

## THE OCEANS: A NEGLECTED MINING FRONTIER

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Man first mined the seas more than 4,000 years ago. First he discovered that when sea water evaporated it left a thin deposit of salt. Soon he learned that he could create artificial ponds of sea water and produce salt by solar evaporation, a method still in use today. Other products were also manufactured from the sea in early times. The Phoenicians "mined" the tiny marine snail, *Murex*, in order to produce a bromine dye we call "Tyrian purple." Islanders in the South Pacific learned to quarry coral reefs to produce building blocks. In other areas oyster shells have long been used in the production of lime.

Although the sea supplied a few needed materials, it was ignored as a source for a number of important minerals. Only during the past century, as the known supply of commercially important minerals on land decreased, has man thought of the sea as a major origin for them. In recent years iron, tin, gold, and even diamonds have been profitably mined from the continental shelf in various parts of the world. In addition to salt, magnesium, bromine, and other elements have been extracted from sea water commercially.

Mineral deposits occurring beyond the shoreline can be separated into three groups. The first is the ocean itself. The "chemical soup" which we call sea water covers approximately 71 percent of the earth's surface; its volume is on the order of 300 million cubic miles; it contains virtually all of the elements known to man. Table 1 lists some of the important elements in sea water and their abundance.

In the second group of mineral deposits are those beneath the continental shelf. These include petroleum, gas, sulfur, and coal. Because these deposits are not related directly to the present ocean, they will not be considered in this paper.

Minerals which have been concentrated on the ocean floor, either by physical or by chemical oceanographic processes, constitute the third group. Deposits concentrated by physical oceanographic processes are the beach placers, either exposed along the margin of the seas or submerged on the continental shelf. More or less related to the beach placers but not actually

formed by marine processes are those stream placers which formed during the Pleistocene Epoch when sea level was lower. These deposits were submerged during the post-glacial rise of the sea. The deposits formed by chemical oceanographic processes are termed authigenic, and include primarily glauconite, phosphorite, and manganese.

### Placers

Placers of both beach and stream types exist on the continental shelf. In some parts of the world, both have been mined successfully for tin, magnetite, ilmenite, chromite, gold, and diamonds. The presence of the placers on the continental shelf is related to the lowering of sea level which took place during the last major Pleistocene glaciation (Wisconsin stage). During glacial periods water, which normally would have returned to the sea as runoff, was added to the glaciers in the form of ice. Continued evaporation of water from the sea and the failure of it to return resulted in a lowering of the sea surface. The minimum level of the sea during the Wisconsin glaciation has been estimated as about 300 to 450 feet below the present sea level. For convenience, we may assume that during the period of maximum Wisconsin glaciation the shoreline existed at about the position of the present 70-fathom\* contour. Streams discharging into the ocean at that time would have formed placers in the area shoreward of the present 70-fathom line. With the rise of sea level accompanying the melting of the glaciers, these placers were submerged and may have been covered by sediments deposited under normal shallow marine conditions. Stream placers on the continental shelf are usually related to streams with known placers on land, and in general are oriented at right angles to the present shoreline and to the contours of the continental shelf.

Beach placers are best developed near the mouths of streams that carry commercially important minerals. These placers are developed as low, elongate ridges parallel to the shoreline in response to surf action and long-shore currents. The oscillating motion of water in waves, which wash up on the beach and then run back to sea, tend to winnow the finer and lighter particles and leave behind the coarser and heavier grains. Because most of the minerals of economic importance in beach sands are heavier than the non-economic ones, they lag behind and become concentrated along the shore. The richest beach placers are formed where sands are reworked by both streams and waves. Submerged beach placers may occur between the present shoreline and the Wisconsin level, now at a depth of about 70 fathoms.

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\* One fathom equals 6 feet.

Table 1. Abundance of some elements in solution in sea water\*  
(Adapted from Mero, 1963)

Element	Weight Percent (% $\times 10^4$ )	Tons of element per cubic mile of sea water	Total tonnage of element in oceans
Chlorine	18,930	$89.4 \times 10^6$	$29.3 \times 10^{15}$
Sodium	10,561	$49.7 \times 10^6$	$16.3 \times 10^{15}$
Magnesium	1,272	$6.0 \times 10^6$	$2.0 \times 10^{15}$
Calcium	400	$1.9 \times 10^6$	$0.6 \times 10^{15}$
Potassium	380	$1.8 \times 10^6$	$0.6 \times 10^{15}$
Bromine	65	306,000	$0.1 \times 10^{15}$
Strontium	13	61,200	$20,100 \times 10^9$
Silicon	4.0	21,200	$6,950 \times 10^9$
Aluminum	0.5	2,360	$770 \times 10^9$
Lithium	0.1	470	$154 \times 10^9$
Phosphorus	0.1	470	$154 \times 10^9$
Barium	0.05	235	$77 \times 10^9$
Iron	0.02	94	$31 \times 10^9$
Manganese	0.01	47	$15 \times 10^9$
Copper	0.01	47	$15 \times 10^9$
Zinc	0.005	24	$7,850 \times 10^6$
Lead	0.004	19	$6,230 \times 10^6$
Molybdenum	0.0005	2.4	$790 \times 10^6$
Silver	0.0003	1.4	$470 \times 10^6$
Vanadium	0.0003	1.4	$470 \times 10^6$
Nickel	0.0001	0.47	$154 \times 10^6$

\*Abstracted from Sverdrup, Johnson, and Fleming, 1942, The Oceans.  
Prentice-Hall, New York.

### Authigenic Deposits

Authigenic minerals form on the sea floor by direct chemical precipitation from sea water. Although there are a considerable number of these minerals, only three which have known economic potential will be considered: glauconite, phosphorite, and manganese (see Figure 1).

### Glauconite

Glauconite is considered by most geologists to be a greenish, argillaceous mineral closely related to the micas. Essentially it is a hydrous potassium iron silicate. It has been used as a soil conditioner and as a water softener, but might be commercially important as a source of potash. Approximately 5,600 tons of this mineral was produced annually between 1957 and 1961 from a source in New Jersey (H. D. Hess, written communication, 1963).

Glauconite is extremely common on the outer continental shelf and on the upper continental slope where it appears to be forming at the present time. Although relatively little is known concerning the origin of the mineral, numerous observations have been made of its occurrence. Cloud (1955) summarizes these observations and lists the apparent physical limits of its formation. Glauconite occurs mainly in areas where detrital deposition is extremely slow, usually near the boundary between the continental shelf and the continental slope. In areas of glauconite accumulation, the sea water generally has a normal salinity and oxygen content, although micro-reducing environments may be present, for example inside the tests of foraminifera. Glauconite has been collected from the bottom in water 5 to 1,000 fathoms deep, but appears to be best developed in water 10 to 400 fathoms deep. It has been observed only in waters of moderate temperature, and generally does not form in warm water. In the tropics it has been found only at depths below 30 to 130 fathoms. The writer knows of no estimates of the amount of glauconite existing on the ocean floor, but the abundance of the mineral along the edge of the continental shelf off western North America suggests that it must be tremendous.

### Phosphorite

Phosphorite has been collected from the continental shelves of Australia, Japan, Spain, South America, and the United States (Mero, 1961). This material, a potential source of phosphate fertilizer, coats rocks and forms nodules ranging from sand size to two feet in diameter. The nodules are hard, dense, brown to black objects with smooth, glazed surfaces. Most of the small nodules are pure phosphorite; larger ones may be conglomeratic, including rock fragments or smaller phosphorite nodules. Mineralogically, phosphorite consists of collophane and francolite (Mero, 1961). Chemical analyses (Table 2) indicate that the phosphorite nodules contain about 29 percent  $P_2O_5$ , slightly less than the phosphate deposits being mined in Idaho, Florida, and Tennessee.

Phosphorite forms in environments of slow deposition as at the edge of

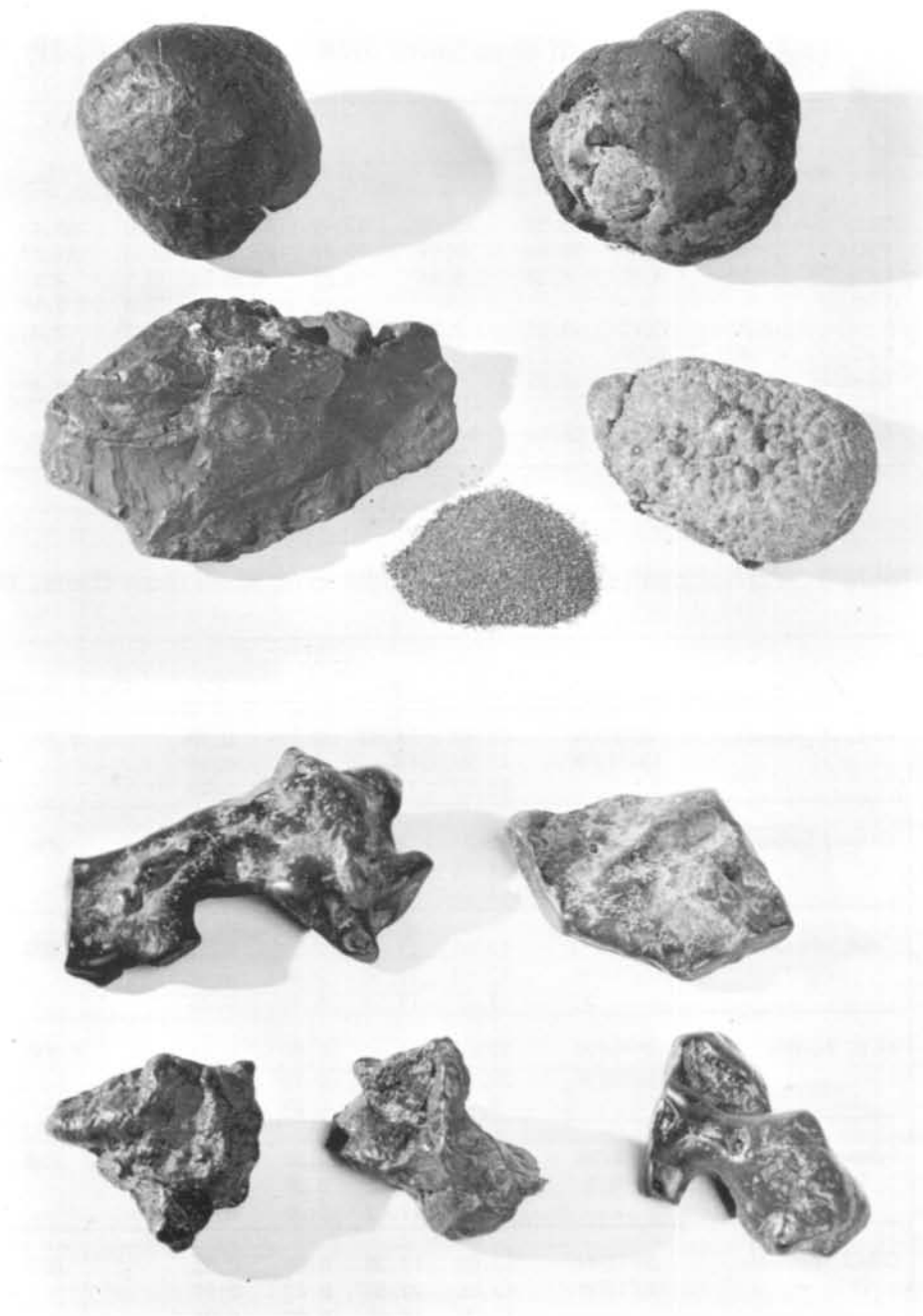


Figure 1. Marine authigenic minerals. Top: manganese nodules and glauconite grains. Bottom: phosphorite nodules.

Table 2. Analyses of phosphorite (from Emery, 1960, p. 72).

	California Sea Floor Samples						Idaho	Fla.	Tenn.
	69	106	127	158	162	183			
CaO	47.35	45.43	45.52	46.58	37.19	47.41	48.0	36.4	45.4
P <sub>2</sub> O <sub>5</sub>	29.56	29.19	28.96	29.09	22.43	29.66	32.3	31.3	31.0
CO <sub>2</sub>	3.91	4.01	4.30	4.54	4.63	4.87	3.1	2.2	2.2
SO <sub>3</sub>	-	-	-	-	-	-	2.3	0.1	1.3
F	3.31	3.12	3.07	3.15	2.47	3.36	0.5	2.0	3.8
R <sub>2</sub> O <sub>3</sub>	0.43	0.30	2.03	0.70	3.93	1.40	1.2	12.7	4.6
Organic	0.10	1.90	2.25	0.44	0.35	1.50	-	6.2	3.8
Total	84.66	83.95	86.13	84.50	71.00	88.20	87.4	90.9	92.1

Table 3. Partial analyses\* of some sea floor manganese (from Dietz, 1955).

Location		Fe	Mn	Ni	Co	Depth (in fathoms)
N.E. of Hawaii	27°20'N	16.47	14.30	0.20	0.20	2,790
	150°10'W	17.99	14.44	0.32	0.21	
		16.53	14.90	0.29	0.12	
Gilbert Seamount	52°47'N	15.07	18.52	0.30	0.25	800
	150°05'W	14.78	19.95	0.31	0.31	
		14.54	19.96	0.31	0.37	
Cape Johnson Guyot	17°04'N	12.86	21.40	0.60	0.61	1,000
	177°15'W	12.60	22.58	0.65	0.64	
		14.71	19.11	0.48	0.38	
N.E. Pacific	40°14'N	12.00	13.48	0.21	0.15	2,790
	155°05'W	12.23	13.34	0.16	0.12	
		9.16	10.78	0.24	0.07	
Sylvania Seamount	11°57'N	17.20	18.58	0.37	0.08	750
	164°46'E	15.64	15.22	0.39	0.32	
		14.50	17.62	0.38	0.24	
GA-3 Seamount	56°10'N	13.03	19.38	0.58	0.23	800
	145°15'W	12.86	22.53	0.42	0.19	
		13.29	18.69	0.53	0.35	
(*Analyses made on three separate pieces of the same nodule. All results given in weight percent.)						

the continental shelf and the tops of submarine banks and ridges. Water depth appears to exert little, if any, control on the formation of the material; samples have been dredged from about 1,900 fathoms. Although deep occurrences of the nodules are known, the mineral is most common in water depths of 20 to 200 fathoms. Most known deposits are in regions where phosphate-rich water at moderate depth is brought to the surface as a result of upwelling. It is believed by several workers (d'Anglejan, 1964, and Wyatt, 1956) that where cool, deep waters supersaturated with tri-calcium phosphate rise to the surface, the increase of temperature and pH and decrease of pressure result in colloidal precipitation of the phosphate. Because the colloidal particles carry a charge, they are attracted to solid objects on the sea floor about which they form a nodule.

Emery (1960) estimates approximately one billion tons of phosphorite off the coast of southern California. If only 10 percent of this is economically important, it will be possible to produce half a million tons per year for 200 years. Mero (1961) believes that phosphate fertilizer from this source will compete successfully in the West Coast fertilizer market with phosphates now brought in from the continental sources to the east. Techniques for recovering the phosphorite on a commercial basis are currently being developed.

### Manganese

Deep-sea manganese nodules have probably received more public attention during recent years than any of the other marine mineral deposits. These nodules, some smooth and some knobby, range in size from peas to potatoes. They are light brown to earthy black, friable, fairly soft, and range in density from about 2.1 to 3.1 grams per cubic centimeter. Internally they are usually layered, frequently around a nucleus such as a shark's tooth, a whale's earbone, a micrometeorite, or another hard object.

The nodules consist primarily of manganese and iron oxides, but contain small percentages of other important metals. The chemical composition of some Pacific Ocean nodules is given in Table 3, taken from Dietz (1955). Petrographic and X-ray studies of the nodules indicate that they are complex and might properly be considered as rocks. They have a layered structure in which layers of  $\text{MnO}_2$  alternate with disordered layers of hydrated  $\text{Mn}(\text{OH})_2$  plus  $\text{Fe}(\text{OH})_3$ .

Like the other authigenic minerals, manganese nodules occur in areas of extremely slow deposition, in this case in the abyssal depths of the oceans. The large nodules are common only at the surface of the sediments, but smaller ones may be present within the sediment. The nodules appear to be most common in areas of red clay, but are also found where organic oozes

cover the deep ocean floor. Photographs of the sea floor where manganese nodules are abundant show scour and ripple marks, indicating active bottom currents in such areas.

Since the Challenger Expedition of the 1870's, when manganese nodules were first collected, geologists and chemists have pondered their origin. At the present time three theories are prevalent. Goldberg and Arrhenius (1958) suggest that the ocean is saturated with respect to manganese and iron and that the addition of these two elements by river runoff causes precipitation of hydrated oxides in colloidal form. As the colloids settle they "scavenge" cobalt, nickel, copper, molybdenum, and other metals from the sea water. The colloidal particles carry a charge, and when they reach the sea floor they are attracted to any projecting objects, for example, sharks' teeth. Bottom currents carry a new supply of water bearing the colloids to the nucleus, and the nodules are thereby built up layer by layer. The rate of accretion in this manner is of the order of 0.01 to 1.0 mm per 1,000 years.

A second theory favors biological activity as a cause of the precipitation, and is based on the discovery of bacteria on some of the nodules (Butkevich, 1928). It is generally conceded that the bacteria are on the nodules, but it has not been demonstrated convincingly that they cause precipitation of manganese and iron in the deep sea environment.

Recently, a third hypothesis has been proposed by Bonatti and Nayudu (in press). On the basis of petrographic evidence they believe many of the nodules to be the result of submarine alteration of volcanic rocks. Their evidence has prompted a reexamination of many nodules from different parts of the Pacific. It has been suggested by Arrhenius, Mero, and Korkisch (1964) that both the volcanic and the precipitation hypotheses may account for the nodule formation. Further, they suggest that the percentage of cobalt in the nodules varies according to origin and that it may be possible to distinguish the two types on the basis of the manganese-cobalt ratio; a low ratio for the volcanic type, a high ratio for the type formed by slow precipitation.

Whatever the origin of the nodules, they are certainly abundant. It has been estimated from deep-sea photographs and dredge hauls that in some parts of the Pacific there are more than 8 pounds of nodules per square foot, more than 100,000 tons per square mile. Mero (1962) suggests there may be as much as a trillion tons of nodules on the floor of the Pacific alone.

### Oceanic Prospecting

Prospecting for minerals on the floor of the ocean is now possible. Considerable information is available on the conditions of occurrence for both



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authigenic and placer deposits, and equipment can be obtained for submarine exploration.

The hypsographic curve of Figure 2 summarizes the depth distribution of placer and authigenic deposits in the Pacific Ocean. The curve represents the percentage of Pacific Ocean bottom of different water depths. Indicated on the curve are the depth zones in which placer deposits, glauconite, phosphorite, and manganese nodules are most likely to exist. The area of the Pacific Ocean represented by each zone is also indicated. Placer deposits occur in the interval 0 to 70 fathoms, which represents an area of about 2.8 million square miles or approximately 4 percent of the total area of the Pacific Ocean. Glauconite is most likely in the depth interval 10 to 400 fathoms, which is about 7 percent of the Pacific Ocean basin or approximately 5.0 million square miles. For phosphorite the depth of occurrence is primarily 20 to 200 fathoms, representing 5 percent of the basin or 3.5 million square miles. Manganese nodules occur at depths generally greater than 200 fathoms, common to about 93 percent of the Pacific, an area of about 65 million square miles.

From this type of analysis it is possible to make a first approximation of the potential prospect areas, keeping in mind that not all of the area is suitable for accumulation of a given mineral deposit. Manganese nodules, for example, do not occur in areas of relatively rapid deposition of detrital sediment. From knowledge of the distribution of deep-sea sediment, the area of terrigenous deposition would be eliminated. Only the areas of relatively slow deposition in which the biogenous oozes and red clays are present would be considered in prospecting for the nodules. Fortunately, this type of information is available.

In prospecting for phosphorite, areas where depth of water ranges from 20 to 200 fathoms should be outlined. Particular attention would be focused on those spots where phosphate-rich water is brought to the surface by upwelling. Again, there is a considerable amount of information available on the location, period, and nature of the upwelling process (Wyatt and Kujala, 1962).

Placer deposits lie between the 70 fathom contour and the shoreline. The position of known placers on land, and the location of streams draining mineralized zones would be used to determine the favorable areas on the continental shelf for initial exploration.

General mineral prospect areas for the northeast Pacific are shown in Figure 3. The areas outlined are based primarily on the bathymetry of the region. Placer prospects are shown in the areas shallower than 70 fathoms. Glauconite and phosphorite prospects are mapped together for the interval from 70 to 400 fathoms. It is quite possible that these two authigenic minerals might occur in water less than 70 fathoms deep. However, they would

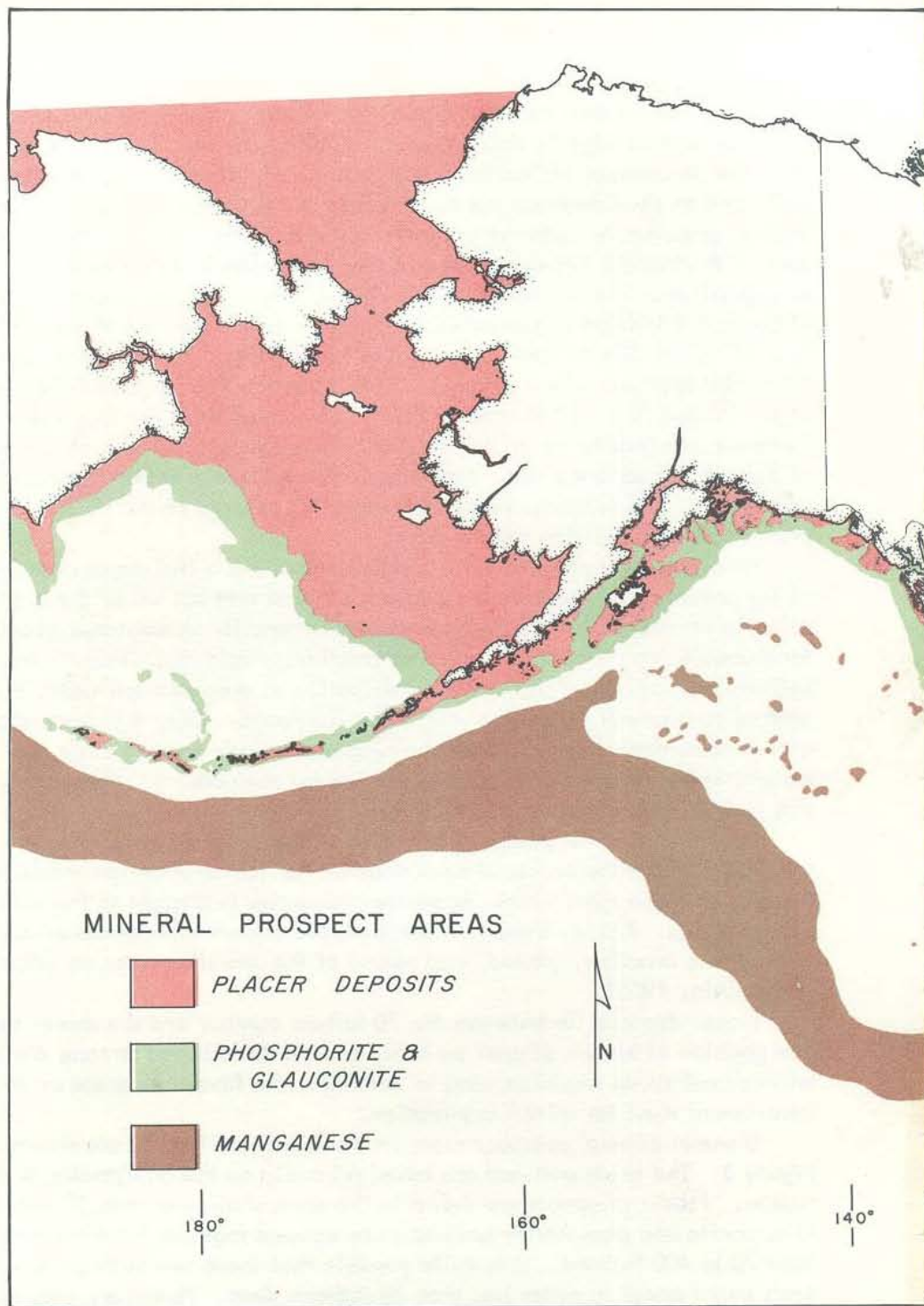


Figure 3. General mineral prospect area of the northeast Pacific Ocean

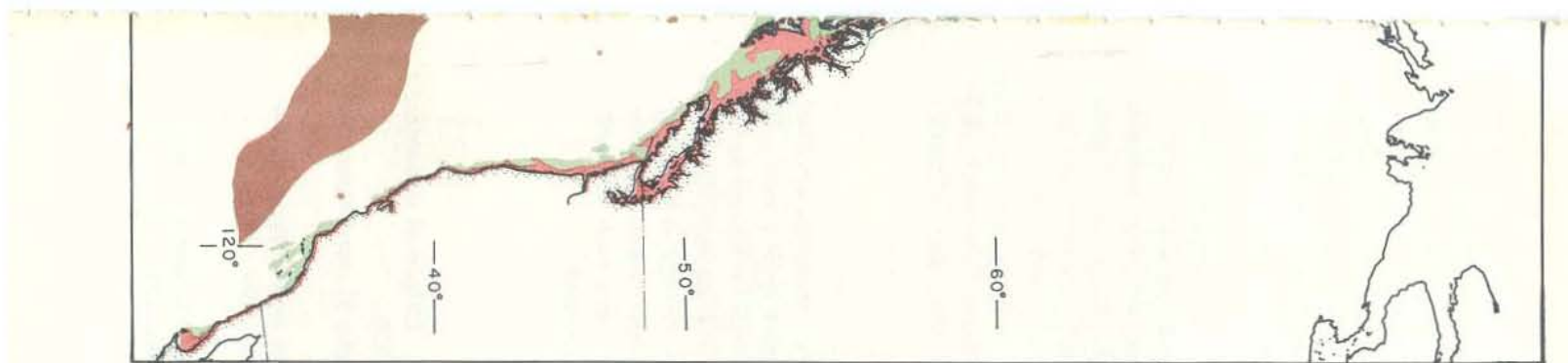
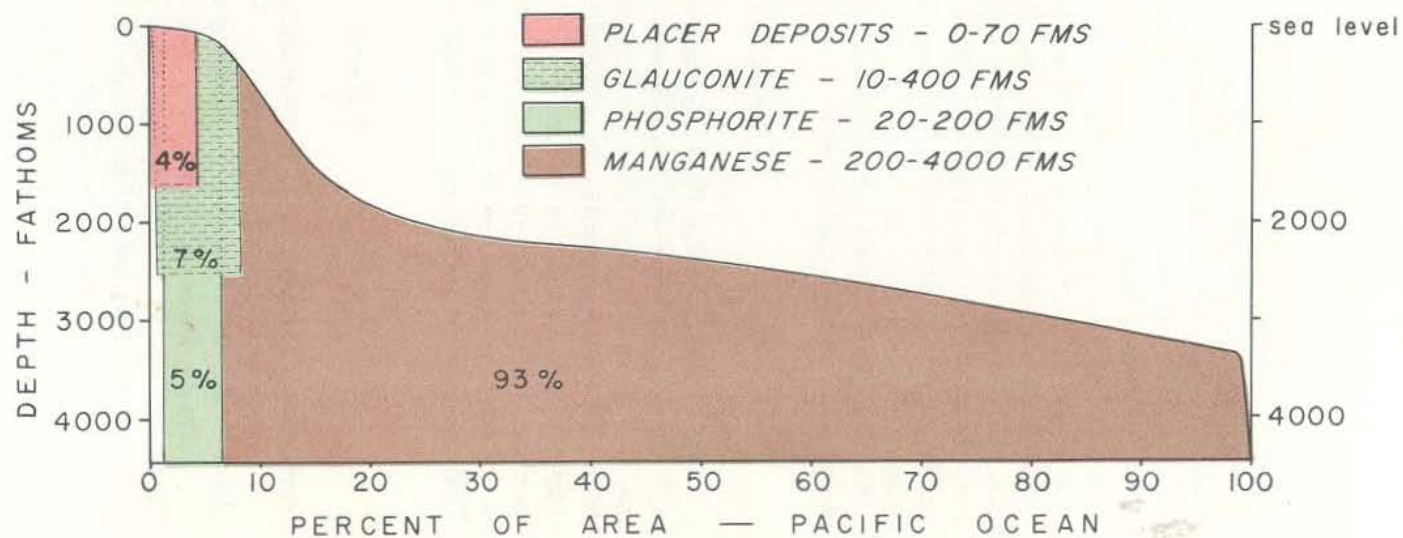


Figure 2. Hypsographic curve showing the percentage of Pacific Ocean floor on which various mineral deposits are likely to occur.



not be in the same area as the placer deposits, because the placers are detrital minerals and are concentrated in areas of detrital deposition.

The manganese nodule area, which is indicated seaward of the other prospects, does not conform strictly to bathymetry. Deep sea terrigenous sediment is known to be present over much of the floor of the Bering Sea and much of the abyssal plain area adjacent to the United States and Canada. The isolated manganese prospects off Canada and Alaska are based on known occurrences of the nodules on the summits of seamounts rising above the abyssal plains.

Geological and geophysical equipment designed for oceanographic research can be used in the prospecting for marine mineral deposits. Echo-sounders and sub-bottom profilers can delineate ancient drainage patterns, buried erosional terraces on which beach placers might occur, and Pleistocene beaches. Bottom sampler and gravity and jet coring devices can be used to obtain surface and subsurface samples of sediment and rock. A variety of dredges is available for the collection of rocks or nodules. Deep sea cameras will obtain photographs of manganese nodules from which estimates of abundance can be made. In shallow water, television is feasible.

### Conclusion

It is inevitable that the known commercial mineral resources on land will be expended and new deposits must be found to take their places. The day will certainly come when the mineral prospector will be forced to look to the sea for ore deposits. In all likelihood the sea will be exploited successfully long before that day arrives. Advancing technology is bringing us closer to the time when those with initiative and imagination will turn to the sea simply because it is easier to make a profit there than on land. That day may not be far away. In fact -- it may be at hand.

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#### NEW EXHIBITS AT PORTLAND OFFICE

On display in the department's Portland office is a 5-foot bathymetric relief model of the continental terrace which lies off the Oregon coast. The three-dimensional model, which was built by C. J. Newhouse, illustrates graphically the bathymetric charts compiled by Dr. John V. Byrne for a series of Ore Bin articles on the continental terrace. Contours on the model are shown in fathoms and depth in progressively darker shades of blue. Outlined are the areas of federal lands offered for lease and the 3-mile limit of state-owned offshore land.

Another new display in the department's Portland office is a collection of volcanic bombs, lava, cinders, and other once-molten materials that erupted from recent volcanoes in Oregon. Most of the specimens came from Diamond Craters in central Harney County and were collected by Norman Peterson and Edward Groh, whose report on this unique volcanic area appeared in the February issue of The Ore Bin.

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### PRELIMINARY GEOCHEMICAL DATA IN OPEN FILE

The results of the analysis of 982 stream-sediment samples, collected as a part of the Department's geochemical sampling program, are available for inspection at the Department's office in Portland. Samples were analyzed by rapid wet-chemical methods for copper, zinc, and molybdenum. The information will not be published until field checks can be made to verify anomalies.

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### PLASTIC RELIEF MODEL OF STATE INSTALLED IN DEPARTMENT

A plastic relief model of Oregon has been installed in the Department's office in Portland. The model, composed of 18 separate sheets obtained from the Army Map Service, measures approximately 7 by 10 feet. Vertical exaggeration is twice the horizontal. The completed map clearly shows up many geological relationships and provides a reasonably accurate topographic base for the entire state.

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### ANTELOPE-ASHWOOD REPORT PUBLISHED BY USGS

Recently issued by the U. S. Geological Survey is Bulletin 1161-D, "Geologic Reconnaissance of the Antelope-Ashwood Area, North-Central Oregon," by Dallas L. Peck. The area described and mapped covers about 750 square miles in Jefferson, Wasco, Crook, and Wheeler Counties. Rocks exposed include partially metamorphosed pre-Tertiary rocks; Eocene Clarno Formation; late Oligocene and early Miocene John Day Formation; middle Miocene Columbia River Basalt; Pliocene The Dalles Formation; Pliocene or Pleistocene basalt; and Quaternary loess and alluvium. Special emphasis is given the John Day Formation, which consists of about 4,000 feet of tuff and rhyolitic ash and lava flows, divisible into nine mappable members. Discussed in some detail is the Friday Ranch agate deposit, which occurs at the base of a welded ash flow in the John Day Formation.

The 26-page bulletin contains photographs and a geologic map. It may be obtained from The Superintendent of Documents, U.S. Government Printing Office, Washington, D. C. The price is 65 cents.

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### BRISTOL REAPPOINTED TO GOVERNING BOARD

Governor Hatfield has reappointed Fayette I. Bristol to the department's Governing Board for a 4-year term beginning March 16, 1964 and ending March 15, 1968. Mr. Bristol, who is President of the Bristol Silica Co., Grants Pass, Oregon, has been a member of the board since April 1961.

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### EXPLORATION CONTRACT APPROVED FOR OREGON KING

Oregon King Consolidated Mines, Inc., of Portland has contracted with the Office of Minerals Exploration for assistance to explore for silver and gold in Jefferson County, Oregon. Total cost of the work is estimated at \$55,150, of which the Government participation is \$27,575.

Work will consist of underground exploration by drifting, crosscutting, and long-hole drilling for silver- and gold-bearing ore bodies in shear zones cutting andesitic country rock of the Clarno Formation.

Control of the Oregon King mine near Ashwood was acquired by the applicant in 1962. In preparation for the exploration, a shaft and several levels have been rehabilitated.

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### POWER LINE AIDS MINERAL INDUSTRY

The longest tower-to-tower span of electric distribution line in Oregon is in a power-distribution facility servicing Oregon's mineral industry. The big span, which was built by the California-Pacific Utilities Co., covers a horizontal distance of 3,380 feet, or well in excess of 0.6 of a mile, according to Cal-Pacific officials. This distribution facility carries 22,000 volts across the summit of the Elkhorn range, Baker County, from the Marble Creek quarry of the Chemical Lime Co. to a newly developed quarry located at the head of Baboon Creek, also in Baker County. Intended use of the power is for the crushing plant at the new quarry.

This same distribution facility contains a second span of notably long proportions - 2,988 feet, horizontal tower-to-tower distance. Both long spans occur in the section of line located west of the Elkhorn summit.

Chemical Lime produces a variety of burned lime products at a plant located in the Baker Valley, at Wingville. Since the beginning of operations in 1957, raw limestone has been obtained from the Marble Creek quarry.

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#### HELLGATE CANYON

Hellgate Canyon is a narrow, steep-walled canyon about half a mile long, where the waters of the Rogue River flow swift and deep. This scenic attraction can be enjoyed by those who drive along the Rogue through the historic mining center of Galice in southern Oregon. Vantage points along the Merlin-Galice road, high on the north edge of the canyon, provide spectacular views. The feature is 14 miles by road northwest of Grants Pass.

The Rogue has carved this canyon in hard, massive, gray-green rocks which, because of their color, are commonly called "greenstones." These rocks were originally products of volcanoes and consisted of layered dacitic tuffs, andesitic agglomerates, and lava flows. As the result of heat and pressure from deep burial and subsequent folding they have been altered (metamorphosed) almost beyond recognition. The greenstones are interbedded with sedimentary rocks of the Galice Formation of Late Jurassic age, and thus are about 150 million years old.

Prominent serpentine dikes have intruded the greenstones along two major northeast-trending faults named for Hellgate Canyon. East Hellgate fault crosses the river at the upper entrance to the canyon and is visible as a zone of highly sheared serpentine in the road cuts. West Hellgate fault is less sharply defined. It crosses  $1\frac{1}{2}$  miles down the river and fans out in a broad zone of sheared serpentine near Hellgate Bridge. The serpentine within the faults is a greenish-black, altered, igneous rock with characteristic waxy luster on its sheared surfaces.

The main controlling factor in the shaping of the valley of the Rogue has been the hardness of the rock encountered by the river as it carved its way downward. Hellgate Canyon marks an abrupt change in the river gradient. Upstream from the canyon the Rogue glides with gentle gradient in a broad, alluviated valley which is underlain by easily eroded, in part decomposed, diorite. Downstream the river dashes through a steep canyon with numerous rapids in the more resistant rocks of the Galice, Rogue, and Dothan Formations. (Photograph by Oregon State Highway Dept., Travel Division)



## THE RESIDUAL EXPANSIBILITY OF PUMICE

By N. S. Wagner\* and L. L. Hoagland\*\*

Pumice is a glassy, volcanic rock with a frothy texture. Its color is generally whitish or pearly gray, but sometimes tan. The texture and composition of this rock, when fresh and unweathered, make it suitable for use as a natural lightweight aggregate. Pumice aggregate has its chief application in lightweight, fire-resistant, and insulating materials in which structural strength is needed.

Perlite, another volcanic glass of similar chemical composition, is a dense rock that, when crushed and heated to certain temperatures, expands and produces a synthetic pumice. Like pumice, it is marketed for a number of lightweight aggregate purposes. Expanded perlite, however, is many times lighter in weight than pumice and consequently is more successful in extra-lightweight applications.

The purpose of this study was to determine if pumice, which is so similar chemically to expanded perlite but is heavier, has the capacity for further expansion. Laboratory experiments proved that additional cellularity could be induced in the pumice treated and that an extra-lightweight aggregate could be produced.

### Laboratory Tests and Results

Expansion tests were run on pumice samples originating from sources in the Bend area, Deschutes County, where fine-quality pumice block and plaster sand aggregate has been produced continuously since 1946. Both fresh and moderately weathered pumice were tested at the outset to determine if any capacity for expansion existed and whether or not alteration had any appreciable bearing on the expansibility. The samples for this phase of the investigation originated from widely dispersed locations and were furnished by William E. Miller, Central Oregon Pumice Co., Bend, Oregon. The samples were all crushed and screened to a minus 20, plus 28 mesh. Testing was carried out in an electric muffle furnace at 1,900°F with five-second exposures per test. Results are listed on the following page.

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<u>Locality</u>	<u>Sample description</u>	<u>Volume increase</u>
1.	Fresh, commercial grade pumice	100 %
2.	Same	95 %
3.	Same	105 %
4.	Moderately weathered pumice	none
5.	Same	50 %
6.	Same	30 %

These results indicate that some pumice has a capacity to develop a cellularity over and above that with which it was endowed by nature. Since this capacity is greatest in fresh, unweathered material, Locality 3 was selected as offering the material best suited for continued study. A new sample was therefore acquired from this source and its volume increase checked by a repeat test on a fraction again screened minus 20, plus 28 mesh and again exposed to 1,900° F. for five seconds. Volume increase for this check test was 110 percent, which compares favorably with the initial (105 percent) expansion result.

Using a coarser (minus 2.362 mm, plus 2.00 mm) fraction, test portions of this sample were expanded at 50° intervals from 1,700° to 1,900° F. and held in the furnace for 15-second intervals:

<u>Degrees F.</u>	<u>Volume increase</u>
1,900	90 %
1,850	100 %
1,800	110 %
1,750	95 %
1,700	75 %

Microscopic examination of the expanded products reveals that considerable fusing and collapse of the bubbles had taken place on the surface of the particles in the test made at 1,900° F. Conversely, no fusing or collapse of the surface structures is evident on the particles from the test portions expanded at temperatures of 1,800° F. or lower, despite the prolonged heating. From these observations it is apparent that maximum expansion for this particular pumice takes place in the vicinity of 1,800° F., that temperatures below 1,750° F. result in only partial expansion, and that destruction of induced cellularity is appreciable at temperatures above 1,850° F. The volume increase of 110 percent shows that it is technically possible to reduce the weight of this particular pumice by half. Pumice in aggregate form normally weighs 33 pounds per cubic foot. The artificially expanded

aggregate would then weigh about 15 pounds per cubic foot -- a weight closely approaching that of expanded perlite. Expansion of perlite in a muffle furnace usually results in volume increases somewhat lower than are obtained by expansion in a commercial plant. If this holds true for pumice, an even lighter expanded product might be obtained.

### Conclusions

Although a great deal more study will have to be made before the expansibility potential of pumice can be fully evaluated, the present findings suggest that such study is warranted because (1) some pumice does have a capacity to expand, and (2) the expanded product is competitive from a weight standpoint for many of the extra-lightweight aggregate applications.

Future investigation will necessarily have to include tests to determine if pumice from other localities will expand as did the Locality 3 pumice. Needed also will be studies to establish processing costs and the suitability of artificially expanded pumice as an aggregate. Should further study prove fresh pumice expansible, the economics of expansion feasible, and the expanded product physically suitable for use in the field of special-purpose, extra-lightweight aggregate applications, then the expansibility potential of this "common variety" rock could be of considerable commercial importance.

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### BUFFALO MINE TO EXPAND OPERATIONS

Jim Jackson, operator of the Buffalo mine in Grant County, has been granted a Small Business Administration loan of \$105,000 with which to expand operations and up-date facilities. The Buffalo has been the state's principal lode-gold producer for many years. Exploratory development during the past 3 years has demonstrated downward continuation of the vein to the 600 level and its persistence for a strike length of several hundred feet. Production during this exploratory period has been limited to the milling of development rock. In 1963 approximately 1,400 tons of such ore produced nearly 320 tons of concentrates. Jackson reports that increased silver values have been found on the 600 level.

As a result of the loan a more accelerated mining program is planned for the coming summer.

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## 1964 AMC MINING CONVENTION PLANS PROGRESS

Arrangements for the 1964 Metal Mining and Industrial Minerals Convention of the American Mining Congress to be held in Portland September 13 to 16 are nearing completion, J. Allen Overton, Jr. (AMC Executive Vice President), announced in Portland concluding meetings held April 7 and 8 of the convention chairmen and the program committee.

Under the direction of General Chairman Earl S. Mollard (Western States Representative of The Hanna Mining Co., Myrtle Creek, Oregon, and chairman of AMC's Western Division) the arrangements committee is developing plans for the various convention activities which include a welcoming luncheon, two evening functions, special events for the ladies, and field trips. Wesley P. Goss (President, Magma Copper Co., Superior, Arizona), program chairman, announced upon completion of his committee's meeting that the Portland convention will have one of the most outstanding programs ever presented by the AMC.

The following Pacific Northwest industry leaders are serving in important arrangement committee posts:

Ernest G. Swigert, honorary chairman, Chairman of the Board, Hyster Co., Portland, Oregon; Earl S. Mollard, general chairman, Western States Representative, The Hanna Mining Co., Myrtle Creek, Oregon; Hollis M. Dole, secretary, State Geologist, State of Oregon Department of Geology and Mineral Industries, Portland; Veryl N. Hoover, co-chairman of the welcoming committee, Vice President of Pacific Power & Light Co., Portland; Frank E. McCaslin, co-chairman of the welcoming committee, President of Oregon Portland Cement Co., Portland;

Fayette I. Bristol, co-chairman of the welcoming committee, President of Bristol Silica Co., Rogue River, Oregon; Donald R. Dawson, chairman of the publicity committee, of Dawson, Turner & Jenkins, Portland; Donald Tilson, co-chairman of the trips committee, Regional Manager, Aluminum Co. of America, Vancouver, Washington; Emmons Coleman, co-chairman of the trips committee, Manager, The Hanna Mining Co., Riddle, Oregon; James H. McClain, co-chairman of the trips committee, Assistant to General Manager, Wah Chang Corp., Albany, Oregon; Mrs. Earl S. Mollard, honorary chairman of the ladies' committee; and Mrs. Veryl N. Hoover, Mrs. Fayette I. Bristol, and Mrs. Frank E. McCaslin, co-chairmen of the ladies' committee.

Hotel reservations are being handled through the American Mining Congress Housing Bureau, operated by the Portland Convention Bureau at 1020 S. W. Front Ave., Portland, Oregon 97214. First assignment of accommodations will be made in June.

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