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Geology Along Topographic Profile for Near-Surface Test Facility

K. R. Fecht

January 1978

Prepared for the United States
Department of Energy
Under Contract EY-77-C-06-1030

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Informal Report

GEOLOGY ALONG TOPOGRAPHIC PROFILE FOR
NEAR-SURFACE TEST FACILITY

K. R. Fecht
Earth Sciences Group
Research Department

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for
Basalt Waste Isolation Program

January 1978

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ABSTRACT

The U. S. Department of Energy, through the Basalt Waste Isolation Program within Rockwell Hanford Operations, is investigating the feasibility of terminal storage of radioactive waste in deep caverns constructed in the Columbia River Basalt. This report represents a portion of the geological work conducted in support of the Engineering Design Unit to evaluate the west end of Gable Mountain as a site for in situ testing of the thermo-mechanical behavior of basalt.

The surficial geology of the west end of Gable Mountain was mapped in a reconnaissance fashion at a scale of 1:62,500 to identify geologic features which could affect siting of the proposed facilities. A detailed study of the geological conditions was conducted along a traverse across the most probable site for the proposed project.

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INTRODUCTION

The purpose of this study was to conduct geologic investigations on the west end of Gable Mountain as part of the Near-Surface Test Facility siting studies at Hanford. The location of the study area is shown in Figure 1.

This geologic work was conducted by the Earth Sciences Group of the Research Department at the request of the Engineering Design Unit of the Basalt Waste Isolation Program. It is within the general scope of the fiscal year 1978 geologic work being conducted on Gable Mountain by the Earth Sciences Group for the Geosciences Unit of the Basalt Waste Isolation Program, but provides added detail that was requested by the Engineering Design Unit for information needed in evaluating various Near-Surface Test Facility sites on Gable Mountain.

The geologic investigations were conducted on December 12, 1977 and consisted of two tasks. Task 1 was a detailed study of the geologic conditions along a traverse across the most probable site for the proposed Near-Surface Test Facility project. Task 2 was a geologic reconnaissance of the west end of Gable Mountain to identify geologic features which could affect siting of the proposed facilities. The results of both tasks are presented in this report.

PREVIOUS STUDIES

Since the startup of the Hanford operations, the Gable Mountain-Gable Butte area has been examined as part of numerous hydrologic, geologic, and geophysical studies.⁽¹⁻¹²⁾ Three of these studies^(7,10,11) were concerned specifically with the structure and stratigraphy of the Gable Mountain-Gable Butte area. Their observations and interpretations were incorporated into this study.

METHODS OF INVESTIGATION

Basalt Waste Isolation Program personnel surveyed an approximate north-south traverse across the west end of Gable Mountain with a theodolite and determined elevations along the traverse at horizontal intervals of 100 feet. This provided vertical control during geologic mapping.

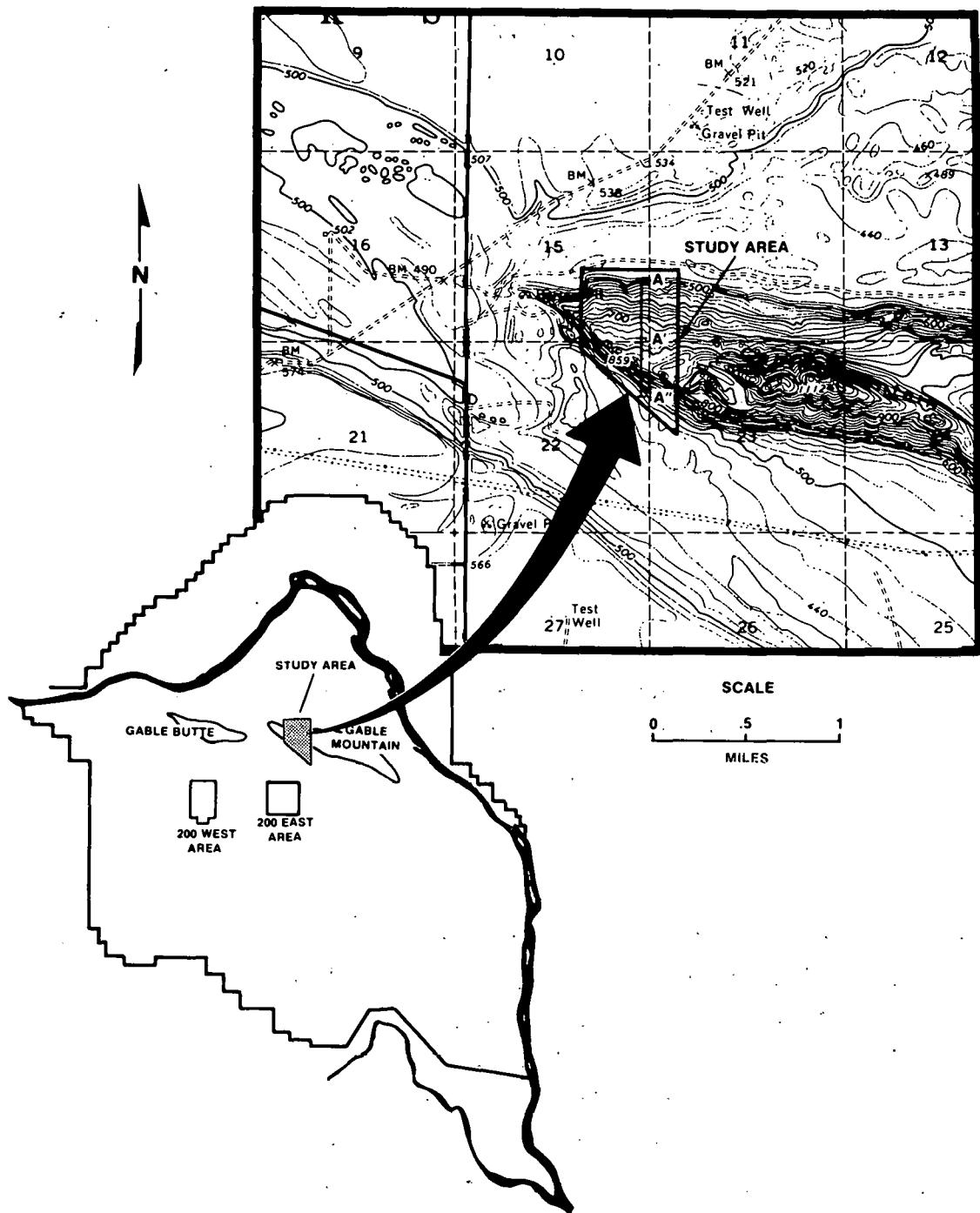


FIGURE 1
LOCATION OF GABLE MOUNTAIN STUDY AREA

Detailed mapping along the traverse consisted of: (1) hand-specimen examination of basalt outcrop for petrographic characteristics and post-solidification deformation; (2) description of exposed geologic units and potential zones of deformation not related to cooling or deposition; and, (3) correlation of the geologic units and intraflow structures present.

Geologic measurements between traverse stations and on the south face of Gable Mountain (Plate 1, Stations -6+00 to 0+00) were made with a tape and Brunton compass. Geologic observations, measurements, and other data were recorded in a field notebook.

Seven basalt samples were collected from four flows and analyzed for CaO and TiO₂ chemical composition using Rockwell Hanford Operations' energy dispersive X-ray fluorescence unit. These seven samples were oriented before being collected in order to determine the natural remanent magnetic polarities using a flux gate magnetometer.

The chemical composition, natural remanent magnetism, stratigraphic position, and hand-specimen petrography were used in basalt unit identification and correlation. The analytical data and stratigraphy are given in Figures 2 and 3. Sample localities are recorded on Plates 1 and 2.

TOPOGRAPHY

The south-facing cliff of basalt along the southern part of the study area (Plate 1, Stations 0+00 to -1+50) is termed the "southern Gable Mountain escarpment" in this report. The base of this escarpment is covered by talus (Plate 1, Stations -1+50 to -4+50). Exposed in this escarpment are the Elephant Mountain flow, Rattlesnake Ridge Interbed, and the upper part of the Pomona flow. The Elephant Mountain flow also forms another small escarpment on the west and north ends of the study area. The seven to ten-degree slope over most of the northern three-quarters of the study area (Plate 1, Stations 0+00 to 22+00) is primarily a dip slope (see Figure 4) of the Elephant Mountain flow.

STRATIGRAPHY

Exposed on the western end of Gable Mountain are four basalt flows of Saddle Mountains Basalt: Elephant Mountain; Pomona; Gable Mountain; and,

(1) SAMPLE NO.	(2) STRAT POS.	(3) PETROGRAPHIC CHARACTERISTICS	(4) BULK ROCK CHEMISTRY (wt%) CaO TiO ₂	(5) NRM POLARITY	(6) FLOW IDENTIFICATION
C6000	1	NEARLY APHYRIC	7.2 3.2	NORMAL	ELEPHANT MOUNTAIN
C6001	1	NEARLY APHYRIC	7.2 2.5	NORMAL	ELEPHANT MOUNTAIN
C6002	1	NEARLY APHYRIC	7.6 2.4	NORMAL	ELEPHANT MOUNTAIN
C6003	1	NEARLY APHYRIC	7.6 2.2	NORMAL	ELEPHANT MOUNTAIN
C6005	2	ABUNDANT OLIVINE	8.8 1.2	REVERSED	POMONA
C6006	4	DIABASIC TEXTURE	9.6 1.2	NORMAL	HUNTZINGER
C6007	3	PHYRIC	6.4 2.2	NORMAL	GABLE MOUNTAIN

- (1) Sample localities are given on Plates 1 and 2.
- (2) Stratigraphic sequence from youngest flow (1) to oldest flow (4).
- (3) See Plate 2.
- (4) Determined using energy dispersive X-ray fluorescence unit.
- (5) Natural remanent magnetic polarity determined using flux gate magnetometer.
- (6) See Figure 3.

FIGURE 2
FLOW IDENTIFICATION

FECHT (1978)	WPPSS (1974)	BROOKS (1974)	BINGHAM et al (1970)
ELEPHANT MOUNTAIN	ELEPHANT MOUNTAIN	ELEPHANT MOUNTAIN	ELEPHANT MOUNTAIN
POMONA	POMONA	POMONA	POMONA
ESQUATZEL (GABLE MOUNTAIN)	PRIEST RAPIDS FLOWS	UNCORRELATED CHEMITYPE 2	PRIEST RAPIDS 4
ASOTIN (HUNTZINGER)		UNCORRELATED CHEMITYPE 1	PRIEST RAPIDS 3

FIGURE 3

BASALT STRATIGRAPHY EXPOSED ON GABLE MOUNTAIN

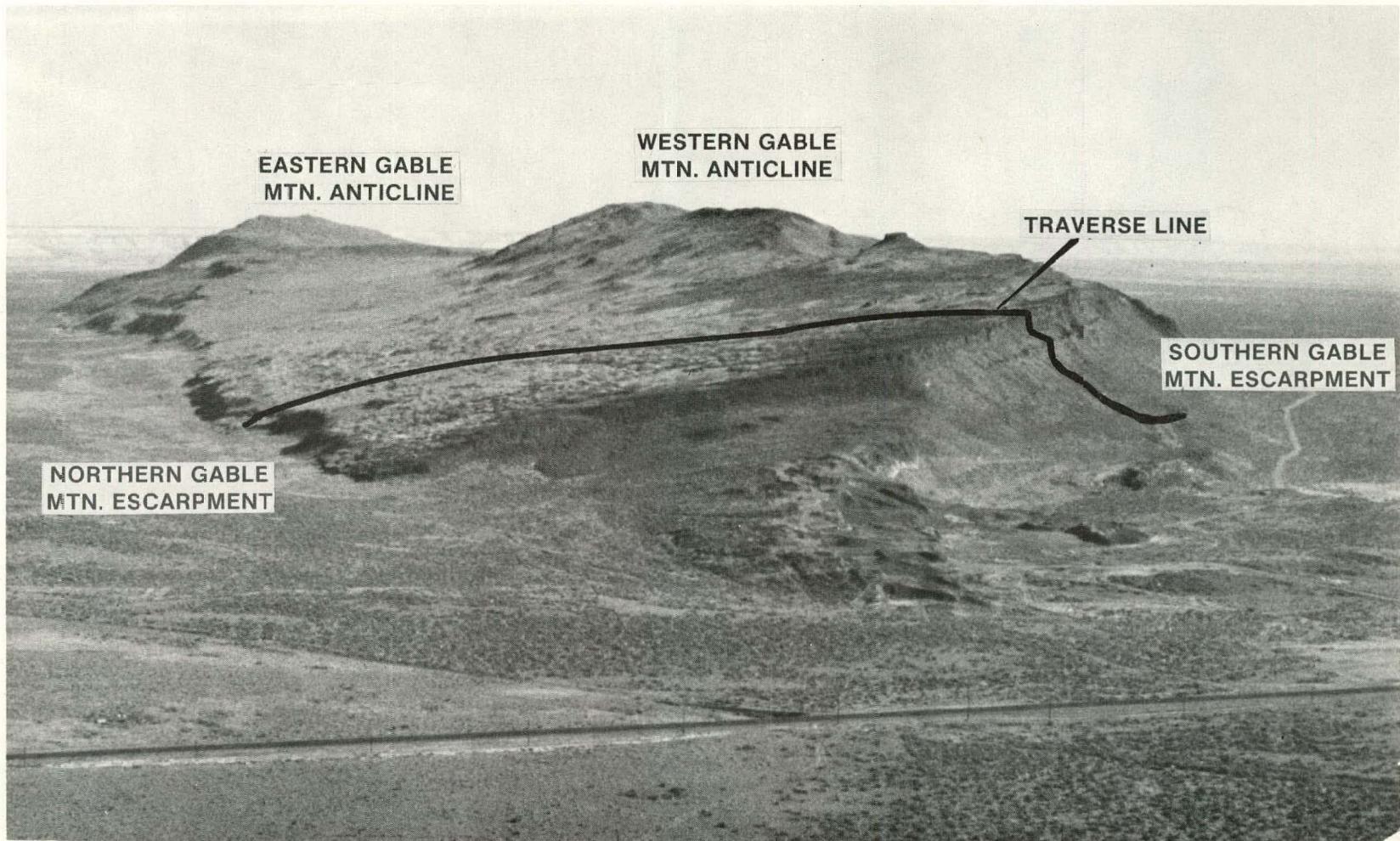


FIGURE 4
WESTERN END OF GABLE MOUNTAIN

Huntzinger, youngest to oldest, respectively (Figure 5). Intercalated between the basalt flows are two sedimentary interbeds of the Ellensburg Formation. The upper sedimentary unit is Rattlesnake Ridge, which is situated between the Elephant Mountain and Pomona flows and is exposed on the southern Gable Mountain escarpment. Core from Well DB-9, located on the west end of Gable Mountain, reveals the lower sedimentary unit, the Selah Interbed, between the Pomona and Gable Mountain flows (Figure 6); the Selah is not exposed at the surface in the study area.

The Tertiary basalt flows and interbedded Ellensburg sediments are overlain by Quaternary sedimentary units. These Quaternary units include glaciofluvial sands and gravels, eolian silts and fine sands, basalt rubble, talus, and landslide debris.

Descriptions of the geologic units present on the western end of Gable Mountain and a geologic map showing their distribution are given on Plate 2.

GEOLOGIC STRUCTURE

Because this study was conducted to assist the Basalt Waste Isolation Program in their siting studies for the Near-Surface Test Facility project, investigations of specific types of geologic structures were emphasized. These included: (1) attitude of strata; (2) fracturing due to deformation; (3) faulting; and, (4) primary structures.

ATTITUDE OF STRATA

The basalt flows and interbed exposed along the traverse dip seven to ten degrees to the north (Figure 4). These geologic units are on the gently dipping north limb of an asymmetric fold, the western Gable Mountain anticline. The south limb of the western Gable Mountain anticline is exposed east of the study area. Within the study area, the south limb and crestal portion of the anticline were apparently stripped away by the catastrophic floods from glacial Lake Missoula producing the southern Gable Mountain escarpment.

At the northern limit of the study area (Plate 1, Stations 22+00 to 25+00), the dip of the Elephant Mountain flow steepens, as evidenced by an approximate 32-degree north dip (Plate 2), east of the study area. The

SADDLE MOUNTAIN BASALT

ELLENBURG FORMATION

ELEPHANT MTN. MEMBER (Tsem)	ELEPHANT MTN. FLOW	
		RATTLESNAKE RIDGE (Ter)
POMONA MEMBER(Tspo)	POMONA FLOW	
		SELAH (Tes)
ESQUATZEL MEMBER (Tse)	GABLE MTN. FLOW	
ASOTIN MEMBER (Tsh)	HUNTZINGER FLOW	

FIGURE 5

UPPER TERTIARY STRATIGRAPHY OF GABLE MOUNTAIN

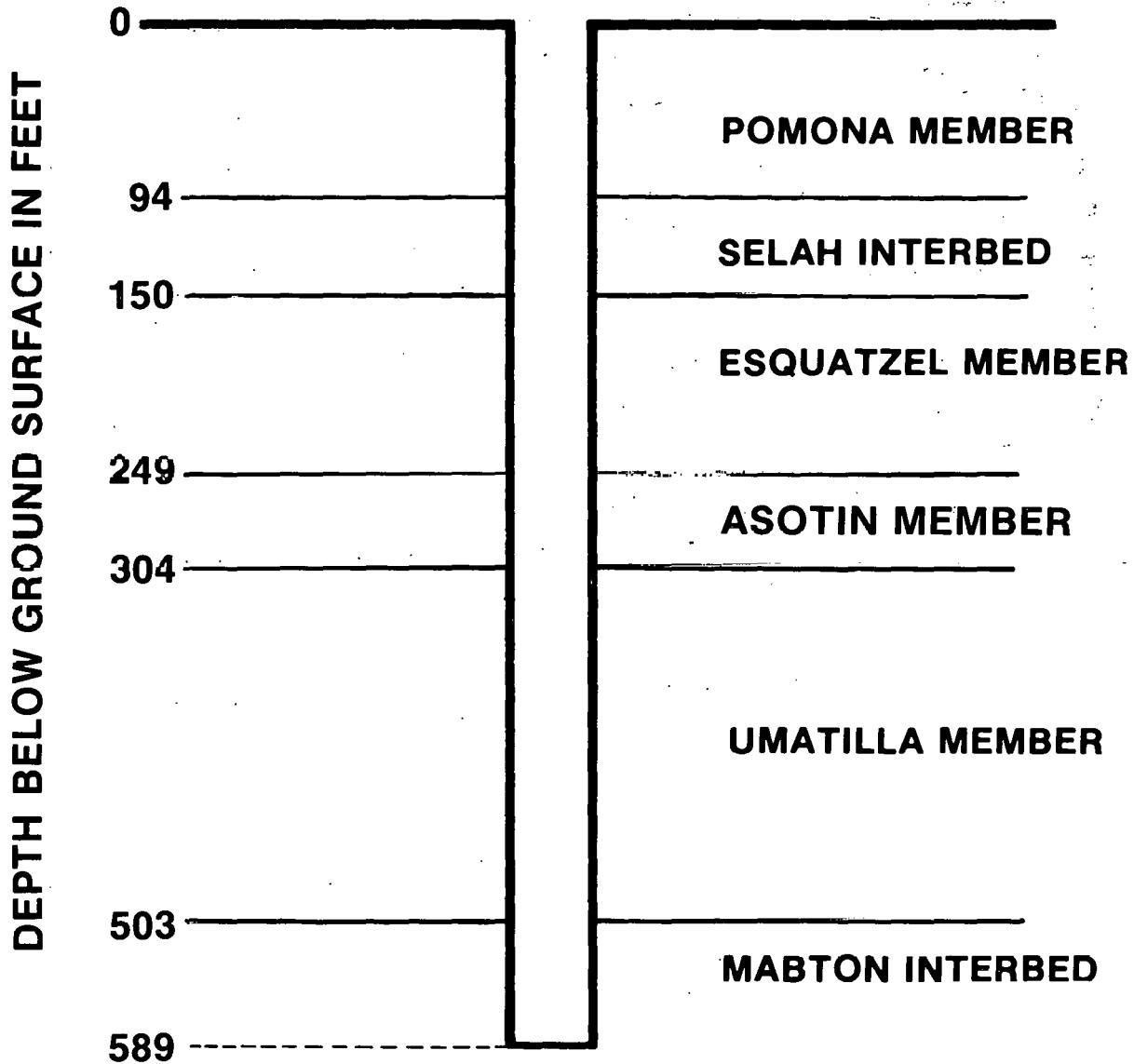


FIGURE 6
STRATIGRAPHY IN WELL DB-9

Missoula glacial flood waters have also stripped the basalt from the northern edge of Gable Mountain forming a 20-foot escarpment (Figure 7).

FRACTURING DUE TO DEFORMATION

Between Stations -2+00 and 22+00 (Plate 1), the ubiquitous fractures in the basalt flows are primary structures related to the cooling history of the flows. Here, no evidence for shearing, brecciation, displacement, or other deformation was found other than that which would be produced during cooling. Post-solidification deformation would, however, be expected along the east-west-trending anticlinal axis of the western Gable Mountain anticline that is projected south of Station -6+00 (Plate 1) outside of the study area. As stated above, this portion of the anticlinal axis was eroded and then covered during the Missoula glacial floods. Such deformation can be observed about one mile east of the study area.

A second flexure and area of post-solidification fracturing is inferred immediately north of Station 22+00 (Plate 1), based upon the apparent steepening of the Elephant Mountain flow observed east of Station 24+00 (Plate 2). Although this flexure is on the very northern limit of the study area, the inferred post-solidification fracturing could impact on the Near-Surface Test Facility site located near the northern limit of the study area.

FAULTING

The geologic units were examined for evidence of faulting. Field criteria used for the identification of possible faults were: (1) shearing; (2) brecciation; (3) displacement; or, (4) linear escarpments. Examination of the geologic units revealed no evidence of shearing, brecciation, or displacement in the study area. One prominent linear escarpment, the southern Gable Mountain escarpment, is interpreted as an erosional escarpment (see "Attitude of Strata"), but its tectonic significance is not known because of the limited exposure. This study, as with the three previous studies,^(7,10,11,) revealed no evidence of exposed faults within the study area or evidence for projecting faults known from elsewhere in the Hanford vicinity into the study area. However, immediately east of the study area on the western Gable Mountain anticline is a northerly trending fault which is exposed on the southern Gable Mountain escarpment. Stratigraphic offset can be seen near the

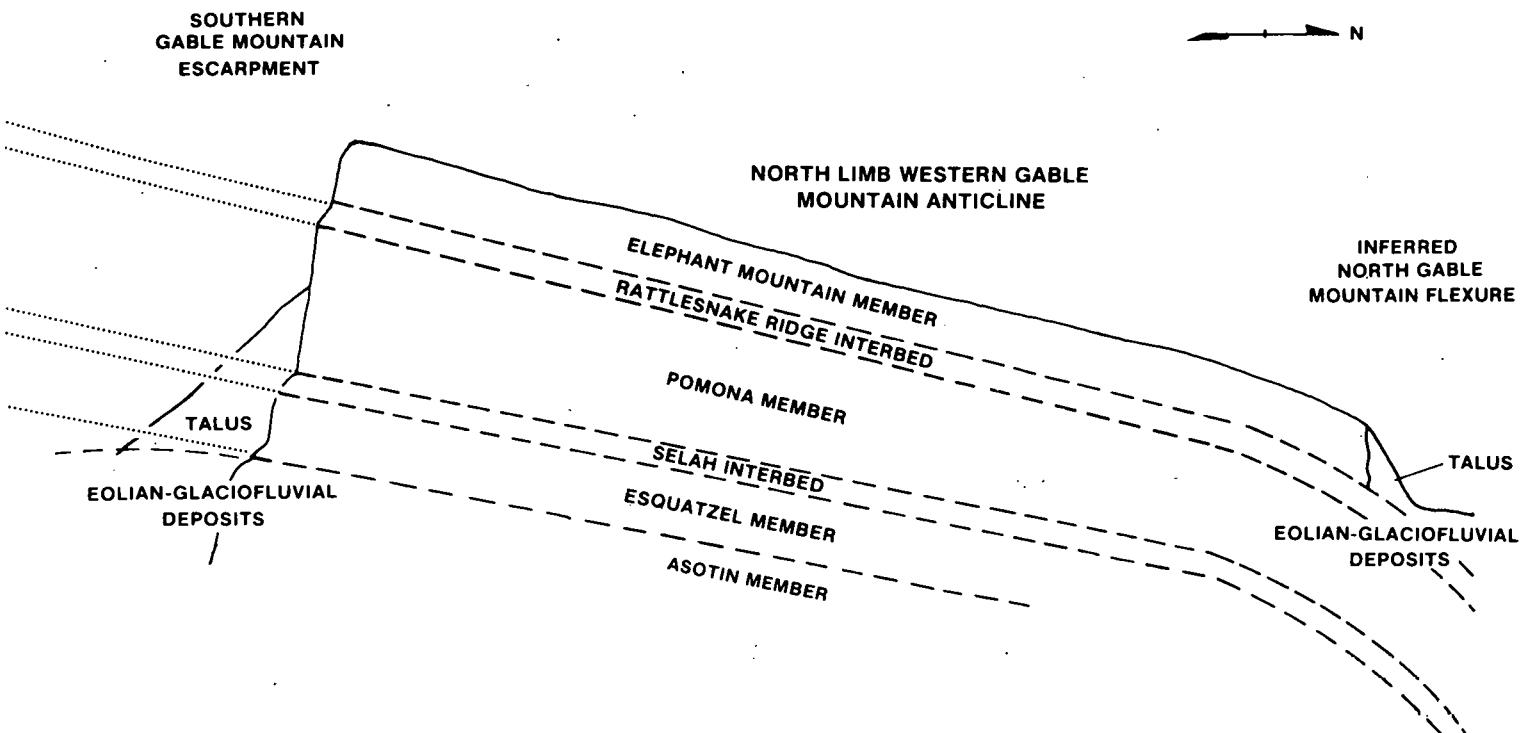


FIGURE 7

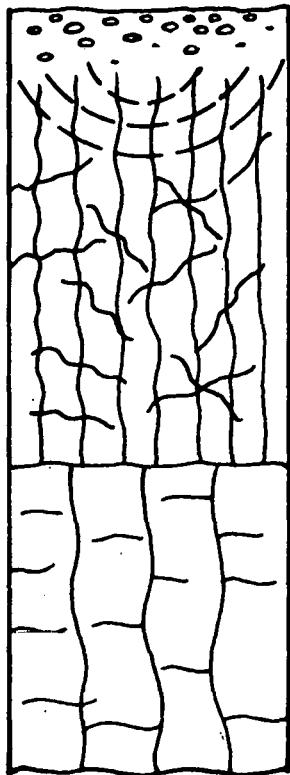
GENERALIZED GEOLOGIC CROSS SECTION, WESTERN END OF GABLE MOUNTAIN

ridge crest where the Pomona flow is in juxtaposition with the Elephant Mountain flow with about 33 feet of vertical displacement. The fault plane, which is totally obscured by talus debris, is estimated to dip at 30 degrees to the east as suggested by Bingham, et al. (7) The stratigraphic relationships and dip of the fault plane indicate the fault to be a low-angle reverse fault with about 82 feet of offset. The trace of the fault over the northern flank of the western Gable Mountain anticline is discernible for only 130 to 165 feet beyond the crest before becoming obscured in the scabland topography and a veneer of eolian loess. No evidence of shearing or brecciation in basalt outcrops was noted north of where the fault is last exposed.

PRIMARY STRUCTURES

Close examination of primary structures in the study area was limited to the Pomona flow, because the entablature of this flow has been identified as the most likely zone for the Near-Surface Test Facility subsurface facilities. A typical flow from Columbia River Basalt has three primary structures: (1) flow top; (2) entablature; and, (3) colonnade (Figure 8). The Pomona flow in the study area has these typical primary structures plus one other, informally named anomalous zone in this report.

The Pomona flow is exposed only along the southern and western escarpments in the study area. Along these escarpments, the principal primary structures in the Pomona flow are: (1) the flow top; (2) the upper colonnade; (3) the entablature; and, (4) the lower colonnade. The flow top consists of a highly vesicular, glassy basalt grading downward into the more dense basalt of the upper colonnade. The upper colonnade consists of near-vertical, massive, long, undulating columns (1.5 to 3.0 feet in diameter) with many cross joints and large scattered vesicles. The upper colonnade grades abruptly downward into the entablature. The entablature consists of near-vertical, long, well-developed, slender columns (0.5 to 1.0 feet in diameter), but displays hackly jointing formed by the intersection of the ubiquitous vertical joints and cross joints. The entablature appears to constitute nearly two-thirds of the Pomona flow in the study area. The contact between the entablature and



FLOW TOP

**VESICULAR, GLASSY,
LOCALLY SCORIACEOUS**

ENTABLATURE

**LONG SLENDER COLUMNS
COMMONLY BROKEN INTO
HACKLY FRAGMENTS**

COLONNADE

**LARGE BLOCKY
UNDULATING COLUMNS**

FIGURE 8

MAJOR INTRAFLOW STRUCTURES

(After D. A. Swanson^[12])

lower colonnade is poorly exposed. The lower colonnade, which comprises less than one-third of the Pomona flow, consists of near-vertical, large, blocky, well-developed columns (1.3 to 2.0 feet in diameter).

Two anomalous zones representing localized, abrupt changes in primary structure of the Pomona flow have been identified in the southern Gable Mountain escarpment (Figure 9). These anomalous zones are highly vesicular, rubbly portions of the flow top that extend downward into the upper colonnade. The upper part of the entablature beneath these anomalous zones consists of long, slender columns arranged in a fan-shaped pattern that stands in sharp contrast to the long, slender columns arranged in a near-vertical pattern elsewhere in the Pomona entablature. Although these anomalous zones appear to be local features, their northern extent closer to the proposed Near-Surface Test Facility site is not known. The proximity of these anomalous zones to the proposed Near-Surface Test Facility site is important because of their potential influence on the thermal and mechanical response of the Pomona basalt during operation of the facilities.

ACKNOWLEDGMENTS

Mr. S. D. Sharpe surveyed the traverse and determined the station elevations; Mr. R. K. Ledgerwood provided core well logs and helpful well log interpretations. Ms. M. G. Jones analyzed the basalt samples for CaO and TiO₂ using the energy dispersive X-ray fluorescence unit. Special thanks goes to Dr. C. W. Myers for his many useful suggestions, comments, and reviews during the course of this work. Their assistance is most appreciated.

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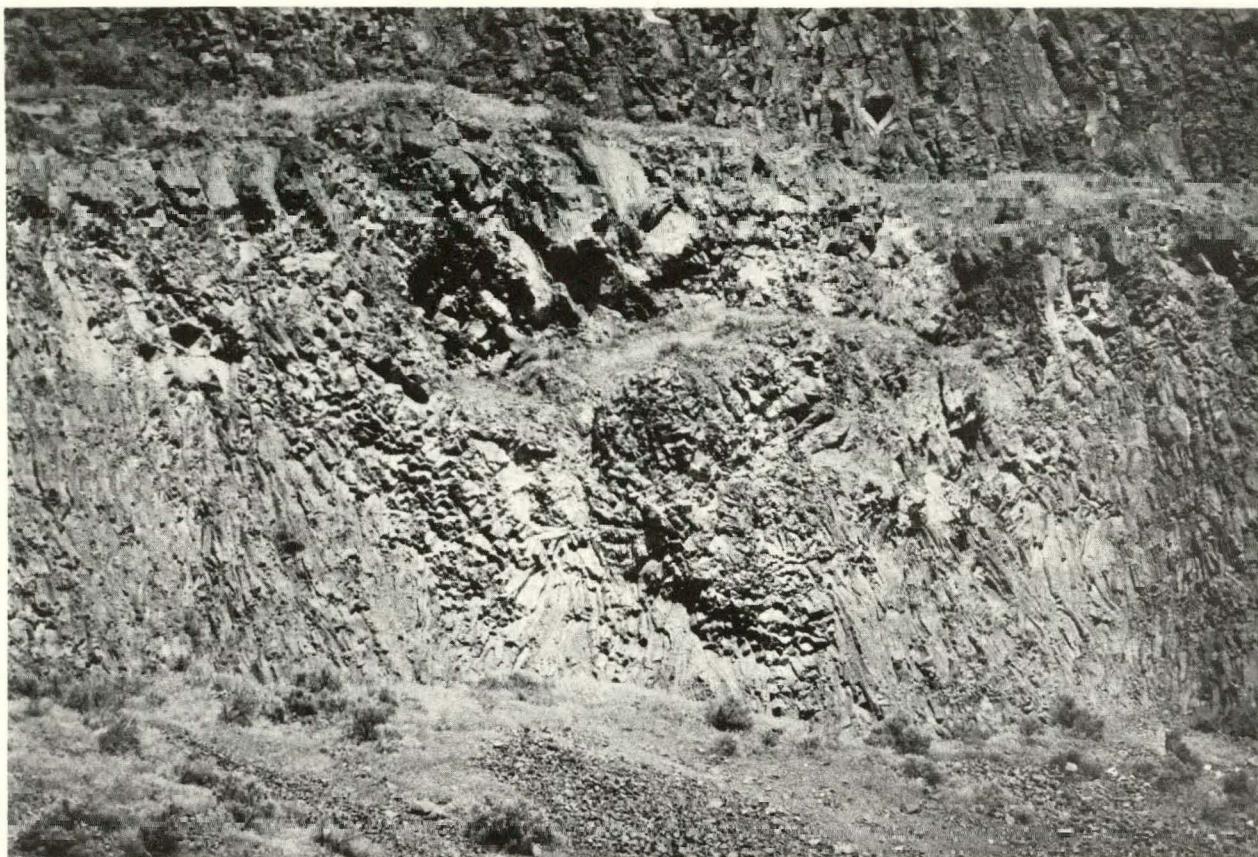


FIGURE 9

ANOMALOUS ZONES IN POMONA FLOW,
SOUTHERN GABLE MOUNTAIN ESCARPMENT

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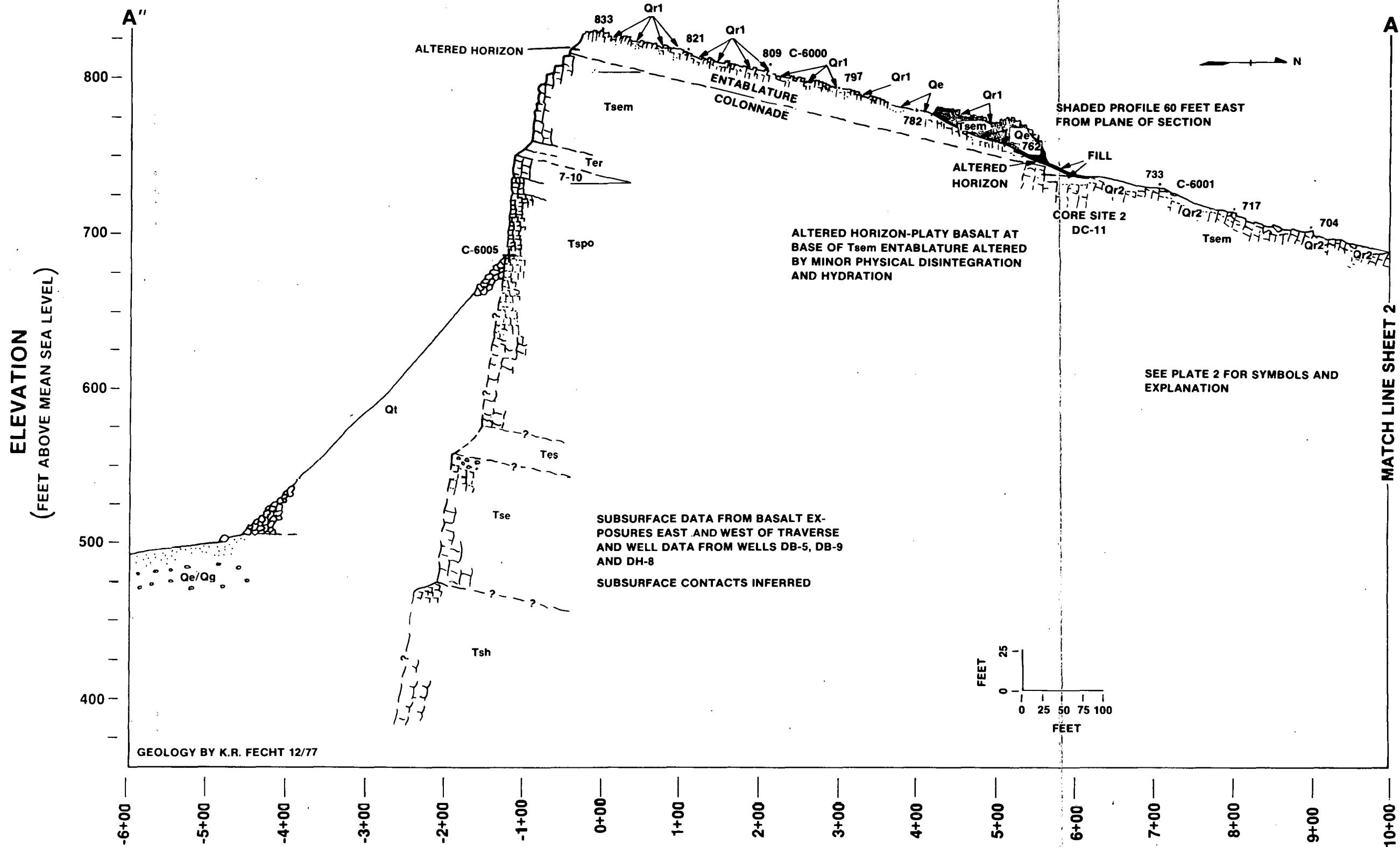
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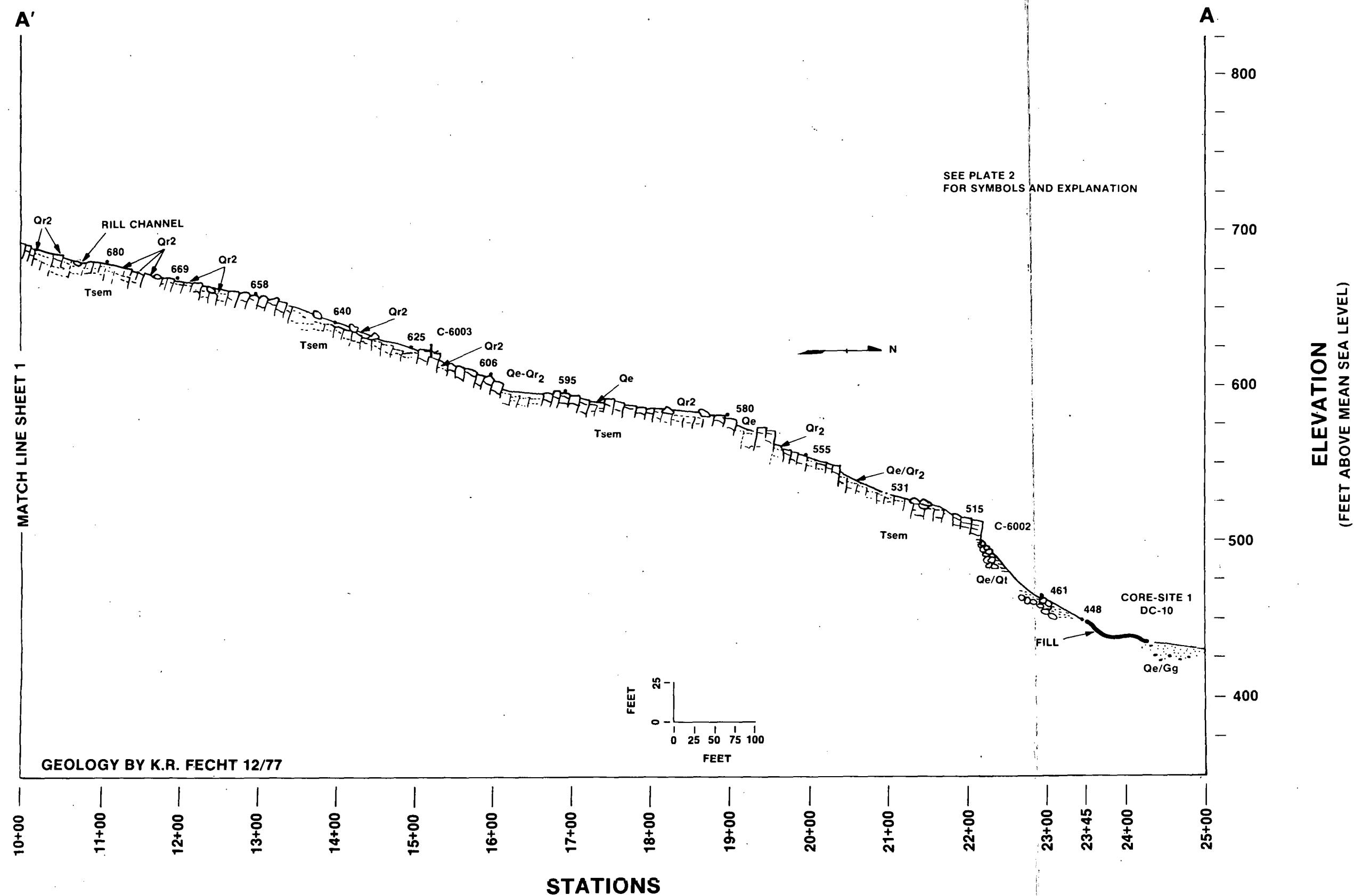
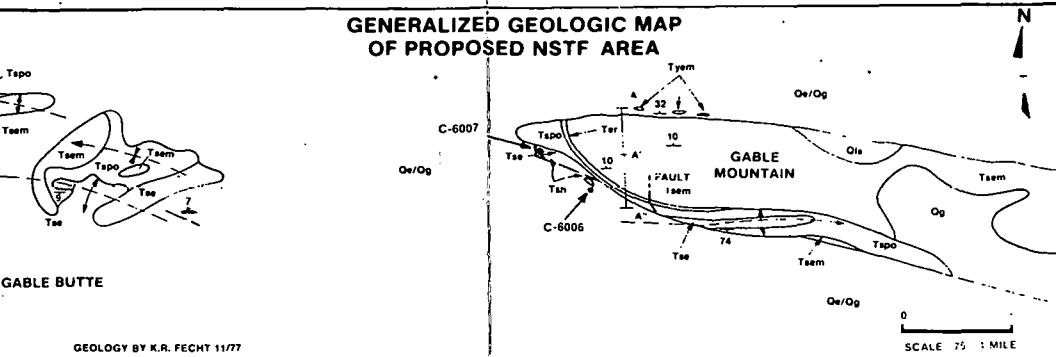


PLATE 1 - SHEET 2

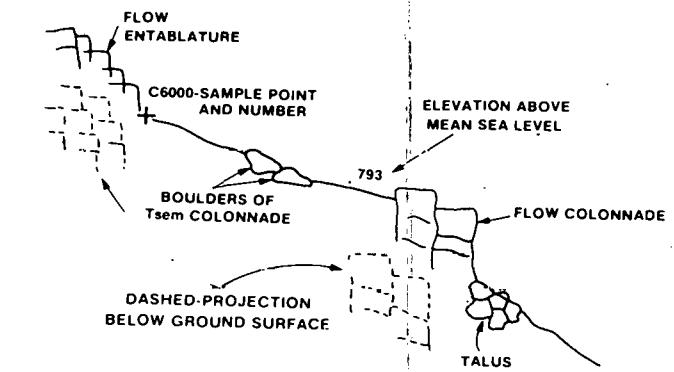
TOPOGRAPHIC PROFILE FOR PROPOSED NEAR-SURFACE TEST FACILITY SITE

LEGEND

UNIT SYMBOLS	UNITS	DESCRIPTION OF UNITS
QUARTERNARY	Qe	EOLIAN DEPOSITS FINE GRAINED SANDS AND SILTS DEPOSITED BY WIND, BUFF-BROWN COLOR, THIN VENEER ON GABLE MOUNTAIN (UP TO 2 FEET THICK), UP TO 20 FEET THICK COVERING GLACIO-FLUVAL DEPOSITS.
	QIs	LANDSLIDE ANGULAR FRAGMENTS OF BASALT MIXED WITH SEDIMENTS, CHARACTERIZED BY IRREGULARLY HUMMOCKY TOPOGRAPHY.
	Qt	TALUS ANGULAR FRAGMENTS OF MASS WASTED BASALT AT THE BASE OF CLIFFS.
	Qr₁	RUBBLE-ELEPHANT MOUNTAIN ENTABLATURE HACKLY BASALT RUBBLE OF ELEPHANT MOUNTAIN ENTABLATURE TYPICALLY LESS THAN 1.5 FEET IN DIAMETER, MIXED WITH EOLIAN SILT.
	Qr₂	RUBBLE-ELEPHANT MOUNTAIN COLONNADE MASSIVE SUBROUNDED OFTEN VESICULAR BASALT BOULDER RUBBLE OF ELEPHANT MOUNTAIN COLONNADE, TYPICALLY GREATER THAN 2 FEET IN DIAMETER, MIXED WITH EOLIAN SILT.
	Qg	GLACIOFLUVIAL DEPOSITS COARSE SANDS AND GRAVELS WITH SOME SILT DEPOSITED BY GLACIAL FLOODWATERS.
	Tsem	ELEPHANT MOUNTAIN NEARLY APHYRIC BASALT, ENTABLATURE OF CRUDE HACKLY COLUMNS 26 FEET THICK WITH ERODED SURFACE, COLONNADE 46 FEET THICK, MASSIVE BLOCKS, NORMAL TO TRANSITIONAL PALEOMAGNETIC POLARITY.
	Ter	RATTLESNAKE RIDGE SEDIMENTARY INTERBED, UPPER PORTION FINE TO MEDIUM GRAINED VITRIC TUFFS, REWORKED, LIGHT GRAY COLOR, LOWER PORTION FINE TO MEDIUM GRAINED TUFFS AND MICAECOUS SANDS, CROSS BEDDED, ORANGE-BROWN COLOR.
	Tspo	POMONA SLIGHTLY PHRYIC BASALT WITH ABUNDANT OLIVINE UPPER COLONNADE 20 FEET THICK, BLOCKY, ENTABLATURE 108 FEET THICK (ESTIMATED), LONG UNDULATING COLUMNS WITH FAN JOINTING COMMON, LOWER COLONNADE 60 FEET THICK (ESTIMATED), BLOCKY, REVERSED PALEOMAGNETIC POLARITY.
	Tes	SELAH SEDIMENTARY INTERBED, TUFFACEOUS SILTSTONE WITH FINE SAND STRINGERS, GRAY TO GREEN COLOR.
TERTIARY	Tse	ESQUATZEL (GABLE MOUNTAIN) PHRYIC BASALT, FLOW TOP SCORIACEOUS TO VESICULAR BRECCIATED, ENTABLATURE DENSE WITH VESICLE SHEETS, COLONNADE, BLOCKY MASSIVE, NORMAL PALEOMAGNETIC POLARITY.
	Tsh	ASOTIN (HUNTZINGER) PHRYIC BASALT, SALT & PEPPER DIABASIC TEXTURE, MASSIVE, NORMAL PALEOMAGNETIC POLARITY.



SYMBOLS



Qe/Qg Qe UNIT MANTLES Qg UNIT

Tsem-Qr. Tsem UNIT PRESENT WITH Qr. UNIT

CONTACT BETWEEN LITHOLOGIES & INTRALITHIC DISCONTINUITIES

SOLID LINE WHERE ACCURATELY KNOWN _____

DASHED LINE IF APPROXIMATELY KNOWN _____

QUERIED DASHED LINE WHERE INFERRED _____ ?

PLATE 2