RHO-BWI-LD-5
Informal Report

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Geology of Gable Mountain-Gable Butte Area

K. R. Fecht

September 1978

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

Rockwell International

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Rockwell Hanford Operations
Energy Systems Group
Richland, WA 99352

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PRELIMINARY REPORT

This Report contains information of a preliminary nature. It is subject to revision or correction and therefore does not represent a final Report. It was prepared primarily for internal use within The Rockwell Hanford Operations. Any expressed views and opinions are those of the Author and not necessarily of the Company.

RHO-BWI-LD-5
Informal Report

GEOLOGY OF GABLE MOUNTAIN-GABLE BUTTE AREA

K. R. Fecht
Basalt Geosciences Unit
Research Department

for
Basalt Waste Isolation Program

September 1978

Rockwell International
Rockwell Hanford Operations
Energy Systems Group
Richland, Washington 99352

A B S T R A C T

Gable Mountain and Gable Butte are two ridges which form the only extensive outcrops of the Columbia River Basalt Group in the central portion of the Pasco Basin. The Saddle Mountains Basalt and two interbedded sedimentary units of the Ellensburg Formation crop out on the ridges. These include, from oldest to youngest, the Asotin Member (oldest), Esquatzel Member, Selah Interbed, Pomona Member, Rattlesnake Ridge Interbed, and Elephant Mountain Member (youngest). A fluvial plain composed of sediments from the Ringold and Hanford (informal) formations surrounds these ridges.

The structure of Gable Mountain and Gable Butte is dominated by an east-west-trending major fold and northwest-southeast-trending parasitic folds. Two faults associated with the uplift of these structures were mapped on Gable Mountain. The geomorphic expression of the Gable Mountain-Gable Butte area resulted from the complex folding and subsequent scouring by post-basalt fluvial systems.

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INTRODUCTION

PURPOSE

Rockwell Hanford Operations, under contract to the U. S. Department of Energy, is assessing the feasibility of using Columbia River Basalt as a medium for the final storage of commercial nuclear waste. Current emphasis is on the Columbia River Basalt of the Pasco Basin which includes the Hanford Site (Figure 1). Two ridges, Gable Mountain and Gable Butte, are the only extensive outcrops of Columbia River Basalt in the central portion of the Pasco Basin. Knowledge of the geology exposed on these two ridges is essential for evaluating sites being considered for the construction of a waste repository in the Pasco Basin.

The study of Gable Mountain and Gable Butte described in this report had the following objectives:

1) Map and describe the rock units and geologic structures exposed on Gable Mountain and Gable Butte and project these structural and stratigraphic features into the adjacent subsurface using available borehole data as control for projections;

2) Map and describe the fluvial sediments that surround Gable Mountain and Gable Butte;

3) Evaluate the west end of Gable Mountain for use as a near-surface test facility; the near-surface test facility is an underground test facility being constructed on the west end of Gable Mountain to test the thermal and mechanical response of basalt rock to electric heater and spent fuel loadings; geologic studies specifically for the siting of this facility are being finalized;

4) Make preliminary geologic interpretation based on the above studies of the geologic features of the Gable Mountain-Gable Butte area as they relate to basalt repository siting considerations in the Pasco Basin.

GEOGRAPHY AND LOCATION

The study area includes Gable Mountain, Gable Butte, and the adjacent fluvial plain covering a total of approximately 210 square kilometers near the center of the Hanford Site (Figure 1). Gable Mountain covers approximately 14 square kilometers, reaching elevations of 330 and 339 meters on the eastern and western summits, respectively. Gable Butte covers an area of approximately 5 square kilometers, reaching an elevation of 235 meters near its eastern end. Gravel bars that form part of the fluvial plain surrounding Gable Mountain and Gable Butte range in elevation from 128 to 213 meters.

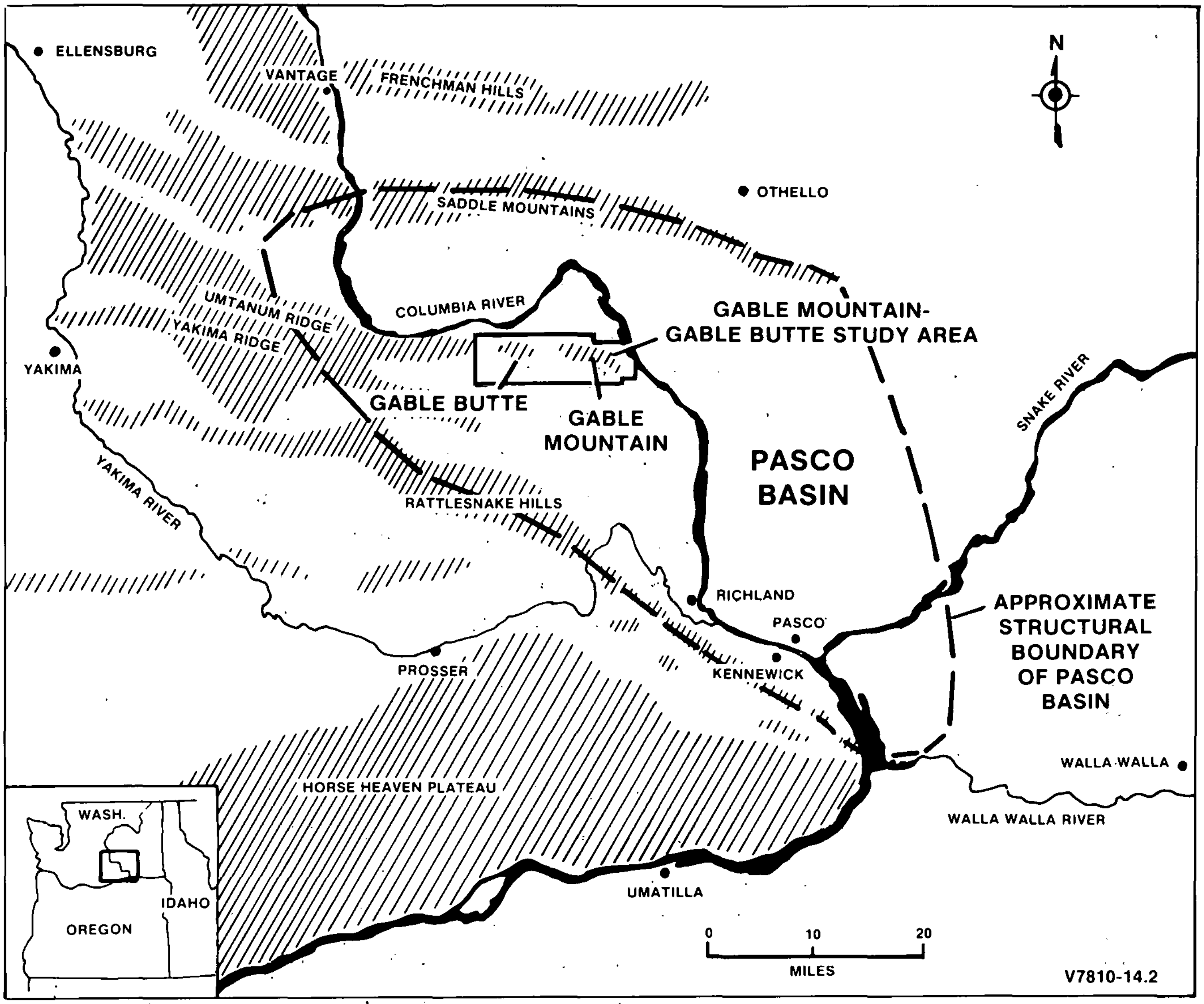


FIGURE 1

LOCATION MAP OF THE PASCO BASIN,
INCLUDING THE HANFORD SITE

PREVIOUS WORK

Since the startup of operations at the Hanford Site, the Gable Mountain-Gable Butte area has been examined as part of numerous geologic, hydrologic, and geophysical studies. Geologic studies included mapping of the basalts, interbedded sediments, and post-basalt sediments on the ridges (Schmincke, 1964; Bingham, et al., 1970; Newcomb, et al., 1972; Brooks, 1974; and WPPSS, 1974) and the logging of trenches constructed to evaluate geologic features on Gable Mountain (Converse, Davis and Associates, 1969 and 1971). Hydrologic studies included test wells drilled into the confined and unconfined aquifers on the flanks of Gable Mountain and Gable Butte (Hart and Frank, 1965; Mudd, et al., 1970). Geophysical studies included regional and local gravity and magnetic studies (Raymond, 1958; Raymond and McGhan, 1963; Peterson and Brown, 1966; Deju and Richard, 1976; Swanson and Wright, 1976; Lillie and Richard, 1977; Richard and Lillie, 1977; Swanson, et al., 1977).

METHODS AND PROCEDURES

Geologic mapping for this study was done on 1:6,000-scale aerial photographs and transferred to a 1:24,000-scale composite base map made by enlarging the 1:62,500 Hanford and Coyote Rapids quadrangle sheets published by the U. S. Geological Survey (Plates 1 through 4). Legends for Plates 1, 3, and 4 are given in Figures 2, 3, and 4. Oblique photographs of Gable Mountain were used to aid in field mapping.

Basalt units were identified from whole rock chemical analyses and flux gate magnetic polarity measurements. Sample locations are shown on Plate 3. The whole rock chemical analyses were of three types: atomic absorption analyses (Table I); wavelength dispersive X-ray fluorescence analyses (Table II), and semi-quantitative energy dispersive X-ray fluorescence analyses (Table III). Measurements of magnetic polarity were made using a flux gate magnetometer (Table II).

Rockwell Hanford Operations standard operating procedures were used as a guide for all field mapping, field measurements, and chemical analyses. Field mapping activities were conducted during January and February 1978.

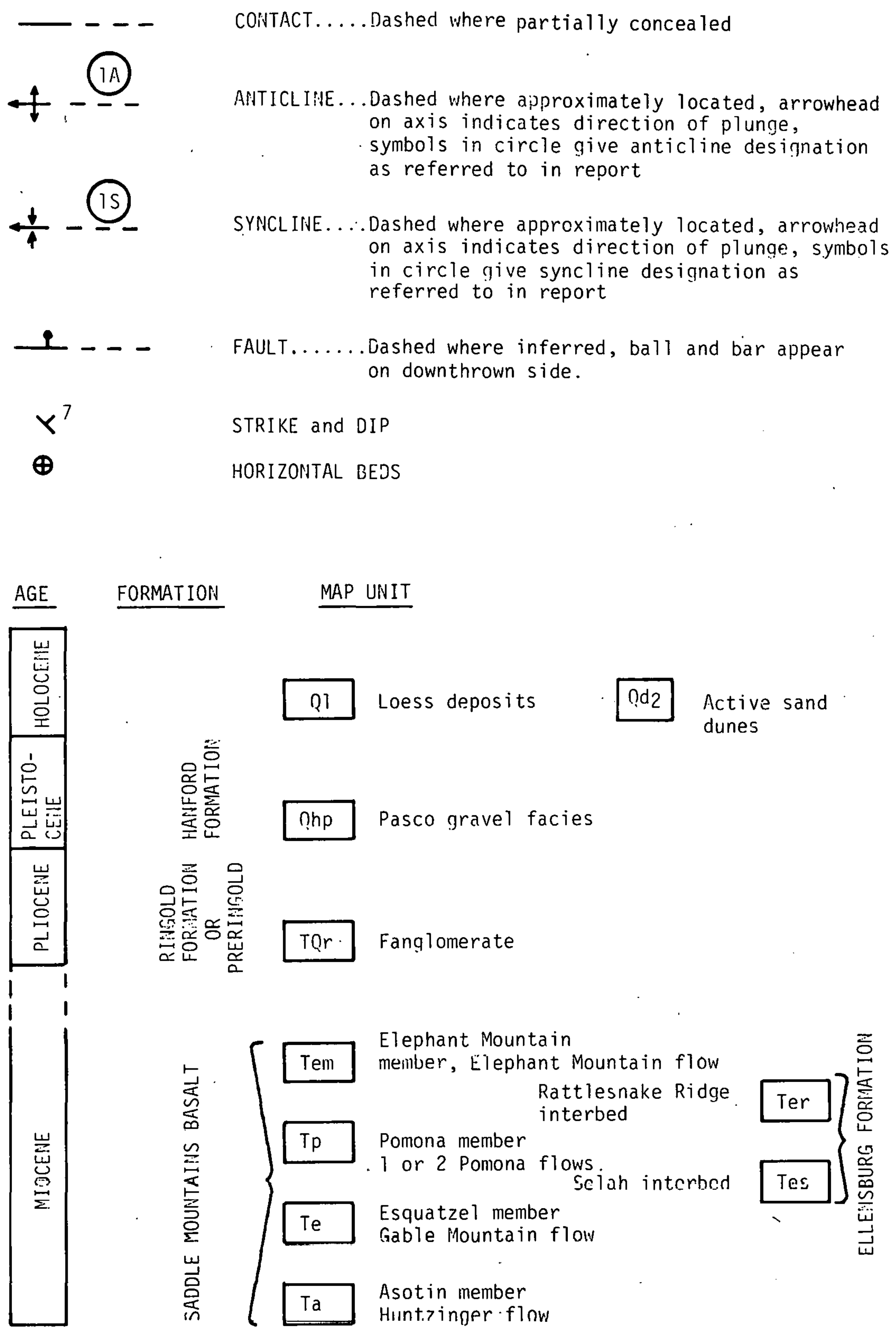


FIGURE 2

LEGEND FOR PLATE 1

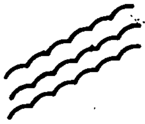

Man-made and natural ponds

\+ Glacial erratics....Location of large (>0.5 meter diameter) ice-rafted erratics

——— Margins of channels, bars, and landslides

– – – Approximate margins of channels and bars


Current direction


Giant current ripples

CHANNEL DEVELOPMENT

QUATERNARY

Qalc	Post-glacial Columbia River channel
Qgc_4	Lowest abandoned flood channel
Qgc_3	
Qgc_2	
Qgc_1	Highest abandoned flood channel

BAR DEVELOPMENT

QUATERNARY

Qgb_3	Youngest major bar development
Qgb_2	Highest bar development
Qgb_1	Lowest bar development

FIGURE 3

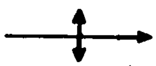
LEGEND FOR PLATE 3

Elevation in feet above mean sea level
Area of basalt outcrop shaded
Contour interval = 50 feet

51-75 — Well number
+ 265 ← — Elevation top of basalt


Well location

51-75
+(265) ← — Parentheses designate elevation at bottom of well, not basalt


ANTICLINE..arrowhead on axis indicates direction of plunge

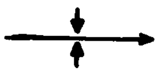

SYNCLINE...arrowhead on axis indicates direction of plunge

FIGURE 4

LEGEND FOR PLATE 4

TABLE I

ATOMIC ABSORPTION ANALYSES

SAMPLE NUMBER	A-1001	A-1004	A-1005	A-1017	A-1020	A-1021	A-1023	A-1024	A-1025	A-1026	A-1027
SiO_2,%	49.5	51.4	49.4	52.0	47.4	52.9	50.9	43.2	45.4	51.5	51.5
Al_2O_3,%	14.4	14.1	12.4	12.5	13.0	12.4	12.5	12.0	12.0	12.5	12.5
FeO,%	10.4	01.2	14.2	14.5	13.8	13.2	14.4	14.5	14.9	13.8	13.0
MgO,%	6.8	6.7	4.7	4.2	3.6	4.3	4.2	4.2	4.3	5.0	3.7
CaO,%	11.5	10.9	8.6	8.5	8.5	8.3	8.0	8.1	8.5	8.6	8.5
Na_2O,%	2.5	2.5	2.7	2.7	2.7	2.6	2.6	2.3	2.7	2.5	2.6
K_2O,%	0.51	0.52	1.04	2.39	0.97	1.30	1.38	1.32	1.32	0.81	0.88
MnO,%	0.19	0.16	0.22	0.21	0.18	0.23	0.23	0.20	0.22	0.18	0.18
TiO_2,%	1.61	1.72	3.14	3.21	3.15	3.11	[illegible].13	2.98	3.02	3.02	3.01
SrO,%	0.040	0.040	0.043	0.031	0.033	0.031	0.029	0.028	0.030	0.031	0.031
Volatility,%	2.78	2.14	1.12	0.78	2.16	1.41	1.16	2.20	0.49	4.23	3.14
Ba, ppm	1371	882	1263	870	570	725	700	550	550	490	720
Zn, ppm	91	87	132	163	134	149	150	134	144	147	151
Co, ppm	44	45	45	45	38	49	21	21	23	23	27
Pb, ppm	20	20	23	29	24	30	30	24	24	24	20
Cu, ppm	112	74	44	20	20	17	27	20	12	20	20
Cr, ppm	177	179	89	30	30	30	45	38	38	30	53
Ni, ppm	35	14	14	21	14	14	28	14	14	14	14
Rb, ppm	65	60	60	11	15	15	19	19	19	11	11

TABLE II

WAVELENGTH DISPERSIVE X-RAY FLUORESCENCE ANALYSES

SAMPLE NUMBER	SiO_2 %	Al_2O %	TiO_2 %	FeO* %	MnO %	CaO %	MgO %	K_2O %	Na_2O %	P_2O_5 %
DC-10 - 47.5	50.58	13.97	3.67	14.95	0.20	8.17	4.31	1.32	2.32	0.52
DC-10 - 216.5	52.18	15.72	1.60	10.81	0.18	10.81	6.78	0.45	2.22	0.23
DC-10 - 290.0	52.14	15.57	1.59	10.43	0.18	10.73	6.40	0.50	2.24	0.23
DC-10 - 382.5	52.21	14.42	2.97	14.13	0.20	7.65	3.84	1.84	2.36	0.38
DC-10 - 449.0	51.03	16.43	1.38	9.77	0.17	11.22	7.83	0.14	1.84	0.19
DC-11 - 53.5	51.08	13.98	3.50	14.58	0.22	8.53	4.23	1.35	2.34	0.19
DC-11 - 143.0	51.30	15.44	1.60	10.89	0.19	10.86	6.86	0.44	2.19	0.24
DC-11 - 266.0	51.18	15.53	1.62	11.00	0.19	10.80	6.85	0.56	2.03	0.24
DC-11 - 334.5	52.63	14.04	3.06	13.72	0.21	7.86	3.86	1.75	2.47	0.40
DC-11 - 360.5	49.87	16.70	1.45	10.27	0.20	11.57	7.82	0.05	1.94	0.23

*FeO = FeO + Fe_2O_3.

TABLE III

SEMI-QUANTITATIVE ENERGY DISPERSIVE X-RAY FLUORESCENCE ANALYSES

SAMPLE NUMBER	CaO Wt%	TiO_2 Wt%	Ba ppm	FLUX GATE MAGNETIC POLARITY
C6000	7.2	3.2		+
C6001	7.2	2.5		+
C6004	7.6	1.8		+
C6005	8.8	1.2		-
C6006	9.6	1.2		+
C0007	6.4	2.2		+
C6029	8.1	2.3		
C6030	8.6	2.2		
C6031	8.0	2.1		
C6032	8.7	2.2		
C6033	8.1	2.1		
C6034	8.2	2.1		
C6035	9.9	2.1		
C6036	9.9	2.1		
C6037	8.1	2.0		
C6038	8.6	1.9		
C6039	9.0	1.8		
C6040	9.5	2.0		
C6041	8.7	2.1		
C6042	10.2	1.8		
C6043	9.4	1.8		
C6044	10.1	1.8		
C6045	9.0	2.9		+
C6046	9.6	1.3		-
C6047	9.6	1.5		-
C6048	6.1	2.2		+
C6049	6.1	2.2		+
C6050	8.4	1.5		-
C6051	5.9	2.3		+
C6052	5.9	2.3		+
C6053	7.8	1.5		-
C6054	4.7	2.9		+
C6055	4.7	2.0		+
C6056	6.7	3.2		+
C6057	7.3	1.1		-
C6058	6.7	3.2		+
C6059	9.0	1.0		-
C6060	8.1	1.1		-
C6061	4.0	1.0		+

Table III (continued)

SAMPLE NUMBER	CaO Wt%	TiO_2 Wt%	Ba ppm	FLUX GATE MAGNETIC POLARITY
K8000	7.7	3.0	610	+
K8004	10.1	1.7	315	-
K8007	6.3	2.8	655	+
K8008	10.1	1.7	340	-
K8010	7.3	3.7	1130	+
K8013	10.2	1.1	355	
K8014	10.1	1.2	230	+
K8022	7.1	2.3	566	+
K8023	6.9	2.5	573	I
K8024	7.2	4.2	586	
K8025	9.5	1.1	306	-
K8026	7.1	2.8	625	+
K8029	7.9	2.6	595	+
K8030	7.9	2.5	500	+
K8031	7.7	2.7	575	+
K8033	7.7	3.0	490	+
K8034	6.1	2.5	685	+
K8035	7.7	3.0	660	+
K8037	6.8	2.6	540	+
K8039	10.1	1.3	320	-
K8040	10.0	1.6	355	-
K8041	7.0	2.5	660	+
K8042	8.1	3.0	520	+
K8043	6.2	2.6	510	+
K8054	10.0	1.6	370	-
K8057	9.9	1.2	475	-
K8059	7.7	3.2	705	+
K8060	8.0	2.4	640	+
K8062	10.0	1.5	335	-
K8067	10.1	1.2	335	-
K8071	7.7	3.3	510	+
K8072	9.1	3.0	525	+
K8074	9.6	1.3	480	-
K8076	7.8	3.8	540	+
K8077	9.7	1.3	345	-
K8080	9.8	1.3	305	-

Table III (continued)

SAMPLE NUMBER	CaO Wt%	TiO_2 Wt%	Ba ppm	FLUX GATE MAGNETIC POLARITY
K8082	9.3	1.2	275	-
K8083	7.8	3.8	595	+
K8084	9.8	1.3	325	-
K8085	9.5	1.2	365	-
K8086	6.7	3.1	610	+
K8087	8.2	2.8	485	+
K8088	8.3	2.8	535	+
K8091	10.0	1.6	485	-
K8099	7.5	3.5	485	+
K8100	8.5	2.7	500	+
K8101	7.4	3.3	400	+
K8104	7.0	2.5	630	
K8105	7.8	3.4	505	+
K8106	7.7	3.9	640	+
K8107	10.0	1.4	425	-
K8113	7.9	3.1	600	+
K8114	7.8	2.7	610	+
K8115	7.7	3.3	610	+
K8117	7.9	2.6	610	+
K8118	6.0	1.9	990	+
K8119	8.1	4.0	1560	+

wt% = weight percent

ppm = parts per million

\+ = normal polarity

\- = reversed polarity

ACKNOWLEDGMENTS

I would like to thank the many Rockwell Hanford Operations' geologists for their stimulating discussions regarding this study. In particular, I would like to thank Mr. D. J. Brown, Mr. J. N. Gardner, Dr. F. E. Goff, Ms. M. G. Jones, Mr. R. K. Ledgerwood, Mr. J. T. Lillie, Dr. C. W. Myers, and Dr. S. P. Reidel. Mr. Ledgerwood also assisted in interpreting the core from holes in the study area. Messrs. W. E. Brooks and R. S. Cockerham provided whole rock chemical analyses of basalt samples from Gable Mountain. I would especially like to thank Dr. Myers for his endless help during the study and for critically reviewing the manuscript.

REGIONAL SETTING

The Columbia Plateau lies in an intermontane basin between the Rocky Mountains and the Cascade Range (Fenneman, 1928) and is underlain principally by a thick sequence of tholeiitic flood basalts and minor interbedded sediments of Oligocene to Miocene age (Raymond and Tillson, 1968; Swanson and Wright, 1976). The Pasco Basin is the approximate central and lowest portion of the Columbia Plateau, both topographically and structurally, and contains more than 3,000 meters of volcanic rock and interbedded sediments (Peterson and Brown, 1966; Raymond and Tillson, 1968). During the late stages of flood basalt volcanism, northwest-to west-trending folds began forming in the central part of the plateau (Bentley, 1977). These folds, known as the Yakima fold belt (WPPSS, 1977), include the Umtanum Ridge structure. The Umtanum Ridge structure plunges into the Pasco Basin and Gable Mountain and Gable Butte are small isolated anticlinal ridges representing an eastward extension of this structure.

Late Cenozoic folding and subsidence resulted in the deposition of fluvial sediments transported from the surrounding highlands by ancestral rivers flowing into and through the Pasco Basin. These sediments form the Ringold formation of Pliocene age (Gustafson, 1978). The late Quaternary history of the central Columbia Plateau is characterized by periodic episodes of catastrophic proglacial flooding separated by prolonged periods of loess accumulation (Bretz, 1969; Fryxell and Cook, 1964; Newcomb, 1961; Baker and Nummendal, 1978). Flood waters deeply scoured the basalt and Ringold surfaces and deposited up to 213 meters of glaciofluvial sediments in the Pasco Basin. These sediments are informally named the Hanford formation. The last floods occurrred about 13,000 years before present (Mullineaux, et al., 1977). Flood deposits cover most of the Ringold formation in the central Pasco Basin and all basalt except for that comprising Gable Mountain and Gable Butte.

STRATIGRAPHY

INTRODUCTION

Basalt flows from the Asotin, Esquatzel, Pomona, and Elephant Mountain members of the Saddle Mountains Basalt and two intercalated sedimentary interbeds (Selah and Rattlesnake Ridge) of the Ellensburg Formation are exposed on Gable Mountain and Gable Butte (Figure 5). The Ringold formation, the glaciofluvial sands and gravels (Hanford formation), and a veneer of eolian loess cover parts of the flanks of Gable Mountain and Gable Butte and the surrounding plain. These rock units constitute the upper part of the Pasco Basin stratigraphic section (Figure 6).

Correlations of rock units and stratigraphic relations in the Gable Mountain-Gable Butte area are shown in Figure 5. The stratigraphic nomenclature used in this report is given in Figure 6. A photo-mosiac locating features in the Gable Mountain-Gable Butte area referred to in this report is given in Figure 7.

DESCRIPTION OF ROCK UNITS

General descriptions of rock units are given below. Features used to distinguish various basalt units in the Gable Mountain-Gable Butte area are summarized in Table IV.

Asotin Member

The oldest basalt flow exposed in the study area is the Huntzinger Flow, which here represents the Asotin Member of the Saddle Mountains Basalt (Swanson, et al., 1978). Exposures of this flow are limited to small outcrops on the southern flank of the western Gable Mountain anticline along the southern Gable Mountain escarpment (Figure 7).

There, outcrops of the Huntzinger Flow are rubbly, weathered, and have less than one meter of exposed thickness. Core Hole DB-9, located on the west end of Gable Mountain, indicates the flow is about 25 meters thick (Figure 5).

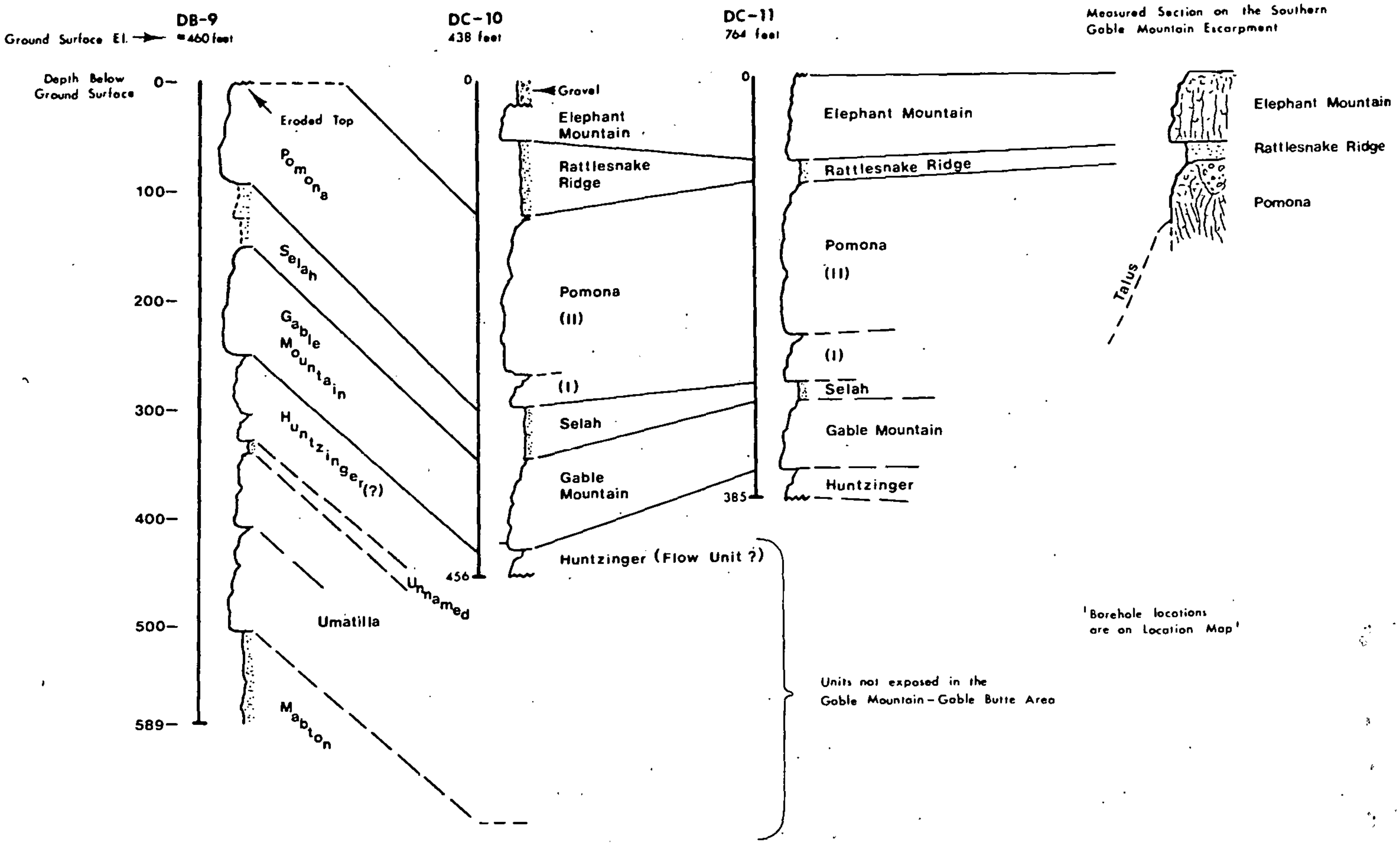


FIGURE 5

BOREHOLE CORRELATIONS OF BASALT UNITS AND INTERBEDS IN THE GABLE MOUNTAIN-GABLE BUTTE AREA

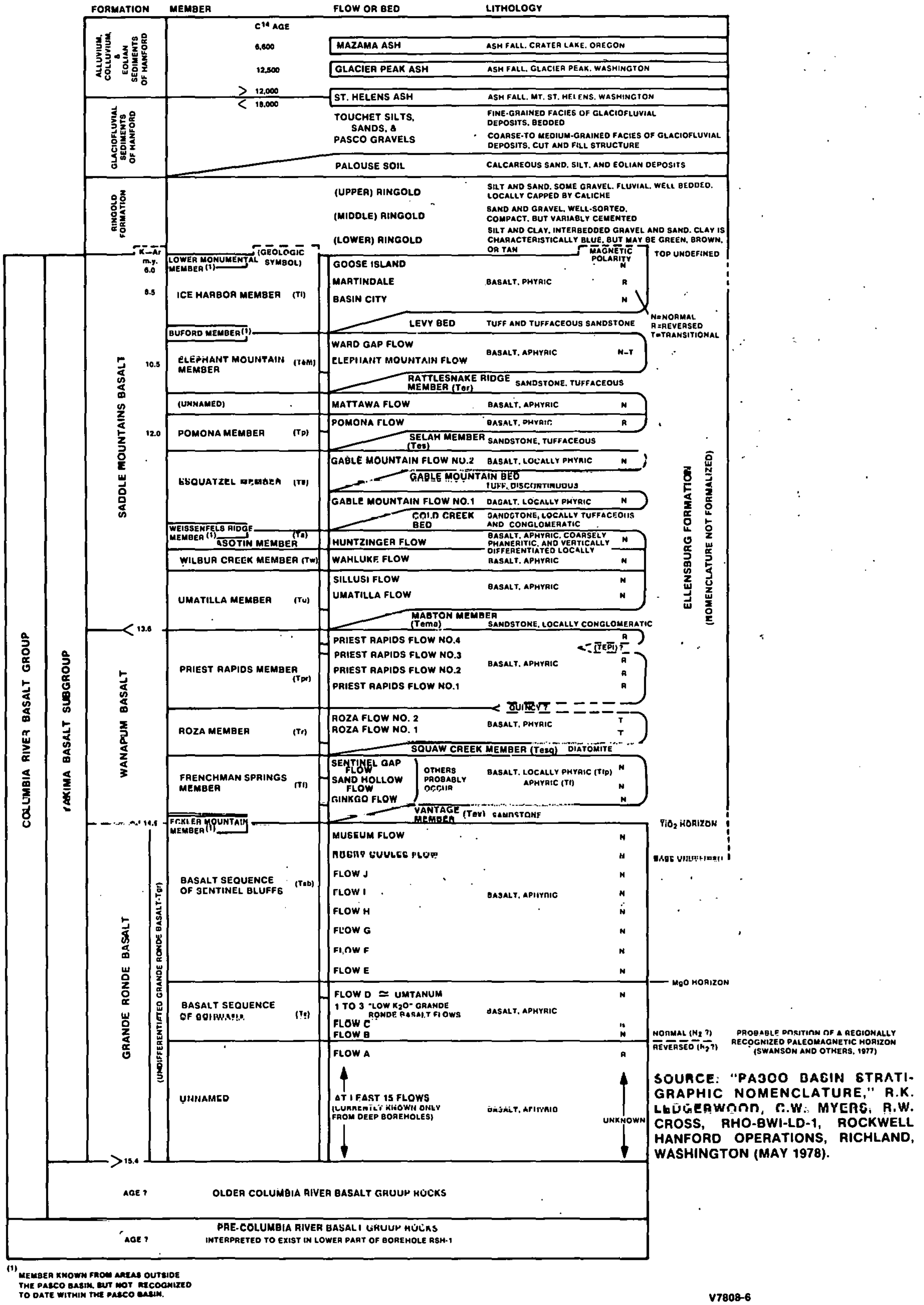


FIGURE 6

PASCO BASIN STRATIGRAPHIC NOMENCLATURE

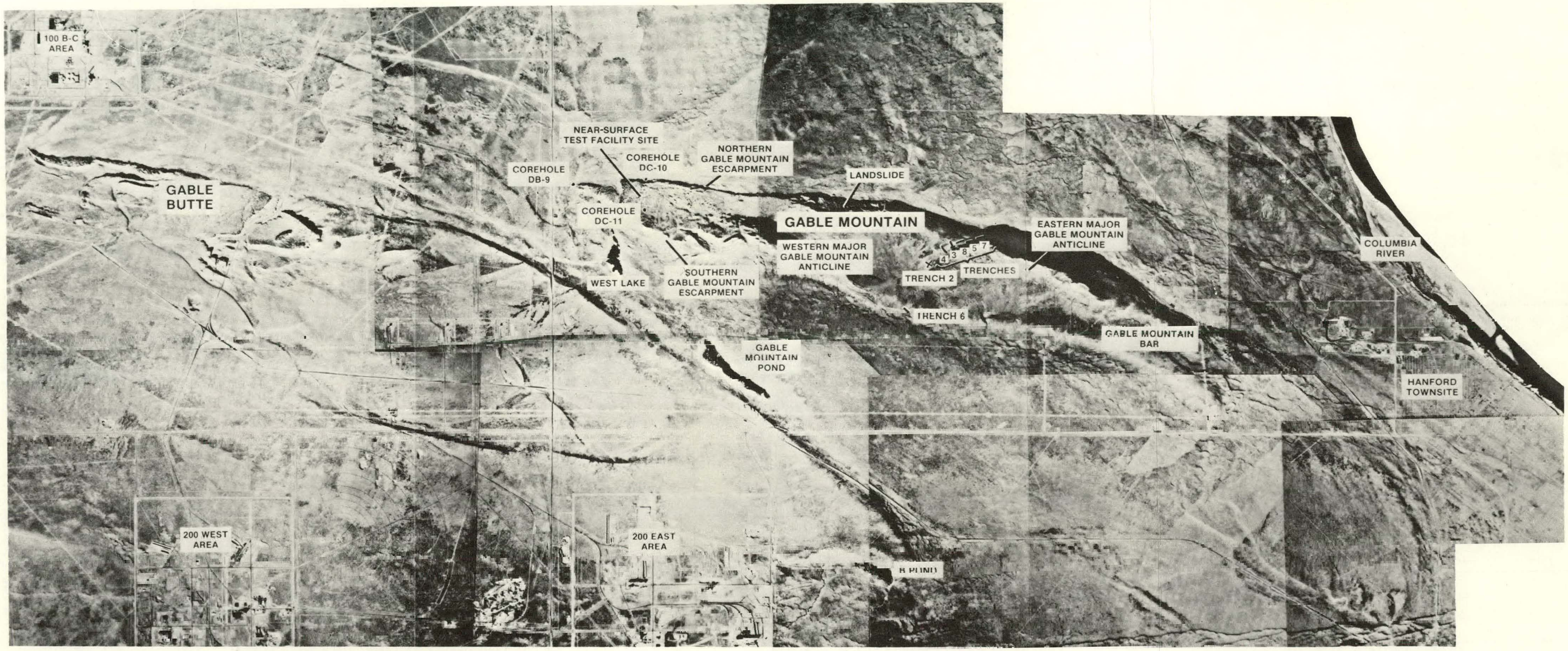


FIGURE 7

LOCATION MAP - GABLE MOUNTAIN-GABLE BUTTE

TABLE IV

SUMMARY OF FEATURES USED TO IDENTIFY BASALT UNITS IN THE GABLE MOUNTAIN-GABLE BUTTE AREA

BASALT UNIT	RELATIVE CaO/TiO2	MAGNETIC POLARITY	MICROSCOPIC & MEGASCOPIC FEATURES
Elephant Mountain Member	Low	Normal - transitional	Coarse to medium texture, sparsely plagioclase phyric
Pomona Member	High	Pomona II reversed; Pomona I not known	Sparsely plagioclase phyric; megascopic olivine
Esquatzel Member	Low	Normal	Sparsely plagioclase phyric; slightly diktytaxitic
Asotin Member	High	Normal	Diabasic; gray, ophitic pyroxene, black groundmass

Esquatzel Member

The Gable Mountain flow* of the Esquatzel Member of the Saddle Mountains Basalt directly overlies the Huntzinger Flow. The Gable Mountain flow is about 21 meters thick near the crest of Gable Mountain and Gable Butte, and thickens to about 31 meters on the lower flanks of Gable Mountain and Gable Butte (Figure 8). It consists of 3 main intraflow structural units: a colonnade; an entablature; and, a flow top. The colonnade forms the basal one-third of the flow and makes an abrupt, sharp contact with the underlying Huntzinger Flow; this is shown in Core Hole DB-9 (Figure 5). The colonnade is generally uniform throughout, with poor to moderately well-developed columns, 40-70 centimeters in diameter, containing numerous cross-fractures (Figure 8) and scattered vesicles. The colonnade grades gradually into the central entablature which forms about two-thirds of the total flow. The entablature is hackly to slightly columnar with numerous vertical fractures and scattered vesicles. The flow top of the Gable Mountain flow does not crop out in the study area, but was penetrated in Core Holes DC-9, DC-10, and DC-11 (Figure 5). In these holes, the flow top is interpreted as being rubbly, palagonitic, and abundantly vesicular.

Selah Interbed

The Selah Interbed of the Ellensburg Formation overlies the Gable Mountain flow of the Saddle Mountains Basalt. The name Selah is used here for the interbed between the Pomona and Esquatzel members. No good exposures of the Selah Interbed crop out in the study area, except for a few prominent benches partially covered with talus.

Core Hole DC-11, located high on the northern flank of the western Gable Mountain anticline, penetrated about 5 meters of the Selah Interbed. There, it is an orange to brown, fine-grained vitric tuff.

In Core Hole DC-10, located on the lower northern flank of the western Gable Mountain anticline, the Selah Interbed is about 11 meters thick, and the upper 5 meters is vitric tuff similar to that in Core Hole DC-11; the lower 6 meters is fine- to medium-grained arksoic sand. At its contact with the Pomona Member, the Selah Interbed is baked as the result of heat from the overriding Pomona flow

*Two Gable Mountain flows have been recognized locally in the Pasco Basin (Figure 6). It is not known which, if either, of the two Gable Mountain flows is represented by the flow described here; hence, it is referred to simply as the Gable Mountain flow.

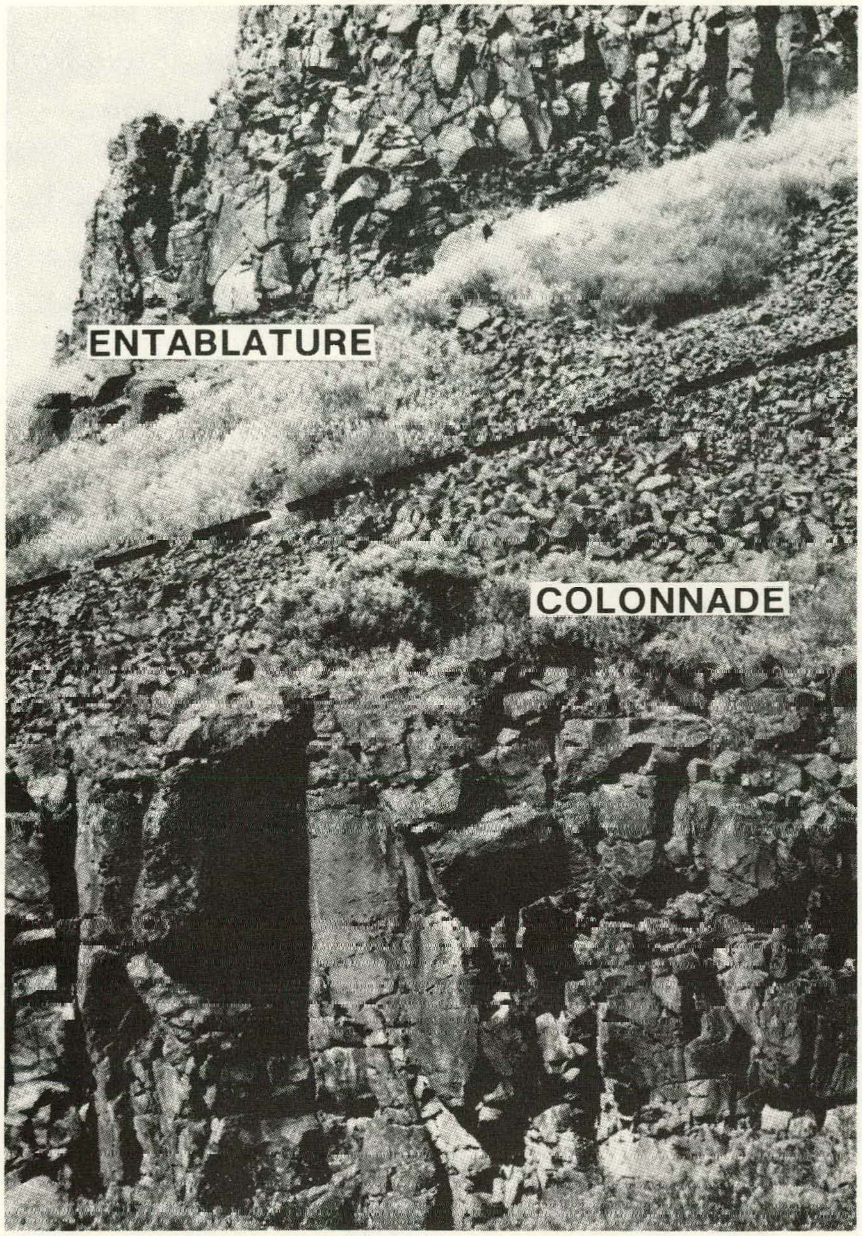


FIGURE 8

OUTCROP OF GABLE MOUNTAIN FLOW ON GABLE BUTTE

Pomona Member

The Pomona Member of the Saddle Mountains Basalt, generally thought to be a single flow throughout the region, consists of two basalt flows (or flow units) on Gable Mountain. These flows are informally named Pomona I (lower) and Pomona II (upper) and are locally separated by a tuffaceous interbed about 60 centimeters thick. The Pomona I overlies the Selah Interbed and is known only from Core Holes DC-10 and DC-11; elsewhere it is covered. The Pomona I is 7.9 meters and 11.6 meters thick in Core Holes DC-10 and DC-11, respectively, and exhibits medium-grained texture with plagioclase phenocrysts. The flow top and flow bottom are vesicular and glassy. The central portion of the flow is dense with few vesicles and exhibits moderate vertical jointing and cross-jointing. The major element chemistry of the Pomona I and Pomona II is similar (Table III).

The Pomona II unit of the Saddle Mountains Basalt locally overlies a thin tuffaceous interbed separating it from the underlying Pomona I unit. The Pomona II is about 44 meters thick on the western Gable Mountain anticline and has 4 intraflow zones: basal colonnade; entablature; upper colonnade; and, flow top.

The basal colonnade of the Pomona II consists of large, blocky, well-developed columns, 0.4 to 0.6 meter in diameter (Figure 9-A). Above the basal colonnade is the entablature, which constitutes nearly two-thirds of the Pomona flow. The entablature consists generally of long, undulating, well-developed, slender columns (about 20 to 30 centimeters in diameter) and displays hackly jointing formed by the intersection of the vertical columnar joints and numerous cross-joints (Figure 9-B). Locally, the columns in the entablature have a radial fanning pattern.

The entablature grades abruptly upward into the upper colonnade, which constitutes less than one-quarter of the flow. The upper colonnade consists of long, undulating columns, 0.45 to 1.0 meter in diameter, with many cross-joints and large scattered vesicles (Figure 9-C).

Locally, within the upper colonnade, are zones of glassy, vesicular basalt with a "frothy" appearance that stand in sharp contrast to the surrounding massive columns (Figure 9-D). These anomalous zones can extend the full length of the upper colonnade, protruding into the top of the entablature which shows fan jointing adjacent to these zones and

FIGURE 9-A

COLUMNS IN THE COLONNADE OF THE POMONA II UNIT

FIGURE 9-B

LONG SLENDER COLUMNS IN THE ENTABLATURE OF THE POMONA II UNIT

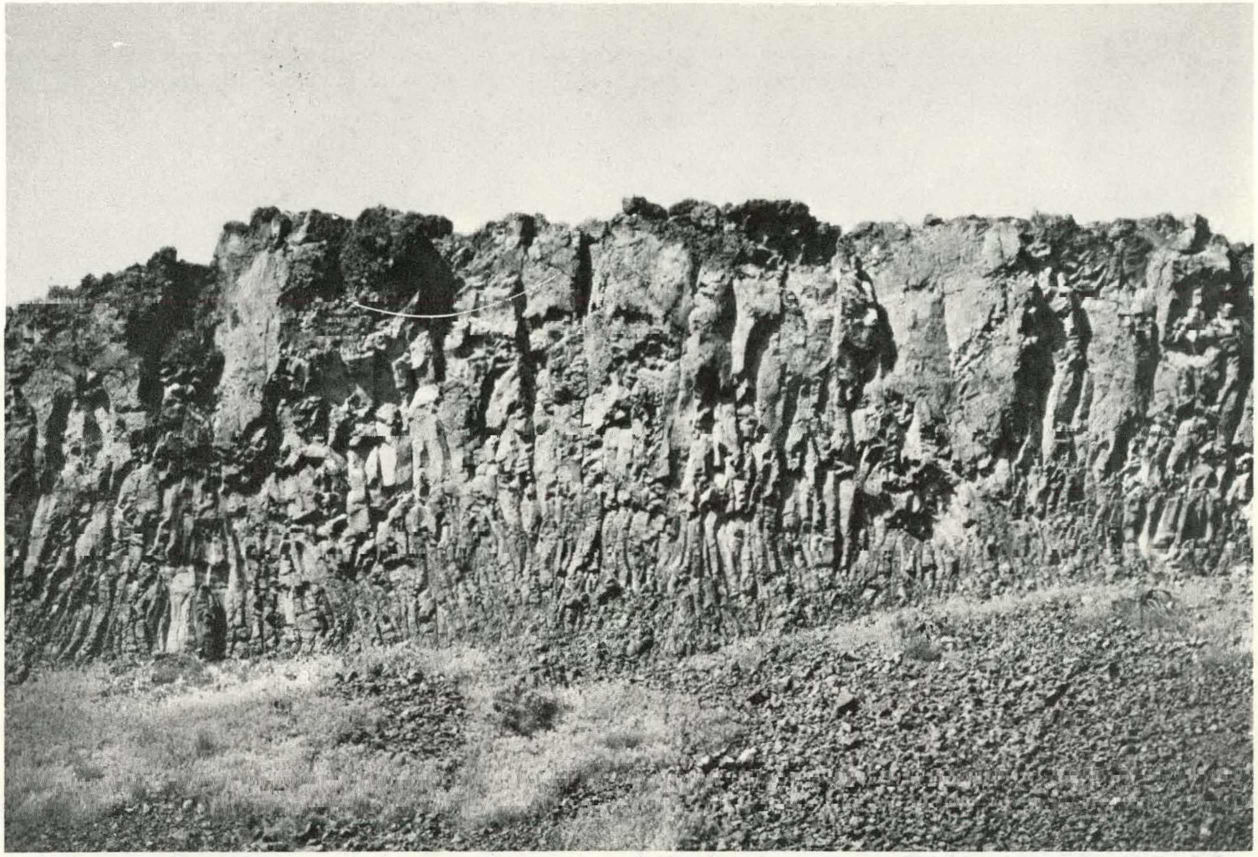


FIGURE 9-C

UPPER COLONNADE AND FLOW TOP OF THE POMONA II UNIT

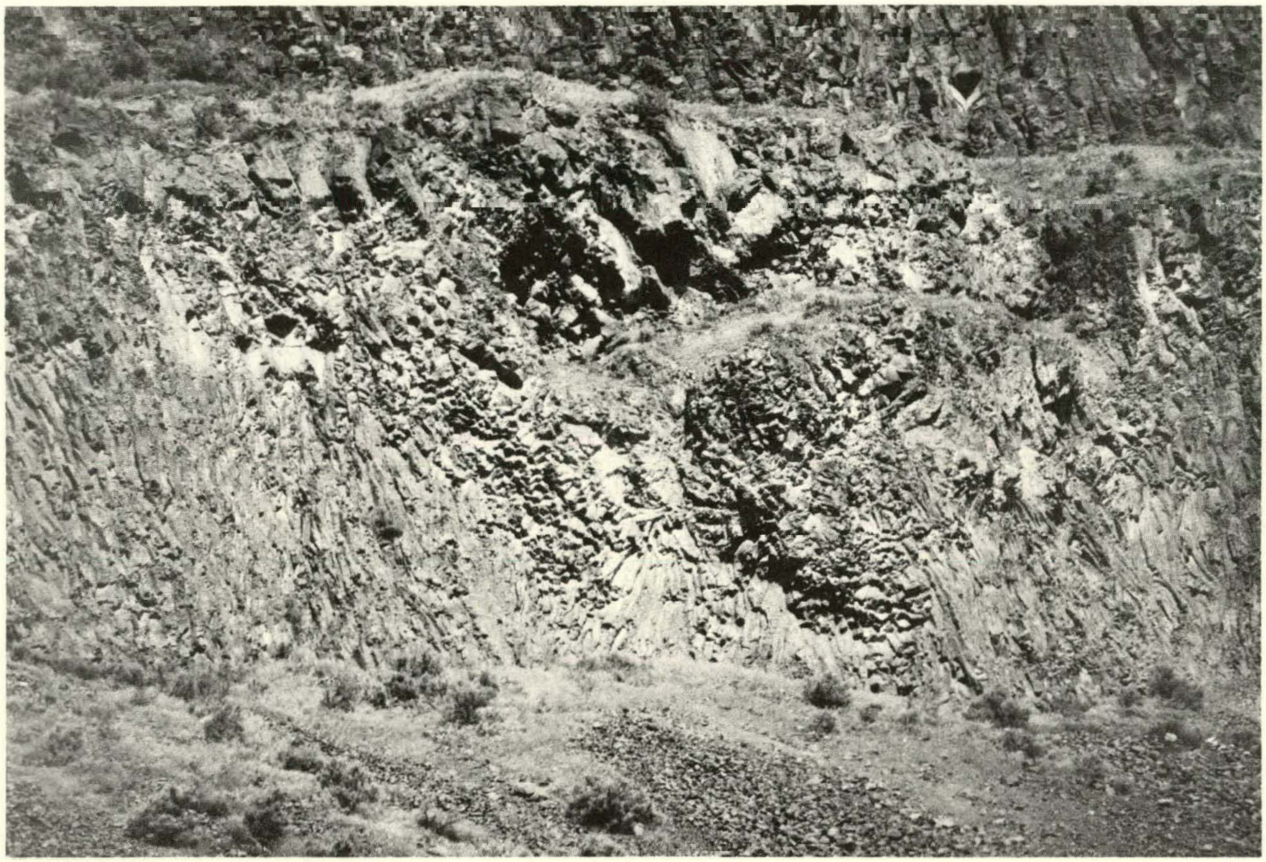


FIGURE 9-D

ANOMALOUS ZONES IN THE UPPER PART OF THE POMONA II UNIT extending to the flow top (Schmincke, 1964). The extent and development of these anomalous zones in the Pomona II basalt on the north flank of the western Gable Mountain anticline was a factor in the site evaluation process for the near-surface test facility.

The flow top of the Pomona II unit consists of a highly vesicular, glassy basalt grading downward into the more dense basalt of the upper colonnade.

Rattlesnake Ridge Interbed

The Rattlesnake Ridge Interbed of the Ellensburg Formation is positioned between the underlying Pomona II unit and the overlying Elephant Mountain flow. Exposures of the Rattlesnake Ridge Interbed are limited to those along the southern Gable Mountain escarpment on the western Gable Mountain anticline, in the trenches in the saddle of Gable Mountain, and at the crest of the eastern major Gable Mountain anticline. At these localities, the Rattlesnake Ridge Interbed varies in thickness from 1.5 to 5.4 meters. On the northern flank of the western Gable Mountain anticline, the interbed thickens toward the north from 6.1 meters in Core Hole DC-11 to 20.7 meters in Core Hole DC-10. Near the crest of the eastern Gable Mountain anticline, the Rattlesnake Ridge Interbed thins to less than 30 centimeters in thickness. On Gable Butte, the Rattlesnake Ridge Interbed is not present; there, the Elephant Mountain flow directly overlies the Pomona II unit.

The Rattlesnake Ridge Interbed consists of an orange to tan, medium-grained, locally cross-bedded, arksoic sand, overlain by a light gray, silty, vitric tuff. Generally, the arksoic sand alone is present where the interbed is less than 50 centimeters thick; however, in the central portion of Gable Mountain, only the vitric tuff is present (Figure 10-A). At its upper contact, the interbed is baked and locally welded by heat from the overriding Elephant Mountain flow. In addition, exposures in Trench 6 indicate that the overriding Elephant Mountain intruded into the top of the Rattlesnake Ridge forming a peperite (Figure 10-B).

Elephant Mountain Member

The youngest basalt flow in the Gable Mountain-Gable Butte vicinity is the Elephant Mountain flow of the Saddle Mountains Basalt. The Elephant Mountain flow overlies the Rattlesnake Ridge Interbed of the

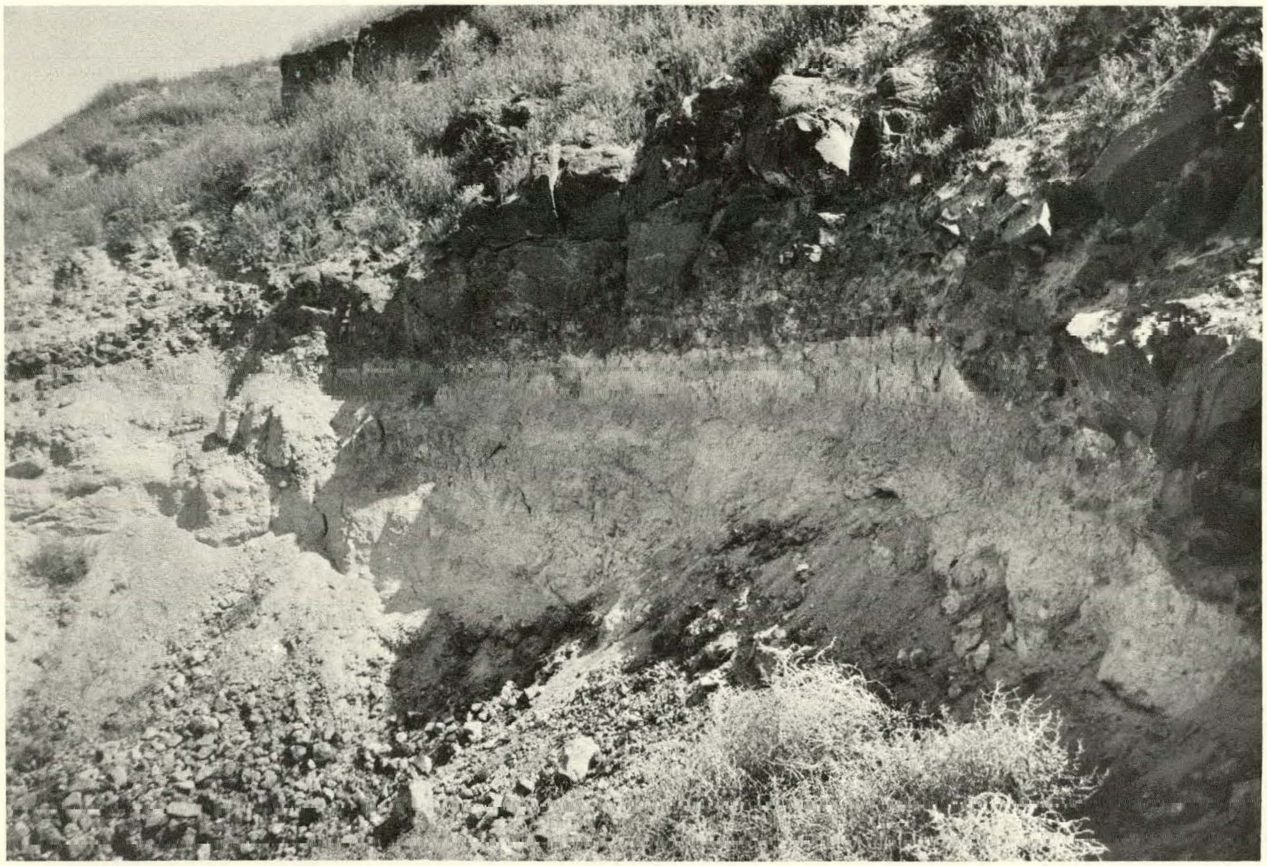


FIGURE 10-A

VITRIC TUFF FACIES OF THE RATTLESNAKE RIDGE INTERBED

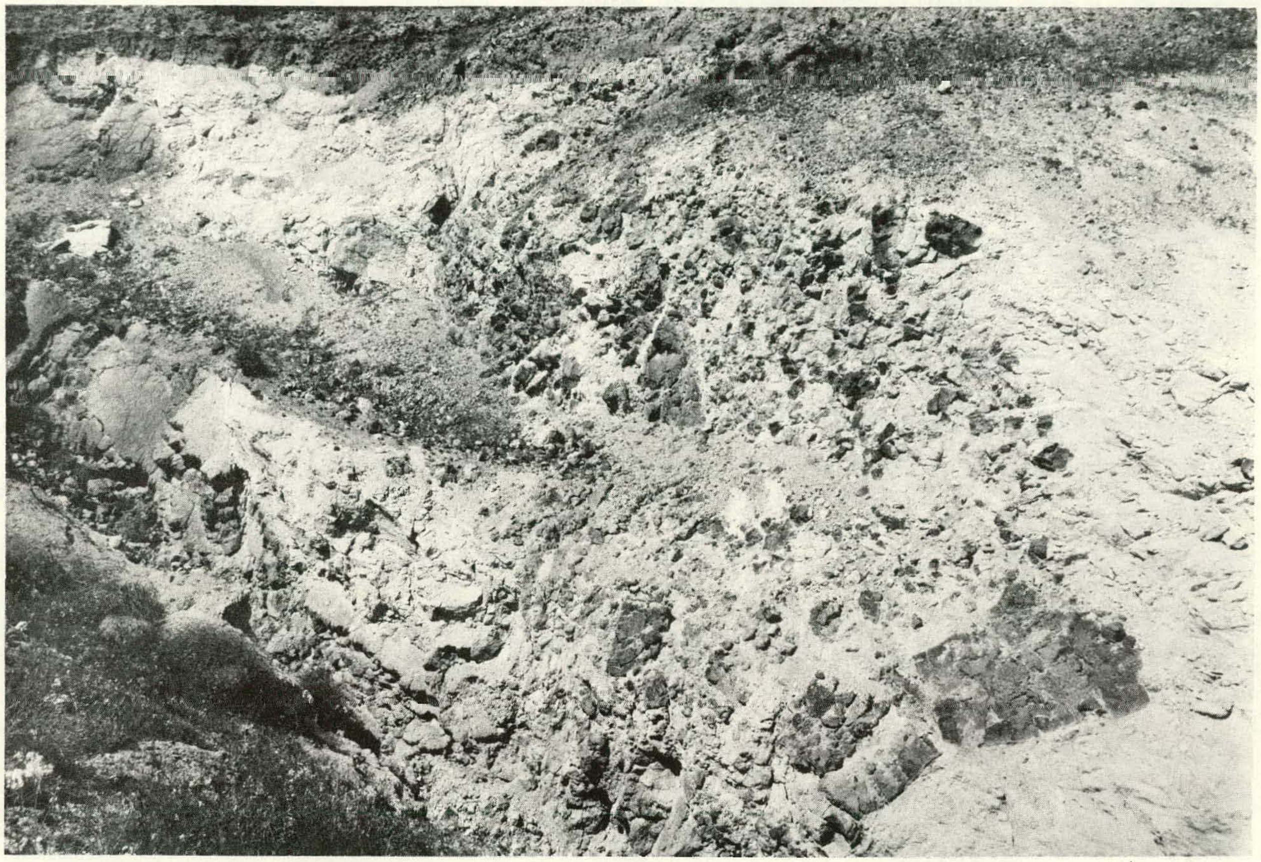


FIGURE 10-B

ELEPHANT MOUNTAIN PEPERITE FACIES OF THE RATTLESNAKE RIDGE INTERBED

Ellensburg Formation. The Elephant Mountain flow is about 25 meters thick and is divided into 3 zones: colonnade; entablature; and, flow top. The colonnade forms about one-third of the total flow. The base of the colonnade has platy joints, numerous cross-fractures, and is nonvesicular (Figure 11-A). This lower zone in the colonnade grades upward into moderate- to well-developed vertical columns, 30-80 centimeters in diameter. At the top of the colonnade, the columns grade abruptly into platy cross-fractures that appear to have been physically altered and hydrated. The basal colonnade grades upward into the central entablature, which comprises about one-half of the total flow. The entablature is hackly, with numerous, irregular cross-fractures, vertical fractures, and has small scattered vesicles near its top. The top of the Elephant Mountain flow has been largely eroded from the study area by the proglacial flood waters. On a small anticline on the east end of Gable Mountain and in the trenches on the north limb of the major eastern Gable Mountain anticline, the Elephant Mountain flow consists of a brecciated, palagonitic flow top at least 4 meters thick. Locally, the palagonitic flow top is incorporated with and overlaid by more massive Elephant Mountain basalt (Figure 11-B).

Ringold Formation and Pre-Ringold Sediments

On the southern flank of the western Gable Mountain anticline, sediments of the Ringold formation, and perhaps sediments of pre-Ringold age, crop out along an erosional escarpment (Figure 12). These sediments are interpreted as a fanglomerate deposited along a series of alluvial fans or rock falls near the base of Gable Mountain. The deposit is approximately 25 meters thick, consisting of angular basalt fragments, well indurated with calcium carbonate. The fanglomerate is probably the sheltered remnant of what was a more extensive fanglomerate that formed along the flanks of Gable Mountain and Gable Butte. This original deposit was most likely eroded by proglacial flood waters and the ancient Columbia River, such that all was removed except for the remnant and an eastward extension beneath the Gable Mountain pendant bar (Plate 3) which would have also been sheltered from fluvial erosion and wave-current action.

FIGURE 11-A

PLATY JOINTS DEVELOPED IN THE LOWER PART OF THE ELEPHANT MOUNTAIN COLONNADE

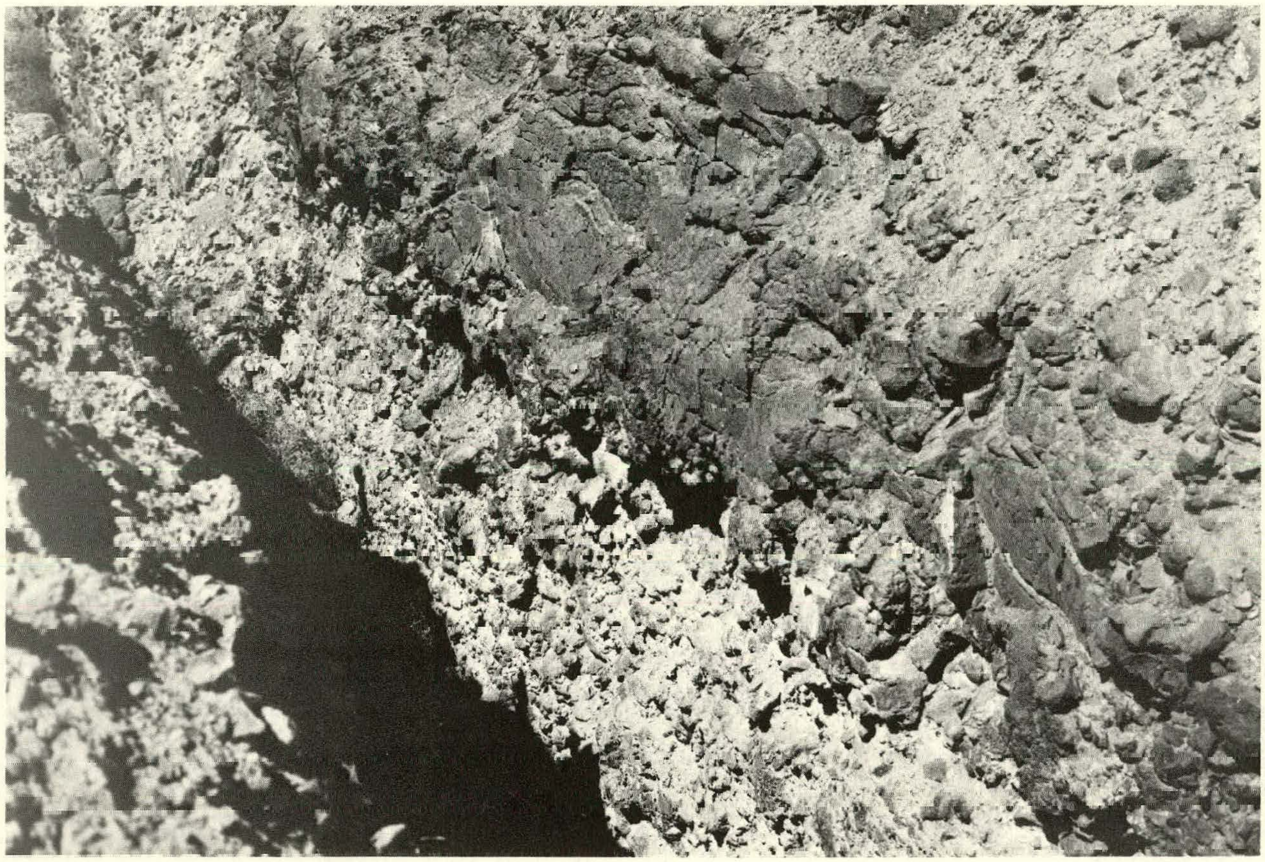


FIGURE 11-B

PALAGONITIC BRECCIA OVERLAIN BY MASSIVE BASALT OF THE ELEPHANT MOUNTAIN FLOW TOP

FIGURE 12

RINGOLD FANGLOMERATE

Hanford Formation (Informal Name)

Coarse sand and gravel aggraded onto the flanks of Gable Mountain and Gable Butte during the waning stages of the proglacial floods from glacial Lake Missoula and other comparable ice margin lakes. These sediments represent the coarse-grained facies or main-channel deposits of the Hanford formation. The sand and gravel deposits formed as large pendant and expansion bars that were later partially eroded by wave-current action from the waning flood waters. The deposits are coarsely bedded and generally display well-developed foreset beds dipping to the south and east. Massive bedding and horizontal bedding are not uncommon. The deposits grade laterally in grain size from predominantly boulders and lag deposits on the northwestern flanks of Gable Butte to predominantly coarse gravel and sand on the southern flank and predominantly coarse and fine sand on the eastern end of Gable Mountain. The coarse and fine sand locally contains clastic dikes.

Loess Deposits

Loess deposits occur on the north (lee) side of Gable Mountain as generally homogeneous, unstratified to poorly stratified, unconsolidated, fine sands and silts. The deposits are up to 20 meters thick in some abandoned glacial flood channels. Elsewhere, the loess has accumulated as thin coverings and fillings in sediments and colluvium and in basalt cooling joints near the ground surface. On the bars and in gravel and sand deposits at lower elevations, the loess is intermixed with reworked coarser sands. The loess tends to be finer grained in the higher regions of the study area probably due to reduced carrying capacity of the winds and increased distance from the areas of deflation.

STRUCTURE

Gable Mountain and Gable Butte are anticlinal ridges of basalt and interbedded sediments standing as the only extensive bedrock outcrops exposed within the central portion of the Pasco Basin. These basalt ridges are surrounded by a plain of fluvial sediments which have filled the Pasco Basin to a maximum depth of 366 meters (Newcomb, et al., 1972). The surface expression of these ridges is a series of doubly plunging, en echelon anticlines and synclines. These structures are interpreted as parasitic folds (Hobbs, et al., 1976) situated within the closure of a larger major fold -- the eastern extension of Umtanum Ridge. The major fold is asymmetrical with a north flank that dips steeply into the Wahluke syncline, and a south flank that dips gently into the Cold Creek syncline (Figure 13).

In the discussion below, frequent reference is made to Plate 1, the geologic map, and Plate 4, the structure contour map. On Plate 1, individual folds have been labeled (e.g., 1A, 2S) to facilitate discussion.

FOLDS

Parasitic Folds

The parasitic folds in the study area are situated within the closure of the major fold and resemble one another geometrically (Table V). Fold axes of the parasitic folds trend west to northwest, with the exception of the syncline on Gable Butte which trends southwest (Syncline 1A, Plate 1). Generally, the parasitic fold axes align parallel to form a westerly trending en echelon pattern across the study area. The axial trends of individual parasitic folds are generally curvilinear (Plates 1 and 4); and the termini of the hinge lines in both anticlinal and synclinal folds are either doubly plunging or subdued by surrounding folds with higher amplitudes and greater wavelengths. The parasitic folds in profile tend to be asymmetrical. The angle subtended by the two limbs (interlimb angle) and the fold closure of the hinge area of the parasitic folds are dependent on the amplitude and wavelength of a given fold. Folds with relatively high amplitudes and short wavelengths tend to have small interlimb angles (<70 degrees) and more angular fold closures (e.g., Anticline 4A, Plate 1). Folds with relatively low amplitudes and long wavelengths tend to have large interlimb angles (>120 degrees) and more rounded fold closures (e.g., Anticline 5A, Plate 1).

Major Fold

The Umtanum Ridge anticline plunges eastward into the Pasco Basin and continues eastward as the asymmetrical major fold of Gable Mountain and Gable Butte. This major fold includes within its fold closure the parasitic folds described above. The geometry of this major fold has

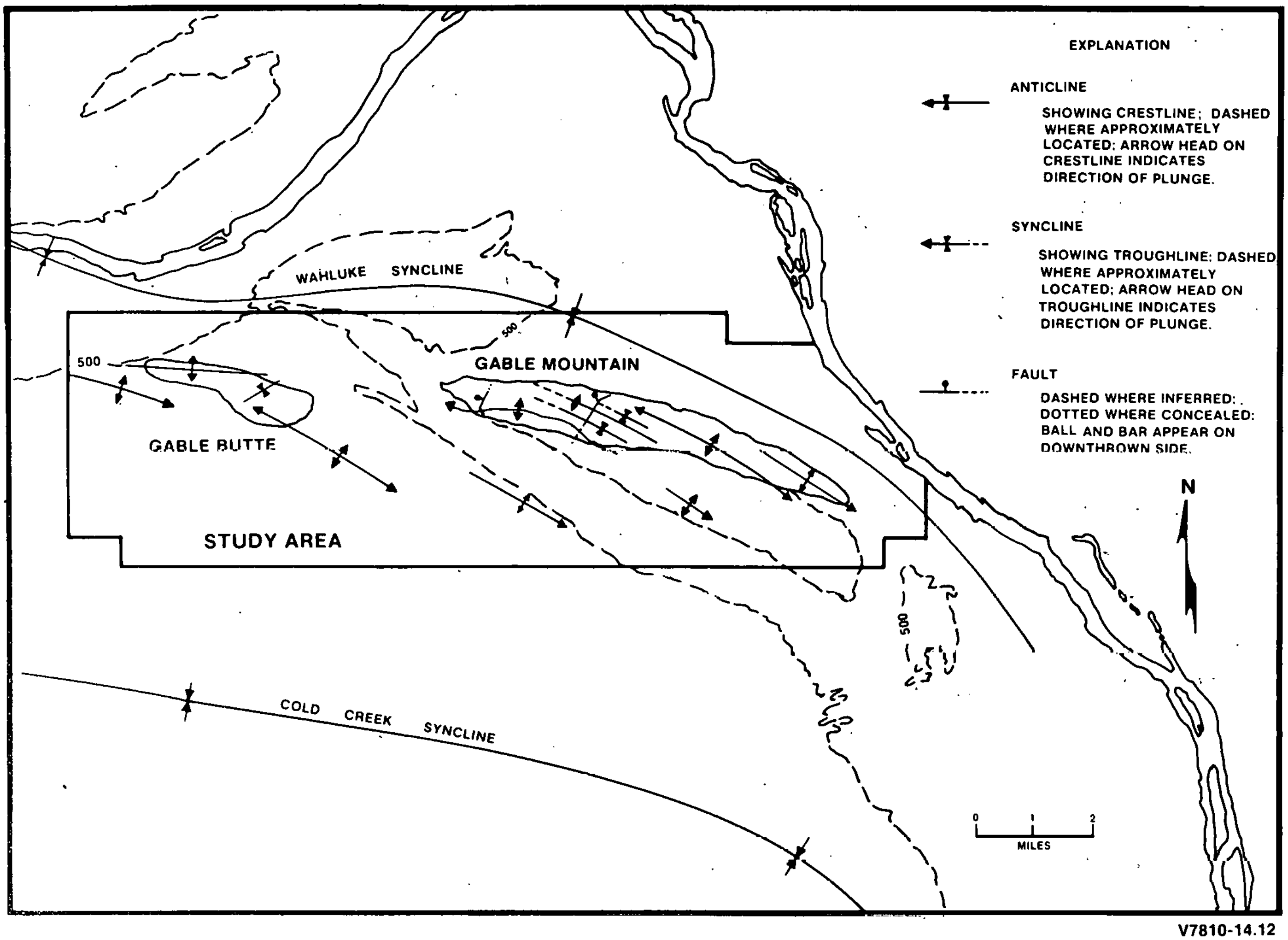


FIGURE 13

MAJOR GEOLOGIC STRUCTURES IN THE GABLE MOUNTAIN-GABLE BUTTE AREA

TABLE V

GEOMETRY OF PARASITIC FOLDS

RIDGE	FOLD DESIGNATION	FOLD AXIS TREND	TERMINUS OF HINGELINE N-W	TERMINUS OF HINGELINE S-E	FOLD ORIENTATION	INTERLIMB ANGLE*	FOLD CLOSURE*
GABLE BUTTE	1A	West-Northwest	--	Plunges	Symmetrical	Open	Rounded
	2A	West	Plunges	--	Asymmetrical	Open-tight	Rounded
	1S	West-Southwest	--	--	Symmetrical	Open-gentle	Rounded
	3A	Northwest	Plunges		Symmetrical	Open	Rounded
GABLE MOUNTAIN	4A	West	Plunges	Plunges	Asymmetrical	Tight	Angular
	2S	West-Northwest	Fades out	Plunges	Asymmetrical	Open	Rounded
	5A	West-Northwest	Fades out	Plunges	Asymmetrical	Open	Rounded
	3S	Northwest	Fades out	Plunges	Asymmetrical	Open	Rounded
	6A	West-Northwest	Fades out	Plunges	Asymmetrical	Tight	Angular
	7A	West-Northwest	Fades out	Plunges	Asymmetrical	Open to Tight	Angular

*Usage is after that given in Hobbs, et al., 1976.

been partially mapped using a combination of outcrop features, geophysical surveys, and well data. The geometry is somewhat obscured by the influence of the parasitic folds.

Sufficient well data are available for about 6 kilometers south of the bedrock exposures on Gable Mountain and Gable Butte to establish that the south limb of the major fold dips at about 2 degrees overall, but locally dips as much as 10 degrees or more. The Elephant Mountain flow is the top flow over most of the southern limb of the major fold, except in local areas between and immediately adjacent to Gable Mountain and Gable Butte which have been eroded by ancestral river systems and glaciofluvial flooding.

The structure of the north limb of the major fold has been partially determined through the combined use of outcrop features, scattered well data, and some magnetic and gravity survey information. Attitudes of the northern-most bedrock exposures on Gable Mountain and Gable Butte (Figure 14 and Plate 1) indicate steeper dips on the north limb than the south limb. Although some of the steeper dips on surface exposures locally may be caused in part by parasitic folds, there does appear to be a steeper north limb than south limb on the major fold. This conclusion is supported by two other lines of evidence: well data; and, geophysical surveys. About 800 meters north of the western Gable Mountain anticline (4A) at Well 699-65-50 (Section 14, Township 13 North, Range 26 East) (abbreviated Sec. 14, T13N, R26E), the basalt surface lies at an elevation of 35 meters below mean sea level, or 419 meters below the crest of the western Gable Mountain anticline, giving an overall dip of approximately 11 degrees to the north; significantly higher than the estimated 2-degree overall dip of the south limb.

Aeromagnetic surveys (Raymond and McGhan, 1963; Swanson and Wright, 1976; WPPSS, 1977) indicate a magnetic anomaly along the ridge crest of Gable Mountain and Gable Butte and a negative magnetic anomaly immediately north of Gable Mountain. The negative magnetic anomaly indicates a thick cover of low magnetic susceptibility sediments overlying the high magnetic susceptibility basalts. Gravity surveys show similar results; a gravity high along the ridge crest and a gravity low immediately north of the ridge. Such distinct lows in aeromagnetics and gravity are not found immediately south of the ridge crest. Thus, both aeromagnetic and gravity data are consistent with the interpretation of a steep north limb based on well and outcrop data.

FIGURE 14

VIEW TOWARD EAST OF A SMALL OUTCROP OF ELEPHANT MOUNTAIN BASALT

FAULTS

Faults on Western Gable Mountain

A northerly trending fault is located near the west end of the western Gable Mountain anticline along the southern Gable Mountain escarpment (Plate 1, NW 1/4, NW 1/4, Sec. 23, T13N, R26E). This fault has been previously mapped by Bingham, et al., (1970) and Newcomb, et al., (1972). Stratigraphic offset can be seen near the ridge crest where the Pomona II unit is in juxtaposition with the Elephant Mountain flow (Figure 15). About 10 meters of offset are estimated at the ridge crest. 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., (1970). The stratigraphic relationships and dip of the fault plane indicate the fault to be a low-angle reverse fault with about 25 meters of offset. The trace of the fault over the northern flank of the western Gable Mountain anticline is discernible for only 40 to 50 meters 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. However, a linear drainage pattern extends north along the north limb of Anticline 4A (Plate 1) to the northern Gable Mountain escarpment. The limited extent of faulting and position on the crest of the western Gable Mountain anticline indicate adjustment of the faulted units in association with uplift of the Gable Mountain-Gable Butte structure.

Faults on Central Gable Mountain

A northeasterly trending sinistral strike-slip fault has been proposed along an escarpment of Elephant Mountain basalt in the central topographic and structural low on Gable Mountain (Figure 16) (Jones and Deacon, 1966). A series of trenches was excavated along the escarpment to expose the fault plane. The trench locations are shown on Figure 7.

At the northeast end of the escarpment (NE 1/4, Sec. 19, T13N, R27E), Trenches 3, 5, and 8 expose a fault plane below the escarpment on the north limb of the eastern Gable Mountain anticline. In Trench 3, the fault plane is striking east-west and dipping 34 degrees south near the base of the Rattlesnake Ridge Interbed.

FIGURE 15

VIEW TOWARD NORTH OF FAULT ON THE WESTERN GABLE MOUNTAIN ANTICLINE

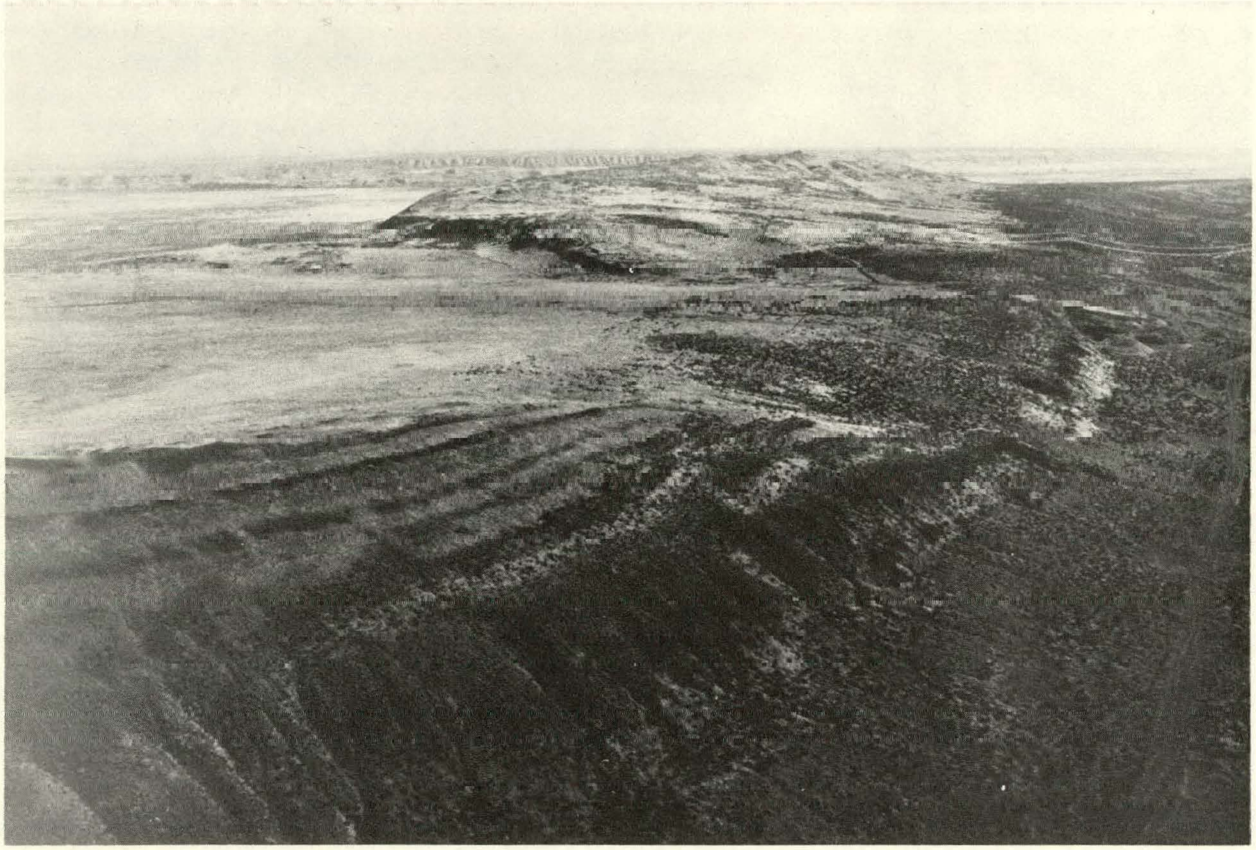


FIGURE 16

ESCARPMENT ON EASTERN GABLE MOUNTAIN

Northeast from Trench 3, in Trenches 8 and 5, the dip of the fault plane, which is found within the Elephant Mountain flow, becomes less steep (25 degrees south in Trench 8 and 10 degrees south in Trench 5) and terminates in the cooling joints at the east end of Trench 5. No evidence for shearing on the steeply dipping flank of the eastern Gable Mountain anticline was found in Trench 7, the northeastern-most trench. Southwest along the escarpment from Trench 3 the thickness of the glaciofluvial gravels precluded trenching the fault plane. However, stratigraphic relationships of the Elephant Mountain flow and Pomona II unit, separated by about 40 meters of stratified Hanford formation sands and gravel, indicate probable faulting.

The gouge zone along the fault plane is generally composed of subrounded, polished basalt fragments with a brown clay matrix. Slickensides that generally subparallel the attitudes of the fault plane are found in the clay. The fault plane, with its generally east-northeast trend and a southerly dip, stands in sharp contrast to the northerly dip and east-to-southeast strike of the basalt and interbedded sediments; this indicates a reverse fault.

The glaciofluvial sediments overlying the fault plane in the trenches show no evidence of deformation either from faulting along the escarpment or folding of this portion of Gable Mountain.

At the southwest end of the escarpment at Trench 6 (SW 1/4, Sec. 19, T13N, R26E), a fault plane is exposed which cuts the Rattlesnake Ridge Interbed and Elephant Mountain flow. These units strike about north 20 degrees east and dip about 30 degrees south within the trench. This differs from the attitudes of the Pomona flow exposed west of the trench and the Elephant Mountain flow to the east which strike about east-west and dip 30-40 degrees south. The shear surface, which forms a thin shear zone composed mostly of clay gouge, strikes north 74 degrees east and dips 25 degrees south. Bingham, et al., (1970) interpreted the sense of movement along the shear zone as reverse faulting. The sediments overlying the fault plane have been radiocarbon dated at older than 40,000 years before present (Bingham, et al., 1970) in Trench 6 and show no indication of deformation.

Trenching in the central portion of Gable Mountain immediately west of the escarpment, Trench 2, did not reach bedrock because of a thick cover of glaciofluvial sediments. Here, also, no evidence for deformation of the sediments was found.

These data and observations are interpreted to indicate the presence of a reverse fault trending generally northeast, coinciding with the escarpment partially eroded by catastrophic flood waters from glacial Lake Missoula. The fluvial sediments overlying the fault plane show no evidence of deformation. Faults with short lateral extent and minor offset are not uncommon with uplift of steeply folded structures of the Columbia Plateau.

LINEAMENTS

Lineaments reported by previous workers and lineaments detected during this study were investigated to determine their relationship with surface exposures and their possible structural or tectonic significance. These lineaments were identified from aerial photos, aeromagnetic surveys, gravity surveys, and subsurface geologic maps (Swanson and Wright, 1976; WPPSS, 1977; Richard and Lillie, 1977; and this report).

Topographic lineaments occur along the north flank of Gable Mountain-Gable Butte and as short lineaments across the structural trends of the parasitic folds. The major westerly trending lineaments align along the north flanks of parasitic folds 2A, 5A, and 6A, the northern Gable Mountain escarpment, and the north limb of the major fold. This lineament along the northern bedrock exposures is partly structural and partly an erosional escarpment formed as a result of catastrophic flooding (Plate 2). The surface expressions of the cross-structural lineaments on Gable Butte (Sec. 18, 19, and 20, T13N, R26E) and the extreme western end of Gable Mountain (SE 1/4, Sec. 15, T13N, R26E) are along escarpments interpreted to be the result of erosion from catastrophic flooding, and not of tectonic origin. Another topographic lineament on the west end of Gable Mountain (Sec. 14 and 23, T13N, R26E) aligns with a fault on the southern Gable Mountain escarpment which trends northward into a linear drainage gully. No evidence for deformation was found along the gully (see section entitled "Faults"). The northeast-trending topographic lineament in the central portion of Gable Mountain (Sec. 19, T13N, R26E) occurs along an escarpment which proved to be a fault scarp partially eroded by the catastrophic flooding of the Pasco Basin (see section entitled "Faults"). No geologic features were found associated with the topographic lineament at the east end of Gable Mountain (Sec. 20 and 21, T13N, R27E).

The Nancy aeromagnetic lineament (WPPSS, 1977) trends northeasterly across the west end of Gable Butte (Sec. 14, T13N, R25E). A north-easterly sinistral strike-slip trending fault was proposed at this location by Jones and Deacon (1966). Continuous basalt outcrop of the Pomona entablature was mapped across the limited outcrop. No evidence of brecciation, shearing, or changes in intraflow structure could be detected. The basalt escarpment at this site appears to be erosional rather than tectonic in origin, supporting the Bingham, et al., (1970) conclusion of no substantiating evidence for faulting at this site. Geophysical lineaments formed by the steep gravity and aeromagnetic gradients exist on the north side of the Gable Mountain-Gable Butte structure. These gradients reflect the steeply dipping north limb of the major fold buried below the fluvial sediments (see section entitled "Folds").

Two northwest-trending lineaments have been identified from the structure contour map on the basalt surface (Plate 4). The first is the lineament between Gable Mountain and Gable Butte; no vertical offset across this lineament has been found. Data from Wells 699-48-49A and 699-48-49B suggest a channel was cut between Gable Mountain and Gable Butte during Ringold time by ancestral river systems and later widened by the catastrophic floods of glacial Lake Missoula. A partial tectonic origin for this lineament is possible, but additional data are needed to test this possibility.

The second lineament is at the east end of Gable Mountain, where the major fold trends southeast. This trend aligns with a number of northwest-trending features on the eastern margin of the Pasco Basin from the Saddle Mountains to the Horse Heaven Hills. The relationships of these topographic and structural features with the Gable Mountain structure are under investigation.

GEOMORPHOLOGY

The geomorphology of the Gable Mountain vicinity is dominated by topographic features resulting from uplift of the Gable Mountain-Gable Butte Ridge and proglacial flooding of the Pasco Basin. Only minor changes in the topography have occurred in the last 13,000 years. The topographic features formed by the proglacial floods and post-flood agents are discussed below and shown on Plate 2.

PROGLACIAL FLOOD LANDFORMS

Late Pleistocene flooding from glacial Lake Missoula and from other comparable ice margin lakes has formed both erosional and depositional features within the Gable Mountain-Gable Butte area. Erosional landforms include scabland features, breached pre-flood structures, and anastomosing channels. Depositional landforms include gravel bars, giant current ripples, and ice-rafted erratics.

Proglacial floods with maximum discharges of approximately 500,000 meters per second (estimated at Rocky Coulee; Baker, 1973) eroded the early Palouse soil and Ringold sediments and the Columbia River Basalt Group in the Gable Mountain vicinity.

Three anticlines exposed on Gable Butte were breached by the proglacial floods forming three eroded anticlinal axes, each flanked by inward-facing erosional scarps which trend parallel to the original axial plane. Gable Mountain was also scarred in a similar manner forming prominent escarpments, with the most prominent of these being the southern and northern Gable Mountain escarpments (Figure 7 and Plate 2).

The scattered occurrence of flood gravels high on the flanks of Gable Mountain and Gable Butte indicates little deposition during maximum flood discharge. Deposition of the gravel bar and ice-rafted erratics occurred after the maximum flood water discharges and during the waning flood water stages The gravel bar deposits in the Pasco Basin occur along a belt that extends from Sentinel Gap in the Saddle Mountains southeast to Wallula Gap. The coarse gravel bar deposits indicate that Gable Mountain lay along the main flood channels. Three types of flood bars (after Baker, 1973) have been identified in the study area (Plate 2):

1) Pendant bars in which flood gravels occur immediately downstream from bedrock projections;

2) Expansion bars in which flood gravels occur as the result of decelerating flow of an expanding reach downstream from a constriction;

3) Compound bars in which flood gravels were deposited downstream from bedrock projections and constrictions.

Parallel asymmetrical ridges, which have been identified as giant current ripples, occur on these bars. Ripple trains occur along the margins of basalt outcrops on the flanks of Gable Butte and at the west end of Gable Mountain. The composition of these ripples is largely coarse gravel mixed with coarse sand. Ice-rafted erratics have also been identified.

LANDSLIDES

A major landslide occurs on the north side of Gable Mountain. Downslope from the landslide scarp, the topography is hummocky with many small, closed depressions and a chaotic mixture of basalt debris. Small slump blocks and marginal transverse, or en echelon, shears can be obscured in the slide. Field evidence indicates the landslide involved only the Elephant Mountain flow and the Rattlesnake Ridge Interbed. This landslide occurred after proglacial flooding, because the surface of the landslide has not been scoured or stripped by the erosion processes which formed the scablands.

POST-GLACIAL LANDFORMS

Relatively minor changes in topography have occurred since recession of the proglacial flood waters. Wind has locally deflated and redeposited silts and sands, forming loess deposits and sand dunes, and scoured and pitted bedrock on the windward exposures. Rainfall on the flanks of Gable Mountain and Gable Butte has resulted in erosion by slope wash. Freezing and thawing of precipitation in the ubiquitous fractures within basalt flows is the principal process in development of talus slopes.

Sand Dunes

Sand dunes were deposited downwind from loess deposits and the fine sands and silt of the Hanford formation. Dune sizes in the study area vary greatly, ranging from a few meters to hundreds of meters in diameter and from a few centimeters to tens of meters in height. The shape of dunes varies from simple to complex forms. In the study, there are generally five forms of dunes present: sigmoidal dunes; sand shadows; seif dunes; dune colonies; and, barchan dunes. The distribution and shape of these dunes indicate an easterly- to northeasterly-prevailing wind direction in the study area since the last major proglacial floods.

Gullies and Rills

In areas of exposed basaltic bedrock, overland flow of water has had little erosional effect. However, on the slopes of gravel bars of the Hanford formation, runoff of water has dissected the bars forming deeply entrenched gullies.

Talus Slopes

Mass wasting in the Gable Mountain-Gable Butte area is dominated by rockfall which has formed massive talus deposits along the extensive flood water-eroded escarpments. Frost action and, to lesser extent, root action releases blocks from the escarpments which accumulate as talus at the escarpment base. The talus debris consists of large angular blocks and commonly has slopes up to 40 degrees. Eolian sands and silts have filled the void areas between blocks in the relatively inactive talus slopes.

SUMMARY

Gable Mountain and Gable Butte form a complex series of anticlinal ridges composed of basalt and interbedded sediments representing the only extensive exposure of bedrock in the central portion of the Pasco Basin. These ridges are up to 331 meters in elevation and are surrounded by a plain of fluvial sediments which vary in elevation from 128 to 214 meters.

The bedrock exposed on Gable Mountain and Gable Butte is composed of basalt flows of the Saddle Mountains Basalt (Asotin, Esquatzel, Pomona, and Elephant Mountain members) and two interbedded sedimentary units of the Ellensburg Formation (Selah and Rattlesnake Ridge). The lower flanks of the ridges and the surrounding plain are a fanglomerate of the Ringold formation and the coarse-grained facies of the Hanford formation. A thin veneer of loess overlies much of the eastern portion of Gable Mountain.

The structure of Gable Mountain and Gable Butte is characterized by a complex series of doubly plunging en echelon anticlines and synclines situated within the closure of a larger, asymmetrical fold; the eastern extension of Umtanum Ridge.

The parasitic folds within the study area resemble one another geometrically. The fold axes of the parasitic folds are curvilinear and

trend easterly and southeasterly under the fluvial plain, with the exception of a southwesterly trending syncline on Gable Butte. The termini of the hinge lines of the parasitic folds are generally doubly plunging, but are often subdued by surrounding folds with higher amplitudes and greater wavelengths. In cross section, the parasitic folds are asymmetrical. The two major Gable Mountain anticlines have opposite directions of asymmetry. The angles subtended by the two flanks (interlimb angle) and the fold closures of the hinge lines of the parasitic folds range from closed to gentle and angular to rounded, depending on the amplitude and wavelength of a given fold.

The westerly trending, asymmetrical major fold which extends over most of the study area has been mapped from surface exposures and geophysical and well data. The southern flank of the major fold has a gentle southerly dip (about 2 degrees). The uppermost flow, extending over most of the southern flank and associated parasitic folds, is the Elephant Mountain flow. There are, however, areas between and immediately adjacent to Gable Mountain and Gable Butte in which stratigraphically lower flows are the uppermost flow, but these areas are the result of extensive erosion by ancestral river systems and glaciofluvial flooding. The north flank of the major fold has a steep northerly dip. The basalt surface, one-half mile north of Gable Mountain, lies at an elevation of 35 meters below mean sea level or 374 meters below the crest of the western Gable Mountain anticline.

Two faults have been identified on the basis of field work conducted to date, both of which are located on Gable Mountain. The first is located near the west end of the western Gable Mountain anticline, along the southern Gable Mountain escarpment. The fault has a northerly trend, but is discernible for only 40 to 50 meters before being obscured. A linear drainage pattern extends north from the fault down the north flank of the western Gable Mountain anticline, indicating a possible northern extension of the fault. On the southern Gable Mountain escarpment, the fault is estimated to dip at 30 degrees east, as suggested by Bingham, et al., (1970). Stratigraphic relationships and the dip of the fault indicate the fault to be low-angle reverse with about 25 meters of offset.

The second fault is located in the central portion of Gable Mountain along a northeasterly trending escarpment. A series of trenches excavated along the escarpment exposed portions of the fault. The fault has a sinuous, northeasterly to easterly trend which terminates to the north on the west end of the eastern Gable Mountain anticline. The dip of the fault varies from 10 to 34 degrees to the south. Stratigraphic and structural relationships indicate the fault to be low-angle reverse with undetermined offset. Undeformed flood gravels of the Hanford formation (informal name) have been dated by radiocarbon techniques as older than 40,000 years.

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PLATE I - PRELIMINARY GEOLOGIC MAP OF GABLE MOUNTAIN AND GABLE BUTTE

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PLATE 2 - BASALT SAMPLE LOCATION MAP, GABLE MOUNTAIN - GABLE BUTTE AREA

POCKET PART 3 OF 4 RHO-BWI-LD-5

PLATE 3 - GEOMORPHIC MAP, GABLE MOUNTAIN - GABLE BUTTE AREA

POCKET PART 4 OF 4 RHO-BWI-LD-5

PLATE 4 - STRUCTURE CONTOUR MAP, TOP OF BASALT, GABLE MOUNTAIN - GABLE BUTTE AREA