

# **The Ore Bin**



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**STATE OF OREGON  
DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES**

## **The Ore Bin**

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## ECONOMICS OF GEOTHERMAL DEVELOPMENT

The following article by Dr. Robert W. Rex is the text of his remarks to the Sub-Committee on Energy, Committee on Science and Astronautics, U.S. House of Representatives, on September 18, 1973. This text was previously published in Geothermal Energy, vol. 1, no. 4, December 1973. We are reprinting it in this issue of The ORE BIN because we believe the thoughts expressed are pertinent to Oregon at this time and should have as wide dissemination as possible.

Dr. Rex is the President of Republic Geothermal, Inc., Playa del Rey, California. He was formerly Exploration Manager of Pacific Energy Corporation, and prior to that he headed the geothermal energy studies at the University of California, Riverside.

For many years, Dr. Rex has been one of the nation's most articulate spokesmen for geothermal power development and a leader in applying the multipurpose concept to development of geothermal resources.

### Hearing on Geothermal Energy

#### Introduction

Mr. Chairman, members of the Sub-Committee:

I am honored to be invited to present comments on H.R. 9658\* and to discuss the potential for geothermal energy in the U.S.

The previous witnesses have given you a picture of Federal effort in geothermal energy research and of the potential both at home and abroad. Dr. Smith\*\* has also informed you of the very exciting and remarkably successful program at the Los Alamos Scientific Laboratory to extract useful heat from hot dry rock. It is my intention to brief you on my determinations

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\*Bill for funding geothermal studies

\*\*Morton Smith, A.E.C. Los Alamos Scientific Laboratory, Project on Extraction of Power from Hot Dry Rock

on the relationship between resource price and the quantity of potentially available resources. Then I intend to present an analysis of the revenue accruing to the government from geothermal development of Federal lands by private industry.

#### U.S. resource size - price relationship

It is my opinion that most of the variations in the estimates of U.S. geothermal potential are caused by variations in the assumed market price for this energy. Most of the conservative estimates were the result of assuming energy prices fixed at the 1970, 1971, or 1972 levels. Clearly this is unrealistic. The National Petroleum Council clearly states that their most recent reserve estimates were based on "current market prices", whatever that means. There is a logical and overweaning reason for this. County government places a property tax on reserves in the ground called the ad valorem tax. No energy extraction company is going to allow an exploration manager to gather data on presently non-marketable reserves because any such action would most probably trigger ad valorem taxes on such marginal reserves. Consequently, the geothermal, oil, and natural gas industries assiduously avoid bankrupting themselves by gathering data on currently non-profitable energy reserves. This means that the public sector has great difficulty in obtaining a realistic appraisal on the relationship between total U.S. recoverable reserves and a reasonable market price for those reserves. I view this head-on conflict between Federal and county interests to be the overwhelming fundamental cause of the present energy crisis. Without this conflict we would long ago have had the necessary information to develop a rational national energy policy and could have avoided the present dislocations.

My colleagues and I have attempted to model many hundreds of geothermal ventures including dry steam, various types of hot water, and hot dry rock. These models suggest the energy price which would be required to sustain a viable corporate venture. Then I have tried to make regional estimates of resource size. The combined results of these analyses are given in Table 1, which compares known, probable, and undiscovered reserves as a function of cost. In order to keep within the areas of maximum data available at the time of preparation of this table, I focused on steam, hot water, and hot dry rock in the states west of the Rockies. The addition of the Gulf Coast potential for the geopressed geothermal resource would serve to substantially increase the present figures.

The two primary points that I would like to make in this area are as follows:

First, the data available suggest that large scale utilization of the U.S. geothermal resource is very close to economic feasibility. Small scale use is developing rapidly at present. Consequently, positive action by the Federal government has the potential for major leverage by the private sector.

By this I mean that the forces of the marketplace are bringing geothermal energy into the U.S. energy portfolio. Congress, however, has the ability, by providing seed money for technology demonstration, to accelerate by from ten to twenty years the pace of development of the U.S. geothermal potential and in this way save substantial foreign exchange liabilities and help control inflation.

Second, there is a large amount of dissolved natural gas in the geopressed Gulf Coast geothermal waters. The dollar value of this gas is about double the value of the thermal and pressure energy. However, the wells to develop this resource will be deep (often 14,000 feet or more) and expensive. The threshold price for this gas is about \$1.00 per mcf [thousand cubic feet]. The Federal Power Commission is presently rejecting sales prices above \$0.50 per mcf. Consequently, the FPC is preventing development of this gas reserve by its pricing policy. It should be noted that imported natural gas costs the U.S. more than \$1.00 per mcf, as does synthetic natural gas. Current fuel oil prices are the equivalent of from \$0.90 to \$1.10 per mcf. This FPC pricing policy is therefore blocking the development of the geopressed natural gas resource.

The Resource Appraisal Panel of the National Science Foundation Conference on Geothermal Energy in September 1972 made a preliminary calculation of the size of the recoverable resource on the Gulf Coast. It is 2,700 trillion cubic feet or enough gas to meet U.S. needs for 50 years.

It is my recommendation that high national priority be given to a research and development program to appraise this resource, demonstrate the technology necessary to utilize it, and develop an understanding of the environmental problems associated with its development. I view this need as so great that I would prefer to see it handled by existing entities such as the non-nuclear activities group of the A.E.C., the National Science Foundation, and the U.S. Geological Survey rather than wait for a new entity. House bill H.R. 9658 is a partial step in this direction, but by itself it is less important than adequate program funding within the present National Science Foundation structure. If H.R. 9658 comes into law, it will be a positive move. If not, it is imperative that present programs be funded at increasing levels to permit acceleration of the pace of development of geothermal technology.

#### Revenue accruing to government from development of Federal lands

It is clearly evident that development of geothermal plants in the U. S. displaces imported petroleum. This means that the fuel bill for the generation of electricity can either be a foreign exchange burden or it can result in economic growth of the U.S. economy and yield tax, royalty, and rental revenue to the government.

In order to illustrate the large contribution that development of Federal lands for their geothermal potential makes to the U.S. taxpayer, I have

Table 1. Amount of producible geothermal energy in the United States  
(Mwcent\* of electricity)

Energy price (mill/kwhr) <sup>a</sup>	Known reserves		Probable reserves		Undiscovered	
	Amount	Areas**	Amount	Areas**	Amount	Areas**
2.9- 3.0	1,000	1	5,000	1	10,000	1
3.0- 4.0	30,000	1-2	400,000	1-4	2,000,000	1-5
4.0- 5.0	---	---	600,000	1-6	12,000,000	1-7
5.0- 8.0	---	---	---	---	20,000,000 <sup>b</sup>	d
8.0-12.0	---	---	---	---	40,000,000 <sup>c</sup>	d

<sup>a</sup> Mills per kilowatt hour in 1972 dollars

<sup>b</sup> Hot, dry rock at less than 6.1 km (20,000 ft.) depth

<sup>c</sup> Hot, dry rock at less than 10.7 km (35,000 ft.) depth

<sup>d</sup> Development of hot, dry rock energy is assumed over 5 percent of the area of the western third of the U.S. Hot, dry rock systems development is based on hydraulic fracturing or cost-equivalent technology. Present drilling technology is assumed; new low-cost deep drilling could substantially improve these economics.

\* Megawatt-Century: steam reserves sufficient to generate one megawatt of electricity for one century using efficiencies of present technology.

\*\* Areas: 1. Clear Lake-The Geysers; 2. Imperial Valley; 3. Jemez area, N.M.; 4. Long Valley, Calif; 5. remainder of Basin and Range area of western U.S.; 6. Hawaii; 7. Alaska

Table 2. Revenue to the public sector from 1,000 megawatts  
for 30 years from Federal land  
(including depletion allowance at 22 percent)

Lease rental	\$ 45,000	
Royalty	244,887,000	
Federal income tax	482,998,000	
Total Federal		\$ 727,930,000
State income tax	107,578,000	
County ad valorem tax	177,154,000	
Total other governments		284,732,000
Total government revenue		\$1,012,662,000

### Appendix to Table 2

1. Plant factor = .909 (100 MW for each 110MW capacity)
2. Well size: 7.5 MW (150,000 lbs/hr)
3. Disposal: 1 disposal well for each producing well (first dry hole used as a disposal well)
4. Drilling program for each 55 MW unit:

Year	1	2	3	4	5	6	7	9	12
Exploratory wells	2	-	-	-	-	-	-	-	-
Development wells	-	3	3	-	-	1	1	1	1
Dry holes	1	1	1	-	-	-	-	-	-
Disposal wells	1	3	3	-	-	1	1	1	1

### 5. Cost of wells:

	<u>Tangible</u>	<u>Intangible</u>	<u>Total</u>
Exploratory	\$117,000	\$273,000	\$390,000
Development	116,000	174,000	290,000
Dry holes	117,000	273,000	390,000
Disposal	36,000	54,000	90,000

6. Gathering lines: \$15.5/KW capacity (\$852,500 for 55 MW unit)
7. No operator fee
8. No production or severance taxes
9. Overhead at \$50,000 per year per unit plus a percentage of land, drilling, and operating expense
10. Depreciation: straight line
11. Geology/Geophysics: \$20,000 in each year of drilling plus \$7,000 per year every year
12. Acreage: 560 acres per 55MW unit
13. Royalty: 10 percent
14. Lease rental: \$1/acre in years 1-4
15. Working capital: \$200,000 per 110 MW capacity
16. All equity capital: no debt structure; no interest accrual
17. Inflation: 5 percent per annum on all costs
18. Steam production begins in year 5
19. Gathering lines constructed in year 4
20. Steam sales price: 4.5 mills/kwhr in year 1; 5 percent yearly increase
21. State income tax at 9 percent
22. Federal income tax: 22 percent on total taxable income  
26 percent on taxable income over \$25,000
23. Ad valorem tax: 10 percent of assessed value (25 percent of market value determined by discounting net income before taxes)

\* \* \* \* \*

analyzed the economics of development of ten 100 megawatt units on Federal lands and considered the income stream accruing to the public sector from the 1,000 megawatts of power over 30 years. The various assumptions that went into these calculations are given in the appendix to Table 2. The calculations are based on development of hot water fields such as are found in many places in the western U.S. There is a possibility of some latitude in local cost factors that vary from field to field but this will have relatively small impact on the tax income stream. The results are given in Table 2.

Every 1,000 megawatts of geothermal development on Federal lands yields about one billion dollars of public revenue; 73 percent to the Federal government, 11 percent to State governments which have income taxes, such as California, and 18 percent to county governments.

I strongly recommend that the enormous return on investment to the government on Federal geothermal research be acknowledged in national energy planning and budgeting. Furthermore, it becomes obvious that the slow pace of implementing the Federal lands leasing program is depriving the Federal government of a significant income stream. It illustrates that the earlier arguments concerning grandfather rights and a possible "give-away" of rights by granting grandfather leases is without basis. The income stream from royalties completely swamps any conceivable lease rental considerations.

If the projections for development of from 40,000 to 90,000 megawatts of geothermal energy in the next decade are realized, we will add 40 to 90 billion dollars in tax revenue to the public treasuries which would otherwise have been lost.

I seriously doubt that any other Federal investment in energy technology stimulation offers a better promise than does geothermal energy in all of its aspects, including hot waters, geopressured resources, and hot dry rock.

\* \* \* \* \*

#### ENERGY FORUM PROCEEDINGS TO BE PUBLISHED

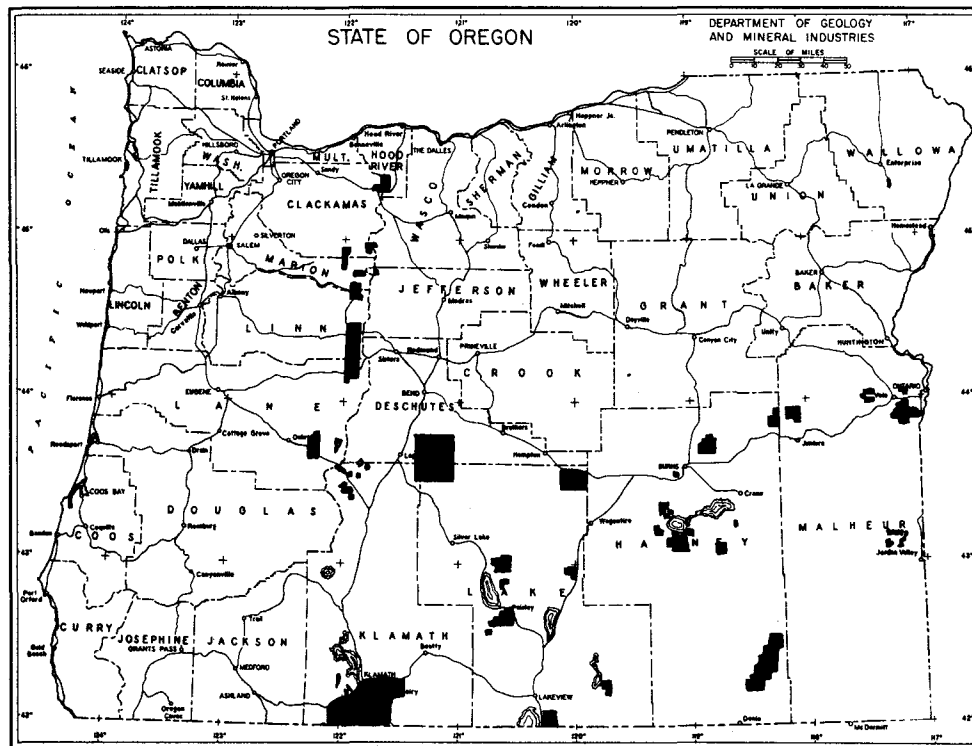
Authorities on wind power, solar power, geothermal power, conversion of oil shale, and coal gasification and liquefaction spoke to a capacity audience at the "Citizens Forum on Potential Future Energy Sources" held January 17, 1974, at Portland State University. Because of the great interest shown in these possible supplementary energy resources, the speakers have agreed to submit their reports to the forum sponsors (this Department and the Portland State University College of Science) for publication in a proceedings volume. Availability of the forum proceedings will be announced in The ORE BIN upon publication.

\* \* \* \* \*



## GEOHERMAL LEASING IN OREGON

February 1, 1974, was the first drawing of wildcat lease applications for geothermal exploration on Federal land in Oregon. Sixty-one companies and individuals filed for a total of nearly one million acres in the western Cascades and southeastern Oregon. In the Cascades, leasing was confined to Hood River, Clackamas, Marion, Linn, and Lane Counties. East of the Cascades, leasing was in Deschutes, Klamath, Lake, Harney, and Malheur Counties with about 200,000 acres filed for in Deschutes, Harney and Malheur Counties. Heaviest filing occurred around Klamath Falls, the Alvord Desert, Glass Buttes, Newberry Crater, and along a north-south band near Belknap Springs.



Approximate locations of geothermal leasing on Federal lands in Oregon.

In some areas of the Alvord Desert, lease filings by three or more companies and individuals overlapped, raising the possibility that the area may be declared a KGRA (Known Geothermal Resource Area), which will require an environmental impact statement before leasing by competitive bidding can begin.

It is unknown whether or not lease applications will be approved in the Newberry Crater, since it is primarily a recreation area.

Sun Oil Co., the largest filer in Oregon, applied for about 158,271 acres. Next largest filer was California Geothermal Inc., with about 99,493 acres, followed by Chevron Oil Co. with about 94,849 acres. However, since the maximum acreage allowed per company or individual is 20,480, many applications will be withdrawn.

Other filers include several individual Oregonians, the Hunt family of Texas, Magma Power Co., Earth Power Co., Gulf Oil Co., and the City of Burbank, California.

Further information on leasing can be obtained from the Bureau of Land Management office in Portland.

\* \* \* \* \*

#### OREGON BLM OFFICER APPOINTED

E. J. Petersen has been named Oregon Associate State Director for the Bureau of Land Management by BLM Director Curt Berklund, effective January 1, 1974. Petersen, who joined BLM in 1949 as a forester in Coos Bay, Oregon, was transferred to California as a district director in 1955 and progressed to the position of Associate BLM Director for California. Archie Craft, BLM Director for Oregon, said that Petersen's broad previous experience will make him a valuable member of the BLM staff, and that he will be particularly helpful in managing recreational use of the national resource lands in Oregon.

\* \* \* \* \*

#### AGE DATES OF OREGON ROCKS TABULATED

Two open-file reports tabulating radiometric ages of Oregon rocks are available for inspection at the Department's library in its Portland office.

One of the reports, entitled "Radiometric ages of Oregon and Washington through June 1972," was compiled by Jennie M. Laursen and Paul E. Hammond, Portland State University, from published and unpublished material. The information in this report is arranged according to geographic areas outlined on accompanying index maps, and specific sample sites are located on state geologic maps.

The second report consists of a series of datings for rocks within the United States compiled from data published from 1956 through 1971. The compilations are by Richard F. Marvin, U.S. Geological Survey, Branch of Isotope Geology, Denver, Colorado. The information is systematized according to year and state. The material available in the Department library is limited to Oregon.

\* \* \* \* \*

## A NEW LOOK AT TEKTITES

Erwin F. Lange  
Portland State University

In The ORE BIN (vol. 27, no. 4, April 1965), the writer called attention to certain similarities and differences that exist between tektites and Oregon's volcanic glasses. At that time there was considerable scientific agreement that tektites were formed by melting and outward splashing of material during the explosive impact of an asteroid, comet, or large meteorite. The main area of disagreement was whether the impact occurred on the earth or the moon. Scientists interested in tektites were about evenly divided between a lunar and terrestrial origin of tektites.

Since that time, tektites have undergone much research based on new and interesting techniques. Also since that time six successful manned moon missions have brought back some 800 pounds of lunar material which has been widely distributed and investigated. Two other areas of the moon were sampled by Russia's unmanned space crafts, Luna 16 and 20, which returned a few ounces of lunar soil to the earth. The careful and intensive investigations of the rocks and soil from the moon do not support a lunar origin of tektites. Many recent studies point more and more to a terrestrial origin.

Tektites are small glassy objects of unusual shape, rarely more than 4 inches in diameter or length. Most of those found are in the shape of spheres, discs, teardrops, and dumbbells (see accompanying photographs). Their form indicates that at one time they were in a hot molten condition and then solidified rapidly after having been aerodynamically shaped. The outer surface is often pitted or covered with worm-like grooves resulting from etching and abrasion. Many of the Australian tektites are encircled with a band or flange of glass, indicating a second period of heating and cooling. Many tektites contain inclusions of air bubbles and of particles, the most common being tiny fused quartz grains called lechatelierites. More recently tiny nickel-iron spherules and the mineral coesite have been detected in tektites, providing evidence that the tektite origin is related to meteoritic impact and explosion.

Unlike meteorites, tektites have never been seen falling, and they are not randomly distributed over the earth's surface. Also, unlike meteorites, they are not being deposited continuously on the earth; instead, they have arrived on at least four separate occasions in four widely separated areas. Today scientists usually refer to the four major tektite areas as strewn fields.

The largest strewn field is in the southwest Pacific region involving Australia, part of China, Indochina, Indonesia, and the Philippine Islands. The associated tektites are generally black but usually appear brown with transmitted light. Dating studies indicate that they are among the youngest



Large tektites from Thailand with teardrop and dumbbell shapes (E. F. Lange collection).



Large button-shaped tektite from Thailand (E.F. Lange collection).

known, with an age of about 700,000 years. A second field is that of the Ivory Coast of Africa, where dating studies show the tektites to be about 1.5 million years old. The third strewn field is a small area in southern Bohemia and southern Moravia, where the tektites, known as moldavites, are generally green and have an age of about 14.8 million years. The moldavites have been known since 1788, when tektites were first referred to in the scientific literature. The oldest tektites are those of Texas and Georgia; they are about 34 million years old.

Much of the newer tektite research deals with a variety of dating studies and with the analysis of trace elements. By using these techniques, attempts have been made to associate the tektites of each strewn field with the formation of a specific meteoritic crater. The Nordlinger Ries, an old meteoritic crater in south-central Germany, has been associated with the moldavite tektite field of Bohemia-Moravia. Impact glass from the crater has about the same age and chemical composition as the moldavites, indicating that both were formed from the same parent material. Africa's Ivory Coast tektites have the same age as impact glass from the great Ashanti Crater, also commonly known as Lake Bosumtvi in Ghana, considered to be a meteoritic crater. These studies strongly indicate that the crater and the tektites were formed at the same time. Glasses from the Henbury, Australia craters have been shown to have a chemical composition similar to the Australian tektites. The Henbury craters cannot, however, account for all of the tektites of the South Pacific. No crater has yet been found for the American tektites.

Deep-sea sediment cores from off the Australian Coast, off the Ivory Coast, and in the Caribbean Sea have resulted in the discovery of a limited number of tiny glassy objects less than a millimeter in size with the characteristic shapes of tektites. These are called microtektites. On the basis of their chemical composition and physical properties they are believed to be a part of the respective Australian, Ivory Coast, and American strewn tektite fields.

In spite of these many studies, which strongly suggest a terrestrial origin, no specific parent materials from which tektites might have originated have yet been identified.

An extraterrestrial origin of tektites is doubtful because tektites are lacking in isotopes that would be formed in space by cosmic ray bombardment. Such isotopes are found in exposed moon rocks and in meteorites that have spent millions of years in space.

The chemical composition of tektites is wholly different from that of meteorites, volcanic rocks, or lunar rocks. Chemically they resemble some terrestrial sandstones such as arkose and graywackes. Many of the moon rocks resemble basalts with some striking differences, these being a lower content of light elements such as sodium and potassium, higher amounts of titanium, zirconium, and yttrium, and low silica concentrations ranging from about 40 to 45 percent. Tektites have high silica content varying from about 60 to 80 percent, with alumina the next most common mineral, ranging



Small tectites  
(1 to 2 inches)  
from Thailand.  
E.F. Lange  
collection.

from about 11 to 15 percent. The rare earth distribution in tectites is wholly different from that in moon rocks.

One of the surprises of the lunar missions was the large number of glassy objects of various colors in the lunar soil. These small objects, mostly less than 1 millimeter in diameter, like microtectites, have many of the usual tectite shapes. The presence of these glassy objects has been explained both as a by-product of meteoritic bombardment and as a scorching phenomenon during a great solar flare. While they resemble tectites, their chemistry is characteristic of moon rocks rather than that of known tectites.

Schnetzer (1970) summarized the origin controversy as follows, "The lunar origin of tectites, a controversial and stimulating theory on the scientific scene for almost 75 years, died on July 20, 1969. The cause of death has been diagnosed as a massive overdose of lunar data."

### Bibliography

The recent literature on tectites is voluminous. The writer suggests the following items, which summarize most of the important literature and expand on the concepts referred to in the above article:

- Barnes, Virgil E., and Barnes, Mildred A., 1973, Tectites: Stroudsburg, Penn., Dowden, Hutchinson, and Ross, Inc., Benchmark Papers in Geology.
- McCall, G. J. H., 1973, Meteorites and their origins: New York, John Wiley and Sons.
- Schnetzer, C. C., 1970, The lunar origin of tectites: Meteoritics, v. 5, p. 221.
- Taylor, Stuart Ross, 1973, Tectites: A post-Apollo view: Earth Science Review, v. 9, p. 101-123.

## IMPORT MINERALS IN JEOPARDY?

In the January 18, 1974 issue of Science, Nicholas Wade warns of the possibility that Third World countries might eventually deny not only oil but other necessary raw materials to the U.S. and other nations. The following excerpts and the accompanying table are from his article entitled "Raw Materials: U.S. Grows More Vulnerable to Third World Cartels." Additional pertinent publications are listed at the end of these excerpts.

Pessimists argue that America's growing dependence on imports for a number of key industrial minerals is making the threat of producer cartels more and more likely. Others believe that as far as nonfuel minerals are concerned, there is at present no commodity whose producers have the right combination of economic strength and political hostility to form a cartel against the United States. Whichever view is correct, the nation's position on nonfuel minerals is an intricate amalgam of diplomacy, economics, and technology, its importance largely unrecognized until the present oil crisis.

But, although rich in minerals, America began in the 1920's to be a net importer. According to the Department of the Interior, U.S. imports of all nonfuel minerals cost \$6 billion in 1971 and are estimated to rise to \$20 billion by 1985 and \$52 billion by the turn of the century.

For 20 nonfuel minerals, including chromium, aluminum, nickel, and zinc, the U.S. already derives more than half of its supply from abroad (see Table 1), and this dependence seems certain to increase. Because of the uneven distribution of minerals in the earth's crust, a handful of countries have dominating positions in several metals. Four countries control more than four-fifths of the world's exportable supply of copper. Malaysia, Thailand, and Bolivia together provide 98 percent of U.S. imports of tin.

Even before the oil crisis broke, concern was expressed for America's vulnerability to group action by producing countries. Collective bargaining by raw materials producers is a "real possibility" in the case of copper, tin, and lead, wrote L. R. Brown of the Overseas Development Council in 1972. More recently, C. F. Bergsten, a former assistant to Henry Kissinger on the National Security Council and now with Brookings Institution, has argued that the U.S.'s neglect of the third world is dangerously myopic in view of the nation's growing dependence on the raw materials controlled by these countries. "Third World countries...have sizeable potential for strategic market power," Bergsten noted in an article in Foreign Policy. If foreign producers lack clout now, they will not always do so. Third world countries expect a rise in standards of living but, while their per capita gross national product has increased somewhat, so has the gap between rich countries and poor. Growth in both affluence and population cannot but intensify the competition for a finite quantity of natural resources. In 1970 the U.S. possessed 5 percent of the world's population but consumed 27 percent of its raw materials, a share difficult to maintain.



Table 1. Percentage of U.S. mineral requirements imported during 1972.  
(Data derived from Mining and Minerals Policy 1973, a report  
by the Secretary of the Interior to the Congress)

Mineral	Percentage imported	Major foreign sources
Platinum group metals	100	U.K., U.S.S.R., South Africa, Canada, Japan, Norway
Mica (sheet)	100	India, Brazil, Malagasy
Chromium	100	U.S.S.R., South Africa, Turkey
Strontium	100	Mexico, Spain
Cobalt	98	Zaire, Belgium, Luxembourg, Finland, Canada, Norway
Tantalum	97	Nigeria, Canada, Zaire
Aluminum (ores and metal)	96	Jamaica, Surinam, Canada, Australia
Manganese	95	Brazil, Gabon, South Africa, Zaire
Fluorine	87	Mexico, Spain, Italy, South Africa
Titanium (rutile)	86	Australia
Asbestos	85	Canada, South Africa
Tin	77	Malaysia, Thailand, Bolivia
Bismuth	75	Mexico, Japan, Peru, U.K., Korea
Nickel	74	Canada, Norway
Columbium	67	Brazil, Nigeria, Malagasy, Thailand
Antimony	65	South Africa, Mexico, U.K., Bolivia
Gold	61	Canada, Switzerland, U.S.S.R.
Potassium	60	Canada
Mercury	58	Canada, Mexico
Zinc	52	Canada, Mexico, Peru
Silver	44	Canada, Peru, Mexico, Honduras, Australia
Barium	43	Peru, Ireland, Mexico, Greece
Gypsum	39	Canada, Mexico, Jamaica
Selenium	37	Canada, Japan, Mexico, U.K.
Tellurium	36	Peru, Canada
Vanadium	32	South Africa, Chile, U.S.S.R.
Petroleum (includes liquid natural gas)	29	Central and South America, Canada, Middle East
Iron	28	Canada, Venezuela, Japan, Common Market
Lead	26	Canada, Australia, Peru, Mexico
Cadmium	25	Mexico, Australia, Belgium, Luxembourg, Canada, Peru
Copper	18	Canada, Peru, Chile
Titanium (ilmenite)	18	Canada, Australia
Rare earths	14	Australia, Malaysia, India
Pumice	12	Greece, Italy
Salt	7	Canada, Mexico, Bahamas
Cement	5	Canada, Bahamas, Norway
Magnesium (nonmetallic)	8	Greece, Ireland
Natural gas	9	Canada
Rhenium	4	West Germany, France
Stone	2	Canada, Mexico, Italy, Portugal

According to Vincent E. McKelvey, chief of the U.S. Geological Survey, the country is in fair shape to supply its needs of most key metals out of its own reserves, if necessary, until the end of the century and beyond. Surveys of the country's mineral resources are far from complete, and there is still the chance that important deposits remain to be discovered. For some commodities, such as manganese, tin, and chromite, the United States must look to foreign sources for future supplies, McKelvey concludes. For others, such as vanadium and tungsten, the ores are there and could be profitably mined with suitable advances in technology and rises in world price. Resources of materials such as iron, molybdenum, copper, lead, zinc, and aluminum are "nearly equivalent to potential demand over the next few decades, and the prospects for new discoveries are reasonably good."

Improving domestic supply is one major approach to increasing self-sufficiency. Others are recycling and substitution. With each of these strategies the room for maneuver appears to be if anything shrinking as new constraints emerge, such as environmental protection and the rising cost of energy. Increasing production is, of course, not the only way to achieve a balance, but there is an evident reluctance in government reports to consider the alternative of reducing demand. This gap has been filled by a committee of the National Materials Advisory Board of the National Academy of Sciences. In a report of 1972 entitled "Elements of a national materials policy," the board criticizes the entire existing system for materials decision-making as "so biased in favor of production and consumption that one can hardly overstress the need for temperance and foresight in monitoring and controlling wasteful and nonessential uses."

Besides improving domestic supplies and reducing waste, the academy committee recommends that technology should be adapted to depend on widespread and abundant basic commodities such as iron, aluminum, magnesium, and the silicates. Failure to adapt will lead, within decades, to the erosion of the mineral position of the United States, "growing economic colonialism, international frictions, steadily deteriorating balance of trade, and a tarnished global image of the nation."

#### Suggested Reading

- Landsberg, H. H. and others, 1963, *Resources in America's future*: Baltimore, Johns Hopkins Press.
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