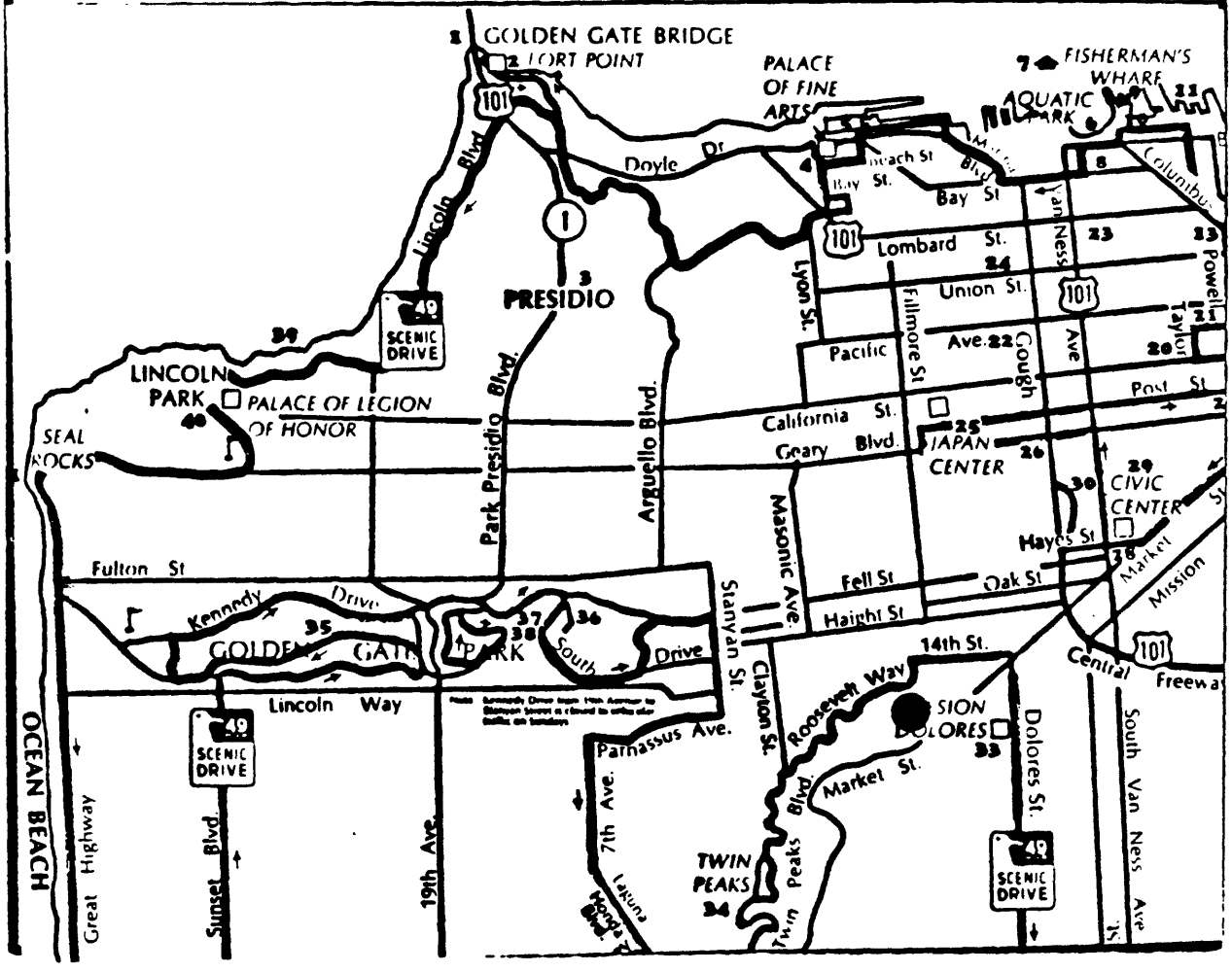
Station No. 1228 Station San Francisco-Randall Jr. Museum, 100 Museum Way

Coordinates 37.76 N, 122.44 W

The site geology consists of folded and faulted Franciscan chert, graywacke sandstone, and greenstone. The instrument sits almost directly on a trace of an inactive fault that traverses through the museum. Settling cracks have been observed throughout the building with one set passing within a few meters of the instrument, although relationship to the fault has not been established.

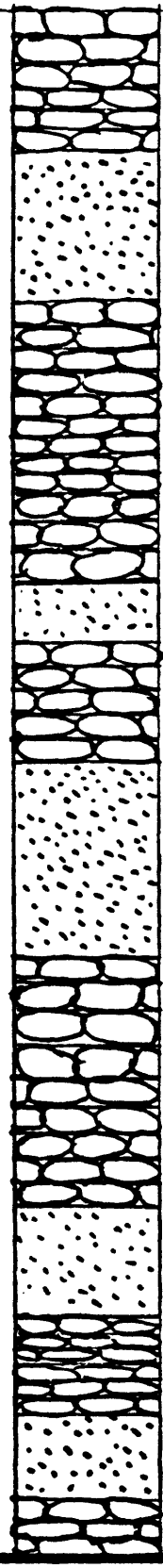
Reference

Silverstein, Barry L., 1974; Field Observations



GEOLOGIC SUMMARY OF STRONG-MOTION SITES

Date 4/78 Station No. 1228 Station San Francisco-Randall Museum

Depth meters	P-Wave m/sec	S-Wave m/sec	Density g/cm³	Log	Site Geology
					Franciscan chert, sandstone, and greenstone.

FR;CH+SS+GS

Station No. 1225 Station San Francisco, VA Hospital

Coordinates 37.63 N, 121.75 W

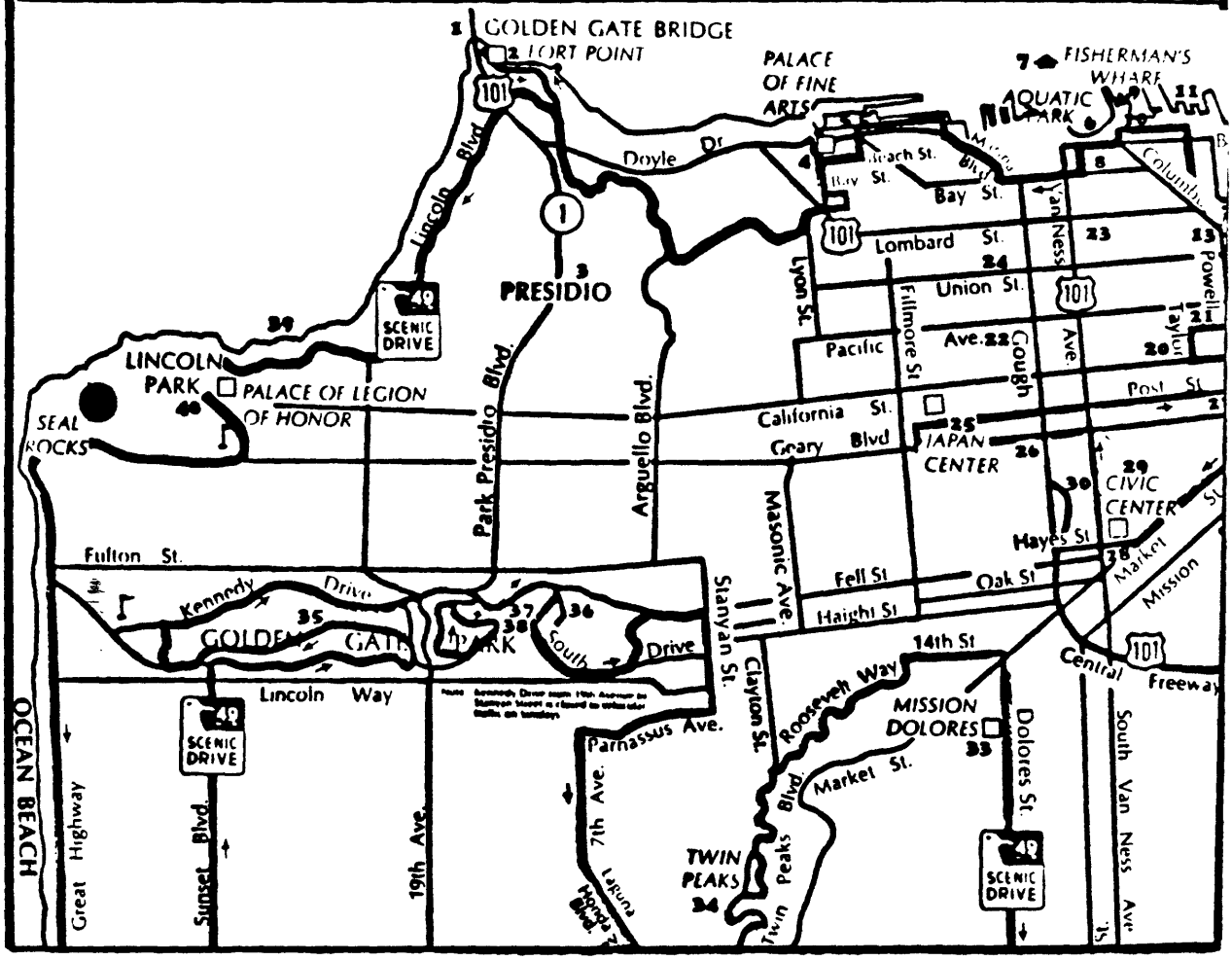
Most of the VA Hospital rests on sheared Franciscan rocks including metamorphics, sandstone, shale, greenstone, and serpentine. This zone of sheared rock is believed to be part of the City College Fault zone.

The hospital site is located at the edge of an active landslide; visual inspection of the landslide in Nov. 1977 showed it to be well covered by bushes, shrubs and trees, suggesting no very recent movement.

References

Dames and Moore., 1972; Site Evaluation Studies, San Francisco, California Veterans Administration; ,2712-006-10

Silverstein, Barry L., 1977; Field Observations



GEOLOGIC SUMMARY OF STRONG-MOTION SITES

Date 4/78 Station No. 1225 Station San Francisco- VA Hospital

Depth meters	P-Wave m/sec	S-Wave m/sec	Density g/cm³	Log	Site Geology
					Sheared complex series of metamorphic crystalline rocks; sandstone, shale, greenstone and associated serpentine. Franciscan rocks.

MIX;FRF

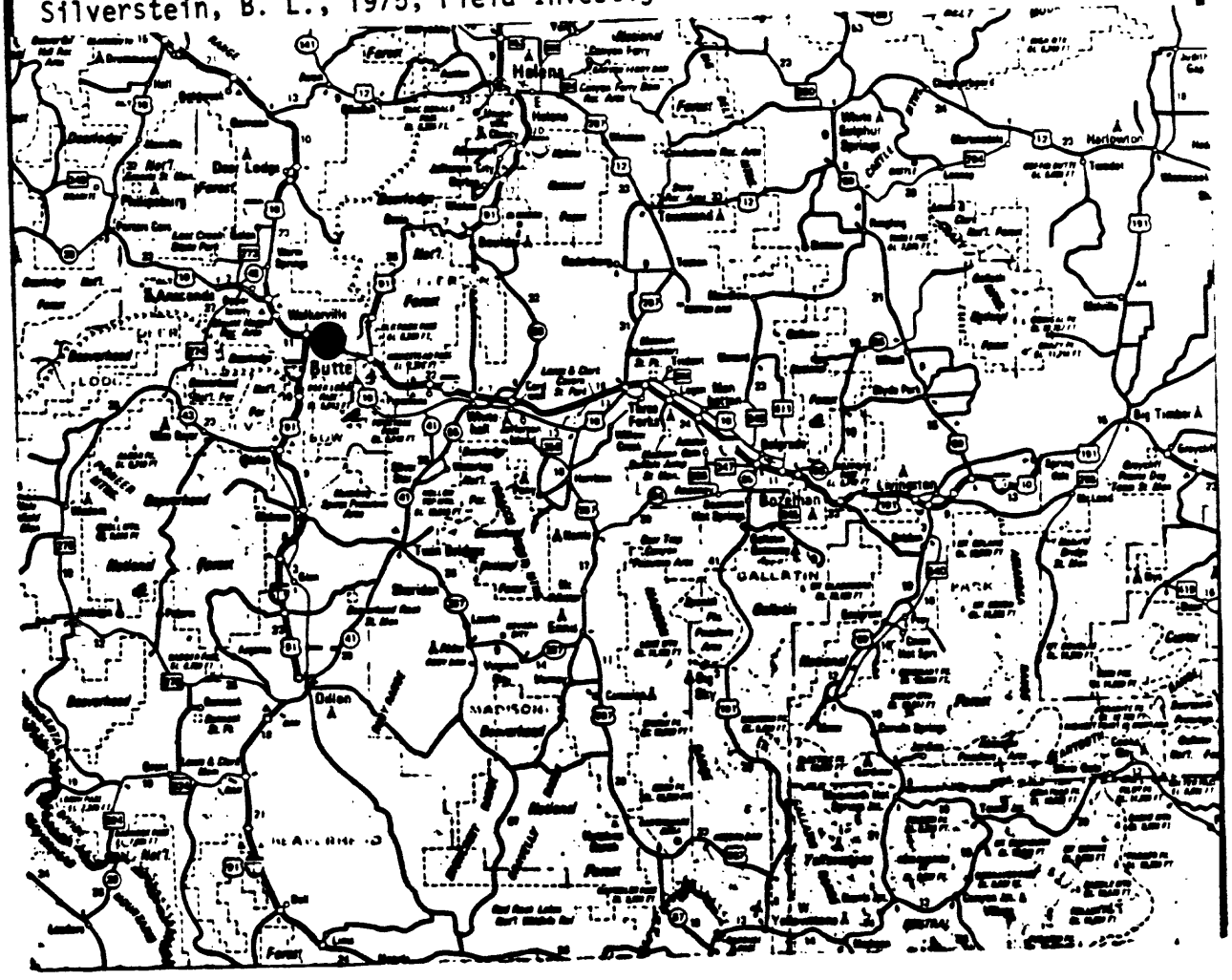
Station No. 2201 Station Butte, Metallurgy Bldg. Montana Tech.

Coordinates 46.02 N, 112.57 W

The site rests directly on a quartz latite dike which has been intruded into the Butte Quartz Monzonite Batholith. The bedrock is highly jointed with no known pattern. The instrument is located about 20m from the edge of a large steep hill. This hill overlooks the Butte Valley which has a maximum alluvial depth of about 180-240m. The depth decreases as one approaches the hill.

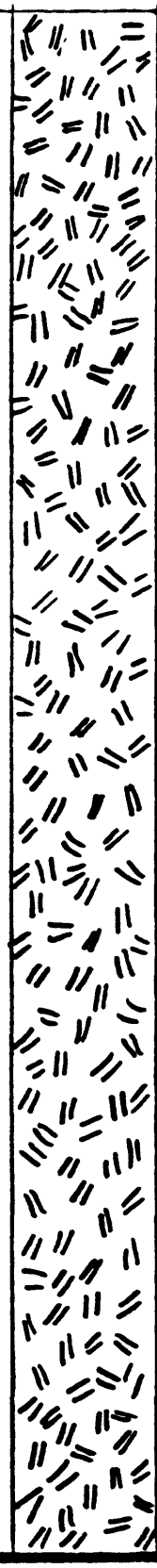
REFERENCE

Dresser, H. W., 1975; Montana Tech. Oral Communication
Silverstein, B. L., 1975; Field Investigation



GEOLOGIC SUMMARY OF STRONG-MOTION SITES

Date 4/78 Station No. 2201 Station Butte, Metallurgy Bldg., MSM

Depth meters	P-Wave m/sec	S-Wave m/sec	Density g/cm³	Log	Site Geology
					Quartz latite dike intruded into a quartz monzonite batholith

Station No. 2008 Station Reno VA Hospital

Coordinates 39.52 N, 119.80 W

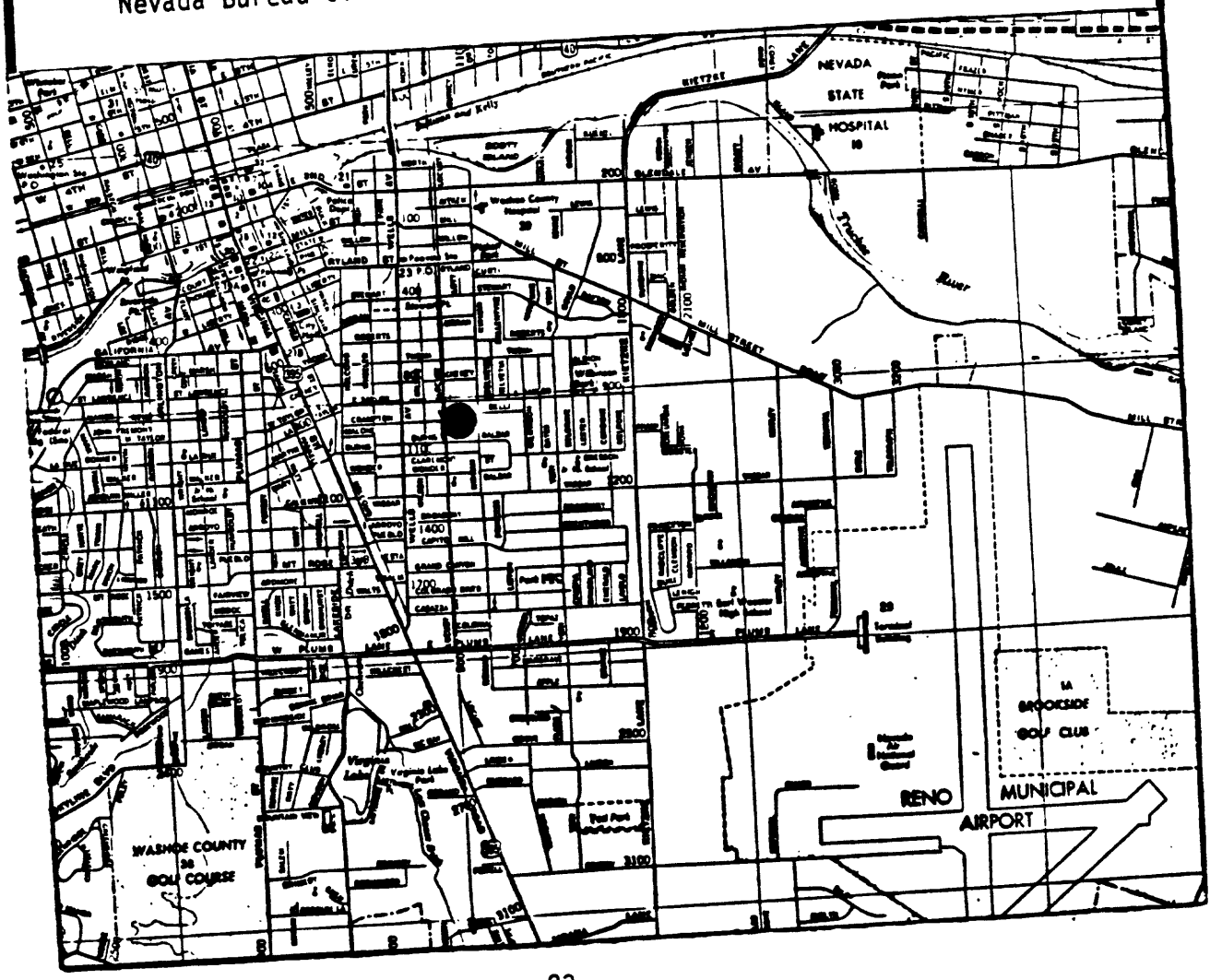
The VA Hospital rests on the Donner Lake Outwash, containing mostly sand size to boulder size sediments. Bingler, (1974) described the material as potentially unstable, unconsolidated outwash deposits. Subject to pronounced slumping and ground disturbance along steep cuts or embankments. Locally may manifest amplified ground motion during a major seismic event.

References

John A. Blume & Assc., 1973; Geologic and Seismic Exposure Evaluation of Hospital Site, Reno, Nevada; V1001P-253

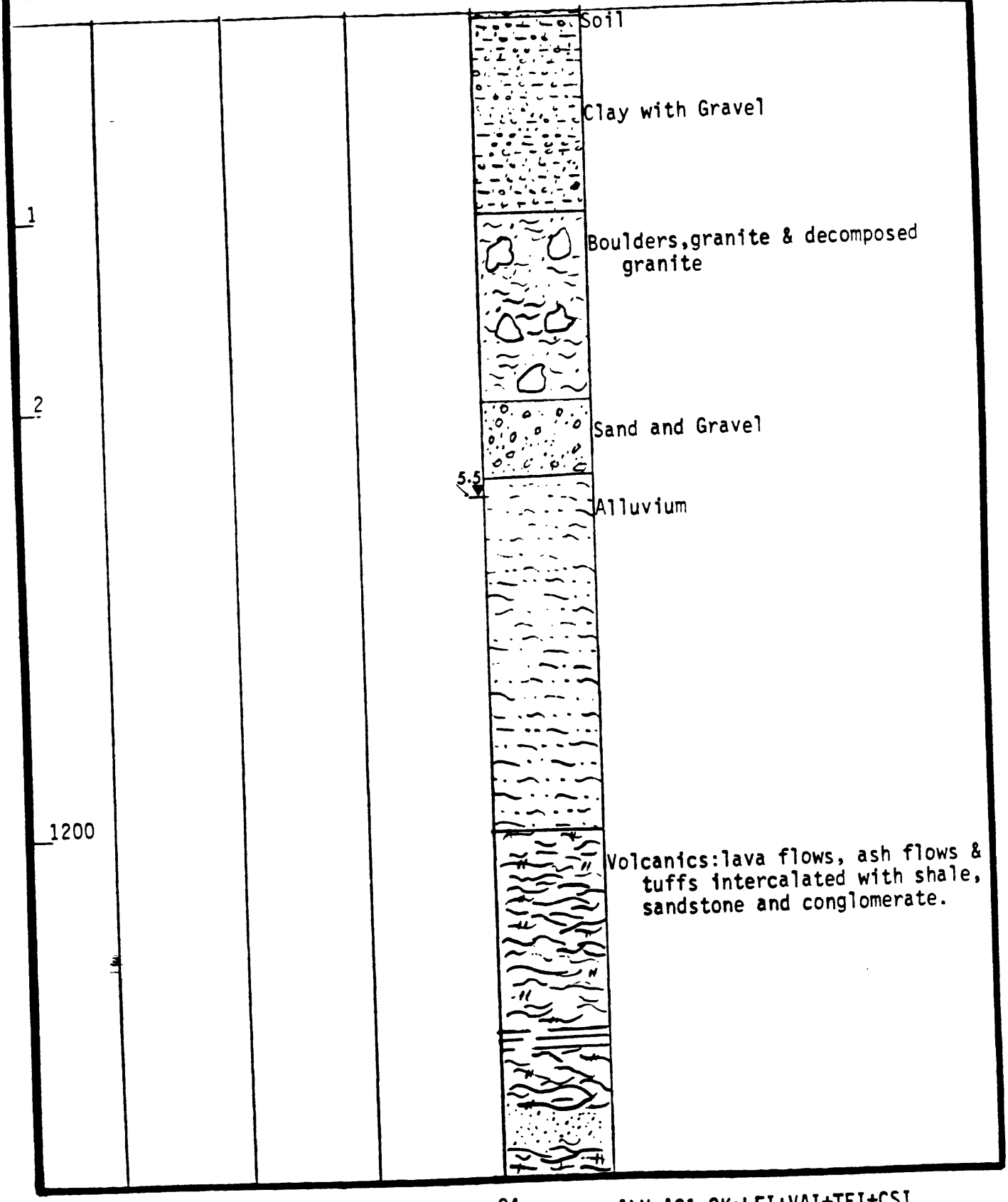
Bingler, E. C., 1974; Earthquake Hazards Map, Reno Folio; Nevade Bureau of Mines and Geology

Bonham, H. F. Jr., and Bingler, E. C., 1973; Geologic Map, Reno Folio; Nevada Bureau of Mines and Geology



GEOLOGIC SUMMARY OF STRONG-MOTION SITES

Date 3/78 Station No. 2008 Station RENO VA HOSPITAL



ALV;AC1.2K;LFI+VAI+TFI+CSI

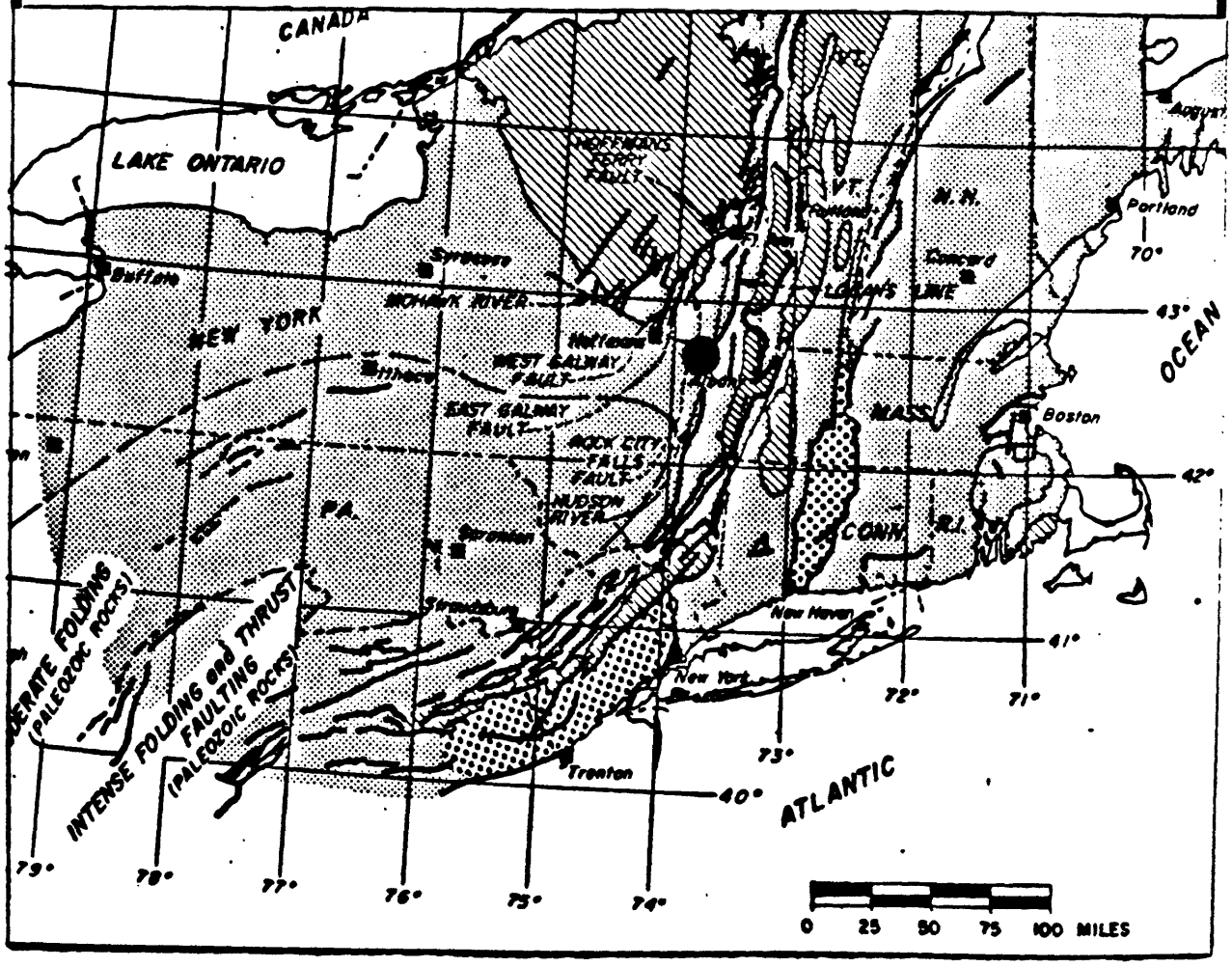
Station No. 2605 Station Albany VA Hospital

Coordinates 42.65 N, 73.77 W

A site profile has a few meters of topsoil and fill overlying 24 to 27m of occasionally varved glacial silts and clays. This is underlain by hard shale which test borings indicate to be fractured. No geologic hazards such as faulting, landslides, possible liquefaction, etc. were found at the site.

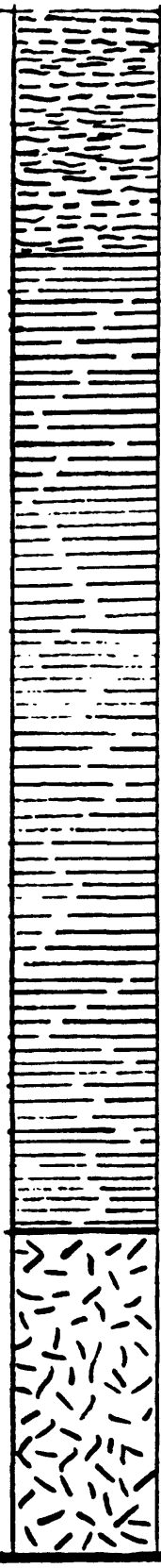
REFERENCE

E. D'appolonia Consulting Engineers Inc., 1973; Final Report Site Evaluation Survey, Veterans Administration Hospital, Albany, N. Y., Project 428-1



GEOLOGIC SUMMARY OF STRONG-MOTION SITES

Date 3/78 Station No. 2605 Station ALBANY, VA Hospital

Depth meters	P-Wave m/sec	S-Wave m/sec	Density g/cm³	Log	Site Geology
					Glacial Deposits: mainly silts and clays.
27					Snake Hill Fm.- Highly fractured shale.
2500					Undifferentiated Precambrian rocks.

ALV;AL27;SHF2.4K;X

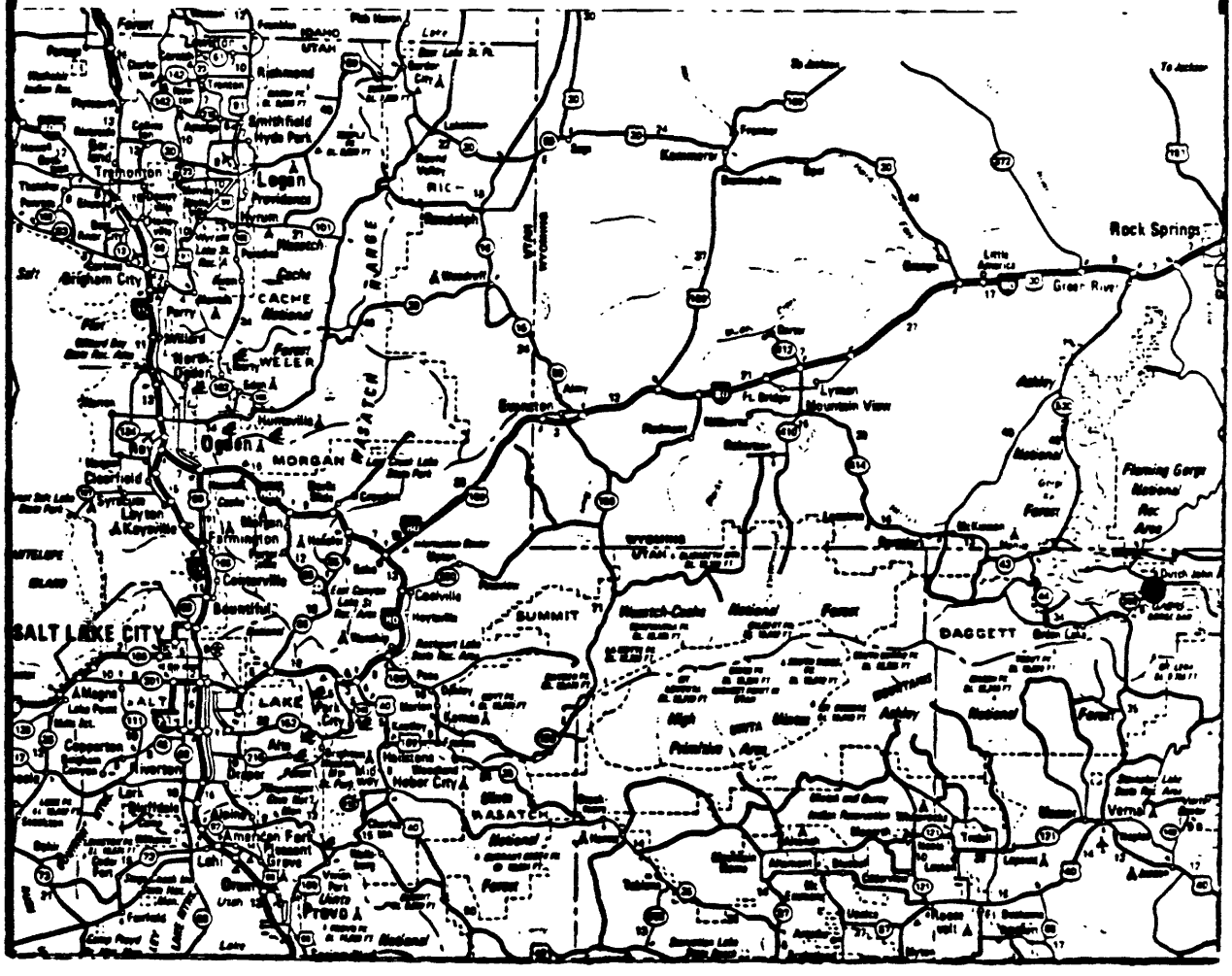
Station No. 2206 Station Flaming Gorge - Seismograph Station

Coordinates 40.927 N, 109.386 W

Except for a small patch of Tertiary conglomerate on the high right abutment, bedrock at this site is the Uinta formation of pre-Cambrian age. It consists of quartzite, quartzite conglomerate, quartzose sandstone, and a few thin beds of shale. All rocks are hard and well cemented. Bedding ranges from 2 to 20 feet apart, with many thick massive ledges 20 to 40 feet high.

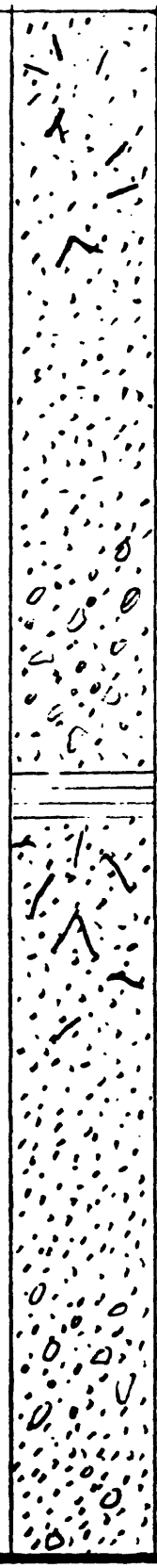
REFERENCE

United States Dept. of the Interior., 1957; Preliminary Geological Report of Flaming Gorge Dam and Reservoir Site, G-109



GEOLOGIC SUMMARY OF STRONG-MOTION SITES

Date 3/78 Station No. 2206 Station FLAMING GORGE- Seismograph Station

Depth 3 meters	P-Wave m/sec	S-Wave m/sec	Density g/cm^3	Log	Site Geology
					Uinta Fm.-quartzite, quartzite conglomerate, quartzose sandstone, and minor beds of shale

SED;QZ+CG+SS+SH

Station No. 2203 Station Logan, Admin. Bldg., USU

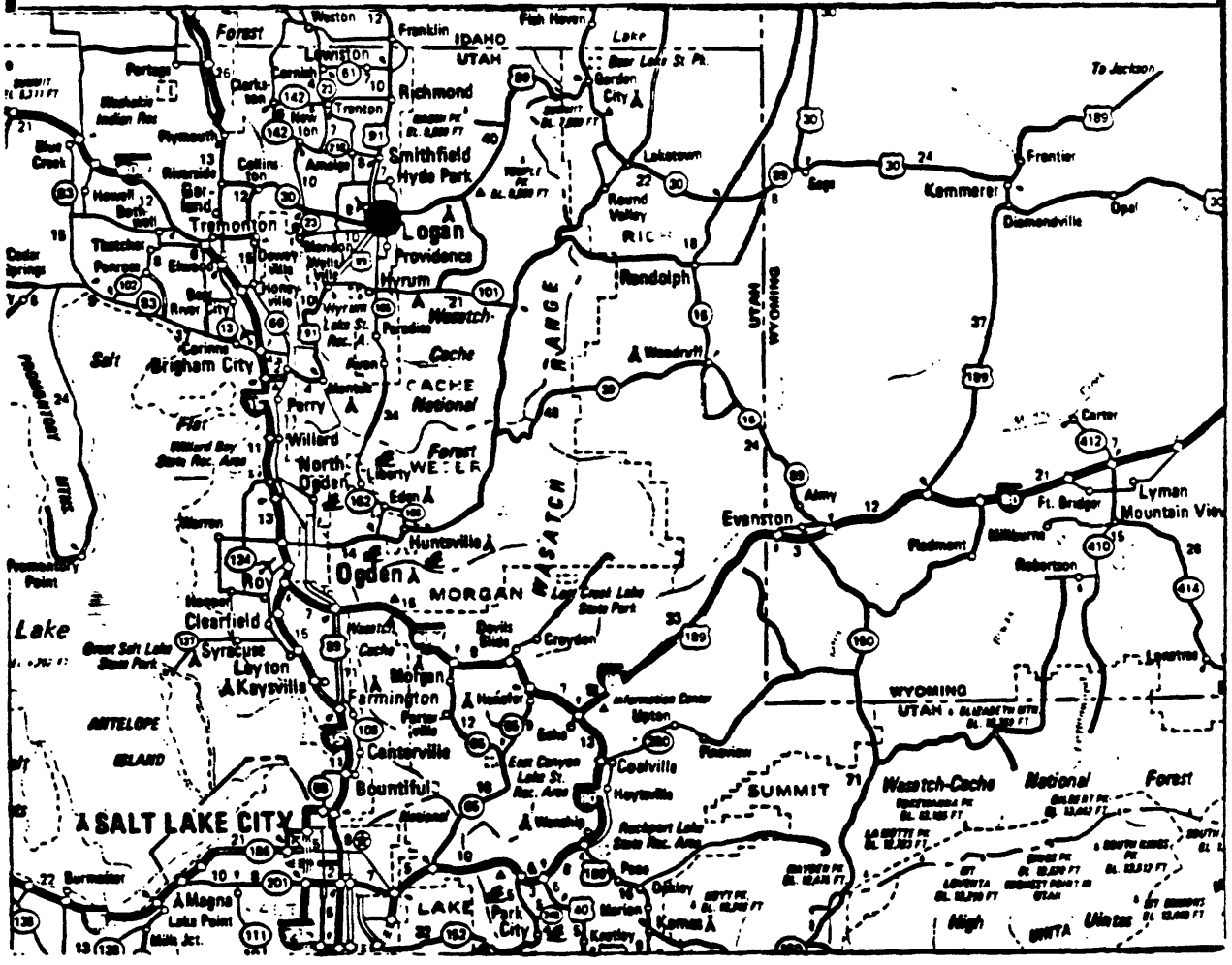
Coordinates 41.75 N, 111.82 W

Utah State University, the site of the accelerograph, sits directly on alluvial deposits in the Cache Valley. These deposits are thousands of feet thick; a thin cap of gravel overlying semiconsolidated fine grained alluvium; dominantly clay and sand.

Appx. 1.6km east of the site there is a 1m fault scarp which indicates recent earthquake activity.

REFERENCE

Hardy, Clyde, Utah State University, 1973; Oral Communications



GEOLOGIC SUMMARY OF STRONG-MOTION SITES

Date 3/78 Station No. 2203 Station LOGAN, ADMIN. BLDG., USU

Depth meters	P-Wave m/sec	S-Wave m/sec	Density g/cm³	Log	Site Geology
					Deep alluvium
600					

ALV;ALD

Station No. 2210 Station Salt Lake City, VA Hospital

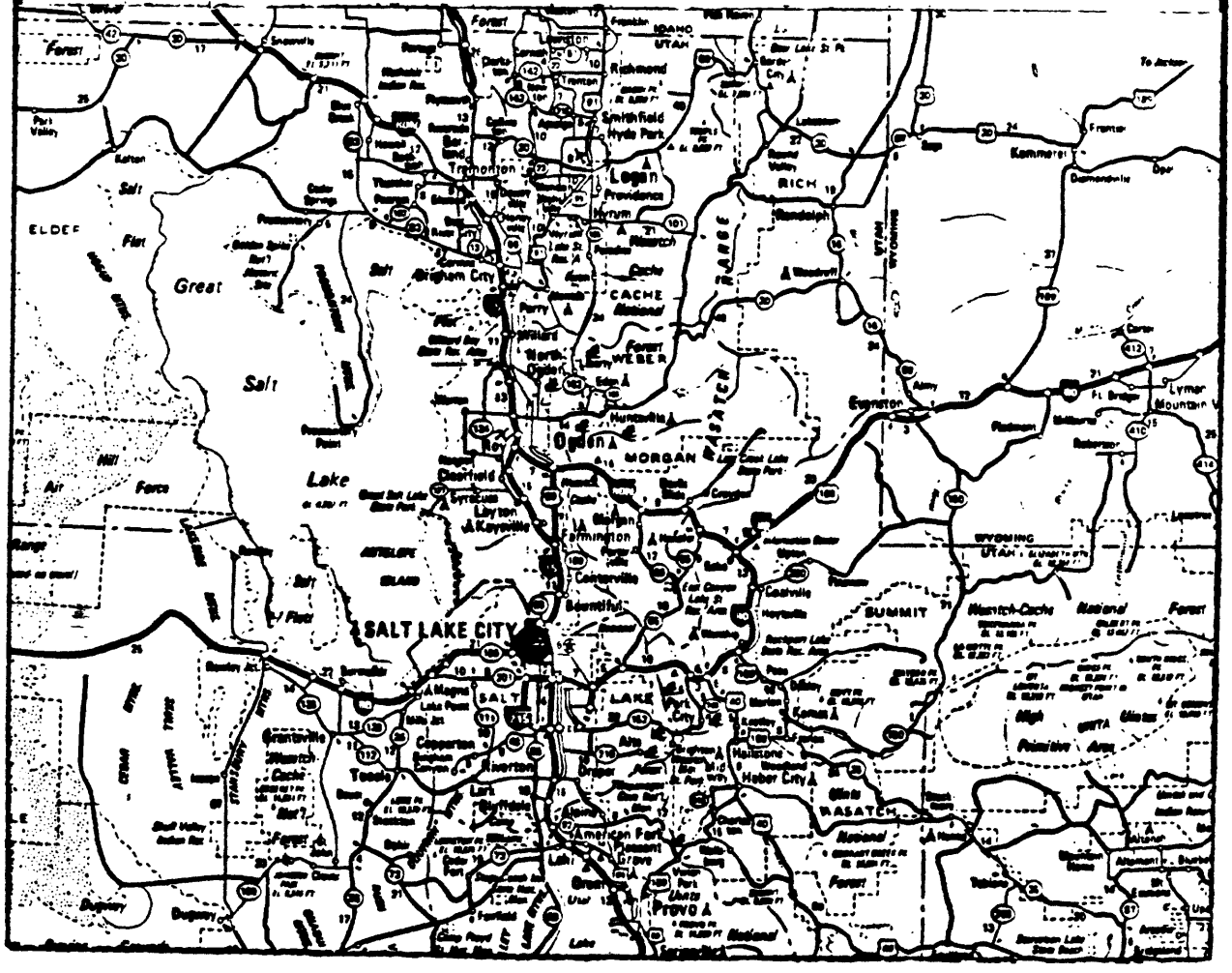
Coordinates 40.76 N, 111.84 W

The most important geologic feature near the site is the Wasatch Fault zone which separates the Basin and Range Province (where the site is) and the Wasatch Range and the Rocky Mountains. Movement as recent as 300 years has been traced within this zone.

The instrument sits on appx. 84m of a sand and gravel fanglomerate. These are underlain by Mesozoic limestone, sandstone and shale.

Reference

Dames and Moore., 1974; Site Evaluation Studies, Earthquake Hazard, Veterans Administration Hospital; Salt Lake City, Utah; Job No. 2712-013-06



GEOLOGIC SUMMARY OF STRONG-MOTION SITES

Date 2/78 Station No. 2210 Station SALT LAKE CITY VA HOSPITAL

Depth meters	P-Wave m/sec	S-Wave m/sec	Density g/cm³	Log	Site Geology
					silty Sand
					Gravel and sand
					gravelly silty Sand
10					Gravel and sand
20					Fanglomerate: sand, gravel, variable amounts of silt.
50					
100					Mesozoic undifferentiated limestone, sandstone and shale.

ALV;AL84;LS+SS+SH

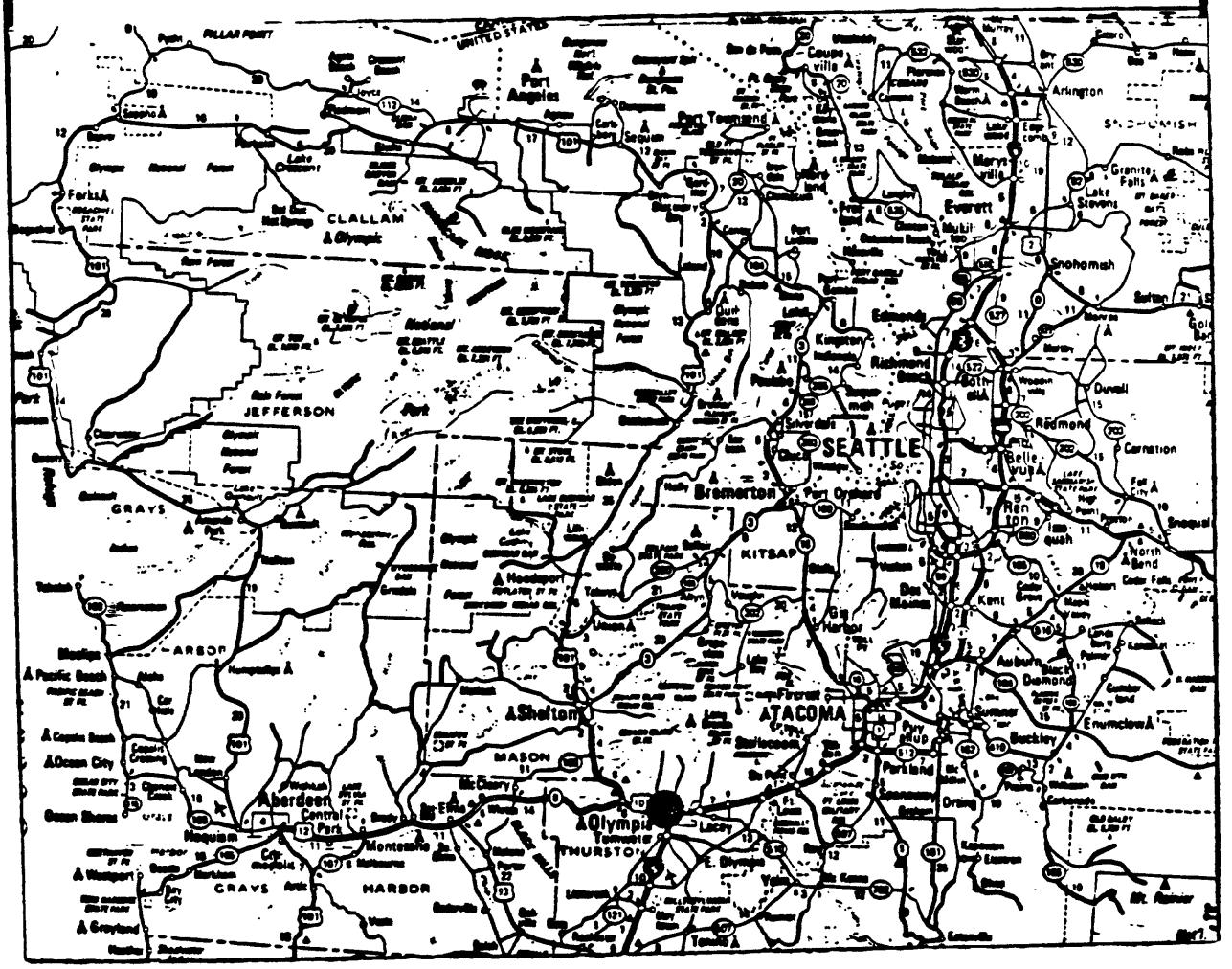
Station No. 2101 Station Olympia Highway Test Lab, State & N. Washington

Coordinates 47.03 N, 122.90 W

The site rests on about 3m of artificial fill, 110m of soft to moderately compact silt and sand (blow counts averaging 30-80 per 0.3m). At about 110 meters the blow count increases to about 121 or more per 0.3m; this may be the surface of older ice compacted Pleistocene sediments. Consolidated rocks are believed to occur at about 240m. The ground water table is probably confined within sand beds below 30m in depth.

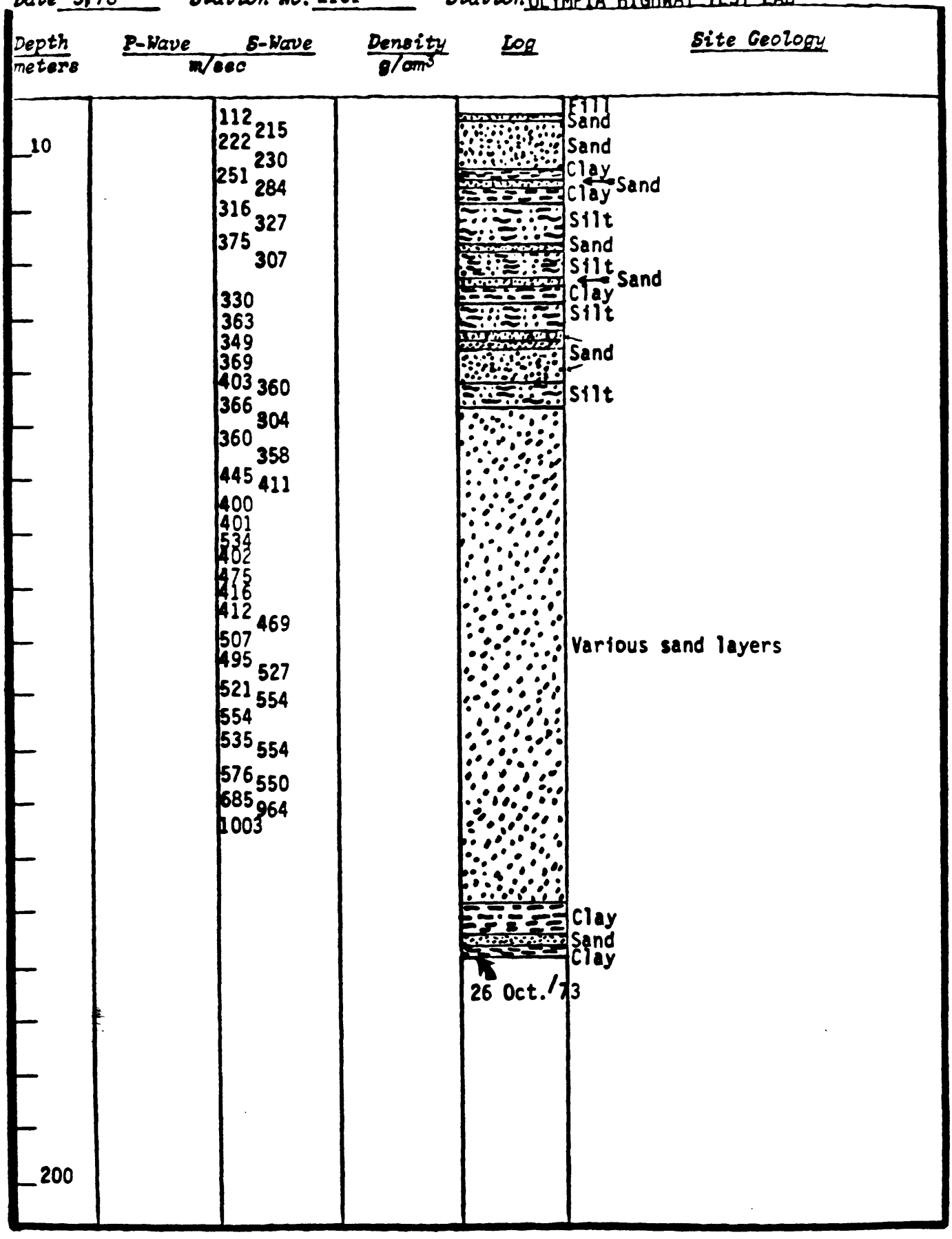
Reference

Washington Public Power Supply Systems, Nuclear Projects., 1974; Preliminary Safety Analysis Report, WNP3; 050508, Ammendment No. 2



GEOLOGIC SUMMARY OF STRONG-MOTION SITES

Date 3/78 Station No. 2101 Station OLYMPIA HIGHWAY TEST LAB



ALV;AL

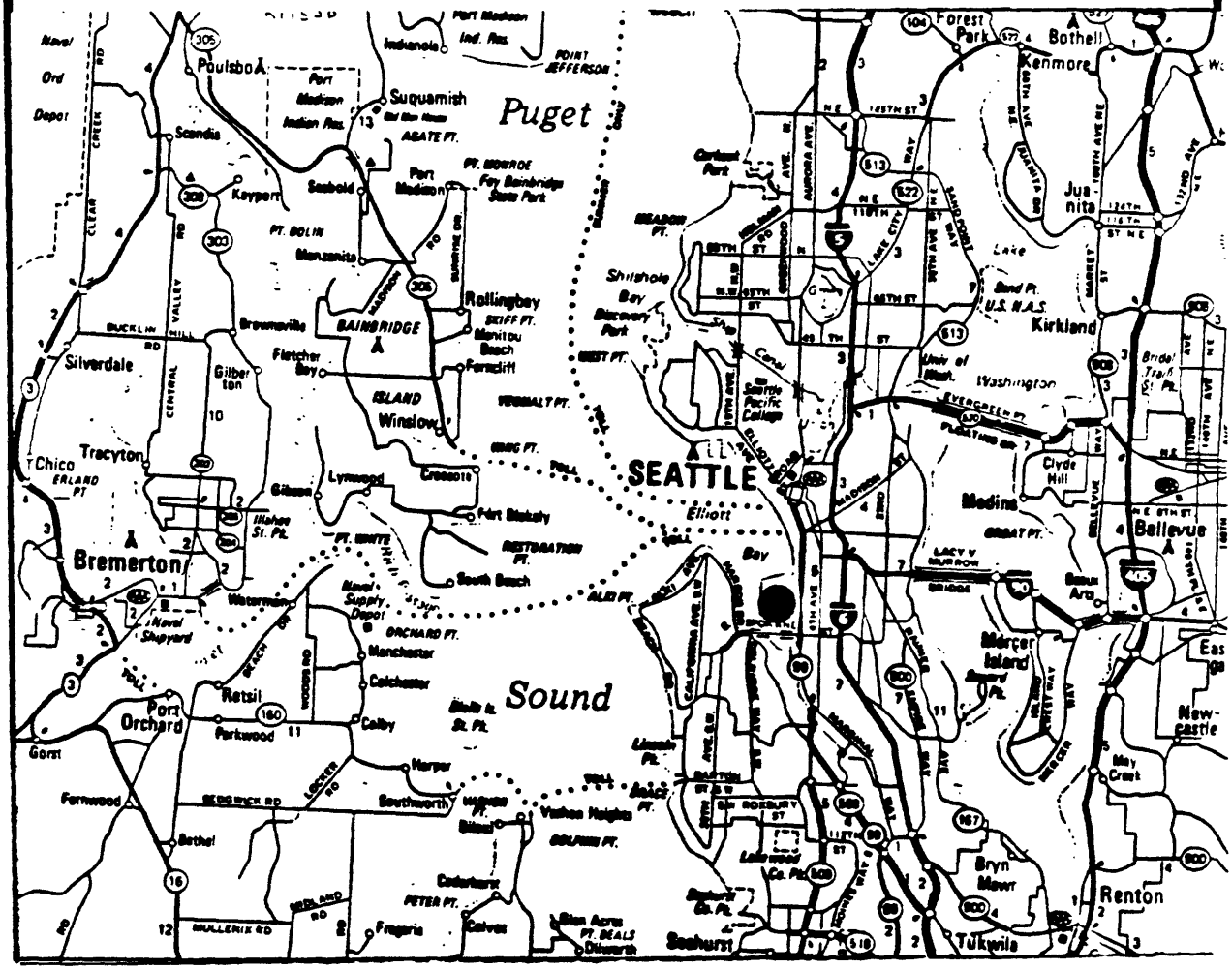
Station No. 2106 Station Seattle Pier 20

Coordinates 47.58 N, 122.35 W

The site rests on a minimum of 40m of alluvial material. The upper 35m or so are mainly silty sand to soft silt. At about 35m a dense glacial till is encountered, the upper few meters having been described as sand gravel to silty clay.

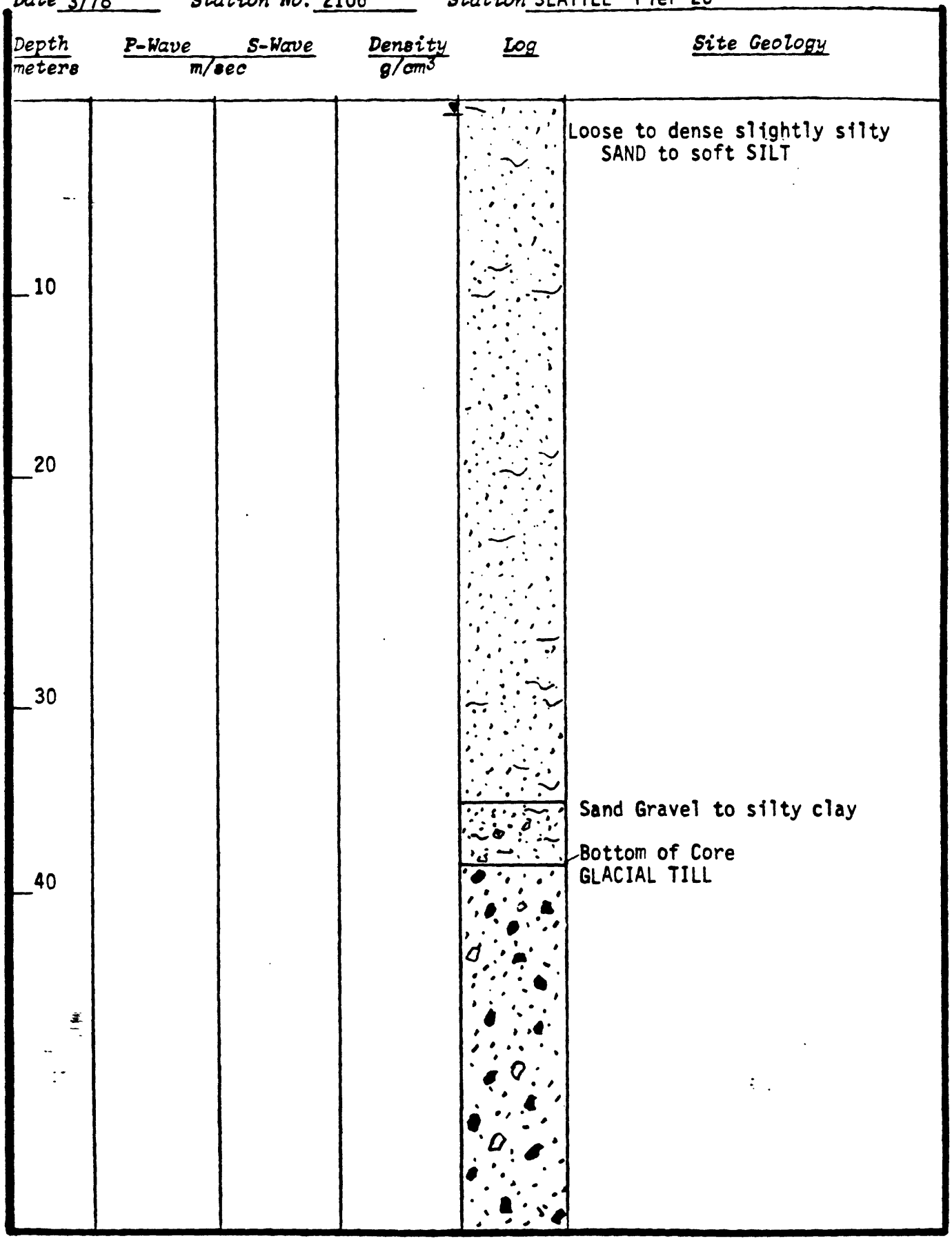
Reference

Neil H. Twelker & Assc., 1973; Port of Seattle, Soils and Foundation Investigation



GEOLOGIC SUMMARY OF STRONG-MOTION SITES

Date 3/78 Station No. 2106 Station SEATTLE Pier 20



ALV;AL40;AL

TABLE I

ALPHABETIZED GEOLOGIC CODE

ROCK TYPES

AC	Coarse Alluvium
AF	Artificial Fill
AG	Agglomerate
AL	Alluvium
AM	Amphibolite
AN	Andesite
BA	Basalt
BR	Breccia
CG	Conglomerate
CH	Chert
CI	Combination Igneous
CM	Combination Metamorphics
CR	Combination Rock Types
CS	Combination Sedimentary
CY	Claystone
DI	Diorite
DK	Dikes or Sills
DO	Dolomite
FR	Franciscan Rocks
GB	Gabbro
GD	Granodiorite
GN	Gneiss
GR	Granite
GS	Greenstone
HF	Hornsfel
LF	Lava Flows
LS	Limestone
MR	Marble
MS	Mudstone
MZ	Monzonite
OB	Obsidian
PH	Phyllite
PU	Pumice
QM	Quartz Monzonite
QZ	Quartzite
RY	Rhyolite
SC	Schist
SH	Shale
SI	Siltstone
SL	Slate
SP	Serpentinite
SS	Sandstone
SY	Syenite
TF	Tuff
VA	Volcanic Ash

CLASS CODE

ALV	Alluvium
IGN	Igneous Rock
MET	Metamorphic Rock
MIX	Mixture of Rock Types
SED	Sedimentary Rock

EXPLANATORY SYMBOLS

C	Cemented
D	Deep
F	Fractured, Sheared, or Jointed
I	Interbedded
K	x1000
L	Layered or Stratified
M	Massive
P	Permafrost
S	Semiconsolidated
U	Unconsolidated
V	Veneer
W	Weathered or Friable
X	Crystalline Basement
;	Overlying
+	And
.	Decimal

Appendix A

A SHALLOW REFRACTION SEISMIC SURVEY AT

STRONG-MOTION STATION APEEL 2

A shallow refraction survey was conducted at APEEL strong-motion station 2 on 20 December 1973 using a Dynametric Seismic Counter, Model 117. Two one-hundred foot reversed spreads (N 47 E) were measured near the instrument building. The energy source was a 15 pound hammer struck against a 5x5x1 inch steel plate that had been "settled" about one inch into the ground by unmeasured impacts. The moving hammer points at 35, 50, 65, 80 and 100 feet. Other interpolated spacings were used when necessary to adequately define the travel/time slope. Microseismic activity was relatively low for this location (near the San Francisco Bay) allowing effective measurements at a greater spread length than normally anticipated. Because of aircraft overflights it was necessary to set the geophones in shallow holes and cover them with approximately four inches of topsoil.

P-wave velocities were measured using a vertical geophone. In a repeat survey we attempted to measure shear wave velocities by switching the counter to a horizontal geophone buried at the end of the spread. The energy source in this instance was created by horizontally striking a steel rod that had been driven into the ground at successive hammer points as well as by the usual hammer/plate method.

The average P-wave velocity measured along the four profiles was approximately 1340 ft/sec (408 m/sec). By incorporating what were apparently later arriving P-waves beyond 70 feet, it was possible to obtain extrapolated measurements across the entire spread length of 100 feet (see travel time curves).

The efforts to measure shear waves were unsuccessful and may be attributed to the following: softness of the soil resulting in large deformations when hitting the steel rod and the limitation of a counter type instrument, i.e., the time count begins upon impact and is terminated when the first wave with an amplitude larger than the pre-set threshold level is detected by the geophone. This means the threshold level must be empirically adjusted above the P-wave amplitude and below the larger S-wave amplitude without benefit of visual recording.

Assuming a Poissons ratio, $\sigma = 0.41$, determined from a previous survey (King and Sembera, 1972), an estimated shear wave velocity of 520 ft/sec (158 m/sec) was calculated from the following relationship:

$$\frac{V_L}{V_T} = \sqrt{\frac{1-\sigma}{\frac{1}{2}-\sigma}}$$

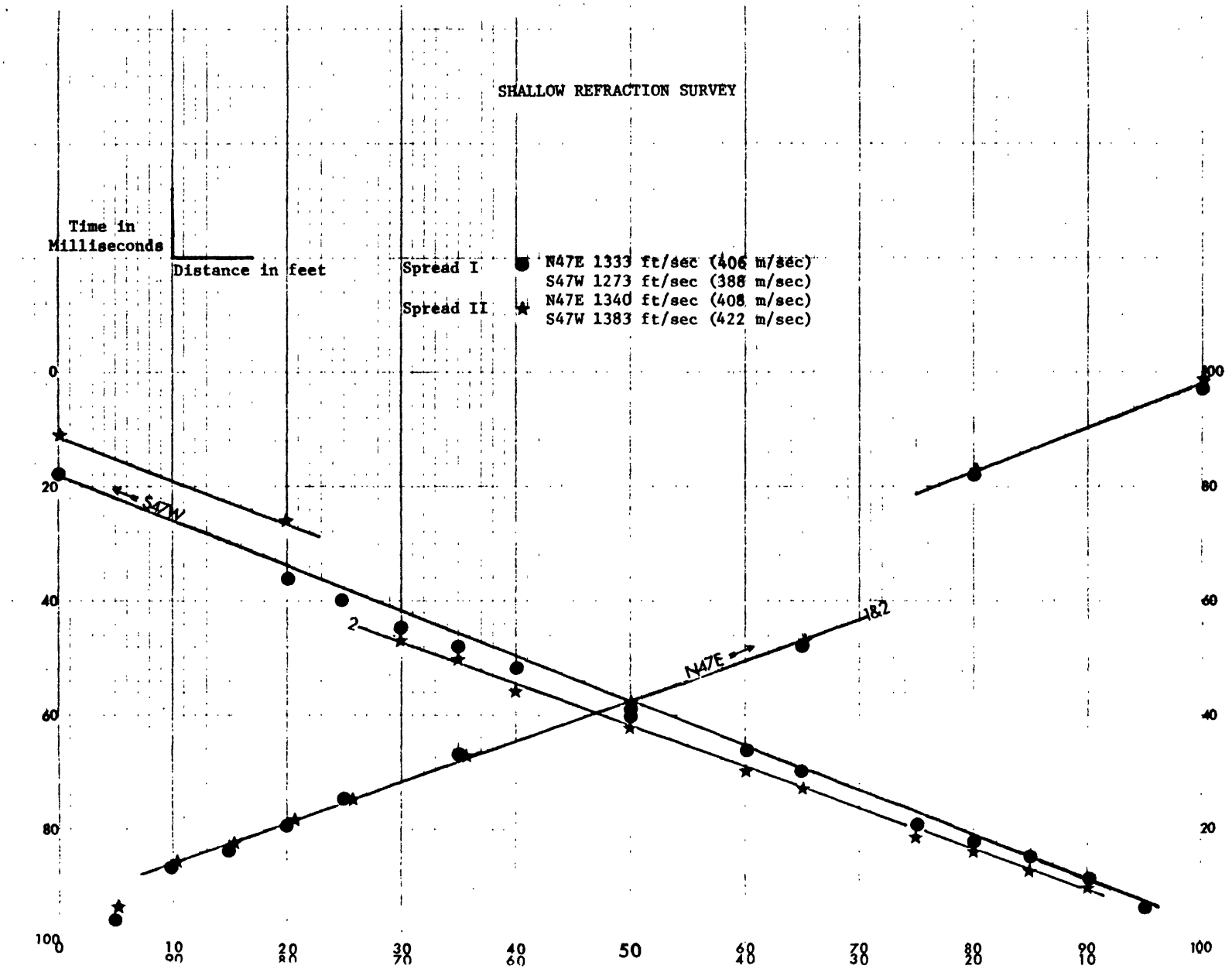
I wish to thank K. Sickles and G. Curtis who were part of the Survey Team.

References

Morrill, B. J., 1972; The Apeel Array: A Site Study: NOAA Technical Report ERL 245-ESL 22, pp 11-12.

King, K. W., Sembura, E. D., 1972; S. M. Site Inspection, Surface Seismic Program, Progress Report #1, 19 p.

Dobrin, M. B., 1960; Introduction to Geophysical Prospecting; McGraw-Hill Book Company.


SHALLOW REFRACTION SURVEY
Time in Milliseconds
Distance in feet
Spread I
N47E 1333 ft/sec (406 m/sec)
S47W 1273 ft/sec (388 m/sec)
Spread II
N47E 1340 ft/sec (408 m/sec)
S47W 1383 ft/sec (422 m/sec)
S47W
N47E
1&2
2
0
20
40
60
80
100
0
10 90
20 80
30 70
40 60
50
60 40
70 30
80 20
90 10
100