OREGON GEOLOGY

published by the

Oregon Department of Geology and Mineral Industries

VOLUME 45, NUMBER 2 FEBRUARY 1983

OREGON GEOLOGY

(ISSN 0164-3304)

VOLUME 45, NUMBER 2 FEBRUARY 1983

Published monthly by the State of Oregon Department of Geology and Mineral Industries (Volumes 1 through 40 were entitled *The Ore Bin*).

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Subscription rates: 1 year, $6.00; 3 years, $15.00. Single issues, $.75 at counter, $1.00 mailed.
Available back issues of *The Ore Bin*: $.50 at counter, $1.00 mailed.

Address subscription orders, renewals, and changes of address to *Oregon Geology*, 1005 State Office Building, Portland, OR 97201.

Send news, notices, meeting announcements, articles for publication, and editorial correspondence to the editor, Portland office. The Department encourages author-initiated peer review for technical articles prior to submission. Any review should be noted in the acknowledgments.

Second class postage paid at Portland, Oregon.
Postmaster: Send address changes to *Oregon Geology*, 1005 State Office Building, Portland, OR 97201.

COVER PHOTO

Oblique aerial photograph of Jordan Craters vent and pit craters. Article beginning on next page discusses ages and chemistry of these and other volcanic rocks in the Jordan Valley area, southeastern Oregon.

OIL AND GAS NEWS

Columbia County

Reichhold Energy Corporation spudded its Columbia County 13-34 well on December 9, 1982, and drilled to a total depth of 2,822 ft, completing the well for gas production on December 23, 1982. This is the second gas completion in as many months for the operator and the eleventh for the field. The well tested at about 500,000 cubic feet per day and is located in sec. 34, T. 7 N., R. 5 W., about 1 mi from the nearest production.

Clatsop County

Diamond Shamrock Corporation has applied for a permit to drill in Clatsop County. To be located 10 mi west of gas production at the Mist Gas Field, the well will also be 1 mi north of a Quintana Petroleum Corporation well drilled two years ago. This well, Watzek 30-1, was drilled to 7,068 ft and abandoned as a dry hole. Details of Diamond Shamrock's well are found in the table below.

Oregon Division of State Lands lease sale

The Division of State Lands has listed over 43,000 acres in Clatsop County to be auctioned at the next lease sale. Parcels range in size from 1.61 acres to 651.62 acres. The townships with the most acreage are T. 4 N., R. 6 W., and T. 4 N., R. 7 W., with 8,213 acres and 8,379 acres available respectively. No date has been set for the auction. More information is available from the Division of State Lands by calling (503) 378-3805.

Recent permits

Permit no.	Operator, well, API number	Location	Status, Depth (ft)
226	Diamond Shamrock Corporation Hummel 22-19 007-00012	NW¼ sec. 19 T. 6 N., R. 6 W. Clatsop County	Application

□

Fireball sighted in December

James B. Marckette, U.S. Geological Survey, sighted a fireball at 11:15 p.m. PST , on December 30, 1982. Marckette, who was looking west from about 2 mi west of Alder Creek on U.S. Highway 26 in northern Oregon, first sighted the fireball at about 30° above the horizon. The fireball, which was visible for about 2 seconds, traveled from north to west, came down at an angle of about 15°, and was last seen about 10° above the horizon to the west. It was about one-sixth the size of the full moon and bright white in color, had a short yellow tail, and cast a shadow.

This sighting has been reported to the Scientific Event Alert Network, Smithsonian Institution. Anyone with any additional information about this or other meteor sightings should contact Dick Pugh, Cleveland High School, 3400 SE 26th Ave., Portland, OR 97202, phone (503) 233-6441. □

CONTENTS

Late Cenozoic volcanic stratigraphy of the Jordan Valley area, southeastern Oregon

by William K. Hart, Department of Geological Sciences, Case Western Reserve University, Cleveland, OH 44106; and Stanley A. Mertzman, Department of Geology, Franklin and Marshall College, Lancaster, PA 17604*

ABSTRACT

Miocene to Recent volcanism in extreme southeastern Oregon has produced thick sequences of basaltic and silicic material. Basalts ranging in composition from low-K, high-alumina olivine tholeiite (HAOT) to alkaline olivine basalt (AOB) and in age from 0 to 10 million years (m.y.) are observed. Thin layers of unconsolidated silicic tuffaceous material are often found as interbeds within the basalt sequence, whereas thick rhyolite flows and ash-flow tuffs predate the basaltic volcanism.

Excellent exposures throughout this area, especially along the Owyhee River and Jordan Creek, allow detailed stratigraphic, geochronologic, and geochemical studies. These investigations reveal a complex suite of basalts which overlap in both space and time. The observed occurrence of coevally erupted, depleted oceanic-type tholeiite (HAOT) and enriched AOB in close geographic proximity is important for regional stratigraphic correlations and petrogenetic models. These AOB's are the youngest reported in this portion of the Great Basin and are volumetrically less significant than the associated tholeiites. The complex volcanic assemblages encountered in the Jordan Valley area probably reflect variations in local and regional tectonic characteristics and upper-mantle processes which together have acted to control the eruptive histories of these lavas.

INTRODUCTION

The geology of the northwestern United States is characterized by extensive outpourings of Cenozoic volcanic material. On the basis of age, tectonic setting, and composition of erupted magmas, four major late Cenozoic volcano-tectonic provinces have been defined. These include the Cascade, Columbia Plateau, Snake River Plain and Basin and Range provinces.

Cascade volcanism is dominated by porphyritic two-pyroxene andesites erupted from large stratovolcanos along a general north-south belt extending from southern British Columbia to northern California. In contrast, volcanism in the other three provinces has been dominated by fissure-erupted, quartz-normative tholeiites (Columbia Plateau), olivine tholeiites and subalkaline rhyolites (western Snake River Plain), and alkaline olivine basalts and sub- to peralkaline rhyolites (Basin and Range).

An additional subprovince, located in the extreme northwestern Basin and Range, was originally defined by Waters (1962) as the Oregon-Modoc Plateau. More recently (e.g., Christiansen and McKee, 1978; Hart, 1982a; Hart and others, 1982), this region has been investigated because its tectonic, geochronologic, and magmatic features overlap with those of the Cascade, Columbia Plateau, Snake River, and southern Basin and Range provinces. The most striking feature of this region is the widespread occurrence of a distinctive low-K, high-alumina olivine tholeiite magma type with many petrographic and chemical features which strongly resemble those of mid-ocean ridge and back-arc basin basalts. Of particular interest is the area between the Owyhee River and Jordan Valley in southeastern Oregon (Figure 1). This area lies adjacent to the western Snake River Plain and provides a unique opportunity to investigate a complex and varied suite of basaltic and rhyolitic volcanic material (Hart and Mertzman, 1980, 1981). The remainder of this paper is devoted to a detailed stratigraphic, K-Ar geochronologic, and chemical discussion of this volcanic sequence.

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JORDAN VALLEY AREA

Introduction

Dominating the pre-Miocene to Miocene record are mineralized, silicic volcanic and plutonic rocks of the Owyhee Mountains (Pansze, 1975; Bennett, 1976). Miocene to Pliocene alkaline basalts and rhyolite ash-flow tuffs and flows typical of the Basin and Range basalt-rhyolite association are also observed. The late Miocene to Recent record is dominated by interbedded basalts, silicic tuffs, breccias and flows, and lacustrine sediments historically considered as part of the Snake River volcanic province (see Armstrong and others, 1975, for summary and references) as well as very young alkaline olivine basalts of the Jordan Valley area. The dominant rock type in this area is basalt, often locally interbedded with silicic tuffs and sediments, reaching thicknesses of approximately 300 m and ranging in age from 0 to 10 m.y. Underlying the basaltic sequence is a sequence of nonmineralized silicic flows and welded vitric tuffs originally defined by Malde and Powers (1962) as the Idavada Volcanics.

Petrography and chemistry

Forty petrographic and chemical analyses of volcanic rocks from the Jordan Valley area indicate the presence of three distinct basalt types: low-K, high-alumina olivine tholei-

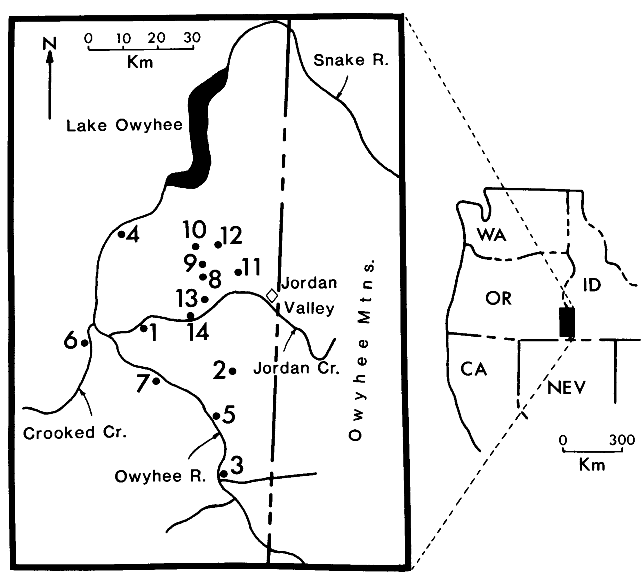

Figure 1. Map showing location of study region and individual sample locations discussed in text.

Table 1. *Chemistry of major units*[a]

	HAOT	TB	AOB					ST	SF
			JC	RBI	RBII	CB	TMH		
SiO_2	47.52	47.40	47.45	48.07	47.65	48.68	46.97	68.87	74.23
TiO_2	1.21	1.84	2.38	2.42	2.10	2.10	1.92	0.72	0.40
Al_2O_3	16.61	16.02	16.15	16.14	16.08	17.01	15.89	13.87	12.42
FeO	10.27	11.36	10.45	10.96	10.78	10.06	11.65	4.08	2.50
MnO	0.17	0.18	0.17	0.17	0.17	0.16	0.17	0.07	0.03
MgO	9.04	8.03	9.09	6.50	7.73	6.48	7.88	1.32	0.15
CaO	11.32	10.93	9.77	9.89	9.31	8.38	10.51	2.55	1.09
Na_2O	2.54	2.57	3.07	3.04	3.21	3.47	2.63	2.83	3.49
K_2O	0.25	0.40	0.69	1.35	1.07	1.88	0.72	4.12	5.00
P_2O_5	0.13	0.28	0.27	0.45	0.35	0.52	0.34	0.13	0.07
Rb	3	5	11	28	16	43	8	143	161
Sr	233	243	659	516	508	478	299	258	115
Ni	165	125	155	72	121	73	116	22	<DL
Ba	107	291	202	405	325	583	334	1024	1482
Zr	108	152	202	270	226	255	183	299	502
V	231	243	211	263	224	195	261	58	20
Y	18	24	<DL	21	19	18	35	56	77
MgO/FeO*	0.88	0.71	0.87	0.59	0.72	0.64	0.68	0.32	0.06
Rb/Sr	0.0013	0.021	0.017	0.054	0.032	0.090	0.027	0.554	1.40

a. HAOT=avg. of 7 low-K, high-alumina olivine tholeiites. TB=avg. of 17 transitional basalts. AOB=avgs. of individual alkaline basalt units: JC=Jordan Craters (1), RBI=Rocky Butte Type I (3), RBII=Rocky Butte Type II (6), CB=Clarke's Butte (1), TMH=Three Mile Hill (1). ST=avg. of 3 unconsolidated tuffaceous silicic units. SF=avg. of 4 rhyolite-flow/ash-flow units. FeO*=total Fe as FeO. All major elements in weight percent, trace elements in parts per million. <DL=less than detection limit.

ite (HAOT); alkaline olivine basalt (AOB); and tholeiites (TB) with characteristics transitional to those of HAOT and AOB. Also occurring in the area are two distinct silicic varieties: Low-SiO_2, unconsolidated tuffaceous units (ST); and high-SiO_2, welded ash-flow and rhyolite-flow units (SF of Table 1).

Petrographically, the HAOT's are characterized by distinctive holocrystalline, equigranular, diktytaxitic, nonporphyritic textures; subophitic to ophitic intergrowths of Ca-plagioclase (An_{60-75}) and augite; and abundant (up to 25 modal percent) intergranular olivine. The AOB's display varied textures, ranging from holocrystalline and diktytaxitic to intersertal, porphyritic, and glomeroporphyritic. These basalts often display a subophitic to intergranular relationship between plagioclase (An_{55-68}) and highly pleochroic titanaugite. In many cases, titanaugite is observed as a phenocryst phase in the AOB's, a feature not observed in HAOT. Modally, in AOB's olivine is less abundant (<20 percent) and clinopyroxene more abundant (>20 percent) than in HAOT's. The transitional basalts (TB's) have characteristics intermediate to and overlapping with both HAOT and AOB. This transition is also seen in the chemical data of Table 1, especially in the concentrations of the incompatible elements K_2O, TiO_2, P_2O_5, Rb, and Ba, which serve to distinguish between these three varieties of basalt. An important point to note is the depleted incompatible element signature of HAOT along with its characteristically high concentrations of CaO, MgO, and Ni and high MgO/FeO*. These characteristics set this basalt apart from other basalts of the northwestern United States (e.g., Columbia River, Steens Mountain, and Snake River).

As previously stated, the silicic material studied can be divided into two groups: tuffaceous units and flow units. The tuffaceous deposits generally occur as thin interbeds between basalt and/or basalt and rhyolite flows and are best categorized as crystal or vitric tuffs. These tuffs display matrices of banded glass, glass shards, flattened vesicles, mafic rock fragments, and deformed pumice balls. Mineralogically, the tuffaceous units are characterized by phenocrystic K-feldspar (anorthoclase and orthoclase) and Na-plagioclase (oligoclase to andesine) as well as scattered crystals of clinopyroxene, hornblende, and quartz. In contrast, the silicic flow units exhibit banded-glass and/or felsitic cryptocrystalline matrices with phenocrysts of Na-plagioclase (andesine to oligoclase), K-feldspar (sanidine and orthoclase), plus one or more of the following phases: clinopyroxene (diopsidic augite to subcalcic augite), orthopyroxene, quartz, magnetite, and zircon. In many cases, quartz and sanidine occur as large phenocrysts, up to 2 mm and 4 mm in length, respectively. Glomeroporphyritic clumps of pyroxene, feldspar, and oxide are common, as are needles of apatite as inclusions in feldspar. Further distinctions between these two silicic groups are obvious when the chemical data of Table 2 are examined. The rhyolite-flow/ash-flow units (SF of Table 1) illustrate chemical characteristics comparable to previously reported analyses of Idavada rhyolite from the western Snake River Plain region (Leeman and Manton, 1971).

* FeO = total Fe as FeO.

Table 2. *K–Ar age data*

Sample #	Map #	Type	K_2O (wt.%)	$\%^{40}Ar^*$	Age[b.] (Ma)
H-8-28C	1	TB	0.39_8	21.24	8.14±0.65
H-8-28D	1	TB	0.25_2	5.11	4.96±0.93
H-8-28E	1	HAOT/TB	0.37_2	18.72	7.05±0.61
H-8-29	2	HAOT/TB	0.35_2	10.89	9.87±1.10
H-8-34	3	TB	0.31_5	13.00	8.21±0.85
H-8-36	3	HAOT/TB	0.29_1	19.70	7.58±0.70
H-8-42	4	TB	0.44_6	16.78	4.49±0.38
H-8-45	4	HAOT	0.32_1	23.49	4.09±0.34
H-8-47	4	HAOT	0.33_2	13.36	4.06±0.41
H-8-69D(1)				16.74	9.95±1.02
H-8-69D(2)	5	TB	0.25_4	18.73	9.81±0.97
H-8-69D(3)				21.20	10.06±0.95
H-8-69G	5	TB	0.42_6	16.28	8.42±0.74
H-9-36A	6	HAOT	0.16_8	2.44	0.91±0.36
H-9-36C	6	HAOT	0.37_8	3.85	1.25±0.28
H-9-37A	7	TB	0.48_0	21.99	7.75±0.58
H-9-37C	7	TB	0.55_1	33.44	9.57±0.60
H-9-37D	7	TB	0.42_9	9.28	1.49±0.18
H-8-57	8	AOB	1.26	-	0.03(max)
H-8-70	9	AOB	1.88_2	4.18	0.25±0.05
JC-4	10	AOB	0.69_2	0.57	0.15(max)
H-9-42	11	HAOT	0.26_2	3.04	0.44±0.16
H-9-44	12	TB	0.40_9	6.20	3.84±0.57
H-9-49	13	TB	0.74_2	9.98	1.86±0.19
SM-75-9	14	AOB	0.99_0	-	0.09(max)
SM-75-12A	14	HAOT	0.35_0	9.46	8.51±1.02

a. $\lambda_\varepsilon=0.581\text{x}10^{-10}\text{yr}^{-1}$ $\lambda_\beta=4.962\text{x}10^{-10}\text{yr}^{-1}$ $^{40}\text{K/K}=1.167\text{x}10^{-4}\ \frac{\text{mol}}{\text{mol}}$

b. Uncertainty in calculated ages estimated by assuming uncertainties of 0.3% in measured isotopic compositions of sample and atmospheric argon, 1.0% in the volume of ^{38}Ar spike, 2.0% in sample heterogeneity and an absolute uncertainty in the measurement of K_2O.

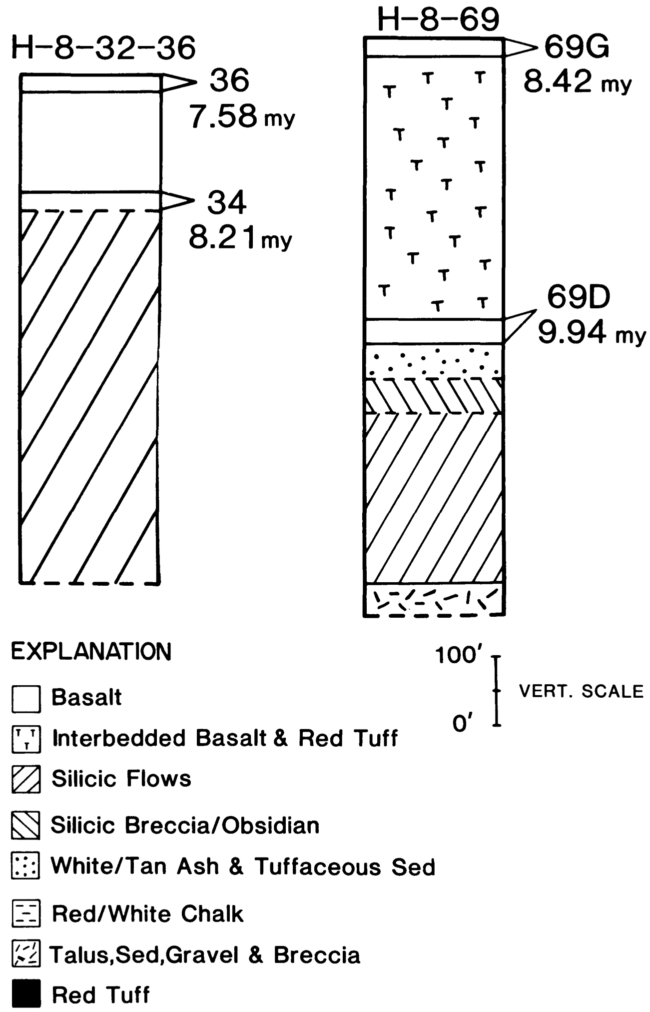

Figure 2. Stratigraphic relationships at map locations 3 (left column) and 5 (right column) of Figure 1.

Stratigraphy and geochronology

Twenty-four basalt samples from fifteen locations throughout the region depicted in Figure 1 have been dated by the K-Ar method (see Hart, 1982a, for experimental techniques). These results are reported in Table 2. Most of the dated samples are from various locations along the Owyhee River where excellent exposures allow construction of detailed stratigraphic sections. The remainder of the sampling was concentrated in the region north of Jordan Creek where a complex assemblage of volcanic material is observed.

Figure 2 illustrates the stratigraphic relationships at map locations 3 and 5. Basalts from these two locations range in age from 7.6 to 9.9 m.y. In both cases, these basalts are of the transitional variety and are underlain by rhyolitic-flow/ash-flow material (SF). Location 5 (sample H-8-69), at the mouth of Soldier Creek, exhibits a thick sequence (approximately 100 m) of interbedded basalt and red silicic tuffaceous material (ST) ranging in age from 8.4 to 9.9 m.y. Basalts of similar age and composition (e.g., sample H-8-29, Table 2) can be traced northeastward from locations 3 and 5 to the foothills of the Owyhee Mountains.

Farther north along the Owyhee River and Crooked Creek, various assemblages of basalt, silicic tuff, and lacustrine sediments occur. The stratigraphic relationships at three places (locations 4, 6, and 7) are illustrated in Figure 3. Location 4 (samples H-8-42-47) is dominated by a thick sequence (approximately 300 m) of white/tan ash and tuffaceous sediment, red/white chalk, and gravel, with basalt flows on top, in the middle, and at the base. These basalt flows are HAOT/TB and display a narrow range in age from 4.1 to 4.5 m.y. The age and lithologies of this exposure correspond to the descriptions and age relationships of the Glenns Ferry-Upper Chalk Butte Formations of the western Snake River Plain (Malde and Powers, 1962). The data and observations suggest that between at least 4 and 4.5 m.y. ago (probably from 2.6 to 6 m.y.) significant lacustrine sedimentation, accompanied by basaltic volcanism of varying compositions, was taking place in portions of the Owyhee River-western Snake River Plain region. Since this time period corresponds to that of active extensional tectonism in this region, the possibility exists that large lakes were formed in grabens created by major episodes of normal faulting. A similar sequence of ash and tuffaceous sediment is seen unconformably underlying a 1.3-m.y.-old HAOT flow at location 6 (sample H-9-36). Capping this sequence is another flow of HAOT dated at 0.9 m.y. Both of these flows appear to have originated from a source, or sources, to the northwest, and neither of the flows is exposed along the eastern side of Crooked Creek. Location 7 (sample H-9-37) yields a sequence of interbedded transitional tholeiite and red silicic tuff similar to that observed at location 5. An age range of 1.5 to >9.6 m.y. is observed for this exposure. It is important to note that the basal TB flow (sample H-9-37A of Table 2) at this location was dated at 7.8 m.y., whereas a TB flow (sample H-9-37C of Table 2) approximately 30 m upsection yielded an age of 9.6 m.y. It is believed that the 7.8-m.y. age of sample H-9-37A is inaccurate due to the presence of abundant altered glass and secondary clay.

The eastern Jordan Creek-Jordan Valley area is of great interest because of the diversity of volcanic material found in close geographic and geochronologic association. Exposure throughout this region is excellent, and good flow-on-flow stratigraphy is revealed in the walls cut by Jordan Creek.

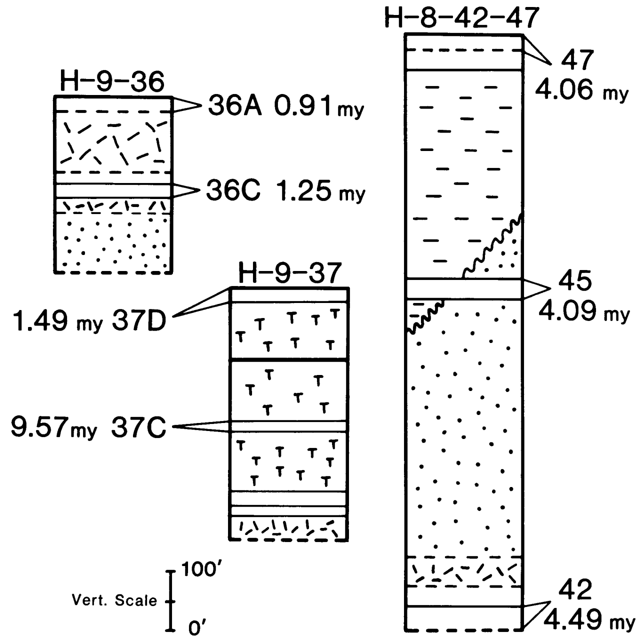

Figure 3. Stratigraphic relationships at map locations 4 (right column), 6 (left column), and 7 (center column) of Figure 1. Symbols as in Figure 2.

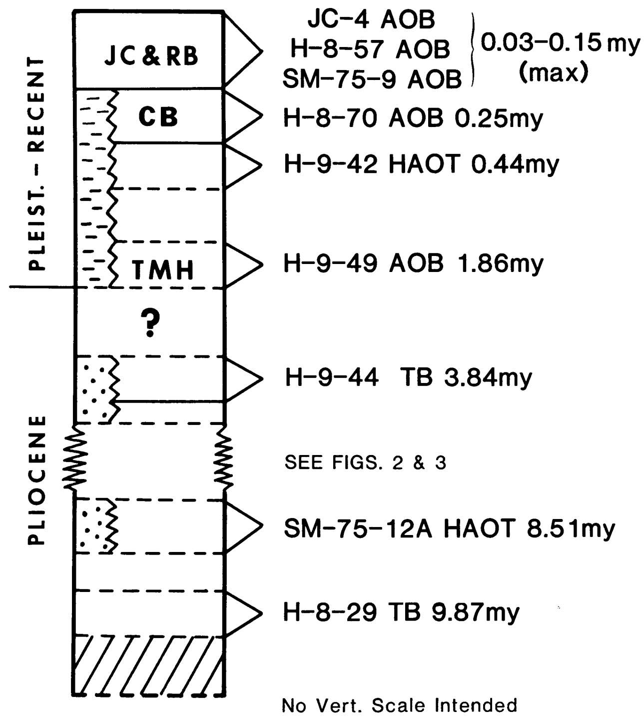

Figure 4. Generalized stratigraphic column for the eastern Jordan Creek-Jordan Valley area. Symbols as in Figure 2 plus JC = *Jordan Craters,* RB = *Rocky Butte,* CB = *Clarks Butte, and* TMH = *Three Mile Hill.*

Basalts ranging chemically from HAOT to AOB, as well as chalk, tuffaceous sediment, ash, and silicic flows, have been identified. Lacustrine sediments are present predominantly in the western portion of this area and appear to pinch out in an eastward direction. In the light of the previous discussion, this occurrence may be considered to mark the eastern edge of an ancient lacustrine system. A generalized stratigraphic column for this area is presented in Figure 4 and a geologic map in Figure 5.

The late Miocene-Pliocene section in this region is characterized by flows of HAOT and transitional basalt (TB) ranging in age from 9.9 to 3.8 m.y. and by basal Idavada rhyolite and interbeds of ash and tuffaceous sediment. Pleistocene to Recent volcanism is concentrated in the area northwest of Jordan Valley and is dominated by eruptions of alkaline olivine basalts. These AOB's have been erupted from a series of N. 10° to 15° W.-trending vents extending from Three Mile Hill to Jordan Craters. Scattered vents farther to the west and east are also observed. These AOB's cover an area of nearly 750 km² and flow up against and over older HAOT, TB, and silicic flows. The southernmost and oldest (1.9 m.y.) of these main vents is Three Mile Hill, a small, partially eroded shield volcano. Clarks Butte, lying approximately 10 km north of Three Mile Hill, has been dated at 0.25 m.y. Flows from this small, collapsed, eroded shield spread out in all directions and exhibit erosional features similar to the older AOB flows. Overlying the flows from both Three Mile Hill and Clarks Butte are younger AOB's (0.03-0.09 m.y. maximum) from Rocky Butte and a source east of Rocky Butte (Skinner Hill). These flows exhibit primary volcanic features such as tumuli, pahoehoe surfaces, and collapse structures. The most pronounced source area for AOB in this region is Jordan Craters, a name which comprises both the main crater and series of northwest-trending spatter cones. The main crater is a large collapse feature nearly 200 m by 100 m and up to 75 m deep. Flows emanate from the south side, and high walls of pyroclastic material and cinder surround the remainder of the crater. The walls of the crater are composed of interbedded basalt, ash, and volcanic breccia; in the southwest wall is exposed also a layer of reddish silicic material which is chemically identical to the Idavada rhyolite found throughout this region. A sample of massive basalt from the eastern wall yields a maximum age of 0.15 m.y. for the main crater. Extending linearly to the northwest from the main crater is a series of five to six spatter cones which may represent the last stages of activity in this region. The flows associated with Jordan Craters are extremely rugged, with numerous collapse features, tumuli, pahoehoe surfaces, and lava tubes. These lavas flow up against TB (3.8 m.y.) to the east, young HAOT (0.44 m.y.) to the southeast, and older tuffaceous sediment and silicic material to the southwest and overlie AOB from Clarks Butte to the south. An important point to note is the occurrence of AOB and HAOT in close

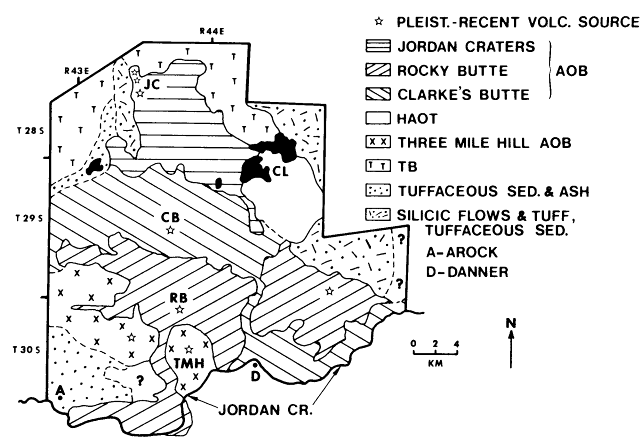

Figure 5. Geologic map of the eastern Jordan Creek-Jordan Valley area. Symbols as in Figure 4 plus CL = *Cow Lakes.*

geographic and geochronologic association. It is also important to note that these volcanic rocks are the youngest AOB's found in the northwestern Great Basin, and with the exception of one flow of Miocene AOB ("Lower Basalt" of Pansze, 1975) in the Owyhee Mountains, the only AOB's recognized in the Jordan Valley area.

DISCUSSION

The complexity of the sedimentary-volcanic sequences in the Jordan Valley area is obvious. Many of the stratigraphic and geochronologic relationships in this region can be grossly correlated with those occurring in portions of the western Snake River Plain. Care must be taken in making these regional correlations because many, if not most, of the sedimentary and volcanic units are local in extent and are often bounded by unconformities. The basalts, which dominate the volcanic sequence, follow the topography onto which they were extruded, giving rise to such features as local basin and channel-fill deposits. In addition, a wide range in basalt compositions is observed, indicating that further care must be taken in attempts at regional correlations.

The close geographic and geochronologic association of a variety of basaltic and rhyolitic composition materials in the Jordan Valley area necessitates calling on complex upper-mantle and/or crustal melting models, possibly coupled with crystal fractionation and magma or source mixing. Such processes have been suggested to account for the elemental characteristics of the observed TB's (Hart and Mertzman, 1981) as well as the elemental and isotopic characteristics of the HAOT's, TB's, and AOB's (Hart, 1982a, b). These petrologic and geochemical models imply that the volcanic rocks erupted in a given area are closely linked to the present and past tectonic characteristics of that area. One can speculate that in a region such as the Jordan Valley area, where two distinct tectonic provinces merge (Basin and Range and Snake River Plain), the associated volcanism will illustrate characteristics common to both provinces. With this in mind, it is suggested that an understanding of the volcanic geology of the Jordan Valley region of southeastern Oregon may be an important step toward understanding the volcano-tectonic evolution of the entire northwestern Great Basin.

SUMMARY

The late Cenozoic geology of the Jordan Valley area is characterized by complex assemblages of interbedded basalts, rhyolites, and lacustrine sediments. The basalts range in composition from low-K, high-alumina olivine tholeiite to alkaline olivine basalt and in age from 0 to 10 m.y. Interbedded with these basalts are silicic volcanic tuffs and lacustrine sediments. Flows and ash flows of unmineralized Idavada rhyolite underlie the basalt-sedimentary sequences throughout this region. The complexities of this area are most likely related to complex and varied petrogenetic processes which are in turn related to the regional tectonic characteristics.

ACKNOWLEDGMENTS

This study was financially supported by the National Science Foundation (EAR 79-04524), Geological Society of America (2340-78 and 2639-80), Sigma Xi, and Case Western Reserve University Graduate Alumni Fund.

We would like to thank J. Aronson and L. Dasch for helpful discussions and R.W. Carlson for critically reviewing the manuscript. W.K.H. would also like to thank members of the Skinner family of Jordan Valley, Oregon, for their hospitality during the 1979 and 1980 field seasons.

REFERENCES CITED

Armstrong, R.L., Leeman, W.P., and Malde, H.E., 1975, K-Ar dating, Quaternary and Neogene volcanic rocks of the Snake River Plain, Idaho: American Journal of Science, v. 275, p. 225-251.

Bennett, E.H. II, 1976, Reconnaissance geology and geochemistry of the South Mountain-Juniper Mountain region, Owyhee County, Idaho: Idaho Bureau of Mines and Geology Pamphlet 166, 68 p.

Christiansen, R.L., and McKee, E.H., 1978, Late Cenozoic volcanic and tectonic evolution of the Great Basin and Columbia Intermontane regions, *in* Smith, R.B., and Eaton, G.P., eds., Cenozoic tectonics and regional geophysics of the western Cordillera: Geological Society of America Memoir 152, p. 283-311.

Hart, W.K., 1982a, Chemical, geochronologic, and isotopic significance of low-K, high-alumina olivine tholeiite in the northwestern Great Basin, U.S.A.: Cleveland, Ohio, Case Western Reserve University doctoral dissertation, 410 p.

——— 1982b, Isotopic characteristics of basalts from the N.W. Great Basin, U.S.A. [abs.]: EOS (American Geophysical Union Transactions), v. 63, no. 18, p. 457.

Hart, W.K., Aronson, J.L., and Mertzman, S.A., 1982, Areal distribution and age of low-K, high-alumina olivine tholeiite magmatism in the northwestern Great Basin, U.S.A.: Submitted to Geological Society of America Bulletin.

Hart, W.K., and Mertzman, S.A., 1980, Late Cenozoic volcanic geology of the Jordan Valley Area, S.E. Oregon: Geological Society of America Abstracts with Programs, v. 12, no. 7, p. 443.

Hart, W.K., and Mertzman, S.A., 1981, Source mixing—an example from basalts of the northwestern U.S.: Geological Society of America Abstracts with Programs, v. 13, no. 7, p. 468.

Leeman, W.P., and Manton, W.I., 1971, Strontium isotopic composition of basaltic lavas from the Snake River Plain, southern Idaho: Earth and Planetary Science Letters, v. 11, p. 420-434.

Malde, H.E., and Powers, H.A., 1962, Upper Cenozoic stratigraphy of western Snake River Plain, Idaho: Geological Society of America Bulletin, v. 73, no. 10, p. 1197-1219.

Pansze, A.J., Jr., 1975, Geology and ore deposits of the Silver City-DeLamar-Flint region, Owyhee County, Idaho: Idaho Bureau of Mines and Geology Pamphlet 161, 79 p.

Waters, A.C., 1962, Basalt magma types and their tectonic associations—Pacific Northwest of the United States, *in* The crust of the Pacific Basin: American Geophysical Union Monograph 6, p. 158-170. □

Oregon Council of Rock and Mineral Clubs gives display case

On December 10, 1982, a display case located in the Capitol Building in Salem and featuring museum-quality specimens of Oregon rocks and minerals along with finished cabochons or slabs was given to the State of Oregon by the Oregon Council of Rock and Mineral Clubs.

Oregon Council representatives assisting in the dedication ceremony were Ted Jackson, President; Keith Wooldridge, Treasurer; and Ted and Mary Arrowood, Carol Lundin, Harold Dunn, Otto DeShon, Vivian Johnson, Jessie Jackson, and Lyle and Florence Riggs.

The current display includes 40 items or groups of specimens loaned by seventeen people representing fifteen Oregon rock clubs. The case, located at the west end of the corridor leading from the Information Desk on the main floor of the Capitol, measures 11 ft long by 3 ft high by 1 ft deep, is constructed of tempered glass and aluminum with adjustable glass shelving, and features diffused lighting.

The Capitol display case was made possible through contributions of member clubs of the Oregon Council and other interested clubs. The first display was installed on November 12, 1982, and will remain for about three months, after which it will be replaced by materials from one of the clubs of the Oregon Council. □

Geochemical evidence for changing provenance of Tertiary formations in northwestern Oregon

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INTRODUCTION

The Cowlitz, Keasey, Pittsburg Bluff, and Astoria Formations exposed near Mist, Columbia County, northwestern Oregon (Figure 1), display geochemical variations that are a reflection of different provenances (Kadri, 1982). These variations and the lithology of clasts within these upper Eocene to middle Miocene marine sedimentary units are used in this paper to infer "continental" and volcanic sources. The Mist area rocks are important because they are the host for the only producing natural gas field in the Pacific Northwest (Bruer, 1980).

STRATIGRAPHY

The Cowlitz Formation is the oldest exposed unit of the thick marine sedimentary sequence that overlies Eocene volcanic rocks and interbedded sedimentary rocks of the Tillamook highlands south of Mist. The Cowlitz Formation consists of fine-grained, well-sorted, micaceous, arkosic sandstone, siltstone, and mudstone.

The Keasey Formation unconformably overlies the Cowlitz Formation (Bruer, 1980) and consists of tuffaceous, concretionary mudstone, siltstone, and minor volcaniclastic sandstone. The Keasey Formation rocks contain abundant volcanic-derived constituents and were deposited in bathyal to outer neritic depth (McDougall, 1980) on a broad, unstable shelf.

The deltaic deposits of the Pittsburg Bluff Formation unconformably overlie the Keasey Formation. Bioturbated arkosic to lithic arkosic sandstone, siltstone, and finely laminated mudstone are the dominant rocks of the Pittsburg Bluff Formation.

The middle Miocene Astoria Formation, which unconformably overlies the Pittsburg Bluff and Keasey Formations, consists of basalt clast conglomerate, sandstone, and siltstone. Lithic arkosic to quartzose sandstone displays ripple lamination and cross-bedding. Flows of the Columbia River Basalt Group cap the stratigraphic section and belong to the Grande Ronde Basalt (low-MgO geochemical type) and the Wanapum Basalt (Frenchman Springs Member). The Columbia River basalt and coevally deposited Astoria Formation lap onto the older rocks.

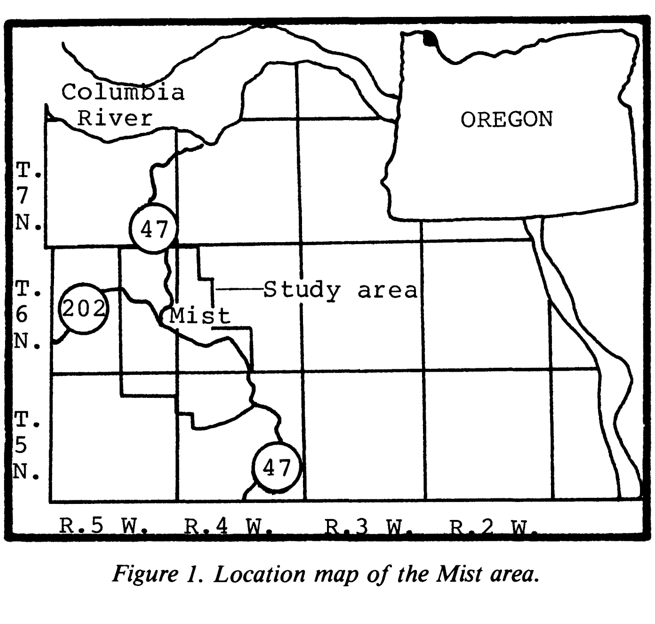

Figure 1. Location map of the Mist area.

GEOCHEMISTRY

In this study, instrumental neutron activation analysis was used to determine concentrations of sodium (Na), potassium (K), iron (Fe), and a number of trace elements in 53 sedimentary rock samples. These samples were analyzed to examine geochemical variations within the Tertiary rocks and to determine the possibility of using geochemical parameters to characterize formations and to identify their provenances.

The sedimentary rocks were disaggregated, and approximately one gram of sample was analyzed. Among the elements detected, Na, K, lanthanum (La), samarium (Sm), scandium (Sc), and thorium (Th) were important in characterizing the formations. Relative concentrations of these elements appear to establish significant groupings.

The Cowlitz Formation has a higher concentration of K and a higher La/Sm ratio than does the overlying Keasey Formation (Figure 2). Th is a "continental" element (Moore, 1972) in that it occurs in greater abundance in typical continental igneous and metamorphic terranes than it does in volcanic rocks of arc complexes or oceanic areas. In the Cowlitz sedimentary rock samples, Th averages 12 parts per million (ppm) (Figure 3), which is closer to the continental average of 9.6 ppm (Taylor, 1964); by contrast, in the Keasey samples, Th averages only 3 ppm, well within the 0.18- to 5.5-ppm range of volcanic rocks of volcanic arcs (Condie, 1976).

The Pittsburg Bluff Formation has higher K and Na concentrations compared to the Keasey Formation (Figure 4), but there is an overlap in the concentrations of Sc and in the La/Sm ratio. Concentration of Th in the Pittsburg Bluff Formation is intermediate to that of the Cowlitz and Keasey Formations (Figure 3).

Rocks of the Columbia River Basalt Group have much higher concentrations of Sc than do the sedimentary rocks. Among the sedimentary rocks analyzed, only those of the

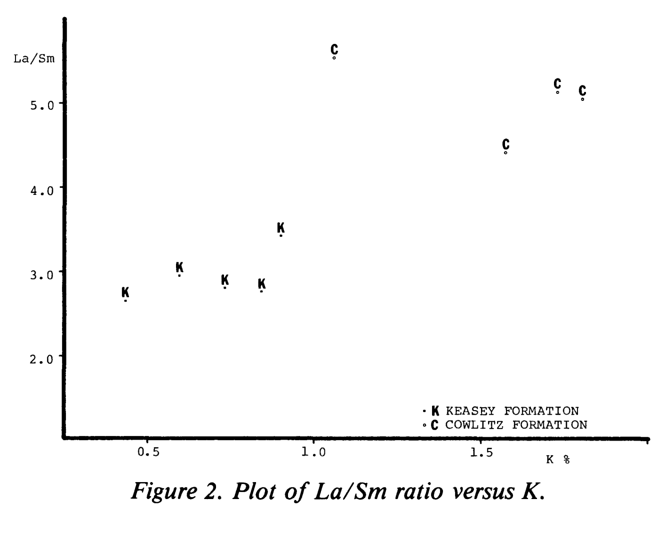

Figure 2. Plot of La/Sm ratio versus K.

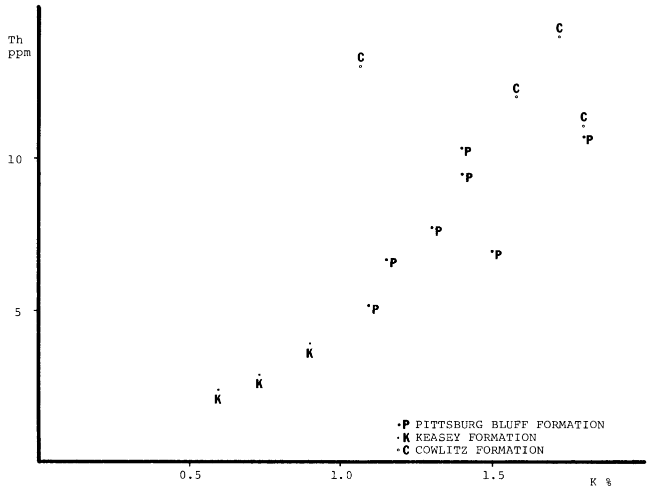

Figure 3. Plot of Th versus K.

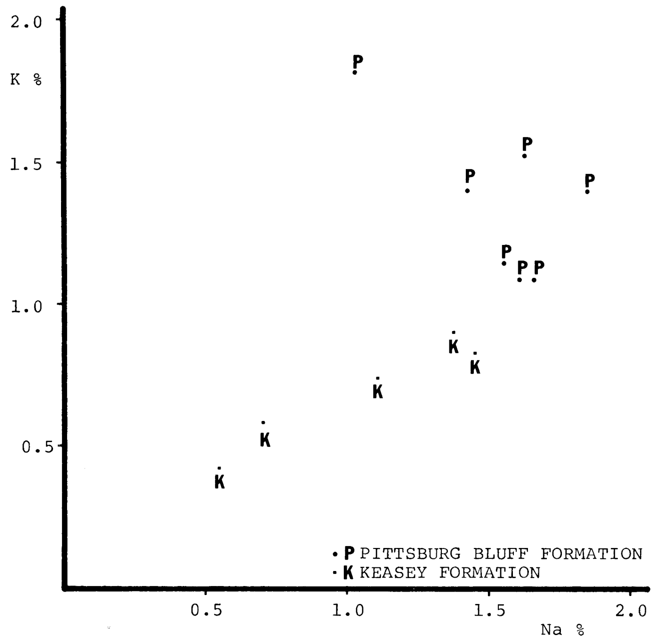

Figure 4. Plot of K versus Na.

Astoria Formation have consistently high Sc concentrations (Figure 5). The Astoria Formation samples that have highest Sc concentrations are pebbly sandstones that contain basalt pebbles with high Sc content.

DISCUSSION

Geochemistry of the sedimentary rocks, together with petrographic evidence, delineates important differences in provenance of the Tertiary rocks of the Nehalem River basin. Relative concentration of elements varies in a consistent manner between the lithostratigraphic units.

The Cowlitz Formation has a higher amount of potassium feldspar and mica (Van Atta, 1971) than any other formation in the Nehalem River basin. Higher K and Th concentrations and higher La/Sm ratios in the Cowlitz rocks further substantiate Van Atta's (1971) conclusion for a granitic and metamorphic provenance for the Cowlitz Formation.

The Keasey rocks contain abundant ash and lapilli as well as basaltic and andesitic rock fragments (Van Atta, 1971).

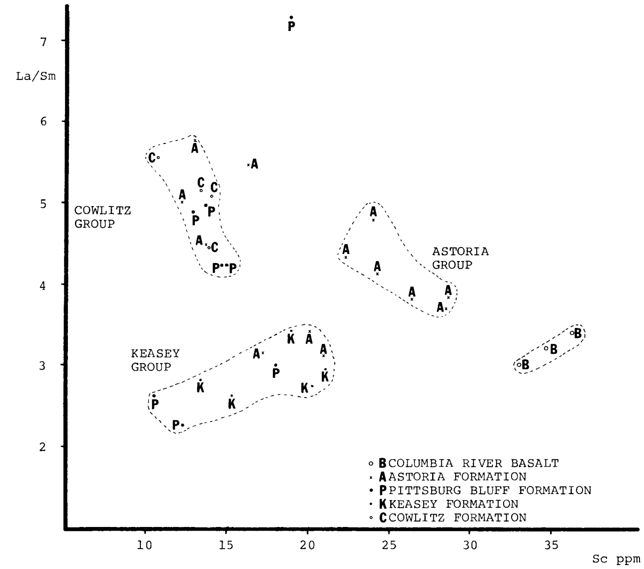

Figure 5. Plot of La/Sm ratio versus Sc.

Geochemically, rocks of the Keasey Formation have relatively low K and Th concentrations and low La/Sm ratios. These geochemical and lithologic data suggest a much greater influence of a volcanic component in the provenance of the Keasey Formation as compared to the Cowlitz Formation. Therefore, a major change from a granitic-metamorphic-dominated provenance to a volcanic-dominated provenance occurs between the Cowlitz and Keasey Formations. Concentration of Th, a "continental" element, is much lower in the Keasey than in the Cowlitz.

Another major change in provenance is recorded by the rocks of the Astoria Formation. Higher Sc concentrations in some of the Astoria Formation samples may be due to the presence of the Columbia River basalt in the provenance.

Geochemical evidence of these three major provenances is shown graphically in Figure 5, a plot of La/Sm versus Sc. The

Table 1. Concentration of elements in analyzed samples.

Sample No.	Na %	K %	La ppm	Sm ppm	Sc ppm	Th ppm
	COWLITZ FORMATION					
22-4-5	2.22±0.01	1.06±0.18	50.30±1.40	9.08±0.19	11.20±0.40	13.0±2.0
6-3-5	1.26 0.01	1.80 0.20	45.90 1.30	9.05 1.18	13.90 0.60	11.0 4.0
32-3-5	0.85 0.0	1.57 0.16	35.80 1.0	8.09 0.14	13.70 0.50	12.0 2.0
TCW3092	1.95 0.01	1.72 0.21	47.00 1.30	9.16 0.18	13.20 0.40	14.0 2.4
	KEASEY FORMATION					
25-6-5	0.71 0.0	0.59 0.08	130.0 3.0	44.0 0.60	20.90 0.50	2.3 0.1
20-6-4	1.11 0.01	0.73 0.10	10.10 0.50	3.60 0.10	13.30 0.50	2.8 0.1
2-5-5	0.56 0.0	0.43 0.06	103.0 2.0	39.0 0.50	15.30 0.40	n.d.
23-6-5	1.39 0.01	0.90 0.13	16.50 0.70	4.83 0.12	18.90 0.50	3.9 0.1
33-6-5	1.46 0.01	0.84 0.12	15.70 0.60	5.66 0.13	20.30 0.50	n.d.
	PITTSBURG BLUFF FORMATION					
23-5-4	1.85 0.01	1.40 0.18	36.10 1.10	7.31 0.15	13.50 0.50	9.4 0.2
23-5-4b	1.81 0.01	1.30 0.18	14.70 0.30	6.45 0.15	12.10 0.50	7.7 0.2
28-6-4	1.43 0.01	1.40 0.17	26.60 0.90	10.20 0.16	10.40 0.40	10.3 2.3
12-6-5	1.55 0.01	1.15 0.14	27.60 0.90	6.55 0.15	14.60 0.50	6.6 0.2
12-6-5b	1.64 0.01	1.52 0.18	25.30 0.80	5.17 0.13	12.80 0.50	6.9 0.1
12-6-5d	1.66 0.01	1.09 0.16	36.90 1.10	5.07 0.13	18.80 0.50	5.1 0.1
11-6-5	1.60 0.01	1.09 0.16	36.90 1.10	12.20 0.19	17.90 0.50	n.d.
4-5-4	1.03 0.01	1.82 0.20	30.00 0.90	7.13 0.14	14.80 0.40	10.7 2.0
	ASTORIA FORMATION					
12-6-5e	0.89 0.01	1.03 0.14	103.0 3.0	33.0 0.50	20.90 0.50	7.2 0.2
12-6-5g	0.53 0.0	0.91 0.10	23.90 0.70	5.51 0.11	22.20 0.50	n.d.
12-6-5h	0.06 0.0	0.06 0.02	17.89 0.60	4.60 0.09	28.50 0.50	6.3 2.1
6-6-4	2.81 0.02	n.d.	19.0 0.80	6.01 0.14	17.10 0.50	n.d.
3-6-5	0.23 0.0	0.62 0.07	33.90 1.00	9.93 0.16	20.00 0.40	n.d.
2-6-5	0.22 0.0	0.63 0.07	32.10 0.90	6.67 0.12	23.90 0.40	10.7 3.3
2-6-5b	0.14 0.0	0.70 0.07	20.30 0.60	4.91 0.09	24.10 0.40	8.8 1.4
25-6-5b	0.15 0.0	1.19 0.13	26.70 0.80	4.89 0.10	16.0 0.40	10.0 3.0
25-6-5d	0.14 0.0	1.27 0.14	23.50 0.70	4.09 0.09	12.90 0.30	10.7 3.1
30-6-4	0.69 0.0	0.98 0.11	37.6 1.0	9.76 0.16	26.3 0.50	8.9 2.1
30-6-4b	0.65 0.0	0.93 0.10	55.6 1.40	14.90 0.20	28.40 0.50	10.0 2.7
2-5-5a	1.17 0.01	1.60 0.18	26.80 0.90	5.96 0.13	13.60 0.50	n.d.
2-5-5c	0.98 0.01	1.50 0.17	22.40 0.80	4.48 0.13	12.10 0.50	8.9 3.4
	COLUMBIA RIVER BASALT					
6-5-4	1.62 0.01	0.65 0.11	21.6 0.70	7.10 0.14	32.90 0.60	n.d.
6-5-4a	2.37 0.01	1.08 0.19	23.50 0.90	7.30 0.17	34.70 0.60	n.d.
6-6-4a	2.84 0.02	1.02 0.20	30.0 1.0	8.78 0.17	36.20 0.70	n.d.

sedimentary rocks plot into three groups: one group consists exclusively of samples from the Astoria Formation, whereas the remaining two groups consist of samples from the Keasey and Cowlitz Formations respectively, and *each* includes samples from the Pittsburg Bluff and Astoria Formations. The samples that plot in the Cowlitz group contain or are geochemically inferred to contain granitic-metamorphic detritus, whereas the samples that plot with the Keasey group have a dominant volcanic component. Thus, the Cowlitz rocks are probably derived from distant granitic-metamorphic terranes and the Keasey rocks from nearby volcanic arcs (western Cascades).

In conclusion, the Cowlitz and Keasey Formations appear to record a change in geologic setting. Deposition of predominantly continental detritus during Cowlitz time was terminated by the onslaught of widespread volcanism in the western Cascades. The concentration of Th in the Pittsburg Bluff Formation is intermediate to that in the Keasey and Cowlitz Formations, and the mixed provenance in the Pittsburg Bluff Formation indicates both "continental" and volcanic sources. The voluminous outpouring of the Columbia River basalt in the middle Miocene embayment contributed detritus to the sediments of the Astoria Formation.

ACKNOWLEDGMENTS

This paper is based on a portion of the research performed for a master's thesis by the primary author under the supervision of thesis advisor G.T. Benson, Portland State University. Kadri also wishes to acknowledge Wesley G. Bruer for his thorough review of a draft of the thesis.

We thank R.E. Thoms and A.G. Johnson, Portland State University, for reviewing this paper. We are especially grateful to Norm MacLeod, U.S. Geological Survey, for his thorough review of the paper and for many helpful and constructive comments.

The primary author acknowledges the financial support of Diamond Shamrock Corporation, Oregon Natural Gas Development Corporation, and Reichhold Energy Corporation.

REFERENCES CITED

Bruer, W.G., 1980, Mist gas field, Columbia County, Oregon: American Association of Petroleum Geologists – Society of Economic Paleontologists and Mineralogists, Pacific Section, 55th Annual Meeting, Bakersfield, Calif., Technical Program Preprints, 10 p.

Condie, K.C., 1976, Plate tectonics and crustal evolution: New York, N.Y., Pergamon Pres, 288 p.

Kadri, M.M., 1982, Structure and influence of the Tillamook uplift on the stratigraphy of the Mist area, Oregon: Portland, Oreg., Portland State University master's thesis, 105 p.

McDougall, K., 1980, Paleontological evaluation of late Eocene biostratigraphic zonations of the Pacific Coast of North America: Society of Economic Paleontologists and Mineralogists Paleontological Monograph 2, 46 p.

Moore, W.S., 1972, Thorium: Element and geochemistry, *in* Fairbridge, R.W., ed., The encyclopedia of geochemistry and environmental sciences: New York, N.Y., Van Nostrand Reinhold, p. 1183-1189.

Taylor, S.R., 1964, The abundance of chemical elements in the continental crust/a new table: Geochimica et Cosmochimica Acta, v. 28, p. 1273-1285.

Van Atta, R.O., 1971, Sedimentary petrology of some Tertiary formations, upper Nehalem River basin, Oregon: Corvallis, Oreg., Oregon State University doctoral dissertation, 245 p. □

OAS to meet this month

The Oregon Academy of Science (OAS) Annual Meeting will be held February 26, 1983, at Willamette University, Salem, OR. This year's theme is Marine Fisheries. For additional information, contact Neal Bandick, Western Oregon State College, Monmouth, Oregon, phone (503) 838-1220.

Geologic and tectonic evaluation of The Dalles quadrangle released

The Oregon Department of Geology and Mineral Industries (DOGAMI) has just released the results of a geologic and neotectonic study of The Dalles 1° × 2° quadrangle, conducted in cooperation with the U.S. Nuclear Regulatory Commission. The release is map GMS-27 in DOGAMI's Geological Map Series.

Geologic and Neotectonic Evaluation of North-Central Oregon: The Dalles 1° × 2° Quadrangle was compiled by James L. Bela. The map set consists of a multicolor geologic compilation map and a detailed two-color neotectonic map, both at a scale of 1:250,000. The area covered by The Dalles quadrangle extends along the Columbia River and spans the tectonic boundary between the geologic provinces of the Cascade Range and the Columbia Plateau.

The geologic map identifies and describes 25 different surficial and bedrock geologic units, shows the general structure of the region, and includes the locations and ages of 23 dated rock samples. The neotectonic map shows, in greater detail, folds, faults, and monoclines which were formed from about the middle Miocene epoch to the present.

Map GMS-27 is available now at the Oregon Department of Geology and Mineral Industries, 1005 State Office Building, Portland, OR 97201. The purchase price is $6. Orders under $50 require prepayment. □

Peterson retires from Department

Norman V. Peterson, District Geologist at the Grants Pass Field Office of the Oregon Department of Geology and Mineral Industries for the last 25 years, retired from the Department in December 1982. During his years with the Department he participated in geologic studies covering most of Oregon and authored or coauthored over 50 articles, papers, and books on both technical and general-interest subjects. He conducted commodity studies of uranium, limestone, diatomite, pumice, perlite, volcanic cinders, and geothermal resources; worked on numerous county studies including Lake, Klamath, Deschutes, Josephine, and Douglas Counties; assisted with geologic mapping of the Crescent and Jordan Valley 1° by 2° quadrangles; participated in the wilderness mineral evaluation in Harney and Malheur Counties; and helped author nuclear power plant siting and volcanic hazards

Norman V. Peterson

studies. He introduced many of our readers to the volcanic wonders of Oregon by his articles and field trip guides about such places as Hole-in-the-Ground, Diamond Craters, Cove Palisades State Park, Fort Rock, Newberry Volcano, and Crack-in-the-Ground. He and Ed Groh edited one of the Department's most popular guidebooks, the *Lunar Geological Field Conference Guidebook*, which focused on the volcanic features found in Oregon.

Following his retirement, he intends to remain active in his profession and in his hobbies which include coin collecting, bee keeping, ski touring, and traveling. □

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