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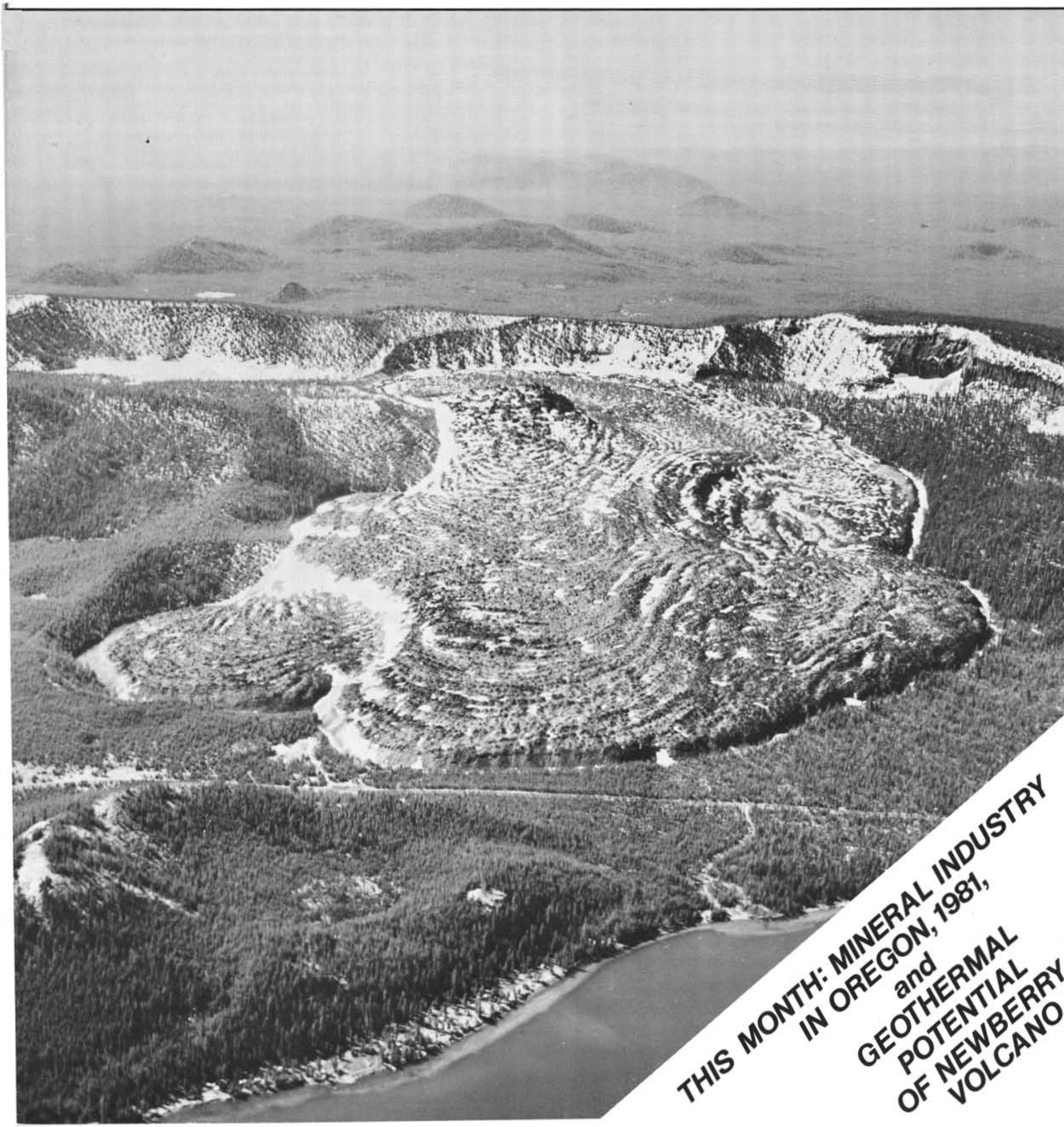

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COVER PHOTO

Looking to south at 1,400-year-old Big Obsidian Flow in caldera of Newberry Volcano. Article beginning on page 44 discusses geothermal potential of this large Quaternary volcano located southeast of Bend in central Oregon. Some data used in article came from U.S. Geological Survey drilling site to left (east) of Big Obsidian Flow. Several of more than 400 cinder cones that occur on flanks of volcano can be seen in background.

OIL AND GAS NEWS

Mist Gas Field:

Reichhold Energy Corporation continues to be the only active operator in the Mist Gas Field at present. The company recently finished the redrill of Columbia County 41-2 in sec. 2, T. 6 N., R. 5 W. The redrill, which reached a depth of 3,040 ft, was abandoned as a dry hole. Reichhold then moved the Taylor Drilling Company rig to Columbia County 12-9, a well drilled in 1980, and redrilled it to a depth of 2,917 ft. This redrill, too, was dry.

Columbia County:

About 10 mi southeast of production at Mist, Reichhold is rigging up to drill Columbia County 32-26. Located near the town of Pittsburg, this well is planned for 6,500 ft of depth. Depending on the results, the well may be followed by one or two others in the area.

State Lands lease sale:

On February 24 and 25, the Oregon Division of State Lands held an oil and gas lease auction in Portland. Over 75 people were present for bidding on 115,533 acres of state property in 15 counties. Bonus bids brought in over $590,000 on 212 of the 311 parcels offered; parcels without bids were awarded to the applicant for the annual rental fee of $1 per acre.

The highest bid was $215 per acre offered by Marathon for a 280-acre tract in Columbia County. Other acreage in Oregon's only gas-producing county went to Nahama and Weagant for $200 per acre.

Elsewhere in the state, bids were far lower. In Washington County, adjacent to Columbia County, several companies competed for acreage, with most of it going to Universal Resources for as high as $62 per acre. Other bidders included Conoco, Marathon, and Nahama and Weagant.

Central Oregon acreage was sought after by several bidders, including Anderson Oil Properties, Depco, EMEFCO, Shell Oil, Texaco, Tyrex, and Universal. Anderson was successful in leasing over 7,000 acres in Gilliam and Morrow Counties at offers averaging about $14 an acre. Depco leased all 13 parcels of submerged and submersible land under the Columbia River, Gilliam County.

Remaining acreage, mainly in Harney, Malheur, and Lake Counties, was awarded to the applicant or went for bids of only a few dollars an acre. Garth Tallman, Jerry Ryan, Inca Oil and Gas, and Anschutz Corporation took most of the acreage in these counties for no bid.

Lease sale results may be obtained from the Division of State Lands, 1445 State Street, Salem, Oregon 97310, phone (503) 378-3805.

Northwest Association of Petroleum Landmen organize:

After the lease sale discussed above, about 25 landmen, consultants, and attorneys gathered to form a Northwest Association of Petroleum Landmen for Oregon, Washington, and Idaho. They will try to affiliate with the nationwide American Association of Petroleum Landmen. A temporary committee was formed to organize the group. □

CONTENTS

Mineral industry in Oregon, 1981

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

INTRODUCTION

The total value of Oregon's 1981 mineral production (preliminary U.S. Bureau of Mines figures, revised; see Table 1) is down about five percent from 1980 figures in spite of increased nickel production by the Hanna Mining Company's nickel mine and smelter at Nickel Mountain near Riddle. Production of most industrial minerals, especially sand and gravel, dropped in 1981 due to the depressed construction industry. Gold production was also down somewhat below the 1980 figure, which had been boosted by production from the Applegate Dam project; furthermore, total value of gold production was significantly affected by the drop in gold price in 1981.

Estimated total gold production figures for 1980 and 1981 (Table 1) were derived by canvassing a number of individual producers. Table 1 also includes some additional estimated production figures from numerous small part-time placer operators. An average value of $600 per ounce was used for the 1980 figure and $475 for 1981. (These figures were obtained by using the Handy and Harmon, New York, monthly price average in *Engineering and Mining Journal.*)

METALS

Gold placer mining continued at several sites during 1981. Veta Grande Corporation purchased the Mormon Basin and Basin Creek Placer Mines about 30 mi southeast of Baker. Both mines were active producers during 1980 and 1981 (Mine 10*). The Sucker Creek Gallagher Placer (Mine 4), which also changed ownership during the year, was purchased by Oscar Nukka. Gold production came from these and many other small placer operations, from a few small lode mines, and, as a major by-product, from the Iron Dyke Mine (Mine 8).

Table 1. *Nonfuel mineral production in Oregon, 1980 and 1981*

Mineral	1980 Quantity	1980 Value ($1,000)	1981[1] Quantity	1981[1] Value ($1,000)
Clays (1,000 short tons)	172	321	80	155
Gem stones	NA	450	NA	500
Gold—recoverable content of ores, etc. (troy oz)[2]	14,268	8,561	10,405	4,942
Nickel—content of ores and concentrates (short tons)	14,653	W	15,608	W
Pumice (1,000 short tons)	1,090	2,734	965	2,600
Sand and gravel (1,000 short tons)	16,005	47,300	14,800	44,200
Silver—recoverable content of ores, etc. (troy oz)	1,000	17	W	W
Stone:				
Crushed (1,000 short tons)	18,380	48,190	15,100	40,900
Dimension (1,000 short tons)	15	231	15	247
Combined value of cement, diatomite, lime, talc, and values indicated above by symbol W	XX	50,364	XX	56,480
Total	XX	158,168	XX	150,024

[1] 1980 and preliminary 1981 data provided by U.S. Bureau of Mines. Production as measured by mine shipments, sales, or marketable production (including consumption by producers). NA = Not available. W = Withheld to avoid disclosing company proprietary data; value included in "Combined value" figure. XX = Not applicable.

[2] Oregon Department of Geology and Mineral Industries canvass; includes estimates of unreported production.

Gold dredges in Illinois River just downstream from McCaleb Ranch, Josephine County.

Mining at the Iron Dyke Mine in eastern Oregon continued during the year, with 40 employees producing about 75 tons per day of sulfide ore bearing gold, silver, and copper. The ore is hauled about 22 mi across the Snake River and up the Kleinschmidt Grade to the Silver King Mill at Cuprum, Idaho.

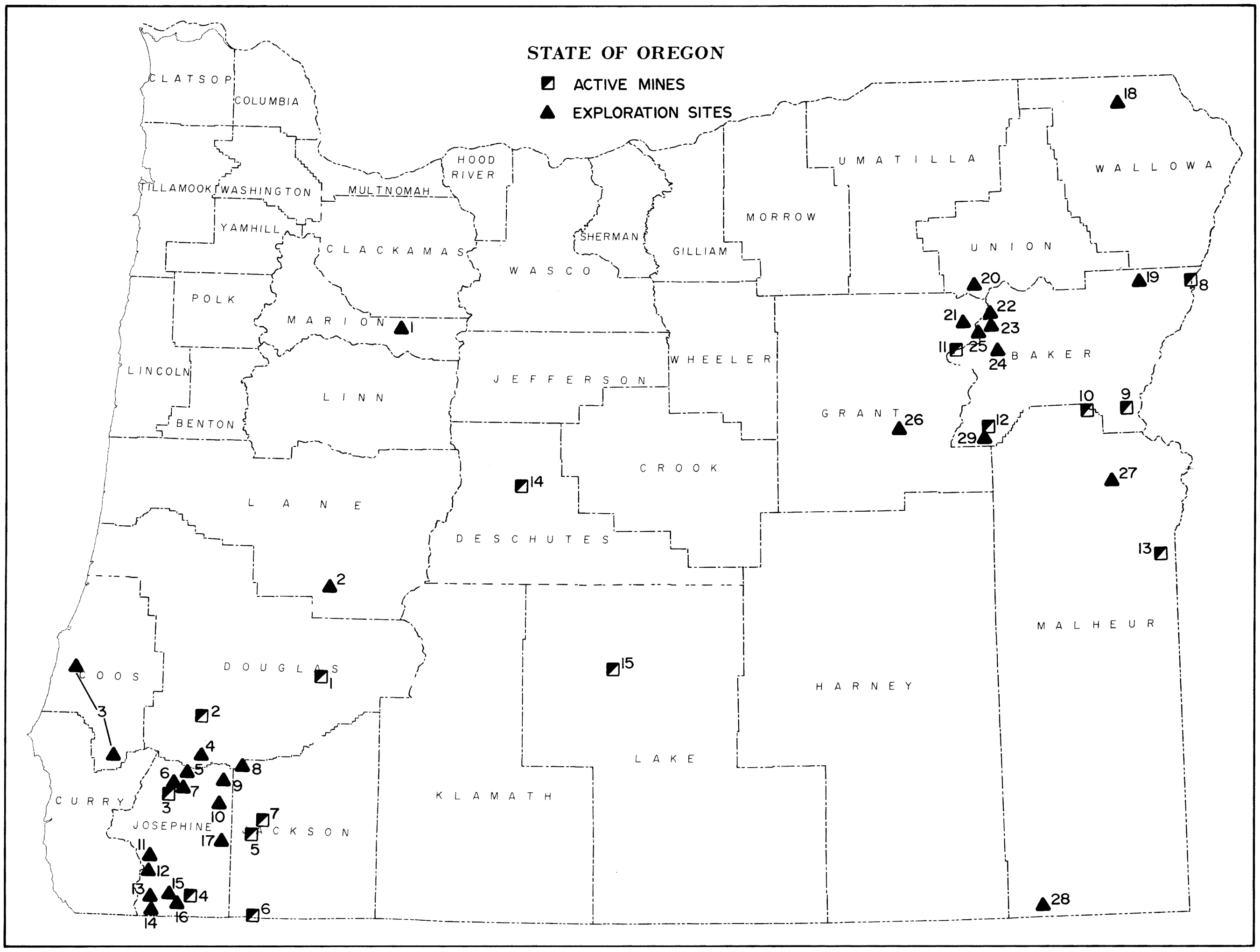
In southwestern Oregon, the Hanna Mining Company's nickel mine and smelter at Nickel Mountain (Mine 2) continued production as the sole domestic source of nickel. The mine currently operates at the per-shift rate of 2,000 short tons of ore containing 0.87 percent nickel which is upgraded by selective screening to provide a smelter-feed content of 0.97 percent. The smelter produces ferronickel containing 51-54 percent nickel. During the first few years of operation, which began in 1954, the initial grade of smelter feed was 1.5 percent nickel. Depletion of higher grade saprolitic and silica-boxwork ore in the main orebody and increased use of ore from the satellite landslide orebodies has resulted in a steady decline in grade during recent years.

The Old Channel Placer Mine (Mine 3) near Galice was reactivated during the year by Wes Pieren. In this operation, bed rock and minor remnant gravels are ripped up, using a bulldozer, loader, and trucks, and run through a sluice. Water for the sluice is recycled from a settling pond with a large diesel-powered pump.

METAL PROCESSING

Oregon's metallurgical industry grew during 1981 with the expansion of Oremet's titanium plant in Albany and with con-

* All mine numbers refer to "Active Mines" on location map and in Table 2.



EXPLANATION

ACTIVE MINES

1. Quartz Mountain Silica
2. Nickel Mountain (Ni)
3. Old Channel Placer (Au)
4. Sucker Creek Placer (Au)
5. Bristol Silica (dolomite)
6. Steatite of Oregon (soapstone)
7. Sylvanite-Lyman (Au)
8. Iron Dyke (Au, Ag, Cu)
9. Oregon Portland Cement (limestone)
10. Mormon Basin Placer (Au)
11. Pyx (Au)
12. Thomason (Au)
13. Adrian (bentonite, zeolite)
14. Cascade Pumice, Central Oregon Pumice
15. Christmas Valley (diatomite)

EXPLORATION SITES AND AREAS

1. North Santiam area (Cu, Zn, Au, Ag)
2. Bohemia district (Cu, Zn, Au, Ag)
3. Coos County coal deposits
4. McCullough Creek area (Cu, Zn, Ag)
5. Goff Prospect (Au, Ag, Cu, barite)
6. Yankee Silver Mine (Au, Ag)
7. Almeda Mine (Au, Ag, Cu, barite)
8. Warner Mine (Au)
9. Yellowhorn Mine (Au)
10. Oak Mine (Au, Cu)
11. Fall Creek Prospect (Cu)
12. Lightning Gulch Group (Au, Ag, Cu)
13. Nickel laterite deposits (Ni, Cr, Co)
14. Turner-Albright Mine (Cu, Au, Co)
15. Esterly Placer area (Au)
16. Queen of Bronze Mine (Cu, Au)
17. Iron Hat Prospect (Cu, Au)
18. Flora coal deposits (lignite)
19. Cornucopia Mine (Au, Ag)
20. Camp Carson Placer (Au)
21. Cougar Mine (Au, Ag)
22. Argonaut Mine (Au, Ag)
23. North Pole, E and E, Columbia Mines (Au, Ag)
24. Sumpter Valley Placer (Au)
25. Bald Mountain, Ibex Mines (Au, Ag)
26. Chambers Mine (Canyon Mountain area) (Cr)
27. Hope Butte (Au)
28. Trout Creek Mountains (U)
29. Grouse Spring Prospect (Cu, Mo)

Mineral industry activity, exploration, and development in Oregon in 1981. Mine and site numbers in text refer to location numbers shown on this map.

Table 2. *Active mines in Oregon, 1981*

Map no.	Name	Location	Comments
1.	Quartz Mountain Silica	Sec. 2 T. 28 S., R. 1 E. Douglas County	Production of 10,000 tons this year.
2.	Nickel Mountain	Sec. 17 T. 30 S., R. 6 W. Douglas County	Continuing production at mine and smelter.
3.	Old Channel Placer	Sec. 35 T. 34 S., R. 8 W. Josephine County	Operator Wes Pieren. Gold production from ripped-up bed rock.
4.	Sucker Creek Placer	Sec. 1 T. 40 S., R. 7 W. Josephine County	Gallagher's washing plant.
5.	Bristol Silica	Sec. 30 T. 36 S., R. 3 W. Jackson County	Produced some dolomite.
6.	Steatite of Southern Oregon	Secs. 10, 11 T. 41 S., R. 3 W. Jackson County	Block soapstone for carving. Production small but increasing.
7.	Sylvanite-Lyman	Sec. 2 T. 36 S., R. 3 W. Jackson County	Small-scale mining of high-grade ore from old workings.
8.	Iron Dyke	Sec. 21 T. 6 S., R. 48 E. Baker County	Owner Texas Gulf, operator Silver King. Massive sulfide ore contains Au, Ag, Cu. Mine employs 40 on five-day basis.
9.	Oregon Portland Cement	Sec. 11 T. 12 S., R. 43 E. Baker County	Continuing operation of new 500,000-ton coal-fired plant.
10.	Mormon Basin Placer	Sec. 21 T. 13 S., R. 42 E. Malheur County	Dragline and washing plant reported production of 10-20 oz of gold per day. Mine was purchased by Vita Grande Corp.
11.	Pyx	Secs. 1, 2 T. 10 S., R. 35 E. Baker County	Small gold production; four employed.
12.	Thomason	Secs. 6, 7 T. 14 S., R. 37 E. Baker County	Unity area. Operator, Art Cheatham. Gold in serpentine shear zone. 1-ton/hr mill, three employed.
13.	Adrian	Sec. 29 T. 23 S., R. 46 E. Malheur County	Teague Mineral Products drying and bagging plant. Small production.
14.	Cascade Pumice, Central Oregon Pumice	Bend area Deschutes County	Continuing operation with increase in annual production.
15.	Christmas Valley	– T. 27 S., R. 17 E. Lake County	Oil-Dri West continuing production for pet litter and floor sweep.

struction at St. Helens, Oregon, of Bergsoe Metal's new 50,000-tons-per-year smelter designed to recover lead from old batteries. Albany Titanium, Inc., announced plans to install a new titanium sponge plant in Albany.

On the negative side were the Reynolds Metals' shutdown of two 25,000-tons-per-year potlines at its Troutdale aluminum plant and Union Carbide's plans to close its Portland ferroalloy plant.

NONMETALS

Oregon's Economic Development Commission approved $1.9 million in industrial development bonds for North Santiam Sand and Gravel, Inc., to expand its cement plant in Marion County and construct an asphalt plant in Linn County. The Portland City Council granted a 35-year conditional-use permit for gravel mining on Ross Island to Ross Island Sand and Gravel Company.

Teague Mineral Products produces bentonite and zeolite for various uses. Production has expanded at the company's drying, grinding, and bagging plant (Mine 13) near Adrian in Malheur County. Zeolite is marketed as a livestock food additive for poultry and hogs.

The Quartz Mountain Silica Mine in Douglas County (Mine 1) saw production reduced to about 10,000 tons during the year, due in part to a 250-percent increase in road-maintenance charges from $1.23 to $4.37 per ton by the U.S. Forest Service. In the past, the mine has usually produced 20,000-25,000 tons per year of quartz that is hauled over 26.4 mi of Forest Service roads on the 75-mi trip to the Hanna nickel smelter. The quartz is smelted with scrap iron to make ferrosilicon which is used in the nickel-reduction process at the smelter near Riddle.

EXPLORATION AND DEVELOPMENT ACTIVITY

Coal

During 1981, considerable interest was shown in coal deposits. Coos County subbituminous deposits (Site 3**) have received much attention, and several companies, including Bear Creek, AMAX, Canasia, and GCO Minerals, have been actively involved in exploration, reconnaissance mapping, and leasing. AMAX conducted a drilling program near Riverton. At year's end, Coos County signed a lease agreement for 4,000 acres with GCO Minerals Company.

A large deposit of low-grade lignite coal 20-40 ft thick in the vicinity of Flora (Site 18), northern Wallowa County, has been explored by Utah International. The company's application to the Wallowa County Planning Commission for a conditional-use permit to excavate a bulk sample of coal was withdrawn last summer, in part due to local ranchers' opposition to strip mining. Further work is reportedly planned by Utah International, which has requested a new conditional-use permit for a sample pit about 5 mi northwest of Flora.

Base metals and precious metals

Interest in exploring for volcanogenic sulfide deposits continued during 1981. An article by Koski and Derkey (*Oregon Geology*, v. 43, no. 9, p. 119-125) describes the genesis of volcanogenic sulfide deposits in southwestern Oregon, where much of the exploration activity has been centered. Mineral deposits along the "Big Yank Lode" mineralized zone, including those of the Silver Peak Mine in Douglas County and the Almeda Mine in Josephine County, are described by Koski and Derkey as island-arc volcanogenic deposits. Exxon is exploring a segment of this zone along McCullough Creek (Site 4), a short distance northeast of Glendale. Other segments under exploration are the Goff Prospect (Site 5), by American Selco; the Almeda Mine (Site 7), by Comanche and Blue Diamond; and the Yankee Silver Mine (Site 6), by owner George Reynolds.

One of the apparently successful exploration programs in southwestern Oregon is the work done by Baretta Mining at the Turner-Albright Mine (Site 14), where sufficient low-grade copper-, zinc-, and gold-bearing sulfide ore has reportedly been blocked out to justify a mining operation. The ore occurs

** All site numbers refer to "Exploration Sites and Areas" on location map and in Table 3.

Table 3. *Exploration sites and areas in Oregon, 1981*

Map no.	Site or area name	Location	Comments
1.	North Santiam area:	Marion County	
	Ruth Mine	Sec. 27 T. 8 S., R. 5 W.	AMOCO drilling and exploring surrounding area of sulfide mineralization in Western Cascades volcanic rocks.
2.	Bohemia district:	Lane County	
	a. Champion and Helena Mines	Secs. 7, 8, 12, 13 T 23 S.; Rs. 1, 2 E.	Hanuman (Galactic Resources, Ltd.) mapping and sampling. Reopened workings, surface and underground; plan to drill.
	b. President Mine (El Capitain)	Sec. 23 T. 23 S., R. 1 E.	Local group plans to build mill.
	c. North Fairview, Lead Crystal, Elephant II, Lizzie Mines	Secs. 2, 11 T. 23 S., R. 1 E.	Guy Leabo and associates constructing small mill for both free milling and complex ore.
3.	Coos County coal deposits	Coos Bay and Eden Ridge, Coos County	Several companies, Bear Creek, AMAX, Canasia, and GCO, involved in exploration, leasing, mapping, and some drilling.
4.	McCullough Creek area	Sec. 30 T. 32 S., R. 6 W. Douglas County	Exxon has done geophysical work, leasing, surface mapping, sampling, and drilling in sulfide-mineralized zone.
5.	Goff Prospect	Sec. 29 T. 33 S., R. 7 W. Josephine County	American Selco drilling segment of Big Yank Lode in area with barite and abundant sulfides.
6.	Yankee Silver Mine	Secs. 25, 26 T. 34 S., R. 8 W. Josephine County	Owner George Reynolds prospecting siliceous gold ore.
7.	Almeda Mine	Sec. 13 T. 34 S., R. 8 W. Josephine County	Comanche Petroleum and Blue Diamond Energy Resources have optioned property, located claims, and done geophysical survey. Hope to develop Au, Ag, and barite ores.
8.	Warner Mine	Sec. 4 T. 33 S., R. 4 W. Jackson County	Galactic Resources opened workings, mapped, and sampled. Plan to drill geophysical anomaly for gold.
9.	Yellowhorn Mine	Sec. 5 T. 33 S., R. 5 W. Josephine County	John Miller reopening mine and building small mill. Three men employed.
10.	Oak Mine	Sec. 4 T. 35 S., R. 5 W. Josephine County	Dennison has conducted geophysical survey and plans to drill anomalies in massive sulfide zone.
11.	Fall Creek Prospect	Sec. 4 T. 38 S., R. 9 W. Josephine County	Mining Enterprises of Arnold, California, has conducted geophysical survey and plans to drill copper prospect.
12.	Lightning Gulch Group	— Tps. 38, 39 S.; R. 9 W. Josephine County	FMC, Inc., conducting geophysical and geochemical surveys, claim staking, and mapping over extensive area.
13.	Nickel laterite deposits	Southwest Oregon	Inspiration Development, U.S. Nickel, and Hanna Mining holding claims and doing assessment work to extend reserves of Ni, Cr, Co in the Josephine ultramafic sheet and other southwest Oregon areas.
14.	Turner-Albright Mine	Secs. 15, 16 T. 41 S., R. 9 W. Josephine County	Baretta Mining recently completed extensive drilling, mapping, and sampling program for Cu, Au, Co.
15.	Esterly Placer area	Sec. 22 T. 40 S., R. 8 W. Josephine County	Cal Nickel exploring, with tentative plans to set up gold mining operation.
16.	Queen of Bronze Mine	Sec. 36 T. 40 S., R. 8 W. Josephine County	Dennison continued mapping and sampling underground plus surface geophysical work for Cu, Au.

Table 3. *Exploration sites and areas in Oregon, 1981—continued*

Map no.	Site or area name	Location	Comments
17.	Iron Hat Prospect	Sec. 17 T. 37 S., R. 5 W. Josephine County	Associated Geologists plan to drill electromagnetic anomaly for Cu, Au.
18.	Flora coal deposits	Northern Wallowa County	Utah International mapping, leasing, and drilling lignite deposit up to 40 ft thick.
19.	Cornucopia Mine	Secs. 27, 28 T. 6 S., R. 45 E. Baker County	United Nuclear Mining and Milling Services, Inc., reopening old gold mine. Plan extensive exploration and testing. Rehabilitated old Coulter adit at 2,000-ft level.
20.	Camp Carson Placer	Sec. 28 T. 6 S., R. 36 E. Union County	Local group has moved in equipment to reactivate gold placer mine.
21.	Cougar Mine	Sec. 27 T. 8 S., R. 35½ E. Grant County	W.A. Bowes and Associates exploring old gold mine last five years. Operations cut back late in 1981.
22.	Argonaut Mine	Sec. 19 T. 8 S., R. 37 E. Baker County	Baker Mines, Ltd., (Norvan, Ltd.), reopening, sampling, and extending old workings for Au.
23.	North Pole, E and E, and Columbia Mines	Sec. 32 T. 8 S., R. 37 E. Baker County	Brooks Minerals and AMAX driving 3,800-ft adit 400 ft below creek level on North Pole-Columbia Lode, 10-300 ft wide and 4.5 mi long, in argillite. Employing average of 30 people. Prior production from lode reported to be about $9 million.
24.	Sumpter Valley Placer	— T. 10 S.; Rs. 37, 38 E. Baker County	Noranda has submitted applications for drilling permits and land acquisition; may redredge.
25.	Bald Mountain and Ibex Mines	Sec. 3 T. 9 S., R. 36 E. Baker and Grant Counties	NERCO, Inc., (Pacific Power and Light) reopening old workings and sampling quartz-calcite vein (5-25 ft wide) in argillite.
26.	Chambers Mine (Canyon Mountain area)	Sec. 13 T. 14 S., R. 32 E. Grant County	American Chrome (Baretta) did some drilling of chromite deposits.
27.	Hope Butte	Sec. 21 T. 17 S., R. 43 E. Malheur County	Homestake Mining exploring area of old Jordan quicksilver prospect for gold in opalized tuffs and rhyolite flows with interbedded lake sediments. Work was begun in 1979 and is continuing.
28.	Trout Creek Mountains	— Tps. 40, 41 S.; Rs. 38, 39 E. Malheur County	Anaconda, Placer Amex, and other major companies continuing exploration for uranium in Miocene ash-flow tuffs and lake sediments of McDermitt Caldera.
29.	Grouse Spring Prospect	Secs. 24, 25 T. 14 S., R. 36 E. Baker County	Johns Manville exploring for Cu, Mo. Did some drilling for assessment work.

in the Josephine ophiolite overlying a sheeted diabase dike complex.

There has been widespread exploration activity in eastern Oregon. Gold-bearing veins in the Cracker Creek area of western Baker County appear to have been the scene of greatest activity. Work to reopen the old E and E and North Pole Mines on the North Pole-Columbia Lode (Site 23) and the Bald Mountain and Ibex Mines (Site 25) continued throughout 1981.

Considerable interest has also been shown in Oregon's epithermal opalized areas and associated quicksilver deposits because large deposits of gold have been found in similar areas in California. Exploration by Homestake at Hope Butte (Site 27) in northern Malheur County is the result of this interest.

Little actual exploration work has been done on chromite deposits in the state, except for American Chrome's brief drilling program on Canyon Mountain (Site 26) near John Day. Industry recognizes the very strategic nature of chromite and is looking into domestic deposits with renewed interest. Nearly all of the known chromite deposits in southwestern Oregon have been investigated, and new mining claims have been located.

Exploration and development on nickel-bearing laterite deposits (Site 13), especially in the Josephine ultramafic sheet, have continued at a somewhat reduced pace. All existing claims are being kept current, and the type of assessment work currently being done generally involves drilling, sampling, and other types of exploration to prove up additional reserves. Nomination of the east side of Eight Dollar Mountain as a Bureau of Land Management Area of Critical Environmental Concern (ACEC) may affect future development of the laterite deposits in that area. □

An estimate of the geothermal potential of Newberry Volcano, Oregon

by Gerald L. Black, Oregon Department of Geology and Mineral Industries

INTRODUCTION

Newberry Volcano is a large Quaternary volcano located in central Oregon about 32 km (20 mi) southeast of Bend (Figure 1). It covers an area of nearly 1,300 km^2 (500 mi^2) and, according to MacLeod and others (1981), consists of "basalt and basaltic andesite flows, andesitic to rhyolitic ash-flow and air-fall tuffs and other types of pyroclastic deposits, dacite to rhyolite domes and flows, and alluvial sediments produced during periods of erosion." More than 400 cinder cones dot the flanks of the volcano. The most recent activity occurred approximately 1,400 years ago in the summit caldera and resulted in the formation of the Big Obsidian Flow. The volcano is considered dormant but capable of future eruptions (MacLeod and others, 1981).

During the summer of 1981, the Geothermal Research Program of the U.S. Geological Survey (USGS) completed drilling a 930-m (3,051-ft) test hole (Newberry 2) in the summit caldera of Newberry Volcano. Fluids at a temperature of 265° C (509° F) were encountered in permeable rocks in the bottom 1.8 m (6 ft) of the hole (Sammel, 1981).

The intent of this paper is to provide a general update of the estimated geothermal electrical generation potential of the volcano, based on refinements in the estimates of reservoir temperature and volume. The temperature refinements are based on considerations of the relative validity of various methods of geothermometry and on data obtained from the USGS drill hole. The volume refinements are based on USGS drill-hole data and on gravity modeling recently completed in the area by the USGS (Williams and Finn, 1981).

PREVIOUS RESERVOIR ESTIMATES

In USGS Circular 790, Brook and others (1979) estimate the mean reservoir thermal energy of Newberry to be $27 \pm 10 \times 10^{18}$ J (joules), resulting in a theoretical electrical generation potential of 740 MWe (megawatts electric). These estimates are based upon a mean reservoir temperature of $230° \pm 20°$ C and a mean reservoir volume of 47 ± 16 km^3.

GEOTHERMOMETRY

Normally, chemical geothermometers are used to estimate the reservoir temperatures of geothermal systems. These temperature-dependent water-rock reactions, however, are valid only for hot-water systems, as the chemical constituents used in the calculations (Na, K, Ca, Mg, SiO_2, Cl) are not soluble in steam (White, 1973). Although there are two hot springs in the summit caldera of Newberry Volcano (East Lake and Paulina Hot Springs), their chemistry is not considered a reliable indicator of reservoir temperature. Both springs issue from lapilli tuffs along the shores of lakes occupying the caldera floor and are characterized by low flow rates and high silica concentrations. Mariner and others (1980) believe that (1) the springs are probably drowned volcanic gas vents, and (2) the solution of glass from the lapilli tuffs could account for observed high silica and magnesium concentrations which, in turn, would be a function of the length of time that heated lake waters were in contact with the tuffs. A warm well located in Little Crater Campground (between East and Paulina Lakes) probably suffers from the same limitations.

Because of the uncertainty surrounding the geothermometers derived from the chemistry of East Lake and Paulina Hot Springs, Brook and others (1979) infer a reservoir temperature of $230° \pm 20°$ C, based on temperatures estimated for other Quaternary volcanoes. Since results of the Newberry 2 test hole (Figure 2) indicate a minimum temperature of 265° C at the top of the reservoir, the problem becomes one of estimating maximum and mean reservoir temperatures. One possible solution is to use the chemical geothermometers while keeping in mind their limitations. Unfortunately, the Na-K, Na-K-Ca, and SiO_2 geothermometers all indicate minimum reservoir

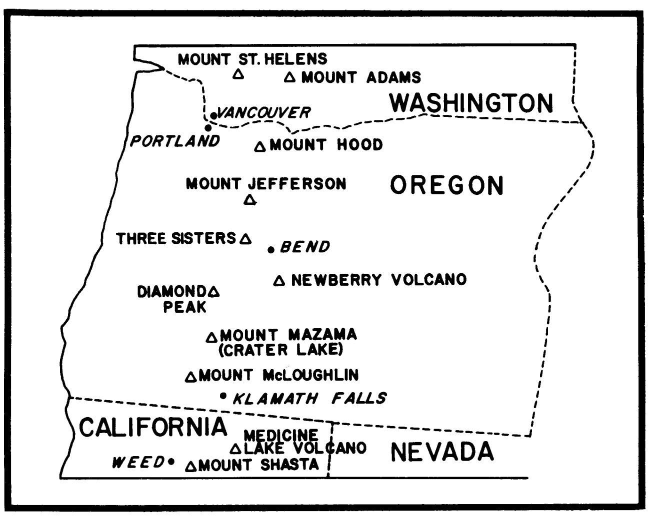


Figure 1. Map showing locations of some major volcanoes in the High Cascades Range of Washington, Oregon, and California. Taken from Sammel (1981).

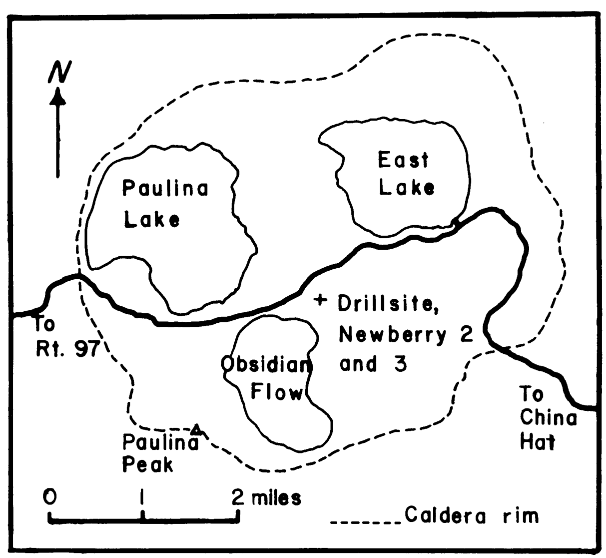


Figure 2. Map of Newberry Caldera, showing the Newberry 2 test site. Taken from Sammel (1981).

temperatures of less than 200° C (Mariner and others, 1980). A new method based on the Na/Li ratio (Fouillac and Michard, 1981) gives reservoir temperatures of 335° C, 375° C, and 370° C for East Lake Hot Springs, Paulina Hot Springs, and the Little Crater Campground warm well, respectively (based on analyses from Mariner and others, 1980).

The reliability of the Na/Li geothermometer is difficult to assess. In general, higher temperatures correspond to lower Na/Li ratios. If, however, the concentration of sodium in the thermal water is a function not only of temperature but also of the length of time that the water has been in contact with lapilli tuffs (Mariner and others, 1980), then the result is a higher Na/Li ratio and a lower estimated reservoir temperature. This implies that the calculated temperatures are minimums, assuming, of course, that the concentration of lithium in the thermal water is a function of subsurface temperature and is not affected by the length of time the water is in contact with the tuffs. This may indeed be the case. According to Fouillac and Michard (1981), the concentration of lithium in thermal waters increases with increasing temperature, varying over about four orders of magnitude between 0° and 300° C. They feel that it is unlikely that the concentration of lithium in thermal waters is due to chemical equilibrium between water and a lithium mineral, and they believe that water-rock ratios and rock type do not affect lithium concentrations. Given these findings, it is possible that the temperatures resulting from Na/Li ratios give useful indications of minimum reservoir temperatures beneath the caldera at Newberry Volcano. Even if Paulina and East Lake Hot Springs are drowned fumaroles, the Na/Li ratios should be characteristic of the temperature of the thermal fluid at the point of mixing. Since the temperature of the mixture is presumably less than the temperature at depth, the resulting Na/Li geothermometer should give useful minimum reservoir temperatures.

Based on the above considerations, a maximum reservoir temperature of 360° C and a mean reservoir temperature of 312.5° C have been selected for use in the calculations of geothermal potential. The maximum is simply the mean of the three Na/Li geothermometers (335° C, 375° C, and 370° C) discussed above, while the mean reservoir temperature is the arithmetic average of the maximum (360° C) and the temperature encountered at the bottom of the Newberry 2 test hole (265° C). These temperatures are higher than those encountered in many producing geothermal fields around the world, but they are not unheard of. The Cerro Prieto field in the Mexicali district of Mexico, for example, produces fluids at temperatures of 310° to 350° C from depths of 1,700-2,000 m (Espinosa, 1982).

RESERVOIR VOLUME

Brook and others (1979) assume a reservoir volume of 47 ± 16 km^3 in their estimation of the geothermal potential of Newberry Volcano. This estimate is based upon a caldera area of 32 km^2 and a minimum, maximum, and most likely depth to the top of the reservoir of 0.5, 2.0, and 1.5 km, respectively. They chose these numbers because the depths to the tops of the reservoirs in most drilled geothermal systems fall within that range and because at the time of their study there were no drill hole data available from Newberry indicating the true top of the reservoir. Assuming a maximum drillable depth of 3 km for the reservoir bottom, Brook and others (1979) calculate a maximum reservoir thickness of 2.5 km, a minimum of 1.0 km, and a most likely thickness of 1.5 km. The results from Newberry 2 indicate a depth to the top of the reservoir of 0.93 km (Sammel, 1981) and thus a calculated reservoir thickness of 2.07 km, the value that is used in this paper in calculating reservoir thermal energy. An important assumption used in the calculation of reservoir volumes is that all portions of the reservoir are considered to be equally porous and permeable; no attempt is made to separate those portions of the reservoir which are porous and permeable from those which are not (Brook and others, 1979).

Williams and Finn (1981), in a reexamination of gravity data from Newberry, delineate a large positive residual gravity anomaly associated with the volcano. The anomaly extends well outside the margins of the volcano, covers an area of approximately 275 km^2 (D.L. Williams, 1982, personal communication), and is interpreted by Williams and Finn (1981) to be a subvolcanic intrusive. The top of the intrusive lies at a depth of less than 2 km (D.L. Williams, 1982, personal communication) and is probably composed of a complex of many separate intrusions in different states of cooling (Williams and Finn, 1981). While it is highly unlikely that temperatures similar to those encountered in the Newberry 2 test hole underlie the entire area of the positive gravity anomaly, calculations will be made using that assumption in order to arrive at an upper limit for the electrical generation potential of the volcano.

ELECTRICAL POWER CALCULATIONS

The techniques developed by Brook and others (1979) for estimating the electrical generation potential of a geothermal area are relatively straightforward, once reasonable estimates of reservoir temperatures and volumes have been made. As a first step, the accessible resource base (the stored heat of the system above 15° C and shallower than 3 km) is calculated, using the formula:

$$q_R = pc \cdot a \cdot d \cdot (t - t_{ref}),$$

where q_R is the reservoir thermal energy in joules (J), pc is the volumetric specific heat of rock plus water (2.7 J/cm^3/° C), a is the reservoir area in km^2, d is the reservoir thickness in km, t is the reservoir temperature, and t_{ref} is the reference temperature (15° C). The value for pc assumes a reservoir porosity of 15 percent and t_{ref} is the mean annual surface temperature, which for simplicity is assumed to be constant throughout the United States.

Once the reservoir thermal energy (q_R) has been calculated, the problem becomes one of determining how much of that energy can be turned into electricity. To generate electricity, the thermal energy of the reservoir is converted into mechanical energy (work), which in turn is converted to electrical energy. The mechanical work available (W_A) at the wellhead can be determined from a graph conveniently provided in USGS Circular 790 (Brook and others, 1979). For a reservoir temperature of 312.5° C and a depth to the center of the reservoir of 2 km, the ratio W_A/q_R is equal to 0.082 ($W_A/q_R =$ 0.082). Hidden within this simple computation are the following important assumptions which are discussed in more detail by Brook and others (1979): (1) In an ideal reservoir, 50 percent of the reservoir thermal energy can be recovered at the wellhead; (2) nonideal reservoir conditions, mostly related to the fact that much of the reservoir volume is not porous and permeable, limit wellhead recoverability to 25 percent of the reservoir thermal energy; and (3) the condenser rejection temperature is 15° C. This last assumption tends to maximize the available work (W_A) term, as the true condenser rejection temperature will usually be higher, around 40° C.

The electrical energy obtainable from a geothermal system is calculated from the equation:

$$E = W_A \cdot \eta_u,$$

where η_u is a utilization factor that accounts for losses that occur in the power cycle (Brook and others, 1979). The value of η_u is simply the ratio of actual work to available work (W_A) for a given system. A value of 0.4 was chosen by Brook and others (1979) as typical of hot water systems and is used in this paper. It should be noted that the calculation of actual work (used in determining η_u) assumes a condenser rejection temperature of 40° C.

Table 1 lists the results of the various calculations made for Newberry Volcano. The values for electrical energy are given in electrical megawatts based on a 30-year life span.

Table 1. *Estimates of volume, temperature, and energies of Newberry Volcano*

Source of calculation	Reservoir volume (km^3)	Reservoir temperature (° C)	Reservoir thermal energy (10^{18} J)	Electrical (MWe for 30 years)
USGS Circ. 790[1]	47±16	230±20	27±10	740
DOGAMI[2]	47	312.5	38	1,316
DOGAMI[3]	66	312.5	53	1,843
DOGAMI[4]	569	312.5	457	15,837

[1] Brook and others, 1979, p. 54.

[2] Oregon Department of Geology and Mineral Industries (DOGAMI) calculation, using reservoir volume estimate of Brook and others (1979) and new temperature data from Newberry 2 test well.

[3] DOGAMI calculation using increases in both reservoir temperature and volume from Newberry 2 hole (Sammel, 1981).

[4] DOGAMI calculation using volume estimate based on gravity work of Williams and Finn (1981).

Two things are immediately obvious from the information contained in Table 1. First, the new data from the Newberry 2 test well more than double the theoretical electrical generation potential of the caldera portion of the Newberry Volcano; and second, there may be enormous potential outside the caldera proper. The 15,837-MWe estimate for the entire gravity anomaly associated with the volcano is, of course, an absolute maximum. It is based on the assumptions that (1) the intrusive causing the gravity anomaly is everywhere providing heat at the rate found in the Newberry 2 test hole, and (2) the reservoir is everywhere 2.07 km thick (i.e., the top of the reservoir lies everywhere at a depth of approximately 1 km). While these assumptions are certainly not completely valid, they provide a useful upper limit on the potential of the volcano. The extent to which they are in error and the true geothermal potential of the volcano can be determined only by exploratory drilling.

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MEETING ANNOUNCEMENTS

GSOC luncheon meetings

The Geological Society of the Oregon Country (GSOC) holds noon meetings in the Standard Plaza Building, 1100 SW Sixth Avenue, Portland, in Room A adjacent to the third floor cafeteria. Topics of upcoming meetings and speakers include:

April 16—*Bella Coola by Freighter and Beyond*: by Phyllis and John Bonebrake, members and president of GSOC, 1975.

May 7—*The Columbia River Gorge: Who Is Watching?* by Nancy Russell, lecturer on Oregon native plants and chairwoman of Friends of the Columbia Gorge.

May 21—*Forty Floods*: by John Eliot Allen, Emeritus Professor of Geology, Portland State University.

For additional information, contact Viola L. Oberson, Luncheon Chairwoman, phone (503) 282-3685.

AIME dinner meeting

The monthly dinner meeting of the Oregon section of the American Institute of Mining, Metallurgical, and Petroleum Engineers (AIME) will be held Friday evening, April 16, at the Flamingo Best Western Motel and Restaurant, 9727 NE Sandy Boulevard in Portland. The speaker will be Herbert H. Kellogg, 1982 Henry Krumb Lecturer and Professor of Metallurgy at the Henry Krumb School of Mines at Columbia University, who will speak on *Energy Use in Metal Production*.

Cocktail hour is at 6 p.m., dinner at 7 p.m., and program at 8 p.m. Reservations should be made by Wednesday, April 14, with either Mike York in Corvallis (phone 757-0349) or the Oregon Department of Geology and Mineral Industries receptionist in Portland (phone 229-5580). □

DOGAMI publishes new geologic map of Bourne quadrangle, eastern Oregon

A new geologic map for a part of eastern Oregon, published by the Oregon Department of Geology and Mineral Industries (DOGAMI), shows gold and silver mines and prospects as well as the geology of a historic mining area.

The multicolored map, *Geology and Gold Deposits Map of the Bourne Quadrangle, Baker and Grant Counties, Oregon*, was prepared by H.C. Brooks, M.L. Ferns, R.I. Coward, E.K. Paul, and M. Nunlist and appears in DOGAMI's Geological Map Series as Map GMS-19. At a scale of 1:24,000, it delineates 11 different bedrock and surficial geologic units, identifies 61 gold and silver lode and placer mines and prospects, and indicates known quartz veins. In three cross sections, it interprets basic geologic structure. Also printed on the map, partly in tabular form, is a summary of geologic and historical data for the deposits.

The Bourne 7½-minute quadrangle covers a part of the northwest corner of Baker County and about one square mile of Grant County. The region's mining areas, especially the North Pole-Columbia lode and the Cracker Creek, Cable Cove, and Rock Creek mining districts, are well known from their active periods between 1895 and 1940, when their total production value was an estimated $11 million.

DOGAMI Map GMS-19 is available now at the Department of Geology and Mineral Industries, 1005 State Office Building, Portland, OR 97201. The purchase price is $5.00. Orders under $20.00 require prepayment. □

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