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Information for contributors

Oregon Geology is designed to reach a wide spectrum of readers interested in the geology and mineral industry of Oregon. Manuscript contributions are invited on both technical and general-interest subjects relating to Oregon geology. Two copies of the manuscript should be submitted, typed double-spaced throughout (including references) and on one side of the paper only. If manuscript was prepared on common word-processing equipment (IBM compatible or Macintosh), a file copy on diskette should be submitted in place of one paper copy (from Macintosh systems, 3.5-inch high-density diskette only). Graphic illustrations should be camera-ready; photographs should be black-and-white glossies. All figures should be clearly marked, and all figure captions should be together on a separate sheet of paper.

The style to be followed is generally that of U.S. Geological Survey publications. (See the USGS manual *Suggestions to Authors*, 7th ed., 1991, or recent issues of *Oregon Geology*.) The bibliography should be limited to references cited. Authors are responsible for the accuracy of the bibliographic references. Names of reviewers should be included in the acknowledgments.

Authors will receive 20 complimentary copies of the issue containing their contribution. Manuscripts, news, notices, and meeting announcements should be sent to Beverly F. Vogt, Publications Manager, at the Portland office of the Oregon Department of Geology and Mineral Industries.

Cover photo

Rare—and lucky—photo of a fireball over Oregon: The Chemult fireball of July 27, 1992. Photo was taken by Scott McAfee from near Crater Lake Lodge. The fireball came out of the zenith, increasing in brightness. See related report by Pugh and McAfee on page 90.

OIL AND GAS NEWS

Drilling begins at Mist Gas Field

Nahama and Weagant Energy of Bakersfield, California, began drilling for natural gas at the Mist Gas Field, Columbia County, during May. The first well drilled was the Longview Fibre 12A-33-75, located in sec. 33, T. 7 N., R. 5 W., Columbia County. The well was drilled to a total depth of 2,475 ft and is currently suspended. The second well of the multi-well program is the Longview Fibre 12B-35-65, located in sec. 35, T. 6 N., R. 5 W., Columbia County, where drilling operations are underway.

NWPA elects officers, announces symposium

At its monthly meeting on May 14, the Northwest Petroleum Association (NWPA) announced the newly elected officers and directors for 1993-94: President, Nancy Ketrenos; Vice president, Bert Mueller; Secretary, Dick Bowen; and Treasurer, Dan Wermiel. The new directors are John Taylor (western Washington), Harry Jamison (eastern Oregon/Washington), Jeff Pennick (Land), Bill Holmes (Legal), and Bob Deacon and Lise Katterman (at large).

The association's 10th annual symposium will be held September 26-28, 1993, at the Inn of the Seventh Mountain in Bend, Oregon. Theme of the symposium will be "Earth Resources and the Pacific Northwest." The technical session will include papers on oil and gas play assessment, minerals, geothermal resources, coastal tectonostratigraphy, the Paleogene Willamette Basin, coal-bed methane, and gas transmission activity. A field trip will be conducted in the Bend-Newberry National Volcanic Monument area and will highlight the geothermal potential and volcanology of central Oregon.

The NWPA meets for monthly luncheon programs and an annual symposium. For details on the meetings and the symposium, contact the NWPA, P.O. Box 6679, Portland, OR 97228-6679.

Recent permits

Permit no.	Operator, well, API number	Location	Status, proposed total depth (ft)
485	Carbon Energy Intl. JCLC Menasha 28-1 36-011-00025	SW¼ sec. 28 T. 26 S., R. 13 W. Coos County	Application; 1,650.
486	Carbon Energy Intl. WNS Menasha 32-1 36-011-00026	SW¼ sec. 32 T. 26 S., R. 13 W. Coos County	Application; 1,600.
487	Carbon Energy Intl. Coos County Forest 7-1 36-011-00027	SE¼ sec. 7 T. 27 S., R. 13 W. Coos County	Application; 4,250.

☐

Grants Pass offers video viewing

The Grants Pass field office of the Oregon Department of Geology and Mineral Industries (DOGAMI) offers a collection of more than 60 videotapes to visitors for in-office viewing.

The collection includes (1) programs for introductory study of various geologic disciplines and the geologic processes those disciplines deal with, (2) presentations of the geology of particular localities, (3) descriptions of mines and mining operations, (4) descriptions of scenic geology and natural history, and (5) a program set for science teachers, presenting ideas, suggestions, and examples for classroom activities.

The videotapes can be viewed at the DOGAMI Grants Pass field office Monday through Friday from 1:00 to 5:00 p.m. Address and phone number are listed in the left-hand column on this page. Interested persons should contact the office for further information or for viewing appointments. ☐

Lithofacies and depositional environment of the Spencer Formation, western Tualatin Valley, Oregon

by Robert O. Van Atta and Richard E. Thoms, Department of Geology, Portland State University, Portland, Oregon 97207

ABSTRACT

The Spencer Formation is a prime natural gas target in the Willamette Valley of western Oregon. It is coeval with the Cowlitz Formation from which gas is produced in the Mist Gas Field of northwestern Oregon. Like the Cowlitz Formation, it includes a clean arkosic sand that is nearly 300 m thick in the Humble Oil Miller No.1 test hole near Albany, Oregon. This paper is based upon detailed studies of both cores and excellent surface outcrops in the western Tualatin Valley of northwestern Oregon. In this area, the most northerly occurrence of the Spencer Formation, it overlies the Yamhill Formation, which is mostly carbonaceous mudstone, with apparent conformity and is overlain by the Pittsburg Bluff Formation. The Spencer Formation can be informally divided into two members: (1) a lower, highly micaceous sandstone (62 m), and (2) an upper member that is micaceous siltstone and mudstone (308–400 m). Locally, the lower member includes a very permeable sandstone that is lithologically indistinguishable from the gas-producing unit known as the "Clark and Wilson sand") of the Mist Field.

Diagenesis of the Spencer Formation in the area of this study was limited to production of some chlorite, smectite, and mixed-layer smectite/illite. Percentages of the authigenic clays are greater in the upper part of the lower member and in the upper member, reflecting a somewhat greater content of volcanic detritus. Vitrinite reflectance of 0.22 indicates a low degree of thermal maturity.

Depositional environments represented in the Spencer range from outer- to mid-neritic (lower part, lower member) to shallow neritic, nearshore, and lagoonal (upper part, lower member) to mid-neritic to upper bathyal depths (upper member).

Based on sandstone framework grain modal composition, the provenance of the Spencer Formation includes both proximal volcanic rocks derived from the east and distal plutonic as well as medium- to high-grade metamorphic rocks probably derived from the region of the present-day northern Cascade Range and the northern Rocky Mountains.

INTRODUCTION

The earliest recorded hydrocarbon exploration activity in the Willamette Valley was in 1934–35, when three wells were drilled in Marion, Benton, and Linn Counties. No other drilling activity was recorded until 1957. From 1957 to 1981, 34 additional wells were drilled to test the Spencer Formation in Benton, Linn, Marion, and Polk Counties (Baker, 1988).

The Spencer Formation is correlative to the productive Cowlitz Formation "Clark and Wilson sand" (Bruer and others, 1984) in the Mist Gas Field, upper Nehalem River basin, northwestern Oregon (Figure 1), and throughout this paper comparisons are made between the arkosic sandstone in the Spencer Formation in the western Tualatin Valley and the arkosic "Clark and Wilson sandstone" of the Cowlitz Formation. The Spencer Formation is considered a potential reservoir for natural gas because of high permeability and porosity in a sandstone member, "Spencer sand" of Bruer and others (1984), and there have been gas shows where it has been penetrated in the northern Willamette Valley. Thus, much of the recent exploration effort in the Willamette Valley has concentrated on the Spencer Formation.

One small gas discovery occurred in the Spencer Formation in 1981 at the American Quasar Hickey 9-12 well in Linn County. Production lasted for five months (Olmstead, 1989) and was abandoned because production volume of gas became subcommercial. To date, no economic gas accumulations have been found.

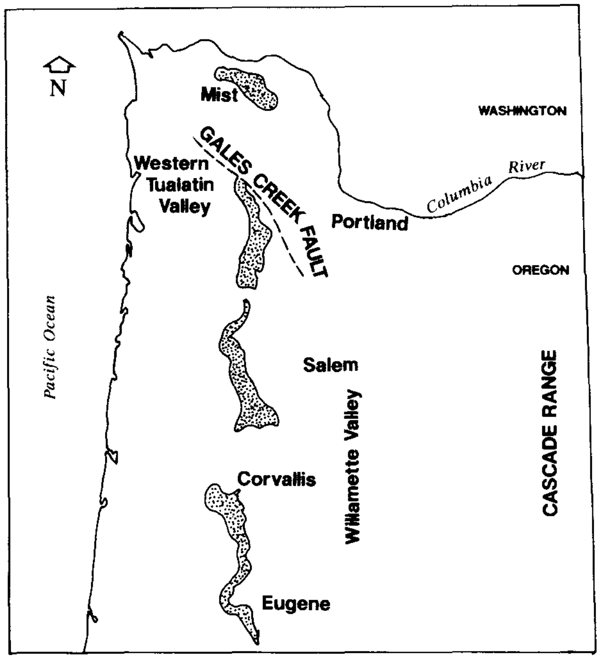


Figure 1. Sketch map of northwestern Oregon. Areas discussed in text are indicated by stippled pattern.

Data presented in this paper were obtained during a detailed study of the stratigraphy and paleontology of Paleogene rocks of the western Tualatin Valley conducted by the authors and by David Taylor, a visiting researcher at Portland State University. Other sources of data not obtained in this study are cited where necessary.

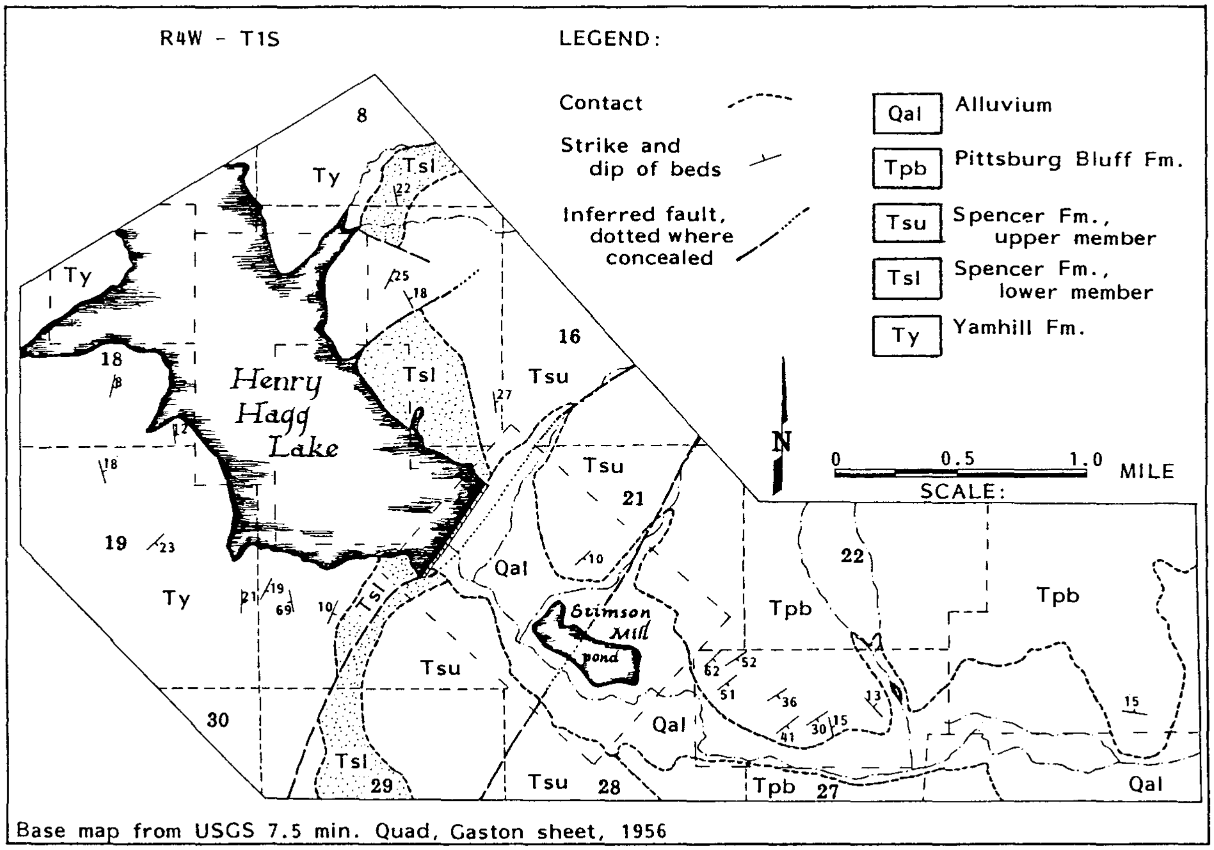
Paleoecologic interpretations proposed in this paper are based upon the following sources: Abbot (1954), Keen (1960), Keen and Coan (1974), and Moore (1976) for mollusks; Ingle (1980) and McKeel (1984) for the foraminifers; and Frey (1975) for trace fossils.

Purpose

The purpose of this paper is to present the results of a detailed study of the Spencer Formation in the northernmost part of its outcrop extent in an effort to determine its environment of deposition, provenance, and correlation to that of the arkosic sandstone of the Cowlitz Formation in the region of the Mist Gas Field 50 km to the north. The western Tualatin Valley area affords a nearly complete stratigraphic section of the Spencer Formation. Additionally, relatively unweathered cores from the lower member of the formation provide the opportunity for petrologic comparison with generally weathered surface samples.

Previous work

Schlicker (1962) first demonstrated that sandstone above the Yamhill Formation in the western Tualatin Valley is correlative to the Spencer Formation. McWilliams (1968) includes the Yamhill-Gales Creek area in his study of paleogene lithostratigraphy and biostratigraphy of west-central Oregon.



Base map from USGS 7.5 min. Quad, Gaston sheet, 1956

Figure 2. Geologic map of the Scoggins Valley area, Washington County, Oregon.

Al-Azzaby (1980) made a detailed study of the sedimentology and stratigraphy of the Spencer Formation in the western Tualatin Valley. He described two informal members of the Spencer Formation in the western Tualatin Valley area, a lower arkosic sandstone and an upper silty sandstone and mudstone that in this paper are combined in a lower member. The upper member in this paper is the mudstone that Al-Azzaby called "Stimson Mill beds."

Cunderla in 1986 completed a study of stratigraphic and petrologic trends within the Spencer Formation, including chemistry and diagenesis, from Corvallis to Henry Hagg Lake. The "lower and upper members" (informal) of his study are equivalent to the lower part and upper part, respectively, of the lower member (informal) distinguished in this report.

The most recent study of the Spencer Formation is that of Baker (1988). Her work was concentrated in the west-central Willamette Valley and focused on stratigraphy and depositional environments that were determined from both surface and subsurface data.

Regional stratigraphic relations

In Washington State, the Spencer Formation is correlative to the Skookumchuck, Spiketon, and Renton Formations of the Puget Group and the younger part of the sandstone of Scow Bay in western Washington.

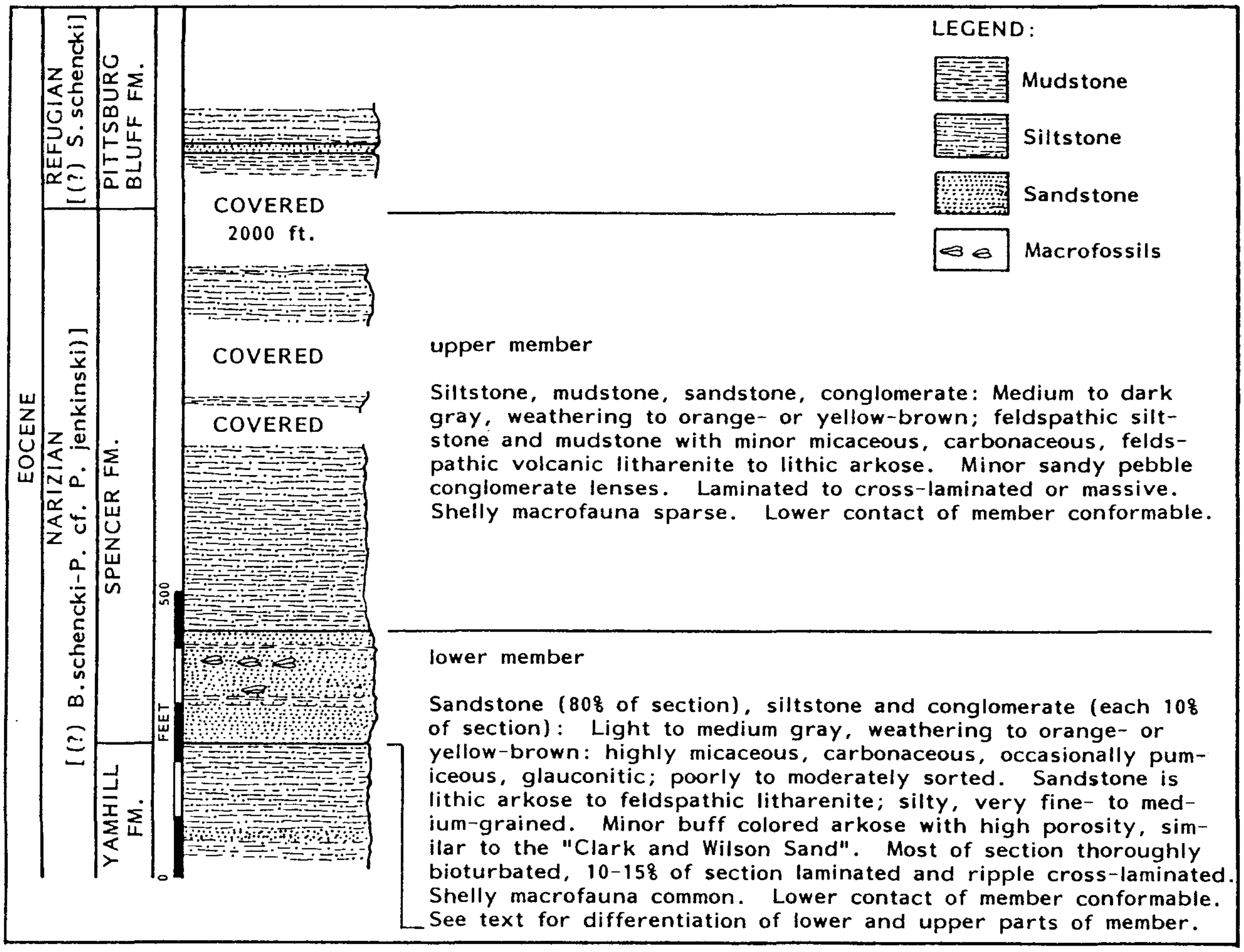
In Oregon, the Spencer Formation can be correlated with the upper middle and upper members of the Coaledo Formation in the southern Coast Range of Oregon and, in the central Coast Range, with siltstone and volcanic rocks of the Nestucca Formation and Yachats Basalt.

Bruer and others (1984) consider the Spencer Formation to be coeval and continuous with the Cowlitz Formation of northwestern Oregon, although nowhere can the Spencer Formation be mapped from the western Tualatin Valley to the Cowlitz Formation in the upper Nehalem River basin, largely because of offset along the Gales Creek fault (Van Atta, unpublished mapping, 1985; Figure 1). Bruer and others also regard permeable arkosic sandstone in the Spencer Formation as coeval with the "Clark and Wilson sand" of the Cowlitz Formation.

The middle to lower upper Eocene (Narizian) Spencer Formation, named by Turner (1938), crops out in a generally narrow, somewhat sinuous band that trends north-south in western Oregon (Figure 1). The type locality is 16 km southwest of Eugene, in the vicinity of Spencer and Coyote Creeks, where the unit is about 77 m thick.

In the southern part of the outcrop belt (Drain to Eugene), the Spencer Formation unconformably overlies either the Tyee Formation or the Lorane Shale and is conformably overlain by the nonmarine Fisher Formation (Hoover, 1963; Gandera, 1977). In the central area (Monroe to Salem), the Spencer Formation is underlain unconformably by either the mid-Eocene Tyee Formation (south of Corvallis) or the lower upper Eocene Yamhill Formation (Corvallis and Albany), depending upon stratigraphic assignment of a thick sandstone lens ("Miller sand," informal; Bruer and others, 1984) lying between the Spencer and Tyee Formations to either the Yamhill or Spencer Formation. In the subsurface, in the eastern and southern parts of the central Willamette Valley, south of Corvallis, the Spencer is underlain by either mudstone, volcaniclastic rocks, or basaltic volcanic rocks of the Yamhill Formation (Baker, 1988).

In the eastern and southern parts of the central Willamette Valley, northwest of Eugene (Figure 1), the upper member (informal) of the Spencer is intercalated with basaltic volcanic rocks that Baker (1988) has termed "eastern Willamette volcanics" (informal). It is



upper member

Siltstone, mudstone, sandstone, conglomerate: Medium to dark gray, weathering to orange- or yellow-brown; feldspathic siltstone and mudstone with minor micaceous, carbonaceous, feldspathic volcanic litharenite to lithic arkose. Minor sandy pebble conglomerate lenses. Laminated to cross-laminated or massive. Shelly macrofauna sparse. Lower contact of member conformable.

lower member

Sandstone (80% of section), siltstone and conglomerate (each 10% of section): Light to medium gray, weathering to orange- or yellow-brown: highly micaceous, carbonaceous, occasionally pumiceous, glauconitic; poorly to moderately sorted. Sandstone is lithic arkose to feldspathic litharenite; silty, very fine- to medium-grained. Minor buff colored arkose with high porosity, similar to the "Clark and Wilson Sand". Most of section thoroughly bioturbated, 10-15% of section laminated and ripple cross-laminated. Shelly macrofauna common. Lower contact of member conformable. See text for differentiation of lower and upper parts of member.

Figure 3. Stratigraphic column for Scoggins Valley, to the east and along north side of Henry Hagg Lake, Washington County, Oregon.

overlain unconformably in the central area by the uppermost upper Eocene to middle Oligocene Eugene Formation.

In the western Tualatin Valley from Yamhill, Oregon, to the Gales Creek fault, the Spencer Formation overlies the Yamhill Formation with apparent unconformity (Al-Azzaby, 1980; Cunderla, 1986), although in the vicinity of Hagg Lake, the Spencer appears conformable over the Yamhill (Van Atta, unpublished mapping, 1985).

The thickness of the Spencer Formation is quite variable throughout its extent. From south to north, its thickness is 45–145 m just east of Drain (Hoover, 1963), 620–840 m north and south of Eugene (Gandera, 1977), 1,385 m near Corvallis (Vokes and others, 1954; Baldwin and others, 1955), and about 615 m in the northernmost outcrop area (Figure 1). Baker (1988) believes, however, that the near-doubled thickness in the central area (Corvallis) may be the result of uncertainty concerning the age of the "Miller sand" (informal; Bruer and others, 1984), as noted above.

Gandera (1977) informally defined two members of the Spencer Formation in its type locality. North of the type locality, Baker (1988) finds that the Spencer Formation consists of two members (informal), traceable from the Corvallis area northward to the western Tualatin Valley: a lower member that consists of micaceous arkosic silty sandstone and siltstone and an upper member that is arkosic to lithic arkosic sandstone and mudstone. From the Corvallis area southward to the type locality, it does not appear possible to separate the formation into mappable members (Cunderla, 1986; Baker, 1988).

Baker (1988) found that the lower sandstone-rich part of the Spencer Formation in the central area can be divided into a lowermost more arkosic part, and an upper part that is more lithic with volcanic rock fragments and with plagioclase feldspar more abundant than potassium feldspar. The lower member is more lithic (volcanic) in both lower and upper parts south of Corvallis as compared to its composition to the north.

The informal members of the Spencer Formation described in the literature may or may not be traceable throughout its occurrence in western Oregon, and any formal proposal to divide the Spencer into an upper and a lower member must await further work.

METHODS

Samples for petrographic study were collected from surface outcrops exposed in Scoggins Valley (Figure 2) and from shallow cores (maximum 77-m depth) that had been taken in the 1970s from these same formations in conjunction with dam-site foundation studies conducted by the U.S. Bureau of Reclamation. The cores were logged for detailed description of primary sedimentary structures and occurrence of fossils. Eight cores in the Spencer Formation (maximum thicknesses 37 m in lower part of lower member, 54 m in upper part of lower member) were studied and sampled. In addition, five samples were taken from core of the "Clark and Wilson sand," Cowlitz Formation (Texaco Clark and Wilson 6–1 well, Columbia County, Oregon, at 943–952 m).

Textural analyses for grain size distribution in the sand-size fraction (-1.0 to +4.0 phi) were done for 56 core samples (28 and 23 samples from the Spencer Formation, lower member, lower part and upper part, respectively; 5 from "Clark and Wilson sand"). Sand-silt-clay ratios were also determined for 66 samples of the lower member of the Spencer Formation (38 from lower part; 28 from upper part).

The size parameters of sandstone samples were determined with a 2-m settling tube. The output of the tube's strain gauge was fed to a programmed microprocessor coupled with a programmable calculator. The calculator was programmed to read out raw and smoothed data tables and to print histograms. Size-frequency data were used to calculate the coarsest 1 percent, phi median, mean, standard deviation, and skewness according to the size parameters of Inman (1952) and Folk and Ward (1957). Moment measures were calculated by means of a computer program created at the School of Oceanography at Oregon State University.

Thin sections from core (24 from Spencer Formation; 4 from "Clark and Wilson sand"), impregnated with colored epoxy, were used to determine and to estimate texture, including pore types, shapes, and distribution. Detrital modes were determined according to the procedures of Dickinson and Suzek (1979). In addition, porosity and diagenetic effects were examined in 10 samples of the lower member of the Spencer Formation by scanning electron mi-

Table 1. *Size parameters of -1 to 5 phi fraction, Spencer and Cowlitz Formations*

Unit, location, sample type	Coarsest 1 percent (phi) Average	Coarsest 1 percent (phi) Range	Median size (phi) Average	Median size (phi) Range	Sorting (σ^0) Average	Sorting (σ^0) Range	Skewness (phi) Average	Skewness (phi) Range	Number of samples
Spencer Formation, lower member (core samples)									
Upper part, Patton and Scoggins Valleys	1.59	—	2.97	1.94-3.60	0.58	0.35-0.84	0.45	–0.17-0.72	16
Lower part, Scoggins Valley	2.43	0.98-2.97	2.80	2.63-3.33	0.39	0.11-0.59	0.38	–0.62-1.97	28
Spencer Formation, western Tualatin Valley (Al-Azzaby, 1980; surface samples)									
Upper part, lower member	—	—	3.72	2.71-4.59	1.91	1.29-2.59	0.74	0.62-0.88	9
Lower part, lower member	—	—	4.09	3.36-4.51	1.84	1.28-2.42	0.72	0.57-0.82	6
Stimson Mill beds (=upper member, this report)	—	—	4.16	3.45-5.46	2.30	1.81-2.74	0.69	0.65-0.74	4
Cowlitz Formation, upper Nehalem River basin									
Arkosic sandstone (surface samples, Van Atta, 1971)	—	—	3.15	2.50-3.70	1.24	0.73-1.99	0.52	0.28-0.74	7
Clark and Wilson sand, Texaco Clark and Wilson 6-1 well (core samples)	2.82	2.71-3.16	2.95	2.78-3.15	0.50	0.44-0.60	0.14	–0.16-0.38	5

Table 2. *Composition averages of sandstone of the Spencer and Cowlitz Formations, based on number of samples as indicated for each unit. Values in percent, except P/K ratio. Qm=monocrystalline quartz; Qp=polycrystalline quartz; F=feldspar; P/K=plagioclase/potash feldspar ratio; Lvm=lithic volcanic and metamorphic rock fragments; L=total lithic rock fragments*

Unit, location, number and type of samples	Qm	Qp	F	P/K	Lvm	L	Mica	Modal composition: QFL Q	F	L	Modal composition: QmPK Qm	P	K
Spencer Formation, lower member													
Upper part, Patton and Scoggins Valleys, 4 core samples	19.2	4.7	34.0	1.3	7.4	13.9	4.5	35	49	16	36	35	29
Lower part, Scoggins Dam, south abutment, 3 core samples	8.9	1.5	43.0	0.5	9.4	9.6	6.8	16	68	16	17	20	63
Spencer Formation, western Tualatin Valley (from Al-Azzaby, 1980)													
12 surface samples; equal to upper part, lower member, this report	30.4	5.6	56.2	1.6	6.4	6.5	4.5	36	56	8	35	40	25
6 surface samples; equal to lower part, lower member, this report	24.2	3.9	61.0	0.9	9.4	9.5	6.7	28	61	11	28	35	37
Cowlitz Formation, upper Nehalem River basin													
Texaco Clark and Wilson 6-1 well, 4 core samples	16.9	2.2	46.0	0.7	1.6	2.5	10.2	27	67	6	24	25	51
Cowlitz Formation, previous work													
Van Atta, 1971, 11 samples	40.0	2.3	38.2	1.1	2.0	8.1	8.2	46	44	10	51	26	23
Timmons, 1981, 6 samples	14.3	7.3	54.5	0.7	6.0	16.2	6.6	26	67	7	21	33	46
Jackson, 1983, 10 samples	26.6	1.7	41.2	1.3	2.8	4.9	9.3	38	55	7	39	34	27

croscopy (SEM). Percent porosity and permeability to air of five of these samples were determined by Core Labs, Inc., Dallas, Texas.

X-ray diffraction analysis of four samples (three from Spencer Formation, one from "Clark and Wilson sand") correlated clay mineralogy with the thin-section and SEM-petrographic studies.

A geologic map of the study area in the vicinity of Henry Hagg Lake, western Tualatin Valley, is given in Figure 2. Figure 3 presents a stratigraphic section of the Spencer Formation compiled from surface data and subsurface information taken from cores. The balance of this paper will concern itself with this region of study.

LITHOFACIES

Lower member

Texture: The rocks of the lower part of the lower member of the Spencer Formation are classified mostly as silty sandstone or sandstone (Folk, 1974). The upper part of the lower member includes silty and muddy sandstone with some interbedded mudstone and sandy siltstone (Figure 4). The upper part is sometimes pebbly with volcanic rock and quartzite clasts up to 12 mm in size. Both parts have angular mudstone clasts up to 6 mm in size.

Compared to the upper part of the lower member, the lower part is somewhat finer and has a narrow range in mean grain size, is well sorted (standard deviation), and is strongly skewed (Table 1 and Figure 5). Samples from the upper part show a much broader range of sorting and skewness, with one-third (nine) of the samples tested showing strong coarse (negative) skewness.

Table 3. *Comparison of lithology and trace fossils, upper and lower parts of the lower member, Spencer Formation*

	Lower part	Upper part
Primary structure		
Massive bedding (bioturbation)	Common	Present
Laminae	Present	Common
Indistinct laminae	Present	Present
Cross-laminae	Present	Present
Indistinct cross-laminae	Present	?
Ripple laminae	—	Present
Textural variants		
Pebbles	—	Common, basalt and mudstone
Mudstone clasts	Present	Present
Coarsening upward cycles	Common	Present
Fining upward cycles	Common	Common
Accessories		
Mica	Abundant	Abundant
Pumice	Common	—
Traces/fossils		
Bioturbation	Abundant	Common
Burrows	Common	Abundant
Mollusk shell		
Articulated	Present	Common
Disarticulated	Common	Abundant
Broken	Common	Very abundant
Wood fragments	Present	—
Plant debris	Abundant	—
Carbon	Common	Flood
Carbon partings	Common	Common

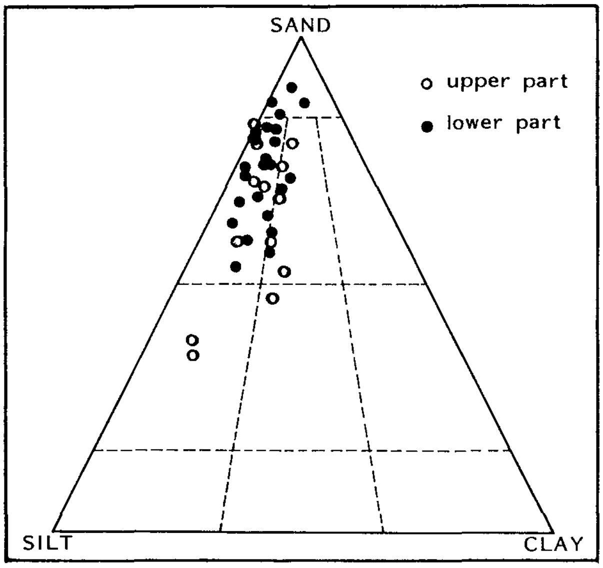


Figure 4. Sand-silt-clay ratio, Spencer Formation, lower member.

The textural size parameters of the "Clark and Wilson sand" in the upper Nehalem River basin are comparable to those of the lower member of the Spencer Formation in the western Tualatin Valley. Samples from cores of the Texaco Clark and Wilson 6–1 well were taken at 943–952 m depth, and samples from other test holes were taken from about 100 m lesser depth in the "Clark and Wilson sand" that may be comparable to the upper part of the lower member of the Spencer Formation (Table 1).

Plots of the coarsest 1 percent (C) vs. the median size (M) in millimeters (Figure 6), produced with the method of Passega (1957), show that values for the lower part of the lower member of the Spencer Formation (28 samples) are tightly grouped. The plots all fall in the turbidity current field. This would indicate rather uniform processes of sediment transport and deposition. However, other evidence of turbidity current deposition in the lower part of the lower member (e.g., Bouma sequences) is absent. It is more likely that simple tractive currents (contour currents?) account for the uniformity of CM values. Plots of C vs. M values for core samples of "Clark and Wilson sand" from the Texaco Clark and Wilson 6–1 well show this sandstone to be like the lower part of the lower member of the Spencer Formation (Figure 6).

In contrast, the upper part of the lower member of the Spencer Formation shows a coarser first percentile for most samples and a very wide deviation in plots of this versus the median size. Part of the plot falls in the field typical of beach processes (Passega, 1957).

Sedimentary features, lower part of lower member: The lower part of the lower member of the Spencer Formation in the Scoggins Valley section as exposed on the north side of Henry Hagg Lake (Figure 3) and in subsurface cores (Table 2) consists of about 25–30 m of massive to faintly laminated, fine- to very fine grained, medium-gray to greenish-gray, highly micaceous, carbonaceous lithic arkose to feldspathic litharenite. Very thin (1.2–2.5 cm) pumiceous beds with reverse grading of pumice suggest an air fall combined with waterlaid sedimentation. Most beds are massive. Both coarsening upward and fining upward sequences can be seen. The lower part of the lower member of the Spencer Formation in the western Tualatin Valley is lithologically quite similar to the Spencer Formation to the south in its type locality near Eugene.

Carbonized wood and plant debris are common. Mollusks, chiefly pelecypods, are represented by infrequent whole valves and some articulated valves but mainly by common disarticulated and broken valves. This strongly suggests a transported association.

Primary structures observed are listed by unit in Table 3.

Sedimentary features, upper part of lower member: Cores taken in Scoggins Valley and in Patton Valley, immediately south of Scoggins Valley (Table 2) yielded samples of the upper part of the lower member. The rock consists of 0.5- to 9-m-thick beds of light-gray to medium-gray (weathers orangish to yellowish brown, especially where it is glauconitic) silty sandstone, pebbly sandstone, and sandy siltstone. In composition, it is a highly micaceous, carbonaceous, glauconitic lithic to feldspathic litharenite with angular to subangular grains. Laminae are composed almost entirely of biotite with minor muscovite.

Creamy gray arkose with high porosity and permeability composes a part of the section. This "clean" (< 5 percent clay) arkose appears only as two 0.3-m beds in cores in the Scoggins section, on the north side of Henry Hagg Lake, but thickens southward, with beds of 9 m thickness in cores in Patton Valley and beds of several tens of meters thickness in hills 0.8 km south of Patton Valley. The upper part of the lower member differs from the Spencer in the Corvallis area in that it includes these interbeds of "cleaner," highly feldspathic sandstone, very similar to the "Clark and Wilson sand" of the Mist area.

Primary structures seen in the upper part of the lower member (Table 3) include laminations and ripple cross-laminations. Massive, bioturbated beds are few. Tubular burrows (counter to bedding) are more common here than in the lower part, consisting of two distinct sizes (4–5 mm and 15–25 mm in diameter). They frequently exhibit well-preserved linings of mica, mud, and green clay (glauconite?).

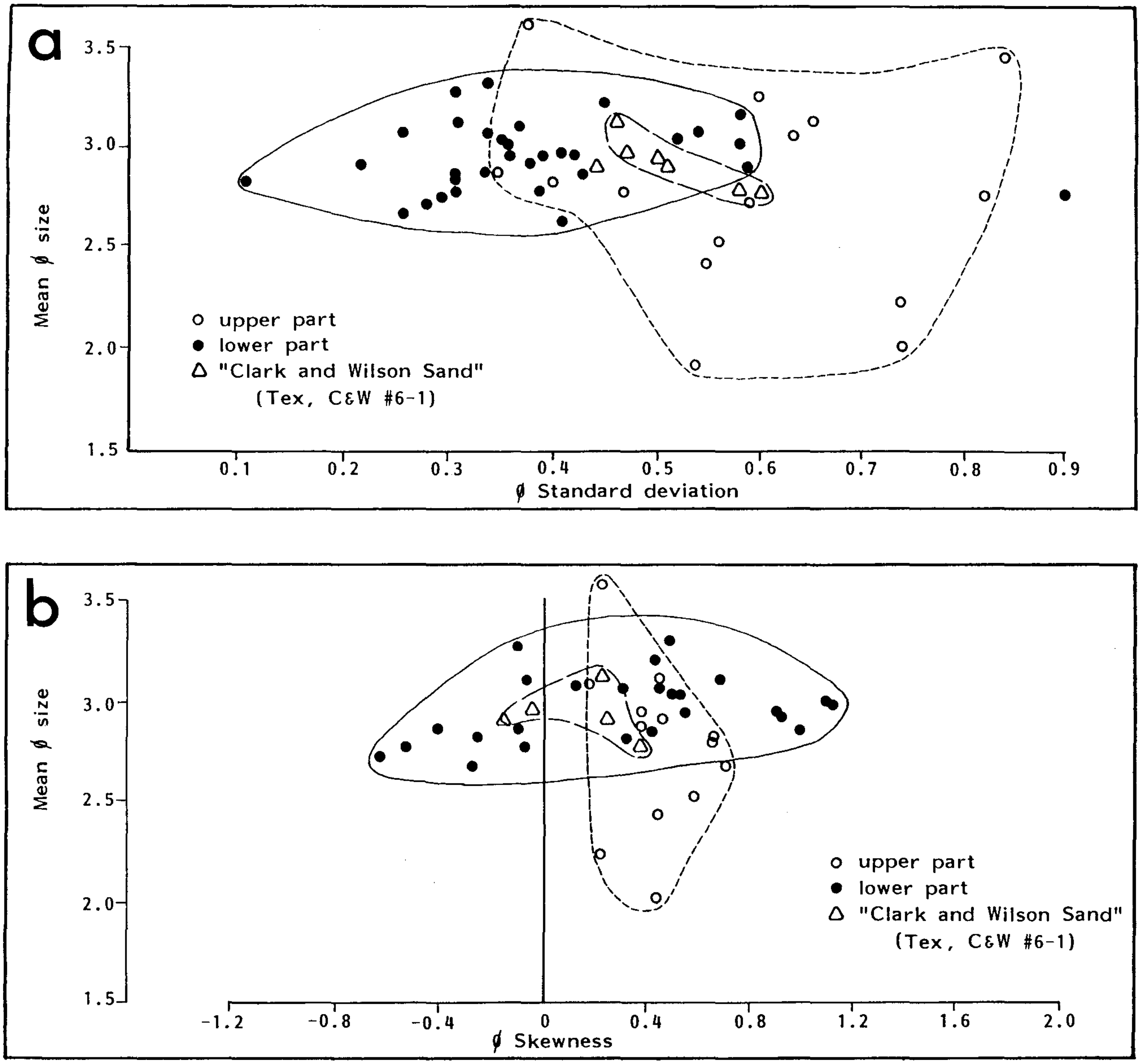


Figure 5. Texture comparison between the lower member of the Spencer Formation, and the "Clark and Wilson sand," of the Cowlitz Formation (Texaco Clark and Wilson 6-1 well), showing (a) mean phi (ϕ) size and phi standard deviation; (b) mean phi and phi skewness.

Table 4. *Permeability[1] and porosity[2] in selected samples, lower member, Spencer Formation, western Tualatin Valley, and Cowlitz Formation, upper Nehalem River basin, Oregon*

Unit, sample number, depth	Permeability (md)	Porosity (%)	Pores			Size (μ)	Distribution	Sand-silt-clay ratio
			Type[3]	Shape	Clay[4]			
Spencer Formation, lower member, upper part								
DH 105-0216, 32 m	—	17.6*	I(D)	Polygonal	—	30-150	Random	—
DH 105-0217, 33 m	—	0.1*	I, M (S)	Linear	—	2-3	Interlaminar (mica)	74-16-9
DH 105-0219, 50 m	167.0	26.3	I, M (D)	Polygonal	Clay in throat	1-3	Random	79-13-8
DH 103-0228, 30 m	1,500	28.8	I (D)	Polygonal	Little authigenic clay	50-100	Random, irregular	84-13-3
DH 103-0229, 42 m	0.6	23.3	—	—	—	—	—	84-9-7
DH 51-0285, 34 m	—	13.2*	I(M)	Polygonal, linear	Smectite closes pore throats	5-10	Random	72-18-1
DH 48-0287, 11 m	—	1.0*	M, F (I)	Linear	Clay bridges pores; throats closed	1-3	Random	—
Spencer Formation, lower member, lower part								
DH 6-0011, 4 m	—	8.0*	I	Linear	Smectite lining; pore throats closed	10-40	Random	73-19-8
DH 6-0016, 17 m	—	10.0	I	Linear	Smectite lining; pore throats closed	5-10	Random	66-22-12
DH 12-0020, 12 m	—	1.0	I, M (F)	Polygonal, linear	—	1-2	Random	45-53-4
DH 12-0022, 17 m	—	12.6*	I (D)	Polygonal, linear	Smectite partly closes pore throats	20-70	Random	82-14-4
Cowlitz Formation, Clark and Wilson sand								
Texaco Clark and Wilson 6-1, 0305	—	13.2*	I (F)	Polygonal, linear	Smectite lining; pore throats closed	10-30	Random	—

[1] Permeability to air; clean, dry core segments. Core Laboratories, Inc. Values in millidarcies (md).

[2] Porosity: Boyle's Law determination with helium. Core Laboratories, Inc. Values marked with * were determined in thin section.

[3] Pore types: I=intergranular; D=dissolution; M=microporosity; F=fractured; S=shrinkage.

[4] Clay determined by X-ray diffractometry.

Table 5. *Porosity and permeability of surface samples, Spencer Formation, according to Schlicker (1962)*

No.	Location	Permeability (md)	Porosity (percent)
1	SE corner sec. 20, T. 1 S., R. 4 W.	184	36
2	SE¼ sec. 32, T. 1 S., R. 4 W.	202	32.2
3	NE¼ sec. 16, T. 2 S., R. 4 W.	1,130	31.7
4	SE¼ sec. 30, T. 3 S., R. 4 W.	812	41.3
5	SW¼ NW¼ sec. 30, T. 3 S., R. 3 W.	736	1.2
6	NW¼ sec. 24, T. 3 S., R. 4 W.	1,850	41.1
7	NE¼ sec. 1, T. 3 S., R. 4 W.	2,200	40.7
8	NW¼ sec. 15, T. 2 S., R. 4 W.	4,510	41.5
9	NE¼ SE¼ sec. 32, T. 1 S., R 4 W.	3,510	32.9

Fossils include articulated and single valves and broken fragments of pelecypods. Rare gastropods are also found. Some mollusks, such as *Solen*, are found in living position. Pelecypods, including the genera *Volsella*, *Solen*, *Nuculana*, *Pitar*, *Spisula*, *Venericardia*, and *Acila* are more numerous than in the lower part. Some shell concentrations form coquinoid biostromes. The overall appearance is that of a transported association mixed with a few deeper water (at least subtidal) *in situ* forms.

Carbonized plant debris is common in both parts of the lower member but can make up 5–10 percent of some beds in the upper part, where wood fragments up to 40 cm in length may be found. *Toredo*-bored wood is also found in the upper part. Wood fragments and carbonized plant debris appears to be detrital.

According to Al-Azzaby (1980), thin (1-cm) layers of coal are very common in the upper part of the lower member of the Spencer Formation just south of Hagg Lake. It appears that this coal is detrital. A 30-cm-thick bed of coal is reported on the bank of a small creek (SW¼ sec. 36, T. 2 S., R. 4 W.) just off Woodland Loop Road, about 6.6 km east of Yamhill, Oregon. This was worked as a coal prospect until 1907 (Oregon Department of Geology and Mineral Industries, 1951). It is not known whether the coal is rooted or not, since it is not now possible to locate this coal bed.

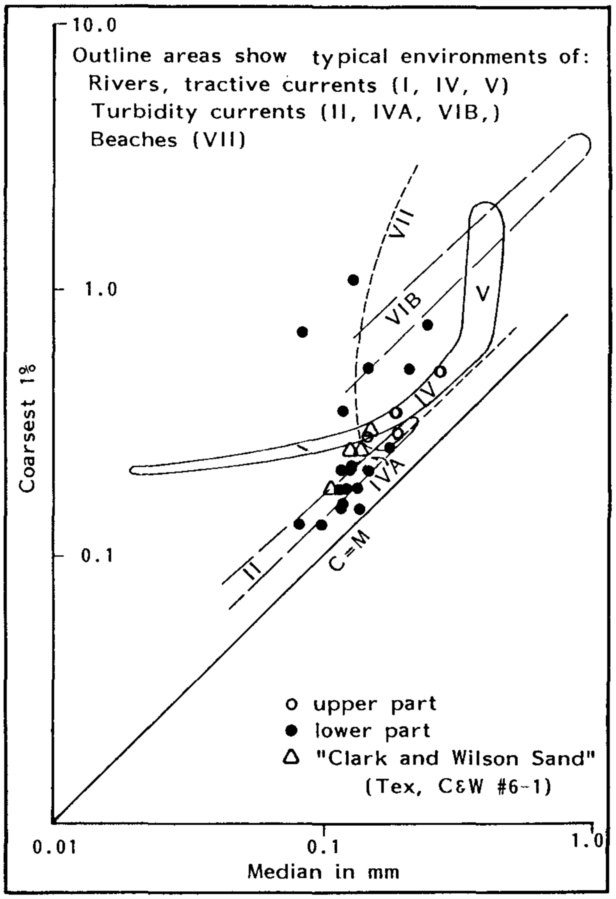


Figure 6. CM diagram of Spencer Formation, lower member, and "Clark and Wilson sand" (Texaco Clark and Wilson 6-1 well).

Clay mineralogy: The clay in the lower part of the lower member of the Spencer Formation includes mostly detrital smectite. A few percent, at most, is authigenic. Variable lesser percentages of kaolinite, chlorite, and mixed layer illite/smectite are also present; the chlorite appears to be mostly authigenic. In the upper part of the lower member, smectite makes up about 50 percent, kaolinite about 35 percent, and chlorite about 15 percent of the clay present. As in the lower part of the lower member, a few percent of smectite and chlorite appears to be authigenic, while the illite/smectite is mostly authigenic. According to Cunderla (1986), mixed layer illite/smectite is more abundant in the upper part of the lower member of the Spencer Formation. This is similar to the clay mineralogy of the Cowlitz Formation in the upper Nehalem River basin (Van Atta, 1971).

Samples of the "Clark and Wilson sand" analyzed for this study showed only smectite clay present.

Throughout the Spencer Formation, the clay minerals are mostly detrital. Scanning electron microscopy reveals that, when smectite and chlorite are present, a small amount is authigenic on grain surfaces in pore spaces (Figure 7a). Samples with a high porosity but low permeability have more authigenic clay, which reduces pore sizes and blocks pore throats.

Porosity and permeability: Porosity and permeability (P/P) in the Spencer Formation vary widely (Table 4). Values of 23.3 percent and 0.6 millidarcies (md) (Sample 0229, DH 103) and 28.8 percent and 1,500 md (Sample 0228, DH 103), measured in core taken in a drill hole in Patton Valley, are typical. The sand content of these two rocks differs by only 1 percent, but the sand in the more permeable rock is coarser, and there is only about half as much clay in it as in the less permeable rock. Table 4 compares measured values of porosity and permeability together with clay present, description of pores, and sand/silt/clay ratios for both the Spencer Formation and the "Clark and Wilson sand" in the Texaco Clark and Wilson 6–1 well.

The arkosic sandstone with the very high permeability (Sample 0228, Patton Valley, Table 4) is very similar to an arkosic sand that makes up most of the section (about 400 m) in Williams Canyon, about 2.5 km south of Patton Valley. It appears that this permeable sandstone thins and thickens (< 1 m to several tens of meters, at least) over a distance of about 16 km. The most probable interpretation would be that the permeable sandstone represents the filling of a major submarine channel. Since mud rocks of the overlying upper member of the Spencer Formation and underlying Yamhill Formation provide a good seal, such buildups of high-P/P sandstone in the Spencer could be excellent reservoirs.

However, scanning electron microscopy (Figure 7) shows that even a small amount of additional clay, some of which appears to be authigenic, is effective in reducing pore throat size to cause a much lower permeability. An arkosic sandstone (Sample 0219) from a test hole in the upper part of the lower member of the Spencer Formation in Patton Valley has a fair porosity (26.3 percent), but authigenic smectite has reduced pore throat size so that permeability is only 167 md (Table 4 and Figure 7b). Samples 0219 and 0228 have very similar sand/silt/clay ratios (79–13–8 and 84–13–3, respectively, Table 4) so that even a 5-percent difference in clay content is effective in drastically reducing permeability. Such differences in permeability in the Spencer sandstones appear to be the rule rather than the exception.

Schlicker (1962) reported highly variable values of permeability for nine surface outcrop samples of Spencer Formation sandstone, as shown in Table 5.

The friability of most surface outcrops of sandstone of the Spencer Formation makes it difficult to collect and transport undisturbed samples. Some of the extremely high porosity and permeability values reported by Schlicker could be due to the way in which samples were collected, although Schlicker (oral communication, 1987) did not believe that this was the cause of the variability. Weathering and partial removal of fines by ground water percolation could also account for some of the exceptionally high permeabilities.

Measurement of P/P in surface outcrops of Cowlitz Formation arkose in the upper Nehalem River basin, reported by Newton and Van Atta (1976), show a range of 30.9–36.2 percent and 31–823 md, respectively. Newton and Van Atta also reported porosity and permeability measurements of arkosic sandstone samples from the Texaco Clark and Wilson 6–1 well. These values show a wide variance (10–37.8 percent and 3–1,302 md).

In summary, arkosic sandstone in the lower member of the Spencer Formation usually has a high porosity (20–30 percent), and the permeability may range from very low to very high values, depending upon the amount of silt and detrital clay and/or the occurrence of authigenic clay, which may or may not plug pore throats. Most porosity is intergranular, with occasional fracture, shrinkage, and microporosity. Pores are usually polygonal in shape, but some are linear. The clay is generally smectite, although some detrital chlorite is present. Authigenic smectite clay most commonly lines pore spaces and reduces pore throat size so as to cause very low permeability.

Diagenesis: In the sandstones, some of the authigenic clay present was probably derived from volcanic rock fragments and plagioclase, which are present in the upper part of the lower member and in the upper member of the Spencer Formation (Table 2). Armentrout and Suek (1985) regard reservoir potential of upper Eocene feldspathic-quartzose sandstones of western Oregon and Washington to be dependent upon the presence or absence of volcanic rock fragments that might be diagenetically altered to pore-filling clay. It does not appear, however, that diagenetic clay forms a very large percentage

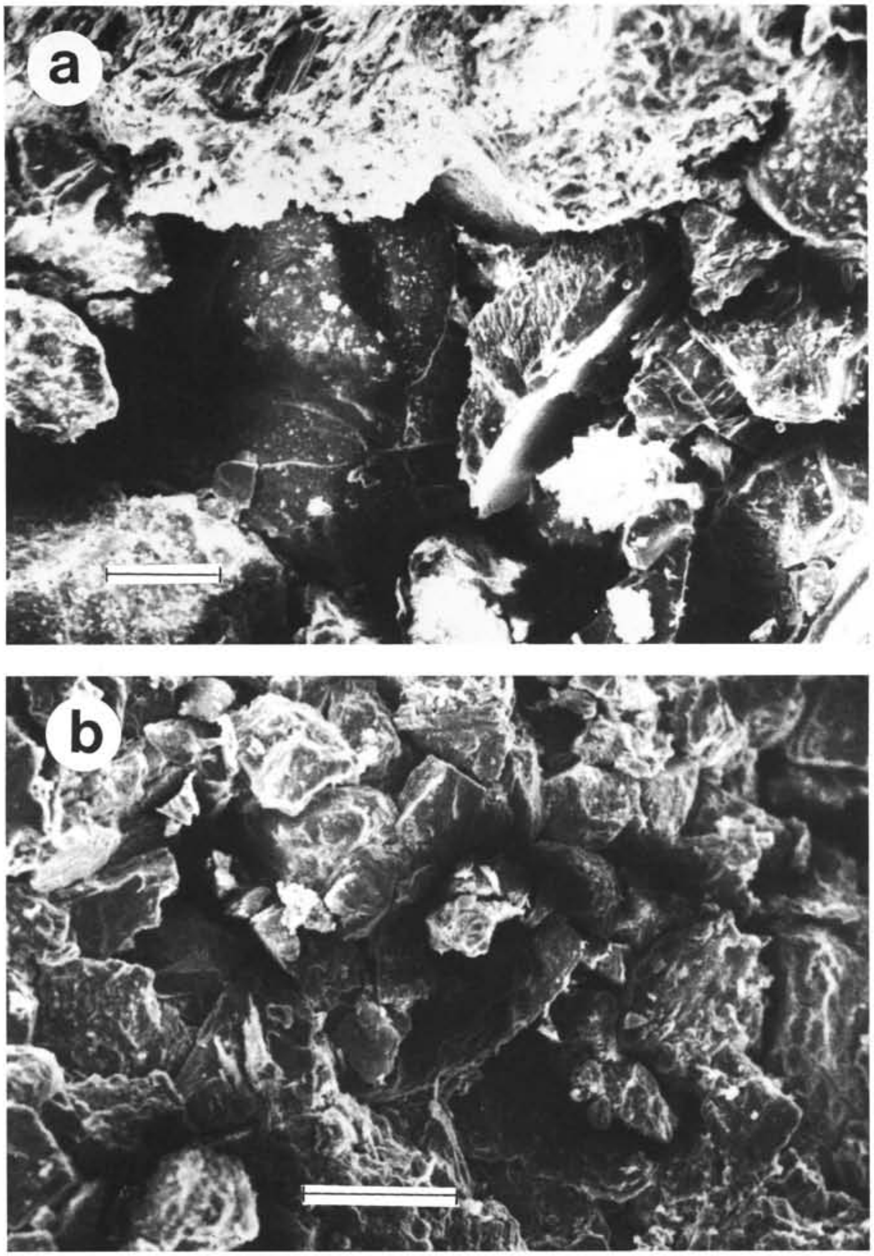


Figure 7. Scanning electron micrographs, Spencer Formation, upper part of lower member. Top (a), DH 103, sample 0228, 30-m depth, arkose, P/P values 28.8 percent / 1,500 md. Scale bar = 100 µm. Bottom (b), DH 105, sample 0219, 50-m depth, arkose, P/P values 26 percent / 167 md. Scale bar = 5 µm.

of the clay fraction of the Spencer Formation sandstone that is being described here, in the present study. The immature nature of carbon, revealed by vitrinite reflectance (0.22), is indicative of shallow burial, which tends to agree with the lesser amount of diagenetic clay in these rocks.

In a study of diagenesis of Spencer Formation sandstone, Cunderla (1986) showed that authigenic potassium feldspar occurring as overgrowths on detrital potassium feldspar and as euhedral crystals is common in the upper part of the lower member (equivalent to his "upper member"). Cunderla also found authigenic heulandite in one subsurface core sample. He stated that the chemical breakdown of plagioclase feldspar, hornblende, and pyroxene and the degradation of volcanic rock fragments led to the enrichment of pore waters in Ca^{++}, K^{+}, and Na^{+}, eventually allowing the precipitation of authigenic feldspar, heulandite, and some authigenic smectite. Water in wells penetrating the Spencer sandstone in the mid-Willamette Valley to the south of the western Tualatin Valley shows high concentrations of the ions listed above as well as several other ion species (Frank, 1974; Gonthier, 1983). Cunderla's SEM and energy dispersive spectrometry (EDS) study showed that authigenic chlorite is probably present because of degradation of biotite.

Contact: The contact between the lower and upper parts of the lower member of the Spencer Formation, as seen in surface outcrops and in cores, is both conformable and gradational. The lower member and the upper member intertongue, but locally the contact is gradational over an interval of about 3–5 m.

Upper member

The upper member of the Spencer Formation, as exposed from the Scoggins Dam eastward along the north side of Scoggins Valley, consists of 308–400 m of medium- to dark-gray micaceous, carbonaceous, feldspathic siltstone and mudstone with minor muddy sandstone and thin pebble conglomerate lenses. The siltstones and mudstones are medium to thickly bedded (0.1–1 m), display thin plane laminations (0.1–0.3 cm), and ripple cross-lamination. The beds are burrowed and are occasionally thoroughly bioturbated. Macrofossils, including *Acila decisa*, *Cochlodesma bainbridgensis*, and *Dentalia* sp., are present and locally may be common. Carbonized wood is locally abundant.

Al-Azzaby (1980) referred to these interbedded and overlying mud rocks, sandstone, and conglomerate as the "Stimson Mill beds" (informal). He considered them lithologically distinct and mappable in this area. It appears, however, because of the presence of identical, thick (0.1–1 m) interbeds of mudstone and siltstone in cores (DH 48 and DH 51, Scoggins Valley) in the upper part of the lower member of the Spencer Formation, that there is insufficient reason to warrant separation of the mudstone into another stratigraphic unit of formation rank.

Contact: The contact with the overlying Pittsburg Bluff Formation was not observed, occurring in a covered interval that probably masks a fault in the vicinity of the contact (Figure 2). The contact is probably unconformable, however, owing to the fact that the Keasey Formation (early Refugian) does not appear to be present in the western Tualatin Valley region, as it is in the upper Nehalem River basin, where it occurs between the Cowlitz and the Pittsburg Bluff Formation.

DISCUSSION

Depositional environment

We interpret from the borehole data (Figures 5 and 6; Tables 1 and 3) that the lower part of the lower member of the Spencer Formation was deposited in a mid- to outer-shelf environment, probably under fairly uniform conditions of sedimentation, such as would prevail under storm wave influence and contour current transport. This is based upon a narrow range in mean phi size and good sorting (Figure 5; Table 1).

In contrast to the lower part, the upper part of the lower member was deposited in a shallower, nearer shore environment in which a wider range of sedimentation processes prevailed. These include storm wave influence, long-shore transport, and proximity of shore and fluvial sedimentation. In this environment, a wider range of sizes of sediments might have been available from various sources, particularly coarse sediment. The presence of an abundance of carbonaceous material and coal (in certain sections) suggests a shallow inner-neritic depth to near-shore to nonmarine environment. Clean arkosic sand may have been deposited as offshore bars.

Kulm and others (1975) found that the mean size and standard deviation of the sand fraction of Holocene southern Oregon mid-shelf sediments are much more tightly grouped compared to the same size parameters of sediments deposited in shallower shelf environments. They also found that skewness of size distribution of mid-shelf sediments showed a much larger range of values than skewness on sediments inshore. The same relationships can be seen in plots of mean phi size vs. standard deviation and mean phi size vs. skewness (Figure 5) of sand-sized fractions from the lower and upper parts of the lower member of the Spencer Formation. This tends to support the conclusion that the lower part of the lower member of the Spencer Formation was deposited in a mid- to outer-shelf environment, while the upper part was deposited in an inner-shelf environment.

In addition to these petrographic indicators, the upper part of the lower member yields a diverse and common macrofauna dominated by pelecypods. Localized shell concentrations and widely distributed fragmental material, which forms several coquinoid layers, indicate reworking and a fairly high energy environment. Trace fossils include both probable upward escape burrows and dwelling burrows, some of which are lined with mica, mud, and sometimes glauconitic material. The fauna is indicative of a shallow but somewhat offshore environment, with water depths of inner neritic to inner tidal.

The upper member contains a macrofauna that, although poorly preserved, indicates a water depth of greater than 23 m. This is substantiated by the finer grained character of the sediment, chiefly siltstone and mudstone. Foraminiferal faunules from the upper member suggest deposition in marine waters of upper bathyal depth.

Most earlier interpretations of the depositional environment of the Spencer have placed it as paralic to inner sublittoral (Armentrout and others, 1983). Thin, low-grade coal is often present in the upper parts of some sections. Baker inferred in her study of sedimentary textures and structures (including detailed examination of hummocky cross-stratification), trace fossils, and body fossils that the lower, predominately sandy member of the Spencer Formation in the central area of its outcrop belt was deposited in inner shelf to littoral depths. The siltstone and mudstone of the upper member was found by Baker to have been deposited at mid- to upper-bathyal depths.

This regressive-transgressive nature of the stratigraphic sequence of the lower and upper members of the Spencer Formation in the western Tualatin Valley is similar to the regressive-transgressive sequence of the "Clark and Wilson sand" and the overlying mudstone of the Cowlitz Formation in the upper Nehalem River basin to the north (R.G. Deacon, personal communication, 1986).

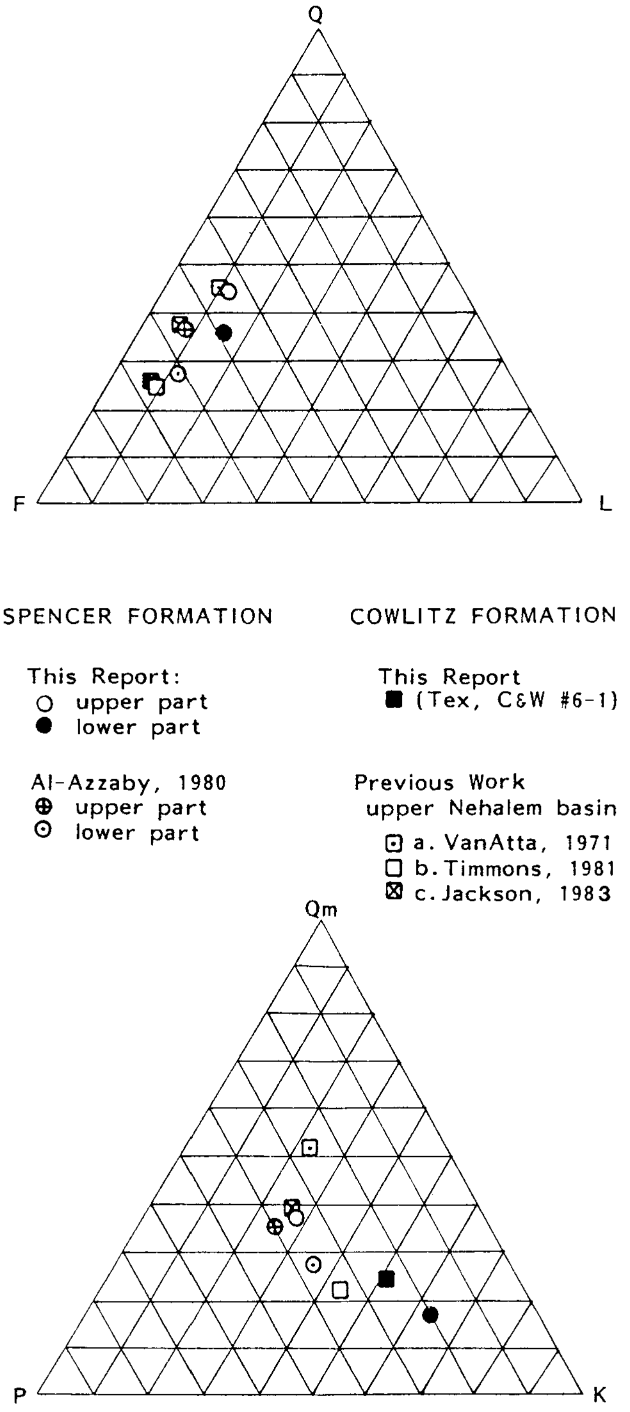


Figure 8. QFL and QmPK content, Spencer Formation, lower member sandstones.

Provenance

The sediments of the Spencer Formation probably originated in a proximal basaltic terrane (undissected magmatic arc) with influx of material fron a more distal plutonic and metamorphic terrane (continental block). The arkose of the upper part of the lower member is almost solely formed of continental block sediment (Figure 8). The sands of central and northern Oregon shelf and littoral environments today are very similar in composition, as the Columbia River (which originates in the northern Rocky Mountains) and streams draining the Oregon Coast Range have contributed most of the Holocene sediment (Cooper, 1958; Scheidegger and others, 1971).

The presence of a fair amount of quartz, good percentages (23–76) of potassium feldspar, and large amounts of mica require that a plutonic and metamorphic provenance contributed a significant amount of sediment. This is most pronounced in the upper part of the lower member of the Spencer Formation. There, thin beds of arkosic sandstone, much like the thicker "Clark and Wilson sand" in the upper Nehalem River basin, are also entirely of plutonic and metamorphic origin. Very little volcanic detritus is found in arkosic sandstone of the upper part of the lower member (Table 2).

During Narizian time, the ancestral northern Cascades of Washington and eastern Laramide plutons were the closest plutonic and metamorphic source areas that might have contributed the amount of quartz and potassium feldspar and large amounts of mica (Miller and Bradfish, 1980). The plutonic and metamorphic rocks of the Klamath Mountains to the south do not have enough potassium feldspar, nor are the metasediments and metavolcanics there rich enough in mica (Heller and Ryberg, 1983).

In the upper Nehalem River basin, eruptive centers (Goble Volcanics?) on the Narizian shelf seem to have been coeval with sedimentation in surrounding environments (Wilkinson and others, 1946; Armentrout and Suek, 1985). However, no volcanics are found intercalated with the Spencer Formation in the western Tualatin Valley borderlands area. Because of this, it is most likely that volcanic components were derived from a region lying close by, in southwestern Washington, where basalt is found intercalated with the Cowlitz Formation.

Clean arkosic sand that makes up from a few to as much as 400 m of the Spencer section in the central and northern Willamette Valley does not appear to be present in the Corvallis area (Cunderla, oral communication, 1987), although thin arkose beds are present in the area of Lorane, south of Eugene. This suggests that Spencer sands deposited in the central and northern area are related to a Narizian depocenter associated with a master stream system that would have originated in a plutonic and metamorphic terrane. Such a provenance likely would have been in the northern Rocky Mountains and/or the northern Cascade Mountains of Washington. The present-day Columbia River is just such a master stream (Whetten and others, 1969), and sands of the lower Columbia are noted as being much like Paleogene and Neogene lithic arkose sandstones of northwestern Oregon and southwestern Washington (Van Atta, 1971; Niem and Van Atta, 1973; Kadri and others, 1983).

The Spencer Formation in the western Tualatin Valley and the Cowlitz Formation in the upper Nehalem River basin appear to be equivalent in terms of age, lithofacies, and environment of deposition.

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Environmentally responsible aggregate mine operators honored at awards ceremony

Outstanding operators of six of the over 750 aggregate mines in Oregon were recognized on May 22, 1993, at the 1993 Annual Convention of the Oregon Concrete and Aggregate Producers Association (OCAPA) at the Inn of the Seventh Mountain in Bend.

The Mined Land Reclamation Program of the Oregon Department of Geology and Mineral Industries (DOGAMI) annually presents awards to mines that employ outstanding environmental operational techniques or have accomplished exemplary reclamation. Nominees for the awards are solicited from a wide variety of sources, and an awards committee of representatives from industry, government, and environmental groups selects the winners.

This year's award plaques were presented to the winners by John D. Beaulieu, Deputy State Geologist, and Frank Schnitzer, Reclamationist, of DOGAMI.

Outstanding Reclamation Award — given for an operation that goes beyond rule requirements and has an innovative approach to reclamation. The award committee voted to give this year's award to two outstanding operators.

The first is Morse Brothers, Inc., Builders Supply of Corvallis, for reclamation of a gravel pit on a farm site, producing a 50-acre pond with an island that provide wildlife habitat, flood water storage capacity, artificial wetlands, and excellent fishing and future recreation potential for the residents of Corvallis and the surrounding areas. Part of the reclamation was voluntary because it occurred on land mined before 1972 that was exempt from reclamation requirements.

Recipients of the 1993 reclamation awards

Outstanding Reclamation Award
Morse Brothers, Inc., Builder's Supply, Corvallis
Cascade Pumice, Laidlaw Butte, Tumalo
Outstanding Operator Award
Cobb Rock, Inc., Beaverton Quarry, Beaverton
Small Operator Reclamation Award
S-C Paving Co., Burdick Pit, Tillamook
Good Neighbor Award
Morse Brothers, Inc., Builders Supply, Corvallis
Johnson Construction Co., Crusher Quarry, Seaside
Agency Award
Oregon State Highway Division, Region 4, Annie Creek, Klamath County

The second recipient is Cascade Pumice, a pumice mining operation at Laidlaw Butte near Tumalo. Cascade Pumice controls approximately 720 acres at this location. Of the 250 acres that have already been reclaimed, 120 acres were done voluntarily. Cascade Pumice restores mined land to approximate original contours. During 1992, an area of 60 acres was backfilled and topsoiled, and 90 acres were seeded. In a location that is surrounded by residences, Cascade Pumice waters mine areas daily during the dry season to support both seeding and dust-control, constructs visual berms to reduce impact on nearby residences, and has left a larger setback than required by law.

Outstanding Operator Award — given to operators who have done an outstanding job of mine development and/or daily operation, including preventing impacts on water quality or other natural resources, having no significant enforcement actions in the last ten years, going beyond rule requirements, using innovative techniques that improve quality of operation, and operating in such a way as to reduce reclamation liability.

This year's award was given to Cobb Rock, Inc., for the Beaverton Quarry on Cooper Mountain near Beaverton. Cobb Rock has maintained highwall benching during active mining and periods of inactivity, thereby improving slope stability, providing a safer work place for employees, and reducing reclamation requirements to a minimum. Cobb Rock has received safety awards on many levels, the latest being the Mine Safety and Health Administration's Certificate of Achievement for 1991—and will undoubtedly receive it again, because it had no lost time due to accidents or injuries in 1992.

Small Operator Reclamation Award — given for the same criteria as for Outstanding Operator Award, only for smaller scale operations. It was awarded this year to S-C Paving Company, a sand and gravel operation at the Burdick Pit on a dairy farm along the Trask River several miles east of Tillamook.

The current operator took over in 1985, facing the immediate task of removing an illegal solid waste landfill left by the previous operator. After the site was cleaned up, the original four acres were backfilled, and new topsoil was added. Four to five additional acres were put into operation, and a two-acre pond was created. Alders have been established, and part of the area may be used for fish rearing. When the mining is completed, the remainder of the site will be backfilled to original grade.

Good Neighbor Award — given for unselfishly working with neighbors and the community in a spirit of cooperation to reflect a positive image of the mining industry. The awards committee chose to present this award again to two operators.

The first winner, Morse Brothers Builder's Supply gravel operation near Corvallis, received the Award because, in addition to award-winning reclamation activities, the company helps neighboring farmers by sharing equipment with them—the action of a truly good neighbor.

The second awardee is the Johnson Construction Co. Crusher Quarry of Seaside. The company voluntarily provides public access to the Necanicum River in an area of high use by maintaining a boat ramp. The company also participates in the Salmon and Trout Enhancement Program for the benefit of sport anglers and the local community and cooperates with local fisheries biologists to develop land use practices that protect aquatic resources.

Agency Award — given separately because reclamation is often underwritten as part of an associated highway construction project, and government sites are exempt from bonding requirements.

The award was given this year to the Oregon State Highway Division, Region 4, at Annie Creek in Klamath County, where an abandoned gravel pit with dangerously steep walls was turned into a snow play area, while at the same time it was producing fill for a nearby road construction project—in the middle of a summer camping and winter ski area. ☐

Glaciation in the central Coast Range of Oregon

by Ewart M. Baldwin, Department of Geological Sciences, University of Oregon, Eugene, Oregon 97403

INTRODUCTION

Glacial cirques are present along the northern edges of several of the prominent, sill-capped peaks in the central Coast Range of Oregon (Figure 1). These were first observed by the writer when he was mapping in the Dallas and Valsetz quadrangles[1] (Baldwin, 1947). In 1945, a disastrous forest fire had swept northward from the Valsetz area, denuding most of the upper Boulder Creek and Laurel Mountain area. Salvage logging had removed many of the remaining blackened trees, so that the area was quite bare and cirques were easy to see. Today, the area is covered by a young forest, which, while it is favorable for the economic future of Oregon, hides much of the geologic evidence. Later mapping in the Spirit Mountain (now Grand Ronde) quadrangle (Baldwin and Roberts, 1952) revealed evidence of glaciation on the north edge of Saddleback Mountain in the extreme south end of the quadrangle. Saddleback Mountain extends across the Salmon River into the southeastern corner of the Hebo quadrangle.

The glacial cirques are nearly all carved in late Oligocene-early Miocene sills, although some of them may have been eroded to the middle Eocene sedimentary rocks below. Stream flow at the extreme headwaters of the streams is not sufficient to excavate the rounded cirques, nor is there the V-shaped valley that running water would produce. Some ponds and small lakes may be the result of landsliding, but the cirques under discussion are in solid intrusive granophyric gabbro seldom given to sliding. If a block did slide, the debris should contain largely blocks of the gabbro, whereas debris down slope differs in size and distribution of rock types. It is true that boulders of gabbro a foot or two in diameter are common at the base of the steeper slopes, but these likely were pushed or carried by ice to a lower level. Gravity might cause some of these boulders to float, even if there were no glaciation, but such boulders make up a small part of the unconsolidated debris down slope.

Marys Peak is 4,097 ft in altitude, the highest peak in the Coast Range. Laurel Mountain is more than 3,700 ft high, and Mount Hebo reaches 3,153 ft. None of these altitudes compare with the general level of glaciation in the Cascade Range to the east. However, during the Wisconsin stage of the Pleistocene glaciation, Puget Sound was filled with a thick sheet of ice as far south as Tenino near Olympia, and alpine glaciation was widespread in the Olympic Peninsula and in the Cascade Range of Washington and Oregon. There should have been a regional chill affecting other parts of the Northwest such as the Coast Range of Oregon. Maximum glaciation brought lowering of the sea by as much as 400 ft, and since altitude is calculated from sea level, all the peaks were 400 ft higher during maximum cooling, which might help in explaining the presence of glaciers.

The Oregon Coast Range is an area of great precipitation. Valsetz, when it existed as a weather station, frequently recorded 120-150 in. of precipitation per year. When the writer was working in the area, frequent winter snow storms would bring several feet of snow, only to be followed by warmer rain sweeping in off the ocean, melting much of the snow, and causing floods. This might be repeated a time or two during a winter. Snow even now accumulates on the northern edges of the peaks and lasts into June. If a regional chill caused the greater part of the precipitation to fall as snow, it could and probably would accumulate in great enough depth to last throughout the year and gradually accumulate as glacial ice. The precipitation is more than adequate if climatic conditions favored the buildup of ice. The cirques are on the north-northeastern edges of the peaks where the ice would be shielded from much of the sun's heat. It is possible that unusual periods of cloudiness also helped to protect the buildup of ice.

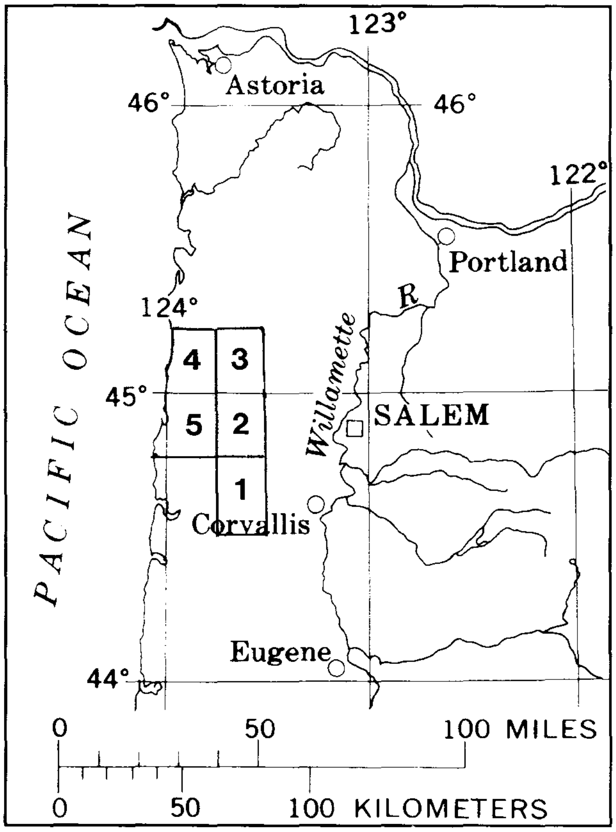

Figure 1. Northwestern Oregon map showing location of areas discussed in text. Numbers identify quadrangles: 1 = Marys Peak; 2 = Valsetz; 3 = Grand Ronde; 4 = Hebo; 5 = Euchre Mountain.

MARYS PEAK

Marys Peak (Figure 2) is the highest peak in the Coast Range and should have some of the better developed glacial features. Two small basins on the northeastern edge are shaped like cirques. The heads of several of the more northerly flowing streams are not well rounded, yet snow and ice should have accumulated. Owing to the steep gradient, the ice may have slipped down the steep slope only to melt at the base. The quadrangle was mapped by Baldwin (1955), who mapped three areas of unconsolidated material on the lower slopes and suggested that they were landslides. However,

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[1] *Unless specified, quadrangle names mentioned in this paper refer to 15-minute quadrangles. For easier reference to current map indexes, the following lists the 7½-minute quadrangles into which the 15-minute quadrangles have been divided. Beginning at the northwest corner, clockwise:*

Euchre Mountain: Devils Lake, Stott Mountain, Euchre Mountain, Mowrey Landing.

Grand Ronde: Niagara Creek, Springer Mountain, Grand Ronde, Midway.

Hebo: Nestucca Bay, Hebo, Dolph, Neskowin.

Marys Peak: Nortons, Summit, Marys Peak, Harlan.

Valsetz: Warnicke Creek, Laurel Mountain, Fanno Ridge, Valsetz. —*ed.*

blocks of sill that would have resulted when pieces of the rim broke off were not present. Scattered rounded boulders were present throughout the material. Sills in the Coast Range are quite stable, and at no place in the study area could the rounded heads of streams be attributed to sliding of sizable masses of gabbro. The writer now has assigned the unconsolidated material to glacial delivery and not to landslides.

LAUREL MOUNTAIN

Laurel Mountain is in the northern part of the Valsetz quadrangle (Figure 3). It is the slightly upturned edge of a large sill that extends southward to Fanno Ridge overlooking Valsetz and westward from the vicinity of Riley Peak into the Euchre Mountain quadrangle. In many places, the sill is 400 or 500 ft thick but even thicker at Fanno Ridge. The area is accessible by private road that extends westward from Black Rock on the Little Luckiamute River and utilizes an abandoned railroad grade past Riley Peak to Boulder Camp, an abandoned logging camp. A road continues through Boulder Pass and on down Mill Creek to Buell in the broad Yamhill River valley.

One of the best developed cirques lies east of Boulder Camp, in the SE¼ sec. 19, R. 7 W., T. 7 S. This is the only cirque where some relatively well-developed lateral moraines were seen. The road down Mill Creek cuts through the lower end of one of the lateral moraines at about one mile from Boulder Pass. The moraine on the northwestern edge of the cirque is better developed. The presence of lateral moraines points to the movement of glacial ice. Since the cirque basins are short, seldom reaching half a mile in length, the ice should have been pushed over the edge, tumbled down the steeper parts of the stream gradient, and melted at the foot of the slope. One would expect to find glacial morainal material at the lower levels. Although boulders of gabbro a foot or two in diameter are common, appreciable morainal material at the lower levels is present only on the lower slopes of Marys Peak.

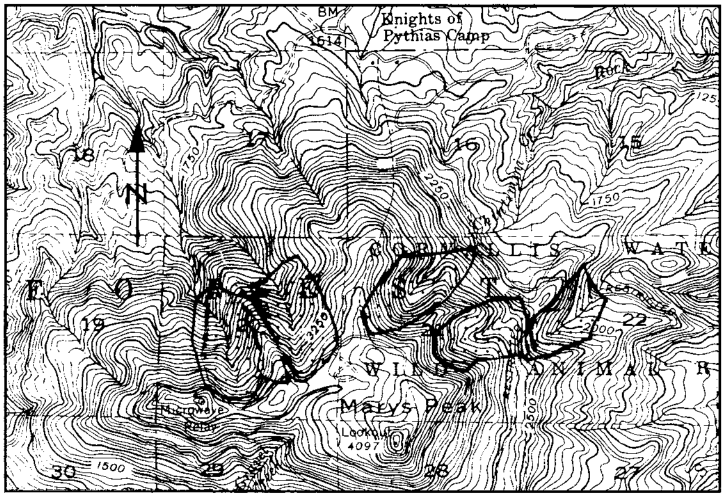

Figure 2. Cirques (outlined) in SE corner of the Marys Peak quadrangle.

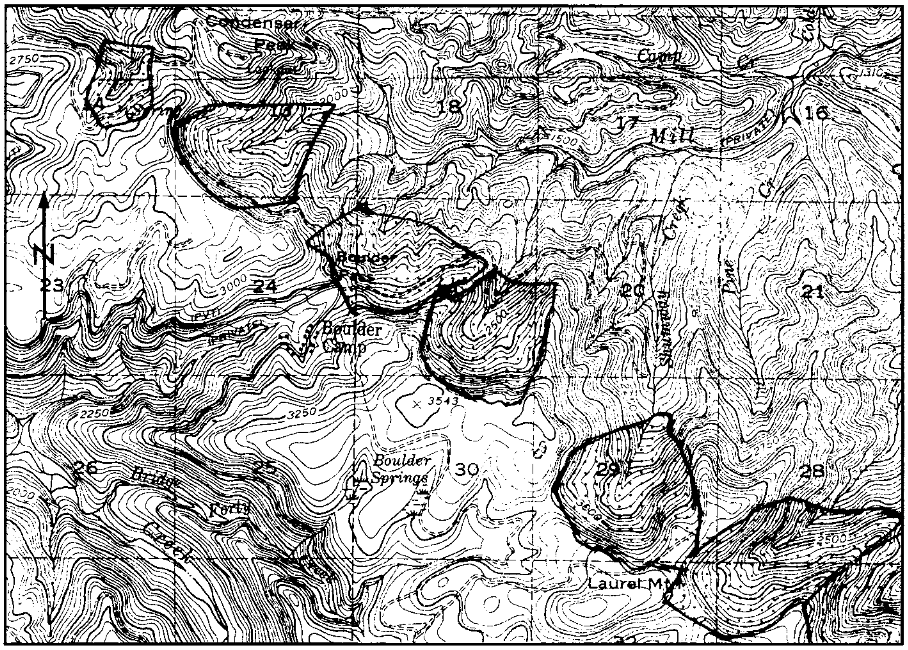

Figure 3. Cirques (outlined) in north-central part of the Valsetz quadrangle.

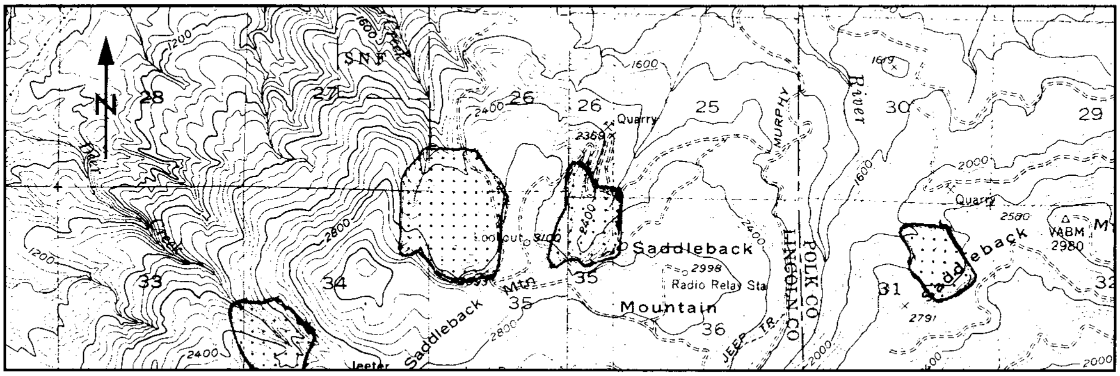

Figure 4. Cirques (outlined) in southernmost part of the Grand Ronde and Hebo quadrangles.

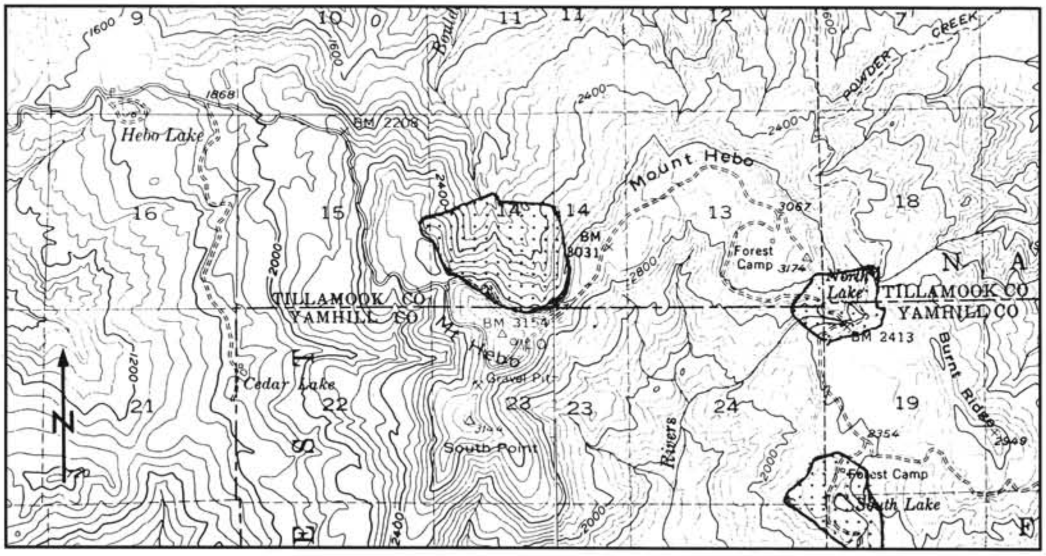

Figure 5. Cirques (outlined) at Mount Hebo in the northern part of the Hebo and Grand Ronde quadrangles.

Figure 6. Air photo of North Lake, Grand Ronde quadrangle Photo by William Eaton.

SADDLEBACK MOUNTAIN

Saddleback Mountain is in the southernmost part of the Grand Ronde (formerly Spirit Mountain) quadrangle (Figure 4), which was mapped by Baldwin and Roberts (1952). The sill continues westward across the headwaters of the Salmon River into the southeast corner of the Hebo 15-minute quadrangle, which was mapped by Snavely and Vokes (1949). The Dolph 7½-minute quadrangle, which covers the southeastern quarter of the Hebo 15-minute quadrangle, has been mapped by Snavely and others (1991). Several cirques are present along the northern edge of this intrusive body, but one of the most evident is in the southeast corner of the Hebo quadrangle. A circular basin is carved in the sill, and hummocky material extends northward. It contains several ponds and marshes. The writer does not consider this a landslide, for, as noted, the sills are rather stable areas and the hummocky topography below appears to be glacial in origin. Many large blocks of sill that would result from sliding are not present in the material below the rim.

MOUNT HEBO

Mount Hebo is in both the Hebo and Grand Ronde 15-minute quadrangles (Figure 5). The mountain is capped by a gabbro sill. The northern side drops off steeply toward the Nestucca River valley. The head of Boulder Creek has a basin that was probably occupied by ice and may have been largely shaped by ice. To the east, several small basins are present at the head of tributaries of Powder Creek and may be in part shaped by ice.

There are several lakes on Mount Hebo. North Lake (Figure 6) and South Lake in the Grand Ronde quadrangle appear to be excavated in solid sill and appear to be of glacial origin. South Lake is longer than it is wide and appears to be dammed by glacial material. Both North and South Lakes occupy positions sheltered from the sun, where snow could accumulate.

On the southwestern side of Mount Hebo, below the sill, are two lakes, Hebo and Cedar Lakes. Neither of these seem to be in ice-sculptured sill material, and they could be landslide lakes. Both lakes are on the sunny side of the mountain and would get what warmth the sun could give. Unless there was unusual buildup of snow or unusual cloudiness, it is difficult to make a case for a solely glacial origin of Hebo or Cedar Lakes.

CONCLUSION

Small glaciers must have been present in the central part of the Oregon Coast Range during stages of late Pleistocene glaciation. The size and distribution may be debatable. This discussion does not exhaust the study of possible glaciation, and it is hoped that further attention will be given to this interesting subject.

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The Chemult, Oregon, fireball of July 1992

by Richard N. Pugh, Science Chair, Cleveland High School, Portland, Oregon, and Scott McAfee, Student Research Assistant, Governor's Office of Emergency Services, Bay Area Regional Earthquake Preparedness Project, State of California

The last major fireball of 1992 over Oregon (see cover photo) occurred on July 27 at 1:07 a.m. PDT (8:07 GMT). A report on it has been published in the *Bulletin of the Global Volcanism Network*, v. 17, no. 9 (September 30, 1992), p. 18.

The fireball was reported by 20 observers. The area in which it was observed extended northeast to Umatilla, south to Klamath Falls, and west to the Rogue River. The object entered the atmosphere over the Fort Rock basin, Lake County, with the end point of its trajectory near Chemult in Klamath County. Most people saw the fireball coming down at a very steep angle.

The duration of the fireball was up to seven seconds. It was brighter than a full moon, lighting up an area of 2,500 km^2 like bright daylight. Its apparent size was two to four times the diameter of a full moon, and its shape was round. Reported colors ranged from blue-green-white to yellow-red-orange. Most observers reported a long blue-green-white tail. Many reported "sparks," and several reported flaring of the fireball. However, there were no reports of fragmentation.

A 10-second sonic boom was heard at Willamette Pass (40 km northwest of Chemult) and Crater Lake (40 km southwest of Chemult). A short, heavy sonic boom was heard 45 km northwest of Paisley, Lake County. These reports of sonic booms indicate that meteorites were produced. However, the low number of observers, the remoteness of the probable fall area, and the nature of the terrain make the chances of recovery very slim.

Everyone in the area of Lake and Klamath Counties who saw or heard this event, should contact Dick Pugh, Cleveland High School, 3400 SE 26th Avenue, Portland, OR 97202, phone (503) 280-5120. ☐

Jerry Gray retires from DOGAMI

Jerry J. Gray retired from the Oregon Department of Geology and Mineral Industries (DOGAMI) on June 30, 1993. A native of Hesperia, Michigan, and graduate of Michigan State University, Gray joined DOGAMI as an independent contractor in 1972 to establish the Mined Land Reclamation Program. He became a permanent staff member in 1974. After working with the Mined Land Reclamation Program until 1976, he continued as an economic mining geologist, with emphasis on conducting and supervising studies related to economic and statistical mineral economics, mineral statistics, mining methods, mining law, and prospecting.

Jerry J. Gray

Prior to working with DOGAMI, Gray was employed by the U.S. Bureau of Mines in Albany, Oregon, and Anaconda Company in Butte, Montana. He also served in the U.S. Army, working as a geologist in the Geochemical Section of the Signal Corps Engineering Laboratories at Fort Monmouth, New Jersey.

During his years with DOGAMI, Gray wrote numerous articles and field trip guides on mining and mineral resources for the *Ore Bin* and *Oregon Geology*. He also conducted a variety of studies related to economic geology and authored many reports including those on mineral and/or rock resources in Coos, Curry, Umatilla, Benton, Polk, Marion, Yamhill, Linn, Clackamas, Columbia, Multnomah, and Washington Counties. He conducted a study of the geology and mineral resources of 18 Wilderness Study Areas in Harney and Malheur Counties that identified several previously unrecognized areas with gold potential. He was senior author of papers on the mineral potential of the Fall Creek mining district, bench testing of silica sand, and the mineral assessment of the southwest quarter of the Stephenson Mountain 30- by 60-minute quadrangle. He was senior author of the mineral resources map of offshore Oregon and coauthor of the geologic map of offshore Oregon and a bibliography of offshore Oregon. He also authored a Special Paper on bentonite in Oregon.

In recent years, Gray prepared and later updated a computerized data base of mineral information for Oregon by county (MILOC), which contains location, commodity, and other data for an estimated 7,899 mineral occurrences, prospects, and mines. The entries are located with latitude, longitude, and UTM coordinates, so that the data base can be used with geographic information systems. This data base was originally released as Open-File Report O-92-2 and will be released in late summer in updated form as Open-File Report O-93-8.

Jerry has become widely known to industry geologists, amateur rock hounds, and recreational gold miners for his wealth of knowledge about the mineral resources of Oregon. In his retirement he plans to continue to explore the mineral resources of Oregon and be active with the mining groups he has worked with over the years. He and his wife Cecelia also plan to travel. ☐

Oregon State Geologist to head Association of American State Geologists

Donald A. Hull, State Geologist for Oregon and Director of the Oregon Department of Geology and Mineral Industries since 1979, will become President of the Association of American State Geologists (AASG) on June 30, 1993. He will succeed Morris Leighton, State Geologist of Illinois.

According to Dr. Hull, "This year, AASG activities will emphasize implementation of the National Geologic Mapping Act and continued cooperative relations with Federal agencies." His term lasts for one year.

AASG was organized in 1908. Its members represent the state geologic surveys in all 50 states and Puerto Rico. AASG members meet annually to exchange information, discuss issues of common interest, develop new initiatives, and consider other topics related to state geologic survey operation and budgets. The leaders meet in Washington, D.C., to confer with officials of Federal agencies, members of Congress, and staff members of Congressional committees who have responsibility for matters relating to geology, energy and mineral resources, natural hazards, and the environment.

Although responsibilities of various state geological surveys differ from state to state, depending on the enabling legislation and traditions under which each survey developed, almost all state surveys function as a basic geologic information source for the public and for their state government's executive, legislative, and judicial branches. Some surveys, including Oregon's, also have regulatory responsibilities for oil, gas, and geothermal exploration and development, and land reclamation during and after mining. They also prepare geologic maps showing distribution of rock formations, specialized maps that are useful to environmental management such as those pointing out areas of potential hazards, or mineral resource maps identifying locations of potentially economic industrial or metallic mineral deposits. State surveys, including Oregon, also maintain repositories of subsurface rock cores and samples. □

DOGAMI geologic-geochemical laboratory closes

Because of curtailment of funds, the Oregon Legislature directed the Oregon Department of Geology and Mineral Industries (DOGAMI) geologic-geochemical laboratory to close its doors on June 30, 1993. Also lost to DOGAMI and the citizens of Oregon were the skilled services of its two geochemists, Gary Baxter and Charles "Chuck" Radasch.

Baxter came to DOGAMI in 1973 after working with Hyster Company of Portland as a materials engineer and after working with Aerojet-General Corporation of Sacramento, California, as a laboratory technician. During Baxter's years with DOGAMI, the laboratory broadened its focus from being an assaying facility for metallic-mineral ores to handling systematic physical testing of samples for evaluation of the quality of industrial mineral deposits and providing needed support to DOGAMI geologic mapping projects.

Radasch joined DOGAMI in 1987 after working as a technician and chemist for Teledyne Wah Chang, Albany, and as a research technician for Battelle Northwest Laboratories, Richland, Washington. During his tenure with DOGAMI, Radasch also helped with many other projects, including organization and maintenance of the sample collection. □

Wampler joins DOGAMI's MLR staff

The Mined Land Reclamation (MLR) Program of the Oregon Department of Geology and Mineral Industries (DOGAMI) has increased its staff by the addition of Peter Wampler, who has joined the program as an environmental specialist.

Wampler is currently a student at Oregon State University, where he is completing a Master of Science degree in geology. His studies also include a minor in geography, concentrating on geographic information systems. He received a Bachelor of Science degree in geology from Western Washington University in 1987. His thesis

(Continued on next page)

CORRECTION

FOR *OREGON GEOLOGY*, VOLUME 55, NUMBER 3

A very unfortunate error occurred on pages 63 and 64 of the May 1993 issue, in the article "Geology near Blue Lake County Park, eastern Multnomah County, Oregon," by James N. Bet and Malia L. Rosner: The Figures 6 and 7 were inadvertently switched, so that page 63 shows Figure 7 (without a caption), and page 64 shows Figure 6 with the caption for Figure 7.

We deeply regret this mishap and hope to correct the situation at least somewhat with this notice and the following instructions:

Please use the reprinted captions below for your copy of *Oregon Geology*: Cut them along the lines around the text and affix the caption for Figure 7 below the photo at the bottom of page 63 and the caption for Figure 6 in such a way that it covers the caption that says "Figure 7" under the photo at the top of page 64.

Figure 6. Closeup of Pleistocene gravel unit 2 exposed during construction activities along NE Sandy Boulevard (see Figure 2 for location). Matrix-supported clasts are typical of the unit within the study area.

Figure 7. Unconformable contacts exposed during construction activities along NE Sandy Boulevard (see Figure 2 for location). Lower contact is the angular unconformity between Pleistocene gravel unit 2 and the underlying Troutdale Formation. Unit designations are the same as in Figure 5.

work is the culmination of several summers of mapping the geology and alteration surrounding the Zortman Mine in east-central Montana.

Prior to graduate school, Wampler worked as an exploration geologist in Nevada, Idaho, and Montana. In Nevada, he was involved in grass-roots exploration for sediment-hosted gold deposits, and in Salmon, Idaho, he performed mapping and drill-core logging to evaluate an advanced gold prospect along the west flanks of the Beaverhead Mountains.

Wampler was born near Richland, Washington, and spent the greater part of his early life in Bellevue, Washington. He lived in Italy for one year while his father worked for the U.S. Army Corps of Engineers in Saudi Arabia. He is an avid mineral collector and enjoys hiking, fishing, gold panning, gardening, and just about any other activity that takes place outdoors. ☐

BLM offers new version of *Archaeology of Oregon*

Until recently, archaeological finds on the Oregon coast showed only 3,000 years of human inhabitation. An archaeological project in the 1980s at Lake Tahkenitch unearthed evidence of an 8,000-year-old campsite. These finds and several more dramatic discoveries are included in the latest version of *Archaeology of Oregon*, a book that was first published in 1984 and whose latest edition went out of print in 1992.

Archaeology of Oregon, third revised edition, 1993, was written by C. Melvin Aikens, professor at the University of Oregon, and published by the U.S. Bureau of Land Management (BLM), Oregon State Office. It provides a complete overview of the prehistory of Oregon and incorporates the latest findings of archaeological importance in Oregon—some of them published here for the first time.

An introductory chapter explains what archaeology is about in general and what its study objects are in the Pacific Northwest; a concluding chapter places the Oregon scene in perspective in the North-American context. Between them, five chapters treat the archaeological record of the original Oregonians according to five regions of Oregon that remind (not surprisingly) of the geomorphic divisions of the state.

The book describes tools and prehistoric weapons used by Native Americans of the Oregon country and shows how individuals and groups adapted to the various environments.

The 302-page, richly illustrated book, whose plasticized cover will stand some field-trip use, is both an introduction and a reference tool. It is a bargain for $9.50 at The Nature of Oregon Information Center of the Oregon Department of Geology and Mineral Industries in the State Office Building in Portland (see page 96 for address and other ordering information). —*From BLM news release*

GSA annual meeting offers education

In conjunction with its annual meeting, October 25-28, 11993, in Boston, the Geological Society of America (GSA) offers twelve continuing education courses, which are held immediately before or after the annual meeting. Participation in these does not require registration for the annual meeting. The following list is restricted to titles, dates, and enrollment limits of the classes:

1. GIS and the geosciences. October 23; 100.
2. Urban geology: Foundation for inner city health. October 23; 25.
3. Asia: A continent built and assembled over the past 500 million years. October 23-24; 50.
4. Contaminant hydrogeology: Practical monitoring, protection, and cleanup. October 23-24; 40.
5. Fracture mechanics of rock. October 23-24; 50.
6. Alternative pedagogies in geological sciences: A workshop. October 24; 40.
7. Application of sedimentological information to hydrogeological problems. October 24, 50.
8. Computer mapping at your desk that really works. October 24; 30.
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The address for further information is GSA Annual Meeting, P.O. Box 9140, Boulder, CO 80301-9140. Deadline for preregistration to the meeting is September 24. —*GSA news release*

USBM has state mineral summaries now available by fax

The U.S. Bureau of Mines (USBM) now offers information through an easy-to-use automated fax response system. The MINES FaxBack service allows callers to retrieve information and order publications for immediate delivery to their fax machines. MINES FaxBack works from any Group III-compatible fax machine that is equipped with a touch-tone telephone (either a built-in handset with touch-tone capability or a separate touch-tone telephone plugged into the fax machine's phone jack). After calling MINES FaxBack, the requester is guided by a series of voice messages that assist the caller in ordering the desired documents. The caller pays for the phone call that also includes the time needed to deliver the requested document to the caller's fax machine.

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The state mineral summary for Oregon is Document 984193 and consists of four pages. The procedure is summarized in the following directions:

1. Use the touch-tone handset attached to your fax machine or connect a touch-tone telephone to the fax machine's telephone jack.
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4. After completing your selection, press the start button on your fax machine. —*USBM news release*

Dear *Oregon Geology* subscriber,

The Oregon Department of Geology and Mineral Industries is conducting a survey of its readers. We want to know more about them and what they want from *Oregon Geology* as we make decisions about how to serve them best in the future. Please check the most appropriate responses in this survey, and do not put your name on the survey. Return it to **Publications Manager, Oregon Department of Geology and Mineral Industries, Ste. 965, 800 NE Oregon St. #28, Portland, OR 97232**, as soon as possible. We'll publish the results in an upcoming issue of *Oregon Geology*. Please use one survey form per respondent.

Thank you for your help and interest.

1. What is your gender? Check one category.

female___
male___

2. What is your age? Check one category.

under 18___
18-34___
35-45___
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65 or older___

3. What is the highest level of education you have achieved? Check one category.

attended high school___
high school graduate___
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college graduate___
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engineer___
educator___
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natural resource agency employee___
legislator___
planner___
politician___
work in forestry industry ___
work in health care field___
scientist___
own a business___
work in tourism industry___
work in sales___
work in computers or software___
farmer___
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mine developer, owner, or operator___
work in sand, gravel, or crushed rock industry___
self-employed___
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other occupation not mentioned (specify)__________
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$20,000 to $29,999___
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hiking___
hunting___
fishing___
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studying history___
archaeology___
astronomy___
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reading__
watching TV___
member of environmental group___
other (specify)______________

7. Why do you subscribe to *Oregon Geology*? Check **all** categories that apply.

interested in geology___
want to keep up with current activities in geology___
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interested in news related to geologic hazards___
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somewhat satisfied___
neither satisfied nor dissatisfied___
somewhat dissatisfied___
dissatisfied___

10. If you are dissatisfied or somewhat dissatisfied, please explain briefly why.

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each month___ every two months___ every three months___ once a year___

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If yes, what annual subscription rate would you be willing to pay? Check one response.

$9___ $10___ $11___ $12___ $13___ $14___ $15___ $16___ $17___ $18___

13. We are considering adding advertising to *Oregon Geology* to help cover the cost of production. Mark the response that indicates your feelings about this.

good idea___ doesn't matter to me___ bad idea___

14. Oregon is a beautiful state, and color photographs would show more of its beauty and make it easier to understand the geology. Would you be willing to pay more per year for an annual subscription in order to have color photographs in *Oregon Geology*? yes___ no___ depends___

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If yes or depends, mark **all** other topics that interest you.

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wildlife___
paleontology___
biology___
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agriculture___
history___
archaeology___
geography___
wetlands___
conservation issues___
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Oregon coast___
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weather___
climate___
outdoor recreation___
other (specify)________________

16. Would you be interested in expanding the focus of *Oregon Geology* to the entire Pacific Northwest? Mark one category.

yes___ no___

17. Additional brief comments related to *Oregon Geology*:

Again, thank you for your help!

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