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HEAT FLOW AND GEOTHERMAL STUDIES IN
THE STATE OF WASHINGTON

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INTRODUCTION

Existing geothermal gradient and heat flow data for the state of Washington are summarized in this report. In addition, information on mean-annual ground surface temperatures is included. The data on which this report are based are published heat flow and geothermal gradient studies, and data collected by personnel from the Geothermal Laboratory at Southern Methodist University in conjunction with J. Eric Schuster and Mike Korosec of the Washington Department of Natural Resources (DNR). These data consist of accurate, detailed temperature-depth measurements in selected available holes throughout the State of Washington made between 1979 and 1982. Measurements of thermal conductivity on selected rock samples from these drill holes and ancilliary information required to assess the significance of the data and calculate heat flow values were obtained as well. Also included in this report is a brief discussion of temperature data based on logs made by the U.S. Geological Survey Water Resources Division (WRD) in the early 1970's. Additional detailed, temperature-depth logs collected by personnel at Washington State University (WSU) over many years (Stoffell and Widness, 1983) are not discussed.

In the first section of the report, information is presented on the mean-annual ground-surface temperatures throughout the state of Washington. In the second part of the report the various geothermal data are presented and the heat flow and geothermal gradient results from each physiographic province within the state of Washington are discussed. In the third part of the report these data are interpreted in terms of average regional heat flow and depth of isotherms. Listings of temperature versus depth for individual drill holes are available on open file at the DNR office in Olympia. Only selected temperature-depth logs of special interest are illustrated in this report.

BACKGROUND OF MEASUREMENTS

The history of geothermal measurements in Washington began in the 1930's when U.S. Geological Survey personnel, directed by Van Ostrand, made temperature measurements at several oil wells. These data became available in open file in 1964 (Spicer, 1964) and have been made available more generally in recent years (Gaffanti, 1984). Temperature data from two of these wells (20N/28W-8 and 11N/26E-20CC) are included in the data set in this report. Estimated heat flow values have been calculated for these two holes based on thermal conductivity values measured on surface samples from lithologic units encountered in these holes.

Following these studies, there was a long hiatus until the early 1960's when R. F. Roy made heat flow measurements in the Metaline mining district in northeastern Washington. He also measured temperatures in a deep hydrocarbon exploration well drilled on the Columbia Plateau (Development Associates Basalt Explorer no. 1, 21N/31E-10CB). The heat flow values in the Metaline

district were published in 1963 (Roy, 1963; Roy et al., 1968). Also in the 1960's measurements were made at several localities in the state by the U.S. Geological Survey geothermal group at Menlo Park. These results were published by Sass et al. (1971). In the mid-1960's investigations were started by the senior author of this report. The first results of these studies were published by Blackwell (1969). Preliminary results of additional studies were published by Blackwell (1974). The most up-to-date summary of heat flow and geothermal gradient from a statewide point of view is contained in the 1974 report. In that paper several preliminary heat flow values were discussed. Final heat flow values for these sites are included in this report. Temperature-depth data, individual thermal conductivity measurements, terrain correction information, etc. for each hole measured in the 1960's are listed in Sass and Monroe (1974).

In the 1970's detailed studies of the Turtle Lake Quadrangle, north-eastern Washington, (the subject of a M.S. thesis by Steele, 1975) and the Indian Heaven area in the southern Washington Cascade Range (the subject of a geothermal assessment study by Schuster et al., 1978) were published. In the mid-1970's water chemistry studies indicated the possibility of anomalous heat flow values in the southern Columbia Plateau area (Swanberg and Morgan, 1979), and in 1978 a reconnaissance logging program was carried out to investigate regional geothermal gradients and heat flow. All the results up until 1979 are summarized by Blackwell (1980). That report is the starting point for the data collection and discussion included in this report.

DATA PRESENTATION

Geothermal gradient, heat flow, and ancillary information for drill holes in the state of Washington are summarized in Table 1. Included in Table 1 are location, hole name, elevation, uncorrected and corrected geothermal gradient, depth interval over which the geothermal gradient was measured, collar elevation, date of logging of the hole, surface temperature, thermal conductivity, corrected heat flow, heat flow data quality, and brief lithologic summary of the rocks encountered in the hole. Only holes where gradients or heat flow are considered to be of C quality (see below) or better are included in Table 1. Poor quality data (D and X) are included in Appendix A.

Individual holes are located by latitude and longitude to the nearest tenth of a minute, if possible. The holes are also located by township and range. Location within the section is by quarter section where A = northeast quarter, B = northwest quarter, C = southwest quarter, D = southeast quarter, and 13ABD indicates a hole in the southeast quarter of the northwest quarter of the northeast quarter of section 13. Thermal conductivity values are based on measurements of core or cutting samples, or are estimated from lithology (values in parentheses). The heat flow values are generally given to the nearest 1 mWm^{-2} , but based on the errors of the values associated in each case, the second decimal place may not be significant. The quality value of A, B, or C implies a heat flow value with an estimated error of $\pm 5\%$, $\pm 10\%$, and $\pm 25\%$ respectively. A quality value of G indicates that a heat flow value is associated with a geothermal system. A quality value of D or X (Appendix A) indicates that no reliable heat flow value may be obtained. In some cases a reliable gradient may be calculated from the D quality data, however.

Table 1. Geothermal data of acceptable quality from the state of Washington. Collar elevation is in m, surface temperature is in °C, uncorrected and corrected gradients are in °C/km, thermal conductivity is in $\text{Wm}^{-1}\text{K}^{-1}$, and heat flow is in mWm^{-2} . Date is date hole was measured. Brackets around the thermal conductivity values signify that the values were estimated from the known lithology of the well. In lithology column C.R. stands for Columbia River basalt. The quality indicator is described in the text. The references to published data (R column) are: (1) Blackwell (1969); (2) Blackwell (1974); (3) Blackwell et al (1980); (4) Roy (1963); (5) Sass et al (1971); (6) Schuster et al (1978); and (7) Steele (1975).

THW/RNG SECTION	N LAT DEG MIN	W LONG DEG MIN	HOLE NO. (DATE)	COLLAR ELEV.	SURFACE TEMP.	DEPTH INTERVAL	AUG. TC (SE)	NO. TC	UN. GRAD (SE)	CO. GRAD (SE)	CO. H.F. (SE)	Q H.F.	LITHOLOGY SUMMARY	R
40V27E- 683	48-59.94	119-29.59	DDH-E 7/17/71	487	11.20	155.0 225.0			23.6 .2	20.9			A GREENSTONE SCHIST	
40V27E- 682	48-59.94	119-29.26	DDH-C 7/17/71	487	9.50	45.0 210.0			21.3 .1	18.8			A GREENSTONE SCHIST	
40V27E- 681	48-59.84	119-29.39	DDH-A 7/17/71	487	11.40	50.0 140.0			30.2 .7	26.7			B GREENSTONE SCHIST	
40V27E- 684	48-59.79	119-29.50	DDH-F 7/17/71	487	9.60	60.0 200.0			25.5 .1	22.6			A GREENSTONE SCHIST	
40V27E- 68DC	48-59.74	119-29.19	DDH-K-5 7/17/71	463	10.75	60.0 180.0	3.16 .08	19	25.2 .1	22.3	70		A GREENSTONE SCHIST	
40V33E- 28CD	48-59.71	118-35.91	DDH-702 7/15/71	1147	6.30	75.0 205.0	3.17 .13	22	25.2 .6	22.7	72		A MESOZOIC GREENSTONE	
40V33E- 20BB3	48-59.67	118-35.95	DDH-7011 7/22/71	1135	6.10	80.0 215.0	3.15 .13	20	25.0 .3	22.5	71		A MESOZOIC GREENSTONE	
40V33E- 20BB1	48-59.63	118-36.06	DDH-7012 7/15/71	1104	6.10	100.0 150.0			25.5 .3	23.9			B MESOZOIC GREENSTONE	
40V33E- 20BB2	48-59.57	118-36.00	DDH-7013 7/22/71	1097	5.85	130.0 155.0			25.8 .3	23.2			B MESOZOIC GREENSTONE	
40V43E- 35D	48-55.25	117-20.00	METL-CS2 8/24/61	674		350.5 381.0	5.15	14	25.6	23.0	118		B METALINE LS (DOLOMITE)	R
40V43E- 35D	48-55.25	117-20.00	METL-CS9 8/29/61	736		327.7 358.2	4.81	5	20.0 1.0	18.2	87		B METALINE LS (DOLOMITE)	R
39V41E- 28DB	48-55.00	117-35.66	DDH-3 6/16/65	707	6.67	100.0 240.0	5.98 .04	16	23.7 .1	20.8	124		B DOLOMITIC META. FORMA.	86
39V41E- 28AB	48-54.93	117-35.85	DDH-2 6/17/65	780	5.87	290.0 340.0	6.02 .04	16	22.0 .1	20.4	123		B DOLOMITIC META. FORMA.	86
39V41E- 28B1	48-54.87	117-35.95	DDH-4 6/16/65	817	6.78	120.0 200.0			14.1 .4	12.4			C DOLOMITIC META. FORMA.	
39V41E- 28B3	48-54.86	117-36.07	DDH-5 6/16/65	853	6.78	120.0 180.0			17.2 .4	15.1			C DOLOMITIC META. FORMA.	
39V41E- 28BD	48-54.82	117-35.99	DDH-1 6/15/65	829	6.73	130.0 220.0			18.3 .4	16.1			C DOLOMITIC META. FORMA.	

- 1 = B6
 2 = B7
 3 = BTR
 4 = R
 5 = S71
 6 = SCH
 7 = S75

THIN/RNG SECTION	N LAT DEG MIN	W LONG DEG MIN	HOLE NO. (DATE)	COLLAR ELEV.	SURFACE TEMP.	DEPTH INTERVAL	AVG. TCU (SE)	NO. TC	UN. GRAD (SE)	CO. GRAD (SE)	CO. H.F. (SE)	Q H.F.	LITHOLOGY SUMMARY	R
39N/33E- 14ABB	48-53.11	118-36.03	A TALBOT 9/10/81	548	9.40	14.0 74.0	(2.30)		24.7 .6	29.6	(68)	C	GRANITE	
39N/33E- 13BCA	48-52.84	118-35.32	LD LEWIS 9/15/81	679	9.20	39.0 89.0	(2.30)	1	31.4 .4	34.5	(80)	B	GRANITE	
37N/25E- 8DBC	48-43.01	119-35.46	DDH-1 7/24/71	987	8.20	165.0 435.0	3.50 .13	25	19.4 .2	21.5	75	A	BIOTITE GRANODIORITE	87
37N/25E- 24DCA	48-41.15	119-29.95	R COREY 9/19/81	425	10.50	24.0 123.0	(3.18)	1	24.5 .2	23.3	(74)	B	SCHIST AND GRANITE	
37N/32E- 28D	48-40.33	118-46.49	DAVIS 10/ 9/81	883	7.60	25.0 95.0			19.6 .1	23.5		B	SEDIMENTS	
37N/32E- 33AAC	48-39.99	118-46.38	DDH-3 7/21/70	950	8.20	150.0 250.0	2.41 .04	17	30.9 .2	31.1 .2	76	A	CENOZOIC ANDESITE	
37N/32E- 34B2	48-39.80	118-45.73	DDH-B 7/31/70	1067	6.80	50.0 95.0			24.5 .8			C		
37N/32E- 34B1	48-39.80	118-45.73	DDH-A 7/21/70	1067	7.80	100.0 195.0			21.8 .2			B		
36N/20E- 19ABB	48-36.78	120-23.33	DDH-LD13 8/ 8/71	1134	7.61	75.0 170.0			23.8 .1	23.2		A	MESOZOIC METAMORPHICS	87
36N/20E- 19ADC	48-36.48	120-23.07	DDH-LD10 8/ 8/71	1097	8.80	140.0 275.0	2.88 .08	15	28.3 .2	26.7	77	A	MESOZOIC METAMORPHICS	87
36N/20E- 19DAB	48-36.35	120-23.15	DDH-LD7 8/ 8/71	1097	6.10	240.0 360.0	3.19 .29	4	24.0 .1	23.0	73	A	MESOZOIC METAMORPHICS	87
36N/32E- 25ACC	48-35.63	118-44.48	KONZ 11/18/81	728	8.20	44.0 74.0			35.3 .7	31.8		C		
34N/ 1E- 1CBB	48-27.48	122-38.04	DDH-1 8/ 2/71	129	10.55	90.0 220.0	2.96 .04	25	12.7 .1	12.6 .1	37	A	QUARTZ DIORITE	
34N/26E- 23DA	48-25.77	119-30.96	DANIKOV 9/17/81	379	11.10	104.0 184.0	(1.97)	1	24.5 .1	27.0	(53)	B	GRANITE	
33N/31E- 14BDA	48-21.75	118-52.59	DDH-1 6/20/70	1182	5.93	130.0 230.0	3.36 .13	17	16.5 1.7	20.3 1.0	68	B	ARGILLITE & QTZ MONZ.	87
33N/31E- 14ACB	48-21.75	118-52.35	DDH-3 8/ 7/70	1182	7.20	205.0 270.0	3.11 .08	9	20.4 .3	22.4	70	A	QTZ. MONZ. PORPHYRY	87
THIN/RNG SECTION	N LAT DEG MIN	W LONG DEG MIN	HOLE NO. (DATE)	COLLAR ELEV.	SURFACE TEMP.	DEPTH INTERVAL	AVG. TCU (SE)	NO. TC	UN. GRAD (SE)	CO. GRAD (SE)	CO. H.F. (SE)	Q H.F.	LITHOLOGY SUMMARY	R
33N/31E- 14BDC	48-21.65	118-52.78	DDH-2 6/20/70	1134	5.97	120.0 200.0	3.36 .13	18	16.8 .2	19.5	66	A	ARGILLITE & QTZ. MONZ.	87
32N/40E- 4ADD	48-18.13	117-45.64	L HEINE 9/ 7/81	536	10.80	49.0 117.0	(4.39)	1	15.7 .3	14.1	(62)	B	QUARTZITE	
31N/44E- 34ADD	48- 8.77	117-13.27	ACI CAMP 8/19/81	740	8.10	95.0 155.0	(2.05)	1	28.3 .7	27.7	(57)	B	GRANITE	
30N/16E- 34ADD	48- 6.15	120-49.81	DDH-1 8/ 5/70	1158	1.22	20.0 175.0			49.0 5.5			C		
30N/33E- 31BDU	48- 3.52	118-42.40	DDH-A 8/11/66	892	6.64	115.0 195.0	3.81	2	14.6 .1	19.7	75	A	ALTERED QTZ. BT MONZONITE	87
30N/39E- 36DDB	48- 3.47	117-49.52	RDH CU-2 7/25/81	652	7.66	30.0 145.0 210.0			57.2 .5 .7			B	TERTIARY SEDIMENTS	
30N/33E- 31CAB	48- 3.35	118-42.40	DDH-B 8/23/66	1036	6.84	120.0 255.0	4.15 .21	11	11.6 .1	17.9	75	A	ALTERED QTZ. BT MONZONITE	87
30N/33E- 31CAC	48- 3.21	118-42.40	DDH-C 8/16/67	953	7.68	90.0 420.0 420.0 470.0	3.76 .17 .21	28 8	11.5 .2 17.4 1.4	15.8	59	A	ALTERED QTZ. BT MONZONITE	87
29N/37E- 36DDD	47-58.50	118- 4.00	DDH-2 10/15/72	877	6.20	60.0 360.0	3.13	25	28.4 .3	27.0	85	A	PHYLLITE - ARGILLITE	575
29N/42E- 5D	47-56.90	117-31.55	EICHMEYER 9/ 4/81	658	9.40	19.0 144.0	(2.43)		27.5 .3	27.5	(66)	B	SED/CLAY TO GRANITE	
29N/37E- 9DBD	47-56.60	118- 9.20	S-9 8/11/70	652	10.34	100.0 133.0	3.00 .04	6	25.0 .1	25.1	76	B	PHYLLITE - ARGILLITE	575
29N/44E- 31ADD	47-52.99	117-16.98	M POWERS 7/ 8/81	711	9.30	154.0 264.0	(2.76)	1	22.6 .1	24.9	(68)	B	SED/CLAY TO GRANITE	
27N/37E- 28BB	47-52.40	118- 7.40	W-EAST 8/10/72	587	11.40	90.0 150.0	3.31 .04	6	24.8	26.7	87	B	PORPHYRITIC QTZ. MONZ.	575
27N/37E- 34AA	47-52.40	118- 7.40	W-WEST 8/10/72	573	11.20	60.0 100.0	3.26	6	25.5	27.8	91	B	PORPHYRITIC QTZ. MONZ.	575

THW/RNG SECTION	N LAT DEG MIN	W LONG DEG MIN	HOLE NO. (DATE)	COLLAR ELEV.	SURFACE TEMP.	DEPTH INTERVAL	AUG. TOU (SE)	NO. UN. TC	UN. GRAD (SE)	CO. GRAD (SE)	CO. H.F. (SE)	G H.F.	LITHOLOGY SUMMARY R
27N/37E- 22CDD	47-49.08	118- 7.77	DDH-SF15 8/15/81	542	10.60	140.0 225.0			34.9 .1			A	VOLCANICS
27N/38E- 28BEB	47-49.00	118- 1.50	S-28 8/10/72	548	8.50	100.0 145.0	2.54	2	33.8	33.0	84	B	PALEOZOIC MAR.-HORFEL S75
27N/37E- 26AAD	47-48.87	118- 5.92	TAYLOR 8/17/81	481	10.40	140.0 358.0			40.3			A	VOLCANICS
26N/44E- 12AAC	47-46.10	117-10.80	MANZ 7/25/81	838	8.40	120.0 159.0	(3.26)	1	24.7 .3	27.2	(89)	B	GRANITE
26N/34E- 10CAB	47-45.87	118-31.18	CTY CSTN 8/30/81	745	9.30	14.0 59.0			44.0 2.1			B	BASALT ?????
						14.0 199.0			36.8 1.4			B	
						109.0 199.0	(1.59)	1	55.4 .2	55.4	(88)	B	
26N/33E- 18ACA	47-45.20	118-42.50	DOE WILB 8/27/81	684	10.50	25.0 100.0			26.8 1.3			C	BASALT
						25.0 129.0	(1.59)		31.9 1.3	31.9	(51)	C	
						100.0 129.0	(1.59)		52.9 1.5	52.9	(84)	C	
26N/13E- 27BA	47-43.20	121- 7.21	DNR-SO2 9/25/81	841	4.50	40.0 150.0	2.68 .17	7	36.5 .2	26.1	70	B	BIOTITE SCHIST
26N/13E- 28CD	47-42.66	121- 8.50	DNR-SO1 9/25/81	841	3.29	20.0 100.0	2.06 .17	7	58.3 1.2	48.4	100	B	PHYLLITE
						60.0 100.0	2.06 .17	7	67.2 .5	55.6	115	B	
26N/ 9E- 44DA	47-40.97	121-38.92	DDH-12 8/24/70	1176	4.25	120.0 145.0	3.03	2	10.5 .1	20.0	61	C	
24N/44E- 6BC	47-36.30	117-17.99	D BLACK 8/28/81	914	8.50	64.0 81.0	(2.38)	1	15.4 1.6	20.0	(48)	C	GRANITE
24N/44E- 10AD	47-35.38	117-13.22	V CARROL 7/26/81	749	8.00	25.0 147.0	(3.43)	1	27.4 .1	(30.1)	(103)	B	GRANITE
THW/RNG SECTION	N LAT DEG MIN	W LONG DEG MIN	HOLE NO. (DATE)	COLLAR ELEV.	SURFACE TEMP.	DEPTH INTERVAL	AUG. TOU (SE)	NO. UN. TC	UN. GRAD (SE)	CO. GRAD (SE)	CO. H.F. (SE)	G H.F.	LITHOLOGY SUMMARY R
24N/36E- 16AAB	47-34.70	118-16.37	DOE TST6 8/29/81	720	9.30	66.0 139.0	(1.59)		58.7 .7	58.7	(93)	B	C. R. BASALT
						66.0 225.0	(1.59)		53.3 .9	53.3	(85)	B	
24N/31E- 16BCC	47-34.55	118-56.07	DOE TST5 8/27/81	562	10.30	19.0 149.0	(1.59)		58.7 .9	52.8	(84)	B	C. R. BASALT
						19.0 204.0	(1.59)		53.0 .9	58.3	(93)	B	
23N/11E- 1C	47-30.51	121-21.24	DDH-1 6/25/65	838	4.67	80.0 130.0	3.93 .21	9	16.2 .3	14.7	58	C	SILICIFIED B6 GRANDIORITE
23N/43E- 8AB	47-30.41	117-23.81	AUDRBERG 7/27/81	737	10.70	95.0 125.0	(1.34)	1	41.6 1.3	41.6	(56)	B	BASALT
23N/11E- 10DCA	47-29.52	121-24.15	DDH-2 7/24/65	585	12.68	86.6 251.0	3.03 .08	24	25.2 1.0	18.6	56	C	GRANDIORITE (ARTESIAN) B6
23N/ 6E- 18ADD	47-29.00	122- 5.00	BEACH 4/30/80	158	6.20	61.0 92.4			20.1 .8			C	SANDSTONE
22N/11E- 48DA	47-25.54	121-24.80	DNR-SO1 10/13/81	903	4.93	110.0 145.0	2.97 .21	7	16.7 .1	14.7	44	B	PHYLLITE
22N/20E- 26CBB	47-22.11	120-18.00	NORCO-1 8/ 4/70	762	11.60	310.0 900.0	2.18 .21	18	26.8 .2	28.4	62	A	RY. ARKOSE & SANDSTONE B7
21N/31E- 10CB	47-20.00	118-55.00	DAGE-1 8/31/61	503		61.0 1250.0	1.67 .21		42.0 2.0	42.0	70	B	C. R. BASALT B7
20N/22E- 12ABC	47-14.65	120- .78	WELCH 11/13/81	390	14.00	49.0 169.0	(1.59)	1	26.1 1.3	26.0	(41)	D	C. R. BASALT
						49.0 264.0	(1.59)	1	32.1 1.0	32.0	(51)	C	
20N/12E- 8	47-14.27	124-11.47	UD-MO 1 0/ 0/30	20	9.20	304.8 1066.8	(1.30)		27.4 2.4	27.4	(36)	B	SHALE 87
20N/15E- 18DD	47-13.22	121- .46	DDH-E 7/14/72	704	7.20	5.0 200.0			20.8 3.5			C	COAL & SHALE

THW/RNG SECTION	N LAT DEG MIN	W LONG DEG MIN	HOLE NO. (DATE)	COLLAR ELEV.	SURFACE TEMP.	DEPTH INTERVAL	AVG. TCJ (SE)	NO. TC	UN. GRAD (SE)	CO. GRAD (SE)	CO. H.F. (SE)	Q H.F.	LITHOLOGY SUMMARY	R
15N/17E- 23CBD	47- 7.27	120-40.88	THORP1 7/28/80	716	10.00	110.0 170.0			31.2 .6				B	
						10.0 170.0	(1.38)	1	29.4 .5	29.4 .5	(41)	B		
18N/ 9E- 29CB	47- .54	121-41.70	DNR-WTRJ 9/15/81	850	6.20	115.0 140.0	2.39 .21	8	24.2 .4	19.6	47	B	PYROXENE RYOLITE(MI)	
18N/26E- 35C	47- .26	119-31.73	F SHINN 8/26/81	345	14.90	70.0 100.0	(1.59)		49.8 1.0	49.8	(79)	C	BASALT ?	
17N/ 3E- 20AAA	46-59.22	122-22.78	MILLER 6/27/81	145		140.0 178.0			24.5 .2			C		
16N/18E- 38DD	46-54.40	120-33.68	KUTTER1 7/14/80	820	9.75	100.0 150.0			29.6 .2	29.6 .2		B		
16N/19E- 12DB	46-53.37	120-23.45	BADGER 11/30/81	664	10.16	59.0 333.0	(1.55)	1	27.3 1.1	27.3	42	C	C. R. BASALT	
						59.0 154.0	(1.55)	1	29.4 .6	29.4	(46)	C		
16N/31E- 15B	46-52.75	118-55.10	WHOLMAN 1/22/81	432	13.50	10.0 230.0	(1.59)		59.1 1.8	59.1	(94)	C	C. P. BASALT	
						10.0 50.0	(1.59)		47.0 1.3	47.0	(75)	C		
						170.0 230.0	(1.59)		57.3 1.5	57.3	(91)	B		
16N/16E- 24CCD	46-51.45	120-46.55	DGF2 7/ 1/80	832	9.29	10.0 175.0			54.3 1.4			B		
						10.0 85.0			49.6 .4	45.6		B		
16N/ 4E- 23DDD	46-51.01	122-15.36	ANDERSON 8/19/79	432	8.35	25.0 66.5	(1.97)	2	9.0 .5	10.2	(21)	C	BASALT	
16N/12E- 24DD	46-51.00	124- 6.00	TH-1 8/ 4/71	3	11.20	60.0 155.0	1.48 .04	22	25.5 2.2	26.5	39	A	GRAVEL, SAND & CLAY	87
16N/17E- 29ADB	46-50.96	120-43.40	DGF1 7/ 1/80	670	9.28	70.0 120.0			31.6 .4	29.0		B		
THW/RNG SECTION	N LAT DEG MIN	W LONG DEG MIN	HOLE NO. (DATE)	COLLAR ELEV.	SURFACE TEMP.	DEPTH INTERVAL	AVG. TCJ (SE)	NO. TC	UN. GRAD (SE)	CO. GRAD (SE)	CO. H.F. (SE)	Q H.F.	LITHOLOGY SUMMARY	R
16N/21E- 33CD	46-49.63	120-12.37	YFC3 7/15/80	795	9.78	10.0 100.0	1.38		30.6 1.6	37.2	52	B		
						40.0 90.0	1.38	4	36.9 1.1	44.8	62	B		
15N/17E- 23ABC	46-46.90	120-39.95	DAY1 6/30/80	634	9.31	40.0 130.0			36.7 .6			B	SANDSTONE & CLAY	
						150.0 222.0			41.6 .5			B		
						40.0 222.0	(1.59)		38.7 .3	36.5	(58)	B		
15N/ 4E- 14DDA	46-46.78	122-15.32	B LINDSEY 8/19/79	566	6.79	100.0 122.0	1.72 .17	2	14.6 .6	19.8	34	C	BASALT	
15N/ 6E- 22ABD	46-46.49	122- 1.77	ASHFORD-1 7/17/79	965	5.84	30.0 68.0			13.7 .3			C	SHALE, COAL & SANDSTONE	
15N/18E- 28DD	46-45.37	120-34.54	MENILLY2 7/ 4/80	500	13.20	60.0 85.0			18.6 .9			C	SANDSTONE	
						30.0 85.0			22.4 .7			C		
15N/17E- 36AAA	46-45.13	120-38.49	DNRUEVAS 10/ 9/80	493	11.19	60.0 80.0			29.0			B	CLAY, SAND, GRAVEL, CONG	
						.0 80.0			27.9			B		
						75.0 595.0	(1.46)		33.3 .7	31.6	(46)	B		
14N/ 2E- 4ABD	46-43.99	122-56.24	THOMAS 6/15/79	85	8.88	90.0 150.5			20.8 .3	20.2		B		
14N/16E- 1CBD	46-43.77	120-46.74	SHROCK 7/12/80	641	10.99	20.0 110.0	(1.46)		35.9 1.0	35.9 1.0	(53)	C	ANDESITE	
14N/44E- 18CC	46-43.72	117-13.28	R MARLOW 9/ 2/81	781	9.30	54.0 89.0	(1.59)		22.9 .6	22.9	(36)	C	C. R. BASALT	
14N/10E- 8DCB	46-42.89	121-34.68	RDH-ONP 9/15/81	490	6.24	75.0 115.0	2.18 .08	10	45.5 .5	33.8	74	B	Eocene VOLCANICS	

TUNING SECTION	N LAT DEG MIN	W LONG DEG MIN	HOLE NO. (DATE)	COLLAR ELEV.	SURFACE TEMP.	DEPTH INTERVAL	AUG. TOU (SE)	NO. TC	UN. GRAD (SE)	CO. GRAD (SE)	CO. H.F. (SE)	Q H.F.	LITHOLOGY SUMMARY	R
14N/17E- 13ADC	46-42.20	120-38.35	MURRAY3 7/ 7/80	533	13.29	20.0 60.0			55.5 1.3	56.9		B		
						80.0 130.0			48.7 3.0	49.9		B		
14N/18E- 25DBB	46-40.40	120-36.05	MCFLINE 7/ 8/80	432	11.75	40.0 55.0			50.8 2.6			C	SAND AND CLAY	
						20.0 55.0	(1.46)		40.7 2.0	39.0	(57)	C		
14N/14E- 25BDC	46-40.39	121- 1.76	DNR-TWIL 9/15/81	744	9.83	25.0 150.0	1.30 .13	10	93.3 .3	67.0	87	B	C. R. BASALT	
14N/15E- 25CBD	46-40.25	120-59.25	SHLDCR 6/29/80	696	9.19	55.0 67.0			66.1 2.4	43.7		C	ALLUVIUM	
14N/ 14- 25CBA	46-40.21	122-46.33	REYNOLDS 6/15/79	125	8.96	75.0 92.3			19.9 1.1	19.0		C	COALBEARING SHOOLKUPHUCK	
13N/12E- 4AB	46-39.10	121-19.80	DNR-COUR 9/15/81	1006	3.83	60.0 150.0	2.02 .21	8	65.3 .2	46.0	93	A	SANDY SLTSTL MUDSTONE(JR)	
13N/12E- 2AB	46-39.00	121-17.02	DNR-SROG 9/15/81	1006	5.79	35.0 150.0	2.56 .13	9	43.5 .2	42.3	108	A	AMPHIBOLITE (JR)	
13N/11E- 2DC	46-38.32	121-23.49	RDH-WTPS 8/27/79	1366	4.19	10.0 148.5	1.84 .15	21	52.4 .3	45.0	83	A	Eocene (P/O) VOLCANICS	
13N/ 4- 7ABA	46-38.02	123-13.57	ARNOLD 9/ 1/79	85	8.41	110.0 128.5	1.99	1	20.6 .9	20.6	41	B	BLUE CLAY	
13N/19E- 11DBC	46-37.50	120-24.75	THEIGHTS 6/29/80	609	13.75	100.0 160.0			35.3 1.4			C	C. R. BASALT	
						50.0 160.0	(1.59)		34.2 .4	32.8	(52)	B		
13N/ 9E- 16BCA	46-37.22	121-41.59	RDH-PKLD 9/ 4/79	359	7.33	10.0 152.0	1.59 .10	19	45.2 .4	43.5	70	A	VOLCANIC SEDIMENTS	
13N/ 5E- 18ABD	46-36.96	122-13.63	ROM 1 6/15/79	358	7.25	10.0 55.0	(1.09)		31.5 1.0	26.9	(29)	C	Eocene(?) SEDIMENT RX	
13N/29E- 13DB	46-36.77	119- 7.28	BAILIE 2/26/81	231	14.00	10.0 210.0	(1.59)		(48.3) 2.1	(48.3)	(77)	C	C. B. BASALT	
TUNING SECTION	N LAT DEG MIN	W LONG DEG MIN	HOLE NO. (DATE)	COLLAR ELEV.	SURFACE TEMP.	DEPTH INTERVAL	AUG. TOU (SE)	NO. TC	UN. GRAD (SE)	CO. GRAD (SE)	CO. H.F. (SE)	Q H.F.	LITHOLOGY SUMMARY	R
13N/ 14- 18CBB	46-36.71	122-51.85	OLSON 5/26/79	85	10.07	65.0 91.0			11.5 .7	11.5		C	TERTIARY (?) SEDIMENT RX	
13N/19E- 23ABB	46-36.70	120-24.70	WATKINS1 6/16/80	402	13.62	20.0 70.0			27.8 .5	26.5		C	GRAVEL, CLAY AND SAND	
13N/ 14- 19DCD	46-35.36	122-51.12	SUNDIN 1 6/ 7/79	93	10.40	40.0 225.0			21.3 .2	21.3		A	TERTIARY (?) SEDIMENT RX	
13N/26E- 25	46-35.00	119-31.00	DH-1 1/13/70	168	15.18	53.3 182.9	1.71 .03	19	37.2 .3	37.2	64	A	BASALT	571
13N/ 3- 35BAB	46-34.49	123- 1.51	MOHORIC 8/31/79	170	10.00	105.0 140.0			25.5 .5			C		
						120.0 135.0	1.60	1	29.4 .5	29.4	47	C		
12N/17E- 11BBB	46-33.05	120-40.11	DECOLC-7 6/17/80	425	8.65	10.0 130.0	(1.46)		(34.2)	(34.2)	(50)	D	GRAVEL, CLAY AND SAND	
						80.0 120.0	(1.46)		64.2 1.0	64.2	(94)	C		
12N/ 2E- 5DCD	46-32.65	122-34.73	PLANT 6/16/79	284	7.36	125.0 155.0	(1.67)		22.7 .2	25.4	(38)	B	TERTIARY VOLCANICS	
12N/ 14- 7AB	46-32.68	122-50.81	RDH-SUB 1/ 7/72	152	9.00	50.0 565.0	(1.26)		29.0 .2	29.0	(36)	A	SHALE, SS & SILTSTONE	
						90.0 360.0	(1.09)	59	33.2 .2	33.2	(36)	A		
						375.0 565.0	(1.46)		25.2 .1	25.2	(37)	A		
12N/ 14- 8DAB	46-32.35	122-49.46	SU-12 1/12/72	161		110.0 365.0	(1.09)	59	27.3 .3	27.3	(30)	A		
						260.0 578.0	(1.46)		21.5 .3	21.5	(31)	A		
12N/ 14- 8CAB	46-32.28	122-50.20	SU-14 6/13/67	156	7.81	100.0 400.0	(1.09) .04	59	33.8 .1	33.8	(36)	A	SHALE, SS & SILTSTONE	571
12N/ 14- 8DAD	46-32.18	122-49.46	SU-11 6/12/67	157	10.60	100.0 340.0	(1.09) .04	59	34.6 .2	34.6	(37)	A	SHALE, SS & SILTSTONE	571

THWING SECTION	N LAT DEG MIN	W LONG DEG MIN	HOLE NO. (DATE)	COLLAR ELEV.	SURFACE TEMP.	DEPTH INTERVAL	AUG. TC (SE)	NO. TC	UN. GRAD (SE)	CO. GRAD (SE)	CO. H.F. (SE)	Q H.F.	LITHOLOGY SUMMARY	R
12N/2E- 90AD	46-32.07	122-33.17	LOPK 3 6/23/79	146	8.58	60.0 206.0	(1.67)		23.0 .3	23.0	(39)	B	BASALT	
12N/14- 90CC	46-31.99	122-48.66	SJ-4 6/12/67	165	9.00	100.0 360.0	(1.09) .04	59	32.8 .2	32.8	(36)	A	SHALE, SS & SILTSTONE	571
						710.0 760.0	1.77 .01	5	18.2 .1	18.2	32	A		
12N/14- 90CC	46-31.93	122-50.52	RDH-SJ07 1/12/72	152	9.10	45.0 150.0	(1.09)	59	27.7 .4	27.7	(30)	A	SHALE, SS & SILTSTONE	
						150.0 395.0	(1.09)	59	33.5 .1	33.5	(36)	A		
						395.0 640.0	(1.46)		24.6 .1	24.6	(36)	A		
12N/14- 17BAD	46-31.75	122-49.48	SJ-10 3/19/73	167	9.50	90.0 348.0	(1.09)	59	34.8 .2	34.8	(38)	A	SHALE, SS & SILTSTONE	
12N/14- 17ADA	46-31.65	122-50.07	SJ-902 3/19/73	158	9.30	90.0 340.0	(1.09)	59	32.7 .2	32.7	(36)	A	SHALE, SS & SILTSTONE	
						340.0 690.0	(1.46)		24.8 .1	24.8	(36)	A		
						690.0 847.0	(1.76) .01	5	22.2 .2	22.2	(39)	A		
12N/20E- 16CA	46-31.56	120-19.54	DNR-ELPH 8/ 1/81	497	12.50	100.0 400.0	(1.59)		41.5 .1	41.5	(66)	C	C.R. BASALT	
12N/7E- 16CC	46-31.37	121-56.37	RDH-RAND 11/13/79	274	9.04	90.0 129.0			34.3 .5			B		
						35.0 129.0	1.75 .08	10	41.6 .6	41.6	73	A		
12N/3E- 17DCB	46-31.33	122-27.54	AUST 7/ 4/79	226	8.84	90.0 138.5	(1.67)		20.5 .6	20.5	(34)	B	EOCENE (?) BASALT	
12N/22E- 13CDC	46-31.25	120- .71	CHANGALA 10/14/80	521	13.50	60.0 200.0	(1.59)		34.3 .2	33.3	(53)	B		
12N/3E- 19CDB	46-30.44	122-29.23	MOSSRK-1 8/ 1/79	348	8.04	65.0 232.5	(1.67)		27.0 .4	27.0	(45)	C	EOCENE-OLIGO VOLCANICS	
THWING SECTION	N LAT DEG MIN	W LONG DEG MIN	HOLE NO. (DATE)	COLLAR ELEV.	SURFACE TEMP.	DEPTH INTERVAL	AUG. TC (SE)	NO. TC	UN. GRAD (SE)	CO. GRAD (SE)	CO. H.F. (SE)	Q H.F.	LITHOLOGY SUMMARY	R
12N/20E- 36CD	46-28.64	120-15.78	CHEYNERD 6/18/80	411	14.90	10.0 90.0			45.8 2.8			C	SEDIMENTS & BASALT	
						10.0 360.0	(1.59)		(32.3)	(32.3)	52	C		
11N/21E- 79AC	46-27.53	120-13.50	GARETSON 12/ 5/80	390	15.00	215.0 395.0	(1.59)		31.4 .1	31.4	(50)	B	C. R. BASALT	
						85.0 450.0	(1.59)		33.7 .3	32.9	(52)	B		
11N/21E- 17ABD	46-26.70	120-13.75	CLYDE 12/ 4/80	378	14.00	145.0 225.0			40.8 .9			C	C. R. BASALT	
11N/21E- 16CDB	46-26.10	120-12.15	RAISSIER 11/19/80	388	15.47	10.0 60.0			77.9 3.6	75.0		C	SEDIMENTS & BASALT	
						60.0 130.0			48.7 .7	48.0		C		
						130.0 210.0	(1.59)		41.0 .7	41.0	(65)	C		
11N/24E- 15 1	46-26.00	119-47.00	RS-1 6/ 7/67	875	9.11	900.0 2500.0	1.59 .13	6	35.2 .2	37.5	60	B	BASALT	571
11N/24E- 15 2	46-26.00	119-47.00	RS-2 1/14/69	875	10.40	58.0 119.0	1.72 .04	14	28.1 .2	33.3	57	B	BASALT	571
11N/21E- 22AC	46-25.84	120-10.53	SANDLIN 6/19/80	390	15.20	20.0 365.0			33.4 .5			C	SEDIMENTS & BASALT	
						30.0 150.0			43.1 .9					
						150.0 330.0	(1.59)		28.8 .2	28.8	44	B		
11N/26E- 23BB	46-25.68	119-16.62	BATTLE 2 2/24/81	121	15.20	20.0 290.0	(1.59)		37.7 .3	37.7	60	B	C. R. BASALT	
11N/26E- 20CC	46-25.17	119-35.38	UC-SOC 1 0/ 0/30	445	15.20	30.5 670.6	(1.59)		37.4 4.4	35.6	(57)	B	C. R. BASALT	571

TUNING SECTION	N LAT DEG MIN	W LONG DEG MIN	HOLE NO. (DATE)	COLLAR ELEV.	SURFACE TEMP.	DEPTH INTERVAL	AUG. TOU (SE)	NO. UN. TC	UN. GRAD (SE)	CO. GRAD (SE)	CO. H.F. (SE)	D H.F.	LITHOLOGY SUMMARY	R
11N/22E- 30BA	46-25.00	120- 7.13	CHAPPELL 7/31/81	366	12.40	50.0 270.0	(1.59)		49.4 .5	49.4	(79)	C	C. R. BASALT	
						50.0 150.0	(1.59)		43.9 .2	43.9	(70)	B		
11N/22E- 28CB	46-24.57	120- 4.51	SPALD R 8/ 2/81	402	12.50	27.0 104.0	(1.59)		42.5 .1	42.5	(67)	B	C. R. BASALT	
						27.0 210.0	(1.59)		39.7 .3	39.7	(63)	B		
11N/46E- 32BCA	46-23.49	117- 4.52	WPC7-WJ 2/15/78	359	11.00	15.0 405.0	(1.59)		35.6	35.6	(57)	B	BASALT WITH CLAY	
11N/45E- 32DAB	46-23.28	117-11.46	SILCOOTW 2/19/78	544	11.50	10.0 192.0	(1.59)		31.3 .5	32.0	(51)	B	C. R. BASALT	
10N/ 4E- 2DBA	46-22.65	122-15.95	DNR 83-1 7/22/83	488		25.0 140.0			50.0			B	ALLUVIUM & VOLCANICS	
10N/41E- 30BD	46-22.37	117-39.50	NEIBLDAW 8/ 3/78	896	9.30	10.0 90.0	(1.59)		22.1 .6	27.2	(43)	C	C. R. BASALT	
10N/28E- 10ACC	46-21.97	119-17.43	BATTELLE 2/11/81	115	15.10	5.0 120.0	(1.59)		34.3 1.0	34.3	(54)	C	C. R. BASALT	
10N/28E- 14ABD	46-21.73	119-16.13	BATTELLE 2/11/81	115	14.10	530.0 605.0	(1.59)		42.1 .6	42.1	(67)	B	C. R. BASALT	
						110.0 510.0	(1.59)		40.1 .2	40.1	(64)	B		
10N/ 6E- 8DDA	46-21.58	122- 4.47	DDH-9 10/25/72	1140	4.00	80.0 135.0			14.4 .5	(21.6)		C	DACITE PORPHYRY	B7
						80.0 270.0			9.9 1.1	(14.9)		C		
						120.0 270.0	3.68 .17	6	(12.5)	(18.5)	(68)	C		
TUNING SECTION	N LAT DEG MIN	W LONG DEG MIN	HOLE NO. (DATE)	COLLAR ELEV.	SURFACE TEMP.	DEPTH INTERVAL	AUG. TOU (SE)	NO. UN. TC	UN. GRAD (SE)	CO. GRAD (SE)	CO. H.F. (SE)	D H.F.	LITHOLOGY SUMMARY	R
10N/28E- 14	46-21.12	119-16.19	DDH-3-WJ 8/12/70	120		174.0 608.0	1.65 .07	16	25.1 .3	25.1	41	A	C. R. BASALT	S71
						608.0 1079.0	1.52 .03	15	34.6 .3	34.6	53	A		
						174.0 1079.0	1.59		30.0	30.0	47	A		
10N/ 6E- 18BDB	46-21.10	122- 6.40	DDH-1 10/31/71	853	8.62	205.0 210.0	3.85 .13	6	(22.0)	(18.0)	(70)	C	DACITE PORPHYRY	B7
10N/24E- 36BD	46-18.70	119-45.43	ANDSN1 4/ 8/81	420	11.70	20.0 125.0	(1.59)		62.0 1.0	62.0	(99)	C	C. R. BASALT	
						125.0 200.0	(1.59)		34.0	34.0	(54)	C		
10N/39E- 32BCA	46-18.33	117-57.87	DAYTON 11/19/81	502	9.40	49.0 229.0	(1.59)	1	32.0 .7	31.6	(50)	C	C. R. BASALT	
9N/ 24E- 1ADB	46-17.72	122-52.14	MOCK 8/ 3/79	196	8.57	20.0 135.0	(1.59)	1	13.5 .2	14.2	(23)	C	CLAY, SS & BASALT	
9N/32E- 13BA	46-16.04	118-45.21	POWER-WJ 2/10/78	262	15.00	135.0 210.0	(1.59)		34.8 .6	34.8	(55)	B	BASALT WITH INTERBEDS	
9N/ 5E- 18BB	46-15.95	122-14.22	DDH-STH1 11/14/79	78	7.48	30.0 80.0			17.8 .3			B	ANDESITE LAPARS	
						30.0 122.5	1.81 .06	15	20.1 .5	20.1	36	B		
9N/27E- 23CA	46-14.82	119-24.17	DNR-KID3 3/10/81	280	14.20	160.0 350.0	(1.59)		43.1 .2	43.1	(69)	B	C. R. BASALT	
8N/44E- 2AAD	46-12.27	117-15.00	REEVES-WJ 7/28/78	1050	9.50	10.0 89.0			16.7 .6			C	C. R. BASALT	
8N/ 4E- 14DD	46-10.37	122-16.10	DDH-STH2 11/14/79	1066	5.50	112.0 150.0			34.4 1.0			B		
						50.0 150.0	1.85 .06	17	24.2 .8	24.2	45	B		

THIN/RING SECTION	N LAT DEG MIN	W LONG DEG MIN	HOLE NO. (DATE)	COLLAR ELEV.	SURFACE TEMP.	DEPTH INTERVAL	AUG. TOU (SE)	NO. TC	UN. GRAD (SE)	CO. GRAD (SE)	CO. H.F. (SE)	B H.F.	LITHOLOGY SUMMARY R
6V/33E- 21D	46- 9.31	118-40.99	GLUCK-HJ 2/ 3/78	288	13.40	15.0 50.0 200.0	(1.59)		58.6 1.6 37.7 1.0	58.6	(60)	B	C. R. BASALT
6V/25E- 36AB	46- 8.38	119-37.78	DNRGOLD 3/13/81	329	13.60	5.0 240.0	(1.59)		35.0 1.7	35.0	(56)	C	
7V/46E- 29A	46- 7.99	116-59.88	DODD-HJ 2/18/78	991	5.80	160.0 275.0	(1.59)		27.6 .7	36.1	(57)	C	BASALT (?)
7V/ 8E- 25CD	46- 7.50	121-46.20	DGER-4 9/14/76	1207	3.10	85.0 150.0	1.25 .03	5	48.5 .5	44.5	56	A	VESICULAR BASALT SCH
7V/ 9E- 17AA	46- 5.90	121-42.00	DGER-3 9/13/76	960	4.60	115.0 150.0	1.24 .11	4	58.5 2.5	53.4	66	A	VOLCANO- CLASTIC SCH
7V/36E- 17CAD	46- 5.39	118-20.30	HGCC-HJ 8/ 8/78	307	14.30	100.0 225.0	(1.59)		35.4 .5	35.4	(57)	B	C. R. BASALT
7V/46E- 13BA	46- 5.25	116-59.01	MELBAR 3/ 4/78	300	14.60	15.0 85.0	(1.59)		53.0 1.0	40.8	(65)	C	C. R. BASALT
7V/36E- 25AAC	46- 3.66	118-22.22	ARTIDBLH 1/30/78	259	11.00	85.0 260.0	(1.59)		34.0	34.0	(54)	C	C. R. BASALT
7V/23E- 36BCA	46- 3.02	119-52.52	DNRCHES2 11/18/80	326	16.31	40.0 155.0			17.5 .2			B	C. R. BASALT
7V/ 8E- 35C	46- 2.90	121-45.00	DGER-7 9/14/76	1213	2.80	15.0 25.0	(1.17)		70.0	58.0	(67)	C	UNCON. GLAC. SEDIMENT SCH
6V/33E- 10BD	46- 1.46	118-37.30	BRYAN-HJ 2/ 2/78	143	12.00	10.0 60.0 305.0	(1.05)		78.9 4.8 69.0 8.0	78.9	(73)	B	CEMENTED GRAVEL/CLAY
6V/33E- 10AD	46- 1.01	118-40.65	GARDIN-HJ 2/ 2/78	175	7.80	20.0 85.0	(1.05)		104.1 5.0	106.8	(112)	C	CEMENTED GRAVEL
6V/ 7E- 23BAC	45-59.90	121-53.60	DGER-5 9/14/76	914	4.80	100.0 150.0	1.23 .06	6	51.0 .4	49.8	61	A	BASALT SCH
THIN/RING SECTION	N LAT DEG MIN	W LONG DEG MIN	HOLE NO. (DATE)	COLLAR ELEV.	SURFACE TEMP.	DEPTH INTERVAL	AUG. TOU (SE)	NO. TC	UN. GRAD (SE)	CO. GRAD (SE)	CO. H.F. (SE)	B H.F.	LITHOLOGY SUMMARY R
6V/19E- 24BC	45-59.52	120-22.97	FUSTER 11/28/81	1116	7.00	29.0 152.0	(1.59)	1	37.6 1.1	37.6	60	D	C. R. BASALT
						14.0 29.0	(1.59)	1	64.8 1.9	64.8	(105)	D	
						59.0 139.0	(1.59)	1	41.2 .7	41.2	(65)	C	
6V/ 9E- 25AAC	45-58.60	121-37.40	DGER-2 9/13/76	884	4.00	100.0 150.0	1.42 .03	8	53.8 .8	52.7	75	A	VOLCANO- CLASTIC SCH
6V/ 1E- 50DC	45-56.41	122-42.87	EPPERSON 8/16/79	95	9.78	100.0 177.5	(1.72)	1	19.6 .1	21.5	(37)	B	SANDSTONE & SHALE
6V/21E- 16CAB	45-55.00	120-11.49	DOE TST7 8/23/81	706	15.11	74.0 224.0	(1.59)		49.2 6.3	49.2	(78)	D	C. R. BASALT
						224.0 394.0	(1.59)		27.2 .7	17.2	(44)	C	
6V/14E- 22BCB	45-54.46	121- 2.86	URBAN 9/12/79	585	11.57	40.0 137.5	(1.59)	1	29.7 .3	31.2	(50)	B	C. R. BASALT
6V/ 1E- 23CBA	45-54.12	122-39.35	GRIMM 8/ 1/79	158	8.97	120.0 246.0	(1.30)	1	32.1 .2	32.1	(42)	B	SANDSTONE & SHALE
6V/ 2E- 250BC	45-53.16	122-30.08	HAGEDORN 7/31/79	201	8.10	70.0 156.0	(1.59)		33.2 .3	32.0	(51)	B	BASALT ?
6V/15E- 28DDD	45-53.04	120-55.60	H FREER 7/14/81	585	9.91	55.0 145.0	(1.59)		24.7 .4	24.7	(39)	B	QUART. BASALT
6V/ 3E- 280CC	45-52.96	122-27.00	DREW 8/ 1/79	351	8.06	70.0 97.5	(2.01)		20.4 .3	20.4	(41)	C	
4V/ 2E- 14BA	45-50.22	122-31.72	EBNER 1 8/13/81	76	8.34	122.0 192.0 192.0 215.0	(1.05)		38.4 .2 25.6 .3	38.5	(40)	B	CLAY AND BASALT
							(1.59)			25.6	(41)	B	

THW/RNG SECTION	N LAT DEG MIN	W LONG DEG MIN	HOLE NO. (DATE)	COLLAR ELEV.	SURFACE TEMP.	DEPTH INTERVAL	AUG. TCU (SE)	NO. TC	UN. GRAD (SE)	CO. GRAD (SE)	CO. H.F. (SE)	Q H.F.	LITHOLOGY SUMMARY	R
4N/ 3E- 18CCB	45-49.61	122-29.51	HOARSH 6/24/79	131	8.99	40.0 107.5			30.0 .6	29.4		B		
						85.0 107.5			30.7 .9	29.8		B		
						50.0 109.0			31.1 .1	30.6		B		
4N/13E- 24BC	45-49.40	121- 7.72	DNR-KLKT 9/14/81	146	14.18	70.0 110.0	1.39 .13	6	50.5 .5	37.1	52	C	C. R. BASALT	
4N/ 3E- 20ADD	45-49.10	122-27.33	WINSTON 7/28/79	210	8.32	135.0 220.0	(1.59)	1	38.3 .1	38.0	(60)	B	Eocene Basalt	
4N/ 1E- 21ACD	45-49.01	122-41.24	KING 8/ 2/79	79	8.72	155.0 236.0			24.7 .2	24.7		B	SAND, CLAY, Basalt	
4N/ 7E- 21CD	45-48.63	121-57.19	DNR-TRCK 9/10/81	354	5.92	50.0 150.0	1.22 .13	9	87.3 .2	75.4	92	A	Vol-clastic Mudflows	
3N/ 5E- 48DB	45-46.49	122-12.10	SS-20 9/15/76	553	6.13	35.0 300.0	(2.80) .08		24.4 .2	24.4	(68)	A	Qtz. Diorite Granodiorite	
3N/ 5E- 48CA	45-46.48	122-12.08	SS-18 9/15/76	549	6.50	30.0 140.0	(2.80) .08		20.3 .2	20.3	(57)	B	Qtz. Diorite Granodiorite	
3N/ 5E- 4ACB	45-46.46	122-11.76	SS-23 9/15/76	564	6.02	15.0 150.0	(2.80) .08		16.7 .2	16.7	(47)	B	Qtz. Diorite Granodiorite	
						150.0 245.0	(2.80) .08		24.6 .2	24.6	(69)	B		
3N/ 5E- 4ACA	45-46.44	122-11.63	SS-21 9/15/76	570	6.35	25.0 305.0	(2.89) .08		23.5	23.5	(66)	A	Qtz. Diorite Granodiorite	
3N/ 5E- 48DC2	45-46.39	122-13.02	SS-22 9/16/76	545	6.70	30.0 220.0	(2.80) .08		23.2 .3	23.2	(65)	A	Qtz. Diorite Granodiorite	
3N/ 5E- 4CAB	45-46.25	122-11.98	SS-3 9/16/76	521	6.85	205.0 290.0	(2.80)		24.4 .2	24.4	(68)	A	Qtz. Diorite Granodiorite	
3N/ 5E- 4CAC	45-46.21	122-11.96	SS-6 9/16/76	539	5.78	15.0 120.0	(2.89) .08		22.8 .2	22.8	(64)	B	Qtz. Diorite Granodiorite	
						120.0 215.0	(2.80)		29.2 .2	29.2	(82)	A		
THW/RNG SECTION	N LAT DEG MIN	W LONG DEG MIN	HOLE NO. (DATE)	COLLAR ELEV.	SURFACE TEMP.	DEPTH INTERVAL	AUG. TCU (SE)	NO. TC	UN. GRAD (SE)	CO. GRAD (SE)	CO. H.F. (SE)	Q H.F.	LITHOLOGY SUMMARY	P
3N/10E- 10CCB	45-45.36	121-32.68	TENNANT 11/24/81	362	6.22	99.0 263.0	(1.59)		17.0 .3	17.0	(27)	C	C. R. BASALT	
						199.0 263.0	(1.59)		18.3 1.0	21.5	(34)	C		
3N/13E- 13CA	45-44.66	121- 6.95	O SEARLE 7/17/81	661	10.23	70.0 195.0	(1.59)		34.4 1.3			C	C. R. BASALT	
						160.0 195.0	(1.59)		35.1 .5	39.0	(62)	C		
3N/13E- 21AB	45-44.23	121-10.94	J MOTT 7/ 9/81	512	10.76	65.0 150.0	(1.59)		28.5 .9	33.5	(53)	C	C. R. BASALT	
3N/21E- 19BAB	45-44.12	120-13.55	RB-1 10/30/74	120	15.40	30.0 70.0	(1.59)		54.3 2.0	53.8	(85)	C	C. R. BASALT	
3N/ 8E- 21BDD	45-44.07	121-48.24	DNR-CRSN 9/14/81	137	7.01	5.0 114.0	1.60 .13	13	167.6	166.0	265	G	Quartz Diorite	
3N/ 3E- 21DAB	45-43.77	122-26.23	ZINTZ 7/ 9/79	250	8.83	30.0 103.0	(1.59)		26.7 .2	27.0	(42)	B	Eocene Basalt	
3N/ 3E- 21BBD	45-43.60	122-26.40	BOTHILLR 7/ 5/79	219	8.85	30.0 188.0	(1.59)	1	28.7 .3	27.0	(42)	B	Eocene Basalt	
3N/ 7E- 25DA	45-42.88	121-52.90	SMITH 11/23/81	270	7.57	59.0 213.0	(1.26)		27.9 .7	26.8	(34)	B	Vol-clastic Rocks	
3N/11E- 29CCA	45-42.76	121-27.61	BNG CTY1 7/ 8/81	46	13.04	70.0 100.0	(1.59)		35.3 .5	35.3	(56)	C	C. R. BASALT	
3N/ 7E- 36BDD	45-42.34	121-51.96	NIX 9/ 8/79	146	9.72	15.0 150.0			36.6 .2	38.1		B	Oligocene Volcanics	
						200.0 290.0			24.0 .1	24.4		B		
						15.0 290.0	(1.46)		31.4 .3	32.7	48	C		
3N/11E- 34DBB	45-42.12	121-24.66	HEANEY 7/ 4/81	183	11.30	25.0 100.0	(1.59)		36.6 .7	36.6	(58)	C	C. R. BASALT	

TIN/RNG SECTION	N LAT DEG MIN	W LONG DEG MIN	HOLE NO. (DATE)	COLLAR ELEV.	SURFACE TEMP.	DEPTH INTERVAL	AUG. TOU (SE)	NO. TC	UN. GRAD (SE)	CO. GRAD (SE)	CO. H.F. (SE)	Q H.F.	LITHOLOGY SUMMARY R
2V 3E- 120AD	45-40.03	122-22.58	VALDESE 1/ 2/80	365	8.77	100.0 127.0			27.5 .4			B	Eocene Basalt
						25.0 127.0	(1.59)	1	23.1 .3	23.1	(37)	B	
2V 7E- 160CC	45-39.16	121-57.51	RDH-NBU3 9/11/81	14	11.57	10.0 155.0			107.3 2.0			G	Vol-clastic Rocks
						80.0 155.0	(1.46)		90.6 .9	82.4	(121)	G	
2V 7E- 228BA2	45-38.91	121-56.13	DH-1203 10/28/75	41	9.30	45.0 80.0			34.8 2.1			C	
2V 7E- 218AC	45-38.90	121-57.24	RDH-NBU2 9/11/81	14	9.44	50.0 195.0	(1.46)		142.6 5.3	129.6	(190)	G	Vol-clastic Rocks
2V 7E- 228BA7	45-38.88	121-56.14	USCE1440 4/12/77	51	9.45	20.0 84.5			30.4 2.8			C	CLAY, SILT & SANDSTONE
						50.0 84.5			42.4 2.3			C	
2V 7E- 228BA1	45-38.88	121-56.15	DH-1201 10/28/75	45	9.95	40.0 82.0			40.5 1.2			B	CLAY, SILT & SANDSTONE
2V 7E- 228BA8	45-38.86	121-56.15	USCE1329 4/12/77	51	9.94	25.0 75.0			29.3 1.5			B	CLAY, SILT & SANDSTONE
2V 7E- 228BC3	45-38.77	121-56.32	USCE1378 4/12/77	26	9.59	45.0 68.3			36.7 .9			C	CLAY, SILT & SANDSTONE
2V 7E- 200CA	45-38.43	121-58.52	RDH-NBU1 5/ 1/81	21	7.01	42.7 186.0			50.0 .4			B	Vol-clastic Rocks
						100.6 179.9	1.40	5	54.2 .4	49.3	69	B	
2V 3E- 210C	45-38.43	122-27.10	RDH-CAY3 9/ 4/80	610	9.65	65.0 145.0		2	35.2 .6	35.0		B	SANDSTONE & CLAY, GRAVEL
2V 3E- 210C	45-38.33	122-26.42	RDH-CAY2 2/ 6/80	79	9.02	30.0 73.0	1.34 .09	9	37.9 .9	37.0	49	B	CLAY, BASALT & GRAVEL
2V 5E- 360DA	45-36.75	122- 7.50	GROSS 7/10/79	268	8.04	10.0 30.0			43.5 .3	36.3		C	Basalt & SANDY CLAY
						30.0 50.0	(1.05)		65.0 4.9	54.2	57	C	
						50.0 90.0	(1.59)		45.5 .7	45.5	(72)	C	
2V 5E- 360DB	45-36.72	122- 7.65	PATTEN 7/25/79	274	7.05	10.0 30.0			46.2 1.8	38.5		B	CLAY AND BASALT
						30.0 55.0	(1.05)		67.1 2.8	55.9	(59)	B	
						55.0 105.0			42.9 1.6	35.8		B	
						105.0 129.0	(1.05)		76.4 1.9	63.7	(67)	B	
1V 3E- 208	45-38.92	122-23.88	RDH-CAY1 2/ 6/80	87	9.89	80.0 150.0	1.99 .04	17	31.8 .2	31.8	90	A	Basalt & CLAYSTONE

Usually the poor quality data are affected by intrahole water flow in holes which are intended to be water wells, and thus were uncased and ungrouted over at least part of their depth.

Terrain corrections have been made or estimated for all of the holes listed under the corrected heat flow column. The terrain corrections were generally made by the technique of Blackwell et al. (1980), or by the technique of Birch (1952). Other aspects of the heat flow/geothermal gradient measurement and calculation techniques are discussed by Roy et al. (1968) and others. A recent summary of hardware techniques for heat flow studies is contained in Blackwell and Spafford (1985).

The location of all holes for which logs were obtained by SMU/DNR are shown on Figure 1 (from Table 1 and Appendix A). Also shown are physiographic provinces for the state. Since the heat flow and geothermal gradient patterns are related to the geology and tectonics as embodied in the different provinces, these areas make natural divisions for discussing geothermal potential.

Summary maps of the heat flow and geothermal gradient data are shown as Figures 2 and 3, respectively. The data illustrated were taken from Table 1. Only one symbol is shown for each site, and where appropriate, the results have been averaged to give the values shown on the map. Both the geothermal gradient and heat flow maps have been contoured. The contouring was done by hand and at least partially based on presumed association with physiographic setting. This assumption is necessary in the northern Cascade Range and coastal provinces because of the scarcity of data within these areas. Another large data gap exists in the southeastern Washington. There seems to be

Figure 1. Location and physiographic province outline map for the state of Washington. Volcanoes in the Cascade Range are also shown for reference. Sites of holes which were logged by SMU/DNR as part of this project are illustrated in the figure. The solid symbols indicate sites where reasonable quality data (shown in Table 1) were obtained. Solid circles = A-quality values; solid squares = B-quality values; and solid triangles = C-quality values. The open symbols show sites where poor quality data (Appendix A) were obtained. Open circles = D-quality values, and open triangles = X-quality values.

Figure 2. Heat flow map of the state of Washington. Data of acceptable quality (Table 2) are plotted on this figure. The map is contoured where data density permits. Physiographic province outlines from Figure 1 are shown as an overlay on the map. The volcanoes in the Cascade Range (large solid triangles) are also shown for reference. Solid circles = A-quality values, open circles = B-quality values, and open triangles = C-quality values. The location of the cross-section illustrated in Figure 6 is indicated on the map.

Figure 3. Geothermal gradient map for the state of Washington. Geothermal gradients from holes or sites of acceptable quality (Table 2) are shown in this figure. Where feasible the gradients are contoured. Physiographic province outlines from Figure 1 are shown as an overlay on the map. Symbols as in Figure 2.

little water well development along a broad northwest-southeast trending zone through the Columbia Plateau. With the exception of a few points near the center of this zone, an area 60 to 70 km wide and 200 km long has no heat flow data available. This data gap makes interpretation of the Columbia Plateau results problematical. The major patterns within the state are, however, quite well documented.

In the following sections geothermal data from each major physiographic division of the state will be discussed individually. The data are summarized in the final section.

MEAN ANNUAL GROUND SURFACE TEMPERATURE

The various research groups (WRD, WSU, SMU/DNR) have measured temperature as a function of depth in a large number of water wells in the Columbia Plateau, but, as will be discussed in a subsequent section, interpretation of individual temperature-depth curves is very difficult because of the ubiquitous presence of borehole water disturbances in the wells. These water disturbances often make it very difficult to decipher the appropriate geothermal gradient for an individual hole. Therefore, another type of systematic approach to interpretation of the data was attempted. This approach involved obtaining a bottom hole temperature from the logs for each well and independently estimating the mean-annual ground-surface temperatures at each site. The difference of these two temperatures divided by the depth of the hole gives an approximation of the geothermal gradient at each site.

Thus, as part of the analysis of the data, mean-annual ground-surface temperatures in various provinces were obtained and analyzed. The mean-annual

ground-surface temperature for each individual well, where such a quantity can be determined, is listed with each site in Table 1 (and in a few cases for the holes listed in Appendix A). The temperatures were obtained by extrapolating the temperature-depth curve from the shallowest observed point to the surface. The data listed in Table 1 were analyzed by calculating a best-fitting straight line to groups of surface temperature-collar elevation data from each province or group of provinces. Results from four of these fits are shown in Table 2A. Surface temperature versus collar-elevation plots for the data from Table 1 are shown in Figure 4. Also shown on Figure 4 are the best-fitting straight lines for two of the groups of data.

On the basis of visual inspection, surface temperatures in the coastal provinces and in the western part of the Cascade Range appear to be controlled by similar influences. Data from the Columbia Plateau and northern Rocky Mountains also seem to be related. This grouping makes climatic sense, as a major factor controlling the weather is the Cascade Range axis, with much warmer and dryer weather in eastern Washington and cooler and damper weather in western Washington. Fits are also listed in Table 2A for the Northern Rocky Mountains and the Columbia Plateau provinces, individually. However, in each province there is only a limited range of elevation. Consequently, the fits are not as well determined, and the correlation coefficients are the lowest of the groups presented in Table 2A.

The variation of temperature at any individual elevation is quite large, on the order of $\pm 2^{\circ}\text{C}$ for the Northern Rocky Mountains and Columbia Plateau provinces, and $\pm 1.5^{\circ}\text{C}$ for the coastal provinces. Obviously, estimation of the surface temperature with these equations is relatively inaccurate. In an

Table 2: Mean annual ground surface temperature. In the first part of the table (A), the results of least-squares fits to surface temperature and elevation data in the form of the equation $T_s = T_o + \alpha'z$ are presented. In the second part of the table (B), least-squares fits to surface temperature, elevation, slope orientation and slope angle data in the form of the equation $T_s = T_o + \alpha'z + b\phi + c\theta$ are presented. T_s is mean annual ground-surface temperature, T_o is temperature at sea level, z is elevation (in kilometers), α' is lapse rate (in $^{\circ}\text{C}/\text{km}$), ϕ is slope angle in degrees and θ is slope orientation in degrees.

(A)

$$T_s = T_o + \alpha'z$$

	T_o $^{\circ}\text{C}$	α' $^{\circ}\text{C}/\text{km}$	N	Correlation Coefficient
Coastal Provinces + Western Cascade Range	9.78	-4.8	91	0.76
Northern Rocky Mountains	12.68	-5.7	35	0.74
Columbia Plateau + N.R.M.	15.98	-8.7	81	0.84
Columbia Plateau	15.98	-7.7	74	0.70

(B)

$$T_s = T_o + \alpha'z + b\phi + c\theta$$

	T_o $^{\circ}\text{C}$	α' $^{\circ}\text{C}/\text{km}$	b Deg.	c Deg.	Corr. Coef.
Coastal Provinces + Southern Cascade Range	10.31	-5.82	+0.024	-0.0002	0.89
Northern Cascade Range + N.R.M.	13.30	-6.87	+0.064	-0.001	0.86
Columbia Plateau	14.85	-5.1	-0.076	-0.0001	0.78

Figure 4. Surface temperature versus elevation plots for the state of Washington. Temperature data are plotted as a function of elevation for different groups of physiographic provinces. Straight lines illustrating the fit to data from the coastal provinces and western Cascade group of data (solid line to left), and the Columbia Plateau-Northern Rocky Mountain-Northeast Cascades group of data (solid line to right) are included. The two-dimensional fit from Table 2 for the Columbia Plateau-Northern Rocky Mountains is illustrated as a dashed line. Data from the Coastal Province and western Cascade Range are plotted with x's, data from the Northern Rocky Mountains are plotted with circles, and data from the Columbia Plateau are plotted with dots.

attempt to improve the accuracy of the estimation, the additional parameters of the slope orientation and inclination at each particular site were included in the calculated fits. Detailed studies discussed by Blackwell et al. (1980) indicate that within small geographic areas much of the actual variation in ground-surface temperature is related to microclimatic effects, in addition to the commonly recognized effect of elevation (controlled primarily by the lapse rate of air). All of the data that were available through 1979 were analyzed using a multiple linear regression program in order to get as accurate a model of the mean-annual ground surface temperature as possible. At that time many of the SMU/DNR holes in the Columbia Plateau were not available, and data from the Oregon part of the Columbia Plateau were included so that a larger data set could be examined. The resulting equations calculated using data from three provinces or groups of provinces are shown on Table 2B. The equations are somewhat different from those shown in Table 2A, because they include the additional terms of slope orientation and slope inclination, and because the same data sets are not compared. Correlation coefficients are improved slightly in all cases compared to similar data sets using elevation alone (Table 2A). However, it is quite clear from the size of the slope orientation and inclination terms that these effects are relatively minor. For example, localities with the same elevation and slope angle on opposite sides of a hill (i.e., a 180° difference in slope orientation) in the Northern Cascade Range and the Northern Rocky Mountains would have a maximum difference in surface temperature of 0.2°C. The maximum temperature difference in the same situation in the other two provinces would be less than 0.1°C. Similarly, for typical slope angles in the Columbia Plateau (less than 10°), the effect on the temperature would be less than .8°C.

The constant and elevation terms for the Columbia Plateau relationship can be used to plot a straight line in elevation-temperature space (see Figure 4). However, this straight line only represents part of the relationship. Plotted in this way the two relationships (from Table 2A and 2B) cross at 500 m and are never more than about 1°C different. Since the curve lifted in Table 2B for the Columbia Plateau was not constrained by the Northern Rocky Mountain data, it tends toward higher temperatures at higher elevations. For the purposes for which this information is used, the two equations can be considered statistically equivalent. The relationship in Table 2B is used in the analysis in a subsequent section of gradients from water wells logged by the WRD in the Columbia Plateau.

COASTAL PROVINCES

Included in this section is a discussion of heat flow values from the Puget Lowland, the Coast Ranges, and the western part of the southern Cascade Range (see Figure 1). The Olympic Mountains and Willapa Hill provinces are essentially untested at the present time, however. These provinces are underlain by Cenozoic rocks that have had a complex history. In northwestern Washington one heat flow measurement was obtained on Fidalgo Island from the older ophiolite complex exposed there (34N/1E-2CBB). Most of the rocks in the province are volcanic and volcanoclastic units, and thermal conductivity values tend to be below average for continental material. Hence, for a given heat flow, geothermal gradients will be slightly higher than in a basement terrain.

Throughout much of the Puget Lowland, there is a thick sequence of glacial till and gravel. Gradients are abnormally low within this glacial

till and gravel due to the generally active groundwater flow in these very porous and permeable units. This circulation causes lower temperatures at depth beneath the major population centers than would be expected based on the average gradient values found in the bedrock units.

The heat flow values for this province are shown on the map in Figure 2 and in histogram form (from data listed in Table 1) in Figure 5. Geothermal gradients are shown on the map in Figure 3 and as a histogram in Figure 5. The range in geothermal gradients is from $38^{\circ}\text{C}/\text{km}$ to $10^{\circ}\text{C}/\text{km}$. The higher geothermal gradients are usually associated with lower thermal conductivity rocks (such as the clay rich units). For example, the drill hole located at 12N/1W-9CCC has a range of geothermal gradient of $18\text{--}33^{\circ}\text{C}/\text{km}$; this variation in gradient is province associated with thermal conductivity variations within the hole. The average geothermal gradient of $24.5 \pm 1.3^{\circ}\text{C}/\text{km}$ is associated with the volcanic units that make up the bulk of the rocks exposed. Heat flow values are below normal in this province, ranging from as low as 20 to as high as 55 mWm^{-2} . The average is $39.8 \pm 1.6 \text{ mWm}^{-2}$, which is well below the typical continental average of 60 mWm^{-2} . Hence, the geothermal potential in these provinces for anything except warm water is quite small. The only thermal manifestations are associated with hot springs in the Olympic Mountains. No data have been obtained in the vicinity of these thermal anomalies, so the geothermal significance of those features cannot be assessed from the present data. It does not appear to be very great, however.

The origin for this low heat flow is associated with the subduction of the Juan de Fuca oceanic plate beneath the western part of North America. As the oceanic block sinks beneath the continental plate, the upper part of the

Figure 5. Histograms of geothermal gradient (A) and heat flow (B) for the coastal provinces are shown. Values are taken from Table 1. Provinces included are the Puget Lowlands, Olympic Mountains, Willapa Hills, and the Cascade Mountains west of the high heat flow zone. Band of gradients in gradient plot shows range in gradient in hole 12N/1W-9CCC associated with lithologic variations.

oceanic plate absorbs heat from the continental block, causing the low heat flow. This zone of abnormally low heat flow has been identified from British Columbia to Baja California (Roy et al., 1972; Hyndman, 1976; Blackwell, 1978). The intermediate focus earthquakes beneath the Puget Sound area are a manifestation of this subduction activity. The heat flow pattern in Oregon has been discussed in detail by Blackwell et al. (1982). In Oregon an abrupt change in heat flow from low along the coastal provinces to high in the Cascade Range is associated with a north-south zone in the western Cascade Range marked by hot springs. A similar type of boundary exists in the southern Washington Cascade Range described in the following section.

CASCADE RANGE

Regional Geothermal Setting The Cascade Range is obviously the province of greatest medium- and high-temperature geothermal potential in Washington. Clear indications of such geothermal potential within the province include five active or dormant stratovolcanoes and numerous hot springs. A major part of the project involved the drilling of a number of holes in the central and southern Cascades in order to evaluate the thermal conditions there. The northern Cascades remain relatively unstudied as there are only two drill holes there. Results from those two drill holes are described by Korosec (1983).

There have been extensive studies of geothermal gradient and heat flow in the Cascade Range in Oregon. Major results include the location of a sharp eastward transition from lower than normal heat flow to much higher than normal heat flow within the Western Cascade Range, and mapping of a high heat

flow zone for the length of Oregon. Average heat flow values in the high heat flow zone are $100 \pm 7 \text{ mWm}^{-2}$ and average gradient values are $64 \pm 4^\circ\text{C/km}$ (Blackwell et al., 1982; Black et al., 1983).

As part of the Oregon studies, extensive drilling was carried out near the Mt. Hood volcano (just a few kilometers south of the Columbia River). The results of the heat flow studies there are described by Steele and Blackwell (1982). The heat flow data in northern Oregon indicate that the average heat flow value in the high heat flow zone decreases in amplitude between Mt. Jefferson and Mt. Hood so that the background heat flow in the vicinity of Mt. Hood is 70 to 80 mWm^{-2} instead of the 100 mWm^{-2} observed south of Mt. Jefferson. One of the remarkable things about the heat flow and gradient pattern is the sharp western boundary to the high heat flow zone. The change from high to low heat flow occurs over a distance of approximately 20 km. The resulting half-width of 10 km indicates a depth of the source of less than 8 to 10 km. Heat flow measurements in British Columbia indicate a similar pattern of low heat flow along the coast and high heat flow inland, although the high heat flow values range from only 60 to 80 mWm^{-2} . The transition from low to high heat flow occurs along a line of gravity gradients, anomalous uplift rates, and faulting (Lewis et al., 1985; Hyndman, 1976).

Washington Cascade Range Heat Flow Within the state of Washington there is a transition in the geologic nature of the Cascade Range. South of approximately 47° , the geology of the Cascade Range is predominantly of Cenozoic volcanic rocks (similar to that in Oregon). There is a significant amount of late Cenozoic basaltic volcanism in the areas between the major stratovolcanoes,

Mt. Hood, Mt. St. Helens, and Mt. Rainier. Two of these centers are the Indian Heaven area in the south central part of the range and the Simco volcanic field to the southeastern part of the range. North of Mt. Rainier, the bedrock geology is predominantly early and pre-Cenozoic crystalline rocks, including both granitic intrusive rocks and metamorphic rocks. The only late Cenozoic volcanic rocks are the andesite volcanoes themselves, Glacier Peak and Mt. Baker.

The heat flow and geothermal gradients in the Indian Heaven area were studied by Schuster et al. (1978) using a number of drill holes. They found typical gradients of about $50^{\circ}\text{C}/\text{km}$ and heat flow values of about 60 to 70 mWm^{-2} . In 1981 a line of drill holes along the Cowlitz River was established as part of this project. Drilling was contracted and coordinated by the Washington Department of National Resources with the temperature and thermal conductivity measurements being made by personnel from S.M.U.

The results of the heat flow measurements along this cross section are shown in Figure 6. A pattern similar to that observed in Oregon was obtained, although with a slightly reduced amplitude. Heat flow values west of approximately 122° West longitude are below the continental average and were discussed in the previous section. Typical values are 30 to 40 mWm^{-2} , and typical gradients are 15 to $25^{\circ}\text{C}/\text{km}$. Heat flow values east of that line are typically 70 to 90 mWm^{-2} , and gradients range between 34 and $67^{\circ}\text{C}/\text{km}$. West of approximately $120^{\circ}45'$, heat flow values decrease to less than 60 mWm^{-2} , and geothermal gradients range from only 30 to $40^{\circ}\text{C}/\text{km}$. The eastern boundary of the high heat flow along the Cascade Range axis is not as well located as the western boundary and is of lower relief than the western boundary (10-20 mWm^{-2}

Figure 6. Heat flow cross section for the southern Cascade Range. Heat flow data are plotted as a function of distance along a line which passes approximately along the Cowlitz River in southwestern Washington. The location of Mt. Rainier is shown for reference.

instead of $30\text{--}40 \text{ mWm}^{-2}$). These results, together with the results from the Indian Heaven area, document a broad zone of high heat flow along the axis of the Washington Cascade Range. The sharp boundary to the west is analogous to the anomaly characteristics in Oregon.

This contrast in heat flow and geothermal gradient is clearly illustrated by temperature-depth curves from the Cascade Range and coastal provinces shown in Figure 7. Most of the holes that might be part of what could be called a "Cascade Anomaly" are shown as are about half of the wells in the low heat flow zone to the west. The difference between the two sets of data is immediately obvious, and there is no doubt that they are parts of quite separate data sets.

As shown in Figure 6, the least distance between holes that are part of the low heat flow zone and holes that are part of the high heat flow zone is approximately 20 km (distance between holes 13N/5E-18ABD and 12N/7E-16CC). This is about the same distance as the boundary between the high and low heat flow zones in Oregon and British Columbia, suggesting a similar depth to the source causing the contrast in heat flow. A similar half-width seems to be implied for the eastern side, although the boundary is constrained at only one location.

Unlike the situation in Oregon, where the heat flow zone has been identified for a lateral distance of several hundred kilometers, the high heat flow zone along the Cascade axis in Washington seems to be discontinuous. For many years the only heat flow values in the Cascade Range were those published by Blackwell (1969) near Snoqualmie Pass in the central Washington Cascades. Heat flow values there are approximately normal for continents, and the

Figure 7. Temperature-depth curves for the Cascade Range and Coastal provinces. Illustrated are plots of temperature-depth data for many of the holes in the coastal provinces (low heat flow) and the Cascade Range high heat flow region (see Figure 2). Also illustrated are curves for the two holes west of Mt. St. Helens to illustrate their association with the low heat flow province.

inference was reached that there was no significant anomaly associated with the Cascades. These data stood uncontested until the heat flow measurements of the Oregon program were carried out in 1976.

In addition to the holes discussed by Blackwell (1969), a measurement was obtained just north of the Snoqualmie Pass area at a mineral exploration location, and two holes were drilled in the area as part of this project. Two other holes were drilled near the hot spring at Stevens Pass.

The heat flow values from the two holes drilled near Snoqualmie Pass (22N/11E-4BDA and 23N/11E-33CAB, Appendix B) are both low/normal and confirm the normal values obtained by Blackwell (1969). In addition, a drill hole just to the south of Mt. Rainier also has a normal heat flow value. However, at Stevens Pass one of the heat flow values is anomalously high, and is obviously affected by the hot spring circulation, whereas the other heat flow value is approximately typical for those seen in the Cascade anomaly zone between Mt. Rainier, Mt. St. Helens, and Mt. Adams. The only hole north of these holes is on the slopes of Mt. Baker near Baker Hot Springs. It is clearly affected by the hot spring circulation and does not give a typical background value for that area (Korosec, 1983). However, as discussed above, data from British Columbia suggest the presence of an axis anomaly in the Cascade Range in British Columbia. Therefore, the reason for the low values observed in the Snoqualmie Pass vicinity is not obvious. The values could be local anomalies due to some sort of water circulation, although this explanation seems unlikely since the holes are scattered over a large area and are in a variety of topographic settings. A discontinuous heat source at depth is an alternative and favored explanation for these variations in heat flow.

An interesting result of this drilling project is that Mt. St. Helens sits almost exactly on the boundary between high and low heat flow, and thus would presumably be in the most western position for a volcano associated with the Cascade Range arc. Mt. Adams appears to lie close to the eastern boundary of this anomaly. Therefore, the presence of two volcanoes at the same latitude might be explained by the fact that they are fed by local concentrations of magma which span the width of the anomalous zone, whereas at Mt. Rainier the magma is fed from the center of the anomalous heat flow zone.

Temperature-depth curves from two holes immediately west of Mt. St. Helens are superimposed on Figure 7 and clearly indicate their association with the low heat flow set of holes. These holes were drilled in 1979. The planned drilling project on the east side of Mt. St. Helens for 1980 could not be carried out, and hole 9N/5E-18BB was buried by the debris flow associated with the collapse of the north side of the volcano on May 18, 1980.

Another anomalous feature of the heat flow along the Cascade Range axis is associated with the Columbia River. Although there are several heat flow values that were typical of the anomaly zone (60 to 70 mWm^{-2}), east of Bonneville and including much of the Simco volcanic field, heat flow values average about 50 mWm^{-2} , and typical gradients are 30°C/km . Temperature-depth curves from holes in the Columbia Gorge typically suggest low gradients and often appear to be curved, possibly indicating regional down-flow of water. Temperature-depth curves from the Quaternary volcanics often are very complicated, and in some cases show evidence of transient lateral flow of warm water. Examples of the different types of temperature-depth curves are illustrated in Figure 8. Because no deep holes have been drilled in the

Figure 8. Temperature-depth curves for holes in the Columbia gorge. The highest gradients are in the Bonneville hot spring area, while typically low gradients are observed elsewhere. Gradients with a component of apparent lateral warm water flow are common in the area of Townships 4N/15E to 17E. Every fifth point on each log is plotted by a symbol.

gorge, or in the vicinity of the Simco volcanic field, the observed pattern may need some revision when more data are obtained. However, it seems quite clear that there must be lower heat flow values in this part of the Cascade Range axis than there are to the north and to the south. It would be extremely important from a geothermal point of view to know whether this change in heat flow is associated with fluid circulation or with a gap in the heat source at depth. If it is associated with fluid circulation, then warm fluid must be circulating upward laterally at some depth, and there might be significant undiscovered potential for geothermal resources in the Columbia Gorge. Geothermal conditions there need to be tested by drilling specifically for heat flow/geothermal gradient studies and to depths greater than 150 m to determine the controls on the heat flow in that part of the Cascade Range.

In summary, heat flow in the Washington Cascade Range is much more complex and variable than that observed in the Oregon Cascade Range. The origin of the more complex pattern is not identified; some of the variation may be due to lateral variation in the strength or depth to the heat source that causes the high heat flow. Some of the variation may be due to local fluid flow conditions, and some of the variation may be due to the much larger thermal conductivity contrasts than are observed in Oregon. In Oregon almost all the rocks are volcanic and have approximately equal thermal conductivities. In Washington, however, there is quite a wide range of conductivity, from quartzite, as in hole 23N/11E-4DD in Snolqualmie Pass, to values typical of volcanic rocks. Consequently, gradients, even without variations in heat source strength and fluid flow effect, can be expected to be much more variable than in Oregon. The fractured granitic and metamorphic rocks in the

northern part of the Washington Cascade Range may be more brittle and more capable of holding open fractures, and thus be more susceptible to fluid circulation. Indeed the major geothermal field at Meager Mtn. (Fairbanks et al., 1982), where temperatures in excess of 200° have been obtained from holes drilled in fractured granitic rocks, indicates that there is certainly potential for deep fluid circulation in the geological environment existing in the Washington Cascade Range.

NORTHERN ROCKY MOUNTAINS

The northern Rocky Mountains physiographic province occupies the northeastern quarter of the state of Washington. The geology is complex, reflecting the Paleozoic and Mesozoic tectonic history of the Cordilleran Mountain chain. The area has extensive exposures of granitic basement rocks of Mesozoic and very early Cenozoic age. A few areas of Cenozoic rock exist, such as the Republic graben and other similar small extensional features. These features generally developed 30 to 45 m.y. ago during an extensional phase of tectonic activity. The province has been quite stable during the last 20 to 30 m.y. The topographic relief is high but the area is not extremely rugged. Unlike areas of similar geology in central Idaho, there are a few hot springs in the Northern Rocky Mountains in Washington. Thus there is very little overt evidence that might suggest high or moderate temperature geothermal potential. Indeed temperature measurements in over 50 holes in this province have yet to identify a gradient in excess of 35°C/km, with the one exception of a hole in very low thermal conductivity Cenozoic clay.

Histograms of corrected gradients and heat flow from data listed in Table 1 are shown in Figure 9. The average geothermal gradient is $26.0 \pm 1.2^\circ\text{C/km}$ and the average heat flow is $74.9 \pm 2.9 \text{ mWm}^{-2}$. The measured gradients for the holes of acceptable quality range from 14°C/km for hole 22N/11E-4BDA to 45°C/km in hole 30N/13E-36DDB. This range in gradient reflects variations in thermal conductivity and not variations in heat flow. The highest gradient is observed in unconsolidated to semiconsolidated clays and silts within a small Cenozoic basin, and the lowest geothermal gradient is associated with the highest thermal conductivity rocks, i.e. quartzites. In general, gradients of 30°C/km or higher are associated with Cenozoic volcanic and sedimentary rocks that have generally lower thermal conductivities than the older rocks. Gradients between 20 and 30°C/km are associated with granitic rocks that make up a large fraction of the bedrock of the Northern Rocky Mountains.

The heat flow at one of the sites in the Northern Rocky Mountains, the Wilbur site in 3N/33E, has been discussed in detail by Blackwell et al. (1980), in association with terrain corrections for heat flow. Even though the uncorrected gradients vary by a factor of 3, the corrected heat flow values and gradients for all the holes are similar and are typical of others observed in the province.

There is a very small variation of heat flow values. The lowest heat flow is 48 mWm^{-2} in hole 24N/44E-6BC. This hole is relatively shallow; it has a gradient typical of other granitic gradients in this province, but a lower thermal conductivity. The heat flow in an adjacent hole (24N/44E-10AD) has a slightly higher than average gradient and thermal conductivity, which gives a higher than average heat flow. A possible explanation for these local

Figure 9. Histograms of geothermal gradient (A) and heat flow (B) for the Northern Rocky Mountain Province. Data are taken from Table 2.

variations in heat flow is small scale variations in conductivity, so that in this local area there is not a direct correlation between thermal conductivity and geothermal gradient. Another possible explanation is a sampling problem in these water wells; only a grab sample from a cuttings pile was obtained for thermal conductivity measurement.

Two sites of normal gradient but slightly high heat flow are found in extreme northeastern Washington (Roy et al., 1968; Blackwell, 1969). These values have been interpreted to give normal heat flow values with the high apparent heat flow associated with the refraction of heat into the very high thermal conductivity dolomites encountered at these two localities. In this case, the gradients are a more accurate measure of the background thermal conditions than are the heat flow values.

As discussed by Blackwell (1974), heat flow values in the Northern Rocky Mountains are typical of those observed throughout the Cordilleran Thermal Anomaly Zone, which includes the Basin and Range province and the Northern Rocky Mountains. No radioactivity determinations have been made as part of this study, but based on knowledge of the distribution of radioactivity in this province, the pattern remains as discussed by Blackwell (1974). Lower values of heat flow ($65 - 70 \text{ mWm}^{-2}$) are associated with lower values of heat generation. The highest heat flow values, particularly those near the Spokane River west of the town of Spokane, are associated with radioactivity values that are above the background and range up to $4 \text{ } \mu\text{Wm}^{-3}$ (Steele, 1975). Based on a comparison of these data to those from other parts of the Cordillera, it would appear that the mantle heat flow in this region is on the order of 60 mWm^{-2} , and the slope associated with the heat production from the upper part of the continental crust is on the order of 10 km.

COLUMBIA PLATEAU

Introduction The Columbia Plateau occupies the southeastern third of the state of Washington. The geothermal conditions in this area are of considerable interest. Irrigation development of groundwater aquifers along flow contacts between basalt layers and in interbedded sedimentary rocks has been widespread, and a number of the water wells have been drilled to quite great depths. If an economic incentive exists, this major water resource might be a major geothermal resource as well. Geothermal energy may be used in many different ways associated with the many farming-and industrial-related projects in the Columbia Basin. Consequently, the object of this section of the report is to evaluate the geothermal conditions in this province. Because of the large number of wells and the importance of the groundwater resources, extensive hydrologic studies have been carried out in various parts of the Columbia Plateau. However, the regional setting of the detailed hydrologic studies and the way the many aquifers and areas of development interrelate is a subject for which there is very little information.

Recently, great interest has been shown in the area for gas exploration, and several wildcat wells have been drilled. In this case, knowledge of the subsurface temperatures and geothermal gradients is important in determining the amount and rate of organic maturation occurring beneath the basalt.

The thermal data for the Columbia Plateau have been collected by three different organizations - the U.S. Geological Survey Water Resources Division (WRD) operating out of Tacoma, Washington; the Department of Hydrology at Washington State University (WSU), Pullman; and Southern Methodist University/

Washington Department of Natural Resources. Some aspects of the copious WSU data base have been discussed briefly by Stoffell and Widness (1983a,b) and Widness (1983). Many of the well logs have been presented by Biggane (1980) and Stoffell and Widness (1983b).

Complexity of Temperature Logs We compiled an extensive data base of temperature logs for use in this study in an attempt to evaluate the background thermal conditions of the Columbia Plateau and in order to look for local thermal anomalies that might indicate higher than average potential for geothermal energy in particular places in the Columbia Plateau. In spite of this extensive data base, however, there are still many uncertainties about the thermal conditions in the Columbia Plateau. Most of these uncertainties arise from the fact that the holes that have been logged have been drilled almost exclusively as water wells, and the casing and cementing programs have obviously been minimal. Further, there are no holes that have been continuously cored and from which reasonably accurate in situ thermal conductivity estimates can be obtained. Hence we have little idea of possible vertical or lateral variations in thermal conductivity that undoubtedly must occur due to interbeds and the different proportions of vesicular versus non-vesicular basalts. The most serious problem, however, is the nature of the hydrology associated with the basaltic aquifers. The permeabilities across individual basalt flows are quite low, whereas along contacts between flows, permeabilities are quite high. Also recharge to the aquifers is quite distant from the points of development of the aquifers, and flow paths within the aquifer system may be complex and time dependent. Temperature logs for water

wells in the Columbia Plateau are typically some of the most complex these authors have ever encountered, and the logs are most difficult to interpret. Thus in spite of this large data base, the thermal pattern of the Columbia Plateaus still quite ambiguous.

Some of these complexities can be illustrated by reference to specific temperature-depth curves for some of these wells. One of the most interesting wells, the Development Associates Basalt Explorer No. 1 (DABE-1), is represented by a series of logs. This well was drilled as a hydrocarbon exploration test in 1960. It was first logged by R. F. Roy on 8/31/61 (see Figure 10). Subsequently, the hole had a checkered history that culminated with its being plugged for a time by local ranchers because they could hear fluid cascading down the hole. It was opened by the U.S. Geological Survey Water Resources Division for hydrologic tests in 1972, at which time it was logged by the WSU group and by the U.S.G.S. geothermal studies program, Menlo Park, California. The hole was subsequently plugged back to a depth of 730 m and is maintained as a water level monitor well by the WRD. Well logs measured in 1981 by the SMU group, and on 6/15/72 by the WSU group are also shown in Figure 10.

Water flow conditions on the original logging in 1961 appear to be the simplest. Water entered the hole at the water table (at a depth of approximately 40 m), flowed down the hole to a depth of between 700 and 800 meters, and exited into the formation at that depth. Below 800 m, the gradient was nearly constant, and the temperature-depth curve was quite linear except for the very bottom part of the hole. The bottom isothermal section may have been due to additional intrahole water flow or due to the fact that

Figure 10. Temperature-depth curves for Development Associates Basalt Explorer #1. Three logs measured over a 20 year period are illustrated for this hole. Logs were obtained by R. F. Roy of Harvard University (1961), personnel from Washington State University (1972), and SMU (1981). Every fifth point on each log is plotted by a symbol.

the cable had hung up (and this fact was not recognized). The hole was logged to the end of the cable at about 1200 m.

When the hole was cleaned out in 1972, the flow pattern had changed drastically. In 1972 water flow in the hole was both up and down from an entry point of about 500 m. The rate of flow down the hole was quite low and occurred between depths of about 500 and 800 m. The artesian (up) flow occurred between 500 and 300 m. The presence of up-flow is indicated by temperatures above the interpolated temperature-depth curve from below 900 m and the surface temperature intercept (about 12°C). The curved temperature-depth relationship between 200 and 300 m and the higher than interpolated temperature suggest up-flow with that part (200-300 m) of the hole being heated from invasion of the formation at 300 m by the upward flowing warm water (from 500 m). The sharp negative-slope part of the curve between 500 and 600 m is very difficult to explain unless up- or down-flow in an aquifer outside the well bore is included. The temperature data between 100 and 200 m may represent the background gradient and thus may be unaffected by water flow in the 1972 log.

Following plugging of the hole a second time and its development as a water level monitor well, the flow pattern of the hole changed again. When the well was logging during 1981, there was down-flow through most of the hole, with water entering at the water table and exiting at two locations, between 210 and 300 m and at a depth of approximately 450 m. An aquifer at 300 meters was either donating fluid or extracting fluid. Based on local aquifer conditions within the boreholes, gradients both higher and lower than the 'true' value might be encountered. For example, if the probe had not been

able to reach below 300 m in DABE-1 during the different times of logging (perhaps because of a casing change, partial hole collapse, etc.), gradients ranging from 0 to 55°C/km would have been measured.

Most of the holes in the Columbia Plateau are drilled as water wells; therefore, when a water flow of appropriate quantity is encountered or when enough water bearing zones have been encountered to allow development of the appropriate amount of fluid, drilling is terminated. As a consequence, water wells almost without exception bottom in or just below aquifers. Another limitation with the well logs is that logging starts at the water table; consequently, if the well has up-flow from the water table or a deeper aquifer, the first measured temperature may be too high. Logs of many of the wells consist of a vertical line (isothermal). Given the propensity of fluid to flow within the wells following completion, it becomes virtually impossible from a single well to decipher the nature of the thermal and fluid flow conditions existing at that location.

Because of these complexities, different approaches must be employed to determine the thermal characteristics of the Columbia Plateau. We collected as much of our own temperature data as possible, and also interpreted the existing temperature data in the WRD files. A limited amount of time was spent evaluating temperature data from the WSU files. The project remains a useful one for the future in view of the extensive WSU log data base that exists.

Analysis Using WRD Temperature Logs During the early 1970's, the U.S. Geological Survey Water Resources Division (WRD) collected numerous well logs

for the Columbia Plateau. These included flow logs, natural gamma logs, temperature logs, and other sorts of logs recorded in analog form on chart paper. Their primary interests were hydrological/geologic studies, and the temperature data were not extensively used. We attempted to use this large data set in order to obtain a good regional distribution of temperature gradients for the Columbia Plateaus. Because of the complexity of the temperature-depth curves, and the fact that logging did not start until the water table was reached, sometimes tens of meters below the surface, no attempt was made to measure gradients from the logs. Bottom hole temperatures were read from all of the logs and surface temperature was estimated for each of these wells based on the elevation, the direction, and the angle of the slope of the surface at the collar.

The surface temperatures were taken from SMU/DNR well logs, which had temperature measurements in air above the water table, and consequently allow a reasonably accurate estimation of the mean-annual ground-surface temperature. The temperature versus elevation/slope/orientation equation that was discussed in a previous section was used to estimate the appropriate mean annual surface temperature at the hole collar for the WRD logs. The estimated error of this approach, as discussed earlier, is at least several degrees C for any individual hole, but given the large number of holes, the systematic error should be relatively small.

An additional complexity arises in that there is a calibration problem with at least one of the WRD temperature tools. In a direct comparison in 1971 at a hole in Gig Harbor, the WRD tool measured 6°C above the SMU tool. Comparison of our equipment with another WRD tool used for a log at the hole

at Westport, Washington (16N/12W-24DAD), shows that the WRD instrument and the SMU instrument are within 0.5°C of each other and give the same gradients. We attempted to sort through the U.S.G.S. data to isolate the holes which might have this calibration problem. The particular instrument that was found to be inaccurate recorded on the logs in $^{\circ}\text{C}$. It seems to have come in use some time in 1971. In only a couple of cases were there obvious problems associated with calibration, and these will be discussed briefly below. In several of the holes, it appears that one of the instruments may in fact have been calibrated too low, and there are a couple of discrepancies between the calculated surface temperature and the surface temperature extrapolated from the temperature-depth logs. Of course, given the uncertainty of the water flow within the holes, this result is not surprising. In this case, the actual gradient shown was obtained from using an appropriate lower surface temperature to eliminate the negative gradient which would otherwise have occurred.

A number of the WRD logs were digitized in 1979. These data were then sorted to pick out the holes which were the deepest and had logs which had the best chance of showing a gradient. The average gradient for the Columbia Basin was calculated, not including holes less 75 m deep and showing the low temperature calibration problem. The average gradient for this data set was found to be approximately $40.0 \pm 2.1^{\circ}\text{C}/\text{km}$. Table 3 shows the location, elevation, slope angle, slope orientation, calculated surface temperature, bottom hole temperature, depth, and estimated geothermal gradient for these particular WRD drill holes in the Columbia Plateau. A histogram of this data is shown in Figure 11. If all WRD logged holes, including lower quality ones, were used, the average is $37.5 \pm 2.0^{\circ}\text{C}/\text{km}$ (N=143 using data included in Appendix B).

Table 3. Location, terrain and bottom hole temperature data from WRD well logs in the Columbia Plateau. Estimated gradient from calculated surface, and measured bottom hole temperature is shown in last column.

Location	Elevation m	Slope angle degrees	Slope orientation degrees	T _s °C	T _{BHT} °C	Depth m	Calculated Gradient °C/km
3N15E22AD	487.8	0.5	360	12.3	18.11	182.3	31.8
3N15E29BA	487.8	0.5	40	12.3	16.3	182.9	21.6
4N15E16BD	481.7	0	270	12.4	18.5	179.2	34.1
4N16E16CA	512.2	5.0	190	11.9	17.4	103.6	53.4
4N16E28AA	525.9	1.0	280	12.1	19.5	164.6	45.8
4N16E34AD	548.8	0.0	90	12.0	18.5	152.4	42.6
5N15E25DB	658.5	1.0	180	11.43	19.6	213.4	38.5
5N20E27AB	759.1	0.5	180	11.0	22.8	274.3	42.9
5N22E27AA	336.8	2.0	150	12.9	28.2	321.3	47.6
6N30E12DC	359.8	7.0	120	12.5	21.1	298.7	28.8
6N34E7BA	147.9	1.0	180	14.0	40.2	407.2	64.2
6N35E18AA	204.0	0.0	310	13.8	21.3	398.7	46.2*
6N35E31BD	228.0	0.0	360	13.7	19.7	292.6	20.5
7N19E10B	885.0	2.0	135	10.4	14.4	119.5	33.8
7N19E14CC	933.6	1.0	360	10.0	14.2	128.0	32.8
7N27E29DC	350.6	7.0	270	12.5	14.9	142.0	55.6*
7N35E34DB	234.8	1.0	180	13.6	17.0	220.4	35.8*
7N36E14CD	354.0	2.0	270	12.9	15.2	406.6	25.2*
7N36E17CA	300.3	2.0	230	13.2	39.1	713.2	36.4
7N36E18CC	282.0	1.0	230	13.3	18.5	170.7	30.3
7N36E19BB	267.0	1.5	220	13.4	18.2	177.7	27.5
7N36E19BD	271.3	2.0	270	13.3	31.1	470.6	37.8
7N36E33BB	295.7	0.5	250	13.3	30.2	424.0	39.9
8N24E1DA	222.5	3.0	340	13.5	23.6	381.9	26.4
9N21E26CB	214.9	0.0	230	13.7	26.5	294.4	43.3
9N22E11DA	225.6	7.0	270	13.2	20.3	165.8	43.1
10N17E36AA	311.0	1.5	120	13.1	9.2	95.4	2.1*
10N18E5DC	257.6	0.0	300	13.5	20.62	195.1	36.5
10N20E9AA	230.2	0	130	13.7	20.5	256	26.6
10N25E25BC	460.4	2.5	180	12.3	20.6	184.1	45.0
11N16E15DA	388.7	0.5	135	12.8	18.2	219.5	24.4
11N17E16BD	292.7	7.0	360	12.8	31.6	301.8	62.3
11N19E15AA	259.1	0.0	180	13.5	20.8	179.2	40.6
12N17E2AC	432.9	1.0	90	12.6	16.1	85.3	41.5
12N17E7AC	509.1	5.0	360	11.9	19.5	79.3	96.3
12N18E32CA	335.4	3.0	180	12.9	27.9	379.2	39.5
12N20E27CB	376.4	2.5	270	12.7	26.8	397.2	35.4
12N21E20CD	432.8	5.0	360	12.2	24.4	315.2	38.7
12N21E22CD	451.2	2.5	180	12.4	16.6	71.9	58.4
13N19E22CB	332.3	5.0	270	12.8	20.0	79.3	90.6
13N19E24AB	475.6	1.5	230	12.3	44.4	230.4	139.5
13N20E29BB	457.3	2.5	210	12.1	22.7	175.9	60.6
13N21E34AD	705.8	1.0	200	11.2	23.8	310.9	40.5
14N29E9AA	386.0	1.0	120	12.8	22.2	213.4	43.9
14N32E31BB	259.1	0.0	270	13.5	28.5	304.5	49.3

Table 3 (continued)

Location	Elevation m	Slope angle degrees	Slope orientation degrees	T _s °C	T _{BHt} °C	Depth m	Calculated Gradient °C/km
15N31E11BC	381.1	2.0	340	12.7	20.0	212.2	34.4
16N30E26AA	416.1	5.0	250	12.3	26.2	192.0	72.4
16N30E27DA	387.2	2.5	90	12.7	25.2	207.3	60.4
16N30E36CA	375	2.0	360	12.8	19.4	210.6	31.5
17N33E20BB	397	0.0	230	12.8	14.6	97.5	17.9
17N32E12CD	529.9	2.5	330	11.9	21.0	225.6	40.3
18N25E27CC	347.6	0.0	180	13.1	21.2	228.0	35.5
18N26E31BD	344.8	0.0	230	13.1	20.4	215.8	49.1*
18N29E26CA	341.5	0.0	130	13.1	14.7	91.4	17.1
19N28E28DB	326.2	0.5	310	13.1	22.6	292.6	32.2
19N30E13BD	437.5	1.0	135	12.5	20.2	201.2	38.1
19N32E30CC	434.4	2.0	315	12.5	19.2	165.2	40.6
19N33E7AC	536.6	2.0	360	12.0	15.5	185.4	16.8
20N30E21BD	475.6	0.5	250	12.4	25.0	322.8	39.0
20N30E22BA	486.0	0.0	180	12.4	13.5	122.0	9.2
20N30E23BC	484.8	1.5	120	12.2	34.7	337.2	66.8
20N30E28DD	466.5	2.5	335	12.3	28.5	181.4	89.3
20N33E13AA	525.9	1.0	190	12.1	17.8	173.4	32.9
20N35E17BB	604.3	0.0	180	11.8	20.9	231.7	39.4
21N30E26AC	493.9	2.5	180	12.1	21.3	170.7	53.6
21N31E22BC	517.1	3.0	270	12.0	19.8	231.7	33.7
21N31E23BD	541.2	1.0	360	12.0	16.3	225.6	19.1
21N31E27DB	537.6	2.0	40	12.0	18.4	200.0	32.0
21N31E32BB	508.8	1.0	220	12.2	21.0	211.0	41.7
22N30E35BC	525.9	0.5	150	12.1	19.1	194.5	35.8
22N31E24AC	520.7	2.5	220	12.0	17.9	210.1	28.1
24N31E16BC	579.3	1.5	230	11.8	20.1	227.1	36.5
24N32E24AA	593.9	1.0	240	11.7	13.8	120.0	17.5
24N32E30CB	581.7	1.0	20	11.8	19.4	228.6	32.9
24N36E16AA	723.2	2.0	145	11.0	12.6	229.3	7.0
24N41E3CC	724.1	1.0	210	11.1	13.9	122.8	22.8
25N22E22CC	796.3	2.0	180	10.6	12.7	170.7	12.3
25N28E25AB	553.3	0.5	270	12.0	23.0	177.4	62.1
25N30E5DC	573.2	1.0	180	11.7	14.6	197.4	36.9*
25N33E27AA	707.0	2.5	135	11.1	13.0	149.9	12.7
25N36E21BA	728.6	0.5	270	11.1	12.9	120.7	32.2*
25N37E28AA	1285.1	0.5	360	8.3	8.8	68.6	14.6*
26N32E10AD	695.1	1.0	145	11.2	19.2	181.6	43.8

*denotes holes where the extrapolated rather than calculated T_s was used in the gradient calculation.

Figure 11. Histograms of geothermal gradient obtained from analysis of the WRD data for the Columbia Plateau. The technique used to obtain the gradients is discussed in the text. (A) Higher quality data (B) Lower quality data.

Gradients in holes logged by WRD determined this way range from over 100°C/km to less than 10°C/km. An obvious approach is to look for areas with higher-than-average gradients. Four areas that contained several holes with higher-than-average gradients were identified. These were areas referred to as the Wilson Creek anomaly (20N/30E), the Othello anomaly (16N/30E), the Yakima anomaly (13N/20E), and the Lowden anomaly (6N/33E).

The anomalous holes in each of the areas and their geothermal gradients are listed in Table 3. Further examination of data from the Wilson Creek anomaly suggested that the two holes with the highest geothermal gradients, 20N/30E-23BC and 20N/30E-28DD, were affected by the high temperature calibration problem, and equivalent temperatures logged in the same hole or holes in the same section by WSU or by other WRD equipment gave temperatures approximately 8°C lower. If these holes are removed from the consideration, than typical gradients in the Wilson Creek anomaly are approximately the same as gradients in the remainder of the Columbia Plateau.

There are three holes in the vicinity of the Othello anomaly, two of which have gradients significantly higher than the typical Columbia Plateau value and one of which is significantly lower. It would be useful to have addition information in the vicinity of this anomaly.

There are four holes in the general vicinity of the Yakima anomaly. Examination of gradients for the four holes suggests that the calibration problem affected the hole with the highest gradient (13N/19E-24AB). The hole with the second highest gradient was only 79 m deep, and cannot be considered reliable. This leaves two holes, one with a gradient of 60°C/km and a depth of 176 meters, and one with a gradient of 40.5°C/km and a depth of 311 m. The

cause of the high gradients is unresolved. However, none of the holes are very deep, and so deeper holes are required for evaluation. SMU/DNR data in 12S/20E indicates normal Columbia Plateau gradients there.

The Lowden anomaly is south-southwest of Walla Walla. One hole there has a bottom hole temperature of 40.3°C at 407 m. A hole logged by SMU/DNR has significantly a higher geothermal gradient as well (6N/33E-1DBD). Both the Lowden and the Yakima areas have a cover of sedimentary rocks on top of the Columbia River basalt, and there may be a large amount of interbedded sedimentary rock in the upper part of the basalt sequence. It is possible that the high gradients observed in these holes are related to low thermal conductivity in the sedimentary rocks, and are not associated with a geothermal anomaly due to circulating hot water. Further study of this area seems justified.

SMU/DNR Temperature Logs Several examples of temperature-depth curves from the Columbia Plateau are illustrated in this section (various parts of Figure 12). Beginning with the north part of the area (Figure 12a), hole 27N/37E-26AAD is shown as an illustration of a relatively high background gradient in the Northern Rocky Mountains. This hole was drilled in Oligocene volcanic rocks in a small graben along the Spokane River just north of the Columbia Plateau. The corrected geothermal gradient would be approximately 35°C/km because the hole was drilled along the river valley. Thus the gradient is typical for such rocks in the Northern Rocky Mountains. Also shown are temperature-depth curves for holes 24N/34E-16AAB and 24N/31E-16BCC. Although these holes are far apart, they have quite similar gradients, both in excess

Figure 12A. Temperature-depth curves for example holes in the northern part of the Columbia Plateau. Every fifth point on each log is plotted by a symbol.

of 50°C/km. There are sections of differing gradient in each hole, but unfortunately not enough geologic information is available to know whether these variations correspond to geology or whether they are associated with some sort of water disturbance. Nonetheless, these gradients represent above average and quite linear gradients for holes from the Columbia Plateau. Hole 16N/31E-15B is also illustrated. This hole is east of Othello and west of Lynn. It also has quite a high gradient for the Columbia Plateau region. Hole 15N/17E-36AAB at the western edge of the Columbia Plateau along Wenas Creek. The gradient is quite low compared to other holes and unlike many of the other holes, it was drilled in Cenozoic sedimentary rocks. Their conductivity is somewhat lower than that of the volcanic rocks, and so the heat flow in this area is below the average value, as it is all along the east edge of the Cascade Range. Hole 13N/29E-13DB is one of the type examples for artesian conditions within the borehole. Water enters the hole near the bottom just below 200 m and flows uphole to exit at about 170 m. There is an additional effect on the flow by another aquifer at about 190 m, but whether this aquifer donates fluid or extracts fluid from the hole is not clear.

In Figure 12b a series of holes from townships 11N and 12N southeast of the Yakima are illustrated. Some of these holes are quite deep, and some give quite good gradients, while others are very disturbed by water flow. Hole 11N/21E-22AC clearly shows the effects of down-flow within the borehole from a depth of about 370 m to a depth of 430 m. Holes 12N/22E-13CD, 12N/20E-16CA and 11N/21E-7AAC have linear temperature-depth curves. All four holes are the best examples of data from these areas, and data from shallower holes or from other holes equally deep are more difficult to interpret.

Figure 12B. Example temperature-depth curves for wells in the west central part of the Columbia Plateau. Every fifth point on each log is plotted by a symbol.

Several holes from the southern part of the Columbia Plateau are illustrated in Figure 12c. Hole 11N/46E-32BCA is near the eastern margin. This temperature-depth curve is characteristic of up-flow from the bottom of the hole to an exit point in an aquifer at approximately 260 m depth. The average gradient in this hole is $36^{\circ}\text{C}/\text{km}$, which is typical of holes along the east edge of the Columbia Plateau. Hole 10N/24E-36BD shows up-flow from somewhere below the depth logged to a depth of about 220 m; however, the gradient above that zone in the hole is typical of the other gradients in the vicinity. Hole 10N/28E-14ABB is a deep test hole on the Hanford test site and shows a linear gradient. There is a step in the temperature-depth curve at approximately 530 m, which may correspond to some sort of water flow. Hole 9N/27E-23 shows a linear gradient.

Two holes from the Walla Walla area shown in Figure 12d (7N/21E-35AA and 7N/36E-33BB) have quite different temperature-depth curves. Hole 33BB shows clear effects of up-flow from the middle part of the borehole to 200 m and down-flow from the middle part of the borehole to the bottom. The entry point of the water would appear to be on the order of 330 to 400 m. In contrast, hole 35AA shows down-flow from the aquifer at approximately 190 m to bottom of the hole at approximately 300 m. The rather extreme variation in the types of temperature-depth curves in holes that are close together is clearly illustrated by this data set. Hole 6N/33E-1DBD is characteristic of some of the higher gradient holes observed southwest of Walla Walla. This hole has the characteristics of up-flow between a depth of about 300 m and 220 m. Even discounting this up-flow, the gradient for the hole is above average for the Columbia Plateau in general, and the temperature is over 30°C at about 250

Figure 12C. Example temperature-depth curves for holes in the south central part of the Columbia Plateau. Every fifth point on each log is plotted by a symbol.

Figure 12D. Example temperature-depth curves for wells in the southern part of the Columbia Plateau. Every fifth point on each log is plotted by a symbol.

m. Hole 5N/21E-16CAB shows an irregular but linear temperature-depth curve and a relatively low gradient.

Based upon analysis of the detailed temperature logs discussed in the last subsection and the temperature data collected by the WRD, it would appear that the gradient range throughout the Columbia Plateau is between 30 and 55°C/km, with the mean value being $41.1 \pm 2.5^\circ\text{C/km}$. The mean heat flow, excluding data from the western edge of the province is $61.1 \pm 3.5 \text{ mWm}^{-2}$. There is a lack of detailed geological information, and it is not clear whether the variation in gradients is associated with the thermal conductivity variations within the basalts or between basalt and sedimentary rocks, or whether it reflects genuine changes in heat flow in various locations throughout the plateau. There is weak evidence, as presented in Figures 2 and 3, for higher than average gradients on the western and eastern margins of the plateau. Clearly logs from this province are complex and difficult to interpret, and the exact average gradient cannot be determined with the present data set. Temperature logs clearly show differences in aquifer heads and also suggest these aquifer head differences may change with time under the influence of irrigation development. Nevertheless, warm water at a temperature of 45 to 65°C should be encountered everywhere within this province at a depth of one kilometer. No evidence has been discovered for major geothermal anomalies associated with fluid circulation. Because of the head differences, it is clear that various aquifers, even those very close spatially, are not well connected. Local vertical leaks along dikes, in fractures zones or erosional gaps in flows could cause local fluid circulation anomalies, however. Some of these might be discovered as geothermal development proceeds.

DISCUSSION

A summary of the average heat flow and geothermal gradient values for the various provinces for specific areas discussed in this report are shown in Table 4. These results document the variations discussed in previous sections. These results include low heat flow in the coastal provinces west of the Cascade Range heat flow anomaly, variable heat flow in the Cascade Range and typical heat flow values of $70-80 \text{ mWm}^{-2}$ in the Northern Rocky Mountains. It is unfortunate that there are no data for the transition between the Northern Rocky Mountains and the Cascade Range, or for the Cascade Range at the latitude of the Northern Rocky Mountain province. Based on the results from Canada (Lewis et al., 1985), it appears that heat flow values in the two provinces might be similar. If this is the case, the nature of heat loss must be quite different. The heat flow in the Cascades may be related to a heat source at 10 km, whereas the heat source in the Northern Rocky Mountains is associated with current or past thermo/tectonic events associated with the whole Cordilleran Mountain chain and affecting a much larger area than just the volcanic arc.

Heat flow in the Columbia Plateau seems to be significantly lower than that observed in the Northern Rocky Mountains, at least if the area immediately south of the Northern Rocky Mountains is excluded. This difference in heat flow may be associated with differences in heat loss from the mantle or differences in the heat production from radioactivity within the crust. If the crust beneath the Columbia Plateau is thin and mafic as is indicated by seismic refraction data discussed by Hill (1972), then the heat

Table 4. Summary of gradient and heat flow for various areas of Washington

	Gradient			Heat Flow		
	Average	SE	N	Average	SE	N
	$^{\circ}\text{C}/\text{km}$			mWm^{-2}		
Coastal Provinces	24.5	1.3	32	39.8	1.6	29
Northern Rocky Mountains	26.0	1.2	27	74.9	2.9	24
Cascade Range (All except Gorge)	39.9	3.8	22	69.7	3.2	24
Cascade Range (Columbia Gorge)	32.4	2.5	8	50.5	3.9	8
Columbia Plateau (All)	39.8	1.8	54	61.4	2.0	51
Columbia Plateau (Western Margin)	32.8	2.3	7	51.0	1.7	5

flow from the mantle within this province might be essentially the same as the heat flow at the surface.

These patterns in the Pacific Northwest are similar to the patterns discussed by Blackwell (1978), except that there is now much more data on the heat flow in and west of the Cascade Range. Geothermal gradient patterns for Washington are similar to the heat flow patterns; however, there is a major difference in the gradient between the Cascade Range anomaly region in the southern part of the Cascades and the Northern Rocky Mountains even though the heat flow values are quite similar. This difference is associated with the fact that the volcanic rocks in the southern Cascade Range have generally lower thermal conductivities and thus the geothermal gradient is higher by almost a factor of 2. Temperatures are therefore expected to be much higher at depth, and in fact at 10 km, temperatures beneath the Cascade Range are probably twice as high as those beneath the Northern Rocky Mountains. High gradients are also observed in the Columbia Plateau. These high gradients are partially related to the fact that the basalts have a low thermal conductivity. The gradients are slightly lower than those observed in the Cascade Range anomaly area, with the exception of a few holes in the north central part of the plateau. The geothermal gradient beneath the Columbia Plateau will decrease with depth when the pre-basalt rocks are encountered because it is quite likely that the sedimentary/ metamorphic/igneous rocks that make up the basement have higher thermal conductivities than the volcanic rocks. Hence at a depth of 10 km the temperatures beneath the Columbia Plateau are probably closer to those in the Northern Rocky Mountains than to those in the Cascade Range anomaly region.

Because of the relatively high gradients and because of the many existing wells, the low- to medium- temperature geothermal potential for the Columbia Plateau province is quite large. Temperatures of over 40°C will be encountered in drill holes 500-1000 m deep throughout most of the Columbia Plateau. Higher temperatures might be encountered if actual circulating fluid systems could be identified. So far none of these have been encountered. The potential for high temperature geothermal systems is greatest in the Cascade Range. Moderate temperature geothermal potential also exists there, although lack of extensive commercial and industrial development in the area would lower the value of energy compared to similar temperature fluids in the Columbia Basin.

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Appendix A. Geothermal data of poor quality for the state of Washington. Collar elevation is in m, surface temperature is in °C, uncorrected and corrected gradients are in °C/km, thermal conductivity is in $\text{Wm}^{-1}\text{K}^{-1}$, and heat flow is in mWm^{-2} . Date is date hole was measured. Brackets around the thermal conductivity values signify that the values were estimated from the known lithology of the well. In lithology column C.R. stands for Columbia River basalt. The quality indicator is described in the text.

TRV/RG SECTION	N LAT DEG MIN	W LONG DEG MIN	HOLE NO. (DATE)	COLLAR ELEV.	SURFACE TEMP.	DEPTH INTERVAL	AVG. TC (SE)	NO. UN. TC	UN. GRAD (SE)	CD. GRAD (SE)	CD. H.F. (SE)	Q H.F.	LITHOLOGY SUMMARY
37N/33E- 79AA	48-43.52	118-40.94	PRATHER 9/15/81	791	7.60	19.0 62.0			35.5 1.8	34.8		D	
37N/26E- 25A	48-40.84	119-29.92	GILDRY 9/19/81	451	10.00	4.0 134.0						X	
37N/32E- 34B3	48-39.80	118-45.73	DDH-C 7/31/70	1067	7.48	40.0 55.0			36.0 .3			D	
35N/26E- 36DD	48-29.02	119-29.74	DOE TST1 9/21/81	332	12.10	19.0 66.5	(2.65)	1				X	
34N/24E- 20ADB	48-26.04	119-50.71	USFS OK 9/20/81	1646	3.20	59.0 65.0			51.1 1.4			D	
31N/15E- 9/ 2/70	48-11.85	120-58.57	DDH-2 9/ 2/70	1823	2.50	70.0 75.0			21.6 .3			D	
31N/15E- 9/ 2/70	48-11.85	120-58.57	DDH-141 9/ 2/70	1752	3.61	50.0 95.0						X	
31N/25E- 27DC	48-10.54	119-40.38	DOE TST3 9/17/81	249	12.40	14.0 44.0						X	
31N/25E- 27DB	48- 9.27	119-40.61	DOE TST2 9/20/81	268	13.10	24.0 88.0	(2.89)	1				X	
31N/45E- 27CD	48- 9.22	117- 6.18	N HEFNER 9/ 9/81	666	9.50	64.0 115.0	(2.43)	1				X	
28N/42E- 14CDC	47-55.10	117-27.51	MYBRIKEN 7/25/81	634	9.70	35.0 70.0	(2.43)	1	35.6 1.0	35.6	(86)	D	SAND AND BASALT
28N/44E- 24ABB	47-54.97	117-10.98	J OSTBY 9/ 7/81	983	8.00	9.0 98.0	(2.64)	1				X	ALLUVIUM
28N/44E- 30DD	47-53.42	117-17.13	DOE TST4 9/ 6/81	646	8.20	1.0 34.0						X	ALLUVIUM
27N/34E- 18CD	47-52.09	118-28.76	WASH WPC 9/14/81	444	11.00	1.0 151.0						X	SAND TO GRAN TO COBBLES
27N/37E- 10CB	47-51.00	118- 8.00	DDH-SF13 7/24/81	469	10.69	40.0 125.0						X	ALLUVIUM
25N/44E- 32ADD	47-42.49	117-15.67	MAGAN 4/ 4/81	719	9.90	29.0 64.0			34.2 1.0			D	SAND & CLAY

THWING SECTION	N LAT DEG MIN	W LONG DEG MIN	HOLE NO. (DATE)	COLLAR ELEV.	SURFACE TEMP.	DEPTH INTERVAL	AUG. TCJ (SE)	NO. TC	LN. GRAD (SE)	CO. GRAD (SE)	CO. H.F. (SE)	Q H.F.	LITHOLOGY SUMMARY
25V 9E- 4RAD	47-41.07	121-38.92	DDH-11 11/1/72	1231.	3.68	5.0 130.0						X	
25V 42E- 98BD	47-40.97	117-30.84	M MOE 8/20/81	627	8.10	80.0 142.0	(1.59)		41.0 5.6	41.0	(65)	D	SAND, GRAVEL & BASALT
25V 28E- 24B8B	47-39.28	119-15.00	ISAAC 2 1/29/81	554		20.0 130.0						X	
25V 29E- 34DDO	47-36.78	119- 8.93	ISAAC 1 1/29/81	527	11.00	20.0 270.0						X	
24V 29E- 15AB	47-34.78	119- 9.33	ISAAC 3 1/30/81	539	11.45	25.0 310.0						X	
24V 21E- 14DAB	47-34.28	120- 9.37	REYNOLDS 11/12/81	1194	8.40	24.0 85.0	(1.67)	1	14.8 .8	14.8	(24)	D	C. R. BASALT
24V 32E- 26BAA	47-33.08	118-45.29	THOMPSON 9/23/81	566	12.06	44.0 144.0	(1.59)	1				X	BASALT
23V 20E- 29C	47-27.24	120-21.85	GAHRING 9/29/81	356	13.20	99.0 154.0	(2.18)		19.3 .2	21.2	(46)	D	ARKOSE AND S.S. EOCENE?
23V 11E- 33C8B	47-26.13	121-24.53	DNR-SNG2 10/13/81	899		50.0 140.0	3.69 .33	5				X	QUARTZITE (ARTESIAN)
21V 31E- 32B8C	47-16.36	118-57.42	KISSLER 8/21/81	508	13.86	1.0 215.0						X	
20V 22E- 12ABC	47-14.65	120- .78	WELCH 11/13/81	390	14.00	49.0 189.0	(1.59)	1	26.1 1.3	26.0	(41)	D	C. R. BASALT
						49.0 264.0	(1.59)	1	32.1 1.0	32.0	(51)	C	
19V 28E- 4CA	47- 9.88	119-18.96	MOSES LK 8/25/81	349	13.20	19.0 144.0	(1.59)		37.4 3.1	37.4	(59)	D	GRAVEL AND BASALTS
						14.0 54.0	(1.59)		50.9 2.1	50.9	(81)	D	
19V 36E- 14B	47- 8.55	118-14.80	GERING 12/11/80	558		2.0 210.0						X	C. R. BASALT
19V 27E- 18BC	47- 8.52	119-29.25	ELLSTAD 1/23/81	373	12.90	10.0 51.0			75.6 2.1			D	
THWING SECTION	N LAT DEG MIN	W LONG DEG MIN	HOLE NO. (DATE)	COLLAR ELEV.	SURFACE TEMP.	DEPTH INTERVAL	AUG. TCJ (SE)	NO. TC	LN. GRAD (SE)	CO. GRAD (SE)	CO. H.F. (SE)	Q H.F.	LITHOLOGY SUMMARY
19V 26E- 17D	47- 8.20	119-34.83	DODSON 1/11/81	371		10.0 70.0						X	
19V 29E- 17DC	47- 8.00	119-11.70	DUNKIN 1/12/81	371		10.0 160.0						X	
19V 34E- 20A	47- 7.87	118-33.72	KAGBLE 12/11/80	561	10.87	2.0 190.0						X	
19V 17E- 26CDA	47- 6.32	120-40.59	LETSEN 7/28/80	676	9.52	160.0 195.0			42.5 5.0			D	
						10.0 200.0	(1.46)	1	2.4	2.4	(35)	D	
18V 5E- 6CDA	47- 4.18	122-13.21	BENJAMIN 8/22/79	167	8.17	60.0 68.0	(1.67)	1	13.8 .2	10.7	(18)	D	GLACIAL DRIFT
18V 3E- 12DBJ	47- 3.47	122-21.81	BETHL HS 8/21/79	140		.0 85.0	2.47	1				X	GLACIAL DRIFT
18V 25E- 36A	47- .58	119-37.55	BARKER 5 1/11/81	344	15.50	20.0 45.0			27.3 .7	27.3		D	
18V 32E- 33CB	47- .24	118-48.42	FRANZ 11/15/81	428	14.00	164.0 214.0	(1.59)	1	19.1 .3	19.1	(31)	D	BASALT
17V 32E- 14	46-57.60	118-47.17	DNR-CRB 3/12/81	472	14.00	20.0 189.0	(1.59)		42.5 4.0	42.5	(68)	D	
17V 35E- 28DB	46-55.95	118-24.88	BAUMANN 5/ 7/81	548	10.80	25.0 200.0	(1.59)		17.4 4.5	17.4	(28)	D	C. R. BASALT
17V 18E- 34BCC	46-55.23	120-34.75	KUTTER3 7/14/80	746	9.71	50.0 70.0			22.6 .8			D	
17V 35E- 31CCD	46-54.92	118-27.88	BAUMANN2 5/ 7/81	527	10.27	30.0 230.0						X	C. R. BASALT
16V 18E- 4DAA	46-54.24	120-34.29	KUTTER2 7/14/80	768	9.35	.0 40.0						X	
16V 4E- 14CD	46-51.91	122-16.34	W-14P1 12/ 8/71	243	9.31	40.0 75.0			12.4 .6			D	CLAY AND ROCK
16V 4E- 22BAB	46-51.75	122-17.43	DN SMITH 8/19/79	262	9.04	65.0 74.0			9.5 .5			D	

THW/RNG SECTION	N LAT DEG MIN	W LONG DEG MIN	HOLE NO. (DATE)	COLLAR ELEV.	SURFACE TEMP.	DEPTH INTERVAL	AUG. TCU (SE)	NO. TC	UN. GRAD (SE)	CO. GRAD (SE)	CO. H.F. (SE)	Q H.F.	LITHOLOGY SUMMARY
16N/35E- 22CDA	46-51.41	118-24.52	BAUMHILL 2/ 9/78	519	8.80	.0 315.0						X	C. R. BASALT
15N/32E- 16BD	46-49.97	118-47.35	STELGER 6/ 0/80	372	13.00	40.0 100.0			(98.0)			D	
16N/32E- 34BC	46-49.97	118-47.35	PHILLIPS 4/ 9/81	431	13.20	20.0 370.0						X	
15N/17E- 20BD	46-49.00	120-39.30	PICATTI 6/30/80	600	13.53	40.0 90.0	(1.46)		25.2 1.2	23.2	(34)	D	SAND, GRAVEL & CLAY
15N/17E- 24ADD	46-46.70	120-37.50	DAYZ 7/ 1/80	487	10.02	5.0 155.0						X	
15N/14- 21BBB	46-46.63	122-49.17	EDM-1 8/ 9/79	75	11.42	5.0 78.5						X	Eocene SHALE & SANDSTONE
15N/18E- 28AA	46-45.89	120-34.62	MULLY 7/ 4/80	542	13.31	60.0 140.0			9.5 .7			D	SANDSTONE
15N/18E- 28CAD	46-45.52	120-35.04	YOUNG 7/ 2/80	490	11.73	10.0 75.0			27.1 2.1			D	SANDSTONE
						40.0 75.0			17.5 2.5			D	
15N/18E- 29DDD	46-45.20	120-35.67	BOYD 7/ 2/80	469	12.50	.0 60.0						X	SANDSTONE
14N/16E- 1ABC	46-44.14	120-46.29	ENGLAND 7/ 9/80	625	12.35	40.0 105.0			7.3 .5			D	C. R. BASALT
14N/16E- 1ADA	46-44.07	120-45.73	HUCK 7/10/80	633	12.60	130.0 170.0			2.3 .4			D	C. R. BASALT
						10.0 110.0			14.3 .9			D	
14N/25E- 1B	46-44.05	119-38.38	BATTLE 2/25/81	207		5.0 68.0						X	
14N/16E- 1DAH	46-43.88	120-45.77	MARTIN 7/12/80	623	12.50	70.0 115.0	(1.42)	1	24.8 2.2	24.8 2.6	35	D	BASALT
14N/17E- 6BD	46-43.77	120-45.30	PERMAN 7/25/80	610	11.25	45.0 160.0			24.6 3.1			D	BASALT, SS & GRAVEL
THW/RNG SECTION	N LAT DEG MIN	W LONG DEG MIN	HOLE NO. (DATE)	COLLAR ELEV.	SURFACE TEMP.	DEPTH INTERVAL	AUG. TCU (SE)	NO. TC	UN. GRAD (SE)	CO. GRAD (SE)	CO. H.F. (SE)	Q H.F.	LITHOLOGY SUMMARY
14N/ 8E- 6BCC	46-43.76	121-51.13	RDH-LONG 8/14/79	720	6.00	10.0 99.5	1.72 .06	10	> 28.0	> 25.0	> 43	D	VOLCANIC BRECCIA
14N/ 5E- 4CAD1	46-43.43	122-10.98	MOUNCE 6/ 6/79	451	8.65	3.0 49.7						X	TERTIARY (?) SEDIMENT RX
14N/ 5E- 4CAD2	46-43.40	122-10.80	PENNINGTON 6/12/79	449	9.08	3.0 49.0						X	TERTIARY (?) SEDIMENT RX
14N/18E- 70BD	46-42.80	120-37.40	MURRAY 7/ 2/80	655	10.88	10.0 50.0						X	
14N/17E- 19DAB	46-41.15	120-44.70	KNUTSON 7/ 3/80	571	11.72	40.0 65.0						X	SANDSTONE
14N/17E- 19DCB	46-41.01	120-45.02	MINSPRGR 7/ 8/80	599	12.54	10.0 150.0	(1.72)	1	63.2	63.2	(108)	D	C. R. BASALT SEDIMENTS
14N/17E- 20CDD	46-40.80	120-43.80	DARDEN 6/30/80	561	10.15	50.0 60.0			44.0 5.8			D	BASALT, SS & CLAY
						10.0 60.0			35.3 5.4			D	
14N/ 14- 23DDA	46-40.77	122-45.65	AGNEW 6/14/79	135	10.66	1.0 74.5						X	TERTIARY SEDIMENT RX
13N/19E- 12CDD	46-37.30	120-23.90	CARLHILL 7/10/80	579	14.72	20.0 97.5			29.8 2.2	28.9		D	C. R. BASALT
13N/19E- 14AA	46-37.10	120-24.30	WATKINS 7/11/80	561	13.38	10.0 210.5	(1.46)		27.3	26.5	(39)	D	CLAY, SAND, BASALT & SS
13N/ 2E- 17BBB	46-36.94	122-35.47	STANSELL 5/25/79	232	11.27	.0 101.0						X	TERTIARY (?) SHALE
13N/ 14- 17ADA	46-36.93	122-49.43	ANDERSON 5/25/79	92	10.17	.0 54.0						X	CLAY
13N/19E- 23BA	46-36.70	120-24.75	WATKINS 6/16/80	402	14.21	10.0 60.0						X	CLAY & SAND
13N/18E- 15CAD	46-36.70	120-33.70	FOHAZ 7/ 3/80	381	12.52	30.0 55.0			39.2 4.7			D	SANDY CLAY & GRAVEL MATX.
13N/19E- 24AA	46-36.26	120-23.07	GUR-LI 3/13/72	457	16.60	120.0 225.0	(1.59)		26.4 .6	26.4	(42)	D	

THIRING SECTION	N LAT DEG MIN	W LONG DEG MIN	HOLE NO. (DATE)	COLLAR ELEV.	SURFACE TEMP.	DEPTH INTERVAL	AVG. TCU (SE)	NO. TC	UN. GRAD (SE)	CO. GRAD (SE)	CO. H.F. (SE)	Q H.F.	LITHOLOGY SUMMARY
13V 20E- 20BBD	46-36.20	120-20.90	COPPALL 6/28/80	527	14.40	35.0 65.0			17.6 .5			D	BASALT & CLAY
13V 20E- 20BDA	46-36.15	120-21.20	CHAMPOLX 6/28/80	493	11.44	.0 215.0	(1.55)	1	(51.5)	(49.4)	(77)	D	
13V 17E- 29ABD	46-35.60	120-42.49	DECOLC-6 6/17/80	477	12.12	10.0 140.0						X	GRAVEL, CLAY BASALT, CLAYS
13V 24- 25AAA	46-35.32	122-52.05	DRUCOMAN 7/ 5/79	91	10.00	16.0 30.0			18.2 .5	18.2		D	
13V 14- 29DCC	46-34.61	122-49.95	MULZ 6/ 8/79	102	10.46	.0 67.5						X	
13V 21E- 34AD	46-34.35	120-10.29	MARTINEZ 7/22/80	709	11.40	20.0 250.0	(1.59)		> 33.1 .7	> 32.5	> 52	D	BASALT WITH SAND/SHALE
12V 18E- 18D	46-33.48	120-30.75	DECOLC-9 6/16/80	307	13.71	5.0 62.0						X	CLAY AND GRAVEL
12V 4E- 3BCD	46-33.34	122-17.99	MARK 6/ 8/79	316	8.34	27.0 84.0			6.5 .3			D	
12V 4E- 4DAB	46-33.21	122-18.36	BISHOP 6/ 8/79	287	9.03	19.0 42.5	(1.67)		17.4 .8	15.7	(26)	D	BASALT ?
12V 8E- 30CD	46-33.18	121-47.10	RDH-DUSM 9/ 6/79	610	12.05	50.0 146.0	1.68 .06	19	(5.4)	(5.4)	(9)	D	Eocene/OLIGO VOLCANICS
12V 17E- 118BB	46-33.06	120-40.11	DECOLC-7 6/17/80	425	8.65	10.0 130.0	(1.46)		(34.2)	(34.2)	(50)	D	GRAVEL, CLAY AND SAND
						80.0 120.0	(1.46)		64.2 1.0	64.2	(94)	C	
12V 2E- 11AAD	46-32.67	122-30.77	HADDALER 5/24/79	184	10.23	.0 88.0						X	BASALT
12V 16E- 12CC	46-32.38	120-46.36	SHELTON 7/21/80	582	12.36	.0 105.0			(25.1)			D	C. R. BASALT
12V 30E- 11DAC	46-32.20	119- .58	MESATON 1/13/81	207	11.96	25.0 55.0						X	C. R. BASALT
12V 3E- 7CDB	46-32.12	122-29.03	GOODWIN 5/24/79	210	9.33	40.0 86.0	(1.67)		19.1 1.2	19.1	(32)	D	BASALT ?
THIRING SECTION	N LAT DEG MIN	W LONG DEG MIN	HOLE NO. (DATE)	COLLAR ELEV.	SURFACE TEMP.	DEPTH INTERVAL	AVG. TCU (SE)	NO. TC	UN. GRAD (SE)	CO. GRAD (SE)	CO. H.F. (SE)	Q H.F.	LITHOLOGY SUMMARY
12V 1E- 12DCB	46-32.11	122-37.39	TALBOTT 6/ 1/79	171	9.60	30.0 125.0	(1.00)		20.5 1.4	20.5	(21)	D	CLAY, SHALE & SANDSTONE
12V 19E- 17BAD	46-32.00	120-31.25	DOE 11/24/80	280		.0 50.0						X	
12V 16E- 13BEC	46-31.93	120-46.44	HERKE 7/24/80	536	9.82	10.0 70.0			63.9 4.8			D	BASALT WITH SANDY LAYERS
12V 2E- 16AAA	46-31.89	122-33.33	LKSDCH 1 6/23/79	136	9.18	70.0 106.0	(1.67)		18.2 1.4	18.2	(31)	D	
12V 16E- 15DBA	46-31.75	120-48.88	MM WHITE 7/21/80	574	9.82	10.0 75.0						X	
12V 40E- 17ADA	46-31.58	117-49.26	DODGEJCT 2/27/78	381	13.40	.0 90.0						X	C. R. BASALT
12V 21E- 16CA	46-31.52	120-11.94	DNR 7/22/80	481	15.77	10.0 235.0	(1.55)	1	45.5 2.3	42.2	(65)	D	BASALT WITH SAND-CLAY
12V 2E- 16ADC	46-31.50	122-33.38	LMPK 2 6/ 1/79	149	8.65	39.0 59.8	(1.67)		21.1 1.2			D	MID-TERTIARY ANDESITE
12V 23E- 16BBD	46-31.43	119-56.65	BLK RCK 10/25/80	434	9.99	2.0 225.0			50.7 5.9			D	C. R. BASALT
12V 40E- 14DAD	46-31.19	117-45.56	SCOTT-44 7/23/80	591	11.40	15.0 62.5	(1.59)		33.9 .4	40.0	(64)	D	BASALT
12V 23E- 20BAC	46-31.03	119-58.33	BLK RCK2 7/23/80	462	13.03	10.0 100.0	(1.59)	1	22.3 2.7	21.5		D	C. R. BASALT
12V 21E- 22CAC	46-30.75	120-11.30	MARTINEZ 10/22/80	482	16.36	.0 198.0						X	
12V 3E- 23DCC	46-30.34	122-23.76	MARCHANT 6/ 9/79	253	9.34	25.0 81.0			7.6 .1			D	
12V 2E- 20CCC	46-30.24	122-35.57	MFKFS 1 5/22/79	85	9.90	20.0 57.0			25.6 .8			D	ANDESITE FLOWS
12V 7E- 27CAB	46-30.00	121-55.10	POL-RANI 9/ 7/79	281	8.74	15.0 34.3			38.5 .7	36.7		D	
12V 3E- 25CAB	46-29.90	122-22.92	CHURCH-2 8/23/79	420	5.13	136.0 152.0						X	

TUNING SECTION	N LAT DEG MIN	W LONG DEG MIN	HOLE NO. (DATE)	COLLAR ELEV.	SURFACE TEMP.	DEPTH INTERVAL	AUG. TC (SE)	NO. TC	UN. GRAD (SE)	CO. GRAD (SE)	CO. H.F. (SE)	Q H.F.	LITHOLOGY SUMMARY
12N/18E- 25DOB	46-29.67	120-31.25	DOUGLAS 10/31/80	308	13.61	30.0 70.0			53.7 2.1			D	
12N/20E- 31AD	46-29.30	120-21.45	BROOKS 6/17/80	341	13.75	10.0 130.0			29.9 2.3			D	SEDIMENTS & BASALTS
11N/27E- 148AD	46-26.60	119-23.85	BATTLE1 2/11/81	164	14.20	40.0 95.0	(1.59)		41.3 1.5	41.3	66	D	C. R. BASALT
11N/46E- 198B	46-25.40	117- 5.87	PTJALAH 1/17/78	234	12.57	15.0 160.0						X	C. R. BASALT
11N/ 24- 26BDC	46-24.66	122-54.01	WALLACE 8/14/79	24	12.15	190.0 261.5			8.6 .4			D	SILTSTONE & CLAYSTONE
						15.0 190.0			13.6 .1			D	
11N/31E- 33ABD	46-23.92	118-56.07	MUNEL 2 2/ 5/81	192	14.92	20.0 128.0						X	C. R. BASALT
11N/31E- 32DB	46-23.55	118-57.45	MUNEL 1 2/ 5/81	175	14.02	20.0 128.0						X	C. R. BASALT
11N/29E- 34D	46-23.45	119- 9.68	LINDSEY 3/ 9/81	213	12.70	10.0 30.0			108.0 3.1	108.0		D	
10N/27E- 25AAC	46-19.70	119-26.00	BATTLE56 2/24/81	121		10.0 140.0						X	C. R. BASALT
10N/16E- 26ACR	46-19.60	120-46.90	LAUNDCE 6/15/80	378	9.76	20.0 135.0	(1.59)		46.3 7.0	46.3	(74)	D	SAND, GRAVEL & BASALT
10N/39E- 30AA	46-19.43	117-58.63	WARNERJW 2/10/78	512	11.73	5.0 32.5						X	C. R. BASALT
9N/23E- 78CC	46-16.87	119-59.79	MANDRELL 11/17/81	211	13.00	24.0 74.0	(1.59)		58.1 1.5	58.1	(93)	D	BASALT
9N/27E- 168BA	46-16.17	119-26.78	DNRBEN40 3/11/81	219	13.50	70.0 94.0	(1.59)		184.6 7.5	184.6	(293)	D	C. R. BASALT
9N/32E- 17AB	46-16.01	118-49.51	DNR-BF2 4/22/81	158	14.61	7.5 46.0						X	
9N/36E- 30BA	46- 8.95	118-21.44	URANUSJW 1/13/78	262	10.42	10.0 65.0						X	BASALT WITH SOME CINDERS
TUNING SECTION	N LAT DEG MIN	W LONG DEG MIN	HOLE NO. (DATE)	COLLAR ELEV.	SURFACE TEMP.	DEPTH INTERVAL	AUG. TC (SE)	NO. TC	UN. GRAD (SE)	CO. GRAD (SE)	CO. H.F. (SE)	Q H.F.	LITHOLOGY SUMMARY
7N/ 5E- 28A	46- 7.62	122- 9.15	RDH-STM3 11/14/79	805	3.80	25.0 130.0	2.05 .08	13				X	
7N/36E- 198D	46- 4.39	118-21.51	DKFF-WJ 3/15/72	271		110.0 250.0						X	C. R. BASALT
7N/33E- 24DC	46- 3.97	118-37.40	MT-WJ 3/16/72	183	14.80	200.0 235.0	(1.59)		17.0 .5	17.0		D	BASALT
7N/35E- 25ABA	46- 3.79	118-22.34	GUC-WJ 1/30/78	259	11.40	45.0 70.0			33.7 9.8			D	SEDIMENTS & BLUE CLAY
7N/35E- 35AA	46- 2.93	118-22.30	WCOLLWJ 1/30/78	240	15.90	100.0 165.0			27.4 .4			D	BASALT AND CLAY
7N/36E- 33ES	46- 2.89	118-19.29	WJ-7 3/14/72	297	15.59	10.0 425.0	(1.59)		33.3	33.3	53	D	BASALT
7N/25E- 36CC	46- 2.62	119-38.50	DOE PAT 8/24/81	222	13.90	29.0 79.0	(1.59)		32.0 1.0	32.0	51)	D	C. R. BASALT
						29.0 250.0	(1.59)		23.9 2.6	23.9	(38)	D	
7N/34E- 36CAD	46- 2.33	118-30.27	STILERJW 2/ 8/78	173	12.00	10.0 32.5	(1.00)		55.4 3.2	55.4	(56)	D	SEDIMENTS
6N/36E- 40A	46- 1.47	118-20.68	HILLRDLW 1/31/78	290	11.85	35.0 57.5	(1.13)		81.8 3.6	81.8	(93)	D	SEDIMENTS - SILTY CLAY
6N/35E- 10DA	46- .63	118-23.33	WJFLCAMP 3/ 5/80	230	12.08	35.0 125.0			23.7 1.5			D	GRAV. BOULD. CLAY+BASALT
						10.0 176.5			19.1 .7			D	
6N/34E- 120CC	46- .34	118-30.65	FROG-WJ 2/ 8/78	205	13.10	10.0 70.0						X	SAND, GRAVEL & CLAY
6N/19E- 24BC	45-59.52	120-22.97	FOSTER 11/28/81	1116	7.00	29.0 152.0	(1.59)	1	37.6 1.1	37.6	60	D	C. R. BASALT
						14.0 29.0	(1.59)	1	64.8 1.9	64.8	(105)	D	
						59.0 139.0	(1.59)	1	41.2 .7	41.2	(65)	C	

THWING SECTION	N LAT DEG MIN	W LONG DEG MIN	HOLE NO. (DATE)	COLLAR ELEV.	SURFACE TEMP.	DEPTH INTERVAL	AUG. TCU (SE)	NO. TC	UN. GRAD (SE)	CO. GRAD (SE)	CO. H.F. (SE)	Q H.F.	LITHOLOGY SUMMARY
SV23E- 36BD	45-57.73	119-52.50	DWYCR1 5/ 6/81	252	12.80	20.0 90.0 160.0	(1.59)		23.1 1.2 48.9 1.4			D	C. R. BASALT
SV15E- 7AB	45-56.34	120-58.47	PRESCOTT 12/14/81	713	9.00	54.0 84.0	(1.59)		31.4 1.4	31.4	(50)	D	QUAT. BASALT
SV15E- 136DC	45-55.25	120-52.68	MELLSMAN 12/ 1/81	818	7.46	.0 166.5						X	QUAT. BASALT
SV21E- 16CAB	45-55.00	120-11.49	DOE TST7 8/23/81	706	15.11	74.0 224.0 394.0	(1.59)		49.2 6.3 27.2 1.7	49.2	(78)	D	C. R. BASALT
SV 8E- 22ABC	45-54.80	121-46.80	DGER-6 9/14/76	1067	2.58	15.0 55.0	1.26 .21					X	QUAT. BASALT
SV 2E- 24DDA	45-53.91	122-29.51	WALLAM 8/ 1/79	243	8.74	35.0 104.0	(1.46)	1				X	VOLCANICS & BASALT
SV17E- 33BB	45-52.89	120-41.54	MCKAY 11/28/81	701	17.95	39.0 177.0 134.0 169.0	(1.42)	1	53.4 4.7 52.9 1.4	53.5	(76)	D	QUAT. BASALT
SV15E- 31CBB	45-52.32	120-59.20	WAPAT. 10/ 8/81	509	12.17	59.0 139.0						X	QUAT. BASALT
SV16E- 31CC	45-52.22	120-51.67	CASE 11/21/81	640	10.93	19.0 124.0	(1.59)	1				X	QUAT. BASALT
SV14E- 36CDC	45-52.21	121- .09	RICHARD 12/15/81	488	11.00	49.0 116.5						X	QUAT. BASALT
4N17E- 3AC	45-51.77	120-39.95	B COLE 7/16/81	689	11.94	20.0 200.0	(1.59)		30.5 2.1	30.5	(49)	D	QUAT. BASALT
4N15E- 2BC	45-51.71	120-54.15	CASE 2 11/21/81	533	11.40	19.0 152.5						X	QUAT. BASALT
4N16E- 16CCD	45-49.51	120-49.07	BLDL 1 7/15/81	506	12.10	80.0 150.0 205.0	(1.59)		45.3 1.6 34.7 1.2	45.3	(72)	D	C. R. BASALT
4N16E- 21BA	45-49.40	120-49.09	O LEARY 7/16/81	506	13.40	70.0 150.0	(1.59)		18.8 1.5	18.9	(30)	D	C. R. BASALT
3V 5E- 4BDA	45-46.50	122-11.94	SS-8 10/ 9/75	565	6.71	20.0 70.0	(2.80) .08	22	15.1 1.7	15.1	(42)	D	QTZ. DIORITE GRANDIORITE
3V 5E- 4BDC1	45-46.45	122-11.98	SS-4 7/14/75	558	6.90	30.5 152.4	(2.80) .08		15.5 1.2	15.5	(44)	D	QTZ. DIORITE GRANDIORITE
3V13E- 1DC	45-46.16	121- 7.24	WAGNER 12/ 9/81	634	9.61	20.0 87.0	(1.59)		27.3 1.8	27.0	(44)	D	C. R. BASALT
3V18E- 11CBA	45-45.45	120-31.65	GOODNOE 12/24/81	403	13.44	50.0 110.0	(1.59)		29.9 1.4	32.9	(52)	D	C. R. BASALT
3V12E- 9DD	45-45.41	121-18.07	MEAUER 12/ 4/81	521	11.37	19.0 139.0	(1.51)	1				X	C. R. BASALT
3V12E- 13DCC	45-44.46	121-14.82	JELLM 12/12/81	402	12.06	1.2 95.5						X	C. R. BASALT
3V 3E- 23BDB	45-43.98	122-24.38	PLEJ 7/31/79	442	8.02	30.0 183.5	(1.59)		22.5 1.0	27.3	(44)	D	Eocene BASALT
3V11E- 24ACD	45-43.98	121-22.17	NER SHT 7/ 8/81	317	11.37	50.0 235.0						X	BASALT
3V14E- 19CA	45-43.75	121- 6.32	PARISH 12/ 9/81	630	10.55	20.0 140.2	(1.59)	1	(36.7)	(36.7)	(58)	D	C. R. BASALT
3V12E- 21DD	45-43.58	121-18.18	BAILEY 12/ 3/81	295	13.97	19.0 143.0	(1.38)	1				X	C. R. BASALT
3V 8E- 27ACD	45-43.17	121-46.79	CALLAHAN 9/14/79	115	7.73	60.0 84.0			29.2 2.2	30.9		D	EO-OLIGO VOLCANICS
3V11E- 30ADA	45-43.15	121-28.32	BNG CTY2 7/ 8/81	46	9.75	20.0 87.5						X	C. R. BASALT
3V 7E- 25DB	45-42.87	121-53.11	THOMPSON 11/22/81	250	8.20	39.0 56.0	(1.26)		32.4 1.1	31.0	(49)	D	VOL-CLASTIC ROCKS

TIN/RNG SECTION	N LAT DEG MIN	W LONG DEG MIN	HOLE NO. (DATE)	COLLAR ELEV.	SURFACE TEMP.	DEPTH INTERVAL	AUG. TOU (SE)	NO. TC	UN. GRAD (SE)	CO. GRAD (SE)	CO. H.F. (SE)	O H.F.	LITHOLOGY SUMMARY
3V/12E- 28DCD	45-42.63	121-18.36	BRADLEY 9/13/79	161	10.96	35.0 165.0	(1.59)		33.0 2.4	33.9	(54)	D	C. R. BASALT
3V/11E- 34BD	45-42.16	121-24.90	MCBRIDE 12/ 2/81	231	10.70	59.0 106.4	(1.59)		32.6 1.3	32.6	(52)	D	C. R. BASALT
3V/13E- 31CB	45-42.10	121-14.11	L. DANIEL 7/10/81	274	10.56	120.0 170.0	(1.59)		25.2 .7	26.2	(42)	D	C. R. BASALT
3V/15E- 34CCB	45-41.80	120-55.46	JACKEL 9/13/79	594	10.80	40.0 149.0	(1.59)	1	26.8 1.5	28.0	> 44	D	C. R. BASALT
2V/13E- 16CA	45-39.44	121-11.47	ZEIGLER 12/10/81	89	14.34	44.0 97.0						X	BASALT
2V 7E- 22BBA3	45-38.90	121-56.11	DH-1204 10/28/75	42	10.10	40.0 60.0			24.6 1.3			D	
2V 7E- 22BBA4	45-38.87	121-56.09	DH-1209 10/28/75	52	10.61	15.0 63.0			22.3 2.9			D	CLAY, SILT & SANDSTONE
2V 7E- 22BBA6	45-38.86	121-56.09	DH-1029 10/28/75	52	11.41	15.0 80.0			18.6 1.1			D	CLAY, SILT & SANDSTONE
2V 7E- 22BBA5	45-38.86	121-56.05	DH-1210 10/28/75	52	12.25	30.0 68.7			5.1 2.5			D	CLAY, SILT & SANDSTONE
2V 7E- 22ABC	45-38.85	121-55.70	DH-1083 10/28/75	51	9.38	5.0 65.0			19.4 2.9			D	CLAY, SILT & SANDSTONE
2V 7E- 22BBC1	45-38.77	121-56.34	USCE1462 4/12/77	25	8.90	20.0 52.5			45.6 6.5			D	CLAY, SILT & SANDSTONE
2V 7E- 22BBD1	45-38.77	121-56.18	USCE1385 4/12/77	27	10.45	10.0 73.0			33.9 1.0			D	CLAY, SILT & SANDSTONE
2V 7E- 22BBC2	45-38.76	121-56.34	USCE1465 4/12/77	25	9.17	20.0 61.5			47.2 2.5			D	CLAY, SILT & SANDSTONE
2V 7E- 22BBC3	45-38.76	121-56.22	USCE1371 4/12/77	27	10.32	15.0 58.5			31.2 2.4			D	CLAY, SILT & SANDSTONE
2V 7E- 22BBC4	45-38.75	121-56.29	USCE1455 4/12/77	26	10.43	25.0 65.1			29.9 3.7			D	CLAY, SILT & SANDSTONE
2V 7E- 22BBD2	45-38.75	121-56.14	USCE1475 4/12/77	29	10.18	20.0 57.0			39.2 3.7			D	CLAY, SILT & SANDSTONE
2V 4E- 24CCA	45-38.34	122-15.87	L. COOY 7/ 2/81	290	9.52	30.0 90.0						X	BASALT
2V 3E- 26AAC	45-38.34	122-24.04	FRENCH 6/10/79	134	11.39	.0 54.0						X	CLAY, SAND & GRAVEL
2V 4E- 29ABB	45-38.11	122-20.46	WITTERS 6/30/79	207	10.14	5.0 52.0						X	SANDSTONE & CLAYSTONE
2V 4E- 29ACB	45-37.90	122-20.43	WILLIAMS 6/27/79	201	11.49	5.0 61.5						X	CLAY
2V 4E- 27DAA	45-37.61	122-17.52	PG SMITH 7/ 2/81	88	10.82	20.0 37.5						X	
2V 5E- 35BBL	45-37.14	122- 9.76	RICHARDS 9/ 7/79	414	8.15	10.0 103.0	(1.59)	1				X	VOLCANICS
2V 5E- 34CC	45-36.60	122-11.00	KADON 12/ 8/81	271	8.85	45.0 105.0 105.0 124.0	(1.46)		23.0 .5	36.5	(38)	D	GRAVEL AND CLAY
							(1.05)		35.7 1.4	36.0	(37)	D	
1V 4E- 6BCC	45-36.06	122-22.28	ZIMMER 7/ 9/79	164	10.49	10.0 46.5						X	CLAY & ROCK
1V 3E- 6CCD2	45-36.00	122-29.33	NIELSEN 2 6/25/79	62	11.08	10.0 75.0						X	CLAY, SAND & GRAVEL
1V 3E- 6CCD1	45-36.00	122-29.33	NIELSEN 1 6/26/79	62	11.37	10.0 57.5						X	CLAY, SAND & GRAVEL
1V 4E- 5DAD	45-35.91	122-19.94	HATTON 6/19/79	135	10.69	40.0 65.0						X	
1V 5E- 1CDD	45-35.65	122- 8.12	SKY CS 1 9/ 6/79	37	11.28	10.0 46.5						X	
1V 3E- 11CDC	45-34.92	122-24.36	CRAN ZIL 9/ 6/79	8	14.87	10.0 73.0						X	SANDY CLAY & BASALT

APPENDIX B

Location	Elevation m	T _s °C	T _{BHT} °C	Depth m	Calculated Gradient °C/km
4N16E21AB	506.1	12.3	18.0	150.6	37.8
6N24E22AD	167.7	14.0	22.5	195.1	43.5
6N34E3CB	196.0	13.8	17.2	50.9	57.5
7N26E5AB	344.5	13.1	19.2	326.5	18.7
10N24E24BA	551.8	12.1	14.3	109.8	20.0
11N18E30AD	260.7	13.5	18.0	103.7	43.4
11N22E21CC	420.7	12.7	22.3	207.3	46.2
12N22E14BA	603.6	11.4	15.2	149.1	25.4
12N22E15AC	579.3	11.9	12.8	37.8	22.8
12N22E29AA	548.8	12.1	12.2	102.1	0.7
13N18E12AA	437.5	12.6	24.8	200.6	60.7
14N20E20CC	658.5	11.5	17.0	183.5	30.1
15N18E29BA	515.2	12.2	13.2	106.7	8.9
17N26E8CD	347.6	13.1	18.0	97.6	50.3
17N26E35DA	341.5	13.1	15.2	49.4	41.5
17N34E7CC	426.8	12.7	17.4	201.2	23.3
18N18E36AB	498.2	12.3	28.4	262.2	61.3
18N29E28CD	341.5	13.1	15.0	61.0	30.8
18N29E34CC	341.5	13.2	16.9	133.8	28.5
18N31E2AD	372.9	13.0	13.0	122.0	0.0
18N31E18BA	396.3	12.8	21.8	240.2	37.3
18N34E32DC	498.5	12.3	16.2	182.9	21.2
19N28E29CB	320.1	13.2	19.7	232.0	27.7
19N29E9DD	375.0	13.0	16.7	170.7	21.9
19N30E20BB	419.5	12.7	13.5	307.0	2.5
19N30E28BC	417.7	12.7	11.4	211.0	- 6.3
19N31E24BC	451.2	12.6	17.9	190.6	28.1
19N32E15CC	495.4	12.3	15.4	205.8	14.9
19N33E8CA	547.3	12.1	13.5	134.2	10.6
19N35E14CD	548.8	12.1	16.4	186.3	22.9
19N36E2AA	579.3	11.9	12.3	115.8	3.5
20N29E15AD	410.7	12.8	10.6	158.5	-13.4
20N30E23A	501.5	12.2	19.2	219.5	31.7*
20N31E6CA	485.1	12.4	13.9	182.9	8.2
20N31E14AA	457.3	12.5	13.6	132.0	7.7
20N32E15CA	510.7	12.3	14.7	237.8	10.1
20N34E10BD	583.8	11.9	17.8	237.8	24.8
20N36E6DD	585.4	11.9	14.2	135.9	17.0
21N30E12BA	485.1	12.4	13.3	231.7	3.9
21N31E24CA	538.1	12.1	14.9	182.9	15.4
21N32E32DD	529.3	12.2	15.1	182.9	15.8
21N33E5DC	475.6	12.4	10.9	75.6	-20.6
21N33E17DA	543.9	21.1	18.3	207.3	30.0
21N35E7AC	612.2	11.8	20.1	128.0	64.8
22N34E26BA	602.1	11.8	12.7	152.4	6.0

Appendix B (continued)

Location	Elevation m	T _s °C	T _{BHT} °C	Depth m	Calculated Gradient °C/km
22N35E23CB	602.1	11.8	10.3	105.5	-14.0
23N32E3CD	598.5	11.8	15.3	140.2	25.0
23N34E19CD	612.8	11.8	12.8	204.9	5.0
23N41E13BB	731.7	11.2	11.3	164.6	1.1
23N41E13BC	731.7	11.2	14.0	187.2	15.3
23N42E2BD	707.3	11.3	16.4	189.0	27.3
23N42E25BA	722.6	11.2	12.5	134.2	9.7
24N32E11DD	581.4	11.9	10.3	140.2	- 1.6
24N32E35DB	625.0	11.7	12.6	187.8	4.6
24N36E2DC	724.1	11.2	11.3	91.5	1.2
24N36E2DD	731.7	11.2	14.0	187.2	15.2
24N36E16AA	723.2	11.2	13.8	73.2	34.9
24N41E31DC	728.7	11.2	13.5	111.9	20.8
25N22E28AB	792.7	10.8	16.2	184.5	28.9
25N36E25BA	722.6	11.2	12.6	49.6	28.4
26N32E10CD	682.9	11.4	14.6	119.2	26.9
26N33E18CD	686.0	11.4	12.9	152.5	9.9
26N33E29CD	673.5	11.4	13.1	86.7	19.5

The surface temperatures for these holes were calculated using the elevation term only (i.e. the slope and orientation correction was ignored except on the holes indicated by the *).