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Geological Map Series

GMS–116

Geologic Map of the Bonanza Quadrangle, Klamath County, Oregon

by

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1.0 INTRODUCTION

The Bonanza quadrangle is located in the Klamath Basin approximately 21 km (13 mi) east of Klamath Falls, Oregon (Figure 1.1). Northwest-trending valleys and ridges across the quadrangle are typical of the Basin and Range geomorphic province, which extends from Klamath Falls to the Wasatch Range in Utah. Geographic features mentioned in this study are shown in Figure 1.2.

The easternmost extension of Horton Rim trends east-west and ends at Harpold Dam. The Lost River meanders from northeast to southwest across the quadrangle over a broad flood plain, except at Harpold Dam where it cuts a narrow gap through the juncture of the easternmost extension of Horton Rim and northwest-trending ridges. The valleys are elongate, grassy or marshy, and mostly now developed in agriculture. Alkali Lake in the Yonna Valley is an enclosed basin that usually holds a shallow lake. Clays and evaporite salts are evident along the lake's margins.

In the quadrangle, the mountain ranges rise more than 274 m (900 ft) above the adjacent valley floors and are timbered mainly with juniper and sporadic Ponderosa pine and some Douglas fir found mainly on Bryant Mountain. Topographic relief in the quadrangle ranges from about 1,249 m (4,099 ft) at the Lost River on the west edge of the quadrangle to 1,599 m (5,248 ft) on the flanks of Bryant Mountain.

The Bonanza quadrangle is one of several 7.5-minute quadrangles being mapped in the Klamath Basin in conjunction with earthquake hazards and groundwater availability studies being conducted by various state and federal agencies. This mapping was funded in part under the STATEMAP program of the U.S. Geological Survey. This study has delineated faults, characterized lithologic units and rock geochemistry, and provided absolute and relative age constraints for volcanism and sedimentation. This data is crucial for adequately assessing hazard risk and mineral and hydrologic resource potential.

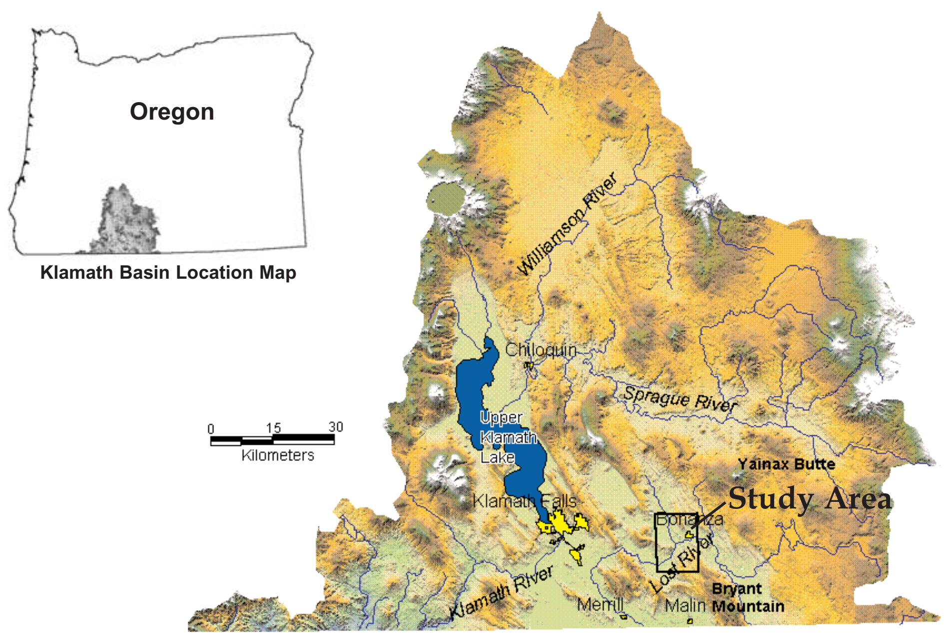

Figure 1.1. Modified shaded-relief map of the Klamath Basin of Oregon, showing the location of the Bonanza quadrangle. The Bonanza quadrangle is outlined in bold.

The oldest rocks in the quadrangle are Miocene age tholeiitic basalt lava flows at Bryant Mountain. These rocks have been exhumed by a large-offset, high-angle normal fault on the west side of Bryant Mountain. Continental sedimentary rocks of Pliocene to Miocene age are deposited on unexposed volcanic rocks of early Pliocene and Miocene age that have been penetrated in drill holes. Lacustrine mudstones are most common in surface outcrop and drill holes, but sandstone beds and paleosols indicate fluvial and deltaic facies. Although some wells in Poe Valley penetrate as much as 230 m

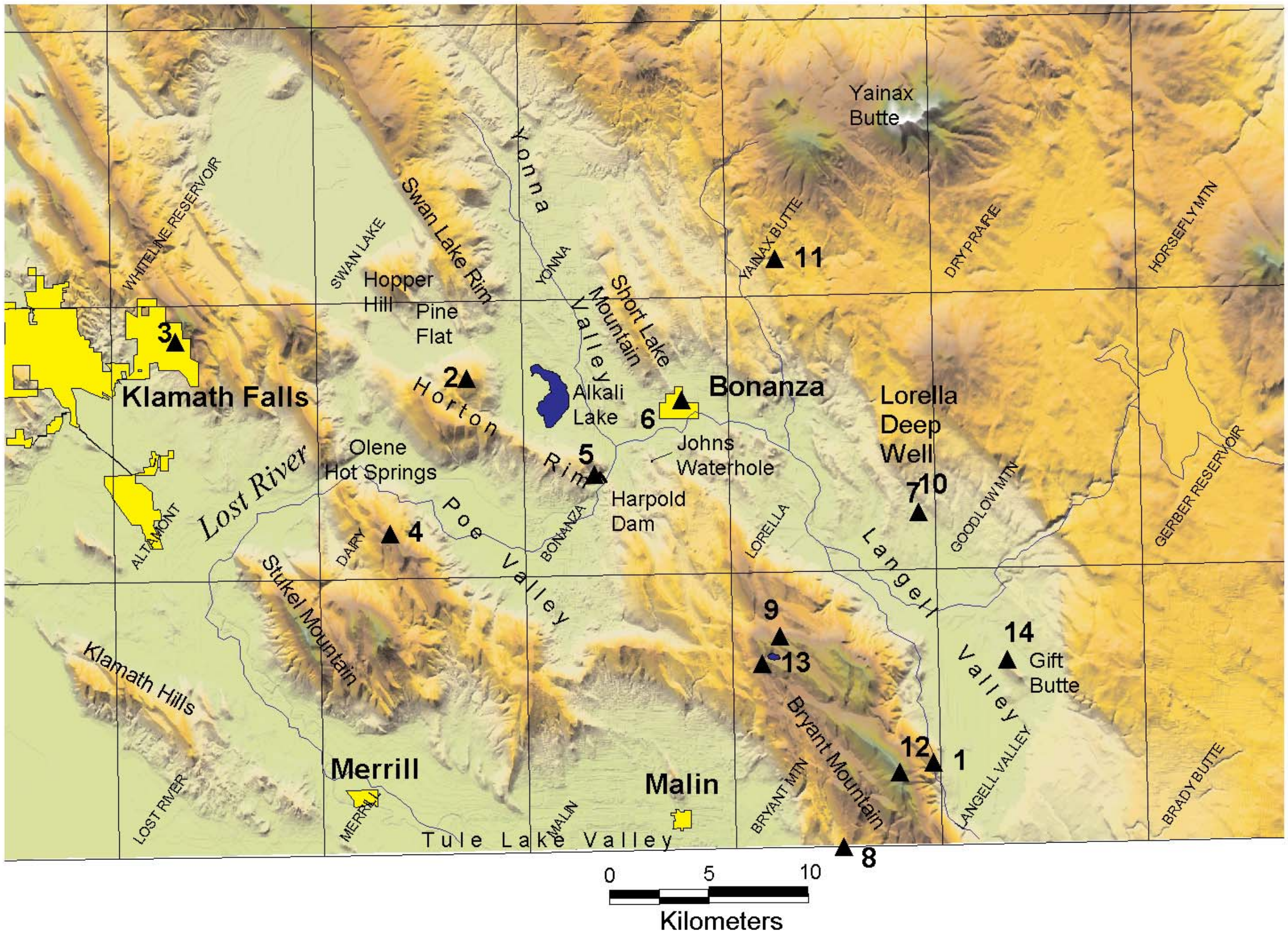

Figure 1.2. Modified shaded-relief map showing the geographic features mentioned in this study and location of samples used for whole-rock $^{40}Ar/^{39}Ar$ radiometric age determinations in the vicinity of the Bonanza quadrangle. Location numbers are keyed to map numbers in Table 1.2.

(750 ft) of sedimentary rocks, typically these units are thinner.

Basaltic andesitic surge deposits indicate explosive water-lava interactions near the lava-sediment interface. Large volumes of primarily basaltic andesite lava from Strombolian-style eruptions have built elongate volcanic edifices that closely follow the predominant northwesterly trend of ranges and faults. Dikes, the source conduits for erupting lava, also trend mostly northwest. Most of these lava flows and their associated dikes are between 3.8 and 4.6 Ma in age. Although volcanism ended in Pliocene time, basin sedimentation, including alluvial fan development and playa lake sedimentation, and tectonic extension, with its associated seismicity, have continued to the present.

Crushed rock resources are abundant, particularly on ridges where soil development is minimal. Cinder resources are much less abundant and all surface deposits have been discovered and partly exploited. Highly transmissive basalt aquifers supply wells that produce water at rates commonly in excess of 1,000 gallons per minute (gpm) and up to more than 5,000 gpm. Wells in fine-grained sedimentary and volcaniclastic rock aquifers produce from a few tens of gpm to a couple hundred gpm.

The quadrangle lies within the seismically active Basin and Range Province. Major faults in the Klamath Falls region have historically generated Richter-magnitude 6.0 and have the potential to produce magnitude 7.3 earthquakes. There is, however, no known historical seismic activity in the quadrangle and this study did not reveal any Quaternary colluvial deposits cut by faults.

1.2 Methodology

Geologic field mapping and sampling for this project was done over a period of five months in conjunction with mapping of the adjacent Dairy quadrangle (Figure 1.2), and augmented by several additional months of analysis, integration, and interpretation of the data in the office. The author was assisted in the field by Robert Newman, a student of Oregon State University, through a grant from the Association of American State Geologists. Mr. Newman conducted numerous independent foot traverses, collecting samples, and providing his observations. Field mapping included mapping on 7.5-minute topography sheets using observations and data collected during both foot and vehicle traverses. Contacts were located where visible or placed based upon interpretation of topography and structure. Geologic contacts and faults were also derived from stereo color infrared aerial photographs at 1:12,000-scale using a Kern PG-2 stereo plotting instrument at various magnifications. Because the PG-2 accentuates vertical relief, it is particularly useful for mapping Quaternary units, and it also allows for accurate mapping of units where subtle changes in slope angle delineate contacts. Poor exposure, however, due to lava rock colluvium (mapped in a few areas) and also soil cover on most slopes, often make contact delineation difficult.

Geologic structures were also derived from USGS Digital Orthophoto Quadrangles (DOQ's) and 10-m Digital Elevation Models (DEM's). The DEM's were rendered in Vertical Mapper, a software module for MapInfo, a Geographic Information System (GIS) software package from the MapInfo Corporation. The various geologic datasets were compared and reconciled variously on paper and in MapInfo. The geologic data collected from visual inspection of units in the field was augmented and integrated with petrographic thin section analyses of samples, geochemical analyses and isotopic age data. The whole-rock X-ray fluorescence (XRF) methodology for determining rock geochemistry (Table 1.1) are described in Mertzman (2000). Duncan and others (1997) describe the whole-rock $^{40}Ar/^{39}Ar$ methodology used for new isotopic analyses cited in Table 1.2, map nos. 2-7, 10, and 13-14.

Wells located near the lines of the cross-sections were used to further constrain subsurface geological interpretations in the cross-sections. A summary of their logs are shown in Table 1.3. The wells are within 600 m of the lines of cross section. All of the well locations are derived from GPS-derived UTM coordinates provided by the Oregon Water Resources Department. On the cross sections, the well locations are projected at right angles to the line of section. Note that when using well data to constrain subsurface structural and stratigraphic relationships in cross section, the well data is deemed pertinent to the fault block into which the well was drilled.

The geology shown on the map (see GMS116map.pdf) should be considered a work-in-progress. Although the map portrays the distribution of the major units and answers many questions, many questions remain to be answered. For example: 1) How much do we know about the lithology and geochemistry of subsurface lava flows (unit Tbu)? Very little, right now. 2) What is the age distribution of younger sediments in the intermontain basins relative to older sediments in the area? This question yet remains unanswered. 3) In many parts of the Klamath Basin, Quaternary faults that cut colluvium have been exposed in man-made quarries, making it possible to identify faults that otherwise would be obscured by very young talus and colluvium. Are all the faults in the Bonanza quadrangle Tertiary age as mapped, or could some of them have experienced Quaternary movement? We don't know. These are a few of the questions facing future geologists and which will require future research.

1.2.1 Geochemistry

Geochemical analysis of samples of the lava flows in the Bonanza quadrangle (Table 1.1) distinctly segregates three major geochemical rock types of increasing SiO_2 content (Figure 1.3): tholeiitic basalt (unit Tbot), the basalt of Johns Waterhole (unit Tbjw), and undivided basaltic andesite

Table 1.2. Analysis of major oxide and selected trace elements, trace metals, and rare earth elements from samples collected in the Bonanza quadrangle and Lorella Deep Well, Klamath County, Oregon. Major oxides reported in weight percent and selected trace elements, trace metals, and rare earth elements in parts per million (ppm). Samples analyzed by the laboratory of Stanley A. Mertzman, Franklin and Marshall College, Lancaster, Pennsylvania.

Map number	Sample number.	Location 1/4	1/4	Sec.	T. (S.)	R. (E.)	UTM (N)	UTM (E)	Quadrangle	Unit	Lithology	SiO^2	TiO^2	Al2O^3	Fe^{2}O^3	FeO	MnO	MgO	CaO	Na^{2}O	K^{2}O	P^{2}O^5	LOI	**Total**	Fe^{2}O^{3}T	Rb	Sr	Y	Zr	V	Ni	Cr	Nb	Ga	Cu	Zn	Co	Ba	La	Ce	U	Th	Sc	Pb
M1	990708-2	SE	NW	29	38	11	4678120	628800	Bonanza	Tba	Basaltic andesite	52.34	1.07	18.86	6.34	2.49	0.15	3.89	7.59	3.67	1.05	0.53	2.16	**100.14**	9.11	8.4	632	28.0	184	206	43	65	11.2	21.5	85	100	29	755	24	48	1.6	5.1	25	12
M9	991027-3	SW	NW	10	39	11	4673420	631830	Bonanza	Tba	Basaltic andesite	52.75	1.10	17.43	2.66	5.84	0.16	4.93	7.72	3.46	1.50	0.44	1.45	**99.44**	9.15	16.7	641	26.6	175	185	56	121	9.6	19.5	63	86	26	625	21	42	1.3	2.8	21	7
M2	990917-4	SE	NW	26	38	11	4678400	633765	Bonanza	Tba	Basaltic andesite	53.52	1.06	17.20	1.68	6.55	0.15	5.02	7.65	3.49	1.73	0.43	1.08	**99.56**	8.96	18.3	629	23.4	165	194	55	111	10.2	21.0	76	81	27	605	21	44	1.6	4.5	21	8
M7	990917-3	SW	SE	35	38	11	4676095	633930	Bonanza	Tba	Basaltic andesite	53.67	1.06	17.14	1.79	6.39	0.16	4.93	7.55	3.47	1.67	0.45	2.38	**100.66**	8.89	17.9	623	23.9	171	203	53	105	10.0	21.1	78	88	27	617	20	44	1.6	4.5	20	9
M5	990709-2	SW	SW	27	38	11	4677540	631400	Bonanza	Tba	Basaltic andesite	54.19	1.00	17.29	2.80	5.08	0.15	4.41	7.60	3.51	1.54	0.44	1.79	**99.80**	8.45	18.6	643	29.0	173	182	43	63	10.5	20.6	79	85	26	823	27	48	1.4	4.8	19	7
M4	990709-1	NE	NE	32	38	11	4677090	629645	Bonanza	Tba	Basaltic andesite	54.33	0.99	17.55	2.47	5.50	0.15	4.36	7.57	3.62	1.60	0.42	1.43	**99.99**	8.58	19.0	634	27.0	171	188	35	61	10.1	20.9	86	84	25	695	22	48	2.3	4.4	20	9
M3	990708-1	--	NW	32	38	11	4676840	628340	Bonanza	Tba	Basaltic andesite	54.63	1.01	17.48	2.54	5.35	0.15	4.37	7.50	3.67	1.68	0.43	0.97	**99.78**	8.49	19.9	625	27.0	176	174	41	89	10.6	20.5	62	82	27	711	24	49	0.9	4.4	19	9
M11	990701-1	NW	NW	21	39	11	4670495	630295	Bonanza	Tbjw	Basalt	48.20	1.15	16.70	4.90	4.78	0.17	8.15	9.11	3.05	0.82	0.35	2.58	**99.96**	10.21	7.6	655	24.0	94	204	117	219	7.8	19.2	91	79	41	379	16	30	1.0	3.7	27	4
M15	990917-1	SE	NE	27	39	11	4668630	633045	Bonanza	Tbjw	Basalt	48.51	1.18	16.85	4.05	5.34	0.16	7.73	9.24	3.05	0.82	0.35	3.02	**100.30**	9.98	7.4	650	23.8	99	234	105	191	7.8	18.5	95	76	37	360	13	28	1.4	4.3	23	4
M14	990729-2	NW	SW	23	39	12	4669810	633385	Bonanza	Tbjw	Basalt	48.55	1.17	16.81	4.37	5.37	0.19	7.77	9.10	3.09	0.87	0.36	2.62	**100.27**	10.34	8.5	667	24.0	96	229	111	202	7.7	20.0	106	79	38	401	14	30	1.2	5.2	28	5
M10	990730-4	SE	SW	11	39	11	4672600	633670	Bonanza	Tbjw	Basalt	48.73	1.28	16.93	2.35	7.34	0.17	7.72	9.15	3.32	0.74	0.38	2.04	**100.15**	10.51	6.8	665	25.0	93	253	109	179	7.4	20.0	88	85	41	334	11	30	1.4	5.5	28	5
M12	990610-2	NW	SE	24	39	11½	4669880	625950	Bonanza	Tbjw	Basalt	48.77	1.28	16.63	8.84	1.55	0.18	6.06	9.13	3.11	0.90	0.43	3.05	**99.93**	10.56	6.3	661	28.0	125	238	89	134	8.4	20.2	81	92	37	478	17	33	1.3	4.2	27	6
M20	990618-2	NW	NE	4	40	12	4665840	630950	Bonanza	Tbjw	Basalt	50.13	1.17	16.92	2.37	6.96	0.18	6.66	9.44	3.16	0.84	0.37	1.28	**99.48**	10.10	9.9	530	27.0	115	242	80	185	8.0	19.9	81	84	35	416	16	28	1.6	3.6	27	5
M13	990819-3	NE	SW	19	39	11	4669670	627440	Bonanza	Tbjw	Basalt	50.17	1.33	17.01	2.49	7.33	0.18	6.27	9.09	3.36	0.95	0.44	0.99	**99.61**	10.64	8.8	651	29.0	130	246	72	129	9.3	19.2	86	89	36	445	16	37	1.5	4.9	26	6
M6	990917-2	SW	SW	35	38	11	4675920	633415	Bonanza	Tbjw	Basalt	50.37	1.22	17.52	7.49	1.95	0.15	4.47	9.74	3.54	1.09	0.42	1.89	**99.85**	9.66	9.4	974	22.1	106	230	44	90	7.4	21.8	101	80	30	509	16	38	1.2	5.3	24	5
M8	991105-1	NE	NW	6	39	11	4675445	627045	Bonanza	Tbjw	Basalt	50.95	1.21	17.45	2.52	6.46	0.16	5.84	8.95	3.34	0.86	0.42	1.29	**99.45**	9.70	8.6	771	26.2	125	236	77	134	8.4	19.6	53	87	32	403	19	38	1.9	2.8	26	5
M19	990617-1	NE	NE	5	40	12	4665825	629910	Bonanza	Tbjw	Basalt	51.20	1.26	16.97	3.29	6.34	0.17	5.91	8.44	3.52	1.00	0.45	1.15	**99.70**	10.34	11.0	630	27.0	127	195	73	124	8.9	20.3	73	85	34	526	16	38	0.7	3.3	22	6
M18	990730-1	NE	NW	35	39	11	4667385	633955	Bonanza	Tbot	Basalt	46.35	1.59	17.45	8.08	4.70	0.22	6.50	9.10	2.80	0.42	0.38	2.84	**100.43**	13.30	3.0	366	39.0	93	269	133	160	6.4	20.8	100	96	53	365	15	23	1.8	3.5	31	3
M17	990730-2	SE	SW	26	39	11	4667800	633860	Bonanza	Tbot	Basalt	47.01	1.62	17.07	12.97	0.23	0.20	7.05	9.74	3.15	0.33	0.37	0.56	**100.30**	13.23	0.8	376	33.0	94	232	110	164	6.8	20.5	92	98	49	329	11	28	1.4	3.2	36	4
M21	990729-1	SW	NE	2	40	11	4665590	634265	Bonanza	Tbot	Basalt	47.67	1.51	17.10	4.02	7.50	0.19	7.17	9.86	3.16	0.41	0.38	0.78	**99.75**	12.36	1.4	405	31.0	87	237	119	140	6.6	20.6	96	86	46	334	10	23	0.6	1.8	29	4
M16	990730-3	NW	SW	26	39	11	4668250	633470	Bonanza	Tbot	Basalt	47.73	1.36	17.25	11.41	0.58	0.20	7.70	10.00	3.01	0.27	0.21	0.62	**100.34**	12.05	1.5	405	21.0	53	151	118	159	4.7	19.5	92	77	43	192	9	16	1.8	3.1	28	3
--	LDW 87	NW	NW	36	39	12	4667742	643784	Lorella	--	Basalt	47.95	0.93	16.94	5.17	4.34	0.17	6.48	10.30	2.27	0.23	0.09	5.30	**100.17**	9.99	7.7	269	23.9	70	227	145	269	3.3	15.5	79	67	40	197	3	11	1.0	1.9	33	4
--	LDW680-685	NW	NW	36	39	12	4667742	643784	Lorella	--	Basalt	49.25	1.29	17.05	4.28	5.71	0.18	6.06	8.53	3.51	0.92	0.46	2.17	**99.41**	10.63	10.8	637	26.7	122	183	82	138	8.2	19.5	73	82	33	462	15	34	1.4	2.4	21	6
--	LDW 905-910	NW	NW	36	39	12	4667742	643784	Lorella	--	Basalt	47.85	1.33	17.40	2.71	7.59	0.18	6.78	9.15	3.04	0.46	0.30	2.84	**99.63**	11.15	4.3	495	25.4	92	208	89	137	8.4	19.6	53	80	36	291	9	20	<0.5	1.6	23	4

Table 1.2. Whole-Rock $^{40}Ar/^{39}Ar$ age determinations for selected samples in the Bonanza quadrangle and from the adjacent area. Map numbers are keyed to Figure 1.2.

Map number	Sample number	Location UTM (N)	Location UTM (E)	Quadrangle	General geographic locale	Lithology	Material dated and method	Calculated age (Ma)	Reference
1	KM86056	4655201*	644507	Bryant Mountain	First flow exposed up from West Langell Valley Road	Basalt	Whole rock[1]	2.61±0.15	Mallin and Hart, 1991
2	990507-4	4674490	621000	Dairy	Horton Rim	Basaltic andesite	Whole rock[2]	3.85±0.06	Hladky, 2003
3	K-90	4676314	606355	Altamont	Base of Hogback Mountain	Basaltic andesite	Whole rock[2]	4.01±0.22	Priest and Hladky, unpub. data
4	990513-2	4666660	617155	Dairy	Dike 4 km southeast of Olene Hot Springs	Basaltic trachyandesite	Whole rock[2]	4.06±0.03	Hladky, 2003
5	990819-3	4669670	627440	Bonanza	Lowest unaltered basalt in county quarry near Harpod Dam	Basalt	Whole rock[2]	4.38±0.06	This map
6	991027-3	4673420	631830	Bonanza	Outskirts of town of Bonanza	Basaltic andesite	Whole rock[2]	4.44±0.04	This map
7	LDW87	4667775	643760	Lorella	87-ft depth, Lorella Deep Well	Basalt	Whole rock[2]	4.65±0.34	Hladky, unpub. data
8	KM87-128	4650945	639996	Bryant Mountain	Highest flow, east side of Tule Lake Valley	Basalt	Whole rock[1]	4.98±0.22	Mallin and Hart, 1991
9	KM86-51	4661527	636794	Bryant Mountain	Highest flow, south end, Harpold Reservoir	Basalt	Whole rock[1]	5.67±0.17	Mallin and Hart, 1991
10	LDW905-910	4667775	643760	Lorella	905-ft depth, Lorella Deep Well	Basalt	Whole rock[2]	5.79±0.12	Hladky, unpub. data
11	S5-10	4680497	636495	Yainax Butte	Near Yainax Butte	Basalt	Plagioclase[3]	6.88±0.60	Pickthorn and Sherrod, 1991
12	KM86-96	4654703	642792	Bryant Mountain	Summit of Bryant Mountain	Basaltic andesite	Whole rock[1]	7.32±0.24	Mallin and Hart, 1991
13	MJ99-82	4660140	635880	Bryant Mountain	Bryant Mountain	Basalt	Whole rock[2]	7.33±0.77	Jenks and Duncan, unpub. data
14	MJ99-02	4660380	648200	Langell Valley	Gift Butte	Basaltic trachyandesite	Whole rock[2]	8.18±0.12	Jenks and Duncan, unpub. data

[1] K-Ar age determination.
[2] Whole-rock $^{40}Ar/^{39}Ar$ age determination, weighted mean plateau age by R. A. Duncan.
[3] Plagioclase was the material dated.

Table 1.3. Drill-hole data along cross-sections A-A' and B-B', Bonanza quadrangle, Klamath County, Oregon. Wells listed in order from left to right along line of section.

Drill-hole number	Line of section	Interval (ft)	Simplified log description
KLAM 10292	A-A'	0-123 123-432	Clay Basalt
KLAM 10258	A-A'	0-418 418-430	Clay Basalt
KLAM 11227	A-A'	0-267	Sandstone and clay
KLAM 13430	A-A'	0-87 87-110	Sandstone and clay Basalt
KLAM 10159	B-B'	0-155	Clay with sand streaks
KLAM 51131	B-B'	0-565 565-1009	Clay with sand streaks Basalt with thin clay seams
KLAM 14795	B-B'	0-350 350-354 354-390 390-460	Shale and clay Basalt Sandstone Basalt

(unit Tba). Basalt (unit Tbot), which crops out on Bryant Mountain, is squarely a basalt (Figure 1.4), distinctly tholeiitic (Figure 1.5), with SiO_2 <48 percent, TiO_2 >1.35 percent, CaO >9 percent, and Ba between 200 and 400 ppm. The basalt of Johns Waterhole (unit Tbjw) is intermediate in silica content compared to the units Tba and Tbot (Figure 1.3), ranges in composition from basalt to basaltic andesite (Figure 1.4), and is calc-alkaline in character, although some samples are nearly tholeiitic (Figure 1.5). SiO_2 content ranges from 48 to 52 percent, TiO_2 ranges from 1.2 to 1.35 percent, CaO is >8.4 percent, and Ba content ranges from 300 to 550 ppm. Basaltic andesite (unit Tba) is the most alkaline and silica rich unit (Figure 1.3) Unit Tba is clearly basaltic andesite in composition (Figure 1.4) and definitely calc-alkaline (Figure 1.5). SiO_2 content exceeds 53 percent, TiO_2 is <1.15 percent, CaO is <8 percent, and Ba content exceeds 600 ppm.

1.2.2 Lorella Deep Well

The Lorella Deep Well (known as KLAM 52096 and KLAM 52204 collectively, sec. 35, T. 39 S., R.12 E., well log available at http://www.wrd.state.or.us) is a 1,005-

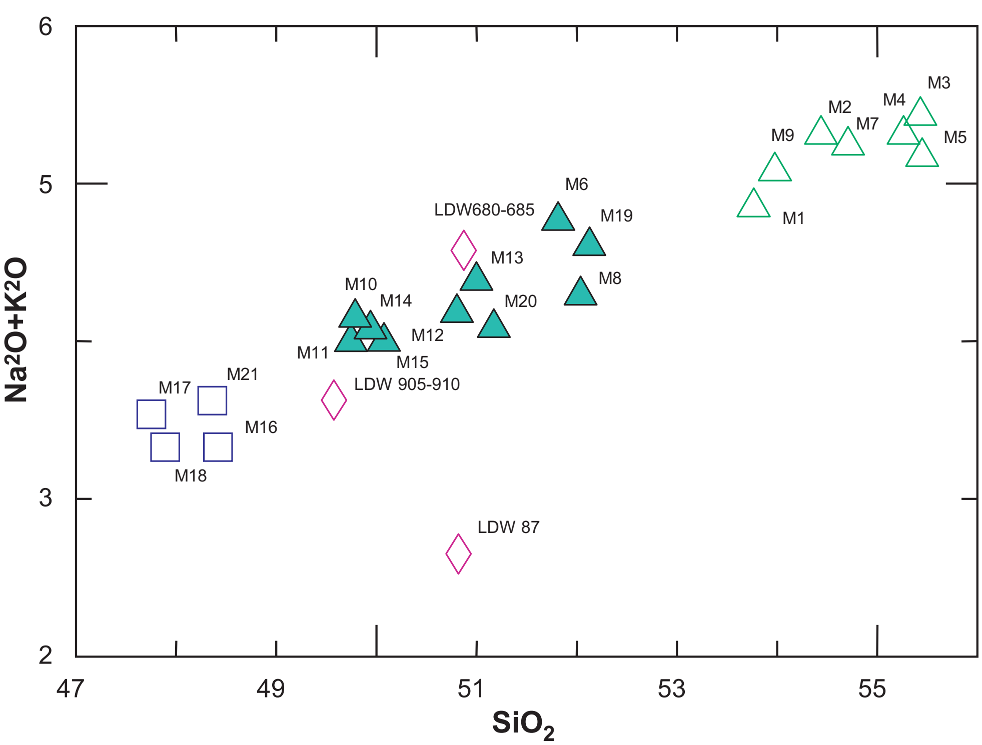

Figure 1.3. Alkalis vs. SiO_2 plot for selected rocks in the Bonanza quadrangle and at the Lorella Deep Well. Numbers refer to Table 1.1 and Map. Open squares, tholeiitic olivine basalt (unit Tbot); diamonds are samples from the Lorella Deep Well; closed triangles, basalt of Johns Waterhole (unit Tbjw); open triangle, Tertiary basaltic andesite (unit Tba). Data for these plots have been normalized and recalculated anhydrous for plotting.

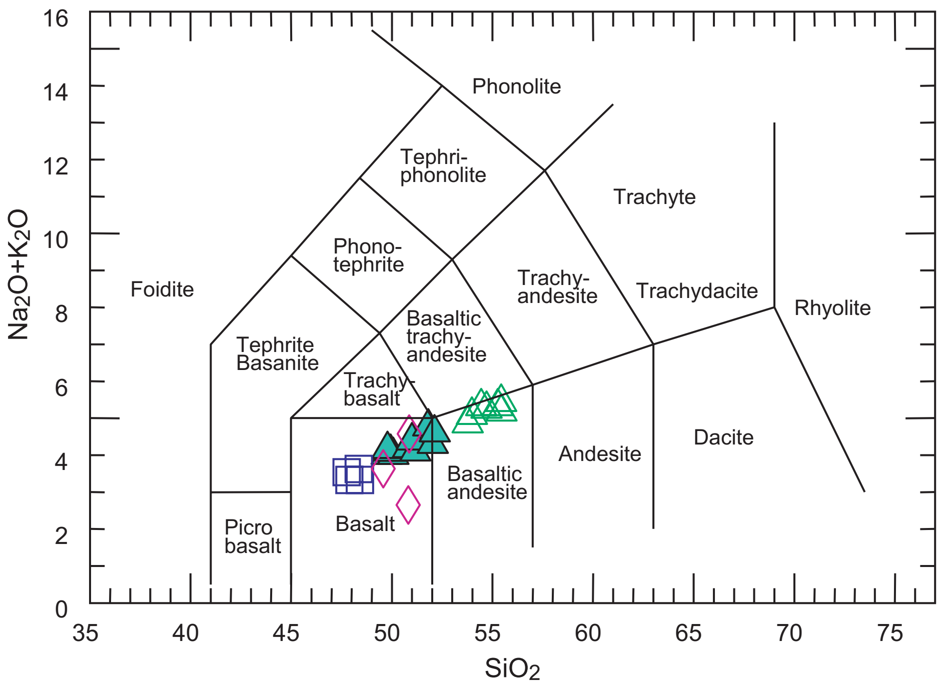

Figure 1.4. Rock classification from Le Bas and Streckeisen (1991) for rocks in the Bonanza quadrangle and at the Lorella Deep Well. Open squares, tholeiitic olivine basalt (unit Tbot); diamonds are samples from the Lorella Deep Well; closed triangles, basalt of Johns Waterhole (unit Tbjw); open triangle, Tertiary basaltic andesite (unit Tba). Source data are found in Table 1.1. Data for these plots have been normalized and recalculated anhydrous prior for plotting.

ft double-completion monitoring well in the adjacent Lorella quadrangle to the east (Figure 1.2). The construction of this well allows for simultaneous monitoring of hydraulic head above the 500-foot and beneath the 950-foot levels.

During drilling, samples of cuttings were collected at 5-foot intervals with a few intervening intervals collected as well. Sample from three intervals were submitted for geochemical analysis. Results of the analysis for sample LDW 87 from the 87-foot level yielded a tholeiitic basalt (Table 1.1, Figures 1.3 and 1.5). This basalt overlies a sedimentary and volcaniclastic sequence and is in a stratigraphically similar position to unit Tbjw in the Bonanza, although it is quite different chemically. The same sample yielded a whole-rock $^{40}Ar/^{39}Ar$ weighted mean plateau age of 4.65 ± 0.34 Ma (Table 1.2 and Figure 1.2, map no. 7). The range of this age overlaps that of basal lava flows of unit Tbjw near Harpold Dam. Results of geochemical analysis for sample LDW 680-685, from a depth of 680 feet, yielded a calc-alkaline basalt (Table 1.1; Figures 1.3 and 1.5). The sample was not dated. Geochemically, sample LDW 905-910, near the bottom of the hole, is a tholeiitic basalt (Table 1.1; Figures 1.3 and 1.5) with an isotopic age of 5.79 ± 0.12 Ma (Table 1.2).

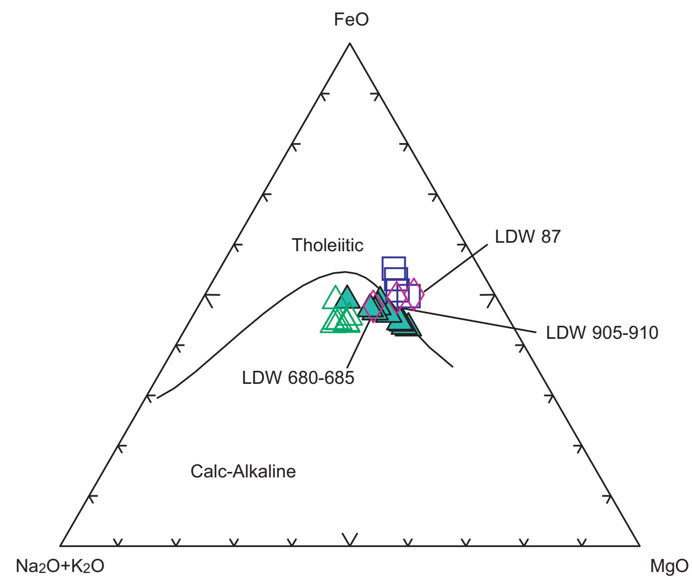

Figure 1.5. Rock classification from Irvine and Baragar (1971) for selected rocks in the Bonanza quadrangle and at the Lorella Deep Well. Open triangle, Tertiary basaltic andesite (unit Tba); closed triangles, basalt of Johns Waterhole (unit Tbjw); open squares, tholeiitic olivine basalt (unit Tbot); and diamonds are samples from the Lorella Deep Well. Source data are found in Table 1.1. Data for these plots have been normalized and recalculated anhydrous for plotting.

2.0 EXPLANATION OF MAP UNITS

The general interrelationships of the map units are shown in Figure 2.1 below. A detailed explanation of the map units follows. The units in Figure 2.1 are chronologically arranged as shown in the time rock chart, where it is apparent that many are coeval.

	Surficial Units
Qal	**Alluvium (Holocene)**
Qws	**Windblown sand (Holocene)**
Qaf	**Alluvial fan deposits (Holocene and Pleistocene)**
Qc	**Colluvium (Holocene and Pleistocene)**
Qap	**Playa deposits (Holocene and Pleistocene)**
Qs	**Lacustrine sediments (Holocene and Pleistocene)**
	Volcanic Units
Tba	**Tertiary basaltic andesite (Pliocene)**
Tbag	**Tertiary basaltic andesite agglutinate (Pliocene)**
Tvc	**Basaltic andesite cinder deposits (Pliocene)**
Tbjw	**Basalt of Johns Waterhole (Pliocene)**
Tab	**Altered basalt (Pliocene)**
Tpt	**Palagonitic tuff (Pliocene)**
Tbu	**Basaltic andesite [shown only in cross sections] (Miocene?)**
Tbot	**Tholeiitic olivine basalt (Miocene)**
	Sedimentary Units
Tms	**Mudstone, siltstone, and sandstone (Pliocene and Miocene)**
Ts	**Sandstone (Pliocene and Miocene)**
Tm	**Diatomaceous and tuffaceous mudstone (Pliocene and Miocene)**
	Intrusions
Tbd	**Basaltic andesite dikes (Pliocene)**

Figure 2.1 Map Units.

2.1 Surficial Units

Qal **Alluvium (Holocene)-**Unconsolidated silt, sand, and minor gravel deposited along the Lost River. Thickness generally 1-3 m (3-10 ft).

Qws **Windblown sand (Holocene)-**Brown, well-sorted sand deposited in swales in upland areas. Thickness generally less than 0.3 m (1 ft).

Qaf **Alluvial fan deposits (Holocene and Pleistocene)-**Fan-shaped deposits of poorly sorted, unconsolidated, sand, soil, gravel, and boulders, deposited at and near the mouths of intermittent highland streams where they debouch onto flatter terrain. Thickness usually a few meters, but as much as 20 m (60 ft).

Qc **Colluvium (Holocene and Pleistocene)-**Unconsolidated to slightly consolidated, poorly sorted soil and fragments of bedrock displaced downslope by gravity-induced creep. May include some landslide deposits. Found on moderate to steep slopes. Colluvium occurs on most hillslopes because of nearly ubiquitous soil development and downslope movement of rocks detached from their bedrock sources, however, colluvium deposits were generally only mapped where thicker than about 2 m. Thickness usually a few meters, but as much as 20 m (60 ft).

Qap **Playa deposits (Holocene and Pleistocene)-**Cream to white, fine silt, mud, and alkali salts deposited in Alkali Lake in Yonna Valley. Thickness variable, to about 10 m (30 ft).

Qs **Lacustrine and paludal deposits (Holocene and Pleistocene)-**Unconsolidated very light-gray or white and pale-pinkish-tan or very light-brown silty sand and silty mud. Although mostly under cultivation now, these deposits originally included both lacustrine (lake) and paludal (marsh) deposits. In the Bonanza quadrangle, these deposits are found on the floors of isolated upland valleys. Interestingly, Short Lake, where one would expect to find lake deposits, has a rocky bottom, along its banks and well out into the lake-the history and origin of this lake basin is yet a puzzle. Deposit thickness up to about 12 m (40 ft).

2.2 Volcanic Units

Tba **Tertiary basaltic andesite (Pliocene)-**Gray- or reddish-brown-weathering, dark-gray fine-grained and seriate basaltic andesite and basalt. Seriate texture (complete gradation from phenocryst to groundmass sizes) of plagioclase and ferromagnesian minerals is common. Contains up to 15 percent olivine, usually partially iddingsitized, with sporadic phenocrysts as large as 1 mm. Plagioclase phenocrysts as large as 2 mm form 30-50 percent of the rock, typically as individual crystals, but as glomerocrysts in some flows. Groundmass typically forms more than 50 percent of the rock, and consists of very fine plagioclase (smaller than 0.05 mm), clinopyroxene, petrographically isotropic glass, olivine, and up to 20 percent fine-grained magnetite. Discontinuity of exposure hampers mapping of individual flows. Chemical analytical data have been subject to the classification of Le Bas and Streckeisen (1991). Following the rock classification of Irvine and Baragar (1971), results of analyses (Table 1.1) indicate all the rocks are calc-alkaline (Figure 1.5). Radiometric age data indicate the unit was erupted in various parts of the region over a period of more than 500,000 years and produced several of the volcanic accumulations topographically expressed today. This conclusion is based on a whole-rock $^{40}Ar/^{39}Ar$ age of 4.01 ± 0.22 Ma from a flow near the base of a thick section in the Altamont quadrangle (Table 1.2 and Figure 1.2, map no. 3), a $^{40}Ar/^{39}Ar$ plateau age of 4.44 ± 0.04 Ma (Table 1.2 and Figure 1.2, map no. 6) from a vesicular and amygdaloidal flow at the outskirts of the town of Bonanza, and a whole-rock $^{40}Ar/^{39}Ar$ plateau age of 3.85 ± 0.06 Ma from the summit lava near Horton Rim in the adjacent Dairy quadrangle (Table 1.2 and Figure 1.2, map no. 2). Maximum thickness about 600 m (2,000 ft).

Tbag **Tertiary basaltic andesite agglutinate (Pliocene)-**Dark-gray or reddish-brown, dark-gray fine-grained seriate and trachytic basaltic andesite agglutinate. Rough irregular surfaces in outcrop. Penetrative iron oxidation, open voids, and zeolite void-filling mineralization are typical. These are coarse-grained, consolidated (welded) pyroclastic vent facies deposits associated with unit Tba. Maximum thickness about 30 m (100 ft).

Tvc **Basaltic andesite cinder deposits (Pliocene)-**Typically partly consolidated to loose, reddish-brown or reddish-gray lapilli, ash, and minor tuff with sporadic agglutinate bombs. These are generally fine-grained, unconsolidated (generally unwelded) pyroclastic vent facies deposits associated with unit Tba. Thickness variable, typically less than 30 m (100 ft).

Tbjw **Basalt of Johns Waterhole (Pliocene)-**Mottled brown- and gray-weathering, dark-gray to black, generally vesicular, water-affected basalt. Comprised of 0-20 percent iddingsitized and variably-altered olivine phenocrysts as large as 1.5 mm and 80 percent or more dark-gray to black mostly cryptocrystalline groundmass formed predominantly of amorphous dark-olive and tan- to bronze-colored clay minerals (probably palagonite), fine-grained irregularly-embayed olivine and pyroxene crystals, and 15 to 30 percent plagioclase microlites. Where less altered, flows are dark-gray, seriate, fine-grained, vesicular, tabular, and either slightly diktytaxitic or microvesicular with groundmass predominantly plagioclase (60 percent), with less than 5 percent each olivine and pyroxene. At the quarries near Harpold Dam, flows several meters thick have hard rinds that are several centimeters thick consisting of banded tan and black palagonite and hyaloclastite; these flows are partly encapsulated within soft beds of palagonitic tuff. Near Johns Waterhole (Figure 1.2), alteration of groundmass typically increases toward the contact with underlying sedimentary units. Analyses of lava flows indicate SiO_2 content usually about 50 percent, and an iron, magnesium, and alkali content that is calc-alkaline but transitionally nearly tholeiitic (Table 1.1; Figure 1.5). The basalt of Johns Waterhole is distinctly intermediate in its silica and alkali contents from unit Tbot and unit Tba (Figure 1.3). A whole-rock $^{40}Ar/^{39}Ar$ plateau age of 4.38 ± 0.06 Ma from the lowest relatively unaltered basalt flow in quarries near Harpold Dam (Table 1.2 and Figure 1.2, map no. 5). Age approximately corresponds to ages within unit Tba, however, stratigraphic relationships northeast of Bonanza indicate its eruption across the area preceeds that of unit Tba. Maximum thickness up to 210 m (700 ft).

Tab **Altered basalt (Pliocene)-**Light-gray to varicolored argillically altered basalt of Johns Waterhole. Typically soft, friable, or compact and brecciated. Probably the result of contact with hot acidic groundwater, the result of now-extinct hot springs. Only one known exposure near Nichols Pump east of the town of Bonanza. Total thickness is probably less than 30 m (100 ft).

Tpt **Palagonitic tuff (Pliocene)-**Tan to orangish-brown, poorly consolidated, thinly bedded to massive, fine-grained, palagonitic ash tuff. Interpreted to be near-vent surge deposits or near-vent diagenetically altered air fall. Exposed at the quarries near Harpold Dam. Spatially related and probably temporally related to eruptions of unit Tbjw. Maximum thickness about 12 m (40 ft).

Tvs **Volcanic surge deposits (Pliocene)-**Dark-tan to gray, planar-stratified, poorly sorted, medium-bedded block-and-ash tuff and thinly to massively bedded lapilli-ash tuff. Coarse facies consists of more than 75 percent subangular to angular basaltic andesitic blocks in argillically or palagonitically altered volcanic lapilli and ash (now mostly clay) matrix. Blocks, where present, range from 6.5 to 15 cm. Fine facies consists of lapilli-sized volcanic lithics in a very fine-grained, argillic (clay) matrix. Where thin bedded, fine facies is interbedded with coarse facies, where massive larger clasts (> 1 cm) are generally absent. The clastic nature, palagonitization, and radial dips are with the pyroclastic deposits of tuff cones and tuff rings. Maximum thickness 210 m (700 ft).

Tbu **Basaltic lava, shown only in cross section (Miocene)-**Dark-gray to black basaltic lava identified in numerous drill holes beneath Poe and Yonna Valleys (Oregon Water Resources Department, 1998). Generally the oldest unit in the quadrangle as shown in cross section (i.e., >7.3 Ma), although this unit may include some subsurface lava flows in the adjacent Lorella quadrangle known to be younger than unit Tbot. Analyses of samples collected from the 1,005-foot Lorella Deep Well in the adjacent Lorella quadrangle yielded an undated calc-alkaline basalt at 680 feet, and a tholeiitic basalt at 905 feet with a whole-rock $^{40}Ar/^{39}Ar$ weighted mean plateau age of 5.79 ± 0.12 Ma (Table 1.2 and Figure 1.2, map no. 10). Similar age rocks may exist in the subsurface beneath unit Tms in the Bonanza quadrangle. Oldest known basaltic rocks in the region include lava flows with ages of 6.88 ± 0.60 Ma near Yainax Butte (Sherrod and Pickthorn, 1992), 7.33 ± 0.77 Ma in the adjacent Bryant Mountain quadrangle for unit Tbot (Table 1.2 and Figure 1.2, map no. 13), and 8.18 ± 0.12 Ma at Gift Butte in the Langell Valley quadrangle (Table 1.2 and Figure 1.2, map no. 14). Presumably, unit Tbu includes rocks of similar age and older. Maximum thickness unknown.

Tbot **Tholeiitic olivine basalt (Miocene)-**Medium-gray, fine-grained, diktytaxitic olivine basalt. Comprises 45 percent slender, elongate plagioclase, 0.2-1 mm; up to 40 percent fresh olivine, 0.1-0.2 mm; 10 percent iddingsite, 0.1-0.2 mm; and 5 percent magnetite smaller than 0.1 mm. Agglutinous intervals, although reddish, retain mineralogy in thin section and diktytaxitic texture. Cryptocrystalline groundmass is absent except in some quenched flows where elongate plagioclase float in 55 percent black glass instead of forming a network with ferromagnesian minerals. Geochemistry (Table 1.1) indicates a low alkali, low silica rock (Figures 1.3 and 1.4) of tholeiitic character (Figure 1.5). A whole-rock $^{40}Ar/^{39}Ar$ age of 7.33 ± 0.77 Ma in adjacent Bryant Mountain quadrangle (Table 1.2 and Figure 1.2, map no. 13). Thickness in quadrangle about 210 m (700 ft).

2.3 Sedimentary Units

Tms **Undifferentiated mudstone, siltstone, and sandstone (Pliocene and Miocene)-**Most readily located by its predominant white to cream-colored mudstone component, this unit also contains some poorly exposed beds of stratified olive-green sandstone (see unit Ts description) and siltstone, and massive to hackly pale-pinkish-gray to pale-orange paleosols. The exposed paleosols have been recolonized with modern roots, making the determination of root traces difficult; however, the paleosols can be distinguished by abrupt upper surfaces with overlying stratified sandstones and internally by their soil structure, characterized by peds and cutans. The hackly texture is due to the network of irregular planes (cutans) surrounding more stable aggregates of soil material (peds). Cutans are typically skins of clay or irregular networks of slickensides due to compaction (Retallack, 1988). Paleosols are massive and poorly bedded with fair induration. As a unit, consistent with the lithologic description and stratigraphic placement of the Yonna Formation (Newcomb, 1958), which name was abandoned by Sherrod and Pickthorn (1992). In the Dairy quadrangle, Tertiary sedimentary rocks are mainly exposed at the major valley floors, although locally they are interbedded within Pliocene lava flows in the mountain ranges. Using isotopic ages, Pickthorn and Sherrod (1990) constrained the age of continental sedimentary rocks in the region at between 6.0 and 3.3 Ma, although more recent work indicates ages as young as Holocene for some fine-grained continental sediments in the region (Adam and others, 1995). Recent age data of overlying lava flows (Table 1.2 and Figure 1.2, map no. 5) indicates that some of these Tertiary sedimentary rocks at the valley floors are older than 4 Ma in the Dairy and Bonanza quadrangles. Regionally, these sedimentary rocks grade upward into lithologically similar Quaternary sediments (Adam and others, 1995). Thickness exceeds 120 m (400 ft). Divided into:

Ts **Sandstone (Pliocene and Miocene)-**Olive-green, well-sorted, fine-grained volcanic sandstone. Typically thinly to medium bedded. Locally contains decimeter-scale cross-beds and scoured surfaces. Composed of 50 percent broken plagioclase and 30 percent olivine crystals and 20 percent dark-gray angular glass and rock fragments, all ranging between 0.2 and 1 mm in size. Maximum thickness about 30 m (100 ft).

Tm **Diatomaceous and tuffaceous mudstone (Pliocene and Miocene)-**White to cream-colored diatomaceous tuffaceous mudstone. Massive and poorly bedded. Fair induration. Where deeply weathered the unit may be only weakly indurated, locally forming a plastic silty clay with loose silty or fine sand interbeds. Sandy interbeds are a minor component. Highly variable thickness; however, wells in Poe Valley (Oregon Water Resources Department, 1998) indicate thickness locally in excess of 230 m (750 ft)

2.4 Intrusions

Tbd **Basaltic andesite dikes (Pliocene)-**Dark-gray to black fine-grained basalt and basaltic andesite dikes. Where fresh up to 10 percent olivine smaller than 1 mm in a very fine grained felsic to glassy matrix. A sample in the adjacent Dairy quadrangle returned a whole-rock $^{40}Ar/^{39}Ar$ weighted mean plateau age of 4.06 ± 0.03 Ma (Table 1.2 and Figure 1.2, map no. 4). The chemistry of that sample was similar to that of unit Tba (Hladky, 2003). Mapped near Harpold Dam intruding surge deposits.

3.0 GEOLOGIC HISTORY

3.1 Landforms and Structures

The principal landforms in the quadrangle are ridges and valleys that trend generally northwest. These landforms are: Horton Rim, Yonna Valley, Poe Valley, Short Lake Mountain, and Byrant Mountain (Figure 1.2). The meandering Lost River cuts across the fabric of the landscape. Outcrops in the ridges indicate faults that are parallel or subparallel to range-bounding faults. The mountain ranges are primarily coalescing basaltic andesitic volcanoes, and erosion has locally exposed their vent deposits. Volcanic piles trending parallel to the major range-bounding faults indicates that the faults and volcanoes were coeval.

Several more faults have been mapped than shown on previous reconnaissance maps (Peterson and McIntyre, 1970; Sherrod and Pickthorn, 1992). Most faults strike northwest, although the range-front fault south of Alkali Lake strikes west-northwest. Several northwest-striking faults are connected by north-striking-faults. Northwest-striking faults generally truncate north-south striking faults. The pattern of faulting produces a series of horsts and grabens mostly of slight structural relief with units usually offset less than few hundred meters. On the west side Bryant Mountain, however, a north-south striking, range-bounding fault juxtaposes Miocene basalt with Pliocene basalt of Johns Waterhole.

Strata generally have an average regional dip that is nearly flat lying (see GMS116map.pdf, cross section A-A'). Original dips of stratified volcanic cones and tilting of individual fault blocks, however, explain locally steeper dips. The variable and radial dip of coarse volcaniclastic strata (unit Tvs) on the west end of section A-A' are explained by the tuff ring there, although faulting may have exaggerated the dip of strata near the fault.

Drill holes indicate that the thickest sections of sedimentary rocks are in Yonna Valley north of Harpold Dam (Oregon Water Resources Department, 1998). Beneath these sedimentary rocks are basaltic lava flows. The sedimentary rocks are highly variable in thickness. The bottom sedimentary contact is poorly constrained because of the paucity and variable accuracy of drill hole data. There is enough data, however, to show that sediment thicknesses can vary greatly, and, near faults, the thickness can change abruptly. The sedimentary section contains mostly lacustrine beds but also includes areally less extensive coarser-grained sandstone. The origin of the sand grains, as interpreted, includes hyaloclastite from lava-water interactions as well as other weathered volcanic sources. The sand was mobilized by small streams that fed Miocene and Pliocene lakes.

Pyroclastic surge deposits and lava flows with palagonitized hyaloclastic rinds exposed at and near the quarries near Harpold Dam indicate explosive and effusive water-lava interactions. Interbedded palagonitic tuff and lava flows produced pillow deltas consist of successive layers of palagonitic ash and palagonitized lava. These eruptions occurred in a Pliocene lake environment.

3.2 History of Volcanism and Sedimentation

The rocks exposed in the Bonanza quadrangle record geologic history since late Miocene time. The oldest rocks (> 7 Ma) in the quadrangle are tholeiitic lava flows at Bryant Mountain. Bryant Mountain (Figure 1.2) is an extensively faulted horst block. Rocks of similar age are exposed on the flanks of Yainax Butte, a steep-sided shield volcano northeast of Bonanza (Table 1.2 and Figure 1.2, map no. 11), at various places on Bryant Mountain (Table 1.2 and Figure 1.2, map nos. 12 and 13), and at Gift Butte in Langell Valley (Table 1.2 and Figure 1.2, map no. 14). Sedimentary rocks, mostly diatomaceous and tuffaceous mudstones, were deposited in lakes onto tectonically extending volcanic rocks during Miocene and Pliocene time. Mudstone of this sedimentary sequence attained thicknesses of a few hundred meters. Relatively small exposures of well-sorted volcanic lithic crystal sandstone attest to higher-energy fluvial environments (small streams) that mobilized sand-sized volcaniclastic material. The source of these sand grains may have been hyaloclastite associated with explosive lava-water interactions. Basaltic surge deposits and basaltic pillow deltas indicate direct water-lava interactions in lacustrine environments. This Pliocene volcanism began about 4.6 Ma. Lava erupted from generally northwest-trending rifts onto sedimentary basins and produced tuff rings, lava flows, and pillow deltas. Interestingly, age data from this quadrangle and the adjacent Dairy quadrangle (Table 1.2 and Figure 1.2) indicate that these volcanoes erupted over a relatively short period of Pliocene time-between 3.8 and 4.5 Ma. By contrast, in the Lorella quadrangle to the east, Pliocene volcanoes were erupting lava flows between 4.6 and 4.7 Ma (Table 1.2). Pliocene volcanoes in the regions produced lava accumulations several hundred meters thick, whose remnants are today's prominent ridges. Faulting modified these volcanoes, and today's ridges are generally fault bounded.

The Quaternary Period in the Bonanza quadrangle is represented primarily by modest sedimentation. The Lost River meanders across its flood plain, and before the advent of manmade controls, deposited silt and mud across its flood plain. Alkali Lake in Yonna Valley continues to receive fine-grained sediments, and dries sufficiently to produce alkali salts around its perimeter. Dicken (1980) claimed the lake is a remnant of pluvial Lake Modoc, a Pleistocene lake that stretched from modern Upper Klamath Lake to Langell Valley and south into California, and covered the bottoms of Yonna and Poe valleys. Other geologists who have worked the area are skeptical that Lake Modoc was ever so extensive (David Sherrod, 2000, personal comm.), rather, several disconnected lakes have occupied valley floors during and since Pleistocene time. This author found no terraces for Lake Modoc in the Bonanza quadrangle, and if it produced more subtle evidence, such as sediments, they have been largely modified by soil development, colluviation, and agriculture.

Other evidence for Quaternary geologic activity in the Bonanza quadrangle is ambiguous. There are no volcanic rocks of Quaternary age in the quadrangle. Local argillic alteration of volcanic units attests to hot spring activity, proximal to faults, which cannot yet be better defined than having occurred since Pliocene time. Tectonism in the region was manifest as recently as 1993, when felt earthquakes struck along the West Klamath Lake fault zone west of Klamath Falls. There is, however, no known historical seismic activity in the quadrangle (Johnson and others, 1994; The Pacific Northwest Seismograph Network, 2003) and this study did not reveal any Quaternary colluvial deposits cut by faults.

4.0 GEOLOGIC RESOURCES AND HAZARDS

4.1 Mineral Resources

The Bonanza quadrangle has high potential for road rock and low potential for cinders. Quarries for these materials are shown on the map. All of the exposed cinder deposits have been partly quarried. Crushed-rock resources are abundant, particularly along ridge tops or in the upper elevations where soil development is minimal. Only one mineral occurrence is located in the state-wide mineral resource database (Gray, 1993): the Harpold quarries located near the center of the quadrangle. The map shows three more quarries. Diatomaceous sediments or clays are possible resources but agricultural uses have been already established on the deposits.

4.2 Groundwater

Numerous water wells are located in the quadrangle and are plotted on the geologic map with Oregon Water Resources' drill-hole log number (KLAM). The lithology, as interpreted, from these wells helped to constrain the geologic map. Table 4.1 lists a generalized interpreted geology of the drill-holes. The original drill-hole logs are available for viewing on the Internet at the Oregon Water Resources Department's website: http://www.wrd.state.or.us.

The most prolific aquifers are basalt units, with wells often producing more than 1,000 gallon per minute (gpm) to a maximum in excess of 5,000 gpm (Table 4.1). Localized argillic alteration of basalt units, probably caused by mostly extinct hydrothermal systems, however, can greatly reduce the transmissivity of basalt aquifers (Hladky and Waff, 2001; Hladky and others, 2002), to the extent that they transmit water at rates similar to those of sedimentary rock acquifers. Wells producing from sedimentary units generally generate a few 10s up to a maximum of approximately 200 gpm (Table 4.1). As a final note, groundwater resources are probably linked to the Lost River, which is the regional discharge. This linkage is currently being explored by the Oregon Water Resources Department.

4.3 Earthquake Hazards

The Bonanza quadrangle lies within the Basin and Range Province, a seismically active region stretching from Klamath Falls to the Wasatch Front in Utah. Historical seismicity in south-central Oregon was demonstrated in 1968 by a swarm of earthquakes in the Adel-Warner Lakes area east of Lakeview. This swarm included shocks up to Richter-magnitude 5.1. (Couch and Johnson, 1968; Jacobson, 1986).

Quaternary faults near Klamath Falls with the potential for damaging earthquakes were delineated previously (Hawkins and others, 1989; Sherrod and Pickthorn, 1992). The earthquake potential for the region was demonstrated on September 20, 1993. A foreshock with Richter magnitude 3.9 was followed by a magnitude-5.9 shock and a magnitude-6.0 earthquake (Wiley and others, 1993). Aftershocks continued for several months. Seismicity was located west of Klamath Falls along the West Klamath Lake fault zone, which is capable of generating 6.0 to 7.3 magnitude earthquakes (Bacon and others, 1999). The Klamath Falls region is recognized as one of Oregon's principal areas for damaging earthquakes (Madin and Mabey, 1996). There is, however, no known historical seismic activity in the quadrangle (Johnson and others, 1994; The Pacific Northwest Seismograph Network, 2003), and this study did not reveal any Quaternary colluvial deposits cut by faults.

Table 4.1. Generalized drill-hole data interpreted from drillers logs for wells plotted on the geologic map of the Bonanza quadrangle.

Well Identification	UTM Coordinates[1] Easting	UTM Coordinates[1] Northing	Surface lithology	Depth to lava (ft)	First water (ft)	Primary aquifer	Static Water level (ft)	Total depth (ft)	Maxium yield (ft)
KLAM 10015	629824.10	4673953.00	Clay	69	69	Basalt	35	83	75
KLAM 10159	624779.80	4665959.00	Clay	N.A.	47	Sand	22	155	20
KLAM 10242	632269.80	4673736.00	Clay	202	175	Basalt	11	212	1000
KLAM 10252	625849.30	4668120.00	Clay	160	160	Basalt	41	543	300
KLAM 10258	628044.40	4670379.00	Clay	418	50	Basalt	47	430	40
KLAM 10292	624634.10	4668271.00	Clay	123	205	Basalt	45	432	1500
KLAM 10316	631828.90	4672927.00	Clay	38	70	Basalt	21	70	60
KLAM 10352	631977.80	4675224.00	Clay	114	114	Basalt	45	180	1500
KLAM 10357	631999.90	4675007.00	Basalt	3	50	Basalt	45	107	600
KLAM 10378	632250.40	4672135.00	Clay	122	99	Basalt	7	186	2960
KLAM 10395	633956.30	4673278.00	Clay	183	130	Basalt	16	305	1500
KLAM 10416	632776.10	4673480.00	Clay	216	47	Sand	7	232	2500
KLAM 10421	631046.50	4675246.00	Clay	149	149	Basalt	45	190	2000
KLAM 10431	631274.20	4671284.00	Clay	6	25	Basalt	24	104	4500
KLAM 10432	629405.70	4671177.00	Clay	87	87	Basalt	29	230	970
KLAM 10440	633784.10	4673472.00	Clay	170	148	Basalt	25	373	2000
KLAM 10443	628082.40	4671134.00	Gravel	455	29	Sand	4	456	2000
KLAM 10448	626338.60	4675172.00	Clay	174	38	Basalt	28	336	850
KLAM 10460	630263.20	4673863.00	Shale	129	168	Basalt	51	432	3000
KLAM 10461	632656.60	4674556.00	Clay	89	92	Basalt	22	150	2000
KLAM 10475	628850.80	4673656.00	Clay	385	412	Basalt	39	452	1300
KLAM 10498	627235.90	4671038.00	Clay	446	458	Basalt	22	521	1500
KLAM 10566	632731.60	4675028.00	Sandstone	14	62	Basalt	N.A.	76	10
KLAM 11003	627562.40	4667607.00	Clay	158	65	Sand	41	200	20
KLAM 11168	631442.10	4672928.00	Clay	N.A.	32	Sandstone	15	73	20
KLAM 11227	628437.10	4669379.00	Sandstone	N.A.	52	Sand	31	267	35
KLAM 11294	633378.80	4672771.00	Clay	43	54	Basalt	8	82	35
KLAM 11473	627412.40	4677741.00	Basalt	0	32	Basalt	46	111	30
KLAM 12363	627771.90	4677051.00	Sandstone	55	30	Basalt	N.A.	177	2800
KLAM 12416	625011.90	4677897.00	Clay	194	194	Basalt	36	280	1600
KLAM 12418	624737.20	4678306.00	Sand	15	183	Basalt	45	175	3000
KLAM 12457	625048.80	4676922.00	N.A.	N.A.	N.A.	N.A.	46	1580	1500
KLAM 12477	632749.90	4678050.00	Clay	75	340	Basalt	340	425	1800
KLAM 13331	632734.80	4675581.00	Boulders	42	N.A.	Basalt	111	125	500
KLAM 13332	632295.60	4675299.00	Clay	32	74	Basalt	37	162	300
KLAM 13353	631448.30	4673349.00	Sandstone	16	52	Basalt	44	76	40
KLAM 13428	631477.70	4670146.00	N.A.	N.A.	N.A.	N.A.	45	200	1000
KLAM 13430	631744.30	4670712.00	Sandstone	87	N.A.	Basalt	52	110	1150
KLAM 13443	627792.20	4667836.00	Shale	87	95	Basalt	38	115	40
KLAM 13456	626534.40	4675076.00	Clay	182	18	Basalt	22	212	35
KLAM 13458	625242.60	4675370.00	Clay	310	315	Basalt	2	348	1500
KLAM 13462	624323.80	4673962.00	Shale	647	465	Basalt	N.A.	763	5500
KLAM 13471	626576.30	4673255.00	Clay	198	198	Basalt	20	410	950
KLAM 13472	626419.20	4671388.00	Clay	365	N.A.	N.A.	N.A.	395	1900
KLAM 14714	627068.40	4664768.00	Clay	160	215	Basalt	N.A.	240	1000
KLAM 14795	627144.80	4665400.00	Clay	350	300	Basalt	2	460	600
KLAM 14796	628178.80	4664991.00	Shale	180	62	Basalt	62	297	1325
KLAM 15149	631728.80	4672710.00	Clay	N.A.	25	Sandstone	11	80	15
KLAM 50318	632099.80	4672665.00	Clay	22	13	Basalt	4	46	50
KLAM 50796	627914.60	4668869.00	Basalt	0	N.A.	Basalt	143	301	24
KLAM 51131	625119.60	4666259.00	Clay	565	116	Sandstone	6	1009	150
KLAM 51922	632442.40	4672845.00	Clay	175	168	Basalt	1	179	N.A.

[1] UTM Zone 10, North American datum, wells located by GPS.

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