File this instruction sheet in the front of Volume 1 as a record of changes.

The following information and check list are furnished as a guide for the insertion of new sheets for Amendment 28 into the Preliminary Safety Analysis Report for the Skagit/Hanford Nuclear Project. This material is denoted by use of the amendment date in the upper right-hand corner of the page.

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affected the Site, the two highest intensities are estimated
to have been IV-V (MM) from the December 14, 1872 earthquake
and IV (MM) from the Milton-Freewater shock of July 15, 23
1936. The maximum acceleration at the Site resulting from
historical or instrumental earthquakes is estimated to have
been 0.015g (see Section 2.5.2.6 WNP-2 FSAR).

A Regulatory Guide 1.60 Spectrum anchored at a peak
acceleration of 0.35g is assigned as the Safe Shutdown 28
Earthquake (SSE). The requirements of this SSE exceed those
for all potential earthquakes discussed in Section 2.5.2.4.

<u>1.2.2.1.2.7 Land use</u>. Natural physical characteristics of the Plant Site, which indicate that the area is ideally situated for and suited for operation of the Plant, include: favorable geographical, geological, and seismological characteristics; adequate water supply; ideal climatological characteristics; and remoteness from population centers or areas of special ecological concern. The Hanford Reservation has served as a nuclear industrial center since 1943 when it was selected by the Federal government as the location for construction of one of the world's first nuclear production reactors. Since 1943, nine plutonium production reactors and a number of test reactors have been constructed and operated at the Hanford Reservation.

23

<u>1.2.2.1.2.8 Population</u>. In 1980 approximately 280,000 people were living within a 50 mile radius of the S/HNP Site. Since the Site is situated within the Hanford Reservation, there are no significant concentrations of population within a 10-mile radius. The closest inhabitants occupy farms located east of the Columbia River, and are thinly spread over five compass sectors. The closest resident is about seven miles south of the Plant. The nearest population centers are the Tri-Cities area of Richland (15 miles to the south-southeast), Pasco (23 miles to the southeast), and Kennewick (23 miles to the SSE-SE); Benton City (16 miles to the south); Mesa (21 miles to the east-northeast); Prosser (24 miles to the southwest); and Othello (26 miles to the north-northeast).

1.2.2.2 General Arrangement of Structures and Equipment

The principal structures to be located in the Plant "Nuclear Island" are the following:

a. Containment -- houses the upper containment pool, the suppression pool, drywell, and major portions of the nuclear steam supply system

b. Auxiliary Building -- houses the Engineered Safety Features, the systems equipment and switchgear, containment switchgear, and portions of the heating and ventilating systems

c. Fuel Building -- houses the fuel storage and shipping area, the Standby Gas Treatment System, the control rod drive pumps, the control rod drive service area and portions of the heating and ventilating systems

d. Enclosure Building -- houses that part of the containment that extends above the roofs of the Auxiliary Building and Fuel Building

e. Radwaste Building -- houses the radioactive waste treatment facilities

f. Control Building -- includes the control room, the computer facility and the cable spreading area

g. Diesel Generator Building.

The arrangement of these structures on the Plant Site is shown in Figure 1.2-1. Figures 1.2-2 through 1.2-8 show the equipment arrangement in the principal buildings.

1.2.2.3 Nuclear System

See 251 NSSS GESSAR.

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See 251 NSSS GESSAR. 6

- A lack of significant or pervasive faults
- Low rates of deformation
- Extensive and little-deformed sedimentary units of Pliocene and younger age
- Low rates of seismic activity and
- A lack of large-magnitude earthquakes.

Geologic knowledge of the Columbia Plateau and the Pasco Basin has evolved over nearly a century of investigations and has been reported in over 3000 publications (Ref 1). Ranging from regional-reconnaissance scale to very detailed site-specific and feature-specific scale, the studies have been conducted for a broad spectrum of purposes: academic, resource, facility construction and environmental protection. The investigations have yielded information that is impressive in amount and variety. Table 2.5-1 provides a chronology by category of some of the previous investigations that have formed the basis for the site-specific studies conducted for the S/HNP Site. It shows, together with the studies described below, that geologic, seismologic, and geotechnical investigations relevant to design and construction of S/HNP have been comprehensive and adequate. Furthermore, the table shows that the Hanford Reservation is virtually unequaled in the United States with regard to the quantity and quality of data applicable to design of critical facilities.

The approach to studies conducted for the S/HNP Site was based on the concept of verifying previously indicated suitable conditions in the Site Area and selected surrounding areas. The techniques employed to verify these conditions included: 23

- Field Mapping
- Trenching
  - Logging
  - Sampling
  - In-Situ Testing
- Rotary and Core Drilling
  - Logging
  - Sampling
  - In-Situ Testing
- Petrologic Analyses
  - Binocular and Petrographic Microscope

- o Downhole Geophysical Logging
  Neutron-Epithermal Neutron
  Natural Gamma
  Neutron-Gamma
  Gamma-Gamma

- o Ground Gravity and Magnetic Surveys

- o Seismic Surveys
  Seismic Refraction
  Downhole in-situ velocity measurements
  Crosshole in-situ velocity measurements

- o Laboratory Testing

- o Geochemical Analysis

Based on the investigations performed for the S/HNP Site, the Site has been found suitable for locating the proposed 23
facilities in that it meets the criteria of Appendix A to 10 CFR 100. The investigations have also been adequate to satisfy the requirements of Regulatory Guide 1.70 and Standard Review Plans. Specifically, the investigations have shown:

- o There is no potential for ground rupture and no need to consider surface displacement in the Plant design.

- o The subsurface soils are competent to provide foundation support for Plant structures under both static and dynamic loading conditions, and there are no areas of active or potential subsidence, uplift or collapse.

- o The groundwater table in the Site Area will remain approximately 100 feet below foundation grade, and will not significantly influence, or be influenced by Site-facility water use.

The maximum acceleration at the Site resulting from historical or instrumental earthquakes is estimated to have been 0.015g (see Section 2.5.2.6 WNP-2 FSAR).

A Regulatory Guide 1.60 Spectrum anchored at a peak 28
acceleration of 0.35g is assigned as the Safe Shutdown Earthquake (SSE). The requirements of this SSE exceed those for all potential earthquakes discussed in Section 2.5.2.4.

## 2.5.1 BASIC GEOLOGIC AND SEISMIC INFORMATION

### 2.5.1.1 Regional Geology

Information regarding the geology and geologic hazards of 23
the region surrounding the Skagit/Hanford Nuclear Project Site is described in Sections 2.5.1.1 through 2.5.1.2.6 of Amendment 18 (October, 1981) to the WNP-2 FSAR and the Washington Public Power Supply System's responses to WNP-2 Questions 361.16, 361.17, 361.20 through 361.25 and additional information transmitted to NRC by the Supply 28
System on April 26, 1982 (Letter, Bouchey to Schwencer) and is incorporated herein by reference. This information is supplemented by Appendix 2S to the Skagit/Hanford Nuclear Project PSAR which synthesizes the presently available data bearing on the causative mechanism for deformation of the Yakima Fold Belt.

### 2.5.1.2 Site Geology

The Skagit/Hanford Nuclear Project (S/HNP) Site Area (2-mile radius) was studied in detail to determine the lithologic, stratigraphic, and structural geologic setting. The regional geologic setting, investigated in cooperation with the Washington Public Power Supply System, is described in Section 2.5.1.1 of the WNP-2 FSAR, Amendment 18. Investigative methods employed in the Site Area included surface geologic mapping, photogeologic analysis, drilling, borehole geophysical logging, sedimentary petrologic studies of drill core and cuttings, and gravity, magnetic, and seismic refraction studies.

These investigations supplemented previous investigations 23
noted in the introduction to Section 2.5 of this PSAR. Data from the S/HNP investigations show that the basalt topography in the Site Area is generally flat, with some minor local warping. The late Miocene to early Pliocene Ringold Formation is deformed over bedrock highs; however, overlying late Pliocene(?) to late Pleistocene flood gravels are generally flat-lying, suggesting tectonic stability since post-Ringold time. The findings of the Site investigation are consistent with those from other local and regional investigations, generally affirming the regional data with respect to amount, nature, and rate of deformation. No evidence for faulting has been observed in the Site Area and no capable faults have been found within 5 miles of the Plant Site. Accordingly, there is no need to consider surface faulting in the design of the Plant.

The Skagit/Hanford Nuclear Project Site Area is in the east-central part of the Pasco Basin, a depression that is partially filled by alluvial and lacustrine sediments of the late Miocene to early Pliocene Ringold Formation. The

Ringold Formation is underlain by a thick sequence of basalt flows of the Tertiary Columbia River Basalt Group and associated interbeds. Sediments overlying the Ringold Formation in the basin include the late Pliocene(?) to late Pleistocene Pre-Missoula and Missoula Flood Gravels (informal names) and Holocene eolian deposits. This stratigraphic assemblage provides the basis for evaluating the presence or absence and nature of geologic features important to Site safety, i.e., potential earthquake sources, zones of potential ground rupture, and foundation support conditions.

The regional context of the Site stratigraphy is described in Section 2.5.1.2.2 of the WNP-2 FSAR, Amendment 18.

The Plant facilities are near the axis of the buried Cold Creek syncline, a structural depression bounded on the north by the Umtanum Ridge-Gable Mountain structural trend and on the south by the Yakima Ridge and Rattlesnake Hills anticlines. The regional context of the Site Area structural geology is described in Section 2.5.1.2.4 of the WNP-2 FSAR, Amendment 18. Within the Cold Creek syncline, minor deformation of the basalt bedrock surface was initiated at least 14 million years (m.y.) ago (Ref 1) and appears to have continued into Ringold time (10.5 to 3.3 m.y. ago). Very minor deformation may have occurred in Post-Ringold time; however, the Site Area is characterized by relative structural stability, consistent with regional evidence for low pre-historic and historic seismicity. 23

The closest fault to the Plant facilities has been recognized in the subsurface on the Southeast anticline (informal name), 5.5 miles northeast of the Plant facilities (Appendices 2K, Section 5.3, and 2R, Section 6.2.1). The closest faults that are associated with the displacement of Pleistocene deposits are the Central and South faults on Gable Mountain (Appendix 2I, Section 6.1 and 6.2), 8 and 7.5 miles, respectively, northwest of the Plant facilities. The regional setting and tectonic evolution of faults are described in Section 2.5.1.2.4 of the WNP-2 FSAR, Amendment 18, and in Appendices 2K, 2N, and 2O of this PSAR.

#### 2.5.1.2.1 Site Physiography

The Pasco Basin, a physiographic and structural depression within the Columbia Basin subprovince of the Columbia Plateau physiographic province, is a 2,000-square-mile, gently undulatory, semi-arid plain interrupted by low-lying hills and sand dunes dissected by intermittent streams. The regional setting of the Site Area physiography is described in Section 2.5.1.1.2 of the WNP-2 PSAR, Amendment 18. The commonly contain interbedded coarse sands. The gravels are characterized by a dominance of basalt, commonly 95 percent, with a few clasts of granitics and metamorphics. The sands are dark gray from the high basalt content, but also contain quartz, feldspar, and mica. Missoula flood gravels are distinguished from Pre-Missoula gravels by the presence of greater than 60 percent basalt in the gravels and sand. They formed as the result of large-scale catastrophic floods released from glacial Lake Missoula in Montana (Ref 9, 10, 11). Missoula flood deposits have been assigned an age range of 13,000 years B.P., based on the presence of St. Helens "S" ash near the top of the unit (Ref 12), to 17,500 to 18,000 years B.P., based on the age of the last major glacial advance in the northern United States (Ref 13). They are equivalent to the upper part of the Pasco Gravels of the Hanford Formation as defined by Myers and Price (Ref 1). Thickness of the Missoula Flood Gravels in the Site Area ranges from approximately 25 to 85 ft. Missoula flood gravels are the chief materials to be involved in the Site excavation. Their foundation engineering properties are good and are described in Section 2.5.4 and Appendix 2Q.

2.5.1.2.2.2.4 Surficial Deposits. Figure 2.5-2 shows the surface geology of the vicinity within a 5-mile radius of the Plant facilities. Surficial deposits include active and stabilized Holocene dune sands, Holocene alluvium, and Pleistocene glaciofluvial sediments. In the southwestern part of the map, the Touchet beds of Flint (Ref 14) represent fine-grained, slackwater sediments deposited distally from the main Pleistocene flood channels. 23

In the Site Area (2-mile radius), a thin mantle of active and stabilized Holocene dune sands blankets the Pleistocene Missoula Flood Gravels. These sands are fine- to medium-grained quartzose or basaltic sands which commonly contain silt (Ref 1). Sparse vegetation stabilizes most of the dunes. The eolian deposits range in thickness from 1 to 10 ft in the Site Area. Most of the surficial deposits will be removed or compacted during Site development and pose no problems for facility design and operation.

2.5.1.2.3 Site Structural Geology

The S/HNP Site Area is in the east-central part of the Pasco Basin, a structural sub-basin of the larger Columbia Basin. The Pasco Basin is partly surrounded by west- and northwest-trending anticlinal ridges, the Yakima Folds, which are separated by broad synclinal troughs. The Saddle Mountains form the northern boundary of the Pasco Basin, and the Rattlesnake Hills and Horse Heaven Hills form the southern boundary. Umtanum Ridge and Yakima Ridge plunge eastward into the basin at the western boundary. The eastern boundary of the basin is formed by a gentle westward dip on the basalt surface. The Plant Site is near the axis of the Cold Creek syncline, a buried structural depression between Gable Butte-Gable Mountain-Southeast anticlines on the north and northeast, and the Yakima Ridge anticline on the west and southwest.

Investigations for S/HNP drew on previous knowledge of local 23
and regional geologic structure (refer to Section 2.5.1.1 of the WNP-2 FSAR, Amendment 18) to develop specific information critical to identifying and characterizing all structures significant for seismic design.

Detailed photogeologic analyses, field mapping and subsurface stratigraphic studies have not identified any faulting within the Site Area. The closest fault to the Plant facilities is 5.5 miles to the northeast on the Southeast anticline, the buried easterly segment of the Umtanum Ridge-Gable Mountain structural trend. This fault was recognized on the basis of an anomalous thickness of the Elephant Mountain flow containing several thin zones of shearing in Corehole 125. Closely spaced coreholes were drilled by Golder Associates for the Washington Public Power Supply System to determine the attitude of this fault and the continuity of overlying Ringold units (Ref 22). The fault is a reverse fault. It strikes N39°W and dips 30°SW. The range of vertical displacement on the fault is 35 to 60 feet. Based on this small amount of displacement, the Southeast anticline fault appears to be a minor feature and probably does not extend any significant distance away from Corehole 125.

The sediments overlying the projection of the fault plane 28
have been penetrated by 11 holes spaced 30 to 100 feet apart along a line 450 feet long. These overlying sediments include the late Miocene lower Ringold Formation (approximately 10 million years old) and the Pleistocene Hanford Formation. Fine-grained units within the Pre-Missoula Gravels of the Hanford Formation near Corehole 125 have been dated on the basis of paleomagnetic analyses as older than 730,000 years. Four stratigraphic contacts, ranging in age from approximately 10 million to at least 730,000 years in age, dip gently across the projection of the fault plane and show no abrupt changes in elevation. Based on these observations, the Southeast anticline fault has not been active for approximately 10 million years and is therefore not capable.

The South fault, 7.5 miles north on the south flank of Gable Mountain, is the closest known fault to the Plant facilities 23

which is associated with displacement of Pleistocene sedi-
ments (Appendix 2O, Section 6.2.3). The South fault is
inferred to have moved in late Pleistocene time on the basis
of deformation observed in clastic dikes present along the 23
fault. The Central fault, 8 miles to the northwest on Gable
Mountain, has displaced overlying Missoula glaciofluvial
deposits (dated at 13,000-17,500 B.P.) in a reverse sense a
maximum of 0.2 ft (Appendix 2O, Section 6.1.3).

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# APPENDIX 2K

# GEOPHYSICAL INVESTIGATIONS

# UMTANUM RIDGE TO SOUTHEAST ANTICLINE

# HANFORD SITE, WASHINGTON

prepared for

NORTHWEST ENERGY SERVICES COMPANY

October, 1981

(Amended October, 1982)

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Figure No.

# 1.0 INTRODUCTION

As part of the investigations of the Umtanum Ridge-Gable 23
Mountain structural trend, geophysical field studies were
conducted for Northwest Energy Services Company (NESCO)
from February 1980 to June 1981. The geophysical
investigations were part of the overall siting study for
the Skagit/Hanford Project. Amendment 28 updates Appendix
2K to reflect additional investigations conducted on the 28
Southeast anticline by the Washington Public Power Supply
System and the May Junction monocline by NESCO during 1982.

The geophysical investigation focused primarily on the bedrock configuration of the Hanford Site (Figure 2K-1). This report describes the geophysical investigations of the Umtanum Ridge-Gable Mountain structural trend, its associated structures, Gable Butte and Gable Mountain, and a buried ridge, informally named the Southeast Anticline, trending southeasterly from Gable Mountain.

The present area of study covers nearly 200 square miles of the Hanford Site, which is located in the central portion of the Yakima Fold Belt of the central Columbia Plateau of south-central Washington (Figure 2K-1). The bedrock units, the Miocene Columbia River Basalt Group, are overlain by as much as 700 feet of Late Tertiary and Quarternary sediments and sedimentary rocks.

The drilling performed by Golder Associates encountered the
Elephant Mountain Member of the Saddle Mountains Basalt as
the youngest bedrock unit in all boreholes. Consequently,
the top of bedrock can be considered a structural surface
on the top of the Elephant Mountain Member, except south of
Vernita Bridge, where the Elephant Mountain Member is not
present (Figure 2K-2); the older Pomona Member is the 23
uppermost basalt unit in this area. These geologic
conditions are favorable for the geophysical investigation
of subsurface structure. The density contrast between the
sediments and the basalt is 0.3-0.7 g/cm$^3$. The Bouguer
gravity anomaly map for the Hanford Site is an approximate
structural contour map with an arbitrary datum and a
conversion factor of 150 feet of basalt elevation per 1
milligal of gravity relief. The conversion factor was
determined from comparison of the profile of top of basalt
(based on logging of drillholes and analysis of cuttings
and core) with the gravity anomaly along the same profile.
If no erosion of the Elephant Mountain basalt has occurred,
then the top of basalt is a structural surface. However,
some erosion has occurred. On the basis of the measured
thickness of the Elephant Mountain basalt in all holes that
extended through the unit, the erosion has removed
differentially at most 80 feet of basalt. Therefore, the
top of basalt is a structural surface within $\pm 40$ feet

(except in the area of Vernita Bridge where the unit is not present).

The conversion factor of 150 feet = 1 milligal is the average value determined for several profiles. It varies by approximately 20% over the study area as a result of the variation of the density of the Ringold Formation, which in turn is controlled by the relative thickness of coarse and fine units.

## 1.1 SCOPE OF INVESTIGATION

The geophysical investigations of the Umtanum Ridge-Gable Mountain structural trend were designed to delineate bedrock topography and examine specific structures within each area described below and shown on Figure 2K-2.

### 1.1.1 Umtanum Ridge-Gable Mountain Area

The Umtanum Ridge-Gable Mountain geophysical studies were designed to determine the structural continuity or discontinuity between Umtanum Ridge and Gable Mountain. Aeromagnetic and gravity data acquired for the Washington Public Power Supply System by Aeroservice, Inc. and Weston Geophysical Corporation, respectively, were interpreted by Weston Geophysical Corporation (1978a, 1978b, 1978c, Washington Public Power, 1977) as indicating possible structural continuity from Umtanum Ridge to Gable Mountain. Myers and Price (1979) concluded that the Gable Butte structure was a second-order fold on a continuous, primary fold linking Gable Mountain with Umtanum Ridge. Accordingly, gravity and land magnetic data were acquired and interpreted in order to analyze and characterize the structural continuity or discontinuity of the Umtanum Ridge to Gable Mountain trend.

### 1.1.2 Central Gable Mountain, DB-10, May Junction Areas

The Central Gable Mountain-DB-10 area was investigated to determine the structural relationships between this area and the Umtanum ridge structure as well as to augment geologic investigations of faulting. Corehole DB-10 encountered two zones of reverse faulting with a combined offset estimated to be 160 feet (Myers and Price, 1979). Weston Geophysical conducted a program of seismic refraction, gravity and land magnetics to complement the geological studies of the faults.

Geophysical data were acquired on Gable Mountain to assist in the investigation of faults in the central Gable Mountain area. The geophysical program of seismic refraction, gravity and land magnetics was designed to assist in tracing the faults, as well as to investigate features believed related to the observed offset. Seismic refraction data were also utilized in feasibility studies for various trench localities on Gable Mountain.

The May Junction linear, initially defined on the basis of aeromagnetic data (Myers and Price, 1979), was investigated by seismic refraction and gravity data acquired by Weston Geophysical and drilling data collected by Golder Associates to characterize the structural relationships between this feature and the Umtanum Ridge-Gable Mountain structural trend.

### 1.1.3 Southeast Anticline

The third major area of investigation was the subsurface ridge informally named the Southeast Anticline. The aeromagnetic data acquired by Washington Public Power Supply System shows a magnetic high trending southeasterly from the eastern end of Gable Mountain. Extensive seismic refraction, gravity and land magnetic data were acquired and interpreted in order to characterize the Southeast Anticline and the structural relationships between the Southeast Anticline and the first-, second-, and third-order folds of the Umtanum Ridge-Gable Mountain structural trend.

# 2.0 SUMMARY AND CONCLUSIONS

## 2.1 SUMMARY

The results of the geophysical investigation implemented by 23
Weston Geophysical for the Skagit/Hanford Project characterize the subsurface basalt topography of the Hanford Site. The basalt surface, based on geologic information, can be considered a structural surface, except in the area south of Vernita Bridge.

New geophysical data obtained for the Skagit/Hanford
Project consist of approximately 10,700 closely spaced, 28
surveyed, and high precision gravity stations; 500 line miles of land magnetic profiles; and 72 line miles of seismic refraction profiles. Previously acquired data utilized in this study include aeromagnetic data, gravity data, and seismic refraction data collected for Washington Public Power Supply System, as well as aeromagnetic data, gravity data, and seismic reflection data acquired by Rockwell Hanford Operations.

Two principal structural features have been delineated by the geophysical investigations, the Gable Butte-Gable Mountain segment of the Umtanum Ridge-Gable Mountain structural trend and the Southeast Anticline. The Gable Butte-Gable Mountain segment of the Umtanum Ridge-Gable Mountain structural trend, is a broad, low amplitude anticline within the Hanford Site and is bounded on the east by the May Junction monocline. The various faults reported on Gable Mountain and in DB-10 are features within
the Gable Butte-Gable Mountain segment. 23

A subsurface, bedrock ridge, the Southeast Anticline, has been defined as an 8-mile long, low amplitude anticlinal fold. The Southeast Anticline is separate from and extends 1 mile to the northwest of the eastern end of the Gable Mountain portion of the Gable Butte-Gable Mountain segment.

## 2.2 CONCLUSIONS

### 2.2.1 GABLE BUTTE-GABLE MOUNTAIN SEGMENT

The gravity anomaly associated with the Gable Butte-Gable Mountain segment of the Umtanum Ridge-Gable Mountain structural trend is a 5 milligal gravity high extending from the eastern end of Umtanum Ridge to the May Junction monocline. The Gable Butte-Gable Mountain segment, defined primarily by gravity data, is a segment of the Umtanum Ridge-Gable Mountain structural trend, although indicative of a change in structural style from the single anticlinal ridge of Umtanum Ridge to the broad, first-order fold with superimposed, second-order anticlines of the Gable Butte-Gable Mountain segment. This change in structural style occurs at the eastern end of Umtanum Ridge south of Vernita Bridge. The broad, first-order antiform is bounded on the east by the monoclinal flexure resulting in the May Junction linear.

### 2.2.1.1 DB-10 Area

The gravity and seismic refraction data are consistent with the geologic interpretation (Golder Associates, 1981, Figure 20-69) that the upper DB-10 fault strikes north-south and dips 30° to the west. 23

Based on seismic refraction velocity data, the length of the upper DB-10 fault appears to be 2,400 feet, limiting the fault to the small, northwest-trending, anticlinal fold south of Gable Mountain.

### 2.2.1.2 May Junction Monocline

The May Junction monocline trends north-south for a distance of 2 1/2 miles from the eastern end of Gable Mountain, has a maximum relief of 300 feet, and a maximum dip on the eastward sloping rock surface of 10°. An 28 elongate gravity high indicative of an anticlinal fold extends across the southern portion of the May Junction monocline.

The seismic refraction data for the May Junction and DB-10 areas indicate an anisotropic condition in the basalt. The bedrock velocities are higher in a north-south direction than in an east-west direction. The anisotropy suggests that fracturing is oriented north-south, parallel to the May Junction monocline. 23

### 2.2.2 SOUTHEAST ANTICLINE

The Southeast Anticlne is a separate structure from the first-order fold of the Gable Butte-Gable Mountain segment. The Southeast Anticline is also separate from the second-

order fold, Gable Mountain, and extends 1 mile to the
northwest beyond the eastern end of Gable Mountain. 23

The trend of the Southeast Anticline changes from northwest
to east-northeast at its southeastern end and does not 28
extend east of the Columbia River.

foot intervals in the monitoring hole (Figure 2K-5).
Typically, multiple shots were used and the cable adjusted
(overlapped) to obtain data at 5-foot intervals to various
depths (usually the top of basalt).

The downhole data for each borehole were computer processed
and an average velocity value determined for the overburden
column. Time-distance plots of the data were also
constructed in order to define the velocity interfaces.
The downhole velocity data in profile form is presented in
Attachment A.

The average velocities determined from downhole along a 23
given seismic line were then used to convert the time
profile of the 16,000 ft/sec. refractor to a depth profile
(Section 4.1.1.1.1).

## 4.1.2 GRAVITY DATA

### 4.1.2.1 Data Acquisition and Processing

Approximately 10,700 gravity stations were established 28
along traverse lines within the Hanford Site at the
locations shown on Figure 2K-6. All data points were
acquired utilizing Lacoste-Romberg Model G gravimeters,
capable of 0.01 milligal reading precision. All gravity
measurements were made in reference to local base stations
established from the Washington gravity base station
network (Pasco B Station, Nilson, 1976). 23

The gravity data were generally acquired at a 400-foot
station interval along the traverse lines (Figure 2K-6).
In areas where greater detail was required to more closely
determine the location of a causative feature for an
anomaly, stations were established at a 100-foot interval.
Additional gravity stations were also established in
Sections 32 and 33 of T13N, R27E, approximately one mile
south of Gable Mountain (Figure 2K-6A) to investigate the 28
May Junction monocline. The stations were located along
eleven traverse lines (8A-8N, 8J and portions of Lines 8
and D) at 100-foot intervals.

Gravimeter dial readings were converted to milligal values
utilizing conversion factors appropriate to the instrument
(supplied by the manufacturer). The data were corrected
for instrumental and tidal drift by means of base station 23
reoccupations at intervals of three hours or less. The
drift was considered linear over this time period.

Subsequent to correcting the gravity observations for instrumental and tidal drift, the data were corrected for latitude as well as station elevation and assumed rock density (combined free air and Bouguer corrections). The gravity data were all reduced to a datum elevation of sea level utilizing a density of 2.67 g/cm$^3$. The resulting simple Bouguer gravity values, in the vicinity of Gable Mountain and Umtanum Ridge, were individually corrected for the surrounding variations in terrain according to Hammer (1939) and Douglas and Prahl (1971). The effects of variations in the terrain within a 13.6 mile radius were applied to each station in these two localities.

The resultant gravity data points were then processed and contoured to produce total, regional and residual Bouguer anomaly maps.

### 4.1.3 LAND MAGNETIC DATA

#### 4.1.3.1 Data Acquisition and Processing

Land magnetic data were acquired along five hundred miles of traverse lines during this investigation. All data were acquired utilizing proton precession magnetometers and were recorded to the 1.0 gamma reading accuracy of the instruments. Local base stations were used for standard closure procedures to monitor the diurnal variations of the earth's magnetic field. 23

The magnetic data were acquired at 100-foot intervals for one-quarter to one-third of the data collected along the lines illustrated in Figure 2K-6. The remaining data were acquired at 50-foot intervals.

Subsequent to correcting the diurnal drift, the data for each line were plotted in profile form and evaluated collectively with the seismic refraction and the gravity data for the same line.

## 4.2 SUPPLEMENTAL GEOPHYSICAL DATA

### 4.2.1 DATA SUPPLIED BY WASHINGTON PUBLIC POWER SUPPLY SYSTEM

The Washington Public Power Supply System provided gravity, land magnetic, aeromagnetic and seismic refraction data to augment the data acquired for Northwest Energy Services Company. The Supply System data were used to assist in planning of the NESCO programs as well as combined with NESCO data to increase the data base available for interpretation.

The interpretations by Weston Geophysical (Weston Geophysical, 1978c; Washington Public Power Supply System, 1977, Appendix 2R-1) of both the gravity and land magnetic data provided guidelines for new programs.

The aeromagnetic data acquired by the Supply System (Figure 2K-7) were also utilized in the geophysical investigation 23
of the Hanford Site. Details of the aeromagnetic survey, as well as previous interpretations, can be found in Washington Public Power Supply System (1977, Appendix 2R-I) and Weston Geophysical (1978a).

Seismic refraction data collected by Weston Geophysical in the vicinity of the Supply System sites (Washington Public Power Supply System, 1974) provided guidelines for data acquisition and processing techniques, as well as additional input concerning the seismic characteristics of the overburden of the Hanford Site.

Additional gravity and magnetic data in the vicinity of Line 4A (Figure 2K-7A) and gravity data on Savage Island and east of the Columbia River (Figure 2K-7B) acquired for 28
the Supply System (Weston Geophysical, 1982) supplemented the NESCO data base for further evaluation of the Southeast anticline.

### 4.2.2 DATA SUPPLIED BY ROCKWELL HANFORD OPERATIONS

Rockwell Hanford Operations provided land magnetic and gravity data, aeromagnetic contour maps of a multi-level survey, and prints of processed reflection data. These data, acquired during Rockwell's siting program for a 23
nuclear waste repository, were utilized in program planning and were evaluated relative to the data obtained for the Skagit/Hanford Project. The locations of the Rockwell reflection profiles and those Rockwell gravity data utilized in this study are shown on Figure 2K-8.

# 5.0 RESULTS OF INVESTIGATIONS

## 5.1 REGIONAL GEOPHYSICAL SETTING

The Central Columbia Plateau of south-central Washington has been studied extensively during the past five to ten years. A large volume of geophysical data has been acquired by the United States Geological Survey (Swanson, et al., 1979 and Zietz, et al., 1971), by Rockwell Hanford Operations in their siting program for a waste repository (Myers and Price, 1979, and others), by various consultants to Washington Public Power Supply System (Weston Geophysical, 1978a; 1978b; 1978c; Washington Public Power Supply System, 1981, 1977) and through the present investigations for NESCO.

The gravity map for the Central Columbia Plateau (Figures 2K-9 and 2K-10) defines a north-northeast trending, semi-rectangular gravity high with two "lobes" extending from its southeastern and southwestern extremities. The rectangular high has been interpreted as defining a thick section of relatively high density material. The lower, high density body underlies 1-2 kilometers of Columbia River Basalts and has been modeled at 3-5 kilometers thick. The sides of the lower body dip inward at slopes ranging from 5°-45° (Washington Public Power Supply System, 1981, Appendix 2.5L). The present study area is located over the central portion of the rectangular high and is underlain by 5-7 kilometers of basalt and probable basaltic material. The generalized configuration of the subsurface basalt topography of the Hanford Site is depicted on the Hanford 1° gravity map (Figure 2K-12). The Gable Butte-Gable Mountain segment of the Umtanum Ridge-Gable Mountain structural trend is indicated by an elongate, 5 milligal gravity high trending N75°W, north of the Skagit/Hanford site.

Interpretations of aeromagnetic data for the Columbia Plateau also indicate an excess thickness of dense, magnetic rocks beneath the plateau. Zietz et al. (1971) interpreted a high-level (15,000 feet above sea level) survey and postulated the thickest section of basalt as underlying the region along the eastern margin of the Hanford Site. The interpretations of low-level surveys (Washington Public Power Supply System, 1977, Appendix 2R-I; Swanson et al., 1979; Weston Geophysical, 1978a) have characterized the prominent anticlinal ridges of the Yakima Fold Belt and defined the subsurface extensions of these ridges within the Hanford Site. Swanson et al. (1979)

## 5.2.4.2 Discussion of Results

### 5.2.4.2.1 Aeromagnetic Data

The existing aeromagnetic data, those of Washington Public Power Supply System and Rockwell Hanford, exhibit similar features to those identified from the gravity data collected for Northwest Energy Services Company. The prominent north-south magnetic feature is the May Junction linear of Rockwell (Myers and Price, 1979). This north-south gradient (Figure 2K-46) intersects the northwest-trending magnetic anomalies to the west and bounds a large, 23
regional magnetic low to the east. The May Junction linear indicates the location of a known bedrock gradient with up to 350 feet of relief based on drill hole and other geophysical data.

### 5.2.4.2.2 Gravity Data

The Bouguer gravity map of the May Junction area shown in Figure 2K-47 was processed with a density of 2.67 g/cm$^3$. Because of the contrast in density between basalt and sediments (0.3 to 0.7 g/cm$^3$), the map is controlled mainly by the topography of the basalt. The gravity data acquired along eleven east-west traverse lines intersecting the trend of the May Junction monocline (Figure 2K-6A) provides greater detail on the configuration of the top-of-basalt. The gravity anomaly contours, as illustrated on the detailed Bouguer gravity map of the area (Figure 2K-47A), are consistent with a north-south trending bedrock surface sloping gently toward the east. The north-south trending May Junction gradient is produced by the change in depth to the top of basalt of approximately 350 feet. 28

A model of the subsurface geology that satisfies both the results of drilling and the gravity along Line 8C is shown on Figure 2K-47B. The densities used for the units are 2.60 g/cm$^3$ for the basalt, 2.45 g/cm$^3$ for the Ringold Basal Unit I gravel, and 2.0 g/cm$^3$ for the Rattlesnake Ridge interbed and the remainder of the sedimentary section. The elevation of the basalt surface varies smoothly. The maximum slope of the basalt surface along the May Junction structure at Line 8C is 10$^{\circ}$ as determined by drilling data and gravity modeling.

5.2.4.2.3 Seismic Data

The north-south trending May Junction linear observed in the gravity and magnetic data is clearly present on seismic lines 7 and 8. Both lines show a steep rise of the bedrock surface from east to west with a maximum relief of 350 feet. As shown in the bedrock contour map (Figure 2K-48), the northwest-trending DB-10 ridge is not distinct at its projected intersection with Lines 7 and 8. The dominant north-south May Junction monocline interferes with the northwest trend of the DB-10 anticline. The bedrock surface on Line 8 is irregular at the intersection of the two trends.

The bedrock velocities in the DB-10 and May Junction areas are indicative of anisotropic conditions. They are consistently higher along north-south trending seismic profiles than on east-west profiles. 23

5.2.4.3 Interpretation

The May Junction monocline produces prominent anomalies in both the magnetic and gravity fields. The data indicate the presence of an eastward-dipping monocline about 2,000 feet wide that strikes north-south for a distance of approximately 2½ miles. This interpretation is consistent with the drill hole profile shown in Figure 2K-43 (provided that the interference of structures in the DH-97, DH-93 area is recognized) and the drilling data noted on Figure 2K-47B. There is no evidence in the seismic refraction or the gravity data to support the fault near Station 435 as proposed on the basis of the seismic reflection data by Seismograph Services Corporation (in Myers and Price, 1979 and shown on Figure 2K-45). The change of Bouguer gravity anomaly across the May Junction monocline is due to the 28 change of elevation of the top of basalt, change of density in the Ringold section and variation of the regional Bouguer gravity anomaly; the change in elevation of the top of basalt accounts for at least 90% of the change. No evidence for offset is present.

In the DB-10 and May Junction areas, the bedrock velocities are higher in a north-south direction than in an east-west direction. The higher velocities (14,000 to 15,000 ft/sec.) approximate the bedrock velocities measured in 23 other areas (16,000 ft/sec.). The minimum values, however, are significantly lower (approximately 12,000 ft/sec.) and could be caused by (1) primary features in the basalt, (2) anisotropic (horizontal) stress, and (3) open fractures developed in the basalt and oriented north-south. Cause No. 1 is rejected because the same basalt unit is present elsewhere on the reservattion and does not exhibit anisotropy outside the DB-10 area. Cause No. 2 is rejected as the chief cause of anisotropy because of the magnitude of the stress difference that is required. Nur and Simmons (1969) showed that a stress difference of 400 bars produced 15% anisotropy in dry Barre granite. A much larger stress difference would be required for saturated or partially saturated rock. We attribute the cause of the anisotropy to cause number 3, fractures in basalt.

The broad, first-order antiform of the Gable Butte-Gable Mountain segment is bounded by the May Junction monocline. An elongate gravity high indicative of a small anticlinal fold extends across the southern portion of the May Junction monocline. The geometry does not imply an age relationship between the two features. This small northwest-trending anticline is separate and distinct from the Southeast Anticline.

23

## 5.3 SOUTHEAST ANTICLINE

### 5.3.1 INTRODUCTION

The aeromagnetic data acquired by Washington Public Power Supply System (Figure 2K-49) show a magnetic high trending southeasterly from the eastern end of Gable Mountain. Two aeromagnetic survey blocks are joined along the axis of this magnetic high. Those individual flight lines which overlap from one survey block to another have been evaluated and confirm that the magnetic high is real and not an artifact of merging the two aeromagnetic survey blocks. Rockwell's 1980 aeromagnetic survey of the Hanford Reservation area further confirms the existence of this aeromagnetic high. Extensive seismic refraction, gravity and land magnetic data were acquired to characterize this anticlinal ridge and to define the structural relationships between the Southeast Anticline and the first-, second-, and third-order folds of the Umtanum Ridge-Gable Mountain structural trend.

## 5.3.2 DISCUSSION OF RESULTS

### 5.3.2.1 Magnetic Data

An aeromagnetic high, generally symmetrical in shape,
trends in a southeasterly direction from the eastern end of 23
Gable Mountain to the vicinity of Line 4C. At this
location the anomaly decreases in amplitude and appears to
be offset to the southwest. This lower amplitude magnetic
high continues trending southeasterly and then easterly in
the vicinity of Lines 4E and 4F.

The individual land magnetic profiles (Figure 2K-50)
indicate a feature which may be more complex than the
aeromagnetic data would indicate. A sharp anomaly (A)
trends in a S60°E direction from Line 3 to Line 1-A but is 24
not traceable south of Line 1-A. The single peaked,
magnetic anomaly on Line 1 broadens and divides into two
more subdued peaks (B and b) in the vicinity of Line 4B.
The northeasterly of the two southeast trends decreases in
amplitude to a magnetic low (C) on Line 4D. The 23
southwesterly of the two southeast-trending highs appears
to continue southeast of Line 4D but is then offset in an
en echelon manner, similar to the aeromagnetic data, to a
southeasterly-trending lower amplitude magnetic high on
Lines 4E and 4F (D).

Land magnetic data acquired for the Supply System in the
immediate vicinity of Borehole 125 on Line 4A (Weston 28
Geophysical, 1982) have been contoured and are shown on
Figure 2K-50A. A small residual magnetic high of approximately 25 gammas, located just southwest of Borehole 125,
is consistent with a small undulation in the top of basalt.

### 5.3.2.2 Gravity Data

The gravity data processed at a density of 2.67 g/cm$^3$
(Figure 2K-51) define a gravity high trending southeasterly
from the Gable Mountain area. Detailed gravity coverage
(Figure 2K-6) shows that the northwest portion of this 23
gravity feature is quite linear and appears to extend one
mile northwest of the eastern end of Gable Mountain.

The southeast-trending gravity high is generally symmetrical in shape and decreases in amplitude toward the southeast. Assuming that 1 milligal gravity is equal to about 150 feet of basalt relief, the basalt surface slopes at angles ranging from 5 to 13 degrees. The gravity data clearly indicate that the southeast-trending feature changes trend to east-northeast in the vicinity of Lines 4C and 4D. 23

Gravity data acquired for the Supply System (Weston Geophysical, 1982) provides additional information on two aspects of the Souteast anticline. First, a detailed survey in the immediate vicinity of Borehole 125 on Line 4A (Figure 2K-7A) has delineated a small localized rise in the surface of basalt consistent with the results of the detailed drilling program in that area (Golder Associates, 1982). This localized rise is indicated as anomaly A on 28
the residual Bouguer anomaly map for the area (Figure 2K-51A). Second, additional data acquired on Savage Island and east of the river (See Fig 2K-7B) constrain the extent of the Southeast anticline. The residual Bouguer gravity anomaly attributed to the Southeast anticline terminates in the vicinity of Savage Island (Figure 2K-51B). Therefore, the Southeast anticline does not extend east of the Columbia River.

### 5.3.2.3 Seismic Refraction Data

Seismic refraction data across the Southeast Anticline have been acquired and profiled along Lines 3 (Figure 2K-52), 1 (Figure 2K-54), 4A (Figure 2K-55), and 4B (Figure 2K-56) and on the southwesterly side of the feature on Line 2 (Figure 2K-53). Seismic data were also obtained for portions of Lines 4C (Figure 2K-57), 6 (Figure 2K-58), and 6A (Figure 2K-59) to provide more information on the configuration of the bedrock surface in the area where the gravity and magnetic data indicated a change in the orientation of the feature. Seismic data were acquired on Line 6B (2K-60) to explore the northeast flank of the Southeast Anticline. 23

Overburden seismic velocities in the area of the Southeast Anticline are, in general, typical of those encountered elsewhere in the Hanford Reservation. The low velocity (2,500-3,000 ft/sec.) overburden has a uniform thickness of approximately 100 feet except at the northeast limit of the area near the Columbia River where it thins to 50 feet. Higher velocity overburden materials (9,500-10,000 ft/sec.) underlie the lower velocity material southwest of the bedrock high. The seismic velocity of this material changes to 6,500-7,500 ft/sec. northeast of the bedrock ridge.

The seismic velocity of competent basalt in the vicinity of the bedrock ridge is 15,000-16,000 ft/sec. Highly fractured basalt above a depth of 250 feet in Boring 125 (Line 4A, Figure 2K-55) correlates with a seismic velocity of 7,500 ft/sec. The higher velocity overburden materials also have a velocity of 7,200-7,500 ft/sec. over the anticline, precluding a determination of the lateral extent of the fractured basalt along Line 4A. To the southeast of Boring 125, the velocity of 9,000-9,500 ft/sec. is indicative of cemented overburden materials as identified in Boring 122A. In Boring 109, northeast of Boring 125, the 7,200-7,500 ft/sec. material has been identified as overburden.

The fractured basalt encountered on Line 4A in the vicinity of Boring 125 probably extends along strike of the ridge. Differences between the seismic top of rock elevations and borehole bedrock elevations also occur on Lines 1, 3 and 4B along the southwest side of the bedrock ridge. Basalt elevations in Boreholes 105 (Line 1) and 37 (Line 3) are 50 to 100 feet above the seismic top of high velocity bedrock (16,000 ft/sec.). The materials above the 16,000 ft/sec. horizon have a seismic velocity of 6,800-7,500 ft/sec. and are described in the boring logs as "weathered basalt." To
the southeast, on Line 4B, "extremely weathered, fractured 23
basalt" was logged in Boring 101 at elevation 234, 75 feet above the top of seismic high velocity basalt.

The profiles for Lines 1 (Figure 2K-54), 3 (Figure 2K-52), and 4A (Figure 2K-57) show slopes on the high velocity bedrock ranging from $5^{\circ}$ to $9^{\circ}$ on each side of the bedrock high. The profile of the southwestern side of the bedrock ridge on Line 2 (Figure 2K-53) also exhibits a bedrock slope of approximately $10^{\circ}$. All of the bedrock slopes described above are smooth.

The top of high velocity basalt contour map (Figure 2K-61) compiled from the seismic refraction data for the Southeast Anticline defines a southeast-trending, broadly asymmetrical anticline feature. The anticline extends from the vicinity of Line A to Line 4B where it changes trend from a southeasterly to an east-northeasterly direction. The southwest flank of the anticline has a slightly steeper gradient than the northeast flank. The feature becomes symmetrical as it changes trend to the east-northeast; the maximum slopes on either flank of the ridge decrease to $8^{\circ}$.

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## 5.3.3 INTERPRETATION

Gravity, seismic refraction, land magnetic and aeromagnetic 23
data have defined a southeast trending anticlinal shaped
feature extending from the vicinity of Line A to Line 4C
where it changes trend to east-northeasterly but does not
extend east of the Columbia River. Geochemical analysis of 28
drill cuttings in this location identified the basalt
surface as the same basalt unit. The anticlinal
interpretation is based on the symmetry and broad shape of
the aeromagnetic and land magnetic profiles across the
feature, as well as the slope of the basalt surface as 23
defined by the gravity and seismic data. Slopes on the
basalt surface as determined from the seismic and gravity
data range from 5 to 16 degrees.

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TABLE 2K-1
STRATIGRAPHIC SECTIONS IN TEST PITS 1 TO 7*

**SOUTHWEST TEST PITS**
p-wave = 5,000 to 9,000 ft/sec)

| Depth in Feet | |
|---|---|
| | PIT 6 |
| 0 to 3 | Tan, silty sand. |
| 3 to 5 | Black sand and pebbles. |
| 5 to 6 | Pebble to boulder clasts and tan, silty, clayey sand weakly cemented by caliche in west end of pit and 12-foot square, one-foot high basalt outcrop in east end of pit. |
| | PIT 4 |
| 0 to 3 | Tan to brown silty sand. |
| 3 to 5.5 | Black sand with some gravel. |
| 5.5 to 8 | Pebble to 3-foot boulder clasts with tan, silty, clayey sand. |
| | PIT 1 |
| 0 to 3.5 | Tan, silty sand. |
| 3.5 to 6 | Black, medium sand and some gravel. |
| 6 to 8 | Black, medium sand with pebble to 2-foot boulder clasts, tightly packed and cemented by caliche to a weak conglomerate. |
| 8 to 9 | Same as 6- to 8-foot depth interval but matrix changes to a tan, silty clay. |
| | PIT 3 |
| 0 to 3 | Tan to brown, silty sand. |
| 3 to 7.5 | Pebble to 3-foot boulder clasts with tan to black sand. |
| | PIT 7 |
| 0 to 4 | Tan, silty sand. Loose to weakly consolidated. |
| 4 to 13 | Grain supported sub- to well-rounded pebble-cobble clasts with medium black silty sand matrix, some caliche on cobbles, loose to weakly consolidated. |

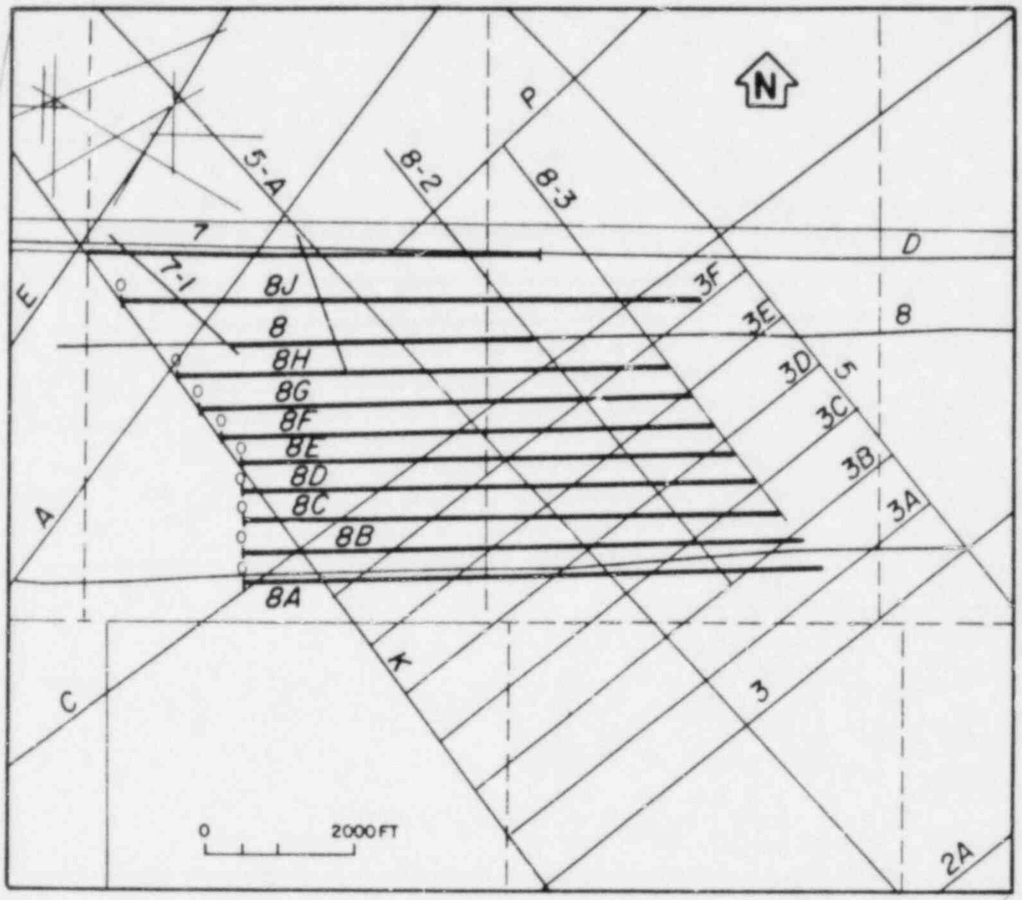
**NORTHEAST TEST PITS**
p-wave = 3,000 to 4,000 ft/sec)

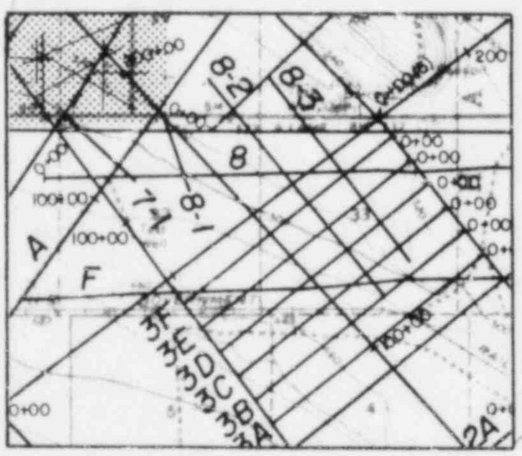
| Depth in Feet | |
|---|---|
| | PIT 2 |
| 0 to 3.5 | Tan, silty sand. |
| 3.5 to 7 | Cross bedded black sand with some pebbles. |
| 7 to 9 | Black sand and pebble to 4-foot boulder clasts. |
| | PIT 5 |
| 0 to 2.5 | Tan, silty, fine sand. |
| 2.5 to 4.5 | Black (basaltic) fine to coarse sand. |
| 3.5 to 6.5 | Black, fine to coarse, sand with increasing percentage of pebble to boulder clasts downward. |

*Test Pit information provided by Golder Associates.

Table 2K-2 deleted.

Table 2K-3 deleted.




FROM FIGURE 2K-6

PUGET SOUND POWER & LIGHT COMPANY
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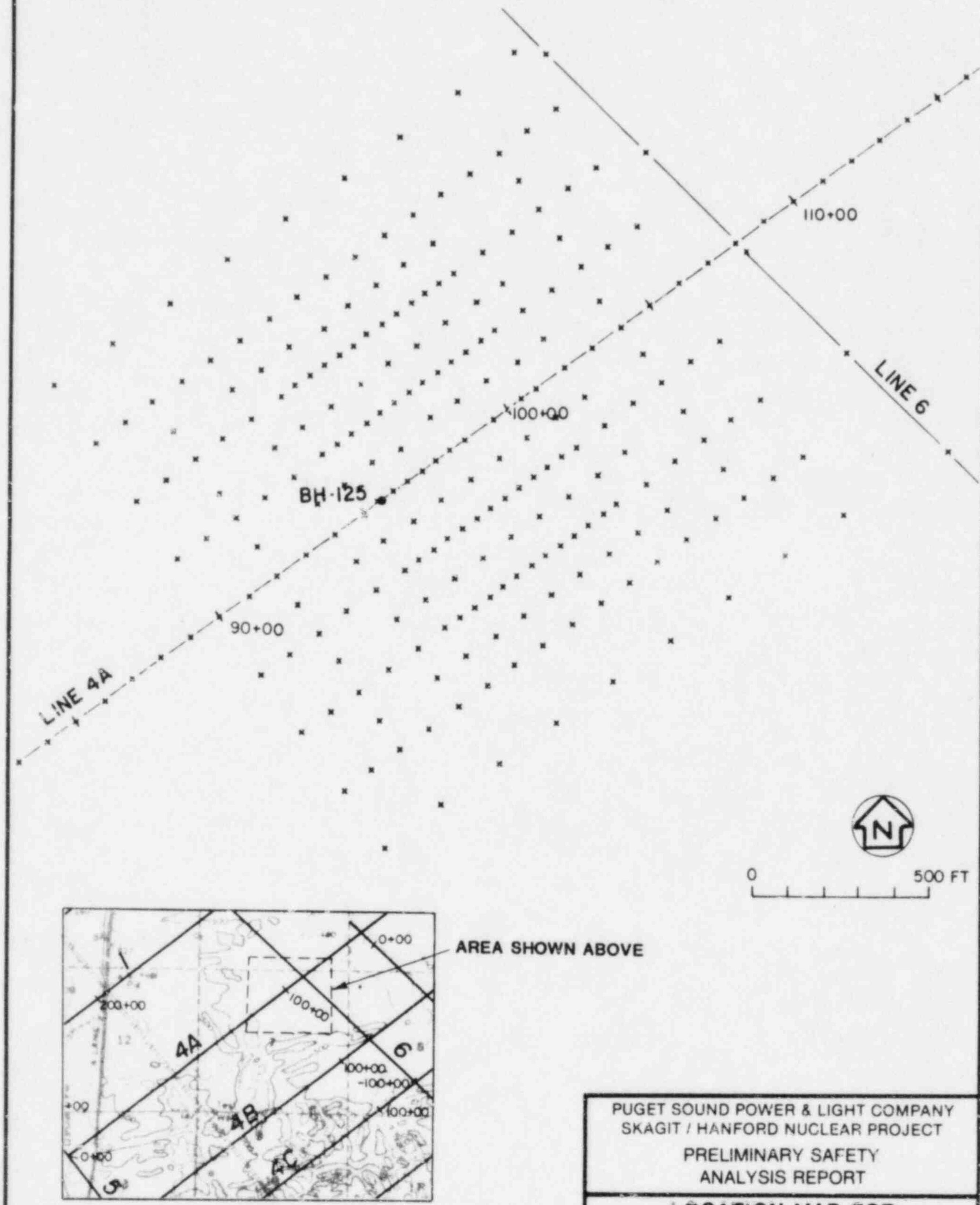
PRELIMINARY SAFETY ANALYSIS REPORT

**LOCATION MAP FOR MAY JUNCTION MONOCLINE GRAVITY STUDIES**

**FIGURE 2K-6A**




FROM FIGURE 2K-6

PUGET SOUND POWER & LIGHT COMPANY
SKAGIT / HANFORD NUCLEAR PROJECT
PRELIMINARY SAFETY ANALYSIS REPORT

LOCATION MAP FOR SUPPLY SYSTEM GRAVITY COVERAGE VICINITY BOREHOLE 125

FIGURE 2K-7A


Data acquired for NESCO

Data acquired for the Supply System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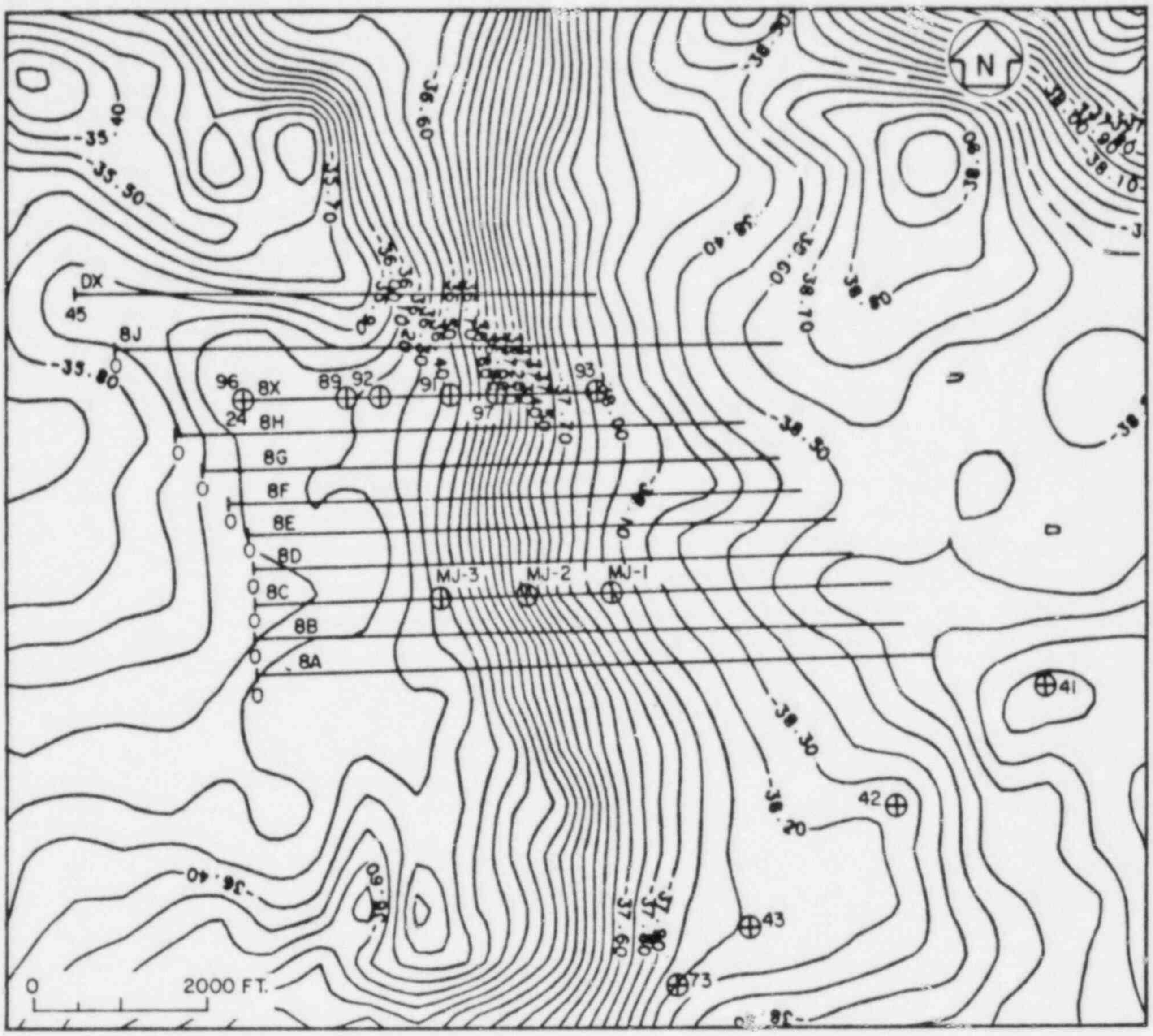
**LOCATION MAP FOR GRAVITY COVERAGE SAVAGE ISLAND AND VICINITY**

**FIGURE 2K-7B**




Contour Interval: 0.1mgal
Data reduced at 2.00g/cm3
⊕ Drill hole location

Note: Difference of approximately 18 mgal between this map and 2K-47 due to:

1) Different Bouguer reduction densities
2) Different reference base datum

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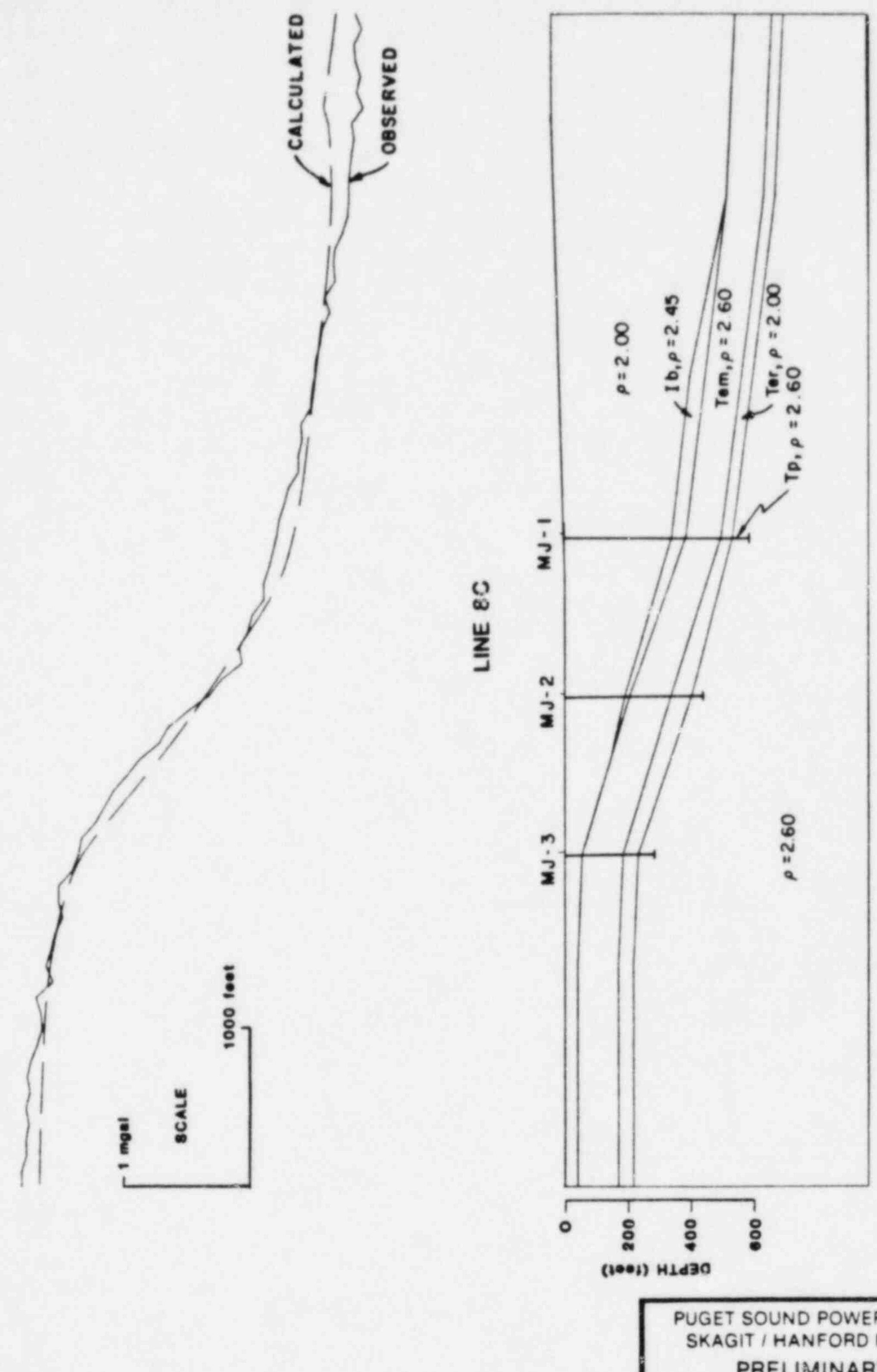
**TOTAL BOUGUER GRAVITY ANOMALY MAP MAY JUNCTION AREA**

FIGURE 2K-47A

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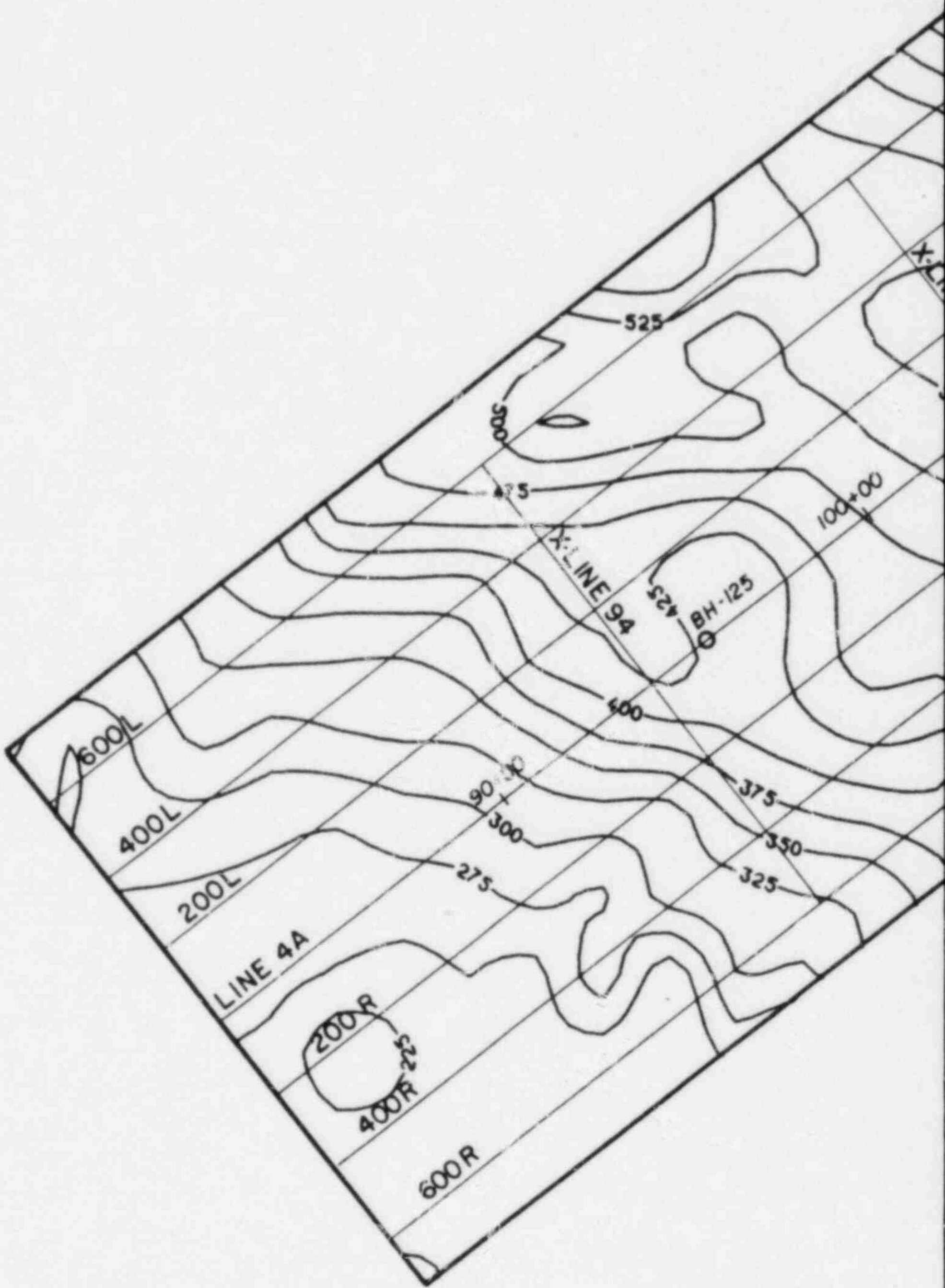
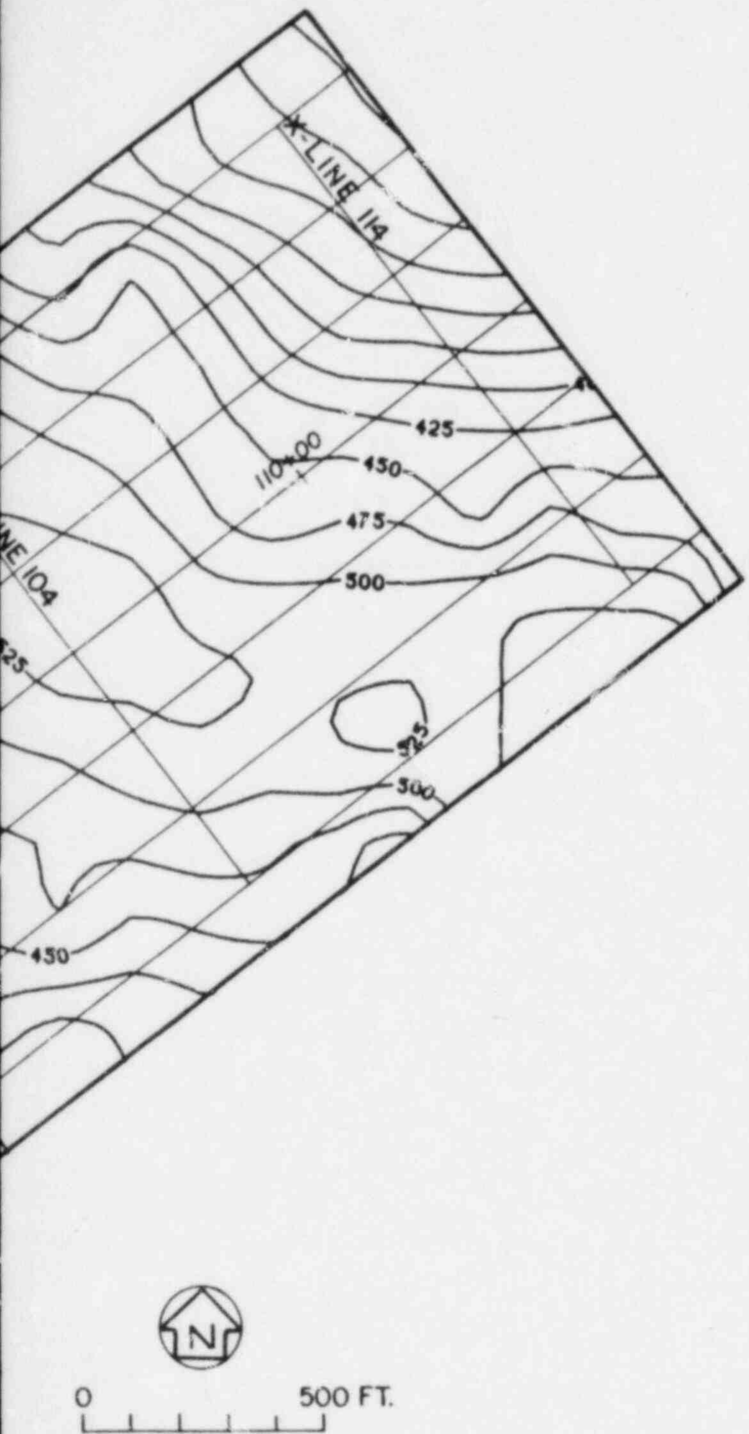
**GEOLOGIC MODEL OF GRAVITY LINE 8C**

FIGURE 2K-47B



525
500
475
X-LINE 94
100+00
425
BH-125
400
375
350
325
300
275
90+00
600L
400L
200L
LINE 4A
200R
225
400R
600R




CONTOUR INTERVAL : 25 GAMMAS

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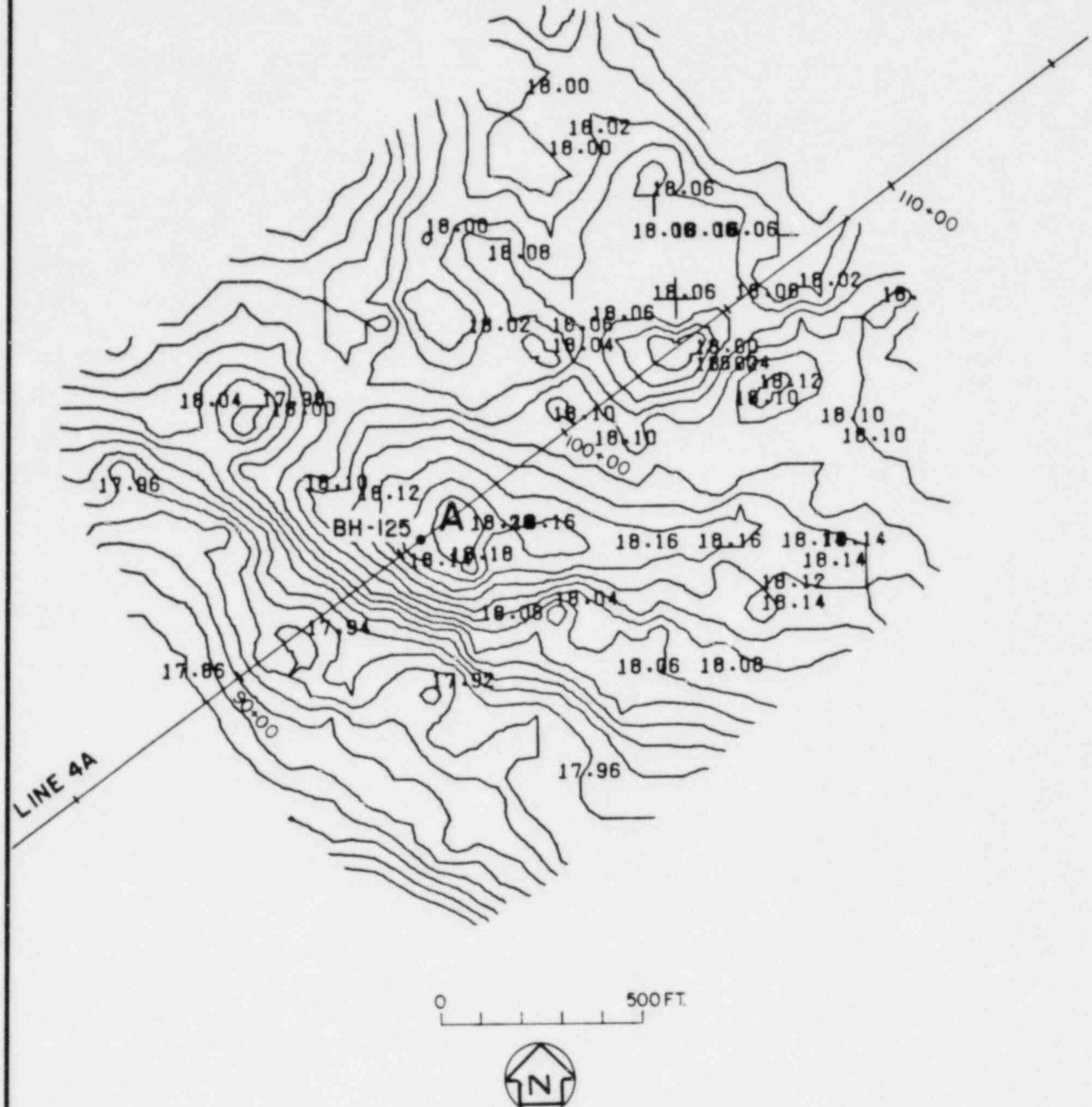
**LAND MAGNETIC CONTOURS VICINITY OF BOREHOLE 125**

**FIGURE 2K-50A**




Data reduced at 2.67g/cm3

Contour Interval: 0.02mgal

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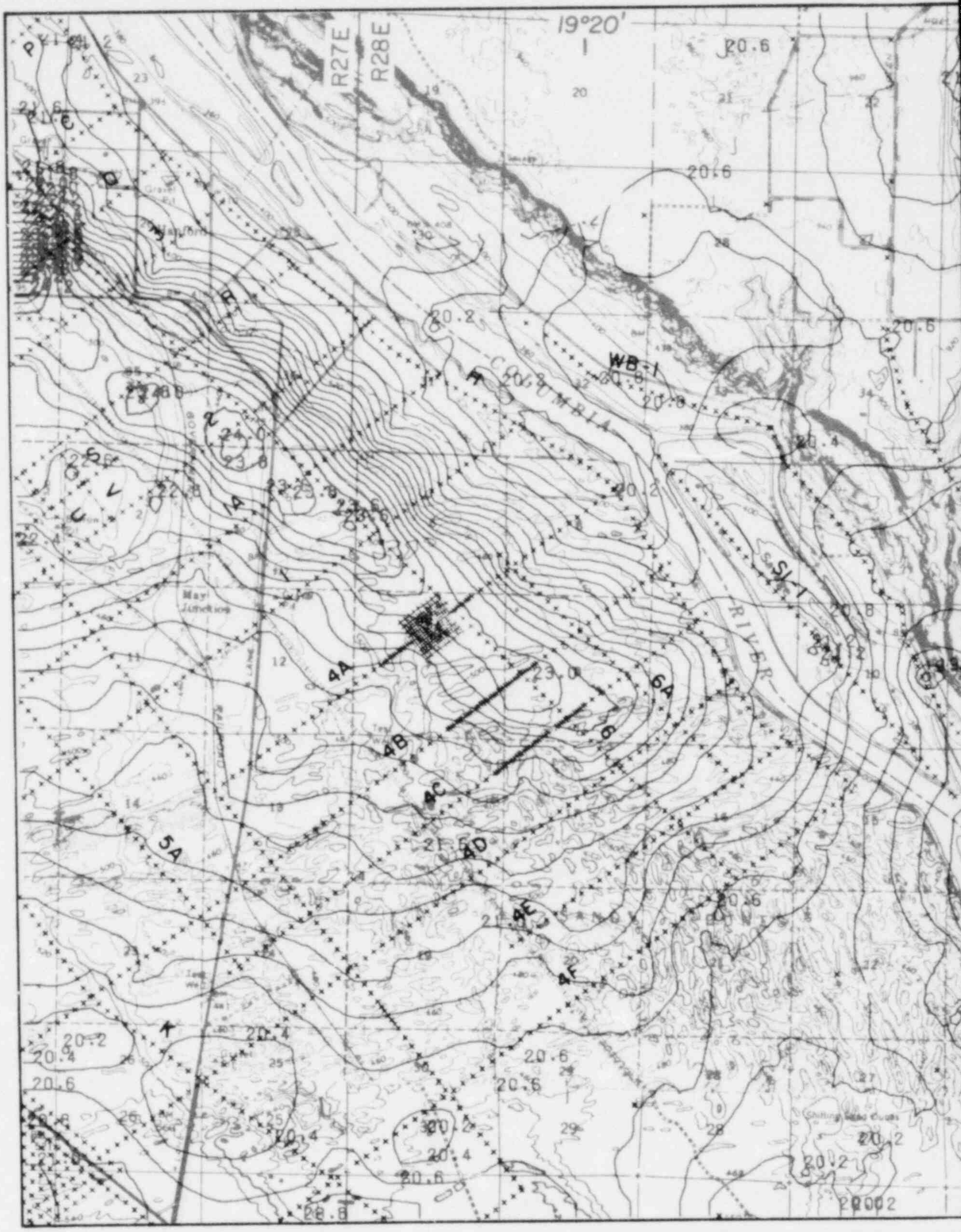
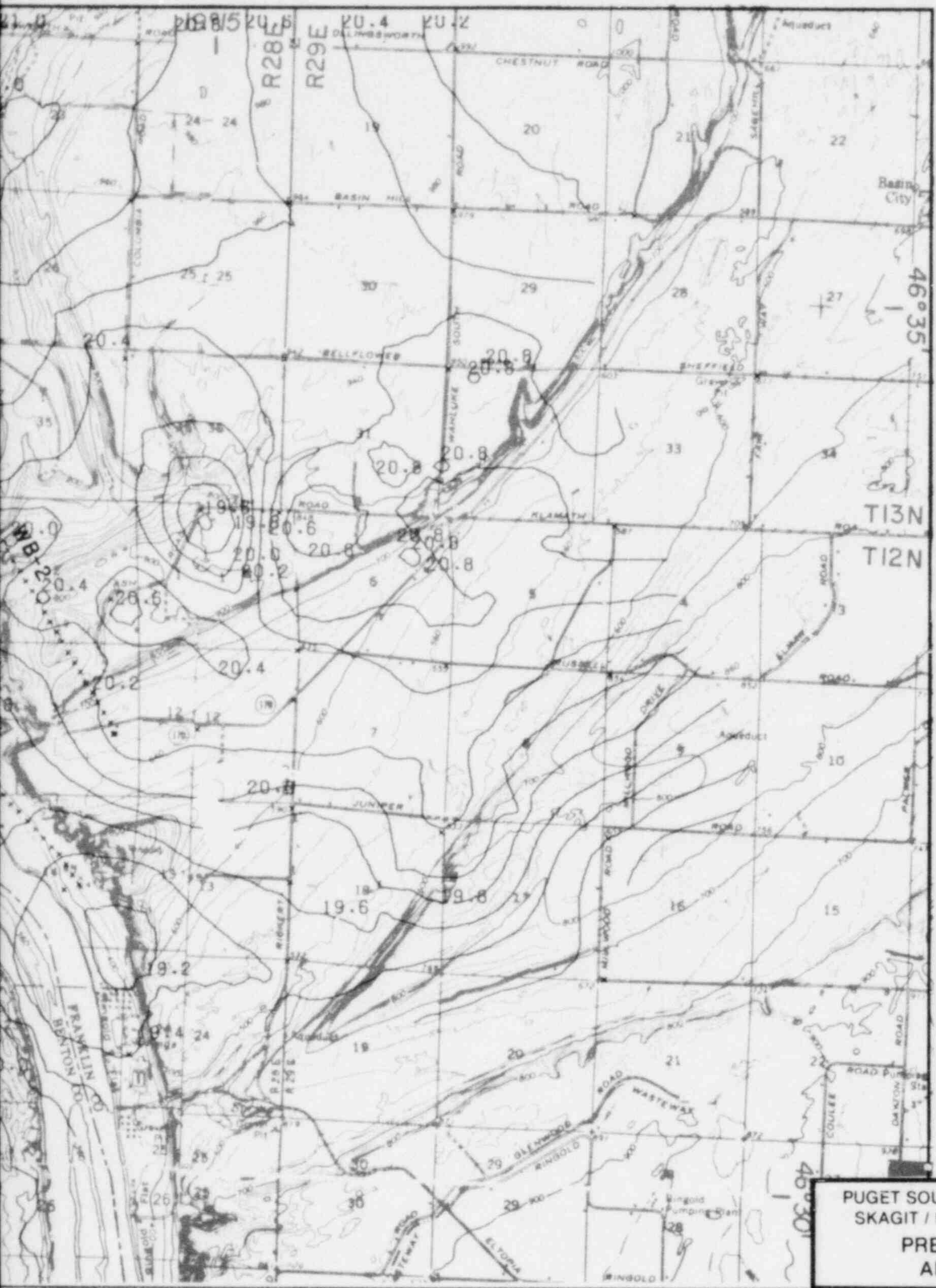
**RESIDUAL BOUGUER GRAVITY ANOMALY MAP VICINITY BOREHOLE 125**

**FIGURE 2K-51A**




CONTOUR INTERVAL:
DATA REDUCED AT 1.8

× GRAVITY STATION




.20 Mgal
g/cm³

0 1 Mile

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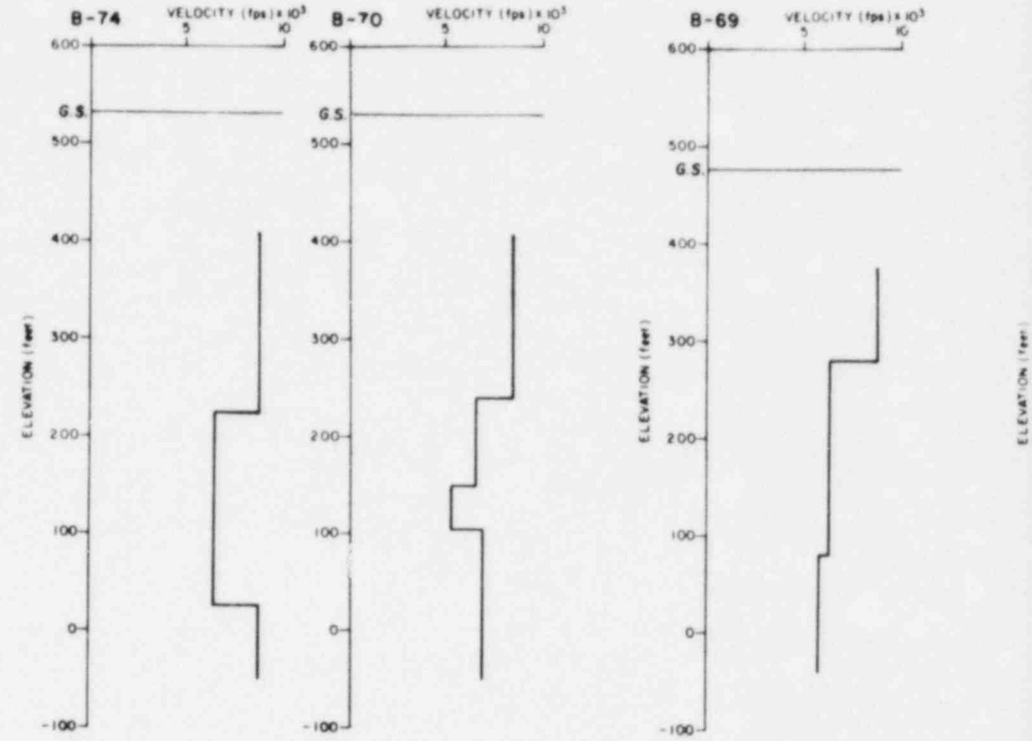
**RESIDUAL BOUGUER GRAVITY ANOMALY MAP SAVAGE ISLAND AREA**

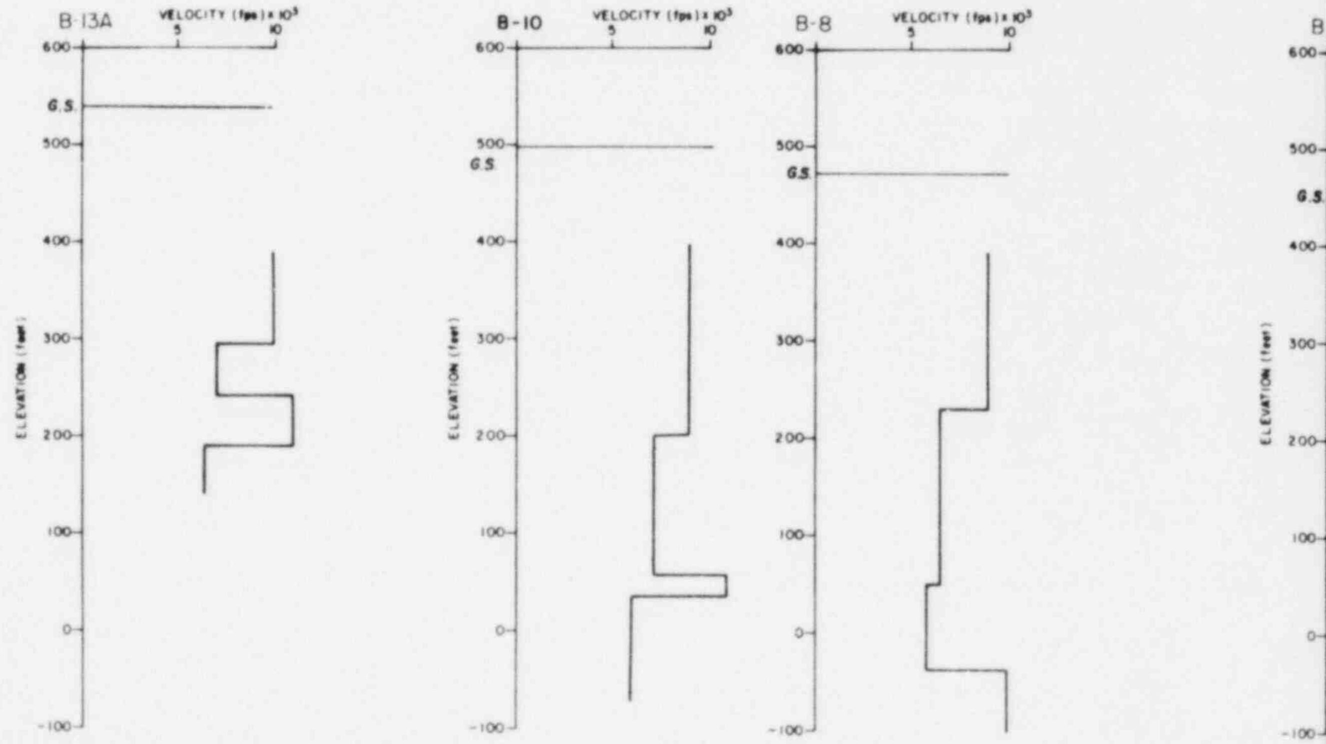
**FIGURE 2K-51B**

LINE 2

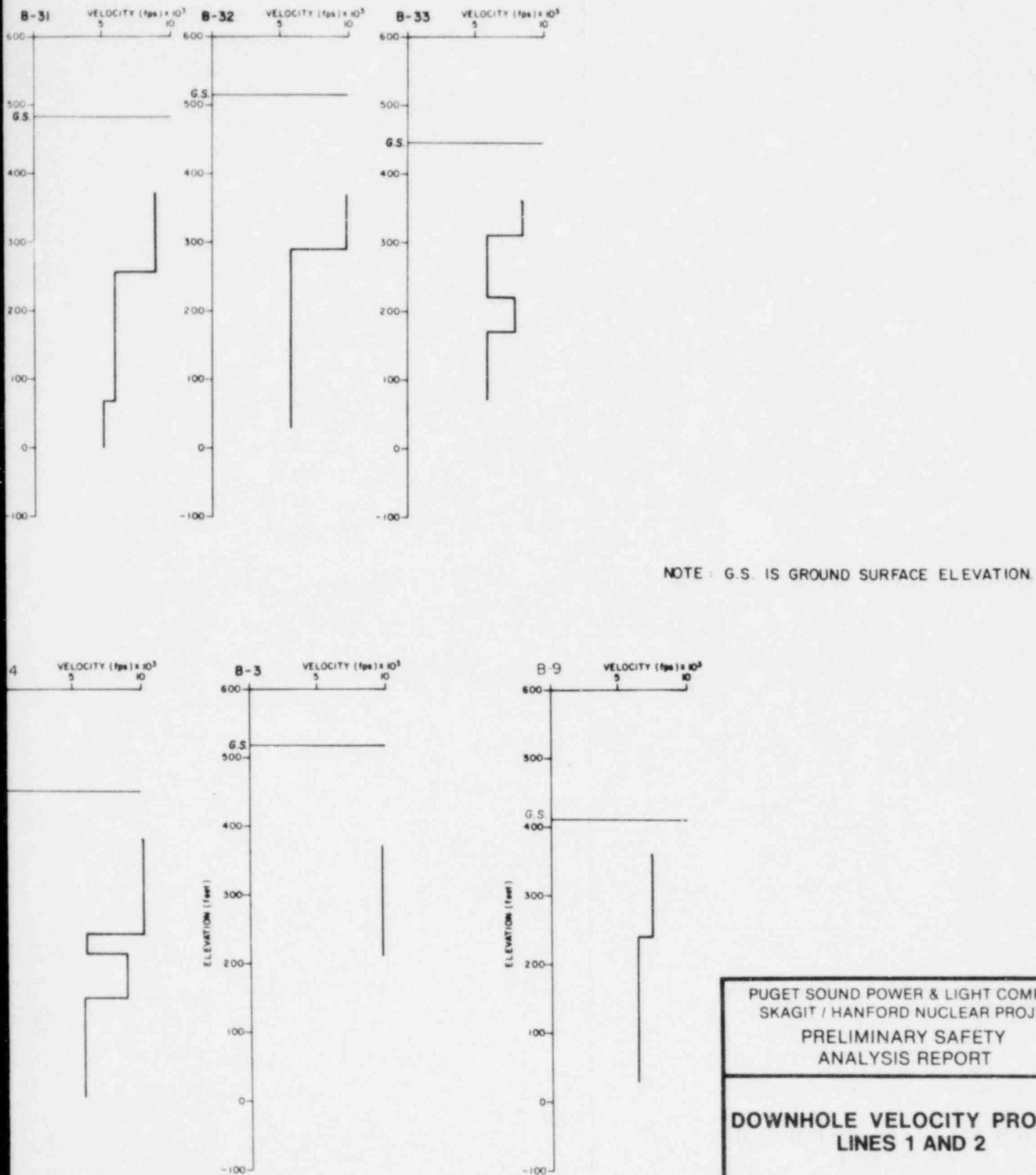


B-74
B-70
B-69
VELOCITY (fps) x 10³
5
10
G.S.
ELEVATION (feet)
600
500
400
300
200
100
0
-100


LINE 1



B-13A
B-10
B-8
VELOCITY (fps) x 10³
5
10
G.S.
ELEVATION (feet)
600
500
400
300
200
100
0
-100

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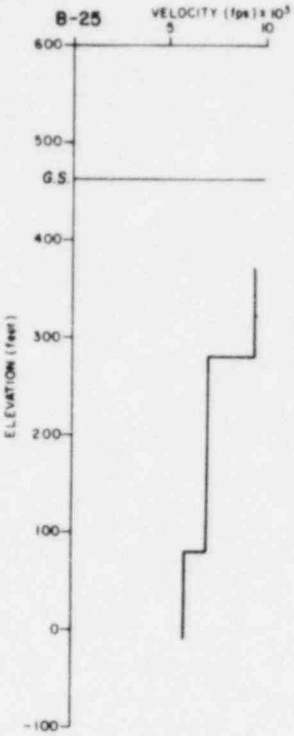
**DOWNHOLE VELOCITY PROFILE, LINES 1 AND 2**

FIGURE 2K-A1

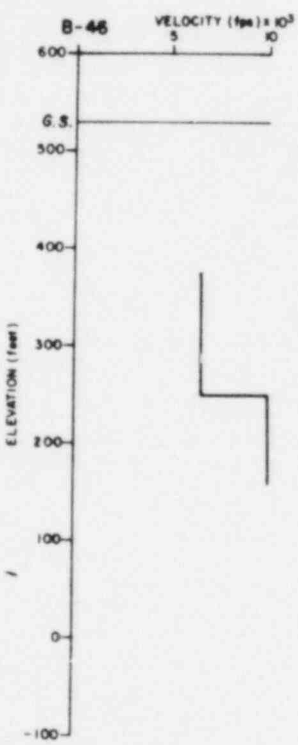
## LINE 5



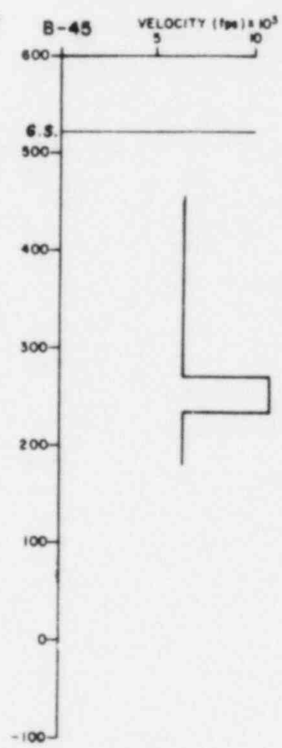
B-25
VELOCITY (fps) x 10³
5
10
600
500
G.S.
400
300
200
100
0
-100
ELEVATION (feet)


B-29
VELOCITY (fps) x 10³
5
10
600
500
G.S.
400
300
200
100
0
-100
ELEVATION (feet)

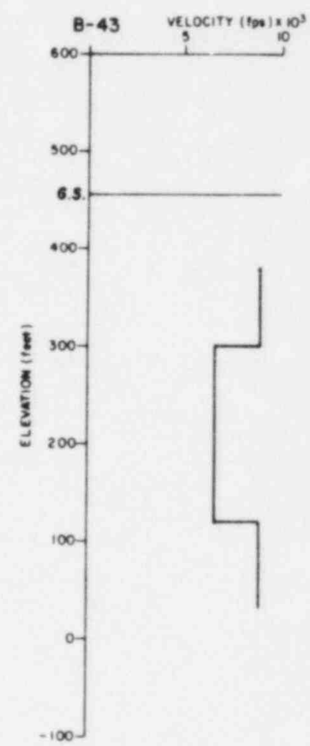

## LINE 3



B-46
VELOCITY (fps) x 10³
5
10
600
G.S.
500
400
300
200
100
0
-100
ELEVATION (feet)

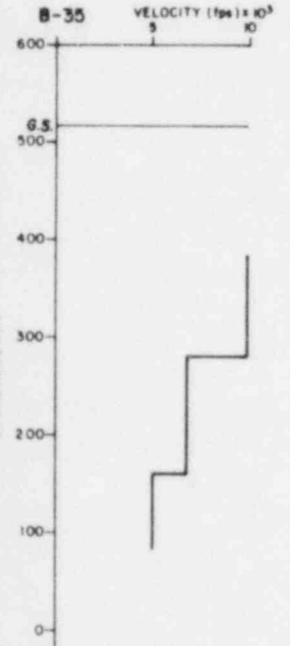



B-45
VELOCITY (fps) x 10³
5
10
600
G.S.
500
400
300
200
100
0
-100

B-43
VELOCITY (fps) x 10³
5
10
600
500
G.S.
400
300
200
100
0
-100
ELEVATION (feet)

NOTE: G.S. IS GROUND SURFACE ELEVATION.

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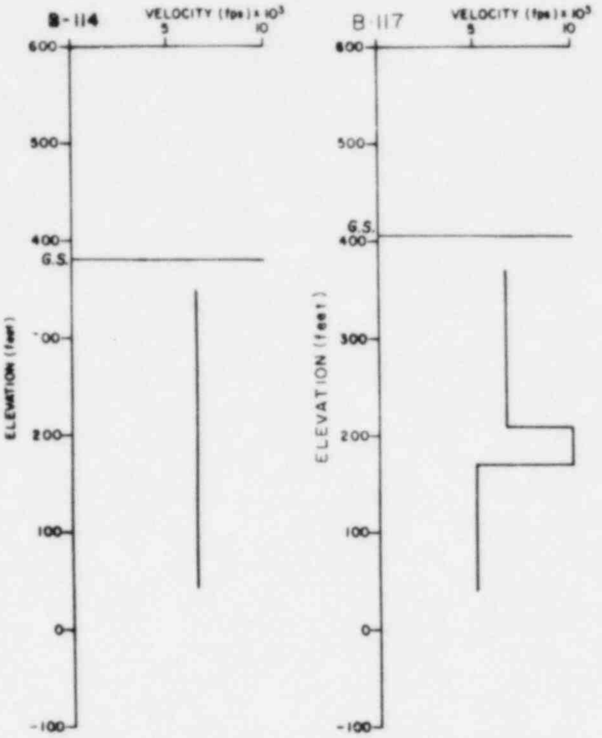
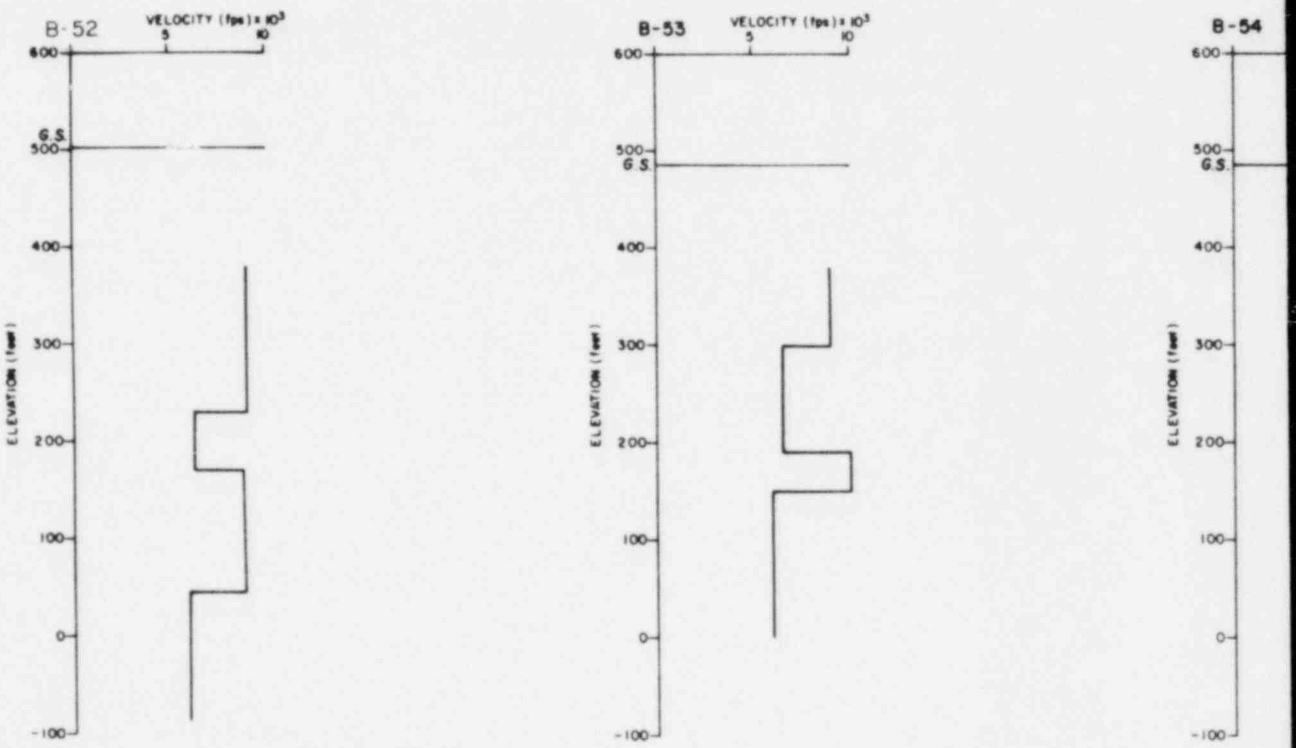
**DOWNHOLE VELOCITY PROFILE, LINES 3 AND 5**

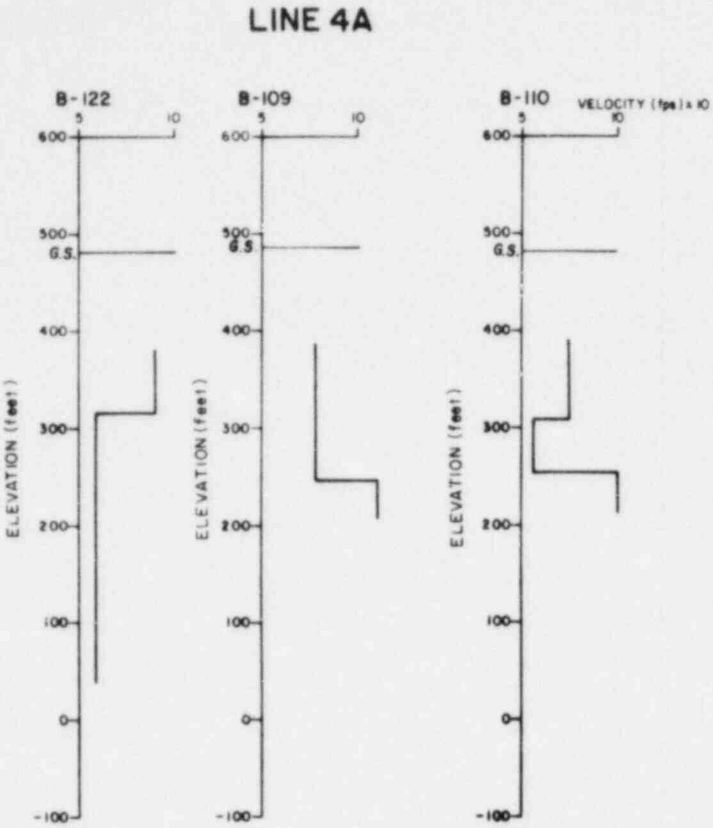
FIGURE 2K-A2

## LINE 6B

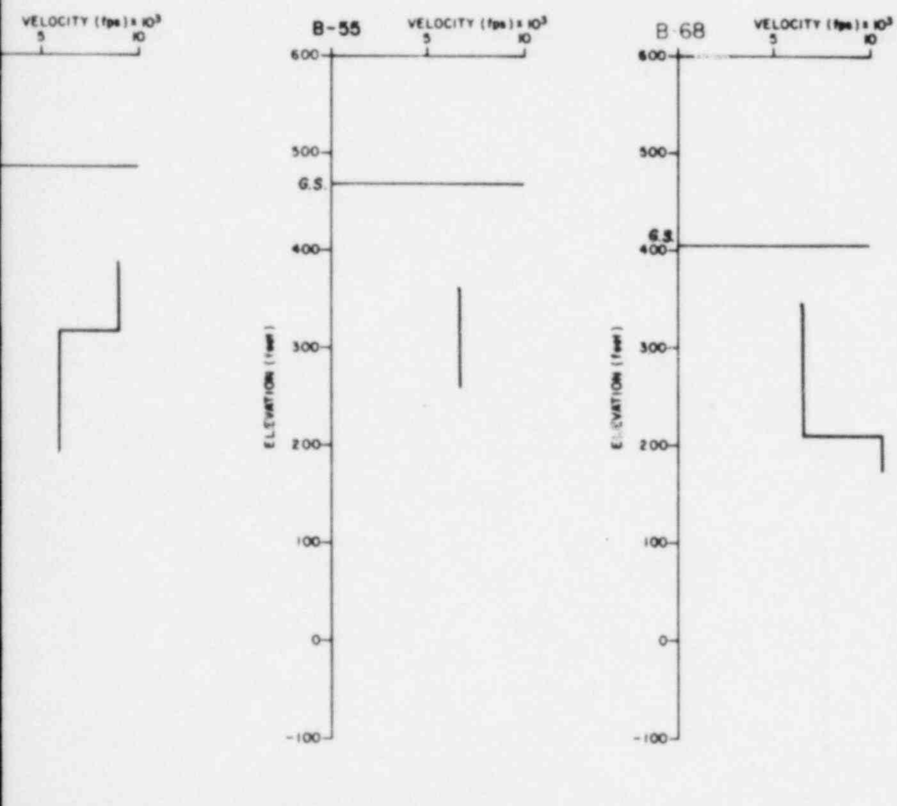



## LINE 4C






NOTE: G.S. IS GROUND SURFACE ELEVATION.

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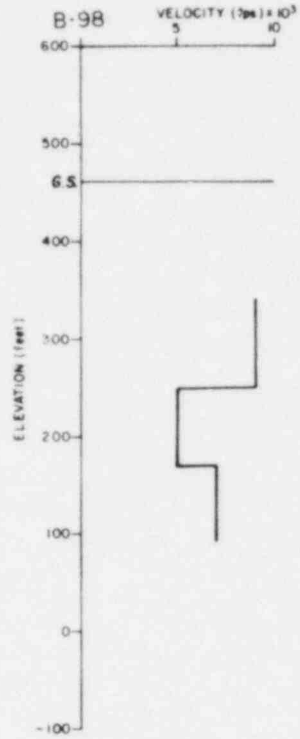
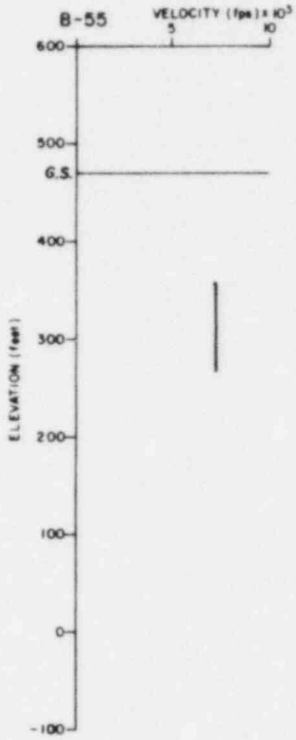
**DOWNHOLE VELOCITY PROFILE, LINES 4A, 4C AND 6B**

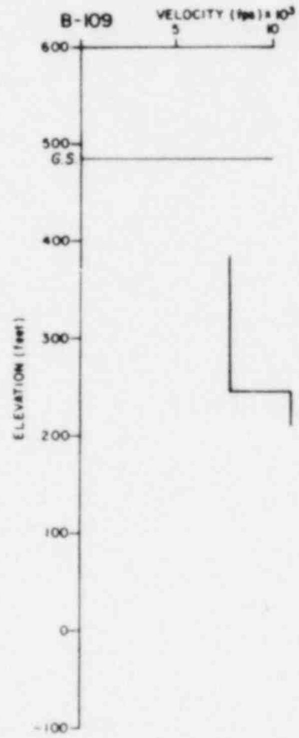
FIGURE 2K-A3

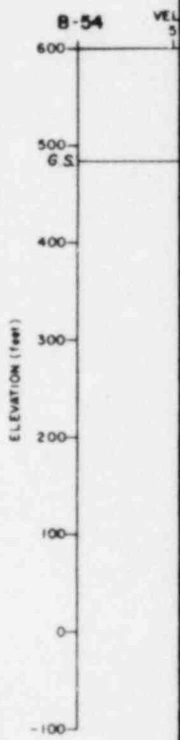
# LINE 6A

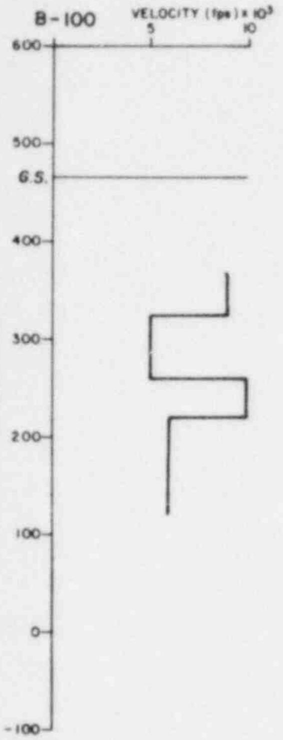



# LINE 6






NOTE: G.S. IS GROUND SURFACE ELEVATION.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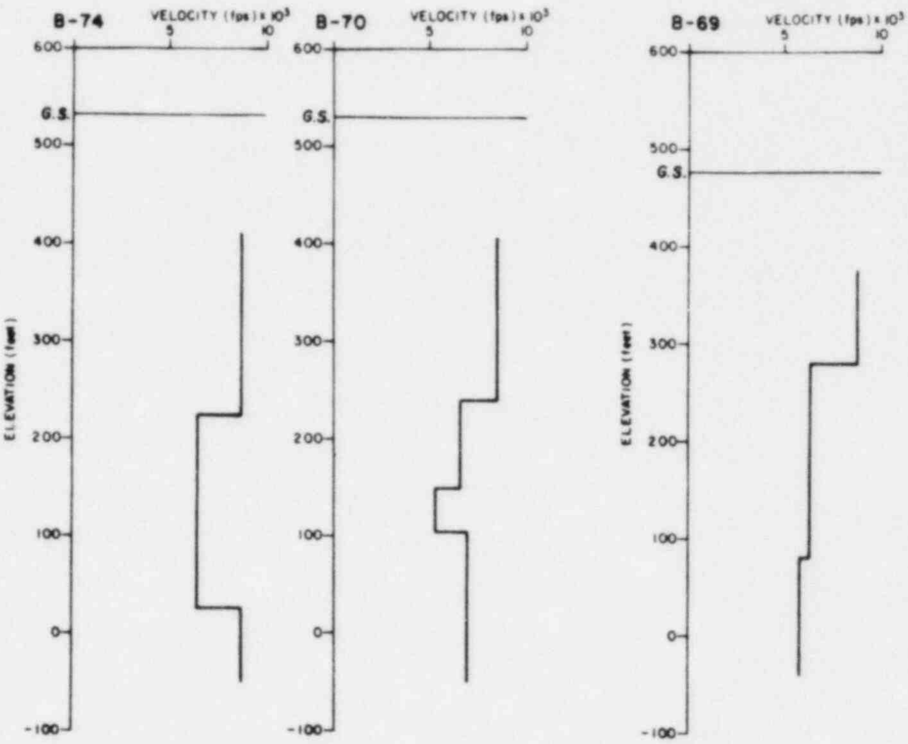
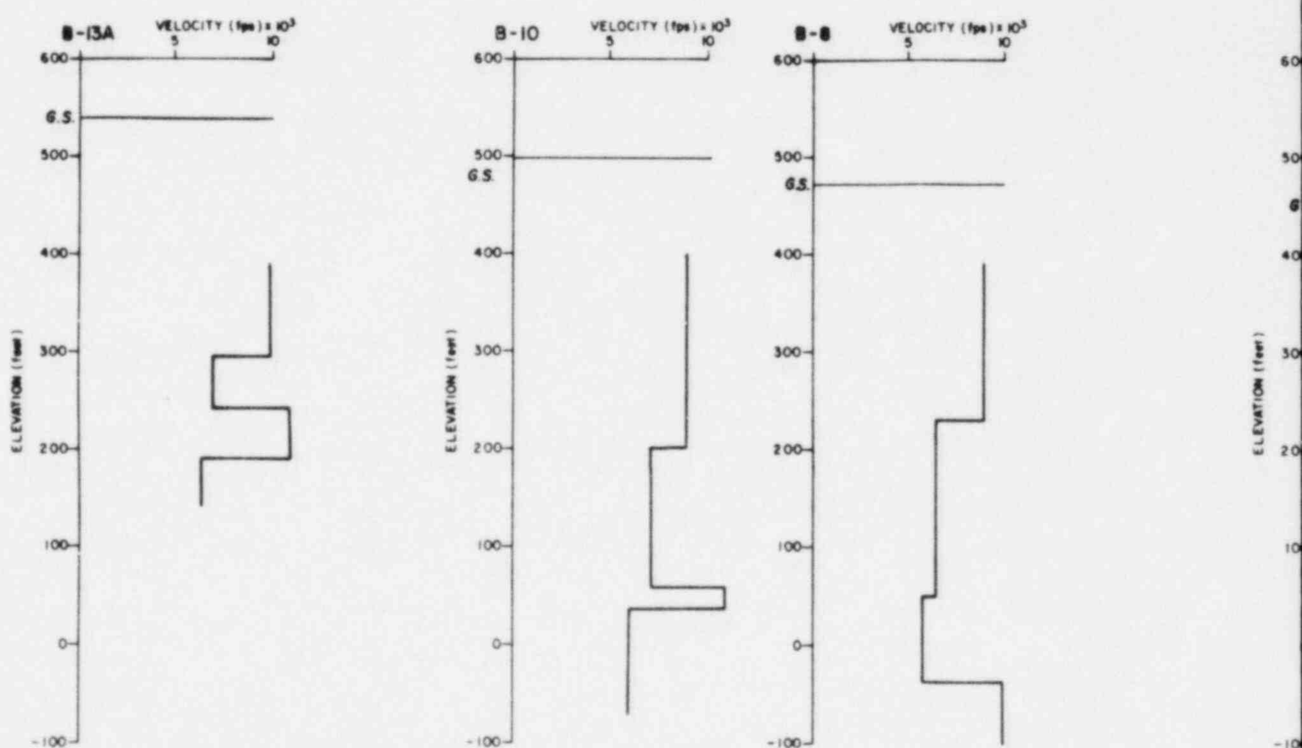
**DOWNHOLE VELOCITY PROFILE, LINES 6 AND 6A**

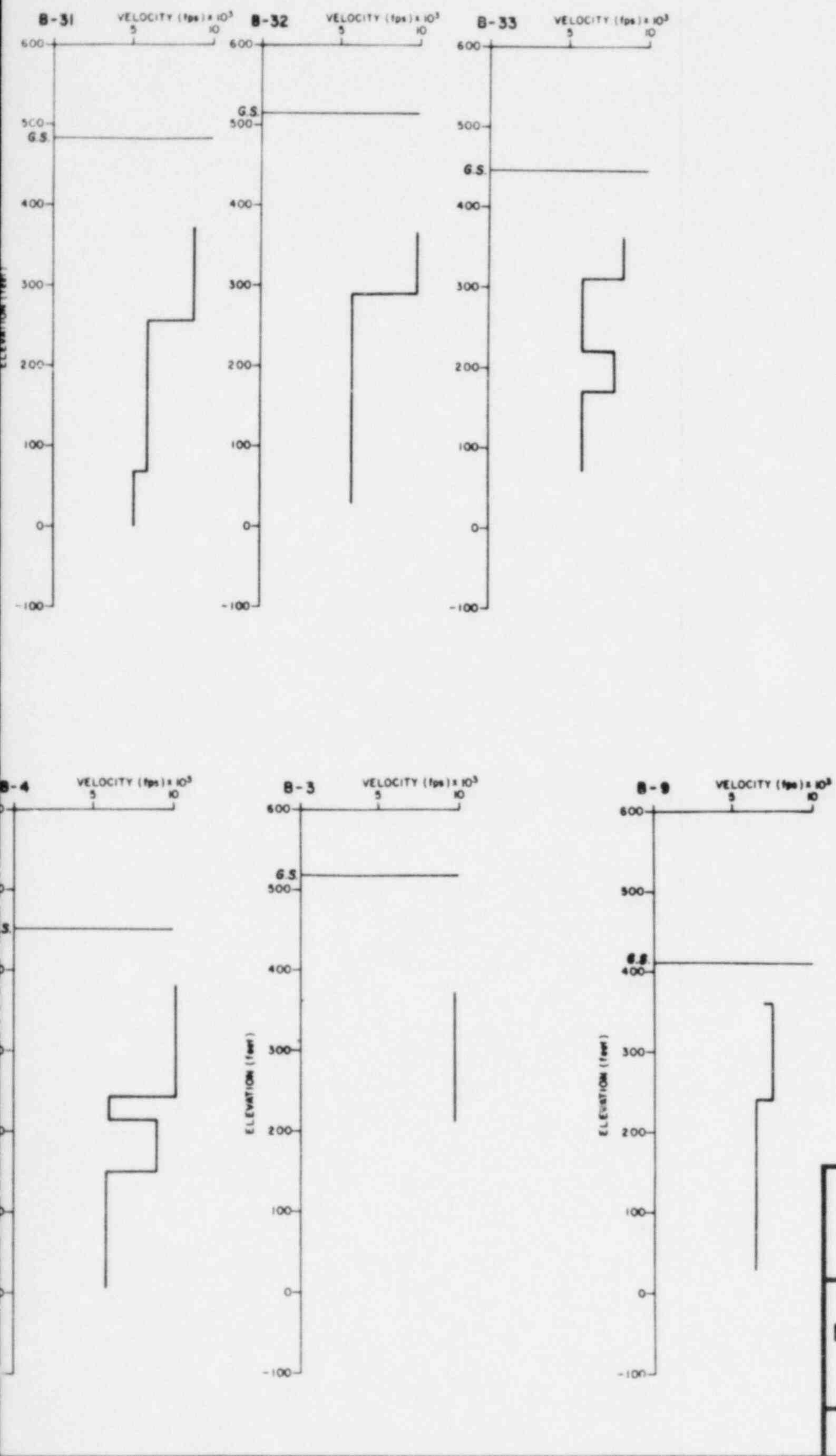
FIGURE 2K-A4

LINE 2


B-74
VELOCITY (fps) x 10^3
B-70
VELOCITY (fps) x 10^3
B-69
VELOCITY (fps) x 10^3
G.S.
G.S.
G.S.
ELEVATION (feet)
ELEVATION (feet)
ELEVATION (feet)

LINE 1


B-13A
VELOCITY (fps) x 10^3
B-10
VELOCITY (fps) x 10^3
B-8
VELOCITY (fps) x 10^3
G.S.
G.S.
G.S.
ELEVATION (feet)
ELEVATION (feet)
ELEVATION (feet)
ELEVATION (feet)

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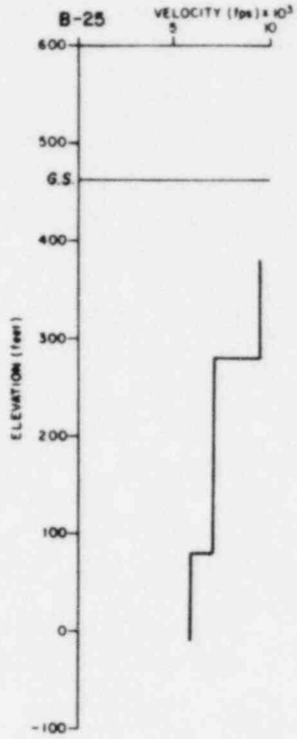
**DOWNHOLE VELOCITY PROFILE, LINES 1 AND 2**

**FIGURE 2L-A6**

## LINE 5

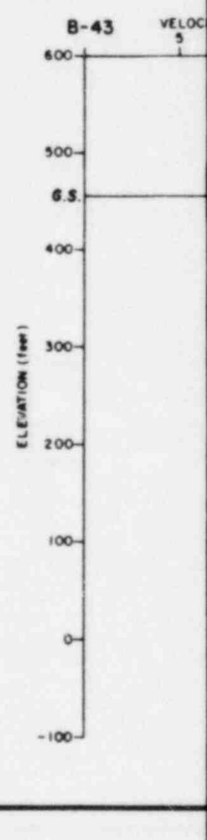


B-25
VELOCITY (fps) x 10³
5
10
600
500
G.S.
400
300
200
100
0
-100
ELEVATION (feet)

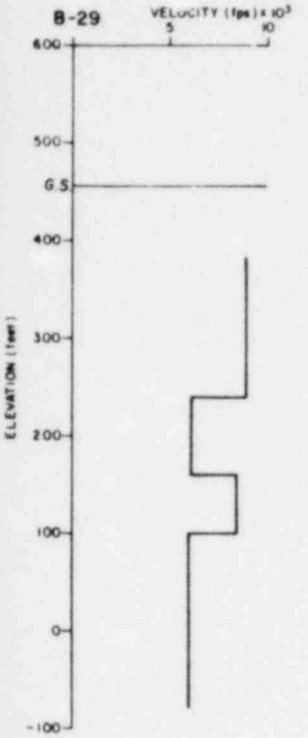

## LINE 3

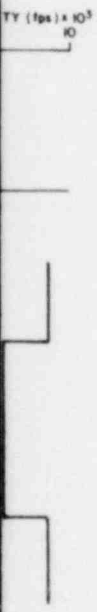
B-46
VELOCITY (fps) x 10³
5
10
600
G.S.
500
400
300
200
100
0
-100
ELEVATION (feet)

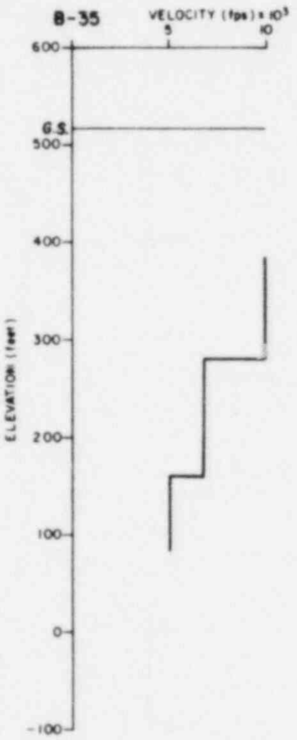

B-45
VELOCITY (fps) x 10³
5
10
600
G.S.
500
400
300
200
100
0
-100

B-43
VELOC
5
600
500
G.S.
400
300
200
100
0
-100
ELEVATION (feet)

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**DOWNHOLE VELOCITY PROFILE, LINES 3 AND 5**

FIGURE 2L-A7

# Appendix 2R

## Stratigraphic Investigation of the Skagit/Hanford Nuclear Project

by

Gary D. Webster and James W. Crosby III

with
Golder Associates

Prepared for Golder Associates
Bellevue, Washington

Geological Engineering Section
Washington State University
Pullman, Washington 99164
November, 1981

(Amended October, 1982)

FIGURES

| NUMBER | TITLE |
|---|---|
| 2R-A-88 | Interpretive Petrographic Log, Drillhole S-1 |
| 2R-A-89 | Interpretive Petrographic Log, Drillhole S-2 |
| 2R-A-90 | Interpretive Petrographic Log, Drillhole S-3 |
| 2R-A-91 | Interpretive Petrographic Log, Drillhole S-4 |
| 2R-A-92 | Interpretive Petrographic Log, Drillhole S-5 |
| 2R-A-93 | Interpretive Petrographic Log, Drillhole S-6 |
| 2R-A-94 | Interpretive Petrographic Log, Drillhole S-7 |
| 2R-A-95 | Interpretive Petrographic Log, Drillhole S-8 |
| 2R-A-96 | Interpretive Petrographic Log, Drillhole S-9 |
| 2R-A-97 | Interpretive Petrographic Log, Drillhole S-10 |
| 2R-A-98 | Interpretive Petrographic Log, Drillhole S-11 |
| 2R-A-99 | Interpretive Petrographic Log, Drillhole S-12 |
| 2R-A-100 | Interpretive Petrographic Log, Drillhole S-13 |
| 2R-A-101 | Interpretive Petrographic Log, Drillhole S-14 |
| 2R-A-102 | Interpretive Petrographic Log, Drillhole S-15 |
| 2R-A-103 | Interpretive Petrographic Log, Drillhole S-16 |
| 2R-A-104 | Interpretive Petrographic Log, Drillhole S-17 |
| 2R-A-105 | Interpretive Petrographic Log, Drillhole S-18 |
| 2R-A-106 | Interpretive Petrographic Log, Drillhole S-19 |
| 2R-A-107 | Interpretive Petrographic Log, Drillhole S-20 |
| 2R-A-108 | Interpretive Petrographic Log, Drillhole S-21 |
| 2R-A-109 | Interpretive Petrographic Log, Drillhole S-22 |
| 2R-A-110 | Interpretive Petrographic Log, Drillhole S-23 |
| 2R-A-111 | Interpretive Petrographic Log, Drillhole S-24 |

TABLES

## 4.3 INTERPRETIVE PROCEDURES

The Elephant Mountain Member of the Saddle Mountains Basalt Formation is the youngest basalt present throughout the study area (see Section 5.1 for details). This flow is assumed to have been extruded over a geologically short period of time (Shaw and Swanson, 1970; Swanson and others, 1973). The top of the flow probably had a nearly horizontal attitude in the Pasco Basin at the time that it crystallized. A sequence of vesicular basalt grading downward into non-vesicular porphyritic basalt is recognized in both cores and cuttings throughout the study area. Weathering of the top of the Elephant Mountain flow prior to the deposition of the overlying Ringold Formation is recognized in many cores and drill cuttings by the presence of a residual clay paleosol (B- and C-horizons) grading downward into unweathered vesicular basalt. The time duration for the formation of this clay paleosol is unknown but could have been a few hundred to several tens of thousands of years, depending upon climatic conditions. No major erosional relief is recognized on this surface throughout the Site, because the vesicular flow top is found in most drillholes penetrating the basalt. Thus, the top of the Elephant Mountain flow is judged to be a reliable horizon for stratigraphic and structural interpretations.

Unit boundaries determined on the basis of the petrologic and geophysical analyses have been used as markers of stratigraphic contacts. These contacts are interpreted as having formed generally planar subhorizontal surfaces at the time of deposition and as being approximately time-correlative. The subhorizontal surface interpretation is supported by the general presence of fine-grained sediments in the upper part of each unit. These sediments would have been removed by erosion if much topographic relief had developed throughout the area prior to burial by the overlying unit. The time-correlative interpretation is supported by the presence of volcanic ash in a paleosol near the top of Unit I in drillholes 1 and E-19. Although not shown to be the same lithologic unit, an ash has also been identified in the Unit I paleosol in drill cuttings from each of the three subareas of this study.

The geochemical nature of the A-horizon gamma ray spike is not presently known; however, it is consistently associated with the upper part of the paleosol of Unit I, and the two are believed to be genetically related. The paleosol consists of a light to dark olive gray mixture of clay, silt, and sand. It contains weathered organic debris as seen in some cores and has been bioturbated. It is interpreted to be an aggrading soil A-horizon, developed in an alluvial

environment. Independent identification of the top of the paleosol from the drill cuttings and the geophysical A-horizon gamma ray spike from the geophysical logs for 93 drillholes throughout the study area resulted in the markers being within plus or minus 10 feet of each other in 88
percent of the drillholes and within plus or minus 5 feet of 23
each other in 60 percent of the drillholes. Statistically, therefore, and making allowance for indexing errors, the A-horizon and paleosol appear coincident within expected experimental error, and this lends considerable credence to the value of the A-horizon as a stratigraphic marker. For consistency in map construction, the geophysical A-horizon
was selected as the top of Unit I. In five drillholes (47, 28
96, 97, and 99 and MJ-2), the top of Unit I was determined from cuttings at the top of the paleosol; the geophysical A-horizon was not recognized or geophysical logs were not available for these holes.

Other contacts used in the interpretation are those between Units II and III, III and IV, and between Unit IV and the Pre-Missoula Flood Gravels. Each unit is bounded on top and bottom by unconformities. The unconformities are recognized by the sharpness of the contact in cores and on the geophysical logs and by the abrupt change in lithology from silts and sands below into gravels above. Unconformities between the Ringold units were found to coincide with the contacts between coarse and fine depositional sequences that are well displayed on borehole geophysical logs. Variations were noted in the type of fine-grained sediment below the same gravel unit as these contacts were traced laterally. Although the boundaries might be expected to mark an irregular surface, they have been found to be laterally continuous and to lie on apparently subhorizontal and subplanar surfaces throughout most of the study area. The unconformities
below Units I and II are developed upon paleosols. Paleo- 23
sols are not found at the tops of Units II through IV. However, the upper, fine parts of each of these units are commonly present and suggest 1) that little erosion occurred on the tops of these units after deposition, and 2) that the time between deposition and burial of the units was insufficient for paleosols to develop. These factors indicate that these contacts provide markers useful for stratigraphic and structural interpretation where sufficient section is present to insure correlation of Ringold units.

The post-Columbia River Basalt history of the study area is based on an interpretation of structural contour maps (Figures 2R-7 to 2R-12), isopach maps (Figures 2R-13 to 2R-18), one-to-one scale cross-sections (Figures 2R-19 to 2R-28), and computer-drawn geophysical cross-sections (Figures 2R-B-1 to 2R-B-56, Appendix 2R-B-III). These figures have been generated from the drillhole lithologic contain mica and up to 20 percent mafics. Erosional unconformities occur at the base and top of Unit III.

Based on lithologic similarity, Unit III gravels and fines are believed to correlate with the lower gravels of the middle Ringold unit as defined by Tallman and others (1979). Middle Ringold gravels are exposed at the base of the bluffs along the eastern side of the Columbia River south of Ringold Flat, approximately 8 to 12 miles east of the study area.

#### 5.2.2.4 Unit IV

Gravelly sands to sandy gravels in the basal part of Unit IV are lithologically like those in the base of Unit III and also grade upward into finer clastic sediments. Fine sediments in the upper part of Unit IV are interbedded yellowish-gray to dusky-yellow silts, sands, silty sands, and sandy silts. Grains are angular to subangular, moderately to well-sorted, contain up to 25 percent mafics, and commonly are uncemented. They are megascopically very similar to the fine-grained sediments in the upper part of Unit III.

Based on lithologic similarity, the gravels of Unit IV are believed to correlate with the upper gravels of the middle Ringold unit as defined by Tallman and others (1979). Fine sediments of Unit IV are considered to correlate with the basal part of the upper Ringold unit of Tallman and others (1979). Both middle and upper Ringold sediments are exposed along the bluffs on the eastern side of the Columbia between Taylor and Ringold Flats in the eastern part of the Pasco Basin.

### 5.2.3 BOREHOLE GEOPHYSICAL CHARACTERISTICS OF THE RINGOLD UNITS

Throughout most of the central and southern part of the study area, the Ringold sequence displays a uniform but somewhat atypical group of geophysical characteristics. They are atypical in that the natural gamma activity of many of the coarse clastic zones is greater than that of the associated fine clastics. This is contrary to the normal expectation for an alluvial environment, whereas the porosity and density responses, as indicated on the neutron logs, are generally typical of such settings. Individual fine and coarse clastic sequences commonly can be traced on the geophysical logs for considerable distances (to the limits of the study area in the case of some fine-grained units). More detailed information on the geophysical characteristics of each stratigraphic unit and the resolution of the borehole geophysical responses is presented in Appendix 2R-B-II. Table 2R-3 summarizes the geophysical characteristics of each unit.

Source-detector spacing of the neutron-epithermal neutron tool used in these investigations moved the neutron response beyond the "cross-over" zone, so that increases in hydrogen, or water content, lowered the number of detectable epithermal neutrons. Accordingly, a high water content in the sediments causes a reduction in neutron flux or an excursion to the left on the logs. As fine-grained sediments characteristically have higher percentages of interstitial voids than do coarse sediments, they have higher porosities, contain more water, and display reduced neutron activity. Therefore, the sedimentary units can be seen on the neutron logs to represent generally fining-upwards cycles of deposition and to display typical neutron responses.

Comparison of logs from certain adjacent drillholes suggests 23
the presence of minor local cut-and-fill structures within cycles. It is evident, too, that facies changes are common in some of the units, as would be anticipated in an alluvial depositional environment. Where facies change rapidly, some subtle geophysical markers probably cannot be followed with confidence in drillholes more than a few hundred feet apart.

In the southern part of the Southeast anticline area, in the eastern part of the May Junction area, and in the Site area (Figure 2R-13), drillholes commonly intercept the basal conglomeratic and gravel unit below the fine-grained sequence of sedimentary Unit I. This conglomeratic-gravel unit has been treated as though it were the basal unit of Unit I. However, the physical and chemical characteristics of these deposits as indicated by the geophysical logs are grossly different from the overlying Ringold section. The basal conglomerate of Unit I has a higher density and lower porosity than younger gravels in cores of drillholes 73 and 78 and could cause gravimetric determinations of depth to basalt to be in error.

Over the Southeast anticline and the May Junction monocline, the Unit I section thins, largely through the elimination of
the gravel facies but also by thinning of the fine-grained 28
clastic facies. In these areas, the characteristic
geophysical signatures of the units on the logs are more 23
subtle than in the remainder of the study area.

b. More sediment was transported into the Pasco
Basin during Ringold, Pre-Missoula, and Missoula
times than could be removed, or general
subsidence of the Pasco Basin occurred during
this time interval,

c. Coarse-grained sediments of the Missoula Flood
Gravels were derived from different areas and
were deposited by different processes than the 23
coarse-grained Ringold sediments, and

d. Coarse-grained sediments of the Pre-Missoula
Flood Gravels were derived from the same areas
but were deposited by a different process than
those of the Ringold sediments.

4. Gravels of Basal Unit I contain many non-basaltic
clasts, thin to the northeast and northwest, and 28
are confined to the central and southern parts of
the study area. This suggests that: 23

a. The Southeast anticline and May Junction mono-
cline were low-lying positive areas while the 28
gravels of Basal Unit I were being deposited,
and

b. Offlap, pinchout, or infilling of structural 23
lows in the study area to the south and west of
the Southeast anticline and south and east of 28
the May Junction monocline occurred during Basal
Unit I time.

5. Gravels of Basal Unit I thicken in the southern
part of the May Junction area and thin to the east.
Fine-grained sediments of Unit I are thin in the
southwestern part of the May Junction area and
thicken to the east. Basal gravels of Unit I are
thinner (approximately 25 feet) in drillhole S-3
than in all surrounding drillholes. Fines of Unit
I are considerably thicker (approximately 45 feet)
in drillhole S-3 than in all surrounding drill-
holes. This is interpreted in the following
manner: 23

a. A change of facies is believed to occur in Unit
I with the basal gravels interfingering into
fine sediments in the southwestern to eastern
part of the May Junction area and in the
vicinity of drillhole S-3 in the Site area, and

b. The fine-grained sediments in the upper part of
Unit I are a part of the same depositional
cycle as the basal gravels but represent a
decrease in the energy level.

6. Sediments in Upper Unit I are composed of olive-gray to brownish-gray silts and clays with some very fine to fine sand. They are uncemented, contain organic fragments, are bioturbated in some areas, and may show thin laminations. They are 23
present throughout the study area except along the northwestern part of the crest of the Southeast anticline and the crest of the subsurface ridge of basalt on the western side of the May Junction mono- 28
cline in the May Junction area. These sediments are interpreted as:

   a. An aggrading paleosol, probably developing on a flood plain, and

   b. An indication of landscape stability for the late part of Unit I time. 23

7. Upper Unit I sediments are present throughout the study area except along the northwestern part of the crest of the Southeast anticline (drillholes 105, 34, 38, and 37) and the crest of the subsurface basalt ridge on the western side of the May Junction monocline (drillholes 92 and MJ-3). They 28
thin around these structures and thicken to the southeast. This is interpreted in the following manner:

   a. Paleoslopes existed to the southeast during Upper Unit I time, and

   b. The Southeast anticline and subsurface basalt ridge west of the May Junction linear were low-lying positive areas during deposition of the Upper Unit I sediments or were uplifted and stripped of Upper Unit I sediments prior to deposition of Unit II sediments.

8. Fine sediments of Unit II are characterized by 23
varicolored to gray-green waxy clays throughout the study area to the south and west of the Southeast anticline. This suggests that:

   a. The area to the south and west of the Southeast anticline was the site of deposition of very fine-grained sediments during part of Unit II time, and

   b. These sediments reflect low energy environments or that source areas were providing only fine-grained sediments during this time.

Basal Unit I gravels are present to the southwest of the Southeast anticline area. They thin, pinch out, or have been removed by erosion across the anticline, suggesting that the structure was a positive area during Basal Unit I time. The Basal Unit I gravels are not present on the northeastern side of the structure. Structural and topographic relief on the Southeast anticline must have been low during Basal Unit I time or the clay paleosol on top of the basalt would have been removed by erosion.

Uper Unit I fine-grained sediments thin across the southeastern part of the Southeast anticline. The northwestern part of the crest of the structure lacks Upper Unit I sediments, suggesting that this part of the structure was either a positive area during Upper Unit I time or that post-depositional erosion removed the sediments. The presence of the paleosol at the top of Upper Unit I sediments across the southeastern part of the Southeast anticline indicates landscape stability in late Unit I time for the Southeast anticline area. Minor erosion of Upper Unit I sediments is interpreted in the vicinity of drillhole 99 on the southeastern end of the structure.

Within the Southeast anticline area, Unit II sediments are unconformable above Unit I, thin at least 132 feet toward the Southeast anticline, and are interpreted to cross the southeastern part of the structure. The gravel horizon occurring to the southwest in the lower part of Unit II pinches out toward the anticline. The varicolored and gray-green waxy clays common in the upper parts of Unit II in the southern and central parts of the study area are not present over the Southeast anticline. Loss of the basal gravels and waxy clays and thinning of Unit II sediments over the Southeast anticline suggests that the structure was a positive feature during Unit II time; some uplift and erosion could have occurred following deposition of these sediments. Channeling of Upper Unit II fines in the vicinity of drillhole 99 is believed to have occurred. Probable dune sand and find-grained fluvial sediments at the top of Unit II show no evidence of the development of a paleosol.

Units III and IV both thin toward the flanks but do not cross the crest of the Southeast anticline. Such behavior may be a result of erosion or non-deposition, and it is here interpreted that the Southeast anticline was a positive area during Units III and IV time.

Glaciofluvial sediments of the Pre-Missoula Flood Gravels unconformably overlie the Ringold across the Southeast anticline. Their presence, however, is uncertain over the northwestern part of the structure along Line 3 in drillholes 37 and 38 (Figure 2R-20). In the vicinity of drillholes 54, 55, 68, 99, 101, and 103, Pre-Missoula Flood Gravels are noted to fill a channel cut into the Ringold sediments. Missoula Flood Gravels unconformably overlie the Pre-Missoula Flood Gravels throughout the Southeast anticline area, and surficial dune sands and fluvial deposits of Recent age are present over most of the area today. No deformation of any of the post-Ringold sediments is recognized in the southeast anticline area. 23

A fault was recognized on the southwestern flank of the Southeast anticline (Figure 2R-7) on the basis of fault breccia and an anomously thick section of the Elephant Mountain member in corehole 125. A study carried out by Golder Associates (1982) for Washington Public Power Supply System determined the attitude, displacement and capability of this fault. Eleven drillholes, spaced 30 to 100 feet apart, indicate that the fault has a reverse sense of movement, strikes N39°W and dips 30°SW. The range of vertical displacement on the fault is 35 to 60 feet, and the range of dip-slip displacement is 70 to 110 feet. Based on this small amount of displacement, the Souteast anticline fault is interpreted to be a minor feature which probably does not extend any significant distance away from corehole 125. Four stratigraphic contacts across the projection of the fault plane (Elephant Mountain basalt/Ringold Upper Unit I contact, the contact of a lower fine-grained and upper coarse-grained subunit of Ringold Upper Unit I, Ringold Upper Unit I/Ringold Unit II contact and Ringold Unit II/Pre-Missoula contact) showed no abrupt changes in elevation. Based on these observations, the Southeast anticline fault has not been active for approximately 10 million years. It has clearly not been active since Pre-Missoula time (730,000 years before present) and is, therefore, not capable. 28

Based upon the similarity of structural patterns in the cross-sections, structural contour, and isopach maps, and the amount of thinning of stratigraphic units displayed in these illustrations, the Southeast anticline is interpreted to have developed intermittently throughout Ringold time. Deformation may have been most intense during Unit II and Unit III time and diminished during Unit IV time. 23

### 6.2.2 MAY JUNCTION AREA

The May Junction area includes the May Junction monocline and the area between the monocline, the Southeast anticline, and the Site area. The north-south-trending May Junction monocline is defined by the eastern boundary of a gravity high associated with the Gable Butte/Gable Mountain segment of the Umtanum Ridge/Gable Mountain structural trend (Weston 28

Geophysical Corp., 1981b). Relief on this feature is approx-
imately 300 feet, with a slope of 10 degrees or less on the 28
basalt surface. To the east, a gentle southward-slipping
(less than 1 degree) surface forms the northern flank of a 23
southeasterly-plunging syncline. The Ringold Formation
thins over the basalt high to the west of the May Junction
monocline as shown on the isopach map (Figure 2R-18) and the 28
cross-sections (Figures 2R-22 to 2R-24). Because a complete
stratigraphic sequence of Ringold sediments is not present,
correlations over this structure are questioned.

Gravels of Basal Unit I are present throughout the area 23
except where they pinch out or have been removed by erosion
on the flank of the Southeast anticline and over the
northern part of the May Junction monocline on Line 8. The 28
interpretation that the Basal Unit I gravels overlie the
structure on the southwestern end of Line 3 suggests that
deformation of this structure occurred after the deposition
of the gravels.

Upper Unit I fine-grained sediments in the May Junction area
are interpreted to thin or interfinger with a thickened 23
gravel interval in the southwestern part of the area.

A normal sequence of Unit II sediments is present in the eastern part of the May Junction area. To the southwest (Line 3) the gray-green waxy clays become varicolored. These sediments generally thin toward the May Junction monocline and are interpreted to pinch out or have been removed by erosion over the northern part of the structure in the vicinity of Lines 8 and 8C. Unit III and Unit IV sediments are interpreted to be present only on the flanks of the monocline. The absence of Units I through IV could be a result of erosion or non-deposition. Pre-Missoula and Missoula Flood Gravels overlie the Ringold sediments.

The shallow and uniform dip of the sediments and basalt
units across the May Junction monocline, and the generally
uniform and typical thickness of the Elephant Mountain 28
member and Rattlesnake Ridge interbed encountered along Line
8 and 8C, indicate that the May Junction monocline is not
fault controlled. The shallow dip of stratigraphic units (7
to 10 degrees) indicates that, although the monocline is a
prominent geophysical feature, only minor deformation has
taken place in the basalt or overlying sediments along the
trend of the monocline. This minor deformation has clearly
been accommodated by the warping which produced the mono-
cline.

It is postulated that deformation of the May Junction monocline commenced in post-Elephant Mountain Member time (less than 10.5 million years B.P.) and probably diminished in Unit IV time (early Pliocene). No deformation is recognized in the post-Ringold sediments in the May Junction area.

### 6.2.3 SITE AREA

The structural contour map on top of basalt in the Site area (Figure 2R-7) indicates that the basalt surface underlying the Site area is of generally low relief, with typical slopes on the order of 1 degree or less. The relief on the basalt surface is interpreted to be the result of gentle folding which has produced three dominant features. These are the Cold Creek syncline in the southern part of the Site area, an unnamed gentle east-west trending anticline in the 23 central part of the Site area, and a syncline along the northern edge of the Site area.

The Cold Creek syncline trends northwest and plunges gently to the southeast through the Site area (Myers and Price, 1979). A local depression occurs along the axis of the syncline in the vicinity of drillhole S-16. The bedrock surface in the lowest portion of this depression is approximately 150 feet below the surrounding bedrock surface. The syncline is asymmetrical, with the steeper southwestern limb formed by a northwest trending flexure in the Site area (Weston Geophysical Corp., 1981a). The maximum slope on the southwestern flank of the syncline is approximately 5 degrees.

Along Line X-1 (Figure 2R-28), which generally parallels the axis of the syncline, Ringold Units I through III maintain a constant thickness and parallel the basalt surface; however, the upper fine-grained part of Unit IV is thinner in drillhole S-17 than elsewhere on Line X-1. This reduced thickness is due either to erosion or non-deposition and suggests uplift of the basalt underlying the Ringold section in this area during or after the deposition of Unit IV sediments. Ringold Units III and IV are interpreted to be absent in drillhole S-24 on Line 4D (Figure 2R-26) on the southwestern flank of the Cold Creek syncline. The absence of these units suggests similar uplift and erosion after Unit II time and possibly during or after Unit IV time.

A small, generally east-west trending anticlinal feature occurs on the bedrock surface on the northern limb of the Cold Creek syncline. The relief across this flexure is 250 feet on the southern flank and 100 feet on the northern flank, with the northern flank sloping more steeply (maximum of 3.5 degrees). The Ringold formation is warped over the anticline, and the upper, fine-grained part of Ringold Unit IV is thinner over the structure along Line 1 (Figure 2R-25), Line M (Figure 2R-27), and Line W (Figure 2R-28). The reduced thickness of Unit IV may be interpreted to suggest that upwarping of the anticline and consequent thinning of Unit IV by erosion or non-deposition occurred during or shortly after Unit IV time.

With the exception of drillhole S-24 on Line 4D, the entire Ringold section is present in the Site area. Thinning or elimination of Unit IV occurs only over bedrock highs, suggesting that deformation in the Site area occurred during or after Unit IV time (early Pliocene). Uplift and erosion along Line 4D clearly occurred after Unit II time, probably during or after Unit IV time, to be consistent with the time of deformation of the surrounding structures. No deformation is recognized in the post-Ringold sediments which are present throughout the Site area.

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MAJOR STRUCTURAL FEATURES IN STUDY AREA

FIGURE 2R-2


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DRILL HOLE LOCATION MAP SHOWING AREAS DISCUSSED IN TEXT

FIGURE 2R-4

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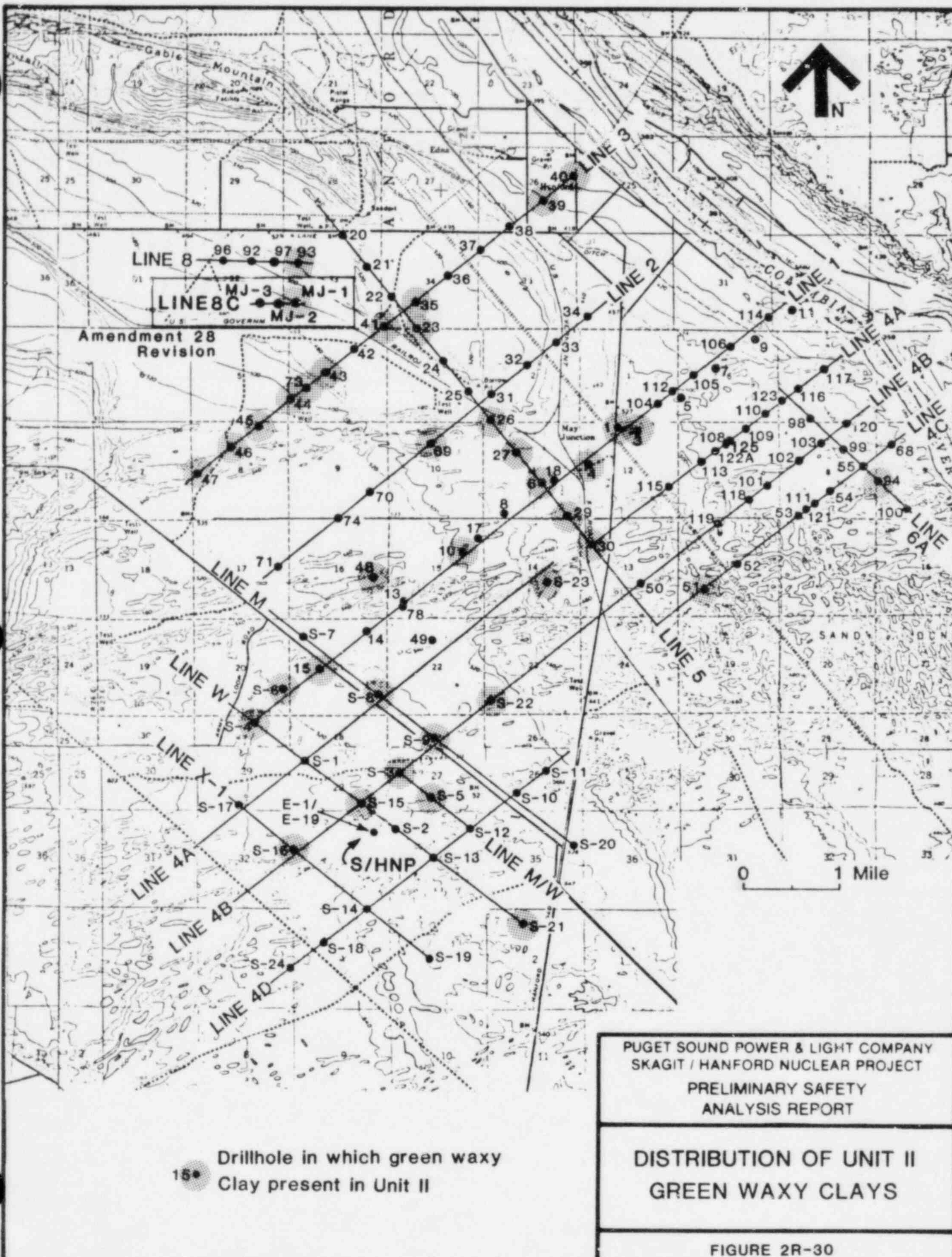


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DISTRIBUTION OF UNIT II GREEN WAXY CLAYS

FIGURE 2R-30

**DRILL HOLE** 97

Project No : 803-1701H
Elevation : 513.2 ft.
Total Depth : 339 ft.
Coordinates : N453,790.15; E263,334.42
Date Completed : 9/18/80

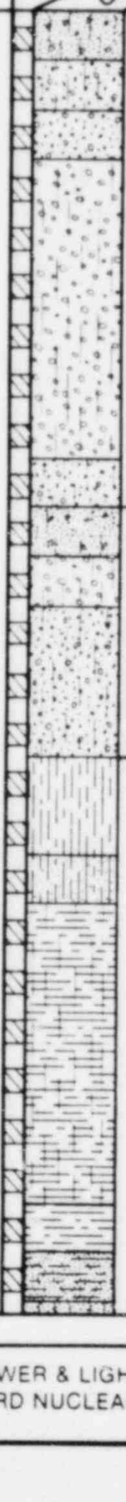
SAMPLE TYPE
- Cuttings
- 95 ■ Core, Number Indicates % Core Recovery
- C 2015 ⊡ XRF, With Sample Number Chemical Results Listed in Table 2R-1



Unit Column Refers to General Stratigraphic Divisions Identified Within the Site Area:

- M - Missoula
- PM - Pre-Missoula
- IV - Ringold, Unit IV
- III - Ringold, Unit III
- II - Ringold, Unit II
- I-u - Ringold, Unit I-upper
- I-b - Ringold, Unit I-basal
- Columbia River Basalt Group
  - Tem - Elephant Mountain Member
  - Ter - Rattlesnake Ridge Interbed
  - Tp - Pomona Member
  - B - Basalt, Undifferentiated

Elevation scale (MSL): 510, 500, 490, 480, 470, 460, 450, 440, 430, 420, 410, 400, 390
Depth scale (ft.): 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 110, 120, 130



| Lithologic Description | Unit |
|---|---|
| Gravelly silty SAND. Light-olive-brown. Very-fine- to fine- and coarse- to very-coarse-grained. Gravel 85% basalt clasts. | M |
| Silty sandy GRAVEL. 70% basalt clasts. Sand coarse- to very-coarse-grained; angular to subrounded. | M |
| Sandy GRAVEL. 70% basalt clasts. Sand very-fine- to coarse-grained; angular to subangular; 35% mafics. | M |
| Silty GRAVEL. 80-90% basalt clasts. | M |
| Silty sandy GRAVEL. 80% basalt clasts. Sand coarse- to very-coarse-grained, some medium-grained; angular to subrounded. | M |
| Gravelly silty SAND. Fine- to very-coarse-grained, mostly medium-grained. 20% mafics. Silt adheres to grains. | PM |
| Silty GRAVEL. 40% basalt clasts. Silt adheres to clasts. No cement. | PM |
| Silty sandy GRAVEL. 35% basalt clasts. Sand medium- to very-coarse-grained, fining downward; angular to subrounded; 20-30% mafics, decreasing with depth. Silt adheres to grains. No cement. | PM |
| SILT. Yellowish-gray. Subrounded fragments. | II? |
| Sandy SILT. Yellowish-gray. Subrounded fragments. Sand very-fine-grained. | II? |
| Silty CLAY. Light-brown. Subrounded fragments. | II? |
| CLAY. Light-brown. Subrounded fragments. | II? |
| Sandy CLAY to clayey SAND. Moderate-brown. Sand very-fine-grained. | II? |

28

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**LOG OF DRILL HOLE 97**

FIGURE 2R-A-59

**DRILL HOLE** MJ-1

Project No : 823-1036
Elevation : 476.3 ft.
Total Depth : 573.0 ft.
Coordinates : N451,449.33; E264,631.23
Date Completed : 9/15/82

SAMPLE TYPE
- Cuttings
- 95 Core, Number Indicates % Core Recovery
- C 2015 XRF, With Sample Number
  Chemical Results Listed in Table 2R-1

Page 1 of 8

Unit Column Refers to General Stratigraphic Divisions Identified Within the Site Area :

- M - Missoula
- PM - Pre-Missoula
- IV - Ringold, Cycle IV
- III - Ringold, Cycle III
- II - Ringold, Cycle II
- I - Ringold, Cycle I
- B - Basalt, Undifferentiated
- EM - Elephant Mountain Member
- RR - Rattlesnake Ridge Interbed
- P - Pomona Member

| Elevation (ft.MSL) | Depth (feet) | Sampled Interval | Graphic Log | Lithologic Description | Unit |
|---|---|---|---|---|---|
| | | | | Gravelly silty SAND. Light-olive-brown. Medium- to very-coarse-grained. | M |
| 470 | | | | Gravelly silty SAND. Olive-gray. Very-fine- to very-coarse grained, fining with depth. 60 to 75% basalt grains. Angular to subrounded. | |
| | 10 | | | | |
| 460 | | | | | |
| | 20 | | | Gravelly silty SAND. Medium-dark-gray grading to medium-gray at 30 to 35 ft. 55 to 80% basalt grains, decreasing with depth. Very-fine- to very-coarse-grained. Angular to subrounded. Gravel 75% basalt clasts. | |
| 450 | | | | | |
| | 30 | | | | |
| 440 | | | | Silty GRAVEL to gravelly SILT. Light-olive-gray. Ferruginous stain. Gravel basaltic; possibly caved. | PM |
| | 40 | | | Gravelly SILT to silty GRAVEL light-olive-gray. | |
| 430 | | | | Gravelly sandy SILT to silty sandy GRAVEL. Light-olive-gray. Spotty ferruginous stain. Sand very-fine- and medium- to coarse-grained. | |
| | 50 | | | | |
| 420 | | | | Silty sandy GRAVEL. 30 to 50% basalt clasts, decreasing with depth. Sand very-fine- to very-coarse-grained; mostly coarse- to very-coarse grained; 20% basalt grains. | |
| | 60 | | | Gravelly SAND. Yellowish-gray. Fine- to medium-grained. 10% mafics. Angular to subangular. Trace silt. | |

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**LOG OF DRILL HOLE MJ-1**

FIGURE 2R-A-112

**DRILL HOLE** MJ-1 Page 2 of 8

| Elevation (feet-MSL) | Depth (feet) | Sampled Interval / Graphic Log | Lithologic Description | Unit |
|---|---|---|---|---|
| 410 | | | Sandy GRAVEL. 20% basalt clasts. Sand fine- to coarse-grained; 10 to 15% mafics; angular. Trace silt. | |
| | 70 | | Gravelly silty SAND. Yellowish-gray to light-olive-gray. 20 to 25% mafics. Very-fine- to coarse-grained. Angular to subangular. | |
| 400 | | | Gravelly SAND to sandy GRAVEL. Yellowish-gray to light-olive-gray. Fine- to very-coarse-grained; mostly very-coarse-grained. 30% basalt grains. | |
| | 80 | | | |
| 390 | | | Gravelly silty SAND. Yellowish-gray to light-olive-gray. Very-fine- to very-coarse-grained. Grain size decreases and sorting is poorer with depth. 25 to 30% basalt grains. Silt increases with depth. | |
| | 90 | | Silty sandy GRAVEL to gravelly silty SAND. 45% basalt clasts. Sand as above. | PM |
| 380 | | | Gravelly silty SAND. Yellowish-gray to light-olive-gray. Very-fine- to medium-grained; mostly medium-grained. 15 to 20% mafics. Local ferruginous stain. | |
| | 100 | | Silty sandy GRAVEL. Matrix as above. Local ferruginous stain. No sandy cement rinds. | |
| 370 | | | Gravelly silty SAND to silty sandy GRAVEL. Yellowish-gray. Very-fine- to coarse-grained. 10 to 15% mafics. No sandy cement rinds. | |
| | 110 | | | |
| 360 | | | Gravelly SAND to sandy GRAVEL. Yellowish-gray. Fine- to medium-grained. 7 to 10% mafics. Angular to subangular. Clean. Gravel 15% basalt clasts; no sandy cement rinds. | |
| | 120 | | Sandy GRAVEL to gravelly SAND. Sand as above. Some pebbles with yellow sandy cement rinds (reworked Ringold?). | |
| 350 | | | | |
| | 130 | | | |
| 340 | | | Gravelly SAND. Yellowish-gray to dusky yellow. Fine- to medium-grained; mostly medium-grained. 7-10% mafics. Angular to subangular. Abundant gravel clasts with yellow sandy cement rinds. | IV |
| | 140 | | | |

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LOG OF DRILL HOLE MJ-1

FIGURE 2R-A-112

DRILL HOLE MJ-1



| Elevation (feet-MSL) | Depth (feet) | Lithologic Description | Unit |
|---|---|---|---|
| 330 | 150 | Silty sandy GRAVEL. Matrix yellowish-gray to dusky yellow. Sand fine- to medium-grained; mostly medium-grained; 5 to 7% mafics; angular to subangular. Yellow sandy cement rinds on gravel clasts. | IV |
| 320 | 160 | Gravelly SAND. Yellowish-gray grading downward to dusky yellow. Very-fine- to medium-grained; mostly medium-grained. 5 to 7% mafics. Angular to subangular. Abundant yellow sandy cement rinds. | |
| 310 | | Silty SAND. Yellowish-gray to dusky yellow. Very-fine to medium-grained; mostly fine- to medium-grained. 5 to 7% mafics. Trace gravel. | |
| | 170 | Silty SAND to sandy SILT. Dusky yellow. Very-fine-grained. | |
| 300, 290, 280 | 180, 190 | SAND. Yellowish-gray. Fine- to medium-grained; mostly medium-grained. 7 to 10% mafics. Angular to subangular. Trace silt from 180 to 190 ft. Micaceous at 185 to 190 ft. and 195 to 200 ft. Trace gravel with yellow sandy cement rind at 195 to 200 ft. | |
| | 200 | Sandy GRAVEL to gravelly SAND. Yellowish-gray to dusky yellow. Abundant yellow sandy cement rinds. | |
| 270 | | Gravelly SAND. Dusky yellow. Local ferruginous stain and cement. | III |
| | 210 | Gravelly SAND. Light-olive-gray. Fine- to medium-grained; mostly medium-grained. 15 to 20% mafics. Wood fragments. Micaceous. Sandy cement rinds. | |
| 260 | | SAND. Light-olive-gray. Very-fine- to medium-grained; mostly medium-grained. 20% mafics. Micaceous. | |
| | 220 | GRAVEL. Trace sand. 15 to 20% basalt clasts. Trace sandy cement rinds. | |

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LOG OF DRILL HOLE MJ-1

FIGURE 2R-A-112

DRILL HOLE MJ-1 Page 4 of 8

| Elevation (feet-MSL) | Depth (feet) | Lithologic Description | Unit |
|---|---|---|---|
| 250 | | GRAVEL, as above. Pyrite on some clasts. | |
| | 230 | Sandy GRAVEL. 35% basalt clasts. Local pyrite. Minor yellow sandy cement rinds. Sand matrix fine- to medium-grained. | III |
| 240 | 240 | Gravelly sandy SILT, with CLAY and ash-like fragments. Very-light-gray, olive-gray, and light-olive-gray. Gravel and sand probably caved. Pyrite fragments. Some silt and clay fragments laminated. | |
| 230 | 250 | Gravelly silty SAND, with CLAY fragments. Light-olive-gray. Very-fine- to medium-grained. | |
| 220 | 260 | SAND, with clay and white ash-like fragments. Yellowish-gray. Very-fine to fine-grained. Mostly fine-grained. 5 to 7% mafics. Trace gravel. | |
| 210 | | Gravelly silty SAND with SILT fragments. Yellowish-gray. Very-fine- to medium-grained. 10% mafics. Angular to subangular. | |
| | 270 | Gravelly sandy SILT to CLAY. Yellowish-gray. Slight waxy luster to clay. | II |
| 200 | | Gravelly sandy SILT to gravelly silty SAND. Yellowish-gray. Sand very-fine-grained. | |
| | 280 | Gravelly silty SAND. Yellowish-gray. Very-fine- to fine-grained; mostly very-fine-grained. 3% mafics. Angular to subangular. | |
| 190 | | Silty SAND, with CLAY fragments. Dark yellowish-brown. Sand as above. | |
| | 290 | Silty SAND, with silty SAND to sandy SILT fragments. Yellowish-gray. Very-fine- to medium-grained. 2 to 3% mafics. | |
| 180 | 300 | Gravelly silty SAND, with CLAY fragments. Sand yellowish-gray. Clay dark-yellowish-brown. Very-fine- to medium-grained. | |

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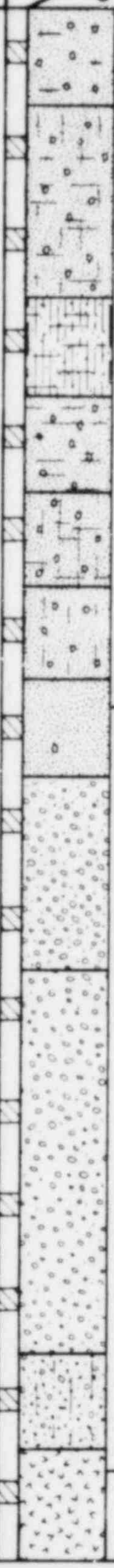
LOG OF DRILL HOLE MJ-1

FIGURE 2R-A-112

**DRILL HOLE** MJ-1 Page 5 of 8



| Elevation (feet-MSL) | Depth (feet) | Lithologic Description | Unit |
|---|---|---|---|
| 170 | | Gravelly SAND, with dark yellowish-brown CLAY fragments. Yellowish-gray. Fine- to coarse-grained; mostly medium-grained. 3% mafics. | |
| | 310 | Gravelly silty SAND, with silty clayey sand fragments. Light-olive-gray. Very-fine- to medium-grained; mostly fine-grained. 2 to 3% mafics. Angular to subangular. | |
| 160 | 320 | Sandy clayey SILT. Olive-gray. | |
| 150 | | Gravelly clayey SAND. Olive-gray. Medium- to coarse-grained. | 1-u |
| | 330 | Gravelly silty SAND, with SILT and CLAY fragments. Light-olive-gray. Very-fine- to coarse-grained. 3% mafics. Local ferruginous stain. | |
| 140 | | Gravelly SAND, with SILT fragments. Light-olive-gray. Fine- to medium-grained; mostly medium-grained. 5% mafics. Local ferruginous stain. | |
| | 340 | SAND. Light-olive-gray. Medium-grained. 5 to 7% mfaics. Micaceous. Trace gravel. | |
| 130 | 350 | Sandy GRAVEL. 20% basalt clasts increasing downward to 40 to 45% basalt clasts. Some sandy cement rinds. Blue cast to some basalt clasts. Local ferruginous stain and cement. | |
| 120 | 360 | GRAVEL. Trace sand. 30 to 40% basalt clasts. Sandy cement rinds. Blue cast to some basalt clasts. | 1-b |
| 110 | 370 | | |
| 100 | | Silty sandy GRAVEL. 30 to 40% basalt clasts. Sand very-fine- to medium-grained; yellowish-gray. | |
| | 380 | Basalt. Dark-gray. Caved gravel clasts. | Tem |

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**LOG OF DRILL HOLE MJ-1**

FIGURE 2R-A-112

DRILL HOLE MJ-1 Page 6 of 8

| Elevation (feet-MSL) | Depth (feet) | Lithologic Description | Unit |
|---|---|---|---|
| 90 | | BASALT, as above. Some vesicles. | |
| | 390 | | |
| 80 | | BASALT. Dark-gray. Weathered. Vesicular. Some vesicles filled with green and white clay. | |
| | 400 | | |
| 70 | | | |
| | 410 | BASALT. Dark-gray. Vesicular. Moderately fresh. Some caved gravel. | |
| 60 | | | |
| | 420 | BASALT sand. Grayish black. Fresh. Ground to sand size by drill bit. | Tem |
| 50 | | | |
| | 430 | BASALT. Brownish-gray to grayish black. Fresh. Trace vesicles. Local pyrite mineralization at 430 to 435 ft. | |
| 40 | | BASALT. Dark-gray to grayish black. Fresh. Nonvesicular. | |
| | 440 | BASALT. Olive-gray to olive-black. Vesicular. Some vesicles filled with green clay. Some brecciated clay fragments. | |
| 30 | | BASALT. Dark-gray. Fresh. Nonvesicular. Trace silt from 450 to 460 ft. | |
| | 450 | | |
| 20 | | | |
| | 460 | BASALT. Olive-gray. Fresh. Trace silt. Nonvesicular. | |

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LOG OF DRILL HOLE MJ-1

FIGURE 2R-A-112

DRILL HOLE MJ-1 



| Elevation (feet-MSL) | Depth (feet) | Sampled Interval | Graphic Log | Lithologic Description | Unit |
|---|---|---|---|---|---|
| 10 | | | | BASALT, as above. Local calcite mineralization at 465 to 470 ft. | Tem |
| | 470 | | | | |
| 0 | | | | | |
| | 480 | | | | |
| -10 | | | | | |
| | 490 | | | | |
| -20 | | | | BASALT. Olive-gray. Moderately weathered. Vesicular. Vesicles filled with yellowish-green clay. | Ter |
| | 500 | | | Sandy clayey SILT to sandy silty CLAY. Light-olive-gray. | |
| -30 | | | | Clayey silty SAND. Light-olive-gray. Local pyrite cement. Very-fine- to medium-grained. Angular to subangular. | |
| | 510 | | | | |
| -40 | | | | SAND. Light-olive-gray to yellowish-gray. Fine- to coarse-grained; mostly coarse-grained. 3 to 5% mafics. Angular to subangular. | |
| | 520 | | | | |
| -50 | | | | SAND, as above, with pinkish-gray to light-greenish-gray CLAY fragments. | |
| | 530 | | | SILT, with CLAY fragments and SAND. Light-olive-gray; pinkish-gray and light-greenish-gray. Silt tuffaceous. Clay with waxy luster. | Tp |
| -60 | | | | BASALT. Brownish-black. Highly vesicular. Many vesicles filled with clay. Caved sand, silt, and clay fragments. | |
| | 540 | | | | |

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LOG OF DRILL HOLE MJ-1

FIGURE 2R-A-112

DRILL HOLE MJ-1 Page 8 of 8

| Elevation (feet-MSL) | Depth (feet) | Sampled Interval | Graphic Log | Lithologic Description | Unit |
|---|---|---|---|---|---|
| -70 | 550 | | | BASALT, as above. | |
| -80 | 560 | | | | Tp |
| -90 | 570 | | | BASALT. Dark-gray. Fresh. Nonvesicular from 560 to 570 ft. Minor vesicles at 570 to 573 ft. | |
| -96.7 | | | EOH 573' | | |

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LOG OF DRILL HOLE MJ-1

FIGURE 2R-A-112

**DRILL HOLE** MJ-2

Project No : 823-1036
Elevation : 470.2 ft.
Total Depth : 425 ft.
Coordinates : N451,412.95; E263,630.25
Date Completed : 9/3/82

**SAMPLE TYPE**

- Cuttings
- 95 ■ Core, Number Indicates % Core Recovery
- C2015 ⊡ XPF, With Sample Number — Chemical Results Listed in Table 2R-1

Page 1 of 6

Unit Column Refers to General Stratigraphic Divisions Identified Within the Site Area :

| | | |
|---|---|---|
| M - Missoula | III - Ringold, Cycle III | B - Basalt, Undifferentiated |
| PM - Pre-Missoula | II - Ringold, Cycle II | EM - Elephant Mountain Member |
| IV - Ringold, Cycle IV | I - Ringold, Cycle I | RR - Rattlesnake Ridge Interbed |
| | | P - Pomona Member |

Elevation (ft.MSL) / Depth (feet) scale: 470 / 0; 460 / 10; 450 / 20; 440 / 30; 430 / 40; 420 / 50; 410 / 60

| Lithologic Description | Unit |
|---|---|
| Gravelly silty SAND. Medium-light-gray. 75% basalt grains. Coarse- to very-coarse-grained. | M |
| Gravelly silty SAND to silty sandy GRAVEL. Medium-light-gray. 75% basalt grains. Coarse- to very-coarse-grained. | M |
| Gravelly silty SAND. Medium-light-gray. 75% basalt grains. Medium- to very-coarse grained; mostly medium-grained. | M |
| Gravelly sandy SILT. Medium-gray. Gravel 60% basalt clasts. | M |
| SAND. Medium-dark-gray. Medium- to very-coarse-grained; mostly coarse-grained. 70% basalt grains. Trace silt. | M |
| Gravelly silty SAND. Moderate yellowish-brown grading downward to yellowish-gray. Moderately well to poorly sorted. 5 to 10% mafics, increasing with depth. Micaceous. Angular to subangular. | PM |
| Gravelly SAND. Yellowish-gray. Very-fine- to fine-grained. 5-7% mafics. Angular to subangular. Gravel 20% basalt clasts. Trace silt at 45 to 50 ft. | PM |
| Gravelly silty SAND to silty sandy GRAVEL. Light-olive-gray. 10 to 15% mafics. Fine- to coarse-grained. Gravel 25 to 30 % basalt clasts. | PM |
| Silty sandy GRAVEL. Moderate olive-brown. No cement rinds. Silt adheres to clasts. Sand fine- to medium-grained. | PM |
| Gravelly silty SAND. Dark yellowish-brown. Fine- to medium-grained. 15% mafics. Silt adheres to grains. Subangular to subrounded. | PM |

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**LOG OF DRILL HOLE MJ-2**

FIGURE 2R-A-113

DRILL HOLE MJ-2



| Elevation (feet-MSL) | Depth (feet) | Lithologic Description | Unit |
|---|---|---|---|
| 400 | 70 | Gravelly silty SAND, as above. Micaceous. Ferruginous stain. Fine- to medium-grained; mostly medium-grained. No cement rinds on gravel clasts. | PM |
| | | Silty SAND. Dusky yellow. Very-fine- to medium-grained, mostly medium-grained. 5 to 7 % mafics. Large muscovite flakes. | |
| 390 | 80 | Gravelly silty SAND. Dusky yellow. Very-fine- to medium-grained; mostly very-fine-grained. 2 to 3% mafics. No cement rinds on gravel clasts. | |
| | | Gravelly clayey SILT to gravelly silty CLAY. Yellowish-gray to dusky yellow. Gravel probably caved. | |
| 380 | 90 | Gravelly SILT, with CLAY fragments. Yellowish-gray. Sand very-fine-grained. | |
| 370 | 100 | SILT, with CLAY fragments. Yellowish-gray to 130 ft.; yellowish-gray to dusky yellow from 130 to 140 ft. Trace gravel at 100 to 105 ft. Clay fragments decrease with depth. | |
| 360 | 110 | | II? |
| 350 | 120 | | |
| 340 | 130 | | |
| 330 | 140 | SILT. Yellowish-gray to dusky yellow. | |

DRILL HOLE MJ-2 

| Elevation (feet-MSL) | Depth (feet) | Lithologic Description | Unit |
|---|---|---|---|
| | | Sandy SILT. Yellowish-gray to dusky yellow. Sand very-fine-grained. Trace clay fragments. | |
| 320 | 150 | Silty SAND to sandy SILT. Dusky yellow. Very-fine- to fine-grained 2-3% mafics. Angular to subangular. | |
| 310 | 160 | Silty SAND. Dusky yellow grading downward to light-olive-brown. Very-fine- to medium-grained; mostly very-fine- to fine-grained. 3 to 5% mafics. Angular to subangular. | II? |
| 300 | 170 | Sandy SILT to silty SAND. Dusky-yellow. Sand very-fine-grained. Clayey in part. | |
| | | Sandy SILT. Yellowish-gray. Sand very-fine-grained. | |
| 290 | 180 | Gravelly SAND. Light-olive-gray. Fine- to coarse-grained; mostly fine- to medium-grained. 15 to 20% mafics. Sandy cement rinds on some gravel clasts. Trace silt at 185 to 190 ft. | 1-u? |
| 280 | 190 | Sandy GRAVEL to gravelly SAND. 45 to 50% basalt clasts. Sandy cement rinds on some clasts. Sand yellowish-gray; mostly medium-grained; 7 to 10% mafics. | |
| | | Gravelly SAND. Light-olive-gray. Medium-grained. Micaceous. Sandy cement rinds on some gravel clasts. | 1-b? |
| 270 | 200 | Sandy clayey GRAVEL. Clay light-olive-gray; possibly weathered basalt clay. | |
| | | BASALT. Olive-gray. Weathered and vesicular at 205 to 210 ft. | |
| 260 | 210 | BASALT. Dark gray. Moderately fresh. Vesicular. Some yellowish-green clay in vesicles. | Tem |
| 250 | 220 | | |

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LOG OF DRILL HOLE MJ-2

FIGURE 2R-A-113

DRILL HOLE MJ-2 Page 4 of 6

| Elevation (feet-MSL) | Depth (feet) | Sampled Interval / Graphic Log / Lithologic Description | Unit |
|---|---|---|---|
| 240 | 230 | BASALT. Medium-dark-gray to 255 ft. Weathered. Vesicular. Some vesicles filled with yellowish-green to white clay. | |
| 230 | 240 | | |
| 220 | 250 | BASALT. Dark-gray. Fresh. Minor vesicles to 265 ft. Minor clay (caved?). | |
| 210 | 260 | | Tem |
| 200 | 270 | BASALT. Dark-gray. Fresh. Nonvesicular. Local pyrite or calcite mineralization on some surfaces. Minor vesicles from 270 to 280 ft. and from 290 to 300 ft. | |
| 190 | 280 | | |
| 180 | 290 | | |
| 170 | 300 | | |

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LOG OF DRILL HOLE MJ-2

FIGURE 2R-A-113

DRILL HOLE MJ-2



| Elevation (feet-MSL) | Depth (feet) | Lithologic Description | Unit |
|---|---|---|---|
| 160 | 310 | BASALT. Dark-gray. Fresh. Nonvesicular. Local calcite or pyrite on some surfaces from 320 to 330 ft. | Ten |
| 150 | 320 | | |
| 140 | 330 | BASALT. Dark-gray. Vesicular. Vesicularity increases with depth. Vesicles at 335 to 340 filled with green clay. | |
| 130 | 340 | Clayey SILT to silty CLAY. Light-olive-gray. | Ter |
| 120 | 350 | SILT to clayey SILT. Grayish-yellow-green. Tuffaceous. | |
| 110 | 360 | Clayey SILT, with CLAY and tuffaceous fragments. Pale olive. | |
| 100 | 370 | | |
| 90 | 380 | | |

DRILL HOLE MJ-2 Page 6 of 6

| Elevation (feet-MSL) | Depth (feet) | Sampled Interval | Graphic Log | Lithologic Description | Unit |
|---|---|---|---|---|---|
| 80 | 390 | | | Clayey SILT as above. Pale-olive to grayish-olive. Vesicular basalt clasts in sample at 395 to 400 ft. | Ter |
| 70 / 60 / 50 | 400 / 410 / 420 | | | BASALT. Dark-gray. Moderately fresh. Vesicular. Some vesicles filled with green clay. Caved material from Rattlesnake Ridge interbed from 405 to 420 ft. Basalt extremely vesicular from 415 to 420 ft. | Tp |
| 45.2 | | | EOH 425' | | |

## DRILL HOLE MJ-3

Page 1 of 4

Project No : 823-1036
Elevation : 468.5 ft.
Total Depth : 273 ft.
Coordinates : N451,378.18; E262,629.38
Date Completed : 8/26/82

SAMPLE TYPE
- ▨ Cuttings
- 95 ■ Core, Number Indicates % Core Recovery
- C 2015 ⊡ XRF, With Sample Number
  Chemical Results Listed in Table 2R-1

Unit Column Refers to General Stratigraphic Divisions Identified Within the Site Area :

| | | |
|---|---|---|
| M - Missoula | III - Ringold, Cycle III | B - Basalt, Undifferentiated |
| PM - Pre-Missoula | II - Ringold, Cycle II | EM - Elephant Mountain Member |
| IV - Ringold, Cycle IV | I - Ringold, Cycle I | RR - Rattlesnake Ridge Interbed |
| | | P - Pomona Member |

| Elevation (ft.MSL) | Depth (feet) | Lithologic Description | Unit |
|---|---|---|---|
| | | Silty sandy GRAVEL to gravelly silty SAND. 50 to 55% basalt clasts. Sand yellowish-gray; very-fine-grained; angular to subangular. | M |
| 460 | 10 | Gravelly SAND. 75% basalt grains. Very-coarse-grained. Angular to subangular. | M |
| 450 | 20 | Silty sandy GRAVEL to gravelly silty SAND. 50 to 75% basalt clasts. Sand poorly sorted; very-fine- to very-coarse-grained; 45 to 60% basalt grains; angular to subangular. | M |
| 440 | 30 | Gravelly silty SAND. Yellowish-gray to dusky yellow. Very-fine-grained. <1% mafics. Angular to subangular. Gravel <45% basalt clasts. | PM |
| 430 | 40 | Silty sandy GRAVEL to gravelly silty SAND. 20-25% basalt clasts. No cement rinds. Sand moderately to poorly sorted; 5-7% mafics; subangular to subrounded; yellowish-gray to dusky yellow. | PM |
| 420 | 50 | Gravelly silty SAND. Yellowish-gray to dusky yellow. 7-10% mafics. Very-fine to medium-grained. Angular to subrounded. Gravel 25% basalt clasts; no cement rinds. | PM |
| | | Silty sandy GRAVEL. <50% basalt clasts. No cement rinds. Matrix light-olive-gray to moderate-olive-brown. Clay at 55 to 60 ft; possibly weathered basalt clay. | PM |
| 410 | 60 | BASALT. Oive-gray. Weathered. Nonvesicular. | Tem |

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**LOG OF DRILL HOLE MJ-3**

FIGURE 2R-A-114

DRILL HOLE MJ-3 Page 2 of 4

| Elevation (feet-MSL) | Depth (feet) | Sampled Interval | Graphic Log | Lithologic Description | Unit |
|---|---|---|---|---|---|
| 400 | 70 | | | BASALT. Olive-gray. Weathered. Silt and clay at 70 to 75 ft. | |
| 390 | 80 | | | BASALT. Medium-dark-gray at 75 to 80 ft. Dark-gray from 80 to 135 ft. Fresh, vesicular to 135 ft. Some vesicles filled with yellowish-green or white clay. | |
| 380 | 90 | | | | |
| 370 | 100 | | | | Tem |
| 360 | 110 | | | | |
| 350 | 120 | | | | |
| 340 | 130 | | | | |
| 330 | 140 | | | BASALT. Dark-gray. Fresh. Nonvesicular. Calcite on fracture surface at 140 to 145 ft. | |

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LOG OF DRILL HOLE MJ-3

FIGURE 2R-A-114

**DRILL HOLE** MJ-3 Page 3 of 4

| Elevation (feet-MSL) | Depth (feet) | Sampled Interval | Graphic Log | Lithologic Description | Unit |
|---|---|---|---|---|---|
| 320 | 150 | | | BASALT. Dark-gray. Fresh. Nonvesicular. Calcite on fracture surface at 170 to 175 ft. | Tem |
| 310 | 160 | | | | |
| 300 | 170 | | | | |
| 290 | 180 | | | BASALT. Medium- dark-gray from 175 to 185 ft. Fresh. Minor vesicules at 180 to 185 ft. | |
| 280 | 190 | | | Clayey SILT to silty CLAY. Light-olive-gray. Caved vesicular basalt clasts. | Ter |
| | | | | Clayey SILT. Light-olive-gray. Tuffaceous. | |
| 270 | 200 | | | Clayey SILT to silty CLAY. Light-olive-gray. Tuffaceous. | |
| | | | | Silty CLAY to clayey SILT. Grayish-yellow-green. Tuffaceous. | |
| 260 | 210 | | | Sandy clayey SILT to sandy silty CLAY. Grayish-yellow-green. Tuffaceous. | |
| | | | | Sandy silty CLAY to sandy clayey SILT. Grayish-yellow-green. Tuffaceous. | |
| 250 | 220 | | | Sandy clayey SILT. Grayish-yellow-green. Tuffaceous. Sand very-fine-grained. | |

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LOG OF DRILL HOLE MJ-3

FIGURE 2R-A-114

**DRILL HOLE** MJ-3 

| Elevation (feet-MSL) | Depth (feet) | Sampled Interval / Graphic Log | Lithologic Description | Unit |
|---|---|---|---|---|
| | | | Sandy clayey SILT, as above. | Ter |
| 240 | 230 | | | |
| 230 | 240 | | BASALT. Medium-gray grading downward to medium-dark-gray. Moderately fresh. Vesicular. Some vesicles filled with green or white clay. | |
| 220 | 250 | | BASALT. Dark-gray from 245 to 260 ft. fresh. Vesicles decreasing. Calcite crystals at 250 to 255 ft. | Tp |
| 210 | 260 | | | |
| | | | BASALT. Grayish-black from 260 to 270 ft. Fresh. Large vesicles at 265 to 270 ft. Increase in size of plagioclase phenocrysts at 260 to 265 ft. | |
| 200 | 270 | | | |
| 195.5 | | EOH 273' | | |

| | | |
|---|---|---|
| PUGET SOUND POWER & LIGHT COMPANY<br>SKAGIT / HANFORD NUCLEAR PROJECT | LOG OF DRILL HOLE MJ-3 | FIGURE 2R-A-114 |

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QUESTION 231.5 (Regulatory Staff Position):

Additional investigations may be required of the Applicant to confirm the presence or absence of potentially hazardous geologic structure which may have been identified through existing data utilized in the response to RAI 231.4 but which lacks sufficient resolution for determination of capability or noncapability.

RESPONSE:

Subsequent to the Applicant's response to Question 231.4 and a meeting with the NRC staff on July 8 and 9, 1982, the staff determined that some additional investigations were required in one area for which there was not, in their judgment, sufficient information to confirm the presence or absence of hazardous geologic structure. Their request for additional information was forwarded to the Applicant in the form of Question 231.14. The Applicant's response to this request for additional information is provided in Amendment 28 to the PSAR.

QUESTION 231.14

The Applicant will conduct a core boring program of sufficient scope to determine if the May Junction monocline is fault controlled. If fault controlled, this program should provide sufficient new subsurface evidence demonstrating that the fault is not capable. This may include other subsurface techniques and information to supplement the core borings. This program should be of sufficient scope to define the attitude, sense of movement and age of last movement of the fault and be designed to carefully recover and define the overlying formations in this area.

RESPONSE:

In response to this question, the Applicant undertook a program of exploration using gravity measurements and rotary-wash borings. This program developed sufficient evidence to demonstrate that the May Junction monocline is not fault controlled. Thus, core borings were not required.

Definition of May Junction Monocline

The May Junction monocline is defined by the 2000-foot wide, north-south gravity gradient extending 2.5 miles through Sections 28, 29, 32 and 33 of T13N, R27E, and Sections 4 and 5 of T12N, R27E (S/HNP PSAR, Appendix 2K, Figure 2K-15). It was first recognized on the basis of aeromagnetic data (Myers and Price, 1979) and termed the May Junction linear (Magnetic Features Map, RHO-BWI-ST-4, Plate 111-6d). Investigations for the S/HNP PSAR, including gravity surveys and drilling, showed that the aeromagnetic linear was produced by a gentle easterly slope on the buried bedrock surface. On the basis of this bedrock structure, indicated both by gravity surveys and drilling, the feature was interpreted to be a gentle monoclinal fold and termed the May Junction monocline.

Exploratory Program

In a meeting with the NRC staff and representatives of the USGS on July 21, 1982, a program of investigations to address Question 231.14 was proposed by the Applicant. The program contemplated three steps. First, a gravity survey would be performed to characterize the May Junction monocline in greater detail so that locations for rotary-wash borings could be selected. Next, rotary-wash

QUESTION 231.14 (Cont'd)

borings would be drilled to evaluate the bed rock structure. And, finally, core borings would be drilled to determine the characteristics of any faults that might be discovered. The NRC staff agreed that the program was responsive to their request for additional information (NRC Letter, Novak to Myers dated August 4, 1982) and the program was implemented.

New gravity stations were established in Sections 32 and 33 of T13N, R27E, approximately 1 mile south of Gable Mountain (Figure 231.14-1), along nine new traverse lines (8A-8H, 8J) and portions of Lines 8 and D at 100-foot station intervals. All gravity stations were surveyed and both vertical and horizontal control provided to the nearest 0.1 foot. The newly acquired data were evaluated in profile. They were also combined with the NESCO data set (S/HNP PSAR, Appendix 2K) to produce a total Bouguer gravity anomaly map (Figure 231.14-2). The gravity anomaly contours on the May Junction monocline are consistent with a north-south trending bedrock surface sloping gently and uniformly downward toward the east.

Line 8C was chosen as a drilling location because of the typical character of the gravity profile (Figure 231.14-3) and the anticipation of a thick section of Ringold. Three rotary-wash boring locations, spaced equidistantly across the steepest part of the gravity anomaly, were selected and discussed with the NRC and USGS staffs.

The rotary method of drilling was used because the most important contacts in the section for determining the bedrock structure are the basalt/sediment contacts, which are easily recognized from data generated by this drilling technique. The elevations of these contacts were determined from detailed examination of the lithologic characteristics of the drill cuttings (Figures 231.14-4A, B and C) combined with interpretation of four down-hole geophysical logs for each hole (Figures 231.14-5A, B, C and D). The elevations of these contacts, particularly the Ringold Formation/Elephant Mountain member contact, the Elephant Mountain member/Rattlesnake Ridge interbed contact and the Rattlesnake Ridge interbed/Pomona member contact, were used to determine the thickness and dip of the various units along the line of section. Table 231.14-1 shows the thickness of the several units encountered in the three holes. Figure 231.14-6 shows the correlation between stratigraphic units recognized in borehole MJ-1 on Line 8C and holes drilled on Line 8 to

QUESTION 231.14 (Cont'd)

the north and Line 3 to the south, thus demonstrating the continuity of stratigraphic units along the strike of the monocline. Figure 231.14-7 shows the geologic cross section across the monocline at Line 8C.

Results:

The above investigation has shown the following:

1. Gravity anomaly and top-of-basalt contours are consistent with those drawn from earlier data and portray a gentle ($7^{o}$ to $10^{o}$) continuous slope without abrupt irregularity.

2. Borehole intercepts of the top-of-basalt lie along a nearly straight line.

3. The Elephant Mountain basalt/Rattlesnake inter-bed/Pomona basalt contacts are nearly parallel and define unit thicknesses that vary slightly but which are well within the range of normal thickness for these units throughout the Hanford Reservation.

4. The entire Ringold section is present in the most downslope boring (MJ-1) and correlates well with other borings along strike.

Interpretation of Results

There are four lines of evidence which indicate that the May Junction monocline is not fault controlled. These are:

- the smooth surface of the basalt as defined by drilling and gravity (Figures 231.14-7 and 231.14-8),
- the shallow ($7^{o}$ to $10^{o}$) dip of the stratigraphic units which form the monocline,
- the uniform dip ($\pm 3^{o}$) of the stratigraphic units between the drill holes and
- the generally uniform and typical thicknesses of the Elephant Mountain member encountered along the line of section.

QUESTION 231.14 (Cont'd)

The shallow dip of the units across the strike of the monocline had been recognized from previous geologic and geophysical studies (S/HNP PSAR, Appendices 2R and 2K). Results of the present investigation have confirmed this observation and have specifically shown that the units do, in fact, have a shallow dip ($7^{\circ}$ to $10^{\circ}$) along Line 8C (Figure 231.14-2). The units for which this shallow dip has been confirmed along Line 8C include Ringold Unit I, Elephant Mountain member, Rattlesnake Ridge interbed and the Pomona member. The shallow dip of these units indicates that, although the monocline is a prominent geophysical feature, only minor deformation has taken place in the basalt or overlying sediments along the trend of the monocline. This minor deformation has clearly been accommodated by the warping which produced the monocline.

In addition to the very gentle dip of the sediments and basalt units across the monocline, the fact that the dip of the units remains nearly constant between the drill holes indicates an absence of fault control. If the feature were fault controlled, and some offset of the basalt and overlying sedimentary units had occurred, such an offset would be reflected by variations in dip across the feature. Since there are no significant ($>5^{\circ}$) variations in dip and contacts across the feature lie along nearly straight line projections, there can be no significant fault offset between the drill holes. There is certainly no offset of the type that might be associated with a fault presumed to have caused nearly 300 feet of relief on the bedrock surface over a distance of only 2.5 miles.

Table 231.14-1 shows the elevations of contacts and thicknesses of units encountered in the three rotary holes. The Elephant Mountain member, in particular, is shown to have a very uniform thickness along the line of section. Some thickening is observed in MJ-2 in the Rattlesnake Ridge interbed; however, it is well within the normal range of variability in thickness of this unit observed elsewhere in the Pasco Basin where faults are known to be absent. None of the units show changes in thickness which could be interpreted to result from thinning or thickening due to displacement on a fault.

Upon completion of the rotary drilling program, a model of the subsurface geology that satisfies both the results of drilling and the gravity along Line 8C was constructed (Figure 231.14-8). The densities used for the units are 2.60, $g/cm^3$ for the basalt, 2.45 $g/cm^3$ for the Ringold

QUESTION 231.14 (Cont'd)

Basal Unit I gravel, and 2.0 g/$cm^3$ for the Rattlesnake Ridge interbed and the remainder of the sedimentary section. The modelled basalt surface varies smoothly. The change of Bouguer gravity anomaly across the May Junction monocline is due to the change of elevation of the top of basalt, change of density in the Ringold section and variation of the regional Bouguer gravity anomaly. The change in elevation of top of basalt accounts for at least 90% of the change. No evidence for offset is present.

Conclusions

Based upon all the available data, the following conclusions are drawn:

1. The May Junction monocline is a broad, gently-sloping fold in the basalt/interbed sequence;

2. No evidence of irregularities in the basalt surface or in subjacent or suprajacent units has been found to suggest fault offset;

3. Cumulative evidence indicates an absence of evidence for faulting or "fault control."

Based on these investigations and the other data available, investigations on the May Junction monocline have been adequate to provide reasonable assurance that the feature is not fault controlled. No further investigative work is needed to confirm this conclusion.

TABLE 231.14-1 Sheet 1 of 2

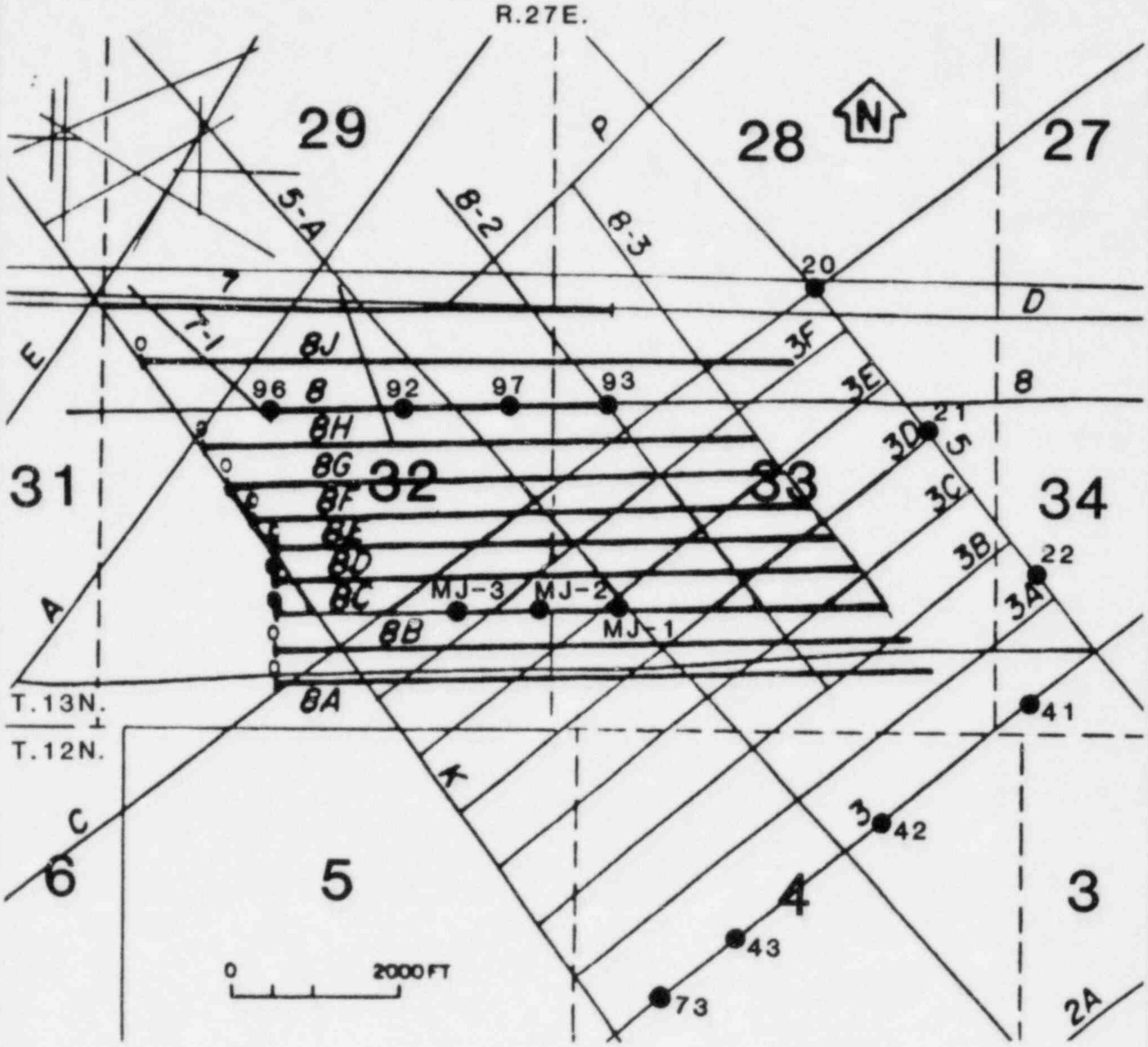
ELEVATIONS OF CONTACTS AND THICKNESSES OF UNITS ENCOUNTERED IN DRILLHOLES ALONG LINE 8C

| | MJ-3 | MJ-2 | MJ-1 |
|---|---|---|---|
| Top IV | | | |
| Depth | NP | NP | 124 |
| Elevation | NP | NP | 352 |
| Thickness IV | 0 | 0 | 82 |
| Top III | | | |
| Depth | NP | NP | 206 |
| Elevation | NP | NP | 270 |
| Thickness III | 0 | 0 | 36 |
| Top II | | | |
| Depth | NP | 85 | 242 |
| Elevation | NP | 385 | 234 |
| Thickness II | 0 | 95 | 66 |
| Top I-u | | | |
| Depth | NP | 180 | 308 |
| Elevation | NP | 290 | 168 |
| Thickness I-u | 0 | 10 | 33.5 |
| Top I-b | | | |
| Depth | NP | 190 | 341.5 |
| Elevation | NP | 280 | 135 |
| Thickness I-b | 0 | 14.5 | 39.5 |
| Top Tem | | | |
| Depth | 55 | 204.5 | 381 |
| Elevation | 413.5 | 266 | 95 |
| Thickness Tem | 127.5 | 127 | 113.5 |
| Top Ter | | | |
| Depth | 182.5 | 331.5 | 494.5 |
| Elevation | 286 | 139 | -18 |
| Thickness Ter | 46 | 65.5 | 35 |

TABLE 231.14-1 Sheet 2 of 2

| | MJ-3 | MJ-2 | MJ-1 |
|---|---|---|---|
| Top Tp | | | |
| Depth | 228.5 | 397 | 529.5 |
| Elevation | 240 | 73 | -53 |
| Thickness Tp | - | - | - |

NP = Not Present
IV = Ringold Unit IV
III = Ringold Unit III
II = Ringold Unit II
I-u = Ringold Upper Unit I
I-b = Ringold Basal Unit I
Tem = Elephant Mountain Member
Ter = Rattlesnake Ridge Interbed
Tp = Pomona Member

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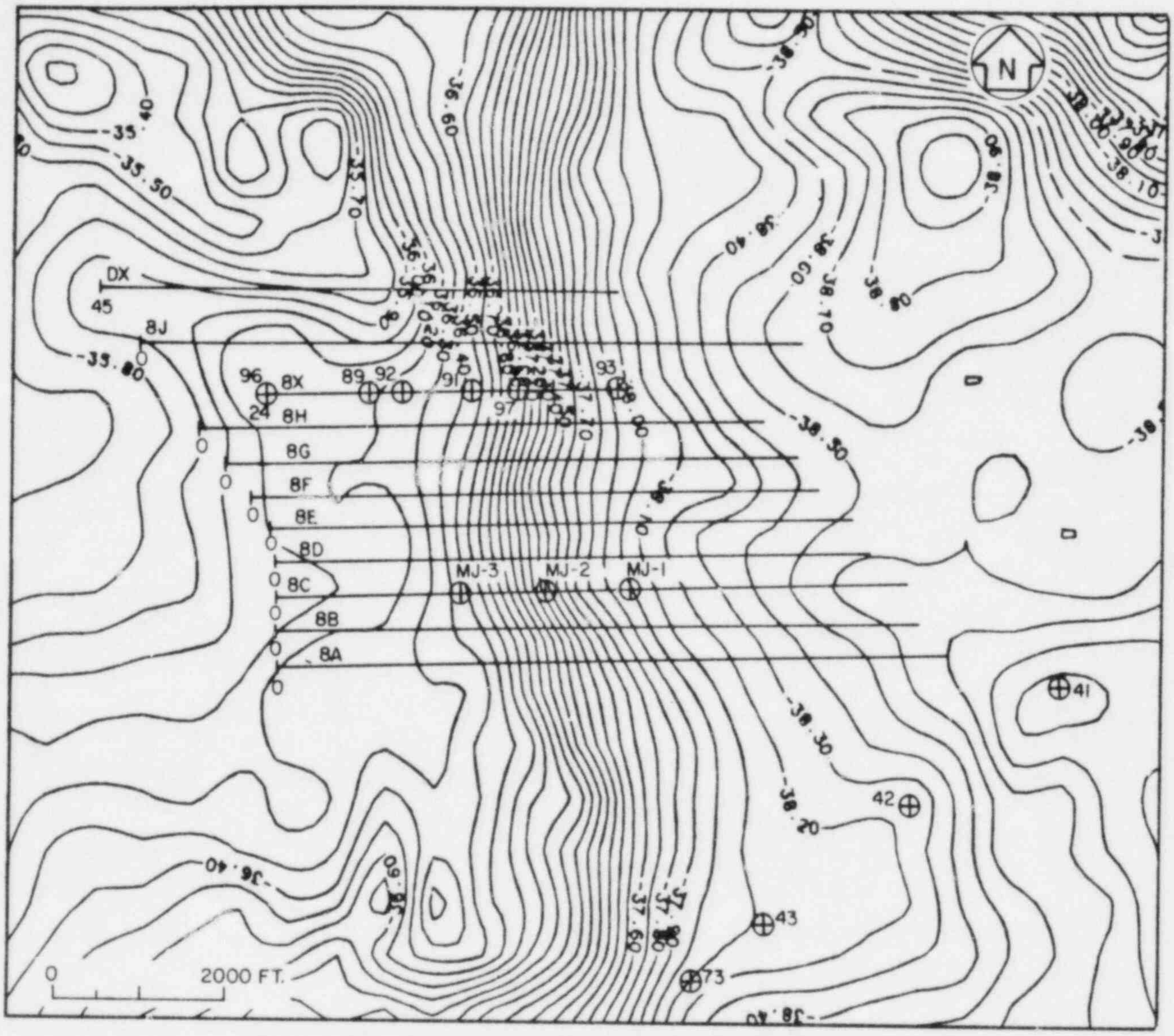
LOCATION MAP

FIGURE 231.14-1




Contour Interval: 0.1mgal

Data reduced at 2.00g/cm3

⊕ Drill hole location

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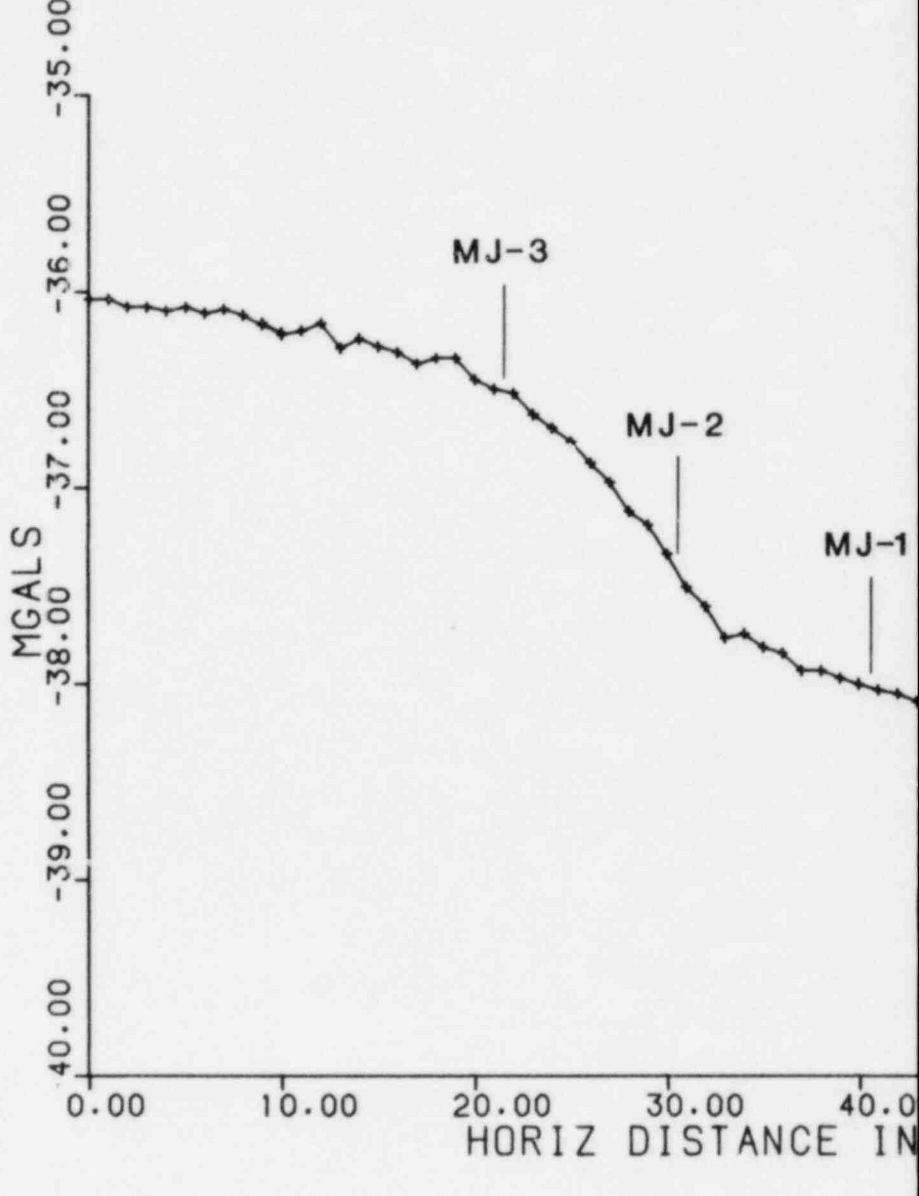
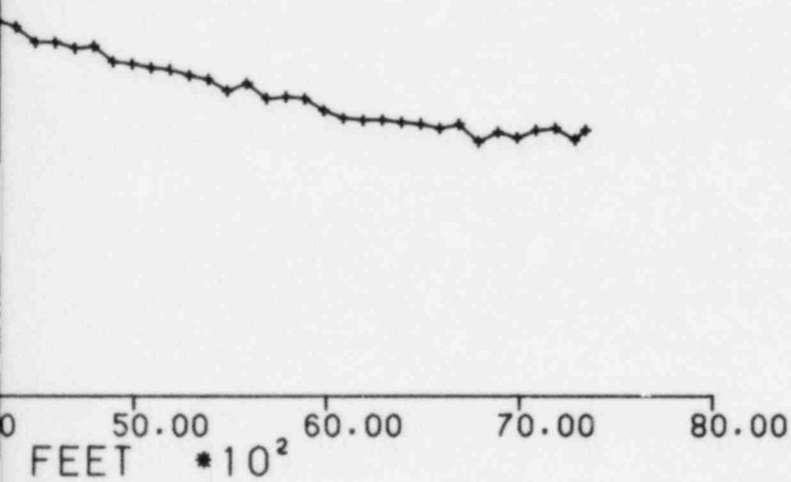
TOTAL BOUGER GRAVITY ANOMALY MAP
MAY JUNCTION AREA

FIGURE 231.14-2


MJ-3
MJ-2
MJ-1
MGALS
-35.00
-36.00
-37.00
-38.00
-39.00
-40.00
0.00
10.00
20.00
30.00
HORIZ DISTANCE IN

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GRAVITY PROFILE OF LINE 8C

FIGURE 231.14-3

# DRILL HOLE MJ-1

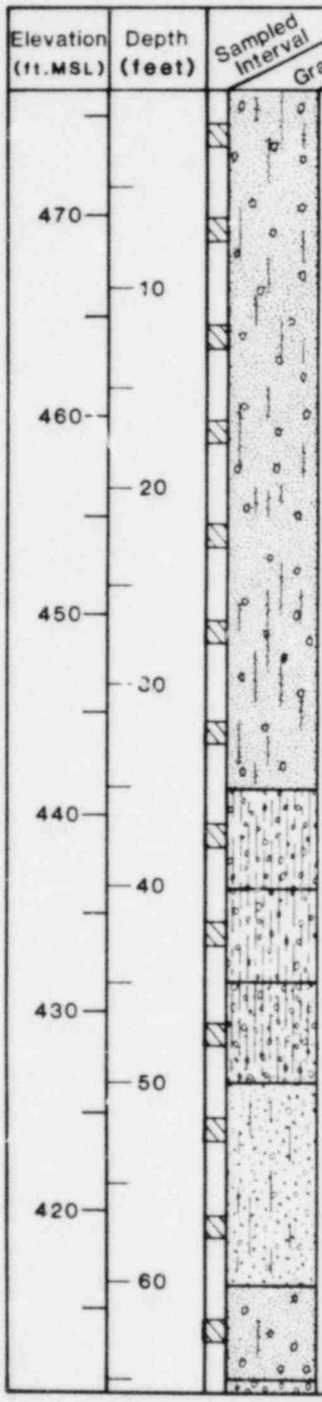
Project No : 823-1036
Elevation : 476.3 ft.
Total Depth : 573.0 ft.
Coordinates : N451,449.33; E264,631.23
Date Completed : 9/15/82

SAMPLE TYPE
Cuttings
95 Core, Number Indicates % Core Recovery
C 2015 XRF, With Sample Number
Chemical Results Listed in Table **2R-1**

Page 1 of 8

Unit Column Refers to General Stratigraphic Divisions Identified Within the Site Area :

- M - Missoula
- PM - Pre-Missoula
- IV - Ringold, Cycle IV
- III - Ringold, Cycle III
- II - Ringold, Cycle II
- I - Ringold, Cycle I
- B - Basalt, Undifferentiated
- EM - Elephant Mountain Member
- RR - Rattlesnake Ridge Interbed
- P - Pomona Member




| Lithologic Description | Unit |
|---|---|
| Gravelly silty SAND. Light-olive-brown. Medium- to very-coarse-grained. | M |
| Gravelly silty SAND. Olive-gray. Very-fine- to very-coarse grained, fining with depth. 60 to 75% basalt grains. Angular to subrounded. | M |
| Gravelly silty SAND. Medium-dark-gray grading to medium-gray at 30 to 35 ft. 55 to 80% basalt grains, decreasing with depth. Very-fine- to very-coarse-grained. Angular to subrounded. Gravel 75% basalt clasts. | M |
| Silty GRAVEL to gravelly SILT. Light-olive-gray. Ferruginous stain. Gravel basaltic; possibly caved. | PM |
| Gravelly SILT to silty GRAVEL light-olive-gray. | PM |
| Gravelly sandy SILT to silty sandy GRAVEL. Light-olive-gray. Spotty ferruginous stain. Sand very-fine- and medium- to coarse-grained. | PM |
| Silty sandy GRAVEL. 30 to 50% basalt clasts, decreasing with depth. Sand very-fine- to very-coarse-grained; mostly coarse- to very-coarse grained; 20% basalt grains. | PM |
| Gravelly SAND. Yellowish-gray. Fine- to medium-grained. 10% mafics. Angular to subangular. Trace silt. | PM |

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LOG OF DRILL HOLE MJ-1

FIGURE 231.14-4A

DRILL HOLE MJ-1 

Elevation (feet-MSL): 410, 400, 390, 380, 370, 360, 350, 340

Depth (feet): 70, 80, 90, 100, 110, 120, 130, 140

| Lithologic Description | Unit |
|---|---|
| Sandy GRAVEL. 20% basalt clasts. Sand fine- to coarse-grained; 10 to 15% mafics; angular. Trace silt. | PM |
| Gravelly silty SAND. Yellowish-gray to light-olive-gray. 20 to 25% mafics. Very-fine- to coarse-grained. Angular to subangular. | PM |
| Gravelly SAND to sandy GRAVEL. Yellowish-gray to light-olive-gray. Fine- to very-coarse-grained; mostly very-coarse-grained. 30% basalt grains. | PM |
| Gravelly silty SAND. Yellowish-gray to light-olive-gray. Very-fine- to very-coarse-grained. Grain size decreases and sorting is poorer with depth. 25 to 30% basalt grains. Silt increases with depth. | PM |
| Silty sandy GRAVEL to gravelly silty SAND. 45% basalt clasts. Sand as above. | PM |
| Gravelly silty SAND. Yellowish-gray to light-olive-gray. Very-fine- to medium-grained; mostly medium-grained. 15 to 20% mafics. Local ferruginous stain. | PM |
| Silty sandy GRAVEL. Matrix as above. Local ferruginous stain. No sandy cement rinds. | PM |
| Gravelly silty SAND to silty sandy GRAVEL. Yellowish-gray. Very-fine- to coarse-grained. 10 to 15% mafics. No sandy cement rinds. | PM |
| Gravelly SAND to sandy GRAVEL. Yellowish-gray. Fine- to medium-grained. 7 to 10% mafics. Angular to subangular. Clean. Gravel 15% basalt clasts; no sandy cement rinds. | PM |
| Sandy GRAVEL to gravelly SAND. Sand as above. Some pebbles with yellow sandy cement rinds (reworked Ringold?). | PM |
| Gravelly SAND. Yellowish-gray to dusky yellow. Fine- to medium-grained; mostly medium-grained. 7-10% mafics. Angular to subangular. Abundant gravel clasts with yellow sandy cement rinds. | IV |

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LOG OF DRILL HOLE MJ-1

FIGURE 231.14-4A

DRILL HOLE MJ-1 Page 3 of 8

| Elevation (feet-MSL) | Depth (feet) | Lithologic Description | Unit |
|---|---|---|---|
| 330 | 150 | Silty sandy GRAVEL. Matrix yellowish-gray to dusky yellow. Sand fine- to medium-grained; mostly medium-grained; 5 to 7% mafics; angular to subangular. Yellow sandy cement rinds on gravel clasts. | IV |
| 320 | 160 | Gravelly SAND. Yellowish-gray grading downward to dusky yellow. Very-fine- to medium-grained; mostly medium-grained. 5 to 7% mafics. Angular to subangular. Abundant yellow sandy cement rinds. | IV |
| 310 | | Silty SAND. Yellowish-gray to dusky yellow. Very-fine to medium-grained; mostly fine- to medium-grained. 5 to 7% mafics. Trace gravel. | IV |
| | 170 | Silty SAND to sandy SILT. Dusky yellow. Very-fine-grained. | IV |
| 300, 290, 280 | 180, 190 | SAND. Yellowish-gray. Fine- to medium-grained; mostly medium-grained. 7 to 10% mafics. Angular to subangular. Trace silt from 180 to 190 ft. Micaceous at 185 to 190 ft. and 195 to 200 ft. Trace gravel with yellow sandy cement rind at 195 to 200 ft. | IV |
| | 200 | Sandy GRAVEL to gravelly SAND. Yellowish-gray to dusky yel[illegible]. Abundant yellow sandy cement rinds. | IV |
| 270 | | Gravelly SAND. Dusky yellow. Local ferruginous stain and cement. | III |
| | 210 | Gravelly SAND. Light-olive-gray. Fine- to medium-grained; mostly medium-grained. 15 to 20% mafics. Wood fragments. Micaceous. Sandy cement rinds. | III |
| 260 | | SAND. Light-olive-gray. Very-fine- to medium-grained; mostly medium-grained. 20% mafics. Micaceous. | III |
| | 220 | GRAVEL. Trace sand. 15 to 20% basalt clasts. Trace sandy cement rinds. | III |

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LOG OF DRILL HOLE MJ-1

FIGURE 231.14-4A

**DRILL HOLE** MJ-1 Page 4 of 8

| Elevation (feet-MSL) | Depth (feet) | Lithologic Description | Unit |
|---|---|---|---|
| 250 | | GRAVEL, as above. Pyrite on some clasts. | III |
| | 230 | Sandy GRAVEL. 35% basalt clasts. Local pyrite. Minor yellow sandy cement rinds. Sand matrix fine- to medium-grained. | |
| 240 | 240 | Gravelly sandy SILT, with CLAY and ash-like fragments. Very-light-gray, olive-gray, and light-olive-gray. Gravel and sand probably caved. Pyrite fragments. Some silt and clay fragments laminated. | |
| 230 | 250 | Gravelly silty SAND, with CLAY fragments. Light-olive-gray. Very-fine- to medium-grained. | II |
| 220 | 260 | SAND, with clay and white ash-like fragments. Yellowish-gray. Very-fine to fine-grained. Mostly fine-grained. 5 to 7% mafics. Trace gravel. | |
| 210 | | Gravelly silty SAND with SJ T fragments. Yellowish-gray. Very-fine- to medium-grained. 10% mafics. Angular to subangular. | |
| | 270 | Gravelly sandy SILT to CLAY. Yellowish-gray. Slight waxy luster to clay. | |
| 200 | | Gravelly sandy SILT to gravelly silty SAND. Yellowish-gray. Sand very-fine-grained. | |
| | 280 | Gravelly silty SAND. Yellowish-gray. Very-fine- to fine-grained; mostly very-fine-grained. 3% mafics. Angular to subangular. | |
| 190 | | Silty SAND, with CLAY fragments. Dark yellowish-brown. Sand as above. | |
| | 290 | Silty SAND, with silty SAND to sandy SILT fragments. Yellowish-gray. Very-fine- to medium-grained. 2 to 3% mafics. | |
| 180 | 300 | Gravelly silty SAND, with CLAY fragments. Sand yellowish-gray. Clay dark-yellowish-brown. Very-fine- to medium-grained. | |

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**LOG OF DRILL HOLE MJ-1**

FIGURE 231.14-4A

**DRILL HOLE** MJ-1 Page 5 of 8

Elevation (feet-MSL): 170, 160, 150, 140, 130, 120, 110, 100

Depth (feet): 310, 320, 330, 340, 350, 360, 370, 380

| Sampled Interval / Graphic Log | Lithologic Description | Unit |
| --- | --- | --- |
| | Gravelly SAND, with dark yellowish-brown CLAY fragments. Yellowish-gray. Fine- to coarse-grained; mostly medium-grained. 3% mafics. | |
| | Gravelly silty SAND, with silty clayey sand fragments. Light-olive-gray. Very-fine- to medium-grained; mostly fine-grained. 2 to 3% mafics. Angular to subangular. | 1-u |
| | Sandy clayey SILT. Olive-gray. | 1-u |
| | Gravelly clayey SAND. Olive-gray. Medium- to coarse-grained. | 1-u |
| | Gravelly silty SAND, with SILT and CLAY fragments. Light-olive-gray. Very-fine- to coarse-grained. 3% mafics. Local ferruginous stain. | 1-u |
| | Gravelly SAND, with SILT fragments. Light-olive-gray. Fine- to medium-grained; mostly medium-grained. 5% mafics. Local ferruginous stain. | 1-u |
| | SAND. Light-olive-gray. Medium-grained. 5 to 7% mfaics. Micaceous. Trace gravel. | 1-b |
| | Sandy GRAVEL. 20% basalt clasts increasing downward to 40 to 45% basalt clasts. Some sandy cement rinds. Blue cast to some basalt clasts. Local ferruginous stain and cement. | 1-b |
| | GRAVEL. Trace sand. 30 to 40% basalt clasts. Sandy cement rinds. Blue cast to some basalt clasts. | 1-b |
| | Silty sandy GRAVEL. 30 to 40% basalt clasts. Sand very-fine- to medium-grained; yellowish-gray. | 1-b |
| | Basalt. Dark-gray. Caved gravel clasts. | Tem |

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**LOG OF DRILL HOLE MJ-1**

FIGURE 231.14-4A

DRILL HOLE MJ-1 Page 6 of 8

| Elevation (feet-MSL) | Depth (feet) | Lithologic Description | Unit |
|---|---|---|---|
| 90 | | | |
| | | BASALT, as above. Some vesicles. | |
| | 390 | | |
| 80 | | BASALT. Dark-gray. Weathered. Vesicular. Some vesicles filled with green and white clay. | |
| | 400 | | |
| 70 | | | |
| | 410 | BASALT. Dark-gray. Vesicular. Moderately fresh. Some caved gravel. | |
| 60 | | | |
| | 420 | BASALT sand. Grayish black. Fresh. Ground to sand size by drill bit. | Tem |
| 50 | | | |
| | 430 | BASALT. Brownish-gray to grayish black. Fresh. Trace vesicles. Local pyrite mineralization at 430 to 435 ft. | |
| 40 | | BASALT. Dark-gray to grayish black. Fresh. Nonvesicular. | |
| | 440 | | |
| | | BASALT. Olive-gray to olive-black. Vesicular. Some vesicles filled with green clay. Some brecciated clay fragments. | |
| 30 | | | |
| | | BASALT. Dark-gray. Fresh. Nonvesicular. Trace silt from 450 to 460 ft. | |
| | 450 | | |
| 20 | | | |
| | 460 | | |
| | | BASALT. Olive-gray. Fresh. Trace silt. Nonvesicular. | |

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LOG OF DRILL HOLE MJ-1

FIGURE 231.14-4A

DRILL HOLE MJ-1 Page 7 of 8

| Elevation (feet-MSL) | Depth (feet) | Sampled Interval | Graphic Log | Lithologic Description | Unit |
|---|---|---|---|---|---|
| 10 | 470 | | | BASALT, as above. Local calcite mineralization at 465 to 470 ft. | Tem |
| 0 | 480 | | | | |
| -10 | 490 | | | | |
| -20 | | | | BASALT. Olive-gray. Moderately weathered. Vesicular. Vesicles filled with yellowish-green clay. | |
| | 500 | | | Sandy clayey SILT to sandy silty CLAY. Light-olive-gray. | Ter |
| -30 | | | | Clayey silty SAND. Light-olive-gray. Local pyrite cement. Very-fine- to medium-grained. Angular to subangular. | |
| -40 | 510 | | | SAND. Light-olive-gray to yellowish-gray. Fine- to coarse-grained; mostly coarse-grained. 3 to 5% mafics. Angular to subangular. | |
| -50 | 520 | | | SAND, as above, with pinkish-gray to light-greenish-gray CLAY fragments. | |
| | 530 | | | SILT, with CLAY fragments and SAND. Light-olive-gray; pinkish-gray and light-greenish-gray. Silt tuffaceous. Clay with waxy luster. | Tp |
| -60 | 540 | | | BASALT. Brownish-black. Highly vesicular. Many vesicles filled with clay. Caved sand, silt, and clay fragments. | |

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LOG OF DRILL HOLE MJ-1

FIGURE 231.14-4A

DRILL HOLE MJ-1 Page 8 of 8

| Elevation (feet-MSL) | Depth (feet) | Sampled Interval | Graphic Log | Lithologic Description | Unit |
|---|---|---|---|---|---|
| -70 | | | | | |
| | 550 | | | BASALT, as above. | |
| -80 | | | | | |
| | 560 | | | | Tp |
| | | | | BASALT. Dark-gray. Fresh. Nonvesicular from 560 to 570 ft. Minor vesicles at 570 to 573 ft. | |
| -90 | | | | | |
| | 570 | | | | |
| -96.7 | | | EOH 573' | | |

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LOG OF DRILL HOLE MJ-1

FIGURE 231.14-4A

**DRILL HOLE** MJ-2

Page 1 of 6

Project No : 823-1036
Elevation : 470.2 ft.
Total Depth : 425 ft.
Coordinates : N451,412.95; E263,630.25
Date Completed : 9/3/82

SAMPLE TYPE
- Cuttings
- 95 Core, Number Indicates % Core Recovery
- C 2015 XRF, With Sample Number; Chemical Results Listed in Table 2R-1

Unit Column Refers to General Stratigraphic Divisions Identified Within the Site Area :

- M - Missoula
- PM - Pre-Missoula
- IV - Ringold, Cycle IV
- III - Ringold, Cycle III
- II - Ringold, Cycle II
- I - Ringold, Cycle I
- B - Basalt, Undifferentiated
- EM - Elephant Mountain Member
- RR - Rattlesnake Ridge Interbed
- P - Pomona Member

| Elevation (ft. MSL) | Depth (feet) | Lithologic Description | Unit |
|---|---|---|---|
| 470 | | Gravelly silty SAND. Medium-light-gray. 75% basalt grains. Coarse- to very-coarse-grained. | M |
| | | Gravelly silty SAND to silty sandy GRAVEL. Medium-light-gray. 75% basalt grains. Coarse- to very-coarse-grained. | M |
| 460 | 10 | Gravelly silty SAND. Medium-light-gray. 75% basalt grains. Medium- to very-coarse grained; mostly medium-grained. | M |
| | | Gravelly sandy SILT. Medium-gray. Gravel 60% basalt clasts. | M |
| 450 | 20 | SAND. Medium-dark-gray. Medium- to very-coarse-grained; mostly coarse-grained. 70% basalt grains. Trace silt. | M |
| 440 | 30 | Gravelly silty SAND. Moderate yellowish-brown grading downward to yellowish-gray. Moderately well to poorly sorted. 5 to 10% mafics, increasing with depth. Micaceous. Angular to subangular. | PM |
| 430 | 40 | Gravelly SAND. Yellowish-gray. Very-fine- to fine-grained. 5-7% mafics. Angular to subangular. Gravel 20% basalt clasts. Trace silt at 45 to 50 ft. | PM |
| 420 | 50 | Gravelly silty SAND to silty sandy GRAVEL. Light-olive-gray. 10 to 15% mafics. Fine- to coarse-grained. Gravel 25 to 30 % basalt clasts. | PM |
| | | Silty sandy GRAVEL. Moderate olive-brown. No cement rinds. Silt adheres to clasts. Sand fine- to medium-grained. | PM |
| 410 | 60 | Gravelly silty SAND. Dark yellowish-brown. Fine- to medium-grained. 15% mafics. Silt adheres to grains. Subangular to subrounded. | PM |

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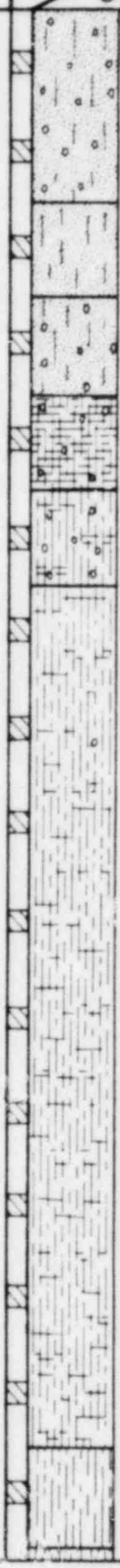
**LOG OF DRILL HOLE MJ-2**

FIGURE 2R.14-4B

DRILL HOLE MJ-2 Page 2 of 6

| Elevation (feet-MSL) | Depth (feet) | Lithologic Description | Unit |
|---|---|---|---|
| 400 | 70 | Gravelly silty SAND, as above. Micaceous. Ferruginous stain. Fine- to medium-grained; mostly medium-grained. No cement rinds on gravel clasts. | PM |
| | | Silty SAND. Dusky yellow. Very-fine- to medium-grained, mostly medium-grained. 5 to 7 % mafics. Large muscovite flakes. | |
| 390 | 80 | Gravelly silty SAND. Dusky yellow. Very-fine- to medium-grained; mostly very-fine-grained. 2 to 3% mafics. No cement rinds on gravel clasts. | |
| | | Gravelly clayey SILT to gravelly silty CLAY. Yellowish-gray to dusky yellow. Gravel probably caved. | II? |
| 380 | 90 | Gravelly SILT, with CLAY fragments. Yellowish-gray. Sand very-fine-grained. | |
| | | SIL[illegible] AY fragments. Yellowish-gray to 130 ft.; yellowish-gray to [illegible] ow from 130 to 140 ft. Trace gravel at 100 to 105 ft. Cla[illegible] gments decrease with depth. | |
| 370 | 100 | | |
| 360 | 110 | | |
| 350 | 120 | | |
| 340 | 130 | | |
| 330 | 140 | SILT. Yellowish-gray to dusky yellow. | |



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LOG OF DRILL HOLE MJ-2

FIGURE 231.14-4B

DRILL HOLE MJ-2 Page 3 of 6

| Elevation (feet-MSL) | Depth (feet) | Lithologic Description | Unit |
|---|---|---|---|
| | | Sandy SILT. Yellowish-gray to dusky yellow. Sand very-fine-grained. Trace clay fragments. | |
| 320 | 150 | Silty SAND to sandy SILT. Dusky yellow. Very-fine- to fine-grained 2-3% mafics. Angular to subangular. | |
| 310 | 160 | Silty SAND. Dusky yellow grading downward to light-olive-brown. Very-fine- to medium-grained; mostly very-fine- to fine-grained. 3 to 5% mafics. Angular to subangular. | II? |
| 300 | 170 | Sandy SILT to silty SAND. Dusky-yellow. Sand very-fine-grained. Clayey in part. | |
| | | Sandy SILT. Yellowish-gray. Sand very-fine-grained. | |
| 290 | 180 | Gravelly SAND. Light-olive-gray. Fine- to coarse-grained; mostly fine- to medium-grained. 15 to 20% mafics. Sandy cement rinds on some gravel clasts. Trace silt at 185 to 190 ft. | 1-u? |
| 280 | 190 | Sandy GRAVEL to gravelly SAND. 45 to 50% basalt clasts. Sandy cement rinds on some clasts. Sand yellowish-gray; mostly medium-grained; 7 to 10% mafics. | |
| | | Gravelly SAND. Light-olive-gray. Medium-grained. Micaceous. Sandy cement rinds on some gravel clasts. | 1-b? |
| 270 | 200 | Sandy clayey GRAVEL. Clay light-olive-gray; possibly weathered basalt clay. | |
| | | BASALT. Olive-gray. Weathered and vesicular at 205 to 210 ft. | |
| 260 | 210 | BASALT. Dark gray. Moderately fresh. Vesicular. Some yellowish-green clay in vesicles. | Tem |
| 250 | 220 | | |

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LOG OF DRILL HOLE MJ-2

FIGURE 231.14-4B

DRILL HOLE MJ-2 Page 4 of 6

| Elevation (feet-MSL) | Depth (feet) | Sampled Interval | Graphic Log | Lithologic Description | Unit |
|---|---|---|---|---|---|
| 240 | 230 | | | BASALT. Medium-dark-gray to 255 ft. Weathered. Vesicular. Some vesicles filled with yellowish-green to white clay. | |
| 230 | 240 | | | | |
| 220 | 250 | | | BASALT. Dark-gray. Fresh. Minor vesicles to 265 ft. Minor clay (caved?). | |
| 210 | 260 | | | | Tem |
| 200 | 270 | | | BASALT. Dark-gray. Fresh. Nonvesicular. Local pyrite or calcite mineralization on some surfaces. Minor vesicles from 270 to 280 ft. and from 290 to 300 ft. | |
| 190 | 280 | | | | |
| 180 | 290 | | | | |
| 170 | 300 | | | | |

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LOG OF DRILL HOLE MJ-2

FIGURE 231.14-4B

DRILL HOLE MJ-2 Page 5 of 6

| Elevation (feet-MSL) | Depth (feet) | Sampled Interval / Graphic Log | Lithologic Description | Unit |
|---|---|---|---|---|
| 160 | 310 | | BASALT. Dark-gray. Fresh. Nonvesicular. Local calcite or pyrite on some surfaces from 320 to 330 ft. | Tem |
| 150 | 320 | | | |
| 140 | 330 | | BASALT. Dark-gray. Vesicular. Vesicularity increases with depth. Vesicles at 335 to 340 filled with green clay. | |
| 130 | 340 | | Clayey SILT to silty CLAY. Light-olive-gray. | Ter |
| 120 | 350 | | SILT to clayey SILT. Grayish-yellow-green. Tuffaceous. | |
| 110 | 360 | | Clayey SILT, with CLAY and tuffaceous fragments. Pale olive. | |
| 100 | 370 | | | |
| 90 | 380 | | | |

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LOG OF DRILL HOLE MJ-2

FIGURE 231.14-4B

DRILL HOLE MJ-2 Page 6 of 6

| Elevation (feet-MSL) | Depth (feet) | Sampled Interval / Graphic Log | Lithologic Description | Unit |
|---|---|---|---|---|
| 80 | 390 | | Clayey SILT, as above. Pale-olive to grayish-olive. Vesicular basalt clasts in sample at 395 to 400 ft. | Ter |
| 70 | 400 | | BASALT. Dark-gray. Moderately fresh. Vesicular. Some vesicles filled with green clay. Caved material from Rattlesnake Ridge interbed from 405 to 420 ft. Basalt extremely vesicular from 415 to 420 ft. | Tp |
| 60 | 410 | | | |
| 50 | 420 | | | |
| 45.2 | | EOH 425' | | |

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LOG OF DRILL HOLE MJ-2

FIGURE 231.14-4B

## DRILL HOLE MJ-3

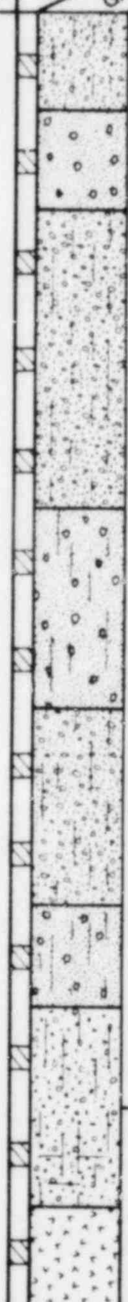
Project No : 823-1036
Elevation : 468.5 ft.
Total Depth : 273 ft.
Coordinates : N451,378.18; E262,629.38
Date Completed : 8/26/82

SAMPLE TYPE
- Cuttings
- 95 Core, Number Indicates % Core Recovery
- C 2015 XRF, With Sample Number
  Chemical Results Listed in Table 2R-1



Unit Column Refers to General Stratigraphic Divisions Identified Within the Site Area :

| | | |
|---|---|---|
| M - Missoula | III - Ringold, Cycle III | B - Basalt, Undifferentiated |
| PM - Pre-Missoula | II - Ringold, Cycle II | EM - Elephant Mountain Member |
| IV - Ringold, Cycle IV | I - Ringold, Cycle I | RR - Rattlesnake Ridge Interbed |
| | | P - Pomona Member |



| Elevation (ft.MSL) | Depth (feet) | Lithologic Description | Unit |
|---|---|---|---|
| | | Silty sandy GRAVEL to gravelly silty SAND. 50 to 55% basalt clasts. Sand yellowish-gray; very-fine-grained; angular to subangular. | M |
| 460 | 10 | Gravelly SAND. 75% basalt grains. Very-coarse-grained. Angular to subangular. | M |
| 450 | 20 | Silty sandy GRAVEL to gravelly silty SAND. 50 to 75% basalt clasts. Sand poorly sorted; very-fine- to very-coarse-grained; 45 to 60% basalt grains; angular to subangular. | M |
| 440 | 30 | Gravelly silty SAND. Yellowish-gray to dusky yellow. Very-fine-grained. <1% mafics. Angular to subangular. Gravel <45% basalt clasts. | PM |
| 430 | 40 | Silty sandy GRAVEL to gravelly silty SAND. 20-25% basalt clasts. No cement rinds. Sand moderately to poorly sorted; 5-7% mafics; subangular to subrounded; yellowish-gray to dusky yellow. | PM |
| 420 | 50 | Gravelly silty SAND. Yellowish-gray to dusky yellow. 7-10% mafics. Very-fine to medium-grained. Angular to subrounded. Gravel 25% basalt clasts; no cement rinds. | PM |
| | | Silty sandy GRAVEL. <50% basalt clasts. No cement rinds. Matrix light-olive-gray to moderate-olive-brown. Clay at 55 to 60 ft; possibly weathered basalt clay. | PM |
| 410 | 60 | BASALT. Oive-gray. Weathered. Nonvesicular. | Tem |

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LOG OF DRILL HOLE MJ-3

FIGURE 231.14-4C

DRILL HOLE MJ-3 Page 2 of 4

| Elevation (feet-MSL) | Depth (feet) | Sampled Interval | Graphic Log | Lithologic Description | Unit |
|---|---|---|---|---|---|
| 400 | 70 | | | BASALT. Olive-gray. Weathered. Silt and clay at 70 to 75 ft. | |
| 390 | 80 | | | BASALT. Medium-dark-gray at 75 to 80 ft. Dark-gray from 80 to 135 ft. Fresh, vesicular to 135 ft. Some vesicles filled with yellowish-green or white clay. | |
| 380 | 90 | | | | |
| 370 | 100 | | | | Tem |
| 360 | 110 | | | | |
| 350 | 120 | | | | |
| 340 | 130 | | | | |
| 330 | 140 | | | BASALT. Dark-gray. Fresh. Nonvesicular. Calcite on fracture surface at 140 to 145 ft. | |

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LOG OF DRILL HOLE MJ-3

FIGURE 231.14-4C

DRILL HOLE MJ-3 Page 3 of 4

| Elevation (feet-MSL) | Depth (feet) | Sampled Interval | Graphic Log | Lithologic Description | Unit |
|---|---|---|---|---|---|
| 320 | 150 | | | BASALT. Dark-gray. Fresh. Nonvesicular. Calcite on fracture surface at 170 to 175 ft. | |
| 310 | 160 | | | | Tem |
| 300 | 170 | | | | |
| 290 | 180 | | | BASALT. Medium- dark-gray from 175 to 185 ft. Fresh. Minor vesicules at 180 to 185 ft. | |
| 280 | 190 | | | Clayey SILT to silty CLAY. Light-olive-gray. Caved vesicular basalt clasts. | |
| 270 | | | | Clayey SILT. Light-olive-gray. Tuffaceous. | |
| | 200 | | | Clayey SILT to silty CLAY. Light-olive-gray. Tuffaceous. | Ter |
| 260 | | | | Silty CLAY to clayey SILT. Grayish-yellow-green. Tuffaceous. | |
| | 210 | | | Sandy clayey SILT to sandy silty CLAY. Grayish-yellow-green. Tuffaceous. | |
| 250 | | | | Sandy silty CLAY to sandy clayey SILT. Grayish-yellow-green. Tuffaceous. | |
| | 220 | | | Sandy clayey SILT. Grayish-yellow-green. Tuffaceous. Sand very-fine-grained. | |

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LOG OF DRILL HOLE MJ-3

FIGURE 231.14-4C

DRILL HOLE MJ-3 Page 4 of 4

| Elevation (feet-MSL) | Depth (feet) | Sampled Interval / Graphic Log | Lithologic Description | Unit |
|---|---|---|---|---|
| 240 | 230 | | Sandy clayey SILT, as above. | Ter |
| 230 | 240 | | BASALT. Medium-gray grading downward to medium-dark-gray. Moderately fresh. Vesicular. Some vesicles filled with green or white clay. | Tp |
| 220 | 250 | | BASALT. Dark-gray from 245 to 260 ft. fresh. Vesicles decreasing. Calcite crystals at 250 to 255 ft. | |
| 210, 200 | 260, 270 | | BASALT. Grayish-black from 260 to 270 ft. Fresh. Large vesicles at 265 to 270 ft. Increase in size of plagioclase phenocrysts at 260 to 265 ft. | |
| 195.5 | | EOH 273' | | |

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LOG OF DRILL HOLE MJ-3

FIGURE 231.14-4C

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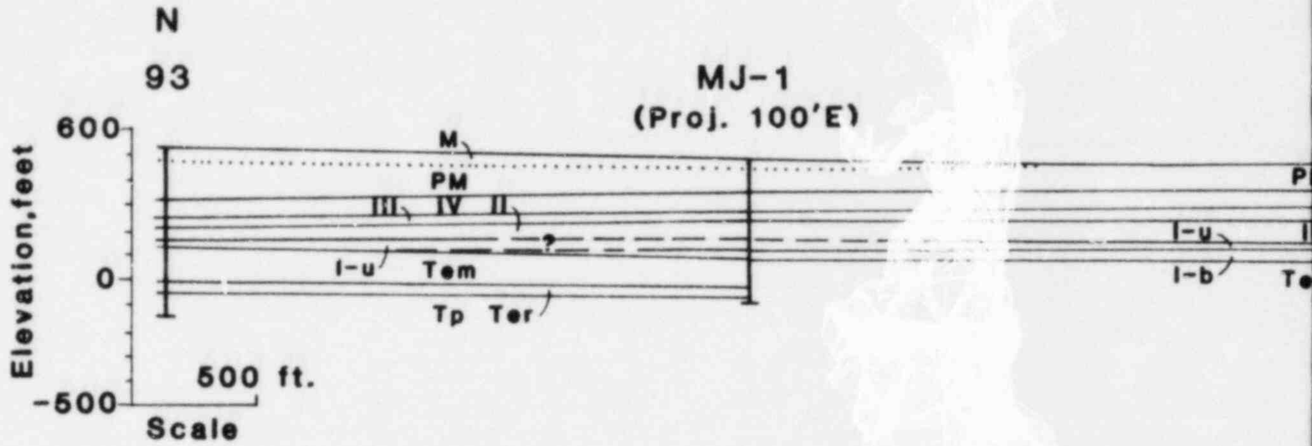
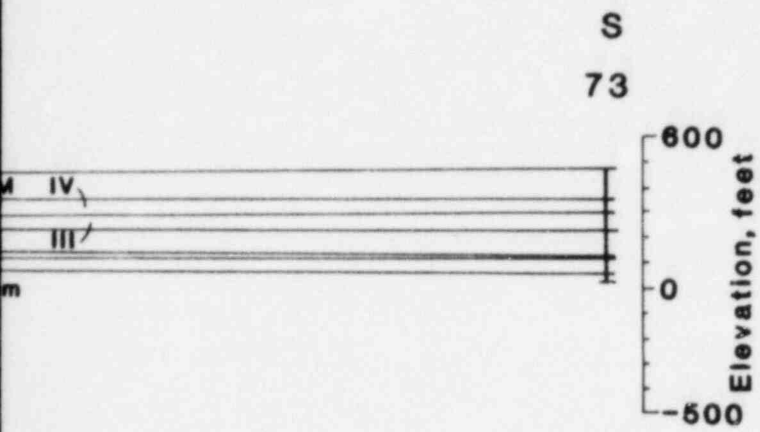


N
93
MJ-1
(Proj. 100'E)
600
0
-500
Elevation, feet
500 ft.
Scale
M
PM
III
IV
II
?
I-u
Tem
Tp
Ter
I-u
I-b




## EXPLANATION

| | |
|---|---|
| M | MISSOULA FLOOD GRAVELS |
| PM | PRE-MISSOULA FLOOD GRAVELS |
| | RINGOLD FORMATION |
| IV | UNIT IV |
| III | UNIT III |
| II | UNIT II |
| I-u | UNIT I - upper |
| I-b | UNIT I - basal |
| | COLUMBIA RIVER BASALT GROUP |
| Tem | ELEPHANT MOUNTAIN MEMBER |
| Ter | RATTLESNAKE RIDGE INTERBED |
| Tp | POMONA MEMBER |
| ............ | Gradational contact between Missoula and Pre-Missoula Flood Gravels |
| - -?- - | Inferred or indeterminate contact |

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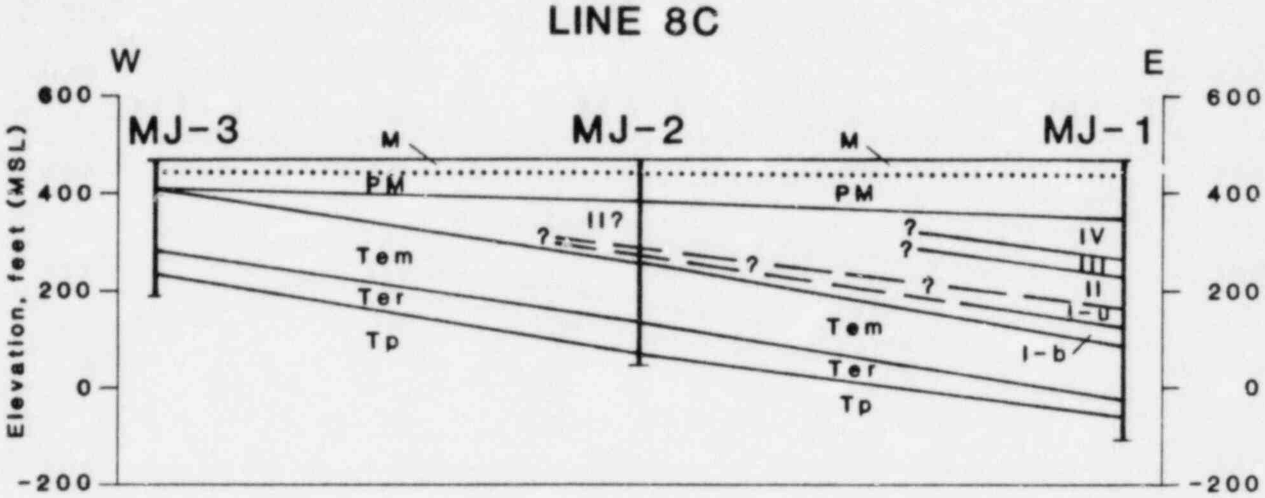
NORTH-SOUTH GEOLOGIC CROSS SECTION DRILLHOLE 93 TO 73

FIGURE 231.14-6




## EXPLANATION

| | |
|---|---|
| M | MISSOULA FLOOD GRAVELS |
| PM | PRE-MISSOULA FLOOD GRAVELS |
| | RINGOLD FORMATION |
| IV | UNIT IV |
| III | UNIT III |
| II | UNIT II |
| I-u | UNIT I - upper |
| I-b | UNIT I - basal |
| | COLUMBIA RIVER BASALT GROUP |
| Tem | ELEPHANT MOUNTAIN MEMBER |
| Ter | RATTLESNAKE RIDGE INTERBED |
| Tp | POMONA MEMBER |

............ Gradational contact between Missoula and Pre-Missoula Flood Gravels

– –?– – Inferred or indeterminate contact

NOTE: Unit designations are questioned where identification of unit is uncertain.

0 400
Scale, Feet
Horizontal = Vertical

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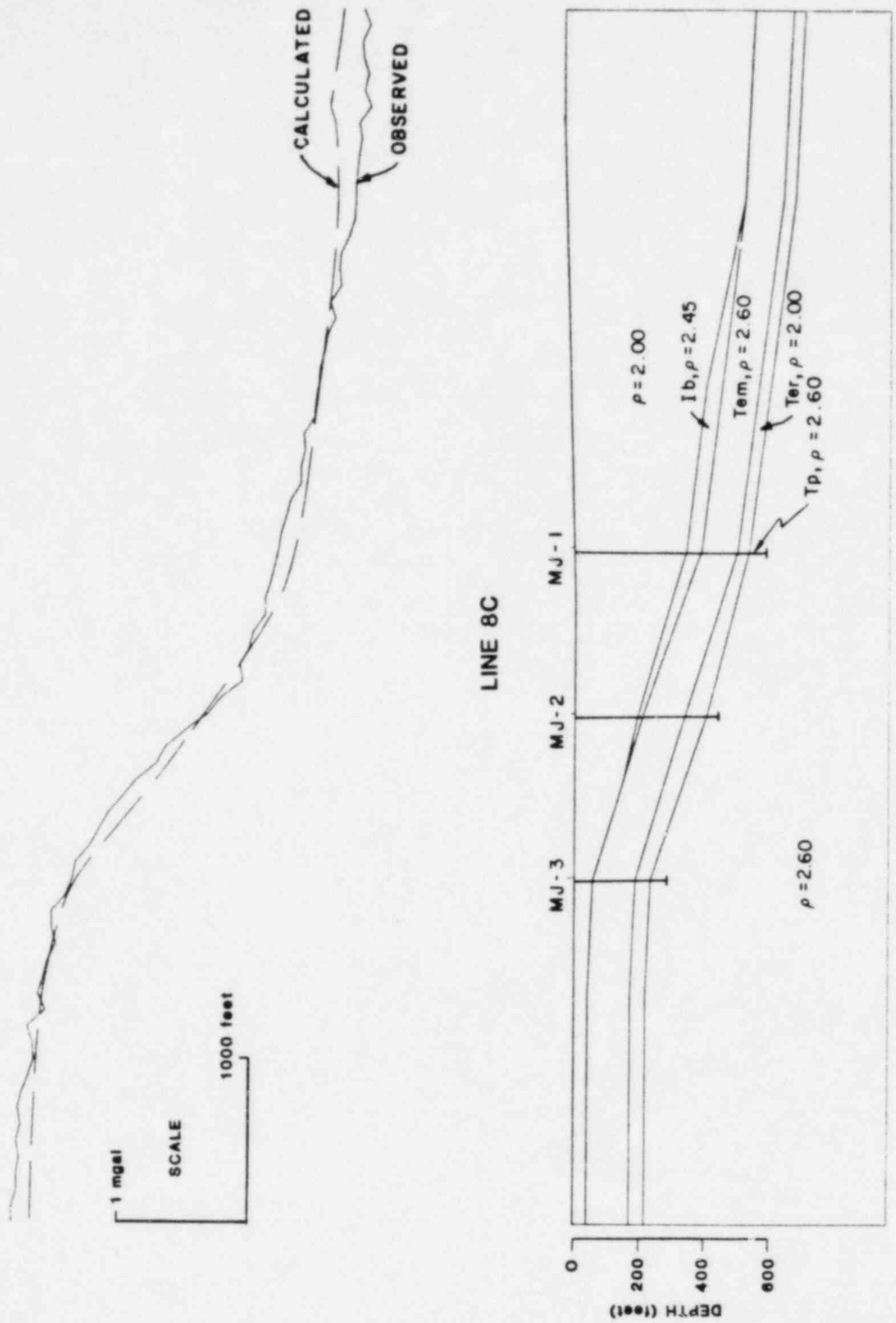
GEOLOGIC CROSS SECTION LINE 8C

FIGURE 231.14-7

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**GEOLOGIC MODEL OF GRAVITY LINE 8C**

**FIGURE 231.14-8**

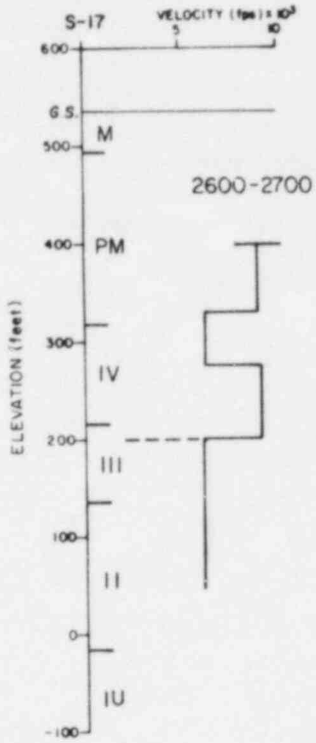
QUESTION 231.15

Provide a table and/or other device showing the relationship between the various site area lithologies and velocities (downhole, crosshole and refraction).

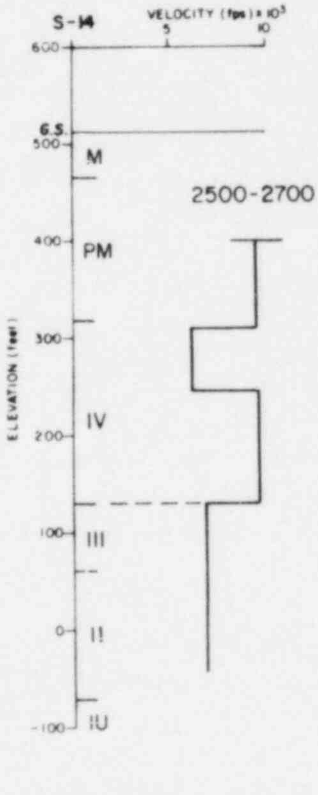
RESPONSE:

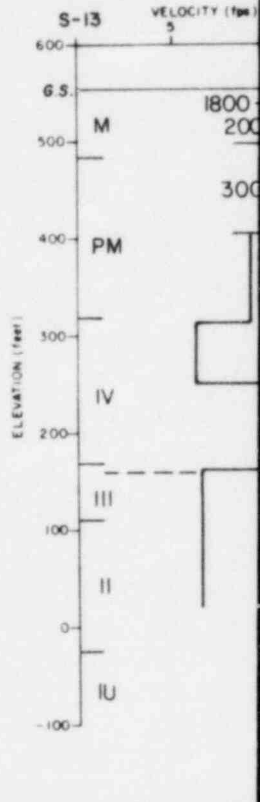
The downhole velocity profiles presented in Appendix 2K and 2L have been annotated to indicate seismic velocities for the near-surface layers as determined from surface refraction and crosshole measurements together with the identification of the stratigraphic horizons as obtained from the boring logs prepared by Golder Associates and presented in Appendix 2R. The correlations observed on the enclosed annotated velocity profiles (Figures 231.15-1 through Figure 231.15-6) are shown schematically on Figure 231.15-7.

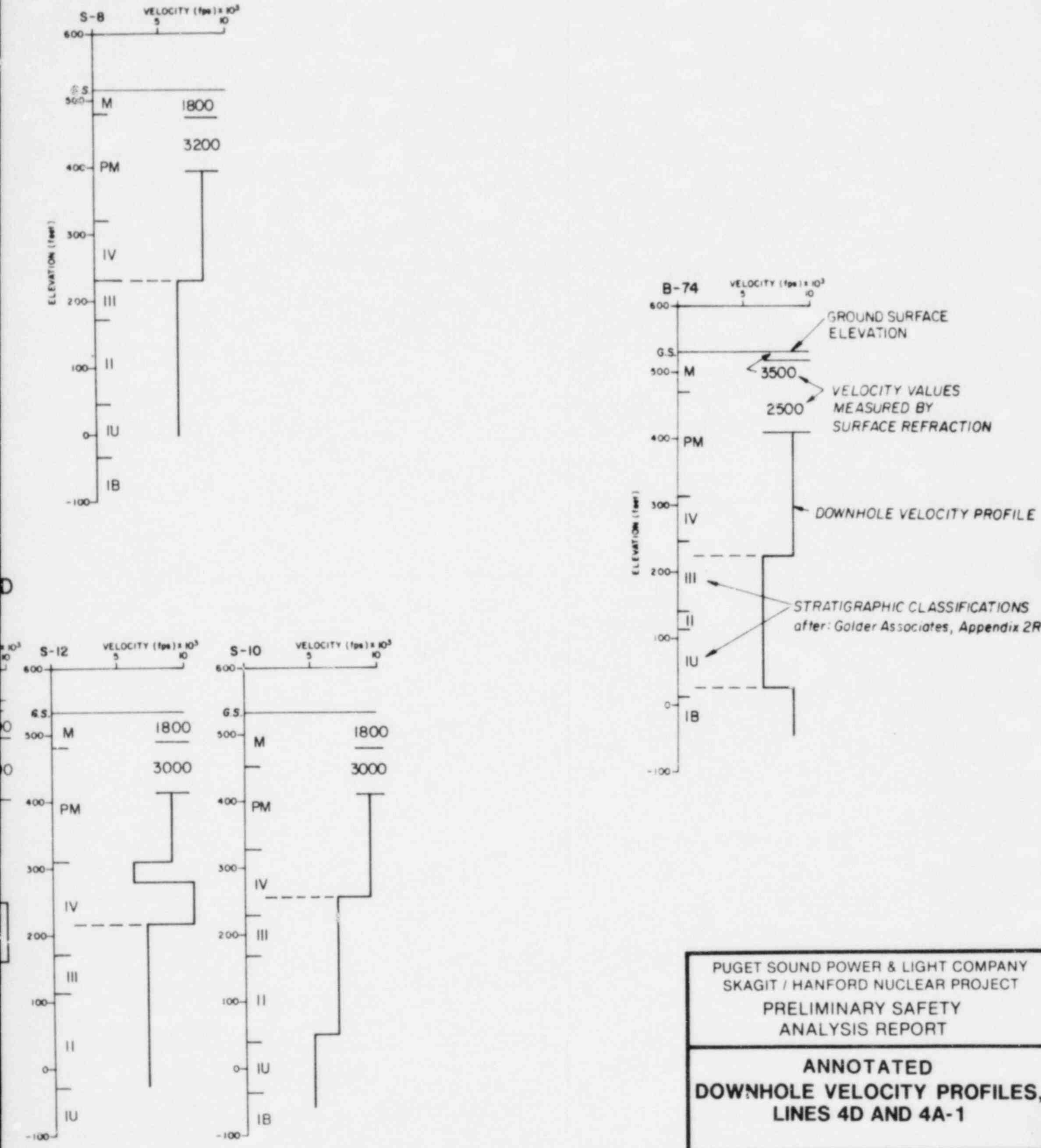
LINE 4A-1




LINE 4



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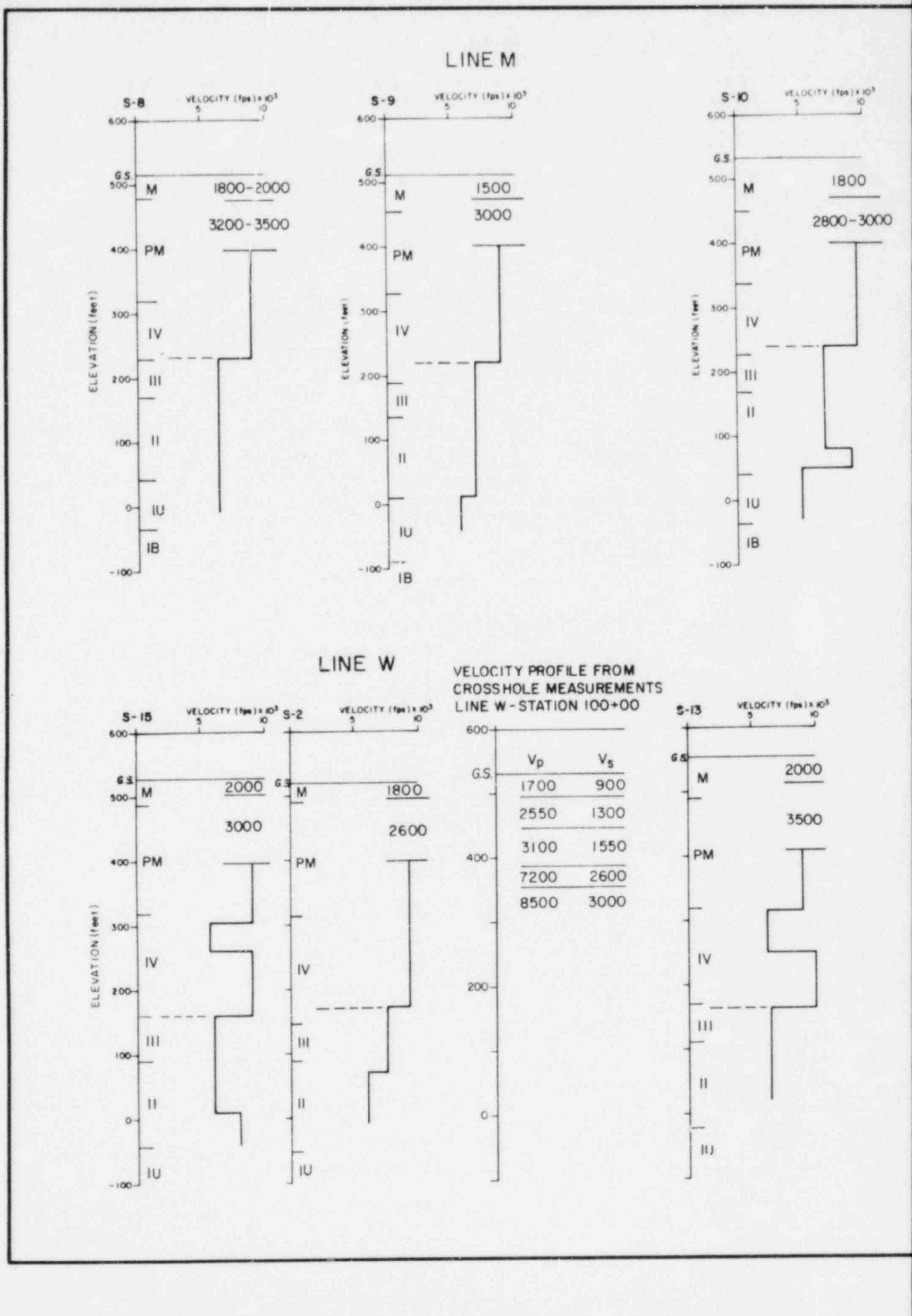
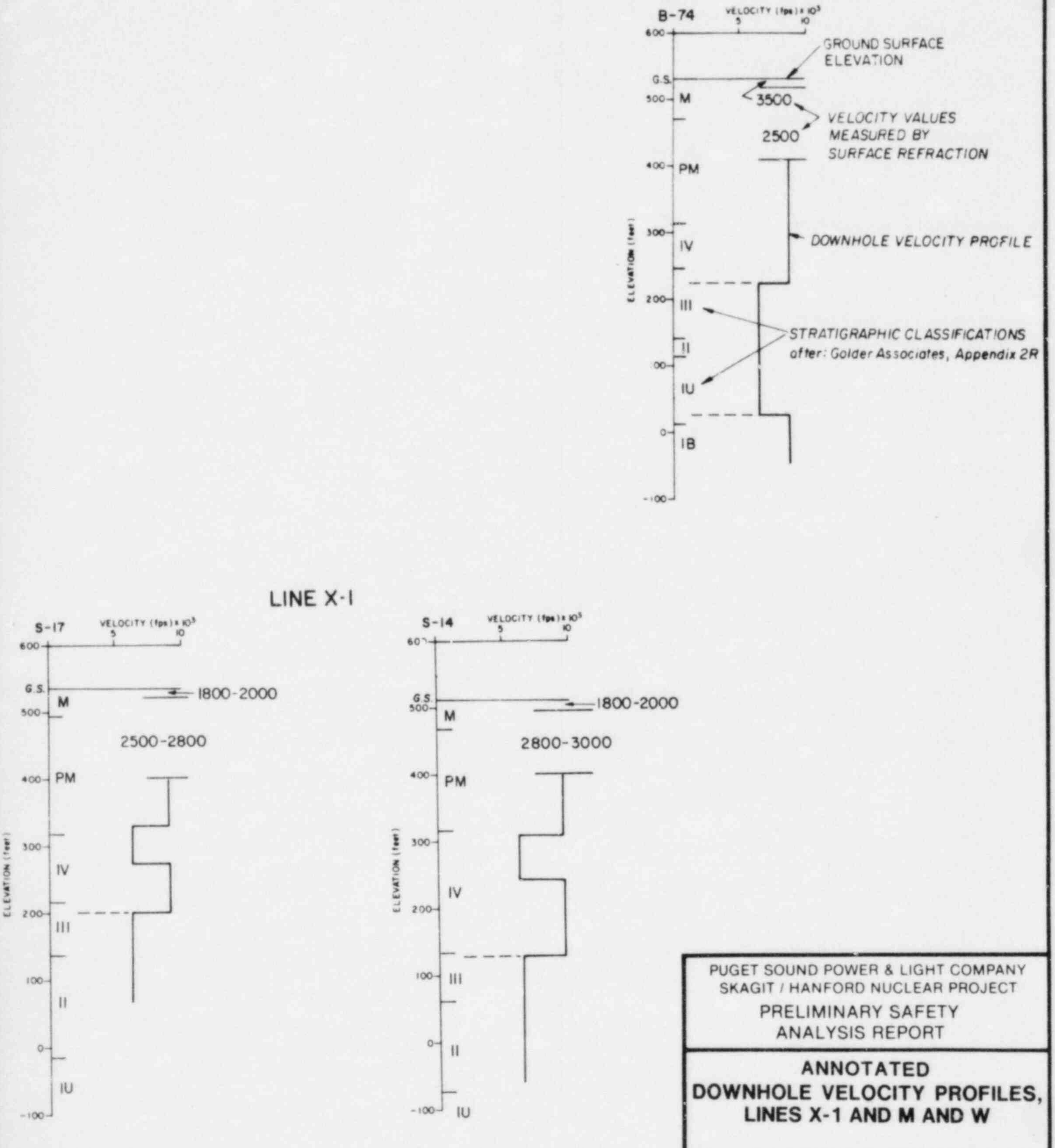
**ANNOTATED DOWNHOLE VELOCITY PROFILES, LINES 4D AND 4A-1**

**FIGURE 231.15-1**



LINE M
S-8
VELOCITY (fps) x 10^3
ELEVATION (feet)
G.S.
M
1800-2000
3200-3500
PM
IV
III
II
IU
IB
S-9
1500
3000
S-10
1800
2800-3000
LINE W
S-15
2000
3000
S-2
1800
2600
VELOCITY PROFILE FROM
CROSSHOLE MEASUREMENTS
LINE W - STATION 100+00
Vp Vs
1700 900
2550 1300
3100 1550
7200 2600
8500 3000
S-13
2000
3500

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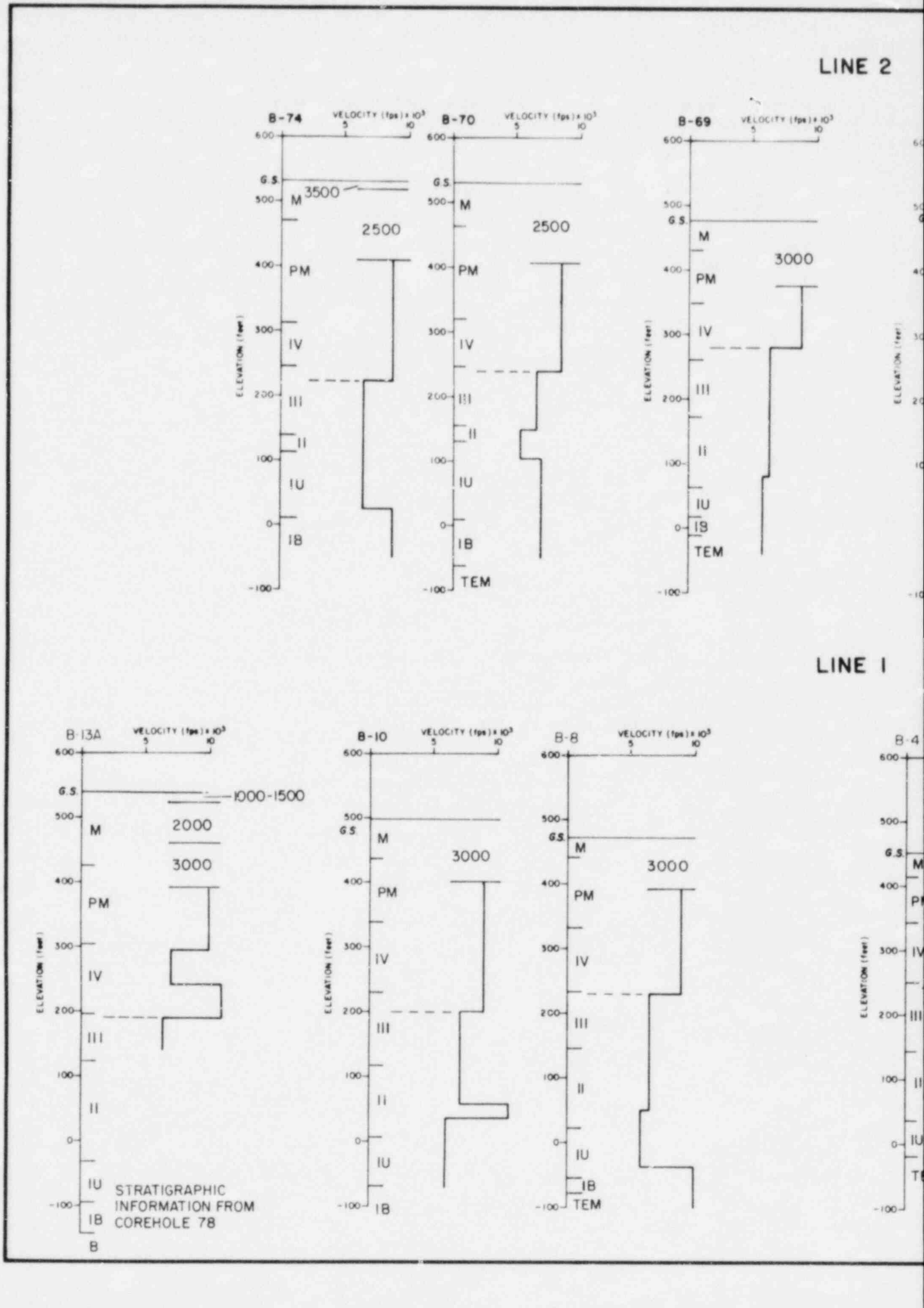
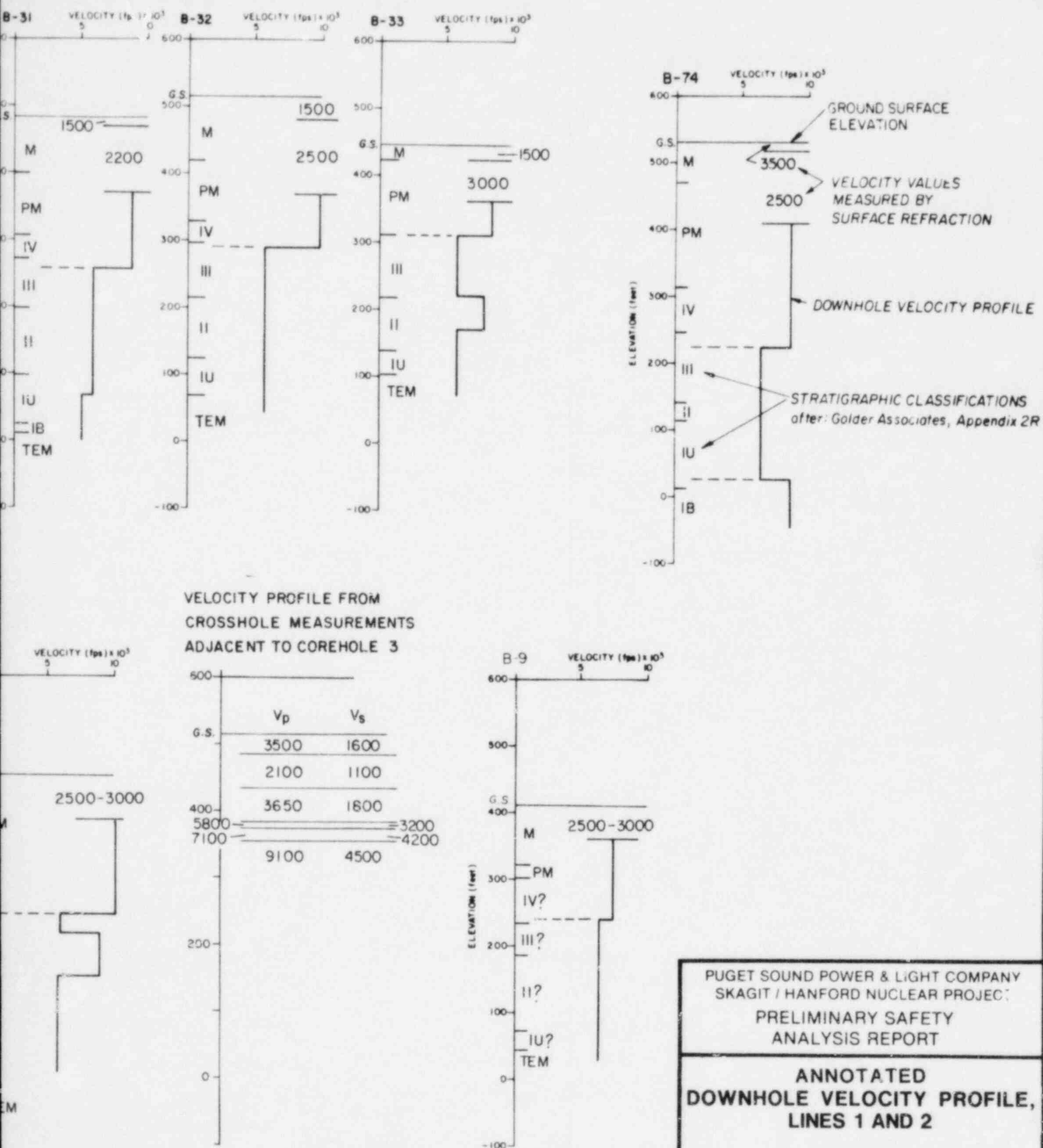
**ANNOTATED DOWNHOLE VELOCITY PROFILES, LINES X-1 AND M AND W**

**FIGURE 231.15-2**


LINE 2
B-74
VELOCITY (fps) x 10³
G.S.
3500
2500
M
PM
IV
III
II
IU
IB
ELEVATION (feet)
B-70
2500
TEM
B-69
3000
LINE 1
B-13A
1000-1500
2000
3000
STRATIGRAPHIC
INFORMATION FROM
COREHOLE 78
B
B-10
B-8
B-4

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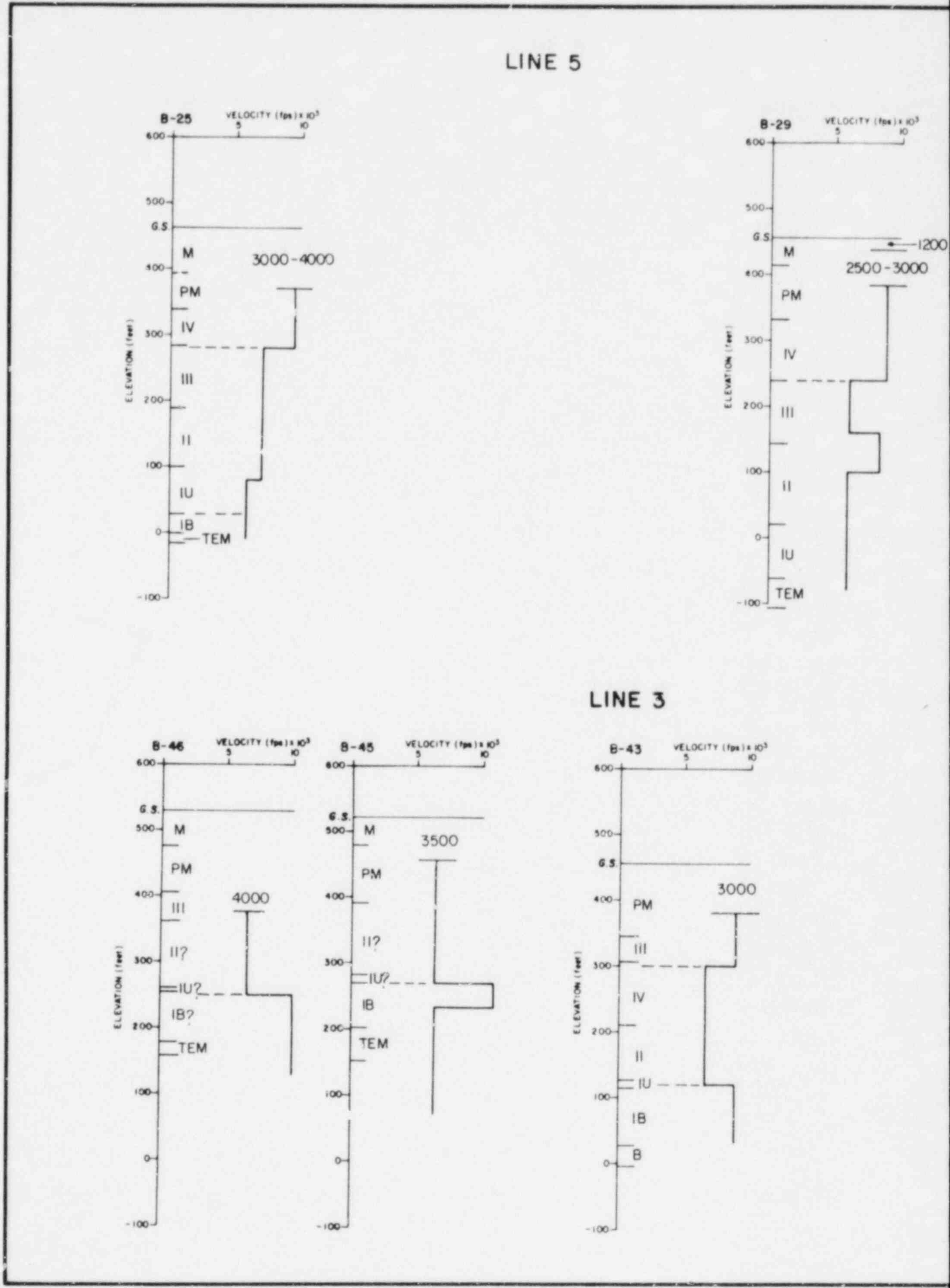
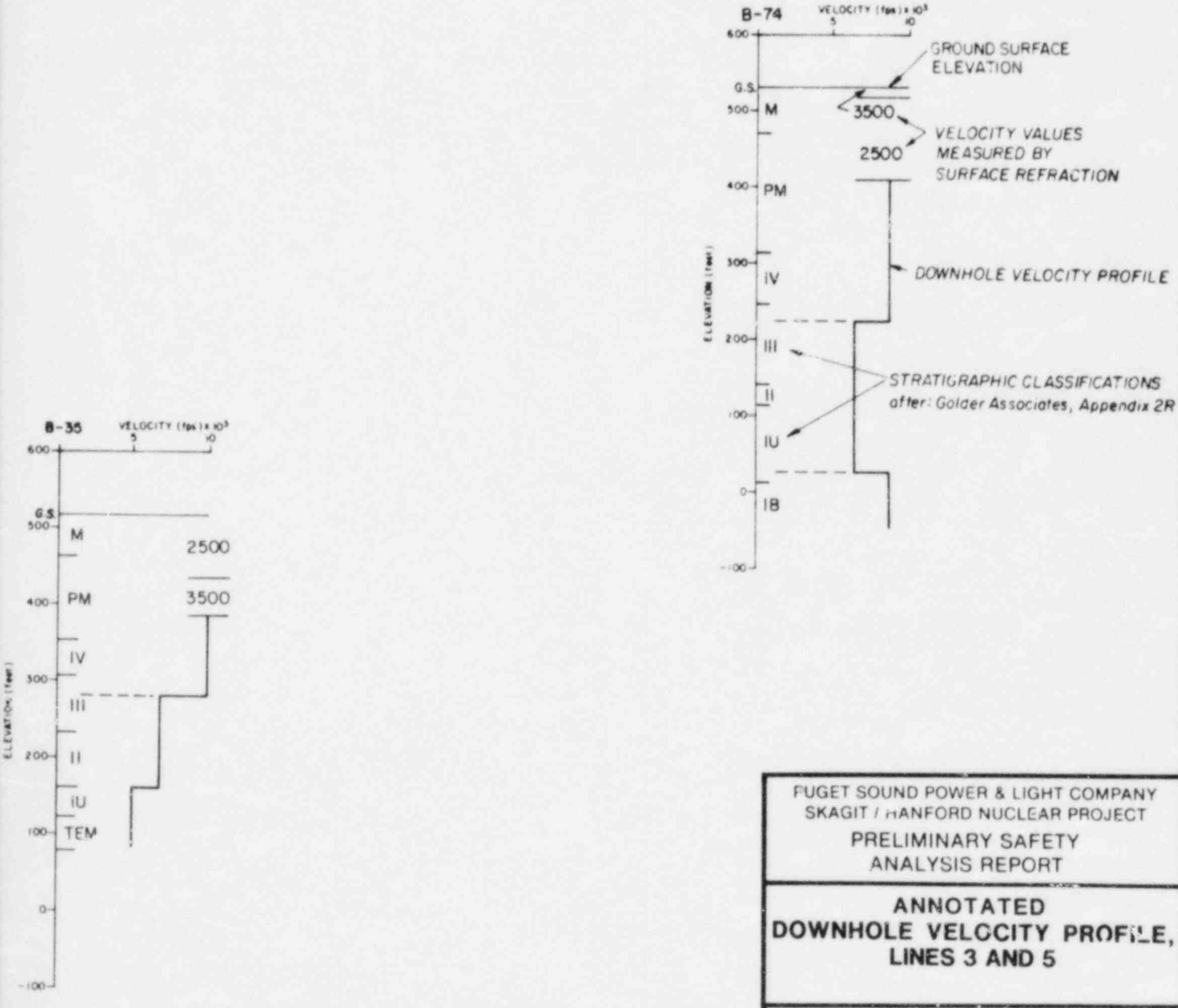
**ANNOTATED DOWNHOLE VELOCITY PROFILE, LINES 1 AND 2**

FIGURE 231.15-3


LINE 5
B-25
VELOCITY (fps) x 10³
5
10
600
500
G.S.
M
PM
IV
III
II
IU
IB
TEM
3000-4000
300
200
100
0
-100
ELEVATION (feet)
B-29
VELOCITY (fps) x 10³
5
10
600
500
G.S.
M
400
PM
IV
III
II
IU
TEM
1200
2500-3000
300
200
100
0
-100
ELEVATION (feet)
LINE 3
B-46
VELOCITY (fps) x 10³
5
10
600
G.S.
500
M
PM
400
III
II?
IU?
IB?
TEM
4000
300
200
100
0
-100
ELEVATION (feet)
B-45
VELOCITY (fps) x 10³
5
10
600
G.S.
500
M
PM
400
II?
IU?
IB
TEM
3500
300
200
100
0
-100
B-43
VELOCITY (fps) x 10³
5
10
600
500
G.S.
400
PM
III
IV
II
IU
IB
B
3000
300
200
100
0
-100
ELEVATION (feet)

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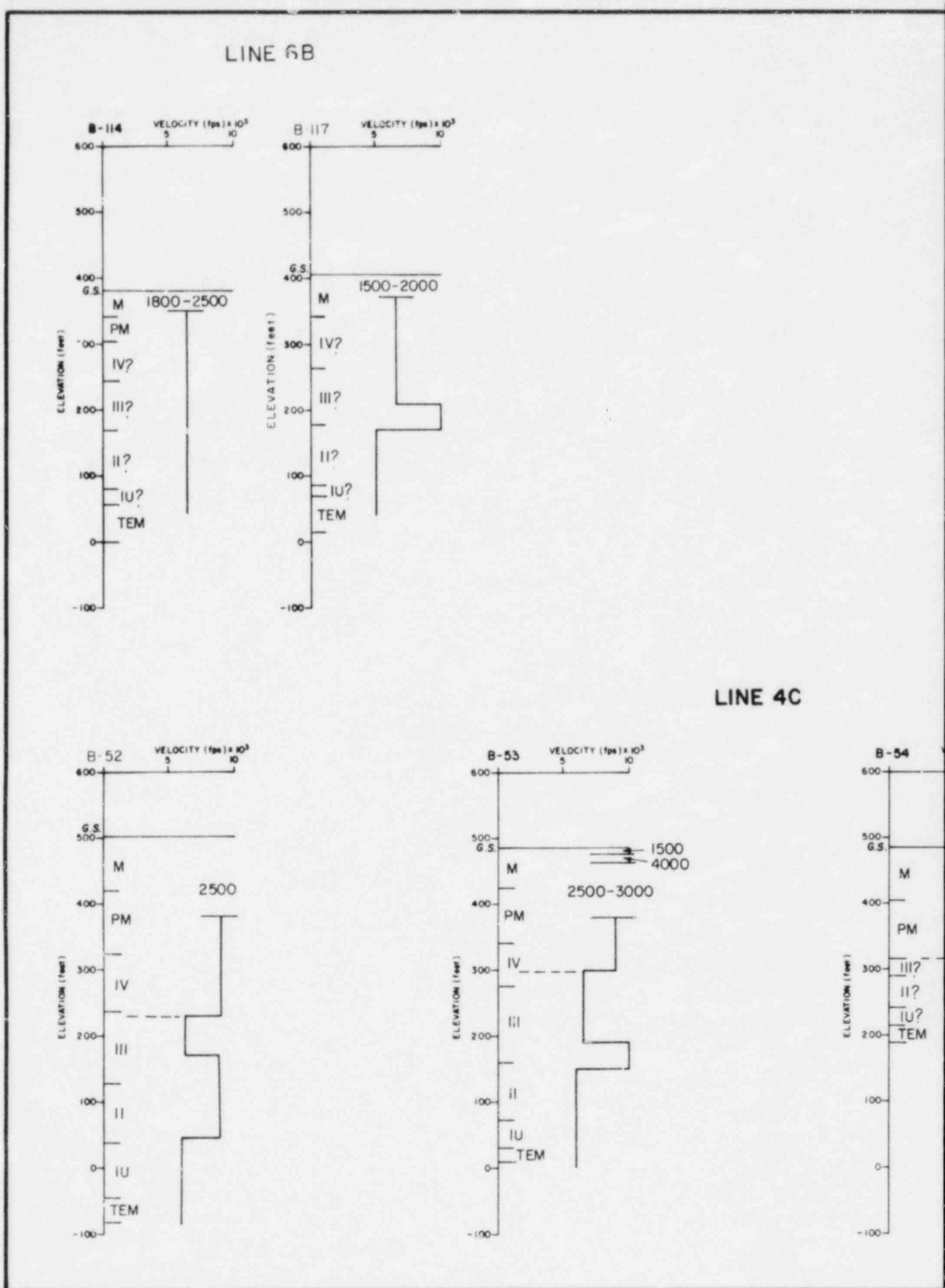
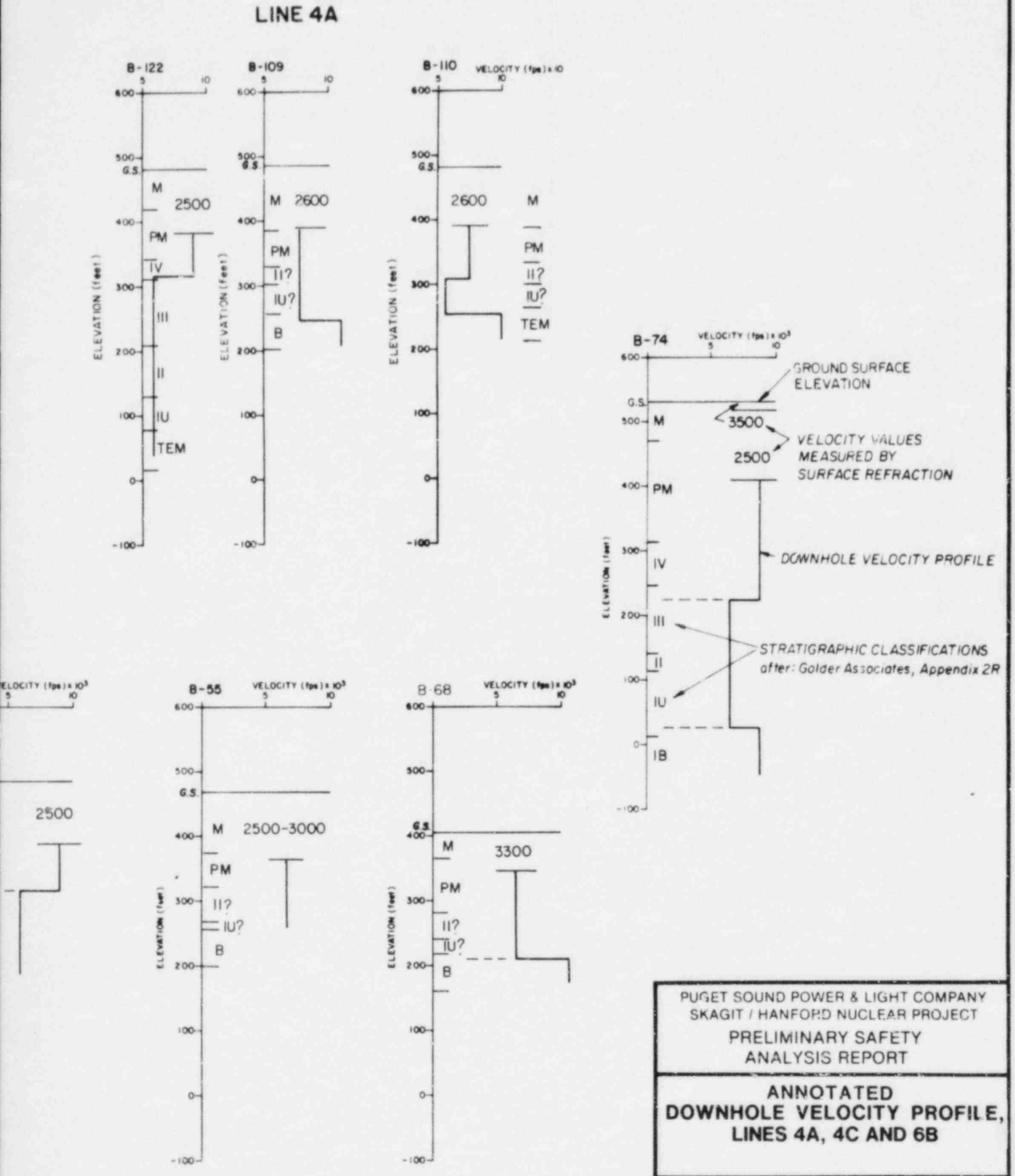
**ANNOTATED DOWNHOLE VELOCITY PROFILE, LINES 3 AND 5**

**FIGURE 231.15-4**


LINE 6B
B-114
VELOCITY (fps) x 10³
1800-2500
G.S.
M
PM
IV?
III?
II?
IU?
TEM
ELEVATION (feet)
B-117
1500-2000
G.S.
M
IV?
III?
II?
IU?
TEM
LINE 4C
B-52
2500
G.S.
M
PM
IV
III
II
IU
TEM
B-53
1500
4000
2500-3000
G.S.
M
PM
IV
III
II
IU
TEM
B-54
G.S.
M
PM
III?
II?
IU?
TEM

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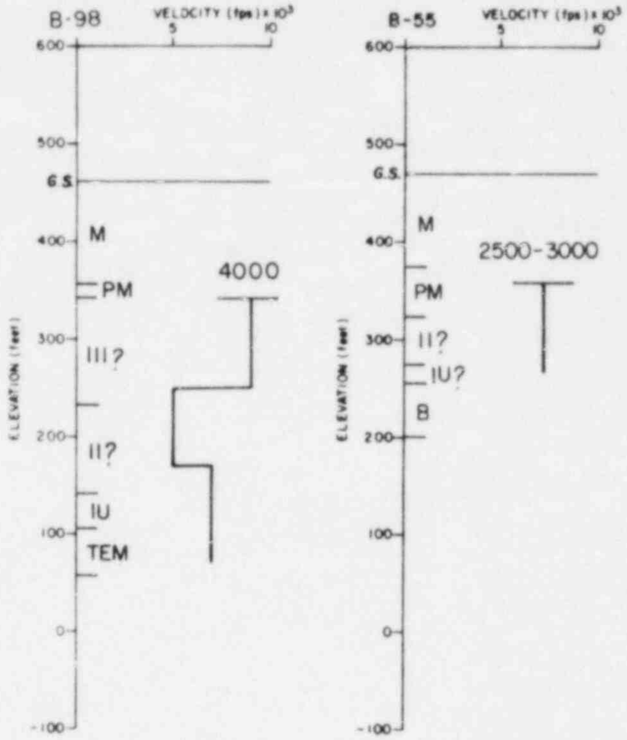
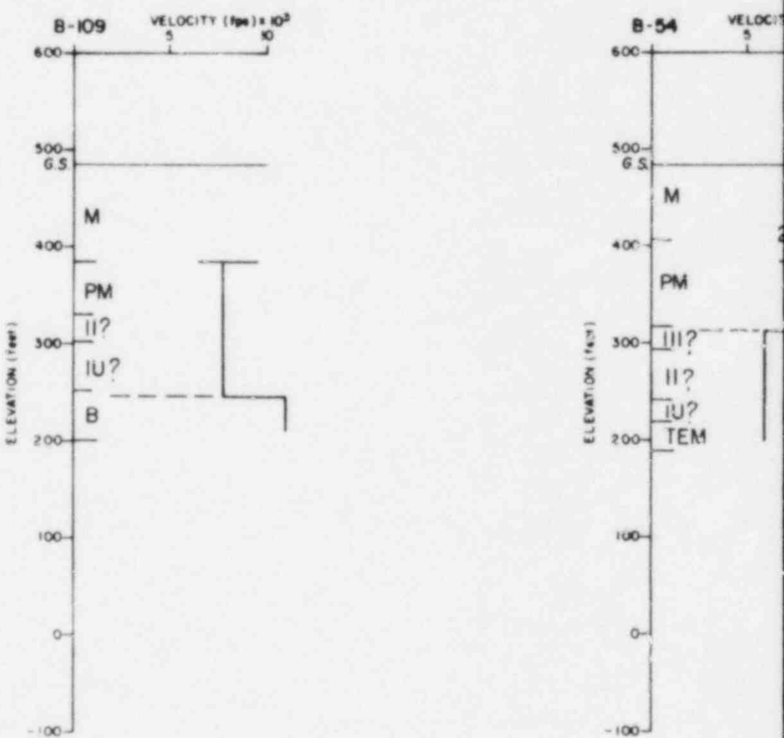
**ANNOTATED DOWNHOLE VELOCITY PROFILE, LINES 4A, 4C AND 6B**

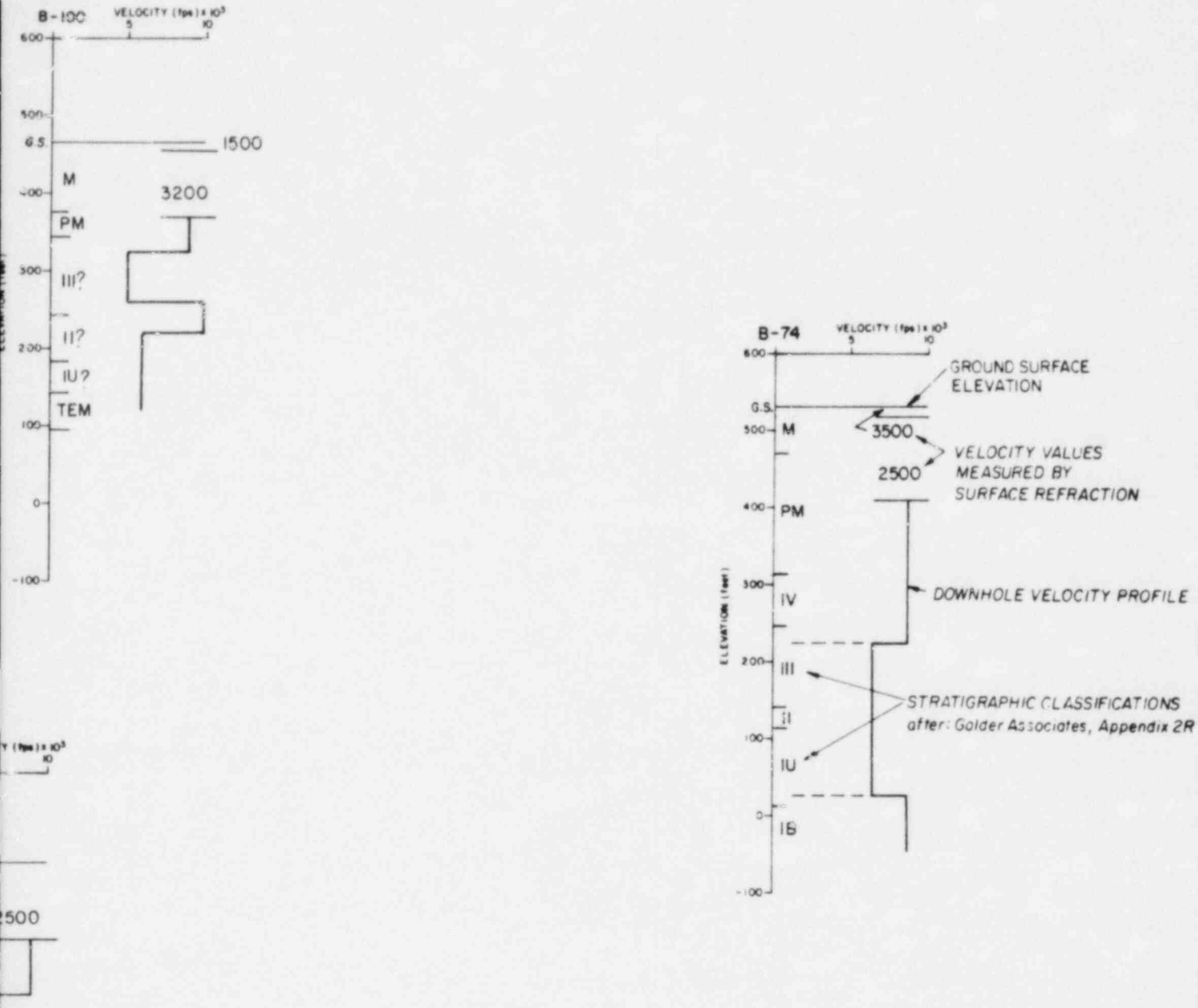
FIGURE 231.15-5

## LINE 6A




## LINE 6



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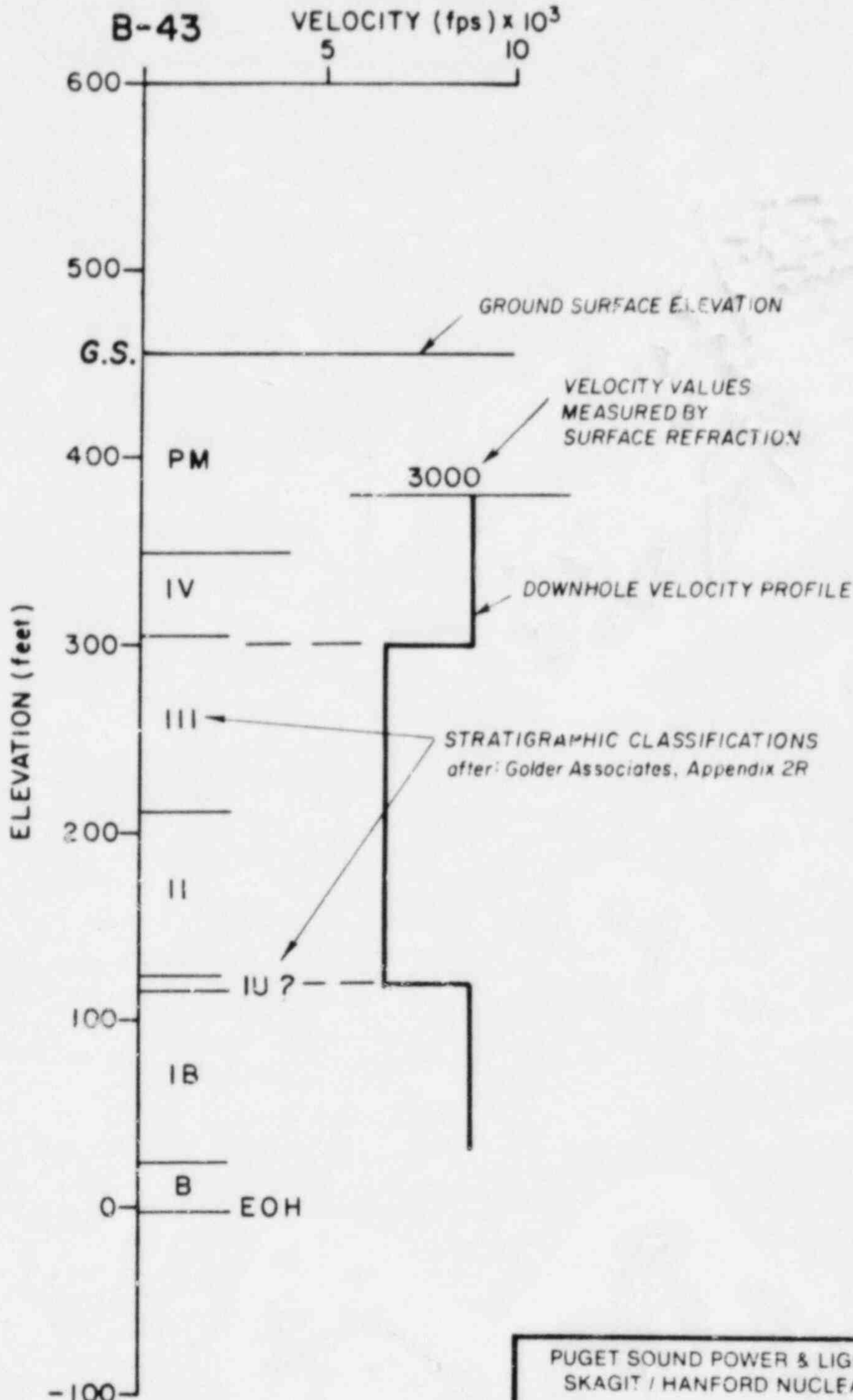
**ANNOTATED DOWNHOLE VELOCITY PROFILE, LINES 6 AND 6A**

**FIGURE 231.15-6**

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**TYPICAL
VELOCITY/STRATIGRAPHIC
CORRELATION**

**FIGURE 231.15-7**