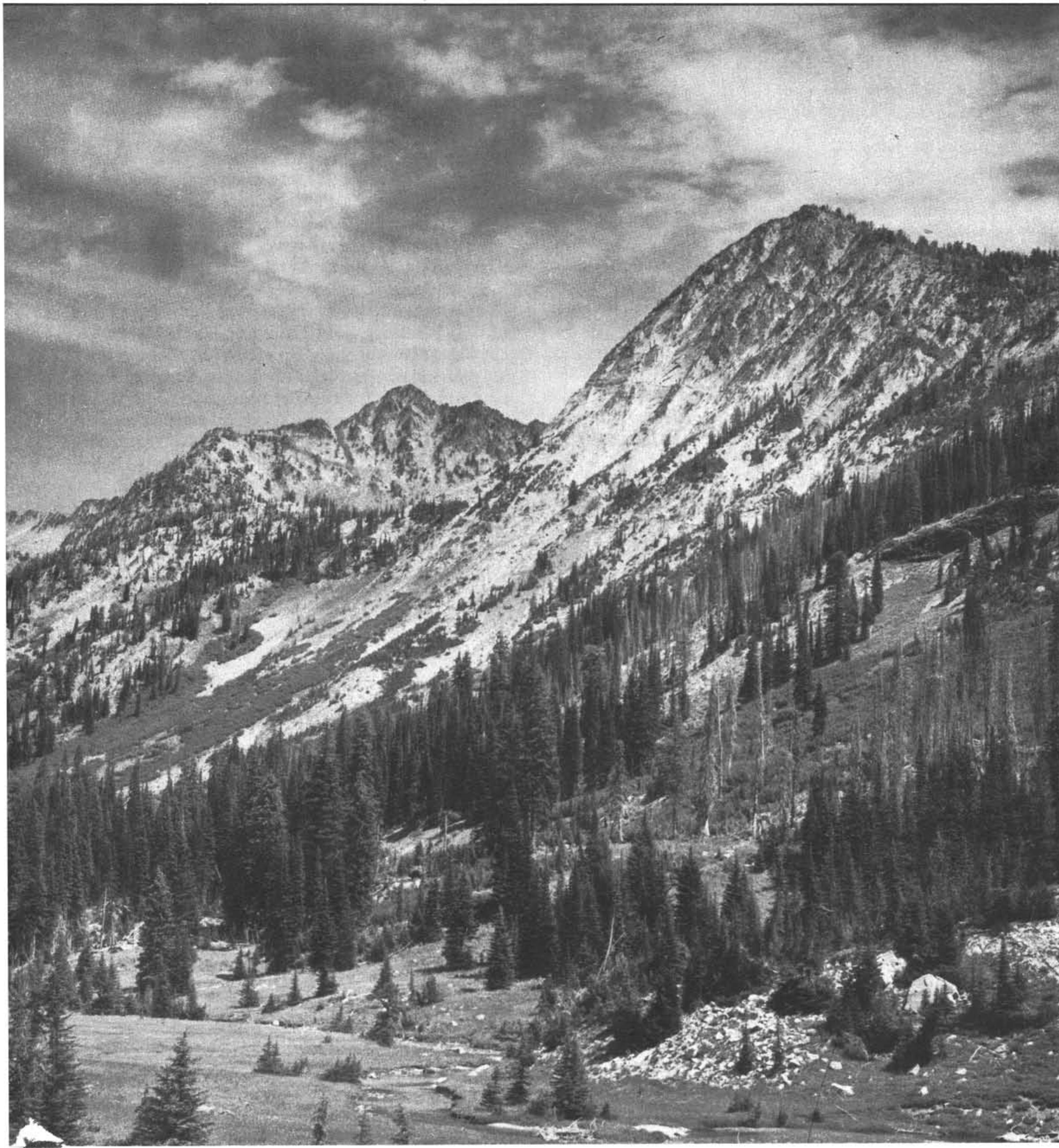
OREGON GEOLOGY

formerly THE ORE BIN

published by the Oregon Department of Geology and Mineral Industries

VOLUME 42, NUMBER 1 JANUARY 1980



OREGON GEOLOGY

(ISSN 0164-3304)

VOLUME 42, NUMBER 1 JANUARY 1980

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

Main Office: 1069 State Office Building, Portland 97201, phone (503) 229-5580.

Baker Field Office: 2033 First Street, Baker 97814, phone (503) 523-3133.
Howard C. Brooks, Resident Geologist

Grants Pass Field Office: 312 S.E. "H" Street, Grants Pass 97526, phone (503) 476-2496.
Len Ramp, Resident Geologist

Mined Land Reclamation Program: 1129 S.E. Santiam Road, Albany 97321, phone (503) 967-2039.
Standley L. Ausmus, Supervisor

Subscription rates: 1 year, $4.00; 3 years, $10.00. Single issues, $.40 at counter, $.50 mailed.
Available back issues of *The Ore Bin:* $.25 at counter, $.50 mailed.

Address subscription orders, renewals, and changes of address to *Oregon Geology,* 1069 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,* 1069 State Office Building, Portland, OR 97201.

COVER PHOTO

The Granite Mountains, located on the southern end of the Wallowa Mountains in northeastern Oregon. These mountains are part of the Upper Jurassic-Lower Cretaceous Wallowa Batholith. (Photo courtesy Oregon State Highway Department)

Mineral quadrangle map now available

The *Geologic Map of the Oregon part of the Mineral quadrangle*, by H.C. Brooks, was released by the Oregon Department of Geology and Mineral Industries last December. It is GMS-12, map no. 12 in DOGAMI's Geologic Map Series.

The map is on a scale of 1:62,500 (about 1 inch = 1 mile) and covers the Oregon side of the Snake River Canyon between Powder River on the north and Hibbard Creek on the south. Printed on a topographic base, the black-and-white map identifies 12 different rock units, distinguishing some of them by patterns of differing texture.

Approximately half of the map area is underlain by metamorphosed late Paleozoic and Mesozoic marine sedimentary and volcanic rocks cut by small granodiorite plutons of late Jurassic age; the other half is underlain by continental volcanic and sedimentary rocks of Cenozoic age.

GMS-12 may be purchased from DOGAMI's Portland and Baker offices. Mailed orders should be addressed to the Oregon Department of Geology and Mineral Industries, 1069 State Office Building, Portland, OR 97201, or 2033 First Street, Baker, OR 97814. The price is $2.00 per map. Payment must accompany orders of less than $20.00. □

CONTENTS

NEXT MONTH

Geologic Field Trip Guide through the North-Central Klamath Mountains, by M.A. Kays and M.L. Ferns

Forecasting rock material demand: an overview of several techniques and detailed review of two

by Jerry J. Gray, Economic Geologist, Oregon Department of Geology and Mineral Industries

Managing rock resources can be reduced in its simplest form to: (1) a matching of supply with demand, and (2) a rational development of policies that conform to the constraints defined by supply and demand.

In Oregon, rock resource assessments are being developed by the Oregon Department of Geology and Mineral Industries on a regional basis to conform to market areas. These assessments provide needed information on supply. Demand is modeled in the Department's Special Paper 5, *Analysis and Forecasts of the Demand for Rock Materials in Oregon.*

The following article compares and contrasts various statistical methods for forecasting demand for rock resources. The applicability of each method is a function of available data, available funding, and desired resolution.

The article digresses slightly from the mainstream of geology but demonstrates very conclusively the practical application of geologic inventory data in addressing the needs of society.

—J.D.B.

INTRODUCTION

Society must provide for the future availability of needed resources. Through ORS 215.055 and LCDC Goal 5, Topic B, the State of Oregon formally directs counties and cities to take into consideration lands that are, can be, or should be utilized for material resources or for the processing of mineral aggregates in the adoption of any land use ordinance. LCDC Goal 9, Guideline A-2 states: "The economic development projections and the comprehensive plan which is drawn from the projections should take into account the availability of the necessary natural resources to support the expanded industrial development and associated populations. The plan should also take into account the social, environmental, energy, and economic impacts upon the resident population."

To do this, counties and other planning units need to know what their present mineral inventories are, what inventories they will need in the future, and where those inventories will be found. Such resource planning must take place before the mineral resource land base has been preempted by zoning for other uses.

The Oregon Department of Geology and Mineral Industries recently published Special Paper 5, *Analysis and Forecasts of the Demand for Rock Materials in Oregon*, by Friedman and others (1979). This report is the culmination of many years of Departmental study of rock material demand. Special Paper 5 is technically written for a limited audience; its application and the mineral production data contained within, however, concern a much broader audience. With the aim of making the report and data more readily usable in any given situation, the present paper reviews the forecast modeling spectrum from the very simple to beyond that presented in Special Paper 5, with emphasis on two particular types of modeling, so that anyone involved in forecasting can choose the type of modeling most appropriate for his needs. It also presents a cookbook approach to forecasting, relying mainly on Department studies by Schlicker and others (1978), Gray and others (1978), and Friedman and others (1979, the Special Paper mentioned above). Readers wishing to study the theory behind the forecasting techniques should consult the references listed at the end of this paper.

DATA BASE

Data for mineral economic marketing or forecasting studies are collected by the U.S. Bureau of Mines in its annual canvass of mineral producers and made available in various Bureau of Mines publications. In Special Paper 5, the Oregon Department of Geology and Mineral Industries published 15 tables (Tables 31 to 46) of Bureau of Mines statistics for Oregon's 13 marketing units, the State as a whole, and that production that could not be assigned to a single county (mainly U.S. Forest Service stone output). The statistics include tonnage and value statistics by year from 1940 through 1976 for sand and gravel and stone (including any cinder used for road metal) and for the two commodities combined. These 15 tables provide a starting point for demand analysis and forecasting for any area in the State. Other economic statistics can be obtained from the Oregon Employment Division, Research and Statistics Section; the Oregon Department of Transportation, Policy and Program Development Section; the Center for Population Research and Census, Portland State University; the U.S. Department of the Interior, Bonneville Power Administration; and the Oregon Department of Revenue.

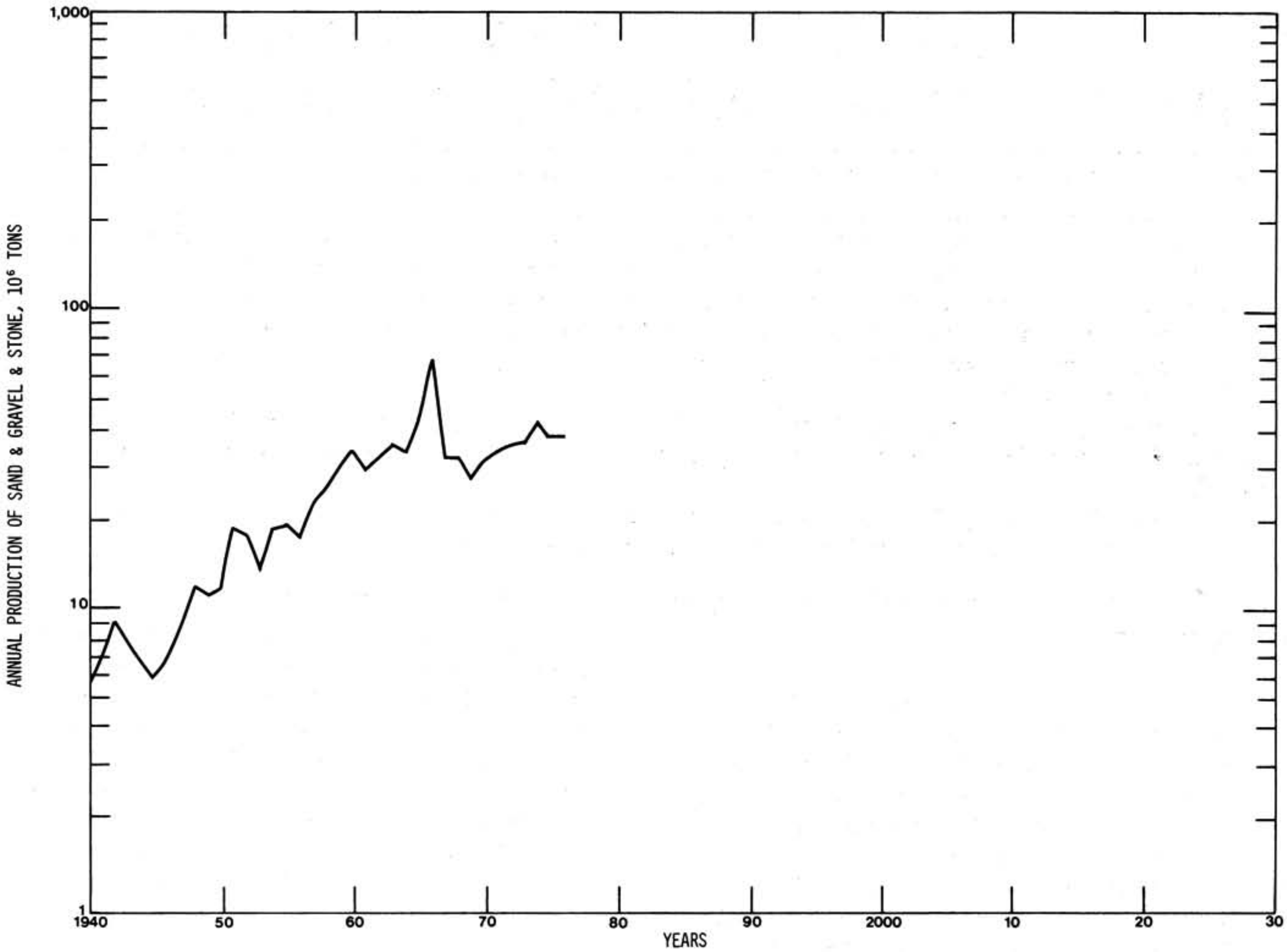


Figure 1. Oregon's annual production tonnages of sand and gravel and stone vs. time.

OVERVIEW OF FORECASTING TECHNIQUES

Introduction

All forecasting starts with an examination of the past. One relatively informal way is to consult an experienced rock material industry expert. On a more sophisticated level, one can study past production figures, statistical trends, economic cycles, or demographic changes. The past may be shown on a graph in which past production is related to time (Figure 1) or some other economic factor such as population (Figure 2). For forecasting, the scale used to record the past is extended into the future, and the trend line or correlations are extended over the scale. The scale can be either arithmetic, logarithmic, or exponential.

Forecasting costs time and money. As the sophistication increases, so does the cost. Thus, for example, the input-output method of modeling discussed later in this paper is so costly that its use in forecasting rock material demand is not feasible. All current methods of modeling, however, are described below, proceeding from the simplest to the more sophisticated.

Opinion polling

Opinion polling consists simply of asking several rock material industry experts what the future holds for rock material demand. The results are then averaged. Averaging good forecasts with bad forecasts, however, has a few shortcomings. Care should be taken in selecting experts, because if the experts consulted are producers, their estimates might be high. Individual producers tend to believe that their firms will grow at rates faster than that of the market as a whole.

For a small market area with only two or three producers, however, their estimates on the amount of land that will be needed to insure a good future supply of rock material may provide all the demand analysis that is needed by the local planner.

Freehand time trending

The next type of modeling consists of plotting rock material production against time, drawing a smooth curve through the data points, and extending the curve into the future. Figure 3 shows Oregon's sand and gravel

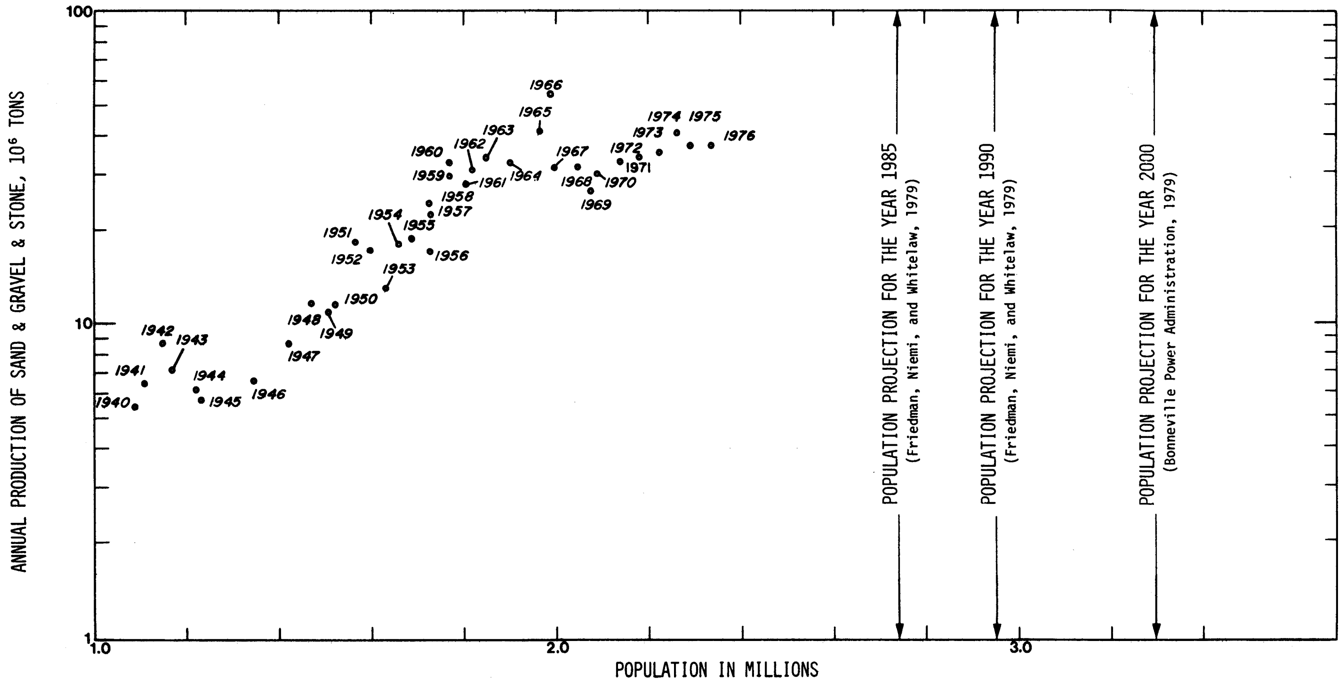


Figure 2. Oregon's annual production tonnages of sand and gravel and stone vs. population.

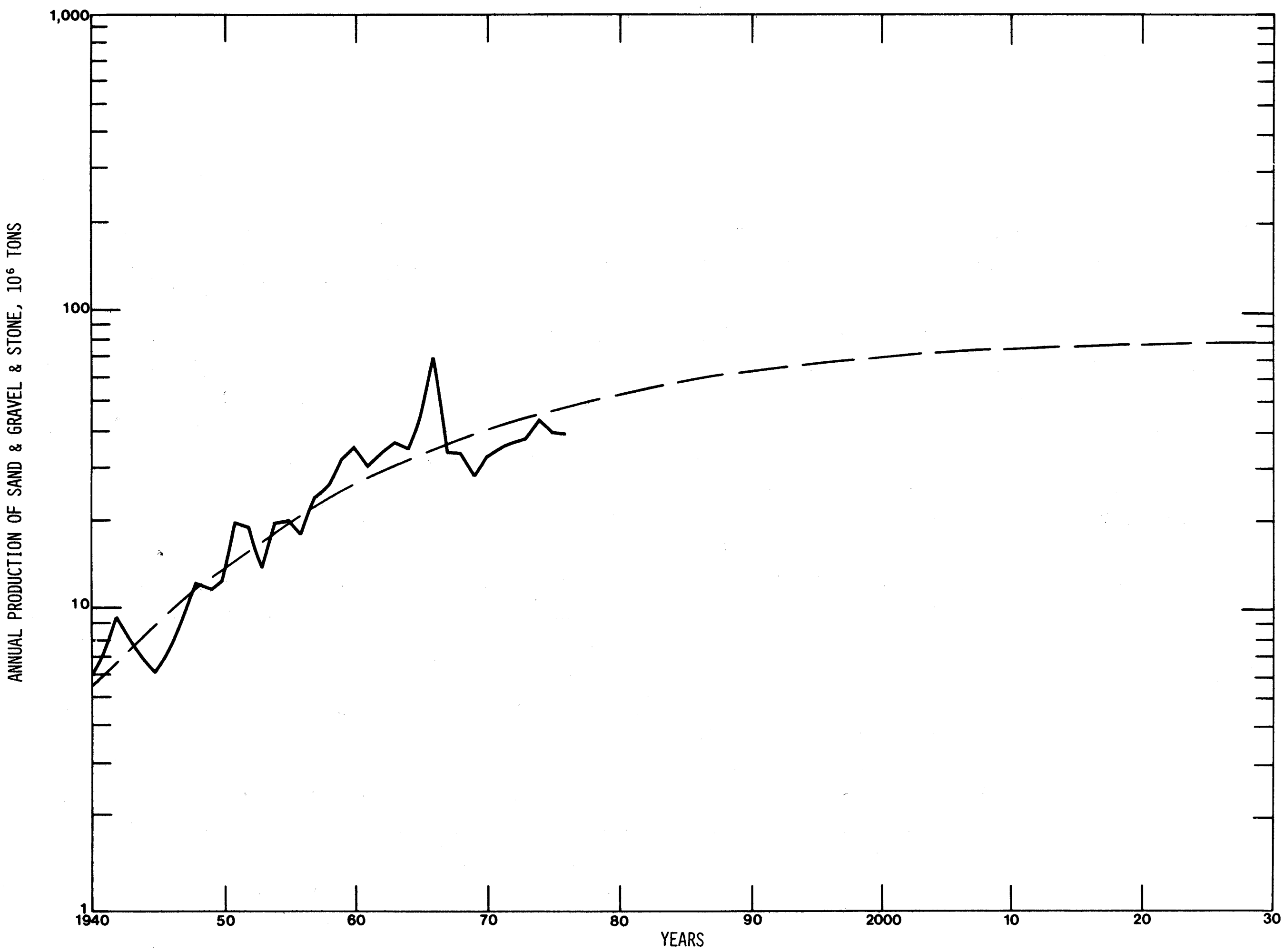


Figure 3. Oregon's annual production tonnages of sand and gravel and stone vs. time, with freehand-drawn curve.

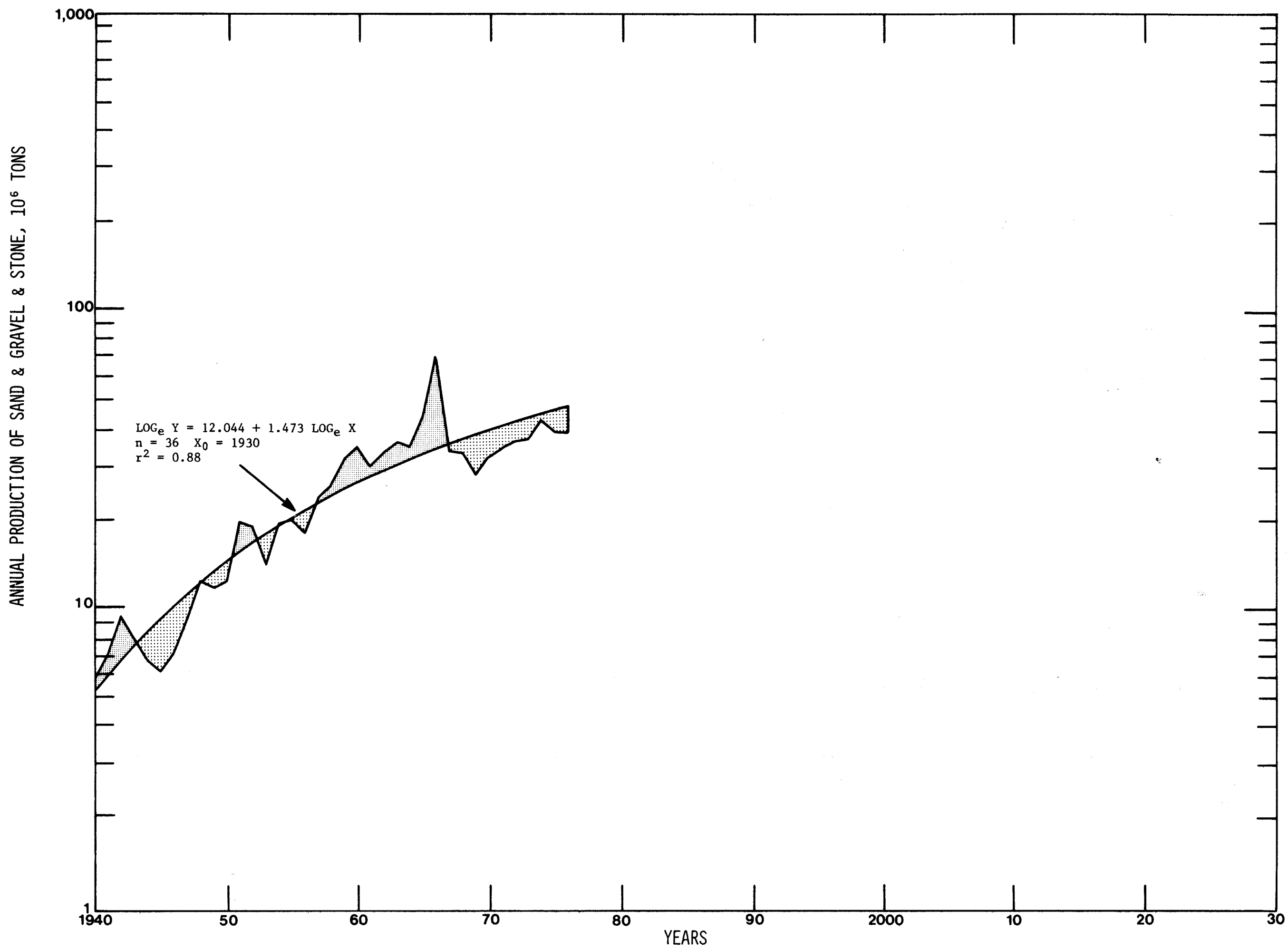


Figure 4. Oregon's annual production tonnages of sand and gravel and stone vs. time, with least-squares curve. Shaded area above curve nearly equals the shaded area below curve. Sum of the two areas is at a minimum.

and stone annual tonnages plotted against time, with a freehand curve drawn through the data points so that half of the points are above the curve and half are below. The advantage of this type of modeling is that it is fast. The disadvantages are that there is no way to judge how well the curve fits the data points and there is no measure of how the rise and fall of output tonnages over time may affect the forecast. For small market areas, production can swing up and down wildly, and the selection of linear trends is somewhat arbitrary.

Least-squares time trending

The least-squares technique is a statistical way of passing a curve (or a straight line) through a set of data points in such a way that square units of area over the curve will equal those under the curve and the sum of those areas will be the smallest possible amount. The degree to which the curve fits its data points is given a statistical number from 0 to 1 and is indicated by the symbol r^2. In general terms, the r^2 represents the total size of square area over and under the curve. An r^2 of 1 is a perfect fit, meaning there are no data points above or below the curve (Figure 4). An r^2 of 0 means that the data points vary so much that there is no linear trend within the data. The least-squares technique is discussed in greater detail later in this paper.

Other time trend techniques

When the economic base is small, another way to forecast is to compare the local market area to the surrounding larger market area or to a market area that has already passed through the economic stages the smaller area is experiencing (e.g., state vs. county, as in Figure 5).

This approach is good if data are available for a county but not for a city: demand can be estimated for the county, and city-to-county ratios, based on such economic factors as population, miles of streets and roads, or value of building permits, can be used to split out the city's portion of the total county rock material demand.

This technique can also be used as a check for

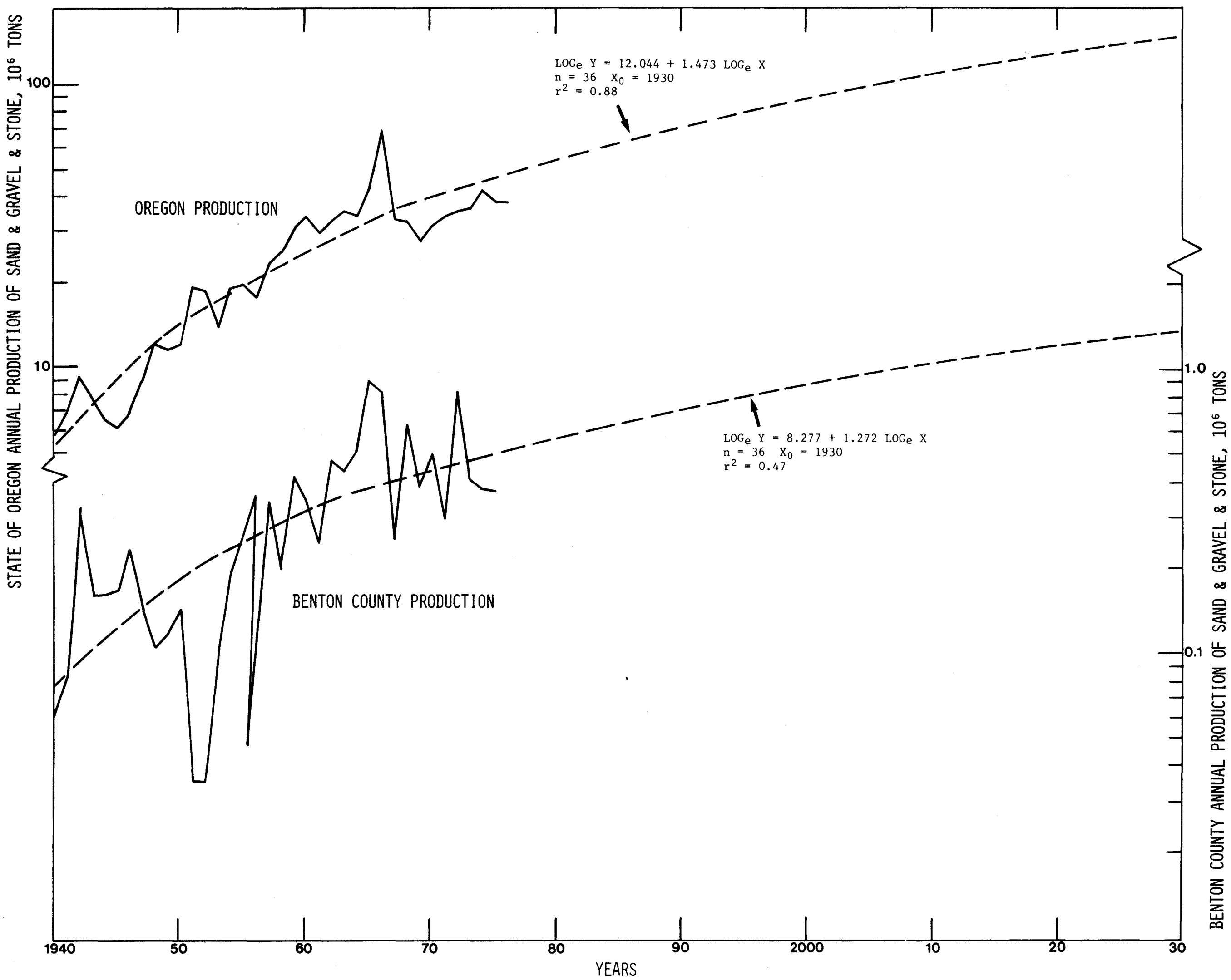


Figure 5. Oregon's and Benton County's annual production tonnages of sand and gravel and stone vs. time, with least-squares curve.

Table 1. *Present and predicted production of sand and gravel and stone**

Area	1976 Production (tons)	1976 Per capita consumption (tons)	2000 Estimated production (tons)	2000 Per capita consumption (tons)
State of Oregon	37,903,905	16	88,852,000	26
Willamette Valley	18,991,621	12	46,907,000	22
Benton County	538,142	8	1,468,339	16

* Source: Gray and others, 1978.

reasonableness of a forecast. After the forecast has been obtained, the tonnages are checked against an as yet unused economic factor. If this is population, for example, the local per capita figure is compared to the larger marketing area's per capita figure. If the two differ greatly, a second look at the economic base of the smaller marketing area may be needed.

Table 1, for example, shows the relationship between the present (1976) output of two larger marketing areas and a smaller marketing area and the predicted production for the year 2000 for the three market areas. To check the reasonableness of the smaller area (Benton County) forecast, per capita consumption is also shown. The Benton County per capita figure of 16 is reasonable when compared to the State per capita figure of 26, if the characteristics of the two markets are also compared. The State's economy is well diversified, but that of Benton County is not.

Econometrics/multiple regression analysis

Econometrics/multiple regression analysis compares rock material output (a dependent variable) to several economic factors (independent variables). This technique uses the demand from each of the independent variables to build a model of total demand. The independent variables relate only to that portion of rock material output which is controlled by the market place. They do not relate to demand caused by external influences, such as a Federal dam building program. The econometrics/multiple regression analysis technique and the result of its use in Special Paper 5 are discussed in the second half of the present paper.

Input-output table

The basis for the input-output system of economic analysis and forecasting is that all of the economy is interrelated. The output from one segment of the economy becomes part of the input to several other segments. A change in one segment affects all the other segments of the economy.

If enough data can be gathered to build an input-output table, economic analysis of market demand and forecasting can be studied in great detail. However, the cost of obtaining data to build an input-output table is very high. Even at the State level, it will normally be too high for the benefit gained.

If the State had an input-output table, the effect of shortages and high prices of gasoline and fuel oil, for example, could be followed through the economy. The points of stress on other segments of the economy would be very clear. Such a table would be very useful in predicting the effects of the closure of a major rock material resource throughout a local economy, when, for example, a price rise could be anticipated to cover transportation costs from the next closest supply.

THE TWO MOST USEFUL TECHNIQUES

Because least-squares time trend modeling and econometrics/multiple regression analysis are the two most useful techniques for projecting local- and State-level rock material demand, we shall now discuss them in some detail. The discussion of the least-squares time trend technique relies mainly on those of Schlicker and others (1978) and Gray and others (1978). Discussion of the econometrics modeling is based mainly on its use by Friedman and others (1979).

Least-squares correlations are easy to perform with a modern, handheld, programmable calculator. With the manufacturer's instructions, the calculator can be programmed and a correlation run in a very short time. Econometrics/multiple regression analysis cannot be performed very easily with a calculator. Most computer centers, however, have standard programs for executing multiple regressions, and the cost is quite reasonable.

Least-squares time trending

An example of least-squares time trending is the correlation of the State's output of sand and gravel and stone with time, using different lengths of base years (Figure 6), as done by Gray and others (1978). For this example, the State's annual production tonnages for sand and gravel and stone were plotted on semilog graph paper to show the pattern of production over the period from 1940 to 1976.

The next step was to choose the most desirable length of the data base. The exponential-type curve of least squares produces a simple straight line on semilog paper; therefore, this type was used to determine the length of the data base. The general formula for the exponential-type curve of least squares is $\text{Log}_e\ Y = \text{Log}_e\ a + bX$, leading, in the case of using the total time span, to the formula $\text{Log}_e\ Y = 15.77 + 0.057X$, when $n = 36$ and $X_0 = 1940$. In these formulas, Y is the dependent variable (production tonnages), a is the constant where the curve crosses the x-axis, b is the slope of curve, and X is the independent variable (time). The n is the number of years used in the least-squares correlation, and X_0 is the starting year.

Four models were developed: the first model spanned the total time from 1940 through 1975; for the second model, the time span was shortened by 10 years to 1950 through 1975; the third model was shortened by another 10 years to 1960 through 1975; and the fourth model was again shortened by 10 years to 1970 through 1975. The r^2 values ranged from 0.01 to 0.83. Perfect correlation between time and production is 1.0, and no correlation is 0.0.

Each trend was projected to the year 1990. Figure 6 shows that the length of the data base influences the projection for the year 1990. The range of projections using different data base lengths was from 38 to 122

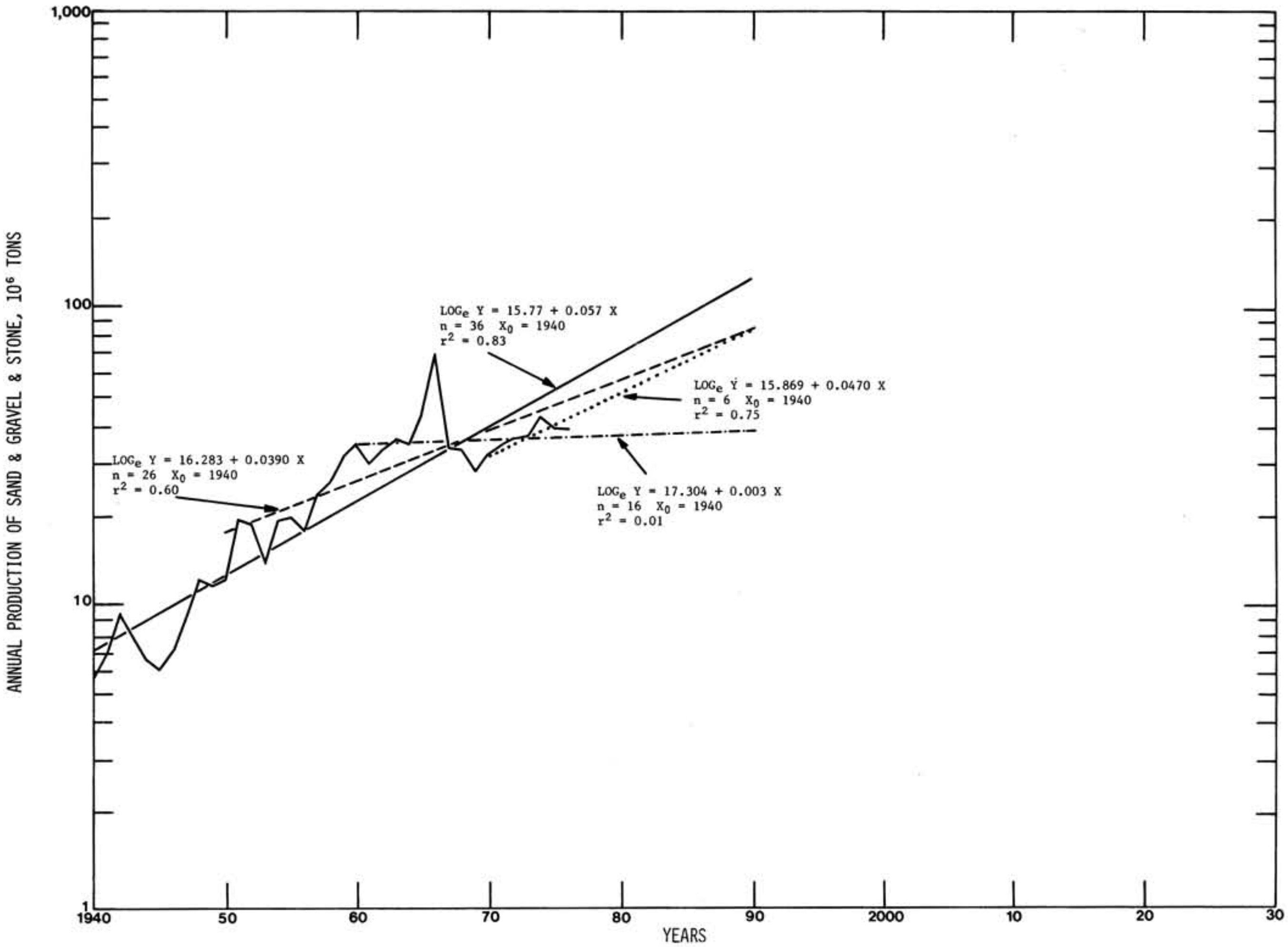


Figure 6. Oregon's annual production tonnages of sand and gravel and stone vs. time. Four exponential least-squares curves with different data base lengths are also plotted, with trend lines extending to the year 1990.

million tons per year. The model that gave the highest r^2 value (0.83) used the total length of the time series.

The model with the highest r^2 value in Figure 6 and the historic series were replotted as the top model in Figure 7. The arithmetic least-squares type of curve with the general formula of $Y = a + bX$ was tried in the bottom model. It had an r^2 value of 0.73. Finally, the power-curve least-squares type of curve with the general formula $\text{Log}_e\, Y = a + b\,\text{Log}_e\, Y$ was tried (middle model). It had an r^2 value of 0.88 and therefore was accepted as best for projecting the State's future consumption.

In the six least-square correlations shown in Figures 6 and 7, the forecasts for the year 2030 range between 43 and 1,193 million tons. The most reasonable forecast and the one with the highest r^2 is the middle model in Figure 7. It predicts production of 150 million tons.

In Special Paper 5, Friedman and others called least-squares modeling "growth rate modeling" and used the exponential-type curve with the general formula of $\text{Log}_e\, Y = \text{Log}_e\, a + bX$.

The final forecasting results of the two studies under consideration (Gray and others, 1978; Friedman and others, 1979) are shown in Table 2. Production statistics used by Friedman and others in their study did not include those listed under various counties (Table 45, Special Paper 5) and those used for dams (Table 46, Special Paper 5). Therefore, to make the two studies comparable in this paper, the forecasts for Oregon by Friedman and others were expanded by the statistical means listed in Table 3b.

Statistical models should be evaluated in terms of their consistency with the real world. In both studies, the forecasts for 1990 range from 17 to 31 million tons for the Portland area and from 39 to 88 million tons for the State. The forecasts for the year 2030 range from 35 to 639 million tons for the Portland area and from 53 to 548 million for the State. Because three of the five forecasts indicate that the Portland area will have a larger annual demand than will the State as a whole, they do not conform to the real world and are therefore not valid.

A further way to judge the models is to examine over time the percentage of annual demand that the Portland area of Clackamas, Columbia, Multnomah, and Washington Counties added to the State total. As Table 4b shows, the average percentage for the years

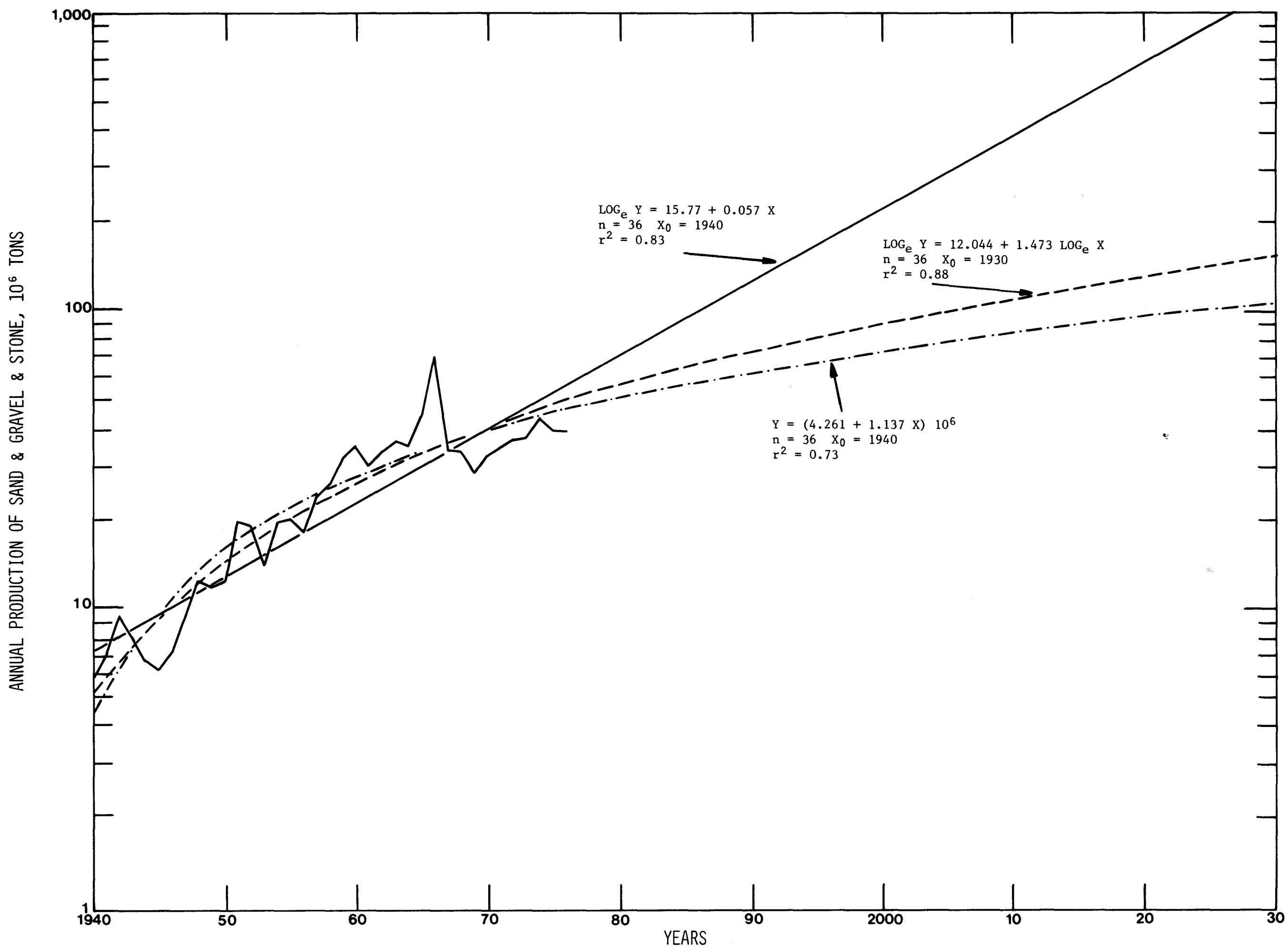


Figure 7. Oregon's production tonnages of sand and gravel and stone vs. time, with different types of least-squares curves and their trend lines extended to the year 2030.

1940 to 1976 was 24.4 percent. The range of limits for a 99-percent confidence interval around that mean is from 21.1 to 27.6 percent. The average percentage for the years 1964 to 1976 was 25.4, and the 99-percent confidence interval range is from 18.4 to 32.4. As the statistics show, there has been no great change in the Portland area's annual production percentage of the State's total. Also, there is nothing in the annual production data to indicate that the percentage will change radically between 1976 and 2030.

Therefore, any forecast which makes the Portland area's demand less than 18 percent or more than 33 percent of the State's total should be viewed cautiously. Using this test as a guide, we find only the first two of the forecasts given in Table 2 to be reasonable.

A note of caution is appropriate for such time-trend modeling. In times of marked change in construction, population, or other factors which determine demand, projections which appear valid in terms of r^2 may nevertheless fail to be accurate indicators of future demand. Forecasts should be tested and updated as new data become available.

Econometrics/multiple regression analysis

With econometrics/multiple regression, the correlation of least squares is taken a step further. A dependent variable such as the production of sand and gravel and stone is correlated to two or more explanatory variables such as price or population. The correlation can be simultaneous or by one variable at a time. This correlation allows periodic updating of the model as revised figures for the independent variables are obtained.

Econometric models have the following general form: $Y = b_0 = b_1X_1 + b_2X_2 + \ldots b_nX_n$, where Y = the dependent variable; b_0 = the intercept term (a constant); $X_1, X_2, X_3, \ldots X_n$ = explanatory variables; and $b_1, b_2, \ldots b_n$ = the coefficients of $X_1, X_2, \ldots X_n$.

The explanatory variables employed in Special Paper 5 by Friedman and others were population, employment, price, State highway expenditures, and real income. These were the only economic variables available with adequate historical data.

In essence, multiple regression analysis results in an equation of the best straight line formed by the mathe-

Table 2. *Projections of annual demand for sand and gravel and stone, determined by the least-squares method*

Models by base years and commodity	Portland area* 1990 forecast** (million tons)	Portland area* 2030 forecast** (million tons)	Oregon 1990 forecast** (million tons)	Oregon Portland area* demand as percent of Oregon demand	Oregon 2030 forecast** (million tons)	Oregon Portland area* demand as percent of Oregon demand
$\text{Log}_e Y = a + b \text{ Log}_e X$ (Gray and others, 1978)						
Base years 1940-76 (sand and gravel and stone)†	17(1)	35(1)	71(2)	24	150(2)	23
$\text{Log}_e Y = \text{Log}_e a + bX$ (Friedman and others, 1979)						
Base years 1950-76 (sand and gravel and stone)†	20(3)	116(3)	71(4) × 1.205‡ = 86	23	379(4) × 1.205‡ = 457	25
Base years 1964-76 (sand and gravel and stone)	31(5)	356(5)	34(6) × 1.138‡ = 39	80	98(6) × 1.138‡ = 112	318
Base years 1950-76 (sand and gravel)	11(7)	40(7)	37(8)	–	167(8)	–
Base years 1950-76 (stone)	16(9)	599(9)	36(10)	–	288(10)	–
Subtotal (1950-76)	27	639	73 × 1.205‡ = 88	31	455 × 1.205‡ = 548	117
Base years 1964-76 (sand and gravel)	21(11)	269(11)	18(12)	–	17(12)	–
Base years 1964-76 (stone)	8(13)	80(13)	18(14)	–	31(14)	–
Subtotal (1964-76)	29	349	36 × 1.138‡ = 41	71	47 × 1.138‡ = 53	659

* Clackamas, Columbia, Multnomah, and Washington Counties.

** Each forecast was derived from one of the models listed below. Number in parentheses indicates model number:

1. $\text{Log}_e Y = 11.025 + 1.377 \text{ Log}_e X$
2. $\text{Log}_e Y = 12.044 + 1.473 \text{ Log}_e X$
3. $\text{Log}_e Y = 15.08 + 0.0436X$
4. $\text{Log}_e Y = 16.41 + 0.0418X$
5. $\text{Log}_e Y = 15.64 + 0.0614X$
6. $\text{Log}_e Y = 17.21 + 0.0053X$
7. $\text{Log}_e Y = 14.93 + 0.032X$
8. $\text{Log}_e Y = 15.94 + 0.0374X$
9. $\text{Log}_e Y = 12.93 + 0.091X$
10. $\text{Log}_e Y = 15.32 + 0.052X$
11. $\text{Log}_e Y = 15.18 + 0.064X$
12. $\text{Log}_e Y = 16.74 - 0.0015X$
13. $\text{Log}_e Y = 14.44 + 0.057X$
14. $\text{Log}_e Y = 16.37 + 0.013X$

† Most reasonable projections.

‡ Expansion factor taken from Table 3b.

matical regression of the dependent variable. In other words, it provides the equation which best describes the dependent variable (annual sand and gravel and stone output) as a function of the explanatory variables.

Friedman and others (1979) tried many econometric models for the State; for the Portland area of Clackamas, Columbia, Multnomah and Washington Counties; and for other substate areas. For some models, the dependent variable was sand and gravel combined with stone; for other models, the dependent variable was either sand and gravel or stone. For economic and statistical reasons, very few models were usable. Table 5 contains the 1990 forecasts from the most usable models.

Of the six unmodified models (models 1, 2, 3, 4, 6, and 7 in a footnote to Table 5), only four have r^2 values high enough to be useful for making planning decisions. The models for the Portland area are good, with r^2 values in the 0.90's. The 1990 forecasts are the same for all rock material, either directly by the all-rock material model (sand and gravel and stone) or by adding the sand and gravel model forecast to the stone model forecast.

We find the State's forecasts are low, when compared to those of the Portland area. As discussed earlier, the Portland area should account for only 25 percent of Oregon's total demand; and for a 99-percent confidence interval, its share should be 18 to 33 percent. The Portland area forecasts have high r^2 values and fall within the range indicated by the two usable forecasts listed in Table 2. If an assumption is made that the Portland area will have 25 percent of the demand for all rock materials, then the Oregon demand will be four times the 19 million tons listed for the Portland area in Table 5. This figure of 76 million tons falls within the State's range of 71 to 86 million tons shown in Table 2. The sand and gravel unmodified model in Table 5 has an r^2 of 0.75 and a forecast of 31 million tons. The stone unmodified model has an r^2 of 0.25, which is too low to be useful. Therefore, if the stone forecast is discarded and the sand and gravel forecast is subtracted from the 76-million-ton forecast for all-rock material, the 1990 stone forecast is 45 million tons.

Based on the above figures, the ratio of sand and gravel demand over sand and gravel and stone is 0.408. This statistic compares very favorably with the three ratios of 0.421, 0.436, and 0.485 obtained by using the three least-squares forecast models of Gray and others (1978), as shown in Figure 8.

The 1990 range of forecast from Tables 2 and 5 is from 17 to 20 million tons of all rock material for the

Table 3a. *Factors needed to expand the adjusted Oregon annual production of sand and gravel and stone**

Year	Expansion factor	Year	Expansion factor	Year	Expansion factor	Year	Expansion factor	Year	Expansion factor	Year	Expansion factor
1940	1.692	1947	1.383	1953	1.302	1959	1.100	1965	1.141	1971	1.130
1941	1.866	1948	1.643	1954	1.351	1960	1.177	1966	2.063	1972	1.094
1942	1.403	1949	1.348	1955	1.029	1961	1.157	1967	1.116	1973	1.027
1943	1.392	1950	1.604	1956	1.033	1962	1.132	1968	1.126	1974	1.128
1944	1.208	1951	2.008	1957	1.069	1963	1.127	1969	1.107	1975	1.146
1945	1.235	1952	1.210	1958	1.078	1964	1.205	1970	1.204	1976	1.227
1946	1.138										

* Factors used by Friedman and others (1979) to make their figures compatible with figures published by Gray and others (1978) and Friedman and others (1979).

Table 3b. *Means of expansion factors for base-year intervals and 99-percent confidence intervals determined by* K *and* t *statistics*

						K statistic		*t* statistic	
						$\bar{X} \pm K_{\alpha/(2\sigma/\sqrt{n})}$*		$\bar{X} \pm t_{\alpha/2;\,(n-1)s/\sqrt{n}}$*	
Years**	n	Mean	s or σ	$K_{\alpha/2}$	$t_{\alpha/2;\,n-1}$	Lower limits	Upper limits	Lower limits	Upper limits
1940-76	36	1.259	0.235	0.500	2.727	1.239	1.279	1.152	1.366
1950-76	26	1.205	0.203	0.500	2.787	1.185	1.225	1.094	1.316
1963-76	13	1.137	0.052	0.500	3.055	1.130	1.144	1.093	1.181
1964-76	12	1.138	0.055	0.500	3.106	1.130	1.146	1.089	1.187

* Two-tailed test.

** 1966 expansion factor omitted.

Portland area and from 71 to 86 million tons for the State as a whole. Sand and gravel contributes 41 percent of all rock material demand, and stone the remaining 59 percent.

Friedman and others (1979) describe a method of modifying the Portland-area models to fit the State by substituting a State-level intercept. By applying this method, we arrive at the 1990 forecasts as developed in modified models 3 and 8 of Table 5, which predict that the sand and gravel production (or demand) will be greater than that of stone. The case illustrates the importance of the supply factor; the current State-wide tightening of the sand and gravel supply will result in future production of less sand and gravel than stone. Supply may not function directly as an explanatory variable for demand, but indirectly it does so. A forecast that does not reflect supply may therefore not be valid.

The concept of price

The analysis by Friedman and others (1979) of the relative price relationship between sand and gravel and stone for the Portland area can be viewed in light of the area's supply situation. The published annual values given for the commodities are measured at the pit or plant and therefore omit most transportation costs. If there are ample supplies of sand and gravel and stone, the delivered value may be twice that of the pit or plant value. If the supply of a commodity becomes tight, the price based on the published value may not change, but the delivered price may be three or four times the pit or plant price. The extra cost is transportation.

The Portland-area sand and gravel forecast model 3 of Table 5 shows that if all explanatory variables are kept constant except price and if price rises $1.00, demand will fall by 4.6 million tons. Under the same conditions, the Portland-area stone demand (model 6 of Table 5) will fall only 2.5 million tons. This indicates that the supply is tighter for sand and gravel than it is for stone. The tight supply of sand and gravel is causing a price rise in all rock material resources. The stone industry is benefitting the most because the centrally located pits of sand and gravel are being depleted, while the stone quarries still have reserves.

Using an econometric model design to analyze the relative price relationship between sand and gravel and stone, Friedman and others (1979) state: "For example, the model indicates that a 10-percent increase in the price of sand and gravel relative to the price of stone occurring in the absence of changes in the other explanatory variables would produce a 3-percent decrease in the quantity of sand and gravel demanded and an 11-percent increase in the quantity of stone demanded" (p. 37).

Alternatively, one could state that, as the supply of sand and gravel tightens another 3 percent, the price of sand and gravel will rise by 10 percent and the output of stone will rise by 11 percent. The downward trend in sand and gravel's portion of total output of sand and

Table 4a. *The Portland area's* annual production of rock material as a percent of Oregon's total annual production*

Year	Percent	Year	Percent	Year	Percent	Year	Percent
1940	18.4	1950	27.0	1960	17.6	1970	28.9
1941	24.7	1951	19.7	1961	17.2	1971	29.2
1942	22.0	1952	45.6	1962	12.6	1972	35.5
1943	28.2	1953	26.0	1963	15.4	1973	36.0
1944	28.3	1954	21.1	1964	16.9	1974	26.6
1945	27.0	1955	27.7	1965	13.9	1975	24.6
1946	30.6	1956	28.5	1966	8.3	1976	28.1
1947	22.3	1957	20.0	1967	21.3		
1948	25.9	1958	21.7	1968	31.3		
1949	26.5	1959	16.8	1969	29.9		

* Clackamas, Columbia, Multnomah, and Washington Counties.

Table 4b. *Means of Portland area's* total annual production for base-year intervals and 99-percent confidence intervals determined by* K *and* t *statistics*

						K statistic		*t* statistic	
						$\bar{X} \pm K_{\alpha/(2\sigma/\sqrt{n})}$**		$\bar{X} \pm t_{\alpha/2;\,(n-1)s/\sqrt{n}}$**	
Years	n	Mean (percent)	s or σ	$K_{\alpha/2}$	$t_{\alpha/2;\,n-1}$	Lower limits	Upper limits	Lower limits	Upper limits
1940-76	37	24.36	7.23	0.500	2.722	23.77	24.95	21.12	27.60
1950-76	27	23.98	8.21	0.500	2.779	23.19	24.77	19.59	28.37
1964-76	13	25.42	8.26	0.500	3.055	24.28	26.57	18.42	32.42

* Clackamas, Columbia, Multnomah, and Washington Counties.
** Two-tailed test.

Table 5. *1990 projections of annual demand for sand and gravel and stone, determined by the econometric method*

		Oregon			
		Unmodified models		Modified models	
Commodity with base years of 1963-76	Portland area* forecast** (million tons)	Forecast** (million tons)	Portland area as percent of Oregon	Forecast** (million tons)	Portland area as percent of Oregon
Sand and gravel and stone	19(1)	41(2) × 1.137† = 47	40	—	—
Sand and gravel	11(3)	31(4)	—	27(5)	—
Stone	8(6)	13(7)	—	25(8)	—
Subtotal	19	44 × 1.137 = 50	38	52 × 1.137 = 59	32

* Clackamas, Columbia, Multnomah, and Washington Counties.

** Each forecast was derived from one of the models listed below, using medium estimates given in Friedman and others (1979, Table 12) for the explanatory variables. Number in parentheses indicates model number. Models 5 and 8 are the same as models 3 and 6 modified by changing the intercept to fit Oregon rather than the Portland area. The r^2 values are given for each model, except for the modified two.

1. $Y = 1{,}440{,}651 - 6{,}667{,}195$ (price) $+ 0.39$ (population) $+ 39.54$ (employment) $+ 0.046$ (highway expenditures) $r^2 = 0.91$
2. $Y = 1{,}272{,}446 + 5{,}473{,}334$ (price) $- 0.80$ (population) $+ 21.93$ (employment) $+ 0.064$ (highway expenditures) $r^2 = 0.17$
3. $Y = 3{,}572{,}790 - 4{,}616{,}027$ (price) $+ 5.50$ (population) $+ 8.61$ (employment) $+ 0.033$ (highway expenditures) $r^2 = 0.93$
4. $Y = -8{,}280{,}846 + 4{,}146{,}131$ (price) $- 11.99$ (population) $+ 45.39$ (employment) $+ 0.086$ (highway expenditures) $r^2 = 0.75$
5. $Y = 2{,}329{,}623 - 4{,}616{,}027$ (price) $+ 5.50$ (population) $+ 8.61$ (employment) $+ 0.033$ (highway expenditures) —
6. $Y = -1{,}601{,}970 - 2{,}502{,}933$ (price) $- 5.52$ (population) $+ 3.19$ (employment) $+ 0.014$ (highway expenditures) $r^2 = 0.70$
7. $Y = 29{,}836{,}530 - 9{,}335{,}489$ (price) $+ 2.20$ (population) $- 7.34$ (employment) $- 0.023$ (highway expenditures) $r^2 = 0.25$
8. $Y = -157{,}972 - 2{,}502{,}933$ (price) $- 5.52$ (population) $+ 3.19$ (employment) $+ 0.014$ (highway expenditures) —

† Expansion factor taken from Table 3b.

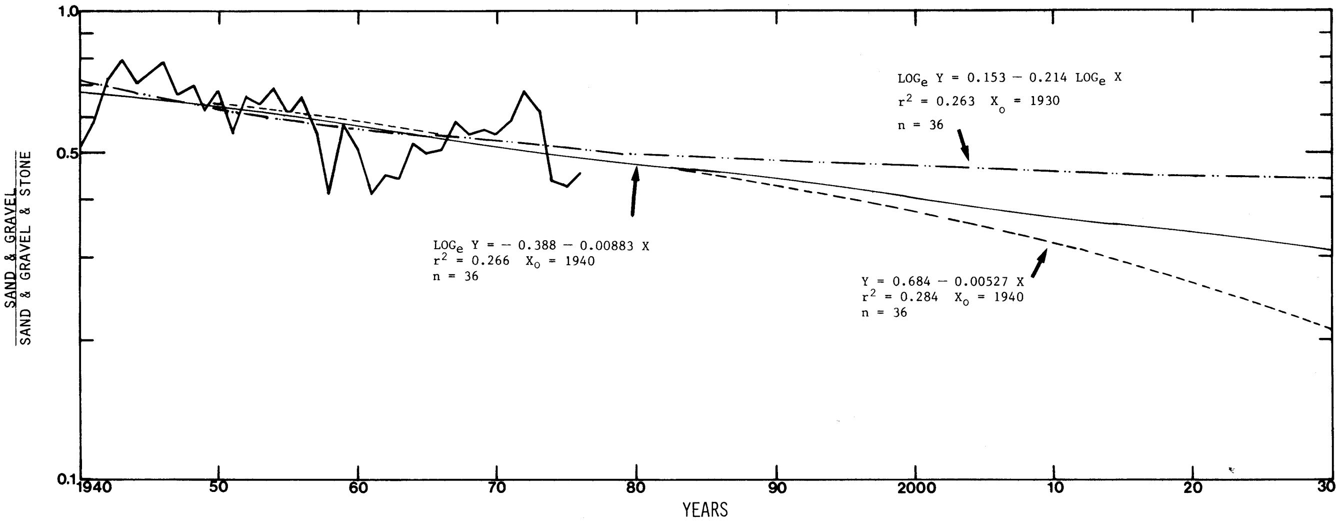


Figure 8. Oregon's annual production tonnage ratios of sand and gravel to sand and gravel and stone vs. time.

gravel and stone shown by Gray and others (1978, Figure 8) also reflects the tightening of sand and gravel supplies compared to those of stone.

STEPS TO FORECAST MODELING

1. **State the problem.** For most of the State, the problem is to determine how much land will be needed for rock material production to supply present and future needs of the local area and of the State. To answer this question, an inventory of rock material supplies must be made, and the rate at which those supplies are being depleted must be shown. Rock resource assessments and demand modeling address the two main aspects of the problem.

2. **Obtain production statistics for all-rock material (sand and gravel and stone) and other economic statistics for the State and for the substate marketing area.** The rock material data can be found in the appendix of Special Paper 5. The substate areas were chosen so that imports into and exports out of the substate areas were in balance, and production statistics consequently represented consumption. One of the major findings in Special Paper 5 is that forecast modeling does not work for areas smaller than a substate marketing area. In areas smaller than a marketing area, imports do not equal exports. Also, because of the small size of the economic base, output of rock material can vary widely. Consequently, forecasting should not be performed at the city level.

3. **Plot the all-rock material production statistics against time for both the substate marketing area and the State.** This gives a graphic picture of the peaks and valleys of substate area output in comparison to that of the State. From the graph, the extent to which the substate area is in step with the State can be determined.

4. **Plot all-rock material annual production against such other economic variables as population, employment, and price.** If any correlation exists between the rock material annual output and another economic variable, these graphs will show linear trends.

5. **Review the graphics to determine how output has reacted during the past and then decide what length of time should be used for the forecasting base and which level of forecast modeling is needed.** Extending trend lines out into the future can be done by drawing a line freehand through the data points on a graph and extending it into the future or by using the least-squares and/or econometrics/multiple regression methods. After forecasts have been made for all-rock material at the State and substate levels, they should be compared. Demand for a substate cannot grow larger than that for the State as a whole. The past substate percentages should be reviewed in relation to those of the State to see if the percentages changed much during the base years. If they did not change during the base years but show a major change by the end of the forecast, an explanation should be sought.

6. **Separate the two commodities and plot them against time.** There is a good chance that one will show greater growth than the other. The output or growth is a function of supply, not demand, because the two commodities are interchangeable.

In many parts of the State, the supply of gravel is tight because of adverse zoning and land use; therefore, stone often shows faster growth than sand and gravel.

7. **Prepare forecast models for each of the commodities.** The two year-end forecasts should be added together and compared to the forecast obtained by modeling all-rock material. Again, a part cannot become larger than the whole. If the two models do not equal the total, and one model has a much higher r^2 value than the other, use the forecast from that model and subtract it from the all-rock-material forecast to

determine the forecast for the other commodity. Note whether or not supplies of the commodities are large enough so that the past relationships will be able to continue. If supplies for one commodity are tighter than for the other, its prices probably will rise with no increased output. Prices probably will also rise for the other commodity, but its output will rise as well.

SUMMARY AND CONCLUSIONS

This paper reviews forecast modeling techniques and discusses in detail the two methods of building forecast models presented by Gray and others (1978) and Friedman and others (1979). For most forecasting, the two methods, least squares and econometric/multiple regression, are most useful to the local planner.

For general modeling techniques, modeling should start at the State level and proceed down to the substate area and ultimately to the local area. The demand of a local area cannot grow larger than that of the substate area, and the substate demand cannot grow larger than the State's demand. Modeling should proceed from all-rock material down to each of the commodities. The demand for one commodity cannot grow larger than the total rock material demand.

The economic activities of man create demand for all rock material, but it is the adequacy of supply for the two commodities that determines their price and output. By comparing the least-squares technique to the econometric technique, we conclude that the Portland area will have a 17- to 20-million-ton demand for all rock material by 1990 and Oregon 71 to 86 million tons. By the year 2030, Portland's demand will have grown to between 35 and 116 million tons and Oregon's to between 150 and 457 million tons.

The adequacy of supply must also be viewed from the standpoint of the one-time-only, nonrecurring demand such as that created by a major dam project. This type of demand shows up as peaks in the time trend graphs for the State as a whole and is part of the demand forecast for the State. It is impossible, however, to predict when and where such a demand surge will occur again. If the possibility exists that this type of project may occur within a planning area, then supplies must be large enough to meet the extra demand.

To properly address the problem of supplying adequate rock material resources, demand models and resource assessments are both needed. Knowledge of the constraints defined by the resource assessments and of the nature and the current status of the industry allow proper selection and realistic interpretation of the demand models.

SELECTED REFERENCES

Bonneville Power Administration, 1979, Population, employment and households—projection to 2000 for Oregon: Portland, Oreg., Bonneville Power Administration, Branch of Power Resources, 81 p.

Bowker, A.H., and Lieberman, G.J., 1959, Engineering statistics: Englewood Cliffs, N.J., Prentice-Hall, Inc., 585 p.

Evans, J.R., 1979, Forecasting sand and gravel, crushed stone and aggregate demand in the United States: Minerals Engineering, v. 31, no. 1, p. 54-61.

Forrester, J.W., 1961, Industrial dynamics, chapter 4, models: New York, M.I.T. Press and John Wiley and Sons, Inc., p. 49-59.

Friedman, J.M., Niemi, E.G., and Whitelaw, W.E., 1979, Analysis and forecasts of the demand for rock materials in Oregon: Oregon Department of Geology and Mineral Industries Special Paper 5, 84 p.

Gray, J.J., Allen, G.R., and Mack, G.S., 1978, Rock material resources of Clackamas, Columbia, Multnomah, and Washington Counties, Oregon: Oregon Department of Geology and Mineral Industries Special Paper 3, 54 p.

Johnson, R.E., Jr., 1964, Observations on a region analysis: Washington, D.C., Division of Economic Analysis, U.S. Bureau of Mines, unpublished report, 22 p.

Kingston, G.A., 1962, The steel industry of the Columbia Basin: Pacific Northwest Economic Base Study of Power Markets—Steel, v. 11, part 7F, Bonneville Power Administration, 58 p.

Kingston, G.A., and Knostman, R.W., 1964, Observations on the use of multiple regression analysis: Albany, Oreg., Albany Office of Mineral Resources, U.S. Bureau of Mines, unpublished report, 22 p.

Lloyd, B.S., 1967, Economic advice no. 14—methodology of projecting demand for minerals: Washington, D.C., Division of Economic Analysis, U.S. Bureau of Mines, unpublished report, 6 p.

Schlicker, H.G., Gray, J.J., and Bela, J.L., 1978, Rock resources of Benton County, Oregon: Oregon Department of Geology and Mineral Industries Short Paper 27, 49 p.

Stobaugh, R.B., 1965, Chemical marketing research: Chemical Engineering, v. 72, no. 11, p. 153-160.

White, T.W., 1970, Analyzing local market potential for aggregates: Rock Products, v. 73, no. 9, p. 96-98, 135-136. □

meeting announcements

Each month, space permitting, upcoming meetings will be announced in this column. Information should reach this office no later than six weeks before a meeting. Please be specific and give full name of the organization; exact subject, location, and time of the meeting; and the name, address, and phone number of person to contact for questions or reservations.

GSOC luncheon programs announced

The Geological Society of the Oregon Country announces the following luncheon program schedule. All luncheon programs will take place at noon, in Room A (adjacent to the cafeteria) of the Standard Plaza Building, 1100 SW Sixth Avenue, Portland.

January 18	Speaker:	John Haffnagle, The Nature Conservancy
	Subject:	Oregon's Nature Conservancy program
February 1	Speaker:	Jim Doane, Bureau of Hydroelectric Power, City of Portland
	Subject:	Hydroelectric power installation at Bull Run Dams
February 15	Speaker:	Vernon Newton, Oregon Department of Geology and Mineral Industries
	Subject:	Oil and gas activity in Oregon
March 7	Speaker:	Tom McAllister, Outdoors Editor, The Oregon Journal
	Subject:	Inland passage, north Alaska
March 14	Speaker:	Donald Godard, Oregon Department of Energy
	Subject:	Nuclear energy: The Three Mile Island accident and the storage of spent fuel rods

For further information, contact the luncheon program chairperson, Viola L. Oberson, phone 282-3685. □

DOGAMI staff moves back to remodeled quarters

The remodeling of the ninth and tenth floors of the State Office Building in Portland has been completed, and the State Geologist, Deputy State Geologist, professional staff, cartographers, and editor have moved back to Room 1069. The library and business office are on the ninth floor. Check the directory in the lobby for correct room numbers. □

Regional metals and minerals conference to meet in May

The Pacific Northwest Metals and Minerals Conference will be held May 7-9, 1980, at the Olympic Hotel in Seattle, Washington.

Joint hosts for the conference are the North Pacific Section of the American Institute of Mining, Metallurgical, and Petroleum Engineers and the Puget Sound Chapter of the American Society for Metals.

Theme of the conference will be: "Materials Problems of the 80's." The program will include technical sessions on such subjects as metallurgy, geology, and mining; industrial exhibitions by sixteen exhibitors; mini-courses on items such as business economics, computers, and statistical analysis; and a ladies' program, including tours and luncheons.

Conference chairman is Roger V. Carter, Chief of Metals Technology, Boeing. Further information will be forthcoming in the society publications. □

(C) Punch–ROTHCO

"... *but you can call me Rex.*"

ABSTRACTS

The Department maintains a collection of theses and dissertations on Oregon geology. From time to time we will print abstracts of new acquisitions that we feel are of general interest to our readers.

Stratigraphy, structure, and petrology of Columbia River Basalt in a portion of the Grande Ronde River—Blue Mountains area of Oregon and Washington, by Martin Edward Ross (Ph.D. in Geology, University of Idaho, 1978)

Grande Ronde, Wanapum, and Saddle Mountains Basalts are exposed in the canyons of the Grande Ronde River and its tributaries in northeastern Oregon and southeastern Washington. The detailed stratigraphy of these Miocene to Pliocene basalts has been established in a portion of this area using a combination of flow and interbed mapping and correlations based on chemical, petrographic, and paleomagnetic properties of each flow.

The Grande Ronde flows have only a moderate range of compositions and form a chemical group most likely derived from a homogeneous magma source. Chemical compositions of most of the flows were very similar, but at least six of the flows have relatively distinct chemistries. I have found that at least eight of the Grande Ronde flows contain significant amounts of orthopyroxene and have relatively high mean SiO_2 contents, indicating they might more accurately be considered tholeiitic andesites.

All four of the Grande Ronde magneto-stratigraphic units of Swanson and Wright (1976) are present, with N_2 confined mainly to the central, structurally lowest portion of the study area. This, along with the thickening of the Troy flow and of the R_2 magnetic interval in the same area, suggests that deformation began prior to the end of Grande Ronde volcanism.

Six flows of Wanapum Basalt overlie the Grande Ronde sequence. Four of these occur as two pairs (Dodge flows and Kuhn Ridge flows), with each pair forming a distinct chemical and petrographic unit. Source dikes for the Dodge flows have been recognized and mapped within the area.

Five flows of Saddle Mountains Basalt and three sedimentary interbeds occur above the Wanapum Basalt sequence. Near-vent andesite ejecta and volcanic breccia are associated with the Grouse Creek sedimentary interbed in the southwest portion of the study area. This andesite predates the Wenaha flow and postdates the Eden flow. A source dike for the Wenaha flow was recognized and mapped.

The Wanapum and Saddle Mountains flows and flow pairs are chemically and petrographically distinct from one another. Roza and Umatilla are the only two Wanapum and Saddle Mountains chemical types of Wright and others (1973) that occur in the study area. This compositional diversity requires a complex magmatic history, probably involving more than a single parent magma.

A detailed investigation of chemical variations across each of four Wanapum and Saddle Mountains dikes shows that SiO_2, TiO_2, and K_2O decrease inward from chilled margins as MgO and perhaps CaO and total iron increase. P_2O_5 varies systematically only within the Wenaha dike, in which it decreases inward from the chilled dike margin. Several hypotheses have been considered in my attempt to explain these trends. I favor a model in which progressive partial melting at the magma source produced a series of melts increasingly depleted in silica and incompatible elements.

Petrographic and mineralogic variations across the dikes were also studied in detail. There is substantial evidence of fractional crystallization within the dikes with the following being the most significant: plagioclase becomes increasingly more sodic toward the interior of each dike, and orthopyroxene, when present, is restricted to the chilled margins. These mineralogic trends are superimposed on the more primary chemical trends, indicating that fractional crystallization occurred after partial melting, perhaps during magma ascent and intrusion.

These magmatic processes operating in the formation of each dike might also play significant roles in the evolution of entire groups of flows derived from a common source. This study of trends within the individual dikes provides a new approach to the investigation of Columbia River Basalt magmas.

The presence of broad folds; strike-slip faults showing a second, lesser dip-slip movement; a monocline; and normal faults indicates the area was subjected to a nearly north-south compression followed by relaxation and tensional tectonic forces. This deformation was superposed on the regional subsidence of the Columbia Plateau centered about the Pasco Basin. Subsidence and folding seem to have occurred throughout the period of Yakima Basalt volcanism. The Blue Mountains anticlinal uplift and down-warping of the Grouse Flat syncline accelerated after Wanapum Basalt volcanism. This resulted in Saddle Mountains units being thicker and more confined to the structurally low area toward which they thicken.

The well-formed meanders of the Grande Ronde

(See **Columbia River Basalt**, *p. 18)*

Mined Land Reclamation hearings scheduled

The Governing Board of the Oregon Department of Geology and Mineral Industries has approved the Department's draft of proposed amendments to the Mined Land Reclamation Administrative Rules and has authorized public hearings on it. The proposed rule changes pertain to larger, open-pit mining sites and quarries, but not to placer gold mines in active streams or small-scale recreational mining.

Three public hearings have been or will be conducted around the State by the Department: Portland, January 8, 1980, 9:00 a.m.-4:30 p.m., at the Oregon Department of Fish and Wildlife Building. Roseburg, January 10, 1980, 9:00 a.m.-5:00 p.m., in the Roseburg City Hall Council Chambers. Baker, January 22, 1980, 1:00 p.m.-5:00 p.m. and 7:00 p.m.-9:30 p.m., at the School District Building, 2990 Fourth Street.

Copies of the draft proposal are available at the offices of the Department in Portland, Baker, Albany, and Grants Pass. Written testimony has been received at the hearings held already. More will be received at the last public hearing or may be submitted directly to the Department, c/o Stan Ausmus, 1129 SE Santiam Road, Albany, OR 97321, by February 1, 1980. Comments and questions should be directed to the Albany office, c/o Stan Ausmus or Barbara DeClue, phone: 967-2039. □

(**Columbia River Basalt,** *from p. 17)*
River developed originally on a relatively flat plateau surface. After downcutting of a few hundred feet had occurred, the meanders were able to more easily enlarge and migrate within the thick sedimentary interbeds within the Saddle Mountains sequence prior to significant deformation in the area. Entrenchment of the meanders then occurred during uplift of the Blue Mountains. The absence of more massive and resistant pre-Tertiary rocks along the course of the river allowed it to maintain its meanders within the basalts during entrenchment.

REFERENCES CITED

Swanson, D.A., and Wright, T.L., 1976, Magnetostratigraphic units in the Yakima basalt, southeast Washington: Geological Society of America Abstracts with Programs (Cordilleran Section), v. 8, no. 3, p. 413-414.

Wright, T.L., Grolier, M.J., and Swanson, D.A., 1973, Chemical variation related to the stratigraphy of the Columbia River Basalt: Geological Society of America Bulletin, V. 84, no. 2, p. 371-386. □

Geothermal lease regulations: BLM proposes changes

In the interest of expediting the leasing and development of lands with potential geothermal resources, the Bureau of Land Management has proposed two amendments to the Code of Federal Regulations on noncompetitive geothermal leases.

The first change affects existing leasing units which have become available again because they are on lands on which leases have been canceled or relinquished, lands on which leases expired at the end of their primary or extended terms, or lands on which leases have been terminated for nonpayment of rent. Such leases would no longer fall under the requirement for competitive leasing when two or more applications are filed for the same leasing unit. Instead, a public drawing would establish an order of priority among the applications, and leases would be issued on the basis of it.

The second change affects lands designated as Known Geothermal Resource Areas (for competitive bidding), which were so designated solely because of overlapping noncompetitive applications. If, as has been the case too frequently, the competitive leasing attracts no bids, the lands could be reclassified for noncompetitive leasing. With regard to the procedure to be used in awarding the leases, the Department of Energy advocates priority of filing date, and BLM favors a drawing among the applications of the same filing period.

The proposals have been published in the Federal Register, v. 44, no. 228 (Nov. 1979), p. 67598-99. Written comments are due by January 25, 1980. Address: Director (650), Bureau of Land Management, Department of the Interior, 1800 C Street NW, Washington, D.C. 20240. □

We're late

Your copy of the January issue of *Oregon Geology* reached you later than usual this month because we moved back to our remodeled offices during December, making it impossible to meet our usual publication schedule. We apologize. □

PUBLICATIONS ORDER

Omission of price indicates publication is in press. Minimum mail order 50¢. All sales are final. Publications are sent postpaid. Payment must accompany orders of less than $20.00.

Fill in appropriate blanks and send sheet to Department (see address on reverse side).

YOUR NAME ______________________________

ADDRESS ______________________________

______________________________ Zip__________

Amount enclosed $__________

OREGON GEOLOGY

____ Renewal ____ Subscription ____ Gift

____ 1 Year ($4.00) ____ 3 Years ($10.00)

NAME ______________________________

ADDRESS ______________________________

______________________________ ZIP __________

(If Gift, From: ______________________________)

ORDER FORM - CUT ON DASHED LINE

Available publications

MISCELLANEOUS PAPERS	Price	No. Copies	Amount
1. A description of some Oregon rocks and minerals, 1950: Dole	$ 1.00		
4. Laws relating to oil, gas, and geothermal exploration and development in Oregon			
Part 1. Oil and natural gas rules and regulations, 1977, rev. 1979	1.00		
Part 2. Geothermal resources rules and regulations, 1977, rev. 1979	1.00		
5. Oregon's gold placers (reprints), 1954	.50		
6. Oil and gas exploration in Oregon, rev. 1965: Stewart and Newton	3.00		
7. Bibliography of theses on Oregon geology, 1959: Schlicker	.50		
Supplement, 1959-1965: Roberts	.50		
8. Available well records of oil and gas exploration in Oregon, rev. 1973: Newton	1.00		
11. Collection of articles on meteorites, 1968 (reprints from *The Ore Bin*)	1.50		
13. Index to *The Ore Bin,* 1950-1974	1.50		
14. Thermal springs and wells, 1970: Bowen and Peterson (with 1975 supplement)	1.50		
15. Quicksilver deposits in Oregon, 1971: Brooks	1.50		
16. Mosaic of Oregon from ERTS-1 imagery, 1973	2.50		
18. Proceedings of Citizens' Forum on potential future sources of energy, 1975	2.00		
19. Geothermal exploration studies in Oregon – 1976, 1977	3.00		
20. Investigations of nickel in Oregon, 1978: Ramp	5.00		
GEOLOGIC MAPS			
Geologic map of Galice Quadrangle, Oregon, 1953	1.50		
Geologic map of Albany Quadrangle, Oregon, 1953	1.00		
Reconnaissance geologic map of Lebanon Quadrangle, 1956	1.50		
Geologic map of Bend Quadrangle and portion of High Cascade Mountains, 1957	1.50		
Geologic map of Oregon west of 121st meridian, 1961	2.25		
Geologic map of Oregon east of 121st meridian, 1977	3.75		
GMS-3: Preliminary geologic map of Durkee Quadrangle, Oregon, 1967	2.00		
GMS-4: Oregon gravity maps, onshore and offshore, 1967 (folded)	3.00		
GMS-5: Geologic map of Powers Quadrangle, Oregon, 1971	2.00		
GMS-6: Preliminary report on geology of part of Snake River Canyon, 1974	6.50		
GMS-7: Geology of the Oregon part of the Baker Quadrangle, Oregon, 1976	3.00		
GMS-8: Complete Bouguer gravity anomaly map, Cascade Mountain Range, central Oregon, 1978	3.00		
GMS-9: Total field aeromagnetic anomaly map, Cascade Mountain Range, central Oregon, 1978	3.00		
GMS-10: Low- to intermediate-temperature thermal springs and wells in Oregon, 1978	2.50		
GMS-11: Preliminary geothermal resource map of Oregon (upon written request only)	free	(one copy per customer)	
GMS-12: Geologic map of the Oregon part of the Mineral quadrangle	2.50		
OIL AND GAS INVESTIGATIONS			
3. Preliminary identifications of foraminifera, General Petroleum Long Bell #1 well	2.00		
4. Preliminary identifications of foraminifera, E.M. Warren Coos County 1-7 well, 1973	2.00		
5. Prospects for natural gas production or underground storage of pipeline gas	5.00		
MISCELLANEOUS PUBLICATIONS			
Landforms of Oregon (17 × 12 inches)	.50		
Mining claims (State laws governing quartz and placer claims)	.50		
Geological highway map, Pacific NW region, Oregon-Washington (published by AAPG)	3.00		
Fifth Gold and Money Session and Gold Technical Session Proceedings, 1975	5.00		
Sixth Gold and Money Session and Gold Technical Session Proceedings, 1978	6.50		
Back issues of *The Ore Bin*	25¢ over the counter; 50¢ mailed		
Colored postcard, *Geology of Oregon*	10¢ each; 3 for 25¢; 7 for 50¢; 15 for 1.00		

OREGON GEOLOGY

1069 State Office Building, Portland, Oregon 97201

Second Class Matter
POSTMASTER: Form 3579 requested

Available publications (continued)

BULLETINS	Price	No. Copies	Amount
33. Bibliography (1st supplement) geology and mineral resources of Oregon, 1947: Allen	1.00	____	____
36. Papers on Tertiary foraminifera: Cushman, Stewart and Stewart, 1949: v. 2	1.25	____	____
39. Geology and mineralization of Morning Mine region, 1948: Allen and Thayer	1.00	____	____
44. Bibliography (2nd supplement) geology and mineral resources of Oregon, 1953: Steere	2.00	____	____
46. Ferruginous bauxite deposits, Salem Hills, 1956: Corcoran and Libbey	1.25	____	____
49. Lode mines, Granite mining district, Grant County, Oregon, 1959: Koch	1.00	____	____
53. Bibliography (3rd supplement) geology and mineral resources of Oregon, 1962: Steere and Owen	3.00	____	____
57. Lunar Geological Field Conference guidebook, 1965: Peterson and Groh, editors	3.50	____	____
62. Andesite Conference guidebook, 1968: Dole	3.50	____	____
63. Sixteenth biennial report of the Department, 1966-1968	1.00	____	____
64. Mineral and water resources of Oregon, 1969 (unbound, without maps and tables)	2.00	____	____
65. Proceedings of Andesite Conference, 1969: (copies)	10.00	____	____
67. Bibliography (4th supplement) geology and mineral resources of Oregon, 1970: Roberts	3.00	____	____
68. Seventeenth biennial report of the Department, 1968-1970	1.00	____	____
71. Geology of selected lava tubes in Bend area, Oregon, 1971: Greeley	2.50	____	____
72. Bedrock geology of the Mitchell Quadrangle, Wheeler County, 1971	3.00	____	____
76. Eighteenth biennial report of the Department, 1970-1972	1.00	____	____
77. Geologic field trips in northern Oregon and southern Washington, 1973	5.00	____	____
78. Bibliography (5th supplement) geology and mineral resources of Oregon, 1973: Roberts	3.00	____	____
79. Environmental geology inland Tillamook and Clatsop Counties, 1973: Beaulieu	7.00	____	____
81. Environmental geology of Lincoln County, 1973: Schlicker and others	9.00	____	____
82. Geologic hazards of Bull Run Watershed, Multnomah, Clackamas Counties, 1974: Beaulieu	6.50	____	____
83. Eocene stratigraphy of southwestern Oregon, 1974: Baldwin	4.00	____	____
84. Environmental geology of western Linn County, 1974: Beaulieu and others	9.00	____	____
85. Environmental geology of coastal Lane County, 1974: Schlicker and others	9.00	____	____
86. Nineteenth biennial report of the Department, 1972-1974	1.00	____	____
87. Environmental geology of western Coos and Douglas Counties, 1975	9.00	____	____
88. Geology and mineral resources of upper Chetco River drainage, 1975: Ramp	4.00	____	____
89. Geology and mineral resources of Deschutes County, 1976	6.50	____	____
90. Land use geology of western Curry County, 1976: Beaulieu	9.00	____	____
91. Geologic hazards of parts of northern Hood River, Wasco, and Sherman Counties, Oregon, 1977: Beaulieu	8.00	____	____
92. Fossils in Oregon (reprinted from *The Ore Bin*), 1977	4.00	____	____
93. Geology, mineral resources, and rock material of Curry County, Oregon, 1977	7.00	____	____
94. Land use geology of central Jackson County, Oregon, 1977: Beaulieu	9.00	____	____
95. North American ophiolites, 1977	7.00	____	____
96. Magma genesis: AGU Chapman Conference on Partial Melting, 1977	12.50	____	____
97. Bibliography (6th supplement) geology and mineral resources of Oregon, 1971-75, 1978	3.00	____	____
98. Geologic hazards of eastern Benton County, 1979: Bela	9.00	____	____
SPECIAL PAPERS			
1. Mission, goals, and purposes of Oregon Department of Geology and Mineral Industries, 1978	2.00	____	____
2. Field geology of SW Broken Top Quadrangle, Oregon, 1978: Taylor	3.50	____	____
3. Rock material resources of Clackamas, Columbia, Multnomah, and Washington Counties, Oregon, 1978: Gray	7.00	____	____
4. Heat flow of Oregon, 1978, Blackwell, Hull, Bowen, and Steele	3.00	____	____
5. Analysis and forecasts of the demand for rock materials in Oregon, 1979	3.00	____	____
7. Pluvial Fort Rock Lake, Lake County, Oregon	4.00	____	____
SHORT PAPERS			
18. Radioactive minerals prospectors should know, 1976: White, Schafer, Peterson	.75	____	____
19. Brick and tile industry in Oregon, 1949: Allen and Mason	.20	____	____
21. Lightweight aggregate industry in Oregon, 1951: Mason	.25	____	____
24. The Almeda Mine, Josephine County, Oregon, 1967: Libbey	3.00	____	____
25. Petrography, type Rattlesnake Formation, central Oregon, 1976: Enlows	2.00	____	____
27. Rock material resources of Benton County, 1978: Schlicker and others	4.00	____	____

OREGON GEOLOGY

formerly THE ORE BIN

published by the Oregon Department of Geology and Mineral Industries

VOLUME 42, NUMBER 2 FEBRUARY 1980

OREGON GEOLOGY

(ISSN 0164-3304)

VOLUME 42, NUMBER 2 FEBRUARY 1980

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

Main Office: 1069 State Office Building, Portland 97201, phone (503) 229-5580.

Baker Field Office: 2033 First Street, Baker 97814, phone (503) 523-3133.
Howard C. Brooks, Resident Geologist

Grants Pass Field Office: 312 S.E. "H" Street, Grants Pass 97526, phone (503) 476-2496.
Len Ramp, Resident Geologist

Mined Land Reclamation Program: 1129 S.E. Santiam Road, Albany 97321, phone (503) 967-2039.
Standley L. Ausmus, Supervisor

Subscription rates: 1 year, $4.00; 3 years, $10.00. Single issues, $.40 at counter, $.50 mailed.
Available back issues of *The Ore Bin:* $.25 at counter, $.50 mailed.

Address subscription orders, renewals, and changes of address to *Oregon Geology,* 1069 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,* 1069 State Office Building, Portland, OR 97201.

COVER PHOTO

Siskiyou Divide on the California-Oregon border; looking east from Jackson Gap. Field trip guide beginning on next page discusses the geology of this metamorphic terrane.

SMAC reports on year's activities

The purposes of the State Map Advisory Committee (SMAC) are to (1) recognize and pursue mapping goals for the State of Oregon; (2) promote coordination of programs, policies, and resources of the various agencies that make maps; and (3) bring the benefits of mapping more effectively to the people of Oregon. Through coordinated planning, SMAC also works to (1) effectively utilize all mapping resources, (2) improve mapping services to the State, and (3) minimize unnecessary duplication of effort.

Because of the inadequate topographic map coverage for the State of Oregon, SMAC during 1979 placed top priority on completion of the 7½-minute topographic map base. Plan development and communications involved SMAC, the U.S. Geological Survey, the Office of the Governor, and the Congressional Delegation. An eight-year plan for completion of the State's 7½-minute topographic map base has been developed.

At SMAC's meeting held December 14, 1979, in Salem, State agencies identified topographic mapping priorities in groups and quantities consistent with the eight-year plan, the logistic requirements of regional mapping, and the priorities of Federal agencies. These priorities are overlain with Federal input in developing mapping strategies for the State.

Other major SMAC activities during 1979 included (1) presentation of mapping functions and services of the U.S. Geological Survey; (2) participation in the pilot computerized map index project for the NCIC of the U.S. Geological Survey; (3) brief examination of SLAR imagery with emphasis on its application and limitations; (4) progress toward the completion of a brochure of map products available to the public from the many agencies in the State; (5) participation in a peripheral manner in the ongoing evaluation of the possible benefits of computer hardware and software as they relate to the map needs of Oregon (primary responsibility for this function resides in the Executive Department); and (6) representation of the State of Oregon on a regional and national basis for the development of a topographic map program for Oregon. □

CONTENTS

Geologic field trip guide through the north-central Klamath Mountains

by *M.A. Kays, Geology Department, University of Oregon, Eugene 97403; and*
M.L. Ferns, Oregon Department of Geology and Mineral Industries, Baker Field Office, Baker 97814

INTRODUCTION

This field trip guide summarizes geologic relations in the north-central Klamath Mountains of northern California and adjacent Oregon (Figure 1). The geology of the area is notable for the great diversity in metamorphic and plutonic rock types and for the structural complexities of the various lithologic units. In preparing the field trip guide, we have drawn from the geology described in several publications by Hotz (1967; 1971a, b; 1979) and in a number of unpublished doctoral dissertations (Pratt, 1964; Medaris, 1966; Barrows, 1969) and masters' theses (Engelhardt, 1966; Heinrich, 1966; Donato, 1975; Ferns, 1979). The field trip guide also includes results of unpublished mapping and field studies by the University of Oregon Geology Summer Field Camp in the southern parts of the Talent and Ashland quadrangles in Oregon.

Two important and obvious geologic features observed in traversing the area of this field trip guide are (1) progressively metamorphosed western Paleozoic and Triassic belt rocks which range in grade from greenschist to amphibolite facies, and (2) greenschist-facies Condrey Mountain Schist which also contains glaucophane-crossite and stilpnomelane. The progressively metamorphosed sequence, with grade increasing structurally downward, is sharply juxtaposed with and separated from the underlying glaucophanitic greenschist-facies rocks. The rocks of the western Paleozoic and Triassic belt and the Condrey Mountain Schist have overlapping radiometric ages.

This field trip guide was prepared for the 76th Annual Meeting of the Cordilleran Section of the Geological Society of America, which will be held in March, 1980, in Corvallis, Oregon.

SALIENT FEATURES OF THE REGIONAL GEOLOGIC SETTING

Rock units and their ages

In the northern and approximately central parts of the area of this field trip guide (Figure 1), rocks of the western Paleozoic and Triassic belt are sharply juxtaposed with the Condrey Mountain Schist along a folded thrust fault. Evidence obtained from mapping along the Klamath River at the contact of the Paleozoic and Triassic belt with the western Jurassic belt Galice Formation suggests that Galice rocks served as the protolith for the Condrey Mountain Schist (Klein, 1977). However, this interpretation is presently incompatible with the presumed age of the Galice Formation and the metamorphic ages obtained for the Condrey Mountain Schist (Lanphere and others, 1968; Suppe and Armstrong, 1972).

Granitoid rocks of dominantly Late Jurassic age abundantly intrude the western Paleozoic and Triassic belt rocks but are rather scarce in the Condrey Mountain Schist. Hotz (1971a) reports potassium-argon mineral ages ranging from 146 to 160 m.y. obtained from biotite and hornblende separates from the plutons of the field trip guide area. The plutonic rocks range in composition from diorite through quartz monzonite, but quartz diorite is most plentiful.

Serpentinized peridotite occurs in sheet-like bodies tectonically interleaved and folded together mostly with amphibolite-facies metamorphosed western Paleozoic and Triassic belt rocks. Pyroxenite and gabbro occur usually as smaller bodies within or closely associated with serpentinized peridotite. However, it is not clear in all cases how the gabbro and pyroxenite are related. In some places, both are metamorphosed and have mineral assemblages consistent with those of their host peridotite.

Metamorphism

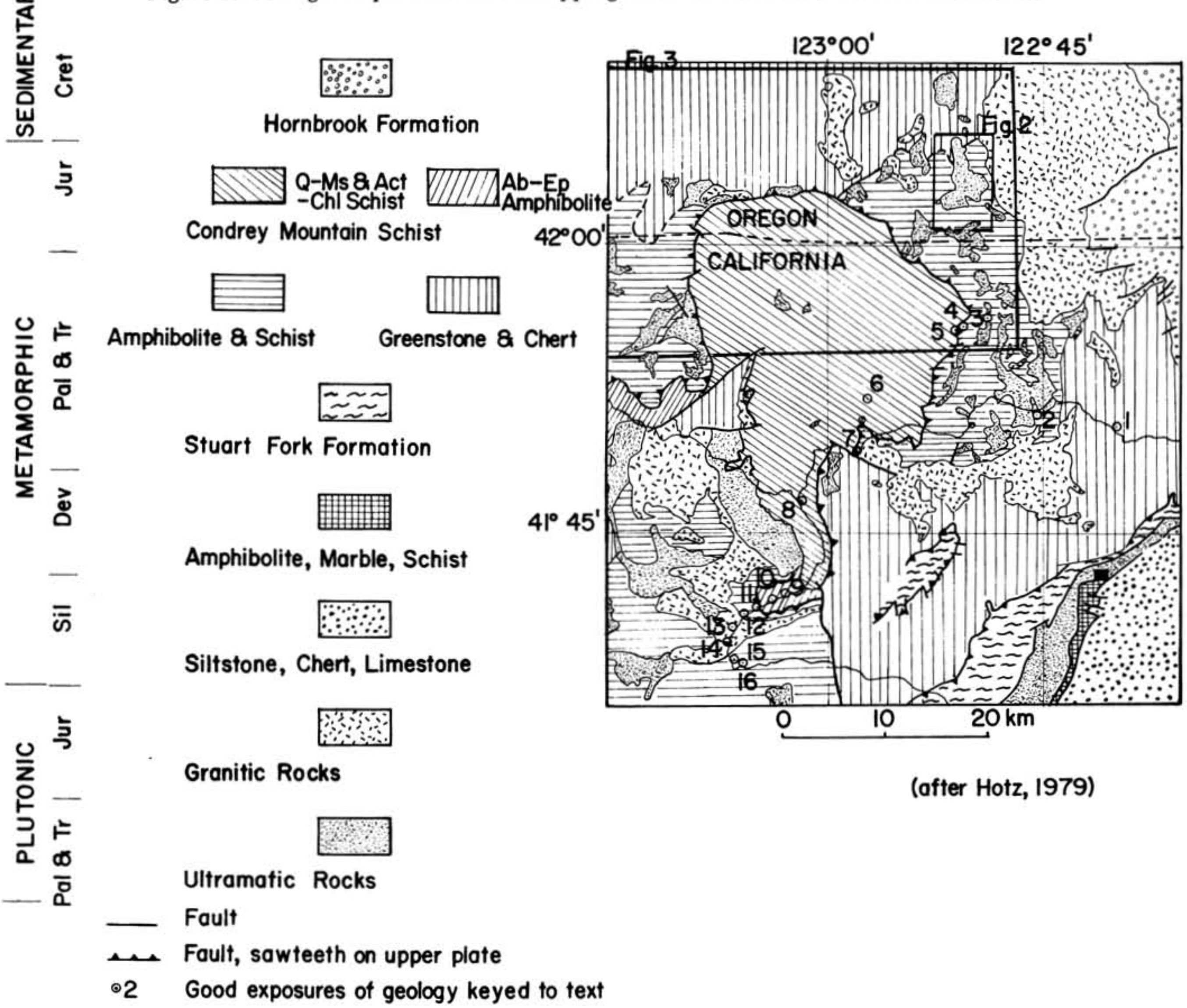
The grade of metamorphism in the Paleozoic and Triassic belt rocks generally increases toward the contact with the underlying Condrey Mountain Schist. For example, in traversing westward from Interstate 5 on California State Highway 96 along the Klamath River, the grade of metamorphism in Paleozoic and Triassic belt rocks changes from feebly metamorphosed greenschist-facies metabasalt with relict volcanic textures to thoroughly recrystallized, medium-grade amphibolite-facies schists and gneisses. The metamorphic grade increases toward the contact with the underlying Condrey Mountain Schist, and upon crossing that boundary there is a sharp reversal in grade to glaucophanitic greenschist facies. As Donato and others point out in an article to be printed later this year in *Oregon Geology*, the presumption is that glaucophane and crossite (± stilpnomelane) are distributed more abundantly in the structurally lower levels of the Condrey Mountain Schist. The mineral assemblage suggests a higher pressure, lower temperature metamorphism for these schists. The overlap in metamorphic ages of the western Paleozoic and Triassic belt schists and gneisses and the Condrey Mountain Schist (Lanphere and others, 1968; Suppe and Armstrong, 1972; Kays and others, 1977) and the distribution of metamorphic facies in these terranes suggest that structural juxtaposition was accompanied by recrystallization in both terranes.

Structure

Detailed mapping by Hotz (1967), Ferns (1979), and Kays (unpublished) indicates that western Paleozoic and Triassic belt rocks are cut by thrust faults. The thrust planes are marked in the most obvious cases by the occurrence of ultramafic rocks. The thrust faults appear to represent zones of movement associated with emplacement of nappes or sheets of Paleozoic and Triassic rocks. An early and apparently primary foliation in the nappes is axial planar to large recumbent folds that are roughly concordant with the thrust planes. Detailed mapping in the Wrangle Gap-Red Mountain area (Ferns, 1979, and unpublished) and adjoining areas indicates that the thrust faults, the recumbent folds of nappes, and the metamorphosed assemblages in the western Paleozoic and Triassic belt rocks and Condrey Mountain Schist were all subsequently folded (Figures 2, 3, and 4).

In some places within the area covered by this field trip guide, especially to the east of the Condrey Mountain Schist, the western Paleozoic and Triassic belt rocks and serpentinized peridotites form a mélange. Mapping indicates that the mélange was subsequently folded, thus forming an unusual assemblage of broken, but

Figure 1. Geologic map and index to mapping in the north-central Klamath Mountains.



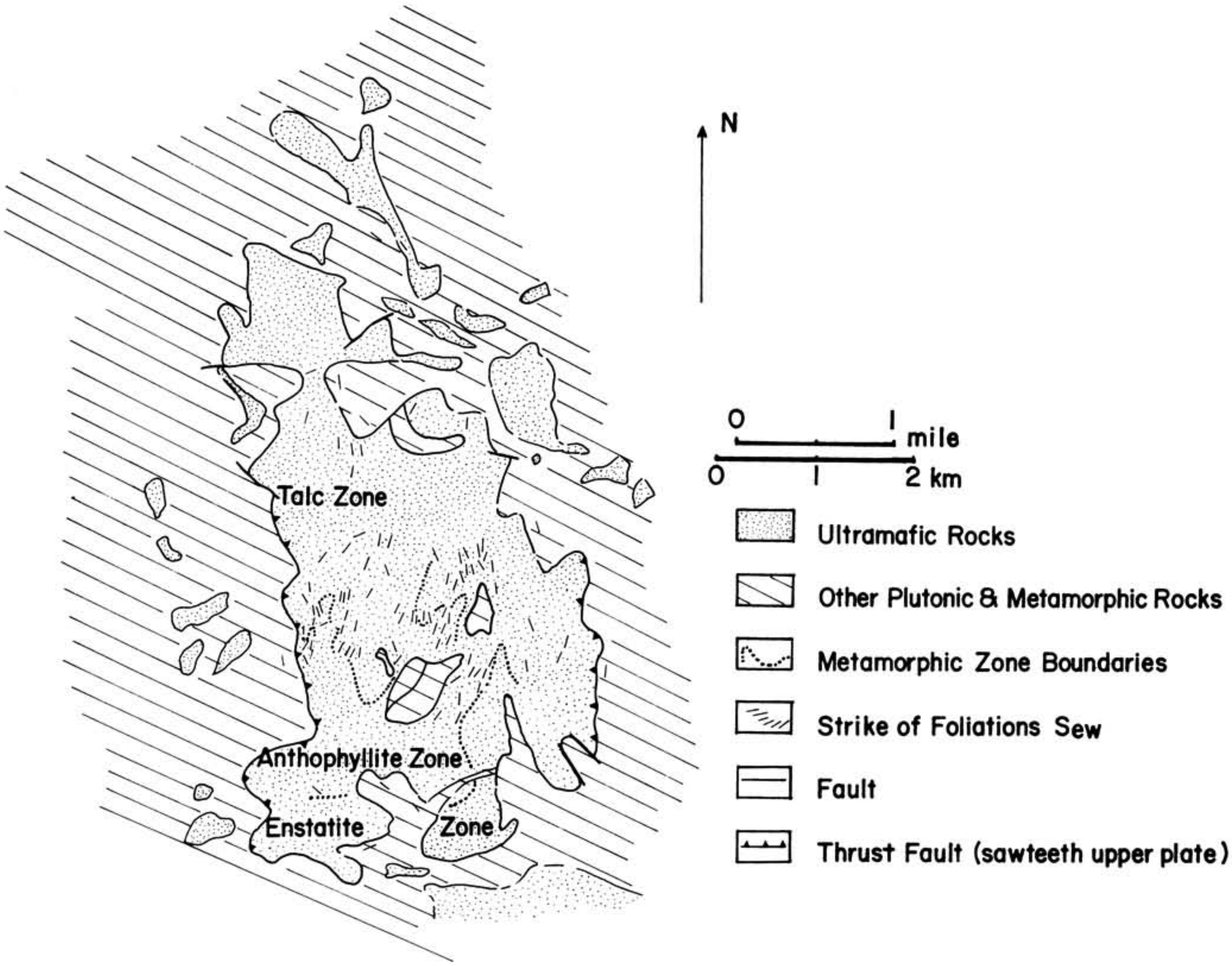


Figure 2. Folded nature of metamorphic isograds in the Wrangle Gap-Red Mountain ultramafic body (after Ferns, 1979).

coherently folded, and metamorphosed rocks. Since the same folds affect both the mélange and the parts that are not fragmented, the mélange must be related to early deformation that was apparently associated with nappe emplacement.

A regional compilation map (centerfold) of the northern part of the area of the field trip guide shows that the higher grade metamorphosed western Paleozoic and Triassic belt rocks and associated serpentinized ultramafic rocks end abruptly just to the north of the Oregon-California line. We interpret the boundary between higher grade and more feebly metamorphosed rocks as marking the northern termination of the napped sequence of Paleozoic and Triassic rocks. The boundary was affected at a later time by normal faulting.

We therefore interpret the axial planar foliation (S_{ew} in Figure 3), roughly coincident with the thrust planes that floor the nappes, as having evolved during or as a consequence of thrust movement. The dominant north-south-trending folds that affect all the pre-Tertiary rock units evolved through later east-west compression and crustal shortening that have in some places nearly obliterated the evidence for the early thrust movement. We term the axial planes of the later folds "S_{ns}" (Figure 3). Thus, the early recumbent folds were subsequently folded about axes that now trend approximately north-south. The last folding also affected the Condrey Mountain Schist. Donato and others will address the problem of the structure of these rocks in their upcoming *Oregon Geology* article. Relations between axial planes of folds, axial planar foliations, and later deformation are summarized in the sketches of Figure 3.

ROCK UNITS AND THEIR METAMORPHISM

The rock units briefly described in the following summary are presented in observed structural sequence

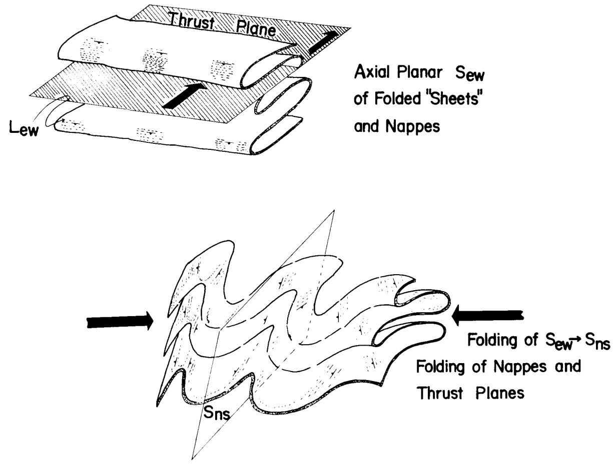


Figure 3. Presumed sequence of folding in western Paleozoic and Triassic belt rocks in the Wrangle Gap-Red Mountain area.

from lowest to highest. The stratigraphic relations between these rock units are poorly understood. Some of the correlations between metamorphosed units are tentative, but, it is hoped, "reasonable guesses." For more details than can be provided here, the reader is referred to the excellent summary by Hotz (1979) on the regional character of metamorphism in the north-central Klamath Mountains.

Condrey Mountain Schist

Since Donato and others will discuss the characteristics of these rocks at some length in their upcoming article, we restrict the following discussion to a brief summation of the salient features of the Condrey Mountain Schist. These rocks are thoroughly recrystallized schists of two main kinds (Hotz, 1979): (1) black to dark-grey graphitic quartz-mica schists, and (2) green actinolite-chlorite schists with glaucophane and stilpnomelane as important additional minerals that occur abundantly in certain zones within this rock unit. The very well-developed metamorphic fabric is the result of at least two episodes of folding and recrystallization. Hotz reports two main assemblages in the quartz-mica "blackschists": (1a) quartz-muscovite-albite-chlorite-graphite, and (1b) quartz-albite-muscovite-epidote-chlorite. There are three important assemblages in the actinolite-chlorite "greenschists": (2a) quartz-albite-actinolite-chlorite-epidote, (2b) albite-actinolite-chlorite-epidote-quartz-muscovite, and (2c) glaucophane-epidote-quartz-albite-chlorite-sphene.

Barrows (1969) has mapped interlayered "greenschist" and "blackschist" units exposed along the lower reaches of the Scott River near its confluence with the Klamath River. Hotz (1971b) correlates these units with the Condrey Mountain Schist. Both units have conformable quartz veins that are locally auriferous; quartz veins are especially abundant in graphitic micaceous schists. Barrows shows that the interlayered sequence of rocks grades upward into epidote-amphibolite-facies schists and gneisses along the Scott River between McGuffy Creek and Townsend Gulch. Barrows also indicates that the albite-epidote-blue-green-hornblende-bearing schists may grade upward to regionally metamorphosed amphibolite-facies plagioclose-hornblende ± garnet ± clinopyroxene schists and gneisses between Tompkins Creek and George Allen Gulch along the Scott River.

Amphibolite-facies Paleozoic and Triassic rocks

Rocks of this grade are widespread in a zone surrounding the Condrey Mountain Schist, as shown by Hotz (1979, Fig. 1, p. 3; 1971b, Plate 1). In the Condrey Mountain, Talent, Ruch, and Seiad Valley 15-minute quadrangles, amphibolites occur as foliated hornblende-plagioclase (An_{25-35})-sphene-(opaques) gneisses that are clinopyroxene bearing in places. Massive or unfoliated amphibolites also occur and consist of plagioclase (An_{25-35})-sphene-apatite-opaques. Metasedimentary rocks are interlayered and folded together with the amphibolites. The metasedimentary rocks are phyllites or schists and consist of quartz-biotite-sodic plagioclase ± muscovite ± garnet ± chlorite (after biotite). Graphitic quartz-rich schists are rather widespread and also contain minor biotite, tremolite, and, in some places, pyrite. Tourmaline-bearing quartzites are important members of the metasedimentary sequence.

In the Wrangle Gap-Red Mountain area, the metabasalts have amphibolite-facies mineral assemblages and show the same general patterns of metamorphic zonation as do the adjacent ultramafic rocks. Unfortunately, there are no clearly diagnostic mineral assemblages in the mafic rocks. However, some estimate of temperature-pressure conditions can be made from coexisting mineral phases in the metasedimentary rocks. The assemblages are (1) calcite-diopside-quartz in the marbles, (2) clinozoisite-quartz-hornblende-plagioclase-opaques in the graphitic cherts, and (3) garnet-biotite-potassium feldspar-muscovite-sillimanite in the micaceous quartzites. A rough petrogenetic grid based on experimentally determined reaction equilibria (approximately the same as those observed) is considered in a later section along with other equilibria recognized in the ultramafic rocks. The grid serves to bracket conditions of peak metamorphism in the amphibolite-facies rocks.

Greenschist-facies Paleozoic and Triassic rocks

Predominantly basic and spilitic metavolcanic rocks occur interlayered with siliceous metasedimentary rocks at higher structural levels in the area covered by this field trip guide. These rocks apparently grade downward into higher grade amphibolite-facies rocks, as previously described. However, there are complexities caused by the thrust faults and "Schuppen-like" or mélange sequence, and the interpretation assumes that a uniform thermal gradient existed through these disturbed zones of rocks.

The least metamorphosed rocks have relict volcanic textures and structures including pillows, rubbly scoriaceous zones, muddy inter-pillow material, and "vesicularity" developed through weathering of amygdaloidal calcite fillings within pillows. Usually the thin, glassy pillow selvages show a higher degree of recrystallization. As Hotz (1979) indicates, these low-grade rocks have no apparent metamorphic fabrics but do contain albite, chlorite, veinlets of carbonate, and local prehnite. Well-formed relict phenocrysts of clinopyroxenes occur in some places. More completely recrystallized metavolcanic rocks also contain actinolite, biotite, clinozoisite-epidote, and sphene, in addition to those minerals already mentioned. These metavolcanic rocks are frequently referred to as greenstone.

The metasedimentary rocks interlayered with the low-grade metavolcanic rocks are dark-gray to black argillite, recrystallized chert, and rare lenticular beds of marble. At lowest grade, assemblages in argillaceous rocks consist of quartz-muscovite-organic matter with chlorite and local albite and actinolite; at higher grade, biotite replaces chlorite (Hotz, 1979). Calcite is locally abundant in the slaty or argillaceous rocks.

Metamorphosed ultramafic rocks

In the area covered by this field trip guide, ultramafic rocks are mostly serpentinized and occur as conformable, folded sheets, their mineralogy consistent with that of the surrounding metamorphosed rocks. Evans (1977) has shown that the mineralogy of such peridotites as these may be diagnostic of metamorphic grade for rock compositions in the system CaO-MgO-SiO_2 and closely approaching initial compositions in the $CaMgSi_2O_6$ (diopside)-Mg_2SiO_4 (forsterite)-$Mg_2Si_2O_6$ (enstatite) triangle (Figure 4). Frequently, too, the ultramafic rocks are tectonically interleaved or folded together with amphibolite-facies rocks, and there is a tendency for the surrounding rocks to become higher grade with proximity to the ultramafic sheets.

The general consistency between mineral assemblages and structures of the ultramafic rocks is well illustrated in the Wrangle Gap-Red Mountain area. Here, Ferns (1979) has shown that several equilibria among minerals of the ultramafic rocks define (1) a talc zone in which olivine and tremolite may also be present, (2) a zone characterized by anthophyllite and tremolite whose formation may be dependent on instability of the assemblage talc + olivine, and (3) an enstatite zone in which enstatite interrupts anthophyllite-olivine stability (Figures 2 and 4). Antigorite or some other variety of serpentine mineral and diopside are also commonly present. The equilibria defining temperature-pressure conditions for the Wrangle Gap-Red Mountain ultramafic body are summarized below and in Figure 4:

$$\text{Antigorite} = 18\ \text{forsterite} + 4\ \text{talc} + 27\ H_2O \quad (1)$$

$$9\ \text{talc} + 4\ \text{forsterite} = 5\ \text{anthophyllite} + H_2O \quad (2)$$

$$\text{Talc} + \text{forsterite} = 5\ \text{enstatite} + H_2O \quad (3)$$

$$\text{Anthophyllite} + \text{forsterite} = 9\ \text{enstatite} + H_2O \quad (4)$$

$$5\ \text{chrysotile} = 6\ \text{forsterite} + \text{talc} + 9\ H_2O \quad (5)$$

$$2\ \text{diopside} + \text{talc} = \text{tremolite} \quad (6)$$

$$\text{Tremolite} + \text{forsterite} = 2\ \text{diopside} + 5\ \text{enstatite} + H_2O \quad (7)$$

$$\text{Clinochlore} = \text{forsterite} + \text{spinel} + 2\ \text{enstatite} + 4\ H_2O \quad (8)$$

Since there are presently no compositional data on mineral phases at Wrangle Gap-Red Mountain, temperature-pressure estimates are based on pure mineral phase equilibria. We also assume $P_{H_2O} = P_{total}$ and that P_{CO_2} was low or insignificant, which seems a reasonable assumption in that carbonate phases are absent in the serpentinized peridotite. Note then that the occurrence of chlorite and tremolite in all three zones indicates that recrystallization conditions must lie within the tremolite + olivine stability field. This field is bounded by the reaction curves for equilibria (6) and (7) and is roughly correlative with amphibolite-facies metamorphism. The olivine + anthophyllite assemblage places further restrictions on the temperature-pressure conditions at Wrangle Gap-Red Mountain. Experimentally determined curves for (2) and (4) will bracket these conditions if $P_{H_2O} = P_{total}$.

The serpentinized peridotite has certain characteristics which suggest a serpentinite protolith was subsequently metamorphosed. Thus, mapped isograds in peridotite reflect regional changes in temperature-pressure conditions during metamorphism. Since space does not permit a detailed presentation of all evidence for prograde recrystallization of a serpentinite protolith, the important characteristics are summarized below (after Ferns, 1979):

(1) There is a consistent, zonal pattern in the way in which enstatite, talc, and anthophyllite are distributed in the peridotite (Figure 2).

(2) Large, elongate anthophyllite crystals occur in radiating clusters, a texture consistent with metamorphic recrystallization of serpentinized peridotite (Moore and Qvale, 1977).

(3) The harzburgites are uniformly low in CaO and Al_2O_3, characteristics which Evans (1977) suggests reflect serpentinized parents.

(4) The calc-silicate zones which have developed along the borders of tectonic gneiss blocks within the ultramafic body have mineral assemblages which indicate amphibolite-facies metamorphism (reaction 11, Figure 5). These rocks are apparently metamorphosed rodingites which form initially only under low temperatures of serpentinization (Coleman, 1967).

(5) Both olivine and enstatite are generally free of opaque inclusions. Recrystallization temperatures and pressures for the Wrangle Gap-Red Mountain prograde metamorphism can be estimated from the combined petrogenetic grids for assemblages recognized in the ultramafic and associated metasedimentary rocks and metarodingites (Figure 5). Bracketing by equilibrium in the ultramafic and associated metamorphosed rocks gives the range 570 to 720°C and 2.8 to 5.2 kb.

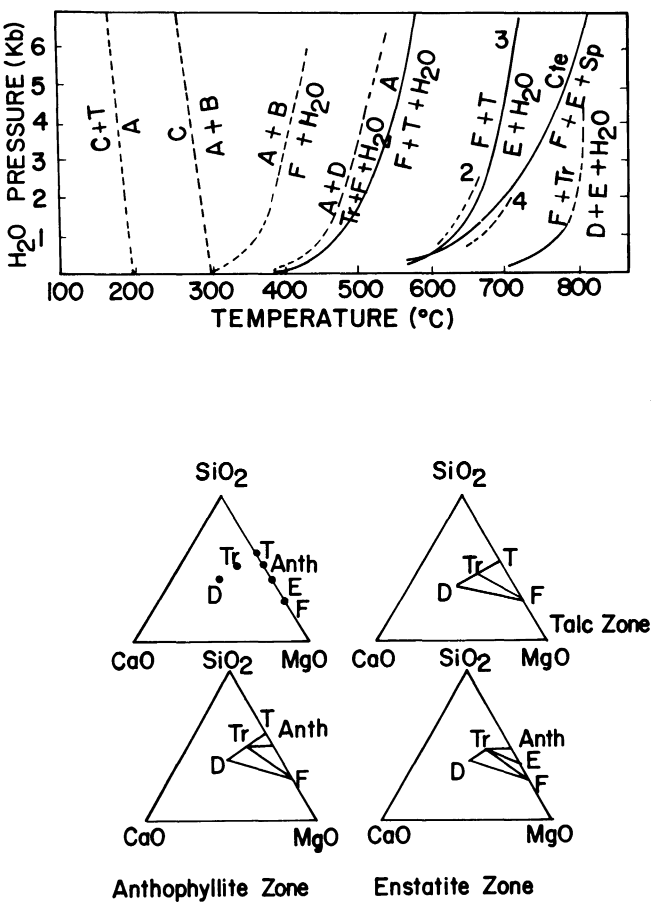


Figure 4. Metamorphic equilibria defining conditions of peak metamorphism in the ultramafic rocks. Ultramafic mineral assemblages in the system CaO-MgO-SiO_2. Abbreviations used are as follows: Clinochlore (C), antigorite (A), brucite (B), talc (T), forsterite (F), diopside (D), tremolite (Tr), enstatite (E), chlorite (Cte), and spinel (Sp).

PLUTONIC ROCK UNITS

Hotz (1971a) has studied and described the petrographic features and chemical compositions of plutons in the Klamath Mountains and reported their ages. We therefore provide only a brief summary of the major varieties of plutonic rock types and some of their outstanding features. For more information than can be included here, the reader is referred to the article by Hotz.

Gabbro-pyroxenite

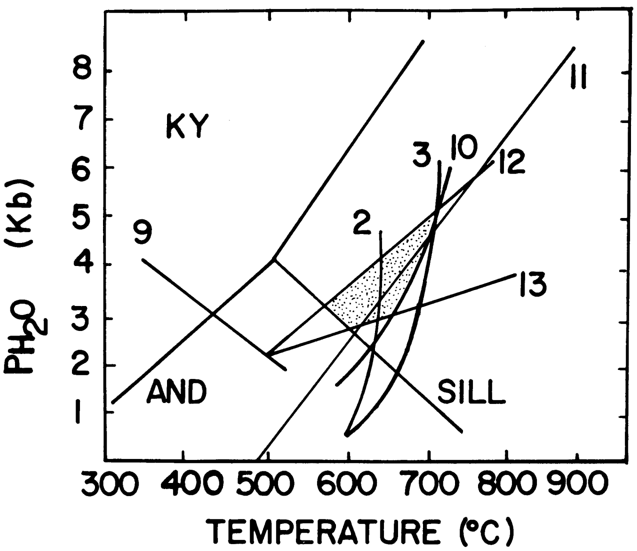
Small bodies of calcium-rich ultramafic rocks in the compositional range clinopyroxenite-wehrlite-pyroxene gabbro are generally associated with larger bodies of serpentinized peridotite. Only a few bodies have an areal distribution of more than 1 km². Where they occur in peridotite, the bodies frequently have tectonized, sheared boundaries. The bodies may be strongly banded with alternating layers of clinopyroxene or tremolite and partially serpentinized olivine-rich layers.

The gabbro bodies may be clinopyroxene bearing, but the pyroxenes are sometimes altered to hornblende. The contact relations of the gabbro bodies are in many places obscured by later deformation, but contacts appear to be intrusive into peridotite. Metamorphic fabrics are quite variable and range from well-developed gneissic fabrics to directional fabrics with only weak, mafic mineral preferred orientation.

Late Jurassic plutons

Granitoid plutonic rocks are plentiful as small stocks less than a mile in diameter but also occur with outcrop area of 150 km² or more, as in the case of the Ashland pluton. The larger plutons tend to be elongate with their long axes parallel to the north-south arcuate trend of the Klamath Mountains province. The plutons range in composition from diorite and gabbro to quartz monzonite, with quartz diorite (tonalite) being most widespread.

Donato (1975) has shown that a 75-km² portion of the Ashland pluton consists of all the above-mentioned rock types. The pluton has a strongly foliated western margin consisting, from west to east, of hornblende tonalite, hornblende granodiorite, and hornblende quartz monzonite. Further eastward, there is granular, unfoliated biotite granodiorite and biotite quartz monzonite. Large xenolithic blocks of hornblende diorite occur throughout the biotite-bearing quartz monzonite-



(2) $9T + 4F = 5Anth + H_2O$

(3) $T + F = E + H_2O$

(9) $Crd + Ms_{ss} = Bio + Als + Q + Ab_{ss} + H_2O$

(10) $Ms + Q = Sill + Ksp + H_2O$

(11) $Gr + Q = An + 2Wo$

(12) $Ms_{ss} + Ab_{ss} + Q = Ksp_{ss} + Als + H_2O$

(13) $Bio_{ss} + Ab_{ss} + Q + Als = Ksp_{ss} + Crd + H_2O$

Figure 5. Metamorphic equilibria defining conditions of peak metamorphism in Paleozoic and Triassic belt rocks. Stippled area represents possible temperature-pressure regime. Abbreviations used are the same as in Figure 4 and as follows: Anthophyllite (Anth), cordierite (Crd), muscovite (Ms), biotite (Bio), aluminum silicate (Als), quartz (Q), albite (Ab), sillimanite (Sill), K-feldspar (Ksp), grossular (Gr), anorthite (An), wollastonite (Wo), and solid solution subscript (ss).

granodiorite but are restricted to smaller disk-shaped schlieren in the more mafic, hornblende-bearing rock types of the western margin.

CONCLUSION

The increase in grade of metamorphism in the western Paleozoic and Triassic belt rocks toward structurally lower levels of the plate and the association there with abundant, tectonically interleaved sheets of ultramafic rocks are probably not fortuitous. We interpret the increase in grade and the association of rock types to be a normal "view" downward through deformed oceanic floor, culminating in a disrupted ophiolitic sequence. The increase in grade of metamorphism with proximity to the ultramafic rocks may reflect the oceanic geotherm near to the oceanic ridge in the western Paleozoic and Triassic belt crustal sequence.

Subduction of the western Jurassic belt rocks or thrusting of the western Paleozoic and Triassic belt rocks may have initiated in response to collapse of a Jurassic back-arc basin. The basin fronted the continental crustal section to the southeast and rested on an oceanic floor of western Paleozoic and Triassic belt rocks continuing below the continental margin. Early deformation-folding of the lower part of the oceanic sequence with disrupted-interleaved ultramafic rocks may have developed before decay of the oversteepened oceanic geotherm. Late folding of the juxtaposed sequence of western Paleozoic and Triassic belt rocks and the underlying Condrey Mountain Schist may have developed in response to Late Jurassic Pacific-North American Plate convergence.

ACKNOWLEDGMENTS

The authors wish to thank Mary Donato of the U.S. Geological Survey for her help in preparing and editing this field trip guide.

REFERENCES

Barrows, A.G., 1969, Geology of the Hamburg-McGuffy Creek area, Siskiyou County, California, and petrology of the Tom Martin ultramafic complex, California: Los Angeles, Calif., University of California doctoral dissertation, 301 p.

Coleman, R.G., 1967, Low-temperature reaction zones and Alpine ultramafic rocks of California, Oregon, and Washington: U.S. Geological Survey Bulletin 1247, 49 p.

Donato, M.M., 1975, The geology and petrology of a portion of the Ashland pluton, Jackson County, Oregon: Eugene, Oreg., University of Oregon master's thesis, 89 p.

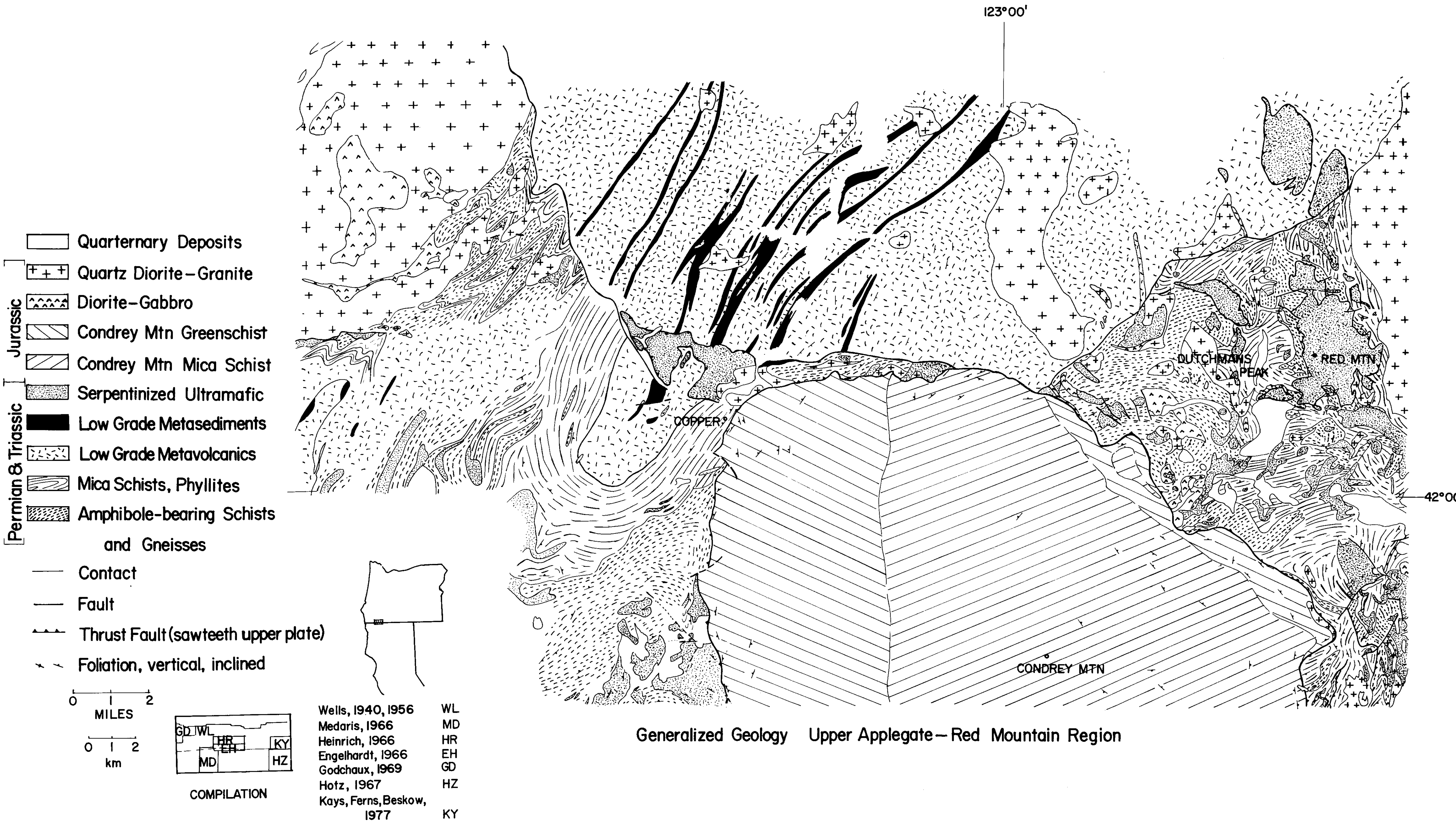
Donato, M.M., Coleman, R.G., and Kays, M.A., 1980, Geology of the Condrey Mountain Schist, northern Klamath Mountains, California and Oregon: Oregon Department of Geology and Mineral Industries, Oregon Geology [in press].

Engelhardt, C.L., 1966, The Paleozoic-Triassic contact in the Klamath Mountains, Jackson County, southwest Oregon: Eugene, Oreg., University of Oregon master's thesis, 98 p.

Ernst, W.G., 1973, Interpretative synthesis of metamorphism in the Alps: Geological Society of America Bulletin, v. 84, no. 6, p. 2053-2078.

Evans, B.W., 1977, Metamorphism of Alpine peridotite and serpentine: Annual Review of Earth and Planetary Science, v. 5, p. 397.

Ferns, M.L., 1979, The petrology and petrography of the Wrangle



Geologic map compilation for the northernmost part of the field trip guide.

Gap-Red Mountain ultramafic body, Klamath Mountains, Oregon: Eugene, Oreg., University of Oregon master's thesis, 124 p.

Godchaux, M.M., 1969, Petrology of the Greyback igneous complex and contact aureole, Klamath Mountains, southwestern Oregon: Eugene, Oreg., University of Oregon doctoral dissertation, 223 p.

Heinrich, M.A., 1966, Geology of the Applegate Group, Kinney Mountain area, southwest Jackson County, Oregon: Eugene, Oreg., University of Oregon master's thesis, 107 p.

Hotz, P.E., 1967, Geologic map of the Condrey Mountain quadrangle and parts of the Seiad Valley and Hornbrook quadrangles, California: U.S. Geological Survey Geological Quadrangle Map GQ-618, scale 1:62,500.

——— 1971a, Plutonic rocks of the Klamath Mountains, California and Oregon: U.S. Geological Survey Professional Paper 684-B, 20 p.

——— 1971b, Geology of the lode gold districts in the Klamath Mountains, California and Oregon: U.S. Geological Survey Bulletin 1290, 91 p.

——— 1979, Regional metamorphism in the Condrey Mountain quadrangle, north-central Klamath Mountains, California: U.S. Geological Survey Professional Paper 1086, 25 p.

Kays, M.A., Ferns, M.L., and Beskow, L., 1977, Complementary meta-gabbros and peridotites in the northern Klamath Mountains, U.S.A., *in* Dick, H.J.B., ed., Magma genesis: Oregon Department of Geology and Mineral Industries Bulletin 96, p. 91-107.

Klein, C.W., 1977, Thrust plates of the north-central Klamath Mountains near Happy Camp, California: California Division of Mines and Geology Special Publication 28, p. 23-26.

Lanphere, M.A., Irwin, W.P., and Hotz, P.E., 1968, Isotopic age of the Nevadan orogeny and older plutonic and metamorphic events in the Klamath Mountains, California: Geological Society of America Bulletin, v. 79, no. 8, p. 1027-1052.

Medaris, L.G., 1966, Geology of the Seiad Valley area, Siskiyou County, California, and petrology of the Seiad ultramafic complex: Los Angeles, Calif., University of California doctoral dissertation, 359 p.

Moore, A.C., and Qvale, H., 1977, Three varieties of Alpine-type ultramafic rocks in the Norwegian Caledonides and Basal Gneiss Complex: Lithos, v. 10, p. 150.

Pratt, W.P., 1964, Geology of the Marble Mountain area, Siskiyou County, California: Palo Alto, Calif., Stanford University doctoral dissertation, 116 p.

Suppe, J., and Armstrong, R.L., 1972, Potassium-argon dating of Franciscan metamorphic rocks: American Journal of Science, v. 171, no. 3, p. 217-233.

Wells, F.G., 1940, Preliminary geologic map of the Grants Pass quadrangle, Oregon: Oregon Department of Geology and Mineral Industries map, scale 1:96,000.

——— 1956, Geology of the Medford quadrangle, Oregon-California: U.S. Geological Survey Geological Quadrangle Map GQ-89, scale 1:96,000.

ROAD LOG

(See Figure 1 for route and stops as indicated below.)

Km	Mi	
0.0	0.0	Begin mileage, intersection of Interstate 5 and California Highway 96, which follows the Klamath River. On this part of the field trip we will observe an increase in metamorphic grade in Paleozoic and Triassic belt rocks. We begin here in feebly metamorphosed metavolcanic rocks with relict textures and poorly developed or nonexistent metamorphic fabrics. Apparently, the rocks are oceanic and include pillowed lavas, flow breccias, and interlayered cherts, cherty argillites, etc. We will proceed through low-grade greenschist-facies rocks, presumably rather high in the pile, through to amphibolite-facies schists and gneisses with good metamorphic fabrics toward the base of the sequence of Paleozoic and Triassic belt rocks. At the base, the amphibolite-facies schists and gneisses are in thrust contact with the underlying Condrey Mountain Schist.
3.5	2.2	Old highway to Yreka.
6.6	4.1	Ash Creek bridge.
10.4	6.5	Turnoff to Tree of Heaven Campground.
12.0	7.5	**Stop 1.** The Paleozoic and Triassic belt pillowed lava sequence begins here and continues for a short distance. The pillows are well formed and may have relict "pseudo-vesicles" owing to weathering of amygdaloidal fillings. Other relict features include well-formed augite phenocrysts.
14.1	8.8	Lime Gulch.
20.0	12.5	Empire Creek.
22.7	14.2	**Stop 2.** Beginning of roadcut with non-foliated, low-grade amphibolite-facies rocks, with relict porphyritic texture locally (Hotz, 1967). The amphibolites are tectonically interleaved with the surrounding ultramafic rocks.
27.8	17.4	Beaver Creek road; turn right.
29.0	18.1	Smith Mine road.
29.4	18.4	Outcrop, folded fine-grained biotite schist.
32.2	20.1	Outcrop, biotite schist and amphibolite gneiss, apparently interlayered. The schist is fine grained and has a good cleavage. The amphibolite is fine to medium grained and is composed of plagioclase and hornblende. The hornblende has a good pre-

Km	Mi	
		ferred elongation.
33.3	20.8	Outcrop of amphibolite; leave paved road.
35.4	22.1	Turnoff to Beaver Creek Campground. Stay on Beaver Creek road.
36.5	22.8	**Stop 3.** Good outcrop of locally garnetiferous, medium-grained quartz-biotite schist. Note intersection of Beaver Creek road with U.S. Forest Service (USFS) road to Wards Fork Gap and Deer Creek Camp. We will turn here and proceed along the Wards Fork road, ultimately to the contact of the Paleozoic-Triassic belt rocks with the Condrey Mountain Schist.
38.2	23.9	**Stop 4.** Good outcrop to view Paleozoic-Triassic belt amphibolite gneiss and biotite schist and their apparent interlayered nature.
40.2	25.1	Road intersection with USFS Road 47N40. Turn left (west). The contact between the Condrey Mountain Schist and Paleozoic-Triassic amphibolites and biotite schists (**Stop 5**) is on Road 47N40 half a mile from the intersection. Road 47N40 circles around the head of the gulch that is visible from the road intersection, and the contact is just on the other side of the gulch.
		Return to Highway 96 and start new mileage.
0.0	0.0	Intersection of Beaver Creek road and California Highway 96; turn right.
1.4	0.9	Klamath River Lodge on the right.
3.4	2.1	Exposures of ultramafic rocks on the right.
4.3	2.7	Klamath River Community Hall; golf course across the river.
6.7	4.2	Walker Bridge.
7.4	4.6	Road to Deer Camp; turn right. California Highway Maintenance Building is just on the left at the road intersection.
9.3	5.8	Road to Deer Creek on right. Continue on main road and observe the occurrence of recumbent folded, shallow-dipping Condrey Mountain Schist composed of graphitic quartz-mica schist (blackschist) and interlayers of actinolite-chlorite schist (greenschist).
13.1	8.2	Doggett Creek and road intersection. Continue uphill on USFS Road 46N52 and stay on this road until mile point 11.3. Pretty good exposures of Condrey Mountain Schist are just beyond the road intersection.
13.6	8.5	Note the blue-colored road rock composed of crushed Condrey Mountain greenschist-blueschist.
16.6	10.4	Road intersection; continue on USFS Road 46N52.
18.1	11.3	Road intersection; go right on gravel road. Condrey Mountain greenschist with blackschist interlayers is exposed here.
23.2	14.5	**Stop 6.** Blueschist quarry. At this locality (SW ¼ sec. 31, T. 47 N., R. 9 W., west of Kohl Creek), blueschist and greenschist are interlayered. Both rock types have good foliation that is crenulated or crinkle-folded. Foliation is apparently axial planar to early folds. Folding can be observed on the scale of a hand specimen. Note, too, that in some places there are two crenulations at nearly right angles. One crenulation is nearly parallel with axial planes of early folds, whereas the other is later and mostly with north-south orientation—the same as folding in the surrounding Paleozoic and Triassic belt rocks. The layered aspect of the glaucophane schists is emphasized by layers of epidote and white mica. The greenschists consist of fine-grained actinolite, chlorite, and muscovite; note that they have good cleavage nearly parallel with schistosity. Both rocks have quartz veins largely parallel with layering. The blueschists have lenses that are epidote-rich. Return to Highway 96.
		Start new mileage.
0.0	0.0	Intersection of road to blueschist quarry and Highway 96; turn right.
1.4	0.9	Oak Knoll Ranger Station (USFS).
1.6	1.0	Doggett Creek.
5.8	3.6	Kohl Creek. There are good exposures of Condrey Mountain blackschist with abundant quartz veining along this part of the road.
8.6	5.4	**Stop 7.** Good exposures of Paleozoic and Triassic belt schists and gneisses, apparently interlayered quartz-biotite schists and amphibolite gneisses, cut by metamorphosed mafic dikes.
9.3	5.8	Outcrop of leucocratic, medium-grained quartz monzonite intrusive rock, probably Jurassic in age, which cuts Paleozoic and Triassic sequence.
10.4	6.5	Bridge over the Klamath River. Old placer workings, used now for gravel.
12.3	7.7	Horse Creek store.
13.4	8.4	Extensive roadcut in Condrey Mountain greenschist opposite broad bend in the

Km	Mi	
		Klamath River.
16.3	10.2	Continue on Condrey Mountain greenschist—good exposures.
18.4	11.5	Blue Heron boat access.
19.8	12.4	Road intersection and confluence of Klamath and Scott Rivers. Begin new mileage.
0.0	0.0	Scott River road.
0.3	0.2	**Stop 8.** Extensive outcrop of Condrey Mountain Schist. Just opposite the bridge over the Scott River is rather "massive" greenschist with structure resembling pillow structure but with a fair schistosity. The rock is fine to medium grained and is composed of quartz, chlorite, albite, ± actinolite, ± pale pink garnet, and some scattered grains of bright-green mica (fuchsite?). Note that rocks locally have quartz veining conformable with schistosity but develop lenticular or "augen-like" appearance as schistosity improves. The rock grades along the outcrop to muscovite-richer schist with dark-brown to black chlorite and graphite. Note the recumbent folds with westerly-dipping axial planar foliation. The greenschist may also be feldspathic with fine, disseminated garnets rolled within their foliation planes; locally the feldspathic-micaceous greenschist is epidote-rich. The quartz veins are folded by "first" folds and in places are ptygmatic. Note, however, that the "first" folds are crenulated near the contact of the greenschist and blackschist (south end of outcrop). Some outstanding folds are obvious in the greenschist with amplitudes of 15 to 20 m and wavelengths possibly about one-third of the amplitude. In the area where good folds are exposed, there is an early schistosity nearly at right angles to the folded foliation planes. Note, too, the crenulation of foliation parallel with axial planes of these folds.
4.3	2.7	Intrusion of quartz-rich granodiorite into Condrey Mountain Schist. Exposures of the pluton start in Franklin Gulch. The foliation of the pluton is parallel to that of the surrounding feldspathic greenschist.
5.3	3.3	Confluence of Mill Creek and Scott River at Scott Bar. Gold mine across Scott River with gold apparently in quartz veins of interlayered blackschist-greenschist. As we progress southward along the Scott River for the next few miles, we pass through an apparently gradational sequence of greenschist facies-amphibolite facies rocks as mapped by Barrows (1969). The greenschists are correlated by Hotz (1971) with the Condrey Mountain Schist. However, Hotz interprets the amphibolite-facies rocks as belonging to the Paleozoic and Triassic belt sequence.
7.7	4.8	Exposure of quartz-chlorite-feldspar schist ± actinolite. The rock is somewhat fissile, but the schistosity is not well developed.
11.0	6.9	Good chlorite-actinolite schist with feldspar. The schist locally develops a gneissic fabric owing to alignment of actinolite. The rock is a bit coarser grained than previous exposures.
11.7	7.3	George Allen Gulch. We are now well into the unit with mineralogy of epidote-amphibolite facies which Barrows (1969) correlates with Condrey Mountain Schist of Hotz (1971b). The road is narrow here, and it is difficult to get to good exposures.
12.8	8.0	**Stop 9.** Sugarpine Gulch. Dark-green gneissic rock, fine- to medium-grained, with abundant amphibole (hornblende? or actinolite?) which occurs as elongate, acicular grains up to several millimeters long; note that plagioclase is also elongate and similar in size. There is crenulation of poorly developed schistosity (cleavage) and the hornblende-plagioclase lineation. Compare with earlier exposures of Condrey Mountain Schist.
14.4	9.0	**Stop 10.** McCarthy Creek. Very definite change in texture and fabric; the hornblende-plagioclase gneiss is coarser grained and has a strong, gneissic fabric.
16.5	10.3	**Stop 11.** Good medium- to coarse-grained amphibolite gneiss with local, strong segregation of hornblende in lenses and layers which alternate with plagioclase-rich layers. Barrows (1969) shows this rock as correlative with the Condrey Mountain Schist through progressive increase in grade of metamorphism. Note, too, that this amphibolite gneiss is locally garnetiferous with fine-grained garnets in the feldspathic layers. The layering here is textural and compositional, from 1 or 2 cm to 15 cm thick.
16.6	10.4	Gold Flat.
17.4	10.9	**Stop 12.** Tompkins Creek. Follow path to Tompkins Creek to gain access to outcrops along the Scott River, where there are excellent exposures of coarse-grained,

Km	Mi	
		well-foliated, garnetiferous hornblende-plagioclase gneiss. Hotz (1971b) correlates this rock with higher grade parts of the Paleozoic and Triassic belt; Barrows (1969) shows the rock as correlative with, but a higher grade part of, the Condrey Mountain Schist. Note that the foliation in the gneiss is approximately parallel to axial planes of nearly recumbent folds. The foliation is amplified by quartz-feldspar-rich and hornblende-rich segregations. Intrusion into the amphibolite gneiss by the adjacent quartz diorite may be responsible for the coarse-grained, granular quartz-feldspar-rich segregations. The layers with hornblende-garnet porphyroblasts are also folded, and the garnets are as large as 1.5 cm in diameter. Garnet seems to concentrate in the hornblende-rich layers and is flattened parallel with lineation or gneissosity in the plane of foliation.
17.4	10.9	Crossing Tompkins Creek. Note that we are in a coarse-grained gneissic rock of plutonic origin and quartz-diorite composition, with hornblende as the dominant mafic silicate.
19.0	11.9	**Stop 13.** Walk back about 0.2 mi. Here we have a medium- to coarse-grained black or dark-green gneiss with hornblende and plagioclase. The gneissic fabric fades locally. Note the recumbently folded pegmatitic plagioclase + hornblende intrusive(?) rock. The rock here is apparently part of a larger plutonic complex with overall tonalitic composition; this rock is dioritic or gabbroic.
19.8	12.4	Middle Creek.
20.3	12.7	**Stop 14.** The host rock here is part of the same intrusive complex as the last stop but has large, rounded xenoliths of ultramafic rock. The xenoliths are composed of coarse-grained hornblende and clinopyroxene. The xenoliths occur in clusters in dioritic gneiss exposures all along the roadcut. The plutonic complex is apparently Jurassic in age.
22.1	13.8	Bridge Flat USFS Campground.
22.6	14.1	Kelsey Creek and bridge over Scott River. Now we are back into higher grade metamorphic parts of the Paleozoic and Triassic belt rocks of Hotz (1971b).
22.7	14.2	Kelsey Creek USFS Guard Station.
23.4	14.6	Spring Flat USFS Campground.
23.7	14.8	**Stop 15.** Interlayered medium-grained micaceous quartzite and biotite schist with some lenses of marble. The quartzite shows extreme plastic deformation and has fine-grained clusters of garnet. Note folding with foliation approximately parallel to axial planes of folds.
24.6	15.4	Big bend in the river. Medium- to coarse-grained plagioclase-hornblende gneiss and ultramafic rock composed of talc-antigorite and possibly anthophyllite and tremolite. The amphibolite is isoclinally folded.
25.9	16.2	**Stop 16.** Good roadcut. Note that a leucocratic, medium-grained granodiorite with gneissic fabric is intrusive into quartz-feldspar-biotite schist. The plutonic body has xenoliths of the surrounding biotite-rich schist. The xenoliths are lenticular and have a schistosity that is probably derived from the host Paleozoic and Triassic belt schists. Amphibolite gneiss is dominant at the opposite end of the roadcut, apparently interlayered with biotitic schists.
27.2	17.0	Turnoff to Indian Scotty Campground.
34.2	21.4	Paleozoic-Triassic belt amphibolite gneiss.
34.6	21.6	Crossing fault into low-grade Paleozoic and Triassic belt greenstone-chert association.
35.7	22.3	Exposures of low-grade Paleozoic and Triassic belt metasedimentary and volcanic rocks.

End of field trip. Continue on the Scott River road toward Fort Jones and to the intersection with California Highway 3. Turn left (northeast) and proceed through Fort Jones to Yreka and Interstate 5. □

Claim deadline passes: 29,400 filed with OSO

About 29,400 mining claims were filed with BLM's Oregon State Office before the October 22, 1979, deadline, according to Diane Livengood of the Records and Data Management Branch.

Filing was required for miners who located their claims on Federal land before October 21, 1976. Claims located since then must be filed with the BLM within 90 days.

Claims not filed with the BLM are voided by law.

—BLM News Clips □

Schlicker enters private practice

Herbert G. Schlicker, Engineering Geologist for the Oregon Department of Geology and Mineral Industries since 1955, left the Department on January 1, 1980, to open his own engineering geology firm, H.G. Schlicker and Associates, Banfield Plaza, Portland.

During his almost twenty-five years with the Department, Schlicker provided leadership in many new ways. Together with Lloyd Staples, University of Oregon, he was instrumental in bringing about the registration of geologists in Oregon. Schlicker, who is currently serving on the State of Oregon Board of Geologist Examiners, was first Chairman of that board. He also planned and conducted numerous geology and engineering geology studies for the Department, including the Department's first rock material resource assessment, *Gravel Resources in Relation to Urban Development in the Salem Area* (1961), and together with Robert Deacon, its first engineering geology study, *Engineering Geology of the Tualatin Valley Region, Oregon* (1967).

A native of Grangeville, Idaho, and graduate of Oregon State University, Schlicker came to the Department after working as a soils engineer with the Oregon Highway Department and as a geologist for a Louisiana oil company.

Since 1955, Schlicker was principal author, investigator, or compiler of 26 published studies and co-author of four. He also produced more than 100 unpublished reports and geologic studies for State and local governmental agencies and the U.S. Geological Survey. In addition, he provided engineering geology information to individuals, companies, and government bodies. He served as the Chairman of the Geology Section of the Oregon Academy of Science, Chairman of the Engineering Geologists of Oregon, and Chairman and Treasurer of the Oregon Section of the American Institute of Professional Geologists. He was a member of the Advisory Committee of the Association of Engineering Geologists and the Hazards Committee of the American Institute of Professional Geologists.

Schlicker's final report for the Department is the soon-to-be-published Bulletin 99, *Geology and Geologic Hazards of Northwestern Clackamas County, Oregon.* □

Herbert G. Schlicker

Geologists in eastern Oregon face awesome challenge

During the early Cenozoic, 50 to 15 m.y. ago, rotation of the Coast Range (Simpson and Cox, 1977; Beck and Burr, 1979) and probable concomitant rotation across Oregon of the Cascade Range volcanic arc (Hammond, 1979) from the Mesozoic continental margin to the east left many fault blocks of Mesozoic terranes, some possibly oil-bearing, in eastern Oregon. Subsequent extension during the late Cenozoic, 15 m.y. ago to the present, has caused recurrent volcanism and burial of most Mesozoic blocks. The positions of these blocks are problematical. Deep exploratory drilling through the volcanic cover could penetrate grabens filled with interbedded volcanic and volcaniclastic sedimentary rocks, eruptive centers along fault zones, as well as detached Mesozoic blocks lacking stratigraphical and structural continuity. Geologists face an awesome challenge in restoring the fault blocks, like putting together a jigsaw puzzle on a treadmill.

REFERENCES

Beck, M.E., Jr., and Burr, C.D., 1979, Paleomagnetism and tectonic significance of the Goble Volcanic Series, southwestern Washington: Geology, v. 7, no. 4, p. 175-179.

Hammond, P.E., 1979, A tectonic model for evolution of the Cascade Range, p. 219-237, *in* Armentrout, J.M., Cole, M.R., and TerBest, H.J., eds., Cenozoic paleography of the western United States: Pacific Section, Society of Economic Paleontologists and Mineralogists, 335 p.

Simpson, R.W., and Cox, Allen, 1977, Paleomagnetic evidence of tectonic rotation of the Oregon Coast Range: Geology, v. 5, p. 585-589.

—Paul E. Hammond, Department of Earth Sciences, Portland State University P.O. Box 751 Portland, Oregon 97207 □

Answers to frequently asked questions about gold mining

DOES GOLD OCCUR IN OREGON?

Lode and placer gold has been mined from many parts of the State. The southwestern and northeastern corners of the State have the highest production of both lode and placer gold. Minor output has come from the other corners of the State.

WHERE CAN I OBTAIN INFORMATION ABOUT PAST GOLD MINES AND MINING, INCLUDING MAPS?

The following can be purchased from the Portland, Grants Pass, and Baker offices of the Department of Geology and Mineral Industries:

(1) Mineral and Water Resources of Oregon (Bulletin 64), 1969 .... $2.00
(2) Oregon's Gold Placers (Misc. Paper 5), 14 p. .... .50
(3) Skin Diving for Gold in Oregon (The Ore Bin, April 1961), 8 p. .... .35
(4) Lest We Forget (The Ore Bin, Dec. 1976), 17 p. .... .35
(5) Special Gold Issue (The Ore Bin, April 1973), 16 p. .... .35
(6) Geology, Mineralization and Mining Field Guides for the Cascade Range (The Ore Bin, June 1977, Dec. 1977, May 1978, and June 1978). Price per issue.................... .35
(7) Recreational Gold Packet (includes items 2, 3, and 4 above, plus an 8½ × 11 mineral localities map and a list of Department publications) 1.00

Allow 1 month for delivery of publications ordered by mail. Payment must accompany orders less than $20. All sales are final. Foreign orders must be paid in U.S. dollars.

The following out-of-print reports can be read at most libraries, including the Department's:

(1) Gold and Silver in Oregon (Bulletin 61)
(2) Oregon Mineral Deposits Map and Key (Misc. Paper 2)

WHAT LANDS ARE OPEN FOR PROSPECTING AND MINING?

Land ownership for the surface and for mineral rights can be determined from the local County Assessor's maps. Patented mining claims are treated the same as any other privately owned land. Most U.S. Forest Service and U.S. Bureau of Land Management lands, shown on their published maps, are open for prospecting; however, much of the better lode and placer ground has already been staked.

HOW CAN I TELL IF AN AREA HAS BEEN STAKED?

All unpatented mining claims are recorded in the local County Courthouse and with the U.S. Bureau of Land Management, 729 N.E. Oregon Street (P.O. Box 2965), Portland, Oregon 97208 (telephone: 503 231-6283). The BLM records may be easier to work with than the county's.

SUPPOSE I FIND SOME GOLD, WHAT THEN?

The gold is yours to keep, give away, or sell. There is no limit to the amount. The U.S. Government no longer buys gold. Gold may be sold to individuals, jewelry manufacturers, or gold buyers. Best prices are received for good-sized nuggets or visible gold mineral specimens which have a collectors' value rather than a metal value. There is no fixed price for gold, with sales consummated between a willing buyer and a seller, at an agreed-upon price.

DO I NEED PERMISSION TO PROSPECT AND STAKE A MINING CLAIM ON PUBLIC LANDS?

On public lands that have not been withdrawn from mineral entry, Federal permission is not needed to prospect or stake a mining claim.

WHAT ARE THE RULES AND REGULATIONS FOR GOLD MINING?

The Department can supply a copy of the State Mining Code for 50¢, and the U.S. Bureau of Land Management has printed "Staking a Mining Claim on Federal Lands" for free distribution. For sale at most stationers are two forms which show how to stake either a lode or a placer claim. Each has a brief synopsis of the mining law. The forms are Form No. 830 (Notice of Vein or Lode Locations in Oregon) and Form No. 897 (Notice of Placer Location—Oregon). The forms are 20-30¢ each. If prospecting or mining is to go beyond the handtools stage, then the U.S. Forest Service and the U.S. Bureau of Land Management may require a notice of intent or a plan of operation, and the Oregon Department of Geology and Mineral Industries may require a surface mining permit, depending on the size of the proposed mining development.

Most gold panners and those with small dredges, however, are not interested in locating a mining claim and want only to do some recreational placer mining. No permits are required, and unless the miners unduly muddy the waters in a stream, there will be no problems. A report entitled "Recreational Mining Can Be Compatible with Other Resources," which gives the best

(See **Gold Mining,** *p. 38)*

Federal geothermal lease sale held in January

The U.S. Bureau of Land Management held a geothermal lease sale in Portland on January 8, 1980. Four energy companies—Anadarko Production Co., Hunt Oil Co., International Energy Corp., and Union Oil—were successful bidders on the parcels located in the Alvord, Breitenbush, Crump, and Klamath Falls Known Geothermal Resource Areas (KGRA's).

Sixty-two parcels were offered by the Federal government. Forty-nine parcels received no bids, and seven others were withdrawn.

Leases cover a 10-year period and give successful bidders a right to develop geothermal resources. Royalties begin when production is marketed.

Details on the bidding are as follows:

Parcel	Acreage	Area	Company	Amount ($)	Cost per acre ($)
13	2,280	Alvord	Anadarko	236,367.60	103.67
14	2,463	Alvord	Anadarko	90,605.33	36.78
33	1,029	Breitenbush	Union Oil	10,341.45	10.05
39	118	Klamath Falls	Intercontinental	917.53	7.78
50	2,371	Crump	Hunt Oil	4,833.35	2.04
51	2,344	Crump	Hunt Oil	4,828.58	2.06

—Data from USBLM Oregon State Office news release, January 14, 1980 □

Josephine County mineral study completed

The Oregon Department of Geology and Mineral Industries announces the completion of its investigation of the geology and metallic mineral deposits of Josephine County. Bulletin 100, entitled *Geology and Mineral Resources of Josephine County, Oregon*, by Len Ramp and Norman V. Peterson, presents the results of the investigation.

Bulletin 100 contains several multicolor geologic maps at various scales, a mine location map at a scale of 1:125,000 (one inch equals two miles), and a table that presents data from 470 mines. The accompanying 45-page text discusses the geology and geologic units of the County and evaluates the mineral-resource potential of the various units. It also contains pictures and accounts of some of the mineral exploration and mining that took place in Josephine County in the past.

Bulletin 100 may now be purchased for $9.00 from the Department's Portland and Grants Pass offices. Mailed orders should be addressed to the Oregon Department of Geology and Mineral Industries, 1069 State Office Building, Portland, Oregon 97201, or 312 S.E. "H" Street, Grants Pass, Oregon 97526. Payment must accompany orders under $20.00. □

(**Gold Mining**, *from p. 37)*

time to work in a stream, can be obtained from the Environmental Management Section of the State of Oregon Department of Fish and Wildlife (506 S.W. Mill Street, P.O. Box 3503, Portland, Oregon 97208—telephone: 229-5408).

Care must be taken not to trespass on valid mining claims or privately owned land. Good outdoor manners and a concern for the environment are essential.

WHERE CAN I GET MY SAMPLES ASSAYED FOR GOLD?

The Oregon Department of Geology and Mineral Industries has a complete assay service at its Portland headquarters. Samples of black sand concentrates, raw bank run sand and gravel, or ore specimens should weigh at least 1 pound for best results, and not over 5 pounds. An extra $3.00 fee is charged if the sample is over 5 pounds. The charge for assaying a sample for gold and silver is $10.00 for lode samples and $12.00 for placer samples (payment should accompany the samples). There is an additional sample preparation charge of $3.00 if the sample is wet and needs to be dried. If the sample is 3 inches or larger, a $3.00 fee is charged for crushing. There is no charge for identifying rocks and minerals unless special tests are required. Simple tests for gold are contained in "Oregon's Gold Placers," listed above.

Rocks and minerals also can be identified at the U.S. Bureau of Mines, 1450 Queen Street, S.W. (P.O. Box 70), Albany, Oregon 97321. □

PUBLICATIONS ORDER

Omission of price indicates publication is in press. Minimum mail order 50¢. All sales are final. Publications are sent postpaid. Payment must accompany orders of less than $20.00.

Fill in appropriate blanks and send sheet to Department (see address on reverse side).

YOUR NAME ____________________

ADDRESS ____________________

____________________ Zip__________

Amount enclosed $__________

OREGON GEOLOGY

____ Renewal ____ Subscription ____ Gift

____ 1 Year ($4.00) ____ 3 Years ($10.00)

NAME ____________________

ADDRESS ____________________

____________________ ZIP __________

(If Gift, From: ____________________)

ORDER FORM - CUT ON DASHED LINE

Available publications

MISCELLANEOUS PAPERS	Price	No. Copies	Amount
1. A description of some Oregon rocks and minerals, 1950: Dole	$ 1.00		
4. Laws relating to oil, gas, and geothermal exploration and development in Oregon			
Part 1. Oil and natural gas rules and regulations, 1977, rev. 1979	1.00		
Part 2. Geothermal resources rules and regulations, 1977, rev. 1979	1.00		
5. Oregon's gold placers (reprints), 1954	.50		
6. Oil and gas exploration in Oregon, rev. 1965: Stewart and Newton	3.00		
7. Bibliography of theses on Oregon geology, 1959: Schlicker	.50		
Supplement, 1959-1965: Roberts	.50		
8. Available well records of oil and gas exploration in Oregon, rev. 1973: Newton	1.00		
11. Collection of articles on meteorites, 1968 (reprints from *The Ore Bin*)	1.50		
13. Index to *The Ore Bin,* 1950-1974	1.50		
14. Thermal springs and wells, 1970: Bowen and Peterson (with 1975 supplement)	1.50		
15. Quicksilver deposits in Oregon, 1971: Brooks	1.50		
16. Mosaic of Oregon from ERTS-1 imagery, 1973	2.50		
18. Proceedings of Citizens' Forum on potential future sources of energy, 1975	2.00		
19. Geothermal exploration studies in Oregon – 1976, 1977	3.00		
20. Investigations of nickel in Oregon, 1978: Ramp	5.00		
GEOLOGIC MAPS			
Geologic map of Galice quadrangle, Oregon, 1953	1.50		
Geologic map of Albany quadrangle, Oregon, 1953	1.00		
Reconnaissance geologic map of Lebanon quadrangle, 1956	1.50		
Geologic map of Bend quadrangle and portion of High Cascade Mountains, 1957	1.50		
Geologic map of Oregon west of 121st meridian, 1961	2.25		
Geologic map of Oregon east of 121st meridian, 1977	3.75		
GMS-3: Preliminary geologic map of Durkee quadrangle, Oregon, 1967	2.00		
GMS-4: Oregon gravity maps, onshore and offshore, 1967 (folded)	3.00		
GMS-5: Geologic map of Powers quadrangle, Oregon, 1971	2.00		
GMS-6: Preliminary report on geology of part of Snake River Canyon, 1974	6.50		
GMS-7: Geology of the Oregon part of the Baker quadrangle, Oregon, 1976	3.00		
GMS-8: Complete Bouguer gravity anomaly map, Cascade Mountain Range, central Oregon, 1978	3.00		
GMS-9: Total field aeromagnetic anomaly map, Cascade Mountain Range, central Oregon, 1978	3.00		
GMS-10: Low- to intermediate-temperature thermal springs and wells in Oregon, 1978	2.50		
GMS-11: Preliminary geothermal resource map of Oregon (upon written request only)	free	(one copy per customer)	
GMS-12: Geologic map of the Oregon part of the Mineral quadrangle	2.50		
OIL AND GAS INVESTIGATIONS			
3. Preliminary identifications of foraminifera, General Petroleum Long Bell #1 well	2.00		
4. Preliminary identifications of foraminifera, E.M. Warren Coos County 1-7 well, 1973	2.00		
5. Prospects for natural gas production or underground storage of pipeline gas	5.00		
MISCELLANEOUS PUBLICATIONS			
Landforms of Oregon (17 × 12 inches)	.50		
Mining claims (State laws governing quartz and placer claims)	.50		
Geological highway map, Pacific NW region, Oregon-Washington (published by AAPG)	3.00		
Fifth Gold and Money Session and Gold Technical Session Proceedings, 1975	5.00		
Sixth Gold and Money Session and Gold Technical Session Proceedings, 1978	6.50		
Back issues of *The Ore Bin*	25¢ over the counter; 50¢ mailed		
Colored postcard, *Geology of Oregon*	10¢ each; 3 for 25¢; 7 for 50¢; 15 for 1.00		

OREGON GEOLOGY

1069 State Office Building, Portland, Oregon 97201

Second Class Matter
POSTMASTER: Form 3579 requested

Available publications (continued)

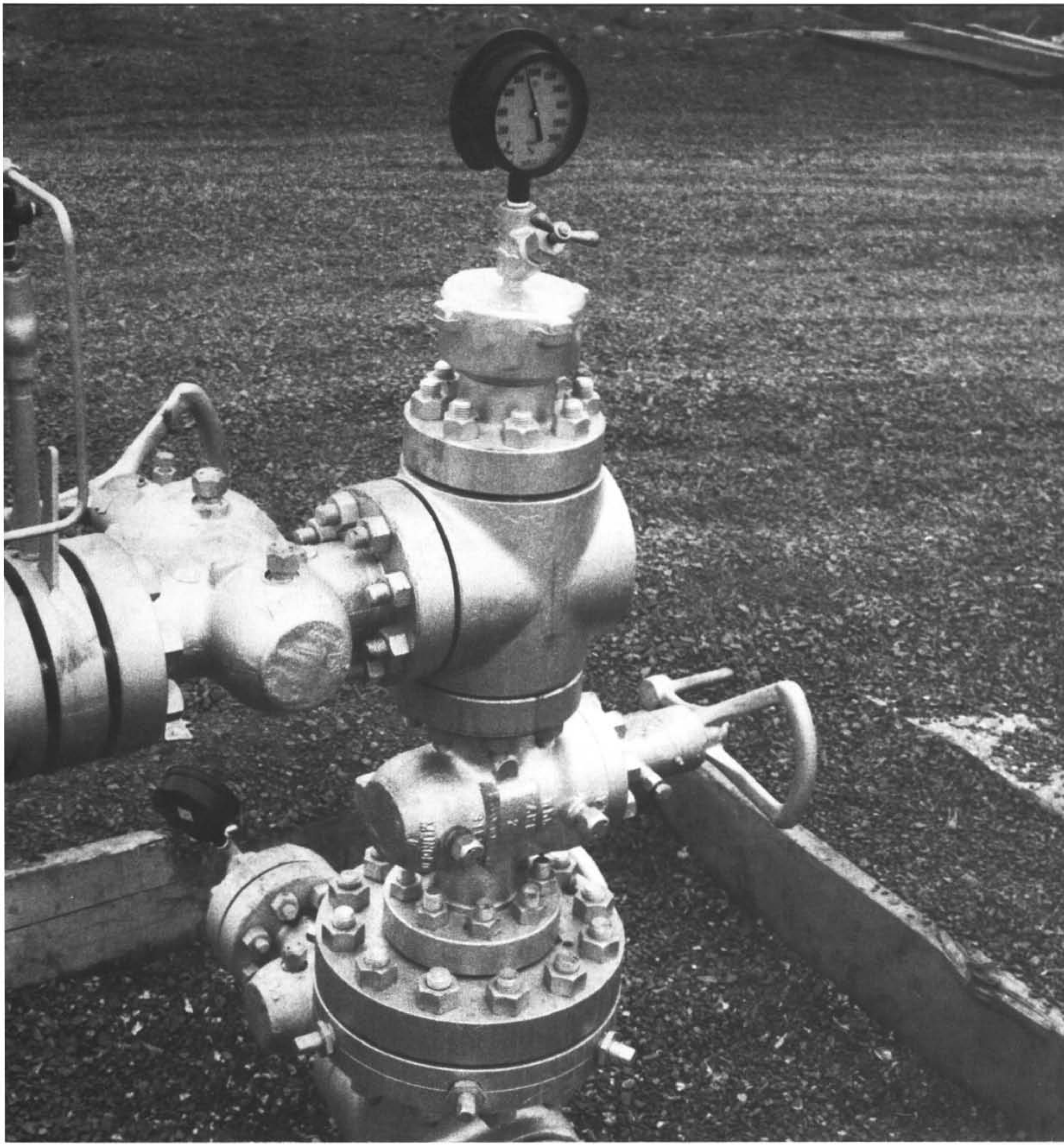
BULLETINS	Price	No. Copies	Amount
33. Bibliography (1st supplement) geology and mineral resources of Oregon, 1947: Allen	1.00	______	______
36. Papers on Tertiary foraminifera: Cushman, Stewart and Stewart, 1949: v. 2	1.25	______	______
39. Geology and mineralization of Morning Mine region, 1948: Allen and Thayer	1.00	______	______
44. Bibliography (2nd supplement) geology and mineral resources of Oregon, 1953: Steere	2.00	______	______
46. Ferruginous bauxite deposits, Salem Hills, 1956: Corcoran and Libbey	1.25	______	______
49. Lode mines, Granite mining district, Grant County, Oregon, 1959: Koch	1.00	______	______
53. Bibliography (3rd supplement) geology and mineral resources of Oregon, 1962: Steere and Owen	3.00	______	______
57. Lunar Geological Field Conference guidebook, 1965: Peterson and Groh, editors	3.50	______	______
62. Andesite Conference guidebook, 1968: Dole	3.50	______	______
63. Sixteenth biennial report of the Department, 1966-1968	1.00	______	______
64. Mineral and water resources of Oregon, 1969 (unbound, without maps and tables)	2.00	______	______
65. Proceedings of Andesite Conference, 1969: (copies)	10.00	______	______
67. Bibliography (4th supplement) geology and mineral resources of Oregon, 1970: Roberts	3.00	______	______
68. Seventeenth biennial report of the Department, 1968-1970	1.00	______	______
71. Geology of selected lava tubes in Bend area, Oregon, 1971: Greeley	2.50	______	______
76. Eighteenth biennial report of the Department, 1970-1972	1.00	______	______
77. Geologic field trips in northern Oregon and southern Washington, 1973	5.00	______	______
78. Bibliography (5th supplement) geology and mineral resources of Oregon, 1973: Roberts	3.00	______	______
81. Environmental geology of Lincoln County, 1973: Schlicker and others	9.00	______	______
82. Geologic hazards of Bull Run Watershed, Multnomah, Clackamas Counties, 1974: Beaulieu	6.50	______	______
83. Eocene stratigraphy of southwestern Oregon, 1974: Baldwin	4.00	______	______
84. Environmental geology of western Linn County, 1974: Beaulieu and others	9.00	______	______
85. Environmental geology of coastal Lane County, 1974: Schlicker and others	9.00	______	______
86. Nineteenth biennial report of the Department, 1972-1974	1.00	______	______
87. Environmental geology of western Coos and Douglas Counties, 1975	9.00	______	______
88. Geology and mineral resources of upper Chetco River drainage, 1975: Ramp	4.00	______	______
89. Geology and mineral resources of Deschutes County, 1976	6.50	______	______
90. Land use geology of western Curry County, 1976: Beaulieu	9.00	______	______
91. Geologic hazards of parts of northern Hood River, Wasco, and Sherman Counties, Oregon, 1977: Beaulieu	8.00	______	______
92. Fossils in Oregon (reprinted from *The Ore Bin*), 1977	4.00	______	______
93. Geology, mineral resources, and rock material of Curry County, Oregon, 1977	7.00	______	______
94. Land use geology of central Jackson County, Oregon, 1977: Beaulieu	9.00	______	______
95. North American ophiolites, 1977	7.00	______	______
96. Magma genesis: AGU Chapman Conference on Partial Melting, 1977	12.50	______	______
97. Bibliography (6th supplement) geology and mineral resources of Oregon, 1971-75, 1978	3.00	______	______
98. Geologic hazards of eastern Benton County, 1979: Bela	9.00	______	______
100. Geology and mineral resources of Josephine County, Oregon, 1979: Ramp and Peterson	9.00	______	______
SPECIAL PAPERS			
1. Mission, goals, and purposes of Oregon Department of Geology and Mineral Industries, 1978	2.00	______	______
2. Field geology of SW Broken Top quadrangle, Oregon, 1978: Taylor	3.50	______	______
3. Rock material resources of Clackamas, Columbia, Multnomah, and Washington Counties, Oregon, 1978: Gray	7.00	______	______
4. Heat flow of Oregon, 1978, Blackwell, Hull, Bowen, and Steele	3.00	______	______
5. Analysis and forecasts of the demand for rock materials in Oregon, 1979	3.00	______	______
7. Pluvial Fort Rock Lake, Lake County, Oregon	4.00	______	______
SHORT PAPERS			
18. Radioactive minerals prospectors should know, 1976: White, Schafer, Peterson	.75	______	______
19. Brick and tile industry in Oregon, 1949: Allen and Mason	.20	______	______
21. Lightweight aggregate industry in Oregon, 1951: Mason	.25	______	______
24. The Almeda Mine, Josephine County, Oregon, 1967: Libbey	3.00	______	______
25. Petrography, type Rattlesnake Formation, central Oregon, 1976: Enlows	2.00	______	______
27. Rock material resources of Benton County, 1978: Schlicker and others	4.00	______	______

OREGON GEOLOGY

formerly THE ORE BIN

published by the Oregon Department of Geology and Mineral Industries

VOLUME 42, NUMBER 3 MARCH 1980



OREGON GEOLOGY

(ISSN 0164-3304)

VOLUME 42, NUMBER 3 MARCH 1980

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

Main Office: 1069 State Office Building, Portland 97201, phone (503) 229-5580.

Baker Field Office: 2033 First Street, Baker 97814, phone (503) 523-3133.
Howard C. Brooks, Resident Geologist

Grants Pass Field Office: 312 S.E. "H" Street, Grants Pass 97526, phone (503) 476-2496.
Len Ramp, Resident Geologist

Mined Land Reclamation Program: 1129 S.E. Santiam Road, Albany 97321, phone (503) 967-2039.
Standley L. Ausmus, Supervisor

Subscription rates: 1 year, \$4.00; 3 years, \$10.00. Single issues, \$.40 at counter, \$.50 mailed.
Available back issues of *The Ore Bin:* \$.25 at counter, \$.50 mailed.

Address subscription orders, renewals, and changes of address to *Oregon Geology,* 1069 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,* 1069 State Office Building, Portland, OR 97201.

COVER PHOTO

Reichhold Energy Corporation's Columbia County 1, discovery well of the Mist Gas Field. In 1979, Oregon joined the ranks of producing states with this discovery and four other producers in the field. In late December, this well produced 300,000 cu ft per day through a new pipeline to existing lines in Clatskanie, approximately 8 mi to the north.

GSA geologic field trip guide released

A guide for geologic field trips in western Oregon has just been released by the Oregon Department of Geology and Mineral Industries (DOGAMI). Bulletin 101, entitled *Geologic Field Trips in Western Oregon and Southwestern Washington,* was prepared by the Geology Department of Oregon State University in cooperation with DOGAMI for the annual meeting of the Cordilleran Section of the Geological Society of America to be held in Corvallis, Oregon, in March 1980.

Gathered from 23 contributors, the 232-page bulletin describes the geology of eight field trips in selected areas of the Oregon Coast Range, the Klamath Mountains, the Oregon Cascades, and parts of southwestern Washington. A ninth field trip deals with beach processes and erosion problems of the Oregon coast. Each trip guide consists of an introductory discussion, a bibliography, and a trip itinerary.

Copies of Bulletin 101 are available for purchase at DOGAMI's Portland, Baker, and Grants Pass offices; price is \$9.00 per copy. Mailed orders should be addressed to the Oregon Department of Geology and Mineral Industries at one of the following addresses: 1069 State Office Building, Portland, OR 97201; 2033 First Street, Baker, OR 97814; or P.O. Box 417, Grants Pass, OR 97526. Orders under \$20.00 must be prepaid. □

CONTENTS

NEXT MONTH

Geothermal exploration in Oregon, 1979, by Joseph F. Riccio and Dennis L. Olmstead, Oregon Department of Geology and Mineral Industries.

Mineral industry in Oregon, 1979

by Jerry J. Gray, Economic Geologist, Albany Field Office; Howard C. Brooks, Resident Geologist, Baker Field Office; Norman V. Peterson, District Geologist, and Len Ramp, Resident Geologist, Grants Pass Field Office, Oregon Department of Geology and Mineral Industries

ABSTRACT

According to U.S. Bureau of Mines figures, the 1979 value of mineral output in Oregon rose 16 percent over that of 1978. Preliminary estimates indicate that production value rose $20.4 million, from $128.8 million in 1978 to $149.2 million in 1979. Rock materials (clay, pumice, sand and gravel, and stone) continued to account for the major portion of the 1979 total production value—64 percent, compared to 67 percent in 1978. The other two principal commodities were cement and nickel.

Mining exploration and development in Oregon focused on base metals, gold, silver, nickel, uranium, limestone, bentonite clay, block soapstone, and diatomite. The price rise of gold and silver brought increased exploration and mine development activity for these precious metals. In a number of cases, abandoned mines that had been productive in the past were rehabilitated. Old workings were extended, and new ones started. A major placer gold mine was brought into production in Malheur County.

Exploration for minerals in 1979 led to more uranium finds in southeastern Oregon. Major exploration efforts began and are continuing for gold, silver, volcanogenic sulfides, and nickel laterite.

Oregon's mineral production values for 1978 and 1979 are summarized in Table 1. This table does not include an additional estimated $600 million from the production of aluminum, carbide, nickel, steel, titanium, and zirconium from metallurgical plants employing approximately 10,500 people.

METALS

Mining and exploration for base metals, gold, silver, nickel, and uranium were conducted by major firms. Between January 1 and December 31, 1979, the price of gold rose from $223 to $512 per oz and that of silver from $6 to $28 per oz, overshadowing price rises in most other metals. Oregon's output of precious metals increased with the startup of two large placer operations, the influx of recreational miners using small portable dredges, and the installation of gold-saving equipment at private sand and gravel plants and at the aggregate source for the U.S. Army Corps of Engineers Applegate Dam project (point 2, Figures 1* and 2). By the end of the year, $285,000 worth of gold had been recovered from the Applegate gravel. Because much of the gold mined in Oregon comes from small placer

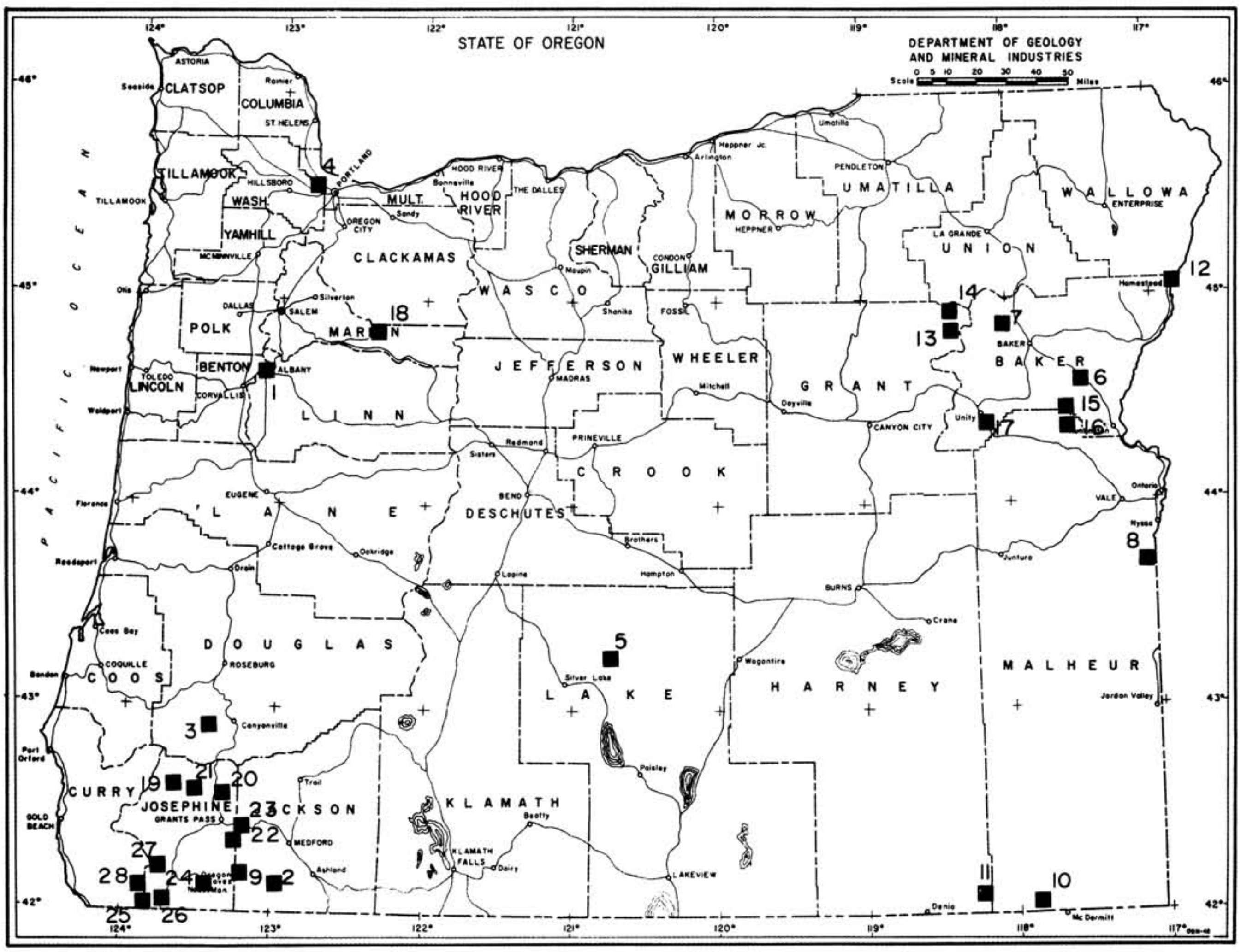
* All point numbers refer to locations shown on the map in Figure 1.

Table 1. *Oregon's mineral production values for 1978 and 1979*

Mineral commodity	1978 Value (thousands)	1978 Percent	1979* Value (thousands)	1979* Percent
Sand and gravel	$ 44,510	34	$ 51,000	34
Cement, copper, diatomite, lime, nickel, talc, and tungsten	41,872	32	52,275	35
Stone	39,510	31	41,763	28
Pumice	2,016	2	2,172	1
Gold	66	–	1,155	0.8
Gemstones	600	0.5	500	0.3
Clays	261	0.2	292	0.2
Silver	9	–	17	–
Total	$128,844	99.7**	$149,174	99.3**

* Preliminary data provided by U.S. Bureau of Mines.

** Percentages do not total 100 because of individual rounding.



LEGEND

1. Albany (Ti, Ni)
2. Applegate Dam (Au)
3. Nickel Mountain-Silver Peak (Ni-Cu, Zn, Ag)
4. Portland (stone)
5. Christmas Valley (diatomite)
6. Durkee (cement)
7. Blue Mountain Lime (limestone)
8. Adrian (bentonite)
9. Steatite of Oregon (soapstone)
10. McDermitt (U)
11. Trout Creek (U)
12. Iron Dyke (Cu, Au)
13. Cougar-New York (Au, Ag)
14. Buffalo Mine (Au, Ag)
15. Mormon Basin (Au)
16. Basin Creek (Au)
17. Unity (Cu)
18. Santiam mining district (Cu)
19. Almeda Mine (Ag, Cu)
20. Greenback Mine (Au, Ag)
21. Benton Mine (Au)
22. Dixie Queen Mine (Au)
23. Lyman Mine (Au, W)
24. Boswell Mine (Au)
25. Turner-Albright Mine (Cu)
26. Queen of Bronze Mine (Cu, Au)
27. Eight Dollar Mountain (Ni)
28. Rough and Ready Ridge (Ni)

Figure 1. Mineral industry activity, exploration, and development in Oregon in 1979. Point numbers in text refer to location numbers shown on this map.

mines that do not report their production, it is likely that the State's formal production statistics will never accurately reflect the total gold output.

Hanna Mining Company's mine (point 3) at Riddle in Douglas County continued to be the nation's only domestic mine source of nickel. Output rose from 13,509 tons in 1978 to 18,274 tons in 1979. During 1979, the surplus ferronickel inventories that had caused the smelter to be closed for 6 weeks in 1978 were eliminated.

Oregon Metallurgical Corporation announced plans to increase the titanium sponge capacity at its Albany plant (point 1) in Linn County by 50 percent, at a cost of $6 million. Increased aircraft industry demand for titanium and the relative price rise for foreign sponge caused by the falling value of the dollar on the world market provided the need for the expansion.

Figure 2. Panoramic view of one end of the U.S. Army Corps of Engineers Applegate Dam project, in which sand and gravel, Oregon's major mineral commodity, is being utilized as fill. When completed, the dam will be 242 ft high and 1,200 ft long and will contain 3 million cubic yards of fill. The tall concrete structure on the left is the intake tower for the dam. The downstream side of the dam is to the right.

The dark strip in the center of the photograph is the impervious clay core that is being compacted. The core extends into a notch cut in the bed rock, thereby keying the entire dam into bed rock. Lighter areas on both sides of the core are composed of crushed gravel. The outer layer of the dam will be made of coarser material.

Major mineral commodities being used in the dam are clay, cement, and sand and gravel. As the sand and gravel is processed for use as concrete aggregate and fill, the gold content is also recovered. By the end of 1979, $285,000 of gold had been recovered. (Composite photo courtesy U.S. Army Corps of Engineers)

INDUSTRIAL MINERALS

Sand and gravel and stone accounted for 62 percent of the total value of Oregon's 1979 mineral products (Figure 2), as compared with 65 percent in 1978. A major tightening of the rock-material resource supply for the Portland area occurred when the Portland Development Commission purchased the Rivergate Rock Products Company quarry (point 4) for $3.65 million. Because the quarry operation would have conflicted with that of a new silicon wafer plant nearby, drilling and blasting were stopped at the end of October. All equipment and stockpiles of crushed stone are to be removed by May 1980.

Deposits of sand and gravel and stone are nonrenewable and are rapidly being depleted or removed from mining by urbanization. As the demand increases and supply shrinks, the price will inevitably rise. Careful planning, however, will extend the useful life of the deposits. The Department continued its rock-material program to help such planning by publishing Special Paper 5, *Analysis and Forecasts of the Demand for Rock Materials in Oregon*, by Friedman and others (1979). The paper provides forecasts for the State and several substate areas and for the commodities of sand and gravel and stone. The study also gives forecasting methodologies that can be used by the planner at the local level.

Diatomite, composed of the siliceous skeletons of microscopic aquatic plants called diatoms, was mined, processed, and sold for pet litter, fertilizer filler, insecticide carrier, and floor sweep absorbent by American Fossil, Inc., at its diatomite operation (point 5) in Christmas Valley, Lake County. During 1979, the operation was sold to Oil-Dri West, who obtained industrial revenue bond financing totaling $1.5 million from the Oregon Economic Development Council for the purchase and expansion of the operation.

The Oregon Portland Cement Company completed construction of its new cement plant (point 6) near Durkee, Baker County. Test runs began in early November. The new plant, with a capacity of about 500,000 tons of cement per year, is twice as large as the one it replaced at Lime. Limestone for the plant comes from a nearby quarry.

Blue Mountain Lime Company purchased the limestone deposits and a treatment plant formerly owned by Chemical Lime Company. The plant is located about 5 mi north of Baker, in Baker County, and the limestone deposits (point 7) are in the Elkhorn Mountains about 10 mi to the west. The Chemical Lime Company operated fairly continuously between 1958 and 1970, producing chemical-grade lime and lime products for the metallurgical and construction industries. The Blue Mountain Lime Company now has developed small markets for ground limestone for agricultural purposes, such as soil additives and feed supplements. It is utilizing high-quality limestone which, because it was undersize (minus ⅜ in.), was stockpiled during the Chemical Lime Company operation. Equipment for drying, grinding, and screening the limestone has been installed. Most of the product sold was pulverized to minus 40 mesh.

Teague Mineral Products, Malheur County, produced about 6,000 tons of bentonite clay used for binder in sandcasting molds, pond sealants, and fire retardants. The clay was mined from pits near the head of Succor Creek and was trucked to a drying-bagging plant (point 8) near Adrian, Malheur County.

Steatite of Oregon continues to mine and market block soapstone from its Jackson County deposit (point 9), for art carving and other specialty uses.

EXPLORATION AND DEVELOPMENT

The McDermitt Caldera, located in the southwest corner of Malheur County, continues to be a target for uranium exploration. In 1978, Placer Amex, Inc., announced the discovery of an orebody (point 10) located in tuffaceous lake sediments of late Miocene age and estimated to contain 13 million tons of 0.05 to 0.06 percent U_3O_8. In 1979, Anaconda also announced a uranium find (point 11), this time in the southeast corner of Harney County. Mining companies have staked 5,000 mining claims in Malheur County and 400 in Harney County.

During 1979, the Iron Dyke Mine (point 12) in Baker County was bought by Texas Gulf, Inc., from the Butler family. The purchase price for the Iron Dyke and the Red Ledge property in Idaho was $1.5 million. Texas Gulf formed a joint venture with Silver King Mining of Salt Lake City, Utah, to mine and mill ore from the Iron Dyke. Starting in September 1979, ore was trucked 22.5 mi to Silver King's 800-tons-per-day mill near Cuprum, Idaho, for concentration. Thirty-five people were employed at the mine by the end of the year. Past recorded production was about 7,000 tons of copper, 35,000 oz of gold, and 256,000 oz of silver. The main period of operation was between 1916 and 1928.

W. A. Bowes and Associates continued exploration and development work at the Cougar Mine (point 13) in the Granite district of Grant County. A 1,700-ft inclined shaft, driven on a 12-percent grade to get beneath the pre-1942 workings, was completed by the end of the year. The mine was originally opened before 1900; production during the last period of operation (1938-1942) was about 10,000 oz of gold and 10,000 oz of silver.

The Buffalo Mining Company, a group of Seattle investors, is reopening the gold and silver Buffalo Mine (point 14), last operated in the mid-1960's. The 600-adit level and the flotation mill are being rehabilitated.

Mormon Basin Mines Company began a 200-cubic-bank-yards-per-hour gold placer mining operation (point 15) in Mormon Basin, Malheur County. A few miles down Basin Creek, Delta Investors continued to produce placer gold from a 60-cubic-bank-yards-per-hour operation (point 16). Johns-Manville has filed about 330 mining claims since 1976 in the Camp Creek and Bullrun Creek drainages (point 17) south of Unity, Baker County. Preussag, Canada Ltd., working under an exploration agreement with Johns-Manville, did some geologic mapping, soil and rock chip sampling, and diamond drilling along an altered and mineralized zone, which is about 8 mi long and 1 mi wide. No commercial quantities of ore have yet been discovered. Johns-Manville's interest in the area followed an Oregon Department of Geology and Mineral Industries stream-sediment geochemical sampling program which indicated zinc and copper anomalies in the area. During 1979, the Department placed on open file two geologic maps by Howard Brooks (Open File Reports 0-79-6 and 0-79-7), which give brief discussions of the mineralization in this area.

Two firms have land positions within the Santiam mining district (point 18) in Marion County. Shiny Rock Mining Company, whose land until this year was leased by Freeport Minerals, controls the northeastern half of the district and AMOCO the southwestern half. The Santiam district contains zoned mineralization with copper in the center. During 1978, Freeport did some deep drilling on Shiny Rock's side of the center zone. On the other side of the center zone, AMOCO is continuing a program of test drilling, plus geological mapping and geochemical and geophysical studies.

In southwestern Oregon, volcanogenic sulfide exploration activity on the Big Yank mineralized zone, from the Silver Peak Mine (point 3) in Douglas County to the Almèda Mine (point 19) near Galice in Josephine County, has been continuing over the past five years, with as many as four major companies involved at various times. Work has involved geologic mapping, geochemical soil sampling, airborne and surface geophysical surveying, and diamond drilling at various places along the zone. Thus far, no firm plans for mining development have been announced.

Exploration and development activities at gold lode mines include the extension of a new crosscut at the Greenback Mine (point 20); preliminary development work at the Benton Mine (point 21); and small-scale mining activities at the Dixie Queen (point 22), Lyman (point 23), and Boswell (point 24) Mines.

Copper-cobalt exploration activity included drilling at the Turner-Albright Mine (point 25) and mapping and sampling at the Queen of Bronze Mine (point 26).

Nickel laterite exploration activity by private firms continued during 1979, and the U.S. Bureau of Mines supervised the mining of a 160-ton bulk ore sample from each of two deposits, the Eight Dollar Mountain (point 27) and Rough and Ready Ridge (point 28). A small portion of the sample was used for research at the Bureau of Mines Albany Research Center, and the rest

(See **Mineral industry**, *p. 54)*

Oil and gas exploration and development in Oregon, 1979

by Dennis L. Olmstead, Geologist, Oregon Department of Geology and Mineral Industries

ABSTRACT

During 1979, hydrocarbons were discovered in commercial quantities for the first time in Oregon. The gas discovery, named the Mist Gas Field, was in the northwestern corner of the State in Columbia County. A pipeline was constructed so production could be started by the end of 1979.

During the year, leasing for oil and gas exploration was active, extending from the Coast Range to parts of eastern Oregon. Continued interest in leasing during early 1980 and many additional applications to drill wells indicate that 1980 will be a very active year for exploration.

INDUSTRY ACTIVITY

In terms of oil and gas activity, the word "development" applies to Oregon at last. Until 1979, drilling in Oregon was confined to exploration and the search for a

Figure 1. Mist Gas Field, Columbia County, Oregon. Five wells were completed in 1979 in the sands of the upper Eocene Cowlitz Formation by Reichhold Energy Corporation and its partners. One of the wells, Columbia County 1, was producing at year's end, with a production of 300,000 cubic feet per day. Production is now about five million cubic feet per day from three wells.

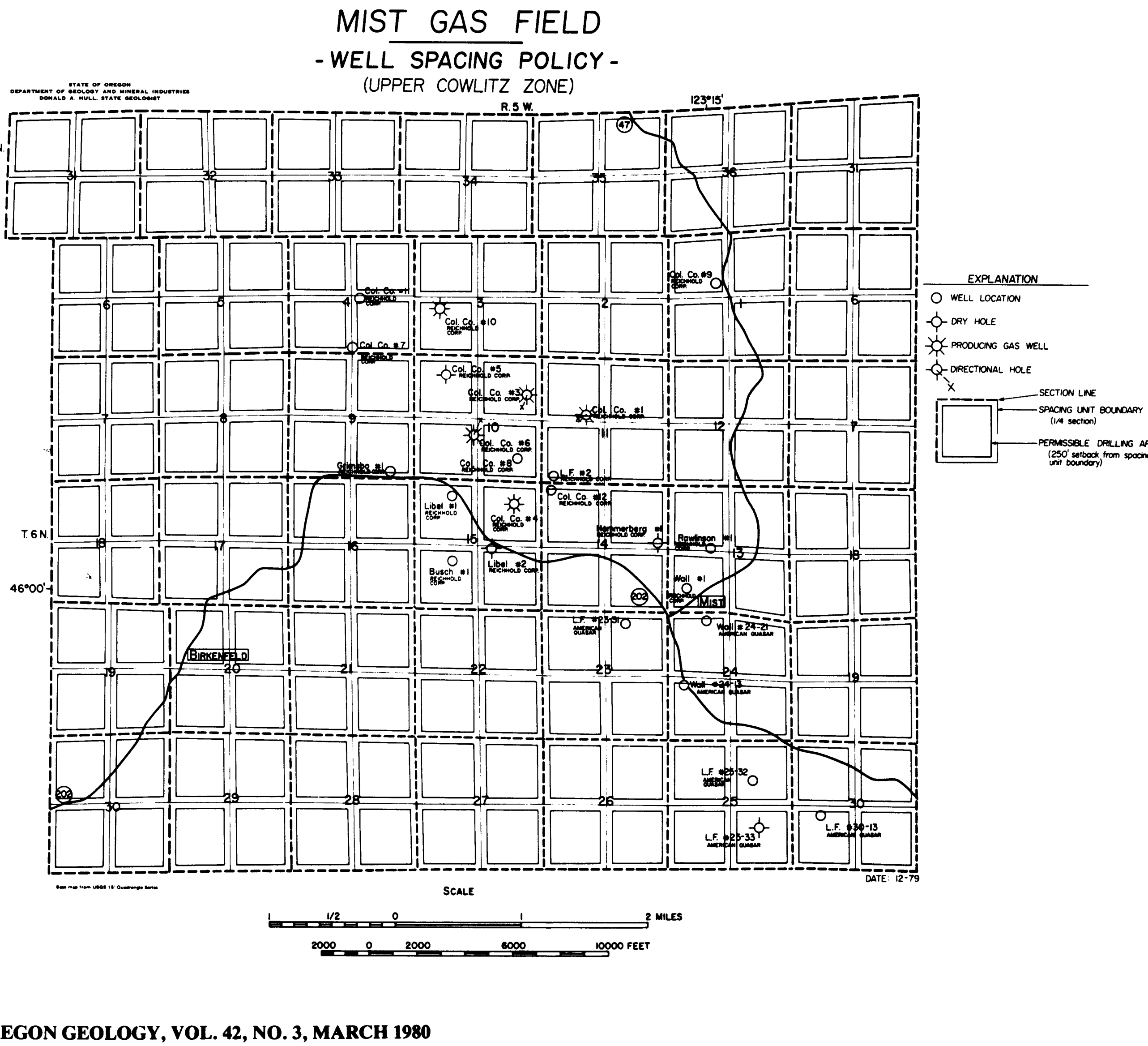


Table 1. *Oil and gas permits and drilling activity in Oregon, 1979*

Permit no.	Operator	Well name	Location	TD = Total depth (ft) RD = Redrill depth (ft)	Status
69 RD	Reichhold Energy Corporation	Columbia County 1	NW¼ sec. 11 T. 6 N., R. 5 W. Columbia County	TD: 3,111 RD: 2,965	Redrilled in 1979. Discovery: Mist Gas Field.
71	Reichhold Energy Corporation	Columbia County 2	NE¼ sec. 14 T. 6 N., R. 5 W. Columbia County	TD: 2,780	Abandoned, dry hole.
72	Reichhold Energy Corporation	Columbia County 3	NE¼ sec. 10 T. 6 N., R. 5 W. Columbia County	TD: 2,932 RD: 2,992	Completed, gas. Mist Gas Field.
75	Mobil Oil Company	Sutherlin Unit 1	SW¼ sec. 36 T. 24 S., R. 5 W. Douglas County	TD: 13,177	Abandoned, dry hole.
76	Agoil of Oregon	Hay Creek Ranch 2	NW¼ sec. 6 T. 11 S., R. 15 E. Jefferson County	TD: 2,065	Suspended, dry hole.
81	Mobil Oil Company	Ira Baker Unit 1	NE¼ sec. 28 T. 15 S., R. 3 W. Linn County	TD: 10,412	Abandoned, dry hole.
85	Farnham Chemical	Normark 4	NE¼ sec. 36 T. 11 S., R. 2 W. Linn County	–	Permit issued.
86	Reichhold Energy Corporation	Columbia County 4	NE¼ sec. 15 T. 6 N., R. 5 W. Columbia County	TD: 3,000	Completed, gas. Mist Gas Field.
87	Reichhold Energy Corporation	Columbia County 5	NW¼ sec. 10 T. 6 N., R. 5 W. Columbia County	TD: 3,100 RD: 3,116	Abandoned, dry hole.
88	Reichhold Energy Corporation	Grimsbo 1	SE¼ sec. 9 T. 6 N., R. 5 W. Columbia County	–	Permit issued.
89	Reichhold Energy Corporation	Libel 1	NW¼ sec. 15 T. 6 N., R. 5 W. Columbia County	–	Permit issued.
90	John T. Miller	Bursell 1	NW¼ sec. 14 T. 8 S., R. 5 W. Polk County	TD: 2,015	Abandoned, dry hole.
91	Reichhold Energy Corporation	Columbia County 6	SW¼ sec. 10 T. 6 N., R. 5 W. Columbia County	TD: 3,466 RD 1: 2,956 RD 2: 2,614	Completed, gas. Mist Gas Field.
92	Reichhold Energy Corporation	Columbia County 7	SE¼ sec. 4 T. 6 N., R. 5 W. Columbia County	–	Permit issued.
93	American Quasar Petroleum Company	Longview Fibre 30-13	SW¼ sec. 30 T. 6 N., R. 4 W. Columbia County	–	Permit issued.
94	American Quasar Petroleum Company	Longview Fibre 25-33	SE¼ sec. 25 T. 6 N., R. 5 W. Columbia County	TD: 7,000	Abandoned, dry hole.
95	Reichhold Energy Corporation	Columbia County 8	SE¼ sec. 10 T. 6 N., R. 5 W. Columbia County	–	Permit issued.
96	Reichhold Energy Corporation	Libel 2	SE¼ sec. 15 T. 6 N., R. 5 W. Columbia County	TD: 2,857	Abandoned, dry hole.
97	Floyd L. Cardinal	Watson 1	NE¼ sec. 14 T. 7 N., R. 9 W. Clatsop County	–	Permit issued.

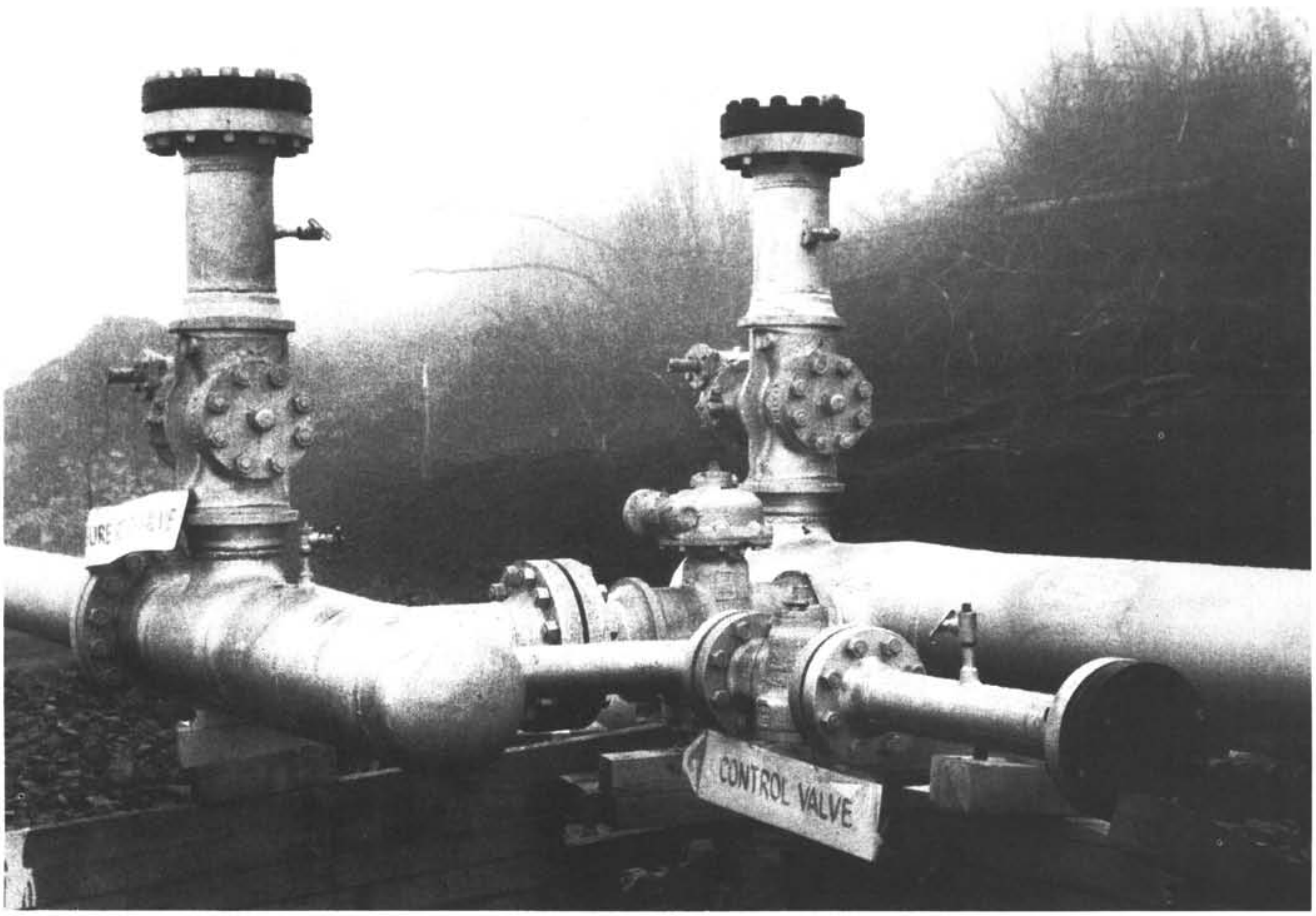
Table 1. *Oil and gas permits and drilling activity in Oregon, 1979 (continued)*

Permit no.	Operator	Well name	Location	TD = Total depth (ft) RD = Redrill depth (ft)	Status
98	Reichhold Energy Corporation	Columbia County 9	NW¼ sec. 1 T. 6 N., R. 5 W. Columbia County	–	Permit issued.
99	Reichhold Energy Corporation	Columbia County 10	SW¼ sec. 3 T. 6 N., R. 5 W. Columbia County	TD: 2,983	Completed, gas. Mist Gas Field.
100	Reichhold Energy Corporation	Columbia County 11	SE¼ sec. 11 T. 6 N., R. 5 W. Columbia County	–	Permit issued.
101	Reichhold Energy Corporation	Hammerberg 1	NE¼ sec. 14 T. 6 N., R. 5 W. Columbia County	TD: 2,851 RD: 3,318	Abandoned, dry hole.
102	Reichhold Energy Corporation	Wall 1	SW¼ sec. 13 T. 6 N., R. 5 W. Columbia County	–	Permit issued.
103	Reichhold Energy Corporation	Busch 1	SW¼ sec. 15 T. 6 N., R. 5 W. Columbia County	–	Permit issued.
104	Reichhold Energy Corporation	Rawlinson 1	NW¼ sec. 13 T. 6 N., R. 5 W. Columbia County	–	Permit issued.
105	Reichhold Energy Corporation	Longview Fibre 2	SW¼ sec. 11 T. 6 N., R. 5 W. Columbia County	–	Permit issued.
106	American Quasar Petroleum Company	Longview Fibre 6-21	NW¼ sec. 6 T. 5 N., R. 4 W. Columbia County	–	Permit issued.
107	American Quasar Petroleum Company	Longview Fibre 31-33	SE¼ sec. 31 T. 6 N., R. 4 W. Columbia County	–	Permit issued.
108	American Quasar Petroleum Company	Crown Zellerbach 15-14	SW¼ sec. 15 T. 6 N., R. 4 W. Columbia County	TD: 3,219	Abandoned, dry hole.
109	American Quasar Petroleum Company	Crown Zellerbach 21-41	NE¼ sec. 21 T. 6 N., R. 4 W. Columbia County	–	Permit issued.
110	American Quasar Petroleum Company	Wall 24-21	NW¼ sec. 24 T. 6 N., R. 5 W. Columbia County	–	Permit issued.
111	Reichhold Energy Corporation	Crown Zellerbach 3	SE¼ sec. 6 T. 4 N., R. 3 W. Columbia County	–	Permit issued.
112	Reichhold Energy Corporation	Crown Zellerbach 4	NW¼ sec. 36 T. 5 N., R. 4 W. Columbia County	TD: 6,063	Abandoned, dry hole.
113	American Quasar Petroleum Company	Longview Fibre 36-41	NE¼ sec. 36 T. 6 N., R. 5 W. Columbia County	–	Permit issued.
114	American Quasar Petroleum Company	Longview Fibre 31-21	NW¼ sec. 31 T. 6 N., R. 4 W. Columbia County	–	Permit issued.
115	Reichhold Energy Corporation	Columbia County 12	NW¼ sec. 14 T. 6 N., R. 5 W. Columbia County	–	Permit issued.
116	Oregon Natural Gas Development Company	Crown Zellerbach 1	NW¼ sec. 13 T. 2 S., R. 10 W. Tillamook County	TD: 6,158	Abandoned, dry hole (1980).

Table 1. *Oil and gas permits and drilling activity in Oregon, 1979 (continued)*

Permit no.	Operator	Well name	Location	TD = Total depth (ft) RD = Redrill depth (ft)	Status
–	John T. Miller	John Stump 1	NW¼ sec. 26 T. 8 S., R. 5 W. Polk County	–	Application received.
118	American Quasar Petroleum Company	Crown Zellerbach 29-14	SW¼ sec. 29 T. 6 N., R. 4 W. Columbia County	TD: 2,880	Abandoned, dry hole.
119	American Quasar Petroleum Company	Wall 24-13	SW¼ sec. 24 T. 6 N., R. 5 W. Columbia County	–	Permit issued.
120	American Quasar Petroleum Company	Longview Fibre 23-31	NE¼ sec. 23 T. 6 N., R. 5 W. Columbia County	–	Permit issued.
121	American Quasar Petroleum Company	Longview Fibre 25-32	NE¼ sec. 25 T. 6 N., R. 5 W. Columbia County	–	Permit issued.
122	American Quasar Petroleum Company	Crown Zellerbach 14-21	NW¼ sec. 14 T. 5 N., R. 5 W. Columbia County	–	Permit issued.

Figure 2. Northwest Natural Gas pipeline and control valves, Mist, Oregon. Designed and constructed in 1979, the new 12-in. pipeline connects the Mist Gas Field to the existing system at Clatskanie, 7 mi to the north. These valves are located at the Northwest Natural Gas gathering facility near Mist.



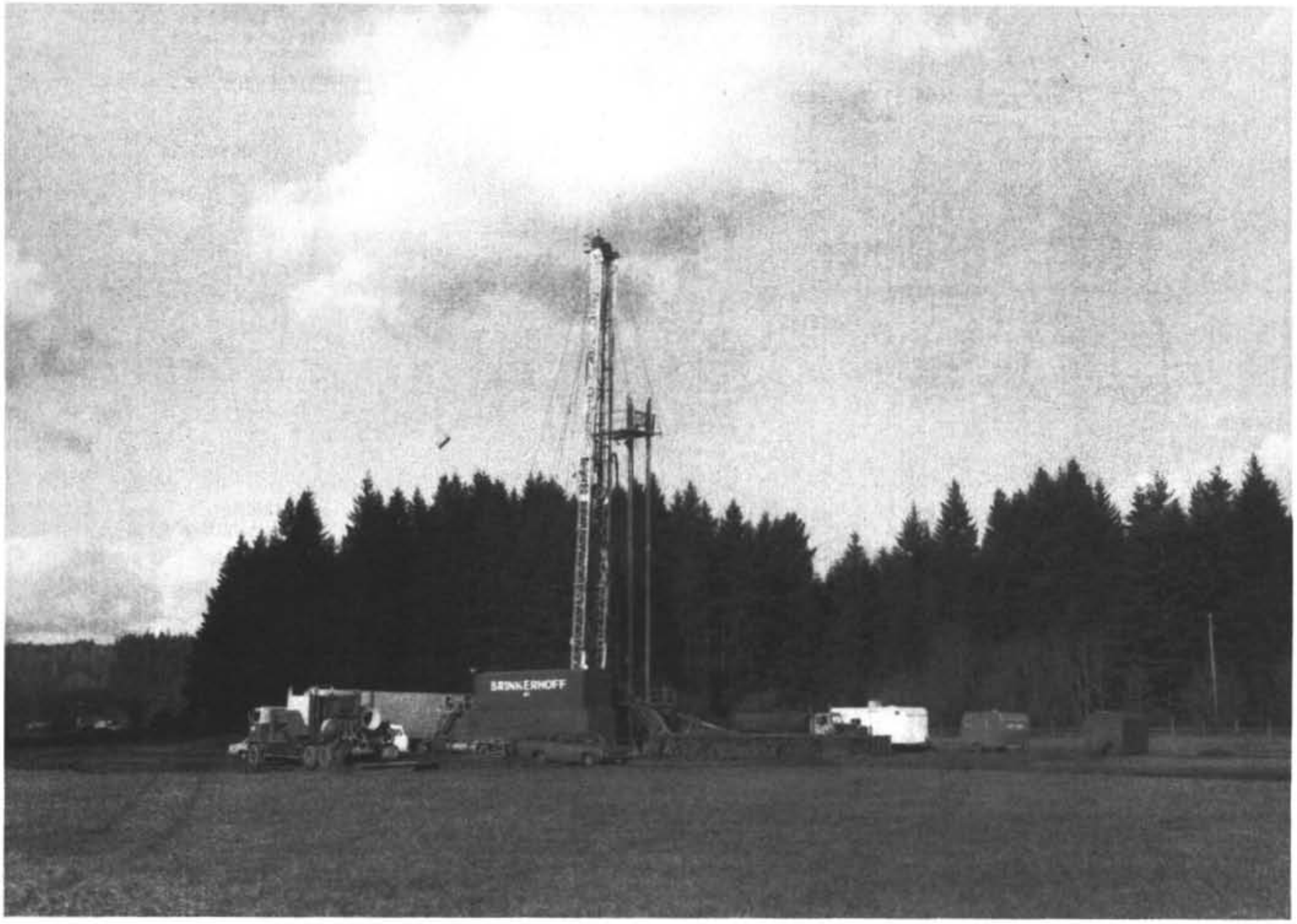


Figure 3. Brinkerhoff-Signal rig, drilling American Quasar Petroleum's Wall 24-13, 1 mi south of Mist, Oregon. This rig, the only one to work through the winter in Columbia County, also drilled an exploratory well in Tillamook County for Oregon Natural Gas Development Corporation.

gas storage site, but drilling during the year (Table 1) resulted in the discovery of the Mist Gas Field in Columbia County (Figure 1).

The discovery well, Columbia County 1, was first drilled during 1977 by a partnership composed of Reichhold Energy Corporation, Northwest Natural Gas Company, and Diamond Shamrock Corporation. The well was drilled for the dual purpose of discovering hydrocarbons or a gas storage reservoir. Gas shows existed in the Columbia County well, but they were considered to be noncommercial. Redrilled in 1979, the well produced a sizeable quantity of gas from the upper Cowlitz sand of the upper Eocene Cowlitz Formation. The initial test showed a flow rate of over 1.6 million cubic feet per day (MMcfd) and a shut-in pressure of 970 psi. The gas contained 92 percent methane and provided a heating value of 950 Btu per cubic foot.

The Mist gas discovery well was followed shortly by four more producers, all drilled by Reichhold and its partners within 1½ mi of the discovery well. These wells were all completed in the same sand at depths of 2,000 to 2,800 ft with a combined capacity of about 17 MMcfd. Further drilling in the vicinity has been carried out by Reichhold and by American Quasar Petroleum Company.

The discovery finally occurred after more than 200 dry holes were drilled throughout the State, including five in the Mist area alone. The northwest-trending structure in the Mist Gas Field consists of a highly faulted anticline, and the five producers appear to be completed in three separate pools.

Gas flowed from one of the wells in late December through a new 12-in. pipeline to the existing Northwest Natural Gas pipeline system (Figure 2) in Clatskanie.

Its 0.3 MMcfd will be augmented in 1980 as gathering lines are installed for the remaining producers. Further drilling is also expected in the area (Figure 3).

Elsewhere in the State, deep exploratory drilling was carried out by Mobil Oil Company in Douglas and Linn Counties. Sutherlin Unit 1 was drilled north of Roseburg to a depth of 13,177 ft and abandoned as a dry hole in April 1979. Mobil also drilled another deep

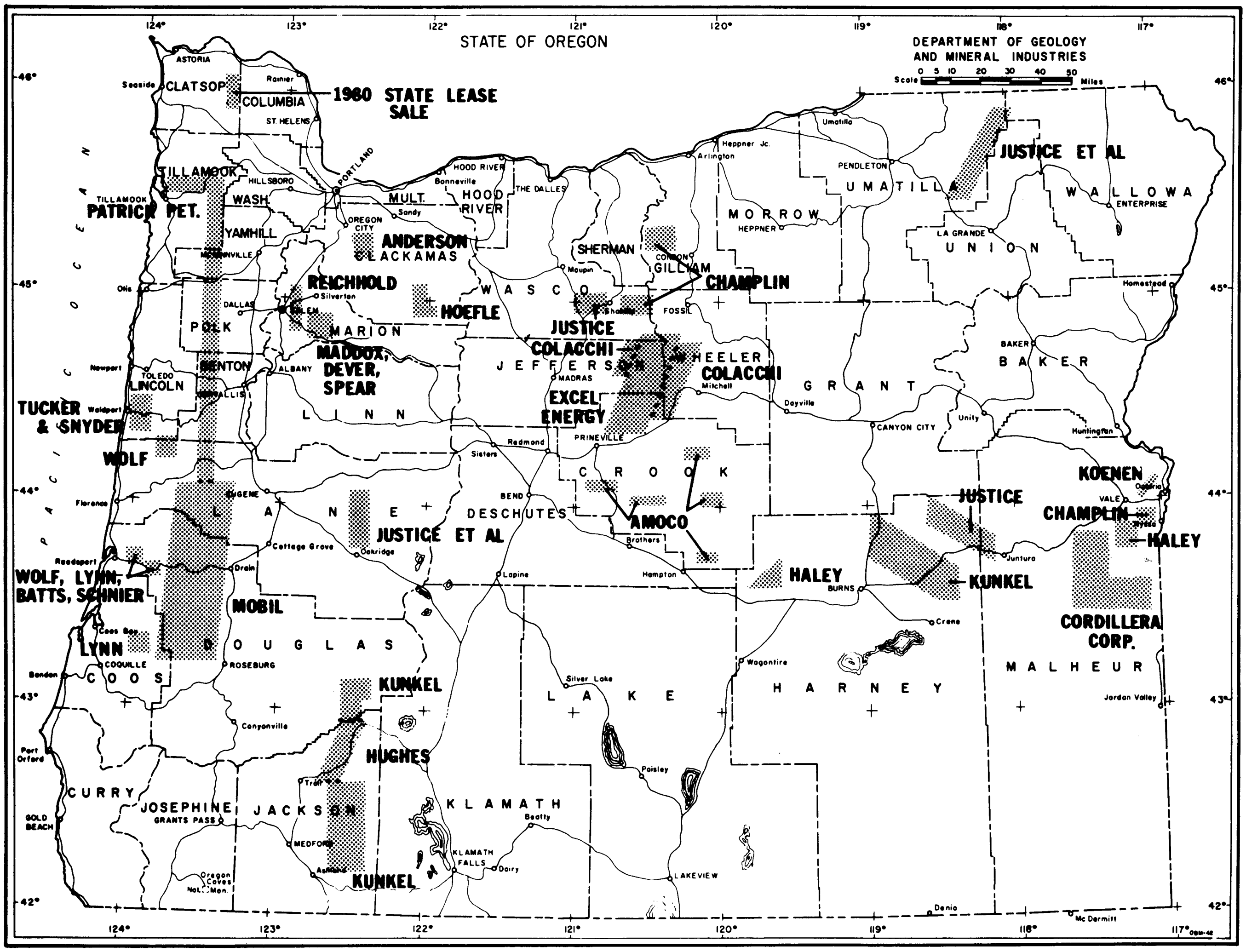


Figure 4. Oil and gas leases in Oregon, 1979.

exploratory well to 10,412 ft in southern Linn County, north of Eugene. This well, Ira Baker 1, was also a dry hole. Although both were dry, the drilling of these wells was encouraging, because it demonstrated the industry's willingness to drill deep holes in Oregon.

Drilling in the rest of the State consisted of a well in Jefferson County and one in Polk County. These dry holes were drilled to total depths of about 2,000 ft. At the year's end, Oregon Natural Gas Development Corporation was drilling an exploratory well in Tillamook County. This well, Crown Zellerbach 1, was abandoned as a dry hole in January 1980.

Leasing was very active in 1979 and continued into early 1980. Counties in northwestern Oregon enjoyed popularity stemming from the Mist gas discovery. Reichhold Energy Corporation and its partners, as well as American Quasar Petroleum Company, continued to be major leaseholders in Columbia County. Of the major oil companies, Mobil was active in leasing as well as drilling. Coos, Douglas, Lane, and Linn Counties were the sites of nearly 50,000 acres of new Mobil leaseholds.

Statewide, leases of Federal land in 1979 alone accounted for about a quarter million acres of new oil and gas leaseholds. More than 125 individuals and corporations acquired leases last year in the State, demonstrating the increased interest in the State's potential. Douglas County experienced one of the largest increases in oil and gas leasing for the year, with additions of over 125,000 acres on Federal land (Figure 4).

The industry showed further interest in Oregon when, in early 1980, a State Lands Division lease sale brought bonus bids of up to $150 per acre in Clatsop County, adjacent to Columbia County. Eight bidders leased 25,343 acres in Clatsop County. A statewide total of 41,096 acres was leased at this sale, bringing in $1,765,695 in bonus bids. This unusual showing of enthusiasm for Oregon oil and gas prospects points to a promising decade ahead. The relatively high level of drilling in 1979 (Figure 5) will likely continue through 1980 and beyond.

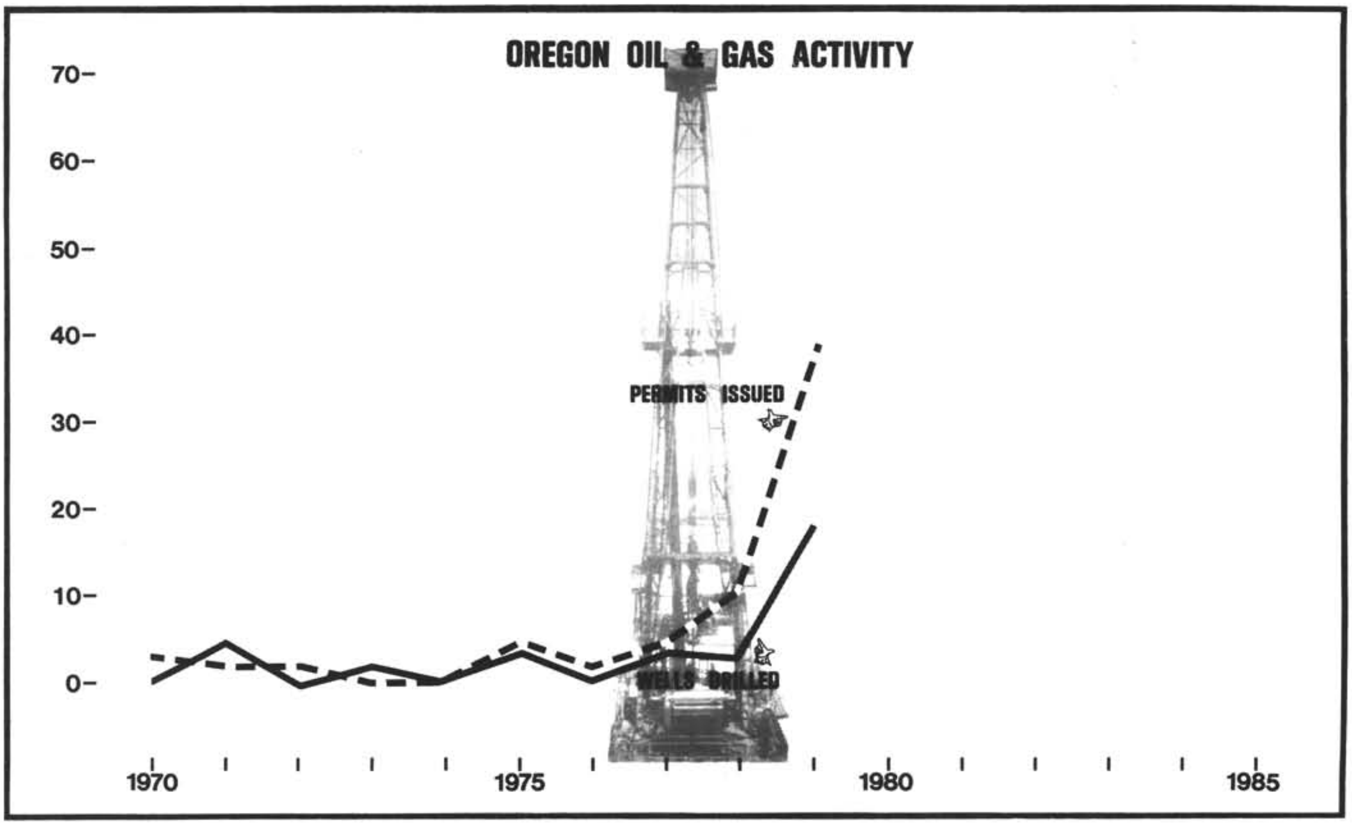


Figure 5. Oil and gas drilling activity in Oregon, 1979. The gas discovery at Mist resulted in a surge of drilling permits and drilling of wells during 1979. Even more activity is expected in Columbia County in 1980. □

State lands yield oil and gas revenue

Seven organizations and six individuals bid a total of $1,765,695 for oil and gas rights on 41,000 acres of State lands in western Oregon that were offered at one auction by the State Lands Division on January 8, 1980. Main interest was in land located in eastern Clatsop County, where bonus bids averaged approximately $60 per acre. The second area of interest was along the coast in Lane and Douglas counties. Bonus bids averaged $5 per acre in that area.

Participants in the bidding included the following:

Kyle R. Miller, Denver, Colorado, 11,000 acres;

Northwest Exploration Co., Denver, Colorado, 9,000 acres;

Nehama and Weagant, Bakersfield, California, 5,600 acres;

Diamond Shamrock Corp., Denver, Colorado, 3,900 acres;

Marvin and Melvin Wolf, Denver, Colorado, 2,500 acres.

High bid of $150 per acre was made by C.J. Ellsworth, Denver, Colorado, on a tract a few miles northeast of the town of Jewell in Clatsop County. □

Correction

The following corrections should be made to your February 1980 issue of *Oregon Geology*.

1. Page 22, second line of **COVER PHOTO** should read: "looking east toward Jackson Gap."
2. Page 33, starting seven lines from the bottom of the first column and continuing to the second column, the following numbers for **Km** and **Mi** should be changed:

13.1	8.2	should read	11.2	7.0
13.6	8.5	should read	11.7	7.3
16.6	10.4	should read	14.7	9.2
18.1	11.3	should read	20.6	12.9
23.2	14.5	should read	21.3	13.3

3. Page 33, nine lines from the bottom of the second column. The description for mile 5.8 should read: "Outcrop of interlayered Paleozoic and Triassic cherts, argillites, and marble, cut by Jurassic quartz monzonite." □

Send us your new address

When you move, don't forget to send your new address to the Oregon Department of Geology and Mineral Industries.

Mined land reclamation in Oregon, 1979

by Standley L. Ausmus, Supervisor, Mined Land Reclamation Program, Albany Field Office, Oregon Department of Geology and Mineral Industries

Surface mining activity in Oregon increased markedly during 1979, as shown by the numbers of inquiries about and applications for surface mining permits. This increased interest in surface mining is particularly true with regard to gold placer mining operations in Baker, Grant, Jackson, Josephine, and northern Malheur Counties. A substantial number of gold placer operations began or significantly expanded during the past year and are now operating under State surface mining permits with approved reclamation plans fully implemented and in place. Several other mines are very close to the start of operations.

The number of aggregate resource mining sites continues to increase at a rate comparable to those of previous years, with some seasonal fluctuation, of course. There have been an average of five new surface mining permits per month and an average of three new limited exemptions or grandfather certificates issued by the Program. This growth rate has been steady since about 1976 and is expected to continue, barring unforeseen economic circumstances. The expanded interest in gold and silver may influence that projection somewhat in the coming months.

As of January 1, 1980, 414 reclamation plans had been approved since the inception of the field program in January 1974. Over that same time span, 34 reclamation projects had been completed, representing approximately 350 acres of reclaimed ground.

A major Department concern of the past year was the rewriting of the administrative rules for the Mined Land Reclamation Program. Revisions were necessitated by the legislative changes which were enacted during the 1975, 1977, and 1979 sessions of the State Legislature. In addition, the Department recognized the need to rewrite, in simple and clear language, the instructions needed and steps to be followed in making application for a surface mining permit and in preparing the reclamation plan.

The initial draft of these proposed administrative rule changes was distributed for review to various mining industry representatives, to the Association of Oregon Counties, to State natural resource agencies, and to other interested parties and associations. Responses to this draft were presented to the Governing Board of the Department on November 20, 1979. A second draft was prepared and reviewed at three public hearings in January.

The third and final hearing on the draft and final Board action took place in February 1980. The revised rules were then sent to the office of the Secretary of State for publication.

Copies of the new rules will be distributed to those on the mailing list and others who have requested copies. Additional copies will be available in the Department's Portland, Albany, Baker, and Grants Pass offices.

Questions concerning the new administrative rules should be directed to the Albany office (phone: [503] 967-2039 or the toll-free number 1-800-452-7813).

The Department would like to take this opportunity to thank those people in government and industry who have labored with us in such a cooperative manner over the past 6 years to make the State surface mining reclamation program a reality and an effective tool in the proper development, conservation, and preservation of our natural resources. Without the support of these State and local agencies and the diligent and cooperative efforts of the miners and the construction industry, this program would not be a reality today. As a result, there has developed in Oregon a reclamation ethic which was, after all, the purpose and the intent of the legislation which brought this program into being in 1972.

It is the Department's determination to continue and to extend that cooperative effort throughout the coming decade as we strive together to meet the continuing and expanding demands of the economy for mineral resources while simultaneously protecting and preserving our environment and the value of the lands which must necessarily be mined for those mineral resources. □

(**Mineral Industry**, *from p. 46)*

was shipped to a pilot plant belonging to the UOP, Inc., a division of Signal Oil, in Tucson, Arizona, to test the Bureau of Mines' newly developed leach process to extract nickel, chromium, and cobalt from the laterites.

A Josephine County mineral report which summarizes information on 470 mines and prospects and contains a countywide geologic map was published by the Department as Bulletin 100, *Geology and Mineral Resources of Josephine County, Oregon* (Ramp and Peterson, 1979). □

PUBLICATIONS ORDER	OREGON GEOLOGY
Omission of price indicates publication is in press. Minimum mail order 50¢. All sales are final. Publications are sent postpaid. Payment must accompany orders of less than $20.00. Fill in appropriate blanks and send sheet to Department (see address on reverse side). YOUR NAME ____ ADDRESS ____ ____ Zip ____ Amount enclosed $ ____	____ Renewal ____ Subscription ____ Gift ____ 1 Year ($4.00) ____ 3 Years ($10.00) NAME ____ ADDRESS ____ ____ ZIP ____ (If Gift, From: ____)

ORDER FORM - CUT ON DASHED LINE

Available publications

MISCELLANEOUS PAPERS	Price	No. Copies	Amount
1. A description of some Oregon rocks and minerals, 1950: Dole	$ 1.00	____	____
4. Laws relating to oil, gas, and geothermal exploration and development in Oregon			
Part 1. Oil and natural gas rules and regulations, 1977, rev. 1979	1.00	____	____
Part 2. Geothermal resources rules and regulations, 1977, rev. 1979	1.00	____	____
5. Oregon's gold placers (reprints), 1954	.50	____	____
6. Oil and gas exploration in Oregon, rev. 1965: Stewart and Newton	3.00	____	____
8. Available well records of oil and gas exploration in Oregon, rev. 1973: Newton	1.00	____	____
11. Collection of articles on meteorites, 1968 (reprints from *The Ore Bin*)	1.50	____	____
13. Index to *The Ore Bin*, 1950-1974	1.50	____	____
14. Thermal springs and wells, 1970: Bowen and Peterson (with 1975 supplement)	1.50	____	____
15. Quicksilver deposits in Oregon, 1971: Brooks	1.50	____	____
16. Mosaic of Oregon from ERTS-1 imagery, 1973	2.50	____	____
18. Proceedings of Citizens' Forum on potential future sources of energy, 1975	2.00	____	____
19. Geothermal exploration studies in Oregon – 1976, 1977	3.00	____	____
20. Investigations of nickel in Oregon, 1978: Ramp	5.00	____	____
GEOLOGIC MAPS			
Geologic map of Galice quadrangle, Oregon, 1953	1.50	____	____
Geologic map of Albany quadrangle, Oregon, 1953	1.00	____	____
Reconnaissance geologic map of Lebanon quadrangle, 1956	1.50	____	____
Geologic map of Bend quadrangle and portion of High Cascade Mountains, 1957	1.50	____	____
Geologic map of Oregon west of 121st meridian, 1961	2.25	____	____
Geologic map of Oregon east of 121st meridian, 1977	3.75	____	____
GMS-3: Preliminary geologic map of Durkee quadrangle, Oregon, 1967	2.00	____	____
GMS-4: Oregon gravity maps, onshore and offshore, 1967 (folded)	3.00	____	____
GMS-5: Geologic map of Powers quadrangle, Oregon, 1971	2.00	____	____
GMS-6: Preliminary report on geology of part of Snake River Canyon, 1974	6.50	____	____
GMS-7: Geology of the Oregon part of the Baker quadrangle, Oregon, 1976	3.00	____	____
GMS-8: Complete Bouguer gravity anomaly map, Cascade Mountain Range, central Oregon, 1978	3.00	____	____
GMS-9: Total field aeromagnetic anomaly map, Cascade Mountain Range, central Oregon, 1978	3.00	____	____
GMS-10: Low- to intermediate-temperature thermal springs and wells in Oregon, 1978	2.50	____	____
GMS-11: Preliminary geothermal resource map of Oregon (upon written request only)	free	(one copy per customer)	
GMS-12: Geologic map of the Oregon part of the Mineral quadrangle	2.00	____	____
OIL AND GAS INVESTIGATIONS			
3. Preliminary identifications of foraminifera, General Petroleum Long Bell #1 well	2.00	____	____
4. Preliminary identifications of foraminifera, E.M. Warren Coos County 1-7 well, 1973	2.00	____	____
5. Prospects for natural gas production or underground storage of pipeline gas	5.00	____	____
MISCELLANEOUS PUBLICATIONS			
Landforms of Oregon (17 × 12 inches)	.50	____	____
Mining claims (State laws governing quartz and placer claims)	.50	____	____
Geological highway map, Pacific NW region, Oregon-Washington (published by AAPG)	3.00	____	____
Fifth Gold and Money Session and Gold Technical Session Proceedings, 1975	5.00	____	____
Sixth Gold and Money Session and Gold Technical Session Proceedings, 1978	6.50	____	____
Back issues of *The Ore Bin*	25¢ over the counter; 50¢ mailed	____	____
Colored postcard, *Geology of Oregon*	10¢ each; 3 for 25¢; 7 for 50¢; 15 for 1.00	____	____

OREGON GEOLOGY

1069 State Office Building, Portland, Oregon 97201

Second Class Matter
POSTMASTER: Form 3579 requested

Available publications (continued)

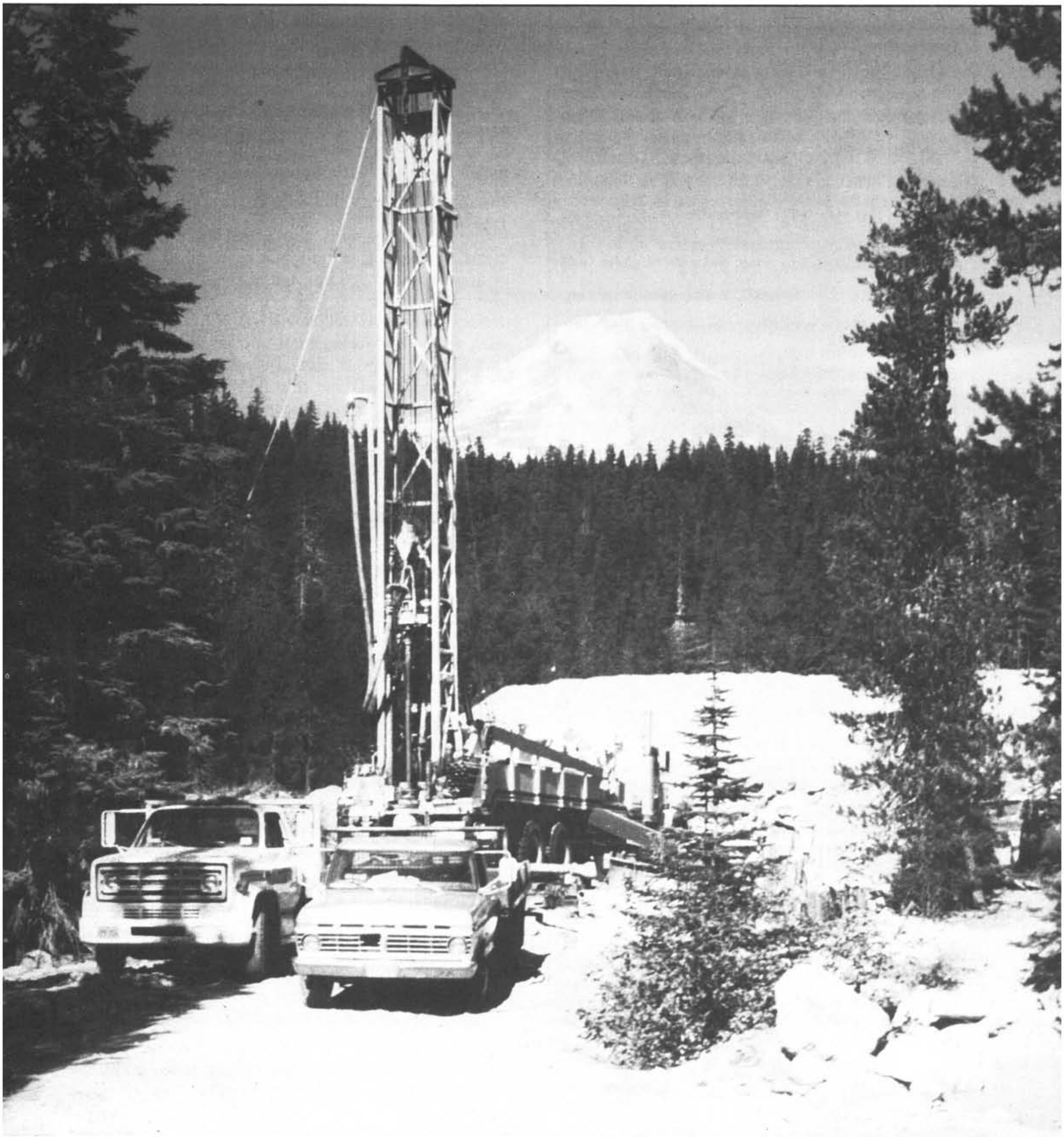
BULLETINS	Price	No. Copies	Amount
33. Bibliography (1st supplement) geology and mineral resources of Oregon, 1947: Allen	1.00	_____	_____
36. Papers on Tertiary foraminifera: Cushman, Stewart and Stewart, 1949: v. 2	1.25	_____	_____
39. Geology and mineralization of Morning Mine region, 1948: Allen and Thayer	1.00	_____	_____
44. Bibliography (2nd supplement) geology and mineral resources of Oregon, 1953: Steere	2.00	_____	_____
46. Ferruginous bauxite deposits, Salem Hills, 1956: Corcoran and Libbey	1.25	_____	_____
49. Lode mines, Granite mining district, Grant County, Oregon, 1959: Koch	1.00	_____	_____
53. Bibliography (3rd supplement) geology and mineral resources of Oregon, 1962: Steere and Owen	3.00	_____	_____
57. Lunar Geological Field Conference guidebook, 1965: Peterson and Groh, editors	3.50	_____	_____
62. Andesite Conference guidebook, 1968: Dole	3.50	_____	_____
63. Sixteenth biennial report of the Department, 1966-1968	1.00	_____	_____
64. Mineral and water resources of Oregon, 1969 (unbound, without maps and tables)	2.00	_____	_____
65. Proceedings of Andesite Conference, 1969: (copies)	10.00	_____	_____
67. Bibliography (4th supplement) geology and mineral resources of Oregon, 1970: Roberts	3.00	_____	_____
68. Seventeenth biennial report of the Department, 1968-1970	1.00	_____	_____
71. Geology of selected lava tubes in Bend area, Oregon, 1971: Greeley	2.50	_____	_____
76. Eighteenth biennial report of the Department, 1970-1972	1.00	_____	_____
77. Geologic field trips in northern Oregon and southern Washington, 1973	5.00	_____	_____
78. Bibliography (5th supplement) geology and mineral resources of Oregon, 1973: Roberts	3.00	_____	_____
81. Environmental geology of Lincoln County, 1973: Schlicker and others	9.00	_____	_____
82. Geologic hazards of Bull Run Watershed, Multnomah, Clackamas Counties, 1974: Beaulieu	6.50	_____	_____
83. Eocene stratigraphy of southwestern Oregon, 1974: Baldwin	4.00	_____	_____
84. Environmental geology of western Linn County, 1974: Beaulieu and others	9.00	_____	_____
85. Environmental geology of coastal Lane County, 1974: Schlicker and others	9.00	_____	_____
86. Nineteenth biennial report of the Department, 1972-1974	1.00	_____	_____
87. Environmental geology of western Coos and Douglas Counties, 1975	9.00	_____	_____
88. Geology and mineral resources of upper Chetco River drainage, 1975: Ramp	4.00	_____	_____
89. Geology and mineral resources of Deschutes County, 1976	6.50	_____	_____
90. Land use geology of western Curry County, 1976: Beaulieu	9.00	_____	_____
91. Geologic hazards of parts of northern Hood River, Wasco, and Sherman Counties, Oregon, 1977: Beaulieu	8.00	_____	_____
92. Fossils in Oregon (reprinted from *The Ore Bin*), 1977	4.00	_____	_____
93. Geology, mineral resources, and rock material of Curry County, Oregon, 1977	7.00	_____	_____
94. Land use geology of central Jackson County, Oregon, 1977: Beaulieu	9.00	_____	_____
95. North American ophiolites, 1977	7.00	_____	_____
96. Magma genesis: AGU Chapman Conference on Partial Melting, 1977	12.50	_____	_____
97. Bibliography (6th supplement) geology and mineral resources of Oregon, 1971-75, 1978	3.00	_____	_____
98. Geologic hazards of eastern Benton County, 1979: Bela	9.00	_____	_____
100. Geology and mineral resources of Josephine County, Oregon, 1979: Ramp and Peterson	9.00	_____	_____
101. Geologic field trips in western Oregon and southwestern Washington, 1980	9.00	_____	_____
SPECIAL PAPERS			
1. Mission, goals, and purposes of Oregon Department of Geology and Mineral Industries, 1978	2.00	_____	_____
2. Field geology of SW Broken Top quadrangle, Oregon, 1978: Taylor	3.50	_____	_____
3. Rock material resources of Clackamas, Columbia, Multnomah, and Washington Counties, Oregon, 1978: Gray	7.00	_____	_____
4. Heat flow of Oregon, 1978, Blackwell, Hull, Bowen, and Steele	3.00	_____	_____
5. Analysis and forecasts of the demand for rock materials in Oregon, 1979	3.00	_____	_____
7. Pluvial Fort Rock Lake, Lake County, Oregon	4.00	_____	_____
SHORT PAPERS			
18. Radioactive minerals prospectors should know, 1976: White, Schafer, Peterson	.75	_____	_____
19. Brick and tile industry in Oregon, 1949: Allen and Mason	.20	_____	_____
21. Lightweight aggregate industry in Oregon, 1951: Mason	.25	_____	_____
24. The Almeda Mine, Josephine County, Oregon, 1967: Libbey	3.00	_____	_____
25. Petrography, type Rattlesnake Formation, central Oregon, 1976: Enlows	2.00	_____	_____
27. Rock material resources of Benton County, 1978: Schlicker and others	4.00	_____	_____

OREGON GEOLOGY

formerly THE ORE BIN

published by the Oregon Department of Geology and Mineral Industries

VOLUME 42, NUMBER 4 APRIL 1980



OREGON GEOLOGY

(ISSN 0164-3304)

VOLUME 42, NUMBER 4 APRIL 1980

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

Main Office: 1069 State Office Building, Portland 97201, phone (503) 229-5580.

Baker Field Office: 2033 First Street, Baker 97814, phone (503) 523-3133.
Howard C. Brooks, Resident Geologist

Grants Pass Field Office: 312 S.E. "H" Street, Grants Pass 97526, phone (503) 476-2496.
Len Ramp, Resident Geologist

Mined Land Reclamation Program: 1129 S.E. Santiam Road, Albany 97321, phone (503) 967-2039.
Standley L. Ausmus, Supervisor

Subscription rates: 1 year, $4.00; 3 years, $10.00. Single issues, $.40 at counter, $.50 mailed.
Available back issues of *The Ore Bin:* $.25 at counter, $.50 mailed.

Address subscription orders, renewals, and changes of address to *Oregon Geology,* 1069 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,* 1069 State Office Building, Portland, OR 97201.

COVER PHOTO

Temperature-gradient drilling on southern flanks of Mt. Hood, Oregon. Article beginning on next page summarizes geothermal exploration activities within the State during 1979.

Department of Geology begins mid-Willamette Valley rock resource study

The Oregon Department of Geology and Mineral Industries (DOGAMI) has initiated a two-year study of the rock material resources of Marion, Polk, Yamhill, and Linn Counties. The study is sponsored by DOGAMI, the Pacific Northwest Regional Commission, and the Oregon Land Conservation and Development Commission.

Because of the significance of rock material in the regional economy, the Department is giving high priority to the development of supply assessments, and the mid-Willamette Valley represents an economic market area of particular importance.

The study will provide basic supply data on land with potential for sand, gravel, and stone production, including a geological unit base map and an inventory of approximately 800 pits and quarries. By combining inventory information with geologic maps and by addressing demand as well, it will establish a broad framework for policy formulation and decision-making in land use and resource management.

Contact person for this study is Jerry J. Gray, Oregon Department of Geology and Mineral Industries, 1129 S.E. Santiam Road, Albany, Oregon 97321, phone (503) 967-2039. □

CONTENTS

NEXT MONTH

Miocene Stratigraphy and Fossils, Cape Blanco, Oregon, by Warren Addicott, U.S. Geological Survey

Geothermal exploration in Oregon, 1979

by Joseph F. Riccio, Geothermal Specialist, and Dennis L. Olmstead, Geologist, Oregon Department of Geology and Mineral Industries

ABSTRACT

Government agencies and university researchers continued their geothermal research effort in Oregon during 1979. The Oregon Department of Geology and Mineral Industries placed emphasis on the evaluation of Oregon's low-temperature resource areas and the geothermal potential of the central Cascades.

Industrial exploration decreased, and no major discoveries were reported. The major effort by industry was the drilling of the 10,050-ft well at Ontario, Malheur County, by Ore-Ida Foods, Inc. During the year, the Department issued permits for 201 temperature-gradient holes less than 500 ft deep and for 35 holes more than 500 ft deep. Ninety shallow and 29 deep holes were actually drilled.

INDUSTRY ACTIVITY

Oregon's deepest geothermal test well (depth 10,050 ft) to date was drilled in Ontario, Malheur County (Figure 1), at a cost of $4.8 million, by Ore-Ida Foods, Inc., in conjunction with the U.S. Department of Energy (USDOE). The well was spudded on August 19, 1979, by Montgomery Drilling Company of Bakersfield, California. Temperatures approximating 400°F were reported from this hole; however, the amount of geothermal fluid recovered from an initial drill-stem test was not sufficient in volume to warrant completion of the well. The hole is currently shut-in, pending further geologic and engineering analyses and additional testing.

The Eugene Water and Electric Board (EWEB) initiated and completed the drilling of six temperature-gradient holes in the central Cascades (Figure 2). Maximum depth of exploration was 1,960 ft. This undertaking was in conjunction with Southland Royalty Company and Sunoco Energy Development Company. Funding, in part, was by USDOE.

The remainder of the exploration effort by industry (Tables 1 and 2) was restricted to the drilling of temperature-gradient holes to depths ranging from 500 to 2,000 ft. Prior to September 1, 1979, prospect wells included only those drilled to 500 ft or less. According to the present Oregon law relating to geothermal exploration and development, however, the term "prospect well" includes any geophysical test well, seismic shot hole, mineral exploration drilling, core drilling, or temperature-gradient test well that is less than 2,000 ft in depth and is drilled during the prospecting for geothermal resources. This change in the law influenced the 1979 trends shown on the graphs in Figures 3 and 4 and the data presented in the abstract.

Old Maid Flat 1, the geothermal exploratory test well drilled on the flanks of Mt. Hood by Northwest Geothermal Corporation, is still shut-in. Plans are currently being formulated to obtain fluid samples for geochemical analyses from several of the potentially producing aquifers. If these tests prove successful, flow testing of the well may be considered for late summer of 1980.

Leasing

Acquisition of geothermal leases continued in Oregon during 1979. The total Federal acreage leased

Figure 1. Ore-Ida Foods, Inc., Well 1, Ontario, Malheur County, Oregon.

Table 1. *Geothermal permits and drilling activity in Oregon, 1979*

Permit no.	Operator	Well name	Location	Total depth (ft)	Status
37	Anadarko Production	Alvord Valley Hole A-7	SW¼ sec. 18 T. 33 S., R. 36 E. Harney County	–	Location, proposed depth 2,000 ft.
38	Anadarko Production	Alvord Valley Hole A-8	SE¼ sec. 14 T. 33 S., R. 35 E. Harney County	–	Location, proposed depth 2,000 ft.
39	Anadarko Production	Alvord Valley Hole A-26	NE¼ sec. 29 T. 34 S., R. 34 E. Harney County	–	Location, proposed depth 2,000 ft.
40	Anadarko Production	Alvord Valley Hole A-31	SW¼ sec. 34 T. 34 S., R. 34 E. Harney County	–	Location, proposed depth 2,000 ft.
41	Anadarko Production	Alvord Valley Hole A-34	NE¼ sec. 8 T. 35 S., R. 34 E. Harney County	–	Location, proposed depth 2,000 ft.
42	Anadarko Production	Alvord Valley Hole B-56	SE¼ sec. 10 T. 37 S., R. 33 E. Harney County	–	Location, proposed depth 2,000 ft.
43	Anadarko Production	Alvord Valley Hole B-61	SW¼ sec. 13 T. 37 S., R. 33 E. Harney County	–	Location, proposed depth 2,000 ft.
44	Anadarko Production	Alvord Valley Hole B-64	NW¼ sec. 22 T. 37 S., R. 33 E. Harney County	–	Location, proposed depth 2,000 ft.
45	U.S. Geological Survey	Newberry Crater 2	SW¼ sec. 31 T. 21 S., R. 13 E. Deschutes County	2,076	Drilling suspended October 1979; will deepen to 3,000 ft in 1980.
46	Ore-Ida Foods, Inc.	Well 1	NE¼ sec. 3 T. 18 S., R. 47 E. Malheur County	10,050	Well suspended for monitoring.
47	Ore-Ida Foods, Inc.	Well 2	SE¼ sec. 3 T. 18 S., R. 47 E. Malheur County	–	Drilling postponed pending evaluation of Well No. 1.
48	Chevron Resources	Neals-Bully Creek 79-2	SE¼ sec. 32 T. 17 S., R. 43 E. Malheur County	–	Location, proposed depth 2,000 ft.
49	Chevron Resources	Neals-Bully Creek 79-4	SW¼ sec. 33 T. 17 S., R. 43 E. Malheur County	2,010	Temperature-gradient well.
50	Chevron Resources	Neals-Bully Creek 79-5	NE¼ sec. 4 T. 18 S., R. 43 E. Malheur County	–	Location, proposed depth 2,000 ft.
51	Chevron Resources	Neals-Bully Creek 79-6	SE¼ sec. 8 T. 18 S., R. 43 E. Malheur County	–	Location, proposed depth 2,000 ft.
52	Chevron Resources	Neals-Bully Creek 79-7	NW¼ sec. 3 T. 18 S., R. 43 E. Malheur County	–	Location, proposed depth 2,000 ft.
53	Chevron Resources	Neals-Bully Creek 79-8	NW¼ sec. 28 T. 17 S., R. 43 E. Malheur County	–	Location, proposed depth 2,000 ft.
54	Chevron Resources	Neals-Bully Creek 79-10	NE¼ sec. 15 T. 18 S., R. 43 E. Malheur County	1,868	Temperature-gradient well.
55	Chevron Resources	Neals-Bully Creek 79-11	NW¼ sec. 9 T. 18 S., R. 43 E. Malheur County	–	Location, proposed depth 2,000 ft.

Table 1. *Geothermal permits and drilling activity in Oregon, 1979 (continued)*

Permit no.	Operator	Well name	Location	Total depth (ft)	Status
56	Union Oil Company	Brooks Scanlon 1	NW¼ sec. 2 T. 24 S., R. 11 E. Klamath County	705	Abandoned, temperature-gradient well.
57	Union Oil Company	Brooks Scanlon 2	SW¼ sec. 5 T. 23 S., R. 11 E. Klamath County	550	Abandoned, temperature-gradient well.
58	Union Oil Company	Brooks Scanlon 3	SW¼ sec. 29 T. 23 S., R. 11 E. Klamath County	–	Will not be drilled.
59	Union Oil Company	Brooks Scanlon 4	NE¼ sec. 15 T. 26 S., R. 12 E. Lake County	–	Will not be drilled.
60	Union Oil Company	Brooks Scanlon 5	SW¼ sec. 36 T. 26 S., R. 12 E. Lake County	975	Abandoned, temperature-gradient well.
61	Union Oil Company	Brooks Scanlon 6	SW¼ sec. 32 T. 25 S., R. 12 E. Lake County	1,010	Abandoned, temperature-gradient well.
62	Union Oil Company	Brooks Scanlon 7	NE¼ sec. 12 T. 17 S., R. 10 E. Deschutes County	–	Will not be drilled.
63	Union Oil Company	Brooks Scanlon 8	SE¼ sec. 30 T. 17 S., R. 11 E. Deschutes County	840	Abandoned, temperature-gradient well.
64	Union Oil Company	Brooks Scanlon 9	NE¼ sec. 27 T. 16 S., R. 10 E. Deschutes County	860	Abandoned, temperature-gradient well.
65	Northwest Natural Gas	Jct. Highways 26 and 35	NE¼ sec. 30 T. 3 S., R. 9 E. Clackamas County	965	Suspended, temperature-gradient well.
66	Northwest Natural Gas	Zigzag 1	NW¼ sec. 14 T. 3 S., R. 8 E. Clackamas County	940	Suspended, temperature-gradient well.
67	Northwest Natural Gas	Still Creek 1	NW¼ sec. 35 T. 3 S., R. 8 E. Clackamas County	–	Location, temperature-gradient well.
68	Eugene Water and Electric Board	Road 075	NE¼ sec. 4 T. 13 S., R. 7 E. Linn County	–	Location, temperature-gradient well.
69	Eugene Water and Electric Board	Sisi Creek	SW¼ sec. 6 T. 8 S., R. 8 E. Clackamas County	1,505	Suspended, temperature-gradient well.
70	U.S. Geological Survey	Pucci Chairlift	SE¼ sec. 7 T. 3 S., R. 9 E. Clackamas County	2,000	To be deepened to approximately 3,000 ft in 1980.
71	Francana Resources, Inc.	Glass Buttes 1	NW¼ sec. 31 T. 22 S., R. 23 E. Lake County	2,000	Abandoned, temperature-gradient well.
72	Francana Resources, Inc.	Glass Buttes 2	SW¼ sec. 17 T. 23 S., R. 23 E. Lake County	–	Location, proposed depth 2,000 ft.
73	Eugene Water and Electric Board	Fish Lake Creek	SE¼ sec. 32 T. 13 S., R. 7 E. Clackamas County	1,837	Suspended, temperature-gradient well.
74	Eugene Water and Electric Board	Twin Meadows	SE¼ sec. 9 T. 12 S., R. 7 E. Clackamas County	1,960	Suspended, temperature-gradient well.

Table 1. *Geothermal permits and drilling activity in Oregon, 1979 (continued)*

Permit no.	Operator	Well name	Location	Total depth (ft)	Status
75	Eugene Water and Electric Board	Poop Creek	SE¼ sec. 5 T. 7 S., R. 8 E. Clackamas County	870	Suspended, temperature-gradient well.
76	Eugene Water and Electric Board	Cinder Cone	NE¼ sec. 10 T. 7 S., R. 8 E. Clackamas County	1,160	Suspended, temperature-gradient well.
77	Eugene Water and Electric Board	Tarzan Spring	SE¼ sec. 4 T. 7 S., R. 7 E. Clackamas County	710	Suspended, temperature-gradient well.
78	Eugene Water and Electric Board	Pinhead	NE¼ sec. 35 T. 7 S., R. 8 E. Clackamas County	–	Location, temperature-gradient well.
79	Eugene Water and Electric Board	Crescent Creek	SE¼ sec. 13 T. 13 S., R. 6 E. Clackamas County	–	Location, temperature-gradient well.
80	Chevron Resources	Jordan 55	NW¼ sec. 9 T. 18 S., R. 43 E. Malheur County	–	Drilling at 2,600 ft, January 1980.

Table 2. *Geothermal prospect permits and drilling activity in Oregon, 1979*

Permit no.	Operator	Issue date	Locations	Comments and status
38	Phillips Petroleum Company	May 1978	Brothers Fault Zone, Lake and Harney Counties	Drilled 17 more 500-ft gradient holes in 1979, continuing the 1978 program.
47	Northwest Natural Gas	Nov. 1978	Mt. Hood Clackamas County	Summit Meadows well drilled to 1,115 ft. Lost Creek well drilled to 431 ft. Clear Fork well drilled to 495 ft.
48	Chevron Resources	April 1979	Bully Creek Malheur County	Drilled two 500-ft and two 2,000-ft gradient holes.
49	Technology International	April 1979	Vale Malheur County	Location, temperature-gradient well.
50	Phillips Petroleum Company	July 1979	Lakeview Harney County	Drilled 24 500-ft gradient holes in 1979.
51	Francana Resources	July 1979	Glass Buttes Lake County	Drilled one hole to 2,000 ft, suspended to monitor temperature.
52	Chevron Resources	July 1979	South Crump Lake Lake County	Drilled 14 500-ft gradient holes in 1979.
53	Chevron Resources	July 1979	Bully Creek Malheur County	Drilled four 500-ft gradient holes in 1979.
54	Oregon Department of Geology and Mineral Industries	Aug. 1979	Cascades Clackamas County	Drilled eight 500-ft gradient holes in 1979.
55	U.S. Geological Survey	Aug. 1979	Mt. Hood Clackamas County	Drilled two wells in 1979; deepest 1,002 ft.
56	Republic Geothermal	Aug. 1979	Vale Malheur County	Drilled four wells in 1979; three to depth of 500 ft and one to 1,500 ft.
57	Anadarko Production Company	Sept. 1979	Alvord Valley Harney County	Drilled six 500-ft and one 900-ft gradient holes in 1979.
58	Union Oil Company	Oct. 1979	Alvord Valley Harney County	Location, temperature-gradient well.
59	Eugene Water and Electric Board	Sept. 1979	Breitenbush Linn County	Location, temperature-gradient well.
60	Oregon Department of Geology and Mineral Industries	Nov. 1979	Lakeview Lake County	Drilled eight 500-ft gradient holes in 1979.
61	Oregon Department of Geology and Mineral Industries	Nov. 1979	La Grande Union County	Drilled two 500-ft gradient holes in 1979.

was a little greater than in 1978. Totals of Federal and State leases in Oregon are shown in Table 3. The acreage noted for the private leases is an estimate because confirmation is difficult.

Table 3. *Geothermal leases in Oregon, 1979*

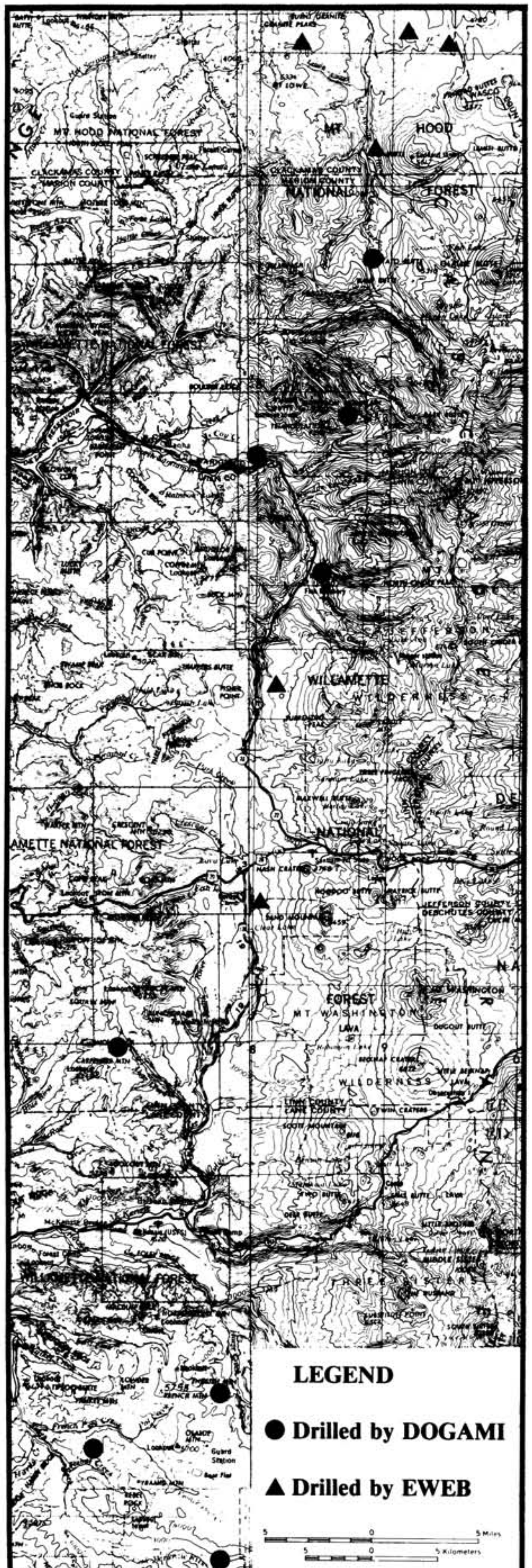
Type of leases	Number	Acres
Federal		
Noncompetitive	113 USBLM*	165,678
	23 USFS**	38,872
Competitive	21 USBLM*	43,082
	4 USFS**	5,818
Applications pending	123 USBLM*	
	368 USFS**	
Total		253,450
State		
Leases active in 1979		8,934
Applications pending		3
Private		
Leases active in 1979 (est.)		160,000

* U.S. Bureau of Land Management
** U.S. Forest Service

There were no U.S. Bureau of Land Management (USBLM) lease sales in calendar year 1979. However, four energy companies—Anadarko Production Company, Hunt Oil Company, Intercontinental Energy Corporation, and Union Oil Company—were successful bidders on the sale held January 8, 1980, on six parcels of Federal land in Oregon in the following KGRA's: Alvord, Breitenbush, Crump, and Klamath Falls (Table 4). Sixty-two parcels were offered by the Federal government. Forty-nine parcels received no bids, and seven others were withdrawn. The withdrawn parcels and those that did not receive bids will be re-offered as part of a geothermal lease sale planned for April 29, 1980.

After the April 29 sale, the USBLM will probably recommend to the U.S. Geological Survey (USGS) that those parcels which received no bids at this and several previous sales be removed from KGRA classification.

A sale of parcels in Oregon in the Belknap-Foley Hot Springs, McCredie, and Newberry Caldera KGRA's is tentatively planned for October 23, 1980, contingent upon the forwarding of leasing recommendations by the USGS.



← *Figure 2. Location of temperature-gradient holes drilled by Eugene Water and Electric Board and Oregon Department of Geology and Mineral Industries, 1979.*

Table 4. *U.S. Bureau of Land Management KGRA lease sales, January 8, 1980*

Parcel	Acreage	Area	Company	Amount
13	2,280	Alvord	Anadarko	$236,367.60
14	2,463	Alvord	Anadarko	90,605.33
33	1,029	Breitenbush	Union Oil	10,341.45
39	118	Klamath Falls	Intercontinental	917.53
50	2,371	Crump	Hunt Oil	4,833.35
51	2,344	Crump	Hunt Oil	4,828.58

RESEARCH

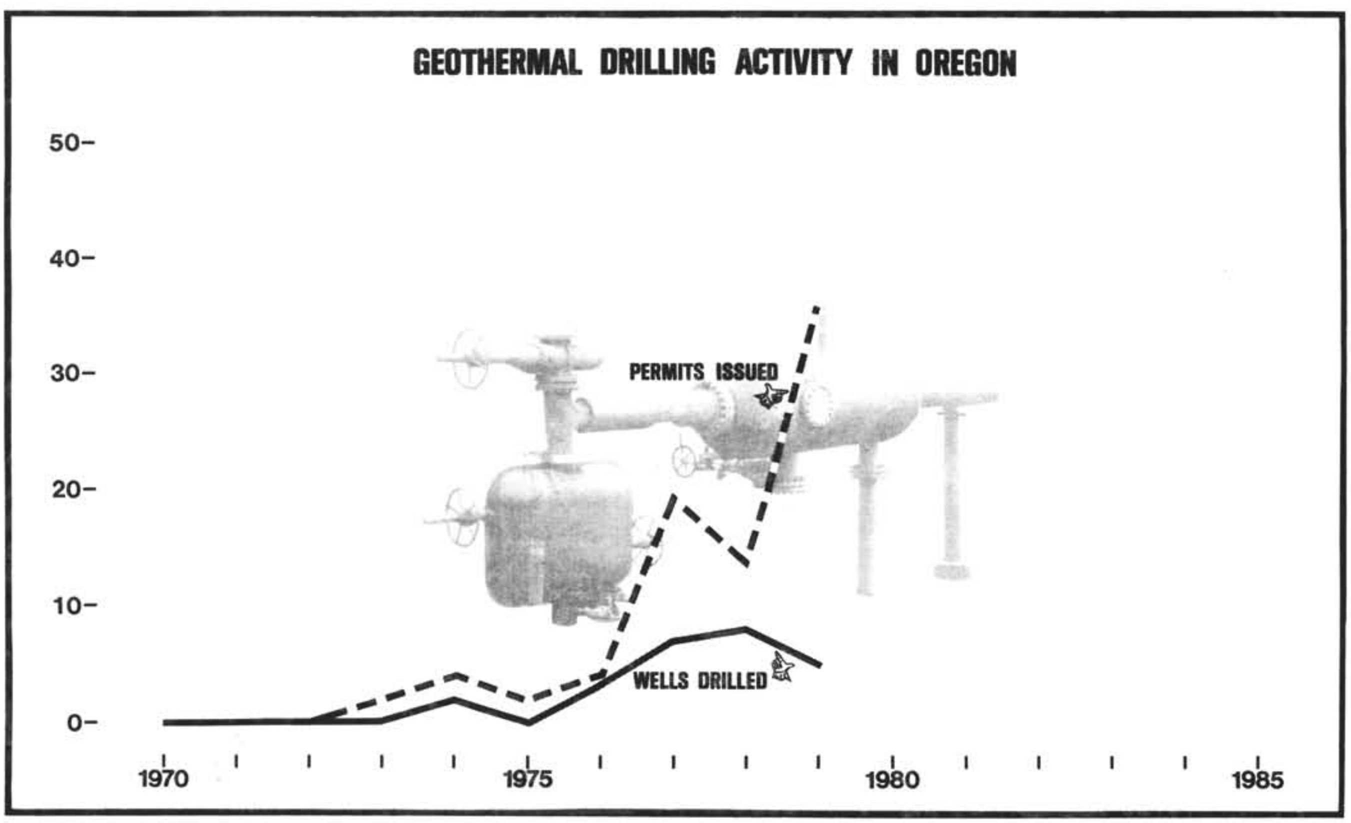
Low-temperature geothermal resources

The first phase of the statewide inventory of low-temperature geothermal resources (geothermal waters with a temperature of 90°C or less) was begun by the Oregon Department of Geology and Mineral Industries (DOGAMI) in July 1977 and completed in June 1979. The inventory consisted of two parts: (1) a compilation of chemical data on thermal springs and wells in Oregon, and (2) an identification of potential low-temperature resource areas on the basis of geochemical, temperature-gradient, heat-flow, geological, and geophysical data. These studies were funded by USDOE.

Forty-seven chemical analyses of thermal waters from Oregon springs or wells, based on both field sampling and literature research, were submitted to the USGS for inclusion in their GEOTHERM data base. These data and 142 others by the USGS are included in Open-File Report 0-79-3, *Chemical Analyses of Thermal Springs and Wells in Oregon*, authored jointly by USGS and DOGAMI. The locations of these thermal springs and wells, as well as others previously identified by DOGAMI, are shown on the Geological Map Series map GMS-10 (1978), which is an update of previously published Miscellaneous Paper 14, *Thermal Springs and Wells in Oregon* (1970).

During the second part of the study, thirty potential geothermal-field areas were identified, and pertinent data about them submitted to the USGS for inclusion in

Figure 3. Geothermal drilling activity in Oregon, 1979.



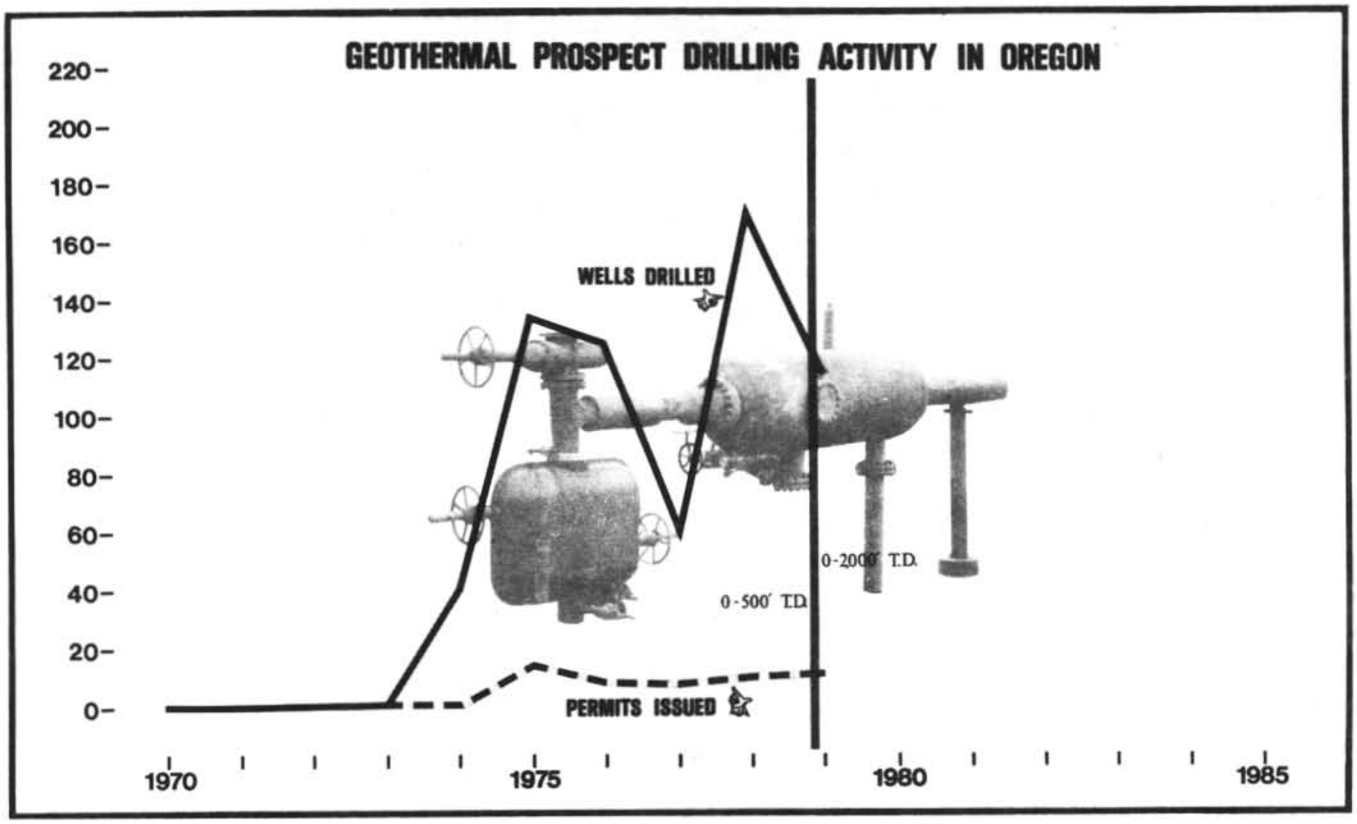


Figure 4. Geothermal prospect drilling activity in Oregon, 1979.

the GEOTHERM data base. Of these areas, nine that are totally in Oregon and three that are partially in Oregon-Idaho, Oregon-Nevada, and Oregon-Washington are favorable for the potential development of low-temperature geothermal resources and are detailed in USGS Circular 790, *Assessment of Geothermal Resources of the United States—1978* (1979). These areas are Belknap-Foley Hot Springs, Willamette Pass, Craig Mountain-Cove (La Grande), Glass Buttes, Northern Harney Basin, Southern Harney Basin, Alvord Desert, Lakeview, Klamath Falls, Western Snake River Basin, McDermitt, and Walla Walla.

Completion of the initial phase of the low-temperature study led to two major Department publications in 1979. GMS-11, *Preliminary Geothermal Resource Map of Oregon* (scale 1:500,000), relates the aforementioned resource areas to pertinent Pleistocene-Holocene geology, geologic structure, heat flow, and thermal springs and wells. Special Paper 4, *Heat Flow of Oregon*, contains extensive newly acquired heat-flow and geothermal-gradient data for the State. These data are presented on a contour map of heat flow (20 mW/m^2 interval) at a scale of 1:1,000,000. The text also contains maps of heat flow and temperatures at a depth of 1 km for $1° \times 1°$ intervals. Histograms and averages of geothermal gradient and heat flow for the various physiographic provinces within the State are also included.

The second phase of the low-temperature study, site evaluation, which commenced in 1979 also through a USDOE contract, consists, in part, of geologic mapping by DOGAMI of the Belknap-Foley Hot Springs area (one 15-minute quadrangle), Willamette Pass area (two 15-minute quadrangles), Lakeview area (portions of three 15-minute quadrangles), and Northern and Southern Harney Basins (four 15-minute quadrangles) (Figure 5). Mapping is in various stages of completion. Mapping of the Craig Mountain-Cove (La Grande) area by Geoscience Research Consultants of Moscow, Idaho, under contract to DOGAMI, has been completed, and results of the study will be published as Special Paper 6 in 1980. The four 7½-minute quadrangles covered by this study include the southwestern portion of the Grande Ronde Valley and adjacent uplands.

Eight temperature-gradient holes were drilled to a maximum depth of 400 ft in the Lakeview area (Figures 6 and 7). Thermal waters collected from springs, wells, and temperature-gradient holes were analyzed, and chemical data were submitted to USGS for inclusion in the GEOTHERM data base.

The westerly two of the four temperature-gradient holes programmed for the La Grande area were drilled in 1979 (Figure 8). Chemical analysis of thermal waters collected from the area's thermal springs and wells is currently under way.

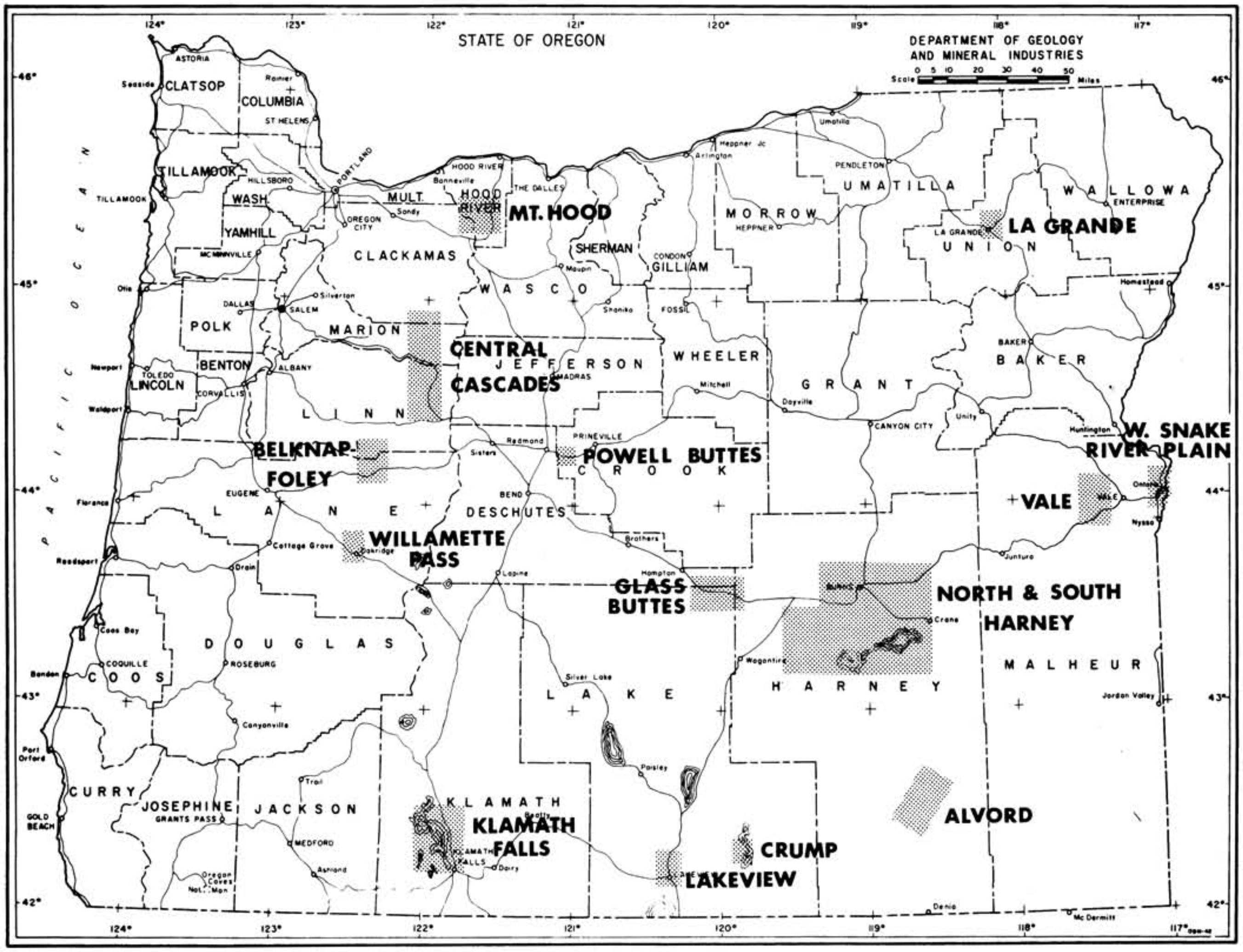


Figure 5. Areas of geothermal activity in Oregon, 1979.

Cascades study

The Department, through a USDOE contract, has initiated a temperature-gradient investigation of the Western and High Cascades of central Oregon. This project should be completed in late 1980. Eight holes up to 500 ft deep (Figure 2) were drilled during 1979; the remaining fourteen (not shown on map) are to be drilled in 1980. Geologic mapping, approximately 1 sq mi in extent, has been completed at each site drilled.

Also, as part of this overall project, several subcontracts to universities have been issued by DOGAMI. Richard Couch and Michael Gemperle, School of Oceanography, Oregon State University, will initiate aeromagnetic and gravity measurements in both the southern and northern Oregon Cascades. Craig White, Department of Geology, University of Oregon, is compiling a stratigraphic, structural, and petrological index of the Breitenbush 15-minute quadrangle and that area included in the drainage of the upper portion of the Molalla River in the northern part of the Mill City 15-minute quadrangle. The tectonic framework of the Western Cascades as deduced from paleomagnetic determination of microplate boundaries is the object of the research activity conducted by Allan Cox, Department of Geophysics, Stanford University. Cyrus Fields, Department of Geology, Oregon State University, will identify fossil hydrothermal systems in the Western Cascades.

Figure 6. Location of temperature-gradient holes, Lakeview area, Oregon.

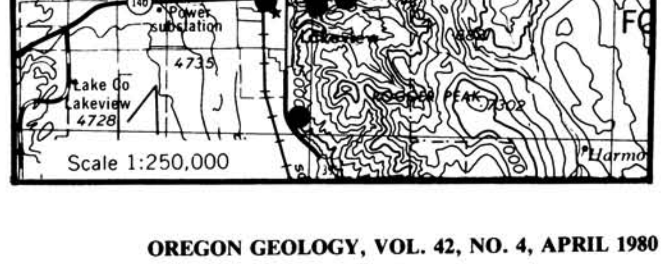


Figure 7. Hunter Hot Springs "Geyser," located north of the city of Lakeview, began erupting in October 1923 while a well was being drilled at this site.

U.S. Geological Survey

As part of the continuing Mt. Hood geothermal assessment program, the USGS has drilled four temperature-gradient holes (Tables 1 and 2) on the south and west flanks of Mt. Hood to a maximum depth of 2,000 ft. The hole at the base of the Pucci Chairlift (35S/9E-7ad) is to be deepened to approximately 3,000 ft in the summer of 1980.

Detailed field mapping and petrological and mineralogical studies of selected areas of hydrothermal alteration associated with active and fossil geothermal systems in the Western and High Cascades was initiated by the USGS in 1979 and will continue into 1980.

The July 1979 issue of *Oregon Geology* (v. 41, no. 7) contains a complete listing of all USGS geothermal research programs relating to the Cascade Range of Oregon.

Oregon Institute of Technology

The Geo-Heat Utilization Center at OIT reports that under the Federal technical assistance program the Center can provide up to 100 hours of free geothermal consultation. The program is intended to provide assistance to persons with little or no experience in geothermics in order to promote the rapid development of geothermal resources.

Other studies in which the Center is currently involved include an inventory and study of potential uses of geothermal resources in Oregon, Washington, Idaho, Montana, Alaska, and Wyoming; a study for the Bonneville Power Administration (BPA) to determine the potential for additional production of electricity through the use of geothermal energy in the BPA service area; an aquaçulture project whereby prawns are raised in geothermal waters from existing wells on the geo-

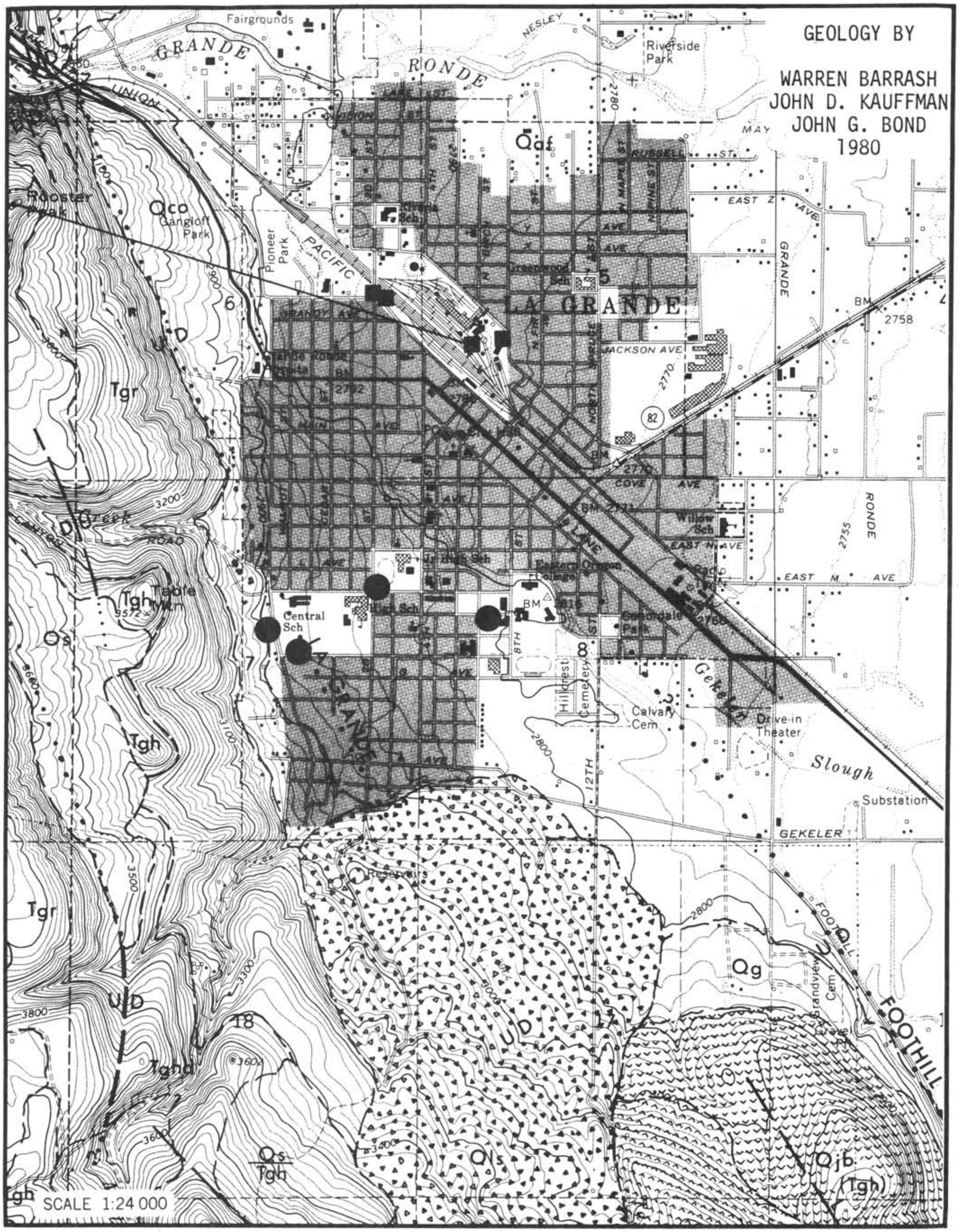


Figure 8. Location of temperature-gradient holes, La Grande area, Oregon.

(See **Geothermal exploration,** *p. 69)*

Abstracts of Department papers given at OAS

These abstracts of papers given at the Oregon Academy of Science, February 23, 1980, at Chemeketa Community College in Salem, summarize some of the findings of the Oregon Department of Geology and Mineral Industries' current research on low-temperature geothermal assessment and geothermal potential assessment of the Western and High Cascades.

HEAT FLOW ALONG THE HIGH CASCADE-WESTERN CASCADE TRANSITION ZONE, OREGON *by George Priest, Joseph Riccio, Neil Woller, and Don Gest, Oregon Department of Geology and Mineral Industries, Geothermal Section, 1069 State Office Building, Portland, Oregon 97201; and Steven Pitts, School of Oceanography, Oregon State University, Corvallis, Oregon 97331.*

Heat flow analysis by DOGAMI indicates that the Western Cascades-High Cascades transition zone is an area of anomalously high heat flow. Heat flow generally increases from the Willamette Valley to the transition zone where numerous hot springs occur, but no reliable data have heretofore been available on the east side of the transition zone. Several 150- to 600-m temperature-gradient holes have been recently completed by both DOGAMI and EWEB on the eastern margin of the transition zone. Preliminary temperature-gradient data indicate that heat flow may decrease both east and west of the transition zone. Thus: (1) there is a local heat source under only the transition zone, or (2) convective downflow occurs over areas east of the hot springs belt over a region of high heat flow with convective upflow along permeable zones at the transition zone. Permeable zones may correspond to high-angle faults which appear to control the distribution of hot springs in the transition zone. Correspondence of a very short-wavelength residual Bouguer gravity low of regional extent along the hot-springs belt supports the interpretation of major high-angle faults in the transition zone. The youthful age of volcanism in the High Cascades implies a major heat source beneath the High Cascade axis. These preliminary findings support model 2; however, the data are too sparse to disprove any model.

RECONNAISSANCE GEOLOGY OF THE OAKRIDGE-WILLAMETTE PASS AREA, CENTRAL CASCADES, OREGON *by David E. Brown, Gary D. McLean, Don Gest, Neil M. Woller, and Gerald Black, Oregon Department of Geology and Mineral Industries, Geothermal Section, 1069 State Office Building, Portland, Oregon 97201.*

Reconnaissance mapping of bedrock units and structures in the Oakridge-Willamette Pass area defines the extent of several geologic units. Included are the Oligocene to Miocene Little Butte Volcanics, a widespread Miocene (?) rhyolite sequence, the Miocene to Pliocene Sardine Volcanics, a Pliocene to Pleistocene High Cascades dacite sequence of limited areal extent, and the Pliocene to Pleistocene High Cascades andesitic lavas. Two major trends of high-angle faults were mapped. One is aligned in a north 5° to 35° west orientation, and the second, and more minor, is aligned north 5° to 45° east. No obvious difference of trends is noted on opposite sides of the Eugene-Denio lineament, which bisects the study area along Kittson Ridge in an approximate north 45° west trend. Of major interest are several lineaments recognizable on SLAR and Landsat imagery. These lineaments, reflected on the surface by pyritization and parallel high-angle faulting, appear to be closely associated with hot springs and hydrothermal alteration. ☐

Major Public Lands Map of Oregon now available from Forestry Department

The multi-colored 1:1,000,000 scale Major Public Lands Map is now available for distribution. The map is available with and without the State Forest Protection District boundaries.

The print includes ten ownership/administration classes, including Board of Forestry, State Land Board, State Parks, State Fish and Wildlife, U.S. Forest Service, Wilderness Area, National Parks, National Wildlife Refuge, Bureau of Land Management, and Lands Managed by Agreement by OSFD. BIA/Tribal Trust Lands will also be noted but have private designation.

The price has been set at $1.25 each. Bulk lots of 1,000 or more will be sold at $.85 each ($850/1,000). Please submit purchase order or payment as follows:

1. Send to: Oregon State Forestry Department
   2600 State Street
   Salem, OR 97310
2. Write order stating type of map and number requested. ☐

(**Geothermal exploration,** *from p. 68)*

thermally heated OIT campus; and a cooperative project with Oregon State University in which a greenhouse is heated by waste waters from the OIT campus heating system, enabling year-round growth of flowers and vegetables. ☐

Ausmus enters Federal service

Standley L. Ausmus, Supervisor of the Mined Land Reclamation Program of the Oregon Department of Geology and Mineral Industries since 1974 (see *Oregon Geology*, v. 41, no. 11, p. 182), left the Department to become Program Director, Abandoned Mined Lands, Office of Surface Mining, U.S. Department of the Interior, Denver, Colorado, on March 3, 1980. There he will serve as principal staff officer for Federal reclamation programs in the Regional Office of Surface Mining. In this capacity, he will provide information on the reclamation of Federal lands and the conduct of the Federal reclamation programs to governmental agencies, industry, and the public. Among his other responsibilities will be the development of guidelines for the evaluation of various Federal projects such as those related to (1) the protection of life, health, and property from the adverse effects of coal-mining practices, and (2) the restoration of land and water degraded by previous coal-mining practices.

During his years with the Oregon Department of Geology and Mineral Industries, the Mined Land Reclamation Program came into being, and Ausmus worked in its administration to develop standards and procedures based on actual field case histories and experiences. The result is a program whose procedures are keyed to Oregon's rather unique reclamation needs. The standards and procedures address reclamation practices, cooperation with other agencies, and land-resource constraints.

The present body of law relative to surface mined land reclamation has been evolving under Ausmus' guidance, and the Department is now promulgating rules and regulations formalizing the administration of the Mined Land Reclamation Act (see p. 54 in the March 1980 issue of *Oregon Geology*). □

DOE issues airborne geophysical surveys

The Grand Junction, Colorado, Office, U.S. Department of Energy (DOE) has placed on open file two aerial geophysical surveys that include parts of Oregon.

Report GJBX-10(80) is an aerial gamma-ray and magnetic survey including the Boise quadrangle, Oregon/Idaho. Report GJBX-20(80) is an aerial radiometric and magnetic survey of the Oregon part of the Klamath Falls quadrangle. The surveys were flown by helicopters during 1978 and 1979 and serve to detect and assess uranium resources.

Both reports are available for inspection at the Portland office of the Oregon Department of Geology and Mineral Industries. □

AAPG 1980 convention to be held in Denver

"What's New—Advances in Exploration Science" is the theme for the 65th Annual Convention of the American Association of Petroleum Geologists and its divisions, the Society of Economic Paleontologists and Mineralogists, the Energy Minerals Division, and the Division of Professional Affairs, to be held June 8-11, 1980, in Denver, Colorado.

The three-day technical program comprises over 50 sessions and includes such topics as Petroleum Geology of China, Stratigraphic Geophysics, Heat Flow and Petroleum Generation/Maturity in Relation to Plate Tectonic Settings, World-Wide Thrust Belt and Foreland-Basin Exploration, Tidal and Near-Shore Sediments and Processes, Petroleum Potential of Deep-Sea Fans, Nuclear Fuels, and Deep Continental Drilling. Poster sessions, short courses, and field trips round out the program. The fifteen field trips include visits to the Wyoming-Utah-Idaho thrust and fold belt and to many of the alternate energy sources in the Rockies.

Of special interest for OSU graduates will be the OSU Alumni Party on Monday, June 9, 5:30-7:30 p.m., at the Denver Hilton Hotel. The party is being organized by Clint Goodwin (M.S. 1972), Bill Hanson (Ph.D. 1976), and Jill Schlaefer (M.S. 1978). Those in attendance will have an opportunity to meet OSU Geology Department Chairman Robert S. Yeats and other OSU faculty members. A sign-up sheet will be at the Alumni Activities Desk in the registration area. □

" YOUR FUTURE LOOKS DARK AND MURKY... LIKE CRUDE OIL..! "

Fossil bear tracks in Lake County, Oregon

by Earl L. Packard and Ira S. Allison, Emeriti Professors of Geology, Oregon State University, Corvallis, Oregon

ABSTRACT

A series of large, five-toed mammal tracks exhibit two undivided foot pads, three distinct anterior claw marks, and two widely divergent outer-claw positions on the forward imprint on a consolidated mudflow deposit in Lake County, Oregon. The tracks evidently were made by a huge extinct bear, comparable in size to the widely occurring *Arctotherium*. Their age is probably Pliocene or early Pleistocene.

Local residents years ago discovered a series of mammalian tracks and reported them to Luther S. Cressman, University of Oregon archeologist, who in turn led us to the find, where we made measurements and took plaster casts. The tracks occur about 500 ft (150 m) south of the north line of the NE¼ sec. 20, T. 39 S., R. 18 E., about 15 mi (24 km) west of Lakeview, Oregon, at an elevation of about 5,000 ft (1,500 m) above sea level.

GEOLOGY

The region is a faulted terrain composed mainly of Cenozoic volcanic rocks (Walker, 1973). The fossil track locality is a gently sloping rock surface beside a shallow, intermittent stream channel. The rock immediately underlying the tracks is a coarse-grained, indurated mudflow composed of angular particles as much as several centimeters in diameter and set in a fine-grained tuffaceous matrix. The bed dips 16°

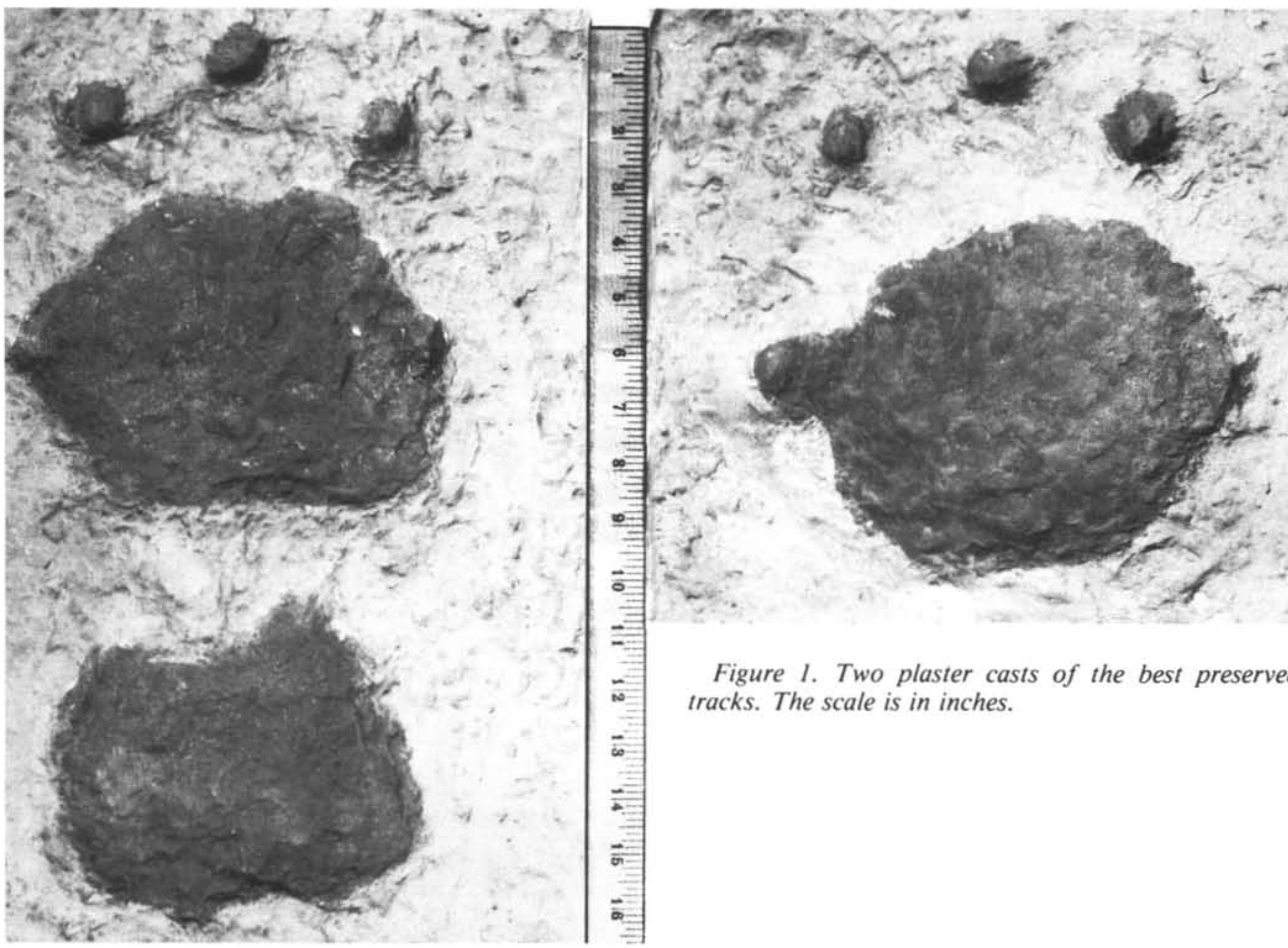


Figure 1. Two plaster casts of the best preserved tracks. The scale is in inches.

westerly and strikes N. 15-20° W. Differential weathering of the mudflow has produced a small-scale roughness and mutilated part of the tracks. The tracks were preserved by an original claw-mark filling and a cover of easily weathered, brown, silty material about 2 in. (5 cm) thick, possibly a basaltic ash fall, part of which remains in some tracks. Still coarser mudflows underlie the fossil bed. Above it are finer grained, light-colored, tuffaceous sandstones and siltstones with fluviatile cross-bedding.

THE TRACKS

The fossil tracks form an alternating series of footprints extending northwesterly for a distance of about 15 ft (5 m), beyond which the tracks become faint, show a few possible claw marks, then turn left downdip for about 12 ft (4 m), and seem to pass under a rocky ledge about 3 ft (1 m) thick. The tracks are spaced about 50 in. (125 cm) apart, indicating a stride considerably greater than that of a man. They are 16 in. (40 cm) apart laterally—clearly those of a large animal. The main prints on each side are double oval-shaped impressions of the soles of the feet. The anterior of each pair also has three central claw marks and a smaller claw mark on each side (Figure 1). There is no suggestion of any toe pads.

The maximum depth of the imprints as measured in the field is about 1.2 in. (30 mm). The claw marks are irregular holes, somewhat modified by weathering, as much as 1 in. (25 mm) deep, with steep posterior margins which indicate their origin from claws rather than from the ends of toes or from hoofs. The anterior track is slightly larger than the posterior. The absence of claw marks on the posterior track is interpreted to indicate that the hind foot overstepped the forefoot in walking—a habit of bears.

The position of the claw marks complicate the identification of the responsible animal species. The central one of the three evenly spaced claw marks, spaced about 3 in. (75 mm) in front of each anterior foot-pad impression, denotes the axial line of the foot. The other two forward claw imprints diverge from the central axis consistently by about 35° and therefore are not from accidental spreading of the toes. The positions of the two lateral claw marks are especially puzzling, as they diverge by about 80° from the axis of the foot.

The lengths of the toes indicated by the tracks correspond closely to the toe bones known from the large extinct fossil bear *Arctotherium,* the only known Pliocene or Pleistocene mammal capable of making such tracks. To our knowledge, however, the amount of spreading of the toes of any arctothere has not been determined. The imprints are larger than those of living bears or extinct true ursids.

POSSIBLE AFFINITIES

The short-faced arctotheres diverged from true ursids in early Cenozoic time. They are represented in the Miocene of Eurasia by *Hyaenarctos* and in the Pliocene by *Indoarctos.* Related forms migrated to South America during late Pliocene and Pleistocene time. An *Indoarctos* possibly occurs in the Pliocene Rattlesnake Formation of the John Day Valley of central Oregon, where it was named *Indoarctos*? *oregonensis* by Merriam, Stock, and Moody (1916). The Rattlesnake fossils include teeth, limb bones, a fifth metacarpal, a second metatarsal, and several phalanges.

Arctotherium is known from the Rancho La Brea deposits of mid-Pleistocene age (Merriam, 1911); the Potter Creek Cave of Northern California (Cope, 1879, 1891); the Port Kennedy Fissure, Pennsylvania (Cope, 1879); and the Yukon (Lambe, 1911). Measurements of several foot bones from the Rancho La Brea and Potter Creek Cave deposits, as given by Merriam and Stock (1925), indicate foot sizes suited to make the Lake County bear tracks.

Because the arctothere foot structure is not fully known, no species reference for the bear that left these tracks is possible at this time.

REFERENCES CITED

Cope, E.D., 1879, The cave bear of California: American Naturalist, v. 13, p. 791.

——— 1891, The California cave bear: American Naturalist, v. 25, p. 997-999.

Lambe, L.M., 1911, On *Arctotherium* from the Pleistocene of Yukon: Ottawa Naturalist, v. 25, p. 21-26.

Merriam, J.C., 1911, Note on a gigantic bear from the Pleistocene of Rancho La Brea, California: University of California Publications, Bulletin of the Department of Geology, v. 6, no. 6, p. 163-166.

Merriam, J.C., and Stock, C., 1925, Relationships and structure of the short-faced bear, *Arctotherium,* from the Pleistocene of California: Carnegie Institution of Washington Publication 347, p. 1-35.

Merriam, J.C., Stock, C., and Moody, C.L., 1916, An American Pliocene bear: University of California Publications, Bulletin of the Department of Geology, v. 10, no. 7, p. 87-109.

Walker, G.W., 1973, Preliminary geologic and tectonic maps of Oregon east of the 121st meridian: U.S. Geological Survey Miscellaneous Field Studies Map MF-495, 2 sheets, scales 1:500,000 and 1:1,000,000. □

USGS leaflet explains Richter, Mercalli earthquake scales

A leaflet explaining how the severity of an earthquake is expressed by two commonly used but highly different methods—the Richter scale and the modified Mercalli intensity scale—has been published by the U.S. Geological Survey (USGS), Department of the Interior, and is available for public distribution.

The leaflet, written in nontechnical terms, is part of a series of popular publications prepared by the USGS to answer inquiries about a variety of earth science subjects. It was prepared to help clarify confusing concepts related to the measurement of earthquakes. Earthquakes can be measured in terms of either the energy released (magnitude) or the effects (intensity). The former is based on instrument recordings; the latter on personal observations. The two methods, expressed by highly differing scales, are often confused by the public.

Single copies of the 15-page illustrated leaflet, titled "The Severity of an Earthquake," may be obtained free upon request from the U.S. Geological Survey's Branch of Distribution, 1200 South Eads St., Arlington, Va. 22202.

A few "briefs" from the leaflet:

- The *intensity* of an earthquake is based on observed effects of ground shaking on people, buildings, and natural features. It varies from place to place within the disturbed region depending on the location of the observer with respect to the earthquake epicenter. Intensity is expressed by the modified Mercalli intensity scale.

- The *magnitude* of an earthquake—expressed by the Richter scale—is related to the amount of seismic energy released at the focal depth of an earthquake. It is based on the amplitude of earthquake waves recorded on instruments which have a common calibration.

- Earthquakes are the result of forces deep within the Earth's interior. The energy from these forces is stored in a variety of ways within the rocks. When this energy is released suddenly, for example, by shearing movements along faults in the Earth's crust, an earthquake results. The area of the fault where the sudden rupture takes place is called the focus or hypocenter of the earthquake. The point on the Earth's surface directly above the focus is called the epicenter of the earthquake.

- Seismic waves, earthquake vibrations that travel through the Earth, are recorded on instruments called seismographs. The instruments record a zigzag trace that shows the varying amplitude of ground oscillations beneath the instrument. Sensitive seismographs, which greatly magnify these ground motions, can detect strong earthquakes from sources anywhere in the world. The time, location, and magnitude of an earthquake can be determined from the data recorded by seismograph stations.

- The Richter scale was developed in 1935 by Charles F. Richter, the California Institute of Technology. On his mathematical scale, which is open-ended, magnitude is expressed in whole numbers and decimals. For example, a magnitude 5.3 might be computed for a moderate earthquake, and a strong earthquake might be rated as magnitude 6.3. Because of the logarithmic basis of the scale, each whole number increase in magnitude represents a tenfold increase in measured amplitude; thus, as an estimate of energy, each whole number step in the scale corresponds to the release of about 31 times more energy than the amount associated with the preceding whole number value.

- Earthquakes with magnitude of about 2.0 or less are usually called microearthquakes; they are not commonly felt by people and are generally recorded only on local seismographs. Events with magnitudes of about 4.5 or greater—there are several thousand such shocks annually—are strong enough to be recorded by sensitive seismographs all over the world. Great earthquakes, such as the 1906 San Francisco earthquake and the 1964 Good Friday earthquake in Alaska, have magnitudes of 8.0 or higher. On the average, one earthquake of such size occurs somewhere in the world each year. Although the Richter scale has no upper limit, the largest known shocks have had magnitudes in the 8.8 to 8.9 range.

- The Richter scale is not used to express damage. An earthquake in a densely populated area which results in many deaths and considerable damage may have the same magnitude as a shock in a remote area that does nothing more than frighten wildlife.

- The modified Mercalli intensity scale is composed of 12 increasing levels of intensity that range from imperceptible shaking to catastrophic destruction designated by Roman numerals (I to XII). It does not have a mathematical basis; instead, it is an arbitrary ranking based on observed effects. The modified Mercalli intensity scale provides a more meaningful measure of severity to the nonscientist than magnitude because it refers to effects actually experienced.

- The following is an abbreviated description of the 12 levels of the modified Mercalli intensity scale:

I Not felt except by a very few under especially favorable conditions.

II Felt only by a few persons at rest, especially on upper floors of buildings.

III Felt quite noticeably by persons indoors, especially on upper floors of buildings. Many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibration similar to the passing of a truck. Duration estimated.

IV Felt indoors by many, outdoors by few during the day. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sounds. Sensation like heavy truck striking building. Standing motor cars rocked noticeably.

V Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop.

VI Felt by all, many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight.

VII Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken.

VIII Damage slight in specially designed structures. Considerable damage in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned.

IX Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations.

X Some well–built wooden structures destroyed; most masonry and frame structures destroyed with foundations. Rails bent.

XI Few, if any, (masonry) structures remain standing. Bridges destroyed. Rails bent greatly.

XII Damage total. Lines of sight and level are distorted. Objects thrown into the air. □

Geothermal Resources Council annual meeting set for September

The Geothermal Resources Council's 1980 annual meeting will be held September 9-11, 1980, at the Hotel Utah, Salt Lake City, Utah. There will be three days of technical, poster, and special sessions, along with commercial and educational exhibits, optional luncheons, a special Alpinefest banquet, and a guests program. In addition, both pre- and post-meeting trips have been scheduled. Interesting special sessions will be devoted to particular topics, such as direct applications of geothermal resources and hot dry rock geothermal energy.

The meeting is intended to provide a forum for exchange of new and significant information on all aspects of the development and use of geothermal resources. Papers are solicited for both the technical and poster sessions, and if accepted, will be printed in the *Transactions* of the Geothermal Resources Council. Deadline for submission of papers in the special summary format required by the Council is Tuesday, May 27, 1980.

For more information, contact Geothermal Resources Council, 1980 Annual Meeting Program, P.O. Box 98, Davis, CA 95616, phone: (916) 758-2360. □

GSOC luncheon programs announced

The Geological Society of the Oregon Country announces the following luncheon program schedule. All luncheon programs will take place at noon in Room A adjacent to the cafeteria on the third floor of the Standard Plaza Building, 1100 SW 6th Ave., Portland.

April 18	Subject:	Hydroelectric power installations at the Bull Run Dams
	Speaker:	James L. Doane, Manager, Bureau of Hydroelectric Power, City of Portland
May 2	Subject:	The State of Oregon Department of Geology and Mineral Industries
	Speaker:	Dr. John D. Beaulieu, Deputy State Geologist
May 16	Subject:	The Western Forestry Center
	Speaker:	Penny Wrobel, Membership Manager, Western Forestry Center
June 6	Subject:	Natural history of Steens Mountain
	Speaker:	Donald D. Barr, biologist-naturalist.

For further information, contact the luncheon program chairperson, Viola L. Oberson, phone 282-3685. □

PUBLICATIONS ORDER

Omission of price indicates publication is in press. Minimum mail order 50¢. All sales are final. Publications are sent postpaid. Payment must accompany orders of less than $20.00.

Fill in appropriate blanks and send sheet to Department (see address on reverse side).

YOUR NAME ______________________

ADDRESS ______________________

______________________ Zip ________

Amount enclosed $ ________

OREGON GEOLOGY

____ Renewal ____ Subscription ____ Gift

____ 1 Year ($4.00) ____ 3 Years ($10.00)

NAME ______________________

ADDRESS ______________________

______________________ ZIP ________

(If Gift, From: ______________________)

ORDER FORM - CUT ON DASHED LINE

Available publications

MISCELLANEOUS PAPERS	Price	No. Copies	Amount
1. A description of some Oregon rocks and minerals, 1950: Dole	$ 1.00	____	____
4. Laws relating to oil, gas, and geothermal exploration and development in Oregon			
Part 1. Oil and natural gas rules and regulations, 1977, rev. 1979	1.00	____	____
Part 2. Geothermal resources rules and regulations, 1977, rev. 1979	1.00	____	____
5. Oregon's gold placers (reprints), 1954	.50	____	____
6. Oil and gas exploration in Oregon, rev. 1965: Stewart and Newton	3.00	____	____
8. Available well records of oil and gas exploration in Oregon, rev. 1973: Newton	1.00	____	____
11. Collection of articles on meteorites, 1968 (reprints from *The Ore Bin*)	1.50	____	____
13. Index to *The Ore Bin,* 1950-1974	1.50	____	____
14. Thermal springs and wells, 1970: Bowen and Peterson (with 1975 supplement)	1.50	____	____
15. Quicksilver deposits in Oregon, 1971: Brooks	1.50	____	____
16. Mosaic of Oregon from ERTS-1 imagery, 1973	2.50	____	____
18. Proceedings of Citizens' Forum on potential future sources of energy, 1975	2.00	____	____
19. Geothermal exploration studies in Oregon—1976, 1977	3.00	____	____
20. Investigations of nickel in Oregon, 1978: Ramp	5.00	____	____
GEOLOGIC MAPS			
Geologic map of Galice quadrangle, Oregon, 1953	1.50	____	____
Geologic map of Albany quadrangle, Oregon, 1953	1.00	____	____
Reconnaissance geologic map of Lebanon quadrangle, 1956	1.50	____	____
Geologic map of Bend quadrangle and portion of High Cascade Mountains, 1957	1.50	____	____
Geologic map of Oregon west of 121st meridian, 1961	2.25	____	____
Geologic map of Oregon east of 121st meridian, 1977	3.75	____	____
GMS-3: Preliminary geologic map of Durkee quadrangle, Oregon, 1967	2.00	____	____
GMS-4: Oregon gravity maps, onshore and offshore, 1967 (folded)	3.00	____	____
GMS-5: Geologic map of Powers quadrangle, Oregon, 1971	2.00	____	____
GMS-6: Preliminary report on geology of part of Snake River Canyon, 1974	6.50	____	____
GMS-7: Geology of the Oregon part of the Baker quadrangle, Oregon, 1976	3.00	____	____
GMS-8: Complete Bouguer gravity anomaly map, Cascade Mountain Range, central Oregon, 1978	3.00	____	____
GMS-9: Total field aeromagnetic anomaly map, Cascade Mountain Range, central Oregon, 1978	3.00	____	____
GMS-10: Low- to intermediate-temperature thermal springs and wells in Oregon, 1978	2.50	____	____
GMS-11: Preliminary geothermal resource map of Oregon (upon written request only)	free	(one copy per customer)	
GMS-12: Geologic map of the Oregon part of the Mineral quadrangle	2.00	____	____
OIL AND GAS INVESTIGATIONS			
3. Preliminary identifications of foraminifera, General Petroleum Long Bell #1 well	2.00	____	____
4. Preliminary identifications of foraminifera, E.M. Warren Coos County 1-7 well, 1973	2.00	____	____
5. Prospects for natural gas production or underground storage of pipeline gas	5.00	____	____
MISCELLANEOUS PUBLICATIONS			
Landforms of Oregon (17 × 12 inches)	.50	____	____
Mining claims (State laws governing quartz and placer claims)	.50	____	____
Geological highway map, Pacific NW region, Oregon-Washington (published by AAPG)	3.00	____	____
Fifth Gold and Money Session and Gold Technical Session Proceedings, 1975	5.00	____	____
Sixth Gold and Money Session and Gold Technical Session Proceedings, 1978	6.50	____	____
Back issues of *The Ore Bin*	25¢ over the counter; 50¢ mailed	____	____
Colored postcard, *Geology of Oregon*	10¢ each; 3 for 25¢; 7 for 50¢; 15 for 1.00	____	____

OREGON GEOLOGY
1069 State Office Building, Portland, Oregon 97201

Second Class Matter
POSTMASTER: Form 3579 requested

Available publications (continued)

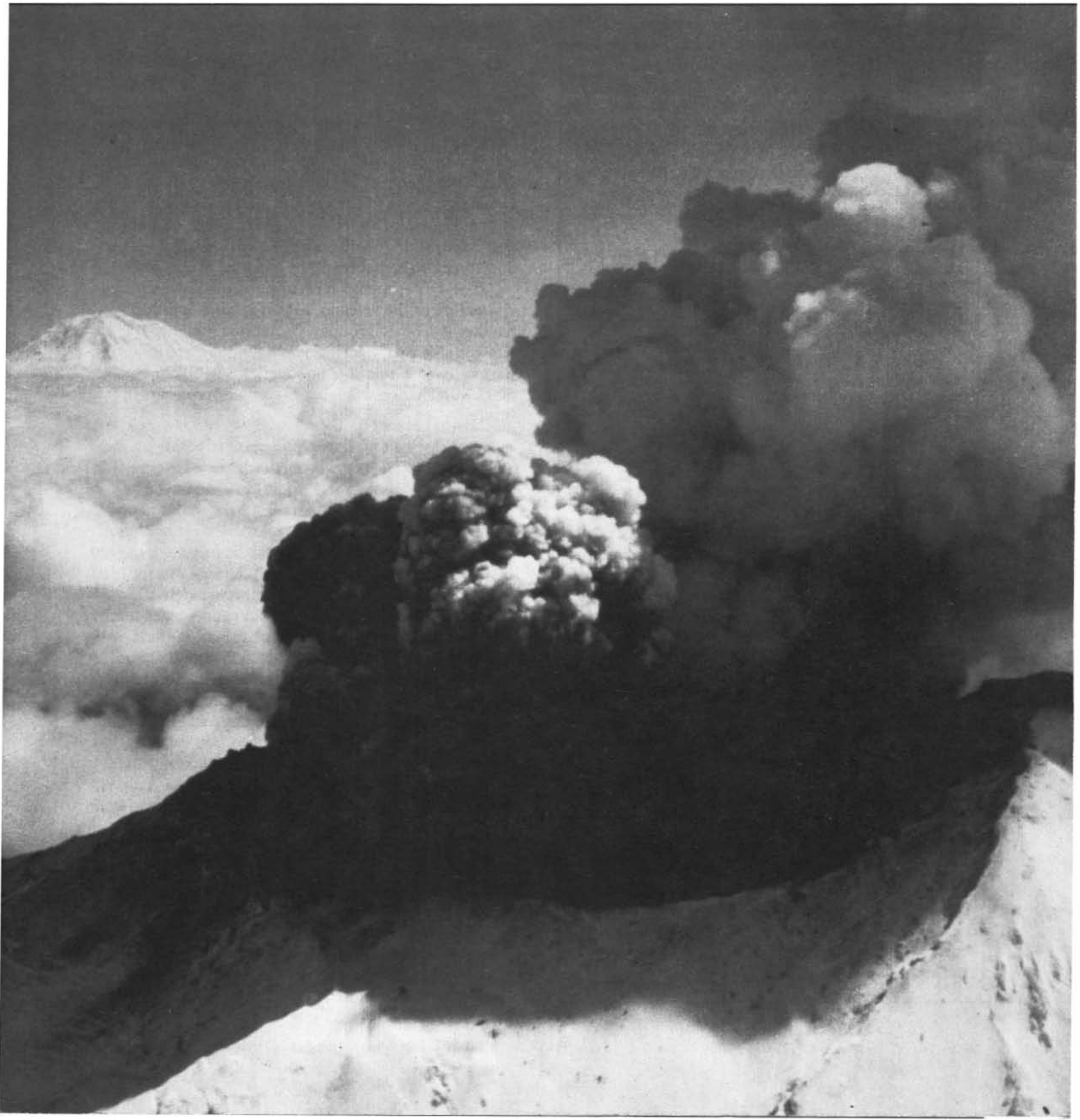
BULLETINS	Price	No. Copies	Amount
33. Bibliography (1st supplement) geology and mineral resources of Oregon, 1947: Allen	1.00		
36. Papers on Tertiary foraminifera: Cushman, Stewart and Stewart, 1949: v. 2	1.25		
39. Geology and mineralization of Morning Mine region, 1948: Allen and Thayer	1.00		
44. Bibliography (2nd supplement) geology and mineral resources of Oregon, 1953: Steere	2.00		
46. Ferruginous bauxite deposits, Salem Hills, 1956: Corcoran and Libbey	1.25		
49. Lode mines, Granite mining district, Grant County, Oregon, 1959: Koch	1.00		
53. Bibliography (3rd supplement) geology and mineral resources of Oregon, 1962: Steere and Owen	3.00		
57. Lunar Geological Field Conference guidebook, 1965: Peterson and Groh, editors	3.50		
62. Andesite Conference guidebook, 1968: Dole	3.50		
63. Sixteenth biennial report of the Department, 1966-1968	1.00		
64. Mineral and water resources of Oregon, 1969 (unbound, without maps and tables)	2.00		
65. Proceedings of Andesite Conference, 1969: (copies)	10.00		
67. Bibliography (4th supplement) geology and mineral resources of Oregon, 1970: Roberts	3.00		
68. Seventeenth biennial report of the Department, 1968-1970	1.00		
71. Geology of selected lava tubes in Bend area, Oregon, 1971: Greeley	2.50		
76. Eighteenth biennial report of the Department, 1970-1972	1.00		
77. Geologic field trips in northern Oregon and southern Washington, 1973	5.00		
78. Bibliography (5th supplement) geology and mineral resources of Oregon, 1973: Roberts	3.00		
81. Environmental geology of Lincoln County, 1973: Schlicker and others	9.00		
82. Geologic hazards of Bull Run Watershed, Multnomah, Clackamas Counties, 1974: Beaulieu	6.50		
83. Eocene stratigraphy of southwestern Oregon, 1974: Baldwin	4.00		
84. Environmental geology of western Linn County, 1974: Beaulieu and others	9.00		
85. Environmental geology of coastal Lane County, 1974: Schlicker and others	9.00		
86. Nineteenth biennial report of the Department, 1972-1974	1.00		
87. Environmental geology of western Coos and Douglas Counties, 1975	9.00		
88. Geology and mineral resources of upper Chetco River drainage, 1975: Ramp	4.00		
89. Geology and mineral resources of Deschutes County, 1976	6.50		
90. Land use geology of western Curry County, 1976: Beaulieu	9.00		
91. Geologic hazards of parts of northern Hood River, Wasco, and Sherman Counties, Oregon, 1977: Beaulieu	8.00		
92. Fossils in Oregon (reprinted from *The Ore Bin*), 1977	4.00		
93. Geology, mineral resources, and rock material of Curry County, Oregon, 1977	7.00		
94. Land use geology of central Jackson County, Oregon, 1977: Beaulieu	9.00		
95. North American ophiolites, 1977	7.00		
96. Magma genesis: AGU Chapman Conference on Partial Melting, 1977	12.50		
97. Bibliography (6th supplement) geology and mineral resources of Oregon, 1971-75, 1978	3.00		
98. Geologic hazards of eastern Benton County, 1979: Bela	9.00		
100. Geology and mineral resources of Josephine County, Oregon, 1979: Ramp and Peterson	9.00		
101. Geologic field trips in western Oregon and southwestern Washington, 1980	9.00		
SPECIAL PAPERS			
1. Mission, goals, and purposes of Oregon Department of Geology and Mineral Industries, 1978	2.00		
2. Field geology of SW Broken Top quadrangle, Oregon, 1978: Taylor	3.50		
3. Rock material resources of Clackamas, Columbia, Multnomah, and Washington Counties, Oregon, 1978: Gray	7.00		
4. Heat flow of Oregon, 1978, Blackwell, Hull, Bowen, and Steele	3.00		
5. Analysis and forecasts of the demand for rock materials in Oregon, 1979	3.00		
7. Pluvial Fort Rock Lake, Lake County, Oregon	4.00		
SHORT PAPERS			
18. Radioactive minerals prospectors should know, 1976: White, Schafer, Peterson	.75		
21. Lightweight aggregate industry in Oregon, 1951: Mason	.25		
24. The Almeda Mine, Josephine County, Oregon, 1967: Libbey	3.00		
25. Petrography, type Rattlesnake Formation, central Oregon, 1976: Enlows	2.00		
27. Rock material resources of Benton County, 1978: Schlicker and others	4.00		

OREGON GEOLOGY

formerly THE ORE BIN

published by the Oregon Department of Geology and Mineral Industries

VOLUME 42, NUMBER 5 MAY 1980



OREGON GEOLOGY

(ISSN 0164-3304)

VOLUME 42, NUMBER 5 **MAY 1980**

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

Main Office: 1069 State Office Building, Portland 97201, phone (503) 229-5580.

Baker Field Office: 2033 First Street, Baker 97814, phone (503) 523-3133.
Howard C. Brooks, Resident Geologist

Grants Pass Field Office: 312 S.E. "H" Street, Grants Pass 97526, phone (503) 476-2496.
Len Ramp, Resident Geologist

Mined Land Reclamation Program: 1129 S.E. Santiam Road, Albany 97321, phone (503) 967-2039.
Paul F. Lawson, Supervisor

Subscription rates: 1 year, $4.00; 3 years, $10.00. Single issues, $.40 at counter, $.50 mailed.
Available back issues of *The Ore Bin:* $.25 at counter, $.50 mailed.

Address subscription orders, renewals, and changes of address to *Oregon Geology,* 1069 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,* 1069 State Office Building, Portland, OR 97201.

COVER PHOTO

Phreatic eruption of Mount St. Helens volcano, Washington. Mount Adams, another Cascade volcano, is in background. White vapor cloud rises above black, ash-laden plume. Photo courtesy Len Palmer, Earth Sciences Department, Portland State University.

To our readers:

On March 27, 1980, Mount St. Helens, located approximately 35 air miles northeast of Portland in the southwest corner of Washington State, began erupting. The volcano has subsequently been monitored by staff of the U.S. Geological Survey housed in the U.S. Forest Service Headquarters in Vancouver, Washington.

The activity of the volcano is of practical and professional interest to a variety of other persons and agencies including the Emergency Services and Geology Departments of Oregon and Washington, utilities, and university geology staffs.

The Oregon Department of Geology and Mineral Industries maintains an interest in the volcano from the standpoint of public safety via coordination with the Oregon Division of Emergency Services and the U.S. Geological Survey. The Oregon National Guard, flying at the request of the Oregon Department of Geology and Mineral Industries, kindly provided the imagery and some of the photographs included in this issue.

The Department plans to pursue no scientific investigation of the volcano, as that is more appropriately handled by other groups. To address our readers' interest in this first volcanic activity in the Pacific Northwest in over a century, however, we will endeavor to make information available as seems appropriate in the future.

CONTENTS

NEXT MONTH

Geology of the Condrey Mountain Schist, Northern Klamath Mountains, California and Oregon, by Mary M. Donato and Robert G. Coleman, U.S. Geological Survey, and M. Allan Kays, Department of Geology, University of Oregon.

Mount St. Helens—an aerial view

by Charles L. Rosenfeld, Assistant Professor of Geography, Department of Geography, Oregon State University, Corvallis, Oregon

After a call from Oregon's State Geologist Donald A. Hull, the Oregon Army National Guard initiated aerial surveillance activity over Mount St. Helens volcano, Washington (Figure 1), as it began erupting during the afternoon of March 27, 1980. Employing both aerial photography and thermal mapping equipment, the OV-1 (Mohawk) aerial surveillance planes of the Guard's 1042 MICAS have provided data to the Oregon Department of Geology and Mineral Industries (DOGAMI) and U.S. Geological Survey (USGS) scientists. While more definitive accounts of this volcanic event are being prepared, it is hoped that this initial account can provide some interesting perspectives.

The first activity sighted was the formation of an explosion crater, flanked by numerous impact craters and accompanied by ash trailing off to the southeast. The initial crater, located north of the peak, was bounded by two east-west trending fracture zones (Figure 2). While no steam or vapors were visible after the initial discharge, the thermal infrared live scanner aboard the aircraft revealed more than ten gas vents or fumaroles (Figure 3).

By March 30, continued phreatic discharges (ground water explosively flashed into steam) had significantly enlarged the original crater and given birth to a new, smaller crater 100 m (300 ft) to the east. Significant ash fall littered the areas east of the activity, and continuing seismic activity along with thermal melting triggered a series of debris avalanches on the southeast flank of the volcano (Figure 4).

Harmonic earthquake tremors, possibly indicating movement of magma, were sporadically reported by the University of Washington Geophysics Program throughout the first week of activity. Phreatic eruptions, such as the one shown in Figure 5, yielded ash fall over a wide area. While estimates of ash fall over Portland's Bull Run Watershed reached 55 tons per square mile, the ash was residual pyroclastic material, leached of most solubles and composed mainly of plagioclase feldspar, and was therefore expected to have no significant acidic impact on the Portland water supply. Juvenile ash, by contrast, could have a considerable sulfur content and therefore an acidic potential.

Activity in the initial crater continued, gradually enlarging it until the wall of the smaller east crater was breached, as shown in the April 4th photograph (Figure 6). The cratered area, now extending the full 510 m (1,700 ft) width between the flanking fracture zones, has subsided significantly, indicating a "graben" structure. Figure 7 is a stereopair of vertical aerial photographs showing the fracture structure of the cratered area as of April 4, 1980. Thermal infrared imagery continues to show relatively localized "hot spots" within the crater, while indicating general, low-level heating of the entire adjacent area.

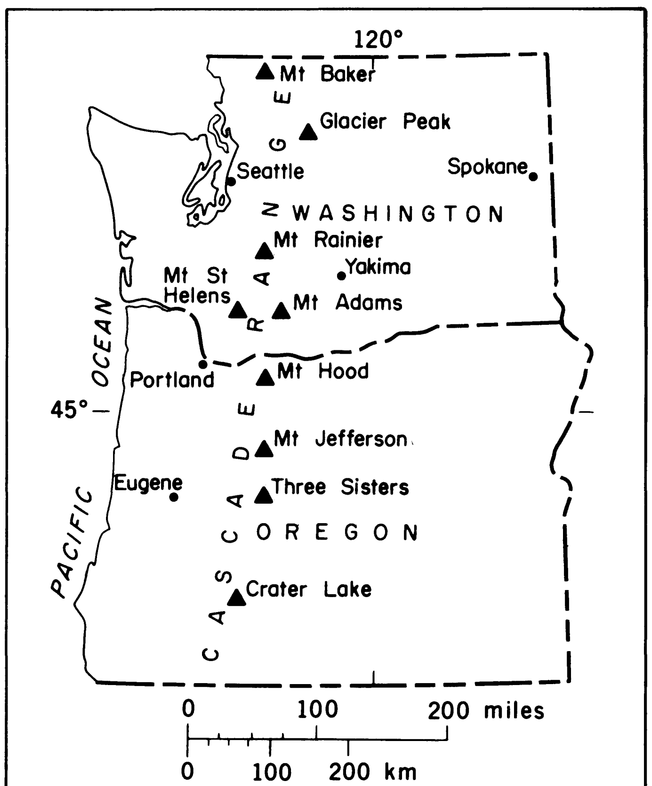
The first two weeks of eruptive activity have enabled the scientific community to learn quite a bit about the behavior of Mount St. Helens, described by Crandell and Mullineaux (1978) as "more active and more explosive during the last 4,500 years than any other volcano in the conterminous United States."

(Additional figures appear on following four pages.)

REFERENCE CITED

Crandell, D.R., and Mullineaux, D.R., 1978, Potential hazards from future eruptions of Mount St. Helens volcano, Washington: U.S. Geological Survey Bulletin 1383-C, 26 p.

Figure 1. Index map of Washington and Oregon showing locations of Mount St. Helens and other volcanoes.



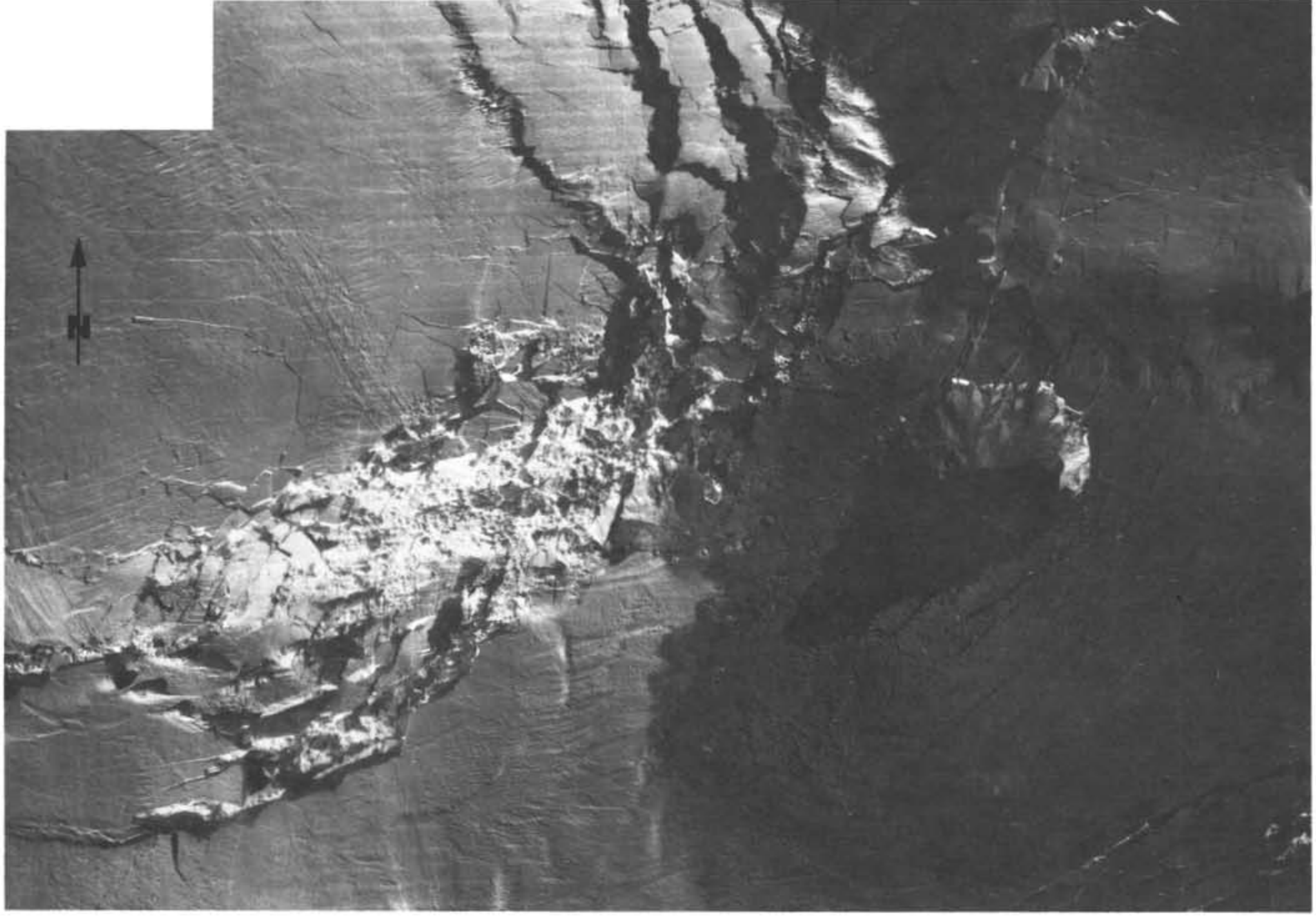


Figure 2. Vertical photo of the initial explosion crater, March 27, 1980, 2 p.m. Fracture zones indicate tensional rift.

Figure 3. Thermal infrared image of the same area, showing the initial crater, March 27, 4:15 p.m. Numerous fumaroles (gas vents) are clustered along the floor of the crater.

Figure 4. Panoramic view of the southeast flank of the mountain, March 30, 11:30 a.m. Note numerous debris avalanches.

Figure 5. Phreatic eruption, April 2, between 8:30 and 9 a.m., viewed from the northwest.

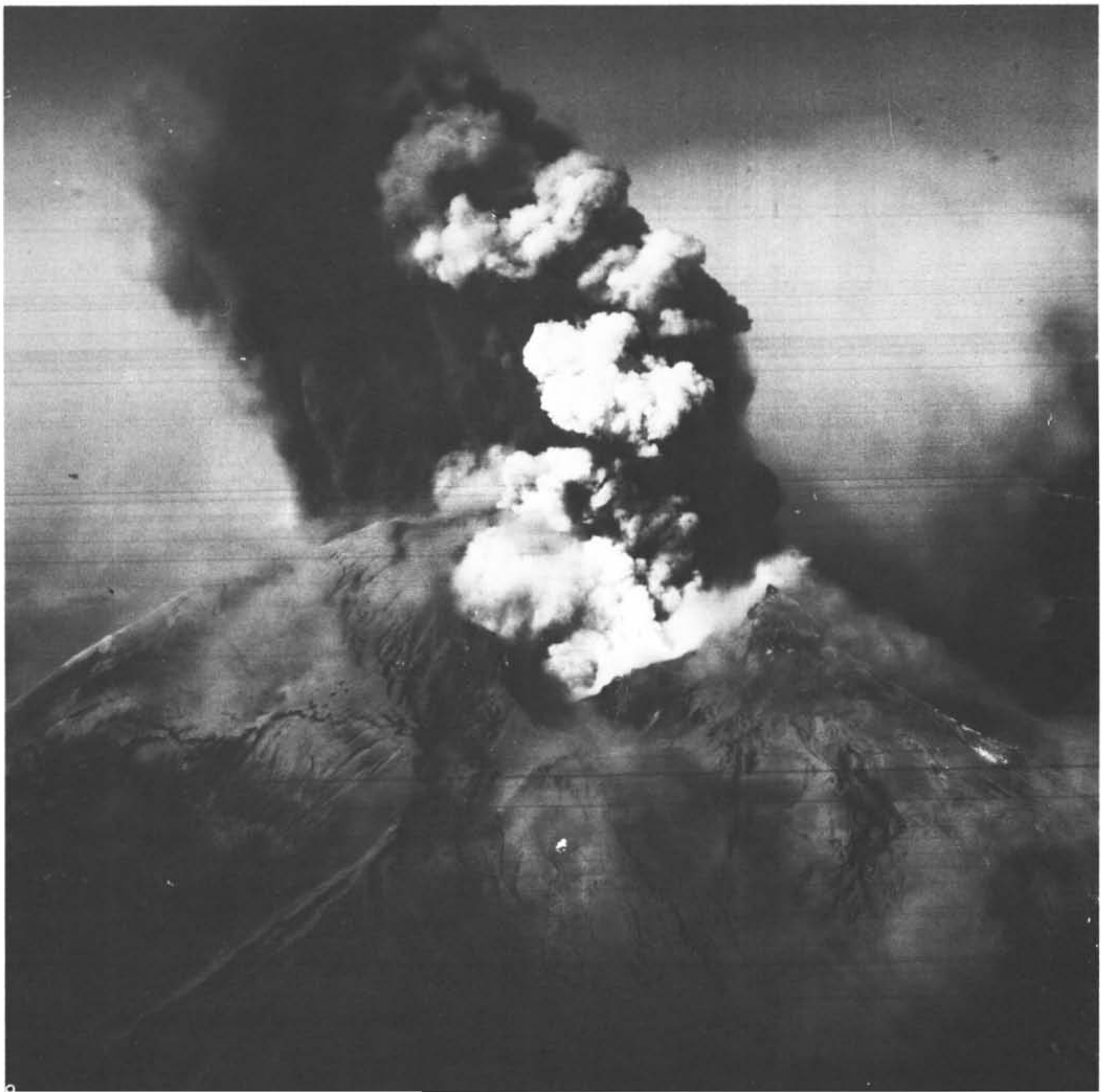


Figure 6. Crater viewed from the northwest, April 4, 1980.

Suggested reading about Mount St. Helens volcano, Washington

Some of these publications are available at local libraries or bookstores. USGS publications are sold through the USGS Public Inquiries Office, Room 678, U.S. Courthouse Building, W. 920 Riverside Ave., Spokane, WA 99201.

Crandell, D.R., and Mullineaux, D.R., 1973, Pine Creek volcanic assemblage at Mount St. Helens, Washington: U.S. Geological Survey Bulletin 1383-A, 23 p.

———1978, Potential hazards from future eruptions of Mount St. Helens volcano, Washington: U.S. Geological Survey Bulletin 1383-C, 26 p.

Crandell, D.R., Mullineaux, D.R., and Rubin, Meyer, 1975, Mount St. Helens volcano; recent and future behavior: Science, v. 187, no. 4175, p. 438-441; reprinted by permission in Oregon Department of Geology and Mineral Industries, The Ore Bin, 1975, v. 37, no. 3, p. 41-48.

Harris, S.E., 1976, Fire and ice, the Cascade volcanoes: Seattle, Wash., The Mountaineers, and Pacific Search Books, 316 p.

Hyde, J.H., 1975, Upper Pleistocene pyroclastic-flow deposits and lahars south of Mount St. Helens volcano, Washington: U.S. Geological Survey Bulletin 1383-B, 20 p.

MacDonald, G.A., 1972, Volcanoes: Englewood Cliffs, N.J., Prentice-Hall, 510 p.

McKee, Bates, 1972, Cascadia, the geologic evolution of the Pacific Northwest: San Francisco, Calif., McGraw-Hill, 394 p.

Mullineaux, D.R., and Crandell, D.R., 1962, recent lahars from Mount St. Helens, Washington: Geological Society of America Bulletin, v. 73, no. 7, p. 855-870. □

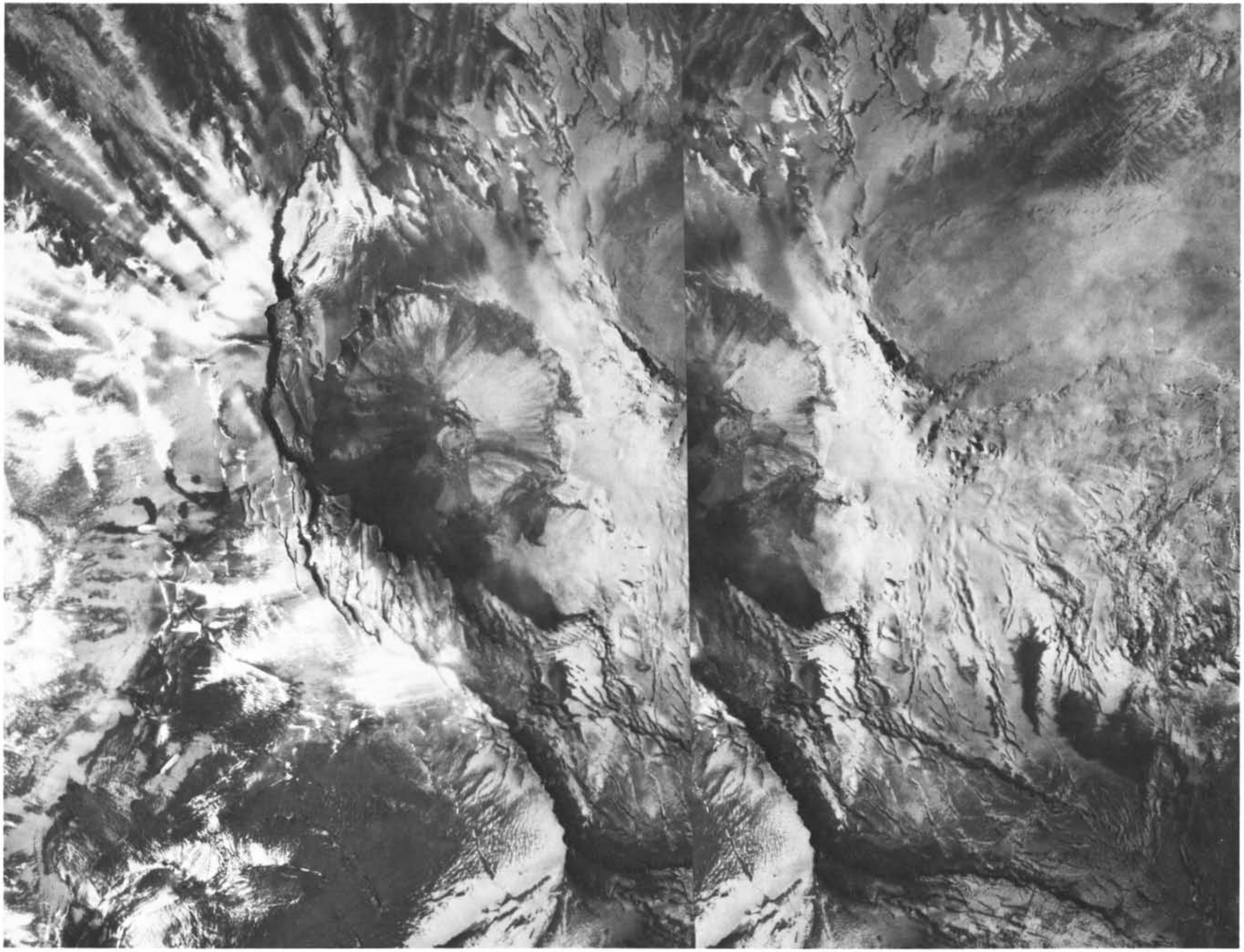
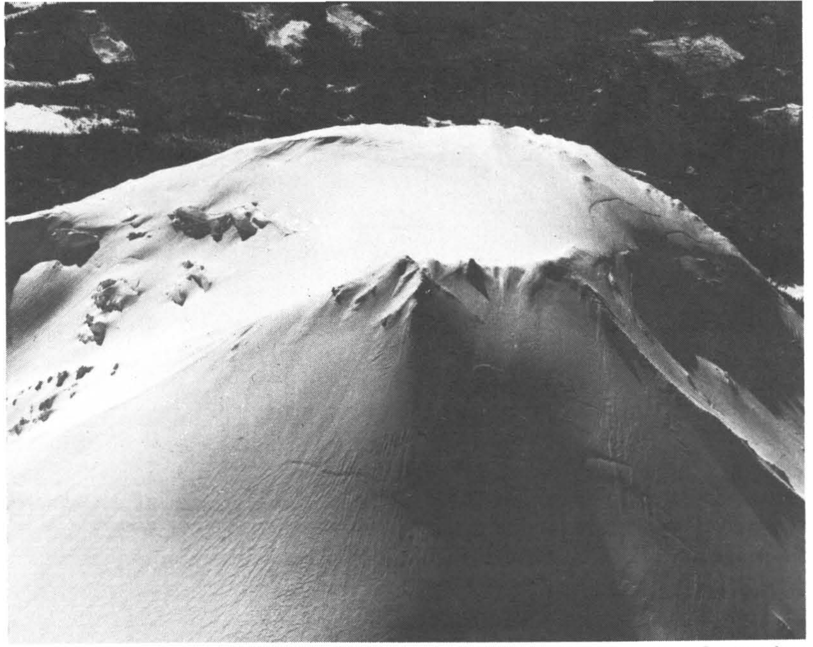


Figure 7. Stereopair of vertical photographs of the crater area, April 4, 1980.

THE DEVELOPMENT OF A CRATER, MOUNT ST. HELENS VOLCANO, 1980



Mount St. Helens before eruptions began.

Photo courtesy Jim Vincent, *The Oregonian*

March 27, 1980, 2 p.m. Note ash surrounding single crater.

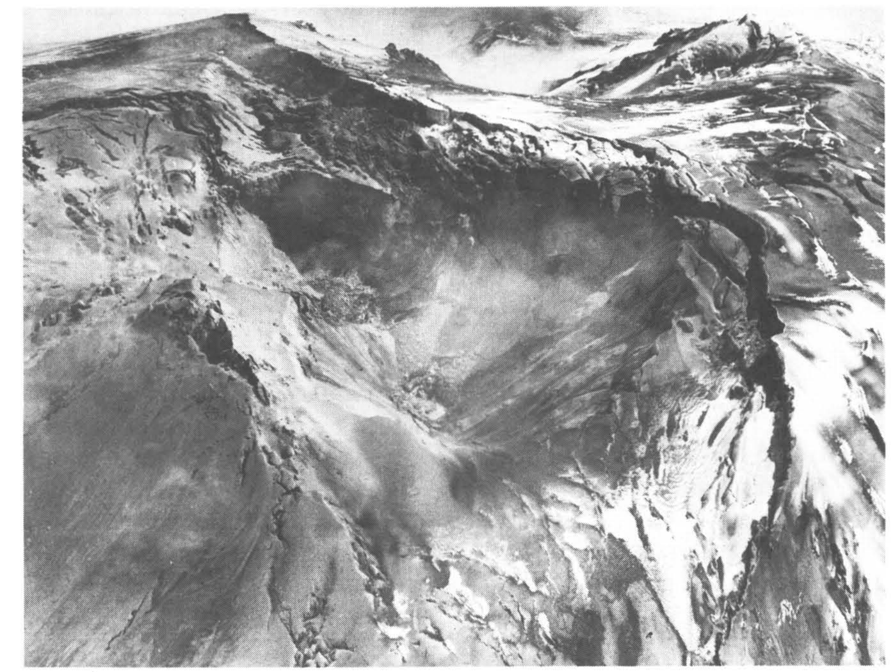
Photo courtesy Michael Lloyd, *The Oregonian*

March 30, 1980, 8 a.m. Two craters have formed.

Photo courtesy Randy Wood, *The Oregonian*

April 2, 1980, 7:45 a.m. Two craters are merging into one.

Photo courtesy Jim Vincent, *The Oregonian*



April 4, 1980, 11:30 a.m. Crater is continuing to enlarge.

Photo courtesy Dale Swanson, *The Oregonian*

Photo courtesy Dale Swanson, *The Oregonian*

April 10, 1980, 9 a.m.

National Earthquake Prediction Evaluation Council established

A National Earthquake Prediction Evaluation Council was established in January 1980 to aid the director of the U.S. Geological Survey (USGS), Department of the Interior, in issuing any formal predictions of earthquakes.

The Council, to be composed of not less than eight federal and non-federal earth scientists, will review data collected by other scientists and recommend to the USGS director whether a formal earthquake prediction or advisory is warranted.

Speaking at a conference on earthquake prediction held in January in Los Angeles, Robert Wesson, Chief of the USGS Office of Earthquake Studies, Reston, Va., described the establishment of the Council as another step toward making earthquake prediction both a scientific and useful reality.

"Hard scientific predictions that spell out when, where, and how large an earthquake is expected are still several years away," Wesson said. "In the interim, however, the Council can play an important role in helping to analyze, interpret, and place in proper perspective significant geophysical data that may come to light.

"The final responsibility for whether and in what manner a prediction will be issued will rest with the USGS director," Wesson said, "but the Council will assure that the best outside expertise is always available to the USGS, and that an orderly process exists to help evaluate the data and their interpretation."

Establishment of the Council implements both the provisions of the Earthquake Hazards Reduction Act of September 1977 and a plan developed by a White House working group that called for expanded membership of an earlier prototype USGS panel. The Council was formally approved by Secretary of the Interior Cecil D. Andrus on August 9, 1979.

The Council is expected to focus its efforts on potentially destructive earthquakes which generally are those of magnitude 5.5 or greater on the Richter Scale. Data for smaller earthquakes also will be reviewed to establish a "track record" for prediction techniques.

Chairman of the Council is Clarence Allen of the California Institute of Technology. Wesson will serve as vice-chairman, and another USGS scientist, Jerry Stephens (Reston, Va.), will serve as executive secretary and a non-voting member. USGS geophysicists named to the Council are C. Barry Raleigh, Robert E. Wallace, James C. Savage, and David P. Hill, all from the USGS Western Regional Research Center, Menlo Park, Calif., and Eric R. Engdahl, USGS Denver, Colo., Federal Center. Non-federal Council members are Keiiti Aki, Massachusetts Institute of Technology; T. Neil Davis, University of Alaska; Thomas V. McEvilly, University of California, Berkeley; and Lynn R. Sykes, Columbia University.

As part of its role in advising the USGS director, the Council may also consider the crucial question of how to release earthquake predictions and warnings in such a way to allow constructive response by state and local officials.

Under terms of the charter, a prediction is defined to mean a statement on the time of occurrence, location, and magnitude of a future significant earthquake based on qualification or evaluation of the uncertainty of those factors. If the USGS director decides to issue a prediction, or an advisory or negative evaluation of a prediction, the first people to be notified are the director of the Federal Emergency Management Agency, the Secretary of the Department of the Interior, and the governors of states affected by the predicted earthquake. □

Interior Department issues temporary regs for hardrock mining on public lands

Temporary regulations that govern hardrock mining on public lands still subject to the Bureau of Land Management's (BLM) wilderness review have been issued by the Department of the Interior.

The final regulations are nearly identical to the proposed regulations except for two changes. First, the "grandfather clause" has been amended to allow mining and grazing uses as of October 21, 1976, to continue to expand in a logical fashion, even if they impair wilderness values. This means, for example, that a change from mineral exploration to production would be allowed if added impacts are not significantly different.

Second, development will be allowed on mining claims on which a valid discovery was made on or before October 21, 1976. However, such development will be subject to measures preventing unnecessary degradation of the public land.

The regulations will be in effect only temporarily, until other proposed rules become final. However, it was necessary to implement the temporary regulations to avoid impairment of wilderness suitability.

The regulations concern only such minerals as gold, silver, lead, zinc, and other minerals considered locatable under the General Mining Law of 1872, as amended. They do not affect leasable or "common variety" minerals such as sand and gravel.

The BLM regulations are similar to those effected by the Forest Service in 1974. □

Miocene stratigraphy and fossils, Cape Blanco, Oregon

by Warren O. Adicott, U.S. Geological Survey, Menlo Park, California 94025

INTRODUCTION

Seacliff exposures of marine sandstone on the southwest Oregon coast near Cape Blanco (Figure 1) contain fossil mollusks, echinoids, and barnacles of Miocene age. Fossil assemblages from the lower part of the Miocene sequence are correlated with the early and middle Miocene fauna of the Astoria Formation of the Newport embayment 200 km to the north. Assemblages that occur above an angular unconformity near the middle of this sequence are comparable to the late Miocene fauna of the Empire Formation of the Coos Bay area about 60 km to the north. Poorly preserved bivalves near the top of the sequence appear to represent a still younger faunal unit contemporaneous with the upper part of the Montesano Formation of Fowler (1965) of western Washington.

The Miocene sequence is in a relatively thin marine section that represents the most complete late Cenozoic sequence exposed on the Oregon coast. The Pliocene Epoch is not represented, but two and possibly three Miocene megafaunal stages are present—the Newportian, Wishkahan, and Graysian Stages (Addicott, 1976)—and there is a well-developed Pleistocene section (Baldwin, 1966; Allison and others, 1962).

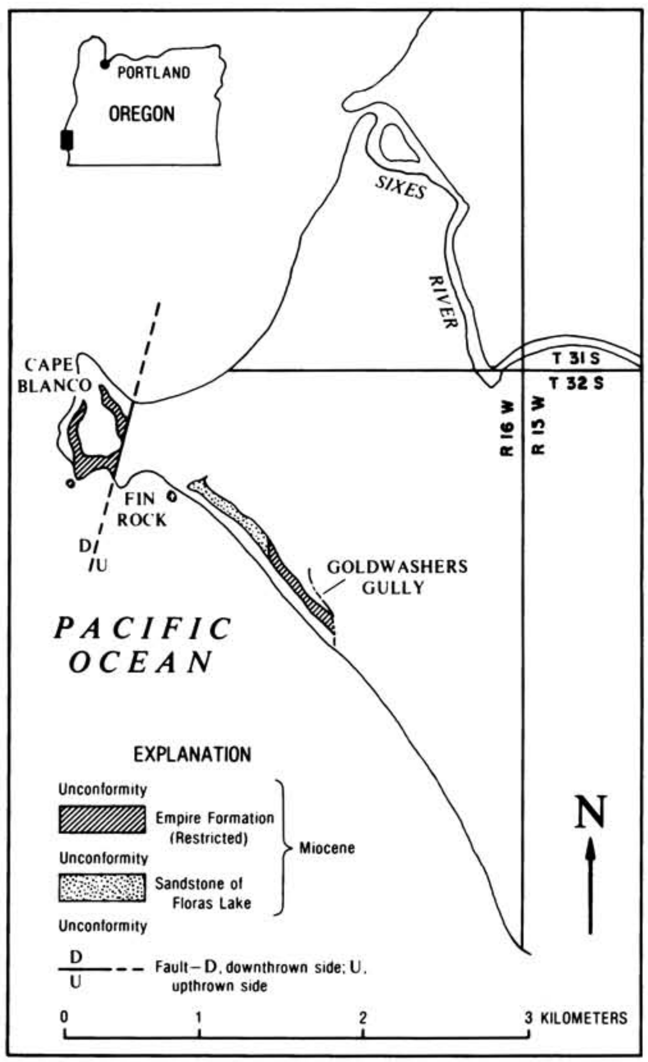
The purpose of this report is to summarize briefly the stratigraphic occurrence of the Miocene molluscan faunas and to illustrate some of the more common and biostratigraphically significant species. I am indebted to Richard Janda for assistance in the field and to Janda, E.J. Moore, and J.A. Barron for technical comments. Fossil photography is by Kenji Sakamoto.

EARLIER WORK

The age of the fossiliferous late Tertiary sandstone at Cape Blanco has been a subject of interest, and at times controversy, over the past 120 years. These strata were first noted by Newberry (1856), who compared them with marine beds exposed at Astoria, Oregon. Diller (1902, 1903) mapped and described the Neogene sequence at Cape Blanco. His fossil collections from near Blacklock Point and southeast of Cape Blanco suggested correlation with the Empire Formation of the Coos Bay area (Dall *in* Diller, 1902).

Controversy over the age of these beds arose from a stratigraphically mixed collection of invertebrates from southeast of Cape Blanco (Arnold and Hannibal, 1913, loc. NP26). This collection was considered to be of middle Miocene age but younger than the fauna of the Astoria Formation. It spanned 200 m or more of section and included molluscan assemblages from what are now known to be two provincial stages, the Newportian and Wishkahan. Subsequently, these strata were considered to be as old as Oligocene (Kew, 1920) and as young as Pliocene (Schenck, 1928; Bandy, 1950). These conflicting views were due, in part, to the composite stratigraphic collection. Clarification finally came when an unconformity was found in the Miocene section southeast of Cape Blanco (Durham, 1953). Arnold and Hannibal's collection had come from both above and below the unconformity.

Figure 1. Index map showing location of Cape Blanco and Miocene sections described in this report.



STRATIGRAPHIC SETTING

The stratigraphic sequence and structure of Cenozoic units near Cape Blanco are complex. Lower and middle Miocene sandstone rests unconformably on Eocene shale and sandstone (Bandy 1944) in the seacliffs southeast of Cape Blanco. In this seacliff section, the lower and middle Miocene unit is unconformably overlain by upper Miocene sandstone and siltstone which, in turn, are unconformably overlain by the Pleistocene Port Orford Formation of Baldwin (1945), a unit rich in molluscan fossils. There is an angular unconformity within the Port Orford Formation. Noteworthy in these Pleistocene strata are the diverse accumulations of *Psephidia* (see Clifton and Boggs, 1970), a minute bivalve that forms prominent white strata near the mouth of Elk River. At Cape Blanco proper, upper Miocene sandstone rests unconformably on Upper Jurassic sandstone and pebbly mudstone (Dott, 1971). Unconformably capping all of the older Cenozoic units at Cape Blanco are marine terrace deposits of late Pleistocene age (Figure 2). Mollusks and a few foraminifers have been identified from these gently warped strata (Bandy, 1950; Addicott, 1964; Kennedy, 1978).

The principal exposures of the Miocene section are in seacliffs about 0.5 km southeast of Cape Blanco and north of Blacklock Point, about 6 km north of Cape Blanco. Other exposures occur at Cape Blanco and several inland localities in the vicinity of Cape Blanco and nearby Port Orford (Koch, 1966). The most complete and most fossiliferous Miocene section is the 260-m-thick seacliff exposure southeast of Cape Blanco which extends from Fin Rock east-southeastward to Goldwasher's Gully. This section (Figure 3) serves as the framework for the stratigraphic and paleontologic descriptions which follow.

The Miocene sequence at Cape Blanco has been known as the Empire Formation of Diller (1903). The Empire Formation was defined for its type section, massive sandstone exposed between Sitka Dock (SW¼ sec. 40, T. 25 S., R. 13 W.) and the bridge (SE¼ sec. 2, T. 26 S., R. 14 W.) at Charleston, near the mouth of Coos Bay, Oregon (Weaver, 1945, pl. 9; Armentrout, 1967, p. 62). Unfortunately, use of this name at Cape Blanco implies correlation with the type Empire Formation. To avoid possible confusion, an informal name—sandstone of Floras Lake—is used for the lithologically distinct lower part of the Miocene sequence that occurs below the unconformity, and the name Empire Formation is used for massive sandstone of late Miocene age that unconformably overlies the sandstone of Floras Lake (Figure 3).

Sandstone of Floras Lake

This name, a term suggested by R.J. Janda (written communication, 1976), is based on the continuously exposed section of massive, conglomeratic, and concretionary sandstone exposed between Blacklock Point and Floras Lake, about 6 to 10 km north of Cape Blanco.

Figure 2. Angular unconformity between massive early and middle Miocene sandstone and flat-lying late Pleistocene terrace deposits near top of seacliff about 1 km southeast of Cape Blanco. Articulated bivalves in the terrace deposits are mostly Saxidomus giganteus *(Deshayes).*

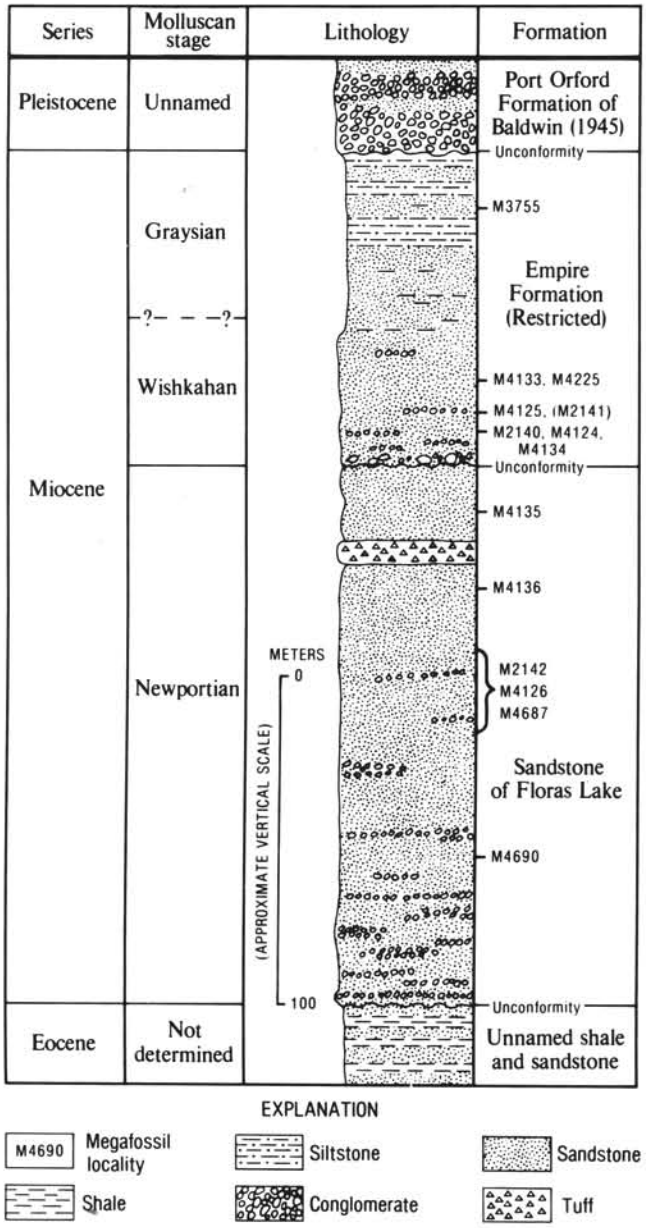


Figure 3. Diagrammatic section showing stratigraphic units exposed in seacliffs between Fin Rock and Goldwasher's Gully, southeast of Cape Blanco.

Although these strata have been referred to the Astoria Formation by Moore (1963), an alternative name is advisable because the lithology of this conglomeratic sandstone and sandstone unit differs significantly from that of the type locality of the Astoria Formation at the mouth of the Columbia River.

The basal part of the Miocene sequence is well exposed at Fin Rock, but the contact with the underlying Eocene shale and sandstone is concealed. The lowest few meters consists of pebble and cobble conglomerate with scattered barnacle plates and specimens of the gastropod *Nucella*. The principal fossiliferous localities in the sandstone of Floras Lake occur in a 50- to 60-m-thick interval below a tuff bed situated near the top of the formation. These concretionary beds are characterized by abundant specimens of the plicate mussel *Mytilus middendorffi* Grewingk. The 7- to 8-m-thick tuff contains poorly preserved fossil leaves of warm climatic aspect (Wolfe and Hopkins, 1967). Above the tuff are 30 m of massive carbonaceous and micaceous sandstone with scattered large flattened concretions. Small, articulated specimens of the bivalve *Spisula albaria* (Conrad) are extremely abundant in these concretions.

Twenty-nine larger marine invertebrates have been identified in collections made from exposures of the sandstone of Floras Lake in the seacliff section east of Cape Blanco (Table 1). The molluscan fauna of this unit is referable to the Newportian Stage (Addicott, 1976) of the Pacific Northwest. Species that are restricted to this stage include the gastropods *Molopophorus matthewi* Etherington and *Nassarius arnoldi* (Anderson) and the bivalves *Macoma flagleri* Etherington and *Mytilus middendorffi* Grewingk. The age of the Newportian is late early and middle Miocene in terms of the European standards (Addicott, 1977).

Correlative faunal assemblages occur at Coos Bay, 60 km to the north, in dredgings from the ship channel (Moore, 1963), and in an 8-m-thick section of sandstone on the east shore of Coos Bay (Baldwin, 1966; Armentrout, 1967). These *Dosinia*-rich collections contain a few specimens of the Newportian species *Mytilus middendorffi* Grewingk (USGS loc. 18284). This distinctive plicate mussel ranged from southern California to the Gulf of Alaska and possibly to Kamchatka in the western North Pacific, during the late early and middle parts of the Miocene (Allison and Addicott, 1976).

The *Mytilus-Balanus-Nucella* assemblages in the lower part of the section are indicative of deposition in an extremely shallow-water environment and proximity to a rocky shoreline. Pebble conglomerate lenses characteristic of these basal strata are similar to the pebble gravel that occurs in present-day surf zone sediments of this area. The disarticulation of these specimens (*Balanus* and *Mytilus*) and their occurrence in conglomerate and pebbly sandstone indicate transport in the surf and breaker zones; the relatively good preservation of these invertebrates, however, suggests that at least some of them were not subjected to prolonged abrasion and that deposition was probably fairly rapid.

Faunal diversity increases markedly upsection with the appearance of many gastropods and sand-dwelling bivalves. *Nucella* and *Mytilus* are joined by the bivalves *Spisula* and *Macoma* and the gastropods *Bruclarkia* and undetermined naticoids. The increase in diversity, together with the appearance of *Katherinella* and *Dentalium*, suggests deepening to about 10 to 20 m in the middle and upper parts of the section southeast of Cape Blanco.

Table 1. *Marine fossils from the Miocene sequence east of Cape Blanco, Oregon*
[x, present; cf., similar form; aff., comparable but specifically distinct; sp., species not determinable; ?, identification doubtful]

	Localities												
	Sandstone of Floras Lake						Empire Formation (restricted)						
Species	M4687	M2142	M4126	M4135	M4136	M4690	M2140	M2141	M4124	M4125	M4133	M4134	M4225
Gastropods:													
Acmaea sp.	—	x	—	—	—	—	—	—	—	—	—	—	—
Bruclarkia oregonensis (Conrad)	x	x	x	x	x	x	—	—	—	—	—	—	—
Cancellaria n. sp.? aff. *C. alaskensis* Clark	—	—	—	—	x	x	—	—	—	—	—	—	—
Cancellaria cf. *C. ocoyana* Addicott	—	—	—	—	x	—	—	—	—	—	—	—	—
Crepidula adunca Sowerby	—	—	—	—	—	—	—	cf.	—	x	—	—	—
Crepidula cf. *C. onyx* Sowerby	—	—	—	—	—	—	—	—	—	x	—	—	—
Crepidula praerupta Conrad	—	—	—	—	x	—	—	—	—	—	—	—	—
Crepidula rostralis (Conrad)	—	x	—	—	—	—	—	—	—	—	—	—	—
Cryptonatica cf. *C. clausa* (Broderip and Sowerby)	—	—	—	—	—	—	—	x	—	—	—	?	—
Cryptonatica oregonensis (Conrad)	x	—	—	sp.	—	—	—	—	—	—	—	—	—
Littorina petricola (Dall)	—	—	—	—	—	—	—	—	—	—	x	—	—
Mediargo sp.	—	—	—	—	—	—	—	x	—	—	—	—	—
Megasurcula sp.	—	—	x	—	—	—	—	—	—	—	—	—	—
Molopophorus cf. *M. anglonanus* (Anderson)	sp.	x	—	—	x	—	—	—	—	—	—	—	—
Molopophorus bogachieli (Reagan)	—	—	—	—	—	—	cf.	x	—	x	—	x	—
Molopophorus matthewi Etherington	—	x	x	—	x	x	—	—	—	—	—	—	—
Nassarius cf. *N. andersoni* (Weaver)	—	—	—	—	—	—	—	—	—	—	—	x	—
Nassarius arnoldi Anderson	—	—	—	—	—	x	—	—	—	—	—	—	—
Natica cf. *N. clarki* Etherington	—	—	x	—	—	—	—	—	—	—	—	—	—
Nucella canaliculata (Duclos)	—	—	—	—	—	—	x	—	—	x	x	—	x
Nucella etchegoinensis (Arnold)	—	—	—	—	—	—	—	x	—	cf.	—	—	—
Nucella lima (Gmelin)	—	—	—	—	—	—	cf.	cf.	—	x	x	x	—
Nucella packi (Clark)	—	x	x	—	cf.	—	—	—	—	—	—	—	—
Ocenebra sp.	—	—	—	—	—	—	—	x	—	—	—	—	—
Olivella cf. *O. ischnon* Keen	x	sp.	cf.	—	?	sp.	—	—	—	—	—	—	—
Opalia wishkahensis Durham	—	—	—	—	—	—	—	—	cf.	—	—	x	—
Ophiodermella cf. *O. olympicensis* Addicott	—	—	x	—	—	x	—	—	—	—	—	—	—
Polinices lincolnensis (Weaver)	x	—	x	—	x	—	—	—	—	—	—	—	—
Priscofusus cf. *P. medialis* (Conrad)	—	—	x	—	—	—	—	—	—	—	—	—	—
Bivalves:													
Acila blancoensis Howe	—	—	—	—	—	—	x	x	x	x	x	—	x
Anadara trilineata (Conrad)	—	—	—	—	—	—	x	—	x	x	—	cf.	?
Clinocardium meekianum (Gabb)	—	—	—	—	—	—	x	x	x	cf.	x	cf.	cf.
Cnesterium aff. *C. scissurata* (Dall)	—	—	—	—	—	—	—	x	—	—	—	—	—
Felaniella parilis (Conrad)	—	—	—	—	—	—	x	—	—	x	—	—	x
Glycymeris gabbi (Dall)	—	—	—	—	—	—	x	—	—	x	—	—	x
Glycymeris grewingki Dall	—	—	—	—	—	—	—	—	x	—	—	—	—
Katherinella cf. *K. angustifrons* (Conrad)	—	x	—	—	x	—	—	—	—	—	—	—	—
Lucinoma cf. *L. acutilineata* (Conrad)	—	—	—	—	—	—	—	—	x	—	—	—	—
Macoma cf. *M. flagleri* Etherington	—	x	x	x	—	x	—	—	—	—	—	—	—
Macoma indentata Carpenter	—	—	—	—	—	—	—	—	—	x	—	—	—
Macoma secta (Conrad)	—	cf.	—	—	—	cf.	x	—	cf.	—	—	—	—
Modiolus sp.	—	—	—	—	—	—	—	x	—	—	—	—	—
Mytilus middendorffi Grewingk	x	x	x	x	x	x	—	—	—	—	—	—	—
Pandora sp.	—	—	—	—	—	—	—	—	—	—	—	—	x

Table 1. *Marine fossils from the Miocene sequence east of Cape Blanco, Oregon (continued)*

Species	Localities: Sandstone of Floras Lake						Localities: Empire Formation (restricted)						
	M4687	M2142	M4126	M4135	M4136	M4690	M2140	M2141	M4124	M4125	M4133	M4134	M4225
Bivalves *(continued)*													
Securella securis (Shumard)	sp.	—	—	—	sp.	—	x	—	x	x	—	x	x
Siliqua cf. *S. lucida* (Conrad)	—	—	—	—	—	—	—	x	—	x	—	—	?
Solen conradi Dall	—	cf.	x	?	—	—	—	—	—	—	—	—	—
Spisula albaria (Conrad)	x	x	x	cf.	cf.	x	—	—	—	—	—	—	—
Spisula cf. *S. albaria coosensis* Howe	—	—	—	—	—	—	x	—	x	x	x	—	—
Spisula praecursor Dall	—	—	—	—	—	—	—	x	—	—	—	—	—
Spisula cf. *S. selbyensis* Packard	—	—	x	—	x	sp.	—	—	—	—	—	—	—
Tellina emacerata Conrad	x	?	x	—	x	—	—	—	—	—	—	—	—
Tellinella merriami (Weaver)	—	—	—	—	—	—	—	x	—	—	—	—	cf.
Tresus pajaroanus (Conrad)	—	—	—	—	—	—	—	—	x	—	—	—	—
Yoldia cf. *Y. carnerosensis* Clark	x	x	x	—	x	x	—	—	—	—	—	—	—
Yoldia cooperi Gabb	—	—	—	—	—	—	x	—	—	—	—	—	—
Echinoids:													
Kewia blancoensis (Kew)	—	—	—	—	—	—	—	x	—	—	—	—	—
Kewia cf. *K. blancoensis etheringtoni* (Weaver)	—	—	x	—	—	?	—	—	—	—	—	—	—
Barnacles:													
Balanus tintinnabulum coosensis Dall	—	—	—	—	—	—	—	x	—	—	—	—	—
Balanus sp.	—	x	x	—	—	—	—	—	—	—	—	—	—

Figure 4. Unconformity between sandstone of Floras Lake and overlying sandstone of the Empire Formation (restricted). View looking north.

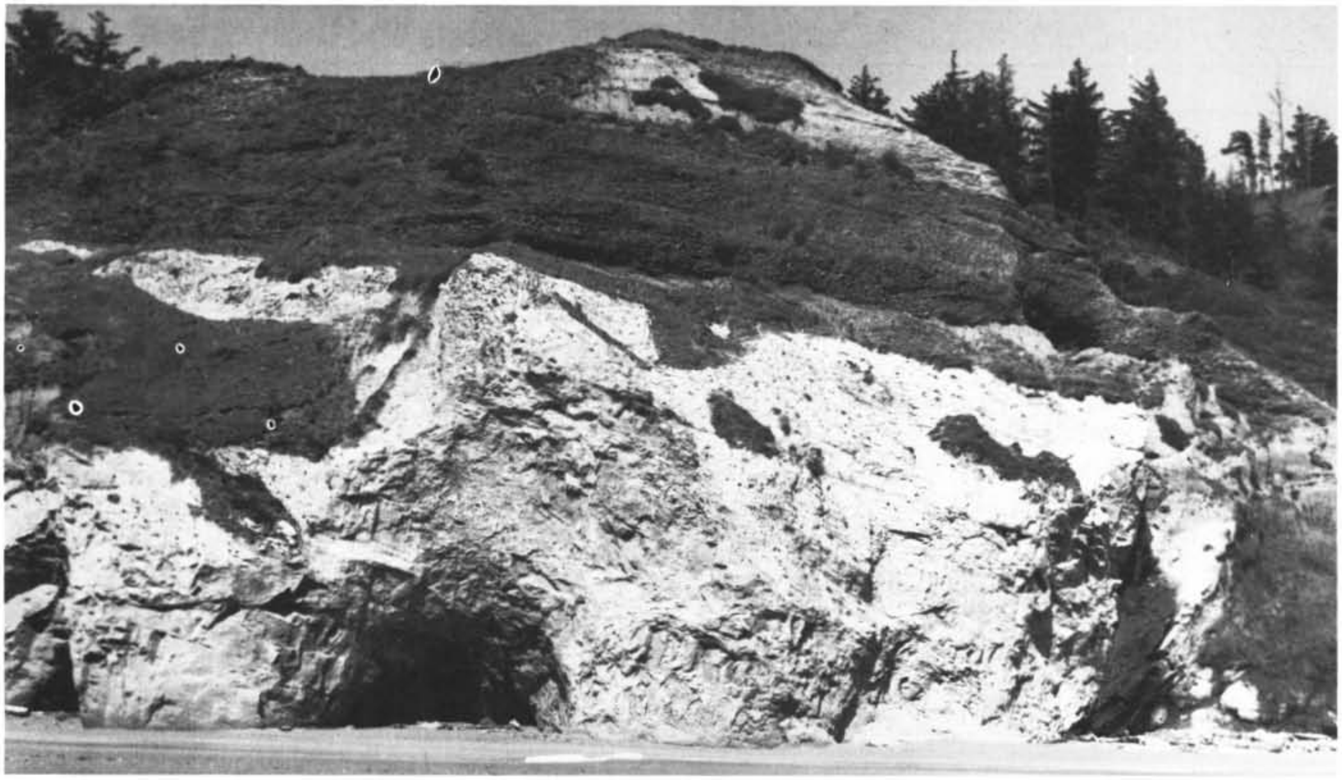


Figure 5. Massive, diatomaceous, sandy siltstone of the upper part of the Empire Formation (restricted) unconformably overlain by fluvial conglomerate of the Port Orford Formation of Baldwin (1945). Fossil locality M3755 occurs at base of seacliff about 100 m farther west. View looking north and about 100 m west of Goldwasher's Gully. Height of seacliff about 60 m.

The stratigraphically highest exposures southeast of Cape Blanco (loc. M4135) are micaceous, fine-grained, thick-bedded sandstone with small articulated specimens of *Spisula* and scattered *Dentalium*. These sediments probably were deposited in relatively deeper and quieter waters than stratigraphically lower parts of the sandstone of Floras Lake.

In summary, the succession of marine communities preserved in the 150- to 180-m early and middle Miocene section southeast of Cape Blanco is suggestive of initial deposition near the top of the inner sublittoral zone (0-100 m) with progressive deepening as deposition continued. However, the 7- to 8-m-thick tuff bed near the top of the unit that contains fossil leaves (Wolfe and Hopkins, 1967, p. 70-71) may indicate a brief reversal of the inferred deepening trend. According to Wolfe (personal communication, March 1977), the preservation of these leaf specimens implies transportation in a high-energy environment. Shoaling in the upper part of the unit is clearly indicated in the Blacklock Point section north of Cape Blanco where fluvial gravel occurs stratigraphically above the tuff bed.

Empire Formation (restricted)

The Empire Formation (restricted), equivalent to the upper part of the Empire Formation of Diller (1903), is separated from the underlying sandstone of Floras Lake by an erosional unconformity exposed at the base of the seacliff about 1.5 km southeast of Cape Blanco (Figure 4). The channeled surface is accentuated by subangular blocks of sandstone and fossiliferous concretions reworked from the underlying unit. These blocks reach a meter or more in thickness and are riddled with mollusk borings. Invertebrates in this basal stratum include *Chlamys*, *Securella*, and *Yoldia*, and the gastropod *Cryptonatica*.

The Empire Formation at Cape Blanco consists of about 100 m of massive sandstone and sandy siltstone. The lowest 35 to 40 m is a massive sandstone unit with several fossiliferous lenses. The lower 14 to 15 m includes a 1-m-thick basal conglomerate which is overlain by more or less massive, concretionary sandstone characterized by lenses of pebble conglomerate. Bedded concretions in this interval contain abundant mollusks of shallow-water aspect. The stratigraphically higher part of this massive sandstone unit is less fossiliferous and contains only scattered lenses of pebble conglomerate.

These strata in turn are overlain by 50 to 60 m of white- to tan-weathering, silty, very fine-grained sandstone and sandy siltstone (Figure 5) containing scattered molds of bivalve mollusks, especially near the top.

Commonly occurring mollusks are the bivalves *Lucinoma annulata* (Reeve), *Macoma* cf. *M. calcarea* (Gmelin), *Nuculana* sp., *Portlandia* sp., *Compsomyax* cf. *C. subdiaphana* (Carpenter), and *Cnesterium scissurata* Dall (USGS locs. M3755, M4223).

The Empire Formation (restricted) is unconformably overlain by poorly consolidated conglomerate and sandstone of the Port Orford Formation of Baldwin (1945). The angular unconformity between the two formations is well exposed near Goldwasher's Gully southeast of Cape Blanco (Figure 6). An intraformational unconformity between buff sand and gravel at the base of the Port Orford and a prominent fluvial gravel that marks the base of the so-called "Elk River Member" of the formation is well exposed in the seacliff immediately southeast of Goldwasher's Gully (Figure 6).

Mollusks referable to the Wishkahan Stage (Addicott, 1976) occur in the basal conglomeratic sandstone of the Empire Formation (restricted) at Cape Blanco and in a 30-m-thick section with three pebbly sandstone lenses in the lower unit. These late Miocene species are listed in Table 1. Species restricted to the Wishkahan Stage include the bivalves *Acila blancoensis* Howe, *Glycymeris gabbi* Dall, *Tellinella merriami* (Weaver), and the gastropod *Opalia wishkahensis* Durham. Other species that appear in the Wishkahan but range into younger strata include the gastropods *Nassarius* cf. *N. andersoni* (Weaver), *Nucella canaliculata* (Duclos), and *Molopophorus bogachieli* (Reagan), and two bivalves—*Clinocardium meekianum* (Gabb) and *Securella securis* (Shumard).

The close identity with the much larger fauna from the type section of the Empire Formation near the mouth of Coos Bay, some 50 km to the north (Dall, 1909; Weaver, 1945; Armentrout, 1967), implies that these two units are contemporaneous, but the mollusks from the lower part of the type Empire Formation at Coos Bay seem to represent a generally deeper water depositional environment. Articulated specimens of *Patinopecten coosensis* (Shumard) are especially abundant in sandstone occurring below the Coos Conglomerate Member at Coos Bay, but this bivalve does not occur in the strata exposed near Cape Blanco. The modern depth distribution of this genus in the eastern North Pacific is greater than about 20 m. Thus the fauna of the Empire Formation at Coos Bay is of somewhat deeper aspect than the intertidal to shallow subtidal fauna of the Empire Formation (restricted) at Cape Blanco.

The previously mentioned bivalve assemblage from the stratigraphically higher, finer grained unit of the Empire Formation (restricted) at Cape Blanco appears to be correlative with the Graysian Stage of western Washington on the basis of a diatom florule of late Miocene age (North Pacific Diatom Zone 14) from USGS loc. M3755 near the top of this upper unit (J.A. Barron, written communication, March 1977). Barron notes that this diatom zone also occurs in siltstone in the upper part of the Montesano Formation of Fowler (1965) in western Washington which is within the type section of the Graysian Stage.

The sequence of depositional environments repre-

Figure 6. Unconformable contact between the Empire Formation (restricted) and the Port Orford Formation of Baldwin (1945). West of Goldwasher's Gully, massive, white-weathering siltstone and silty sandstone are overlain by buff sandstone and interbedded conglomerate. East of Goldwasher's Gully, a prominent unconformity separates the so-called Goldwasher's Gully Member of the Port Orford Formation from the overlying basal conglomerate of the Elk River Member of the same formation. View looking northwest.

sented by the nearly 100 m of Empire Formation (restricted) that crops out southeast of Cape Blanco near Goldwasher's Gully is similar to that of the sandstone of Floras Lake. The high-energy, shoreline environment represented by the fossiliferous basal conglomerate of the Empire Formation (restricted) is succeeded by sandstone and pebble conglomerate containing mollusk and echinoid assemblages comparable bathymetrically to those in the middle to upper part of the sandstone of Floras Lake. The stratigraphically higher silty sandstones and sandy diatomaceous siltstones characterized by a low diversity association of the bivalves *Portlandia*, *Nuculana*, *Compsomyax*, *Lucinoma*, and *Cnesterium* record a middle to outer sublittoral environment and the greatest depths in the entire Miocene sequence at Cape Blanco.

DISCUSSION

There is a striking difference in faunal composition between the two Miocene formations at Cape Blanco (Table 1). Only one species is common to both units, and, in almost every case, genera that are common to both units are represented by entirely different species. A faunal change of this magnitude reflects either a profound change in environmental facies or a significant hiatus in the geologic record. Differences in depositional environments do not seem to account for the observed faunal change; the similar depth and sedimentary facies of each unit, as well as the similar generic compositions of the two faunas, rule out this possibility. It is more likely that the differences are due to the hiatus represented by the unconformity that separates the two units. The time gap cannot be particularly large because the faunas are referable to successive Miocene ages, the Newportian and the Wishkahan. There is, however, an appreciable time span of about 10 m.y. from the base of the Newportian to the top of the Wishkahan. Possibly the Newportian fauna of the sandstone of Floras Lake represents deposition during the earliest part of that age (range: about 18 to 12 m.y. ago), and the Wishkahan fauna of the Empire Formation (restricted) represents deposition during the later part of that age (range: about 12 to 8 m.y. ago).

REFERENCES

Addicott, W.O., 1964, A late Pleistocene invertebrate fauna from southwestern Oregon: Journal of Paleontology, v. 38, no. 4, p. 650-661.

——— 1976, Neogene molluscan stages of Oregon and Washington, *in* Neogene Symposium: Society of Economic Paleontologists and Mineralogists, Pacific Section, San Francisco, Calif., April 1976, p. 95-115, pls. 1-5.

Plate 1. *Fossils from the sandstone of Floras Lake* →
[Specimens natural size unless otherwise indicated]

Figure 1. *Mytilus middendorffi* Grewingk. USNM 264110. USGS loc. M4130.
2. *Liracassis* sp. USNM 245705. USGS loc. M4132.
3. *Natica* cf. *N. clarki* Etherington, ×2. USNM 245700. USGS loc. M4126.
4. *Crepidula rostralis* (Conrad), ×1½. USNM 245708. USGS loc. M2142.
5. *Solen conradi* Dall. USNM 245713. USGS loc. M4126.
6. *Nucella packi* (Clark), ×2. USNM 245694. USGS loc. M4129.
7. *Molopophorus matthewi* Etherington, ×1½. USNM 245702. USGS loc. M2142.
8. *Molopophorus matthewi* Etherington. USNM 245711. USGS loc. M4690.
9. *Molopophorus* cf. *M. anglonanus* (Anderson), ×1½. USNM 264112. USGS loc. M2142.
10. *Tellina emacerata* Conrad. USNM 245726. USGS loc. M4126.
11. *Molopophorus matthewi* Etherington. USNM 245710. USGS loc. M4132.
12, 13. *Olivella* cf. *O. ischnon* Keen, ×4. USNM 245726. USGS loc. M4126.
14. *Molopophorus* cf. *M. anglonanus* (Anderson), ×2. USNM 245706. USGS loc. M2142.
15. *Bruclarkia oregonensis* (Conrad). USNM 245703. USGS loc. M4690.
16. *Priscofusus* cf. *P. medialis* (Conrad), ×1½.USNM 245701. USGS loc. M4126.
17. *Cancellaria* n. sp.? aff. *C. alaskensis* Clark, ×2. USNM 245724. USGS loc. M4136.
18. *Bruclarkia oregonensis* (Conrad). University of Oregon F29713. UO loc. F2011.
19. *Kewia* cf. *K. blancoensis etheringtoni* (Weaver), ×1½. USNM 245725. USGS loc. M4126.
20. *Cryptonatica oregonensis* (Conrad), ×1½. USNM 245727. USGS loc. M4126.
21. *Ophiodermella* cf. *O. olympicensis* Addicott, ×2½. USNM 245714. USGS loc. M4690.
22, 23. *Nucella packi* (Clark), ×1½. USNM 245695. USGS loc. M3637.
24. *Yoldia* cf. *Y. carnerosensis* Clark. USNM 245712. USGS loc. M4126.
25. *Spisula albaria* (Conrad). USNM 245717. USGS loc. M2142.
26. *Yoldia* cf. *Y. carnerosensis* Clark, ×1½. USNM 264113. USGS loc. M2142.
27. *Nassarius arnoldi* (Anderson), ×4. USNM 245727. USGS loc. M4690.
28. *Mytilus middendorffi* Grewingk. USNM 245720. USGS loc. M4130.

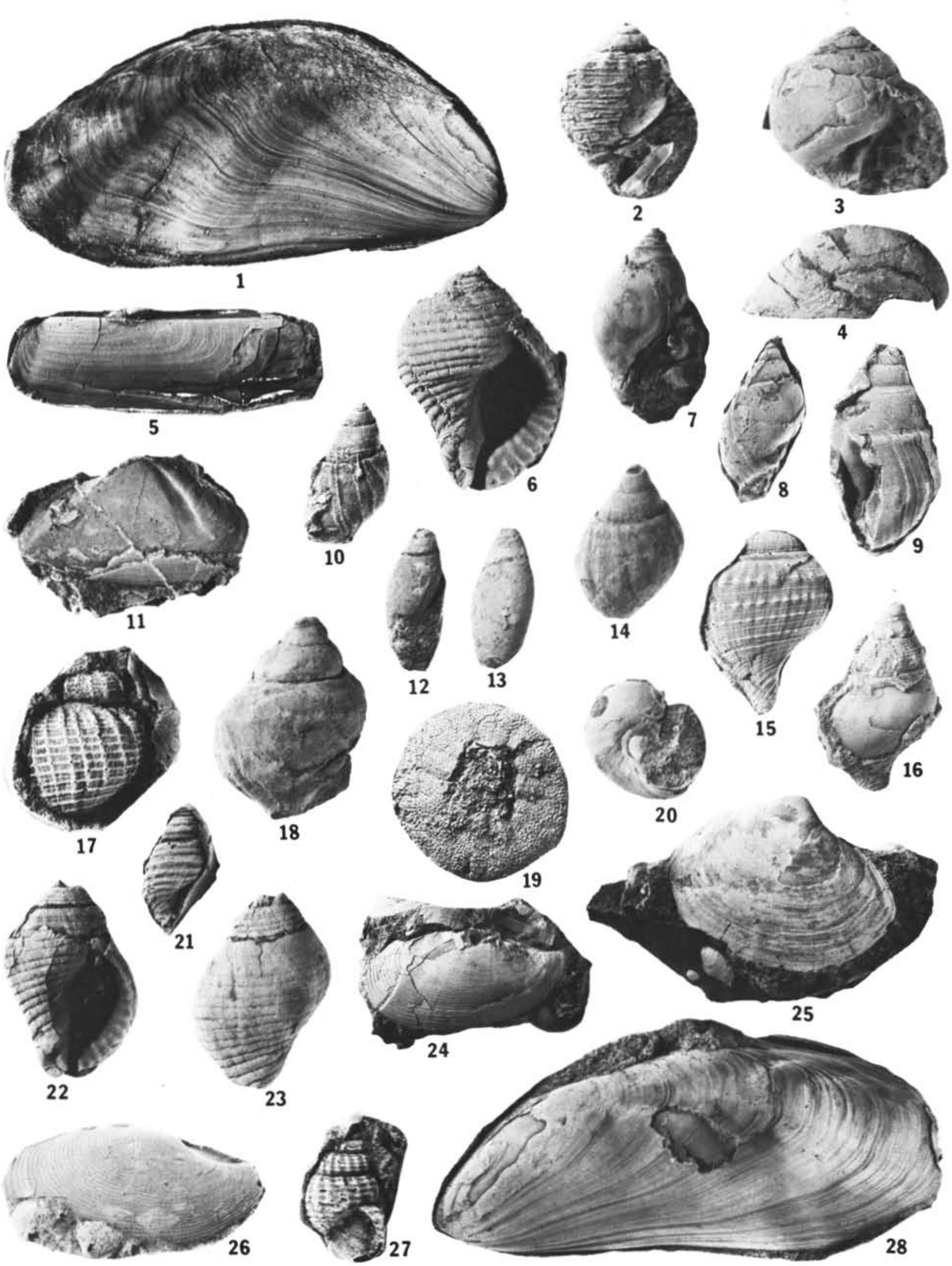


PLATE 1.

——— 1977, Neogene chronostratigraphy of nearshore marine basins of the eastern North Pacific: northwestern Mexico to Canada: International Congress on Pacific Neogene Stratigraphy, 1st, Tokyo, 1976, Proceedings, p. 151-175.

Allison, E.C., Durham, J.W., and Zullo, V.A., 1962, Cold-water late Cenozoic faunas of northern California and Oregon [abs.]: Geological Society of America Special Paper 68 [Abstracts for 1961], p. 2.

Allison, R.C., and Addicott, W.O., 1976, The North Pacific Miocene record of *Mytilus (Plicatomytilus)*, a new subgenus of Bivalvia: U.S. Geological Survey Professional Paper 962, 21 p., 3 pls.

Armentrout, J.M., 1967, The Tarheel and Empire Formations, geology and paleontology of the type sections, Coos Bay, Oregon: Eugene, Oreg., University of Oregon master's thesis, 155 p.

Arnold, Ralph, and Hannibal, Harold, 1913, The marine Tertiary stratigraphy of the north Pacific Coast of America: American Philosophical Society Proceedings, v. 52, no. 212, p. 559-605.

Baldwin, E.M., 1945, Some revisions of the late Cenozoic stratigraphy of the southern Oregon coast: Journal of Geology, v. 53, no. 1, p. 35-46.

——— 1966, Some revisions of the geology of the Coos Bay area, Oregon: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 28, no. 11, p. 189-203.

Bandy, O.L., 1944, Eocene Foraminifera from Cape Blanco, Oregon: Journal of Paleontology, v. 18, no. 4, p. 366-377.

——— 1950, Some later Cenozoic Foraminifera from Cape Blanco, Oregon: Journal of Paleontology, v. 24, no. 3, p. 269-281.

Clifton, H.E., and Boggs, Sam, Jr., 1970, Concave-up pelecypod (*Psephidia*) shells in shallow marine sand, Elk River Beds, southwestern Oregon: Journal of Sedimentary Petrology, v. 40, no. 3, p. 888-897.

Dall, W.H., 1909, Contributions to the Tertiary paleontology of the Pacific Coast, 1: The Miocene of Astoria and Coos Bay, Oregon: U.S. Geological Survey Professional Paper 59, 278 p., 23 pls.

Diller, J.S., 1902, Topographic development of the Klamath Mountains: U.S. Geological Survey Bulletin 196, 69 p., 13 pls.

———, 1903, Description of the Port Orford quadrangle, Oregon: U.S. Geological Survey Geologic Atlas, Folio 89, 6 p.

Dott, R.H., Jr., 1971, Geology of the southwestern Oregon coast west of the 124th meridian: Oregon Department of Geology and Mineral Industries Bulletin 69, 63 p.

Durham, J.W., 1953, Miocene at Cape Blanco, Oregon [abs.]: Geological Society of America Bulletin, v. 64, no. 12, pt. 2, p. 1504-1505.

Fowler, G.A., 1965, The stratigraphy, Foraminifera, and paleoecology of the Montesano Formation, Grays Harbor County, Washington: Los Angeles, Calif., University of Southern California doctoral dissertation, 354 p.

Kennedy, G.L., 1978, Pleistocene paleoecology, zoogeography and geochronology of marine invertebrate faunas of the Pacific Northwest coast (San Francisco Bay to Puget Sound): University of California, Davis, doctoral dissertation, 824 p.

Kew, W.S.W., 1920, Cretaceous and Cenozoic Echinoida of the Pacific coast of North America: University of California Publications, Department of Geological Sciences Bulletin, v. 12, no. 2, p. 23-236, pls. 3-42, 5 figs.

Koch, J.G., 1966, Late Mesozoic stratigraphy and tectonic history, Port Orford-Gold Beach area, southwestern Oregon coast: American Association of Petroleum Geologists Bulletin, v. 50, no.1, p. 25-71.

Moore, E.J., 1963 [1964], Miocene marine mollusks from the Astoria
(Continued on page 98)

Plate 2. *Fossils from the Empire Formation (restricted)* →
[Specimens natural size unless otherwise indicated]

Figure 1. *Crepidula* cf. *C. princeps* Conrad. USNM 264113. USGS loc. M3695.
2. *Siliqua* cf. *S. lucida* (Conrad), ×1½. USNM 264114. USGS loc. M4125.
3. *Macoma indentata* Carpenter. USNM 264115. USGS loc. M4125.
4. *Crepidula adunca* Sowerby, ×1½. USNM 264116. USGS loc. M3965.
5. *Nucella lima* (Gmelin), ×1½. USNM 264117. USGS loc. M4134.
6. *Glycymeris gabbi* Dall. USNM 264118. USGS loc. M2139.
7. *Nucella canaliculata* (Duclos), ×3. USNM 264119. USGS loc. M7369.
8. *Opalia wishkahensis* Durham, ×1½. USNM 264120. USGS loc. M4134.
9. *Nucella lima* (Gmelin), ×1½. USNM 264121. USGS loc. M2141.
10. *Acila blancoensis* Howe, ×1½. USNM 264122. USGS loc. M2141.
11. *Nassarius andersoni* (Weaver), ×3. USNM 264123. USGS loc. M7369.
12. *Felaniella parilis* (Conrad). USNM 264124. USGS loc. M7369.
13, 14. *Kewia blancoensis* (Kew), ×1½. USNM 264125. USGS loc. M2141.
15. *Molopophorus bogachieli* (Reagan). USNM 264126. USGS loc. M4125.
16. *Kewia blancoensis* (Kew), ×1½. USNM 264127. USGS loc. M4121.
17. *Securella securis* (Shumard). USNM 264128. USGS loc. M4125.
18. *Clinocardium meekianum* (Gabb). USNM 264129. USGS loc. M2141.
19. *Securella securis* (Shumard). USNM 264130. USGS loc. M4124.

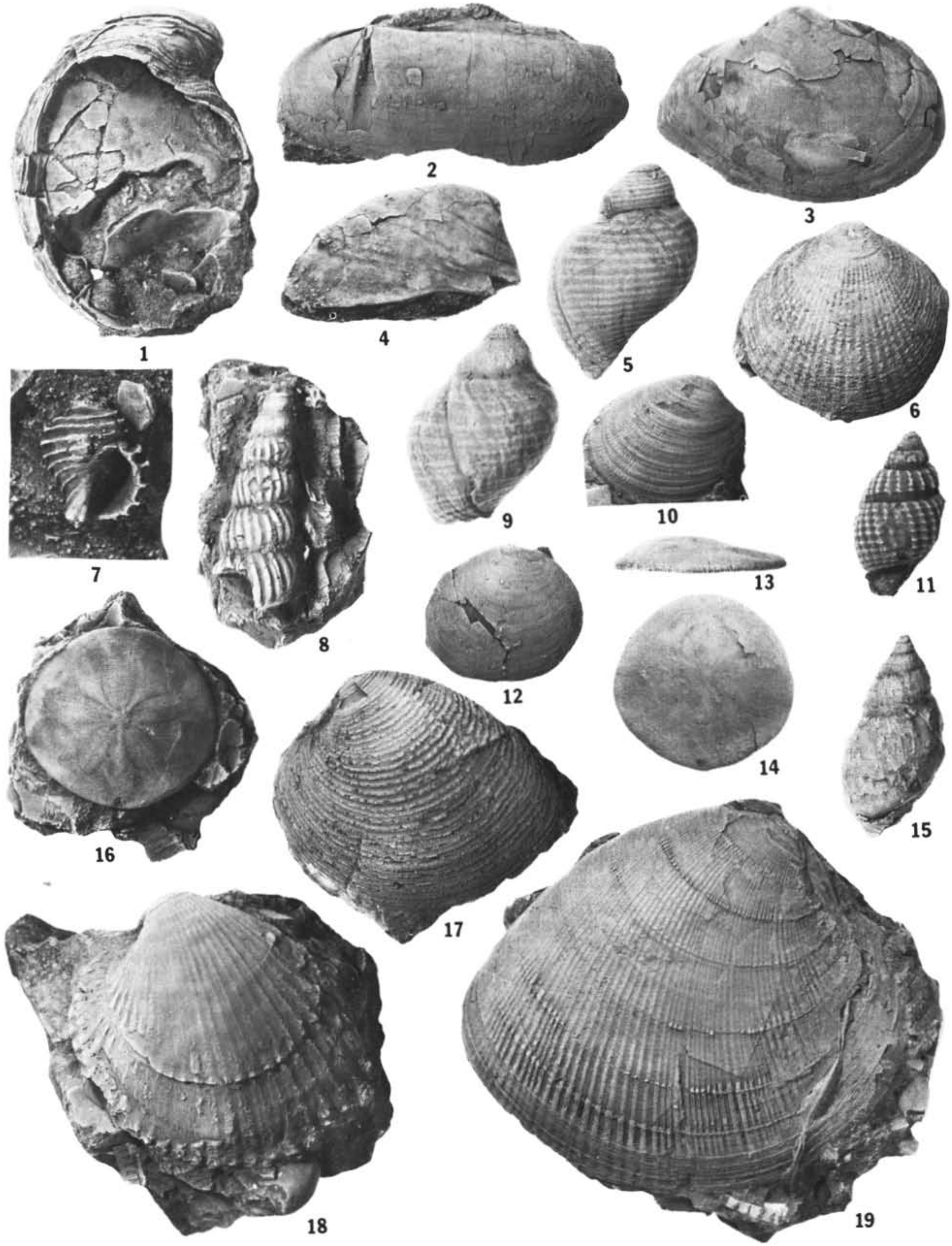


PLATE 2.

Lawson to supervise Mined Land Reclamation Program

On April 1, 1980, Paul F. Lawson became new Supervisor of the Mined Land Reclamation Program of the Oregon Department of Geology and Mineral Industries, replacing Standley L. Ausmus, now with the Office of Surface Mining, U.S. Department of the Interior. For two years prior to accepting his new assignment, Lawson was an Environmental Specialist for DOGAMI, responsible for field enforcement of Oregon's Mined Land Reclamation Act.

Paul F. Lawson

Before coming to the Department in April 1978, Lawson served for twenty years with the U.S. Army, with responsibilities in organization planning and programming, teaching, public relations, statistical research, facilities management, and development and administration of training programs. He has a bachelor's degree from the University of Illinois and a master's degree in earth science teaching from Portland State University.

Lawson's new position includes such duties as supervision of the Mined Land Reclamation Program; coordination of the Mined Land Reclamation Program with local, State, and Federal agencies; investigation of surface mining sites; and review and evaluation of permit applications. □

MOVING?

Don't forget to send us your new address.

Volunteers needed for tephra sampling program

The numerous eruptions of Mount St. Helens have resulted in the deposition of tephra (ash and other airborne volcanic material) over large areas of Washington and Oregon. The Oregon Museum of Science and Industry (OMSI) and the Earth Sciences Department of Portland State University have jointly begun "Operation Tephra," a project designed to study the volume of material erupted in a volcanic event, the characteristics of wind-carried material, patterns of distribution, and, possibly, even something about the geochemistry of the volcano. The project is beginning with a thorough sample-collection program over a wide area and could therefore utilize the help of many interested and dedicated volunteers willing to collect carefully, follow procedures, and stay with the program for a minimum of a month—and longer if possible.

The procedures are relatively simple, as are the equipment requirements: aluminum foil, a box, ziplock and paper bags, marking pens, and masking tape. OMSI has prepared a packet of instructions telling exactly how the sampling is to be done.

Oregon Geology readers interested in participating in this volunteer sampling program should contact Bruce Hansen, Operation Tephra, OMSI Research Center, 4015 SW Canyon Road, Portland, OR 97221, phone (503) 248-5944. □

(**Miocene fossils,** *from page 97)*

Formation in Oregon: U.S. Geological Survey Professional Paper 419, 109 p., 33 pls.

Newberry, J.S., 1856, Report upon the geology of the route [Williamson's survey in California and Oregon]: U.S. Pacific Railroad Exploration Reports (U.S. 33rd Congress, 2nd session, Senate Ex. Document 78 and House Ex. Document 91), v. 6, pt. 2, p. 5-68.

Schenck, H.G., 1928, Stratigraphic relations of western Oregon Oligocene formations: University of California Publications, Department of Geological Sciences Bulletin, v. 18, no. 1, 50 p.

Weaver, C.E., 1945, Stratigraphy and paleontology of the Tertiary formations at Coos Bay, Oregon: Seattle, Wash., University of Washington Publications in Geology, v. 6, no. 2, p. 31-62.

Wolfe, J.A., and Hopkins, D.M., 1967, Climatic changes recorded by Tertiary land floras in northwestern North America, *in* Hatai, Kotora, ed., Tertiary correlations and climatic changes in the Pacific: Pacific Science Congress, 11th, Tokyo, 1967, p. 67-76. □

PUBLICATIONS ORDER

Omission of price indicates publication is in press. Minimum mail order 50¢. All sales are final. Publications are sent postpaid. Payment must accompany orders of less than $20.00.

Fill in appropriate blanks and send sheet to Department (see address on reverse side).

YOUR NAME ____________________

ADDRESS ____________________

____________________ Zip ________

Amount enclosed $________

OREGON GEOLOGY

____ Renewal ____ Subscription ____ Gift

____ 1 Year ($4.00) ____ 3 Years ($10.00)

NAME ____________________

ADDRESS ____________________

____________________ ZIP ________

(If Gift, From: ____________________)

ORDER FORM - CUT ON DASHED LINE

Available publications

MISCELLANEOUS PAPERS	Price	No. Copies	Amount
1. A description of some Oregon rocks and minerals, 1950: Dole	$ 1.00		
4. Laws relating to oil, gas, and geothermal exploration and development in Oregon			
Part 1. Oil and natural gas rules and regulations, 1977, rev. 1979	1.00		
Part 2. Geothermal resources rules and regulations, 1977, rev. 1979	1.00		
5. Oregon's gold placers (reprints), 1954	.50		
6. Oil and gas exploration in Oregon, rev. 1965: Stewart and Newton	3.00		
8. Available well records of oil and gas exploration in Oregon, rev. 1973: Newton	1.00		
11. Collection of articles on meteorites, 1968 (reprints from *The Ore Bin*)	1.50		
13. Index to *The Ore Bin,* 1950-1974	1.50		
14. Thermal springs and wells, 1970: Bowen and Peterson (with 1975 supplement)	1.50		
15. Quicksilver deposits in Oregon, 1971: Brooks	1.50		
16. Mosaic of Oregon from ERTS-1 imagery, 1973	2.50		
18. Proceedings of Citizens' Forum on potential future sources of energy, 1975	2.00		
19. Geothermal exploration studies in Oregon—1976, 1977	3.00		
20. Investigations of nickel in Oregon, 1978: Ramp	5.00		

GEOLOGIC MAPS	Price	No. Copies	Amount
Geologic map of Galice quadrangle, Oregon, 1953	1.50		
Geologic map of Albany quadrangle, Oregon, 1953	1.00		
Reconnaissance geologic map of Lebanon quadrangle, 1956	1.50		
Geologic map of Bend quadrangle and portion of High Cascade Mountains, 1957	1.50		
Geologic map of Oregon west of 121st meridian, 1961	2.25		
Geologic map of Oregon east of 121st meridian, 1977	3.75		
GMS-3: Preliminary geologic map of Durkee quadrangle, Oregon, 1967	2.00		
GMS-4: Oregon gravity maps, onshore and offshore, 1967 (folded)	3.00		
GMS-5: Geologic map of Powers quadrangle, Oregon, 1971	2.00		
GMS-6: Preliminary report on geology of part of Snake River Canyon, 1974	6.50		
GMS-7: Geology of the Oregon part of the Baker quadrangle, Oregon, 1976	3.00		
GMS-8: Complete Bouguer gravity anomaly map, Cascade Mountain Range, central Oregon, 1978	3.00		
GMS-9: Total field aeromagnetic anomaly map, Cascade Mountain Range, central Oregon, 1978	3.00		
GMS-10: Low- to intermediate-temperature thermal springs and wells in Oregon, 1978	2.50		
GMS-11: Preliminary geothermal resource map of Oregon (upon written request only)	free	(one copy per customer)	
GMS-12: Geologic map of the Oregon part of the Mineral quadrangle	2.00		

OIL AND GAS INVESTIGATIONS	Price	No. Copies	Amount
3. Preliminary identifications of foraminifera, General Petroleum Long Bell #1 well	2.00		
4. Preliminary identifications of foraminifera, E.M. Warren Coos County 1-7 well, 1973	2.00		
5. Prospects for natural gas production or underground storage of pipeline gas	5.00		

MISCELLANEOUS PUBLICATIONS	Price	No. Copies	Amount
Landforms of Oregon (17 × 12 inches)	.50		
Mining claims (State laws governing quartz and placer claims)	.50		
Geological highway map, Pacific NW region, Oregon-Washington (published by AAPG)	3.00		
Fifth Gold and Money Session and Gold Technical Session Proceedings, 1975	5.00		
Sixth Gold and Money Session and Gold Technical Session Proceedings, 1978	6.50		
Back issues of *The Ore Bin*	25¢ over the counter; 50¢ mailed		
Colored postcard, *Geology of Oregon*	10¢ each; 3 for 25¢; 7 for 50¢; 15 for 1.00		

OREGON GEOLOGY

1069 State Office Building, Portland, Oregon 97201

Second Class Matter
POSTMASTER: Form 3579 requested

Available publications (continued)

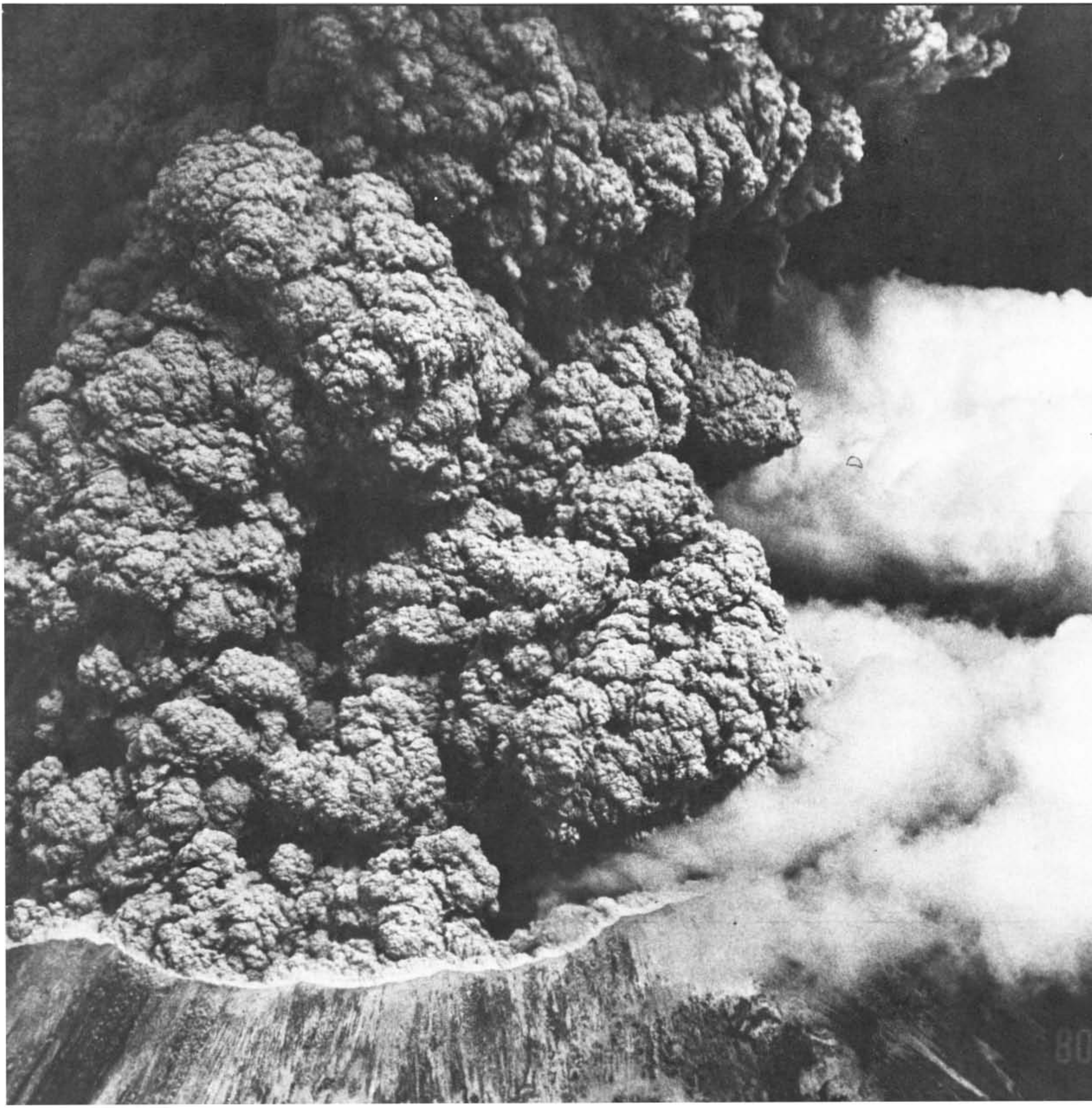
BULLETINS	Price	No. Copies	Amount
33. Bibliography (1st supplement) geology and mineral resources of Oregon, 1947: Allen	1.00		
36. Papers on Tertiary foraminifera: Cushman, Stewart and Stewart, 1949: v. 2	1.25		
44. Bibliography (2nd supplement) geology and mineral resources of Oregon, 1953: Steere	2.00		
46. Ferruginous bauxite deposits, Salem Hills, 1956: Corcoran and Libbey	1.25		
49. Lode mines, Granite mining district, Grant County, Oregon, 1959: Koch	1.00		
53. Bibliography (3rd supplement) geology and mineral resources of Oregon, 1962: Steere and Owen	3.00		
57. Lunar Geological Field Conference guidebook, 1965: Peterson and Groh, editors	3.50		
62. Andesite Conference guidebook, 1968: Dole	3.50		
63. Sixteenth biennial report of the Department, 1966-1968	1.00		
65. Proceedings of Andesite Conference, 1969: (copies)	10.00		
67. Bibliography (4th supplement) geology and mineral resources of Oregon, 1970: Roberts	3.00		
68. Seventeenth biennial report of the Department, 1968-1970	1.00		
71. Geology of selected lava tubes in Bend area, Oregon, 1971: Greeley	2.50		
76. Eighteenth biennial report of the Department, 1970-1972	1.00		
77. Geologic field trips in northern Oregon and southern Washington, 1973	5.00		
78. Bibliography (5th supplement) geology and mineral resources of Oregon, 1973: Roberts	3.00		
81. Environmental geology of Lincoln County, 1973: Schlicker and others	9.00		
82. Geologic hazards of Bull Run Watershed, Multnomah, Clackamas Counties, 1974: Beaulieu	6.50		
83. Eocene stratigraphy of southwestern Oregon, 1974: Baldwin	4.00		
84. Environmental geology of western Linn County, 1974: Beaulieu and others	9.00		
85. Environmental geology of coastal Lane County, 1974: Schlicker and others	9.00		
86. Nineteenth biennial report of the Department, 1972-1974	1.00		
87. Environmental geology of western Coos and Douglas Counties, 1975	9.00		
88. Geology and mineral resources of upper Chetco River drainage, 1975: Ramp	4.00		
89. Geology and mineral resources of Deschutes County, 1976	6.50		
90. Land use geology of western Curry County, 1976: Beaulieu	9.00		
91. Geologic hazards of parts of northern Hood River, Wasco, and Sherman Counties, Oregon, 1977: Beaulieu	8.00		
92. Fossils in Oregon (reprinted from *The Ore Bin*), 1977	4.00		
93. Geology, mineral resources, and rock material of Curry County, Oregon, 1977	7.00		
94. Land use geology of central Jackson County, Oregon, 1977: Beaulieu	9.00		
95. North American ophiolites, 1977	7.00		
96. Magma genesis: AGU Chapman Conference on Partial Melting, 1977	12.50		
97. Bibliography (6th supplement) geology and mineral resources of Oregon, 1971-75, 1978	3.00		
98. Geologic hazards of eastern Benton County, 1979: Bela	9.00		
100. Geology and mineral resources of Josephine County, Oregon, 1979: Ramp and Peterson	9.00		
101. Geologic field trips in western Oregon and southwestern Washington, 1980	9.00		
SPECIAL PAPERS			
1. Mission, goals, and purposes of Oregon Department of Geology and Mineral Industries, 1978	2.00		
2. Field geology of SW Broken Top quadrangle, Oregon, 1978: Taylor	3.50		
3. Rock material resources of Clackamas, Columbia, Multnomah, and Washington Counties, Oregon, 1978: Gray	7.00		
4. Heat flow of Oregon, 1978, Blackwell, Hull, Bowen, and Steele	3.00		
5. Analysis and forecasts of the demand for rock materials in Oregon, 1979	3.00		
7. Pluvial Fort Rock Lake, Lake County, Oregon	4.00		
SHORT PAPERS			
18. Radioactive minerals prospectors should know, 1976: White, Schafer, Peterson	.75		
21. Lightweight aggregate industry in Oregon, 1951: Mason	.25		
24. The Almeda Mine, Josephine County, Oregon, 1967: Libbey	3.00		
25. Petrography, type Rattlesnake Formation, central Oregon, 1976: Enlows	2.00		
27. Rock material resources of Benton County, 1978: Schlicker and others	4.00		

OREGON GEOLOGY

formerly THE ORE BIN

published by the Oregon Department of Geology and Mineral Industries

VOLUME 42, NUMBER 6 JUNE 1980



OREGON GEOLOGY

(ISSN 0164-3304)

VOLUME 42, NUMBER 6 JUNE 1980

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

Main Office: 1069 State Office Building, Portland 97201, phone (503) 229-5580.

Baker Field Office: 2033 First Street, Baker 97814, phone (503) 523-3133.
Howard C. Brooks, Resident Geologist

Grants Pass Field Office: 312 S.E. "H" Street, Grants Pass 97526, phone (503) 476-2496.
Len Ramp, Resident Geologist

Mined Land Reclamation Program: 1129 S.E. Santiam Road, Albany 97321, phone (503) 967-2039.
Paul F. Lawson, Supervisor

Subscription rates: 1 year, $4.00; 3 years, $10.00. Single issues, $.40 at counter, $.50 mailed.
Available back issues of *The Ore Bin:* $.25 at counter, $.50 mailed.

Address subscription orders, renewals, and changes of address to *Oregon Geology,* 1069 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,* 1069 State Office Building, Portland, OR 97201.

COVER PHOTO

Disastrous eruption of Mount St. Helens Volcano, Washington, May 18, 1980. This photo shows west rim of crater, part of the ash-laden plume, and white condensation form clouds caused by the shock wave of the explosive eruption. Photographs and SLAR (side-looking airborne radar) and thermal infrared imagery appearing in this issue were taken by the Oregon Army National Guard.

Mount St. Helens erupts

On May 18, Mount St. Helens shattered the peaceful Sunday morning silence with an explosive eruption that devastated most of the immediate areas to the north and northwest, killed an as yet unknown number of people, caused numerous destructive floods and mudflows, and blanketed much of eastern Washington, northern Idaho, and western Montana with volcanic ash. Succeeding smaller eruptions have deposited ash over parts of Oregon and the rest of Washington. By now, this very active volcano in our midst has affected in one way or another almost all of us living in the Pacific Northwest.

The Oregon Department of Geology and Mineral Industries maintains an interest in the volcano from the standpoint of public safety via coordination with the Oregon Division of Emergency Services and the U.S. Geological Survey. The Oregon National Guard, flying at the request of the Oregon Department of Geology and Mineral Industries, kindly provided the imagery and photographs in this issue.

The article beginning on the next page is preliminary in nature. It was written under a tight time constraint to meet our deadline, and material in it is, of course, subject to further interpretation. Because of the magnitude of this eruption, the article originally scheduled for this issue will appear in next months' *Oregon Geology.* □

Students win 1980 DOGAMI awards

As in previous years, the Oregon Department of Geology and Mineral Industries has again awarded some financial aid for field work to graduate geology students who are active in mapping in Oregon. The following students are the winners of this year's awards:

Name and school	Location and topic of studies
Avramenko, Walter University of Oregon	Echo Mountain, Western Cascades; geology and structure
Coward, Robert Rice University, Houston	Sumpter 30′ sheet; Elkhorn Ridge Argillite
Flaherty, Gerald University of Oregon	McKenzie Bridge, Western Cascades; geology and structure
Hoffman, Charles Portland State University	Salem and Portland Hills; ferruginous bauxite
Mullen, Ellen Oregon State University	Canyon Mountain complex; petrogenesis
Walker, Nicholas UC at Santa Barbara	Eastern Oregon; chronology of pre-Tertiary terrain
Wozniak, Karl Oregon State University	Three Sisters; geology

□

Remote sensing of the Mount St. Helens eruption, May 18, 1980

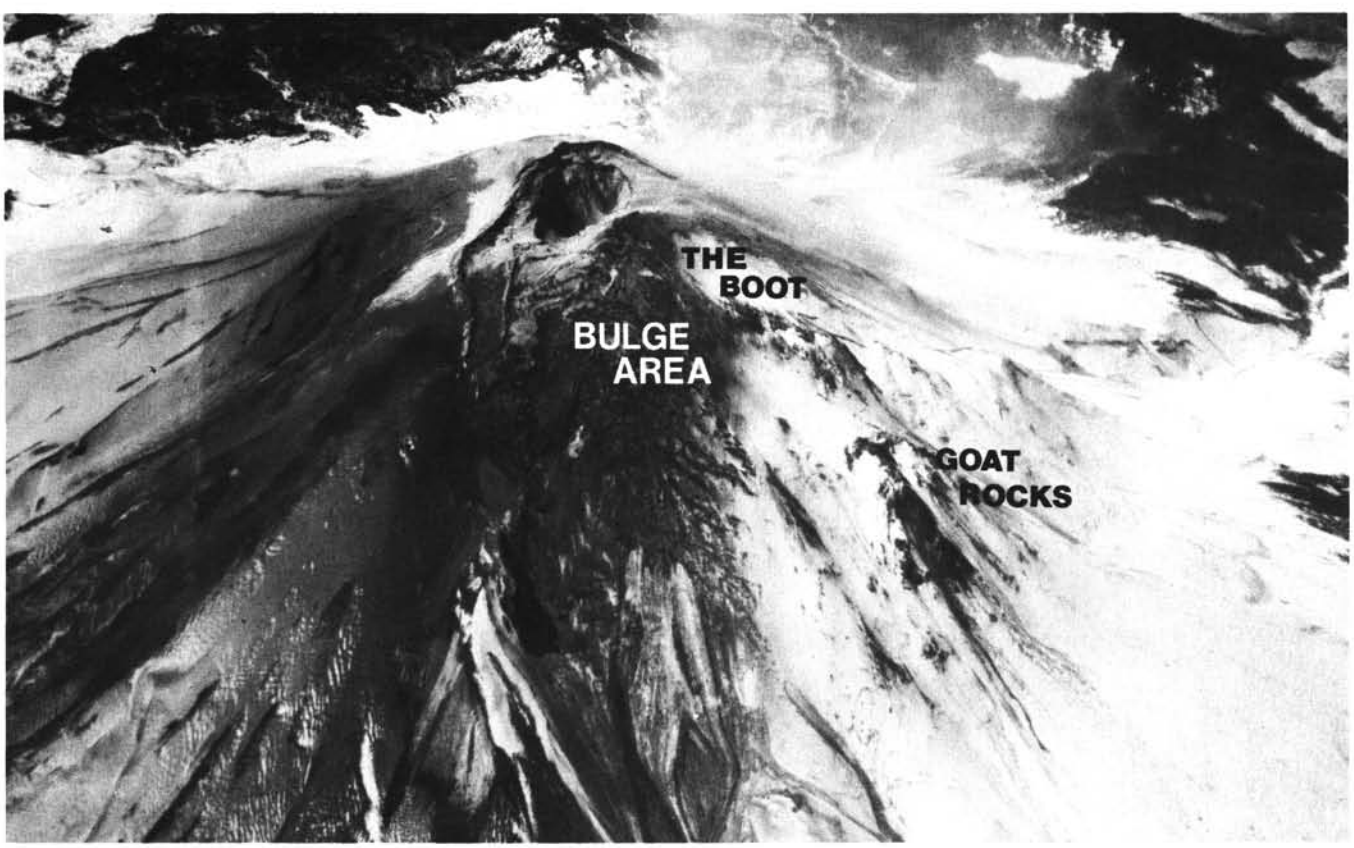
by Charles L. Rosenfeld, Assistant Professor of Geography, Department of Geography, Oregon State University, Corvallis, Oregon

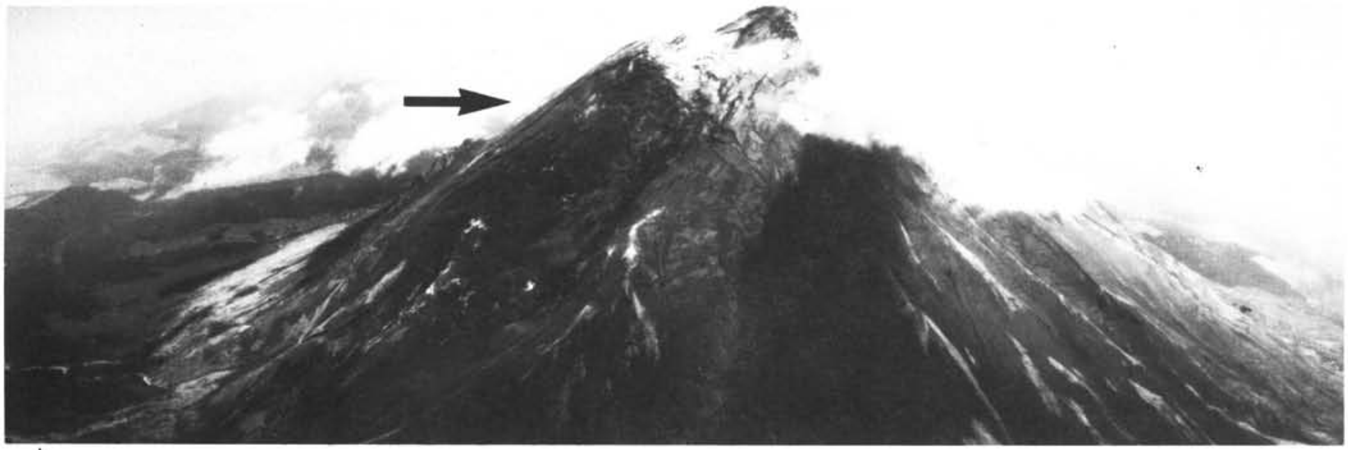
As a result of continued aerial surveillance activity by the Oregon Army National Guard at the request of the Oregon Department of Geology and Mineral Industries, a sharp increase in the thermal activity in the crater area of Mount St. Helens was observed at 5:30 a.m. on Sunday, May 18. An increased number of hot spots were noted on the "Boot" and in the bulge area, which had been swelling at a rate of about 5 ft per day since mid-April. However, just as the thermograph recording film was being developed, information was received that a passing aircraft had witnessed an explosive eruption at 8:30 a.m.

The first of four day-time photo missions was launched from Salem. Initial reports indicated that the top of the mountain had been lowered from the old elevation of 9,677 ft to about the 8,300-ft level. A dense, mushroom-shaped plume of ash rose ominously into the stratosphere, obscuring everything to the north and east of the mountain. Large debris flows were moving down the North and South Forks of the Toutle River, destroying roads and bridges and carrying off log decks in the flooding caused by the rapid melting of the mountain's glaciers.

In an effort to locate the U.S. Geological Survey observation post north of Mount St. Helens, our National Guard Mohawk aircraft skirted the rising ash plume toward the north side of the mountain. We observed that the elevation of the rim of the new crater formed by the eruption dropped dramatically from about 8,300 ft on the south side to about the 4,500-ft level on the north flank and that huge amounts of rock and ash debris had been ejected toward the north. The effects of the shock wave from the blast were terribly evident: entire forests had been leveled and then covered

Northeast side of Mount St. Helens, April 11, 1980, 15 days after first volcanic activity was spotted and 37 days before the violent May 18 eruption that destroyed the north side of the mountain. The area around the bulge began expanding in mid-April and was swelling at a rate of 5 ft per day by May 18.

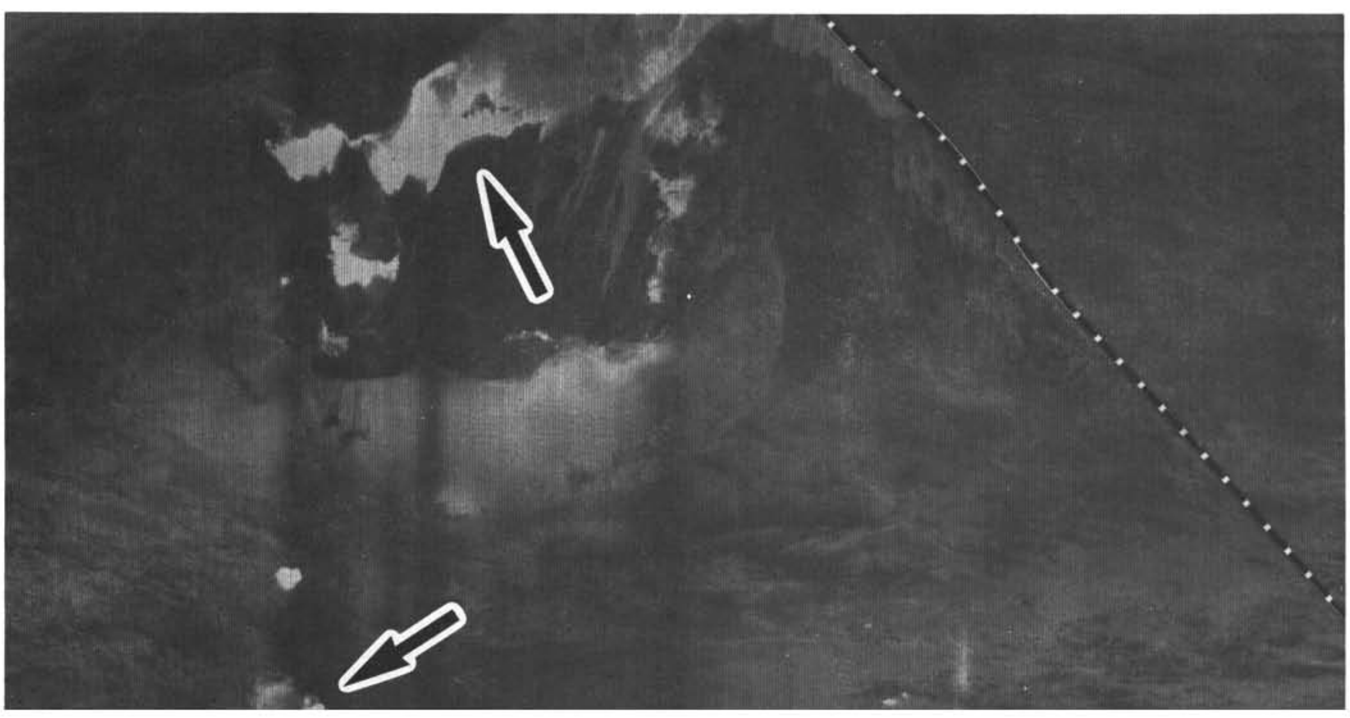




↑ *Two photographs taken roughly six weeks apart of the northwest side of Mount St. Helens show development of bulge (arrow). Upper picture was taken during a small eruption on April 2; lower picture was taken May 17, one day before the May 18 eruption.*

Flying under mushroom-shaped cloud, shortly after May 18 eruption occurred. Ash-laden plume is rising vertically on the left; condensation form clouds are at bottom right. Picture was taken from the north while aircraft was over Coldwater Peak on search and rescue mission. →

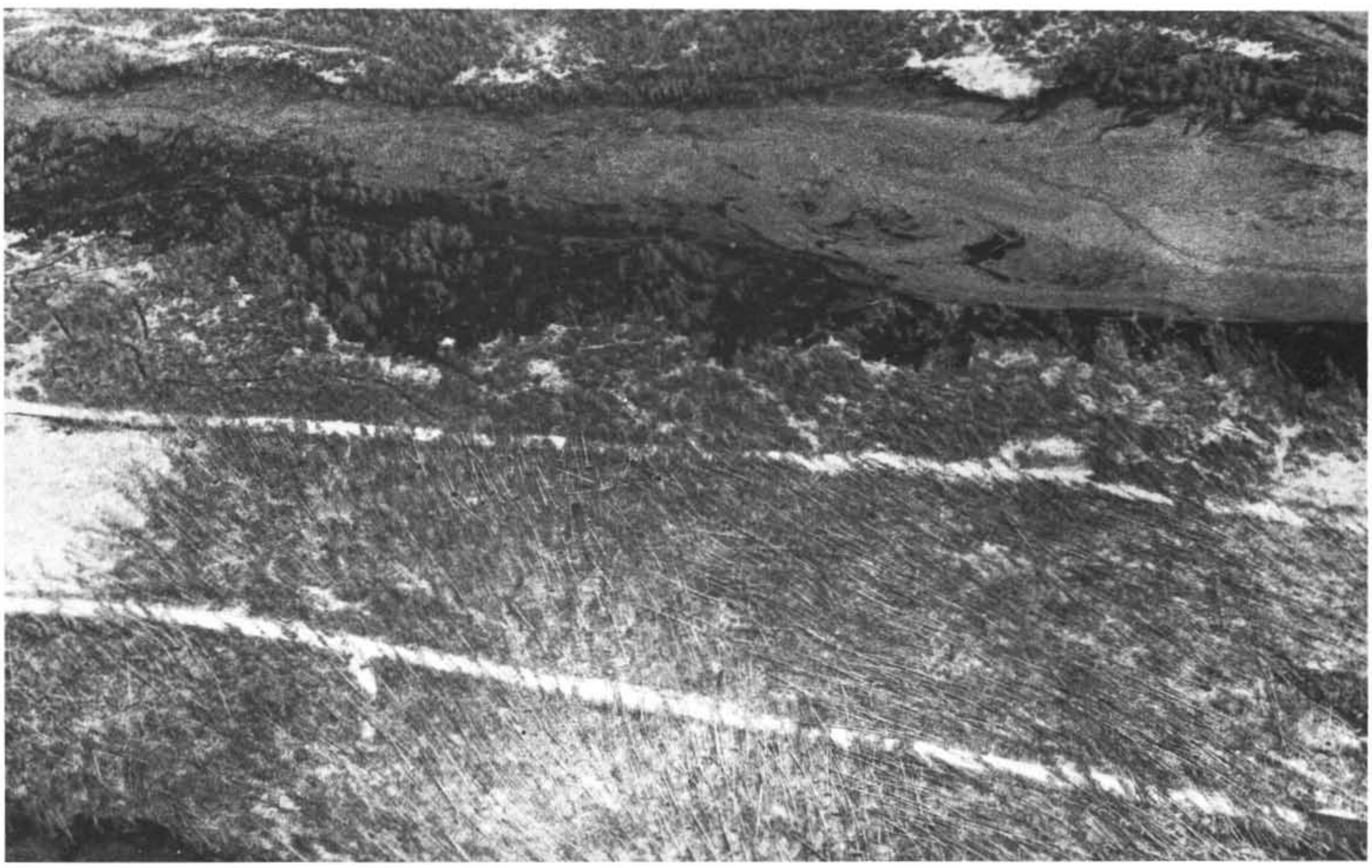
Thermal infrared imagery of an oblique aerial view of the north side of Mount St. Helens, May 18, 5:30 a.m., approximately 3 hours before the eruption began. Hot areas appear white. Dashed line shows part of the outline of the mountain. Top arrow points to hot area around crater; lower arrow indicates heating on the bulge. ↓

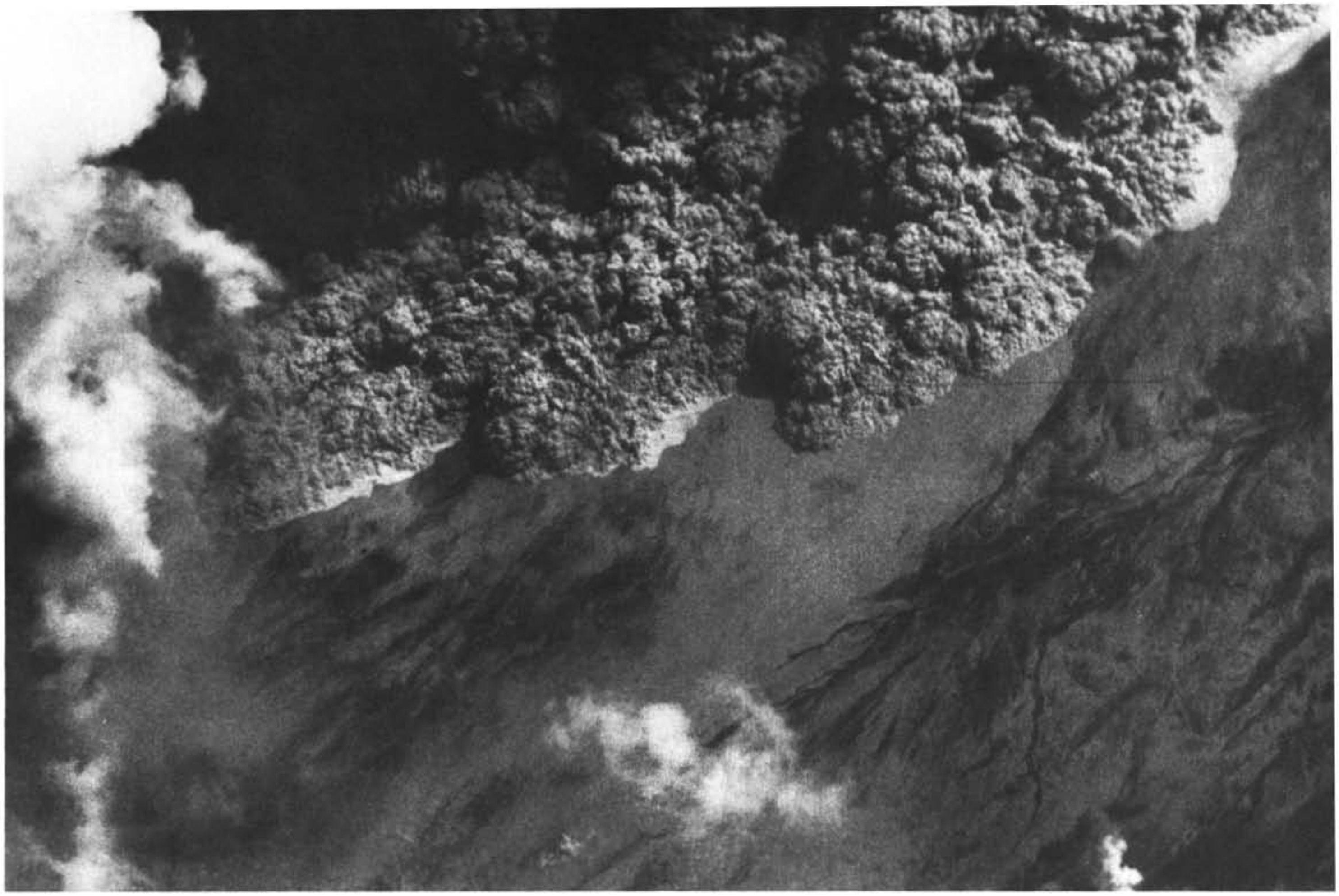



80 5 18

West side of Mount St. Helens, 10:00 a.m., 1½ hours after initial explosion. Elevation of crater rim drops from 8,300 ft on the south side to 4,400 ft on the north.

Trees blown down along the South Fork of the Toutle River, May 18. Mudflow is at top of picture.





Hot ash flow, northwest flank, May 18. Steam on left and in foreground is rising from the Toutle River.

by light-colored ash. The blast effect was quite directional, carrying almost 22 mi to the west and 13 mi to the north of the mountain. We observed numerous hot ash flows on the northwest flank and about 30 small fires in the heaps of shattered timber.

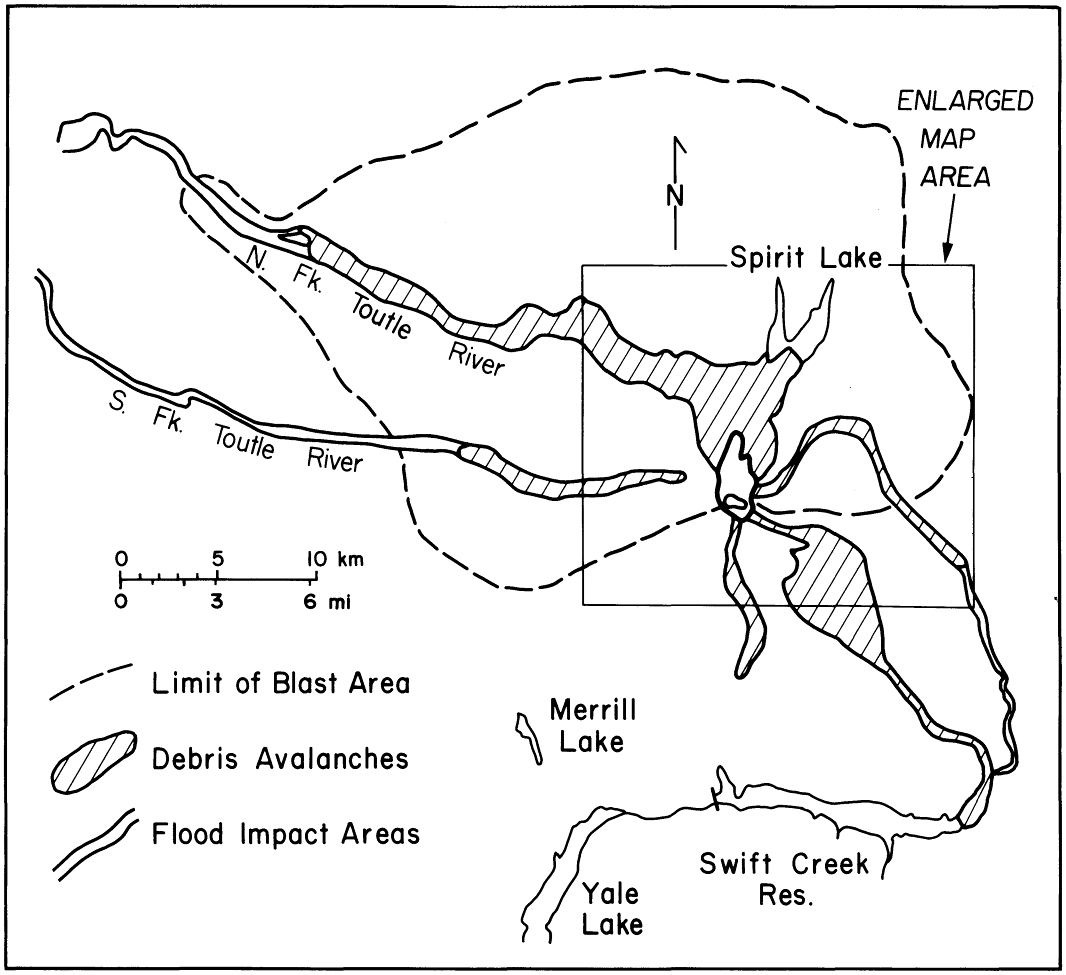
Since our aircraft was unable to penetrate the dense plume that was being carried off to the northeast, we turned and attempted to locate survivors along the North and South Forks of the Toutle River. The North Toutle valley was choked with a rock and mud flow for a distance of over 20 mi west of Spirit Lake. This flow, occasionally over a mile wide, ended abruptly a few miles east of Camp Baker. Beyond this point, floodwaters and mudflows choked with debris were carrying roads, bridges, and log decks down to the Cowlitz River and then out to the Columbia River at Longview, Washington, where, by May 21, siltation had reduced the 40-ft-deep channel to a draft of 12 ft.

At 4:30 p.m., May 18, we obtained a side-looking airborne radar (SLAR) image of Mount St. Helens from the Mohawk aircraft. By transmitting microwaves through the eruptive plume, we were able to produce an image of the concealed crater. This yielded the first measurement of the full dimensions of the explosion crater: 2.2 mi in length from north to south and 1.1 mi in width. Nearly a cubic mile of mountain was gone. The eruptive center was located along the former south "rift" fault, with the floor of the crater sloping down toward the north.

By 3:10 a.m. on Monday, May 19, the eruptive plume had diminished enough to allow a flight across the north flank. On this flight, we directed the SLAR south into the gaping crater. A smaller eruption crater, centered around the former "rift" zone, was located at about the 7,500-ft elevation within the larger explosion crater. Subsequent SLAR images have indicated the presence of small constructional features in this area (see map).

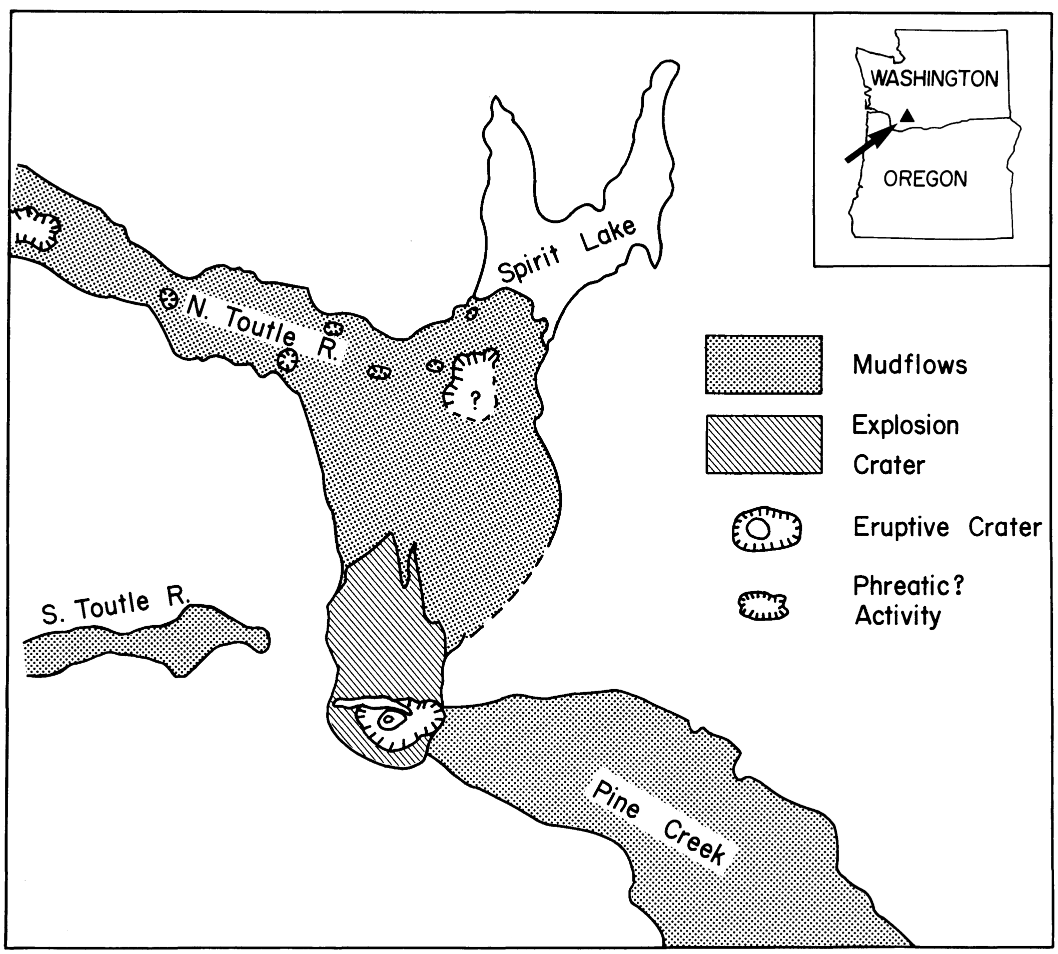
Hot ash flows have continued down the north flank of Mount St. Helens into the former valley of the North Fork of the Toutle River, producing explosions described as "phreatic" upon contact with water in the valley. An infrared thermograph, flown before dawn on Tuesday, May 20, shows a hot ash flow at the base of the north flank and numerous pits caused by phreatic explosions in the North Fork of the Toutle Valley.

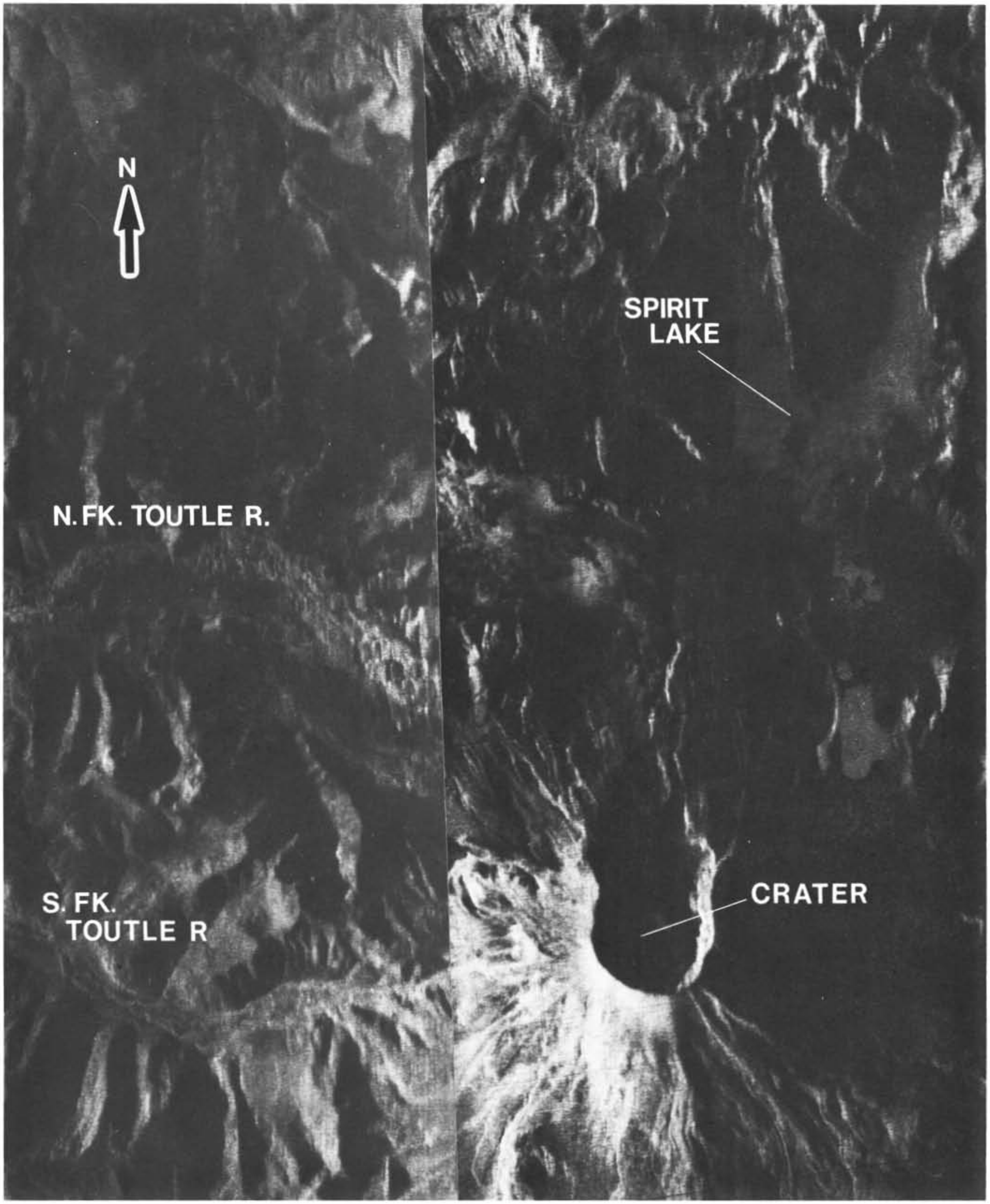
At this writing (May 23), the crater of Mount St. Helens remains obscured by the continuing ash plume. Remote sensing, both thermal and SLAR imagery of the type shown here, is being provided to the U.S. Geological Survey by the Oregon Army National Guard through the Oregon Department of Geology and Mineral Industries.



Map of Mount St. Helens and surroundings. Area inside square is enlarged in map below.

Enlarged map of area immediately around Mount St. Helens Volcano.

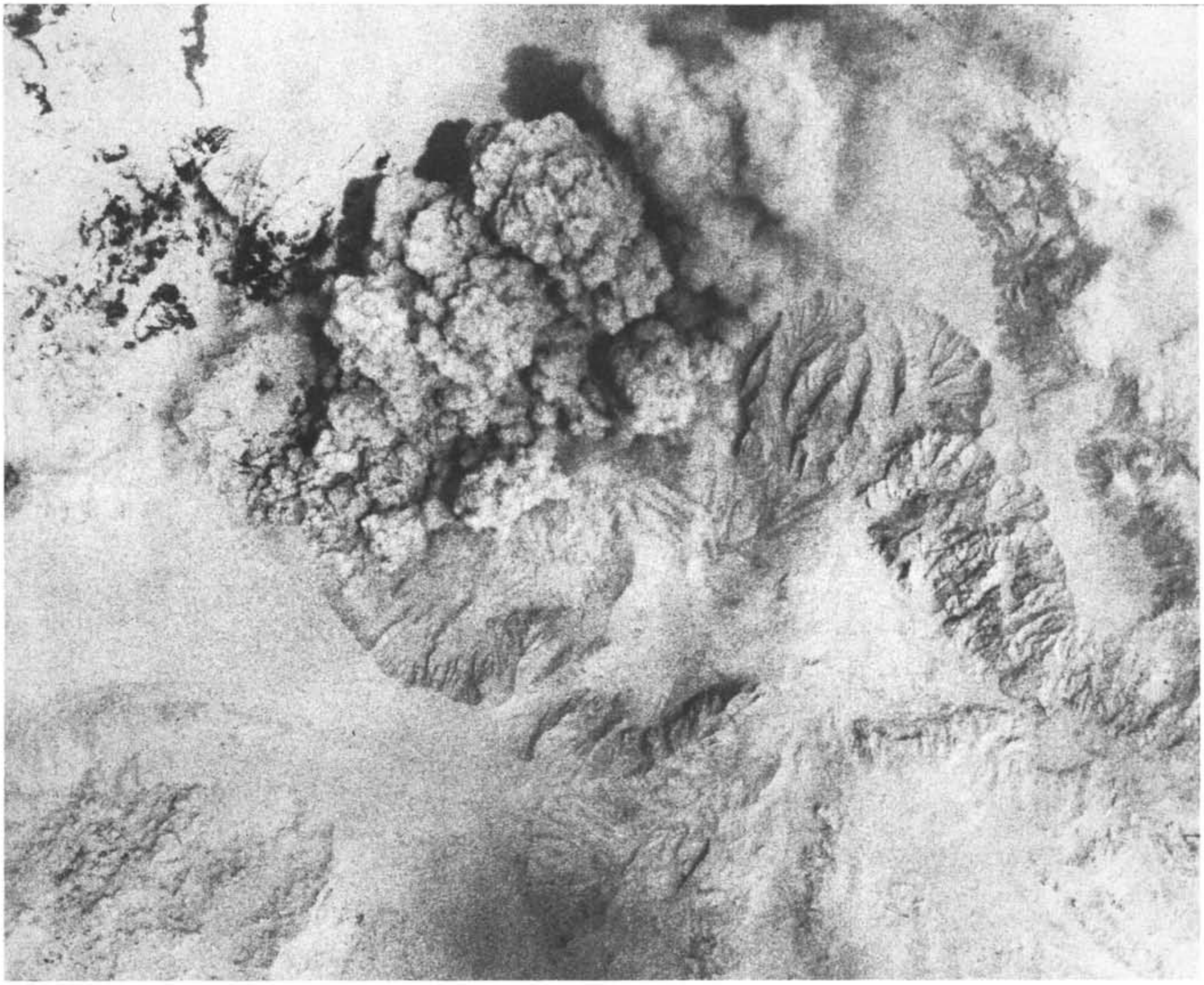




May 18, 4:30 p.m. SLAR imagery obtained through eruptive plume shows crater blown out to the north. North is at top of photograph. At this time, Spirit Lake to the north-northeast is approximately 100 ft deeper than before eruption. Note mudflows on the North and South Forks of the Toutle River, northwest and west of the volcano, and on Pine Creek, to the southeast.

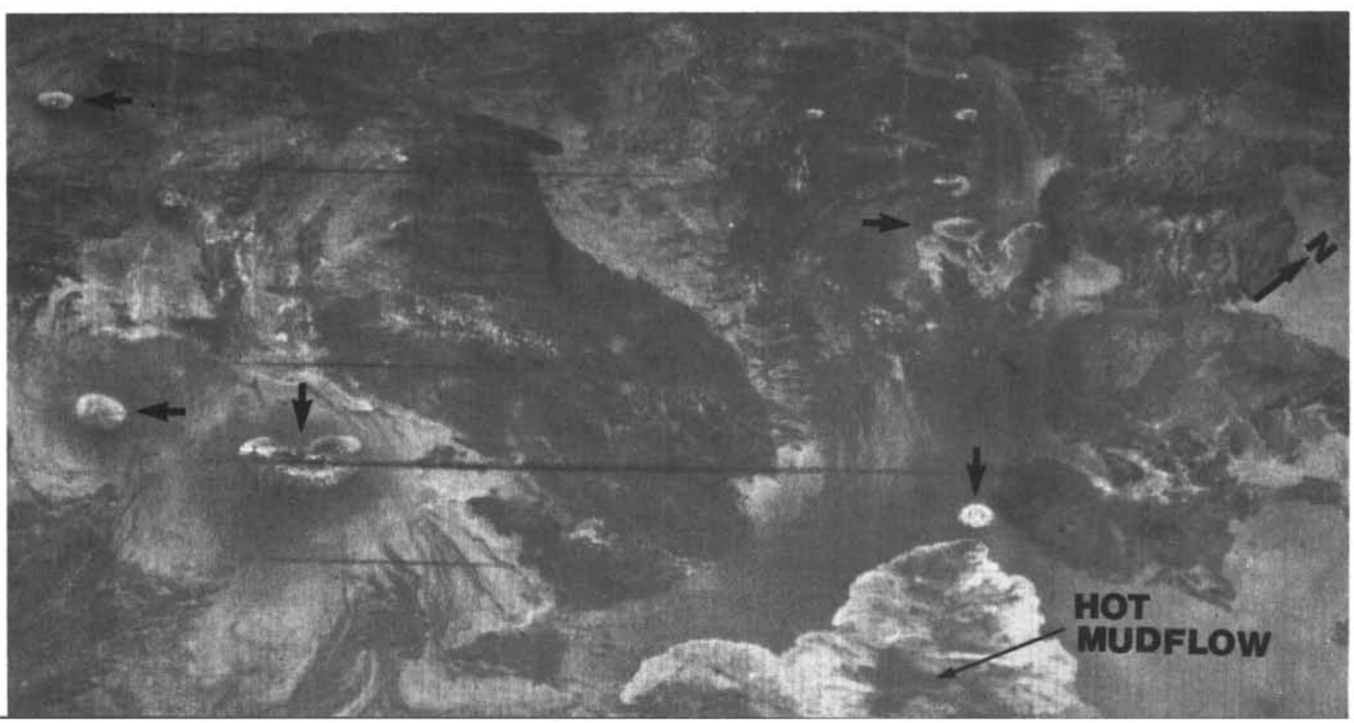
Mudflow on the South Fork of the Toutle River, May 18. Note roads that have been washed out, trees blown down, and forest fire.

Flood and mudflow damage at Camp Baker, 24 river miles west of Mount St. Helens, May 18.

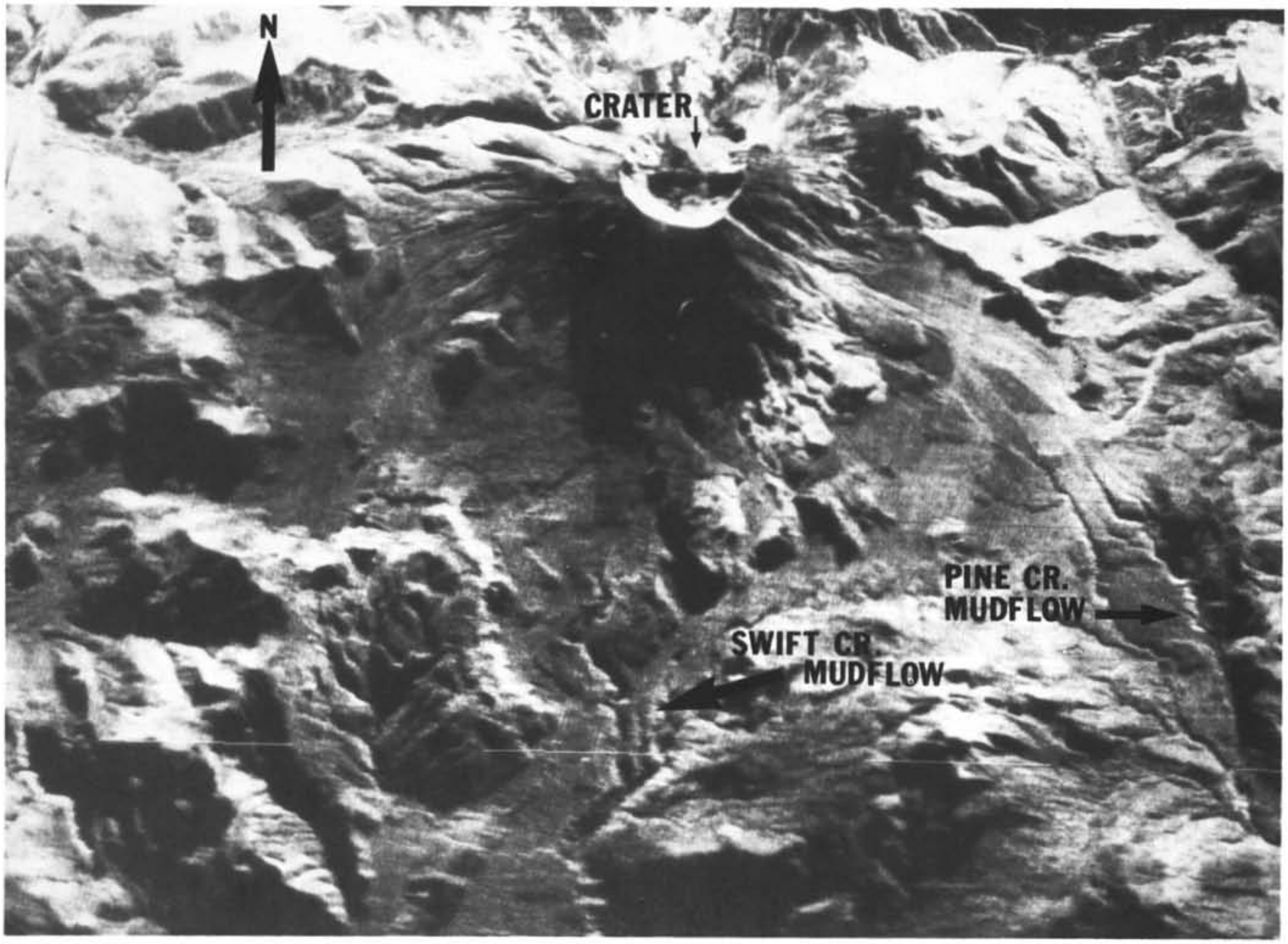


Phreatic explosion craters along North Fork of the Toutle River, north-northwest of Mount St. Helens, May 18. Thick layer of volcanic ash blankets entire area.

Thermal infrared imagery of oblique view of area immediately north of Mount St. Helens, May 20. Hot areas appear white in this imagery. Arrows point to phreatic explosion craters. Hot lahar (mudflow) is coming directly from the mountain. Spirit Lake is to the right, just past the edge of the imagery.

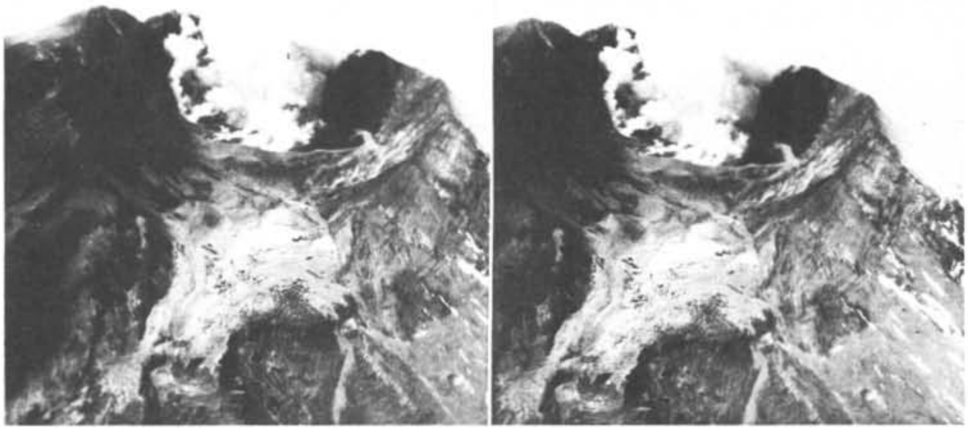


Mount St. Helens from the south, May 19. Pine Creek mudflow shown here entered Swift Reservoir, located about 8 air miles south of the volcano.



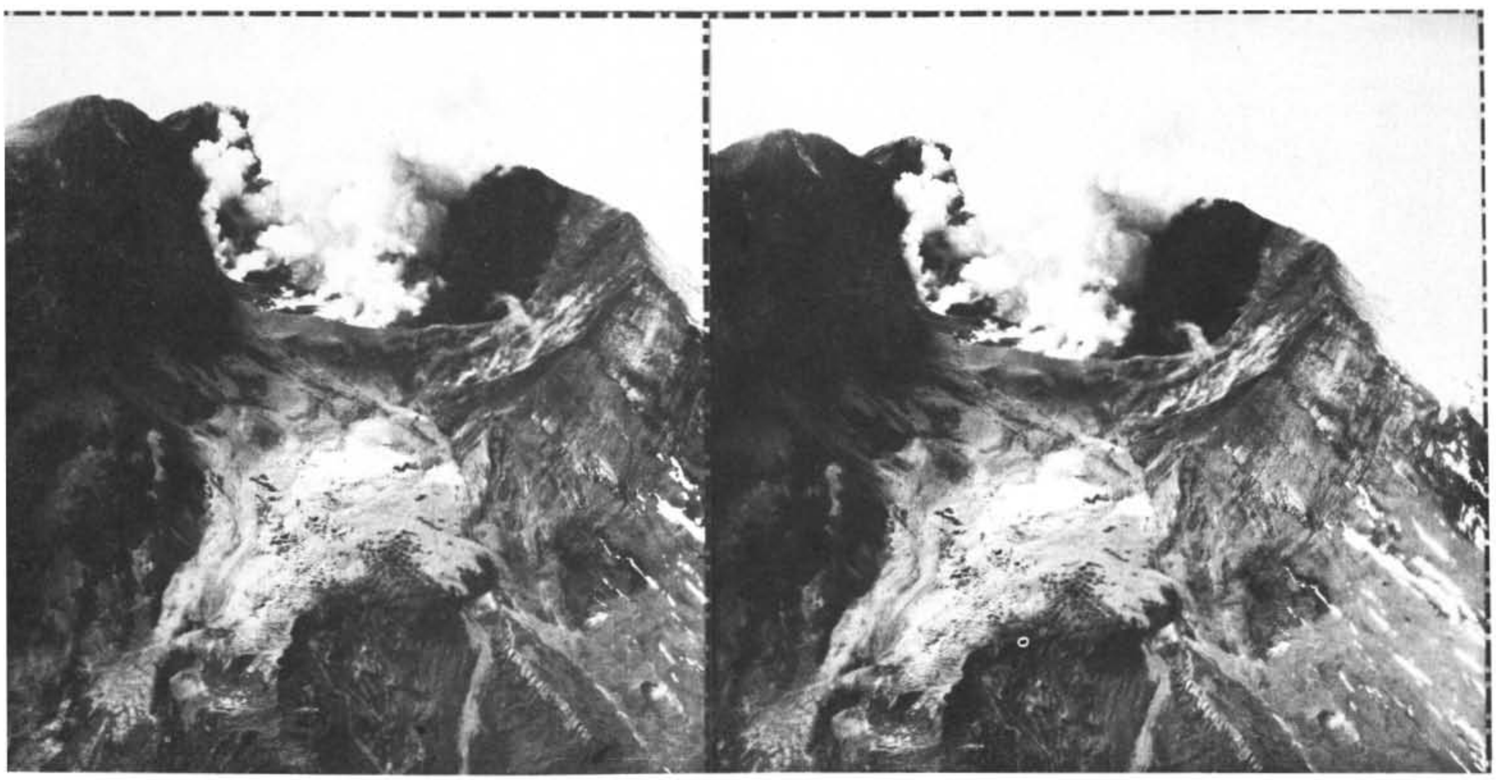
SLAR imagery, May 23, 3:10 a.m. Compare with sketch map of mountain.

SLAR imagery, May 27.



Stereopair of crater, north side, May 30, 1980.

Photographs are reproduced below at a larger size for those readers who want to cut them out and look at them through a stereoscope.



PUBLICATIONS ORDER

Omission of price indicates publication is in press. Minimum mail order 50¢. All sales are final. Publications are sent postpaid. Payment must accompany orders of less than $20.00.

Fill in appropriate blanks and send sheet to Department (see address on reverse side).

YOUR NAME ________________

ADDRESS ________________

________________ Zip________

Amount enclosed $________

OREGON GEOLOGY

____ Renewal ____ Subscription ____ Gift

____ 1 Year ($4.00) ____ 3 Years ($10.00)

NAME ________________

ADDRESS ________________

________________ ZIP ________

(If Gift, From: ________________)

ORDER FORM - CUT ON DASHED LINE

Available publications

MISCELLANEOUS PAPERS	Price	No. Copies	Amount
1. A description of some Oregon rocks and minerals, 1950: Dole	$ 1.00		
4. Laws relating to oil, gas, and geothermal exploration and development in Oregon			
Part 1. Oil and natural gas rules and regulations, 1977, rev. 1979	1.00		
Part 2. Geothermal resources rules and regulations, 1977, rev. 1979	1.00		
5. Oregon's gold placers (reprints), 1954	.50		
6. Oil and gas exploration in Oregon, rev. 1965: Stewart and Newton	3.00		
8. Available well records of oil and gas exploration in Oregon, rev. 1973: Newton	1.00		
11. Collection of articles on meteorites, 1968 (reprints from *The Ore Bin*)	1.50		
13. Index to *The Ore Bin*, 1950-1974	1.50		
14. Thermal springs and wells, 1970: Bowen and Peterson (with 1975 supplement)	1.50		
15. Quicksilver deposits in Oregon, 1971: Brooks	1.50		
16. Mosaic of Oregon from ERTS-1 imagery, 1973	2.50		
18. Proceedings of Citizens' Forum on potential future sources of energy, 1975	2.00		
19. Geothermal exploration studies in Oregon—1976, 1977	3.00		
20. Investigations of nickel in Oregon, 1978: Ramp	5.00		
GEOLOGIC MAPS			
Geologic map of Galice quadrangle, Oregon, 1953	1.50		
Geologic map of Albany quadrangle, Oregon, 1953	1.00		
Reconnaissance geologic map of Lebanon quadrangle, 1956	1.50		
Geologic map of Bend quadrangle and portion of High Cascade Mountains, 1957	1.50		
Geologic map of Oregon west of 121st meridian, 1961	2.25		
Geologic map of Oregon east of 121st meridian, 1977	3.75		
GMS-3: Preliminary geologic map of Durkee quadrangle, Oregon, 1967	2.00		
GMS-4: Oregon gravity maps, onshore and offshore, 1967 (folded)	3.00		
GMS-5: Geologic map of Powers quadrangle, Oregon, 1971	2.00		
GMS-6: Preliminary report on geology of part of Snake River Canyon, 1974	6.50		
GMS-7: Geology of the Oregon part of the Baker quadrangle, Oregon, 1976	3.00		
GMS-8: Complete Bouguer gravity anomaly map, Cascade Mountain Range, central Oregon, 1978	3.00		
GMS-9: Total field aeromagnetic anomaly map, Cascade Mountain Range, central Oregon, 1978	3.00		
GMS-10: Low- to intermediate-temperature thermal springs and wells in Oregon, 1978	2.50		
GMS-11: Preliminary geothermal resource map of Oregon (upon written request only)	free	(one copy per customer)	
GMS-12: Geologic map of the Oregon part of the Mineral quadrangle	2.00		
OIL AND GAS INVESTIGATIONS			
3. Preliminary identifications of foraminifera, General Petroleum Long Bell #1 well	2.00		
4. Preliminary identifications of foraminifera, E.M. Warren Coos County 1-7 well, 1973	2.00		
5. Prospects for natural gas production or underground storage of pipeline gas	5.00		
MISCELLANEOUS PUBLICATIONS			
Landforms of Oregon (17 × 12 inches)	.50		
Mining claims (State laws governing quartz and placer claims)	.50		
Geological highway map, Pacific NW region, Oregon-Washington (published by AAPG)	3.00		
Fifth Gold and Money Session and Gold Technical Session Proceedings, 1975	5.00		
Sixth Gold and Money Session and Gold Technical Session Proceedings, 1978	6.50		
Back issues of *The Ore Bin*	25¢ over the counter; 50¢ mailed		
Colored postcard, *Geology of Oregon*	10¢ each; 3 for 25¢; 7 for 50¢; 15 for 1.00		

OREGON GEOLOGY

1069 State Office Building, Portland, Oregon 97201

Second Class Matter
POSTMASTER: Form 3579 requested

Available publications (continued)

BULLETINS	Price	No. Copies	Amount
33. Bibliography (1st supplement) geology and mineral resources of Oregon, 1947: Allen	1.00		
36. Papers on Tertiary foraminifera: Cushman, Stewart and Stewart, 1949: v. 2	1.25		
44. Bibliography (2nd supplement) geology and mineral resources of Oregon, 1953: Steere	2.00		
46. Ferruginous bauxite deposits, Salem Hills, 1956: Corcoran and Libbey	1.25		
49. Lode mines, Granite mining district, Grant County, Oregon, 1959: Koch	1.00		
53. Bibliography (3rd supplement) geology and mineral resources of Oregon, 1962: Steere and Owen	3.00		
57. Lunar Geological Field Conference guidebook, 1965: Peterson and Groh, editors	3.50		
62. Andesite Conference guidebook, 1968: Dole	3.50		
63. Sixteenth biennial report of the Department, 1966-1968	1.00		
65. Proceedings of Andesite Conference, 1969: (copies)	10.00		
67. Bibliography (4th supplement) geology and mineral resources of Oregon, 1970: Roberts	3.00		
68. Seventeenth biennial report of the Department, 1968-1970	1.00		
71. Geology of selected lava tubes in Bend area, Oregon, 1971: Greeley	2.50		
76. Eighteenth biennial report of the Department, 1970-1972	1.00		
77. Geologic field trips in northern Oregon and southern Washington, 1973	5.00		
78. Bibliography (5th supplement) geology and mineral resources of Oregon, 1973: Roberts	3.00		
81. Environmental geology of Lincoln County, 1973: Schlicker and others	9.00		
82. Geologic hazards of Bull Run Watershed, Multnomah, Clackamas Counties, 1974: Beaulieu	6.50		
83. Eocene stratigraphy of southwestern Oregon, 1974: Baldwin	4.00		
84. Environmental geology of western Linn County, 1974: Beaulieu and others	9.00		
85. Environmental geology of coastal Lane County, 1974: Schlicker and others	9.00		
86. Nineteenth biennial report of the Department, 1972-1974	1.00		
87. Environmental geology of western Coos and Douglas Counties, 1975	9.00		
88. Geology and mineral resources of upper Chetco River drainage, 1975: Ramp	4.00		
89. Geology and mineral resources of Deschutes County, 1976	6.50		
90. Land use geology of western Curry County, 1976: Beaulieu	9.00		
91. Geologic hazards of parts of northern Hood River, Wasco, and Sherman Counties, Oregon, 1977: Beaulieu	8.00		
92. Fossils in Oregon (reprinted from *The Ore Bin*), 1977	4.00		
93. Geology, mineral resources, and rock material of Curry County, Oregon, 1977	7.00		
94. Land use geology of central Jackson County, Oregon, 1977: Beaulieu	9.00		
95. North American ophiolites, 1977	7.00		
96. Magma genesis: AGU Chapman Conference on Partial Melting, 1977	12.50		
97. Bibliography (6th supplement) geology and mineral resources of Oregon, 1971-75, 1978	3.00		
98. Geologic hazards of eastern Benton County, 1979: Bela	9.00		
100. Geology and mineral resources of Josephine County, Oregon, 1979: Ramp and Peterson	9.00		
101. Geologic field trips in western Oregon and southwestern Washington, 1980	9.00		
SPECIAL PAPERS			
1. Mission, goals, and purposes of Oregon Department of Geology and Mineral Industries, 1978	2.00		
2. Field geology of SW Broken Top quadrangle, Oregon, 1978: Taylor	3.50		
3. Rock material resources of Clackamas, Columbia, Multnomah, and Washington Counties, Oregon, 1978: Gray	7.00		
4. Heat flow of Oregon, 1978, Blackwell, Hull, Bowen, and Steele	3.00		
5. Analysis and forecasts of the demand for rock materials in Oregon, 1979	3.00		
7. Pluvial Fort Rock Lake, Lake County, Oregon	4.00		
SHORT PAPERS			
18. Radioactive minerals prospectors should know, 1976: White, Schafer, Peterson	.75		
21. Lightweight aggregate industry in Oregon, 1951: Mason	.25		
24. The Almeda Mine, Josephine County, Oregon, 1967: Libbey	3.00		
25. Petrography, type Rattlesnake Formation, central Oregon, 1976: Enlows	2.00		
27. Rock material resources of Benton County, 1978: Schlicker and others	4.00		

OREGON GEOLOGY

formerly THE ORE BIN

published by the Oregon Department of Geology and Mineral Industries

VOLUME 42, NUMBER 7 JULY 1980

OREGON GEOLOGY

(ISSN 0164-3304)

VOLUME 42, NUMBER 7 **JULY 1980**

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

Main Office: 1069 State Office Building, Portland 97201, phone (503) 229-5580.

Baker Field Office: 2033 First Street, Baker 97814, phone (503) 523-3133.
Howard C. Brooks, Resident Geologist

Grants Pass Field Office: 312 S.E. "H" Street, Grants Pass 97526, phone (503) 476-2496.
Len Ramp, Resident Geologist

Mined Land Reclamation Program: 1129 S.E. Santiam Road, Albany 97321, phone (503) 967-2039.
Paul F. Lawson, Supervisor

Subscription rates: 1 year, $4.00; 3 years, $10.00. Single issues, $.40 at counter, $.50 mailed.
Available back issues of *The Ore Bin:* $.25 at counter, $.50 mailed.

Address subscription orders, renewals, and changes of address to *Oregon Geology*, 1069 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*, 1069 State Office Building, Portland, OR 97201.

COVER PHOTO

Photomicrograph of quartz-mica-graphite variety of Condrey Mountain Schist, discussed in article beginning on page 125. This photo, taken under plane-polarized light, shows incipient development of crenulation cleavage typical of later stages of deformation of Condrey Mountain Schist. Each edge of photo represents about 0.75 cm.

Geologic studies of the La Grande area and Mount Hood now available

The Oregon Department of Geology and Mineral Industries announces the release of two new geologic publications that are part of its geothermal assessment program in the State of Oregon.

Special Paper 6, *The Geology of the La Grande Area, Oregon*, summarizes the results of a recently completed geologic investigation by Warren Barrash, John G. Bond, John D. Kauffman, and Ramesh Venkatakrishnan, Geoscience Research Consultants, under contract to the Department. The 47-page report describes the stratigraphy and structure of the Miocene Columbia River Basalt Group in the general area through which Interstate I-84 (old I-80N) runs between Hilgard and North Union, in eastern Oregon. It includes geologic maps and cross sections of the Hilgard, La Grande SE, Glass Hill, and Craig Mountain 7½-minute quadrangles (scale 1:24,000). Price of Special Paper 6 is $5.00.

Special Paper 8, *Geology and Geochemistry of Mount Hood Volcano*, is the result of a study by Craig White, Department of Geology, University of Oregon, also under contract to the Oregon Department of Geology and Mineral Industries. The 26-page report sells for $2.00 and contains petrologic and geochemical data, including major- and trace-element analyses of Main Stage lavas and post-glacial silicic rocks.

Both papers may be purchased from the Department's Portland, Baker, or Grants Pass offices. They may be ordered by mail from the Portland office. Payment must accompany orders under $20.00. □

June OREGON GEOLOGY late

Due to circumstances beyond our control, the June issue of *Oregon Geology* was printed two weeks later than usual. We apologize for any inconvenience this delay may have caused.

CONTENTS

Sheeted dikes of the Wild Rogue Wilderness, Oregon

by Len Ramp, Grants Pass Field Office, Oregon Department of Geology and Mineral Industries, Grants Pass, Oregon 97526, and Floyd Gray, U.S. Geological Survey, Menlo Park, California 94025

INTRODUCTION

The name "ophiolite" is applied to sequences of rocks consisting, in part, from bottom to top, of peridotite, gabbro, dike swarms, basalt (often as pillows), and oceanic sediments. The basaltic dike swarms (sheeted diabase dikes), apparently feeders for the overlying volcanic rocks, form a continuous layer between them and the underlying gabbro (Figure 1). The dikes are thought to have been intruded along a single, narrow fracture, thereby becoming chilled against previously emplaced, solidified dike rock. Ideally, the dikes pinch downward into the gabbro unit, from which they are thought to have been derived. The relation between the dikes and the underlying gabbro constitutes one of the major field and petrogenetic problems of ophiolite genesis. The central question of the gabbro-diabase relationship was succinctly pointed out by Thayer (1977a) in a discussion of the Troodos Complex:

> "If the dikes are chilled against underlying cumulate gabbro, they cannot be derived from it. If they pinch out downward in the gabbro, as described and postulated, they cannot have come up through it. How then, did they get where they are?"

The great lateral extent of some dike swarms has led geologists to believe that the dikes were formed by repeated injection of magmatic liquid along zones of extreme crustal extension (Moores and Vine, 1971; Kidd and Cann, 1974). Possible sites of such extension zones include island-arc marginal basins, mid-ocean ridges, and stationary hot spots beneath a drifting plate.

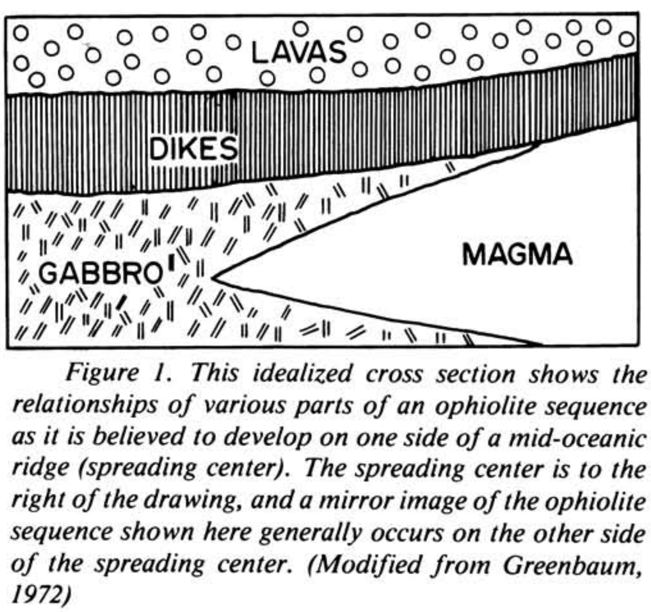


Figure 1. This idealized cross section shows the relationships of various parts of an ophiolite sequence as it is believed to develop on one side of a mid-oceanic ridge (spreading center). The spreading center is to the right of the drawing, and a mirror image of the ophiolite sequence shown here generally occurs on the other side of the spreading center. (Modified from Greenbaum, 1972)

This article discusses dike swarms recently recognized in the Wild Rogue Wilderness, southwestern Oregon.

LOCATION

The recently designated Wild Rogue Wilderness is an elongate area extending from near Agness to the Eden Valley Road just north of Mount Bolivar near the Coos, Curry, and Douglas County boundaries. The area is about 31 km (19 mi) long and from 2 to 8 km (1.3 to 5 mi) wide. Elevations range from about 46 m (150 ft) near the Rogue River at the southern end of the area to 1,316 m (4,319 ft) on top of Mount Bolivar. The area includes about 19 km (12 mi) of the Rogue River from Marial downstream to Big Bend near Illahe (Figure 2; detail on Figure 5).

A study of this wilderness is being conducted jointly by the U.S. Geological Survey, the Oregon Department of Geology and Mineral Industries, and the U.S. Bureau of Mines. The Wild Rogue Wilderness project, a part of a multidisciplinary land-resource study of the Medford 2° quadrangle, emphasizes evaluation of potential mineral resources and their relation to regional geology. Field mapping in the steep, rugged area began in June 1979 and should be completed during the 1980 field season. This article outlines some recent discoveries of the past field season and suggests possible avenues of future research.

PREVIOUS WORK

Previous studies of the area include those by Diller (1914), Butler and Mitchell (1916), Wells (1955), Wells and Peck (1961), Baldwin and Rud (1972), Kent (1972), Purdom (1977), and Ramp and others (1977). Earlier geologic mapping in this area was done at smaller scales than that of the present investigation, and the dikes were grouped along with the volcanic rocks as greenschist-facies metamorphic volcanic rocks, including basalt, andesitic to siliceous tuffs and flows, occasional pillow lavas, tuffaceous sediments, and chert locally intruded by diabasic and gabbroic dikes then considered part of the Rogue Formation. A few areas of similar rocks were mapped about 32 km (20 mi) to the southwest in the vicinity of Saddle Mountain and Gray Butte by Ramp and others (1977, p. 6) and were described as Rogue Formation volcanic rocks intruded by abundant diabasic and gabbroic dikes.

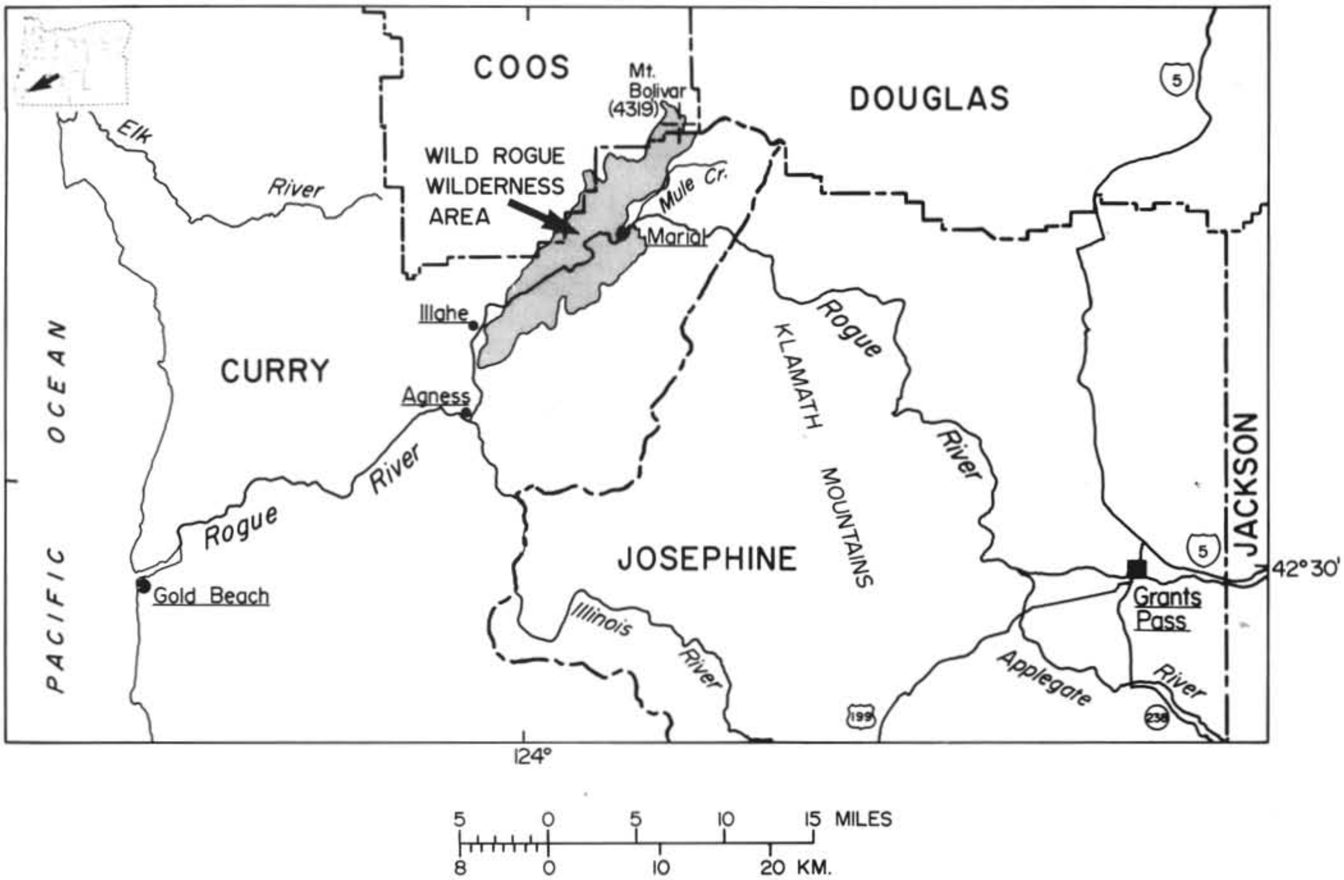


Figure 2. Locality map of the Wild Rogue Wilderness area, southwestern Oregon.

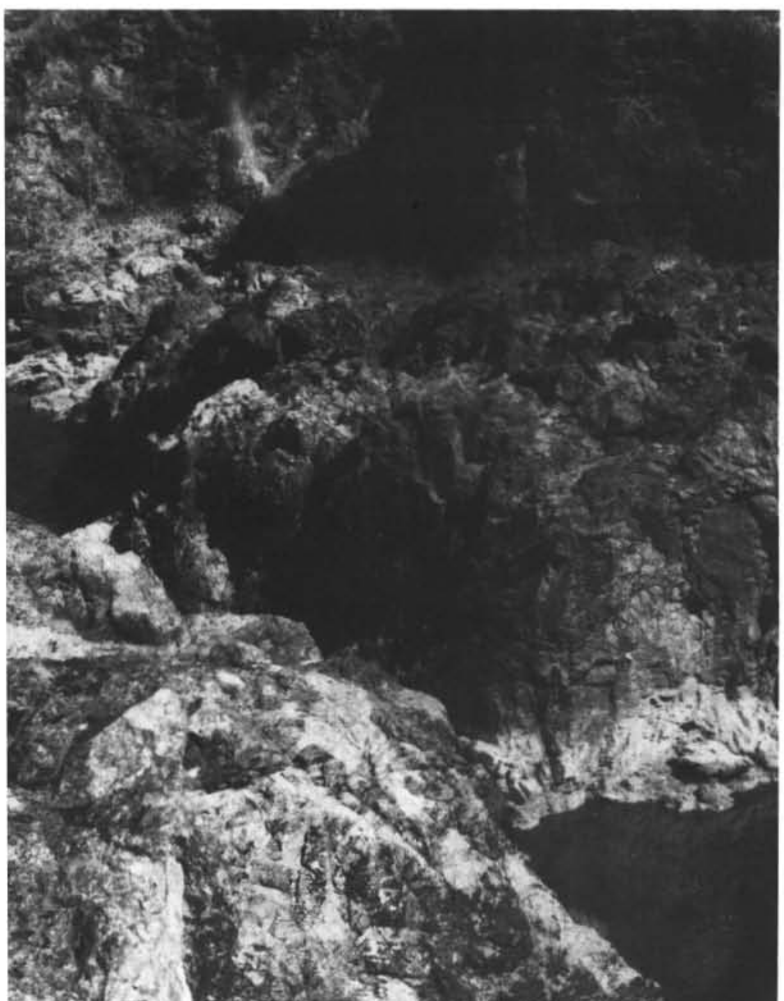


Figure 3. Mule Creek Canyon on the Rogue River near Inspiration Point.

DISCUSSION

The recognition of the extensive sheeted dike unit described in this article is of particular interest to those attempting to construct a model of the tectonic environment of the northern Klamath Mountains of southwestern Oregon. The sheeted dikes are best exposed in Mule Creek Canyon of the Rogue River in the vicinity of Inspiration Point (Figure 3), where they crop out continuously from about 0.5 km (0.3 mi) upstream to 0.8 km (0.5 mi) downstream from the mouth of Stair Creek. The dikes are also well exposed in Mule Creek, on the ridge extending south from Saddle Peaks, and on the south slope and top of Mount Bolivar (Figure 4).

The section of sheeted dikes exposed along the Rogue River in the vicinity of Inspiration Point forms a mappable unit that trends N. 10°-15° E. and is approximately 600 m (2,000 ft) thick (Figure 5). To the northwest, the dikes mapped along the river are faulted against a sequence of silicious tuffs intruded in places by quartz diorite. The fault exposed in the river bank trends approximately N. 55° E. and dips 75° S.E. The southeastern boundary of the dike complex is best exposed in Stair Creek about 180 m (590 ft) upstream from its mouth. At this point the dike unit is in fault

Figure 4. South flank of Mount Bolivar. Dikes trend from the lower right of the photograph to the upper left. Some of the dikes display dark pyrite staining.

contact with the younger marine shale and graywacke of the Jurassic and Cretaceous Dothan Formation (D. Jones, personal communication, 1979).

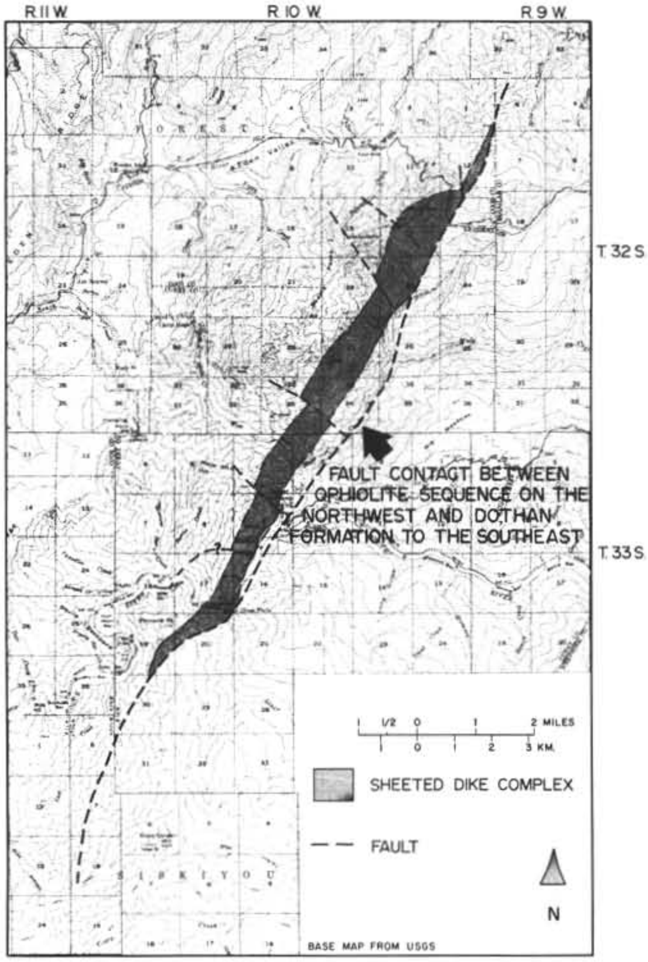
The highly recrystallized and tightly contorted (drag-folded) rocks of both formations suggest that faulting occurred at considerable depth. The dike rocks within about 75 m (250 ft) of the fault have been altered to a chlorite-epidote schist. The juxtaposed sedimentary rock is a highly indurated argillite. The foliation in the schist strikes about N. 20°-50° E. and dips steeply about 75°-85° S.E. Movement along this fault was predominantly vertical, although the orientation of drag folds indicates that some lateral displacement also occurred.

Where relatively undisturbed by faulting, the sheeted dikes strike approximately N. 40°-70° W. and dip nearly vertically. The unit consists of multiple, subparallel dikes with an average thickness of about 1 m (3 ft) but varying from 10 cm (4 in) to 2 m (6 ft). The dikes are composed of medium-grained, occasionally porphyritic rocks containing gray, subophitically intergrown plagioclase and pyroxene. Many of the dikes exposed in the upper Mule Creek drainage are notably porphyritic (Figure 6). A rare, greenish-black, coarse-grained, porphyritic, olivine-bearing dike is exposed near Stair Creek Falls (Purdom, 1977, p. 49). Younger dikes intruding older dikes display chilled margins on one or both sides, and the number of chilled margins is greater on the north side than on the south by a ratio of 3:2.

Most of the dikes measured along the Rogue River strike approximately N. 40°-70° W. and dip steeply to the north, but some rotation of the dikes apparently occurred near the Dothan fault contact, where strike measurements of N. 10°-15° E. with a vertical dip were recorded.

Many of the sheeted units are 100 percent dikes, but screens of gabbroic country rock constitute up to 50 percent of the unit near its eastern margin where mapped along the river. An area about 75 m (250 ft) wide near the mouth of Stair Creek has an estimated 40 percent of gabbro screen, but the percentage of screen decreases to the northwest (Figure 7). Slivers and lenses of gabbro caught up in the dike swarm display a foliation with a fairly constant orientation (Figures 8 and 9). This foliation appears to be a metamorphic fabric, although it may be an inherited cumulate layering. The pieces of gabbroic rock (screen) appear to be slabs of country rock broken and intruded by the dikes.

Preliminary mapping in the vicinity of Mount Bolivar (on the ridge, SW ¼ sec. 14) indicates several irregularly spaced groups of diabase dikes intruding the gabbroic rocks. A similar relation can be seen about 3.2 km



↑ *Figure 5. Preliminary map showing the extent of the sheeted dike unit in the study area. (Mapped by the authors in 1979)*

(2 mi) to the northeast along a logging road (NE ¼ sec. 12). Although more detailed mapping will be required to further characterize the complex, the sheeted dike unit in the Wild Rogue Wilderness was apparently emplaced tectonically along with the incomplete ophiolite sequence. Further study of the critical dike-gabbro contact zone may provide useful insight into the petrogenesis of this part of the ophiolite suite.

Preliminary mapping has outlined a zone of coarse, agglomeritic, plagioclase-rich basalt flows that may represent the initial volcanic expression of the dikes. In one area along Bolivar Creek, the dikes are in close proximity to a very coarse-grained agglomerate consisting of rock fragments as large as 0.5 m (1.5 ft) in diameter and plagioclase phenocrysts in a sparse, fine-grained matrix. The size of the fragments and ratio of fragments to matrix decreases to the north until the fragments disappear. Extensive volcanic rocks lie northwest of the dikes and appear to interfinger with dike rocks only in the vicinity of Diamond Peak and Mount Bolivar.

The age of the dikes is uncertain, but if they are cogenetic with the rocks of the Rogue Formation, which are interpreted as island-arc volcanic rocks, they would also be of early Late Jurassic age. Specimens from some of the dikes appear fresh enough for isotopic age dating, and further sampling for this purpose is intended.

Sheeted dikes somewhat similar to those in the Wild Rogue Wilderness have been described in eastern Oregon by Thayer (1977b, p. 96) and in nearby Del Norte County, Calif., by G. D. Harper (written communication, 1979).

Mineralization in the sheeted dike unit consists of abundant disseminated pyrite in a few of the dikes and occasional, small quartz veins that crosscut the formation and contain minor amounts of gold associated with pyrite. The pyritic dikes show up as brown bands on weathered surfaces (Figure 4). Some mineralization in the area is concentrated near the contact between the dikes and the volcanic rocks, where a zone of leached volcanic rock contains abundant pyrite and chalcopyrite along with minor (or occasional) sphalerite. In some of the volcanic rocks, for example, in the upper Mule Creek drainage, a few prospect cuts and adits are found in a zone of quartz-diorite-impregnated bedded tuff to the northwest of the sheeted dikes. This area appears to be a favorable location for mineralization. The Mule Mountain gold mine located on top of the ridge about 800 m (0.5 mi) north of Inspiration Point is in this zone.

REFERENCES

Baldwin, E. M., and Rud, J. O., 1972, Thrusting of the Rogue Formation near Marial on the lower Rogue River, Oregon: The Ore Bin, Oregon Department of Geology and Mineral Industries, v. 34, no. 4, p. 57-66.

← *Figure 6. Dark-colored andesite porphyry dike with chilled margins penetrates older, light-colored diabasic dike.*

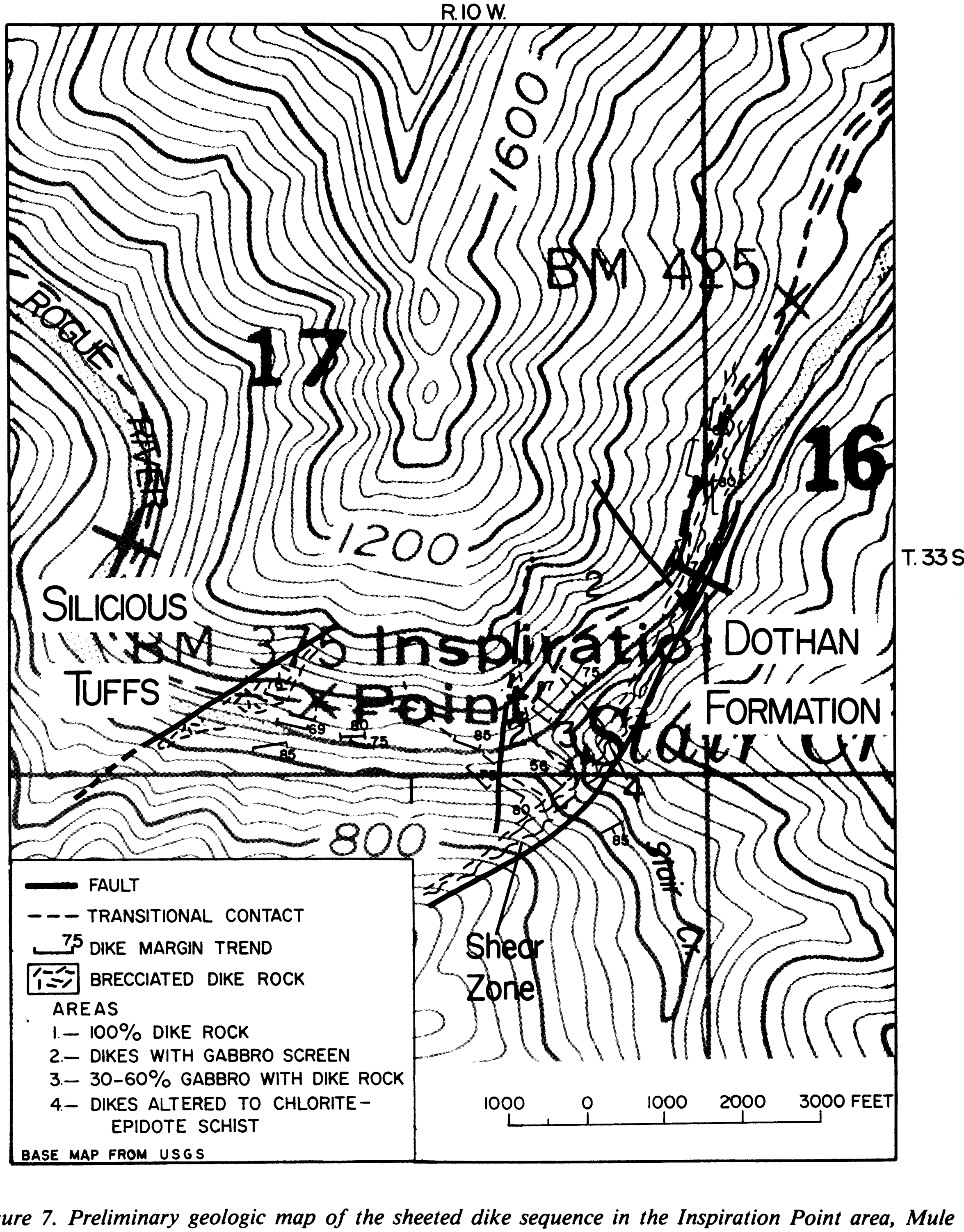


Figure 7. Preliminary geologic map of the sheeted dike sequence in the Inspiration Point area, Mule Creek Canyon.

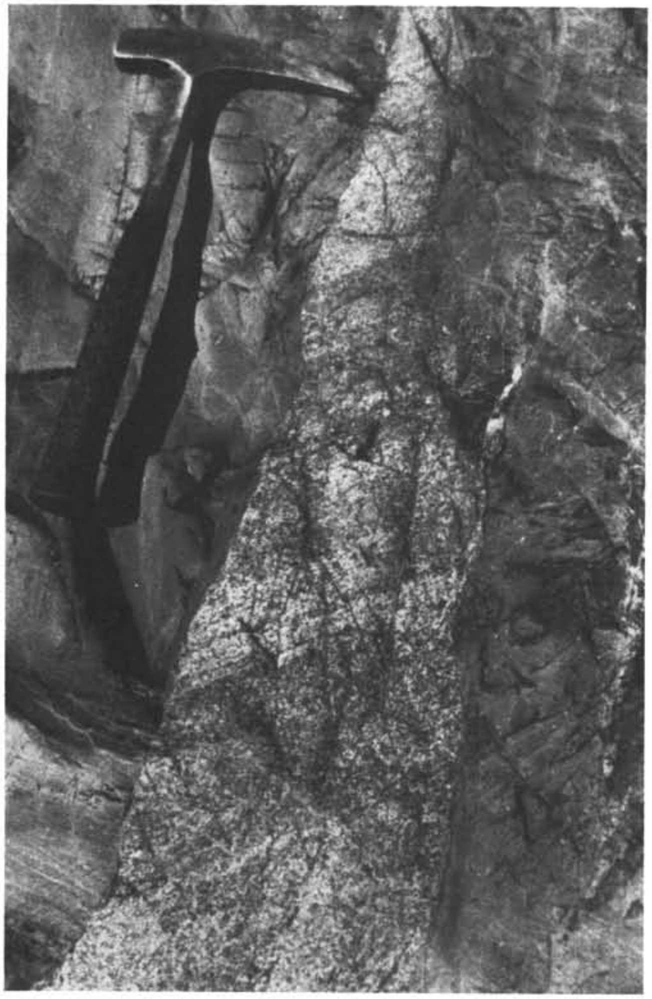


Figure 8. Gabbro screen surrounded on both sides by dikes with chilled margins against the gabbro. Note foliation (bands of light and dark minerals) in gabbro.

Butler, G. M., and Mitchell, G. J., 1916, Preliminary survey of the geology and mineral resources of Curry County, Oregon: Oregon Mineral Resources, Oregon Bureau of Mines, v. 2, no. 2, 136 p.

Diller, J. S., 1914, Mineral resources of southwestern Oregon: U.S. Geological Survey Bulletin 546, 147 p.

Greenbaum, D., 1972, Magmatic processes at ocean ridges, evidence from the Troodos Massif, Cyprus: Nature (Physical Science), v. 238, p. 18-21.

Kent, R. C., 1972, The geology of the southeast quarter of the Bone Mountain quadrangle, Oregon: Portland, Oreg., Portland State University master's thesis, 132 p.

Kidd, W. S. F., and Cann, J. R., 1974, Chilling statistics indicate an ocean-floor spreading origin for the Troodos Complex, Cyprus: Earth and Planetary Science Letters, v. 24, p. 151-155.

Moores, E. M., and Vine, F. J., 1971, The Troodos Massif, Cyprus and other ophiolites as oceanic crust: evaluation and implications: Philosophical Transactions of the Royal Society of London, v. 268A, p. 443-466.

Purdom, W. B., 1977, Guide to the geology and lore of the wild reach of the Rogue River, Oregon: Museum of Natural History Bulletin 22, University of Oregon, Eugene, Oreg., 67 p.

Ramp, Len, Schlicker, H. G., and Gray, J. J, 1977, Geology, mineral resources and rock material of Curry County, Oregon: Oregon Department of Geology and Mineral Industries Bulletin 93, 79 p.

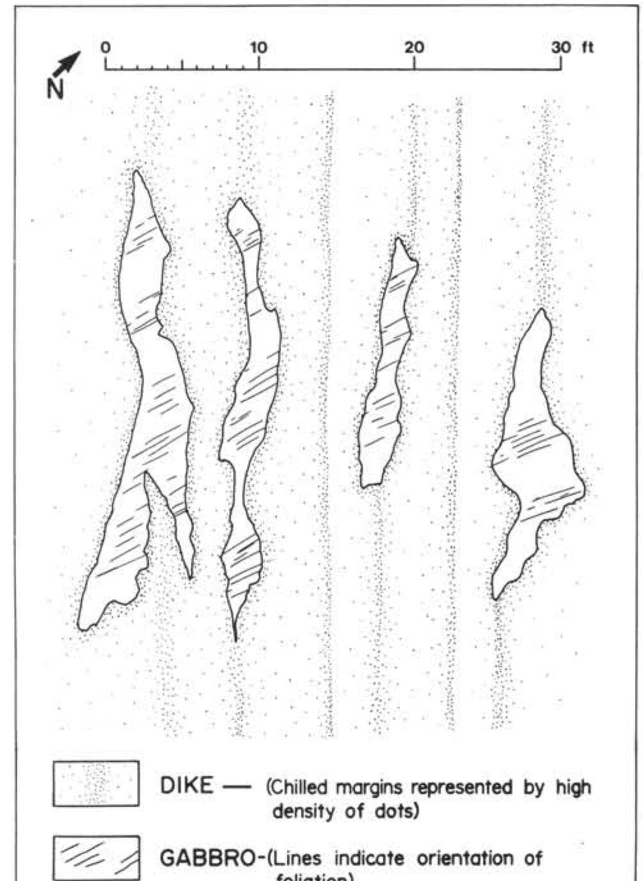
Thayer, T. P., 1977a, Some implications of sheeted dike swarms in ophiolitic complexes: Geotectonics, v. 11, no. 6, p. 419-426 (English translation).

——— 1977b, The Canyon Mountain Complex, Oregon, and some problems of ophiolites, *in* Coleman, R. G., and Irwin, W. P., eds., 1977, North American ophiolites: Oregon Department of Geology and Mineral Industries Bulletin 95, p. 93-105.

Wells, F. G., 1955, Preliminary geologic map of southwestern Oregon west of meridian 122° west and south of parallel 43° north: U.S. Geological Survey Field Studies Map MF-38, scale 1:250,000.

Wells, F. G., and Peck, D. L., 1961, Geologic map of Oregon west of the 121st meridian: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-325, scale 1:500,000

Figure 9. Sketch of outcrop showing typical relationship between dikes and gabbro.



□

Geology of the Condrey Mountain Schist, northern Klamath Mountains, California and Oregon

by M. M. Donato and R. G. Coleman, U.S. Geological Survey, Menlo Park, Calif. 94025, and M. A. Kays, Department of Geology, University of Oregon, Eugene, Oreg. 97403

This paper is intended as a companion piece to the "Geologic Field Trip Guide through the North-Central Klamath Mountains," by M. A. Kays and M. L. Ferns, which appeared in *Oregon Geology*, v. 42, no. 2, February 1980. The two papers represent the material for Field Trip 4 of the March 1980 GSA Cordilleran Meeting and were announced under the title "Geologic Summary for a Field Trip Guide through the North-Central Klamath Mountains" in *Geologic Field Trips in Western Oregon and Southwestern Washington*, Oregon Department of Geology and Mineral Industries Bulletin 101, 1980, p. 77. —Ed.

REGIONAL GEOLOGY

The Condrey Mountain Schist is exposed through a structural window in the so-called western Paleozoic and Triassic belt of the Klamath Mountains of southern Oregon and northern California (Figure 1). On the eastern and southern margins, a low-angle folded thrust fault separates the schist from overlying garnet amphibolite-facies rocks of the western Paleozoic and Triassic belt. On the west, the contact with ultramafic rocks of the Seiad Complex appears to be a high-angle fault. The structurally overlying rocks of the western Paleozoic and Triassic belt, known in Oregon as the Applegate Group, form a diverse assemblage of amphibolite-facies metavolcanic, metasedimentary, and ultramafic rocks intruded by granitic to dioritic plutonic rocks. These rocks are described in detail by Hotz (1979). Evidence for the age of the western Paleozoic and Triassic belt comes from limestone bodies containing fossils of Paleozoic, Triassic, and Jurassic age (Elliott, 1971; Irwin, 1972). The recent recognition of Triassic and Jurassic radiolarians in some cherts of the western Paleozoic and Triassic belt suggests that at least some of the limestones may be blocks in a mélange (Irwin and others, 1977). Based on isotopic measurements of hornblende separates, the age of metamorphism of the amphibolitic rocks that overlie the schist is reported by Kays and others (1977) to be 144 ± 3 m.y.

In lithology and metamorphic grade, the Condrey Mountain Schist presents a strong contrast to the rocks that structurally overlie it. It consists predominantly of black graphitic quartz-mica schist, here referred to as "blackschist," but contains considerable amounts of interlayered chlorite-actinolite schist, a "greenschist," that may be tuffaceous in origin. The greenschist locally contains abundant glaucophane or crossite; lawsonite is not present in any of these rocks. The schist, though strongly deformed and thoroughly recrystallized, is markedly lower in grade than rocks of the overlying belt.

The age of metamorphism of the Condrey Mountain Schist has been determined by several investigators. Lanphere and others (1968) and Suppe and Armstrong (1972) reported isotopic ages of 141 m.y. and 155 ± 3 m.y., respectively, based on muscovite and whole-rock analyses. These ages suggest that the two plates have at least overlapping histories of crystallization. Yet the correlation of the schist with other rocks in the Klamath Mountains has proved to be difficult. On the basis of lithologic similarity and structural and metamorphic evidence, Klein (1977) suggested that the schist is equivalent to the Galice Formation to the west. Overlap of the Galice Formation's Oxfordian to Kimmeridgian age with the apparent metamorphic age of the Condrey Mountain Schist complicates any proposed correlation. Clearly, refinement of the Galice's stratigraphy and age as well as a better notion of structural relations in the overlying plate is needed.

LITHOLOGIES

The dominant rock type in the Condrey Mountain Schist is graphitic quartz-mica schist, "blackschist" (Figure 1). Alternating, thin (millimeter-sized), micaceous and quartzose layers impart a strong schistosity to the rock. Pyrite cubes measuring up to 1 cm on a side are abundant, and many show quartz-pressure shadows. Most of the blackschist is compositionally monotonous, but amounts of quartz, feldspar, and mica vary locally. Rare, but distinctive thin cherty layers occur within the blackschist. The apparent ease with which the blackschist deforms is shown by disharmonic folding in some outcrops. Because incompetency of the blackschist results in shearing of folds, most outcrops display only strong schistosity modified by small-scale crenulations. Rarely, intrafolial folds are observed.

The mineral assemblage in the blackschist is quartz, muscovite, carbonaceous material, chlorite, albite, and pyrite (commonly altered to iron oxides). Accessory minerals include tourmaline, sphene, and clinozoisite.

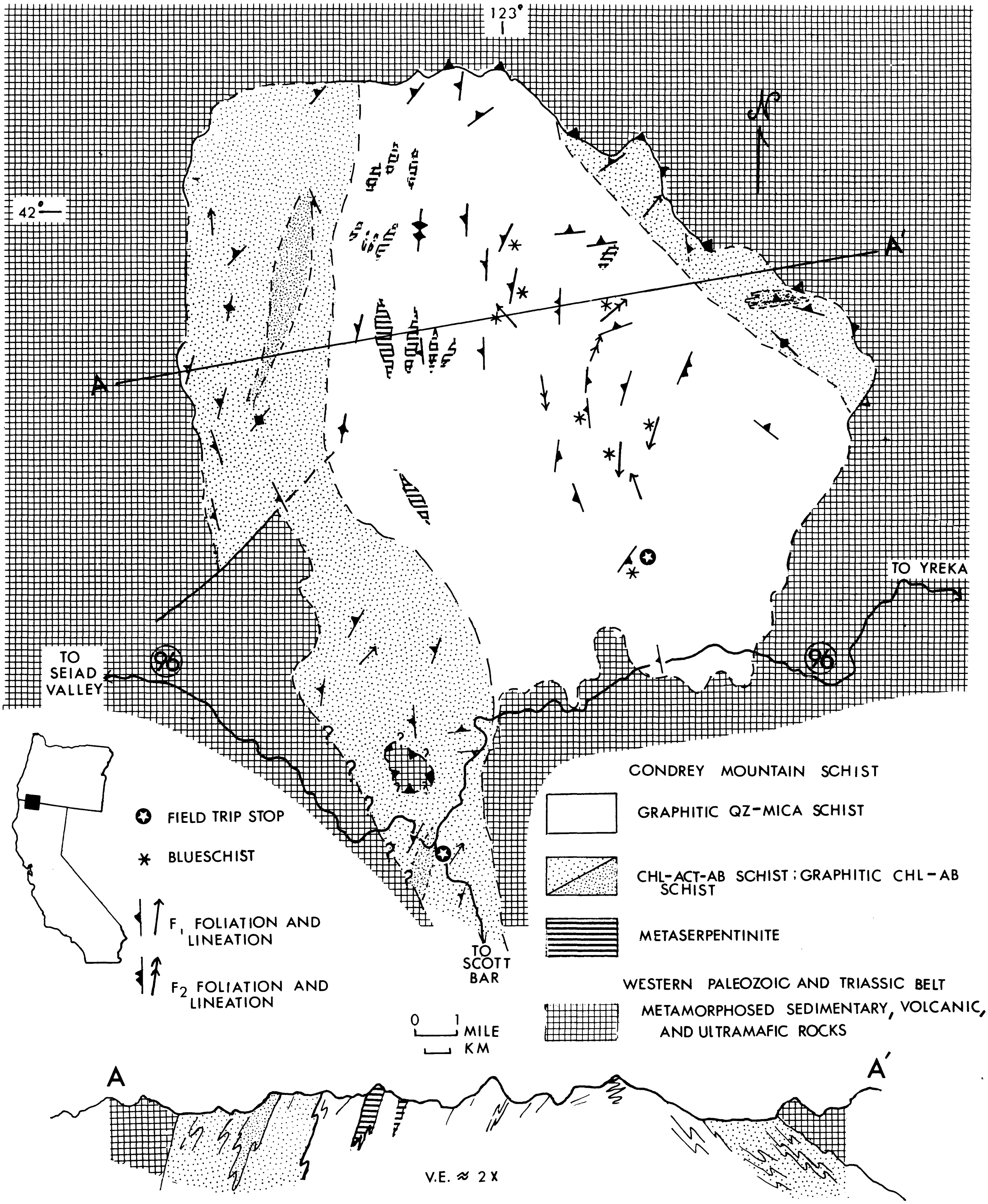


Figure 1. Geologic sketch map and cross section of the Condrey Mountain Schist. Based on mapping by Engelhardt (1966), Hotz (1967), and Donato and Coleman (1979).

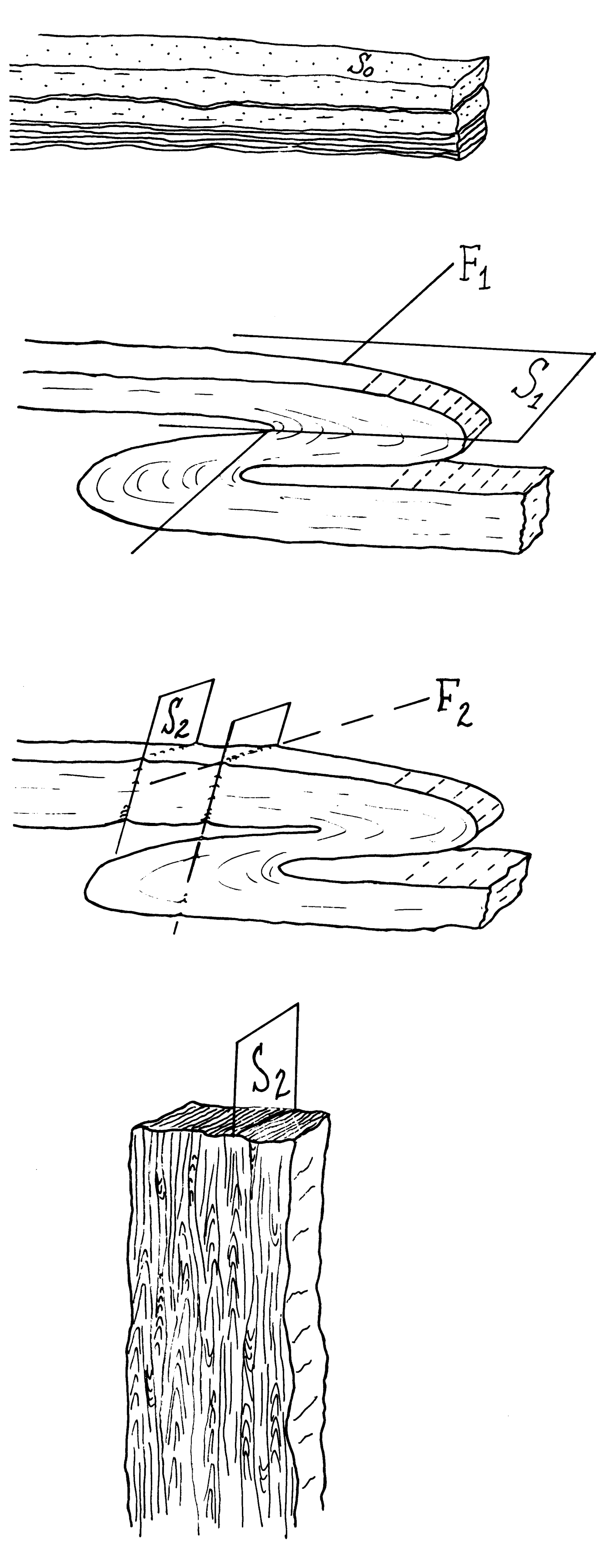
Late-growing stilpnomelane and chlorite pseudomorphs after garnet have been observed in several thin sections. Metacherts contain quartz, riebeckite, garnet, stilpnomelane, and albite.

Conformably interlayered and infolded greenschist is mainly chlorite, albite, actinolite, epidote, and white mica, with minor garnet, stilpnomelane, calcite, and sphene occurring locally. Fine-scale compositional banding visible in some outcrops may reflect primary layering, possibly in a tuffaceous deposit. Compositional variations occur on a scale ranging from millimeters to meters or tens of meters. A graphite- and chlorite-rich variety forms a mappable subdivision of greenschist and is shown in Figure 1.

In several localities, greenschist is interlayered with schist containing crossite or glaucophane as the predominant mineral. We refer to these schists as "blueschist," although they lack the diagnostic blueschist-facies mineral lawsonite. The assemblage is sodic amphibole (crossite and, at some places, glaucophane, by their optical properties), chlorite and epidote (both iron-rich), white mica, albite, garnet, and stilpnomelane. The only mineralogical difference between the greenschists and blueschists is indeed the composition of the amphibole.

Blueschist layers range in thickness and extent from a few centimeters to tens of meters, as seen at a local quarry excavated in blueschist with interlayered greenschist (shown as field trip stop in Figure 1; also stop 6, field trip guide in February 1980 *Oregon Geology*). The presence of these fine-scale intercalations of blueschist and greenschist implies that the dominant factor controlling the mineral assemblage is local layer composition rather than large pressure differences. These schists probably formed under higher than normal greenschist-facies pressures.

Volumetrically minor, but nonetheless significant, is the metaserpentinite that occurs as concordant lenses or pods within the blackschist and greenschist. Most are massive antigorite-magnetite-brucite rocks, but talc-magnesite schist and microgabbro (clinozoisite-actinolite-albite-garnet) are found. Some lenses have rodingite selvages containing nephrite. We are uncertain whether the rocks were serpentinized prior to, or concurrently with, metamorphism. It is clear from their metamorphic assemblages, however, that these rocks have shared the same history of recrystallization as the



→

Figure 2. Sequence of events summarizing the deformational history of the Condrey Mountain Schist. F_1 *and* F_2 *indicate axes of folds resulting from deformational episodes.* S_1 *and* S_2 *indicate schistosity. In the most extreme stage,* S_2 *schistosity completely transposes* S_1*, leaving only rootless intrafolial folds as evidence of* S_1*. Common in the easily deformed blackschist.*

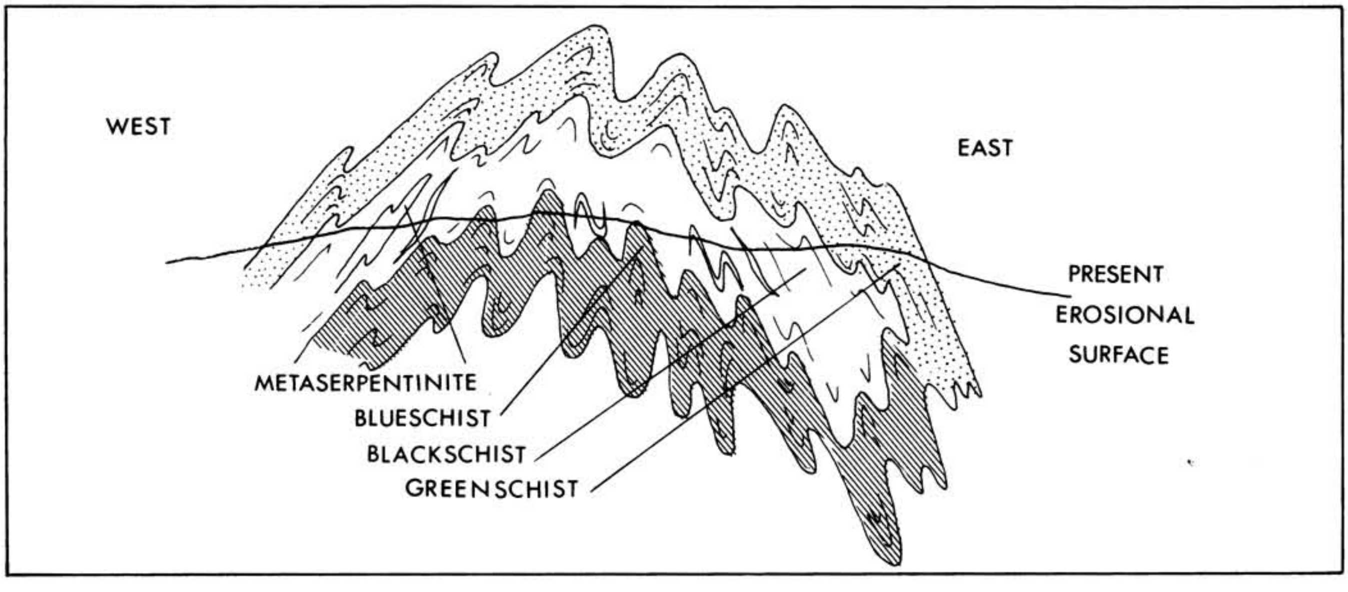


Figure 3. Schematic cross section of the Condrey Mountain Schist. This interpretation of the structure and metamorphism calls upon a nappe-like configuration to produce the observed distribution of lithologic types. Greenschist envelops blackschist on a gross scale. Structurally lower blueschist is exposed in the central zone of the window. In this figure, the "nappe" is drawn overturned toward the east, but present structural information is not sufficient to distinguish between an eastward- and westward-thrust "nappe."

surrounding schist. Their ultimate origin is a mystery. They could be slivers of serpentinite tectonically incorporated early in the history of the Condrey Mountain Schist. Hotz (1979) has interpreted these rocks as remnants of serpentinite occurring between the Condrey Mountain Schist and the overriding plate that were infolded with the schist. If they are, we might expect to see remnants of rocks other than serpentinite, such as amphibolite or other schists found in the upper plate. Another possibility is that the metaserpentinite bodies represent sedimentary serpentinite deposited near a fracture zone on the ocean floor.

A leucocratic igneous body within the Condrey Mountain Schist is exposed in outcrops and roadcuts along the Scott River. It is composed primarily of twinned plagioclase, quartz, chlorite, and white mica and displays a gneissic fabric, thus appearing to have intruded the protolith of the Condrey Mountain Schist before or during metamorphism. Hotz (1979) describes a similar intrusive body near the West Fork of Beaver Creek.

STRUCTURAL GEOLOGY

The Condrey Mountain Schist has a complex deformational history that is yet to be completely understood. Structural information gathered in the course of geologic mapping has led to the following interpretation, summarized in Figure 2.

The schist has undergone two major deformational events: (1) The first event produced isoclinal recumbent folds (fold axes represented by F_1 in Figure 2) whose sense of vergence has not been established. This folding was concurrent with greenschist- to blueschist-facies metamorphism that produced mineral lineations parallel to fold axes. (2) A second period of folding produced north-south-trending crenulations (fold axes represented by F_2 in Figure 2) and associated steeply dipping cleavage, but only minor recrystallization. Deformation seems to indicate an east-west compression of the schist. Later kink folds and associated quartz veins cross the crenulation at a high angle.

The extremely rare occurrence of what may be refolded isoclinal folds within the foliation plane suggests that there may have been two episodes of isoclinal folding prior to the north-south crenulation event. Alternatively, these folds may be single folds "rolled over" upon themselves during a single event. At the present time, we favor the single-fold interpretation because petrographic evidence for two periods of isoclinal folding is lacking.

INTERPRETATION

A late north-south folding is recorded in both the Condrey Mountain Schist and the overlying western Paleozoic and Triassic rocks. The two contrasting units may have been tectonically juxtaposed prior to this event. The structural geology of the overlying plate has not yet been thoroughly investigated. The contrasts in grade (garnet amphibolite vs. greenschist-blueschist) and in lithology (mélange-like oceanic lithosphere vs. deep-water sediments grading upward to island arc [?] volcanic rocks) between the schist and the overlying plate indicate that thrusting brought together units of two differing regimes—an upper, hot oceanic slab and a lower, cooler, predominantly sedimentary sequence of rocks. It is possible that thrusting of the hot upper slab over the lower cooler slab was the event recorded in the Condrey Mountain Schist as F_1. The fact that blueschist seems to be restricted to structurally lower parts of the lower plate (Figure 3) suggests that these rocks were not only insulated from the overlying hotter slab but also metamorphosed at greater depth. Concurrently, upper levels of the lower plate were heated by the hot oceanic slab, thereby producing greenschist assemblages. Rare blue cores in actinolite seem to support a model involving low pressure-temperature conditions followed by increasing temperature. We can speculate that thrusting and metamorphism were related to incipient subduction of these rocks, but hard evidence for this is lacking.

REFERENCES CITED

Donato, M. M., and Coleman, R. G., 1979, Metamorphism and deformation of the Condrey Mountain Schist of Klamath Mountains, California and Oregon: Geological Society of America Abstracts with Programs, v. 11, no. 3, p. 75.

Elliott, M. A., 1971, Stratigraphy and petrology of the Late Cretaceous rocks near Hilt and Hornbrook, Siskiyou County, California, and Jackson County, Oregon: Corvallis, Oreg., Oregon State University doctoral dissertation, 171 p.

Engelhardt, C. L., 1966, The Paleozoic-Triassic contact in the Klamath Mountains, Jackson County, southwestern Oregon: Eugene, Oreg., University of Oregon master's thesis, 98 p.

Hotz, P. E., 1967, Geologic map of the Condrey Mountain quadrangle and parts of the Seiad Valley and Hornbrook quadrangles, California: U.S. Geological Survey Geologic Quadrangle Map GQ-618, scale 1:62,500.

——— 1979, Regional metamorphism in the Condrey Mountain quadrangle, north-central Klamath Mountains, California: U.S. Geological Survey Professional Paper 1086, 25 p.

Irwin, W. P., 1972, Terranes of the Western Paleozoic and Triassic belt in the southern Klamath Mountains, California: U.S. Geological Survey Professional Paper 800-C, p. C103-C111.

Irwin, W. P., Jones, D. L., and Pessagno, E. A., Jr., 1977, Significance of Mesozoic radiolarians from the pre-Nevadan rocks of the southern Klamath Mountains, California: Geology, v. 5, no. 9, p. 557-562.

Kays, M. A., and Ferns, M. L., 1980, Geologic field trip guide through the north-central Klamath Mountains: Oregon Geology, v. 42, no. 2, p. 23-35.

Kays, M. A., Ferns, M. L., and Beskow, L., 1977, Complementary meta-gabbros and peridotites in the northern Klamath Mountains, U.S.A., *in* Dick, H. J. B., ed., Magma genesis: Oregon Department of Geology and Mineral Industries Bulletin 96, p. 91-107.

Klein, C. W., 1977, Thrust plates of the north-central Klamath mountains near Happy Camp, California: California Division of Mines and Geology Special Report 129, p. 23-26.

Lanphere, M. A., Irwin, W. P., and Hotz, P. E., 1968, Isotopic age of the Nevadan orogeny and older plutonic and metamorphic events in the Klamath Mountains, California: Geological Society of America Bulletin, v. 79, no. 8, p. 1027-1052.

Suppe, John, and Armstrong, R. L., 1972, Potassium-argon dating of Franciscan metamorphic rocks: American Journal of Science, v. 272, no. 3, p. 217-233. □

Three companies high bidders for Oregon geothermal parcels

Bids totaling more than a million dollars have been received by the Bureau of Land Management for geothermal rights on 12 parcels of Federal land in southeast Oregon.

Anadarko Production Co., Chevron U.S.A., Inc., and Getty Oil Company are the high bidders and upon the issuance of leases will have the right to develop the geothermal resources. Anadarko was high bidder on three parcels, Chevron on two, and Getty on seven. All of the lands are located in the Alvord or Crump Geyser Known Geothermal Resource Areas.

Sixty-four parcels were offered by the Federal government, with 52 receiving no bids. The geothermal leases cover a 10-year period.

Bidding details are as follows:

Parcel	Acreage	Area	Company	Amount
4	2,563	Alvord	Getty	$ 30,117.37
5	2,566	Alvord	Getty	60,953.43
6	2,360	Alvord	Getty	60,770.00
28	1,830	Alvord	Getty	61,751.70
29	2,542	Alvord	Getty	44,478.35
33	2,400	Alvord	Anadarko	149,664.00
34	2,560	Alvord	Anadarko	397,516.80
35	40	Alvord	Getty	630.00
36	2,520	Alvord	Anadarko	227,379.60
37	2,560	Alvord	Getty	44,802.28
59	2,568	Crump	Chevron	5,785.00
60	81	Crump	Chevron	1,057.00
				$1,084,905.53

□

Chemical analyses of Mount St. Helens pumice and ash

Analyses performed June 4, 1980, by Karl C. Wozniak, Scott S. Hughes, and Edward M. Taylor, Analytical Laboratory, Department of Geology, Oregon State University, Corvallis, Oregon

We are printing these analyses because we believe they may be of interest to the general public and to more specialized groups such as public health officials. Samples were submitted for analysis as indicated. The assistance of Peter W. Lipman, James G. Moore, and Donald A. Swanson, U.S. Geological Survey, and Diane Bender, Washington State University, in obtaining these samples is greatly appreciated.

The samples were analyzed by X-ray fluorescence, except for the oxides of sodium and magnesium, which were analyzed by atomic absorption spectrophotometry.

	1	2	3	4	5	6	7	8
SiO_2	64.3	64.1	64.6	67.7	64.1	64.1	64.2	64.3
Al_2O_3	18.2	17.9	17.8	17.1	18.0	17.5	18.0	18.0
FeO*	4.2	4.2	3.7	3.2	4.2	4.1	4.3	4.0
CaO	4.8	4.8	4.8	4.0	4.8	4.6	4.9	4.7
MgO	2.0	2.0	2.0	0.5	2.0	1.9	1.9	1.8
K_2O	1.45	1.45	1.60	1.85	1.45	1.45	1.45	1.50
Na_2O	4.8	4.8	4.7	5.0	4.7	4.8	4.8	4.7
TiO_2	0.60	0.60	0.70	0.55	0.65	0.60	0.65	0.60
	100.35	99.85	99.90	99.90	99.90	99.05	100.20	99.60

1. Pumice lapilli deposited May 18, 1980, on west fork of Pine Creek at 4,000-ft elevation. Collected May 19 by P. Lipman, J. Moore, and D. Swanson, USGS.**
2. Duplicate analysis of no. 1.**
3. Ash fall, Pullman, Washington. Collected 2:30-3:30 p.m., May 18, by D. Bender, WSU.**
4. Ash fall, Pullman. Collected 12:30-8:00 a.m., May 19, by D. Bender, WSU.**
5. Light-tan pumice lapilli from ash flow erupted May 18. Collected May 21 one mile south of site of Spirit Lake Lodge by P. Lipman, J. Moore, and D. Swanson, USGS.
6. Gray pumice lapilli from blast deposit of May 18. Collected May 24 at crest of ridge between forks of Castle Creek by P. Lipman, J. Moore, and D. Swanson, USGS.
7. Light-tan pumice lapilli from ash flow erupted May 25. Collected May 26 two miles south of site of Spirit Lake Lodge at 3,600-ft elevation by P. Lipman, J. Moore, and D. Swanson, USGS.
8. Light- to dark-gray banded pumice lapilli from ash flow erupted May 25. Same locality as no. 7.

* Total iron content reported as FeO. H_2O-free.
** Previously reported May 21, 1980.

NOTES

Pumices differ chiefly in color due to variations in density (inflation, vesicularity). All are hypersthene-bearing dacites close to the average chemical composition of dacites from other High Cascade volcanoes. The principal crystalline constituent is plagioclase feldspar (10-15 weight percent) with subordinate hypersthene, amphibole, magnetite, and rock fragments. None of the quartz that has so often been reported was found, other than as minute traces in rock fragments. More than 80 percent of the pumice is fresh dacite glass. Variation in chemical composition of the ash-fall deposits is attributable to early fallout of crystals and consequent concentration of glass shards in finer grained deposits farther removed from the volcano. □

Geologic map of southern Washington Cascades now available

The Earth Sciences Department of Portland State University (PSU) announces the publication of a new geologic map (scale 1:125,000) and cross sections of the Cascade Range of southern Washington. The map covers 4,050 sq mi and includes the area between lat. 45°31′ and 47°15′ N. and between long. 120°45′ and 122°22.5′ W.

Based on mapping done through May 1978 by Paul Hammond, Earth Sciences Department, PSU, the two-color, two-sheet map has over 200 map units and shows the extent of glaciation, landslides, alteration zones, mineral and hot springs, and sites of heat-flow holes. Accompanying the map is a 25-page text.

The prepaid cost of the map, including surface mailing, is $18.00 (add $1.00 for mailing outside the conterminous United States). Checks or money orders are payable to Geology Fund, Department of Earth Sciences, PSU; orders should be sent to Department of Earth Sciences, PSU, PO Box 751, Portland, OR 97207. □

GSA offers employment opportunities booklet

A forum on future employment opportunities in the geological sciences was held during the Annual Meeting of the Geological Society of America (GSA) at San Diego, California, on November 4, 1979. The forum was sponsored by the GSA Employment Service as a pilot program to aid persons new to the job market in selecting prospective employers and in determining career goals. Speakers at the forum also provided tips for successful interviews and presented salary survey figures.

A booklet summarizing presentations at the forum is now in print. For a free copy of "Future Employment Opportunities in the Geological Sciences," write to The Geological Society of America, Membership Department, P.O. Box 9140, 3300 Penrose Place, Boulder, Colorado 80301. □

PUBLICATIONS ORDER

Omission of price indicates publication is in press. Minimum mail order 50¢. All sales are final. Publications are sent postpaid. Payment must accompany orders of less than $20.00.

Fill in appropriate blanks and send sheet to Department (see address on reverse side).

YOUR NAME ____________________

ADDRESS ____________________

____________________ Zip__________

Amount enclosed $__________

OREGON GEOLOGY

____ Renewal ____ Subscription ____ Gift

____ 1 Year ($4.00) ____ 3 Years ($10.00)

NAME ____________________

ADDRESS ____________________

____________________ ZIP __________

(If Gift, From: ____________________)

ORDER FORM - CUT ON DASHED LINE

Available publications

MISCELLANEOUS PAPERS	Price	No. Copies	Amount
1. A description of some Oregon rocks and minerals, 1950: Dole	$ 1.00		
4. Laws relating to oil, gas, and geothermal exploration and development in Oregon			
Part 1. Oil and natural gas rules and regulations, 1977, rev. 1979	1.00		
Part 2. Geothermal resources rules and regulations, 1977, rev. 1979	1.00		
5. Oregon's gold placers (reprints), 1954	.50		
6. Oil and gas exploration in Oregon, rev. 1965: Stewart and Newton	3.00		
8. Available well records of oil and gas exploration in Oregon, rev. 1973: Newton	1.00		
11. Collection of articles on meteorites, 1968 (reprints from *The Ore Bin*)	1.50		
13. Index to *The Ore Bin*, 1950-1974	1.50		
14. Thermal springs and wells, 1970: Bowen and Peterson (with 1975 supplement)	1.50		
15. Quicksilver deposits in Oregon, 1971: Brooks	1.50		
16. Mosaic of Oregon from ERTS-1 imagery, 1973	2.50		
18. Proceedings of Citizens' Forum on potential future sources of energy, 1975	2.00		
19. Geothermal exploration studies in Oregon – 1976, 1977	3.00		
20. Investigations of nickel in Oregon, 1978: Ramp	5.00		
GEOLOGIC MAPS			
Geologic map of Galice quadrangle, Oregon, 1953	1.75		
Geologic map of Albany quadrangle, Oregon, 1953	1.00		
Reconnaissance geologic map of Lebanon quadrangle, 1956	1.50		
Geologic map of Bend quadrangle and portion of High Cascade Mountains, 1957	1.50		
Geologic map of Oregon west of 121st meridian, 1961	2.25		
Geologic map of Oregon east of 121st meridian, 1977	3.75		
GMS-3: Preliminary geologic map of Durkee quadrangle, Oregon, 1967	2.00		
GMS-4: Oregon gravity maps, onshore and offshore, 1967 (folded)	3.00		
GMS-5: Geologic map of Powers quadrangle, Oregon, 1971	2.00		
GMS-6: Preliminary report on geology of part of Snake River Canyon, 1974	6.50		
GMS-7: Geology of the Oregon part of the Baker quadrangle, Oregon, 1976	3.00		
GMS-8: Complete Bouguer gravity anomaly map, Cascade Mountain Range, central Oregon, 1978	3.00		
GMS-9: Total field aeromagnetic anomaly map, Cascade Mountain Range, central Oregon, 1978	3.00		
GMS-10: Low- to intermediate-temperature thermal springs and wells in Oregon, 1978	2.50		
GMS-11: Preliminary geothermal resource map of Oregon (upon written request only)	free	(one copy per customer)	
GMS-12: Geologic map of the Oregon part of the Mineral quadrangle	2.00		
OIL AND GAS INVESTIGATIONS			
3. Preliminary identifications of foraminifera, General Petroleum Long Bell #1 well	2.00		
4. Preliminary identifications of foraminifera, E.M. Warren Coos County 1-7 well, 1973	2.00		
5. Prospects for natural gas production or underground storage of pipeline gas	5.00		
MISCELLANEOUS PUBLICATIONS			
Landforms of Oregon (17 × 12 inches)	.50		
Mining claims (State laws governing quartz and placer claims)	.50		
Geological highway map, Pacific NW region, Oregon-Washington (published by AAPG)	3.00		
Fifth Gold and Money Session and Gold Technical Session Proceedings, 1975	5.00		
Sixth Gold and Money Session and Gold Technical Session Proceedings, 1978	6.50		
Back issues of *The Ore Bin*	25¢ over the counter; 50¢ mailed		
Colored postcard, *Geology of Oregon*	10¢ each; 3 for 25¢; 7 for 50¢; 15 for 1.00		

OREGON GEOLOGY

1069 State Office Building, Portland, Oregon 97201

Second Class Matter
POSTMASTER: Form 3579 requested

Available publications (continued)

BULLETINS	Price	No. Copies	Amount
33. Bibliography (1st supplement) geology and mineral resources of Oregon, 1947: Allen	1.00	______	______
36. Papers on Tertiary foraminifera: Cushman, Stewart and Stewart, 1949: v. 2	1.25	______	______
44. Bibliography (2nd supplement) geology and mineral resources of Oregon, 1953: Steere	2.00	______	______
46. Ferruginous bauxite deposits, Salem Hills, 1956: Corcoran and Libbey	1.25	______	______
49. Lode mines, Granite mining district, Grant County, Oregon, 1959: Koch	1.00	______	______
53. Bibliography (3rd supplement) geology and mineral resources of Oregon, 1962: Steere and Owen	3.00	______	______
57. Lunar Geological Field Conference guidebook, 1965: Peterson and Groh, editors	3.50	______	______
63. Sixteenth biennial report of the Department, 1966-1968	1.00	______	______
65. Proceedings of Andesite Conference, 1969: (copies)	10.00	______	______
67. Bibliography (4th supplement) geology and mineral resources of Oregon, 1970: Roberts	3.00	______	______
68. Seventeenth biennial report of the Department, 1968-1970	1.00	______	______
71. Geology of selected lava tubes in Bend area, Oregon, 1971: Greeley	2.50	______	______
76. Eighteenth biennial report of the Department, 1970-1972	1.00	______	______
77. Geologic field trips in northern Oregon and southern Washington, 1973	5.00	______	______
78. Bibliography (5th supplement) geology and mineral resources of Oregon, 1973: Roberts	3.00	______	______
81. Environmental geology of Lincoln County, 1973: Schlicker and others	9.00	______	______
82. Geologic hazards of Bull Run Watershed, Multnomah, Clackamas Counties, 1974: Beaulieu	6.50	______	______
83. Eocene stratigraphy of southwestern Oregon, 1974: Baldwin	4.00	______	______
84. Environmental geology of western Linn County, 1974: Beaulieu and others	9.00	______	______
85. Environmental geology of coastal Lane County, 1974: Schlicker and others	9.00	______	______
86. Nineteenth biennial report of the Department, 1972-1974	1.00	______	______
87. Environmental geology of western Coos and Douglas Counties, 1975	9.00	______	______
88. Geology and mineral resources of upper Chetco River drainage, 1975: Ramp	4.00	______	______
89. Geology and mineral resources of Deschutes County, 1976	6.50	______	______
90. Land use geology of western Curry County, 1976: Beaulieu	9.00	______	______
91. Geologic hazards of parts of northern Hood River, Wasco, and Sherman Counties, Oregon, 1977: Beaulieu	8.00	______	______
92. Fossils in Oregon (reprinted from *The Ore Bin*), 1977	4.00	______	______
93. Geology, mineral resources, and rock material of Curry County, Oregon, 1977	7.00	______	______
94. Land use geology of central Jackson County, Oregon, 1977: Beaulieu	9.00	______	______
95. North American ophiolites, 1977	7.00	______	______
96. Magma genesis: AGU Chapman Conference on Partial Melting, 1977	12.50	______	______
97. Bibliography (6th supplement) geology and mineral resources of Oregon, 1971-75, 1978	3.00	______	______
98. Geologic hazards of eastern Benton County, 1979: Bela	9.00	______	______
100. Geology and mineral resources of Josephine County, Oregon, 1979: Ramp and Peterson	9.00	______	______
101. Geologic field trips in western Oregon and southwestern Washington, 1980	9.00	______	______
SPECIAL PAPERS			
1. Mission, goals, and purposes of Oregon Department of Geology and Mineral Industries, 1978	2.00	______	______
2. Field geology of SW Broken Top quadrangle, Oregon, 1978: Taylor	3.50	______	______
3. Rock material resources of Clackamas, Columbia, Multnomah, and Washington Counties, Oregon, 1978: Gray and others	7.00	______	______
4. Heat flow of Oregon, 1978: Blackwell, Hull, Bowen, and Steele	3.00	______	______
5. Analysis and forecasts of the demand for rock materials in Oregon, 1979: Friedman and others	3.00	______	______
6. Geology of the La Grande area, Oregon, 1980: Barrash and others	5.00	______	______
7. Pluvial Fort Rock Lake, Lake County, Oregon: Allison	4.00	______	______
8. Geology and geochemistry of the Mt. Hood volcano, 1980: White	2.00	______	______
SHORT PAPERS			
18. Radioactive minerals prospectors should know, 1976: White, Schafer, Peterson	.75	______	______
21. Lightweight aggregate industry in Oregon, 1951: Mason	.25	______	______
24. The Almeda Mine, Josephine County, Oregon, 1967: Libbey	3.00	______	______
25. Petrography, type Rattlesnake Formation, central Oregon, 1976: Enlows	2.00	______	______
27. Rock material resources of Benton County, 1978: Schlicker and others	4.00	______	______

OREGON GEOLOGY

formerly THE ORE BIN

published by the Oregon Department of Geology and Mineral Industries

VOLUME 42, NUMBER 8 AUGUST 1980

OREGON GEOLOGY
(ISSN 0164-3304)

VOLUME 42, NUMBER 8 AUGUST 1980

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

Main Office: 1069 State Office Building, Portland 97201, phone (503) 229-5580.

Baker Field Office: 2033 First Street, Baker 97814, phone (503) 523-3133.
Howard C. Brooks, Resident Geologist

Grants Pass Field Office: 312 S.E. "H" Street, Grants Pass 97526, phone (503) 476-2496.
Len Ramp, Resident Geologist

Mined Land Reclamation Program: 1129 S.E. Santiam Road, Albany 97321, phone (503) 967-2039.
Paul F. Lawson, Supervisor

Subscription rates: 1 year, $4.00; 3 years, $10.00. Single issues, $.40 at counter, $.50 mailed.
Available back issues of *The Ore Bin:* $.25 at counter, $.50 mailed.

Address subscription orders, renewals, and changes of address to *Oregon Geology,* 1069 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,* 1069 State Office Building, Portland, OR 97201.

COVER PHOTO

Chevron folds in Roseburg Formation exposed in roadcut on east bank of Umpqua River immediately east of Woodruff Mountain in southwestern Oregon (see article beginning next page). These folds may be associated with a branch of the Bonanza fault. Photo courtesy Ewart Baldwin.

Micropaleontological data from five oil and gas wells released

The Oregon Department of Geology and Mineral Industries (DOGAMI) has released micropaleontological data on samples from five oil and gas test holes drilled along the west side of the Willamette Valley as Open-File Report 0-80-1, *Micropaleontological Study of Five Wells, Western Willamette Valley, Oregon.* The work was performed by Daniel R. McKeel, Consulting Micropaleontologist, under contract to DOGAMI.

The five wells selected for micropaleontological study, located between Forest Grove to the north and Albany to the south, are Texaco Cooper Mountain 1, Reichhold Merrill 1, Reichhold Finn 1, Reserve Bruer 1, and Humble Miller 1. Geologic ages (foraminiferal stages) have been assigned by McKeel to rock units penetrated in the wells. Paleoenvironments are also indicated. Results of the micropaleontological work will be useful for future geologic investigations of the area and western Oregon.

Copies of Open-File Report 0-80-1 may be purchased for $2.00. Address orders to the Oregon Department of Geology and Mineral Industries, 1069 State Office Building, Portland, OR 97201. Payment must accompany orders of less than $20.00. □

CONTENTS

Send us your new address

When you move, don't forget to send your new address to the Oregon Department of Geology and Mineral Industries.

Deposition and deformation of the Eocene Umpqua Group, Sutherlin area, southwestern Oregon

by R.K. Perttu, Bear Creek Mining Company, Spokane, Washington 99213, and
G.T. Benson, Earth Sciences Department, Portland State University, Portland, Oregon 97207

ABSTRACT

The lower to middle Eocene Umpqua Group, 5,000-10,000 m (16,500-33,000 ft) thick, exposed north of Roseburg, Oregon, consists of basal tholeiitic basalt overlain by a thick turbidite sequence and succeeding interbedded siltstone, sandstone, and conglomerate, all involved in northeast-trending folds with local, intensely deformed zones. In contrast, the middle Eocene Tyee Formation, mainly thick-bedded sandstone, of the Coast Range to the west and the upper Eocene and younger andesitic volcanic rocks of the Cascade Range to the east are only slightly deformed around generally north-trending axes. Lithology and current directions suggest contemporaneity of deposition and development of the Umpqua Group structures in the Roseburg-Sutherlin area. Here the Umpqua Group represents the slope development of an accreting continental margin followed by shelf deposits of the Tyee Formation.

INTRODUCTION

Marine sedimentary and basaltic volcanic rocks of the lower to middle Eocene Roseburg and Lookingglass Formations crop out in a broad, north-trending belt north of Roseburg, Oregon (Figure 1). This belt is bounded on the west and north by the slightly younger middle Eocene Flournoy and Tyee Formations which form most of the southern Oregon Coast Range, on the east by upper Eocene and younger andesitic volcanic and associated rocks of the western Cascade Range, and on the south by pre-Tertiary rocks of the northern Klamath Mountains. Structures in the Roseburg Formation are large, northeast-trending, faulted folds that parallel the pre-Tertiary grain in the northernmost Klamath Mountains. These Roseburg Formation structures are quite different from the open, north-trending flexures in the slightly younger Eocene formations of the Coast and Cascade Ranges. Sedimentary structures and facies distribution suggest that deformation of the Umpqua Group was necessarily almost contemporaneous with its deposition, and the two processes must have been interrelated. Furthermore, the changes in lithology and structural trends from the Roseburg Formation to younger units suggest a transition from an active continental slope to a more stable shelf environment.

STRATIGRAPHY

The pre-Tertiary units of the Klamath Mountains crop out south of the Sutherlin area and may partially underlie it. These Klamath Mountains units include Jurassic and Cretaceous graywacke, conglomerate, mudstone, and volcanic rocks, which are generally sheared and/or metamorphosed, with local pods of chert and blueschist and bodies of serpentinite (Ramp, 1972), all with a strong, northeast-trending structural grain. Successively younger units in the Sutherlin area are the Roseburg, Lookingglass, and Flournoy Formations (Umpqua Group); the Tyee Formation; and the volcanogenic rocks of the Western Cascade suite.

Umpqua Group

The Umpqua Formation was defined by Diller (1898) as a thick Eocene sequence consisting predominantly of thin-bedded alternating sandstone and shale overlying and interfingering with volcanic rocks. Baldwin (1965, 1974, 1975) subdivided the Umpqua into the Roseburg, Lookingglass, and Flournoy Formations, permitting elevation of the Umpqua to group status (Thoms, 1975). Baldwin (1974) included the volcanic rocks in the Roseburg Formation but distinguished them on his map; Thoms (1975) referred them to the "Siletz River Formation." We have chosen to call these volcanic rocks Roseburg basalt, following Baldwin.

Roseburg basalt: Basaltic volcanic rocks, mainly pillow lavas and zeolitized breccia with an aggregate thickness of up to 2,000 m (6,600 ft) or more, form the basal unit of the Umpqua Group in the Roseburg area (Baldwin, 1974). The volcanic rocks interfinger with and are overlain by Umpqua Group sedimentary rocks (including units younger than the Roseburg Formation) in cores of structural highs as far north as Drain (Figure 2). The Roseburg basalt is tholeiitic, similar to the lower part of the Siletz River Volcanics of early to middle Eocene age in the northern Oregon Coast Range (Snavely and others, 1968). The basalt is not everywhere present at the base of the Umpqua Group (Figure 1).

Roseburg Formation: The lower sedimentary unit of the Umpqua Group, the Roseburg Formation, includes sandstone, siltstone, mudstone, and minor conglomerate. In the Sutherlin area, the Roseburg sedimentary section is at least 2,500 m (8,000 ft) thick and consists predominantly of rhythmically alternating graywacke and mudstone beds. Most of the sandstone beds were deposited by turbidity currents. Graded bedding is common, with some beds containing more than one grading unit, and scour structures and bioturbation are evident. Conglomerate occurs mainly near the Roseburg basalt, which was the primary source of the clasts. In general, the ratio of sandstone to siltstone in the Roseburg Formation decreases northward, away from the presumed source area.

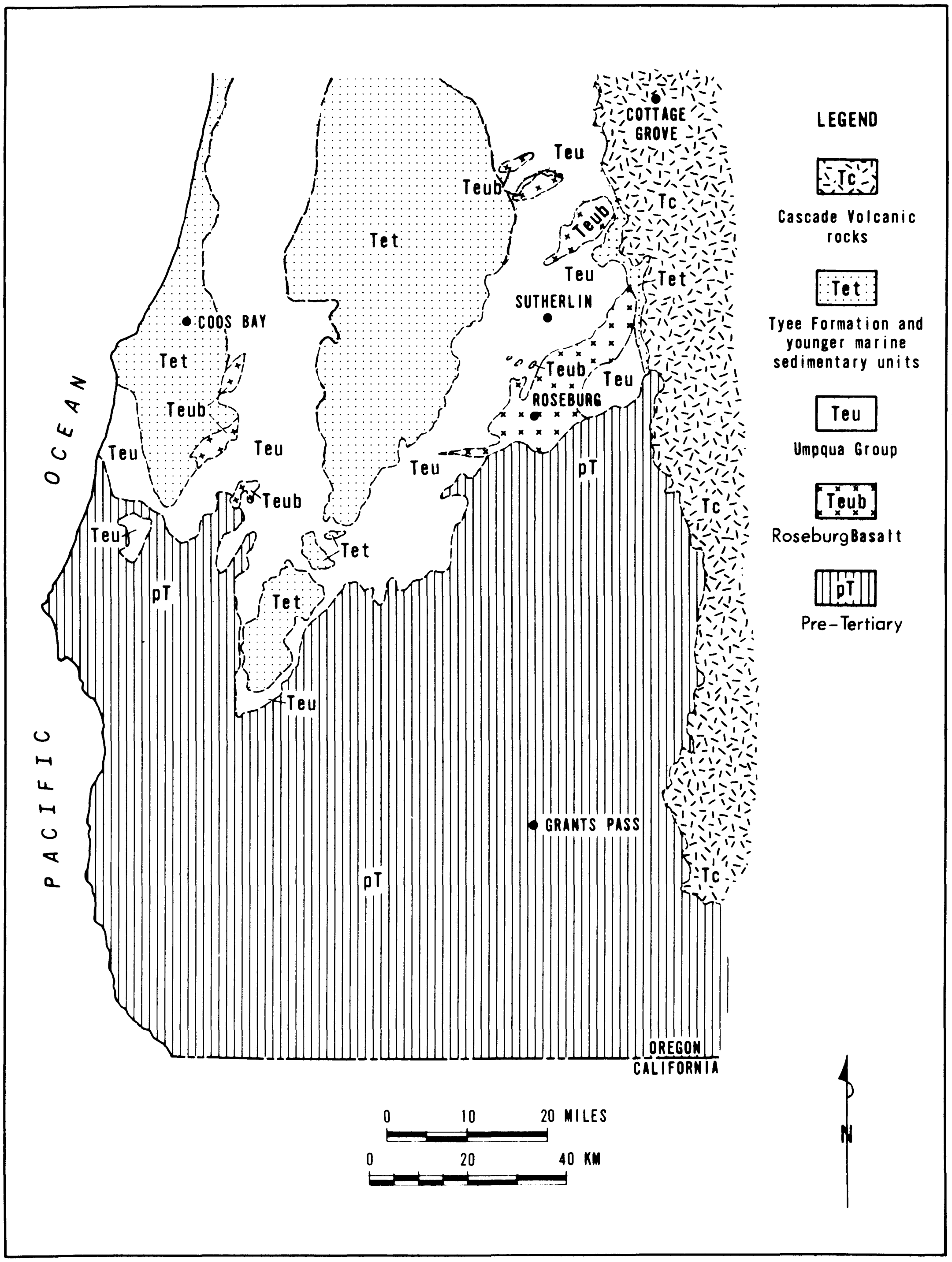


Figure 1. Regional geologic map of southwestern Oregon showing Umpqua Group and adjacent major rock units (modified from Wells and Peck, 1961, and Baldwin, 1976).

Lookingglass Formation: In its type area, southwest of Roseburg, Baldwin (1974) has subdivided the Lookingglass Formation into three members: basal conglomerate and sandstone, middle siltstone and sandstone, and upper sandstone and conglomerate. Further south, where the Lookingglass oversteps the pre-Tertiary, the middle unit becomes coarser; locally, it pinches out and interfingers with the upper and lower members. To the north, the Lookingglass, like the Roseburg, becomes finer grained, and the basal Lookingglass conglomerate is only locally present, as at Woodruff Mountain (Figure 2).

Clasts in the Lookingglass conglomerate include a variety of plutonic and metamorphic rock types apparently derived from Klamath Mountains terranes, in contrast to the predominant basalt pebbles in the Roseburg

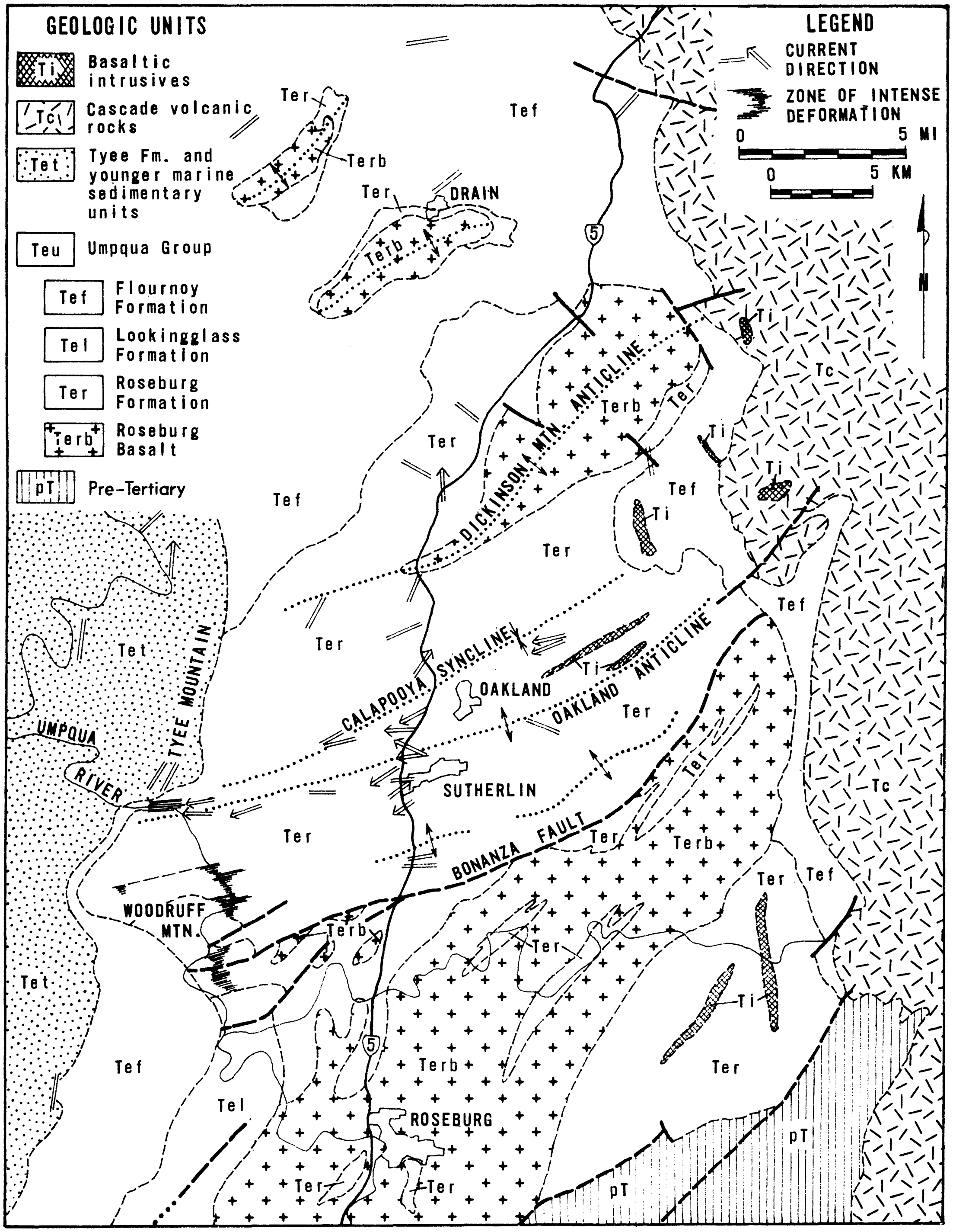


Figure 2. Regional geologic map of the Sutherlin area, Oregon (modified from Ramp, 1972, and Baldwin, 1974).

conglomerate. Lookingglass sandstone beds are generally not graded and, especially to the south, are characterized by fossil assemblages (Baldwin, 1975) suggestive of a shallower depositional environment. The Lookingglass conglomerate at Woodruff Mountain may represent a channel filling on the continental shelf or upper slope.

As a rule, lithology is more consistent in the Lookingglass Formation than it is in the Roseburg Formation; deformation is less intense, with decreasing deformation upward in the formation, and dips are gentler. A regional difference in attitudes has been shown by Girard (1962). Local steep dips in the lower part of the Lookingglass Formation probably mark the dying phases of the Roseburg-style deformation.

Flournoy Formation: West of Roseburg, the Flournoy Formation is about 900 m (3,000 ft) thick and includes a lower unit composed of sandstone and lesser siltstone and an upper unit composed of alternating beds of sandstone and siltstone (Baldwin, 1974). To the south, the Flournoy sandstone becomes coarser grained, thicker, and lithologically very similar to the overlying Tyee Formation. To the north, the Flournoy Formation is finer grained, which is consistent with the regional facies patterns in the Umpqua Group.

Tyee Formation

Resistant sandstone beds of the Tyee Formation form ridges of the southern Oregon Coast Range. In its southern facies (Lovell, 1969), the Tyee Formation is up to 1,500 m (5,000 ft) thick and consists principally of thick-bedded sandstone with lesser siltstone and pebble conglomerate. The sandstone is typically medium- to coarse-grained, micaceous, lithic to feldspathic graywacke. Cross-bedding and channeling, plant remains, and coal lenses are common. To the north, bedding becomes thinner and rhythmic, the ratio of sand to silt decreases (Baldwin, 1975), and fossils are not found (Thoms, 1975). This transition suggests a change from delta to shelf and perhaps marginal basin facies.

Dips in the Tyee Formation are gentle. In particular, the beds exposed in the long Tyee escarpment west of Sutherlin do not reflect either the northeasterly trends or the degree of deformation found in the underlying Roseburg and Lookingglass Formations (Figure 2).

Volcanic units of the Western Cascade Range

Late Eocene and younger volcanic and volcaniclastic rocks of the western Cascade Range overlie Tyee, Umpqua, and pre-Tertiary units east of Sutherlin and Roseburg (Figures 1 and 2). The predominantly andesitic Cascade rocks generally dip gently eastward into a pile thousands of meters thick.

A few sills and dikes of basaltic composition cut the Eocene rocks east of Sutherlin and Roseburg (Figure 2). These intrusions may be as old as late Eocene or as young as Miocene.

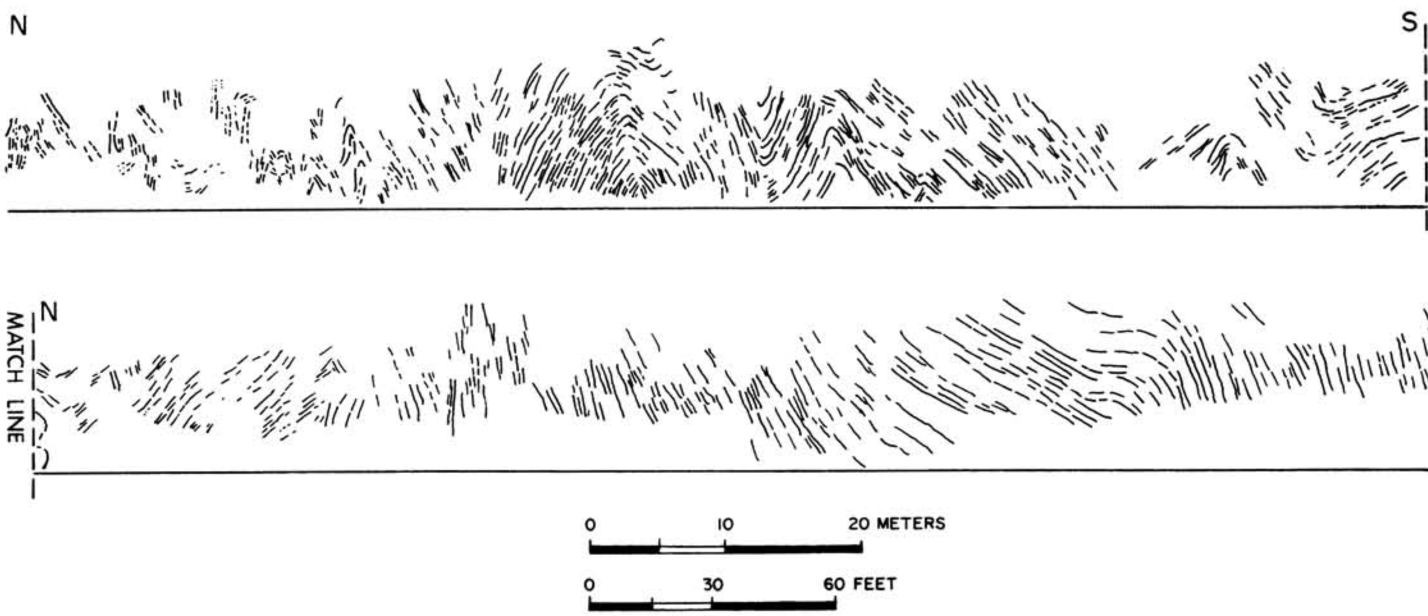
CURRENT DIRECTIONS

Current directions in the Roseburg Formation and in the Flournoy and Tyee Formations, as shown in Figure 2 and plotted in half-rose diagrams in Figure 5, are markedly different. Directions in the Roseburg Formation, based on scour marks (groove and flute casts, bounce and prod marks), show that the turbidity flows were mainly from the east. In contrast, Flournoy and Tyee currents (data mainly from Snavely and others, 1964) flowed northward from the Klamath Mountains province. Only Flournoy and Tyee current directions appearing on the map (Figure 2) are shown in the half-rose diagram (Figure 5); if all of the data of Snavely and others (1964) were included, the northward trend would be much more pronounced.

STRUCTURAL GEOLOGY

The large structures in the Sutherlin area are folds and associated faults which trend generally N. 60° E. (Figure 2), with wave lengths and amplitudes on the order of 10 km (33,000 ft) and 1,000 m (3,300 ft) or more, respectively. The folds are asymmetric; north limbs of the anticlines are typically steep and locally overturned, but south limbs are relatively gentle. The anticlines tend to have sharp hinges, whereas the synclines are open and relatively flat bottomed. Axial traces are sinuous, trending N. 45°-75° E.

Figure 3. Sketch of folds in the Roseburg Formation exposed in a roadcut east of Woodruff Mountain. Some of these folds are shown in the cover photograph.



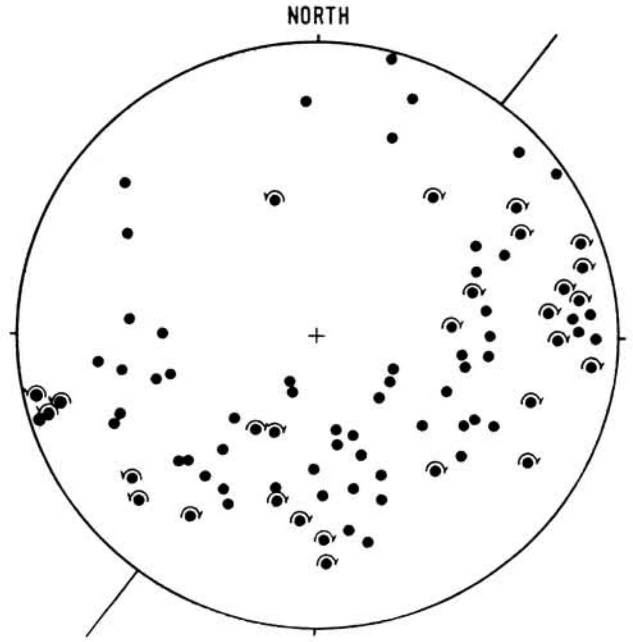


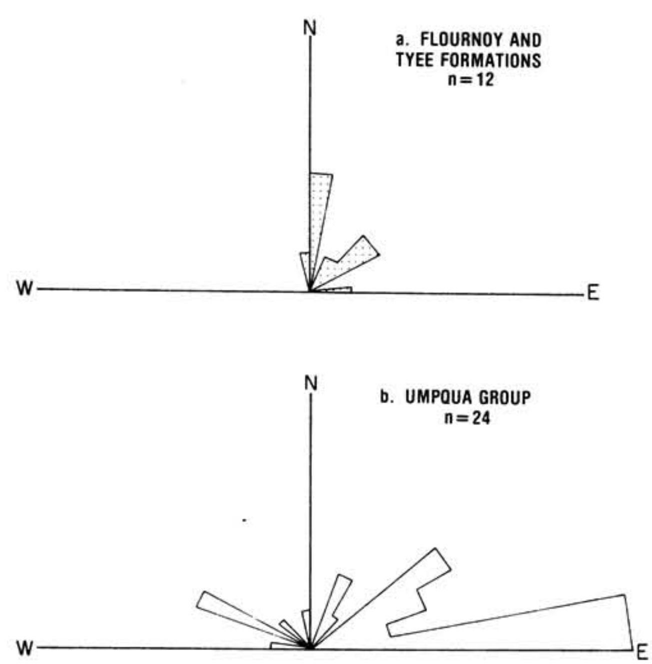
Figure 4. Equal-area diagram of fold axes in the Roseburg Formation near Woodruff Mountain. Arrows show shear (rotation) sense looking down plunge.

The best known fault in the Sutherlin area is the Bonanza fault (Figure 2), which trends northeasterly more or less parallel to the major folds and to the faults in the pre-Tertiary south and east of Roseburg. Baldwin (1964) described the Bonanza fault as a thrust. At the Bonanza mine, east of Sutherlin, the fault zone dips about 45° SE, with the Roseburg basalt moved up and over sedimentary rocks of the Roseburg Formation; dip-slip displacement (dip-separation) is on the order of 1,500 m (5,000 ft). The trace of the Bonanza fault is less certain to the southwest (compare Baldwin, 1964 and 1974, and Ramp, 1972). Near Woodruff Mountain, a branch of the fault apparently offsets the basal Lookingglass conglomerate by an amount considerably less than the maximum displacement in the Roseburg Formation, but the fault does not break the Tyee. Other similar northeast-trending reverse faults occur in the area but are generally of lesser extent and displacement.

Although dips are gentle in the synclines and fairly constant on the limbs of the large anticlines (such as the Oakland anticline), several zones of intense minor folding in the Sutherlin area are noteworthy (Figure 2). One of these zones is exposed along the banks of the Umpqua River just east of Woodruff Mountain. Chevron or accordion folds with wave lengths and amplitudes of 5-10 m (15-30 ft) are typical. A roadcut section about 200 m (650 ft) long, sketched in Figure 3, illustrates the style of folding in this zone. Individual folds are not restricted to a few beds, and the sandstone and shale beds were already considerably lithified before folding. The folds were probably formed at relatively shallow depths, judging from continuity of bedding and constant thickness of sandstone beds even in hinges. These folds are almost certainly not slump structures formed more or less contemporaneously with deposition. The style of folding is controlled by lithology; the accordion folds are best developed in thinly bedded, well-stratified rocks of the Roseburg Formation. An equal-area plot of fold axes (Figure 4) shows considerable scatter, but reversal of shear sense suggests a N. 40° E. (or S. 40° W.) tectonic transport direction (see Hansen, 1971). Given the relatively slight deformation of younger units, refolding is inadmissible as an explanation for the scatter; more likely the scatter happened as the folds were forming.

The origin of these folds is of interest. A preliminary hypothesis that the folds resulted from movement of the thin-bedded Roseburg units beneath the massive Lookingglass conglomerate of Woodruff Mountain is not entirely satisfactory. Deformation in thin Lookingglass beds adjacent to the conglomerate is much less severe, and other zones of intense minor folding are present in the Roseburg where the Lookingglass conglomerate is not present, for example, south of Tyee Mountain (Figure 2). The fold zone near Woodruff Mountain may be related to the Bonanza fault. South and east of Sutherlin, the Bonanza fault juxtaposes Roseburg basalt and sedimentary rocks of the Roseburg Formation. To the west, however, the fault trace splays out into sedimentary rocks, and the intense minor folding may take up part of the displacement. The Bonanza fault does not offset the Flournoy or Tyee Formations, but it may reappear in the Roseburg Formation some 35 km (22 mi) to the west, east of Myrtle Point (see Baldwin, 1974, map), from beneath the Lookingglass Formation.

Figure 5. Half-rose diagrams of current directions in (a) the Flournoy and Tyee Formations, and (b) the Roseburg Formation. Current directions were taken from map shown in Figure 2.



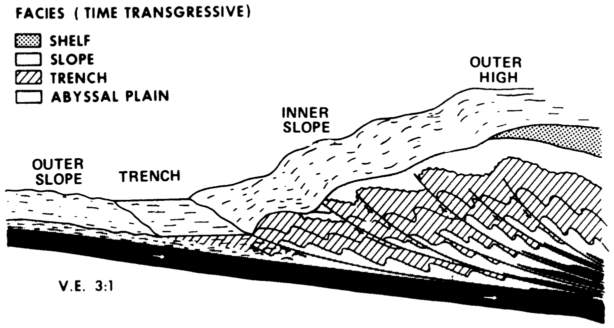


Figure 6. The Umpqua Group may have been deposited on an accreting continental slope and shelf in a fashion similar to that proposed by Seely and others (1974), with whose permission this illustration is reproduced.

SYNTHESIS

One explanation of the structures in the Sutherlin area could be that they were formed in a single deformational event after deposition of the Roseburg sediments and then uplifted and eroded prior to deposition of the Lookingglass Formation. However, the change in rock types going up in the stratigraphic column shows a logical transition from the thin, rhythmic, turbidite slope deposits of the Roseburg Formation to the deltaic or shelf deposits of the nearby Tyee Formation. The large, northeast-trending folds in the Sutherlin area were forming while the Roseburg sediments were being deposited on the continental slope. Decreasing deformation upward in the section also indicates a transition to a more stable shelf environment, and the relationship between stratigraphy and structure suggests that deposition and structural development occurred contemporaneously.

Currents carrying Roseburg sediments may well have been controlled by the growing, northeasterly-trending folds. By the time of deposition of the Tyee Formation, these structures had become inactive, and almost all were buried, although a few remaining topographic highs on the Tyee sea floor locally affected flow patterns, as near Drain. Turbidity flows originating near the top of the slope to the south and east would have been deflected by the developing ridges to flow down trough axes; as each successive trough was filled, or where the divide was low, flows would have overtopped the adjacent downslope ridge and contributed finer grained and progressively younger sediments to the next lower trough. This model, like a series of baffles across a slope, would explain both the Roseburg Formation current directions and the northward change to finer grained facies.

The modern continental margin of Oregon and Washington (Silver, 1971, 1972; Carson and others, 1974; Kulm and Fowler, 1974) is comparable to this model. Longitudinal ridges and troughs characterize the present continental slope. Seismic profiles show these ridges to be anticlinal and commonly bounded by steep faults; the intervening troughs are filled with younger, less deformed sediments, and essentially undeformed shelf deposits cover the slope units with apparent angular discordance. This model is illustrated in Figure 6.

The modern analog suggests that the Umpqua Group and Tyee Formation were sequential parts of an accreting continental margin, with depositional patterns closely related to structural development.

ACKNOWLEDGMENTS

Our thanks to Chris L. Nastrom, who assisted in drafting, to Ewart M. Baldwin for many discussions of Umpqua stratigraphy, and to our colleagues for critically reading the manuscript and patiently listening to our ideas.

REFERENCES

Baldwin, E.M., 1964, Thrust faulting in the Roseburg area, Oregon: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 26, no. 10, p. 176-184.

——— 1965, Geology of the south end of the Oregon Coast Range Tertiary basin: Northwest Science, v. 39, no. 3, p. 93-103.

——— 1974, Eocene stratigraphy of southwestern Oregon: Oregon Department of Geology and Mineral Industries Bulletin 83, 40 p.

——— 1975, Revision of the Eocene stratigraphy of southwestern Oregon, *in* Weaver, D.W., Hornaday, G.R., and Tipton, A., eds., Paleogene Symposium and selected technical papers: Annual Meeting, Pacific Sections, AAPG, SEPM, SEG, Long Beach, Calif., April 1975, p. 49-64.

——— 1976, Geology of Oregon (rev. ed.): Dubuque, Ia., Kendall/Hunt Publishing Co., p. 25.

Baldwin, E.M., and Perttu, R.K., 1980, Paleogene stratigraphy and structure along the Klamath borderland, Oregon, *in* Oles, K.F., Johnson, J.K., Niem, A.R., and Niem, W.A., eds., Geologic field trips in western Oregon and southwestern Washington: Oregon Department of Geology and Mineral Industries Bulletin 101, p. 9-31.

Carson, B., Yuan, J., Meyers, P.B., Jr., and Barnard, W.D., 1974, Initial deep-sea sediment deformation at the base of the Washington continental slope: a response to subduction: Geology, v. 2, no. 11, p. 561-564.

Diller, J.S., 1898, Roseburg folio, Oregon, folio 49 *of* Geologic atlas of the United States: U.S. Geological Survey.

Girard, W.W., 1962, Stereonet analysis of moderately deformed sedimentary strata: Eugene, Oreg., University of Oregon master's thesis, 50 p.

Hansen, E., 1971, Strain facies: New York, Springer-Verlag, 207 p.

Kulm, L.D., and Fowler, G.A., 1974, Oregon continental margin structure and stratigraphy: a test of the imbricate thrust model, *in* Burk, C.A., and Drake, C.L., eds., The

(Continued, p. 146)

A personal account of a nuée ardente on Mount St. Helens during the eruption of May 18, 1980

by Guy H. Rooth, Oregon College of Education, Monmouth, Oregon 97361

INTRODUCTION

On the afternoon of May 18, 1980, while watching the eruption of Mount St. Helens from a plane, I observed a rapidly moving pyroclastic flow (nuée ardente) on the south side of the mountain. Also in the plane was photographer Roland Giesbrecht, who captured the event on film.

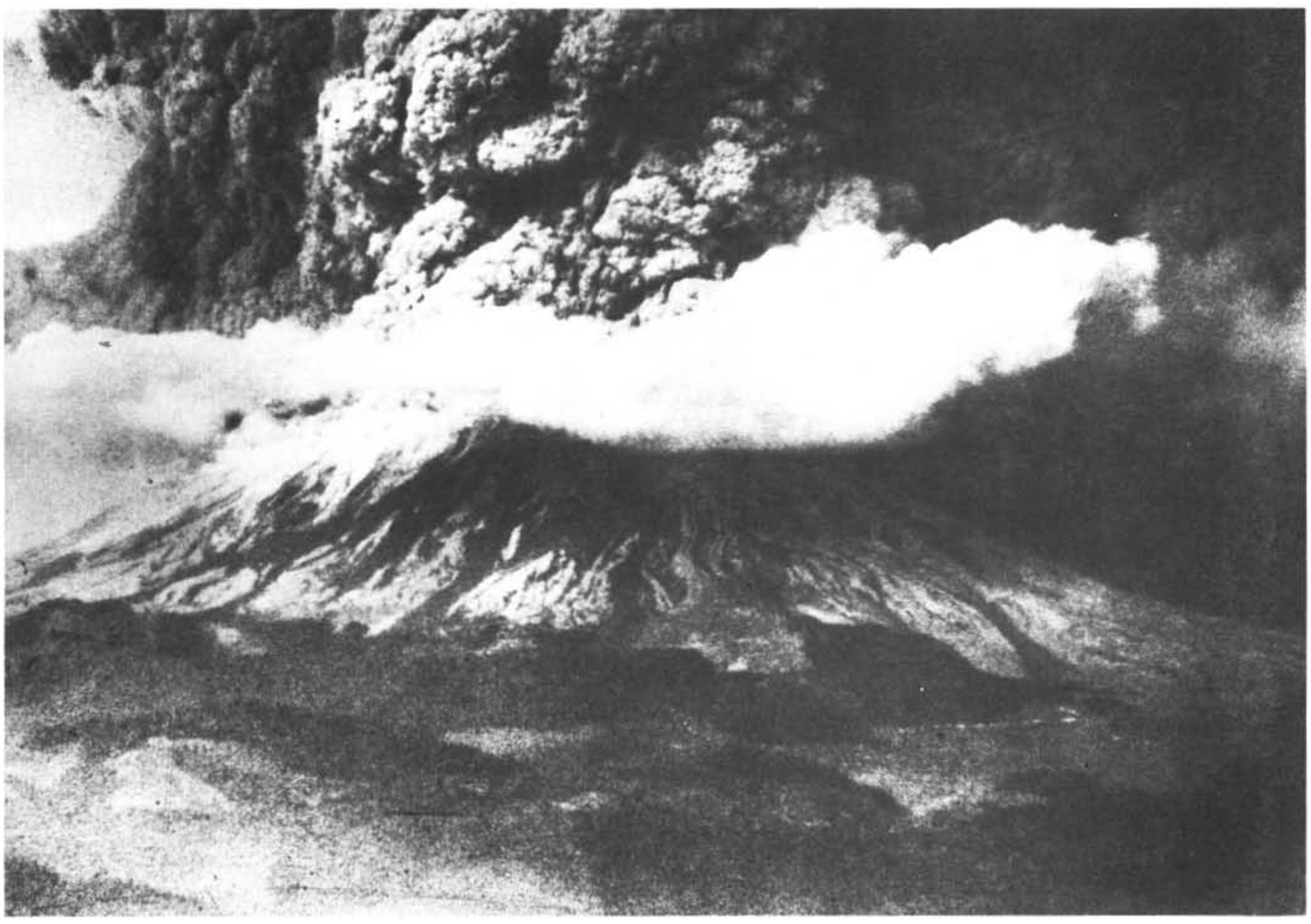
Eyewitness accounts of events of these features by geologists are rare. This may be the first such account from within the continental United States. The purpose of this paper is to describe the event and to encourage others who may have witnessed or photographed it to share their information.

Sheridan (1979) includes all denser-than-air avalanches, streams, and flows within the term "pyroclastic flow." Because two types of pyroclastic flows were observed simultaneously during the May 18 eruption, for purposes of clarity the general term "pyroclastic flow" is restricted in this report to slow-moving flows lacking a suspended cloud of ash. The terms "rapidly moving pyroclastic flow" and "nuée ardente" are used to describe material consisting of a basal avalanche and a suspended cloud of ash, all traveling at high speeds.

EVENTS PRIOR TO THE NUÉE ARDENTE

Our plane arrived in the vicinity of Mount St. Helens shortly after 2 p.m. on May 18, 1980, while the eruption was still in progress. For about an hour and a half, we photographed and observed the mountain from a distance of 20 mi due west, as required by the Federal Aviation Administration. Most of our observations were from an elevation of about 11,000 ft. During that time, the top of the column of eruptive material was hidden from view by a persistent layer of stratus clouds.

Figure 1. Eruption of Mount St. Helens viewed from the west at approximately 3:30 p.m., May 18, 1980. Slow-moving pyroclastic flows visible near summit on northwest side. (Photo courtesy Roland Giesbrecht)



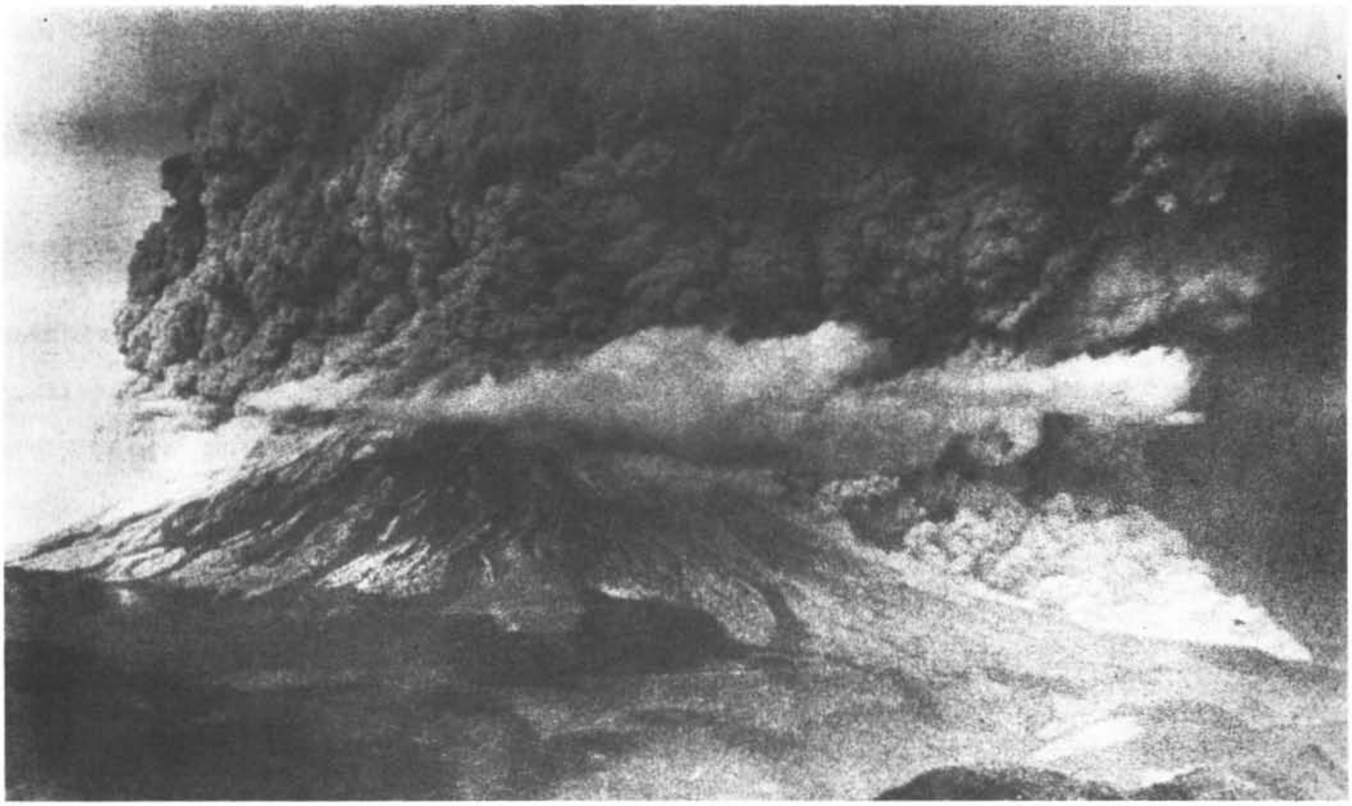
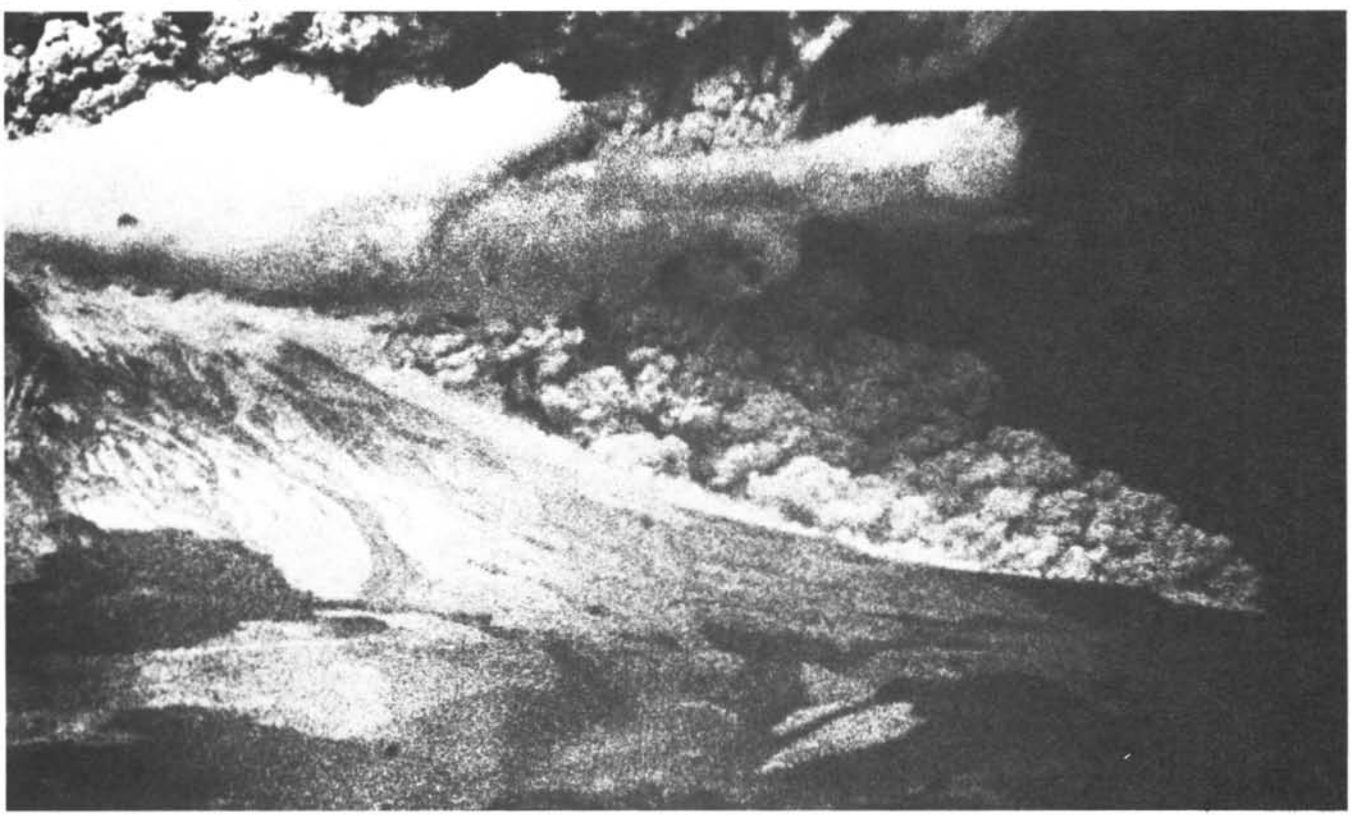


Figure 2. Rapidly moving pyroclastic flow (nuée ardente) on south flank of Mount St. Helens at approximately 3:53 p.m., May 18, 1980. Slow-moving pyroclastic flows still visible on northwest side. 135-mm lens. (Photo courtesy Roland Giesbrecht)

Figure 3. Rapidly moving pyroclastic flow (nuée ardente) on south flank of Mount St. Helens, May 18, 1980, a few seconds after Figure 2. 230-mm lens. (Photo courtesy Roland Giesbrecht)



A large gray column of pumice and ash poured forth from the summit of the volcano. It appeared to hang motionless in the air, but if one looked carefully at a portion of the column, the turbulent motion of the material became readily apparent. Lightning bolts were common. Very little material appeared to be falling near the mountain on the north, west, or south sides. All of the material appeared to be moving turbulently upward within the eruptive column.

Material was emanating equally from the entire summit of the volcano, and one could not tell from the eruptive cloud that a large part of the north slope of the mountain had been blown away during the initial eruption earlier that day.

From a distance of 20 mi, no instances of partial column collapse were observed. For more than half an hour, slow-moving pyroclastic flows could be seen on the northwest side of the volcano (Figure 1). However, at that distance, forward movement of the flows was not discernible.

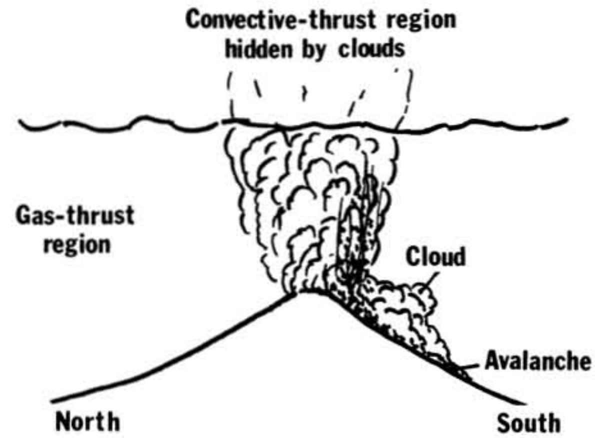


Figure 4. Schematic diagram of eruption of Mount St. Helens, May 18, 1980, showing possible collapse within gas-thrust region which produced the rapidly moving pyroclastic flow (nuée ardente) (after Sheridan, 1979).

OBSERVATIONS OF THE NUÉE ARDENTE

Shortly before 4 p.m., we had finished taking pictures and had turned the plane to the south to return to Salem, Oregon. The photographer, glancing back toward the mountain, called my attention to a change in the nature of the eruption.

I immediately noticed a rounded bulge of material descending from the eruptive column onto the south side of the mountain near the summit. We quickly turned the plane and began taking pictures. The bulge rapidly changed shape and appeared to flow at a high rate of speed down the mountain as a basal avalanche traveling faster than the suspended, turbulent cloud above it.

When the material was nearing the change in slope at the base of the cone of Mount St. Helens, I glanced at my watch, and it read 3:52 p.m. Shortly after that time, Roland Giesbrecht took the photograph in Figure 2 with a 135-mm lens. A few seconds later he took Figure 3 with a second camera equipped with a 230-mm lens. The distance the nuée ardente advanced past a small hill during those few seconds can be seen by comparing the two photographs.

Unknown to me at the time, Charles Rosenfeld of the Geography Department at Oregon State University was in an Oregon Army National Guard plane at a distance of slightly more than a mile from the mountain. His plane was flying from the west side of the mountain toward the south side. He saw the start of the nuée ardente and watched it pass from view beneath his plane in a matter of seconds (personal communication, 1980). He estimated the speed to have been 70 to 100 mi per hour. While he did not witness a collapse of the eruptive column at that time, he had seen a partial collapse a few minutes earlier farther to the west.

It took about two minutes for material to travel from the summit of the volcano out of sight into low hills at the base, a distance of 4 to 5 mi. For the next two minutes, additional material continued to flow down the flanks of the mountain. The suspended cloud was several thousand feet high. Two minutes after the flow had stopped, the remaining suspended material settled to the ground, leaving empty space where the cloud had been. My watch read 3:56 p.m. after the cloud had settled. From the estimates given above, it seems likely that speeds from 60 to more than 100 mi per hour were attained by the rapidly moving basal avalanche part of the flow.

ANALYSIS

During the eruption, only the gas-thrust region of the eruptive column (as described by Sheridan, 1979) was visible. Material was carried upward by the explosive force of the escaping volcanic gases. The overlying convective-thrust portion of the eruptive column is said in newspaper accounts to have reached elevations in excess of 60,000 ft. However, it was not visible to us.

The nuée ardente was probably triggered by a partial collapse of larger tephra material falling back against the south side of the summit of the volcano and trapping gases to provide the high mobility and rate of flow observed (Figure 4). No preceding blast was noticed. Material appeared to fall vertically as a rounded bulge beneath the eruptive column. Once the material had fallen onto the flanks of the mountain, it appeared to flow rapidly as a basal avalanche and suspended cloud. Bolt and others (1975) describe similar occurrences during the eruptions of Soufrière on the island of St. Vincent in 1902 and the Russian volcano Bezymianny in 1956. Sheridan (1979) reports the formation of rapid pyroclastic flows resulting from gravitational collapse of columns during the eruptions of Komagatake in Japan in 1929, Mayon in the Philippines in 1968, and Ngauruhoe in New Zealand in 1975. The eruption witnessed on Mount St. Helens appears to fit into the small to intermediate types of eruptions described by Smith (1960).

ACKNOWLEDGMENTS

I am indebted to Roland Giesbrecht for taking, under very difficult lighting conditions, the photographs which accompany this article. David Woods and Ron Cooper prepared the black-and-white prints. Charles Rosenfeld contributed valuable advice and materials. The manuscript was reviewed by Ray Brodersen.

REFERENCES

Bolt, B.A., Horn, W.L., MacDonald, G.A., and Scott, R.F., 1975, Geological hazards: New York, Springer-Verlag, 328 p.

MacDonald, G.A., 1972, Volcanoes: Englewood Cliffs, N.J., Prentice-Hall, 510 p.

Sheridan, M.F., 1979, Emplacement of pyroclastic flows: a review, *in* Chapin, C.E., and Elston, N.E., eds., Ash-flow tuffs: Geological Society of America Special Paper 180, p. 125-136.

Smith, R.L., 1960, Ash flows: Geological Society of America Bulletin, v. 71, no. 6, p. 795-841. □

New geology glossary adds 3,000 terms

A major dictionary of the earth sciences—the *Glossary of Geology*—is now available in an expanded up-to-date edition. It includes 36,000 terms, compared to 33,000 in the 1972 edition, and reflects changes in the geoscience vocabulary in the last decade.

Changes in the *Glossary* are particularly evident in such active fields as biostratigraphy, remote sensing, plate tectonics, igneous petrology, paleomagnetism, and seismic stratigraphy. The compilers added about 450 new mineral names, more than 100 abbreviations, and nearly 500 new references to the literature.

The new work was edited by Robert L. Bates, who is widely known for his monthly column in *Geotimes*, and Julia A. Jackson of the American Geological Institute. The editors worked with the help of nearly 150 specialists who reviewed definitions, added new terms, and cited references.

Robert L. Bates is emeritus professor at Ohio State University, author of a textbook on geology of industrial rocks and minerals, and an honorary member of the Association of Earth Science Editors. Julia A. Jackson is editor of AGI's newsletter, *Geospectrum*, and a member of AESE.

The *Glossary of Geology* (second edition) has 749 pages and sells for $60. It may be ordered from the American Geological Institute, One Skyline Place, 5205 Leesburg Pike, Falls Church, Virginia 22041. There is a 10 percent discount for bulk orders of 10 or more copies on one order. □

Types of scientific studies conducted on Mount St. Helens, July 1980

The left-hand column in the following table tells the types of scientific studies conducted at Mount St. Helens, Washington, during July. The second column indicates the number of U.S. Geological Survey (USGS) studies. The third column shows the number of entry permits that the St. Helens Coordinating Committee issued to other agencies so that they could conduct their studies.

Type of study	USGS	Other agencies
Educational	—	7
Photography	1	5
Vulcanism, general	1	2
Thermal imagery	2	3
Hazards	1	1
Geomorphology and deformation	1	2
Mud flows	1	4
Tiltmeter	1	1
Tephra	1	11
Geothermal, thermal	1	1
Petrology, geology	1	3
Biology	—	3
Debris flow	2	1
Gas analysis	1	1
Trace elements	1	2
Seismic	1	—
Gravity	1	—
SLAR (Side-Looking Airborne Radar)	1	—
TV	1	1
Engineering	1	—
Pyroclastic flows	1	—
Blast deposits	1	—
Hydrothermal and weathering	1	—
Eruption dynamics	1	—
Electromagnetic	1	—

—Data supplied by the St. Helens Coordinating Committee □

USGS bibliography of continental shelf and coastal zone available

Copies of the U.S. Geological Survey Open-File Report 80-467, *Bibliography of the Geology of the Oregon-Washington Continental Shelf and Coastal Zone, 1899-1978*, by Gretchen Luepke, are available by mail from the Open-File Services Section, Branch of Distribution, U.S. Geological Survey, Box 25425, Federal Center, Denver, CO 80225. Price is $3.50 for each paper or microfiche copy. Orders must specify report number and contain check or money order payable to the U.S. Geological Survey. □

The gold dredge at Whisky Run north of the mouth of the Coquille River, Oregon

by Ewart M. Baldwin, Professor of Geology, Department of Geology, University of Oregon, Eugene, Oregon 97403

The soaring price of gold will no doubt renew interest in gold mining and challenge the ingenuity of those interested in extracting the elusive metal. The many devices constructed to concentrate gold during previous cycles of gold-mining fever in Oregon have ranged from those mechanically quite sound to those that were wholly impractical. Few devices, however, were more bizarre than the dredge shown in Figure 1.

The origin of the photo is unknown, but it has been passed down in the photo files left by the late Warren D. Smith and James Stovall, former professors of geology at the University of Oregon. The location inscribed in pencil on the back of the photo is given as Ophir, at the mouth of Euchre Creek, but that is far from the dredge's final resting place at Whisky Run, in the old Randolph mining district, a placer area along the beach north of the mouth of the Coquille River.

One historical reference to the dredge is a brief comment made by visitors to Whisky Run and quoted by Peterson and Powers (1952, p. 371-372) as follows:

> A big piece of machinery was nearby in a red-rusted and far-gone condition. They judged it to be the remains of the $60,000 contraption brought to Whisky Run by some Minnesota men in 1910 to prove itself to be no good in short order.

R.R. Horner, who worked for the U.S. Bureau of Mines, is also quoted by Peterson and Powers (1952, p. 378):

> Smith R. Bassett, representing Minneapolis parties, designed and built a dredge, mounted on hollow cylindrical wheels about 6 feet in diameter and about 5 feet wide. . . probably the most unique mechanical curiosity of all the devices for recovering gold from the black sands. On the steel frame of the dredge was mounted an endless-chain bucket digging device operated by steam engine. The machine was propelled by its own power and was designed to work the beach deposits lying between high and low tides. It proved a complete failure, as it was unstable and nearly capsized on the first trial run. With great difficulty it was finally dragged back to a place above high tide, where it now rests. This venture is said to have cost between $60,000 and $75,000.

This author examined the files of the *Coos Bay Times* (forerunner of the *Coos Bay World*) for January 1, 1910, to August 10, 1910, but found no reference to the venture. Later files for 1910 were not available. Pre-1915 copies of the *Western World*, published in

Figure 1. Gold dredge at mouth of Whisky Run, about 1910.

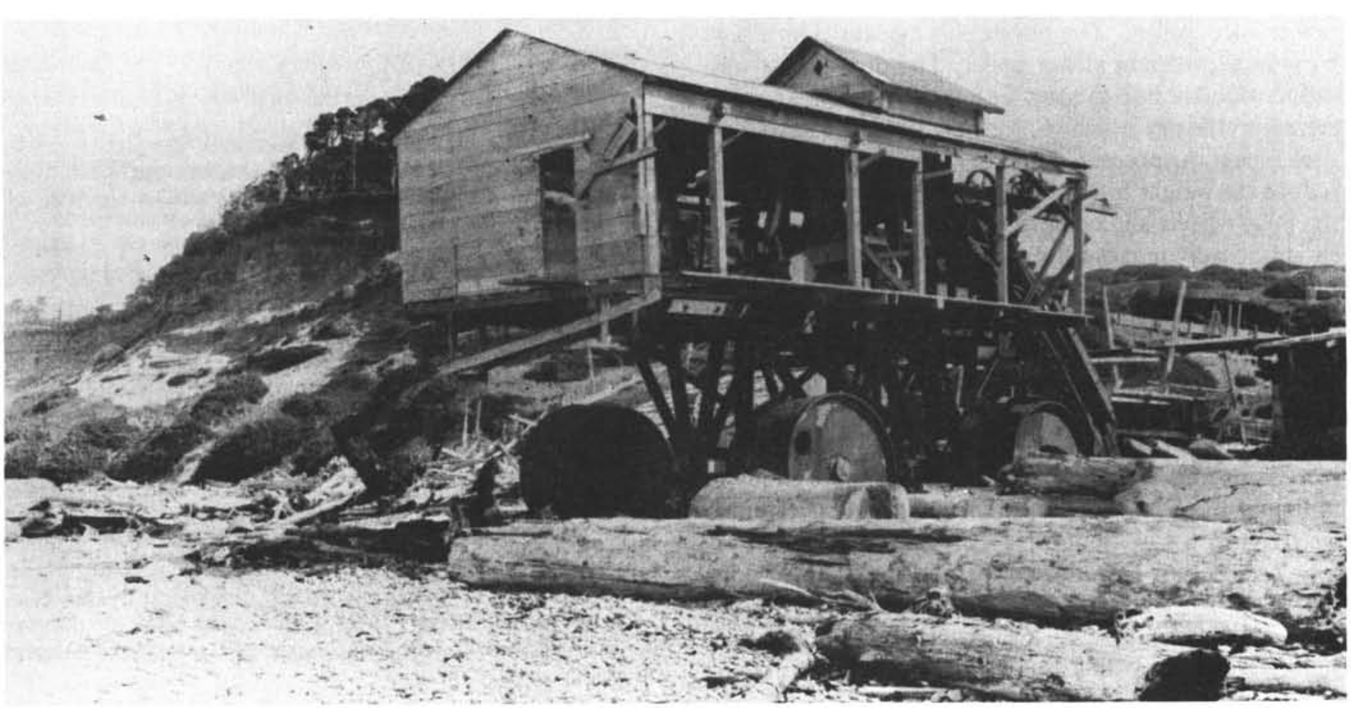


Figure 2. Large rear wheel of dredge, as it appeared in 1949. For scale: John McManigal, left; Len Ramp, center; and Robert Burke, right.

Bandon since 1912, were also unavailable.

The dredge was designed to roll on its large drum-like wheels, which were cleated in the rear where the power was applied. The power was evidently furnished by a small, upright steam boiler. The dredge was supposed to move into the surf at low tide, scoop up sand, retreat to the dry beach to work the sands for gold, and then repeat the process. The story is told that in order to reduce the weight of the dredge, valves were installed in the huge wheels and compressed air was injected, thereby supposedly making the structure lighter.

The dredge was evidently assembled in or near Bandon and moved under its own power along the beach northward to Whisky Run, a distance of approximately 6 mi. The terraces at Whisky Run had been mined off and on since the initial burst of activity in 1853-55, when the Randolph district was in its heyday. The area was revived during World War II, when chromite sands in tailings from some of the earlier gold mining ventures were mined for chromium.

This author first viewed the remains of the dredge in 1943 while working with the Coos County/Oregon Department of Geology and Mineral Industries coal survey (Allen and Baldwin, 1944). Figure 2 was taken during the summer of 1949. A visit to Whisky Run on March 3, 1980, failed to reveal any part of the machinery, but the driftwood was so abundant that metal objects could have been partially buried in the sand and covered by the wood.

REFERENCES CITED

Allen, J.E., and Baldwin, E.M., 1944, Geology and coal resources of the Coos Bay quadrangle, Oregon: Oregon Department of Geology and Mineral Industries Bulletin 27, 153 p.

Peterson, E.R., and Powers, Alfred, 1952 (reprinted 1977), A century of Coos and Curry: history of southwest Oregon: Portland, Oreg., Binford and Mort, 629 p. □

(**Umpqua Group**, *continued from p. 140)*

geology of continental margins: New York, Springer-Verlag, p. 261-283.

Lovell, J.P.B., 1969, Tyee Formation: undeformed turbidites and their lateral equivalents: mineralogy and paleogeography: Geological Society of America Bulletin, v. 80, no. 1, p. 9-21.

Ramp, L., 1972, Geology and mineral resources of Douglas County, Oregon: Oregon Department of Geology and Mineral Industries Bulletin 75, 106 p.

Seely, D.R., Vail, P.R., and Walton, G.G., 1974, Trench slope model, *in* Burk, C.A., and Drake, C.L., eds., The geology of continental margins: New York, Springer-Verlag, p. 249-260.

Silver, E.A., 1971, Tectonics of the Mendocino triple junction: Geological Society of America Bulletin, v. 82, no. 11, p. 2965-2977.

— — — 1972, Pleistocene tectonic accretion of the continental slope off Washington: Marine Geology, v. 13, p. 239-250.

Snavely, P.D., Jr., MacLeod, N.S., and Wagner, H.C., 1968, Tholeiitic and alkalic basalts of the Eocene Siletz River Volcanics, Oregon Coast Range: American Journal of Science, v. 266, no. 6, p. 454-481.

Snavely, P.D., Jr., Wagner, H.C., and MacLeod, N.S., 1964, Rhythmic-bedded eugeosynclinal deposits of the Tyee Formation, Oregon Coast Range: Kansas Geological Survey Bulletin 169, v. 2, p. 461-480.

Thoms, R.E., 1975, Biostratigraphy of the Umpqua Group, southwestern Oregon, *in* Weaver, D.W., Hornaday, G.R., and Tipton, A., eds., Paleogene Symposium and selected technical papers: Annual Meeting, Pacific Sections, AAPG, SEPM, SEG, Long Beach, Calif., April 1975, p. 513-562.

Wells, F.G., and Peck, D.L., 1961, Geologic map of Oregon west of the 121st meridian: U.S. Geological Survey Miscellaneous Geological Investigations Map I-325, in cooperation with the Oregon Department of Geology and Mineral Industries. □

PUBLICATIONS ORDER

Omission of price indicates publication is in press. Minimum mail order 50¢. All sales are final. Publications are sent postpaid. Payment must accompany orders of less than $20.00.

Fill in appropriate blanks and send sheet to Department (see address on reverse side).

YOUR NAME ______________________

ADDRESS ______________________

______________________ Zip ____________

Amount enclosed $ ____________

OREGON GEOLOGY

____ Renewal ____ Subscription ____ Gift

____ 1 Year ($4.00) ____ 3 Years ($10.00)

NAME ______________________

ADDRESS ______________________

______________________ ZIP ____________

(If Gift, From: ______________________)

ORDER FORM - CUT ON DASHED LINE

Available publications

MISCELLANEOUS PAPERS	Price	No. Copies	Amount
1. A description of some Oregon rocks and minerals, 1950: Dole	$ 1.00	____	____
4. Laws relating to oil, gas, and geothermal exploration and development in Oregon			
Part 1. Oil and natural gas rules and regulations, 1977, rev. 1980	1.00	____	____
Part 2. Geothermal resources rules and regulations, 1977, rev. 1979	1.00	____	____
5. Oregon's gold placers (reprints), 1954	.50	____	____
6. Oil and gas exploration in Oregon, rev. 1965: Stewart and Newton	3.00	____	____
8. Available well records of oil and gas exploration in Oregon, rev. 1973: Newton	1.00	____	____
11. Collection of articles on meteorites, 1968 (reprints from *The Ore Bin*)	1.50	____	____
13. Index to *The Ore Bin*, 1950-1974	1.50	____	____
14. Thermal springs and wells, 1970: Bowen and Peterson (with 1975 supplement)	1.50	____	____
15. Quicksilver deposits in Oregon, 1971: Brooks	1.50	____	____
16. Mosaic of Oregon from ERTS-1 imagery, 1973	2.50	____	____
18. Proceedings of Citizens' Forum on potential future sources of energy, 1975	2.00	____	____
19. Geothermal exploration studies in Oregon – 1976, 1977	3.00	____	____
20. Investigations of nickel in Oregon, 1978: Ramp	5.00	____	____
GEOLOGIC MAPS			
Geologic map of Galice quadrangle, Oregon, 1953	1.75	____	____
Geologic map of Albany quadrangle, Oregon, 1953	1.00	____	____
Reconnaissance geologic map of Lebanon quadrangle, 1956	1.50	____	____
Geologic map of Bend quadrangle and portion of High Cascade Mountains, 1957	1.50	____	____
Geologic map of Oregon west of 121st meridian, 1961	2.25	____	____
Geologic map of Oregon east of 121st meridian, 1977	3.75	____	____
GMS-3: Preliminary geologic map of Durkee quadrangle, Oregon, 1967	2.00	____	____
GMS-4: Oregon gravity maps, onshore and offshore, 1967 (folded)	3.00	____	____
GMS-5: Geologic map of Powers quadrangle, Oregon, 1971	2.00	____	____
GMS-6: Preliminary report on geology of part of Snake River Canyon, 1974	6.50	____	____
GMS-7: Geology of the Oregon part of the Baker quadrangle, Oregon, 1976	3.00	____	____
GMS-8: Complete Bouguer gravity anomaly map, Cascade Mountain Range, central Oregon, 1978	3.00	____	____
GMS-9: Total field aeromagnetic anomaly map, Cascade Mountain Range, central Oregon, 1978	3.00	____	____
GMS-10: Low- to intermediate-temperature thermal springs and wells in Oregon, 1978	2.50	____	____
GMS-11: Preliminary geothermal resource map of Oregon (upon written request only)	free	(one copy per customer)	
GMS-12: Geologic map of the Oregon part of the Mineral quadrangle	2.00	____	____
OIL AND GAS INVESTIGATIONS			
3. Preliminary identifications of foraminifera, General Petroleum Long Bell #1 well	2.00	____	____
4. Preliminary identifications of foraminifera, E.M. Warren Coos County 1-7 well, 1973	2.00	____	____
5. Prospects for natural gas production or underground storage of pipeline gas	5.00	____	____
MISCELLANEOUS PUBLICATIONS			
Landforms of Oregon (17 × 12 inches)	.50	____	____
Mining claims (State laws governing quartz and placer claims)	.50	____	____
Geological highway map, Pacific NW region, Oregon-Washington (published by AAPG)	3.00	____	____
Fifth Gold and Money Session and Gold Technical Session Proceedings, 1975	5.00	____	____
Sixth Gold and Money Session and Gold Technical Session Proceedings, 1978	6.50	____	____
Back issues of *The Ore Bin*	25¢ over the counter; 50¢ mailed	____	____
Colored postcard, *Geology of Oregon*	10¢ each; 3 for 25¢; 7 for 50¢; 15 for 1.00	____	____

OREGON GEOLOGY

1069 State Office Building, Portland, Oregon 97201

Second Class Matter
POSTMASTER: Form 3579 requested

Available publications (continued)

BULLETINS	Price	No. Copies	Amount
33. Bibliography (1st supplement) geology and mineral resources of Oregon, 1947: Allen	1.00		
36. Papers on Tertiary foraminifera: Cushman, Stewart and Stewart, 1949: v. 2	1.25		
44. Bibliography (2nd supplement) geology and mineral resources of Oregon, 1953: Steere	2.00		
46. Ferruginous bauxite deposits, Salem Hills, 1956: Corcoran and Libbey	1.25		
49. Lode mines, Granite mining district, Grant County, Oregon, 1959: Koch	1.00		
53. Bibliography (3rd supplement) geology and mineral resources of Oregon, 1962: Steere and Owen	3.00		
57. Lunar Geological Field Conference guidebook, 1965: Peterson and Groh, editors	3.50		
63. Sixteenth biennial report of the Department, 1966-1968	1.00		
65. Proceedings of Andesite Conference, 1969: (copies)	10.00		
67. Bibliography (4th supplement) geology and mineral resources of Oregon, 1970: Roberts	3.00		
68. Seventeenth biennial report of the Department, 1968-1970	1.00		
71. Geology of selected lava tubes in Bend area, Oregon, 1971: Greeley	2.50		
76. Eighteenth biennial report of the Department, 1970-1972	1.00		
77. Geologic field trips in northern Oregon and southern Washington, 1973	5.00		
78. Bibliography (5th supplement) geology and mineral resources of Oregon, 1973: Roberts	3.00		
81. Environmental geology of Lincoln County, 1973: Schlicker and others	9.00		
82. Geologic hazards of Bull Run Watershed, Multnomah, Clackamas Counties, 1974: Beaulieu	6.50		
83. Eocene stratigraphy of southwestern Oregon, 1974: Baldwin	4.00		
84. Environmental geology of western Linn County, 1974: Beaulieu and others	9.00		
85. Environmental geology of coastal Lane County, 1974: Schlicker and others	9.00		
86. Nineteenth biennial report of the Department, 1972-1974	1.00		
87. Environmental geology of western Coos and Douglas Counties, 1975	9.00		
88. Geology and mineral resources of upper Chetco River drainage, 1975: Ramp	4.00		
89. Geology and mineral resources of Deschutes County, 1976	6.50		
90. Land use geology of western Curry County, 1976: Beaulieu	9.00		
91. Geologic hazards of parts of northern Hood River, Wasco, and Sherman Counties, Oregon, 1977: Beaulieu	8.00		
92. Fossils in Oregon (reprinted from *The Ore Bin*), 1977	4.00		
93. Geology, mineral resources, and rock material of Curry County, Oregon, 1977	7.00		
94. Land use geology of central Jackson County, Oregon, 1977: Beaulieu	9.00		
95. North American ophiolites, 1977	7.00		
96. Magma genesis: AGU Chapman Conference on Partial Melting, 1977	12.50		
97. Bibliography (6th supplement) geology and mineral resources of Oregon, 1971-75, 1978	3.00		
98. Geologic hazards of eastern Benton County, 1979: Bela	9.00		
99. Geologic hazards of northwestern Clackamas County, Oregon, 1979: Schlicker and Finlayson	10.00		
100. Geology and mineral resources of Josephine County, Oregon, 1979: Ramp and Peterson	9.00		
101. Geologic field trips in western Oregon and southwestern Washington, 1980	9.00		
SPECIAL PAPERS			
1. Mission, goals, and purposes of Oregon Department of Geology and Mineral Industries, 1978	2.00		
2. Field geology of SW Broken Top quadrangle, Oregon, 1978: Taylor	3.50		
3. Rock material resources of Clackamas, Columbia, Multnomah, and Washington Counties, Oregon, 1978: Gray and others	7.00		
4. Heat flow of Oregon, 1978: Blackwell, Hull, Bowen, and Steele	3.00		
5. Analysis and forecasts of the demand for rock materials in Oregon, 1979: Friedman and others	3.00		
6. Geology of the La Grande area, Oregon, 1980: Barrash and others	5.00		
7. Pluvial Fort Rock Lake, Lake County, Oregon: Allison	4.00		
8. Geology and geochemistry of the Mt. Hood volcano, 1980: White	2.00		
SHORT PAPERS			
18. Radioactive minerals prospectors should know, 1976: White, Schafer, Peterson	.75		
21. Lightweight aggregate industry in Oregon, 1951: Mason	.25		
24. The Almeda Mine, Josephine County, Oregon, 1967: Libbey	3.00		
25. Petrography, type Rattlesnake Formation, central Oregon, 1976: Enlows	2.00		
27. Rock material resources of Benton County, 1978: Schlicker and others	4.00		

OREGON GEOLOGY

published by the

Oregon Department of Geology and Mineral Industries

VOLUME 42, NUMBER 9 SEPTEMBER 1980

OREGON GEOLOGY

(ISSN 0164-3304)

VOLUME 42, NUMBER 9 SEPTEMBER 1980

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

Governing Board

John L. Schwabe, Chairman .... Portland
Robert W. Doty .... Talent
C. Stanley Rasmussen .... Baker

State Geologist .... Donald A. Hull

Deputy State Geologist .... John D. Beaulieu

Editor .... Beverly F. Vogt

Main Office: 1069 State Office Building, Portland 97201, phone (503) 229-5580.

Baker Field Office: 2033 First Street, Baker 97814, phone (503) 523-3133.
Howard C. Brooks, Resident Geologist

Grants Pass Field Office: 312 S.E. "H" Street, Grants Pass 97526, phone (503) 476-2496.
Len Ramp, Resident Geologist

Mined Land Reclamation Program: 1129 S.E. Santiam Road, Albany 97321, phone (503) 967-2039.
Paul F. Lawson, Supervisor

Subscription rates: 1 year, $4.00; 3 years, $10.00. Single issues, $.40 at counter, $.50 mailed.
Available back issues of *The Ore Bin:* $.25 at counter, $.50 mailed.

Address subscription orders, renewals, and changes of address to *Oregon Geology,* 1069 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,* 1069 State Office Building, Portland, OR 97201.

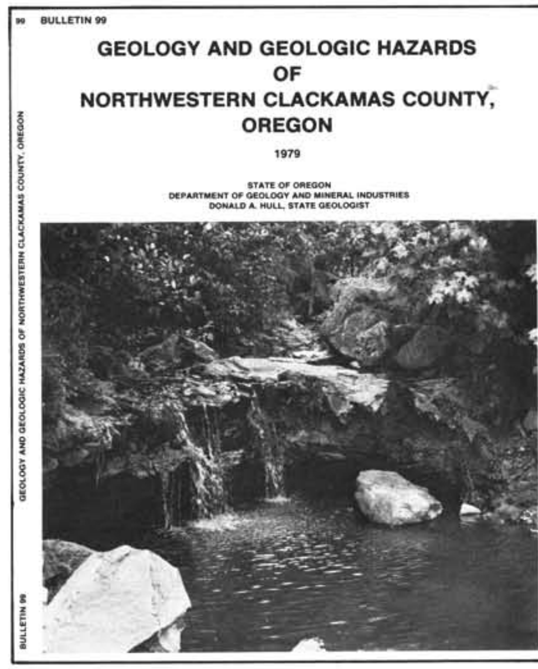
CONTENTS

COVER PHOTO: Golden Falls, Glen Creek valley, Golden and Silver Falls State Park, Coos County. Here stream flows over rocks of the Flournoy Formation, one of the geologic units discussed in article beginning on next page. Photo courtesy Oregon Highway Division.

Geology and geologic hazards study of northwestern Clackamas County now available

The Oregon Department of Geology and Mineral Industries (DOGAMI) announces the completion of its 18-month study of the *Geology and Geologic Hazards of Northwestern Clackamas County, Oregon*, published as Bulletin 99. The study was a joint effort involving DOGAMI, the Oregon Land Conservation and Development Commission, and Clackamas County. Authors of the report are Herbert G. Schlicker and Christopher T. Finlayson.

The bulletin is intended to provide practical information about specific geological hazards and engineering geology conditions in northwestern Clackamas County.



The text describes the surficial and bedrock geologic units found in the study area and describes such geologic hazards as landslides, soil erosion, high ground water and ponding, stream erosion and deposition, earthquakes, and volcanism. Included are a table presenting engineering characteristics of soils developed on each rock unit; matrices relating geologic hazards to geologic units, land uses, and steepness of slope; and flood tables giving stages, elevations, and peak discharges of the ten greatest observed floods on the Willamette, Molalla, Pudding, Tualatin, and Clackamas Rivers and Johnson Creek. In addition, Bulletin 99 contains five geology and five geologic hazard maps covering a total of nine 7½-minute quadrangle maps.

Price of the complete Bulletin 99 is $10.00. Address orders to the Oregon Department of Geology and Mineral Industries, 1069 State Office Building, Portland, Oregon 97201. Payment must accompany orders of less than $20.00. □

Eocene correlations in western Oregon-Washington

by Robert G. McWilliams, Department of Geology, Miami University-Hamilton, Hamilton, Ohio 45011

ABSTRACT

Eocene volcanic rocks and immediately overlying sediments of the Columbia Arc appear to be Tertiary sea floor wedged between the Juan de Fuca and North American Plates. Sea-floor spreading between the Farallon-Kula Plate boundaries can explain the geographic separation of the Roseburg Formation and the true Siletz River Volcanic Series in southwestern Oregon from the coeval true Crescent Formation in northwestern Washington. It can also explain why the younger "Siletz River Volcanic Series" and "Crescent Formation" are found between them in central-western Oregon-Washington.

According to this interpretation, the clockwise rotation of the Oregon Coast Range was produced by flexural-slip folding analogous to that which formed the clockwise-twisted Gorda Basin. The Farallon-Kula Plates were trapped between the North American Plate on the east and the northwesterly-moving Juan de Fuca Plate on the west.

INTRODUCTION

My purpose in this paper is to review the time-stratigraphy of the Oregon-Washington Eocene volcanic rocks and contiguous strata. The time-stratigraphic units used are those based on benthic organisms in California; namely the "stages" of Weaver and others (1944), the zones of Laiming (1939, 1940), and the stages of Mallory (1959) (Figure 1). There have been differences between correlations based on planktonic organisms—particularly calcareous nannoplankton—and benthic organisms. However, Poore (1979) has concluded that the Ulatisian-Narizian stage boundary closely coincides with the *Discoaster sublodoensis* zone and the *Nannotetrina quadrata* zone boundary. Thus correlations based on the Ulatisian-Narizian stage boundary—and that is the most important correlation discussed in this paper—probably approximate time correlation.

Figure 1. Correlation of Eocene time-stratigraphic units based on benthic organisms. After Mallory (1959, p. 74-98) and Rau (1966, Figure 4).

AGE	WEAVER AND OTHERS 1944	LAIMING 1939, 1941		MALLORY 1959
EOCENE	TEJON	?	A-1	NARIZIAN
		A-3	A-2	
	TRANSITION	?		ULATISIAN
	DOMENGINE	B-1A		
		B-1 — B-4		
	CAPAY	C		PENUTIAN

THE PENUTIAN-ULATISIAN BOUNDARY

Portions of the stratigraphic column which straddle the Penutian-Ulatisian stage boundary are shown in Figure 3. The following discussion of time-stratigraphy is keyed to Figure 3 by means of numbers, set off by parentheses, referring to the respective numbered stratigraphic section.

The Penutian-Ulatisian boundary appears to be located within the Roslyn Formation of north-central Washington (Figure 3, section 2). Part of the Roslyn Formation is of Bridgerian age (Wheeler, 1955), which is equivalent to the Ulatisian stage (Evernden and others, 1964, p. 167). The stratigraphic position of the underlying Teanaway Formation between the Paleocene Swauk Formation and the Ulatisian Roslyn Formation indicates it is equivalent to the Roseburg Formation, which is Paleocene to Penutian (early Eocene) in age.

The Raging River Formation of central-western Washington (section 3) is Ulatisian, based on the occurrence of *Gaudryina jacksonensis* var. *coalingensis* Cushman and G. D. Hanna (Vine, 1962b, p. 9). The overlying Tiger Mountain Formation is Domengine (lower Ulatisian), based on fossil leaves (Wolfe, 1968, p. 11). Although the underlying strata are not exposed, it is clear that the Ulatisian-Penutian boundary must be within or below the Raging River Formation.

In central-western Oregon, the uppermost portion of the Siletz River Volcanic Series (section 10) contains *Pseudophragmina psila* (Woodring). This species is unknown above the Penutian stage and occurs together with mollusk fossils which indicate a Capay age (Snavely and Vokes, 1949). Baldwin (1964b, p. 13-14) reviewed all published lists of fossils from the Siletz River Volcanic Series in the Dallas-Valsetz and adjacent areas (section 13) and also assigned a Capay age (Penutian) to the formation.

The King's Valley Siltstone is the uppermost member of the Siletz River Volcanic Series and is Capay (Penutian) near Marys Peak (section 14). The overlying Flournoy Formation (Baldwin, 1975, p. 53), formerly called Tyee and Burpee, is Domengine (lower Ulatisian), based on stratigraphic position (Baldwin, 1955; 1964b, p. 16-17).

The Lorane Siltstone Member (shown in Figure 3 as Lorane Shale) is the uppermost part of the Flournoy Formation (formerly Tyee) in the southwestern Willamette Valley (section 17). Bird (1967, Figure 14) determined a Ulatisian age for these rocks, based on fora-

	PRE-PENUTIAN	PENUTIAN	ULATISIAN	NARIZIAN	POST-NARIZIAN
AMPHIMORPHINA CALIFORNICA C.& M.			X	X	
BULIMINA CORRUGATA C.& S.			X	X	X
B. SCULPTILIS VAR. LACINIATA C.& P.				X	X
CIBICIDES HODGEI C.& S.				X	X
GAUDRYINA COALINGENSIS CUSHMAN	X	X	X		
G. JACKSONENSIS VAR. COALINGENSIS C.& H.	X	X	X		
NODOGENERINA BRADYI CUSHMAN				X	
NODOSARIA LATEJUGATA GÜMBEL			X	X	
PSEUDOPHRAGMINA PSILA (WOODRING)	X	X			
PLECTOFRONDICULARIA MINUTA SULLIVAN				X	
P. SACATENSIS HORNADAY				X	
ROBULUS CHIRANUS CUSHMAN & STONE				X	X
UVIGERINA CHURCHI CUSHMAN & SIEGFUS				X	
U. GARZAENSIS CUSHMAN & SIEGFUS				X	X
VALVULINERIA MENLOENSIS RAU				X	X
VIRGULINA BRAMLETTI G.& M.				X	X
VAGINULINOPSIS MEXICANA VAR. NUDICOSTATA C.&H.	X	X	X		

Figure 2. Table showing known biostratigraphic range of foraminifer species mentioned in text.

minifers. In addition, Stewart (1957, p. 13) reported species indicative of Ulatisian from the rocks now called Flournoy Formation at Comstock Overpass.

In southwestern Oregon, the Bateman Formation of the Umpua River area (section 20) contains Ulatisian foraminifers (Baldwin, 1974, p. 28). Baldwin (1961) summarized the foraminifers indicative of B-1 to B-1A age (lower Ulatisian) and mollusks indicative of the Domengine (lower Ulatisian) from the Elkton Formation in the lower Umpqua River area (section 20). The Flournoy Formation is also Ulatisian and overlies the Lookingglass (middle Umpqua) and the Roseburg (lower Umpqua) Formations, which are Penutian (Baldwin, 1974, p. 8-10, 16, 19).

Bird (1967, p. 77) reported foraminifers indicative of the Ulatisian from the Flournoy Formation at Sacchi Beach (section 21). The Flournoy Formation is in fault contact with the Penutian Roseburg Formation (Baldwin, 1975, p. 54).

THE ULATISIAN-NARIZIAN BOUNDARY

Discussion of the Ulatisian-Narizian boundary is keyed to Figure 4. Numbers set off by parentheses refer to the respective stratigraphic section.

The Aldwell Formation of northwestern Washington (Figure 4, section 1) was assigned a Narizian age by Rau (1964, p. 4-6). Rau noted *Amphimorphina californica* Cushman and McMasters in these strata and indicated that the foraminifer is not diagnostic of the Ulatisian stage because it occurs in Narizian strata in Oregon and Washington. The Crescent Formation between Crescent and Freshwater Bays (section 1) is between Penutian and Ulatisian in age (Berthiaume, 1938; Mallory, 1953; Rau, 1964). I have interpreted it as thrust above the Twin River Formation of Refugian age (McWilliams, 1970, 1971, 1974b). Although the fault relationship has been debated (Brown, 1971; Brown and Hanna, 1971), it is clear that the structural and

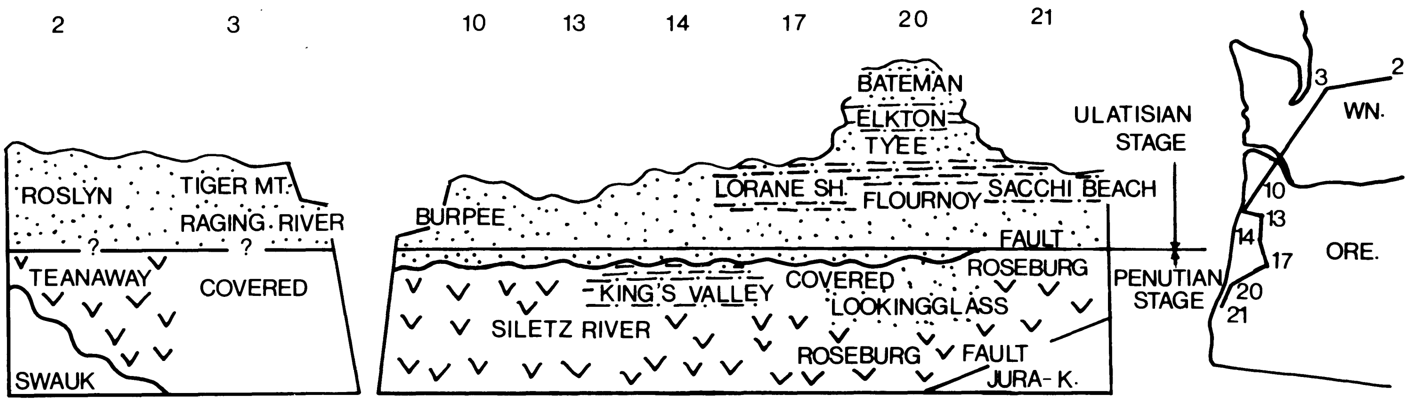


Figure 3. Correlations of Eocene stratigraphic units in western Oregon-Washington based on positions of Penutian-Ulatisian stage boundary. All stratigraphic names are the same as those used in cited reference. Locations of sections and references are as follows: 1) Lake Crescent, Brown and others (1960); 2) Mount Stuart, Smith (1904); 3) Hobart and Maple Valley, Vine (1962a); 4) Satsop River, Rau (1966); 5) Doty-Minot Peak, Pease and Hoover (1957); 6) Chehalis-Centralia, Snavely and others (1958); 7) Toledo-Castle Rock, Roberts (1958); 8) Kelso-Cathlamet, Livingston (1966); 9) Northwestern Oregon, Warren and others (1945); 10) Cape Kiwanda, Snavely and Vokes (1949); 11) Tualatin Valley, Schlicker and Deacon (1967); 12) Sheridan-McMinnville, Baldwin and others (1955); 13) Dallas-Valsetz, Baldwin (1964b); 14) Marys Peak-Alsea, Baldwin (1955); 15) Newport-Waldport, Vokes and others (1949); 16) West-central Willamette Valley, Vokes and others (1954); 17) South-southwest Willamette Valley, Vokes and others (1951); 18) Siuslaw River, Baldwin (1956); 19) Anlauf-Drain, Hoover (1963); 20) Umpqua River, Baldwin (1974); 21) Coos Bay, Baldwin (1975).

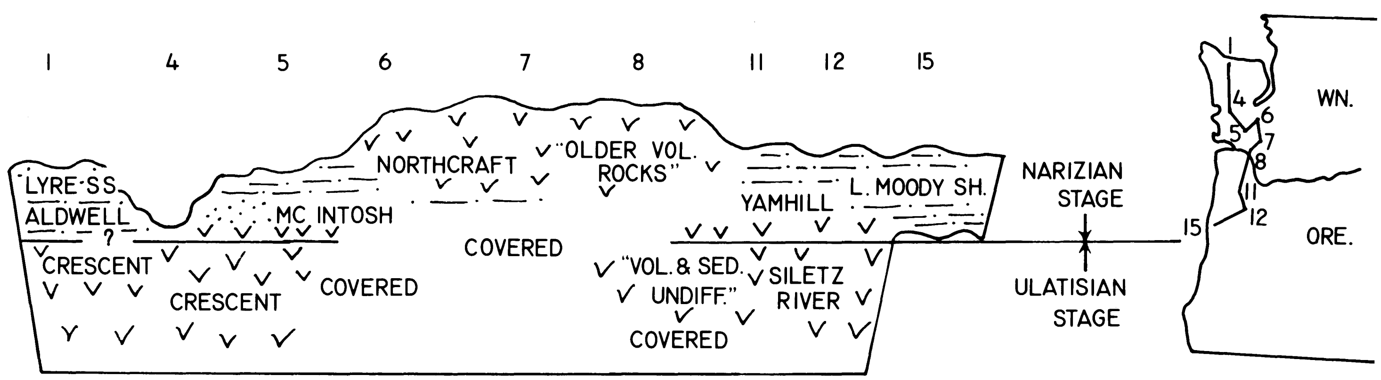


Figure 4. Correlation of Eocene stratigraphic units in western Oregon-Washington based on location of Ulatisian-Narizian stage boundary. Locations of sections and references are same as for Figure 3.

stratigraphic complexities of this locality preclude using it to indicate the age of the uppermost "Crescent Formation" (see Figure 6).

The "Crescent Formation" in the Satsop River area of northwestern Washington (section 4) was interpreted by Rau (1966, p. 24) to be Ulatisian. The writer agrees that localities F-36 through F-39 in the Little River section are Ulatisian (see Rau, 1966, Figure 2). However, the "Crescent Formation" at locality F-62 in the Canyon River section contains *Uvigerina churchi* Cushman and Siegfus, which is unknown below the Narizian. I have studied this locality in the field and have found, in addition, *Bulimina sculptilis* var. *laciniata* Cushman and Parker and *Valvulineria menloensis* Rau, which indicate Narizian.

The McIntosh Formation of the Centralia-Chehalis area (section 6) has been correlated with the B-1A zone (middle Ulatisian) of Laiming (Rau, 1956; Snavely and others, 1951). The evidence presented, however, does not support this correlation, since *Nodosaria latejugata* Gümbel and *Amphimorphina californica* Cushman and McMasters range into the Narizian (see Baldwin and others, 1955; Snavely and others, 1958, p. 18; Rau, 1964, p. 4, 7; Rau, 1966, Figure 5; and McWilliams, 1973b, p. 176, 1974a). Snavely and others (1958) found one locality (f11148) which contains B-1A fossils, but this is "Crescent Formation," not McIntosh Formation (see Pease and Hoover, 1957; Rau, 1958; and Strong, 1966).

Rau (1958) interpreted a pre-Narizian age for the lower McIntosh Formation, based on *Gaudryina coalingensis* Cushman, *Nodosaria latejugata* Gümbel, *Amphimorphina californica* Cushman and McMasters, *Bulimina corrugata* Cushman and Siegfus, *Bulimina* cf. *B. jacksonensis* Cushman, *Baggina tenninoensis* Rau and *Robulus* sp. C. The last-named three have not been reported from dated rocks outside southwestern Washington. Only one of the other four, *Gaudryina coalingensis*, is restricted to the Ulatisian stage and older. However, the many samples independently collected and picked by University of Washington students from the locality where *G. coalingensis* was reported (Rau, 1958, locality 9) show that it is not present. Instead, I have found in these samples abundant *Gaudryina* cf. *G. navarroana* Cushman, which is of unknown time-stratigraphic value on the West Coast. Moreover, I have found additional species not reported by Rau, such as *Robulus chiranus* Cushman and Stone and *Bulimina sculptilis* var. *laciniata* Cushman and Parker, which indicate Narizian rather than B-1A age (middle Ulatisian).

A Narizian age for the McIntosh Formation is supported by Pease and Hoover (1957), who concluded that in the Doty-Minot Peak area the unit is entirely late Eocene in age (section 5). They also reported two late Eocene localities in the underlying "Crescent Formation." This conclusion was corroborated by Strong (1966, p. 12-13), who reported the Narizian foraminifers *Robulus chiranus* Cushman and Stone and *Nodogenerina bradyi* Cushman from the "Crescent Formation" and numerous other species indicative of Narizian from the McIntosh Formation of the Doty-Minot Peak area (section 5). Therefore, given the evidence for Narizian age of the McIntosh Formation and the upper "Crescent Formation," it is my conclusion that the previously assigned B-1A age (middle Ulatisian) and correlation with the Tyee Formation and Sacchi Beach strata cannot be accepted for these formations. Both the Sacchi Beach strata and strata formerly called Tyee north of the Siuslaw River are now recognized to be the older Flournoy Formation (Baldwin, 1975).

The Yamhill Formation in the Tualatin Valley area of northwestern Oregon (section 11) is late Eocene in age (Schlicker and Deacon, 1967). Fossils collected by Robertson and Orr (1973) along Gales Creek at the base of the Yamhill (section 11) include benthic foraminifers indicative of lower Narizian. The underlying unit, "Eocene volcanics and sediments undifferentiated," is also Narizian (Schlicker and Deacon, 1967).

The Yamhill Formation in central-western Oregon (section 12) was named by Baldwin and others (1955), who reported fossil mollusks indicative of a "late Eocene, probably early late Eocene" age (see also McWilliams, 1974a, p. 122-123). Stewart (1957, p. 11, and *in* Baldwin and others, 1955), in apparent contradiction of this, assigned the Yamhill to Laiming's B-1A zone (middle Ulatisian). Current information does not support his correlation. Although *Amphimorphina californica* and *Nodosaria latejugata* are present in the Yamhill Formation, the other B-1A zone (middle Ulatisian) species reported on Stewart's check list are not present in my collections from the Yamhill Formation along Mill Creek and elsewhere (McWilliams, 1973b, tables 1-5 and 7). As noted previously, *Amphimorphina californica* and *Nodosaria latejugata* have been reported in joint occurrence with Narizian foraminifers at many different localities in the Pacific Northwest.

Baldwin (1964b) defined the Rickreall Limestone Member as a part of the Yamhill Formation in the Dallas and Valsetz quadrangles. I interpret the Rickreall Limestone, however, to be a part of the "Siletz River Volcanic Series" because it is Ulatisian age and because its paleoecology closely resembles that of the "Siletz River" (Boggs and others, 1973, p. 653-54; McWilliams, 1973b, p. 170).

I have mapped the basal contact of the Yamhill Formation and shown that it does not interfinger with the underlying Flournoy (formerly Tyee) Formation in the Grand Ronde, Dallas, and Valsetz areas (McWilliams, 1973b). In addition, I have an extensive collection of fossils from the Yamhill Formation in this area (section 12) indicating an age no older than Narizian. Samples from 40 ft above the base of the Yamhill Formation in Rock Creek are Narizian (McWilliams, 1973b, localities 42-43). An exposure 100 ft above the "Siletz River Volcanic Series" in the type Yamhill Formation along Mill Creek is also of Narizian age (McWilliams, 1973b, locality 20). Although this conclusion has been debated (Rau, 1974; McWilliams, 1974a), the same section along Mill Creek has been studied by Gaston (1974), who reported *Plectofrondicularia minuta* Sullivan, *Plectofrondicularia sacatensis* Hornaday, *Uvigerina garzaensis* Cushman and Siegfus, and

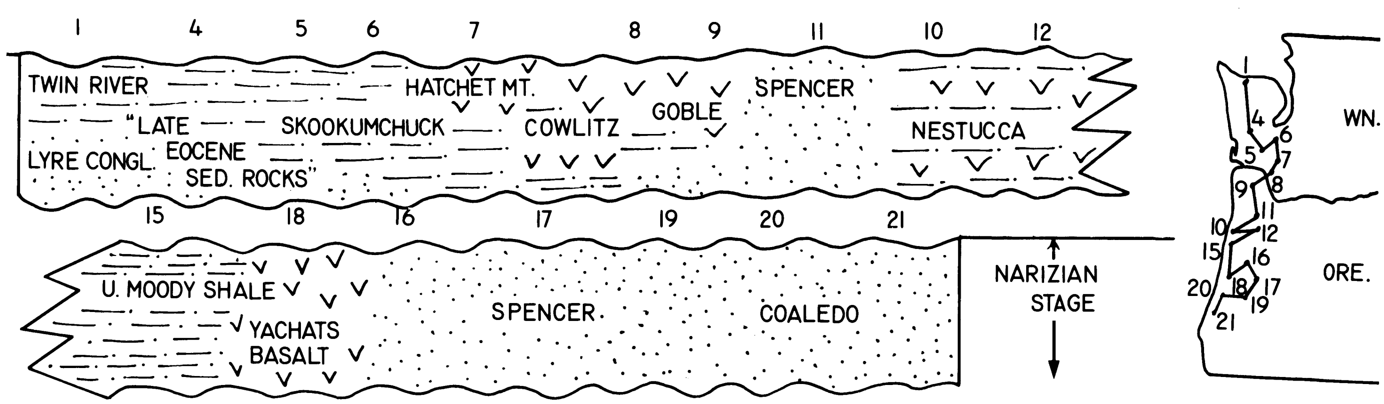


Figure 5. Correlation of upper Narizian stratigraphic units in western Oregon-Washington below Narizian-Refugian stage boundary. Locations of sections and references are same as for Figure 3.

Virgulina bramletti Galloway and Morrey from the lowermost exposed Yamhill Formation. All of these species are unknown from below the Narizian and confirm my interpretation of a Narizian age for the lower Yamhill Formation.

The uppermost "Siletz River Volcanic Series" below this locality contains *Vaginulinopsis mexicana* var. *nudicostata* Cushman and Hanna, which is not known from above the Ulatisian, and *Cibicides hodgei* Cushman and Schenck, of Narizian and post-Narizian time. The joint occurrence of these and other species (McWilliams, 1973b, localities 18-19) indicates that the Ulatisian-Narizian boundary is within the uppermost "Siletz River Volcanic Series" at this locality. Therefore, even the lowermost type Yamhill can be no older than Narizian.

This conclusion is consistent with the Narizian age of the uppermost "Crescent Formation" and overlying rocks in the Satsop River area and in the Doty-Minot Peak area of Washington—and also with the Narizian age of the "Eocene volcanics and sediments undifferentiated" and overlying rocks of the Tualatin Valley, Oregon, area. These Narizian volcanic rocks cannot be volcanic rocks of the Nestucca or Goble Formations because their stratigraphic position is below the Yamhill and McIntosh Formations.

The lower Moody Shale Member of the Toledo Formation is Narizian in the Newport-Waldport area (section 15), based on mollusks (Vokes and others, 1949) and foraminifers (Cushman and others, 1949; McWilliams, 1968, Table 2). The Moody Shale Member overlies the Flournoy Formation (Tyee of Vokes and others, 1949) with angular unconformity (Schenck, 1928, p. 35; McWilliams, 1968, p. 4).

THE UPPER NARIZIAN SEQUENCE

A regional unconformity (Snavely and Wagner, 1964, p. 11) separates the upper Narizian strata with their distinctive molluscan fauna of Tejon age (Turner, 1938; Weaver, 1942) from older rocks. The upper boundary of this sequence is an unconformity which coincides with the base of the Refugian stage (Armentrout, 1973). As the correlations shown in Figure 5 have been proposed by many workers and are generally accepted, they will not be discussed further in this paper.

STRATIGRAPHIC SUMMARY

Eocene rocks of western Oregon-Washington are generally interpreted to be an interfingering sequence of volcanic units and coarse and fine detrital sedimentary rocks (Snavely and Wagner, 1964; Braislin and others, 1971). The stratigraphic relations I interpret are radically different, as shown in Figure 6. The submarine basalts in the northern and southern extremities of western Oregon-Washington appear to straddle the boundary of the Penutian-Ulatisian stages, although only the Penutian portion is preserved below the unconformity in the sections depicted in Figure 3. In central-western Oregon-Washington, the submarine basalts bestride the boundary of the Ulatisian-Narizian stages and are therefore younger. The Narizian Yamhill Formation cannot be a facies of the Tyee, Flournoy, and Bateman Formations because they are Ulatisian. Similarly, the Narizian McIntosh Formation is not a facies of the Tiger Mountain, Raging River, and Roslyn Formations because they are also Ulatisian. The strata which I call "Crescent Formation" and "Siletz River Volcanic Series" and which underlie the Yamhill-McIntosh are Narizian in at least the upper part and therefore younger than any of the known Roslyn, Raging River, Tiger Mountain, Tyee, Flournoy, or Bateman Formations. The geographic distribution of older true Crescent and Teanaway basalts to the north and the Roseburg and true Siletz River Volcanic Series basalts to the south with younger "Siletz River" and "Crescent" basalts in the middle suggests spreading of deep sea floor away from an axis of rifting (McWilliams, 1972, 1978).

PLATE ROTATION

The plate scenario proposed to explain rifting may also explain the clockwise rotation of western Oregon and southwestern Washington indicated by paleomag-

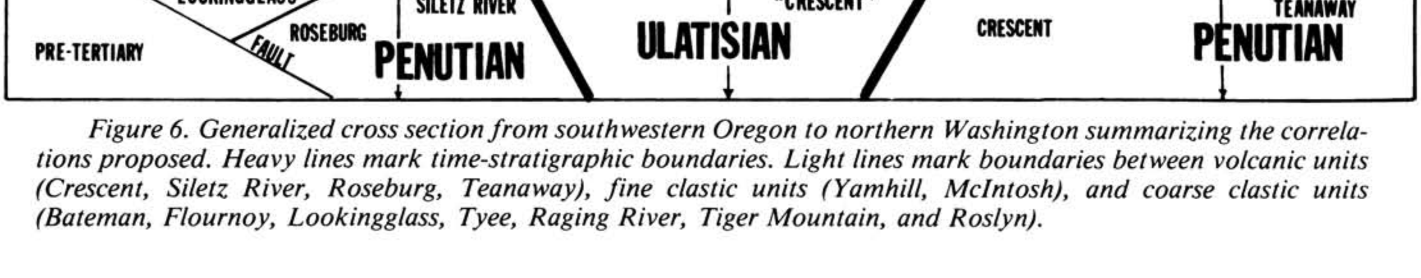


Figure 6. Generalized cross section from southwestern Oregon to northern Washington summarizing the correlations proposed. Heavy lines mark time-stratigraphic boundaries. Light lines mark boundaries between volcanic units (Crescent, Siletz River, Roseburg, Teanaway), fine clastic units (Yamhill, McIntosh), and coarse clastic units (Bateman, Flournoy, Lookingglass, Tyee, Raging River, Tiger Mountain, and Roslyn).

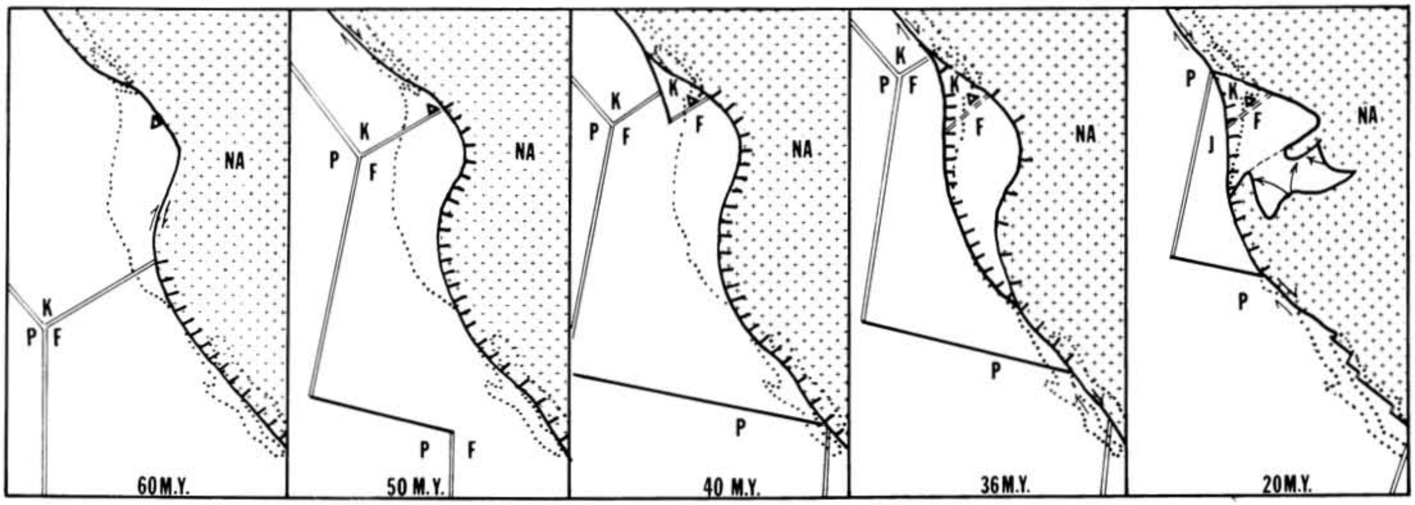


Figure 7. Location of plate boundaries at different times during the Tertiary. Dotted lines show present outline of western North America between Vancouver Island and Baja California. Triangular fragment is schematic representation of part of North American Plate. F = Farallon Plate, K = Kula Plate, P = Pacific Plate, NA = North American Plate. 60 m.y. modified after Hamilton (1969). 36 m.y. modified after Atwater (1970). 20 m.y. modified after Hamilton and Myers (1966).

netism (Simpson and Cox, 1977; Beck and Burr, 1979). Clockwise rotation could be due to flexural-slip folding of the Farallon Plate between 50 and 40 m.y.b.p. (Figure 7). The eastern portion of the Farallon Plate was trapped between a northwesterly moving block on the west (Kula-Farallon Plate) and a westerly moving block on the east (North American Plate). This situation is analogous to the clockwise-twisted Gorda Basin, which is trapped between the Mendocino Fracture Zone and the North American Plate (Silver, 1971).

ACKNOWLEDGMENTS

V. S. Mallory, Burke Museum, University of Washington, and Ewart M. Baldwin, Department of Geology, University of Oregon, read an earlier version of this manuscript and provided valuable help. I assume full responsibility for all ideas and data presented.

REFERENCES

Armentrout, J. M., 1973, Stratigraphic relationships of the Narizian-Refugian boundary in Washington [abs.]: Geological Society of American Abstracts with Programs, v. 5, no. 1, p. 4.

Atwater, T., 1970, Implications of plate tectonics for the Cenozoic tectonic evolution of western North America: Geological Society of America Bulletin, v. 81, no. 12, p. 3513-3535.

Baldwin, E. M., 1955, Geology of the Marys Peak and Alsea quadrangles, Oregon: U.S. Geological Survey Oil and Gas Investigations Map OM-162.

——— 1956, Geologic map of the lower Siuslaw River area, Oregon: U.S. Geological Survey Oil and Gas Investigations Map OM-186.

——— 1961, Geologic map of the lower Umpqua River area, Oregon: U.S. Geological Survey Oil and Gas Investigations Map OM-204.

——— 1964a, Geology of Oregon (2nd ed.): Eugene, Oreg., University of Oregon Cooperative Bookstore, 165 p.

——— 1964b, Geology of the Dallas and Valsetz quadrangles, Oregon (revised ed.): Oregon Department of Geology and Mineral Industries Bulletin 35, 56 p.

——— 1965, Geology of the south end of the Oregon Coast Range Tertiary Basin: Northwest Science, v. 39, no. 3, p. 93-103.

——— 1974, Eocene stratigraphy of southwestern Oregon: Oregon Department of Geology and Mineral Industries Bulletin 83, 40 p.

——— 1975, Revision of the Eocene stratigraphy of southwestern Oregon, *in* Weaver, D. W., Hornaday, G. R., and Tipton, A., eds., Paleogene symposium and selected technical papers, 50th Annual Meeting, Pacific Sections, AAPG, SEPM, SEG, Long Beach, Calif., April 1975, p. 49-64.

Baldwin, E. M., Brown, R. D., Jr., Gair, J. E., and Pease, M. H., Jr., 1955, Geology of the Sheridan and McMinnville quadrangles, Oregon: U.S. Geological Survey Oil and Gas Investigations Map OM-155.

Baldwin, E. M., and Roberts, A. E., 1952, Geology of Spirit Mountain quadrangle, Oregon: U.S. Geological Survey Oil and Gas Investigations Map OM-129.

Beck, M. E., Jr., and Burr, C. D., 1979, Paleomagnetism and tectonic significance of the Goble Volcanic Series, southwestern Washington: Geology, v. 7, no. 4, p. 175-179.

Berthiaume, S. A., 1938, Orbitoids from the Crescent Formation (Eocene) of Washington: Journal of Paleontology, v. 12, no. 5, p. 494-497.

Bird, K. J., 1967, Biostratigraphy of the Tyee Formation (Eocene), southwest Oregon: Madison, Wis., University of Wisconsin doctoral dissertation, 209 p.

Boggs, S., Jr., Orr, W. N., and Baldwin, E. M., 1973, Petrographic and paleontologic characteristics of the Rickreall Limestone (Eocene) of northwestern Oregon: Journal of Sedimentary Petrology, v. 43, no. 3, p. 644-654.

Braislin, D. B., Hastings, D. D., and Snavely, P. D., Jr., 1971, Petroleum potential of western Oregon and Washington and adjacent continental margin, *in* Cram, I. A., ed., Future petroleum provinces of the United States – their geology and potential: Tulsa, Okla., American Association of Petroleum Geologists Memoir 15, v. 1, p. 229-238.

Brown, R. D., Jr., 1971, Evidence for thrust faulting in northern Olympic Peninsula, Washington: discussion: American Association of Petroleum Geologists Bulletin, v. 55, no. 1, p. 126-129.

Brown, R. D., Jr., Gower, H. D., and Snavely, P. D., Jr., 1960, Geology of the Port Angeles-Lake Crescent area, Clallam County, Washington: U.S. Geological Survey Oil and Gas Investigations Map OM-203.

Brown, R. D., Jr., and Hanna, W. F., 1971, Aeromagnetic evidence and geologic structure, northern Olympic Peninsula and Strait of Juan de Fuca, Washington: American Association of Petroleum Geologists Bulletin, v. 55, no. 11, p. 1939-1953.

Cushman, J. A., Stewart, R. E., and Stewart, K. C., 1949, Upper Eocene Foraminifera from the Toledo Formation, Toledo, Lincoln County, Oregon: Oregon Department of Geology and Mineral Industries Bulletin 36, pt. 6, p. 126-146.

Evernden, J. F., Savage, D. E., Curtis, G. H., and James, G. T., 1964, Potassium-argon dates and the Cenozoic mammalian chronology of North America: American Journal of Science, v. 262, no. 2, p. 145-198.

Gaston, L. R., 1974, Biostratigraphy of the type Yamhill Formation, Polk County, Oregon: Portland, Oreg., Portland State University master's thesis, 139 p.

Hamilton, W., 1969, Mesozoic California and the underflow of Pacific mantle: Geological Society of America Bulletin, v. 80, no. 12, p. 2409-2429.

Hamilton, W., and Myers, W. B., 1966, Cenozoic tectonics of the western United States: Reviews of Geophysics, v. 4, p. 509-549.

Hoover, L., 1963, Geology of the Anlauf and Drain quadrangles, Douglas and Lane Counties, Oregon, U.S. Geological Survey Bulletin 1122-D, 62 p.

Laiming, B., 1939, Some foraminiferal correlations in the Eocene of San Joaquin Valley, California, *in* Sixth Pacific Science Congress, Berkeley and San Francisco, Calif., 1939, Proceedings: Berkeley and Los Angeles, University of California Press, v. 2, p. 535-568.

——— 1940, Foraminiferal correlations in the Eocene of the San Joaquin Valley, California: American Association of Petroleum Geologists Bulletin, v. 24, no. 11, p. 1923-1939.

Livingston, V. E., 1966, Geology and mineral resources of the Kelso-Cathlamet area, Cowlitz and Wahkiakum Counties, Washington: Washington Division of Mines and Geology Bulletin 54, 110 p.

Mallory, V. S., 1953, Some lower Eocene correlations on the Pacific Coast [abs.]: Geological Society of America Bulletin, v. 64, no. 12, p. 1520.

——— 1959, Lower Tertiary biostratigraphy of the California Coast Ranges: Tulsa, Okla., American Association of Petroleum Geologists, 416 p.

McWilliams, R. G., 1968, Paleogene stratigraphy and biostratigraphy of central-western Oregon: Seattle, Wash., University of Washington doctoral dissertation, 140 p.

——— 1970, Evidence for thrust faulting in northern Olympic Peninsula, Washington: American Association of Petroleum Geologists Bulletin, v. 54, no. 2, p. 344-349.

——— 1971, [Evidence for thrust faulting in the northern Olympic Peninsula, Washington:] Reply: American Association of Petroleum Geologists Bulletin, v. 55, no. 1, p. 129-131.

——— 1972, Stratigraphic evidence for rifting in western Oregon and Washington [abs.]: Geological Society of America Abstracts with Programs, v. 4, no. 3, p. 197-198.

——— 1973a, Stratigraphic and biostratigraphic position of the Yamhill Formation in central-western Oregon [abs.]: Geological Society of America Abstracts with Programs, v. 5, no. 1, p. 79.

——— 1973b, Stratigraphic and biostratigraphic relationships of the Tyee and Yamhill Formations in central-western Oregon: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 35, no. 11, p. 169-186.

——— 1974a, [The Tyee-Yamhill relationships: a discussion:] Reply to comments: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 36, no. 7, p. 122-125.

——— 1974b, New evidence for thrusting near Freshwater Bay, Olympic Peninsula, Washington [abs.]: Geological Society of America Abstracts with Programs, v. 6, no. 3, p. 219.

——— 1978, Early Tertiary rifting in western Oregon-Washington: American Association of Petroleum Geologists Bulletin, v. 62, no. 7, p. 1193-1197.

Pease, M. H., Jr., and Hoover, L., Jr., 1957, Geology of the Doty-Minot Peak area, Washington: U.S. Geological Survey Oil and Gas Investigations Map OM-188.

Poore, R. Z., 1979, Correlating of Pacific Coast benthic stages and calcareous plankton zonations in California: Geological Society of America Abstracts with Programs, v. 11, no. 3, p. 122.

Rau, W. W., 1956, Foraminifera from the McIntosh Formation (Eocene) at McIntosh Lake, Washington: Contributions from the Cushman Foundation for Foraminiferal Research, v. VII, pt. 3, p. 69-78.

——— 1958, Stratigraphy and foraminiferal zonation in some of the Tertiary rocks of southwestern Washington: U.S. Geological Survey Oil and Gas Investigations Chart OC-57.

——— 1964, Foraminifera from the northern Olympic Peninsula, Washington: U.S. Geological Survey Professional Paper 374-G, 33 p.

——— 1966, Stratigraphy and Foraminifera of the Satsop River area, southern Olympic Peninsula, Washington: Washington Division of Mines and Geology Bulletin 53, 66 p.

——— 1974, The Tyee-Yamhill relationships: a discussion: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 36, no. 7, p. 120-122.

Roberts, A. E., 1958, Geology and coal resources of the Toledo-Castle Rock district, Cowlitz and Lewis Counties, Washington: U.S. Geological Survey Bulletin 1062, 71 p.

Robertson, R. D., and Orr, W. N., 1973, A middle Eocene pelagic foraminiferal fauna from northwest Oregon and its relationship to the West Coast Narizian stage [abs.]: Geological Society of America Abstracts with Programs, v. 5, no. 1, p. 96.

Schenck, H. G., 1928, Stratigraphic relations of western Oregon Oligocene formations: University of California, Department of Geological Sciences Bulletin, v. 18, no. 1, p. 1-50.

Schlicker, H. G., and Deacon, R. J., 1967, Engineering geology of the Tualatin Valley region, Oregon: Oregon Department of Geology and Mineral Industries Bulletin 60, 103 p.

Silver, E. A., 1971, Tectonics of the Mendocino triple junction: Geological Society of America Bulletin, v. 82, no. 11, p. 2965-2977.

Simpson, R. W., and Cox, A., 1977, Paleomagnetic evidence for tectonic rotation of the Oregon Coast Range: Geology, v. 5, no. 10, p. 585-589.

Smith, G. O., 1904, Mount Stuart folio, Washington, folio 106 *of* Geologic atlas of the United States: U.S. Geological Survey.

Snavely, P. D., Jr., and Baldwin, E. M., 1948, Siletz River Volcanic Series, northwestern Oregon: American Association of Petroleum Geologists Bulletin, v. 32, no. 6, p. 806-812.

Snavely, P. D., Jr., Brown, R. D., Jr., Roberts, A. E., and Rau, W. W., 1958, Geology and coal resources of the Centralia-Chehalis district, Washington: U.S. Geological Survey Bulletin 1053, 159 p.

Snavely, P. D., Jr., Rau, W. W., Hoover, L., Jr., and Roberts, A. E., 1951, McIntosh Formation, Centralia-Chehalis coal district, Washington: American Association of Petroleum Geologists Bulletin, v. 35, no. 5, p. 1052-1061.

Snavely, P. D., Jr., and Vokes, H. E., 1949, Geology of the coastal area from Cape Kiwanda to Cape Foulweather, Oregon: U.S. Geological Survey Oil and Gas Investigations Map OM-97.

Snavely, P. D., Jr., and Wagner, H. C., 1963, Tertiary geologic history of western Oregon and Washington: Washington Division of Mines and Geology Report of Investigations 22, 25 p.

——— 1964, Geologic sketch of northwestern Oregon: U.S. Geological Survey Bulletin 1181-M, 17 p.

Stewart, R. E., 1957, Stratigraphic implications of some Cenozoic Foraminifera from western Oregon, [pt. 3:] Eocene: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 19, no. 2, p. 11-15.

Strong, C. P., 1966, Geology of the Pe Ell-Doty area, Washington: Seattle, Wash., University of Washington master's thesis, 150 p.

Turner, F. E., 1938, Stratigraphy and mollusca of the Eocene of western Oregon: Geological Society of America Special Paper 10, 130 p.

Vine, J. D., 1962a, Preliminary geologic map of the Hobart and Maple Valley quadrangles: Washington Division of Mines and Geology Geologic Map GM-1.

——— 1962b, Stratigraphy of Eocene rocks in a part of King County, Washington: Washington Division of Mines and Geology Report of Investigations 21, 20 p.

Vokes, H. E., Myers, D. A., and Hoover, L., 1954, Geology of the west-central border area of the Willamette Valley, Oregon: U.S. Geological Survey Oil and Gas Investigations Map OM-150.

Vokes, H. E., Norbisrath, H., and Snavely, P. D., Jr., 1949, Geology of the Newport-Waldport area, Lincoln County, Oregon: U.S. Geological Survey Oil and Gas Investigations Map OM-88.

Vokes, H. E., Snavely, P. D., Jr., and Myers, D. A., 1951, Geology of the southern and southwestern border areas of the Willamette Valley, Oregon: U.S. Geological Survey Oil and Gas Investigations Map OM-110.

Warren, W. C., Norbisrath, H., and Grivetti, R. M., 1945, Geology of northwestern Oregon west of the Willamette River and north of latitude 45° 15': U.S. Geological Survey Oil and Gas Investigations Map OM-42.

Weaver, C. E., 1942, Paleontology of the marine Tertiary formations of Oregon and Washington: University of Washington Publications in Geology, v. 5 (3 pts.), 789 p.

Weaver, C. E., and others (Western Cenozoic Subcommittee), 1944, Correlation of the marine Cenozoic formations of western North America: Geological Society of America Bulletin, v. 55, no. 5, p. 569-598.

Wheeler, H. E., 1955, Dermatemidid turtle from the Roslyn Formation of Washington [abs.]: Geological Society of America Bulletin, v. 66, no. 12, pt. 2, p. 1668-1669.

Wolfe, J. A., 1968, Paleogene biostratigraphy of nonmarine rocks in King County, Washington: U.S. Geological Survey Professional Paper 571, 33 p., 7 pl. □

Mount St. Helens photos available for purchase from USGS

Over 1,500 frames of photography of the eruption of Mt. St. Helens, taken from April 10 to June 4 and covering most of the significant aspects of the eruption, are now available for purchase from the U.S. Geological Survey (USGS), Department of the Interior.

The initial USGS photography is available in the form of two rolls of microfilm for $15 each. By purchasing the microfilm, or viewing it in one of the USGS offices where it will be available for inspection, the user can view all the photography so far available and then choose which frames to have made into photographs.

"Because of the intense scientific as well as general interest in the eruption, the USGS is trying to make the photography available as quickly as possible," said Allen H. Watkins, chief of the USGS Earth Resources Observation Systems Data Center, the office distributing the volcano photographs and other remotely sensed data such as satellite images. The microfilm is designed particularly for scientists with a serious interest in volcano dynamics and other detailed studies of the eruptive process.

To assist the general public, who may wish to order more limited quantities, the USGS has also selected 12 of the most dramatic prints for direct sale as 9-in. by 9-in. black-and-white photographs at a cost of $3 each. The photos can also be obtained in larger sizes of 18 in. by 18 in., 27 in. by 27 in., and 36 in. by 36 in. for $10, $15, and $20 each, respectively.

The two rolls of microfilm are identified as 1MFUSGS-000S01 and 1MFUSGS-00S02.

Requests for a free list describing the 12 photographs available and orders for microfilm should be sent, along with microfilm identification numbers, to EROS Data Center, U.S. Geological Survey, Sioux Falls, S.D. 57198. All orders must include check or money order payable to the U.S. Geological Survey.

Orders may also be placed over the counter and microfilm viewed at the National Cartographic Information Center (NCIC), U.S. Geological Survey, Room 1C107, National Center, 12201 Sunrise Valley Dr., Reston, Va.; the Eastern NCIC, Rm. 2B200, National Center, Reston; Mid-Continent NCIC, 1400 Independence Rd., Rolla, Mo.; Rocky Mountain NCIC, Rm. H-2206, Bldg. 25, Federal Center, Denver, Colo.; and the Western NCIC, Bldg. 3, Rm. 122, 345 Middlefield Rd., Menlo Park, Calif. □

Oil and gas activity continues to increase

The Oregon Department of Geology and Mineral Industries issued 36 oil and gas drilling permits in the first seven months of 1980. Most of the permits have been in the vicinity of the Mist Gas Field in Columbia County, northwest Oregon. Seven producing wells have been found in the field to date. The Mist gas is the first commercial production in Oregon. Two holes were drilled in the area 34 years ago by Texaco, and the present development resulted from data obtained from them. Since 1975, 21 holes have been put down in the Mist area.

Leasing of oil and gas minerals has continued at a steady pace since the Mist discovery last May. Newest entries to exploration in northwest Oregon include Nehama and Weagant, Bakersfield, California, and AMOCO Production Company, Denver, Colorado.

At present, an estimated 5 million acres are under lease or applied for in the state. The increase in exploration comes at a time when the timber economy is sagging. Although the economic impact of drilling and production is still small in Oregon, it has the prospect of becoming more important in the next few years.

Northwest Exploration Company has drilled three of five locations in southwestern Oregon, where it has an estimated 200,000 acres of leases. A discovery in southwestern Oregon would set off an exploration effort for the next five to ten years.

Table 1. *Oil and gas drilling permits issued since April 1980*

Permit number	Date issued	Company	Lease name	Location
73 RD	3/14/80	Reichhold Energy Corp.	DSC-Longview Fibre 1 Redrill	SW¼ sec. 11, T. 6 N., R. 5 W. Columbia County
123	3/31/80	Reichhold Energy Corp.	Columbia County 11-10	NW¼ sec. 10, T. 6 N., R. 5 W. Columbia County
124	3/31/80	Reichhold Energy Corp.	Columbia County 33-3	SW¼ sec. 3, T. 6 N., R. 5 W. Columbia County
125	3/31/80	Reichhold Energy Corp.	Columbia County 43-11	SE¼ sec. 11, T. 6 N., R. 5 W. Columbia County
126	3/31/80	Reichhold Energy Corp.	Crown Zellerbach 42-1	NE¼ sec. 1, T. 6 N., R. 5 W. Columbia County
127	3/31/80	Reichhold Energy Corp.	Longview Fibre 34-12	SE¼ sec. 12, T. 6 N., R. 5 W. Columbia County
128	3/31/80	Reichhold Energy Corp.	Libel 44-15	SE¼ sec. 15, T. 6 N., R. 5 W. Columbia County
129	3/31/80	Reichhold Energy Corp.	Columbia County 44-4	SE¼ sec. 4, T. 6 N., R. 5 W. Columbia County
130	3/31/80	Reichhold Energy Corp.	Columbia County 21-10	NW¼ sec. 10, T. 6 N., R. 5 W. Columbia County
131	3/31/80	Reichhold Energy Corp.	Columbia County 32-3	NE¼ sec. 3, T. 6 N., R. 5 W. Columbia County
132	3/31/80	Reichhold Energy Corp.	Laubach 34-13	SE¼ sec. 13, T. 6 N., R. 5 W. Columbia County
133	3/31/80	Reichhold Energy Corp.	Libel 22-15	NW¼ sec. 15, T. 6 N., R. 5 W. Columbia County

Table 1. *Oil and gas drilling permits issued since April 1980* (continued)

Permit number	Date issued	Company	Lease name	Location
134	3/31/80	Reichhold Energy Corp.	Longview Fibre 33-12	SE¼ sec. 12, T. 6 N., R. 5 W. Columbia County
135	3/31/80	Reichhold Energy Corp.	White 33-13	SE¼ sec. 13, T. 6 N., R. 5 W. Columbia County
136	4/4/80	Northwest Exploration Co.	Coos County 1	SW¼ sec. 14, T. 27 S., R. 13 W. Coos County
137	4/4/80	Northwest Exploration Co.	Westport 1	SE¼ sec. 16, T. 26 S., R. 13 W. Coos County
138	4/4/80	Northwest Exploration Co.	Fat Elk 1	SW¼ sec. 15, T. 28 S., R. 13 W. Coos County
139	4/4/80	Northwest Exploration Co.	Sawyer Rapids 1	NE¼ sec. 3, T. 23 S., R. 9 W. Douglas County
140	5/13/80	Reichhold Energy Corp.	Longview Fibre 24-12	SW¼ sec. 12, T. 6 N., R. 5 W. Columbia County
141	5/27/80	Northwest Exploration Co.	Fish Trap 1	SE¼NE¼ sec. 32, T. 28 S., R. 13 W. Coos County
142	6/4/80	Reichhold Energy Corp.	Adams 32-34	NE¼ sec. 34, T. 7 N., R. 5 W. Columbia County
143	6/4/80	Reichhold Energy Corp.	Adams 24-34	SW¼ sec. 34, T. 7 N., R. 5 W. Columbia County
144	6/4/80	Reichhold Energy Corp.	Adams 23-34	SW¼ sec. 34, T. 7 N., R. 5 W. Columbia County
145	6/4/80	Reichhold Energy Corp.	Columbia County 21-34	NW¼ sec. 34, T. 7 N., R. 5 W. Columbia County
146	6/4/80	Reichhold Energy Corp.	Columbia County 11-33	NW¼ sec. 33, T. 7 N., R. 5 W. Columbia County
147	6/4/80	Reichhold Energy Corp.	Columbia County 12-9	NW¼ sec. 9, T. 6 N., R. 5 W. Columbia County
148	6/4/80	Reichhold Energy Corp.	Columbia County 32-5	NE¼ sec. 5, T. 6 N., R. 5 W. Columbia County
149	6/4/80	Reichhold Energy Corp.	Columbia County 31-3	NE¼ sec. 3, T. 6 N., R. 5 W. Columbia County
150	6/4/80	Reichhold Energy Corp.	Columbia County 42-4	NE¼ sec. 4, T. 6 N., R. 5 W. Columbia County

Table 1. *Oil and gas drilling permits issued since April 1980* (continued)

Permit number	Date issued	Company	Lease name	Location
151	6/4/80	Reichhold Energy Corp.	Columbia County 22-3	NW¼ sec. 3, T. 6 N., R. 5 W. Columbia County
152	6/21/80	Reichhold Energy Corp.	Longview Fibre 23-12	SW¼ sec. 12, T. 6 N., R. 5 W. Columbia County
153	6/25/80	Reichhold Energy Corp.	Columbia County 13-2	SW¼ sec. 2, T. 6 N., R. 5 W. Columbia County
154	7/8/80	American Quasar Petroleum Co.	Investment Management 34-22	SE¼NW¼ sec. 34, T. 6 N., R. 4 W. Columbia County
155	7/8/80	American Quasar Petroleum Co.	Larkins 23-33	NW¼SE¼ sec. 23, T. 6 N., R. 5 W. Columbia County
156	7/18/80	American Quasar Petroleum Co.	Rau 18-14	SW¼SW¼ sec. 18, T. 6 N., R. 4 W. Columbia County
157	8/20/80	American Quasar Petroleum Co.	Crown Zellerbach 30-33	NW¼SE¼ sec. 30, T. 6 N., R. 4 W. Columbia County
158	Application	Reichhold Energy Corp.	Columbia County 14-2	SW¼ sec. 2, T. 6 N., R. 5 W. Columbia County
159	Application	Reichhold Energy Corp.	Sweet 14-1	SW¼ sec. 1, T. 6 N., R. 5 W. Columbia County
160	Application	Reichhold Energy Corp.	Independence 12-25	NW¼ sec. 25, T. 8 S., R. 4 W. Marion County
161	Application	Reichhold Energy Corp.	Bagdanoff 23-28	SW¼ sec. 28, T. 5 S., R. 2 W. Marion County
162	Application	Reichhold Energy Corp.	Crown Zellerbach 22-6	NW¼ sec. 6, T. 6 N., R. 4 W. Columbia County
163	Application	Northwest Exploration Co.	Fat Elk 2	SE¼ sec. 11, T. 28 S., R. 13 W. Coos County

Table 2. *Oil and gas tests drilled since January 1980*

Permit number	Operator	Well name	Location	Depth (ft)		Status
73 RD	Reichhold Energy Corp.	Longview Fibre 1 Redrill	SW¼ sec. 11, T. 6 N., R. 5 W. Columbia County	2,803	RD	Abandoned 5/10/80.
115	Reichhold Energy Corp.	Columbia County 12	NW¼ sec. 14, T. 6 N., R. 5 W. Columbia County	3,160 3,365	TD RD	Abandoned 3/15/80.

Table 2. *Oil and gas tests drilled since January 1980* (continued)

Permit number	Operator	Well name	Location	Depth (ft)		Status
116	Oregon Natural Gas Development Corp.	Crown Zellerbach 1	NW¼ sec. 13, T. 2 S., R. 10 W. Tillamook County	6,158	TD	Abandoned 1/8/80.
117	John T. Miller	John Stump 1	NW¼ sec. 26, T. 8 S., R. 5 W. Polk County	1,502	TD	Preparing to abandon 7/24/80.
119	American Quasar Petroleum Co.	Wall 24-13	SW¼ sec. 24, T. 6 N., R. 5 W. Columbia County	2,810	TD	Abandoned 1/25/80.
121	American Quasar Petroleum Co.	Longview Fibre 25-32	NE¼ sec. 25, T. 6 N., R. 5 W. Columbia County	2,902 3,261	TD RD	Abandoned 2/14/80.
122	American Quasar Petroleum Co.	Crown Zellerbach 14-21	NW¼ sec. 14, T. 5 N., R. 5 W. Columbia County	1,832	TD	Abandoned 2/22/80.
124	Reichhold Energy Corp.	Columbia County 33-3	SE¼ sec. 3, T. 6 N., R. 5 W. Columbia County	2,750	TD	Completed on 6/4/80 for an estimated flow of 6,000 MCF/D.
125	Reichhold Energy Corp.	Columbia County 43-11	SE¼ sec. 11, T. 6 N., R. 5 W. Columbia County	3,226 3,100 ±	TD RD	Suspended 6/23/80.
126	Reichhold Energy Corp.	Columbia County 42-1	NE¼ sec. 1, T. 6 N., R. 5 W. Columbia County	1,854	TD	Completed 7/22/80 new field extension, 900 MCF/D rate.
129	Reichhold Energy Corp.	Columbia County 44-4	SE¼ sec. 4, T. 6 N., R. 5 W. Columbia County	3,060	TD	Abandoned 5/26/80.
131	Reichhold Energy Corp.	Columbia County 32-3	NE¼ sec. 3, T. 6 N., R. 5 W. Columbia County	3,395	TD	Suspended 5/2/80.
135	Reichhold Energy Corp.	White 33-13	SE¼ sec. 13, T. 6 N., R. 5 W. Columbia County	2,708	TD	Abandoned 5/17/80.
137	Northwest Exploration Co.	Westport 1	SE¼ sec. 16, T. 26 S., R. 13 W. Coos County	3,692	TD	Abandoned 6/27/80.
138	Northwest Exploration Co.	Fat Elk 1	SW¼ sec. 15, T. 28 S., R. 13 W. Coos County	3,110	TD	Abandoned 7/28/80.
139	Northwest Exploration Co.	Sawyer Rapids 1	NE¼ sec. 3, T. 23 S., R. 9 W. Douglas County	5,563	TD	Abandoned 5/31/80.
143	Reichhold Energy Corp.	Adams 24-34	SW¼ sec. 34, T. 7 N., R. 5 W. Columbia County	3,377	TD	Abandoned 7/3/80.
153	Reichhold Energy Corp.	Columbia County 13-2	SW¼ sec. 2, T. 6 N., R. 5 W. Columbia County	–		Redrilling.

□

PUBLICATIONS ORDER

Omission of price indicates publication is in press. Minimum mail order 50¢. All sales are final. Publications are sent postpaid. Payment must accompany orders of less than $20.00.

Fill in appropriate blanks and send sheet to Department (see address on reverse side).

YOUR NAME ______________________

ADDRESS ______________________

______________________ Zip__________

Amount enclosed $__________

OREGON GEOLOGY

____ Renewal ____ Subscription ____ Gift

____ 1 Year ($4.00) ____ 3 Years ($10.00)

NAME ______________________

ADDRESS ______________________

______________________ ZIP __________

(If Gift, From: ______________________)

ORDER FORM - CUT ON DASHED LINE

Available publications

MISCELLANEOUS PAPERS	Price	No. Copies	Amount
1. A description of some Oregon rocks and minerals, 1950: Dole	$ 1.00	____	____
4. Laws relating to oil, gas, and geothermal exploration and development in Oregon			
Part 1. Oil and natural gas rules and regulations, 1977, rev. 1980	1.00	____	____
Part 2. Geothermal resources rules and regulations, 1977, rev. 1979	1.00	____	____
5. Oregon's gold placers (reprints), 1954	.50	____	____
6. Oil and gas exploration in Oregon, rev. 1965: Stewart and Newton	3.00	____	____
8. Available well records of oil and gas exploration in Oregon, rev. 1973: Newton	1.00	____	____
11. Collection of articles on meteorites, 1968 (reprints from *The Ore Bin*)	1.50	____	____
13. Index to *The Ore Bin*, 1950-1974	1.50	____	____
14. Thermal springs and wells, 1970: Bowen and Peterson (with 1975 supplement)	1.50	____	____
15. Quicksilver deposits in Oregon, 1971: Brooks	1.50	____	____
16. Mosaic of Oregon from ERTS-1 imagery, 1973	2.50	____	____
18. Proceedings of Citizens' Forum on potential future sources of energy, 1975	2.00	____	____
19. Geothermal exploration studies in Oregon – 1976, 1977	3.00	____	____
20. Investigations of nickel in Oregon, 1978: Ramp	5.00	____	____
GEOLOGIC MAPS			
Geologic map of Galice quadrangle, Oregon, 1953	1.75	____	____
Geologic map of Albany quadrangle, Oregon, 1953	1.00	____	____
Reconnaissance geologic map of Lebanon quadrangle, 1956	1.50	____	____
Geologic map of Bend quadrangle and portion of High Cascade Mountains, 1957	1.50	____	____
Geologic map of Oregon west of 121st meridian, 1961	2.25	____	____
Geologic map of Oregon east of 121st meridian, 1977	3.75	____	____
GMS-3: Preliminary geologic map of Durkee quadrangle, Oregon, 1967	2.00	____	____
GMS-4: Oregon gravity maps, onshore and offshore, 1967 (folded)	3.00	____	____
GMS-5: Geologic map of Powers quadrangle, Oregon, 1971	2.00	____	____
GMS-6: Preliminary report on geology of part of Snake River Canyon, 1974	6.50	____	____
GMS-7: Geology of the Oregon part of the Baker quadrangle, Oregon, 1976	3.00	____	____
GMS-8: Complete Bouguer gravity anomaly map, Cascade Mountain Range, central Oregon, 1978	3.00	____	____
GMS-9: Total field aeromagnetic anomaly map, Cascade Mountain Range, central Oregon, 1978	3.00	____	____
GMS-10: Low- to intermediate-temperature thermal springs and wells in Oregon, 1978	2.50	____	____
GMS-11: Preliminary geothermal resource map of Oregon (upon written request only)	free	(one copy per customer)	
GMS-12: Geologic map of the Oregon part of the Mineral quadrangle	2.00	____	____
OIL AND GAS INVESTIGATIONS			
3. Preliminary identifications of foraminifera, General Petroleum Long Bell #1 well	2.00	____	____
4. Preliminary identifications of foraminifera, E.M. Warren Coos County 1-7 well, 1973	2.00	____	____
5. Prospects for natural gas production or underground storage of pipeline gas	5.00	____	____
MISCELLANEOUS PUBLICATIONS			
Landforms of Oregon (17 × 12 inches)	.50	____	____
Mining claims (State laws governing quartz and placer claims)	.50	____	____
Geological highway map, Pacific NW region, Oregon-Washington (published by AAPG)	3.00	____	____
Fifth Gold and Money Session and Gold Technical Session Proceedings, 1975	5.00	____	____
Sixth Gold and Money Session and Gold Technical Session Proceedings, 1978	6.50	____	____
Back issues of *The Ore Bin*	25¢ over the counter; 50¢ mailed	____	____
Colored postcard, *Geology of Oregon*	10¢ each; 3 for 25¢; 7 for 50¢; 15 for 1.00	____	____

OREGON GEOLOGY

1069 State Office Building, Portland, Oregon 97201

Second Class Matter
POSTMASTER: Form 3579 requested

Available publications (continued)

BULLETINS	Price	No. Copies	Amount
33. Bibliography (1st supplement) geology and mineral resources of Oregon, 1947: Allen	1.00		
36. Papers on Tertiary foraminifera: Cushman, Stewart and Stewart, 1949: v. 2	1.25		
44. Bibliography (2nd supplement) geology and mineral resources of Oregon, 1953: Steere	2.00		
46. Ferruginous bauxite deposits, Salem Hills, 1956: Corcoran and Libbey	1.25		
49. Lode mines, Granite mining district, Grant County, Oregon, 1959: Koch	1.00		
53. Bibliography (3rd supplement) geology and mineral resources of Oregon, 1962: Steere and Owen	3.00		
57. Lunar Geological Field Conference guidebook, 1965: Peterson and Groh, editors	3.50		
63. Sixteenth biennial report of the Department, 1966-1968	1.00		
65. Proceedings of Andesite Conference, 1969: (copies)	10.00		
67. Bibliography (4th supplement) geology and mineral resources of Oregon, 1970: Roberts	3.00		
68. Seventeenth biennial report of the Department, 1968-1970	1.00		
71. Geology of selected lava tubes in Bend area, Oregon, 1971: Greeley	2.50		
76. Eighteenth biennial report of the Department, 1970-1972	1.00		
77. Geologic field trips in northern Oregon and southern Washington, 1973	5.00		
78. Bibliography (5th supplement) geology and mineral resources of Oregon, 1973: Roberts	3.00		
81. Environmental geology of Lincoln County, 1973: Schlicker and others	9.00		
82. Geologic hazards of Bull Run Watershed, Multnomah, Clackamas Counties, 1974: Beaulieu	6.50		
83. Eocene stratigraphy of southwestern Oregon, 1974: Baldwin	4.00		
84. Environmental geology of western Linn County, 1974: Beaulieu and others	9.00		
85. Environmental geology of coastal Lane County, 1974: Schlicker and others	9.00		
86. Nineteenth biennial report of the Department, 1972-1974	1.00		
87. Environmental geology of western Coos and Douglas Counties, 1975	9.00		
88. Geology and mineral resources of upper Chetco River drainage, 1975: Ramp	4.00		
89. Geology and mineral resources of Deschutes County, 1976	6.50		
90. Land use geology of western Curry County, 1976: Beaulieu	9.00		
91. Geologic hazards of parts of northern Hood River, Wasco, and Sherman Counties, Oregon, 1977: Beaulieu	8.00		
92. Fossils in Oregon (reprinted from *The Ore Bin*), 1977	4.00		
93. Geology, mineral resources, and rock material of Curry County, Oregon, 1977	7.00		
94. Land use geology of central Jackson County, Oregon, 1977: Beaulieu	9.00		
95. North American ophiolites, 1977	7.00		
96. Magma genesis: AGU Chapman Conference on Partial Melting, 1977	12.50		
97. Bibliography (6th supplement) geology and mineral resources of Oregon, 1971-75, 1978	3.00		
98. Geologic hazards of eastern Benton County, 1979: Bela	9.00		
99. Geologic hazards of northwestern Clackamas County, Oregon, 1979: Schlicker and Finlayson	10.00		
100. Geology and mineral resources of Josephine County, Oregon, 1979: Ramp and Peterson	9.00		
101. Geologic field trips in western Oregon and southwestern Washington, 1980	9.00		
SPECIAL PAPERS			
1. Mission, goals, and purposes of Oregon Department of Geology and Mineral Industries, 1978	2.00		
2. Field geology of SW Broken Top quadrangle, Oregon, 1978: Taylor	3.50		
3. Rock material resources of Clackamas, Columbia, Multnomah, and Washington Counties, Oregon, 1978: Gray and others	7.00		
4. Heat flow of Oregon, 1978: Blackwell, Hull, Bowen, and Steele	3.00		
5. Analysis and forecasts of the demand for rock materials in Oregon, 1979: Friedman and others	3.00		
6. Geology of the La Grande area, Oregon, 1980: Barrash and others	5.00		
7. Pluvial Fort Rock Lake, Lake County, Oregon: Allison	4.00		
8. Geology and geochemistry of the Mt. Hood volcano, 1980: White	2.00		
SHORT PAPERS			
18. Radioactive minerals prospectors should know, 1976: White, Schafer, Peterson	.75		
21. Lightweight aggregate industry in Oregon, 1951: Mason	.25		
24. The Almeda Mine, Josephine County, Oregon, 1967: Libbey	3.00		
25. Petrography, type Rattlesnake Formation, central Oregon, 1976: Enlows	2.00		
27. Rock material resources of Benton County, 1978: Schlicker and others	4.00		

OREGON GEOLOGY

published by the

Oregon Department of Geology and Mineral Industries

VOLUME 42, NUMBER 10

OCTOBER 1980

OREGON GEOLOGY

(ISSN 0164-3304)

VOLUME 42, NUMBER 10 OCTOBER 1980

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

Main Office: 1069 State Office Building, Portland 97201, phone (503) 229-5580.

Baker Field Office: 2033 First Street, Baker 97814, phone (503) 523-3133.
Howard C. Brooks, Resident Geologist

Grants Pass Field Office: 312 S.E. "H" Street, Grants Pass 97526, phone (503) 476-2496.
Len Ramp, Resident Geologist

Mined Land Reclamation Program: 1129 S.E. Santiam Road, Albany 97321, phone (503) 967-2039.
Paul F. Lawson, Supervisor

Subscription rates: 1 year, $4.00; 3 years, $10.00. Single issues, $.40 at counter, $.50 mailed.
Available back issues of *The Ore Bin:* $.25 at counter, $.50 mailed.

Address subscription orders, renewals, and changes of address to *Oregon Geology,* 1069 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,* 1069 State Office Building, Portland, OR 97201.

COVER PHOTO

Slide Canyon monocline, here deeply dissected by Menatchee Creek, forms southeast flank of Blue Mountains uplift in northeastern Oregon and southeastern Washington (see article beginning on next page). Grande Ronde Basalt flows of Columbia River Basalt Group are exposed in monocline.

New DOGAMI geologic map of Huntington and Oregon part of Olds Ferry quadrangles released

The Oregon Department of Geology and Mineral Industries (DOGAMI) announces the publication of *Geologic Map of the Huntington and Part of the Olds Ferry Quadrangles, Baker and Malheur Counties, Oregon.* Map GMS-13 is the newest addition to the Department's Geological Map Series and was prepared by Howard Brooks of the Department's Baker field office.

The multicolor map (scale 1:62,500) covers the Huntington quadrangle and the Oregon portion of the Olds Ferry quadrangle in eastern Oregon. It identifies sedimentary, volcanic, and intrusive rocks of Permian, Late Triassic, and Jurassic age and continental sedimentary and volcanic rocks of Miocene and Pliocene age divided into 17 different units. The Huntington and Weatherby Formations and the Jet Creek Member of the Weatherby Formation are named and briefly described as new stratigraphic units.

Price of map GMS-13 is $3.00. Address orders to the Oregon Department of Geology and Mineral Industries, either 1069 State Office Building, Portland, OR 97201, or 2033 First Street, Baker, OR 97814. Payment must accompany orders of less than $20.00. □

Stinchfield appointed to Governing Board

Allen P. Stinchfield, North Bend, has been appointed by Governor Victor Atiyeh to the Governing Board of the Oregon Department of Geology and Mineral Industries. He replaces Robert W. Doty, Talent, whose term ended June 30.

Stinchfield is a vice president of Menasha Corporation, Land and Timber Division, North Bend. He is also Chairman of the Board, Posey Manufacturing Company, Hoquiam, Washington, and a member of the Board of Directors of the Industrial Forestry Association, Oregon Forest Industries Council, Timber Operators Council, all of Portland, and of Anadromous, Inc., North Bend. □

CONTENTS

Tectonic controls of topographic development within Columbia River basalts in a portion of the Grande Ronde River-Blue Mountains region, Oregon and Washington

by M.E. Ross, Department of Earth Sciences, Northeastern University, Boston, Massachusetts 02115

INTRODUCTION

The area discussed in this article covers 515 km^2 (200 sq mi) of northeastern Oregon and southeastern Washington (Figure 1). The town of Troy, Oregon, is located at the confluence of the Grande Ronde and Wenaha Rivers, near the center of the study area. The northern portion, one-third of the total area, is part of the folded and faulted Blue Mountains uplift. The faulted Grouse Flat synclinal basin (Figure 2) occupies the southern portion, the remaining two-thirds of the study area. Approximately 90 percent of the uplifted northern portion and 45 percent of the southern portion of the area consist of steep canyon walls of the Grande Ronde River and its tributaries. The maximum local relief is 915 m (3,000 ft) and occurs within the vicinity of Diamond Peak in the extreme north-central part of the area (Figure 1). The canyons in the southern two-thirds of the area are generally about 610 m (2,000 ft) deep with steep, narrow inner canyons making up about half the total depth. The inner canyons usually open upward onto fairly broad, gently sloping terraces that extend out to meet steep, outer canyon walls (Figure 3). The inner canyons are developed almost entirely in Grande Ronde Basalt of the Yakima Basalt Subgroup of the Columbia River Basalt Group, and the terraces and outer canyon walls are formed in the overlying Wanapum Basalt and Saddle Mountains Basalt, also of the Yakima Basalt Subgroup, and sedimentary interbeds (Figure 3).

STRUCTURAL GEOLOGY

The Blue Mountains uplift in this area consists of the broad, asymmetric Saddle Butte anticline, which trends east to northeast and plunges 7° NE. at its end (Figure 2). The north limb of the anticline generally dips less than 5° N.; locally, however, blocks have been tilted more steeply and in other directions. The shorter south limb of the fold dips up to 9° S. before abruptly steepening along the hinge of the Slide Canyon monocline, which is nearly parallel to the hinge line of the anticline (Ross, 1975, 1978, 1979). The monocline dips up to 49° S., with dips commonly steeper than 25°. Dips abruptly flatten to less than 5° S. along the lower hinge of the monocline to form the north limb of the Grouse Flat synclinal basin. The hinge line shown in Figure 2 is drawn approximately midway across the broad, flat hinge zone of the syncline and is parallel to the fold hinge lines to the north. A maximum structural relief of 850 m (2,790 ft) has been measured on a thick Grande Ronde Basalt flow (Troy flow, see Figure 3) traced across these folds (Ross, 1978).

The July Ridge and Crooked Creek faults (Figure 2), the two normal faults mapped within the Blue Mountains uplift, have vertical offsets of up to 408 m (1,340 ft). The Grande Ronde fault system trends northeast across the southern limb of the Grouse Flat syncline (Figure 2). Within the system, the set of N. 20° E.-striking faults is dominant, but the faults are cut in at least one spot (Squaw Canyon) by a N. 40° W.-trending fault, suggesting they are conjugate. Left-lateral offsets of up to 695 m (2,280 ft) have been measured on two dikes cut by two of the northeast-trending en echelon faults. Dip-slip offsets of up to 207 m (680 ft) occurred subsequently (Ross, 1979).

TECTONIC CONTROLS OF TOPOGRAPHIC DEVELOPMENT

The topography in the Grande Ronde River-Blue Mountains area is controlled to a great extent by tectonic features. The area can be divided conveniently into three topographic zones reflecting differences in underlying structures (see Figure 2): Zone 1, the deeply dissected, well-drained area of the Blue Mountains uplift; Zone 2, the central, poorly drained zone of broad, nearly horizontal uplands dominated by Grouse Flat and extending south from Zone 1 to the Grande Ronde River; and Zone 3, the moderately well-drained, northward-sloping zone south of the Grande Ronde River (Figure 1). Zone 3 can be subdivided into west and east halves (Subzones 3A and 3B, respectively), with the eastern subzone more extensively dissected and better drained. The streams in these zones are classified according to the following scheme: (1) Consequent streams which were either antecedent streams that developed on the initial plateau surface prior to deformation or streams that developed on the plateau surface after initiation of deformation but apparently did not follow recognized tectonically produced weak zones; and (2) subsequent streams that developed along tectonically produced or accentuated weak zones.

Table 1 classifies the major streams and tributaries in the area according to this scheme. A stream may fall into more than one of the categories if the underlying structures change along its length or if its relationship to them changes. This table illustrates the strong tectonic control on stream development in the area.

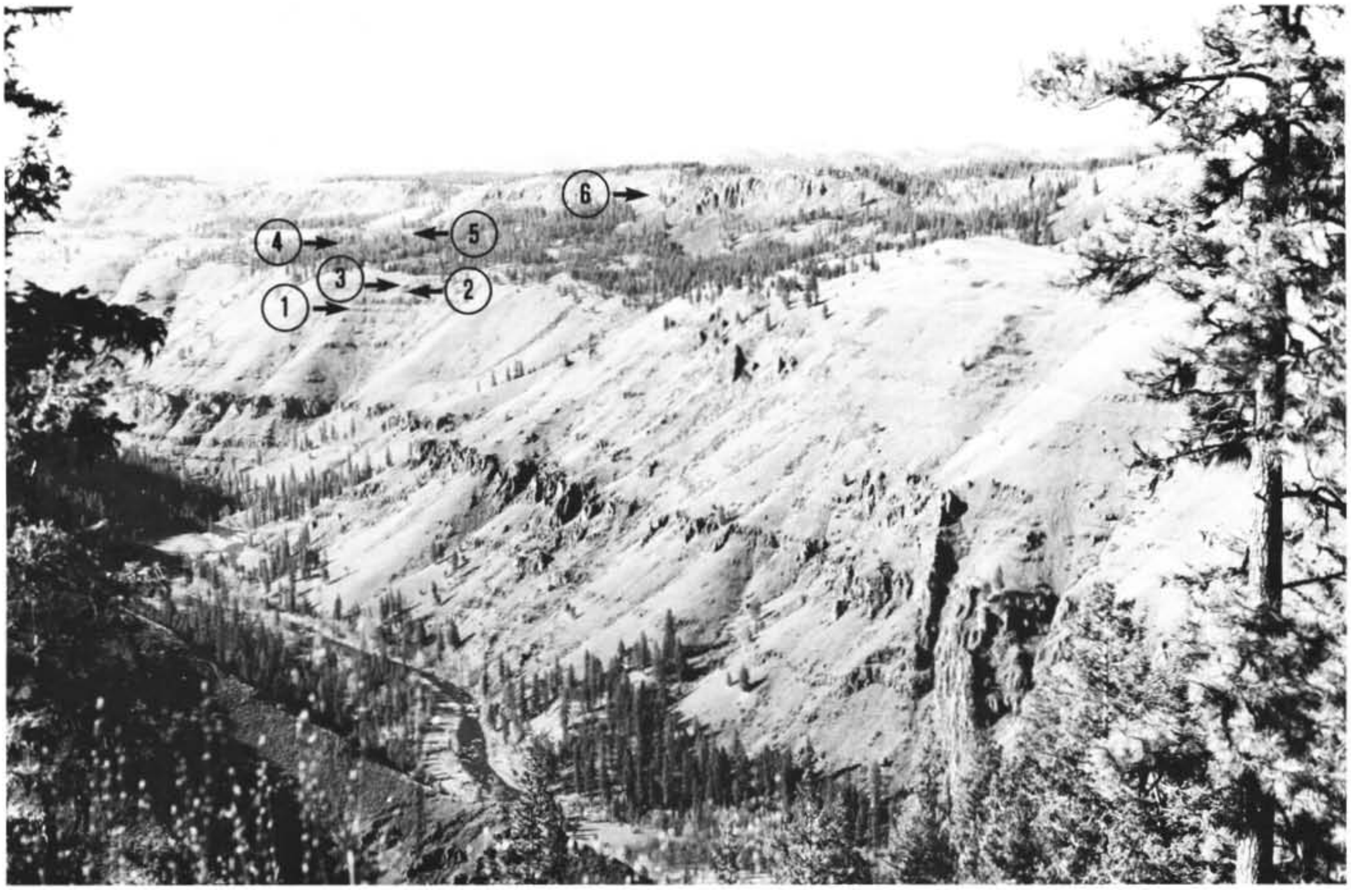


Figure 3. View looking northwest across Wenaha River approximately 4 km (2.5 mi) west of Troy, Oregon. Inner canyon is 366 m (1,200 ft) deep at this point. The Troy flow, which is 87 m (287 ft) thick, forms the prominent cliff midway up inner canyon wall. Numbered stratigraphic reference points are as follows: 1. Contact between R_2 (below) and N_2 magnetostratigraphic units within Grande Ronde Basalt. 2. Base of Wanapum Basalt sequence marked here by two Dodge flows. 3. Powatka flow of Wanapum Basalt, N_2 magnetic polarity. 4. Umatilla flow, normal magnetic polarity, at base of Saddle Mountains Basalt. 5. Grouse Creek sedimentary interbed (covered). 6. Wenaha flow, normal magnetic polarity, of Saddle Mountains Basalt. All magnetic polarities were determined with a portable fluxgate field magnetometer. A source dike for the Wenaha flow is exposed in the right foreground. The snow-covered Blue Mountains form the horizon in the background.

Zone 2

Zone 2 is dominated by the Grouse Flat syncline and consists of a broad, horizontal to nearly horizontal, poorly drained plateau surface. The Wenaha River is the principal stream in this zone and, at the town of Troy, joins the Grande Ronde River, which forms the southern limit of the zone. This section of the Wenaha River seems to be mainly subsequent, with its southeastward-flowing stretch possibly following northwest-trending conjugate joints, or even shears, related to the fault system to the southeast (Figure 2). Bear Creek, Grouse Creek, and perhaps Menatchee Creek follow this same northwest trend and may also be related to joint or shear sets. As a result, all of these streams are classified as subsequent in Table 1. Crooked Creek flows nearly due south in Zone 2 and seems to be consequent upon the northern limb of the Grouse Flat syncline (Figure 2).

Zone 3

Topographic Zone 3 lies south of the Grande Ronde River and is subdivided into west and east halves (Subzones 3A and 3B in Figure 2). Subzone 3A is transitional in character between Zone 2 and Subzone 3B, the latter of which is faulted and better drained than Subzone 3A. Subzone 3A, however, is slightly better drained than Zone 2 and consists of moderately eroded, relatively broad uplands from which much of the uppermost flow of Saddle Mountains Basalt has been stripped. This flow, the Wenaha flow (Walker, 1973), forms rounded, large remnant hills on an otherwise gently northward-sloping surface. Drainage in this portion of Zone 3 apparently is consequent upon the northward-dipping slopes.

The northeast-trending Grande Ronde fault system cuts diagonally across Subzone 3B (Figure 2). The predominant drainage direction is to the northwest,

Table 1. *Geomorphic classification of the major streams in the Grande Ronde River-Blue Mountains area*

Category	Streams
Consequent	
1A-type	Grande Ronde River and its southward-draining tributaries in Zone 1 (Blue Mountains)
1B-type	North-south stretches of Wallupa, Wildcat, Mud, and Courtney Creeks; Crooked Creek on Grouse Flat; Sickfoot Creek
Subsequent	Northwest-southeast-flowing portions of Mud and Courtney Creeks; Bear, Grouse, Buck, and Tope Creeks; perhaps Menatchee Creek on Grouse Flat; Wenaha River

possibly along northwest-trending faults, such as the Squaw Canyon fault, or joints. The streams in Subzone 3B are essentially all subsequent (Table 1). Tope Creek, in the southeast corner of the area, flows N. 20° E., parallel to the strike of the northeast-trending faults, and is probably following a minor joint or fault along which no measurable vertical offset is apparent. Squaw Canyon is formed primarily along the Squaw Canyon fault. Accelerated erosion in response to vertical displacement along the faults has removed most of the Wenaha flow from the plateau surface. Remnants of the flow remain as small, isolated hills over much of Subzone 3B. Incision of streams into the uplifted blocks has exposed the thickest section of Grande Ronde Basalts found anywhere in Zones 2 and 3.

Grande Ronde River

The Grande Ronde River was considered by Russell (1897) to be an antecedent stream, a conclusion with which the present study is in agreement. Locally, however, the river has been deflected by younger features. Horseshoe Bend, the northeasternmost meander within the area, was formed in part along the Horseshoe Bend fault (Figures 1 and 2). The fact that several meanders bordering Zone 3 have northwest-trending arms developed at the mouths of northwest-trending subsequent streams, most notably, Mud and Courtney Creeks (Figure 1), strongly suggests structural control of these portions of the meanders. The anomalously straight, east-flowing stretch of the Grande Ronde River just upstream from its confluence with Wildcat Creek (Figure 1) is less obviously related to the structural trends described so far. The same is true for the relatively straight east-flowing lower 2.5 km (1.5 mi) of the Wenaha River (Figure 1). There are no measurable vertical offsets of the basalts on either side of the rivers along these two sections. These two straight stretches could be controlled by joints or minor faults.

Well-formed entrenched meanders are a striking feature of the Grande Ronde River (Figure 1). Such extensive meandering does not occur in other rivers in the region, including the Snake River into which the Grande Ronde flows 63 km (39 mi) by river and 30 km (18 mi) by air downstream from the area discussed in this article. Lupher and Warren (1942) suggest the meanders may be related in some way to intracanyon lavas which may have blocked the Snake River shortly downstream from the mouth of the Grande Ronde River. They also indicate that the course of the ancestral Snake River did meander downstream from the Grande Ronde River to a degree perhaps comparable to the Grande Ronde during its earlier stages of entrenchment. They suggest that the intracanyon flows in the area may have destroyed these earlier meanders of the Snake River.

Hunt (1967) presents a brief discussion of meandering stream courses on certain streams of the Columbia Plateau, including the Grande Ronde River. He concludes that streams flowing down structural dips develop straight courses and those flowing along or across structures tend to meander. He also suggests that some drainage patterns may be relicts of conditions that no longer exist.

Vallier and Hooper (1976) also relate the straightness of the Snake River and the meandering of the lower Grande Ronde River to the former's following dominant northwest-trending structures and the latter's crossing those trends. They indicate that the incision was due either to uplift resulting from drag along a major northeast-trending vertical fault or uplift of the Blue Mountains after the rivers had cut their channels to near sea level.

Within the study area, meanders are well developed where the Grande Ronde River crosses the structural grain, such as at Horseshoe Bend, but are also well formed where the river runs essentially parallel to prominent fault trends. Also, if meanders along the ancestral Snake River did exist north (downstream) of the mouth of the Grande Ronde River, as implied by Lupher and Warren (1942), then the hypothesis of Vallier and Hooper (1976) is not entirely adequate.

The Grande Ronde River differs from the Snake River in two important aspects: (1) The Grande Ronde encountered thick, sedimentary interbeds early during downcutting, and (2) it has not yet cut down to pre-Tertiary rocks in the meandering, lower 120 km (74 mi) of its course (Swanson and others, 1977; Walker, 1979). The Grande Ronde River probably began to meander across the relatively flat plateau surface prior to deformation. It was able to maintain or re-establish a meandering course during early stages of folding and after extrusion of the last upper Yakima Basalt Subgroup flows (Wenaha and Buford flows and stratigraphic equivalents).

The river was able to increase greatly the breadth and shorten the radii of its meanders during the period of time it cut through the sedimentary interbed that lies beneath the Wenaha flow. The undercutting of the Wenaha flow must have been extensive when the river cut laterally within the underlying sedimentary interbed, as shown by the many large, isolated landslide blocks of the Wenaha flow scattered across the river terraces developed within the sedimentary interbed and underlying flow top.

During uplift of the Blue Mountains, these well-formed meanders became entrenched into the present-day, deep inner canyons of the Grande Ronde River. The absence of more massive and resistant pre-Tertiary rocks along the course of the river allowed preservation of its meanders during entrenchment. Lateral erosion along flow contacts, scoria tops, and closely jointed rock is significantly easier than in more massive igneous and metamorphic rocks, such as those exposed along the Snake River upstream of the mouth of the Grande Ronde River (see Newcomb's map, 1970). This is clearly evident along the Imnaha River, which has cut into large blocks of pre-Tertiary rocks at scattered localities along its length. The canyon of the Imnaha narrows markedly within the pre-Tertiary rocks, compared to its width within the intervening areas of basalt (W. Kleck, 1978, personal communication, my own observations).

Moderate meandering does occur along portions of some of these basalt stretches. The Limekiln fault just upstream from the mouth of the Grande Ronde River marks the downstream end of continuous exposures of pre-Tertiary rocks along the Snake River (Newcomb, 1970; Swanson and others, 1979; Walker, 1979). It is downstream from this point where, as Lupher and Warren (1942) suggest, the ancestral Snake did contain meanders which were subsequently destroyed by intracanyon lavas.

The Grande Ronde River may initially have begun to meander due to its crossing of the predominantly northwest-trending Basin and Range structures, as proposed by Hunt (1967) and Vallier and Hooper (1976). I believe, however, that the river was able to increase and maintain these meanders because of the conditions presented above. The depth attained by downcutting prior to the main uplift of the Blue Mountains is a very important factor. The uplift must have been relatively rapid, as is indicated, among other evidence, by the fact that the meanders are entrenched rather than ingrown (Rich, 1914). If uplift and entrenchment had occurred before the river cut through the interbeds, its meanders would be less well developed, if present at all.

CONCLUSIONS

The topography and stream courses within the area exhibit pronounced structural control. The topographically higher northern one-third of the area coincides with the anticlinal Blue Mountains uplift, and the lower southern portion consists of a broad synclinal basin. Most of the streams are consequent, having developed either on the initial plateau surface (antecedent) prior to deformation or else after initiation of deformation but without pronounced structural control. Many of the lesser streams are subsequent, at least in part flowing along tectonically produced or accentuated weak zones.

The striking and regionally unique entrenched meanders of the Grande Ronde River formed on the original, undeformed plateau surface and were able to enlarge early during downcutting when a thick sedimentary interbed was encountered. During entrenchment in response to regional uplift, the meanders were preserved largely because the river did not encounter the more resistant basement rocks lying stratigraphically below the Columbia River Basalt Group during downcutting along its entire lower course (Ross, 1978, 1980). Northwest-trending faults and joints across which the river flows also assisted in the development of the meanders. During the period of uplift, the broadly meandering Grande Ronde River was entrenched into the deep, narrow, and spectacular canyon through which it flows today.

ACKNOWLEDGMENTS

R.W. Jones and W.A. Newman reviewed the manuscript and offered many helpful suggestions. This investigation is part of a larger project by the author (1978) that was sponsored in part by Rockwell Hanford Operations and the Northwest Colleges and Universities for Science (NORCUS) under the United States Department of Energy Contracts EY-77-C-06-1030 and EY-76-F-06-2225, respectively. Financial assistance was also provided by two Grants-in-Aid of Research from the Society of the Sigma Xi.

REFERENCES CITED

Hunt, C.B., 1967, Physiography of the United States: San Francisco, Calif., W.H. Freeman and Co., 480 p.

Lupher, R.L., and Warren, W.C., 1942, The Asotin stage of the Snake River Canyon near Lewiston, Idaho: Journal of Geology, v. 50, no. 7, p. 866-881.

Newcomb, R.C., 1970, Tectonic structure of the main part of the basalt of the Columbia River Group, Washington, Oregon, and Idaho: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-587, scale 1:500,000.

Rich, J.L., 1914, Certain types of stream valleys and their meaning: Journal of Geology, v. 22, p. 469-497.

Ross, M.E., 1975, The structure of Yakima basalts in a portion of the Grande Ronde River region of northeastern Oregon and southeastern Washington: Geological Society of America Abstracts with Programs, v. 7, no. 5, p. 638-639.

——— 1978, Stratigraphy, structure, and petrology of Columbia River basalt in a portion of the Grande Ronde River-Blue Mountains area of Oregon and Washington: Moscow, Idaho, University of Idaho doctoral dissertation (also Richland, Wash., Rockwell Hanford Operations, RHO-SA-58), 460 p.

——— 1979, Large-scale strike-slip faulting of Columbia River basalt in northeast Oregon: Geological Society of America Abstracts with Programs, v. 11, no. 1, p. 51.

——— 1980, Stratigraphy, structure, and petrology of Columbia River basalt in a portion of the Grande Ronde River-Blue Mountains area of Oregon and Washington [abs.]: Oregon Geology, v. 42, no. 1, p. 17-18.

Russell, I.C., 1897, A reconnaissance in southeastern Washington: U.S. Geological Survey Water-Supply Paper 4, p. 1-76.

(Continued, p. 174)

Geothermal drilling continues at a steady pace

The Department issued 11 permits for geothermal exploration in the first part of 1980. The number of permits appears to be down from last year, but this is because a recent change in the law allows temperature gradient holes to be drilled to a depth of 2,000 ft instead of 500 ft. Therefore, a well that would have formerly been called a geothermal well can now be drilled under a blanket prospect well permit. Geothermal wells require a separate permit for each hole.

No commercial geothermal discoveries have yet been announced, but the recent spectacular eruptions of Mount St. Helens confirm geologists' belief that there is usable heat energy in the Cascade Range. Most drilling thus far in Oregon has been for temperature gradient data. If thermal anomalies are found by gradient drilling or geophysical methods, then deep holes will be put down. This type drilling could get under way in 1981.

Table 1. *Geothermal permits issued since April 1980*

Permit number	Operator	Well name	Location	Status
Geothermal Well #81	NW Geothermal Corp.	Site 7-A Old Maid Flat (Mt. Hood)	Center sec. 15, T. 2 S., R. 8 E. Clackamas County	Drilling at 400 ft, Aug. 6, 1980.
Prospect Well #62	Chevron Resources	–	Alvord Desert Harney County	Preparing to drill 31 500-ft temperature gradient holes.
Prospect Well #63	Robert Dollar Co.	–	Klamath Falls Klamath County	Proposed to drill one 500-ft temperature gradient hole.
Prospect Well #64	Amax Exploration Co.	–	Bully Creek Malheur County	Proposed to drill 3 2,000-ft temperature gradient holes.
Prospect Well #65	Anadarko Production Co.	–	Alvord Desert Harney County	Proposed to drill 11 temperature gradient holes between 500 and 2,000 ft in depth.
Prospect Well #66	Phillips Petroleum Co.	–	Glass Buttes Lake County	Drilled one 2,000-ft temperature gradient hole. Spudded second hole on Aug. 4, 1980.
Prospect Well #67	Hunt Energy Co.	–	Owyhee Reservoir Malheur County	Began drilling on a 23-hole temperature gradient program June 17, 1980.
Prospect Well #68	Oregon Dept. of Geology and Mineral Industries	–	Central Cascades Clackamas and Lane Counties	Have drilled 12 500-ft temperature gradient holes since beginning of June 1980.
Prospect Well #69	Chevron Resources	–	South Warner Valley Lake County	Proposed to drill several 2,000-ft temperature gradient holes.
Prospect Well #70	Chevron Resources	–	S. Crump Lake Lake County	Began drilling on a 17-hole temperature gradient program in early August 1980. Depth will range from 500 to 2,000 ft.

Table 2. *Work done in 1980 under existing geothermal permits*

Permit number	Operator	Well name	Location	Depth (ft)	Remarks
Geothermal Well #10	U.S. Dept. of Energy (NW Natural Gas Co.)	Old Maid Flat Retest (Mt. Hood)	Sec. 15, T. 2 S., R. 8 E. Clackamas County	4,006 TD	Ran formation test, took core. Results were negative.
Geothermal Well #45	U.S. Geological Survey	Newberry Crater 2	SW¼ sec. 31, T. 21 S., R. 31 E. Deschutes County	2,076	Monitoring temperatures.
Geothermal Well #46	Ore-Ida Foods (USDOE grant)	Well 1	NE¼ sec. 3, T. 18 S., R. 47 E. Malheur County	10,050	Monitoring temperature, contemplating additional tests.
Geothermal Well #70	U.S. Geological Survey	Pucci Chair Lift (Mt. Hood)	Sec. 7, T. 3 S., R. 9 E. Clackamas County	2,000	Will deepen to 4,000 ft.
Geothermal Well #80	Chevron Resources	Jordan 1	NW¼ sec. 9, T. 18 S., R. 43 E. Malheur County	2,820 TD	Plugged and abandoned in Feb. 1980.
Prospect Well #34	SUNOCO Energy Development Co.	–	Austin Hot Springs Mt. Hood National Forest	–	Plan to drill 10 500-ft temperature gradient holes in 1980.
Prospect Well #35	SUNOCO Energy Development Co.	–	Central Cascades Willamette National Forest	–	Plan to drill 10 500-ft temperature gradient holes in 1980.
Prospect Well #47	NW Geothermal Corp. (NW Natural Gas Co.)	McGee Creek 1	Mt. Hood area Clackamas County	2,000 TD	Deepened original hole from 770 to 2,000 ft in 1980.
Prospect Well #58	Union Oil Co.	Alvord Desert	Harney County	2,000	Plan to drill one 2,000-ft temperature gradient hole in 1980. □

Updated list of Oregon oil and gas records now available

The Oregon Department of Geology and Mineral Industries (DOGAMI) has completed an updated summary of its oil and gas well records. DOGAMI's Miscellaneous Paper 8, entitled *Available Well Records of Oil and Gas Exploration in Oregon*, is now available in its fourth revised edition.

The paper lists all available well records of oil and gas exploration drilled in Oregon between 1909 and March 1980 in tabular form by county. For each well, the table indicates company and well name; location, date, and depth of the well; and nature and availability of lithologic descriptions, logs, surveys, and samples kept in the DOGAMI collection. An orientation map of Oregon showing the Township and Range system is included to aid the reader in locating the wells. The preface also lists addresses of firms that can provide copies of the complete well records.

Price of the revised Miscellaneous Paper 8 is $2.00. Address orders to the Oregon Department of Geology and Mineral Industries, 1069 State Office Building, Portland, OR 97201. Payment must accompany orders of less than $20.00. □

Civilization exists through geological consent, subject to change without notice.

—Will Durant, via John Allen and the GSOC Newsletter

Newton accepts new position with Northwest Natural Gas

Vernon C. Newton, Jr., petroleum engineer with the Oregon Department of Geology and Mineral Industries for the past 23 years, resigned in August to join Northwest Natural Gas Company. He was the first petroleum engineer hired by the state to regulate exploratory drilling as the search for oil and gas in Oregon intensified during the 1950's. After passage of the Oregon Geothermal Act in 1971, his responsibility was extended to include geothermal drilling.

While he was with the Department, he organized records files of wells drilled in the state and established a sample library, both of which have been used considerably by industry geologists, consultants, and researchers. He authored six major reports on oil and gas exploration in Oregon, the last of which will be released early next year as Oil and Gas Investigation No. 6, *Prospects for Oil and Gas in the Coos Basin, Western Coos, Douglas, and Lane Counties, Oregon.* His study of the oil and gas prospects of the upper Nehalem basin drew attention to the Mist area, where commercial deposits of natural gas were discovered in 1979.

Newton contributed numerous articles to the Department's monthly magazine and to industry journals. He also assisted with investigations of six nuclear power sites and four chemical disposal sites in Oregon.

Vernon C. Newton, Jr.

Newton served on many committees during his tenure with the Department, including the Governor's Nuclear Siting Task Force, Governor's Task Force on Outer Continental Shelf Development, Governor's Committee on Synthetic Chemicals in the Environment, Colorado School of Mines' Potential Gas Committee, Geothermal Resources Council, Regulatory Practices Committee of Interstate Oil Compact Commission, and the American Petroleum Institute Statistics Committee.

He assisted with legislation for the Oregon Tide and Submerged Lands Act, the Oil and Gas Unitization Law, the Oregon Geothermal Law, and Law for the Underground Storage of Natural Gas. Regulations drafted include rules for offshore core drilling, revised oil and gas rules, geothermal rules, and rules for injection of geothermal fluids.

Until Newton's position is filled, Dennis L. Olmstead, also of the Department, is temporarily assuming most of his duties. □

Tek Rock Club 18th Annual Gem and Mineral Show to be held at OMSI this month

The Tek Rock Club has set October 24-26, 1980, as the dates for its 18th Annual Gem and Mineral Show to be held at the Oregon Museum of Science and Industry (OMSI), Portland, Oregon.

The show includes gems and minerals native to the state of Oregon as well as special collections of petrified wood, sunstone, agate, and jasper from surrounding areas. Gemstones finished by some of the finest amateur lapidaries in the Pacific Northwest will be exhibited.

Hours of the show are Friday, October 24, 9 a.m. to 9 p.m.; Saturday, October 25, 9 a.m. to 5 p.m.; and Sunday, October 26, 9 a.m. to 6 p.m. The show is free to all after the OMSI admission. More information may be obtained from Show Chairman Kit Crayne, 20480 S.W. Florence, Aloha, Oregon 97006; phone (503) 649-4065. □

(Tectonic controls, *continued from p. 171***)**

Swanson, D.A., Wright, T.L., Camp, V.E., Gardner, J.N., Helz, R.T., Price, S.A., and Ross, M.E., 1977, Reconnaissance geologic map of the Columbia River Basalt Group, Pullman and Walla Walla quadrangles, southeast Washington and adjacent Idaho: U.S. Geological Survey Open-File Report 77-100, scale 1:250,000.

Vallier, T.L., and Hooper, P.R., 1976, Geologic guide to Hells Canyon, Snake River: Pullman, Wash., Washington State University (Geological Society of America, Cordilleran Section, 72nd annual meeting, field guide no. 5), 38 p.

Walker, G.W., 1973, Contrasting compositions of the youngest Columbia River basalt flows in Union and Wallowa Counties, northeastern Oregon: Geological Society of America Bulletin, v. 84, no. 2, p. 425-429.

— — — 1979, Reconnaissance geologic map of the Oregon part of the Grangeville quadrangle, Baker, Union, Umatilla, and Wallowa Counties, Oregon: U.S. Geological Survey Miscellaneous Investigations Series, Map I-1116, scale 1:250,000. □

PUBLICATIONS ORDER

Omission of price indicates publication is in press. Minimum mail order 50¢. All sales are final. Publications are sent postpaid. Payment must accompany orders of less than $20.00.

Fill in appropriate blanks and send sheet to Department (see address on reverse side).

YOUR NAME ____________________

ADDRESS ____________________

____________________ Zip__________

Amount enclosed $__________

OREGON GEOLOGY

___ Renewal ___ Subscription ___ Gift

___ 1 Year ($4.00) ___ 3 Years ($10.00)

NAME ____________________

ADDRESS ____________________

____________________ ZIP __________

(If Gift, From: ____________________)

ORDER FORM - CUT ON DASHED LINE

Available publications

MISCELLANEOUS PAPERS	Price	No. Copies	Amount
1. A description of some Oregon rocks and minerals, 1950: Dole	$ 1.00		
4. Laws relating to oil, gas, and geothermal exploration and development in Oregon			
Part 1. Oil and natural gas rules and regulations, 1977, rev. 1980	1.00		
Part 2. Geothermal resources rules and regulations, 1977, rev. 1979	1.00		
5. Oregon's gold placers (reprints), 1954	.50		
6. Oil and gas exploration in Oregon, rev. 1965: Stewart and Newton	3.00		
8. Available well records of oil and gas exploration in Oregon, rev. 1980: Olmstead and Newton	2.00		
11. Collection of articles on meteorites, 1968 (reprints from *The Ore Bin*)	1.50		
13. Index to *The Ore Bin*, 1950-1974	1.50		
14. Thermal springs and wells, 1970: Bowen and Peterson (with 1975 supplement)	1.50		
15. Quicksilver deposits in Oregon, 1971: Brooks	1.50		
16. Mosaic of Oregon from ERTS-1 imagery, 1973	2.50		
18. Proceedings of Citizens' Forum on potential future sources of energy, 1975	2.00		
19. Geothermal exploration studies in Oregon – 1976, 1977	3.00		
20. Investigations of nickel in Oregon, 1978: Ramp	5.00		
GEOLOGIC MAPS			
Geologic map of Galice quadrangle, Oregon, 1953	1.75		
Geologic map of Albany quadrangle, Oregon, 1953	1.00		
Reconnaissance geologic map of Lebanon quadrangle, 1956	1.50		
Geologic map of Bend quadrangle and portion of High Cascade Mountains, 1957	1.50		
Geologic map of Oregon west of 121st meridian, 1961	2.25		
GMS-3: Preliminary geologic map of Durkee quadrangle, Oregon, 1967	2.00		
GMS-4: Oregon gravity maps, onshore and offshore, 1967 (folded)	3.00		
GMS-5: Geologic map of Powers quadrangle, Oregon, 1971	2.00		
GMS-6: Preliminary report on geology of part of Snake River Canyon, 1974	6.50		
GMS-7: Geology of the Oregon part of the Baker quadrangle, Oregon, 1976	3.00		
GMS-8: Complete Bouguer gravity anomaly map, Cascade Mountain Range, central Oregon, 1978	3.00		
GMS-9: Total field aeromagnetic anomaly map, Cascade Mountain Range, central Oregon, 1978	3.00		
GMS-10: Low- to intermediate-temperature thermal springs and wells in Oregon, 1978	2.50		
GMS-12: Geologic map of the Oregon part of the Mineral quadrangle, 1978	2.00		
GMS-13: Geologic map of the Huntington and part of the Olds Ferry quadrangles, Oregon, 1979	3.00		
OIL AND GAS INVESTIGATIONS			
3. Preliminary identifications of foraminifera, General Petroleum Long Bell #1 well	2.00		
4. Preliminary identifications of foraminifera, E.M. Warren Coos County 1-7 well, 1973	2.00		
5. Prospects for natural gas production or underground storage of pipeline gas	5.00		
MISCELLANEOUS PUBLICATIONS			
Landforms of Oregon (17 × 12 inches)	.50		
Mining claims (State laws governing quartz and placer claims)	.50		
Geological highway map, Pacific NW region, Oregon-Washington (published by AAPG)	3.00		
Fifth Gold and Money Session and Gold Technical Session Proceedings, 1975	5.00		
Sixth Gold and Money Session and Gold Technical Session Proceedings, 1978	6.50		
Back issues of *The Ore Bin*	25¢ over the counter; 50¢ mailed		
Colored postcard, *Geology of Oregon*	10¢ each; 3 for 25¢; 7 for 50¢; 15 for 1.00		

OREGON GEOLOGY

1069 State Office Building, Portland, Oregon 97201

Second Class Matter
POSTMASTER: Form 3579 requested

Available publications (continued)

BULLETINS	Price	No. Copies	Amount
33. Bibliography (1st supplement) geology and mineral resources of Oregon, 1947: Allen	1.00	____	____
36. Papers on Tertiary foraminifera: Cushman, Stewart and Stewart, 1949: v. 2	1.25	____	____
44. Bibliography (2nd supplement) geology and mineral resources of Oregon, 1953: Steere	2.00	____	____
46. Ferruginous bauxite deposits, Salem Hills, 1956: Corcoran and Libbey	1.25	____	____
49. Lode mines, Granite mining district, Grant County, Oregon, 1959: Koch	1.00	____	____
53. Bibliography (3rd supplement) geology and mineral resources of Oregon, 1962: Steere and Owen	3.00	____	____
57. Lunar Geological Field Conference guidebook, 1965: Peterson and Groh, editors	3.50	____	____
63. Sixteenth biennial report of the Department, 1966-1968	1.00	____	____
65. Proceedings of Andesite Conference, 1969: (copies)	10.00	____	____
67. Bibliography (4th supplement) geology and mineral resources of Oregon, 1970: Roberts	3.00	____	____
68. Seventeenth biennial report of the Department, 1968-1970	1.00	____	____
71. Geology of selected lava tubes in Bend area, Oregon, 1971: Greeley	2.50	____	____
76. Eighteenth biennial report of the Department, 1970-1972	1.00	____	____
77. Geologic field trips in northern Oregon and southern Washington, 1973	5.00	____	____
78. Bibliography (5th supplement) geology and mineral resources of Oregon, 1973: Roberts	3.00	____	____
81. Environmental geology of Lincoln County, 1973: Schlicker and others	9.00	____	____
82. Geologic hazards of Bull Run Watershed, Multnomah, Clackamas Counties, 1974: Beaulieu	6.50	____	____
83. Eocene stratigraphy of southwestern Oregon, 1974: Baldwin	4.00	____	____
84. Environmental geology of western Linn County, 1974: Beaulieu and others	9.00	____	____
85. Environmental geology of coastal Lane County, 1974: Schlicker and others	9.00	____	____
86. Nineteenth biennial report of the Department, 1972-1974	1.00	____	____
87. Environmental geology of western Coos and Douglas Counties, 1975	9.00	____	____
88. Geology and mineral resources of upper Chetco River drainage, 1975: Ramp	4.00	____	____
89. Geology and mineral resources of Deschutes County, 1976	6.50	____	____
90. Land use geology of western Curry County, 1976: Beaulieu	9.00	____	____
91. Geologic hazards of parts of northern Hood River, Wasco, and Sherman Counties, Oregon, 1977: Beaulieu	8.00	____	____
92. Fossils in Oregon (reprinted from *The Ore Bin*), 1977	4.00	____	____
93. Geology, mineral resources, and rock material of Curry County, Oregon, 1977	7.00	____	____
94. Land use geology of central Jackson County, Oregon, 1977: Beaulieu	9.00	____	____
95. North American ophiolites, 1977	7.00	____	____
96. Magma genesis: AGU Chapman Conference on Partial Melting, 1977	12.50	____	____
97. Bibliography (6th supplement) geology and mineral resources of Oregon, 1971-75, 1978	3.00	____	____
98. Geologic hazards of eastern Benton County, 1979: Bela	9.00	____	____
99. Geologic hazards of northwestern Clackamas County, Oregon, 1979: Schlicker and Finlayson	10.00	____	____
100. Geology and mineral resources of Josephine County, Oregon, 1979: Ramp and Peterson	9.00	____	____
101. Geologic field trips in western Oregon and southwestern Washington, 1980	9.00	____	____
SPECIAL PAPERS			
1. Mission, goals, and purposes of Oregon Department of Geology and Mineral Industries, 1978	2.00	____	____
2. Field geology of SW Broken Top quadrangle, Oregon, 1978: Taylor	3.50	____	____
3. Rock material resources of Clackamas, Columbia, Multnomah, and Washington Counties, Oregon, 1978: Gray and others	7.00	____	____
4. Heat flow of Oregon, 1978: Blackwell, Hull, Bowen, and Steele	3.00	____	____
5. Analysis and forecasts of the demand for rock materials in Oregon, 1979: Friedman and others	3.00	____	____
6. Geology of the La Grande area, Oregon, 1980: Barrash and others	5.00	____	____
7. Pluvial Fort Rock Lake, Lake County, Oregon: Allison	4.00	____	____
8. Geology and geochemistry of the Mt. Hood volcano, 1980: White	2.00	____	____
SHORT PAPERS			
18. Radioactive minerals prospectors should know, 1976: White, Schafer, Peterson	.75	____	____
21. Lightweight aggregate industry in Oregon, 1951: Mason	.25	____	____
24. The Almeda Mine, Josephine County, Oregon, 1967: Libbey	3.00	____	____
25. Petrography, type Rattlesnake Formation, central Oregon, 1976: Enlows	2.00	____	____
27. Rock material resources of Benton County, 1978: Schlicker and others	4.00	____	____

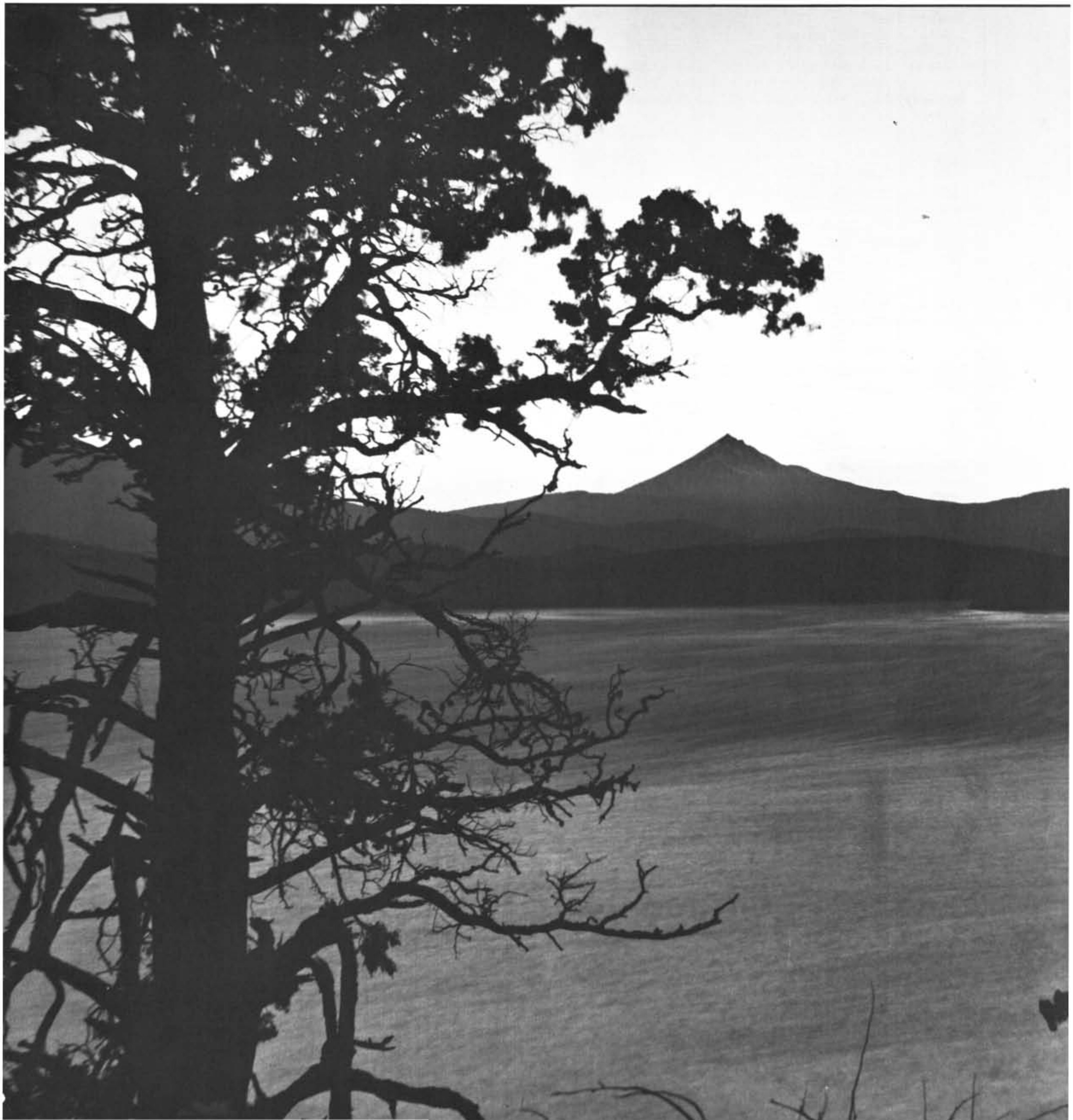
OREGON GEOLOGY

published by the

Oregon Department of Geology and Mineral Industries

VOLUME 42, NUMBER 11

NOVEMBER 1980



OREGON GEOLOGY

(ISSN 0164-3304)

VOLUME 42, NUMBER 11 NOVEMBER 1980

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

Main Office: 1069 State Office Building, Portland 97201, phone (503) 229-5580.

Baker Field Office: 2033 First Street, Baker 97814, phone (503) 523-3133.
Howard C. Brooks, Resident Geologist

Grants Pass Field Office: 312 S.E. "H" Street, Grants Pass 97526, phone (503) 476-2496.
Len Ramp, Resident Geologist

Mined Land Reclamation Program: 1129 S.E. Santiam Road, Albany 97321, phone (503) 967-2039.
Paul F. Lawson, Supervisor

Subscription rates: 1 year, $4.00; 3 years, $10.00. Single issues, $.40 at counter, $.50 mailed.
Available back issues of *The Ore Bin:* $.25 at counter, $.50 mailed.

Address subscription orders, renewals, and changes of address to *Oregon Geology,* 1069 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,* 1069 State Office Building, Portland, OR 97201.

COVER PHOTO

Mt. McLoughlin, seen from Upper Klamath Lake, the shrunken remnant of pluvial Lake Modoc discussed in article beginning on next page. (Oregon Department of Transportation photo)

Mineral resource data now accessible through Department computer terminal

The Oregon Department of Geology and Mineral Industries is offering a new service starting December 1, 1980. The Department, through a computer terminal in the Portland office, now has access to the U.S. Geological Survey's Computerized Resource Information Bank (CRIB) and the Geothermal Sample Data/Chemical Analysis systems. Information on Oregon's metallic deposits, mines, and prospects and geothermal springs and wells can now be retrieved in the form of a computer printout.

At the present time, the CRIB system has 2,800 entries for Oregon. As the Department, under contract to the USGS, updates the system, the total for Oregon may rise to 4,000 or more entries. The northeast portion of the State has been updated, and the southeast section is in the process of being completed. Data from CRIB can be retrieved by county, mining district, deposit name, topographic map, commodity, size, or conceivably by any other of 200 parameters that can be listed for a deposit under CRIB.

Data on 189 of Oregon's thermal springs and wells can also be obtained through the terminal. The Geothermal Sample file contains information concerning the physical characteristics, geology, geochemistry, and hydrology of national and some international geothermal resources. It also includes chemical analyses of water, condensate, and gas.

The Department is offering to extract data from either of the two systems for the cost of the terminal plus staff time. The cost of staff time will probably equal that of the terminal cost. The work must be scheduled in view of other project demands and will therefore require reasonable lead time. For more information, contact Jerry Gray, Albany Field Office, phone (503) 967-2039. □

CONTENTS

Renew your subscription now!

Pluvial Lake Modoc, Klamath County, Oregon, and Modoc and Siskiyou Counties, California

by Samuel N. Dicken, Emeritus Professor of Geography, University of Oregon, Eugene, Oreg. 97403

INTRODUCTION

The Klamath Lakes, Upper and Lower, together with Tule Lake are the shrunken remnants of pluvial Lake Modoc (named in this article by the author). The old pluvial lake, which existed in Pleistocene time, consisted of several connected arms with an overall length of nearly 75 mi (120 km). The southern end was in California, south of Tule Lake; the northern end was near Fort Klamath in west-central Klamath County. At maximum extent, the 400 mi (663 km) of shoreline was at the nearly uniform elevation of 4,240 ft (1,292 m) above sea level. The lake basins were formed by block faulting and igneous activity and partially filled by sediment—cinders, ash, and pumice carried by meltwater from the Cascade Range to the lake. Eight major basins are included in the bed of the old lake. The largest are Upper Klamath, Lower Klamath, and Tule Lakes; the smaller basins, called valleys, are Spring Lake, Poe, Swan Lake, Yonna, and Langell Valleys. At the present time, only Upper Klamath Lake has a large body of water, the largest in Oregon.

PLUVIAL LAKES OF EASTERN OREGON

The pluvial lakes of western North America attracted the attention of geologists and geographers a century ago. The classic studies of Lakes Bonneville in Utah (Gilbert, 1890) and Lahontan in Nevada (Russell, 1885) are well known. Several brief general references have included Oregon's pluvial lakes (Meinzer, 1922; Feth, 1961), some accompanied by small-scale maps showing the general location but no details of shoreline. A map of Pleistocene pluvial lakes in the Great Basin compiled by Snyder and others (1964) from field studies, topographic maps, and aerial photographs indicates areas, names (if any), and outlets. Pluvial Lake Modoc was not included since it is not in the Great Basin. Two Oregon pluvial lakes have been studied and mapped in detail, Fort Rock (Forbes, 1972; Allison, 1979) and Chewaucan (Allison, 1945). Table 1 gives information about the pluvial lakes of eastern Oregon.

In addition to the lakes listed in Table 1, many smaller basins held water in Pleistocene times, when large parts of Klamath, Lake, Harney, and Malheur Counties were covered with water. Many of these lakes are yet unnamed, because the practice of naming the pluvial lakes has been slow to develop. Furthermore, because it would seem desirable that the names should be distinct from those of the present-day lakes, the pluvial lakes now called Malheur and Goose should have new names.

PLUVIAL LAKE MODOC

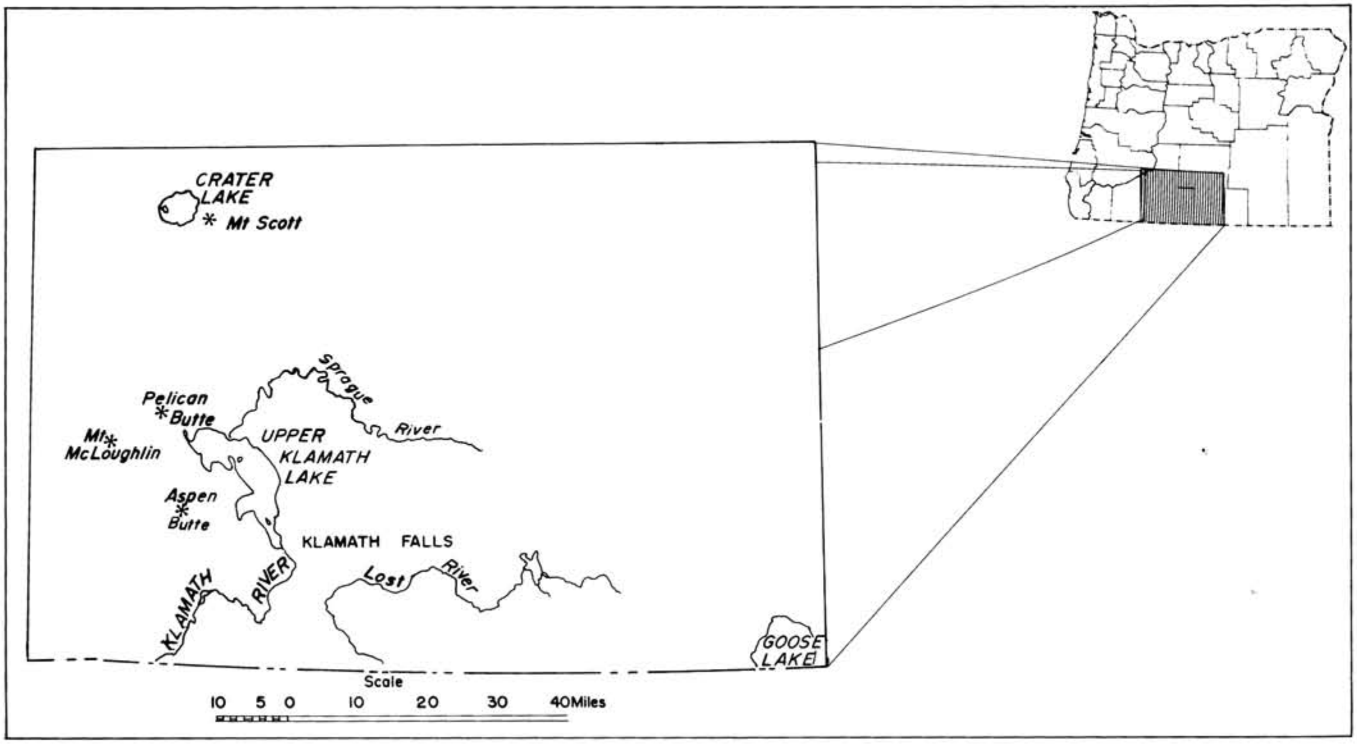
Lake Modoc, which covered an area of 1,096 sq mi (2,839 km^2), differed in some respects from the other pluvial lakes described above. It lay in the Basin and Range Province, not in the Great Basin. The location near the Cascade Range assured a large supply of water down to and including historic time, so that the lake has had a continuous surface outlet. The lake plain, as it is exposed, is nearly level from one end to the other, showing very little evidence of warping. In the pages to follow, the features of the old lake are described with some notes on its evolution and the modifications made by man in the present century.

Lake Modoc was developed on the northwest margin of the Basin and Range Province where block faulting and igneous activity formed numerous closed depressions, intervening ridges, and uplands. This Basin and Range type of structure can be traced through California, Nevada, Arizona, and far into Mexico. In the Lake Modoc area, the fault patterns are unusually complex and closely spaced; the geologic map of western Oregon (Wells and Peck, 1961) shows more than 100 faults in the vicinity of the lake, the major ones trending northwest-southeast. A complex line of faults separates the lake from the east slope of the Cascade Range. On the east side of Upper Klamath Lake, a fresh fault scarp rises abruptly from the lake. The major arms of the lake as well as the ridges are bordered by faults.

Numerous fault blocks in the form of hogback ridges,

Table 1. Other pluvial lakes of eastern Oregon

Pluvial lake name and location	Area	Comments
Fort Rock, Northern Lake Co., Oreg.	585 sq mi (1,510 km^2)	Two lobes, one in Fort Rock Valley, one in Christmas Valley. East-west length, 50 mi (80 km); north-south width, 30 mi (48 km). May not always have had surface outlet.
Chewaucan, Central Lake Co., Oreg.	461 sq mi (1,190 km^2)	Covered area of present-day Summer and Abert Lakes and surrounding marshy lowland. Irregular shape, with length of nearly 50 mi (80 km).
Goose, Southern Lake Co., Oreg.; Modoc Co., Calif.	368 sq mi (953 km^2)	Length, 50 mi (80 km); width, 17 mi (27 km). Dry more than once in historic time; located on southern immigrant trail. Highest of Oregon's pluvial lakes, with highest shoreline near 5,000 ft (1,524 m). Drainage south to Pitt River.
Malheur, Harney Co., Oreg.	920 sq mi (2,380 km^2)	Included present-day Harney and Malheur Lakes and surrounding plains, called Harney Basin. Tributaries from Blue Mountains on the north and Steens Mountains on the south; outlet eastward to Malheur and Snake Rivers.
Coleman, Southwestern Lake Co., Oreg.	483 sq mi (1,250 km^2)	Remnant lakes, known collectively as Warner Lakes, include Bluejoint, Flagstaff, Hart, and Crump Lakes. Long and narrow shape.
Catlow, Harney Co., Oreg.	351 sq mi (909 km^2)	Drained into pluvial Lake Malheur.
Alkali, Eastern Lake Co., Oreg.	212 sq mi	– (549 km^2)
Alvord, Harney Co., Oreg.	491 sq mi (1,270 km^2)	Length greater than 100 mi (161 km); width only 10 mi (16 km).



Map showing locations of some features discussed in this article.

hills, and mountains rise above the plain. Some of the smaller ones, like Miller Hill southeast of Klamath Falls and Turkey Hill near Malin, which were islands in the old lake, provide the best preserved examples of the old shoreline. The larger and higher fault block uplands are called rims, scarps, hills, or mountains according to their size, shape, profile, and the whim of the people who named them. Some of them like Stukel Mountain, Hogback Mountain, and Moyina Hill rise 2,000 ft (610 m) above the lake plain.

Plum Hills, named from the wild plums which grew there once, is a fault splinter, 8 mi (13 km) long, rising to nearly 6,000 ft (1,829 m). Farther east is Hogback Mountain, broader and slightly higher. Stukel Mountain is part of a hilly upland, 10 mi (16 km) long and 7 mi (11 km) wide, between Poe Valley and the lower valley of Lost River. Bryant Mountain is 15 mi (24 km) long and 5 mi (8 km) wide, separating Langell Valley from the basin of Tule Lake. The highest point is just under 6,000 ft (1,829 m). The broader and higher mountains are broken up into ridges and narrow valleys by interior faults. In Modoc and Siskiyou Counties, California, some of the elevations are in the form of conical hills, including cinder cones and dome mountains. A few elevated lava-capped mesas occur, such as Big Tableland southwest of Lower Klamath Lake. The Modoc Lava Beds extend into the lake, covering a part of the old shoreline (Pease, 1965).

Basalt, andesite, and dacite flows and extrusions of cinders, ash, and pumice from numerous vents and fissures contributed to the filling of the depressions between the fault blocks—in some cases to depths of hundreds of meters. Some of the pumice came from the eruption of Mount Mazama only 6,000 years ago, during the formation of Crater Lake. Some pumice eruptions took the form of surface flows, nuées ardentes, which went down stream beds to the lake basins. Nearby mountains such as Mount McLoughlin and Pelican and Aspen Buttes also contributed sediment. Additional material was supplied, almost to historic time, by weathering of the lava flows. Sediment was transported by wind and water, and some large rock fragments found in the soils of the lake plain may have been rafted by ice on the lake. Accumulations of diatoms and peat helped to fill the lake.

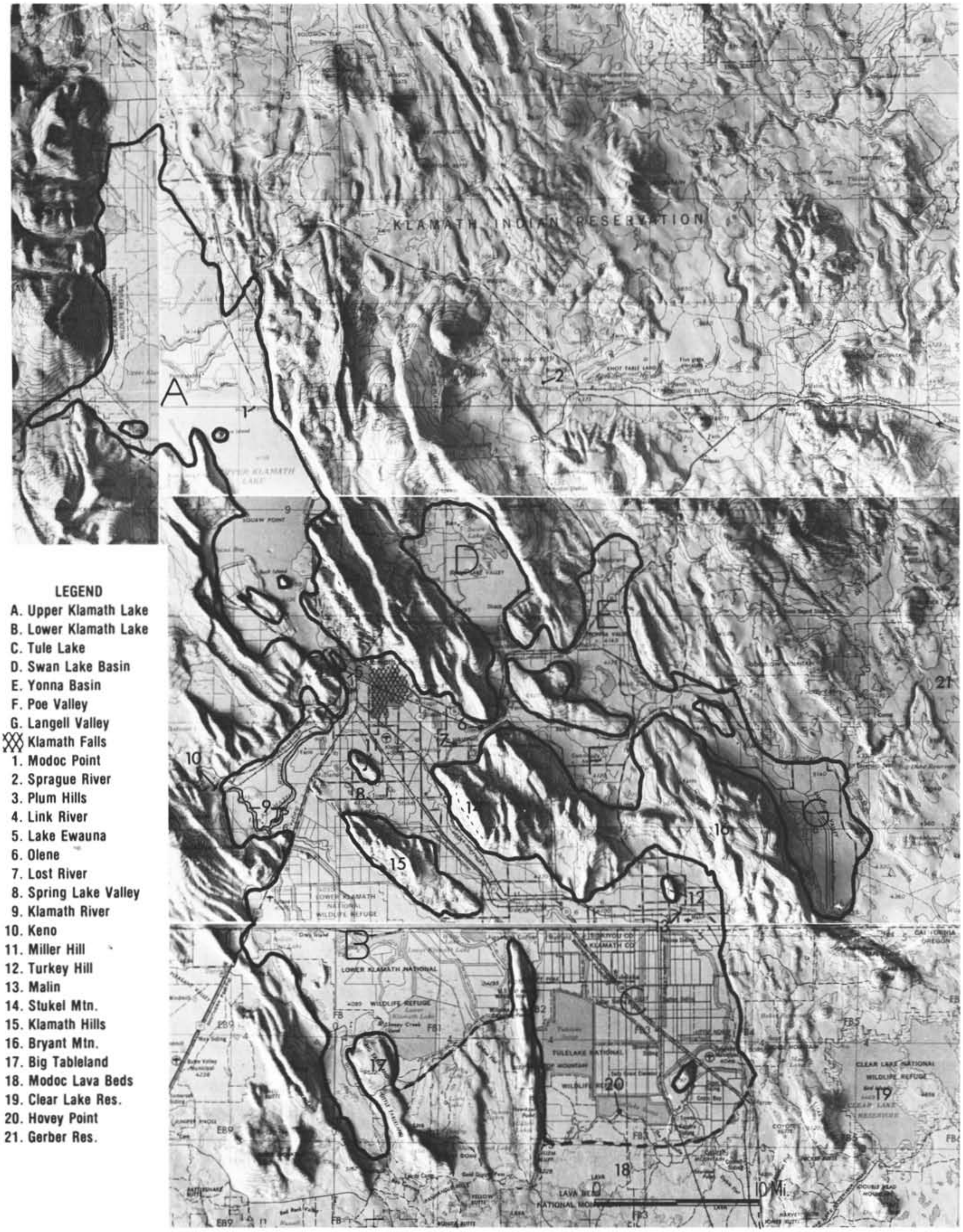
The lake bottom soils have a high water-holding capacity. They are of such a low density that when steamboats ran aground on Lower Klamath Lake at the turn of the century, the disturbed sediment sometimes floated to the surface of the lake.

THE WATERSHED

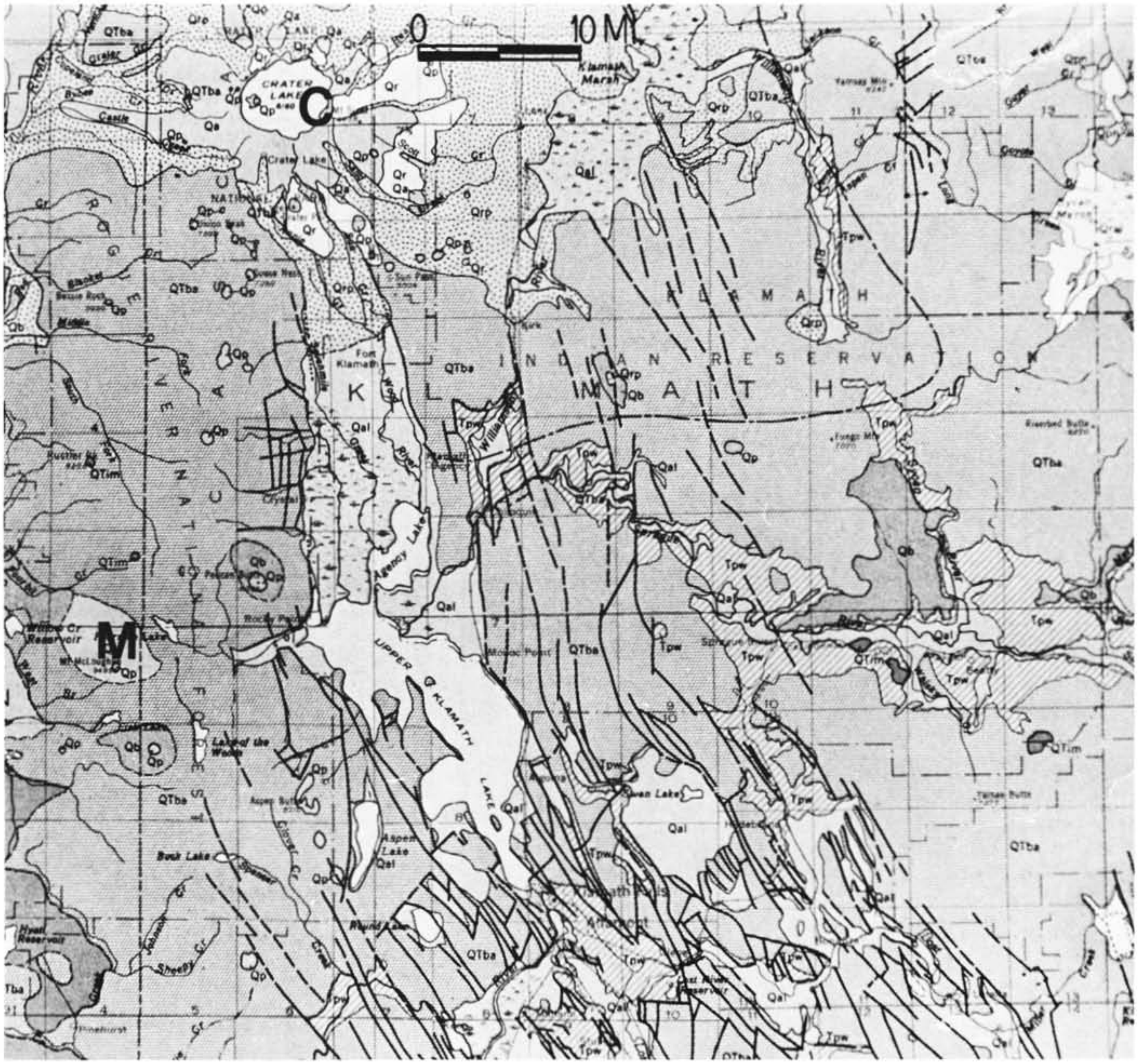
A broad network of surface streams from an extensive watershed brought the sediment to the lake. The watershed includes most of southern Klamath County and smaller parts of Jackson and Lake Counties in Oregon, and the northern parts of Modoc and Siskiyou Counties in California. The drainage area extended from the crest of the Cascades on the west and Crater Lake on the north to as far east as western Lake County.

On the north, Williamson River is the principal stream with tributaries on the east slope of Mount Scott. Streams on its slopes are probably fed by Crater Lake, the level of which scarcely changes, and tend toward a uniform flow. Numerous creeks drain the east front of the Cascades into the basins of Upper and Lower Klamath Lakes. On the east, Sprague River and Lost River have large drainage areas including some of the higher basin ranges.

During the short summers of Pleistocene time, the lake must have been the recipient of almost constant sediment-laden floods, since the climate was wetter as well as colder. Snows were heavy on the higher elevations. The Cascade Range was covered with accumulations of ice, and some peaks had active glaciers. The lake basin was filled to overflowing, and one outlet probably was to the south, from the Tule Lake Basin. This outlet, if it existed, was blocked later by a lava



Preliminary map of area covered by Pluvial Lake Modoc. Highest shoreline (solid line) is near 4,240-ft contour except in the south, where lava flows have encroached on lake bed (dashed line).



Part of geologic map (Wells and Peck, 1961) of Upper Klamath Lake area, showing closely spaced fault pattern. Crater Lake (C) is at upper left. Crest of Cascade Range passes over Mount McLoughlin (M).

flow; however, large quantities of water, but not sediment, were able to escape by seepage—which explains why the water of Tule Lake at the time of discovery was only slightly brackish. The outlet in historic time is to the Klamath River. When Lower Klamath Lake was high, the Klamath River began at Keno; when it was low, the river began at the outlet of Link River, at Klamath Falls. Lake Ewauna is, in effect, merely a wide place in the Klamath River.

THE CHANGING CLIMATE

Tree ring records are perhaps the best measure of climate fluctuations that occurred before precipitation records were available. In a semiarid region, it is assumed that tree growth is limited mostly by moisture. However, other factors such as temperature and tree diseases may affect the thickness of the annual rings. The only rings that could be compared with precipitation records were those that formed after 1884, when records of precipitation were first kept. A study of the annual rings of ponderosa pine (Keen, 1937) included five sites marginal to Lake Modoc. Some of the readings were made from the stumps of harvested trees that were as much as 700 years old. The rings show peak growth in 1673, 1702, 1752, 1775, 1791, 1814, 1861, and 1893. The last two dates are known to have been years of heavy floods.

The tree ring record shows alternating wet and dry periods of varying lengths. The wettest period was from 1670 to 1680. The weather between 1805 and 1840 was wet also; Meriwether Lewis testified to the heavy rains on the Clatsop Plains near Astoria during the winter of 1805-1806. Drought was severe from 1840 to 1854, the period of large-scale migration to Oregon, partly by the southern routes passing through the

Lake Modoc area. At that time, people and livestock suffered severely from lack of water and forage. Precipitation was generally above average from 1860 to 1900, but the period from 1918 to 1936 was a time of severe drought, with dust storms in the latter part of the period. Keen (1937) estimated that the variation of precipitation was up to 60 percent above and below the mean.

Weather Bureau precipitation records begun in 1884 agree partially with the tree ring records. The first three years of record, 1884 to 1886, were above the average precipitation of 13 in. (330 mm) for the entire weather record. From 1904 to 1910, precipitation again was above normal. As noted below, this was a time of low lake levels for Lower Klamath and Tule Lakes. The years 1910 to 1926 were dry, followed by two wet years. Then came the severe drought of 1928 to 1936, when the average rainfall was only 9.1 in. (231 mm). Since that time, the amounts of precipitation have been quite variable. The rainiest year on record with 20 in. (500 mm) of precipitation was in 1948, the year of the great Columbia River flood. The following year, 1949, was the driest: 8.31 in. (211 mm) of precipitation.

It is obvious that a deficiency of water exists in the Lake Modoc area. Evaporation is greater than precipitation in most years, which results in an average deficit of 10 in. (256 mm) (Loy, 1976). Then any part of the Lake Modoc Plain not supplied by tributaries or irrigation tends to become increasingly dry.

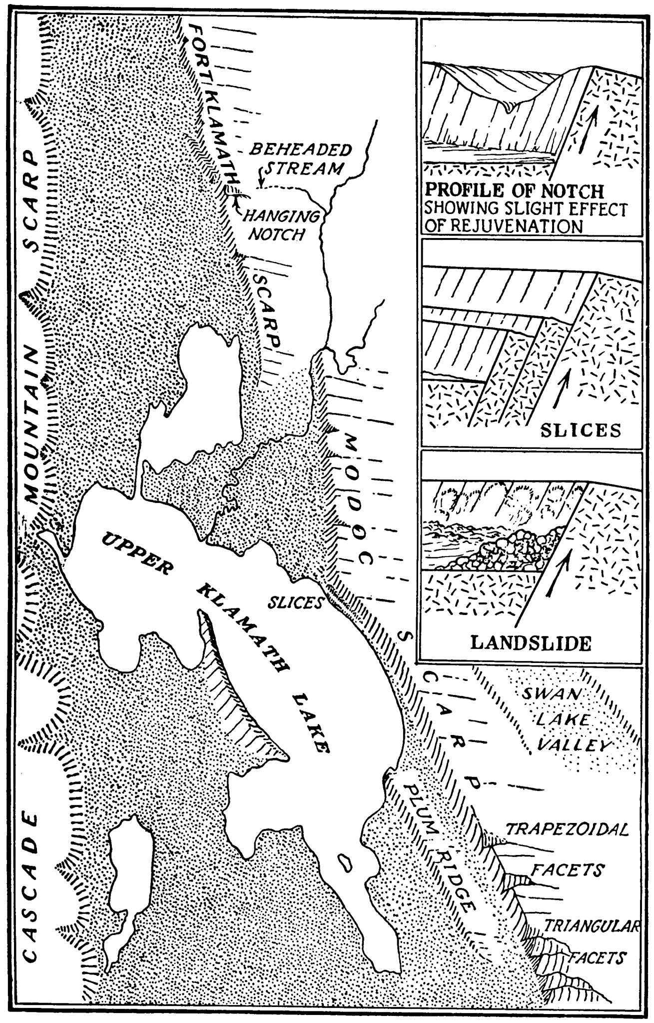
LOWERING OF LAKE MODOC

At the end of the Pleistocene, perhaps 10,000 years ago (Crandell, 1960), the climate gradually settled into its present semiarid, fluctuating, and unpredictable state, and Lake Modoc began to shrink. At first, the lowering of Lake Modoc was uniform for all basins, since all were interconnected. After the climate became drier, the water level was reduced from the maximum of 4,240 ft (1,292 m) to 4,142 ft (1,262 m); the flow from Upper Klamath Lake to the southern basins was diminished; and the lake level dropped further. By 1906, when an accurate survey of lake levels was made, Upper Klamath Lake was at 4,142 ft (1,262 m), Lower Klamath Lake at 4,084 ft (1,245 m), and Tule Lake at 4,056 ft (1,236 m). The bottom of Lower Klamath Lake was at 4,069 ft (1,240 m) and that of Tule Lake at 4,031 ft (1,229 m). The other six basins were completely dry except for a few small pocket lakes or marshy areas. Lake levels fluctuated with the variations of precipitation, and although the lakes rose slightly above the 1906 levels in succeeding years and steamboats served several landings on Lower Klamath Lake as late as 1909 (Drew, 1974), it was evident that Lower Klamath and Tule Lakes were on the way to extinction.

EARLY DESCRIPTIONS OF THE KLAMATH LAKES AREA

Peter Skene Ogden was the first to describe the Klamath Lakes area (Davies, 1961). He arrived from Fort Vancouver with a party of trappers and traders in wet and cold weather in late November 1826, looking for beaver and also seeking a river to the ocean which might be used to transport furs to the ocean. The party visited an Indian village in the middle of Klamath Marsh, where the water was too deep to approach on horseback or on foot. This was near the end of a long, wet cycle, according to tree rings. When J.C. Frémont visited the same marsh in 1843, thinking it was Klamath Lake, he found no difficulty in riding to the village (Frémont, 1856). Frémont surmised that in summer the marsh was a dry savannah.

Ogden reached Upper Klamath Lake near the mouth of



Generalized diagram of Upper Klamath Lake graben. Pluvial Lake Modoc covered entire shaded area. Pictures on right show features found where Basin and Range faulting occurs. (From Lobeck, 1939)

the Williamson River and followed the shoreline southward. At Modoc Point, it was necessary to ascend to the upland, since during severe weather, passage near the lake, with horses, was apparently not feasible. From the Link River, the party traveled in a southeasterly direction through Spring Lake Valley, also known as the main valley, and along Lost River, which was forded with difficulty, the banks being steep and soft and the water deep. Ogden noted a rock barrier or dam in Lost River, "made by the natives for taking small fish." Later travelers called this "a natural bridge" (Williamson and Abbot, 1856; Landrum, 1971).

Ogden missed Lower Klamath Lake but went along the east side of Tule Lake along the route that was later to become a part of the southern immigrant trail. The party then turned westward, reaching and crossing the Klamath River at the hot springs near the present-day Beswick, California.

On the advice of Indians, Ogden rejected Klamath River as a water route to transport furs. There were few small streams with willow and cottonwood and, therefore, few beaver. Because game was very scarce, Ogden's party was forced to purchase dogs from the Indians for food and to eat some of their horses.

John C. Frémont visited Upper Klamath Lake in May 1846, arriving from California via Tule Lake, which he named

Rhett Lake (Frémont, 1856). He found the Link River "unfordable" but crossed it anyway and traveled along the west side of Upper Klamath Lake, not realizing, apparently, that the trail on the east side of the lake was much easier. Frémont described the variety of timber trees on the west side of the lake and determined the latitude and longitude of several points around the lake. He, too, looked in vain for a navigable river leading to the coast, apparently unaware that Ogden and others had made negative reports.

Frémont found the Indians less friendly than on his previous visit to Klamath Marsh, and when the party slept one night with their camp unguarded, three of his men were killed. Frémont's visit was cut short by a summons from California, since he was an army officer on active duty.

Following close on the heels of Frémont was a party from the Willamette Valley, led by Lindsay Applegate, marking out the southern immigrant road. This route crossed the Cascade Range from Jacksonville via Green Springs Pass, crossed the Klamath River at Keno, ran southward along the west side of Lower Klamath Lake, thence eastward, to the north of Tule Lake. The route was much used by the immigrants in spite of Indian hostility.

In August 1855, Lieutenants R.S. Williamson and H.L. Abbot, topographic engineers, arrived in the Klamath Lakes area, charged with surveying two possible routes for a railroad connecting San Francisco Bay with the Columbia River (Williamson and Abbot, 1856). The party, which included several assistants, packers, mules, 100 mounted soldiers, a botanist-geologist, and an artist for sketching landscapes, carried instruments for the determination of latitude and longitude and an odometer, mounted on a cart, for measuring distances traveled. Their lengthy report included the first good maps of the Klamath Lakes. Williamson noted that Lower Klamath Lake had very little water and that the shoreline was

Vertical air photo of lower end of Upper Klamath Lake and Link River. Outlet of river is at lower right. Part of city of Klamath Falls is on right. One irrigation canal takes out from lake near bridge, upper center, and enters tunnel near freeway crossing. Canals also parallel Link River below dam. (U.S. Geological Survey photo)

so miry that it was difficult to water the horses. He reported cattails and bulrushes on the margins of the lake and tules and water lilies in the middle. He mapped the shore vegetation rather than the waterline.

In the summer of 1860, Lieutenant Alexander Piper arrived in the Klamath Lake area with 66 soldiers to establish a military post designed to protect the immigrants from the Indians (Piper, 1968). His first camp was near Keno and Lower Klamath Lake, which he described as "an immense bed of tules with no water visible except for Klamath River." So Piper mapped the shoreline as if the lake were full. His carefully drawn maps included vegetation, streams, lakes, and trails. His chief interest was in wood and water for his camps, grass for his animals, and Indians. A few ranchers were beginning to move cattle into the area, which tended to incite the Indians.

MAN-MADE CHANGES

White settlement in the Klamath Lakes area, delayed by Indian hostilities and the lack of roads, began to pick up in the late 1860's (Sisemore, 1941). The first permanent settler came in 1866, Linkville was settled in 1867, and the name was changed to Klamath Falls in 1893. Klamath County was formed from Jackson County in 1882, and the first census showed 2,444 residents, not including approximately 1,000 Indians.

The establishment of the Klamath Indian Reservation (1870) was intended to solve the Indian problem (Stern, 1970). Both Klamaths and Modocs were included, but the Modocs soon became discontented and left the reservation. They lived by themselves on Lost River or on the shores of Tule Lake, hunting, fishing, and occasionally begging from the settlers. The settlers were unhappy with the situation, and an army unit was sent to arrest Captain Jack, the leader of the Indians. A fight resulted, and the Indians fled southward to the lava beds, which provided strong defense positions. Additional army units were brought in with artillery, and the bloody battles of the Modoc War followed in which the army suffered heavy losses. But the Indians were defeated, their leaders captured, and white settlement began to spread over the area at an accelerated pace.

The settlers found some conditions favorable and some unfavorable. The broad lake plain covered mostly with sagebrush and greasewood (Sweet, 1910) was not too difficult to clear. On the ridges, juniper, wild plum, and ponderosa pine furnished firewood and timber for building; streams and lakes supplied water. Good grazing was available on the lake margins and on the ridges. The unfavorable conditions were the dry climate, later compensated by irrigation, and the cool summers with a constant frost hazard—a condition unsuitable for many crops. Nevertheless, grazing, agriculture, and logging were successful, and slowly the landscape was transformed. Fires, used for clearing the land or set by lightning, burned over some of the timbered land, but forest fires were less damaging here than in western Oregon. A map of forest land shows burned-over areas on ridges in several localities (Leiberg, 1900).

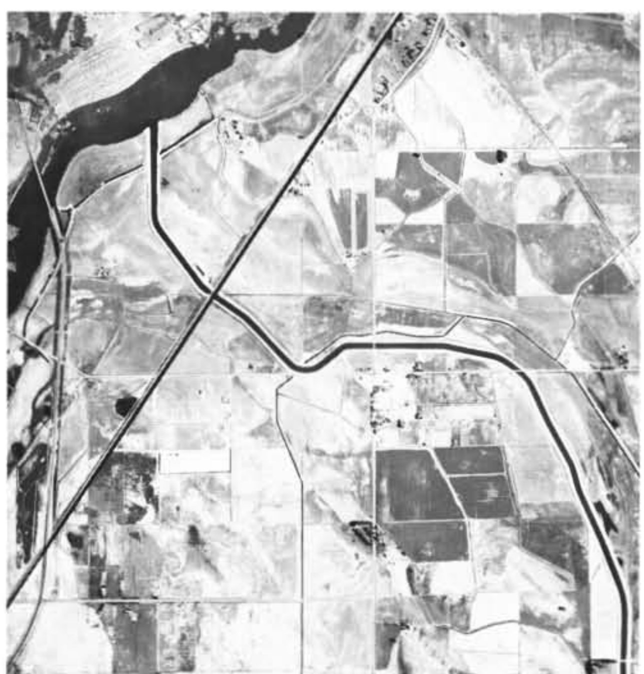
In the early days of settlement, ranchers depended on natural forage, but they were soon sowing rye and harvesting it as hay. In most years, grazing was available all year round, but in times of heavy snows, feeding with hay was necessary. Potatoes were introduced and planted on the lower part of the hill slopes, immediately above the plain where frost hazard was less. The first crops were grown without irrigation.

The first irrigation was by waterwheel on Lost River. The current turned huge wheels to which buckets were attached to lift the water to nearby fields. Large-scale irrigation was introduced in 1884 with the construction of the Klamath Canal (later called the Main Canal), which led southeastward from the upper Link River. One branch paralleled Lost River almost to Tule Lake; another continued eastward through the gap at Olene and into Poe Valley. The waters of the upper Lost River also were diverted into canals.

After 1900, plans were made for more extensive irrigation (Strantz, 1953). In 1905, the three major lakes—Upper Klamath, Lower Klamath, and Tule—were ceded to the United States Government and placed in charge of the Bureau of Reclamation, so that the construction of large irrigation ditches became possible. Construction of the Keno Canal began in 1906 and was completed in 1908 (Gustafson, 1971). It led from Link River down the west side of Lower Klamath Lake, crossing the Klamath River at Keno by means of an inverted siphon. In 1907, Canals A and B led water from Upper Klamath Lake to Spring Lake Valley and to the vicinity of Olene.

In 1908, the first public notice of homesteading brought thousands of potential farmers to the plain. In 1909, additional canals were completed, and the northwestern part of Lower Klamath Lake was cut off by the Southern Pacific Railroad embankment. In 1910, the Clear Lake dam was completed, controlling the flow of Lost River which had been diverted to irrigate Langell Valley. The population of Klamath County had grown to 8,554. Lower Klamath Lake, denied most of its water, became dry in the northern part and available for cultivation. The southern part of this lake was set aside for a wildlife refuge. Tule Lake is now mostly under cultivation; the remaining two sumps are controlled by pumping.

All area shown in this vertical air photo, 3 mi south of Lower Klamath Lake, was part of Lower Klamath Lake until railroad embankment (black line) blocked off Klamath River in 1909. Canal diverts surplus water from Lost River to Klamath River. (Production Marketing Administration photo)



← *Vertical air photo shows lava flow covering old shoreline of pluvial Lake Modoc at Hovey Point on south shore of Tule Lake in Siskiyou County, California. White lines in fields are irrigation ditches. Captain Jack's stronghold was immediately south of bay. (U.S. Geological Survey photo)*

WATER CONTROL

The presence of a large water supply at a higher level than the plain in Upper Klamath Lake, Clear Lake, and Gerber Reservoir makes gravity irrigation possible. Many improvements in the control of water, especially dam construction, made the system more productive and efficient (Strantz, 1953). The dam on the upper part of Link River controls the level of Upper Klamath Lake and is of first importance. Dams at the lower end of Clear Lake and one at Gerber Reservoir help in the control of Lost River. The problem of run-off water from the irrigated lands is solved by drainage and pumping. A channel diverted from Lost River to the Lower Klamath Lake plain reduces the amount of water reaching Tule Lake. Water is pumped from the sumps in the southern part of Tule Lake through a tunnel to Lower Klamath Lake, from which it is pumped into the Klamath River. The controls make it possible to supply water to almost all the plain. Only a few large areas are not irrigated, such as Swan Lake Basin and the northern part of Yonna Basin.

Low dam in upper Link River controls level of Upper Klamath Lake and regulates flow into irrigation canals. ↓

LAND USE

Most of the cropland in Klamath County is in the Klamath Lakes area; the 1974 total was 207,000 acres (84,000 ha). The land in farms and ranches, including the uplands, was 754,000 acres (305,000 ha). Most of the farms in the irrigated areas average less than 160 acres (65 ha), but the average holding is 986 acres (399 ha). Eighty-five percent of the cropland is irrigated, of which 23 percent is pasture. The chief crops are hay, 34 percent; barley, 15 percent; wheat, 6 percent; and potatoes, 5 percent. Livestock in Klamath County includes 39,000 beef cattle, 2,300 dairy cows, and 15,000 sheep. Woodland on farms and ranches runs to 178,000 acres (72,000 ha).

As soon as railroad and highway transportation was available, the lumber industry expanded, with the largest mills located in Klamath Falls. The timber harvest averages nearly 400 million board feet annually, most of it coming from National Forest land.

SUMMARY

Pluvial Lake Modoc, which once covered 1,096 sq mi (2,838 km^2), is now mostly dry land. The drier climate and the lowering of the outlet to the Klamath River are the main causes of the shrinkage. Only Upper Klamath Lake, with an area of less than 100 sq mi (259 km^2), remains. It also is at some risk of shrinkage as it slowly fills with sediment and vegetation, thus reducing the storage capacity.

The plain of Lake Modoc, in effect the exposed bed of the old lake, is the dominant natural resource in a large part of Klamath County and parts of Siskiyou and Modoc Counties in California. Here is most of the cropland, and here most of the people live. The plain is extensive, remarkably level, and at an elevation allowing for easy irrigation. The soils, though not all of the highest quality, are easy to till and irrigate. The location of the plain near the Cascade Range assures a good water supply, as well as a timber resource for the wood industries.

Less favorable factors are the light regional precipitation —significant for grazing areas—and the cool summers, unfavorable for some crops and with risk of frost in every month. The Bureau of Reclamation has established numerous water controls in the form of dams, reservoirs, ditches, canals, and other structures, providing for efficient distribution and use of the water. In the future it may be necessary to construct additional storage facilities on the tributaries to supplement the capacity of Upper Klamath Lake.

REFERENCES CITED

Allison, I.S., 1945, Pumice beds at Summer Lake, Oregon: Geological Society of America Bulletin, v. 56, no. 8, p. 789-807.

——— 1979, Pluvial Fort Rock Lake, Lake County, Oregon: Oregon Department of Geology and Mineral Industries Special Paper 7, 72 p.

Crandell, D.R., 1960, The glacial history of western Washington and Oregon: American Geographic Society Special Publication 35, p. 341-353.

Davies, K.G., ed., 1961, Peter Skene Ogden's Snake Country journal 1826-27: London, England, The Hudson's Bay Record Society, p. 31-57.

Drew, H.S., 1974, Early transportation on Klamath waterways: Klamath County Museum Publication 6, p. 1-103.

Feth, J.H., 1961, A new map of western conterminous United States showing the maximum known or inferred extent of Pleistocene lakes: U.S. Geological Survey Professional Paper 424-B, p. B110-B112.

Forbes, C.F., 1972, Pleistocene shoreline morphology of the Fort Rock Basin, Oregon: Eugene, Oreg., University of Oregon doctoral dissertation, 203 p.

Frémont, J.C., 1856, Memoirs of my life: Chicago, Ill., Longman, Green, and Co., p. 491-507.

Gilbert, G.K., 1890, Lake Bonneville: U.S. Geological Survey Monograph 1, 438 p.

Gustafson, F., 1971, The Klamath Basin: Salem, Oreg., Oregon Water Resources Board, p. 146.

Keen, F.P., 1937, Climatic cycles of eastern Oregon: Monthly Weather Review 65, no. 5, p. 175-188.

Landrum, F.S., 1971, A major monument: Oregon-California boundary: Oregon Historical Quarterly, v. 72, p. 34.

Leiberg, J.B., 1900, Cascade Range Forest Reserve, Oregon, from T. 28 S. to T. 37 S., inclusive, together with the Ashland Forest Reserve and adjacent forest regions from T. 28 S. to T. 41 S., R. 2 W. to R. 14 E., Willamette Meridian, inclusive: U.S. Geological Survey 21st Annual Report, pt. V, p. 209-498.

Lobeck, A.K., 1939, Geomorphology: New York, N.Y., McGraw-Hill, p. 552.

Loy, W.G., 1976, Atlas of Oregon: Eugene, Oreg., University of Oregon, p. 120-121.

Meinzer, O.E., 1922, Map of the Pleistocene lakes of the Basin-and-Range province and its significance: Geological Society of America Bulletin, v. 33, no. 3, p. 541-552.

Pease, R.W., 1965, Modoc County, a geographic time continuum on the California volcanic tableland—pt. 1, Geography of the prehistoric past: University of California Publications in Geography, v. 17, p. 7-45.

Piper, A., 1968, Reports and journal: Oregon Historical Quarterly, v. 69, p. 223-268.

Russell, I.C., 1885, Geological history of Lake Lahontan, a Quaternary lake of northwestern Nevada: U.S. Geological Survey Monograph 11, 288 p.

Sisemore, L., ed., 1941, History of Klamath County, Oregon: Klamath Falls, Oreg., Klamath Falls Historical Society, p. 1-9.

Snyder, C.T., Hardman, G., and Zdenek, F.F., 1964, Pleistocene lakes in the Great Basin: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-416, scale 1:1,000,000.

Stern, T., 1970, The Klamath tribe: Seattle, Wash., University of Washington Press, p. 41-51.

Strantz, M.K., 1953, Reclamation accomplishments, Klamath Project: 1905-1953: U.S. Bureau of Reclamation, Oregon-California, 49 p.

Wells, F.G., and Peck, D.L., 1961, Geologic map of Oregon west of the 121st meridian: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-325, scale 1:500,000.

Williamson, R.S., and Abbot, H.L., 1856, Report of exploration and surveys to ascertain the most practicable and economical route for a railroad from the Mississippi River to the Pacific Ocean: Pacific Railroad reports, v. VI, p. 63-78. □

Brownfield joins DOGAMI staff

On August 27, 1980, Michael E. Brownfield became a member of the Portland staff of the Oregon Department of Geology and Mineral Industries (DOGAMI). He was hired as a geologic mapper to manage and lead the Department's mapping subprogram in northwest Oregon, which includes the Coast Range, Willamette Valley, and northern part of the Oregon Cascades. In terms of geologic mapping, this has been an area of neglect for several years. Recent discoveries of gas in the Mist Gas Field and evolving concepts of plate tectonics now make northwest Oregon an area of priority.

Brownfield will be coordinating efforts with federal and university counterparts, with the long-term goal of the revision of the geologic map of western Oregon.

Michael E. Brownfield

A native Oregonian, Brownfield received his bachelor's and master's degrees from the University of Oregon. Since June 1973, he was a geologist with the U.S. Geological Survey (USGS), doing geologic mapping in the Rocky Mountain coal regions. Before that time, he was an engineering geologist for the Willamette National Forest and was employed in mineral exploration and mapping programs for Humble Oil, Bear Creek Mining Company, and the USGS. He has authored and coauthored several geologic maps and other publications for the Survey.

He is married to Isabelle K. Brownfield, a geologist and archeologist, who is currently working for the Uranium-Thorium Branch of the USGS. The Brownfields are the parents of a daughter, Kathleen Marie, born September 29, 1980. □

Exploration for mineral fuels intensifies in Oregon

Exploration for mineral fuels in Oregon increased dramatically during the past year, and the emphasis is on natural gas. As compared to 1978, expenditures for oil and gas exploration more than doubled in 1979, according to the Oregon Department of Geology and Mineral Industry summary of exploration expenditures in the various segments of the private industry, as shown in the following table:

EXPLORATION EXPENDITURES

	Oil and gas	Geothermal	Metals
1979........	$10,695,000	$1,928,000	$4,037,000
1978........	4,608,000	1,298,000	4,435,000
1977........	2,000,000	600,000	3,600,000
1976........	2,000,000	1,400,000	2,300,000

OIL AND GAS

Industry interest in Oregon's oil and gas potential has been steadily increasing during the past few years. The great upsurge in well drilling followed the discovery of natural gas at Mist in May of 1979.

GEOTHERMAL ENERGY

Geothermal resource exploration by private groups increased modestly in 1979, with the activity divided almost equally between the Western Cascade Range and southeastern Oregon. The less than $2 million of private geothermal exploration expenditures were overshadowed, however, by Federal funding for resource assessment of more than $3.3 million in Oregon during 1979. During the past four years, the ratio of public funding to private investment has increased continually, with the Federal government, principally the U.S. Department of Energy, providing most of the public monies.

METALS

Twenty-eight companies expended significant sums in prospecting for metallic minerals during 1979. Precious metals, uranium, nickel, and copper were the commodities of greatest interest. Exploration projects for metals were concentrated in the Klamath Mountains of southwestern Oregon, the southern portion of Harney and Malheur Counties in the southeastern corner of the State, and various gold mining districts in the Blue Mountains. □

ABSTRACTS

The Department maintains a collection of theses and dissertations on Oregon geology. From time to time we will print abstracts of new acquisitions that we feel are of general interest to our readers.

INTERPRETATION OF GRAVITY MEASUREMENTS MADE IN THE CASCADE MOUNTAINS AND ADJOINING BASIN AND RANGE PROVINCE IN CENTRAL OREGON, by Gerald Stephen Pitts (M.S., Oregon State University, 1979)

Gravity measurements made during the summers of 1975 and 1976 and previously acquired measurements in the Cascade Mountains and adjoining Basin and Range Province in central Oregon provide data for analysis of the crustal structures pertinent to geothermal resources in the area. An average uncertainty of 1.5 mgal in the complete Bouguer gravity anomalies is primarily due to uncertainties in elevation.

A rapid increase of the free-air gravity anomalies, from an average of less than zero over the Miocene Western Cascades to greater than +30 mgal over the Quaternary High Cascade volcanics, is explainable in part as the "Randsenken" or edge effect associated with a relatively abrupt change in the depth of the mantle. Free-air gravity anomalies greater than +90 mgal associated with the Three Sisters volcanic complex and Newberry Caldera are too great to be accounted for by topography alone.

The complete Bouguer gravity anomaly field is dominated by an eastward decreasing regional gradient that is attributable to the eastward thickening of the continental crust. Determination of Bouguer anomalies with different reduction densities suggests that the shield volcanoes of the High Cascades have an average density of at least 2.6 g/cm^3. Lookout Mountain, a 500-m-high basaltic cinder cone, has an average density of 2.30 g/cm^3 which suggests a composition of approximately 40 percent flows and 60 percent cinders.

A residual gravity anomaly field which results from the removal of a regional field from the Bouguer anomalies is dominated by intersecting linear trends of closed positive and negative anomalies that parallel Basin and Range structures in the eastern portion of the map and north-south structures of the Cascade Range in the western portion of the map. These trends of closed anomalies are flanked by continuous linear anomalies with 4 to 10 mgal of relief and typical gradients of 1 to 2 mgal/km. The amplitudes and gradients of the anomalies suggest upper crustal sources.

The analysis of the gravity data presented in this study indicates that structural trends of the Basin and Range Province continue into the Cascades physiographic province and suggests that the location of the major vents of the southern High Cascades Province are strongly influenced by the Basin and Range structures.

The continuous nature of the positive anomaly trends and coincidence of the closed positive residual anomalies with volcanic centers suggest structural control and contemporaneous development. The linear trends of the positive anomalies are interpreted as an indication of lithospheric fractures or lineations of structural weakness in the lower crust which have acted as conduits for the rise of magmas.

The contiguous nature of the negative anomalies west of the High Cascades, which trend north-south, and the anomalies east of the High Cascades, which trend northwest-southeast, are interpreted as an indication of graben-like structures. The north-south trending negative anomalies west of the High Cascades are bounded on the west by a linear anomaly with gradients as high as 4 mgal/km. This anomaly, which is coincident with the valleys of five major rivers, is interpreted as indicating a major normal fault, with the eastern block downdropped to the east. The density contrast of 0.5 g/cm^3 between lower Eocene oceanic basalts and overlying marine sediments that produces the observed anomaly is thought to exist at a depth of 3 to 4 km below sea level and have a vertical extent of 1.2 to 1.5 km.

GEOLOGY AND GEOCHEMISTRY OF A MASSIVE SULFIDE DEPOSIT AND ASSOCIATED VOLCANIC ROCKS, BLUE CREEK DISTRICT, SOUTHWESTERN OREGON, by Cynthia Taylor Cunningham (M.S., Oregon State University, 1979)

The Turner-Albright copper-zinc-gold deposit in the Blue Creek mining district of southwestern Oregon may be classed as an ophiolitic massive sulfide deposit. Mineralization occurs within a series of spilitized tholeiitic basalts and shallow gabbroic intrusions. Replacement of permeable flow breccias and sedimentary sulfide deposition appear to have been the dominant mechanisms of sulfide mineralization. Brecciation and permeability of the rocks may have been increased by explosive hydrothermal activity. A pipe-like zone of hydrothermal silicification, chloritization, and disseminated sulfide mineralization stratigraphically below the deposit indicates proximity to a hydrothermal vent.

Stratigraphic relations suggest that the volcanic rocks hosting the mineralization are of Middle Jurassic age. It is suggested that the basalts formed in a marginal basin to the east of the Jurassic Rogue-Galice island arc.

Sulfur isotope studies of hydrothermal minerals suggest a mixture of magmatic and seawater sulfur in the deposit. Rare-earth element patterns of hydrothermal minerals appear to reflect the chemistry of hydrothermal solutions. Light rare-earth enrichment and positive europium anomalies are consistent with a direct magmatic origin of the metals. However, leaching of metals by reaction of ascending hydrothermal solutions with volcanic rocks cannot be unequivocally discounted on the basis of present experimental data. □

USGS film on natural hazards available

A color-sound motion picture providing information about various natural hazards and methods to mitigate their impacts on lives and property has been produced for the U.S. Geological Survey, Department of the Interior, and is available for public viewing.

The 26½-minute film, titled "When the Earth Moves," focuses on volcanic eruptions, earthquakes, subsidence, landslides, swelling soils, flooding, and glacial outbursts.

Although the film explains the basic causes, nature, and occurrence of the hazards, the major emphasis of the film is on choices people and governments have to mitigate or avoid hazards.

The film includes case histories of various hazards. As planners, scientists, and residents in several communities in different parts of the country are interviewed, the following themes are developed:

1. These hazards are part of natural processes that occur throughout the country, and their damages can affect practically anyone at almost any time.

2. Government and other groups can choose among several alternative methods (land-use planning, structural solutions, and prediction) to reduce damage. For the long term, land-use planning to avoid or minimize exposure to risk may offer the greatest savings, while the "do-nothing" policy, on the other hand, usually has the greatest cost.

3. Federal, state, and local government agencies and the general public need to have earth-science information available for planning and decision making.

"When the Earth Moves" was produced for the USGS by Amram-Nowak Associates, Inc., New York City. Copies of the film are available for viewing on a short-term basis or may be purchased. Information about the availability of the film may be obtained from the U.S. Geological Survey's Branch of Visual Services, 303 National Center, Reston, Va. 22092; phone (703) 860-6171. □

Time to renew

Please note that your subscription expiration date is marked on the front cover of this month's *Oregon Geology*. Because we are unable to notify you by letter when your subscription is about to expire, it will have to be your responsibility to remember to renew at the appropriate time—or sooner if you want to be sure not to miss even one issue of *Oregon Geology*. □

Post-eruption map of Mount St. Helens published by Geo-graphics

Geo-graphics, a private cartographic firm in Portland, has recently published a two-color map of Mount St. Helens showing the effects of the May 18, 1980, eruption. The new crater; areas affected by pyroclastic and debris flows, explosive eruption of hot gas, and mud and ash flows; and the new boundaries of Spirit Lake are plotted on a U.S. Geological Survey topographic map at a scale of 1:62,500 (1 in. = approximately 1 mi). The 23 by 27 in. map covers parts of Cowlitz, Skamania, and Lewis Counties, Washington.

On the reverse side of the map are photographs taken during and following the eruption; sketches showing Mount St. Helens before, during, and after the eruption; a chronology of events leading up to the eruption, and a brief text by Paul Hammond, Patricia Knolls, and Al Cardwell.

The map may be purchased by mail for $5.00 from Geo-graphics, 519 S.W. 3rd, Suite 418, Portland, Oregon 97204; phone (503) 241-9287. Rates for larger orders are available on request. □

U.S. POSTAL SERVICE

STATEMENT OF OWNERSHIP, MANAGEMENT AND CIRCULATION

(Required by 39 U.S.C. 3685)

1. TITLE OF PUBLICATION: OREGON GEOLOGY
A. PUBLICATION NO.: 6 0 0 0 4 0
2. DATE OF FILING: October 1, 1980

3. FREQUENCY OF ISSUE: monthly
A. NO. OF ISSUES PUBLISHED ANNUALLY: 12
B. ANNUAL SUBSCRIPTION PRICE: $4.00

4. LOCATION OF KNOWN OFFICE OF PUBLICATION *(Street, City, County, State and ZIP Code) (Not printers)*
1069 State Office Building, Portland, OR 97201

5. LOCATION OF THE HEADQUARTERS OR GENERAL BUSINESS OFFICES OF THE PUBLISHERS *(Not printers)*
1069 State Office Building, Portland, OR 97201

6. NAMES AND COMPLETE ADDRESSES OF PUBLISHER, EDITOR, AND MANAGING EDITOR

PUBLISHER *(Name and Address)*
Oregon Department of Geology and Mineral Industries, address see 4/5

EDITOR *(Name and Address)*
Beverly Vogt, Oregon Department of Geology and Mineral Industries

MANAGING EDITOR *(Name and Address)*
NONE

7. OWNER *(If owned by a corporation, its name and address must be stated and also immediately thereunder the names and addresses of stockholders owning or holding 1 percent or more of total amount of stock. If not owned by a corporation, the names and addresses of the individual owners must be given. If owned by a partnership or other unincorporated firm, its name and address, as well as that of each individual must be giving. If the publication is published by a nonprofit organization, its name and address must be stated.)*

NAME	ADDRESS
Oregon Department of Geology and Mineral Industries	1069 State Office Building Portland, OR 97201

8. KNOWN BONDHOLDERS, MORTGAGEES, AND OTHER SECURITY HOLDERS OWNING OR HOLDING 1 PERCENT OR MORE OF TOTAL AMOUNT OF BONDS, MORTGAGES OR OTHER SECURITIES *(If there are none, so state)*

NAME	ADDRESS
NONE	

9. FOR COMPLETION BY NONPROFIT ORGANIZATIONS AUTHORIZED TO MAIL AT SPECIAL RATES *(Section 132.122, PSM)*
The purpose, function, and nonprofit status of this organization and the exempt status for Federal income tax purposes *(Check one)*

[X] HAVE NOT CHANGED DURING PRECEDING 12 MONTHS [ ] HAVE CHANGED DURING PRECEDING 12 MONTHS *(If changed, publisher must submit explanation of change with this statement.)*

10. EXTENT AND NATURE OF CIRCULATION	AVERAGE NO. COPIES EACH ISSUE DURING PRECEDING 12 MONTHS	ACTUAL NO. COPIES OF SINGLE ISSUE PUBLISHED NEAREST TO FILING DATE
A. TOTAL NO. COPIES PRINTED *(Net Press Run)*	3,450	3,250
B. PAID CIRCULATION 1. SALES THROUGH DEALERS AND CARRIERS, STREET VENDORS AND COUNTER SALES	118	121
2. MAIL SUBSCRIPTIONS	1,870	1,877
C. TOTAL PAID CIRCULATION *(Sum of 10B1 and 10B2)*	1,988	1,998
D. FREE DISTRIBUTION BY MAIL, CARRIER OR OTHER MEANS SAMPLES, COMPLIMENTARY, AND OTHER FREE COPIES	347	320
E. TOTAL DISTRIBUTION *(Sum of C and D)*	2,362	2,318
F. COPIES NOT DISTRIBUTED 1. OFFICE USE, LEFT OVER, UNACCOUNTED, SPOILED AFTER PRINTING	1,088	932
2. RETURNS FROM NEWS AGENTS	0	0
G. TOTAL *(Sum of E, F1 and 2—should equal net press run shown in A)*	3,450	3,250

11. I certify that the statements made by me above are correct and complete.
SIGNATURE AND TITLE OF EDITOR, PUBLISHER, BUSINESS MANAGER, OR OWNER

12. FOR COMPLETION BY PUBLISHERS MAILING AT THE REGULAR RATES *(Section 132.121, Postal Service Manual)*

39 U. S. C. 3626 provides in pertinent part: "No person who would have been entitled to mail matter under former section 4359 of this title shall mail such matter at the rates provided under this subsection unless he files annually with the Postal Service a written request for permission to mail matter at such rates."

In accordance with the provisions of this statute, I hereby request permission to mail the publication named in Item 1 at the phased postage rates presently authorized by 39 U. S. C. 3626.

SIGNATURE AND TITLE OF EDITOR, PUBLISHER, BUSINESS MANAGER, OR OWNER

PUBLICATIONS ORDER

Omission of price indicates publication is in press. Minimum mail order 50¢. All sales are final. Publications are sent postpaid. Payment must accompany orders of less than $20.00.

Fill in appropriate blanks and send sheet to Department (see address on reverse side).

YOUR NAME ____________________

ADDRESS ____________________

____________________ Zip ________

Amount enclosed $ ________

OREGON GEOLOGY

____ Renewal ____ Subscription ____ Gift

____ 1 Year ($4.00) ____ 3 Years ($10.00)

NAME ____________________

ADDRESS ____________________

____________________ ZIP ________

(If Gift, From: ____________________)

ORDER FORM - CUT ON DASHED LINE

Available publications

	Price	No. Copies	Amount
MISCELLANEOUS PAPERS			
1. A description of some Oregon rocks and minerals, 1950: Dole	$ 1.00		
4. Laws relating to oil, gas, and geothermal exploration and development in Oregon			
Part 1. Oil and natural gas rules and regulations, 1977, rev. 1980	1.00		
Part 2. Geothermal resources rules and regulations, 1977, rev. 1979	1.00		
5. Oregon's gold placers (reprints), 1954	.50		
6. Oil and gas exploration in Oregon, rev. 1965: Stewart and Newton	3.00		
8. Available well records of oil and gas exploration in Oregon, rev. 1980: Olmstead and Newton	2.00		
11. Collection of articles on meteorites, 1968 (reprints from *The Ore Bin*)	1.50		
13. Index to *The Ore Bin*, 1950-1974	1.50		
14. Thermal springs and wells, 1970: Bowen and Peterson (with 1975 supplement)	1.50		
15. Quicksilver deposits in Oregon, 1971: Brooks	1.50		
16. Mosaic of Oregon from ERTS-1 imagery, 1973	2.50		
18. Proceedings of Citizens' Forum on potential future sources of energy, 1975	2.00		
19. Geothermal exploration studies in Oregon – 1976, 1977	3.00		
20. Investigations of nickel in Oregon, 1978: Ramp	5.00		
GEOLOGIC MAPS			
Geologic map of Galice quadrangle, Oregon, 1953	1.75		
Geologic map of Albany quadrangle, Oregon, 1953	1.00		
Reconnaissance geologic map of Lebanon quadrangle, 1956	1.50		
Geologic map of Bend quadrangle and portion of High Cascade Mountains, 1957	1.50		
Geologic map of Oregon west of 121st meridian, 1961	2.25		
GMS-3: Preliminary geologic map of Durkee quadrangle, Oregon, 1967	2.00		
GMS-4: Oregon gravity maps, onshore and offshore, 1967 (folded)	3.00		
GMS-5: Geologic map of Powers quadrangle, Oregon, 1971	2.00		
GMS-6: Preliminary report on geology of part of Snake River Canyon, 1974	6.50		
GMS-7: Geology of the Oregon part of the Baker quadrangle, Oregon, 1976	3.00		
GMS-8: Complete Bouguer gravity anomaly map, Cascade Mountain Range, central Oregon, 1978	3.00		
GMS-9: Total field aeromagnetic anomaly map, Cascade Mountain Range, central Oregon, 1978	3.00		
GMS-10: Low- to intermediate-temperature thermal springs and wells in Oregon, 1978	2.50		
GMS-12: Geologic map of the Oregon part of the Mineral quadrangle, 1978	2.00		
GMS-13: Geologic map of the Huntington and part of the Olds Ferry quadrangles, Oregon, 1979	3.00		
OIL AND GAS INVESTIGATIONS			
3. Preliminary identifications of foraminifera, General Petroleum Long Bell #1 well	2.00		
4. Preliminary identifications of foraminifera, E.M. Warren Coos County 1-7 well, 1973	2.00		
5. Prospects for natural gas production or underground storage of pipeline gas	5.00		
MISCELLANEOUS PUBLICATIONS			
Landforms of Oregon (17 × 12 inches)	.50		
Mining claims (State laws governing quartz and placer claims)	.50		
Geological highway map, Pacific NW region, Oregon-Washington (published by AAPG)	3.00		
Fifth Gold and Money Session and Gold Technical Session Proceedings, 1975	5.00		
Sixth Gold and Money Session and Gold Technical Session Proceedings, 1978	6.50		
Back issues of *The Ore Bin*	25¢ over the counter; 50¢ mailed		
Colored postcard, *Geology of Oregon*	10¢ each; 3 for 25¢; 7 for 50¢; 15 for 1.00		

OREGON GEOLOGY

1069 State Office Building, Portland, Oregon 97201

Second Class Matter
POSTMASTER: Form 3579 requested

Available publications (continued)

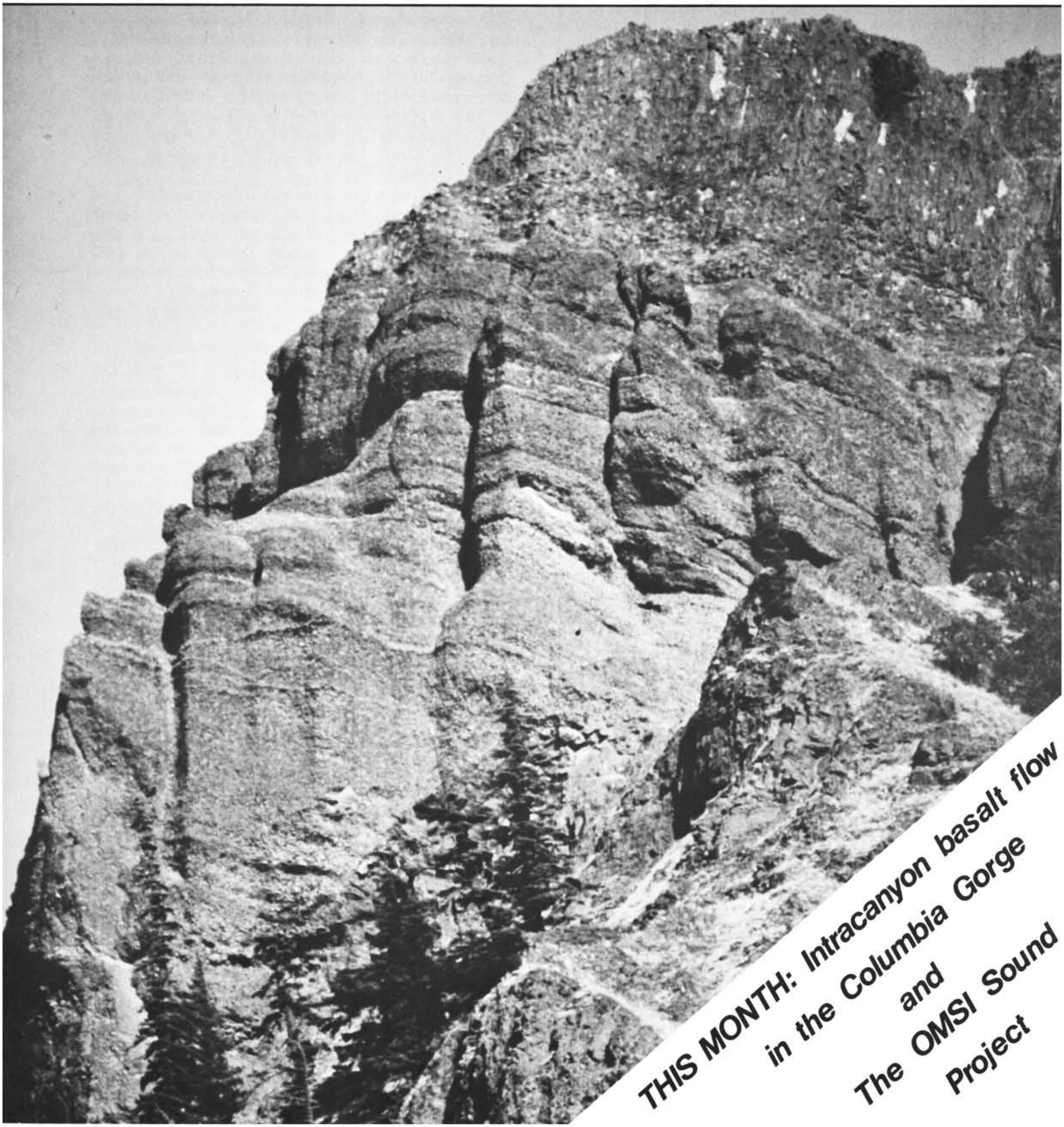
BULLETINS	Price	No. Copies	Amount
33. Bibliography (1st supplement) geology and mineral resources of Oregon, 1947: Allen	1.00	_____	_____
36. Papers on Tertiary foraminifera: Cushman, Stewart and Stewart, 1949: v. 2	1.25	_____	_____
44. Bibliography (2nd supplement) geology and mineral resources of Oregon, 1953: Steere	2.00	_____	_____
46. Ferruginous bauxite deposits, Salem Hills, 1956: Corcoran and Libbey	1.25	_____	_____
49. Lode mines, Granite mining district, Grant County, Oregon, 1959: Koch	1.00	_____	_____
53. Bibliography (3rd supplement) geology and mineral resources of Oregon, 1962: Steere and Owen	3.00	_____	_____
57. Lunar Geological Field Conference guidebook, 1965: Peterson and Groh, editors	3.50	_____	_____
63. Sixteenth biennial report of the Department, 1966-1968	1.00	_____	_____
65. Proceedings of Andesite Conference, 1969: (copies)	10.00	_____	_____
67. Bibliography (4th supplement) geology and mineral resources of Oregon, 1970: Roberts	3.00	_____	_____
68. Seventeenth biennial report of the Department, 1968-1970	1.00	_____	_____
71. Geology of selected lava tubes in Bend area, Oregon, 1971: Greeley	2.50	_____	_____
76. Eighteenth biennial report of the Department, 1970-1972	1.00	_____	_____
77. Geologic field trips in northern Oregon and southern Washington, 1973	5.00	_____	_____
78. Bibliography (5th supplement) geology and mineral resources of Oregon, 1973: Roberts	3.00	_____	_____
81. Environmental geology of Lincoln County, 1973: Schlicker and others	9.00	_____	_____
82. Geologic hazards of Bull Run Watershed, Multnomah, Clackamas Counties, 1974: Beaulieu	6.50	_____	_____
83. Eocene stratigraphy of southwestern Oregon, 1974: Baldwin	4.00	_____	_____
84. Environmental geology of western Linn County, 1974: Beaulieu and others	9.00	_____	_____
85. Environmental geology of coastal Lane County, 1974: Schlicker and others	9.00	_____	_____
86. Nineteenth biennial report of the Department, 1972-1974	1.00	_____	_____
87. Environmental geology of western Coos and Douglas Counties, 1975	9.00	_____	_____
88. Geology and mineral resources of upper Chetco River drainage, 1975: Ramp	4.00	_____	_____
89. Geology and mineral resources of Deschutes County, 1976	6.50	_____	_____
90. Land use geology of western Curry County, 1976: Beaulieu	9.00	_____	_____
91. Geologic hazards of parts of northern Hood River, Wasco, and Sherman Counties, Oregon, 1977: Beaulieu	8.00	_____	_____
92. Fossils in Oregon (reprinted from *The Ore Bin*), 1977	4.00	_____	_____
93. Geology, mineral resources, and rock material of Curry County, Oregon, 1977	7.00	_____	_____
94. Land use geology of central Jackson County, Oregon, 1977: Beaulieu	9.00	_____	_____
95. North American ophiolites, 1977	7.00	_____	_____
96. Magma genesis: AGU Chapman Conference on Partial Melting, 1977	12.50	_____	_____
97. Bibliography (6th supplement) geology and mineral resources of Oregon, 1971-75, 1978	3.00	_____	_____
98. Geologic hazards of eastern Benton County, 1979: Bela	9.00	_____	_____
99. Geologic hazards of northwestern Clackamas County, Oregon, 1979: Schlicker and Finlayson	10.00	_____	_____
100. Geology and mineral resources of Josephine County, Oregon, 1979: Ramp and Peterson	9.00	_____	_____
101. Geologic field trips in western Oregon and southwestern Washington, 1980	9.00	_____	_____
SPECIAL PAPERS			
1. Mission, goals, and purposes of Oregon Department of Geology and Mineral Industries, 1978	2.00	_____	_____
2. Field geology of SW Broken Top quadrangle, Oregon, 1978: Taylor	3.50	_____	_____
3. Rock material resources of Clackamas, Columbia, Multnomah, and Washington Counties, Oregon, 1978: Gray and others	7.00	_____	_____
4. Heat flow of Oregon, 1978: Blackwell, Hull, Bowen, and Steele	3.00	_____	_____
5. Analysis and forecasts of the demand for rock materials in Oregon, 1979: Friedman and others	3.00	_____	_____
6. Geology of the La Grande area, Oregon, 1980: Barrash and others	5.00	_____	_____
7. Pluvial Fort Rock Lake, Lake County, Oregon: Allison	4.00	_____	_____
8. Geology and geochemistry of the Mt. Hood volcano, 1980: White	2.00	_____	_____
SHORT PAPERS			
18. Radioactive minerals prospectors should know, 1976: White, Schafer, Peterson	.75	_____	_____
21. Lightweight aggregate industry in Oregon, 1951: Mason	.25	_____	_____
24. The Almeda Mine, Josephine County, Oregon, 1967: Libbey	3.00	_____	_____
25. Petrography, type Rattlesnake Formation, central Oregon, 1976: Enlows	2.00	_____	_____
27. Rock material resources of Benton County, 1978: Schlicker and others	4.00	_____	_____

OREGON GEOLOGY

published by the

Oregon Department of Geology and Mineral Industries

VOLUME 42, NUMBER 12 DECEMBER 1980



THIS MONTH: Intracanyon basalt flow in the Columbia Gorge and The OMSI Sound Project

OREGON GEOLOGY

(ISSN 0164-3304)

VOLUME 42, NUMBER 12 DECEMBER 1980

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

Main Office: 1069 State Office Building, Portland 97201, phone (503) 229-5580.

Baker Field Office: 2033 First Street, Baker 97814, phone (503) 523-3133.
Howard C. Brooks, Resident Geologist

Grants Pass Field Office: 312 S.E. "H" Street, Grants Pass 97526, phone (503) 476-2496.
Len Ramp, Resident Geologist

Mined Land Reclamation Program: 1129 S.E. Santiam Road, Albany 97321, phone (503) 967-2039.
Paul F. Lawson, Supervisor

Subscription rates: 1 year, $4.00; 3 years, $10.00. Single issues, $.40 at counter, $.50 mailed.
Available back issues of *The Ore Bin:* $.25 at counter, $.50 mailed.

Address subscription orders, renewals, and changes of address to *Oregon Geology,* 1069 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,* 1069 State Office Building, Portland, OR 97201.

COVER PHOTO

Mitchell Point, in the Columbia River Gorge, as seen from rest area of east-bound lane of I-84, just east of mile post 58 and 2.4 mi east of Viento State Park. Article beginning on next page discusses this intracanyon flow of the Pomona Member of the Columbia River Basalt Group.

Looking ahead:

We wish to thank you, our *Oregon Geology* readers, for your interest and support during the past, geologically eventful year.

For next year, we have scheduled a variety of interesting articles on such subjects as (1) the subduction-related origin of the volcanic rocks of the Eocene Clarno Formation near Cherry Creek, Oregon; (2) paleobotany of the Clarno Nut Beds; (3) fossil soils in the Clarno Formation; (4) the petrology and stratigraphy of the Portland Hills Silt—a Pacific Northwest loess; (5) a major Cretaceous discontinuity in north-central Oregon; and (6) the regional stratigraphy and tectonic environment of the Dalles Formation in the Columbia Plateau of Oregon and the formal elevation of the Dalles Formation to the Dalles Group. Also planned is a field trip guide to the pre-Tertiary geology of northeastern Oregon.

We also intend to keep you informed on oil, gas, geothermal, and mineral exploration and development in the State. As new geologic, geophysical, and geochemical data become available through our publications and other outlets, we will inform you. As always, we will print annual summaries, news of the Department, book reviews, and other geologic news throughout the year.

We strive always to make *Oregon Geology* a clearinghouse of geologic information about the State, but meeting this objective also requires continued support and input from you, our readers. Tell us what you like and what you don't like. Tell us what subjects you would like presented in future issues. Send us your news, your articles, your geologic photographs for consideration—for this is your magazine too.

In these inflationary days, costs of producing the magazine continue to increase. A larger circulation will help us keep our costs per copy down. So if your subscription is about to expire, remember to renew it. If you always read a library or borrowed copy, now may be the time to start your own subscription. If you have a friend who is interested in geology, why not give him (or her) a gift subscription to *Oregon Geology*?

Next year should be another great year for *Oregon Geology*. □

CONTENTS

Pomona Member of the Columbia River Basalt Group: an intracanyon flow in the Columbia River Gorge, Oregon

by James Lee Anderson, U.S. Geological Survey, P.O. Box 341, The Dalles, Oregon 97058

ABSTRACT

The Pomona Member of the Saddle Mountains Basalt (Columbia River Basalt Group) occurs as an intracanyon flow greater than 75 m (250 ft) thick along the south side of the Columbia River Gorge beween Mitchell Point and Shellrock Mountain, Oregon. Best exposures are at Mitchell Point, where this flow caps more than 70 m (230 ft) of cobble conglomerate that partially fills a canyon cut into flows of the underlying Frenchman Springs Member. These exposures provide a necessary link between outcrops of the Pomona Member in the Columbia Plateau and western Washington. Post-Frenchman Springs, pre-Pomona canyon cutting implies deformation in the ancestral Cascade Range between about 14.5 and 12 million years ago.

INTRODUCTION

The Pomona Member of the Saddle Mountains Basalt of the Miocene Columbia River Basalt Group has been found both east and west of the present-day Cascade Range. Geologists have long wondered where—and indeed if—it flowed from east to west through the area now covered by mountains. A lava flow in the Kelso-Cathlamet area (Kienle, 1971; Snavely and others, 1973) in southwest Washington is chemically, petrographically, and paleomagnetically identical to the widespread Pomona Member of the Columbia Plateau (Schmincke, 1967; Swanson and others, 1979a). Until now, however, no Pomona outcrops have been located in the broad intervening region, more than 120 km (74 mi) wide, that includes the Willamette lowland, the Cascade Range, and the Hood River Valley (Anderson, 1978; Timm, 1979; Beeson and Moran, 1979). The absence of local sources for the Pomona Member west of the Cascade Range and the presence of known vents in the eastern Columbia Plateau (Camp, *in* Swanson and others, 1979b) support the theory of a pathway through the late Miocene mountains connecting the two areas. It is the purpose of this paper to present the first direct evidence that the Pomona Member crossed the ancestral Cascade Range as an intracanyon flow.

SUBGROUP	FORMATION	MEMBER
YAKIMA BASALT	SADDLE MTNS BASALT	POMONA*
	WANAPUM BASALT	PRIEST RAPIDS*
		FRENCHMAN SPRINGS
	GRANDE RONDE BASALT	

*indicates intracanyon flow

Figure 1. Columbia River Basalt Group stratigraphy in western Oregon.

Many older flows of the Columbia River Basalt Group, identified as part of the Grande Ronde Basalt and Frenchman Springs Member of the Wanapum Basalt (Beeson and Moran, 1979), appear to have entered western Oregon in a generally conformable manner during middle to late Miocene time (Figure 1). The apparent absence of significant erosion between eruptions suggests little or no coeval deformation. These flows poured through a broad lowland, at least 75 km (47 mi) wide, across the site of the present Cascade Range (Figure 2). However, about 14 million years ago, the geography changed significantly, probably as a result of folding and faulting. After this time, flows were essentially restricted to the confines of narrow canyons cut by the ancestral Columbia River into older units of the Columbia River Basalt Group. The oldest flow yet recognized that reflects this change is the Priest Rapids Member (Wanapum Basalt) which fills a canyon at Crown Point in the Columbia River Gorge (Waters, 1973) and in the Bull Run Watershed (Vogt, in progress).

POMONA INTRACANYON FLOW

The Pomona Member, about 12 million years old, also occurs as an intracanyon flow. Excellent exposures up to 75 m (250 ft) thick are present along the south side of the Gorge from 0.8 km (0.5 mi) east of Mitchell Point westward for 10 km (6 mi) to the vicinity of Shellrock Mountain (Figure 3). The outcrops in the Mitchell Point area are the most spectacular and the most accessible, since they are adjacent to Interstate I-84 near river level. Mitchell Point constitutes a record of up to four million years of Columbia River Basalt Group volcanism, beginning at road level (elev. 28 m [94 ft]) in Grande Ronde Basalt (16 to 15 m.y.) and ending at the summit

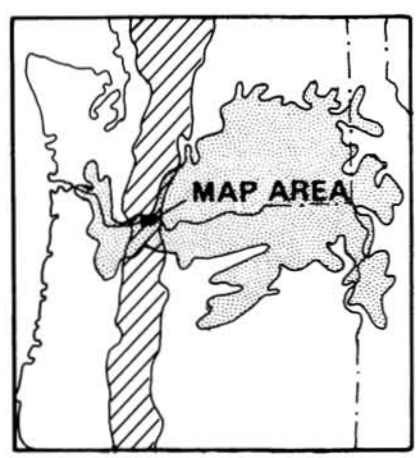


Figure 2. Regional distribution of Columbia River Basalt Group (stippled), shown relative to the Cascade Range (hachured). "MAP AREA" refers to Figure 3. Basalt data after Waters (1961).

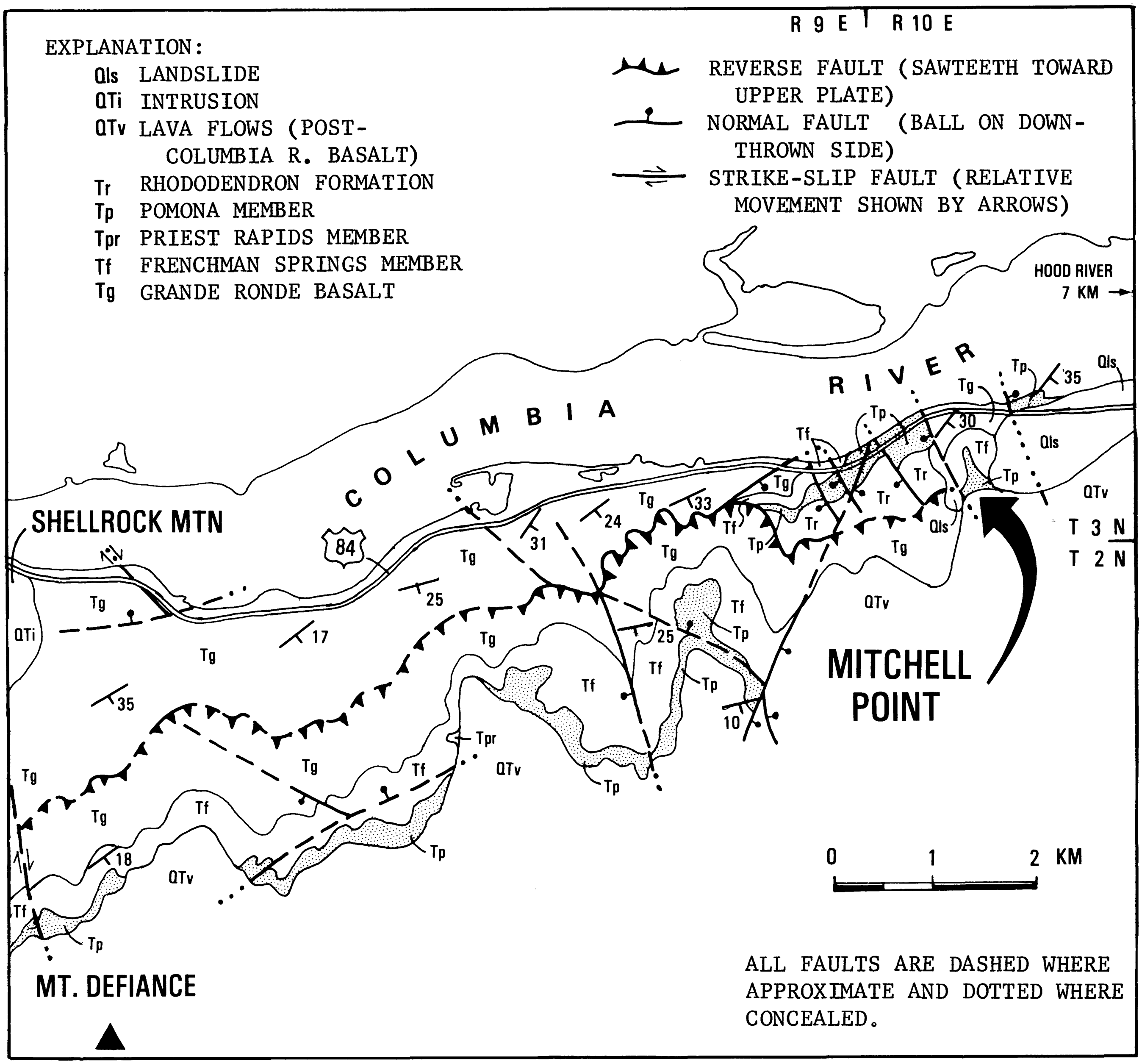


Figure 3. Preliminary geologic map of the Columbia River Gorge between Mitchell Point and Shellrock Mountain. Note distribution of Pomona Member (stippled).

(elev. 353.4 m [1,178 ft]) in the Pomona Member (12 m.y.) (Figure 4).

The cover photograph of this month's magazine shows the intracanyon flow at Mitchell Point. An unconformity is clearly exposed at the top of the Frenchman Springs Member, defining a channel filled with gravel, ranging from about 8 m (26 ft) deep on the south to more than 70 m (230 ft) deep on the north (Figure 5). The flow underlying the gravel on the south is the uppermost flow of a three-flow Frenchman Springs sequence, while the flow on the north is the basal flow. Frenchman Springs overlain by gravel is exposed at highway level west of Mitchell Point (Figure 6). The ancient river channel may have been much deeper farther north, but erosion by the present Columbia River has removed any record of that part of the canyon. The gravel deposit consists of well-cemented basaltic cobble conglomerate with a sandstone matrix (Sceva, 1966). In the conglomerate are also rare quartzite pebbles, scattered wood fragments, and thin lenses of micaceous sandstone. The conglomerate contains abundant angular blocks derived from the Frenchman Springs Member along the channel wall and is therefore the product of caving during alluviation. A palagonite sand deposit 1.5 to 3 m (5 to 10 ft) thick occurs at the base of the Pomona Member; very few pillows are present.

The Pomona Member contains both acicular and equant phenocrysts of plagioclase occurring as single crystals 0.25 to 1.0 cm (0.1 to 0.4 in.) long. This bimodality of crystal habit sets the Pomona apart from underlying flows. Other diagnostic properties include reversed magnetic polarity and distinctive major oxide chemistry (Table 1). The chemical composition of the Pomona Member is relatively lower in FeO, TiO_2, P_2O_5, and K_2O, and higher in MgO and CaO than other flows in the section. The jointing of the Pomona resembles that of numerous flows of Grande Ronde Basalt in the area, a characteristic that may explain why the intracanyon relation-

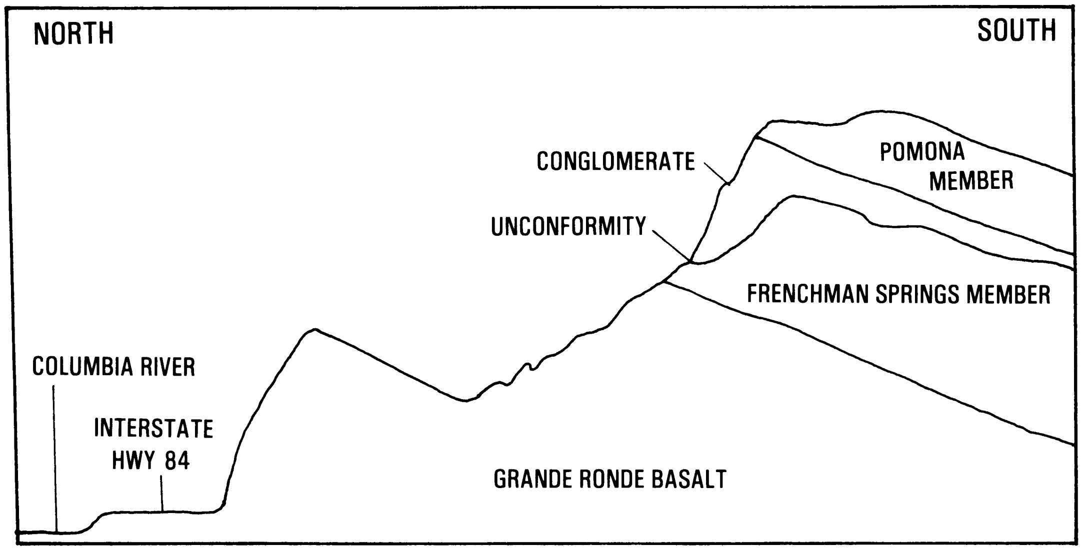


Figure 4. Diagrammatic cross section through Mitchell Point.

ship was not previously recognized (Wells and Peck, 1961; Sceva, 1966; Kienle, 1971; Waters, 1973; Beaulieu, 1977).

The Pomona and earlier flows appear to have been deformed at the same time; the basalt dips 25° to 30° SE and is cut by numerous faults (Figure 3), making it difficult to estimate minimum canyon width. The horizontal component of net slip on the northeast-trending reverse fault in Figure 3, for example, is greater than 1 km (0.6 mi) near Mitchell Point, effectively narrowing the distribution of the Pomona Member.

DISCUSSION

The exposures at Mitchell Point and farther west answer some important questions but raise others. The Pomona Member left the Columbia Plateau along a channel nearly parallel to the present Columbia River. However, the problem of where it entered the Willamette lowland in western Oregon or Washington prior to reaching the known exposures in the Kelso-Cathlamet area is still unresolved. The close proximity of the Pomona intracanyon flow to the present Columbia River suggests that exposures that were once downstream from Shellrock Mountain may have been largely removed by erosion.

Another interesting question involves the contrast between the nature of the Pomona and Priest Rapids intracanyon flows at Mitchell Point and Crown Point, respectively. Palagonite sand is much more abundant at Crown Point, where the Priest Rapids appears to have a much greater overall thickness than does the Pomona. A possible explanation is that Mitchell Point is somewhat south of the deepest part of the river channel filled by the Pomona; under this interpretation, the thick gravel at Mitchell Point could represent a gravel bar or an earlier course of the river. Quartzite represents only a small fraction in the pre-Pomona gravels versus a much greater percentage in post-Pomona Troutdale gravels. This could imply a less extensive drainage network in pre-Pomona time, a

Table 1. *Average major oxide compositions of members of the Columbia River Basalt Group in the Mitchell Point area of the Columbia River Gorge compared with averages of the same members in the Columbia Plateau *†* *(all analyses in weight percent)*

Chemical type	Pomona		Frenchman Springs		High MgO Grande Ronde		Low MgO Grande Ronde	
	Gorge	Plateau	Gorge	Plateau	Gorge	Plateau	Gorge	Plateau
Oxide	(5)**	(30)**	(4)**	(8)**	(10)**	(13)**	(9)**	(8)**
SiO_2	51.60	51.88	51.68	52.29	53.89	53.78	55.50	55.94
Al_2O_3	15.39	14.88	14.25	13.21	15.13	14.43	14.89	14.04
FeO***	10.77	10.55	14.56	14.38	11.64	11.35	12.21	11.77
MgO	6.81	6.96	3.97	4.04	4.86	5.25	3.63	3.36
CaO	10.47	10.67	7.91	7.90	8.35	9.07	7.28	6.88
Na_2O	2.27	2.36	2.51	2.67	2.62	2.83	2.83	3.14
K_2O	0.65	0.64	1.37	1.41	1.15	1.05	1.79	1.99
TiO_2	1.63	1.62	2.98	3.17	1.82	1.78	2.03	2.27
P_2O_5	0.24	0.25	0.55	0.71	0.29	0.28	0.32	0.43
MnO	0.19	0.17	0.22	0.22	0.21	0.19	0.20	0.19

* Plateau averages from Swanson and others, 1979a.
** Number of analyses used in computing average.
*** Total iron.
† Gorge analyses are XRF determinations by P.R. Hooper, Washington State University, Pullman, Wash.

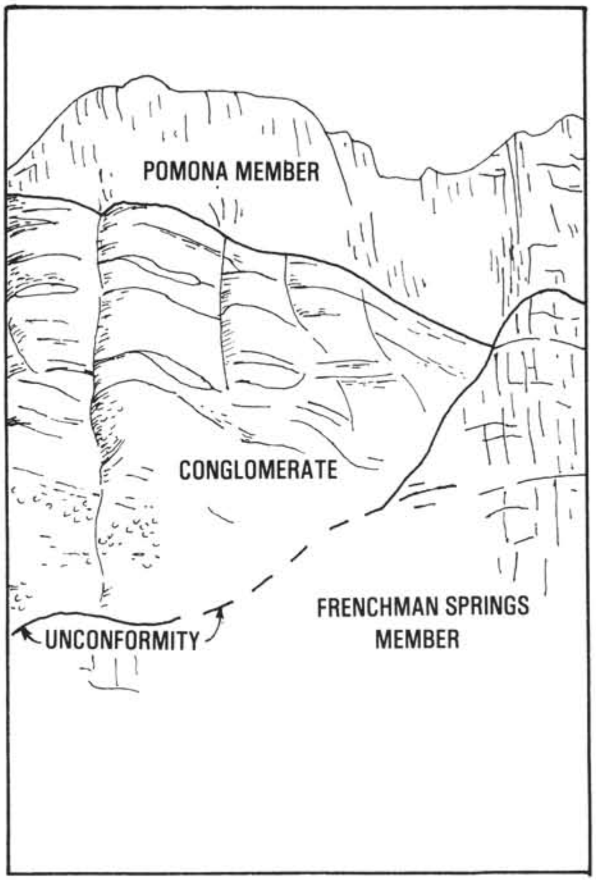


Figure 5. Diagram of photograph showing edge of pre-Pomona canyon and gravel fill.

Figure 6. Pre-Pomona basaltic conglomerate overlying Frenchman Springs Member. Mitchell Point is at left in background.

Figure 7. Closeup of basaltic cobble conglomerate containing rare quartzite pebbles.

change in provenance, or dilution with locally derived basalt detritus during canyon cutting. The alluviated channel at Mitchell Point suggests one or more base level changes in pre-Pomona, post-Frenchman Springs time, conceivably related to regional tectonism in the ancient Cascades 14.5 to 12 million years ago. More data on the distribution of the Pomona Member will help to define the amount of uplift and the nature of deformation in the Cascade Range during the past 12 million years. Work to further determine this distribution is continuing.

ACKNOWLEDGMENTS

Donald A. Swanson, U.S. Geological Survey, Menlo Park, California; Marvin H. Beeson, Portland State University, Portland, Oregon; and Susan M. Price, Rockwell Hanford Operations, Richland, Washington, reviewed this manuscript and provided valuable comments. Geologic mapping was performed under U.S. Geological Survey-U.S. Department of Energy Interagency Agreement EY-78-1-06-1078. The mapping is part of the regional geologic studies effort of the Basalt Waste Isolation Project administered by Rockwell Hanford Operations for the U.S. Department of Energy.

REFERENCES CITED

Anderson, J.L., 1978, The stratigraphy and structure of the Columbia River basalt in the Clackamas River drainage: Portland, Oreg., Portland State University master's thesis, 136 p.

Beaulieu, J.D., 1977, Geologic hazards of parts of northern Hood River, Wasco, and Sherman Counties, Oregon: Oregon Department of Geology and Mineral Industries Bulletin 91, 95 p.

Beeson, M.H., and Moran, M.R., 1979, Columbia River Basalt Group stratigraphy in western Oregon: Oregon Geology, v. 41, no. 1, p. 11-14.

Kienle, C.F., Jr., 1971, The Yakima Basalt in western Oregon and Washington: Santa Barbara, Calif., University of California at Santa Barbara doctoral dissertation, 171 p.

Sceva, J.E., 1966, A reconnaissance of the ground-water resources of the Hood River Valley and the Cascade Locks area, Hood River County, Oregon: Oregon State Engineer Ground Water Report 10, 45 p.

Schmincke, H.-U., 1967, Stratigraphy and petrology of four upper Yakima Basalt flows in south-central Washington: Geological Society of America Bulletin, v. 78, no. 11, p. 1385-1422.

Snavely, P.D., Macleod, N.S., and Wagner, H.C., 1973, Miocene tholeiitic basalts of coastal Oregon and Washington and their relations to coeval basalts of the Columbia Plateau: Geological Society of America Bulletin, v. 84, no. 2, p. 387-424.

Swanson, D.A., Wright, T.L., Hooper, P.R., and Bentley, R.D., 1979a, Revisions to stratigraphic nomenclature to the Columbia River Basalt Group: U.S. Geological Survey Bulletin 1457-G, 59 p.

Swanson, D.A., Wright, T.L., Camp, V.E., Gardner, J.N., Helz, R.T., Price, S.M., Reidel, S.P., and Ross, M.E., 1979b, Reconnaissance geologic map of the Columbia River Basalt Group, Pullman and Walla Walla quadrangles, southeast Washington and adjacent Idaho: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-1139, scale 1:250,000.

Timm, S., 1979, The structure and stratigraphy of the Columbia River basalt in the Hood River Valley, Oregon: Portland, Oreg., Portland State University master's thesis, 60 p.

Vogt, B.F., in progress, The stratigraphy and structure of the Columbia River Basalt Group in the Bull Run Watershed: Portland, Oreg., Portland State University master's thesis.

Waters, A.C., 1961, Stratigraphy and lithologic variation in the Columbia River basalt: American Journal of Science, v. 259, p. 583-611.

——— 1973, The Columbia River Gorge: basalt stratigraphy, ancient lava dams, and landslide dams, *in* Beaulieu, J.D., field trip chairman, 1973, Geologic field trips in northern Oregon and southern Washington: Oregon Department of Geology and Mineral Industries Bulletin 77, p. 133-162.

Wells, F.D., and Peck, D.L., 1961, Geologic map of Oregon west of the 121st meridian: U.S. Geological Survey Miscellaneous Investigations Map I-325, scale 1:500,000. □

Endowment fund established at OSU Geology Department

The Daniel G. Emrick Estate has established an endowment fund of $55,579.71 for the Department of Geology, Oregon State University. Income from this fund will be used in support of departmental field trips and field work. □

REMEMBER to send us your forwarding address when you move. Notifying the Post Office is not enough, because second class mail is not forwarded to you. So keep in touch with us. □

OMSI Sound Project: the acoustic effects of the Mount St. Helens eruption on May 18, 1980

by Clara Fairfield, Curator and Exhibits Designer, Oregon Museum of Science and Industry, 4015 S.W. Canyon Road, Portland, Oregon 97221

One of the many studies currently underway in connection with the May 18 blast of Mount St. Helens is being conducted by the Oregon Museum of Science and Industry (OMSI). The project involves a compilation of more than 1,200 reports from individuals in the Northwest who either heard or felt the cataclysmic eruption and, what is equally important, from those who did *not* hear or feel the sound or shock waves. Preliminary findings are summarized in the following article. OMSI is anxious to hear from any other individuals who experienced acoustic effects related to the eruption. —Ed.

INTRODUCTION

In Hamilton, Montana, about 400 mi due east of Mount St. Helens, the sound of the volcano's eruption on May 18 was described as heavy artillery fire very close by. In the San Juan Islands, people wondered if the Canadian Navy was having gunnery practice. Residents along the central Oregon coast thought they were hearing sonic booms, thunder, and dynamiting all rolled into one 15-minute barrage.

Yet, some who were within 10 mi of the mountain heard nothing. Since the author was able to hear this house-shaking, window-rattling noise near Netarts on the Oregon coast, 116 mi distant from Mount St. Helens, she was surprised to learn that her daughter in Portland, only 45 mi distant, had heard nothing at all. Out of the curiosity about this phenomenon the OMSI Sound Project was born.

A request was sent out through the media asking the general public for information on the intensity of the sound, if heard; on shock waves and earth tremors, if felt; on barometric pressure changes, if noted; and on any unusual animal behavior, if observed. The response has been impressive: over 1,200 replies by mail, many phone calls, and questionnaires filled out by OMSI visitors. People sent newspaper clippings, maps, barograms, photos, even samples of ash.

A map exhibit at OMSI has been developed from this information, with blue pins indicating locations where people heard the eruption and yellow pins showing where the sound was not or barely heard and/or felt.

SOUND PROPAGATION

The "quiet zone" near the volcano turned out to be larger than expected. It extended north-south from near Olympia, Washington, to Albany, Oregon, and east-west from near The Dalles to the coast at Manzanita. To the south, the narrowing of the quiet zone appears to have been related to the crest lines of the Coast Range and the Cascades. Hikers and climbers on Mount Hood, Mount Adams, and Mount Rainier watched the eruption but reported hearing nothing. People in areas near Mount Baker and Mount Jefferson did hear the eruption. Rock slides and avalanches were reported from the North Cascades of Washington.

In Oregon the "loudest zones" appear to have been along the coast from Tillamook to Newport, in central Oregon from Redmond to La Pine, and in southern Oregon in the Medford-Ashland area. In Washington they were along the coast from Ocean Shores to Neah Bay, in the northern parts of Puget Sound and Hood Canal, and on Whidbey Island and the San Juans. In Montana the explosion was heard the loudest east of the Bitterroot Mountains from Hamilton to Flathead Lake and in British Columbia from Victoria to the Cadwellder Range.

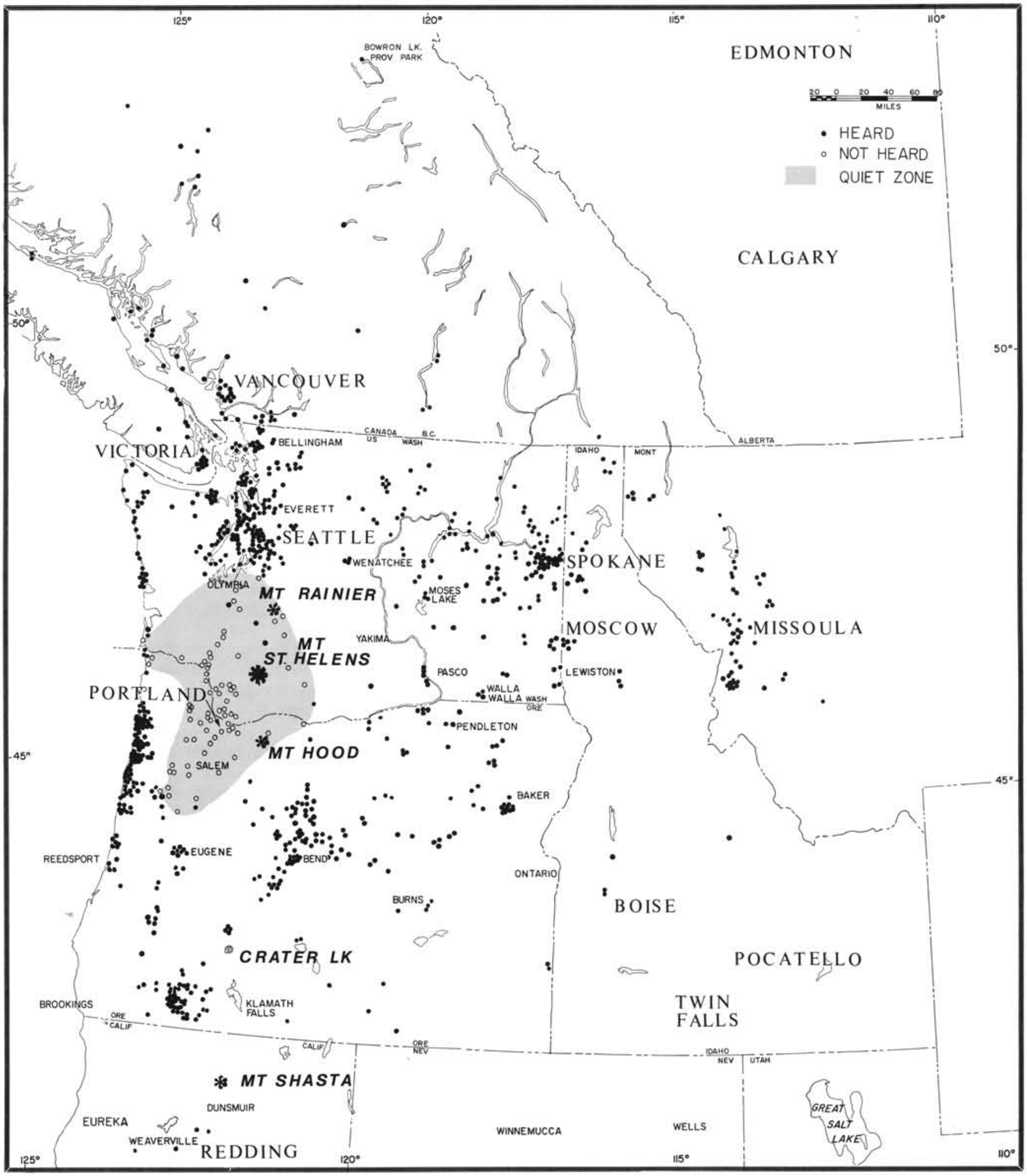
Several known facts and observations are involved in the spreading of the sound of such an explosion: 1. Temperature affects the speed of sound; sound travels faster in warmer air. 2. There is a warm layer of air in the stratosphere that stays at about the 150,000-ft level. 3. When a sound wave reaches a warm layer, the top part of the wave increases in speed, and the path of the wave is refracted, i.e., bent over and directed back toward the ground. 4. If a sound wave is strong enough, it may be refracted at high altitude and reflected by the earth's surface several times. 5. Wind "carries" sound, i.e., sound waves traveling in the same direction as the moving air are less subject to dissipation than those going in other directions. 6. Underground atomic explosions have been known to produce inaudible low-frequency sound waves that can travel around the earth.

The eruption of May 18 was triggered by an earthquake of magnitude 5.1 on the Richter scale. The following explosions occurred less rapidly than an atomic or high-explosive blast, so that much of the audible sound diminished quickly away from the volcano. The sound and pressure waves which traveled upwards from the explosion, however, were refracted by the warm layer in the stratosphere back down to earth. Interpretation of reported sound intensities shows alternating zones of loudness and quiet at increasing distances from the volcano. This indicates that refraction of the explosion sound occurred at least twice. Local topography such as hills, valleys, deep canyons, cliffs, and water bodies also had an effect on where and how loudly the sound was heard in a given location.

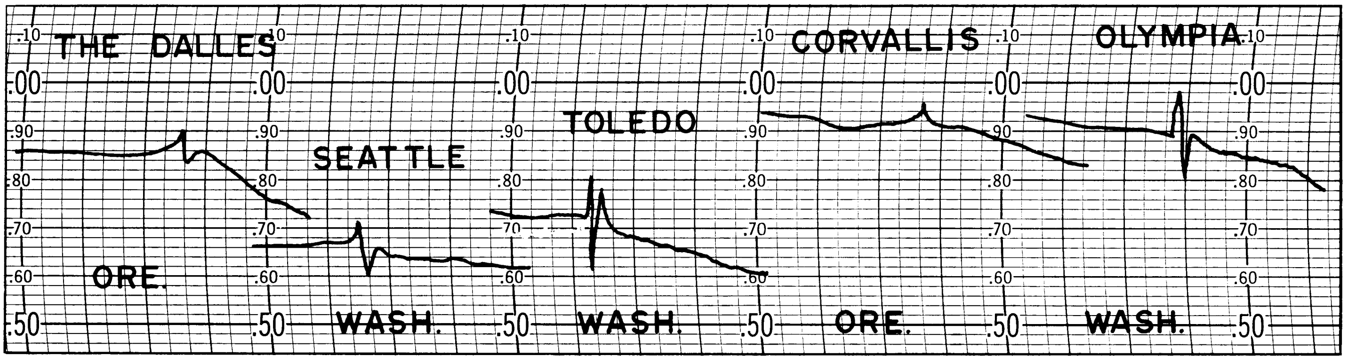
Weather charts show that there was a relatively stable upper air pattern over the entire Pacific Northwest at the time of the explosion. A wind-flow chart for the same day shows strong westerly winds from the surface up to 55,000 ft over the same area. These winds tended to inhibit the spreading of the sound wave to the west.

Finally, recording stations near Washington, D.C., and in New York picked up low frequency sounds several hours after the eruption. Thus we know that these sounds, inaudible to the human ear, were also produced by the eruption.

Sound waves in subsequent eruptions have followed the same pattern as that of May 18, but with much less intensity. Some respondents of the survey are now actually capable of recognizing the sound and identifying the source.



Map showing locations from which OMSI Sound Project received reports of the acoustic effects of the May 18 eruption of Mount St. Helens. Note quiet zone.



Redrafted portions of barograms from various places in the Pacific Northwest, showing the way local barometric pressure was affected by the passage of the sound wave. Note sudden rise and fall in air pressure. Each vertical curved line represents one hour.

BAROMETRIC PRESSURE CHANGES

Barometric pressure was affected over a wide area. Not surprisingly, the greatest effects were felt and recorded within a 100-mi radius. However, barograms from as far away as Las Vegas, Nevada, and Helena, Montana, also exhibited a change in barometric pressure.

Letters describing the way curtains were sucked out of windows and storm doors were pulled out of people's hands document the physical evidence of a sudden change in air pressure. Rattling windows were also attributed to this change. Al Frank of the Atmospheric Sciences Department at Oregon State University is studying this aspect of the eruption and has kindly shared barograms and other weather-related findings with this author. The barograms show the passing of the explosion wave by a sudden sharp rise in air pressure and an almost as sudden drop of equal size immediately thereafter.

SHOCK WAVES AND EARTH TREMORS

Shock wave effects were most commonly described as "whumps" that were felt as well as heard. Houses in the Puget Sound area were "hit with a giant, soft sledge hammer" or a "huge, padded wrecking ball." Numerous people thought someone in the house had fallen down, or someone had driven into the side of the house or garage. In the Portland-Vancouver area, heavy hanging planters, clothes racks, and hanging fireplace tools were seen swaying. Doors slammed or popped open in many locations.

There were many accounts of earth tremors, most within a 100-mi radius. In this area, some people felt the movement but heard either nothing or only the sounds of creaking houses or buildings. Almost everyone who responded had heard windows rattling. There was a report of structural damage from Tillamook, where a garage pulled away from the attached house, and a report of a crack in a garden retaining wall. Residents in travel trailers, campers, and mobile homes all experienced extensive shaking; one reported broken dishes. A number of people were awakened by the movement, and one even fell out of bed.

ANIMAL REACTIONS

Animal behavior was varied. "Hotrod," a ground squirrel near Hood Canal, dropped his sunflower seeds and dashed for cover moments before the eruption was heard. He was not seen for the rest of the day. There were numerous other reports of this kind about both domestic and wild creatures.

Bird reactions were a favorite subject of letter writers. Pheasants were very "noisy," but song birds became very quiet, with little or no flying and very erratic behavior for hours afterward. Even insects were noticed to be "abruptly still" when the sound waves passed by.

Cattle, horses, pigs, dogs, cats, and geese were restless and disturbed throughout the day. Antelope and deer were observed running from an unseen "spook" to the north, east of Redding, California. One deer ran into the side of a moving pickup truck. Rabbits and porcupines were unusually active in mid-morning in the same area. Carp were seen beaching themselves by the dozen at Pot Holes Reservoir behind O'Sullivan Dam in central Washington. Poor fishing was experienced by many. There were numerous complaints of poor clamming even though there was a favorable low tide.

In addition to the Oregon State University research mentioned above, other studies on the sound phenomenon and barometric pressure changes are underway at Sandia National Laboratories and at the University of Victoria, British Columbia.

ACKNOWLEDGMENTS

The author would like to express her gratitude to the following people for their help: Dr. John Walls, meteorologist at KOIN-TV; Laird Brodie, Physics Department, Portland State University; and Albert Frank, Oregon State University. A special thanks to Christie Galen, OMSI Research Center, for many hours of aid.

The data collected for this project are available to anyone interested in further research. The author and OMSI would welcome any additional information or comments on the project. □

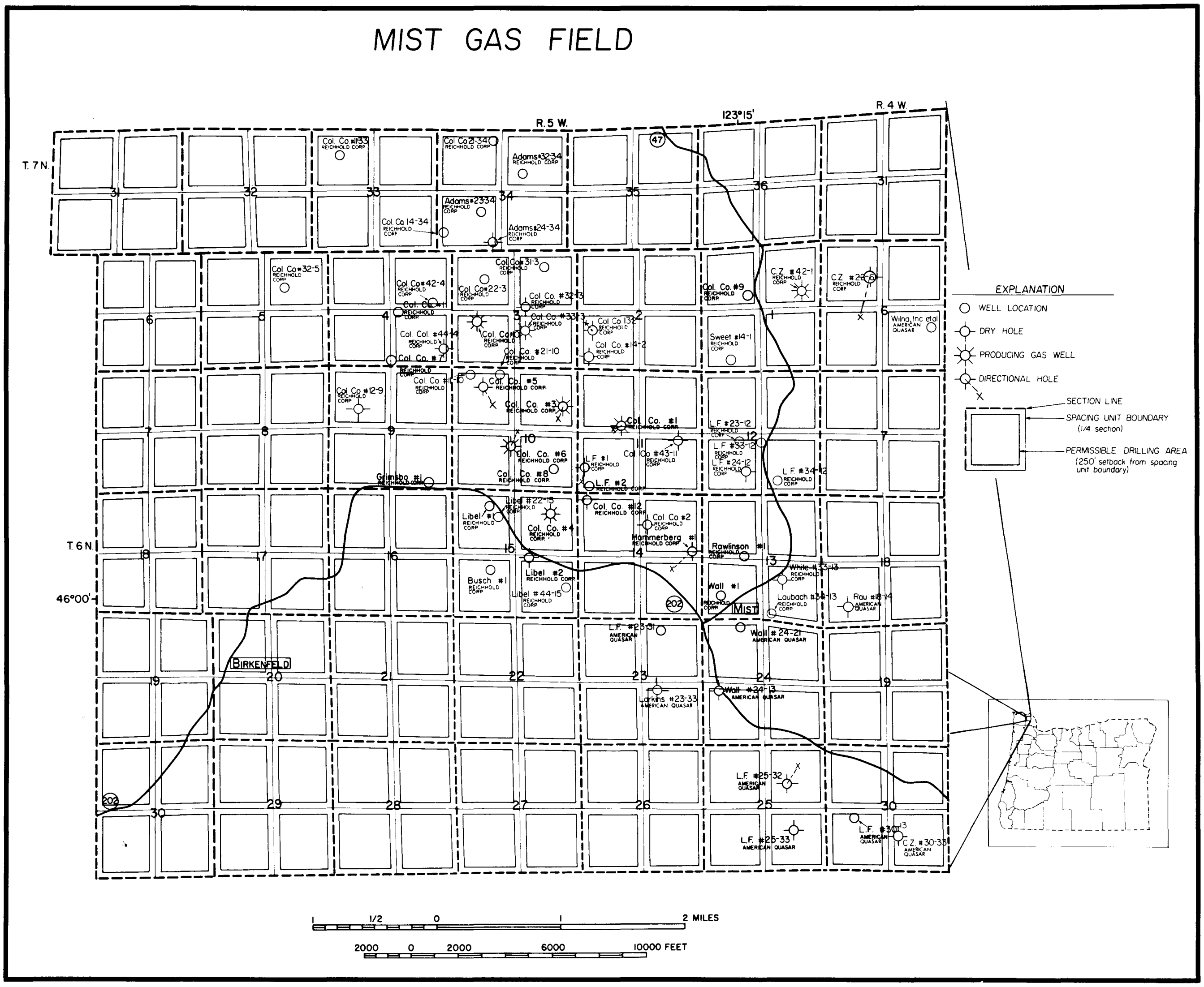
Exploratory drilling continues at Mist

Oregon's first and only gas field was the site of continued drilling activity during 1980. Since the beginning of the year, one drilling rig has been continuously active, drilling wells for American Quasar Petroleum and for the partnership of Reichhold, Diamond Shamrock, and Northwest Natural Gas Company.

Within the field boundaries shown on the map, Reichhold and its partners drilled two producers this year as well as eleven dry holes and six dry redrills. American Quasar drilled five dry holes and two dry redrills. The redrills consisted of directional holes drilled from the surface location of an existing straight hole.

The average depth of straight holes was 2,969 ft this year, while the redrills averaged 3,177 ft in depth. In the holes drilled during 1980, the target sand, the Clark and Wilson, was penetrated at an average depth of 2,350 ft but was often found to contain water rather than gas. The Mist Gas Field is heavily faulted, resulting in small accumulations of gas separated by areas where the sandstone contains only water. Even the depth to the sand was difficult to predict due to the vertical displacement of up to several hundred feet along the steeply dipping faults.

At present, there are five producing wells in the field, providing over 20 million cubic feet of gas per day, which is between five and ten percent of the demand for gas from the distributor, Northwest Natural Gas Company.



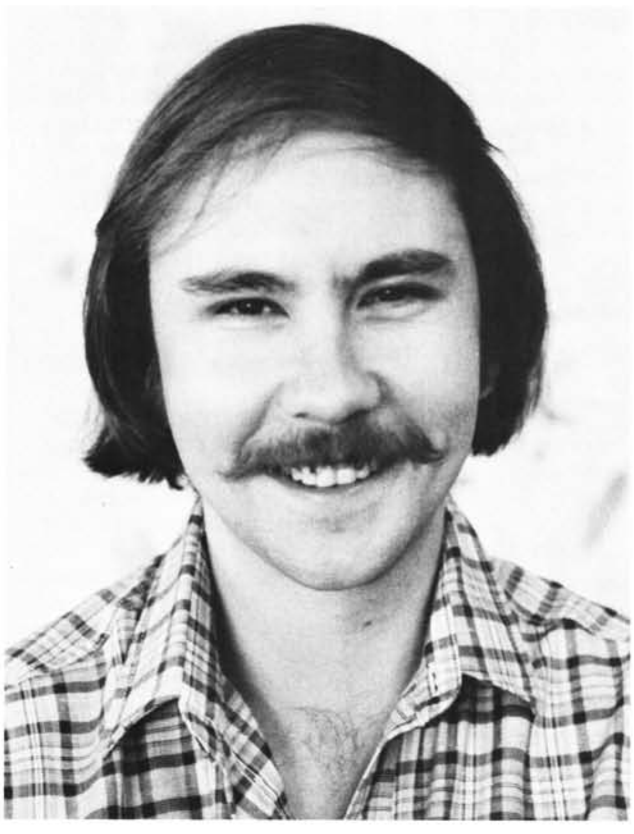
This map of the Mist Gas Field is available from the Department of Geology and Mineral Industries at a scale of 1:24,000 for a price of $5.00. The map is periodically updated.

—Dennis L. Olmstead, Petroleum Geologist, Oregon Department of Geology and Mineral Industries

George Priest to supervise Geothermal Assessment Program

The Oregon Department of Geology and Mineral Industries (DOGAMI) announces the appointment of George R. Priest as the supervisor of its Geothermal Assessment Subprogram. Serving in this capacity, Priest will supervise and direct the Department's efforts to identify and define the geothermal resource base of the State of Oregon and coordinate these efforts with the work of other agencies. DOGAMI's current projects include assessments of various geothermal areas in eastern Oregon, the Western Cascades, and the Mount Hood area.

Priest, a native Oregonian from Klamath Falls, received his education from Oregon State University (B.S. and Ph.D. in geology) and the University of Nevada at Reno (M.S. in geology).



George R. Priest

As part of the Department's geothermal research staff since September 1979, Priest has completed considerable geothermal mapping and geothermal assessment work in the Western Cascades. Prior to that time, he was an assistant professor in the Department of Earth Sciences at Portland State University.

Throughout his years of study, Priest found time to develop his industrial experience in a variety of appointments – by such companies as Chevron Resources Company, Hanna Mining Company, Woodward-Clyde and Associates, and Lawrence Livermore Laboratory–in geothermal and mineral exploration, engineering geology, and geochemistry.

He has produced geologic maps, supervised drilling projects, and conducted geophysical surveys for mineral exploration. He has also performed basic geochemical research on the genesis of uranium ore and translated geologic mapping into nontechnical and engineering terminology for applications in planning and construction.

As a teacher and researcher, Priest has concentrated particularly on volcanology, igneous petrology, and geochemistry. His publications include several papers on the eruptive history and geochemisry of the Little Walker volcanic center in California and a chapter on latites and quartz latites in *Volcanoes and Volcanology*, R. Fairbridge and J. Green, eds., published by Dowden, Hutchinson, and Ross, Inc. His work now will focus on the volcanic and tectonic controls of geothermal systems throughout the State of Oregon. □

Atmospheric effects of Mount St. Helens eruption

Early questions as to whether the volcanic activity of Mount St. Helens, especially the May 18 eruption, would influence the climate of the earth are being addressed gradually.

In the October 16 issue of *Nature*, European researchers M. Ackerman, C. Lippens, and M. Lechevallier of the Institut d'Aéronomie Spatiale de Belgique present preliminary results of photographic observations of the stratosphere.

Comparison of observations on October 10, 1979; May 7, 1980; and June 5, 1980, indicates an abrupt increase of solar radiance on the latest of these dates: after the May 18 eruption and probably shortly after the volcanic material had crossed the Atlantic and arrived over Europe. The increase, by a factor of three, appeared between 15 and 16 km of altitude (about 49,000-52,500 ft), with a sharp cutoff at the upper boundary of the layer.

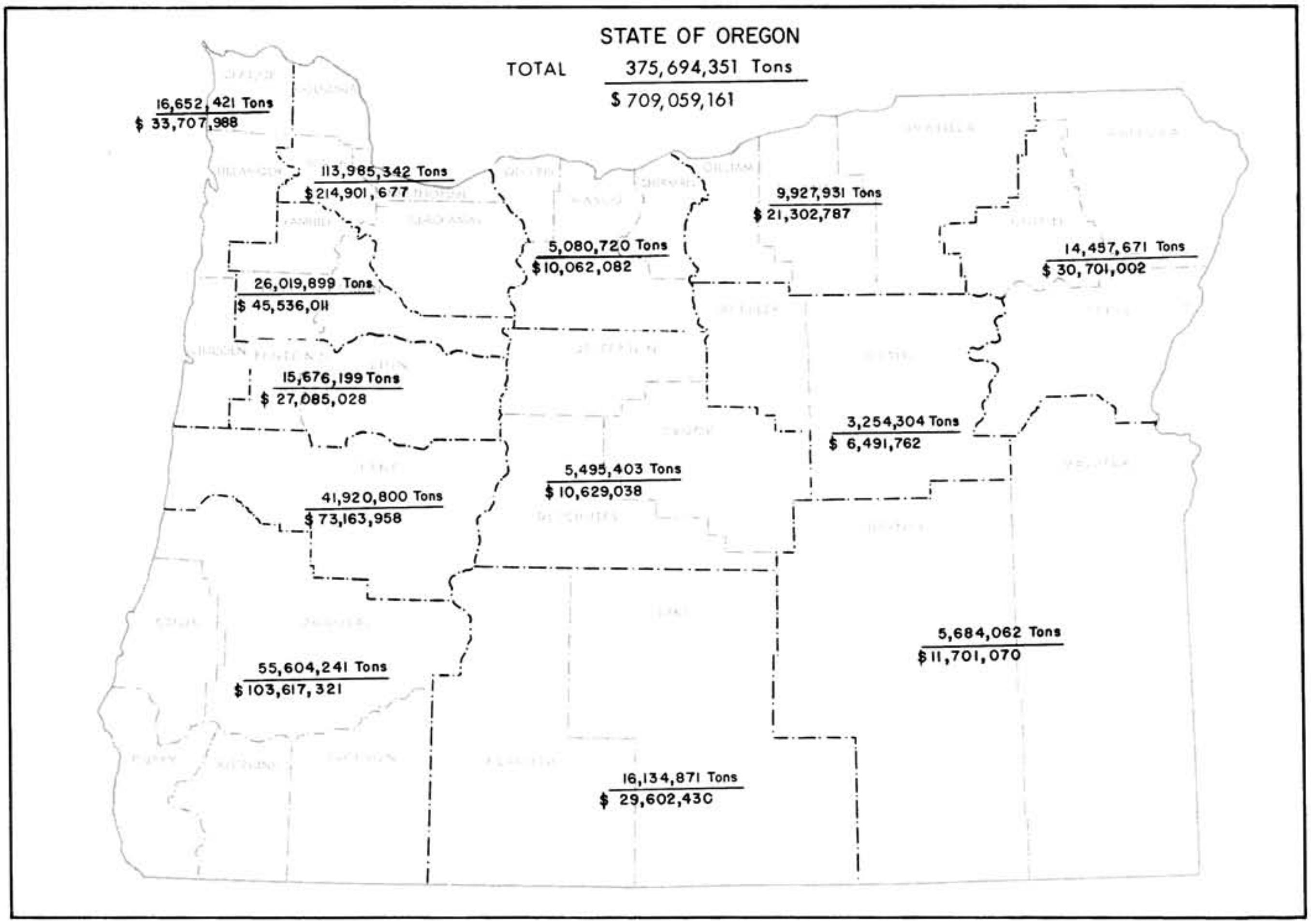
The radiance increase is interpreted as an increase of stratospheric aerosol caused by wide horizontal spreading of material from Mount St. Helens. While more observations are necessary to permit more definite conclusions, the present results indicate the possibility that absorption and reflection of solar energy by the increased stratospheric aerosol layer will cause a slight drop in average temperatures below.

–Klaus Neuendorf, Editor-Librarian, Oregon Department of Geology and Mineral Industries

Large volume of rock material produced in Oregon during last ten years

During the 10-year period from 1970 through 1979, the rock material industry in Oregon produced 376 million tons of sand and gravel and stone (including road metal cinders), worth a total of $709 million. These figures mean that during that time 164 tons of sand, gravel, and crushed rock were mined and processed for each of the 2.3 million men, women, and children in the State.

The $709 million value, equal to $308 for each Oregonian, represents the value of the rock material at the mine site before it was shipped. Transportation from the quarry to the consumer doubles the value of all the tonnage. Twenty-five percent (94 million tons) of the rock material went into the manufacture of concrete; therefore, about $30 for each of those 94 million tons, representing the costs of mixing, transporting, and placing the concrete, can also be added to the pit price and transportation costs. The addition of these other costs means that the total value of the rock materials industry, the largest mineral industry in Oregon, was actually $4.2 billion, which was equal to $1,800 for each Oregon man, woman, and child.



Production tonnages and dollar values of sand and gravel and crushed rock produced in market areas in Oregon from 1970 through 1979. These numbers are based on U.S. Bureau of Mines figures. The Oregon total includes U.S. Forest Service total output of 45,800,487 tons worth $90,557,007 that was reported for the State as a whole and could therefore not be assigned to individual counties.

As the map indicates, output was not uniform throughout the State. Twice as much rock material was mined and consumed in the Portland area as in the next largest marketing area, even though that area, the southwest corner of the State, has over three times the land surface. Production is generally related to size of population, and since most of Oregon's population is west of the Cascades, 82 percent of the total rock material output was also west of the Cascades.

—Jerry J. Gray, Economic Geologist, Oregon Department of Geology and Mineral Industries

Index to OREGON GEOLOGY, v. 42, 1980

PUBLICATIONS ORDER	OREGON GEOLOGY
Omission of price indicates publication is in press. Minimum mail order 50¢. All sales are final. Publications are sent postpaid. Payment must accompany orders of less than $20.00. Fill in appropriate blanks and send sheet to Department (see address on reverse side). YOUR NAME ______ ADDRESS ______ ______ Zip ______ Amount enclosed $______	____ Renewal ____ Subscription ____ Gift ____ 1 Year ($4.00) ____ 3 Years ($10.00) NAME ______ ADDRESS ______ ______ ZIP ______ (If Gift, From: ______)

← ORDER FORM - CUT ON DASHED LINE ←

Available publications

MISCELLANEOUS PAPERS	Price	No. Copies	Amount
1. A description of some Oregon rocks and minerals, 1950: Dole	$ 1.00	____	____
4. Laws relating to oil, gas, and geothermal exploration and development in Oregon			
Part 1. Oil and natural gas rules and regulations, 1977, rev. 1980	1.00	____	____
Part 2. Geothermal resources rules and regulations, 1977, rev. 1979	1.00	____	____
5. Oregon's gold placers (reprints), 1954	.50	____	____
6. Oil and gas exploration in Oregon, rev. 1965: Stewart and Newton	3.00	____	____
8. Available well records of oil and gas exploration in Oregon, rev. 1980: Olmstead and Newton	2.00	____	____
11. Collection of articles on meteorites, 1968 (reprints from *The Ore Bin*)	1.50	____	____
13. Index to *The Ore Bin*, 1950-1974	1.50	____	____
14. Thermal springs and wells, 1970: Bowen and Peterson (with 1975 supplement)	1.50	____	____
15. Quicksilver deposits in Oregon, 1971: Brooks	1.50	____	____
16. Mosaic of Oregon from ERTS-1 imagery, 1973	2.50	____	____
18. Proceedings of Citizens' Forum on potential future sources of energy, 1975	2.00	____	____
19. Geothermal exploration studies in Oregon—1976, 1977	3.00	____	____
20. Investigations of nickel in Oregon, 1978: Ramp	5.00	____	____
GEOLOGIC MAPS			
Geologic map of Galice quadrangle, Oregon, 1953	1.75	____	____
Geologic map of Albany quadrangle, Oregon, 1953	1.00	____	____
Reconnaissance geologic map of Lebanon quadrangle, 1956	1.50	____	____
Geologic map of Bend quadrangle and portion of High Cascade Mountains, 1957	1.50	____	____
Geologic map of Oregon west of 121st meridian, 1961	2.25	____	____
GMS-3: Preliminary geologic map of Durkee quadrangle, Oregon, 1967	2.00	____	____
GMS-4: Oregon gravity maps, onshore and offshore, 1967 (folded)	3.00	____	____
GMS-5: Geologic map of Powers quadrangle, Oregon, 1971	2.00	____	____
GMS-6: Preliminary report on geology of part of Snake River Canyon, 1974	6.50	____	____
GMS-7: Geology of the Oregon part of the Baker quadrangle, Oregon, 1976	3.00	____	____
GMS-8: Complete Bouguer gravity anomaly map, Cascade Mountain Range, central Oregon, 1978	3.00	____	____
GMS-9: Total field aeromagnetic anomaly map, Cascade Mountain Range, central Oregon, 1978	3.00	____	____
GMS-10: Low- to intermediate-temperature thermal springs and wells in Oregon, 1978	2.50	____	____
GMS-12: Geologic map of the Oregon part of the Mineral quadrangle, 1978	2.00	____	____
GMS-13: Geologic map of the Huntington and part of the Olds Ferry quadrangles, Oregon, 1979	3.00	____	____
OIL AND GAS INVESTIGATIONS			
3. Preliminary identifications of foraminifera, General Petroleum Long Bell #1 well	2.00	____	____
4. Preliminary identifications of foraminifera, E.M. Warren Coos County 1-7 well, 1973	2.00	____	____
5. Prospects for natural gas production or underground storage of pipeline gas	5.00	____	____
MISCELLANEOUS PUBLICATIONS			
Landforms of Oregon (17 × 12 inches)	.50	____	____
Mining claims (State laws governing quartz and placer claims)	.50	____	____
Geological highway map, Pacific NW region, Oregon-Washington (published by AAPG)	3.00	____	____
Fifth Gold and Money Session and Gold Technical Session Proceedings, 1975	5.00	____	____
Sixth Gold and Money Session and Gold Technical Session Proceedings, 1978	6.50	____	____
Back issues of *The Ore Bin*	25¢ over the counter; 50¢ mailed	____	____
Colored postcard, *Geology of Oregon*	10¢ each; 3 for 25¢; 7 for 50¢; 15 for 1.00	____	____

OREGON GEOLOGY

1069 State Office Building, Portland, Oregon 97201

Second Class Matter
POSTMASTER: Form 3579 requested

Available publications (continued)

BULLETINS	Price	No. Copies	Amount
33. Bibliography (1st supplement) geology and mineral resources of Oregon, 1947: Allen	1.00		
36. Papers on Tertiary foraminifera: Cushman, Stewart and Stewart, 1949: v. 2	1.25		
44. Bibliography (2nd supplement) geology and mineral resources of Oregon, 1953: Steere	2.00		
46. Ferruginous bauxite deposits, Salem Hills, 1956: Corcoran and Libbey	1.25		
49. Lode mines, Granite mining district, Grant County, Oregon, 1959: Koch	1.00		
53. Bibliography (3rd supplement) geology and mineral resources of Oregon, 1962: Steere and Owen	3.00		
57. Lunar Geological Field Conference guidebook, 1965: Peterson and Groh, editors	3.50		
63. Sixteenth biennial report of the Department, 1966-1968	1.00		
65. Proceedings of Andesite Conference, 1969: (copies)	10.00		
67. Bibliography (4th supplement) geology and mineral resources of Oregon, 1970: Roberts	3.00		
68. Seventeenth biennial report of the Department, 1968-1970	1.00		
71. Geology of selected lava tubes in Bend area, Oregon, 1971: Greeley	2.50		
76. Eighteenth biennial report of the Department, 1970-1972	1.00		
77. Geologic field trips in northern Oregon and southern Washington, 1973	5.00		
78. Bibliography (5th supplement) geology and mineral resources of Oregon, 1973: Roberts	3.00		
81. Environmental geology of Lincoln County, 1973: Schlicker and others	9.00		
82. Geologic hazards of Bull Run Watershed, Multnomah, Clackamas Counties, 1974: Beaulieu	6.50		
83. Eocene stratigraphy of southwestern Oregon, 1974: Baldwin	4.00		
84. Environmental geology of western Linn County, 1974: Beaulieu and others	9.00		
85. Environmental geology of coastal Lane County, 1974: Schlicker and others	9.00		
86. Nineteenth biennial report of the Department, 1972-1974	1.00		
87. Environmental geology of western Coos and Douglas Counties, 1975	9.00		
88. Geology and mineral resources of upper Chetco River drainage, 1975: Ramp	4.00		
89. Geology and mineral resources of Deschutes County, 1976	6.50		
90. Land use geology of western Curry County, 1976: Beaulieu	9.00		
91. Geologic hazards of parts of northern Hood River, Wasco, and Sherman Counties, Oregon, 1977: Beaulieu	8.00		
92. Fossils in Oregon (reprinted from *The Ore Bin*), 1977	4.00		
93. Geology, mineral resources, and rock material of Curry County, Oregon, 1977	7.00		
94. Land use geology of central Jackson County, Oregon, 1977: Beaulieu	9.00		
95. North American ophiolites, 1977	7.00		
96. Magma genesis: AGU Chapman Conference on Partial Melting, 1977	12.50		
97. Bibliography (6th supplement) geology and mineral resources of Oregon, 1971-75, 1978	3.00		
98. Geologic hazards of eastern Benton County, 1979: Bela	9.00		
99. Geologic hazards of northwestern Clackamas County, Oregon, 1979: Schlicker and Finlayson	10.00		
100. Geology and mineral resources of Josephine County, Oregon, 1979: Ramp and Peterson	9.00		
101. Geologic field trips in western Oregon and southwestern Washington, 1980	9.00		
SPECIAL PAPERS			
1. Mission, goals, and purposes of Oregon Department of Geology and Mineral Industries, 1978	2.00		
2. Field geology of SW Broken Top quadrangle, Oregon, 1978: Taylor	3.50		
3. Rock material resources of Clackamas, Columbia, Multnomah, and Washington Counties, Oregon, 1978: Gray and others	7.00		
4. Heat flow of Oregon, 1978: Blackwell, Hull, Bowen, and Steele	3.00		
5. Analysis and forecasts of the demand for rock materials in Oregon, 1979: Friedman and others	3.00		
6. Geology of the La Grande area, Oregon, 1980: Barrash and others	5.00		
7. Pluvial Fort Rock Lake, Lake County, Oregon: Allison	4.00		
8. Geology and geochemistry of the Mt. Hood volcano, 1980: White	2.00		
SHORT PAPERS			
18. Radioactive minerals prospectors should know, 1976: White, Schafer, Peterson	.75		
21. Lightweight aggregate industry in Oregon, 1951: Mason	.25		
24. The Almeda Mine, Josephine County, Oregon, 1967: Libbey	3.00		
25. Petrography, type Rattlesnake Formation, central Oregon, 1976: Enlows	2.00		
27. Rock material resources of Benton County, 1978: Schlicker and others	4.00		