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GEOLOGIC MAP OF THE LA GRANDE RESERVOIR QUADRANGLE, UNION AND BAKER COUNTIES, OREGON

By

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2004

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1.0 INTRODUCTION

The La Grande Reservoir quadrangle lies at the northern end of the Elkhorn Mountains in the Blue Mountain province of Eastern Oregon (Figure 1.1). The majority of the quadrangle consists of mountainous terrain cut by the canyons of North Fork Wolf Creek, Beaver Creek, Whiskey Creek Jordan Creek and Rock Creek.

Elevation ranges from about 1120 m (3675 ft) to 1855 m (6100 ft) (Figure 1.2). The southern two-thirds of the quadrangle is U.S.D.A. Forest Service land; the northern third is private, including corporate timber and rangeland. The southern half of the quadrangle is heavily forested, with forest cover diminishing to the north as the elevation decreases. In the north, much of the area is grassland with limited forest cover (Figure 1.3).

Published geologic mapping for the area is of low resolution (1:250:000; Walker, 1973, Swanson and others, 1981; 1:62,500; Hampton and Brown, 1964) and does not differentiate the volcanic rocks of the area. Field work for this study was carried out in 1997. This map was produced as part of a cooperative program between the Oregon Department of Geology and Mineral Industries (DOGAMI) and the U.S. Geological Survey and is supported in part by the U.S.G.S. under assis-

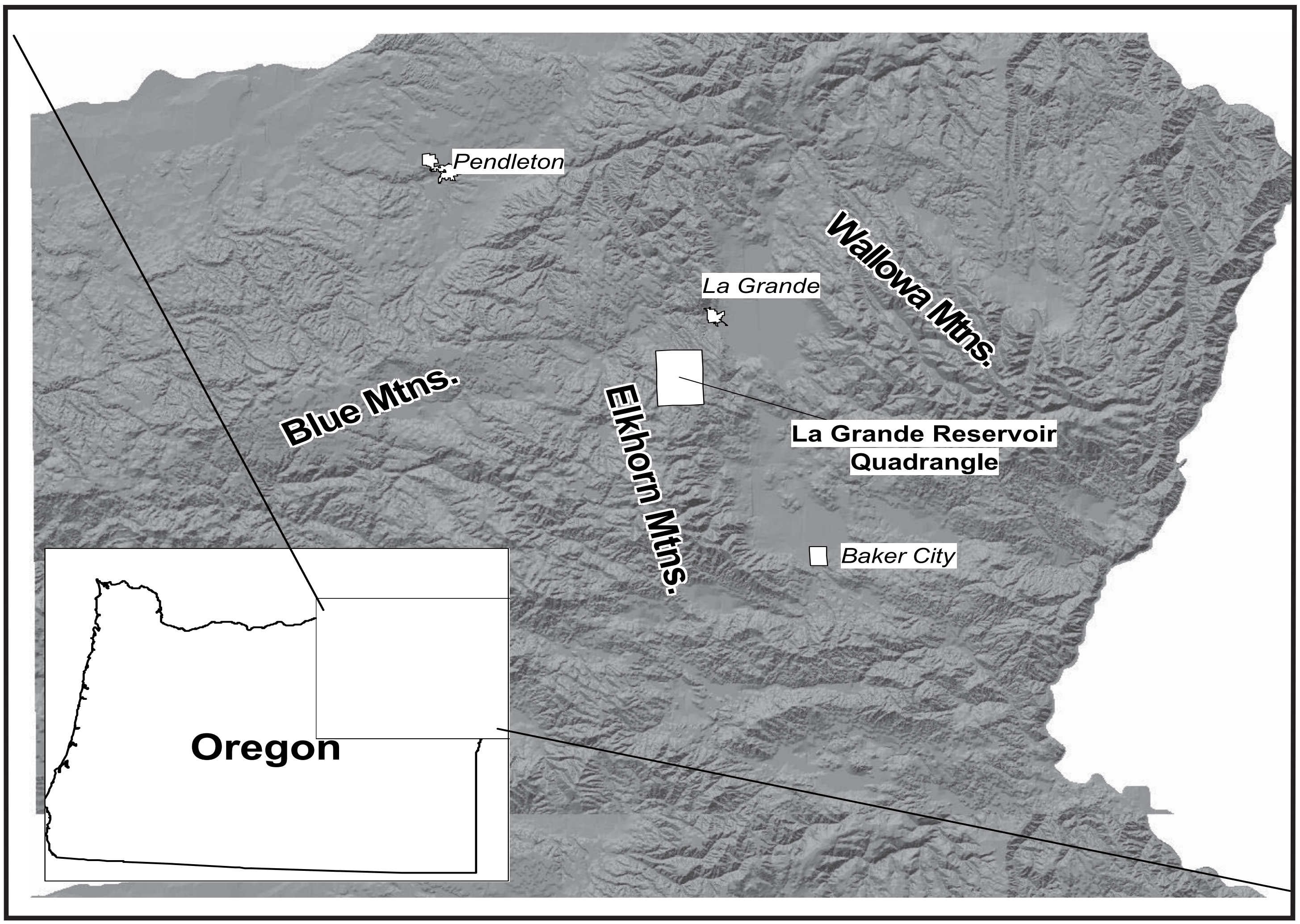

Figure 1.1. Location map, showing quadrangle location on shaded-relief map of northeast Oregon.

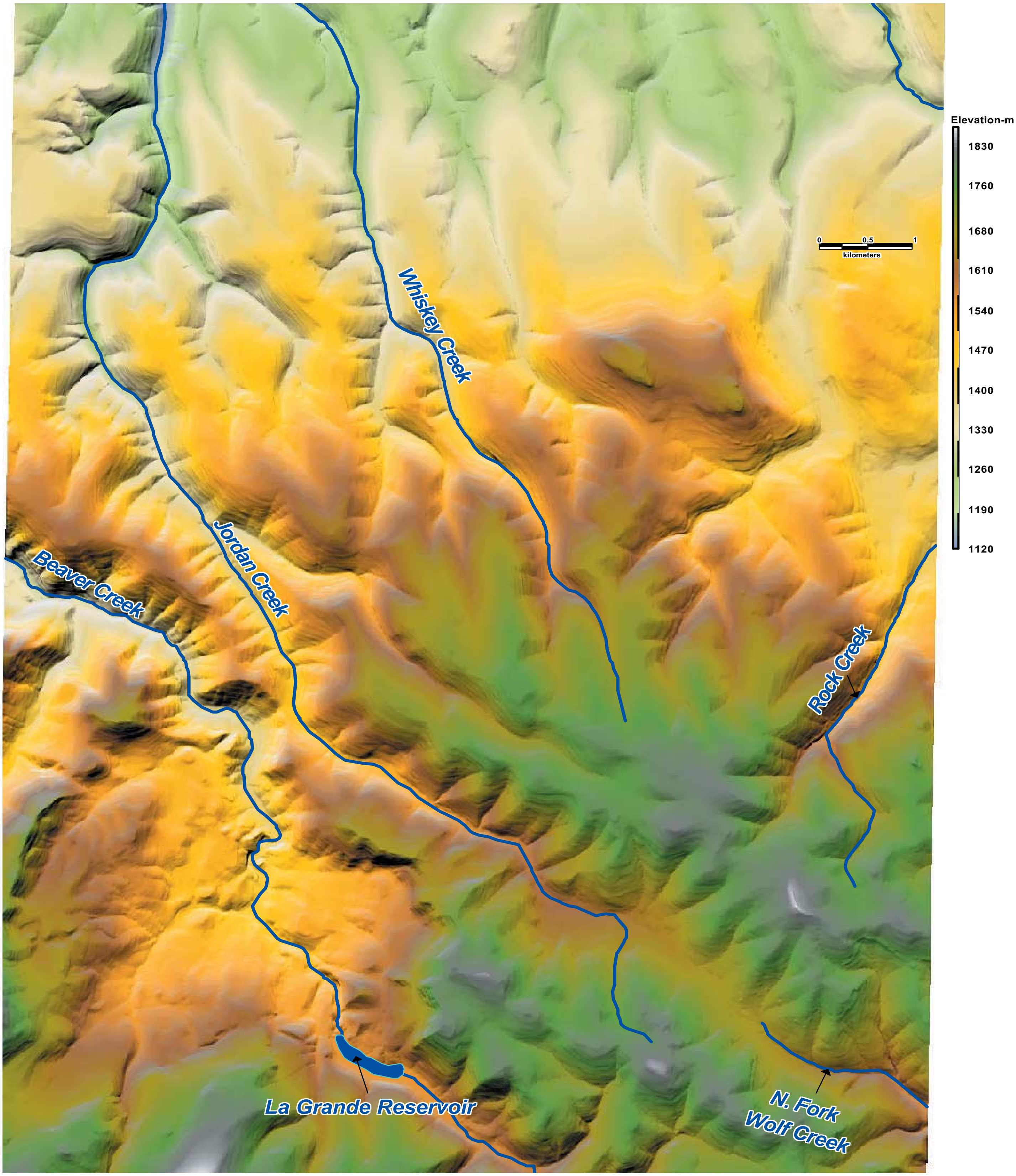

Figure 1.2. Shaded-relief map of the La Grande Reservoir Quadrangle with major streams.

Figure 1.3. Orthophoto of the La Grande Reservoir quadrangle. Note pronounced and persistent bands of trees associated with basalt flow tops.

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Much of the study area is underlain by basaltic andesite flows of the Grande Ronde Basalt of the Columbia River Basalt Group (CRBG). These flows are difficult to distinguish in the field, and are principally divided into four magnetostratigraphic units based on paleomagnetic polarity, and about 17 flow groups defined by geochemistry (see Table 1.1). Many of the flows are so chemically similar that, even with chemical analysis, it is often not possible to assign a given sample to a specific flow unit with confidence.

The Grande Ronde Basalt stratigraphy and structure depicted in this map are supported by 301 paleomagnetic data points, and 58 geochemical data points. The mapping of these units is based on interpretation of these data, so data points are included on the map (See OFR O-04-06map.pdf). Extensive use was also made of airphotos and orthophoto imagery, because the forest cover in the northern half of the map is often restricted to the tops of individual basalt flows. The resulting tree bands can give excellent information on the dip of the flows and can help to locate faults (Figure 1.3). Figure 1.4 shows the actual traverses used to collect data for the map; areas without traverses were interpreted from topography and air photos.

The volcanic rocks of the area are typically fine-grained, so they are assigned rock names on the basis of geochemistry. Nomenclature is based on total alkalis versus silica, following Le Bas and Streckeisen (1991).

Table 1.1. Analysis of major oxide and selected trace elements, trace metals, and rare earth elements from samples collected in the La Grande Reservoir quadrangle, Union County, Oregon.

Map No.	Year	Field Id.	Location UTM (E)	(N)	Elev	Unit	Lithology	Source	Lab	Major Oxides[2] (weight percent) SiO_2	Al_2O_3	TiO_2	FeO	MNO	CaO	MgO	K_2O	Na_2O	P_2O_5	TOTAL	Trace Elements (parts per million) Ni	Cr	Sc	V	Ba	Rb	Sr	Zr	Y	Nb	Ga	Cu	Zn	Pb	La
1	1980	80-099	407764	5007011	5120	Tpd	dacite	Wright et al 1982	WSU	64.27	17.58	0.64	3.61	0.09	5.26	2.31	1.98	3.71	0.3	99.75	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr
2	1980	80-101	410166	5008598	4330	Tpd	dacite	Wright et al 1982	WSU	64.3	17.81	0.61	3.48	0.08	5.18	2.15	2.41	3.44	0.28	99.74	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr
3	1997	AR77	408610	5006466	5340	Tpd	dacite	Madin	XRAL	64.3	16.05	0.67	5.18	0.12	5.7	1.84	1.75	3.93	0.3	98.45	nr	nr	nr	nr	605	28	579	175	16	10	nr	nr	nr	nr	nr
4	1997	Ar314	407070	5010125	4340	Tpab	trachybasalt	Madin	WSU	46.72	15.44	?2.87	12.01	0.17	8.71	7.65	0.92	4.76	0.76	99.24	105	169	23	291	379	4	1274	102	13	7	23	97	132	0	26
5	1997	Ar313BR	406125	5010535	4065	Tpb	olivine basalt	Madin	WSU	52.45	17.15	1.269	9.8	0.137	9.82	5.37	0.66	2.96	0.386	98.2	62	216	30	245	397	7	458	102	23	8	17	36	86	3	5
6	1997	AR49A	410075	5000540	6020	Tpb	olivine basalt	Madin	XRAL	50.3	15.31	1.51	11.26	0.17	9.27	8.26	0.75	2.68	0.4	98.6	nr	nr	nr	nr	298	0	280	118	19	nr	nr	nr	nr	nr	nr
7	1980	80-105	410961	5000343	5900	Tpb	olivine basalt	Wright et al 1982	WSU	51.44	16.38	1.4	9.23	0.16	9.99	7.47	0.86	2.46	0.35	99.74	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr
8	1997	Ar313B	406125	5010535	4065	Tpb	olivine basalt	Madin	WSU	52.57	17.12	1.279	9.73	0.138	9.8	5.39	0.66	2.94	0.384	99.01	64	211	27	243	377	6	456	101	21	8	17	36	84	0	35
9	1980	80-100	409619	5009862	4180	Ttf	andesite	Wright et al 1982	WSU	58.46	14.66	1.95	10.64	0.24	5.27	1.95	2.96	2.96	0.67	99.76	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr
10	1980	80-097	409061	5010370	4030	Ttf	andesite	Wright et al 1982	WSU	58.51	14.55	1.95	10.85	0.23	5.31	1.93	2.87	2.9	0.65	99.75	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr
11	1997	AR16	409700	5005570	4825	Tgn2?	basaltic andesite	Madin	XRAL	53.12	13.68	2.01	13.58	0.2	8.24	4.4	1.19	3.07	0.34	99.4	nr	84	nr	nr	653	25	329	178	40	10	nr	nr	nr	nr	nr
12	1997	AR18	409920	5005740	4750	Tgn2?	basaltic andesite	Madin	XRAL	53.4	13.2	2.12	14.31	0.2	7.94	3.9	1.25	3.17	0.39	99.25	nr	59	nr	nr	720	27	350	179	40	10	nr	nr	nr	nr	nr
13	1997	Ar313A	406120	5010545	4065	Tgn2?	basaltic andesite	Madin	WSU	54.26	13.59	2.104	13.41	0.253	7.73	3.81	1.21	3.21	0.41	99.24	0	21	36	379	651	28	350	165	44	14	21	20	133	5	26
14	1997	Ar315	407380	5009910	4240	Tgn2?	basaltic andesite	Madin	WSU	54.45	13.56	2.103	12.99	0.234	7.73	3.95	1.34	3.24	0.402	99.06	0	18	32	397	640	29	344	163	39	11	22	28	131	3	24
15	1997	Ar76	408665	5006145	5190	Tgn2?	basaltic andesite	Madin	WSU	54.74	13.62	2.13	12.62	0.21	7.64	4.02	1.33	3.31	0.4	99.37	0	21	31	398	612	33	336	163	37	12	24	25	129	6	25
16	1997	Ar93	406210	5002720	5630	Tgn2?	basaltic andesite	Madin	WSU	57.34	13.9	2.11	11.05	0.18	6.53	3.08	1.89	3.47	0.45	98.58	0	18	29	292	793	49	313	191	42	14	22	10	134	7	27
17	1980	80-098	407424	5008471	4560	Tgn2?	basaltic andesite	Wright et al 1982	WSU	53.76	14.97	2.05	11.96	0.21	7.89	4.26	1.78	2.53	0.32	99.73	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr
18	1997	AR12	406400	5004760	5320	Tgn2?	basaltic andesite	Madin	XRAL	55.34	13.25	2.16	13.45	0.17	6.8	3.16	1.68	3.35	0.42	98.85	nr	31	nr	nr	774	41	317	209	41	11	nr	nr	nr	nr	nr
19	1997	Ar114	402590	5004555	5140	Tgr2	basaltic andesite	Madin	WSU	56	13.97	2.27	11.74	0.22	7.17	3.27	1.61	3.34	0.41	98.39	0	20	28	403	771	38	331	174	37	13	26	9	129	5	24
20	1997	Ar220	402645	5002790	5290	Tgr2	basaltic andesite	Madin	WSU	55.15	13.93	2.194	12.31	0.209	7.42	3.72	1.57	3.1	0.401	98.82	2	26	31	372	666	35	310	179	41	14	24	9	130	4	27
21	1997	Ar221	402810	5002710	5445	Tgr2	basaltic andesite	Madin	WSU	56.05	14.26	2.346	11.32	0.156	6.81	3.38	1.75	3.51	0.413	97.9	2	20	29	397	707	47	342	180	37	13	24	12	132	6	24
22	1997	Ar222	403090	5002680	5555	Tgr2	basaltic andesite	Madin	WSU	57.17	13.72	2.223	11.45	0.148	6.21	3.15	2.04	3.43	0.467	98.55	0	20	29	321	795	60	343	183	41	16	23	6	120	9	41
23	1997	Ar244	402210	5007190	4700	Tgr2	basaltic andesite	Madin	WSU	55.01	13.91	2.308	12.83	0.185	7.26	3.55	1.6	2.94	0.392	97.33	0	21	22	390	681	38	340	176	39	14	23	4	121	8	20
24	1980	80-102	409983	5008401	4420	Tgr2	basaltic andesite	Wright et al 1982	WSU	53.15	14.76	2.08	13.72	0.22	7.56	3.93	1.29	2.65	0.35	99.71	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr
25	1997	Ar112	402505	5004680	5315	Tgr2	basaltic andesite	Madin	WSU	54.82	13.97	2.05	11.61	0.2	8.02	4.38	1.53	3.06	0.35	99.05	11	42	34	394	630	36	309	164	35	13	20	36	120	5	19
26	1997	Ar273	404120	5005260	4940	Tgr2?	basaltic andesite	Madin	WSU	55	13.71	2.238	12.67	0.187	7.07	3.75	1.67	3.32	0.39	99.07	0	22	31	393	661	44	326	175	37	13	22	3	121	8	31
27	1997	AR17	409840	5005700	4780	Tgr2?	basaltic andesite	Madin	XRAL	52.52	14.62	2.56	14.21	0.19	7.63	3.6	1.17	2.88	0.36	97.1	nr	50	nr	nr	859	21	340	216	36	12	nr	nr	nr	nr	nr
28	1997	Ar116	402715	5004372	4770	Tgn1	basaltic andesite	Madin	WSU	54.35	14.27	2.1	11.22	0.2	8.38	4.63	1.23	3.24	0.36	99	12	46	33	344	621	27	345	165	37	13	24	54	125	5	22
29	1997	Ar159	402595	5002070	5260	Tgn1	basaltic andesite	Madin	WSU	55.59	13.85	2.174	11.68	0.212	7.45	3.66	1.8	3.14	0.449	98.83	6	26	32	389	749	38	317	180	41	14	23	19	129	4	11
30	1997	Ar182	405408	5001440	5530	Tgn1	basaltic andesite	Madin	WSU	55.39	13.69	2.256	12.6	0.212	7.08	3.36	1.7	3.29	0.408	98.7	0	21	32	382	727	42	338	176	37	14	25	13	124	4	20
31	1997	Ar208	405580	5003975	5100	Tgn1	basaltic andesite	Madin	WSU	55.42	13.78	2.241	12.01	0.182	7.02	3.95	1.66	3.33	0.402	99.18	0	21	29	396	679	41	320	173	35	14	21	11	120	7	31
32	1997	Ar219	402590	5002800	5200	Tgn1	basaltic andesite	Madin	WSU	55.39	13.91	2.159	11.71	0.204	7.75	3.75	1.58	3.15	0.407	99	0	27	34	347	626	35	321	166	38	12	21	12	126	9	48
33	1997	Ar242	402520	5007250	4340	Tgn1	basaltic andesite	Madin	WSU	54.92	13.59	2.097	12.83	0.209	7.27	3.78	1.48	3.44	0.387	98.62	0	23	38	370	628	37	306	171	39	13	21	22	122	6	43
34	1997	Ar243	402430	5006945	4600	Tgn1	basaltic andesite	Madin	WSU	55.43	13.83	2.178	12.4	0.19	7.13	3.49	1.67	3.28	0.399	98.43	0	20	33	382	691	42	322	173	39	13	22	11	123	6	37
35	1997	Ar243R	402430	5006945	4600	Tgn1	basaltic andesite	Madin	WSU	55.43	13.84	2.167	12.35	0.189	7.08	3.51	1.66	3.37	0.401	98.85	0	22	30	394	661	43	323	172	38	14	20	13	128	6	18
36	1997	Ar115	402665	5004430	4940	Tgn1	basaltic andesite	Madin	WSU	55.97	13.91	2.22	11.48	0.21	7.13	3.48	1.79	3.39	0.42	98.77	2	24	27	393	765	40	320	176	39	13	22	14	135	6	15
37	1997	Ar38	409735	4998050	5840	Tgn1?	basaltic andesite	Madin	WSU	56.12	14.09	2.35	11.72	0.16	6.93	3.08	1.67	3.47	0.41	99.18	0	24	28	417	723	47	343	181	40	13	22	6	126	6	8
38	1997	Ar117	402730	5004220	4630	Tgr1	basaltic andesite	Madin	WSU	55.02	13.52	2.36	12.3	0.21	7.61	3.83	1.62	3.17	0.36	98.94	5	24	28	382	614	40	316	190	38	14	22	57	125	5	15
39	1997	Ar118	402740	5004140	4440	Tgr1	basaltic andesite	Madin	WSU	55.31	14.08	2.36	10.7	0.19	7.97	4.13	1.72	3.13	0.42	98.78	16	45	33	325	690	42	345	186	37	14	25	64	120	8	35
40	1997	Ar118R	402740	5004140	4440	Tgr1	basaltic andesite	Madin	WSU	55.13	14.01	2.34	11.09	0.19	7.9	4.15	1.72	3.06	0.41	99.05	16	45	27	333	681	42	346	186	37	14	21	60	120	6	4
41	1997	Ar119A	402746	5004090	4480	Tgr1	basaltic andesite	Madin	WSU	52.98	14.75	2.1	11.06	0.18	9.33	5.13	1.02	3.13	0.3	99.77	23	110	30	333	480	22	358	156	34	12	21	76	109	3	28
42	1997	Ar119B	402746	5004085	4460	Tgr1	basaltic andesite	Madin	WSU	54.81	13.99	2.36	11.32	0.22	7.93	3.97	1.59	3.36	0.44	99.29	19	33	32	415	662	38	311	187	44	14	24	69	127	7	17
43	1997	Ar120	402740	5004010	4330	Tgr1	basaltic andesite	Madin	WSU	53.61	13.81	2.47	12.07	0.22	8.16	4.59	1.49	3.17	0.4	99.47	10	42	29	381	617	38	329	184	39	15	25	43	123	5	24
44	1997	Ar179	405706	5001085	5340	Tgr1	basaltic andesite	Madin	WSU	54.51	13.92	2.21	11.83	0.209	8.04	4.16	1.49	3.23	0.391	99	7	45	30	356	596	32	341	176	38	14	22	56	122	6	9
45	1997	Ar180	405690	5001065	5290	Tgr1	basaltic andesite	Madin	WSU	55.17	13.81	2.34	11.69	0.199	7.74	3.94	1.59	3.18	0.349	98.8	5	25	31	373	578	38	321	185	38	15	23	56	116	6	24
46	1997	Ar181	405731	5001105	5400	Tgr1	basaltic andesite	Madin	WSU	55.56	13.82	2.245	11.8	0.208	7.42	3.68	1.7	3.2	0.37	98.66	0	10	31	358	663	40	334	189	39	14	22	15	121	6	12
47	1997	Ar207	405300	5004155	5075	Tgr1	basaltic andesite	Madin	WSU	54.47	13.87	2.051	12.38	0.2	7.92	4.17	1.52	3.07	0.345	99.09	9	41	30	366	614	35	313	166	37	14	20	33	117	6	33
48	1997	Ar294	401740	4999260	6040	Tgr1	basaltic andesite	Madin	WSU	55.04	14.35	2.076	10.59	0.196	8.35	4.42	1.51	3.11	0.359	99.08	10	48	32	369	748	34	335	168	41	14	21	25	126	5	36
49	1997	AR6	404510	5002160	4760	Tgr1	basaltic andesite	Madin	XRAL	51.69	14.44	2.27	12.92	0.27	9.36	4.69	1.09	2.76	0.37	99.05	nr	121	nr	nr	584	23	355	185	42	10	nr	nr	nr	nr	nr
50	1997	Ar99	403580	5002740	4910	Tgr1	basaltic andesite	Madin	WSU	55.23	13.73	2.31	11.52	0.21	7.75	4.06	1.6	3.26	0.34	98.86	6	23	34	372	611	38	319	180	36	13	20	52	123	6	26
52	1980	80-107	404510	5002159	4750	Tgr1	basaltic andesite	Wright et al 1982	WSU	52.53	15.1	2.22	11.7	0.22	8.9	4.75	1.35	2.66	0.32	99.75	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr
53	1997	Ar295	401724	4999057	5980	Tgr1	basaltic andesite	Madin	WSU	56.79	14.24	1.983	10.83	0.19	7.13	3.58	1.95	2.97	0.335	99.43	1	23	26	330	812	47	327	168	36	11	21	12	120	6	32
54	1996	TF185	410186	4997425	5820	Tgr1?	basaltic andesite	Madin	XRAL	55.69	14.05	2.26	11.62	0.19	7.19	3.59	1.65	3.35	0.41	98.94	nr	nr	nr	nr	705	50	363	200	41	12	nr	nr	nr	nr	nr
55	1980	80-106	404533	5002147	4800	Tgr1	basaltic andesite	Wright et al 1982	WSU	52.13	15.48	2.09	11.5	0.21	9.24	5	1.12	2.71	0.28	99.76	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr
56	1998	Ar103	404490	5001600	4630	Tap	dacite porphyry	Madin	WSU	63.93	15.44	0.977	7.38	0.083	3.99	0.55	3.68	3.57	0.41	97.61	2	3	15	58	936	87	391	345	39	43	26	5	119	21	41
57	1998	Ar103R	404490	5001600	4630	Tap	dacite porphyry	Madin	WSU	64.3	15.52	0.982	6.87	0.084	4.01	0.51	3.68	3.62	0.412	97.49	2	5	13	61	919	87	386	340	39	42	29	6	117	20	32
58	1997	AR1	407880	5000630	5350	Tap	andesite porphyry	Madin	XRAL	62.78	15.72	1	6.23	0.07	5.76	2.42	1.96	3.7	0.2	98.6	nr	93	nr	nr	760	44	381	169	24	13	nr	nr	nr	nr	nr
59	1997	AR147	406080	4998880	5390	Tap	andesite porphyry	Madin	XRAL	62.23	17.18	1.17	5.55	0.07	5.33	1.86	2.47	3.69	0.31	98.35	nr	0	nr	nr	859	48	552	193	17	16	nr	nr	nr	nr	nr

Note: Analytical methods for WSU analyses described in Hooper and others, 1993. Methods for XRAL analyses described in Miller, 1997. All analyses by XRF. Sample numbers ending in "R" denote repeat analysis of the same sample. nr=not reported.

[1]Labels on chemistry data points on map correspond to entries in the Map No. column of this table.

[2]All major oxides reported in normalized values.

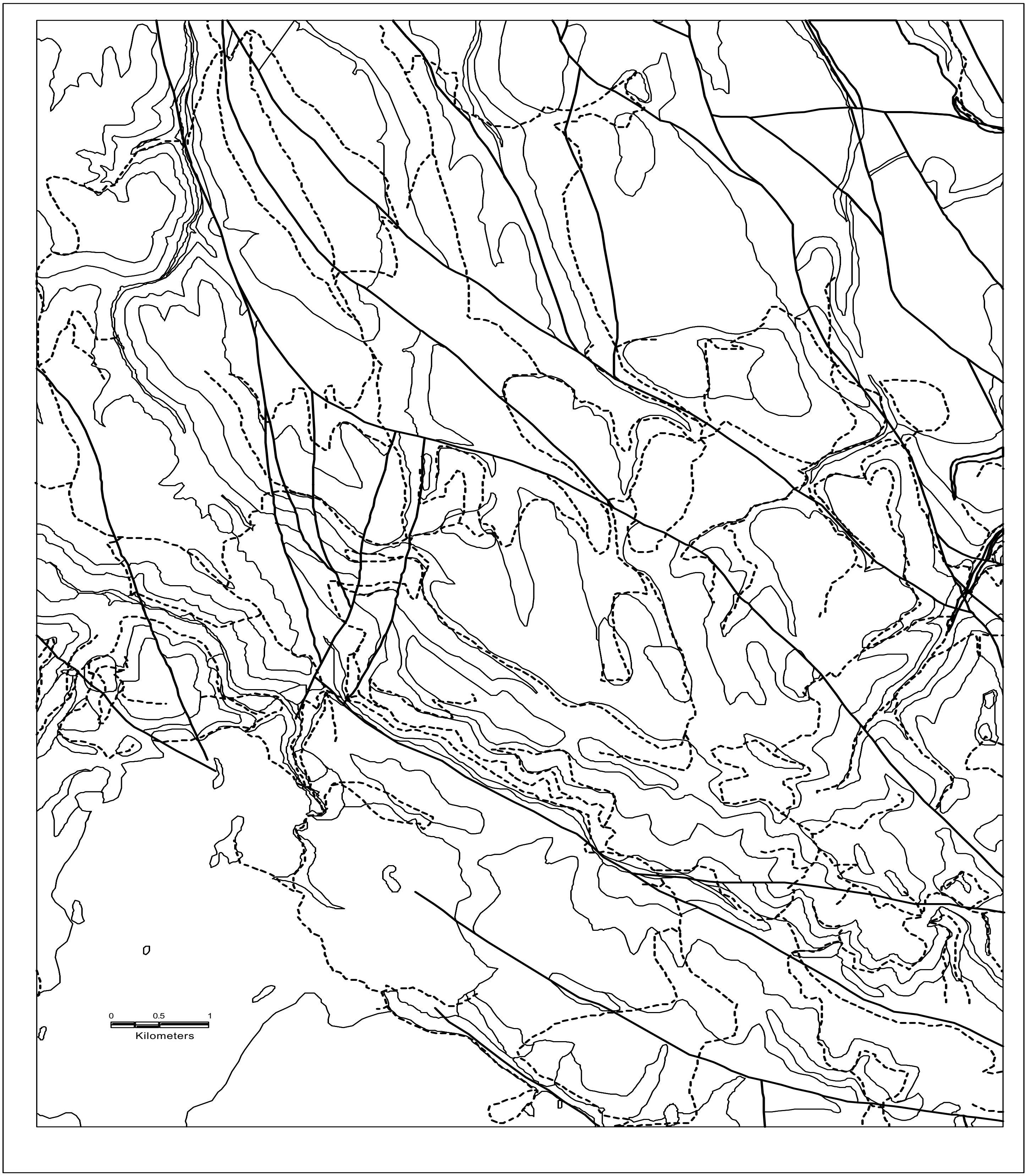

Figure 1.4. Traverse map. Fine lines are geologic contacts, heavy lines faults, dotted lines traverses.

2.0 EXPLANATION OF MAP UNITS

2.1 Surficial Units

Qa **Volcanic Ash (Holocene)**—White, tan and light brown airfall ash deposited by the eruption of Mt. Mazama in southwestern Oregon 6845 ± 50 Radiocarbon years before present (RCYBP) (Bacon, 1983). Forms almost pure deposits up to 0.5 m thick on some flats and swales. Typically absent from ridgecrests and steep slopes with thin soil. Areas shown on this map as unit Qa are those where the unit was actually observed in the field; many other areas of similar aspect and slope may have unmapped deposits.

Qp **Paludal deposits (Holocene)**—Sand, clay, silt and organic material deposited in ponds and marshes occupying closed depressions formed on the surface of major landslides, and in a small lake in the northern portion of the map east of Little Graves Creek (T. 4 S., R. 37 E., Section 3).

Qal **Alluvium (Holocene)**—Sand, silt and pebble-to-boulder gravel deposited by Beaver Creek, Whiskey Creek, Wolf Creek, Rock Creek, Jordan Creek and their tributaries. Alluvium is typically only a few meters thick.

Qls **Landslides (Quaternary)**—Broken and jumbled rock and soil. Many slides are fairly large (over 1 km^2), and deep-seated, involving a considerable thickness (tens of m) of bedrock. Slides are most commonly associated with lava flows overlying sedimentary rocks (Tsv). The largest slide complex is the Beaver Creek slide complex, which covers over 14 km2 in the southeast corner of the map.

Qfg **Outburst flood deposits (Pleistocene)**—Sandy boulder gravel with clasts up to 1m in diameter. Only a small patch is preserved along Beaver Creek in the NW corner of Section 5, T. 5 S., R. 37 E. This unusually coarse gravel was probably deposited by an outburst flood caused by catastrophic emptying of a temporary lake formed by the blockage of Beaver Creek by one of the many upstream landslides.

Qt **Terrace deposits (Pleistocene)**—Cobbles, boulders, pebbles and sand deposited behind a landslide dam on the upper reaches of Beaver Creek.

2.2 Calc-alkaline Volcanic Rocks of the Powder River Volcanic Field

Tpd **Dacite (middle Miocene)**—one or more flows of aphyric dacite, exposed at Elk Mountain in the NE quarter of the map. Dacite is typically grey to purplish grey, and platy, with a sheen to the plate surfaces. Jet black massive dacite and whitish grey highly vesicular dacite are sometimes found at the base and top of the flow respectively. Maximum thickness is 30 to 40 m. The dacite weathers into plates and sheets and is easily distinguishable in soils and colluvium from other lavas in the area, and typically outcrops in cliffs on steeper slopes. The chemistry of the dacite (Table 1.1, Samples 1-3) is generally similar to the chemistry of dacite flows mapped to the southeast (unit Td of Bailey, 1990) as part of the Powder River volcanic field, to the north by Barrash and others (1980) as part of the andesite of Craig Mountain, and on the adjacent Tucker Flat quadrangle (Madin, 1998) as the dacite of Man Ridge. Bailey (1990) reports an age of 13.1 ± 0.2 Ma for similar dacite to the southeast of the quadrangle. Ferns and Madin (1997) report a chemically similar dacite some 25 km north of the map area in an identical stratigraphic setting with an $^{40}Ar/^{39}Ar$ age of 13.38 ± 0.24 Ma.

Tpab **Olivine trachybasalt (middle Miocene)**—At least one flow of black platy trachybasalt with olivine phenocrysts up to 2-3 mm common. Typically forms cliffy outcrops, and weathers light grey. Chemically (Table 1.1, Sample 4), trachybasalt is characterized by low SiO_2 (47 percent), and high TiO_2 (2.87 percent) FeO (12 percent) and Na_2O (4.76 percent). Within the quadrangle, the stratigraphic relationship between the trachybasalt and the other units of the Powder River volcanic field are not clear; trachybasalt always lies directly on older CRBG rocks, and is not overlain by any other unit. On the adjacent (to the east) Glass Hill quadrangle, chemically similar basalt which underlies unit Tpd was reported by Wright and others (1982). Bailey (1990) reports olivine and clinopyroxene phyric alkali basalt from the Powder River volcanic field to the east of the study area which are chemically similar, except for higher SiO_2 (52-53 percent) and lower FeO (8.5-10 percent). The trachybasalt was mapped by Barrash and others (1980) as the dense, glassy facies of the basalt of Glass Hill on the adjacent Glass Hill and Hilgard quadrangles. The age of the trachybasalt is interpreted to be between that of the overlying dacite (13.1-13.38 Ma) and the underlying (?) olivine basalt (13.7 Ma, see below) based on stratigraphic relationships oberved between chemically similar units in nearby areas.

Tpa **Andesite (middle Miocene)**—Flow-on-flow sequence of glassy aphyric basaltic andesite and andesite flows. Mainly massive to platy-jointed, aphyric glassy black andesite flows, typically mottled with light green bands. In thin section, characterized by small pyroxene and plagioclase microphenocrysts set in a very fine-grained pilotaxitic groundmass. The age of the andesite is interpreted to be between that of the dacite (13.1-13.38 Ma) and the olivine basalt (13.7 Ma).

Tpb **Olivine basalt (middle Miocene)**—At least two flows of black to grey plagioclase- and olivine-phyric basalt. One flow (Table 1.1, Samples 6,7) was probably an intracanyon flow, in a canyon cut in sediments that have been almost entirely stripped away. The outcrops typically occur as columnar jointed basalt in elongate bodies along ridgecrests. In several locations, pebble-to-cobble gravel containing metamorphic and granitic clasts occurs between the basalt and the underlying rocks of the CRBG. A second flow (Table 1.1, Samples 5,8) is highly diktytaxitic and grey. Chemically, the olivine basalt is very similar to the low titanium and phosphorus olivine tholeiites (LTPOT) unit of the Powder River volcanic field mapped a few km east of the map area by Bailey (1990) and similar to the basalt of Red Ridge mapped by Madin (1998) in the adjacent Tucker Flat quadrangle. Bailey (1990) reports an $^{40}Ar/^{39}Ar$ age of 13.7 ± 0.1 Ma for one sample of LTPOT. The olivine basalt is also chemically very similar to the diktytaxitic basalt of Glass Hill mapped just a few km to the north by Barrash and others (1980). All measured exposures have reversed magnetic polarity.

2.3 Columbia River Basalt Group

Numerous, voluminous flows of iron-rich basalt and basaltic andesite that originated from fissure vents in eastern Oregon, southeast Washington and western Idaho during the middle Miocene. The CRBG covers 163,700 km^2 in Oregon, Washington and Idaho. Individual flows have volumes as high as 1900 km^3 (Tolan and others, 1989).

Ttf **Andesite of Tucker Flat (middle Miocene)**—several flows of grey to black, glassy to holocrystalline sparsely plagioclase-phyric andesite and basaltic andesite with plagioclase phenocrysts up to 0.5 mm long, and rare plagioclase phenocrysts and plagioclase-pyroxene glomerophenocrysts up to 5 mm long. The thickness ranges from about 50 to 100 m. Chemically (Table 1.1, Samples 9, 10) these flows differ from the underlying Grande Ronde flows (Reidel and others, 1989) by having higher silica (58.5 percent), potassium (2.95 percent) and phosphorus (0.66 percent), and much lower magnesium (1.94 percent) and calcium (5.29 percent). In Figure 2.1, these rocks are plotted in a P_2O_5 versus TiO_2 diagram along with the fields for other units of the CRBG. Clearly, these rocks are chemically distinct from any other CRBG unit, and from the rest of the Grande Ronde Basalt. Unit Ttf is overlain by unit Tpd (~ 13.38 Ma) and overlies N2 Grande Ronde basalt (15.7 ± .03 Ma; Baksi, 1989). Unit Ttf has been dated at 15.5 ±- 0.01 Ma by stepwise $^{40}Ar/^{39}Ar$ technique (Dr. Robert Duncan, personal communication, 1998). Reidel and others (1996) have reported chemically similar rocks in the same stratigraphic position in the La Grande area (50 km north). Bailey (1990) and Wright and others (1982) have also reported chemically similar rocks to the southeast and northwest, respectively, but without a firm stratigraphic correlation. Madin (1998) and Ferns and Madin (1998) have mapped rocks of similar composition (See Figure 2.1) as the ferroandesite of Tucker Flat in the adjacent Tucker Flat quadrangle (to the southeast), and as the ferroandesites of Indian Rock and Tucker Flat in the Summerville Quadrangle, 30 km northeast.

2.3.1 Grande Ronde Basalt

The Grande Ronde Basalt has been divided into four magnetostratigraphic units based on the direction (normal or reversed) of remnant paleomagnetism (from older to younger: Tgr1, Tgn1, Tgr2, Tgn2, Swanson and others, 1979; Reidel, 1983; Reidel and others, 1989; Baksi, 1989). The magnetostratigraphic units have also been divided into numerous flow groups based on geochemistry (Reidel, 1983; Reidel and others, 1989). However, the chemistry of almost all the flow groups is quite similar, and many groups have overlapping chemistry. Several samples in this study could be assigned to a particular flow group based on chemistry (Dr. Stephen Reidel, personal communication, 1998), many others either had chemistry that was not unique enough to make a positive correlation, or had chemistry that was substantially different from the well-established Grande Ronde units. Accordingly, flows were assigned to magnetostratigraphic units based on: a) multiple measurements of magnetic polarity in the field with a hand-held fluxgate magnetometer: b) field stratigraphic relations: and c) chemistry. Magnetostratigraphic mapping was hampered by the relatively common occurrence of lightning-induced magnetism in natural outcrops in the map area. Fully a third of natural outcrops visited had areas sufficiently strongly magnetized by lightning to deflect a compass needle. The majority of reliable paleomagnetic data come from road cuts.

Previous reconnaissance mapping (Swanson and others, 1981) correlated the Grande Ronde flows in the map area exclusively with the R2 and N2 magnetostratigraphic units. In this study, all four units are mapped; three of which are confirmed by chemistry (R1, N1, R2).

The flows of the Grand Ronde Basalt tend to be poorly exposed. Natural outcrops are rare and generally consist of rubbly flow-top breccia. Systematic observation of jointing patterns in the flows was not possible, nor was it possible to knowingly sample for geochemical analysis or magnetic polarity from a particular horizon within individual flows.

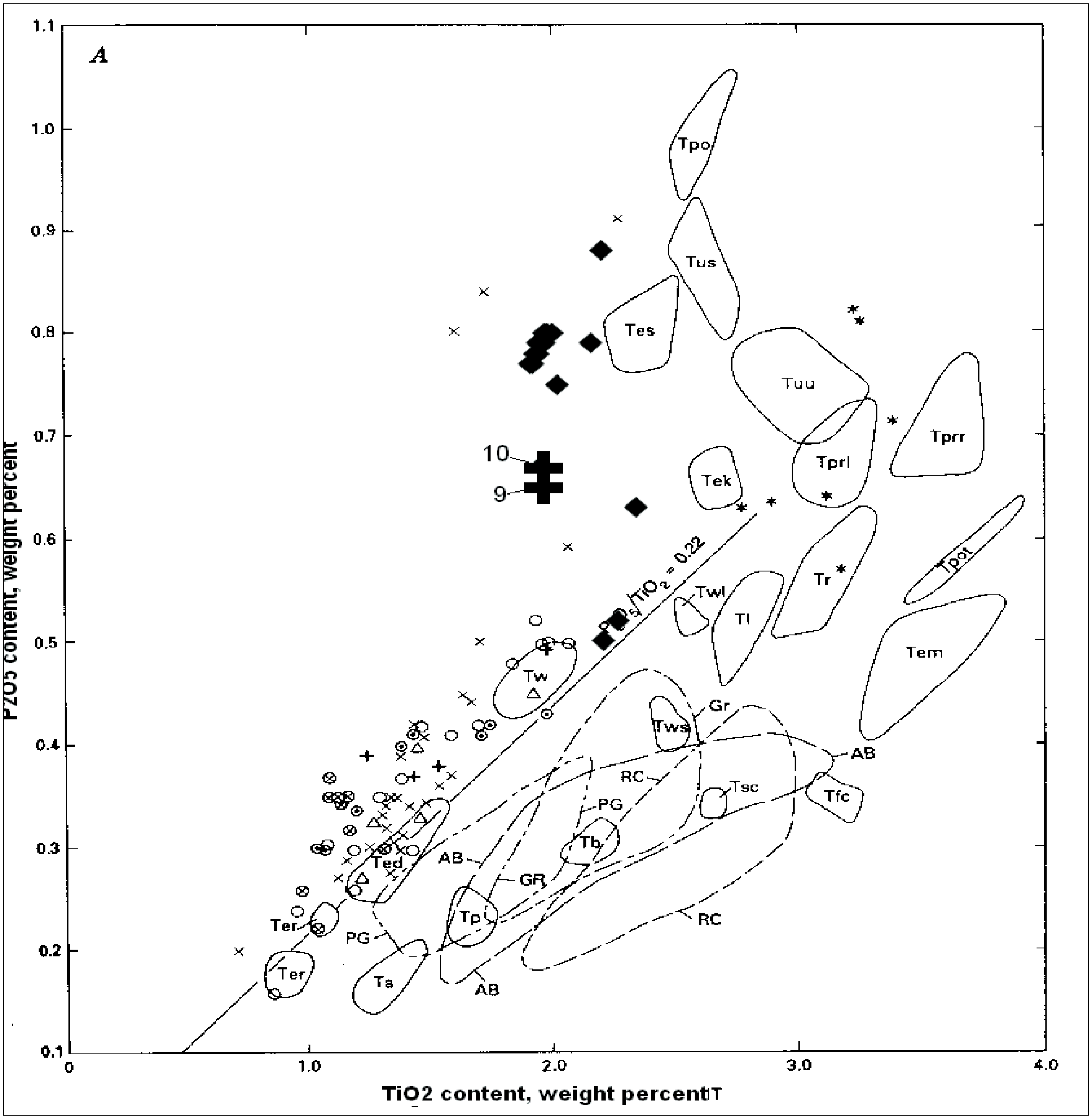

Figure 2.1. Adapted from Figure 4-12 of Hooper and Swanson, 1990. Plots of P205 versus Ti02 contents for the Columbia River Basalt Group (CRBG) and associated volcanic rocks. Flows of the CRBG: AB, Imnaha (AB subgroup); GR, Grande Ronde field; PG, Picture Gorge field; RC, Imnaha (RC subgroup); Ta, Asotin; Tb, Buford; Ted, Dodge; Tek, Lookingglass; Tem, Elephant Mountain; Ter, Robinette Mountain; Tes, Shumaker Creek; Tfc, Feary Creek; Tl, Lower Monumental; Tp, Pomona; Tpo, Powatka; Tpot, Potlatch; Tprl, Lolo; Tprr, Rosalia; Tr, Roza; Tsc, Swamp Creek; Tus, Sillusi; Tuu, Umatilla; Tw, Wilbur Creek; Twl, Lewiston Orchards; Tws, Slippery Creek. Modified from Hooper (1982). Basalt of Powder River and associated volcanic rocks (< 55 weight percent Si02): <, Cricket Flat area; Ä, olivine basalt in La Grande Basin (W. H. Taubeneck, in Wright and others, 1980); /, diktytaxitic olivine basalt from La Grande Basin (W. H. Taubeneck, in Wright and others, 1980); 3, east side of Baker Valley; +, Medical Springs area; 2, west and south sides of La Grande Basin (Barrash and others, 1980); 4E, nepheline basalt from La Grande Basin (Wright and others, 1980); F, andesite of Tucker Flat, this study; ", ferroandesite of Tucker flat from Madin (1998) and Ferns and Madin (in press).

Tgn2 **N2 Magnetostratigraphic unit undifferentiated (middle Miocene)**—Several flows of black-grey glassy to holocrystalline basaltic andesite with common plagioclase phenocrysts up to 1 mm long and rare plagioclase-pyroxene glomerophenocrysts up to 2 mm in length. Chemical analyses of these flows are given in Table 1.1 (Samples 11-18). None of the N2 flows were positively chemically correlated with N2 Grande Ronde flows elsewhere (Dr. Stephen Reidel, personal communication, 1998), and are assigned to this interval on the basis of stratigraphic position and magnetic polarity. The thickness of the unit is up to 50 m, and the age range of the N2 unit is 15.5 Ma to 15.7 ± .03 Ma (Baksi, 1989).

Tgr2 **R2 Magnetostratigraphic unit undifferentiated (middle Miocene)**—several flows of black-grey glassy to holocrystalline basaltic andesite with common plagioclase phenocrysts up to 1 mm long and rare plagioclase-pyroxene glomerophenocrysts up to 2 mm in length. Chemical analyses of these flows are given in Table 1.1 (Samples 19-27). Chemical flow units identified in this interval include Grouse Creek (Sample 112) and Wapshilla Ridge (Samples 114, 244, 220, 221,222) (Dr. Stephen Reidel, Personal Communication, 1998). The remaining samples were not positively correlated, and were assigned to this unit on the basis of stratigraphy and polarity. The unit is up to 100 m thick, and the age range of the R2 unit is 15.7 ± .03 to 15.9 ± .02 Ma (Baksi, 1989).

Tgn1 **N1 magnetostratigraphic unit undifferentiated (middle Miocene)**—Numerous flows of grey to black, glassy to holocrystalline basaltic andesite typically with plagioclase phenocrysts up to 1mm in length and rare plagioclase-pyroxene glomerophenocrysts up to 2 mm in length. Magnetic polarity was normal in almost all exposures where measurements were taken. Chemical analyses of these flows are given in Table 1.1 (Samples 28-37). Chemical flow units identified in this interval are all in the Downey Gulch unit (Dr. Stephen Reidel, personal communication, 1998). The remaining samples were not positively correlated, and were assigned to this unit on the basis of stratigraphy and polarity. The N1 unit is up to 100 m thick, and its age range is 16.1 to 15.9 ± .02 Ma (Baksi, 1989)

Tgr1 **R1 magnetostratigraphic unit undifferentiated (middle Miocene)**—Numerous flows of grey to black, glassy to holocrystalline basaltic andesite with plagioclase phenocrysts up to 1mm in length and rare plagioclase-pyroxene glomerophenocrysts up to 2 mm in length. Almost all exposures had reversed magnetic polarity where measured. Chemical analyses of these flows are given in Table 1 (Samples 38-55). Chemical flow units identified in this interval are in the Buckhorn Springs unit (sample 43), Teepee Butte (Pruitt Draw, Sample 41; Limekiln Rapids, Sample 42), Rogersburg (Samples 38, 39,44, 45, 46) and Center Creek (Sample 47) (Dr. Stephen Reidel, personal communication, 1998). The remaining samples were not positively correlated, and were assigned to this unit on the basis of stratigraphy and polarity. The Pruitt Draw flow is distinctive because it contains common plagioclase phenocrysts up to 3 mm long. The Pruitt Draw flow is exposed in the lower canyon of Beaver Creek in the west-central portion of the map, where it outcrops as a distinctive continuous double cliff in association with the underlying Limekiln Rapids flow. Another plagioclase-phyric flow (sample 49) outcrops as a discontinuous cliff along the north side of the upper canyon of Jordan Creek (Section 32, T. 4 S., R. 37 E., and Sections 3 and 4, T. 5 S., R. 37 E.) This flow is chemically quite different from the Pruitt

Draw flow, and may be a Buckhorn Springs flow similar to that mapped on the adjacent Tucker Flat quadrangle (Madin, 1998). The unit is up to 110 m thick, and its age range is 16.1 to 17 ± .03 Ma (Baksi, 1989).

2.4 Tower Mountain Volcanic Field

Andesite and dacite flows and associated volcaniclastic sediments. Ferns and others (2001) proposed the name Tower Mountain Volcanic Field for a suite of Oligocene age tuffs, flows and intrusions associated with the Tower Mountain Caldera, located some 10 km to the west of the map area.

Tvs **Volcaniclastic rocks (Oligocene)**—tan, white and brown tuff and lahar deposits and volcaniclastic silt and sandstone. Generally massive to crudely bedded, rarely exposed. The majority of the landslides in the map area are associated with this unit. Correlates to the volcaniclastic breccias, conglomerates and tuffs mapped in the adjacent Limber Jim quadrangle by Ferns and Taubeneck (1994).

Tap **Andesite and dacite porphyry (Oligocene)**—several flows of black, brown or pink glassy porphyritic andesite and dacite. The unit is poorly exposed, and typically platy, massive, or agglomeratic. Petrographically, the rocks are commonly flow banded, the groundmass composed of glass and fine plagioclase laths and irregular fine pyroxene grains. The phenocrysts are common, up to 4 mm long and either euhedral to subhedral twinned plagioclase, or irregular anhedral clinopyroxene. Sample 56 (Table 1.1) has rare clinopyroxene, and common subhedral biotite up to 0.5 mm. Chemistry of the unit is given in Table 1.1 (samples 56-59). The unit is at least 100m thick. The unit is correlated with unit Tpa on the adjacent Limber Jim and Fly Valley quadrangles (Ferns and Taubeneck, 1994; Ferns, 1998). On the Fly Valley quadrangle, the unit Tpa is overlain by andesite flows dated at 22.4 ± 0.16 Ma by stepwise $^{40}Ar/^{39}Ar$ dating. The age is further constrained on the adjacent Anthony Butte quadrangle (Madin and Taubeneck, in press) where unit Tap overlies basalt dated at 29.8 ±- 0.39 Ma stepwise $^{40}Ar/^{39}Ar$ dating.

3.0 STRUCTURE

The first-order structure in the area is a gentle dip to the north, with the oldest rocks exposed at the south edge of the quadrangle and successively younger rocks exposed to the north. Two groups of faults are superimposed on this general trend. The northwest-trending Shaw Mountain fault zone traverses the southern half of the map, and the northern half of the map is cut by a second group of north-northwest-trending faults including the Peach Canyon and Graves Creek faults mapped by Barrash and others (1980) on the Hilgard Quadrangle to the north.

3.1 Shaw Mountain Fault Zone

The Shaw Mountain fault zone includes at least five faults, with roughly equal numbers NE side up and NE side down. Vertical offsets are typically on the order of 25 to 75 m. The fault zone appears to have been active before and during the eruption of the Grande Ronde Basalt. The fault zone acts as a barrier that blocked most of R2 and N2 flows, and the R1 and N1 flows were deposited against a north facing topographic escarpment of John Day formation rocks coincident with the Shaw Mountain Fault zone.

The Shaw Mountain Fault Zone also marks the northernmost exposures of the John Day Formation and other older rocks. No fault planes were observed for any of the faults in the Shaw Mountain Fault Zone, so there is no direct evidence for either the dip of the faults or the amount or sense of any horizontal motion.

The Shaw Mountain fault zone was originally mapped and named on the adjacent Tucker flat quadrangle (to the southeast) by Madin (1998). Madin (1998) suggested that the Shaw Mountain Fault there might have a strike slip component, based on the large number of parallel strands and common reversal of sense along strike for individual strands. In the map area, the strand of the Shaw Mountain Fault Zone that runs along the upper reaches of North Fork Wolf Creek and Jordan Creek also has a change in sense of slip along strike. The Shaw Mountain Fault Zone appears to part of a larger northwest-trending fault zone, which is evident as a strong topographic lineament on Side-Looking Airborne Radar (SLAR) imagery (USGS, 1990).

3.2 North-northwest trending faults

The north-northwest trending faults extend from the Shaw Mountain fault zone across the northern half of the mapped area. Most are northeast side down, but a few are northeast-side up. Vertical offsets are typically 20-50 m with the exception of the Graves Creek fault which has an offset of over 100 m. The north-northwest trending faults all tend to bend to the east as they approach the Shaw Mountain fault zone and merge with the strands of the Shaw Mountain fault zone.

Interaction between the two fault zones locally produces complex faulting, such as the horst in section 29, T. 4S., R. 37 E. These faults also cut all of the Miocene volcanic rocks in the area. The Graves Creek fault also appears to have been active during the emplacement of the ferroandesite of Tucker Flat, because it forms the southwest limit of that unit.

4.0 GEOLOGIC HISTORY

The geologic record visible in the La Grande Reservoir quadrangle begins in the Oligocene with the eruption of andesite and dacite porphyry and deposition of volcaniclastic sediments of the Tower Mountain Volcanic Field. These volcanic rocks probably originated from vents located to the west, where Ferns (1998), Ferns and others (2001) and Ferns and Taubeneck (1994) map numerous vents of similar age and composition, including a major silicic caldera complex.

In the middle Miocene, eruption of Grande Ronde Basalt commenced from vents across northeastern Oregon and southeastern Washington, with numerous flows reaching the La Grande Reservoir quadrangle in succession. As the flows were emplaced over a period of several million years, the Shaw Mountain fault was active, dominantly with southwest-side up motion, which provided a barrier which many of the younger Grande Ronde Basalt flows could not pass. Late in this process, the Graves Creek fault also became active, apparently with southwest-side up motion also, and formed a barrier to southwest progress of flows of the andesite of Tucker Flat.

During the latter part of the middle Miocene, eruptions of the Powder River volcanic field commenced, from vents presumably to the east of the map area (Bailey, 1990). At least one of the early flows of olivine basalt filled a river canyon floored in cobble gravel. Subsequent flows of alkali olivine basalt may also have followed channels, or may have spread as sheets over larger areas. The last rocks to be erupted were dacites, which formed a fairly thick sheet capping the whole sequence. It is interesting to note that although the Graves Creek fault was a barrier to the ferroandesite of Tucker Flat, and currently offsets the overlying dacite, that it was not a barrier to the dacite flows when they erupted. Many of the other north-northwest trending faults were probably active during the eruption of the Powder River volcanic field lavas, as these lavas are largely absent from the northwest portion of the map. The Shaw Mountain fault zone was still active at this time, as part of the canyon-filling olivine basalt flow is offset by it.

During the Quaternary, the canyons cut by the major streams in the area began to expose the Oligocene volcanic rocks beneath the overlying Miocene volcanic rocks. As this happened, large landslides were initiated, with failure surfaces in the older volcaniclastic sedimentary rocks. These slides may have been triggered in part by a wetter climate associated with Pleistocene glaciations and by seismic activity associated with some of the many faults in the area. Many of the larger slides clearly originated several tens of thousands of years ago, but may still move periodically during periods of wet climate or seismic shaking. Paludal deposits have filled in many of the depression formed on the surface of the slides over the years, and might provide a record of the age and activity of the slides. At some time during the Quaternary, one of the major slides on Beaver Creek apparently dammed the creek, forming a temporary lake. Abrupt drainage of this lake must have occurred when the lake overtopped the dam, and the resulting catastrophic flood left a deposit of unusually coarse boulder gravel along Beaver Creek (Section 5, T. 5 S., R. 37 E.). Evidence of another landslide dam is apparent further downstream on Beaver Creek (Section 32, T. 4 S., R. 37 E.) where a conspicuous terrace has formed just upstream of a large landslide.

One other anomalous Quaternary feature is the small lake that fills a closed depression in Section 3, T. 4 S., R. 37 E. This depression is located on the crest of a ridge, at the contact between an olivine basalt flow and the underlying Grande Ronde Basalt. There are no streams, even intermittent, leading into or out of the depression, and it is probably filled with groundwater emerging along the fault that runs along its south edge. The depression currently retains open water a meter or two deep even in late summer, and a drainage channel dug by the local landowner has lowered the outlet of the lake by another 1 to 2 m. The origin of this lake is not at all clear, but may be due to eolian erosion of a fine-grained sedimentary layer trapped between the two lava flows.

During the Holocene, sand and gravel alluvium has been deposited in some of the canyons of the major streams in the area, along with some minor alluvial fans at the mouths of intermittent streams. In the latest Holocene, the eruption of Mt. Mazama in the southern Oregon Cascades deposited up to a half meter of air-fall ash over the entire region. Areas exposed to the wind, or with steep slopes or little vegetation were soon stripped of ash, which accumulated in some minor stream valleys in relatively thick, pure deposits. Elsewhere the ash became incorporated in the soil.

5.0 GEOLOGIC RESOURCES AND HAZARDS

5.1 Mineral Resources

The La Grande Reservoir quadrangle has a low potential for mineral resources. Mine sites on the quadrangle are limited to a few pits where the Miocene volcanic rocks have been quarried for road metal for local forest roads.

5.2 Water Resources

The geology of the area is moderately conducive to developing significant groundwater resources. The north dipping Grande Ronde Basalt may have good aquifers in interflow zones, but the deep canyons cut by the major streams may drain these aquifers above stream level, and impermeable Oligocene volcanic rocks may be present at fairly shallow depths beneath the basalt flows.. The Oregon Water Resources Departments database of water well logs does indicate that there is one well within the quadrangle, but that entry is mislocated.

5.3 Geothermal Resources

Energy resources in the quadrangle are probably nil.

5.4 Earthquake and Mass Wasting Hazards

Geologic hazards likely to occur or reoccur in the area include landslides and earthquakes. Landslides are numerous in the area and are typically large, relatively deep-seated block slides with failure planes along weak volcaniclastic sediments underlying the Grande Ronde Basalt. Existing slides and areas where the Oligocene volcanic rocks are exposed or very near the surface should be considered especially hazardous. An added hazard is that many of the existing slides have dammed streams in the steep, narrow valleys; this mechanism has resulted in subsequent outburst flooding in the past as the streams breached the slide dams. Such outburst floods could pose a serious risk to areas a considerable distance downstream from any future slides which dam streams.

The degree of seismic hazard in the area is unknown. Although there are numerous faults, there is no evidence of Quaternary activity on any of them, but Quaternary deposits are sparse on the quadrangle. Recorded seismicity is very low (one event of M 2) but the threshold of detection for seismograph recordings in the area is high, about M 3-3.5. Seismic shaking from earthquakes originating in the nearby Baker and La Grande valleys could be considerable, and the 1000-year probabilistic peak acceleration for the area is .16 G (Madin and Mabey, 1996). It is likely that significant ground shaking in the area would trigger more landslides.

6.0 ACKNOWLEGEMENTS

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