The Ore Bin

Volume 26, No. 10
October, 1964

STATE OF OREGON
DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES

• The Ore Bin •

Published Monthly By

STATE OF OREGON
DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
Head Office: 1069 State Office Bldg., Portland, Oregon - 97201
Telephone: 226 - 2161, Ext. 488

Field Offices

2033 First Street, Baker

239 S. E. "H" Street, Grants Pass

Effective January 1, 1964
Subscription rate $1.00 per year. Available back issues 10 cents each.

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Second class postage paid
at Portland, Oregon

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AN OCCURRENCE OF VERMICULITIZED BIOTITE IN NORTHEASTERN OREGON

By

Lloyd W. Staples* and Howard C. Brooks**

The biotite in parts of the Bald Mountain batholith in northeastern Oregon has been vermiculitized, probably through the action of weathering. In the present investigation, samples from only one small area within the batholith were studied in the laboratory, but spot field tests show that biotite of other exposures of the batholith several miles distant is similarly altered. The matter was originally brought to our attention by Clinton P. Haight of Baker, Oregon, who found that when mica in the area of this study was heated it expanded like vermiculite.

The name "vermiculite" is probably derived from the Latin word *vermiculus*, which is the diminutive of *vermes*, meaning "worm." This refers to the curvy, worm-like appearance of the mica on expansion, which can be produced from the heat of a match. This simple field test, which may yield expansions of greater than 20 percent, is sometimes used to classify mica as a vermiculite. The name is also used more strictly for a mineral species which appears to be a mica but which contains a relatively large amount of water in its structure and no K_2O. The Oregon material discussed here qualifies as a vermiculite only in the first sense, as an expanding material. It is not a true vermiculite mineralogically.

Vermiculites occur in three types of rocks: (1) ultrabasic or basic, such as pyroxenites, serpentines, and dunites; (2) metamorphic, such as schists, gneisses, and marbles; and (3) granitic rocks. Most commercial deposits, as at Libby, Montana, are in ultrabasic or basic rocks and the mineral is a mixed-layer vermiculite-biotite. The type discussed in this paper is formed by alteration of mica in granitic rocks.

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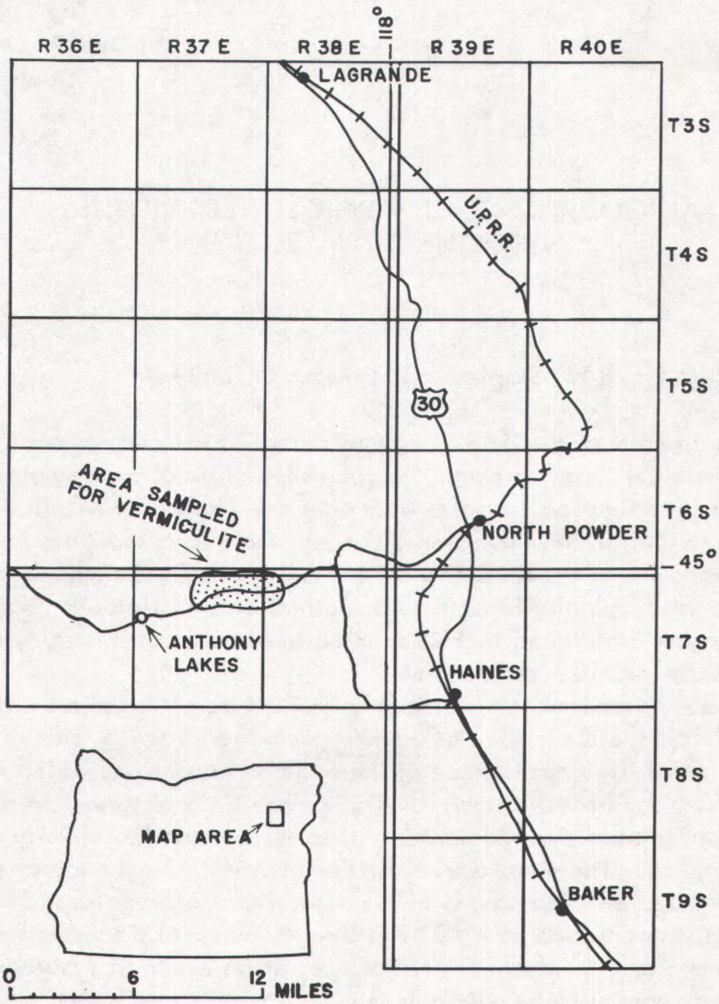

Figure 1. Sketch map showing the location of the area from which vermiculite samples were collected.

Location and Occurrence

The samples studied for this report were taken at random from an area in T. 7 S., Rs. 37 and 38 E. in Baker County (see figure 1). The area lies on the Anthony Lakes road about 10 miles west of North Powder, which is on the Union Pacific Railroad 19 miles north of Baker.

The area lies near the northeast edge of the Bald Mountain batholith, described by Taubeneck (1957). He concluded that the batholith is a composite intrusive comprising at least eight rock types representing a minimum of seven stages of intrusive activity. The rocks range from norite to quartz monzonite. Tonalite, a dioritic rock with quartz, is the most abundant and is the source of the vermiculite. Other minerals recognizable in hand specimens of the tonalite are plagioclase, quartz, hornblende, potash feldspar, and sphene. Except for variations in the mica, grain size of the tonalite usually averages 2 to 3 mm.

The crystal habit, size, and quantity of the mica grains in the tonalite vary considerably from place to place. However, there is considerable uniformity of the mica in any given locality. In parts of the area examined, the mica occurs as well-formed pseudo-hexagonal books, 2 to 6 mm in diameter, throughout zones several hundred feet wide. In such zones the mica is estimated to make up 8 to 12 percent of the rock. In other places the mica is in the form of irregular, paper-thin plates that constitute a smaller percentage of the rock. From a commercial viewpoint it is perhaps noteworthy that the tonalite containing relatively large quantities of thick euhedral grains is commonly disintegrated and crumbles easily in the hands, with the consequent freeing of a large portion of the mica grains.

Mineralogy

The mineralogy of vermiculites was not clearly understood until Gruner (1934) showed that it exists as a distinct mineral with a structural formula $(OH)_2(Mg,Fe)_3(Si,Al,Fe)_4O_{10} \cdot 4H_2O$. The structure consists of magnesium silicate sheets, like mica, interstratified with layers of water. It is the escape of this interstratified water that causes the swelling and exfoliation of the mineral on heating. Half of this water may be driven off at 110° C, and at 750° C the structure collapses to a talc structure. When biotite is altered to vermiculite, there are several intermediate stages in which a mixed-layer biotite-vermiculite structure develops, and these stages are referred to as a "hydrobiotite." During this alteration of biotite there is a loss of potassium and an oxidation of ferrous to ferric iron to neutralize the charge.

Walker (1949) studied the decomposition of biotite in soil, and he shows that there are four stages of weathering leading to true vermiculite. As weathering increases there is a decrease in refractive indices; a color change from black through golden yellow to white; a loss of iron, magnesium, and potassium; and an increase in water. He also notes that the X-ray diffraction pattern shows a change with weathering from a sharp peak at 10 Å toward 14 Å when vermiculite is produced. Using these criteria, the biotite derived from the weathering of the Bald Mountain tonalite was examined and compared. A partial chemical analysis was made by L.L. Hoagland, chemist for the Oregon Department of Geology and Mineral Industries, on two specimens of biotite from the tonalite.

The following table gives a comparison of the analyses for K_2O and H_2O of biotite, hydrobiotite, and true vermiculite.

	1	2	3	4	5
K_2O	8.34	5.76	5.16	3.66	none
H_2O^+	2.42	5.30	8.31	6.70	10.05
H_2O^-	0.48	2.95	6.21	2.38	11.42

1. Biotite. An average from biotite in 16 igneous rocks listed by Deere and others (1962, v. 3, p. 58-60).
2. Sample of biotite from Bald Mt. tonalite, analyzed by L.L. Hoagland, chemist for Oregon Department of Geology and Mineral Industries.
3. Second sample, same as No. 2.
4. Biotite in first stage of weathering listed by Walker (1949, p. 699).
5. Vermiculite (No. 3 of Gruner, 1934, p. 559).

The above table indicates that these samples of Bald Mountain biotite have lost some of their K_2O and this has been replaced by H_2O. If this process were to continue so that all of the K_2O were removed and the structure were essentially mica sheets separated by H_2O, a true vermiculite would result. The table also shows that the Bald Mountain biotite has not lost as much K_2O as Walker's first stage of weathering, but has undergone sufficient hydration to approach a vermiculite.

Walker (1949) notes that there is a consistent relationship in the change in index of refraction, color, and d-spacing of the X-ray diffraction pattern as biotite alters to vermiculite. The following table shows that in biotite, decomposed in the soil, it is possible to relate degree of alteration with decreasing index of refraction and increasing d-spacing, from 10.0 to 14.0 Å.

Order of weathering	n_y	d-basal reflection
0. Fresh black biotite	1.678	10.0 Å
1. Dark brown	1.679	9.8 - 11.0 Å
2. Glistening yellow	1.644	9.8 - 10.9 Å
3. Dull buff	1.635	9.8 - 13.7 Å
4. Dull brown	1.630	14.0 Å

In studying the Bald Mountain biotite, we could distinguish the fairly fresh material from some of the more weathered grains, but it was not possible to determine Walker's four grades from the biotite extracted from the rock. With respect to X-ray studies, the first diffraction pattern made at the University of Oregon geology laboratory was on a relatively fresh biotite and gave a basal d-spacing of 10.04 Å. A sample from another location in the tonalite area was sent to L. L. Brown, Supervisory Geologist of the Petrographic Laboratory of the U.S. Bureau of Mines at Albany, Oregon, who used a chromium target instead of copper, and reported a basal spacing of 15.0 Å. A split of his sample was run at the University of Oregon Geology Department with a copper target, and the 15.0 Å peak was confirmed for this material. This difference in spacings indicates that the Bald Mountain material also has several stages of vermiculitization, even though color is not so diagnostic as in Walker's Scotland material.

Taubeneck (1957, p. 202) notes a range in the tonalite biotites of the beta index of refraction from 1.647 to 1.653. Our material gave a range from 1.630 to 1.680, and this variation can be related to the state of vermiculitization, as indicated by the d-spacings. This is shown below:

	n_y ($\pm$ 0.003)	d-basal reflection
Fresh	1.680	10.00 - 11.00
	1.677	10.04
	1.676	9.87 - 10.36
	1.670	10.47 - 10.98
	1.647	14.40
Altered	1.630	14.58

Many more samples should be studied in order to get a correlation of the d-spacing and indices of refraction of the Bald Mountain material, but the work to date indicates that a correlation is possible. It is also evident that weathering produces a mixed-layer biotite-vermiculite.

Vermiculites may swell from six to 20 times their original thickness. Two samples of the Bald Mountain material tested by Mr. Hoagland gave volume increases at 1900° F of 750 percent and 625 percent, indicating that this material swells enough to be classified as a vermiculite, but the expansion is not as great as in many other vermiculites.

Origin

There has been strong difference of opinion concerning the origin of vermiculites. The principal area of conflict is concerned with the problem of whether the mineral is formed by hydrothermal or supergene solutions. Bassett (1963) clearly presents the arguments for each of these modes of origin. Roy and Romo (1957) state that vermiculite is unquestionably the product of low-temperature weathering and no primary vermiculite can crystallize under even mild hydrothermal conditions. Bassett (1963, p. 64, and written communication, March 2, 1964) notes a granitic occurrence of vermiculite at Daggett Pass on State Route 19, Nevada, southeast of Lake Tahoe. This material has a pearly luster, swells on heating, and has been produced by weathering. He states, "...the material is probably a randomly stacked, mixed-layer vermiculite-biotite with more biotite than vermiculite. This probably is a widespread form of vermiculite that undoubtedly has been identified as biotite many times over."

In the case of the Bald Mountain batholith material, there can be little doubt that weathering and the action of ground-water solutions satisfactorily explain the change from biotite to a hydrobiotite with the expansive powers of a vermiculite.

Economic Aspects

Expanded vermiculite, an extremely light and porous product, is finding wide use as an insulating material, as lightweight aggregate for concrete and plaster, and as a soil conditioner. A large share of the vermiculite used in the Pacific Northwest comes from the Zonolite Co. operations at Libby, Montana (said to be the largest vermiculite mining operation in the world) where vermiculite makes up 30 to 90 percent of the rock mined. Much of the vermiculite occurs in large sheets and blocks which can be selectively mined. The expandable mica of the Bald Mountain tonalite comprises approximately 10 percent of the rock in which it occurs, and being a regularly distributed component of the rock cannot be selectively upgraded during mining. Although the material would have difficulty meeting present competition in the vermiculite market, it remains in reserve as a substantial low-grade vermiculite deposit.

Note: Following submission of this report for publication, the writers, assisted by Norman Wagner and Len Ramp of the Oregon Department of Geology and Mineral Industries, continued preliminary testing of exposures of Jurassic-Cretaceous granitic rocks in other parts of Oregon. It has been found that vermiculitization of the biotites is quite common and a state-wide study of this type of alteration is now in progress. Probably if geologists were to apply the match-heat test to biotites from weathered granitic outcrops elsewhere, they would frequently find that the biotite had been vermiculitized.

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MORE PUBLIC LAND TO BE WITHDRAWN FROM MINING

Oregon public land withdrawals proposed during September total more than a thousand acres. The lands involved are 296.74 acres of National Forest areas in Lane, Jackson, and Josephine Counties requested by the Forest Service for recreational purposes and 960 acres on the Powder River in Baker County requested by the Bureau of Reclamation for the development of a reservoir "to be used for irrigation, flood control, recreation, and fish and wildlife purposes." The lands in question are to be closed to any future mineral entry. Withdrawals in Oregon from January 1964 to date total 46,245 acres!

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DRILLING RECORDS RELEASED FROM CLOSED FILES

The Department is releasing from its confidential files records covering drilling under State permits 45 and 46. Information on drilling done under permit 45 by Two States Oil & Gas Co., Inc., within Vale city limits, sec. 21, T. 18 S., R. 45 E., will be open to public inspection on October 24, 1964. Total depth was 1,185 feet.

Records describing results of drilling done under permit 46 by Reserve Oil & Gas Co. near Lebanon were released October 5, 1964. The Reserve well was drilled in sec. 7, T. 12 S., R. 1 W. Total depth was 8,603 feet.

Reproduction of drilling information released this month can be obtained through the Department.

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THRUST FAULTING IN THE ROSEBURG AREA, OREGON

By Ewart M. Baldwin*

Field evidence strongly suggests that a thrust fault trends northeastward across the Roseburg area in southwestern Oregon. The fault extends from the southwest part of the Sutherlin quadrangle to the northeast part of the Glide quadrangle, a distance of about 22 miles, but, because both ends are probably concealed, its total length may be greater (plate 1). Inasmuch as the fault passes through the Bonanza quicksilver mine and is related to the mineralization, it is referred to as the Bonanza fault. The motion of the thrust was northwestward and involved rocks of the lower member (Baldwin, 1964) of the Umpqua Formation. The intense deformation that produced the thrust occurred near the end of the early Eocene, soon after the deposition of the lower Umpqua member and before deposition of the middle Umpqua member.

General Stratigraphy of the Area

Jurassic and Cretaceous rocks occupy the southeast corner of the map area and are in fault contact with the lower and upper members of the Eocene Umpqua Formation. The Umpqua Formation consists of three units, which are described below. The Tyee Formation of middle Eocene age overlaps the Umpqua Formation at the eastern and northwestern edges of the map area. Basic igneous rocks of middle Tertiary age intrude the early Tertiary formations as sills and dikes. Quaternary alluvium masks older rocks along the Umpqua River and its tributaries. Parts of the area have been mapped in detail by graduate students at the University of Oregon (Lawrence, 1961; Patterson, 1961; Payton, 1961; and Westhusing, 1959).

Umpqua Formation

The Umpqua Formation has been divided, for convenience, into three mappable members: lower, middle, and upper. The break between the lower and middle is of such magnitude, however, that in reality there is only

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* Professor of Geology, University of Oregon, Eugene, Oregon.

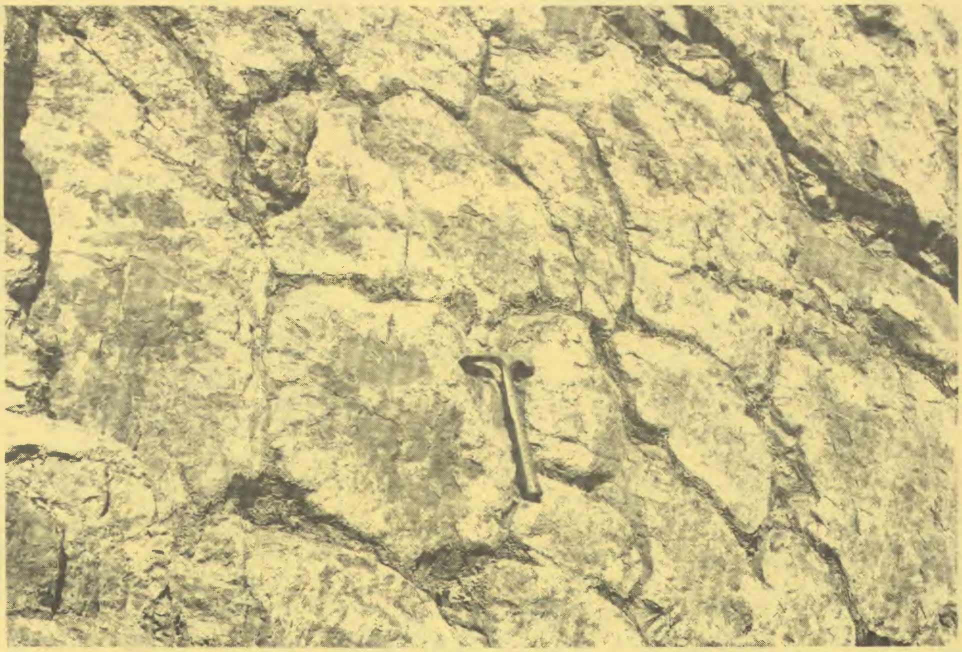
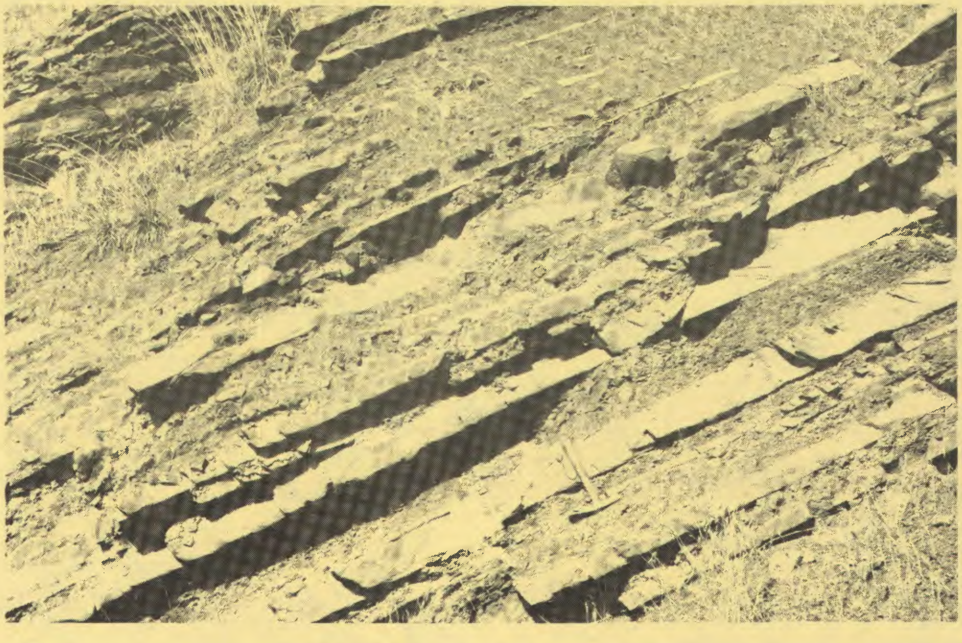
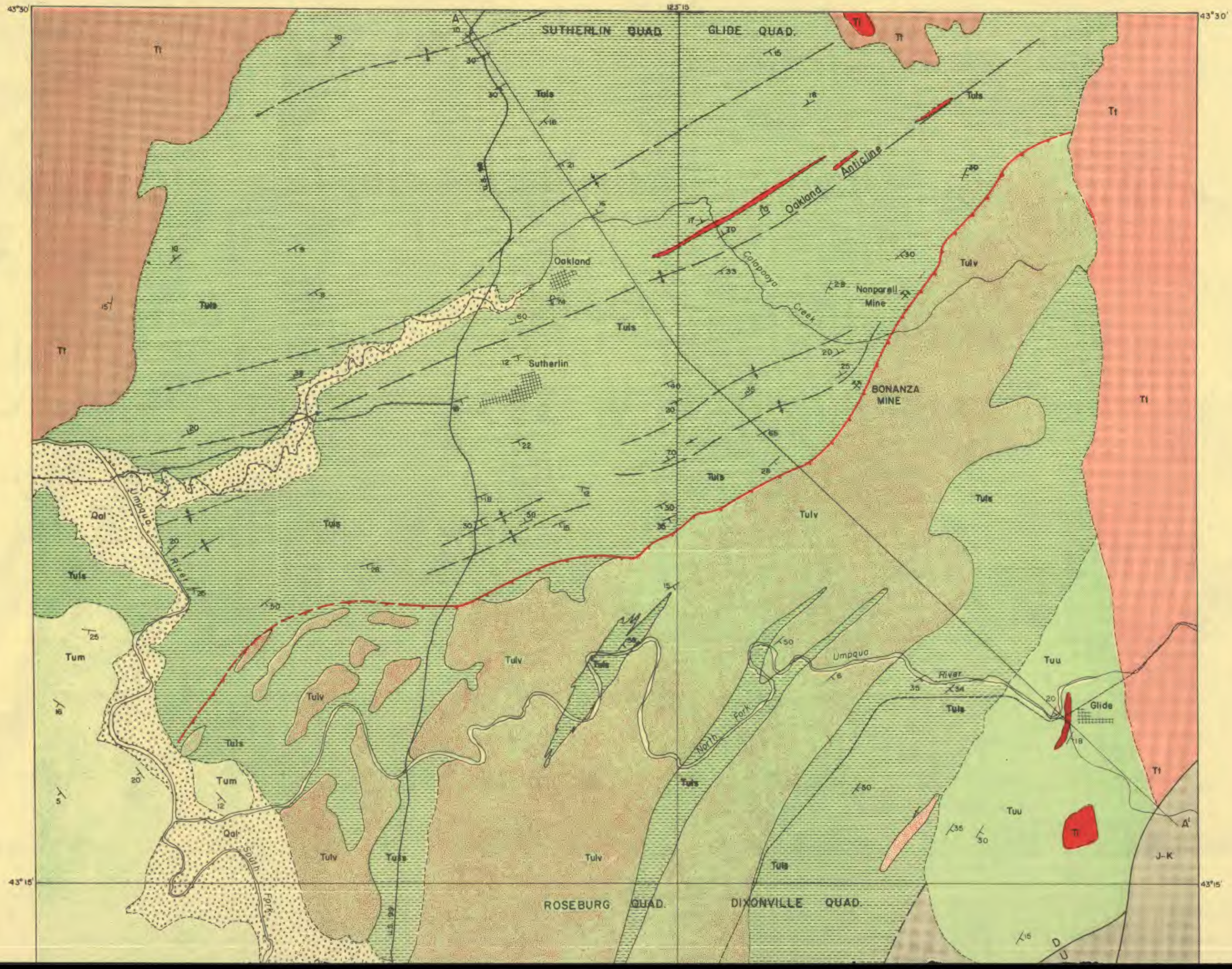


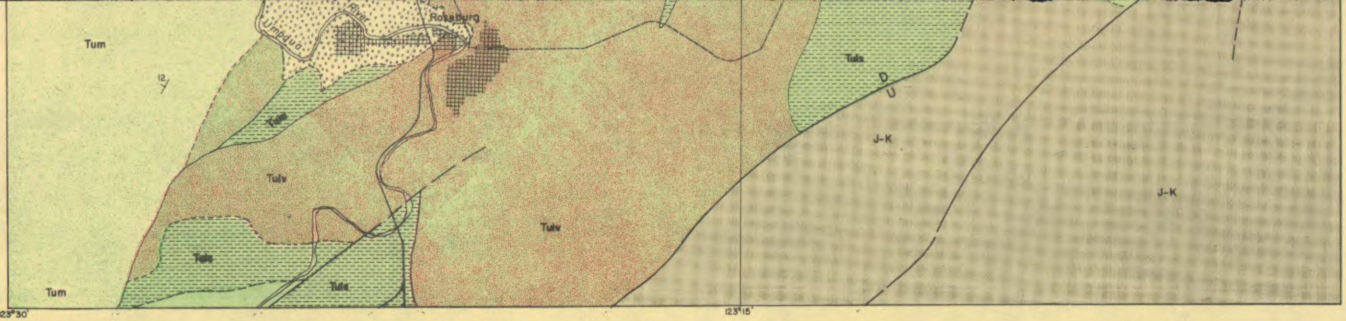
Figure 1. Pillows in basalt of the lower member of the Umpqua Formation exposed along North Fork of the Umpqua River east of Wilbur.

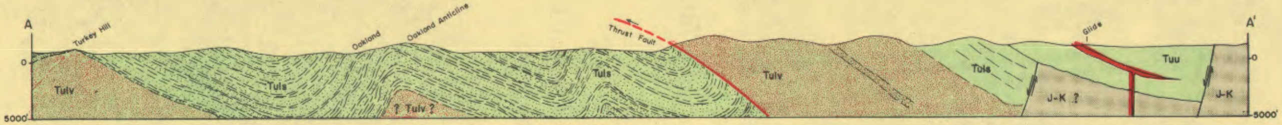
Figure 2. Outcrop of the lower member of the Umpqua Formation along U.S. Highway 99 southwest of Sutherlin. Note rythmic bedding.





43°30'
123°15'
43°30'
SUTHERLIN QUAD.
GLIDE QUAD.
Tt
Tuls
Tulv
Tuu
Tum
Qal
Oakland Anticline
Oakland
Sutherlin
Calapooya Creek
Nonpareil Mine
BONANZA MINE
Umpqua River
North Fork
South Fork
Glide
J-K
A
A'
43°15'
43°15'
ROSEBURG QUAD.
DIXONVILLE QUAD.





EXPLANATION

PRE-TERT. / TERTIARY: EOCENE: UMPQUA FORMATION / QUAT.

- **Qal** — Alluvium (QUAT.)
- **Ti** — Intrusive rock, basic sills and dikes.

UNCONFORMITY

- **Tt** — Tyee Formation. Rythmically bedded marine sandstone and siltstone

UNCONFORMITY

UMPQUA FORMATION

- **Tuu** — Upper member. Basal conglomerate and pebbly sandstone grading upward to siltstone. Coal and oysters.

UNCONFORMITY

- **Tum** — Middle member. Basal conglomerate grading upward to sandstone and siltstone

MAJOR UNCONFORMITY

- **Tuls / Tulv** — Lower member. Predominantly basaltic flows (tulv) and sedimentary rock (tuls) south of thrust fault; rythmically bedded sandstone and siltstone (tuls) north of thrust fault.

UNCONFORMITY

- **J-K** — Jurassic and Cretaceous rocks undifferentiated. (PRE-TERT.)

STRUCTURE SYMBOLS

- Thrust fault
- Fault
- Anticline
- Syncline
- Plunging fold
- 15 — Strike and dip
- 40 — Strike and dip of over turned beds

GEOGRAPHIC SYMBOLS

- Towns and Cities
- Interstate highway
- Hard surface road
- Rivers

Geology by E.M. Baldwin
(Adapted in part from
C.C. Payton, P.V. Patterson
and J.K. Westhusing)

SCALE
1/2 0 1 2 3 4 MILES

N

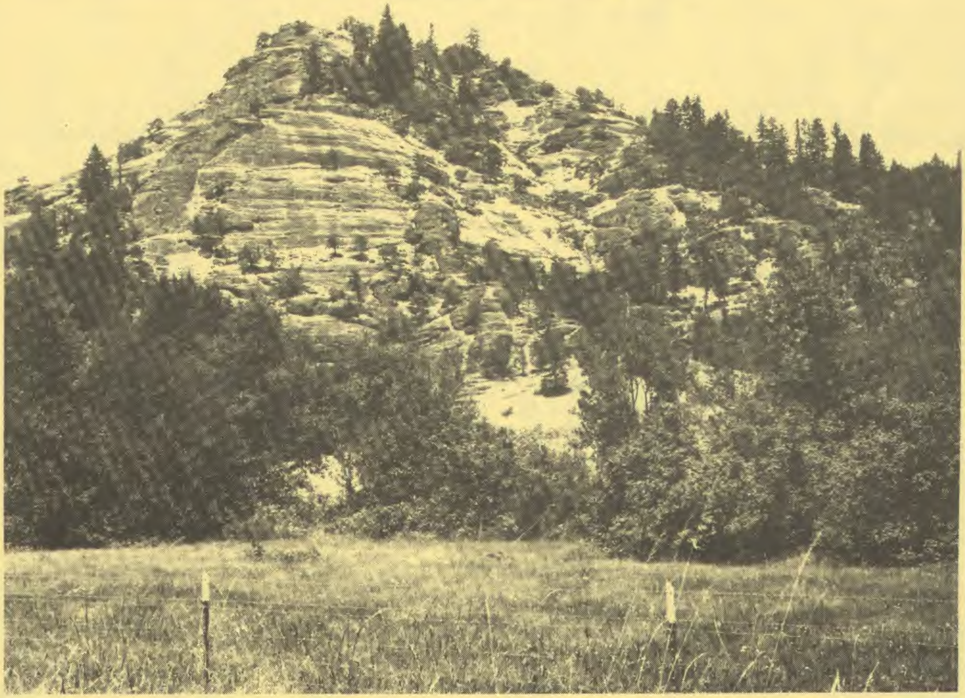


Figure 3. Base of the middle member of the Umpqua Formation at Bushnell Rock (southwest of map area).

Figure 4. Thin-bedded phase of the middle member of the Umpqua Formation on Berry Creek (southwest of map area).

a lower and an upper Umpqua, with the upper unit divided into two parts by a relatively minor unconformity. These divisions are based upon a regional study of the Umpqua Formation in southwestern Oregon (Baldwin, 1963).

The lower member includes all of the basaltic flows of the Umpqua Formation. It consists of basalt breccia and pillow lavas (figure 1) interbedded with lesser amounts of sedimentary rock, overlain by a thick section of rhythmically bedded sandstone and siltstone (figure 2). Two of the most complete sections of the lower member are exposed along Oregon Highway 42 between Coquille and Myrtle Point (south of the map area) and along U.S. Highway 99 between Turkey Hill and the synclinal axis north of Oakland. In both sections the basalt is exposed in the center of the anticlines and is overlain by 6,000 to 8,000 feet of sedimentary rock. It is difficult to determine exactly what strata represent the base of the Umpqua, because the formation is almost everywhere faulted against pre-Tertiary rock. In most exposures, however, basalt is the oldest Eocene rock in evidence.

Both the pre-Tertiary rock and the lower member of the Umpqua Formation are overlain with marked angular unconformity by basal conglomerate of the middle member (figure 3). The unconformity represents one of the most profound breaks in the Tertiary section of western Oregon. The unconformable relationship is best exposed southwest of the map area at Bushnell Rock in the Tenmile area and in Lookingglass Valley. In both areas the basal conglomerate grades upward into sandstone and siltstone, and in places thin-bedded phases are present (figure 4). Along Tenmile Creek the beds have an average dip of 20° to 25° southeastward and range in thickness from 5,000 to 6,000 feet. It is more difficult to determine the dip in Lookingglass Valley, but the thickness of the beds appears to be as great.

The upper member of the Umpqua Formation lies unconformably upon both the lower and middle units, and in some places upon the pre-Tertiary rock. It is best exposed at Glide and southwest of the map area in Camas Valley and Flournoy Valley. The unit has a thin, basal conglomerate or pebbly sandstone grading upward into siltstone, and appears to be of shallow-water origin as shown by beds of coal and numerous oysters. The thickness in Flournoy Valley ranges between 2,500 and 3,500 feet; it is probably as much in Camas Valley and at Glide. At Glide the upper member contains a large fauna of middle Eocene age (Turner, 1938).

General Structural Features

A series of north-east trending faults displaces the Umpqua Formation and older strata southwest of Roseburg, but most of these appear to be high-angle, normal faults affecting beds as young as the upper member of the

Umpqua Formation and perhaps even the overlying Tyee Formation. The Bonanza fault, on the other hand, appears to be a thrust fault that is more closely related to the folds in the lower member of the Umpqua Formation. The lower member is steeply folded along axes commonly trending N. 45° to 75° E. and is generally parallel to the structural trends of the Mesozoic rocks. The folds plunge to the west beneath both the middle member of the Umpqua Formation and the Tyee Formation, and to the east beneath the Tyee Formation.

The absence of the middle member southeast of the fault suggests that the thrust plate was a highland area and perhaps a contributor of sediments to the middle Umpqua unit farther west.

It was not until the middle Eocene that strata of the upper member were deposited in the area east of Roseburg. The sedimentation was initiated by deposition of a thin basal conglomerate against basalt of the lower member of the Umpqua Formation. One such depositional contact can be seen about 100 yards west of the new county bridge over the North Fork of the Umpqua, a mile and a half west of Glide.

The Bonanza Fault

Origin and description

The asymmetry of the folds northwest of the trace of the Bonanza fault is considered to be proof that the direction of thrusting was from the southeast. The folds have relatively gentle dips on the southeast limb and nearly vertical dips in places on the northwest limb. The northwest limb of the Oakland anticline is noticeably steeper than the southeast limb. Along U.S. Highway 99 between Oakland and Sutherlin the steeper side to the north ranges from about 70° to dips overturned slightly to the south. Some of the steeper dips may be on subsidiary folds, but there is little doubt that the axes of the folds northwest of the Bonanza fault are tilted to the northwest.

It seems likely that the thrust which formed the Bonanza fault was initiated at the time of compression, when a fold near the active stress was overturned to the northwest. Slippage then occurred along the axial plane, bringing the basaltic rocks in the center of the anticline over the sedimentary rock that stratigraphically should overlie it. Thus the basalt on the southeast side of the Bonanza fault is correlated with basalt underlying sedimentary rock on Turkey Hill (see cross section on plate 1). On the basis of this interpretation, the lack of sedimentary rock over the basalt southeast of the fault would be due to removal by erosion.

The Bonanza fault appears to cut across the axial trends of several folds south of the Oakland anticline. Its sinuous trace suggests that it may dip less than 45°. Since thrusts are commonly arcuate in the direction of movement, it is possible that, before erosion, the upper plate of the Bonanza fault reached nearly to Sutherlin.

Relation to mineralization

The Bonanza fault appears to be the only zone of faulting in the area that has been mineralized. Distributed along it are a number of quicksilver mines and prospects, including the Bonanza and Nonpareil mines. The Bonanza mine was for many years Oregon's major quicksilver producer. The geology and mineralization at the Bonanza is described by Brown and Waters (1951) and Brooks (1963). According to their interpretation, ascending hydrothermal solutions were guided and localized by shearing and faulting in tuffaceous sandstone of the Umpqua Formation. The shear zone dips about 45° SE. parallel to the bedding, and apparently was caused by reverse movement of the rocks along bedding planes during folding. Rich pockets of ore were deposited beneath flat, gouge-filled thrust faults that transect the bedding shears.

Mineralization evidently occurred in post-Umpqua time for Hoover (1963) indicates that mineralization at the Black Butte mine, a short distance north of the map area, occurs in the Fisher Formation of late Eocene or Oligocene age. It is reasonable to assume that the two areas were mineralized at the same time.

Summary

Evidence for thrusting along the Bonanza fault lies chiefly in the age and position of the strata as determined by a regional study of the Umpqua Formation. Other evidence, such as a northwestward inclination of the folds in the area of the thrust and the shearing and reverse faulting in the Bonanza mine, support the theory that basalt in the lower member of the Umpqua Formation is thrust northwestward over lower Umpqua sedimentary rock. Thrusting came from continued compression after relatively close folding near the end of the lower Eocene. Middle and upper Umpqua strata, unconformable upon the steeply dipping lower Umpqua basalt flows and sedimentary rock, show little evidence of severe compression but instead are cut by normal faults of younger age.

Acknowledgement: This study was partially financed by a University of Oregon Faculty Research Grant.

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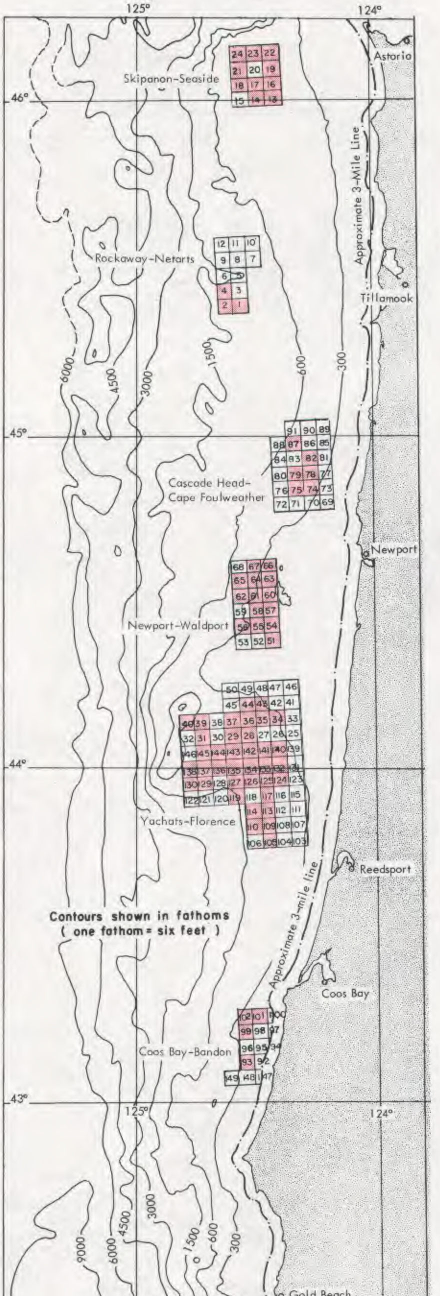
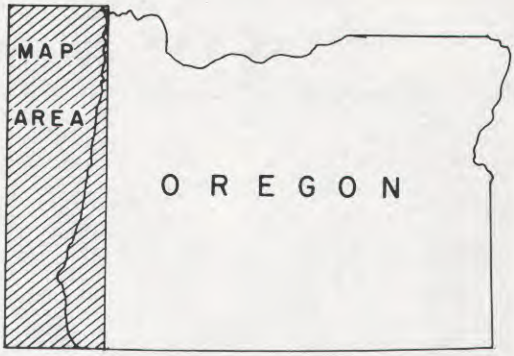
OIL COMPANIES BID ON OREGON'S OFFSHORE

The oil and gas lease sale of Federal outer continental shelf (OCS) lands off Oregon and Washington October 1 resulted in high bonus bids totalling $35,525,168.30. Offered were 196 parcels with 222 bids received on 101 parcels containing 580,689 acres. The average bonus per acre was computed to be $67.36. Of the 101 parcels leased, 74 were off Oregon and 27 off Washington. The OCS lands off Oregon brought $27,760,239.90 and those off Washington $7,764,928.40. Eleven companies participated in varying combinations, as follows: Gulf, Humble, Pan American (Standard of Indiana), Pan American-Atlantic, Pan American-Atlantic-Superior, Pan American-Superior, Richfield, Shell, Standard (of California), Standard-Union, Superior, Texaco-Mobil, Texaco-Mobil-Richfield, and Union. The single parcel (No. 136) obtained solely by Union brought the highest bid, which was $2,165,760 or $376 per acre. The lowest bid was $30,067.20 or $5.22 per acre by Pan American-Atlantic on parcel No. 127.

Map showing Federal lease blocks off the Oregon coast.



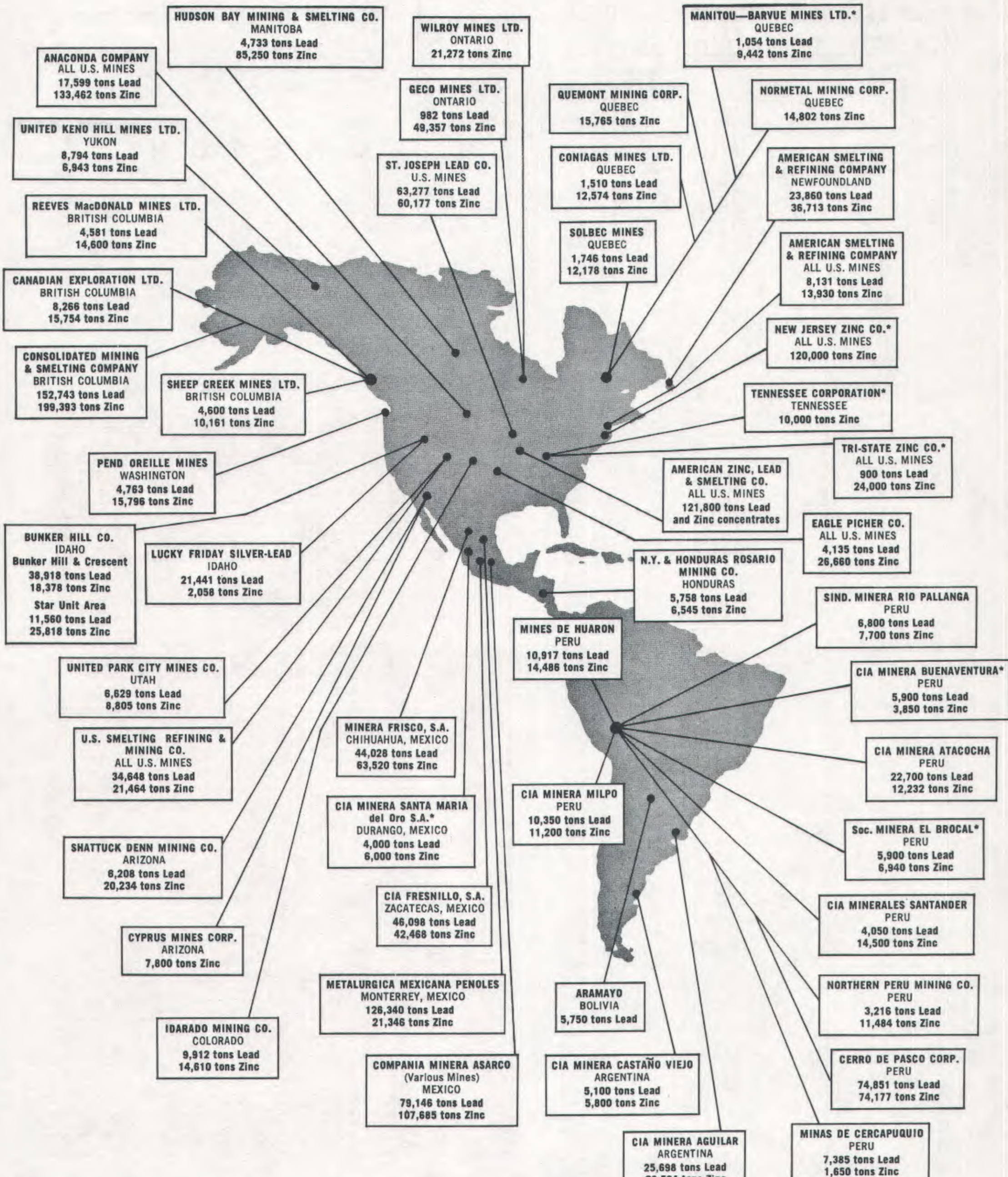


List of Successful Bidders on the Oregon Parcels

Company	Block	Price	Company	Block	Price
Shell	1	$ 35,424.00	Shell	67	$ 116,755.20
Shell	2	55,123.20	Std-Union	74	1,446.336.00
Shell	4	35,424.00	Shell	75	135,936.00
Std-Union 1/	13	43,268.00	Shell	78	652,032.00
Std-Union	14	86,468.00	Std-Union	79	1,012,124.00
Std-Union	16	58,676.00	Pan-Atl	82	57,945.60
Shell	17	87,897.60	Std-Union	87	43,250.00
Shell	18	1,598,400.00	Std-Union	93	43,246.00
Shell	19	41,817.60	S-A-P 4/	99	116,640.00
Std-Union	21	491,684.00	T-R-M	101	101,318.40
Shell	22	504,000.00	S-A-P	102	289,152.00
Std-Union	23	316,892.00	T-R-M	105	101,318.40
Std-Union	24	317,222.00	Pan-Atl	109	1,154,016.00
T-R-M 2/	28	201,308.34	Pan-Atl	110	432,806.40
Shell	29	728,087.50	Tex-Mob 5/	113	1,101,484.80
Std-Union	31	137,136.00	S-A-P	114	1,785,888.00
Shell	34	309,657.60	Pan-Atl	117	231,148.80
Shell	35	87,955.20	Shell	119	756,000.00
Pan-Atl 3/	36	173,779.20	Std-Union	124	748,888.00
Shell	37	206,553.60	Shell	125	620,064.00
Std-Union	39	58,676.00	Richfield	126	41,299.20
Std-Union	40	233,440.00	Pan-Atl	127	30,067.20
Shell	43	1,516,147.20	Shell	129	150,681.60
Shell	44	905,472.00	Std-Union	130	433,666.00
Std-Union	51	462,462.00	Std-Union	132	230,476.00
Pan-Atl	54	87,148.80	Pan-Atl	133	347,961.60
Std-Union	55	1,042,042.00	Pan-Atl	134	145,555.20
Std-Union	56	777,776.00	Std-Union	135	97,922.00
Pan-Atl	57	346,579.20	Union	136	2,165,760.00
Pan-Atl	58	58,176.00	Std-Union	137	43,278.00
Pan-Atl	60	318,067.20	Std-Union	138	86,424.00
Pan-Atl	61	87,782.40	Std-Union	140	57,774.00
Std-Union	62	173,888.00	S-A-P	141	549,504.00
Gulf	63	98,726.40	Pan-Atl	142	87,897.60
Pan-Atl	64	58,924.80	Pan-Atl	143	88,185.60
Std-Union	65	57,776.00	Richfield	144	76,260.40
Gulf	66	98,726.40	Std-Union	145	291,124.00

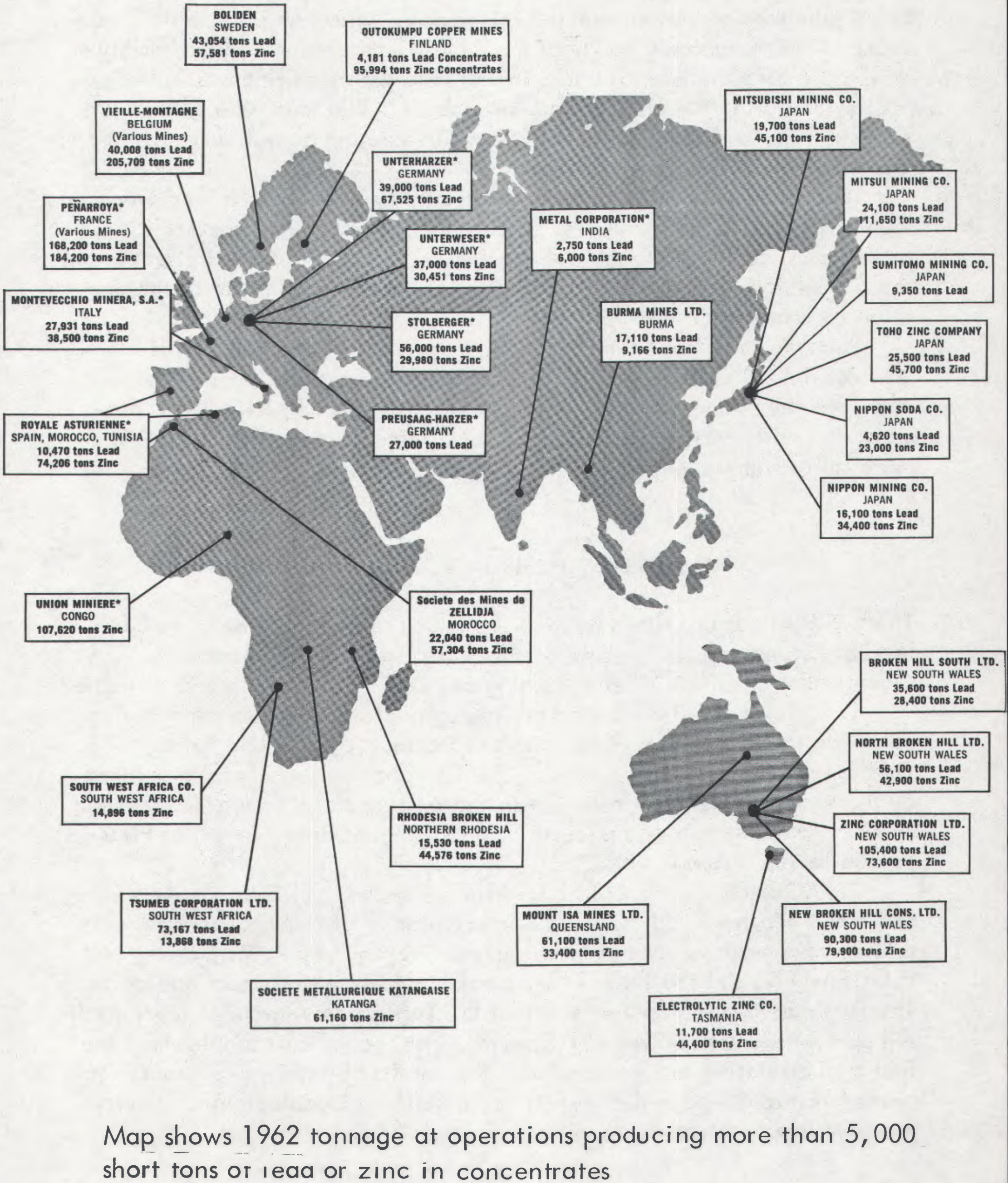
1/ Standard-Union
2/ Texaco-Richfield-Mobil
3/ Pan American-Atlantic Refining
4/ Standard-Atlantic-Pan American
5/ Texaco-Mobil

Principal Lead and Zinc Producers



(Courtesy of American Cyanamid Co., New York).

of the World in 1962



Map shows 1962 tonnage at operations producing more than 5,000 short tons of lead or zinc in concentrates

POZZOLANIC ASH PRODUCED NEAR ARLINGTON

Volcanic ash with pozzolanic qualities near Arlington, Gilliam County, is being produced at a plant erected this year by Permanente Cement Co. Because of the remarkable purity of the deposit, processing consists mainly of drying the pit-run material and grinding it to specified fineness. Plant capacity for storing the ground product is about 3,000 tons, and 15 men are currently employed on a three-shift basis in meeting output demands. Ed Coder is manager of the operation.

At present the entire output is consumed by the John Day and Green Peter dams. This market assures productive operation throughout the next three years, and it is probable that other contemplated dam construction on the Columbia and Snake Rivers will extend the productive life of the operation for many additional years.

Apart from its pozzolanic qualities, tests made recently on this ash (see April 1964 ORE BIN) indicate that the pit-run material is expansible. Although the volume increase is not as great as that of perlite, it is possible that with more experimentation some forms of marketable filtering material or lightweight aggregate can be developed.

* * * * *

NEW SURVEY PUBLICATIONS AVAILABLE

The two publications listed below were issued recently by the U.S. Geological Survey and are for sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402, at prices indicated.

1. "Review and annotated bibliography of ancient lake deposits (Precambrian to Pleistocene) in the Western States," by John H. Feth. U.S. Geological Survey Bulletin 1080. The 120-page bulletin is accompanied by three maps showing distribution in the western states of pre-Tertiary and Tertiary lake deposits and a fourth map showing maximum extent of Pleistocene lakes. Price is $2.50.

2. "Geologic sketch of northwestern Oregon," by P.D. Snavely, Jr., and H.C. Wagner, and "Geologic interpretation of reconnaissance gravity and aeromagnetic surveys in northwestern Oregon," by R.W. Bromery and P.D. Snavely, Jr. Bulletin 1181, parts M and N bound under one cover. The first part is a regional summary of the Tertiary stratigraphy in the northern part of the Coast Range in Oregon. The second part supplements the first by correlating the geology with the results of geophysical work. Included in the 30-page dual report are a combined geologic and gravity map and two aeromagnetic profiles. Price is $1.00.

* * * * *

AVAILABLE PUBLICATIONS

(Please include remittance with order. Postage free. A complete list of publications will be mailed upon request.)

BULLETINS

2.	Progress report on Coos Bay coal field, 1938: F. W. Libbey	0.15
8.	Feasibility of steel plant in lower Columbia River area, rev., 1940: R.M.Miller	0.40
14.	Oregon metal mines handbooks: by the staff	
	C. Vol. II, Section 1, Josephine County, 1952 (2d ed.)	1.25
26.	Soil: Its origin, destruction, preservation, 1944: W. H. Twenhofel	0.45
27.	Geology and coal resources of Coos Bay quadrangle, 1944: Allen & Baldwin .	1.00
33.	Bibliography (1st supplement) of geology and mineral resources of Oregon, 1947: J. E. Allen	1.00
36.	(1st vol.) Five papers on Western Oregon Tertiary foraminifera, 1947: Cushman, Stewart, and Stewart	1.00
	(2nd vol.) Two papers on Western Oregon and Washington Tertiary foraminifera, 1949: Cushman, Stewart, and Stewart; and one paper on mollusca and microfauna, Wildcat coast section, Humboldt County, Calif., 1949: Stewart and Stewart	1.25
37.	Geology of the Albany quadrangle, Oregon, 1953: Ira S. Allison	0.75
40.	Preliminary description, geology of the Kerby quadrangle, Oregon, 1949: Wells, Hotz, and Cater	0.85
41.	Ground-water studies, Umatilla and Morrow Counties, 1949: Norman S. Wagner	1.25
44.	Bibliography (2nd supplement) of geology and mineral resources of Oregon, 1953: M. L. Steere	1.00
46.	Ferruginous bauxite deposits, Salem Hills, Marion County, Oregon, 1956: R. E. Corcoran and F. W. Libbey	1.25
49.	Lode mines, central Granite Mining District, Grant County, Oregon, 1959: Geo. S. Koch, Jr.	1.00
51.	Twelfth biennial report of the Department, 1958-60	Free
52.	Chromite in southwestern Oregon, 1961: Len Ramp	3.50
53.	Bibliography (3rd supplement) of the geology and mineral resources of Oregon, 1962: M. L. Steere and L. F. Owen	1.50
55.	Quicksilver in Oregon, 1963: Howard C. Brooks	3.50

GEOLOGIC MAPS

Prelim. geologic map of Sumpter quadrangle, 1941: J. T. Pardee and others . . .	0.40
Geologic map of the St. Helens quadrangle, 1945: Wilkinson, Lowry, & Baldwin .	0.35
Geologic map of Kerby quadrangle, Oregon, 1948: Wells, Hotz, and Cater . . .	0.80
Geologic map of Albany quadrangle, Oregon, 1953: Ira S. Allison (also in Bull.37)	0.50
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Geologic map of Lebanon quadrangle, Oregon, 1956: Allison and Felts	0.75
Geologic map of Bend quadrangle, and reconnaissance geologic map of central portion, High Cascade Mountains, Oregon, 1957: Howel Williams . . .	1.00
Geologic map of the Sparta quadrangle, Oregon, 1962: Harold J. Prostka . . .	1.50
Geologic map, Mitchell Butte quadrangle, Oregon, 1962: R.E.Corcoran and others	1.50
Geologic map of Oregon west of 121st meridian (over the counter)	2.00
folded in envelope, $2.15; rolled in map tube $2.50	

(Continued on back cover)

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17.	Sodium salts of Lake County, Oregon, 1947: Ira S. Allison & Ralph S. Mason	0.15
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6.	(Supplement) Oil and gas exploration in Oregon, 1960: V.C. Newton, Jr.	0.35
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8.	Available well records of oil & gas exploration in Oregon, rev. 1963: Newton	0.50

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OIL and GAS INVESTIGATIONS SERIES

1.	Petroleum Geology of the Western Snake River Basin, Oregon-Idaho, 1963: V. C. Newton, Jr., and R. E. Corcoran	2.50