MINERAL SHORTAGES

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HEARING

BEFORE THE

SUBCOMMITTEE ON
MINERALS, MATERIALS, AND FUELS

OF THE

COMMITTEE ON
INTERIOR AND INSULAR AFFAIRS
UNITED STATES SENATE

NINETIETH CONGRESS

SECOND SESSION

ON

MINERAL SHORTAGES

MARCH 21, 1968

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MINERAL SHORTAGES

THURSDAY, MARCH 21, 1968

U.S. SENATE,
SUBCOMMITTEE ON MINERALS, MATERIALS, AND FUELS
OF THE COMMITTEE ON INTERIOR AND INSULAR AFFAIRS,
Washington, D.C.

The subcommittee met, pursuant to notice, at 10:05 a.m., in room 3110, New Senate Office Building, Senator Ernest Gruening (chairman of the subcommittee) presiding.

Present: Senators Gruening, Allott, Fannin, and Hansen.

Also present: Jerry T. Verkler, staff director; Stewart French, chief counsel; and E. Lewis Reid, minority counsel.

Senator GRUENING. The hearing will please come to order.

This is an open, public hearing by the Subcommittee on Minerals, Materials, and Fuels of the Senate Interior and Insular Affairs Committee on the increasingly critical problems facing our country with respect to shortages of minerals and our consequent growing dependence on foreign, ocean-borne sources of these minerals.

At this time the subcommittee plans to hear only Federal officials, led by Dr. Walter R. Hibbard, Jr., the very distinguished director of the U.S. Bureau of Mines.

There is also present in the committee room Anthony A. Bertsch, Assistant Administrator of the Business and Defense Services Administration and Harry Callaway, Office of Metals and Minerals, from the Department of Commerce, who will be prepared to answer questions.

Also present is William L. Lawrence, Chief of the Stockpile Requirements Division of the Office of Emergency Planning, who is here as an observer but is prepared to answer questions.

However, if the interest and need shown by these hearings warrant it, the subcommittee will schedule additional hearings to receive the views of the mineral industry and the public.

Dr. Hibbard is an extremely articulate scientist and will develop the case best in his own way. However, by way of background, I would observe that the physical foundation of our society is based on minerals and the materials derived from them. Among all the world's peoples we enjoy the highest standard of living in no small part because we have been able to develop and utilize the abundant mineral resources of the United States. Minerals have played a basic part in our history, our economy. Minerals are woven inextricably into the very fabric of our history, our economy, and our civilization, and they are indispensable to our continued security. Structures, roads, and machines are built largely of minerals; the energy to heat homes and buildings and to drive the machines is mostly mineral; agriculture fertility is maintained by mineral fertilizers; and the national security is provided by military equipment and machines largely of mineral origin.

We are the world's largest consumer of minerals. During the past 30 years we have consumed more minerals than the entire world for all time prior to that. It is a fact that must be faced that we consume more than we produce. And our own national demands are growing in what seems to be geometrical progression.

The value of mineral imports in 1966 was $2.9 billion and exceeded the value of exports by a ratio of more than 3 to 1. In addition, quantities of semiprocessed and manufactured minerals, fuels, and other mineral-related products are imported. Department of Commerce statistics indicate that the total dollar value of these imports was $6.7 billion, with exports of $3.3 billion in the same categories. Actually, today, imports supply more than 75 percent of our needs for 20 different mineral commodities. Unless this particular trend is somehow reversed, there appears no alternative to a steady growth in our reliance on imports.

Yet, at the very time our reliance on foreign, ocean-borne supplies of minerals is increasing, we know we have vast reserves of many of the same minerals within the borders of our own country, or within the North American Continent. Much of these vast reserves are, unfortunately, of low grade, compared to some foreign sources. This fact, plus high production costs in the United States, plus the attractiveness of the growing foreign market, have resulted in what is perhaps a disproportionate emphasis by Americans on the development of foreign mineral resources.

My long interest in the development of the mineral resources of my own State of Alaska, and my service as chairman of the Subcommittee on Mineral, Materials, and Fuels, have impressed me with the great potentials for further discovery of new mineral resources and the further development of these resources now known.

Mineralogically speaking, the United States—and especially my own State of Alaska—may still be an underdeveloped or emerging country.

Over the years, from time to time, various units of the Congress, as well as various commissions appointed by the executive branch, have held hearings and conducted investigations as to the validity of the controversial theory or concept that the United States now is a "have not" nation.

I hope that these hearings will throw additional light on this vital subject and point to what if anything we should and can do about it.

And now, if no member of the subcommittee wishes to make a statement, I will call as our first witness, Dr. Hibbard.

Dr. Hibbard, we are very happy to have you here.

I want to express my regret at the news that you are leaving the Government and going into private industry. Private industry will be the gainer, the Government will be the loser. But we know that your service wherever it is will be of great value to our Nation.

STATEMENT OF DR. WALTER R. HIBBARD, JR., DIRECTOR, BUREAU OF MINES, DEPARTMENT OF THE INTERIOR; ACCOMPANIED BY CHARLES M. MOTTLEY, OPERATIONS RESEARCH SCIENTIST; AND PAUL ZINNER, ASSISTANT DIRECTOR FOR PLANNING

Dr. HIBBARD. Mr. Chairman, may I present my two colleagues, Paul Zinner, Assistant Director for Planning, and Charles Mottley.

Senator GRUENING. We are very happy to have them here.

Dr. HIBBARD. I have here a biographical sketch if you would like to have it for the record.

Senator GRUENING. It will be included in the record at this point.

(The material referred to follows:)

BIOGRAPHICAL SKETCH OF DR. WALTER R. HIBBARD, JR., DIRECTOR, BUREAU OF MINES, U.S. DEPARTMENT OF THE INTERIOR

Dr. Walter R. Hibbard, Jr., has been Director of the Bureau of Mines since December 1, 1965, following his appointment by President Lyndon B. Johnson in October of that year.

Born in Bridgeport, Conn., on January 20, 1918, Dr. Hibbard was graduated from Wesleyan University, Middletown, Conn., in 1939, and received a Doctor of Engineering degree from Yale University in 1942.

Following his military service in World War II as a naval officer attached to the Bureau of Ships, he joined the faculty at Yale as an Assistant Professor and later become Associate Professor.

In 1951 he was recruited by the General Electric Company for its Research and Development Center in Schenectady, N.Y. There he progressed to the position of Manager of Metallurgy and Ceramics Research, directing a broad range of fundamental and applied research projects, a position he held when selected to become Director of the Bureau of Mines.

Dr. Hibbard's achievements in such fields as the plastic deformation of metals and the metallurgy of copper and its alloys have won him wide recognition from many professional societies. In 1950 he received the Raymond Award of the American Institute of Mining, Metallurgical, and Petroleum Engineers. From 1957 to 1961 he served as Director of the Institute, and in 1967 he served as its President. He was named by AIME to receive the Institute's James Douglas Gold Medal, awarded for his notable career. For many years a registered professional engineer, Dr. Hibbard has served as President of the Metallurgical Society of the AIME, and is a past chairman of the Society's committees on the metallurgical profession and on engineering management. In January 1963, he was one of ten eminent metallurgists elected to the newly created grade of Fellow of the Metallurgical Society. In addition, Dr. Hibbard belongs to the British Institute of Metals and the New York Academy of Sciences, and is a fellow of both the American Academy of Arts and Sciences and the American Association for the Advancement of Science. He also is a member of the Materials Advisory Board of the National Academy of Science, and was recently its Chairman. In 1966 he was elected to the newly organized National Academy of Engineering.

Dr. Hibbard is the author of more than 70 scientific papers and has been widely recognized as a major contributor to the science of metallurgy. In 1957 he was a member of the exchange delegation of United States metallurgists visiting the Soviet Union.

He has been elected to many honorary and professional fraternities including Phi Beta Kappa, Sigma Xi, Alpha Chi Sigma, and Gamma Alpha. He also holds an honorary Doctor of Laws degree from the Michigan Technological University, Houghton, Michigan.

Dr. HIBBARD. Mr. Chairman and members of the subcommittee, one of the responsibilities of the Director of the Bureau of Mines is to keep both the executive and legislative branches of the Federal Government advised as to the adequacy and dependability of the supply of mineral materials required by our economy. I appear before you today as your minerals adviser. My purpose is to invite your attention to a situation that is emerging which appears to threaten both the adequacy and dependability of our supply of minerals and mineral fuels. This conclusion has resulted from a long-range study which I initiated a year ago.

Three events motivated this study. In his message to the Congress on June 30, 1967, President Johnson stated:

> Sharply rising world demands threaten to exhaust the best and most accessible deposits of minerals. Rapidly changing demands for materials are bringing changes in our mineral needs. We must understand the technological and economic changes taking place. The last comprehensive study of these problems was completed by the President's Materials Policy Commission in 1952. Much has happened in the past decade and a half. A new examination is needed.

Second, the governmentwide concern for improving the process by which Federal programs are planned needs, in the case of the Bureau of Mines, an effective system to foresee future threats to the mineral supply-demand relationships. Moreover, such a system should suggest where efforts might be most effectively applied to minimize the impact of such threats.

Third, an important element of the Bureau of Mines ongoing mission is:

To conduct the necessary inquiries to provide, in the national interest, the scientific, technical, statistical, and economic information required by the Government and important to the industry in order to assure an adequate, dependable, and timely flow of mineral materials within the economy to support national goals and to meet industrial and social needs at a reasonable cost.

The present study uses some new analytical techniques and, I believe, focuses attention upon some significant developments and important steps that we must take which I would like to discuss with you.

Any appraisal of mineral supply-demand relationship requires a judicious balancing of appropriate facts against a variety of assumptions. One fact we know with certainty is that continued extraction of ore leads to increasing costs as the material being mined gets lower in grade and is drawn from greater and greater depths. Improved technology can make possible the continuation or renewal of work in deposits that would otherwise have been shut down because of competition from ores that are richer and more easily extracted and processed. Just how rapidly improved technology can be developed and applied in searching for new deposits and in bringing them into production is a critical factor that will require close attention and intensive effort for as far into the future as we can see.

Even the most conservative projections of mineral supply and demand emerging from these studies promise significant changes in worldwide consumption patterns, both in quantity and variety of minerals, as well as in sources of mineral supply. These changes will have a comparatively greater impact upon the United States than upon other nations, for many reasons. Not the least of these is that on a per capita basis we consume a disproportionate share of the total world supply, and will doubtless continue to do so.

Of course, our domestic mineral industries now fulfill a substantial portion of our needs and also supply a great variety of minerals to world markets. How long this important domestic capability can be maintained is open to considerable conjecture.

That question lies close to the center of a complex pattern of foreseeable critical issues—issues to which we not only should, but absolutely must, give immediate attention. How effectively this attention is directed will largely determine the degree to which an adequate, dependable, timely, and efficient flow of mineral materials may be achieved in the year 2000, or at any future time, for that matter.

Before describing these issues I would like to briefly outline how the current study is designed and how certain conclusions emerge from the analyses performed to date.

As an initial step we sought to digest large volumes of factual information relative to the present world availability and flow of mineral raw materials. One product of this undertaking was a series of flow-charts depicting the essential supply-demand relationships for some 80 metals, minerals, and mineral fuels. I think you will find these particularly useful in gaining a broad overview of the components of U.S. mineral supply and consuming sectors. The initial charts display material flows in 1966.

We propose to revise these anually. World production is displayed in each instance and, where exports to the United States are recorded, the form and amounts are apparent. All the important components of U.S. supply are indicated, exports and stocks are explained, and the major consuming sectors to which supplies are committed are shown.

Wherever feasible substances are described in terms of elemental content in preference to the mineral forms in which they are commonly priced, traded, and in some instances, consumed, in current marketing patterns. In other words, the aluminum chart is in terms of the element aluminum, whether or not it involves bauxite, aluminum oxide, or metallic aluminum.

Senator GRUENING. Dr. Hibbard, Senator Allott would like you to explain this chart.

Senator ALLOTT. It is very small on our copy. I think you can explain it in 30 seconds.

Dr. HIBBARD. Here is the aluminum chart. All of the units shown are thousands of short tons of aluminum.

Senator HANSEN. That is 2,000 pounds?

Dr. HIBBARD. 2,000 pounds. The primary source is bauxite, but the figures shown are in terms of the aluminum content of the bauxite which was mined. The sum at the lower left is the total world supply as mined in 1966. And as you can see, there are exchanges among the foreign countries.

For example, we imported aluminum from Canada. While Canada itself produced no aluminum ores, they get their ores from Jamaica, Guyana and Surinam.

Senator ALLOTT. So the dotted lines on your chart in your statement indicate the source lines?

Dr. HIBBARD. Yes sir. This is part of the interaction between these commodities in foreign countries.

The top figure is the U.S. mine production, in terms of aluminum units. The open white lines represent the movement of bauxite. And we mine some and we import some. And this makes up part of our U.S. supply. All of the dotted lines are imports of alumina, the oxide, again expressed in terms of the element. And all of the cross-hatched lines are imports of metal.

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Now, our own bauxite production, our imports of bauxite, alumina and metal, our secondary metal, our stocks, and our stockpile releases, constitute the total U.S. supply.

This, minus year-end stocks and exports, is the figure shown as the U.S. demand. That figure, in turn, is distributed among the consuming sectors shown on the chart including construction, transportation, durables, electrical, machinery, containers, abrasives——

Senator GRUENING. Chemical, ceramics, factories, and others.

Dr. HIBBARD. The form in which the aluminum is held in stocks or is exported is also shown below the totals.

Senator GRUENING. Thank you very much.

Dr. HIBBARD. Now, we have done this for 80 commodities. And you might be interested in just taking a quick look at several of these charts. Here is one for copper, which is a critical element today. And here again the same format is used starting with world production. One of our problems, sir, is that we don't know enough about the international exchanges of these materials. But the total world production figure is fairly reliable. The chart shows what part of the total comes into the United States. It shows that of the 1,700,000 tons of copper derived from domestic refinery production, 1,400,000 came from the United States, and the rest realized from treating imported concentrates.

The chart also shows the other major components of U.S. supply like imports of metal, refined secondary metal, low-grade scrap, industry stocks, and stockpile releases. Some of the supply was exported. We bring in ore, refine it, and export it again. Some of it went back to stocks. Again, the chart also shows the consumer pattern.

Senator FANNIN. Do you feel that this is a very accurate figure?

Dr. HIBBARD. It is as accurate as we could get. We used the best figures that were available. And part of our job is to improve upon this kind of information.

Senator GRUENING. Dr. Hibbard, for the purpose of the record it is desirable that we include these charts. And it is a little difficult for the stenotypist to follow when you say, "over here." So I would like to suggest that when you are through that you take these charts and accompany them with a description that will be clear on the record.

Dr. HIBBARD. Yes, sir.

(The data referred to follows:)

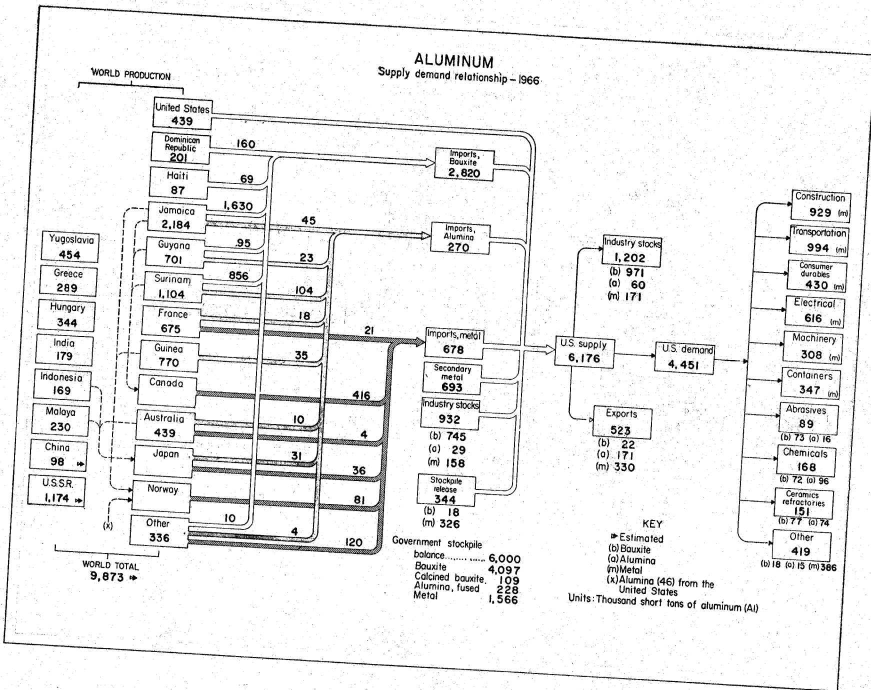
SUPPLY-DEMAND CHARTS

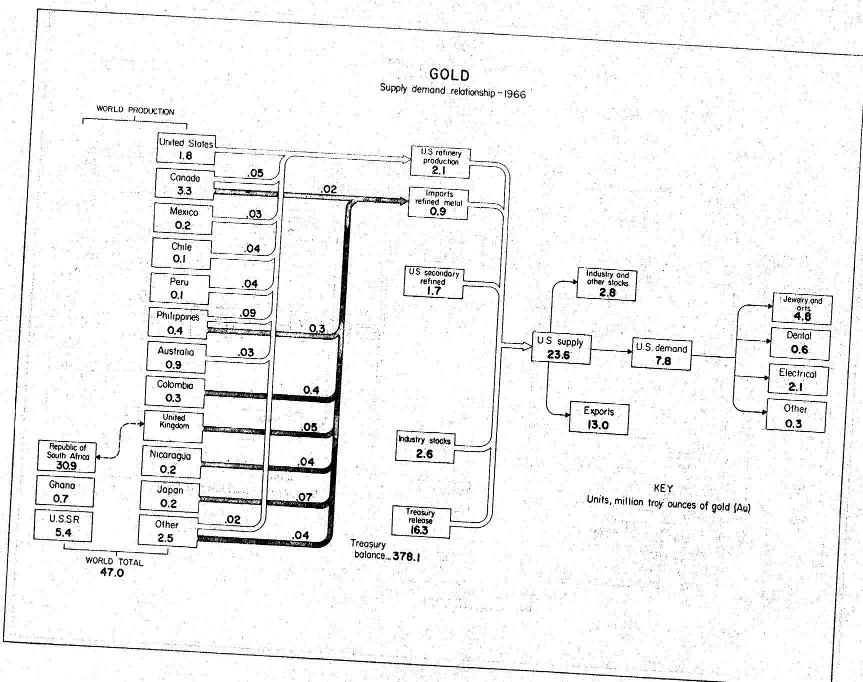
The supply-demand charts are a series of diagrammatic digests describing the important components of the U.S. supply of metals, minerals, and mineral fuels in a given year—in this instance, 1966.

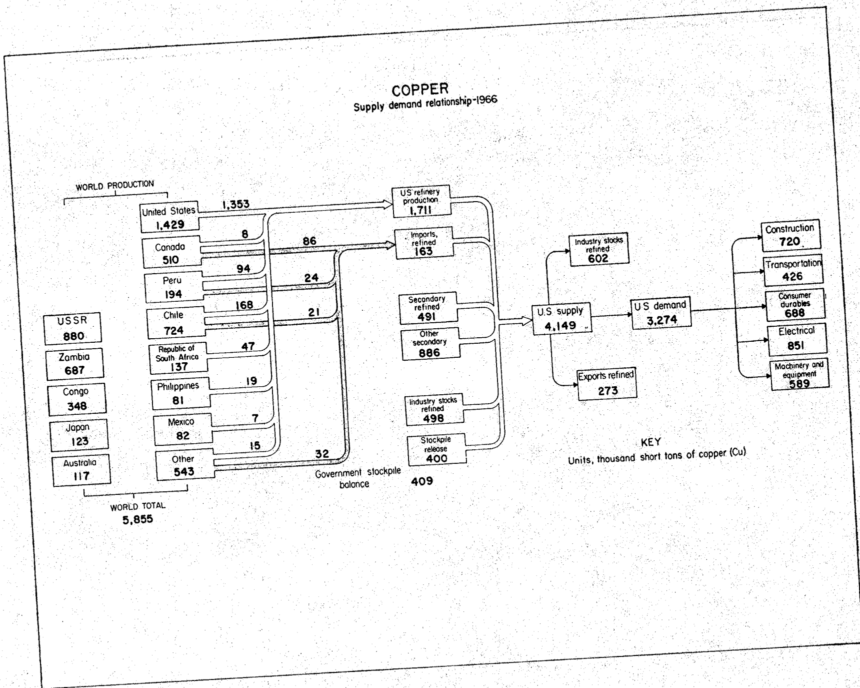
On each chart the major sources of world production are identified. The portions of this production which flowed from all sources and in various forms to the United States during the year are shown. The quantity of each component of U.S. supply is explained. The part of the available supply that was exported or retained in stock at the end of the year is also shown on each chart.

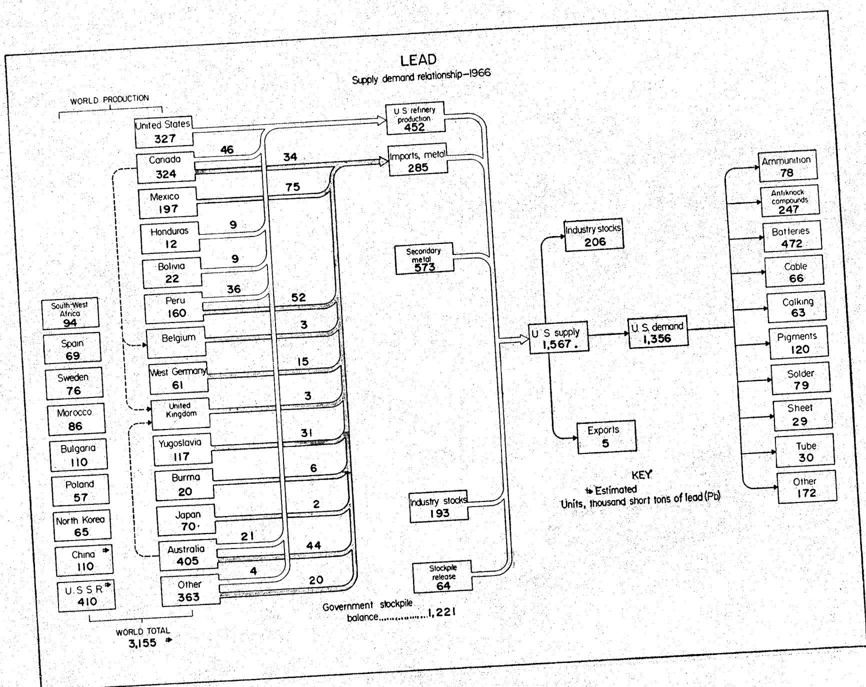
Finally, the uses to which supplies were committed, or the quantity and forms in which substances were destined for consumption during the year, are identified.

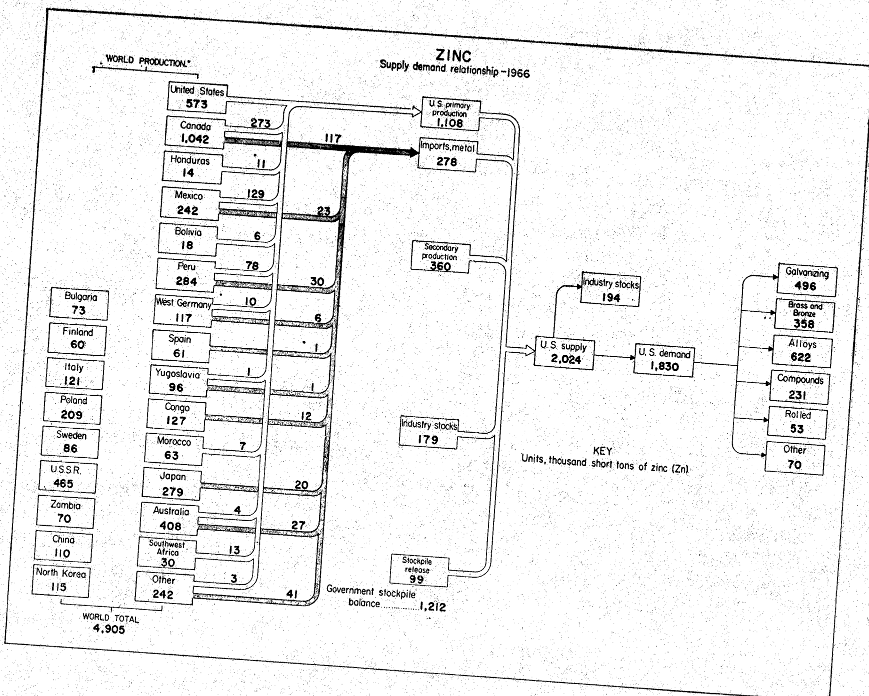
A common general format is used in each of the 80 charts that are being maintained as part of the study of supply-demand relationships. Those shown here are typical of the series.

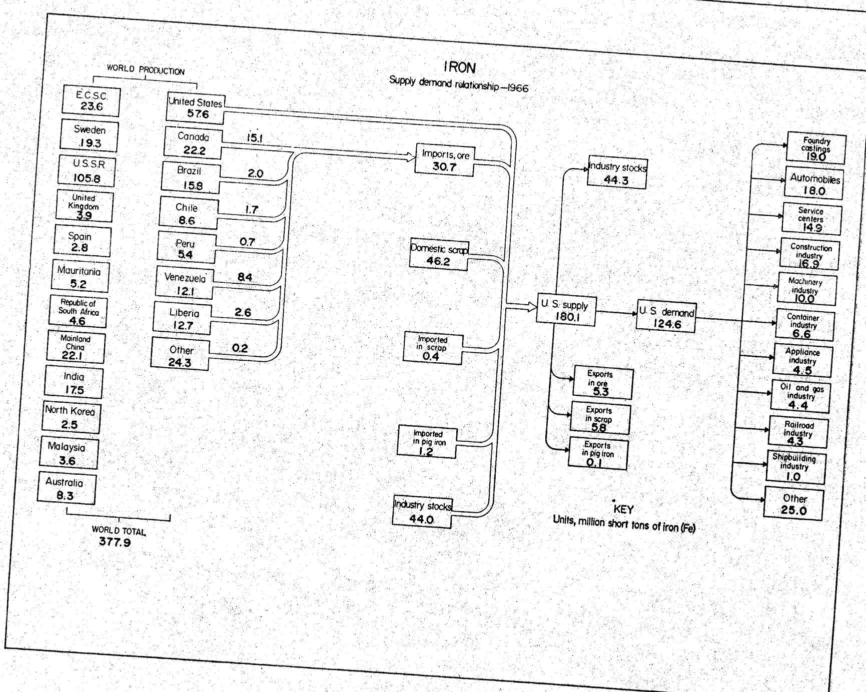

ALUMINUM
Supply demand relationship – 1966
WORLD PRODUCTION
United States 439
Dominican Republic 201
Haiti 87
Jamaica 2,184
Guyana 701
Surinam 1,104
France 675
Guinea 770
Canada
Australia 439
Japan
Norway
Other 336
Yugoslavia 454
Greece 289
Hungary 344
India 179
Indonesia 169
Malaya 230
China 98
U.S.S.R. 1,174
(x)
WORLD TOTAL 9,873
160
69
1,630
45
95
23
856
104
18
21
35
416
10
4
31
36
81
10
4
120
Imports, Bauxite 2,820
Imports, Alumina 270
Imports, metal 678
Secondary metal 693
Industry stocks 932
(b) 745
(a) 29
(m) 158
Stockpile release 344
(b) 18
(m) 326
Government stockpile balance 6,000
Bauxite 4,097
Calcined bauxite 109
Alumina, fused 228
Metal 1,566
Industry stocks 1,202
(b) 971
(a) 60
(m) 171
U.S. supply 6,176
U.S. demand 4,451
Exports 523
(b) 22
(a) 171
(m) 330
Construction 929 (m)
Transportation 994 (m)
Consumer durables 430 (m)
Electrical 616 (m)
Machinery 308 (m)
Containers 347 (m)
Abrasives 89
(b) 73 (a) 16
Chemicals 168
(b) 72 (a) 96
Ceramics refractories 151
(b) 77 (a) 74
Other 419
(b) 18 (a) 15 (m) 386
KEY
Estimated
(b) Bauxite
(a) Alumina
(m) Metal
(x) Alumina (46) from the United States
Units: Thousand short tons of aluminum (Al)


GOLD
Supply demand relationship – 1966
WORLD PRODUCTION
United States 1.8
Canada 3.3
Mexico 0.2
Chile 0.1
Peru 0.1
Philippines 0.4
Australia 0.9
Colombia 0.3
United Kingdom
Nicaragua 0.2
Japan 0.2
Other 2.5
Republic of South Africa 30.9
Ghana 0.7
U.S.S.R. 5.4
WORLD TOTAL 47.0
.05
.02
.03
.04
.04
.09
0.3
.03
0.4
.05
.04
.07
.02
.04
U.S refinery production 2.1
Imports refined metal 0.9
U.S secondary refined 1.7
Industry stocks 2.6
Treasury release 16.3
Treasury balance... 378.1
Industry and other stocks 2.8
U.S supply 23.6
U.S. demand 7.8
Exports 13.0
Jewelry and arts 4.8
Dental 0.6
Electrical 2.1
Other 0.3
KEY
Units, million troy ounces of gold (Au)


COPPER
Supply demand relationship-1966
WORLD PRODUCTION
United States 1,429
Canada 510
Peru 194
Chile 724
Republic of South Africa 137
Philippines 81
Mexico 82
Other 543
USSR 880
Zambia 687
Congo 348
Japan 123
Australia 117
WORLD TOTAL 5,855
1,353
8
86
94
24
168
21
47
19
7
15
32
US refinery production 1,711
Imports, refined 163
Secondary refined 491
Other secondary 886
Industry stocks refined 498
Stockpile release 400
Government stockpile balance 409
Industry stocks refined 602
U.S supply 4,149
Exports refined 273
U.S demand 3,274
Construction 720
Transportation 426
Consumer durables 688
Electrical 851
Machinery and equipment 589
KEY
Units, thousand short tons of copper (Cu)


LEAD
Supply demand relationship—1966
WORLD PRODUCTION
United States 327
Canada 324
Mexico 197
Honduras 12
Bolivia 22
Peru 160
Belgium
West Germany 61
United Kingdom
Yugoslavia 117
Burma 20
Japan 70
Australia 405
Other 363
South-West Africa 94
Spain 69
Sweden 76
Morocco 86
Bulgaria 110
Poland 57
North Korea 65
China 110
U.S.S.R. 410
WORLD TOTAL 3,155
46
34
75
9
9
36
52
3
15
3
31
6
2
21
44
4
20
U.S refinery production 452
Imports, metal 285
Secondary metal 573
Industry stocks 193
Stockpile release 64
Government stockpile balance..............1,221
Industry stocks 206
U.S supply 1,567
Exports 5
U.S. demand 1,356
Ammunition 78
Antiknock compounds 247
Batteries 472
Cable 66
Calking 63
Pigments 120
Solder 79
Sheet 29
Tube 30
Other 172
KEY
Estimated
Units, thousand short tons of lead (Pb)


ZINC
Supply demand relationship–1966
WORLD PRODUCTION*
United States 573
Canada 1,042
Honduras 14
Mexico 242
Bolivia 18
Peru 284
West Germany 117
Spain 61
Yugoslavia 96
Congo 127
Morocco 63
Japan 279
Australia 408
Southwest Africa 30
Other 242
Bulgaria 73
Finland 60
Italy 121
Poland 209
Sweden 86
U.S.S.R. 465
Zambia 70
China 110
North Korea 115
WORLD TOTAL 4,905
273
117
11
129
23
6
78
30
10
6
1
1
1
12
7
20
4
27
13
3
41
U.S. primary production 1,108
Imports, metal 278
Secondary production 360
Industry stocks 179
Stockpile release 99
Government stockpile balance 1,212
U.S. supply 2,024
Industry stocks 194
U.S. demand 1,830
Galvanizing 496
Brass and Bronze 358
Alloys 622
Compounds 231
Rolled 53
Other 70
KEY
Units, thousand short tons of zinc (Zn)


IRON
Supply demand relationship—1966
WORLD PRODUCTION
E.C.S.C. 23.6
Sweden 19.3
U.S.S.R. 105.8
United Kingdom 3.9
Spain 2.8
Mauritania 5.2
Republic of South Africa 4.6
Mainland China 22.1
India 17.5
North Korea 2.5
Malaysia 3.6
Australia 8.3
WORLD TOTAL 377.9
United States 57.6
Canada 22.2
Brazil 15.8
Chile 8.6
Peru 5.4
Venezuela 12.1
Liberia 12.7
Other 24.3
15.1
2.0
1.7
0.7
8.4
2.6
0.2
Imports, ore 30.7
Domestic scrap 46.2
Imported in scrap 0.4
Imported in pig iron 1.2
Industry stocks 44.0
U.S. supply 180.1
Industry stocks 44.3
U.S. demand 124.6
Exports in ore 5.3
Exports in scrap 5.8
Exports in pig iron 0.1
Foundry castings 19.0
Automobiles 18.0
Service centers 14.9
Construction industry 16.9
Machinery industry 10.0
Container industry 6.6
Appliance industry 4.5
Oil and gas industry 4.4
Railroad industry 4.3
Shipbuilding industry 1.0
Other 25.0
KEY
Units, million short tons of iron (Fe)

Dr. HIBBARD. I would like to call attention, if I may, to the gold chart. Using the same format, it shows the world production in 1966. It also shows what was imported into the United States in ores and concentrates and derived as part of the U.S. refinery production. It shows that the balance of the supply comes from secondary sources, industry stocks and Treasury release. The amounts going to major consuming sectors are also shown.

Now, one of the things which is extremely important is the very substantial increase in the use of gold for electronics and electrical purposes. This is a key area as far as the United States is concerned. And I will speak to that later.

Senator HANSEN. Just one question, Dr. Hibbard. Are all of these figures related to a million troy ounces?

Dr. HIBBARD. Yes, sir.

Senator HANSEN. In other words, the electrical industry is using 2.1 million troy ounces of gold?

Dr. HIBBARD. Yes. The electrical industry alone is using more gold than we produce from domestic sources.

Senator FANNIN. Doctor, one of the things that was brought out during our debates on the gold issue was that approximately $1.5 billion of gold is produced each year in the world, and that about $750 million of that is used for industry and the arts. Do your figures bear that out?

Dr. HIBBARD. Jewelry and arts, electrical, those are the two big uses. And this has doubled in the last 5 years.

Senator HANSEN. Of course, this is just the U.S. supply here. Senator Fannin's question was——

Senator FANNIN. Whether or not your figures would bear out the relationship of 2 to 1; in other words, that we produce two times as much gold each year worldwide as is utilized for other than monetary purposes, or hoarding.

Dr. HIBBARD. May I supply the answer to that?

Senator FANNIN. Yes.

Dr. HIBBARD. The world production was 47 million troy ounces in 1966, of which 31 came from South Africa. These figures are as accurate as we could get them. They are not as complete as we would like. We know that there are exchanges in the world market, but we don't have the figures.

Senator FANNIN. But these are the figures that we wonder about.

Senator GRUENING. Dr. Hibbard, while we are on the subject of gold, which seems to be in the news somewhat, I notice that your chart shows a substantial increase in the demand for this mineral in the field of jewelry, in the field of dentistry, and in other fields.

Would you say that present prices, which have resulted from the dedication of the Treasury Department to the mythology that we had to keep the price at $35 an ounce, would be beneficial to our gold mining industry?

Dr. HIBBARD. That is a difficult question to answer, sir. Certainly as a result of many things, including price, the production of gold has decreased over the years. It went through a minimum about 2 or 3 years, and now it is on its way back up again, except for this last year. Any material which is sold today at a price which existed many years ago becomes a bargain as a material. And therefore gold was in fact a bargain. But the surprising thing to me is that within the past few days the price of nonmonetary gold has gone up to a high of approximately $45, and now it seems to be settling back down at—the last figure I saw in Europe was $37.

Now, it is my opinion that a price of $37, or even $44, is not going to be enough incentive for a substantial new gold mine development in gold. That isn't enough money. From our studies the number of gold mines that might open up at, say, a price of $44 is very small.

Senator GRUENING. I share that view. But isn't it gratifying for the first time in may years to go back to the free enterprise system and the law of supply and demand. And since there is increasing demand, as your charts indicate, in various industrial fields, will that be beneficial to the gold miners?

Dr. HIBBARD. Yes. However, as I am going to say in my testimony, one of the basic problems with the gold industry has been the lack of research. The gold processing techniques which are used today, with two exceptions, are over 50 years old. And even under the conditions which have existed in the past 25 years I believe technology could have made an impact on gold production if it had been applied. I think the heavy metal program, which is a joint effort of the Geological Survey and the Bureau of Mines, will bear this out. Speaking as an individual, I can say that I believe that this program is going to multiply the domestic gold production by four.

Senator GRUENING. Now, Dr. Hibbard, you are leaving Government—regrettably, I must say—to go into the field of industrial research. Wouldn't it be very helpful if we could get the Government to help us in some research on how gold could be mined more profitably?

Dr. HIBBARD. In fact, this is the subject of a substantial program in the Bureau. And I believe that as the fruits of this program emerge industry will dig right in and do the research that is needed.

Senator GRUENING. We have here, as members of the committee, Senators who are representing gold-mining States. And because of the arbitrary restrictions which the Government has seen fit to impose to hold the price down to $35 an ounce, gold mining has practically disappeared as a domestic enterprise. I hope, now that we have gone back to the free enterprise system and stopped this discrimination against one unique segment of the mining industry, that we may get a better deal for gold mining. And I am hoping that the Bureau of Mines and the Department of the Interior will cooperate in that effort.

Senator ALLOTT. Mr. Chairman, would it be possible to indulge me for a couple of remarks and maybe a question or two? I have an appropriations hearing also going on at this same time, and I am afraid I am going to have to leave.

Senator GRUENING. I think it is a privilege to hear you, Senator Allott.

Senator ALLOTT. First of all, Doctor. I want to join with the chairman in his remarks. I think it is very regrettable that you are leaving the Government. We were all very happy that you were with us. And we only regret that it wasn't for a longer time. I know that you will find great stimulation in private industry. And I must commend you for your very fine report on the Colorado School of Mines, which was very rewarding to many of us.

Back in 1959, Doctor, I introduced a bill, and a similar bill is now pending in the Congress, which is simply to establish a minerals policy in the United States. I don't think anybody can say today that we have a minerals policy. If we have it has more facets than any diamond that has ever been cut. It is almost impossible to tell what it is. I don't know whether we are trying to follow the old Paley theory or not. I don't know whether our national policy is to promote the production of minerals in this country upon an economically viable basis, or whether it is our intention to tap the world's resources as far as we can.

The present bill is S. 522. It was introduced in January of 1967. We requested department reports on February 2, 1967. These requests were renewed on August 25, 1967, and on February 3, 1968. To date, no reports whatever have been received on that bill.

Now, I happen to believe that this bill, if enacted, would be the broad base from which we could start legislating to develop a sounder minerals industry in this country, particularly in the production field, and that unless we say what our mineral policy is going to be, we are going to keep on flubbing around—and that is as good a word as anything, just flubbing around—for a long, long time.

Now, can you explain to me why there has been no report on this bill from the Department of Interior? Even though they say "We don't like it," why haven't we had something from them?

Dr. HIBBARD. May I comment on that, sir?

Senator ALLOTT. Yes; I am asking the question.

Dr. HIBBARD. I am not prepared to comment on the status of the comments on the bill. But it is with the thought in mind that strategic planning requires that information be brought in in a concise way to those who make policy as a basis for establishing whatever policy is needed to cover the issues which emerge from these studies. This is one of the reasons why I am here today, because I believe that the information which we are going to present this morning will show a clear need for some firm statements of policy.

I happen to believe personally that while no additional authority is required by the Secretary or the Bureau to carry out some of the things that need to be done, that it is highly desirable to focus the attention of the country on the need for new minerals technology. As in the past where you have focused this need by the passage of legislation, such as the Synthetic Fuels Act of not too long ago, you might find it appropriate to consider the possibility of having a National Minerals Technology Act which would focus the needs of the country for a new technology, and might associate with it some upper limits of funding.

And it is for this reason that I am here today, to try to point this out.

Senator ALLOTT. I understand that, Doctor. And I am going to read every word of your statement——

Dr. HIBBARD. What I have just said is not in my statement. This is my personal opinion.

Senator ALLOTT (continuing). Even if I have to leave before you finish it.

Were you ever asked, for example, to comment on S. 522?

Dr. HIBBARD. Yes, sir.

Senator ALLOTT. And did you comment on it?

Dr. HIBBARD. Yes, sir.

Senator ALLOTT. And it left your hands?

Dr. HIBBARD. Yes, sir.

Senator ALLOTT. I want to ask Mr. French at this time, we have never as yet received any comments from the Department of the Interior on that bill, have we?

Mr. FRENCH. No, sir; we have not.

Senator ALLOTT. I think you have answered my question.

Dr. HIBBARD. There is one more question you might ask.

Senator ALLOTT. All right, I will ask it.

Did you comment favorably or unfavorably?

Dr. HIBBARD. Favorably, sir.

Senator ALLOTT. Thank you very much. That is all the better.

Now, if the chairman will indulge me just one moment; in 1959, 1960, 1961, 1962, and 1963, the Senator from Colorado had bills pending in the Senate which provided for the purchase of gold on the open market for the arts and industries. And this was opposed unanimously by the Bureau of the Budget, the Department of the Treasury, and everybody that I can think of who is supposed to be able and intelligent in the monetary field. And yet this is exactly what the United States did in consortium—that has a sort of bad connotation—in consortium with six other nations over the last weekend, is it not? This is what we did last weekend?

Dr. HIBBARD. Yes. In other words, this is a two-price system.

Senator ALLOTT. The arts and industries are going to have to go out on the open market and purchase gold.

The bills which I previously introduced regarding this subject were S. 1539 in the 86th Congress, S. 3385 in the 87th and S. 158 in the 88th Congress. I think it is very well to call attention to the fact that it took about 8 or 9 years for the really able economists and fiscal managers of this country to come around to a position that some of us had tried to get to as long as 8 or 9 years ago.

That is all I have to say, Mr. Chairman.

But, Dr. Hibbard, I do appreciate your help, and I am dreadfully sorry that you are leaving the Government.

Senator GRUENING. Senator Allott, I think it would be useful if the chairman of the subcommittee would address a letter to the Secretary of the Interior to find out what happened to this report after it left the Bureau of Mines and was somehow lost in the Interior Department labyrinth. A search party might help to locate it and bring it to light.

Senator ALLOTT. I think so.

I do have a copy of that letter from the chairman of the full committee to the Secretary on February 2 of this year. And as far as I know, this hasn't been answered yet, either.

Senator GRUENING. There seems to be a strange impediment somewhere. I think it would be worthwhile exploring how these things sometimes seem to get lost.

Senator ALLOTT. I would say this, that I would hate to see this committee or any other committee get to the place where we were legislating without getting reports from the appropriate agencies of the Government.

But I am glad that Dr. Hibbard had an opportunity to clear his own skirts on this particular example. This is just one of dozens where we ask the Department for reports, and then legislation is stymied and stopped and dragged to a standstill for a period of months and sometimes years—legislation that is needed—simply because reports are not forthcoming. And if this continues, we are going to have to adopt a policy of legislating on our own, regardless of what the departments in the Executive Branch of the Government say.

Dr. HIBBARD. Sir, may I go off the record for just a few seconds?

Senator GRUENING. Well, if it must be off the record. But I think it would be much more useful to have it on the record.

Dr. HIBBARD. Then I would prefer to have it on the record.

The problem is not with the Secretary of the Interior.

Senator GRUENING. You think it might be lost in the Bureau of the Budget?

Dr. HIBBARD. Yes.

Senator GRUENING. I think you might be right.

Senator ALLOTT. I ask unanimous consent that the statement I made the other day with relation to the two-price system be placed in the record in my remarks.

Senator GRUENING. It may be so placed.

(The statement referred to follows:)

[From the Congressional Record, Mar. 18, 1968]

THE GOLD SITUATION

Mr. ALLOTT. Mr. President, last Thursday afternoon, March 14, the Senate, by a vote of 39 to 37, removed the gold cover from the currency of the United States.

This morning I note a headline in the newspaper, "Gold Pool Dropped To End Speculation." This is from the newspaper of March 18, 1968. Under that, in headlines, "Two Prices Adopted by Seven Nations." It reads:

"The United States and six cooperating nations yesterday abandoned the gold pool they had been operating for the past six and one-half years and said they would no longer 'buy gold from the market.'"

"In essence the plan, announced at the conclusion of a historic two-day session at the Federal Reserve Board here, is designed to end the speculative drain on official gold reserves.

"It means that there will be a two-price gold system—$35 an ounce for official international transactions, and whatever price develops in an outside 'unofficial' market."

Further on in the same article:

"In a word, the cooperating central banks are going out of the gold buying and selling business—except among themselves.

"That means:

"Central banks will no longer buy newlymined gold from South Africa or any other producer.

"The U.S. Treasury will no longer license, effective today, the sale of gold from its stock to industrial users in this country, who last year tapped Treasury monetary gold for $158 million."

At another point in the same article:

"The cooperating nations are basing their actions on the belief that the future needs of the international monetary system will come from the growth of 'paper gold' rather than the real metal."

Mr. President, I ask unanimous consent that this article be printed in its entirety at the conclusion of my remarks.

The PRESIDING OFFICER. Without objection, it is so ordered.

(See exhibit 1.)

Mr. ALLOTT. Mr. President, the most interesting and most gratifying aspect of the situation to me is that in 1959, 1960, 1961, 1962, and 1963 I proposed legislation, and introduced it in the Senate, to do exactly what these seven "brilliant" nations have finally done in this year of our Lord 1968, 9 years after the bill was first introduced in the Senate.

I do not have a copy of my earliest bill with me, but I do have some remarks that I made in 1966, and I should like to read briefly from those:

"On August 9, 1965, a meeting was arranged by Senator Gruening, and it was attended by Under Secretaries Barr and Deming. During that meeting both gentlemen expressed disapproval of either a subsidized or a two-priced system, stating that in their opinions either proposal would cause greater conversion to gold by foreign holders of dollars in the belief that the price of gold was about to increase. However, this does not explain the massive conversion that has been going on since 1961. Apparently, quite a few prefer gold to dollars now. It is my hope that these hearings will shed some light on why gold is preferred to dollars, and by whom.

"Also, at that meeting, Secretaries Barr and Deming expressed the belief that only two legislative avenues to increase gold production are open. One was to increase the depletion allowance and liberalize depreciation for income tax purposes. The other was to launch a massive effort to improve methods of discovery and refining."

I might say at this point, parenthetically, that the first of these, the attack upon this by the increasing of the depletion allowance and the liberalizing of depreciation for income tax purposes, was very quickly abandoned by the Treasury Department:

"It was suggested that Treasury draft a proposed change to the Internal Revenue Code that would create a more favorable tax climate for the gold miner."

Parenthetically, again, that was never done.

"However, to my knowledge nothing has been submitted. With regard to the launching of a massive effort to improve methods of discovery and refining, there are two basic defects with this suggestion: First, it would take years to complete such research, and assuming that the research was successful, it would take several more years before its results would produce any appreciable increase in production. We do not have years to wait.

"Second, it would require a large investment and generally speaking, the gold industry is not in any position to finance it.

"So, we find ourselves in this position: the proposals that have been made that might have an early effect in increasing gold production are violently opposed by the Treasury Department; and the proposals that are ostensibly acceptable to Treasury are unrealistic or Treasury does not seem prone to act. Inertia has been the one overriding element in the gold situation.

"Most of the gold mining districts are depressed areas with substantial and consistent unemployment. We have a Poverty Program and a whole myriad of other programs to create jobs, but we have nothing for the gold miner. He is forgotten even though the product he could produce is of such great importance to our monetary system.

"There are those who have suggested that we remove the gold backing from our currency"——

This was said over 2 years ago—

"in the mistaken belief that it would have little effect upon our economy and the 'stability of the dollar'. I disagree with that thesis completely. But, judging by what has happened in the past year, namely, the debasing of our coinage and the removal of the gold cover from Federal Reserve deposits, it would appear that that is the direction in which we are headed. If, as has been indicated by Treasury officials, the mere discussion of the gold situation has an unsettling effect upon foreign dollar holders, what would happen to the 'stability' of the dollar if we removed the gold cover? I can assure you that I will never vote to remove the gold cover from our currency. In my opinion, such action would lead to financial chaos in this country."

Mr. President, I have before me excerpts from a speech given on May 4, 1966. I think it is appropriate to repeat again that I did not vote to remove the gold cover from the currency.

Mr. President, I ask unanimous consent to have printed in the RECORD at this point a letter addressed to the Honorable A. Willis Robertson, who was formerly the chairman of the Committee on Banking and Currency, which is dated August 2, 1963.

There being no objection, the letter was ordered to be printed in the RECORD, as follows:

"General Counsel of the
Department of Commerce,
Washington, D.C.

"Hon. A. Willis Robertson,
Chairman, Committee on Banking and Currency, U.S. Senate,
Washington, D.C.

"Dear Mr. Chairman: This is in further reply to your request for the views of this Department on S. 158, a bill 'To prohibit sales of gold by the Government for commercial use or for the arts, or for the purpose of lessening the price and value of gold.'

"S. 158 would monetize all gold holdings and purchases by the U.S. Government by prohibiting the Federal Government from selling gold for non-monetary uses. The sale, the price, and the granting of a license to import gold for non-monetary uses are now within the Executive discretion of the President. Purchases and sales of gold in the United States, including imports and exports, are subject to the 'Gold Regulations,' administered by the U.S. Treasury Department and authorized by the Gold Reserve Act of 1934 (31 U.S.C., Sec. 442). At present, the United States stands ready not only to buy domestically mined gold for $35 an ounce but also to sell for $35 to licensed purchasers for commercial use or for the arts.'

"The Department of Commerce recommends that the bill not be enacted.

"The apparent purpose of the bill is to raise the price of gold for non-monetary uses within the country, without discarding the $35 per ounce monetary price. Since the demand for industrial gold is greater than the amount produced from mines in the United States, the elimination of U.S. Government sales of gold for this purpose might appear to lead to a rise in the price. This, however, would depend on two other conditions, neither of which appears to be barred by S. 158; (1) that the United States would discontinue the purchase and sale of gold to maintain the international price of gold at $35 an ounce; or (2) that the United States would no longer exercise its discretionary power of authorizing imports of gold for industrial uses. So long as both of these practices continue to be honored, the United States in reality, though indirectly, would still be maintaining the $35 price for industrial gold in the United States. The effect of S. 158 would then be academic.

"The passage of a bill obviously intended to raise the price of industrial gold in the United States, whether or not the bill would accomplish this purpose, may be construed by other countries as a step toward devaluation by the United States.

"It is only necessary for such speculation to occur in order for a flight from the dollar to start; and once started, the flight may feed on itself. Confidence in the gold value of the dollar among foreign governments and central banks has been tied to the stability and fixity of the price at $35. Today this relationship is considered to be a foundation stone of Free World economics. S. 158, however, introduces uncertainties regarding this relationship which can affect injuriously the United States and Free World monetary position.

"The use of gold in industry and in the arts in the United States has doubled in recent years. These sales do not draw down the United States monetary gold stock unduly. The importance of gold as a strategic material continues to grow, particularly in the space area. For example, gold foil is used in the electronic assembly for the 'Telstar', the first privately owned satellite, and steering jets for space vehicles are plated with gold to reflect 95% of all radiation to which an orbiting vehicle's surface is exposed. Vaporized gold is deposited on surfaces of small jet controllers used in instrumentation and circuitry as protection against friction and corrosion. New industrial applications for gold are being developed, including greater use of gold in electronic devices, and in other electronic applications.

"Gold continues to be used in dental alloys, in scientific, chemical, and other equipment, and in the arts (jewelry, watches, and decorative articles). The precious-metal jewelry industry in the United States, employing over 25,000 workers and producing goods valued at nearly a half billion dollars annually, uses substantial quantities of gold in the production of what is classified as solid gold jewelry, gold filled and rolled jewelry, and costume jewelry. Recent data on the production, use, import, and export of gold is attached to this report.

"Domestic production of gold, at present, supplies only about a half of the commercial requirements, the other half being obtained from the Government. If the Government were to be prohibited from making such sales, manufacturers would be deprived of this supply for their material requirements, and the cost to them of their remaining supply may be sharply increased, with serious injury to the industry, as well as unemployment in certain areas.

"The beneficiaries of a rise in the price of gold would be: (1) the relatively small number of United States gold miners who have been on notice for many years that the price is fixed at $35; (2) foreign producers, foreign governmental holders, and hoarders of gold; and (3) in a political class by itself, the Soviet Union, which is one of the three major world producers of gold. It is difficult to justify the profits that may accrue to these beneficiaries of S. 158, in the face of the possible dislocations and threats to the United States and Free World monetary systems and economic well being that may result.

"We have been advised by the Bureau of the Budget that there would be no objection to the submission of this report from the standpoint of the Administration's program.

"Sincerely,

"LAWRENCE JAMES,
(for Robert E. Giles)."

[In thousands of fine troy ounces]

	1957	1958	1959	1960	1961	1962
Gold issued for use in industry and the arts in the United States:						
Government-stamped bars issued by the U.S. Mint	604	771	2,354	2,172	2,204	(1)
Bullion in various forms issued by private refiners and dealers	1,638	1,831	821	1,528	1,708	(1)
Total	2,242	2,602	3,175	3,700	3,912	(1)
Secondary materials returned to monetary use and to private refiners and dealers	792	769	653	700	1,137	(1)
Net quantity issued	1,450	1,833	2,522	3,000	2,775	(1)
U.S. mine production	1,794	1,739	1,603	1,667	1,548	1,527
U.S. imports	7,701	8,120	8,485	9,322	1,615	[1] 1,842
U.S. exports	4,806	886	50	47	22,146	[2] 9,596

[1] Not available.
[2] January–November 1962.

Source: U.S. Treasury Department; U.S. Bureau of Mines; U.S. Bureau of the Census.

Mr. ALLOTT. Mr. President, I shall quote from one paragraph of this letter which shows exactly how nearsighted our Government and this administration have been in trying to deal with the gold problem:

"It is only necessary for such speculation to occur in order for a flight from the dollar to start; and once started the flight may feed on itself. Confidence in the gold value of the dollar among foreign governments and central banks has been tied to the stability and fixity of the price at $35. Today this relationship is considered to be a foundation stone of Free World economics. S. 158, however, introduces uncertainties regarding this relationship which can affect injuriously the United States and Free World monetary position."

Mr. President, I ask unanimous consent that S. 158, which I introduced in 1963, be printed in the RECORD at this point.

There being no objection, the bill (S. 158 was ordered to be printed in the RECORD, as follows:

"*Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled*, That all gold held or bought by the United States Treasury, or mints, or assay offices, or by the Federal Reserve banks, shall be construed to be monetary gold. Such gold shall not hereafter be sold for commercial use or for the arts, and no gold shall hereafter be sold by the Treasury, or by the Federal Reserve banks, or for the account of the Treasury or of such banks, directly or indirectly, in the United States, its territories or possessions, for the purpose of depressing the market in gold or lessening the price and value of gold."

Mr. ALLOTT. Mr. President, it will be noted that the wording in S. 158 is the same as the wording in S. 3385, which I introduced in 1962.

In conclusion I wish to point out that Treasury Department officials consistently opposed my legislation on the theory that it would effect the stability of the dollar. This is shown by the letter to former Senator Robertson who was chairman of the Committee on Banking and Currency.

By the action of yesterday it would appear that Treasury officials fear there is an unsettling effect in establishing two prices when the dollar is not under pressure. I said they were wrong and I have been saying it for 9 years. The action of the seven nations setting up a two-price system has proved I was right. If we had taken steps 9 years ago, 8 years ago, 7 years ago, or 5 years ago to adopt the legislation which I offered, it is well possible we would not have been faced with the shameful situation—and it is a shameful situation—in the international arena of being forced to withdraw the gold from behind our currency. We did the same thing in 1965 by withdrawing the gold from our Federal Reserve deposits.

Mr. President, I say they were wrong then and they are wrong now. The time to have established the two-price system was when the dollar was not under attack. It could have been carried out then with a minimum of dislocation. Now we can only hope.

This is another example of why Congress should not be so quick to relinquish all constitutional powers over our money. Congress should review our monetary posture and commence writing guidelines and limitations on our money, in my judgment.

If anything was proved by the last few years, it has been proved that this Government, the Treasury, the Federal Reserve Board, the economic advisers and college economists who told us what to do were wrong. What they told us did not stop the gold drain in this country. Today we are facing even a more serious situation because in 1963, for example, the demand upon our gold production by the arts and industries was only double the amount of our local domestic production of gold. Today that demand has grown to the extent that it would take four times our domestic production, so that demand on our local production for arts and industries is 100 percent greater than it was 5 years ago.

It is very easy to speak in retrospect, but when I consider the short shrift that the bills that I have introduced in the past few years on gold received—and not only bills that I introduced but those of other Senators vitally interested in this great industry who know we have a wealth of gold in this country at our command if we only open our minds and imagination and get our heads out of ruts. It is obvious that we have enough gold to take care of this country. It cannot be processed now, in a month or two, but with a farsighted program we can do it and we will. Those of us who are interested in the gold industry are willing to prove that it can be done.

"EXHIBIT 1

"GOLD POOL DROPPED TO END SPECULATION—TWO PRICES ADOPTED BY SEVEN NATIONS

"(By Hobart Rowen)

"The United States and six cooperating nations yesterday abandoned the gold pool they had been operating for the past six and one-half years and said they would no longer 'buy gold from the market.'

"In essence the plan, announced at the conclusion of a historic two-day session at the Federal Reserve Board here, is designed to end the speculative drain on official gold reserves.

"It means that there will be a two-price gold system—$35 an ounce for official international transactions, and whatever price develops in an outside 'unofficial' market.

"PREVENTING RESALES

"And to prevent any governments or central banks from buying gold at $35 an ounce to resell in the private market at a profit, the cooperating nations said that 'henceforth they will not sell gold to monetary authorities to replace gold sold in private markets.'

"France, for example, will not be allowed to turn in dollars for gold at $35 an ounce if she turns around and sells that gold privately.

"Initial reaction from businessmen and bankers here and abroad was generally favorable. Most observed that it should provide time in which the United States could bring its balance of payments under better control.

"The dramatic moves, announced by Federal Reserve Chairman William McC. Martin, were the answer of the seven nations to last week's crisis buying of gold through the pool in London.

"LOST $1.5 BILLION

"Since devaluation of the British pound last November, the seven nations lost about $1.5 billion in gold to speculators, a drain that they decided could not go on.

"When originally established in November, 1961, the gold pool was intended to diminish the fluctuations in the price of gold by offering small amounts to speculative buyers. It worked well until last year, when the decline in U.S. gold stocks and lack of confidence in the dollar stepped up the pace of the buying.

"Officials said that the London market for gold—as distinguished from the pool—would stay closed for the next two weeks. That is, there will be no 'free' market in gold in London during that period.

"The assigned reason was to provide a cooling off period. But other 'free' or unofficial markets, such as the one in Paris, are unaffected.

"At the same time, the governors of the central banks attending the Washington meeting announced that they would provide new lines of credit to the British, bringing the total available up to $4 billion. Included will be $500 million in a new 'swap' arrangement by the Federal Reserve, part of an over-all $2.275 billion boost in those standby credit arrangements.

"If the seven governments can make the new gold arrangements work, the monetary supply of gold will be 'frozen' at the $41 billion plus now in the system. This is 'sufficient,' they said, in view of the prospective addition of a new paper asset, the Special Drawing Rights.

"The essence of the plan was devised by Italian central banker Guido Carli, who attended the Washington meeting.

"In a word, the cooperating central banks are going out of the gold buying and selling business—except among themselves.

"That means:

"Central banks will no longer buy newly-mined gold from South Africa or any other producer.

"The U.S. Treasury will no longer license, effective today, the sale of gold from its stock to industrial users in this country, who last year tapped Treasury monetary gold for $158 million. They will be able to buy from U.S. mining sources, or on foreign free markets. And the Treasury said it would allow American gold producers to sell as well to foreign buyers.

"The cooperating nations are basing their actions on the belief that the future needs of the international monetary system will come from the growth of 'paper gold' rather than the real metal.

"Officials indicated their belief that the decision to keep the official price at $35 an ounce, and to insulate the existing monetary stock, would deflate the speculative rush.

"It is obvious however, that a two-priced gold system itself does not solve the U.S. balance of payments problem, nor guarantee that U.S. gold stocks won't be tapped by some central banks.

"For example, some smaller central banks, if nervous may accelerate the rate at which they have been exchanging dollars for gold. The United States will sell gold at $35 an ounce—provided they don't resell any to private markets.

"Yesterday's decision amounts to a partial demonetization of gold, in this way: supplies of newly-mined gold and holdings of speculators' and hoarders' gold will no longer have a value as a form of money. They will continue to have a value, perhaps even higher than $35 an ounce, as a commodity, like copper or jute.

"Officials insisted that the new two-priced system for gold would have no effect on the value of the dollar, particularly in the United States, where gold is not part of everyday currency.

"Another big question mark concerns the French. No one expects France to buy gold from the U.S. for speculative resale. But the French could help stimulate a drain on U.S. gold supplies through other nations.

"The other question relating to France will be its willingness to speed along the activation of the Special Drawing Rights system. The French have been trying to persuade their European Common Market partners to surround the SDRs with various limitations.

"But a special statement last night by the International Monetary Fund said that the SDR system was on track.

"One reason for the new aid package to Britain relates directly to the gold speculation of recent weeks. As anxieties mounted, many who held deposits in sterling changed them into dollars, with which they bought gold through the London pool. The new lines of credit are designed to help restore sterling balances.

"The communique noted 'the determined policy' of the U.S. Government 'to defend the value of the dollar through appropriate fiscal and monetary measures and that substantial improvement of the U.S. balance of payments is a high priority objective.'

"No specific deals were made or offered by the United States in support of this commitment, but President Johnson's Saturday statement offering to cut expenditures more deeply in exchange for a tax increase was noted by the participants of the meeting.

"And the suggestion from a top Administration source that any increase in Vietnam troop strength would be 'moderate' was the kind of thing the foreign central bankers had been hoping to hear.

"Note was also taken of the fact, the communique said, that Congress had freed all of the $11.5 billion U.S. gold reserves 'for defending the value of the dollar.'

"One key point of the communique, though it sounded technical, is of major importance: the governors agreed to 'cooperate even more closely than in the past to minimize the flow of funds contributing to instability in the exchange markets.'

"This was directed to this circumstance: As worries about the dollar mounted in the past several weeks, there was a sharp increase in money moving into Germany, because the Deutschemark is considered a strong currency.

"Much of this came from the 'Euro-dollar' market. 'Euro-dollars' are dollars owned by foreigners, and held on deposit in banks. The intent of the closer cooperation mentioned is to facilitate the swapping of currencies, as confidence in the dollar is restored.

"The final line of the communique said that cooperation of other central banks is invited. This direct bid to the French was underscored in a comment by Bank of England Governor Sir Leslie O'Brien who said that the seven nations 'are not anxious to widen the gap between France and the rest of us.'

"Pierre-Paul Schweitzer, managing director of the International Monetary Fund, said in a statement last night:

" 'It is most important that the monetary authorities of all member countries should continue to conduct gold transactions consistently with this undertaking and they should cooperate fully to conserve the stock of monetary gold.

" 'In the longer run it will not be sufficient simply to conserve global reserves. In this connection, it is to be noted that work on the establishment of the Special Drawing Rights facility in the fund is proceeding on schedule. It is to be hoped that this facility will enter into force with the least possible delay . . .' "

Senator GRUENING. Please proceed.

Dr. HIBBARD (referring back to the charts). Whenever feasible, substances are described in terms of elemental content in preference to mineral forms in which they are commonly priced, treated, and in some instances, consumed, in current marketing patterns.

While the resulting units are not familiar in some discussions of current supply-demand relationship, they are essential in speculating upon future sources and end-use patterns.

In addition to the charts and certain explanatory material essential to them, background profiles prepared on each commodity summarize significant information on:

Apparent reserves.—In which apparent domestic reserves are compared to reserves known to be developed elsewhere in the world.

Industry patterns.—In which the structures of the industries at home and abroad are defined.

Consumption patterns.—In which the way materials are marketed and the forms in which they are consumed in the United States and the rest of the world are summarized.

Byproducts and coproducts.—In which a feeling is gained for the complex relationships in mineral supply.

Parenthetically, there are some minerals which are supplied only as byproducts. And if the major metal in the ore is no longer mined, the entire source of this material disappears.

Economic factors.—In which the essential aspects of cost-price relationships are explained.

Technology.—In which the prevailing state of engineering practice is described.

In the presence of these background profiles the nature of probable future supply-demand relationships has been given a great deal of attention. A range of projections has been prepared for each commodity through 1985 and 2000. Projections are based upon econometric techniques after selecting an index considered best applicable to each topic. The projections have been modified to reflect the effects of foreseeable probable and possible technologic advances that would tend to lessen costs, reduce demands, increase supplies, or establish new markets. They have been further modified through introduction of the possible effects of nontechnologic changes like price incentives, import or export controls, international events, and the like.

Specifically the outlook section on each commodity in this study is addressed to:

Future demand.—In which high, median, and low projections of demand in 1985 and 2000, in the United States and in the rest of the world, are estimated.

I would like to emphasize that you can't look at the United States alone, you have to look at mineral supply and demand problems in the context of the entire world picture.

Future supply.—In which the resources likely to be important sources of raw materials in the future, even though noncommercial at present, are assessed and related to projected demands.

And again to deviate for a minute in our petroleum predictions, we believe that production from oil shale is absolutely essential by the year 1985. And in our documents here we have estimated this need at 400 million barrels per year.

Senator HANSEN. Mr. Chairman, if I may, I would like to ask a question.

I am delighted with the awareness that is so evident on these problems of great concern to our country and to our national security as evidenced by Dr. Hibbard's statement. And now he has mentioned oil shale.

Our attention earlier this morning was focused on our domestic needs for aluminum. Dawsonite, recently discovered in the Green River formation, may prove to be a significant domestic source for aluminum.

In January of 1967, Secretary Udall stated as point 1 of his 5-point program for oil shale development that "Pending sodium preference right lease applications"—which would offer one means for developing Dawsonite—"will be properly considered on their merit."

On September 14, 1967, the Secretary testified before this committee on the status of the oil shale development program. At that time, I addressed a question to the Secretary, which was as follows:

"I would observe that some of these applications have been filed with your Department for more than 15 months and I share your hope that there can be an early resolution of them. I think that the industry would certainly welcome the clearing up of the problem that is before you."

On December 12, I wrote to the Secretary and his reply of January 12, 1968, does not indicate to me that the question of pending sodium preference right lease applications is any closer to resolution within the Department.

I wonder if you can give the committee a status report on this question and, hopefully, indicate to the committee that the Department is now in a position to offer some resolution to the applications which are before it.

Dr. HIBBARD. I would be very happy to comment, sir. I cannot speak for the Department in this matter, because it is well beyond the scope of the Bureau of Mines. But significant progress is being made, I can assure you. And attention is being directed to the resolution of this problem. It is just not a simple one. And I am not a lawyer. But it appears to me that the greatest complexities by far are in the legal end and not in the technical end. And it is my personal opinion that if the oil shale industry is not in place by the year 1980 or 1985, it will be because of legal problems, not because of technical problems. And I really can't comment authoritatively on the status of the applications. It is just beyond the scope of my knowledge.

Senator HANSEN. I would like to underscore and reemphasize the importance of the development of the oil shale industry, as has been pointed out so positively here by Dr. Hibbard this morning. If I may, Mr. Chairman, I wish to have introduced into the record at this time an article from the Oil Daily of Friday, February 23, 1968, which describes the increase in daily production limits for the year, recently announced by the Alberta government for the Athabaska tar stands.

Senator GRUENING. It may be placed in the record.

(The material referred to follows:)

[From the Oil Daily, Feb. 23, 1968]

ALBERTA OIL SANDS OUTPUT LIMITS UPPED TO 150,000 BARRELS DAILY

EDMONTON.—Alberta oil sands production was raised to 150,000 barrels per day, more than three times what it is now to encourage development of the sands.

Premier E. C. Manning, announced this week in the legislature the new oil sands policy, raising production limits and redefining oil sands to include other heavy oil.

The new policy is designed to encourage growth in total crude oil markets.

The old production limit was calculated at 5% of the total market for Alberta crude.

Applicants assuring their marketing proposals will open a new market would be allowed to produce sufficient volumes to supply 50% of it. The government believes that applications under this modification of policy would provide the conventional industry with an immediate share of markets.

At present, the province has only one oil sands producer, Great Canadian Oil Sands at Fort McMurray in northeastern Alberta, which is restricted to 45,000 b/d of synthetic crude from the sands.

It is expected the new policy will dwarf the GCOS project through greater production from Athabasca as well as Cold Lake, also in northeastern Alberta.

A. R. Patrick, minister of mines and minerals and industry and development, said this could mean one new large plant or two plants similar in size to the one now in operation.

The minister said he believes there will be a start on some development this year but added that there is a lot of work to be done involving study of the lease to be worked on and that he is not at liberty to reveal details at this stage. Pilot plant work must also be carried out before construction of a commercial plant.

The minister predicted large development within a few years, larger in cost than St. Lawrence Seaway.

The Japanese have plans that stagger the imagination. But details could not be obtained. Japan Exploration Co., in which the government has an interest, has been reported as being interested in developing the oil sands in conjunction with a Canadian firm. At present, Japan is heavily dependent on Middle East sources for its imports of crude oil, to the tune of almost 90%, and is seeking more reliable supplies.

Tentative plans of Japex are reported to involve production of 170,000 b/d from Athabasca. The partly refined crude would be taken some 700 miles by pipeline to the west coast to the Prince Rupert area to be shipped to Japan. Japan would also take the by-products, sulfur and coke. This crude would have the advantage of having a low sulfur content, an important consideration to Japanese refiners.

Manning highlighted possible future developments at a recent meeting of the London Institute of Petroleum, addressing an audience which included the U.K. minister of power, leading industrialists, bankers and civil servants. The institute sponsored a presentation of the GCOS project.

Manning expressed his conviction that markets for Alberta crude will grow. He noted that government policy must plan ahead in view of the four to five year minimum period required to start up an oil sands operation.

Both Manning and R. H. Winters, federal minister of trade and commerce, suggested that future British investment in Alberta's oil sands would be welcomed to develop further the area's enormous synthetic oil potential.

Recoverable reserves, 90% of which are at Athabasca, are estimated at between 300 billion and 350 billion barrels of oil as compared with total proved world reserves of some 390 billion barrels of conventional crude.

Manning stressed, however, that government policy would continue to insist that synthetic crude from Alberta's oil sands must be used to supplement rather than to supplant the province's conventional crude production, as about half of Alberta's conventional production is currently shut in.

The rapid growth in world energy consumption, the advent of giant tankers and improved unit production costs could swing the balance in favor of Canadian oil becoming more competitive, both in North America's east coast markets and overseas, by the time that any new oil sands projects could go into production. The British government's 1967 white paper on fuel policy states that ways of improving the security of U. K. oil supplies are being re-examined, "including the possible development, necessarily long-term, of the vast reserves of oil locked in non-conventional sources, such as the Western Hemisphere oil sands and shales."

Both Shell Canada and the Syncrude Consortium (Imperial Oil, Cities Service and Atlantic Richfield—30% each—and Royalite/British American—10%) whose 1962–63 applications for separate 100,000 b/d oil sands projects were not approved by the Alberta Oil & Gas Conservation Board, have been given permission to reapply by the end of this year.

Senator HANSEN. In brief, the Alberta government increased production capacity from 45,000 barrels a day of synthetic crude from the sands to 150,000 barrels a day.

Last year Fred Hartley, chief executive for the Union Oil Co. of California, indicated to this committee that his company was building a new refinery in Chicago. The thrust of his testimony was that this refinery was being constructed in such a way as to make it capable of handling crude oil from either the Canadian tar sands or Rocky Mountain oil shale.

Mr. Hartley said to the committee:

If anybody had asked me 10 years ago, that synthetic crude oil from tar sands would have gone on the market commercially ahead of oil shale—took that bet and I lost.

*   *   *   *   *   *   *

Further, * * * I would not be surprised if we keep on treating oil shale the way we have in the past, that coal may even win out, too, because you are aware of the fact that there is depletion on coal.

It seems to me, Dr. Hibbard, from everything I can learn, that Canada is moving ahead full bore with its program for increasing synthetic fuel production while we in this country are sitting on dead center. Would you care to comment on the need for synthetic fuel production in this country?

Dr. HIBBARD. Yes, this is covered in the outlook section of our study. We have projections for production in 1980 and the year 2000 at the level of 400 million barrels and 1 billion barrels per year, respectively. We believe these amounts to be very essential to our energy mix. And again I believe that technically we are almost ready to go. The big difference in my opinion between the developments at Athabasca and the developments in Craig or Rifle or in that area are clearly differences of legal complexities and mining laws. I think this will come clearly out of the studies that the Public Land Law Review Commission is making. It is my opinion that significant production capacity won't be in place until there is action taken to clear these legal questions without having to go through all the long and meticulous procedures which now prevail.

Senator HANSEN. So the problems, as I understand you, Mr. Hibbard, are legal problems, legal roadblocks rather than roadblocks insofar as the technical aspects of mining are concerned.

Dr. HIBBARD. All the technical problems are not solved, let me emphasize that. But they are in a position where we could go ahead learning as we go.

Senator HANSEN. But you can't start on that until the legal problems are resolved; is that your point?

Dr. HIBBARD. Yes.

Senator HANSEN. Thank you.

And thank you, Mr. Chairman.

Senator GRUENING. Please proceed, Mr. Hibbard.

Senator ALLOTT. So that you won't have another interruption, may I ask, the study that you are referring to here, in what form will they be published, Doctor? Or will it be published?

Dr. HIBBARD. We will leave with the committee a two-volume version of the study which, at the moment, is a sheaf of working papers 10 feet high. These volumes are the digested appraisals of each commodity. We will also leave with you a summary of the 80 commodity statements contained in a reasonable number of pages. Because we propose to continue the study we do not plan to publish these volumes. I would propose, sir, if you see fit, that the summaries be put in the record.

Senator ALLOTT. I certainly think it should, Mr. Chairman.

I know that the Bureau of Mines has put out each year a compendium of minerals resources reflecting where our minerals come from, their use, and so forth. And I was wondering if this would be published in that form. If not, we might consider having it published as a Senate document or something like that at a later time. I think it is the sort of thing the country needs.

Senator GRUENING. Could these reports be made available to the committee?

Dr. HIBBARD. Yes. We will present you with both the summaries and the commodity statements.

Senator ALLOTT. Thank you.

(The summary referred to is printed as an appendix to the hearing record.)

Dr. HIBBARD. May I continue, sir.

The other factors addressed in the outlook section of the study are "domestic supply," in which potential resources are related to price; "Time-Price Relationships," in which probable price levels are estimated through the remainder of the century; "Possible Advances in Technology," in which the possibility of significant technological advances is assessed and related to the projections; and then a summary or set of "Conclusions."

Finally, the products of the background documentation and the outlook projections were assembled in a series of summary observations in which the essential conclusions relative to each commodity are reduced to those considered significant in some way to a clear understanding of emerging supply-demand relationships.

Except in a few instances when certain figures have been obtained from private sources under agreements to respect the confidentiality of such information, all of the information I have described is available for your use.

I do not propose to burden you with a detailed description of the several matrix systems through which the hundreds of foreseeable issues are being reduced to essential categories. I would be very pleased to explain the process if you would like me to do so.

However, I would like to summarize the findings.

Today the United States is the largest consumer of metals and fuels in the free world. It maintains this position by being the largest producer of minerals and fuels in the free world. Over the years, it has maintained this production leadership, even in the face of the necessity for using lower and lower grade resources and rising labor costs, by an aggressive program of exploration and new discoveries and in advancing technology which has reduced the overall costs of extracting and processing these lower grade ores.

Recent and projected trends indicate that U.S. mining interests are turning to foreign resources. The United States is now the largest importer of minerals and fuels. Over 75 percent of our requirements for a number of important commodities are imported today. This is not new. For many of these commodities we have never had substantial production. However, major tonnages of our key basic materials are coming from foreign operations: 85 percent of our bauxite for aluminum; almost 20 percent of our copper (and probably much more in 1967 and 1968); 40 percent of our iron ore; nearly 40 percent of our zinc and more than 25 percent of our lead; all of our manganese and chromium needed for steel, our gold and silver production is about one-fourth of our industrial consumption.

Our projections based on population growth indicate that by 1985 our mineral and fuel requirements will increase by about 50 percent on the average, and in some cases by as much as 100 percent.

Facilities for this increased supply require on the average about 5 to 10 years leadtime and $100 million per venture to bring them onstream.

There is no evidence that these facilities are being put in place today to provide for this long-range need. And this is what worries me.

Currently a substantial amount of U.S. exploration and investment for facilities in the future is being made in foreign countries—Canada, Australia, South America, and Central Africa. We have some specific data for the last 5 years on the business expenditures for new plant and equipment by the mining and smelting industry. In the last 5 years from the year 1962 through 1966, the foreign investment doubled. During the same 5 years the domestic investment increased by 50 percent. And these data are available if you would like to have them.

Senator Gruening. Dr. Hibbard, do you know whether these foreign investments by American firms will likewise be subdivided as a part of our foreign-aid program?

Dr. HIBBARD. No, sir. These are investments by American companies, I do know that.

Senator GRUENING. They are doing that on their own, and are not being subsidized by Americans?

Dr. HIBBARD. No, sir. I think they are simply responsive to the investment climate overseas.

Senator FANNIN. Dr. Hibbard, does your chart show a breakdown in the different metals industry?

Dr. HIBBARD. No, sir.

Senator FANNIN. Has a considerable part of that been in the copper——

Dr. HIBBARD. Part of it is mining and smelting, and part of it is petroleum. But it doesn't break it down into individual commodities.

Senator ALLOTT. Could I ask that this chart that Dr. Hibbard referred to be inserted in the record?

Senator GRUENING. Without objection, it will be inserted.

(The material referred to follows:)

U.S. BUSINESS EXPENDITURES FOR NEW PLANT AND EQUIPMENT

[In billions of dollars]

Year	Mining and smelting		Petroleum and coal products		Other manufacturing [3]	
	Domestic [1]	Foreign [2]	Domestic [1]	Foreign [2]	Domestic [1]	Foreign [2]
1960	0.99	0.43	2.64	1.47	11.84	1.40
1962	1.08	.44	2.88	1.63	11.80	2.04
1963	1.04	.40	2.92	1.89	12.77	2.25
1964	1.19	.46	3.36	2.07	15.22	3.01
1965	1.30	.65	3.82	2.27	18.63	3.90
1966	1.47	.81	4.42	2.56	22.57	4.63
1967	1.43	.95	4.64	3.38	22.20	5.07

[1] Statistical Abstract of the United States, 1967, table 707, p. 497. Department of Commerce, Bureau of Census. (Excludes Alaska and Hawaii.)
[2] Survey of Current Business, Department of Commerce.
[3] Excludes mining/smelting and petroleum/coal products.

Senator HANSEN. Mr. Chairman, I would like to ask Dr. Hibbard this question:

Are the reports that you referred to and the information that you are presenting now similar or a substitute for the Minerals Yearbook?

Dr. HIBBARD. Oh, no, this is not a substitute for the Minerals Yearbook. The Minerals Yearbook is historical. It tells you what happened last year. This report looks ahead. We are trying to foresee the problems before they arise. The Minerals Yearbook will continue.

Senator FANNIN. Dr. Hibbard, I am wondering whether or not the increased investment in foreign countries has resulted to some extent because of the lack of new findings that have resulted from your research development assistance programs.

Dr. HIBBARD. May I answer that in my testimony. I think there are four reasons why this investment climate is attractive overseas. One of them is, the ores are richer. They are finding ores overseas which are about as rich as our ores 15 or 20 years ago. As a result of this, you can use today's technology to process them. You don't have to do any research, you just go out and find the ore. It is just like you had out in Arizona 15 years ago, you just put in the same technology.

Senator GRUENING. Dr. Hibbard, do these minerals that are developed through foreign investment by American firms compete with our own production? Do they tend to limit our own production?

Dr. HIBBARD. I think they supplement it.

Senator GRUENING. They supplement it?

Dr. HIBBARD. Yes.

Senator GRUENING. They are excess, in other words?

Dr. HIBBARD. But let me see if I can explain what I think the problem is.

If I were the chief executive of a company producing a mineral, and I have so much capital to invest—because there is a limit to available capital—and I say, where shall I put my plant? And I look at the properties in the United States, and I find that the ore is low grade, and that the labor costs are high, and there is a severance tax, and so forth. Then I look in Canada, or Australia, or Peru, or some place, and I see the ores are twice as high in grade, and there is a 3-year forgiveness for income tax, and the labor costs are lower. And I just make a straight business analysis of the relative return of the two possible investments, and if I am a good chief executive officer I will choose the investment which gives me the greatest profit.

And that is what happened. I am not blaming the mining companies for doing this, this is what I would do if I were the president of the company and had a limited amount of capital to invest. I would look at these two ventures and choose the one that is the most profitable.

Senator FANNIN. From the standpoint of what happened in this last strike in the copper industry, isn't it a good example of what may be forced upon—I wouldn't say forced upon the companies, but don't they have a greater advantage now for their foreign production? Will they not be prone to concentrate more on foreign investments, which will mean that that will take care of what has been formerly exported, and that we will have greater imports from other countries? Foreign country supplies may then displace what would normally be produced in Montana and Arizona and some of the other States?

Dr. HIBBARD. I think there is only a limited amount of capital to invest, and if they are going to invest it overseas they are not going to invest it in the United States.

Senator FANNIN. We have heard some copper officials say that they will not be in a position to reopen some of the mines here, because it would not be financially feasible. Consequently they will import. And that will, of course, affect the price of copper. They can produce it must less expensively in the foreign country and market it at prices based on what happened during the copper strike. And we did have copper, perhaps not in the quantity we needed or at the points we needed it, but still there was a considerable supply of copper in inventory. So if we look to the future, our price could be vitally affected because of what is happening; is that not correct?

Dr. HIBBARD. Certainly if the world price goes up—and I believe it will—this would make our existing mines here attractive profitwise.

But again I go back to the other point. If I am a chief executive officer and I look at the two ventures, it isn't whether this one is profitable or not, it is where I make the most profit that I go. And this is the problem. And my job as a chief executive officer would be to maximize the profits for the investment which I can make.

Senator FANNIN. Doctor, you say "if the prices go up," and you anticipate that they will. Is that based upon the standpoint of increased cost of production? Will not the competitive factor from the foreign sources affect that considerably?

Dr. HIBBARD. It will just be the normal economics of a seller's market, because copper is in short supply, and on a seller's market the price normally tends to rise.

Senator FANNIN. But how can you say that when we have a shutdown for 8 months? During that time 85 or 90 percent of the industry was not producing. Doesn't that point to the projection that in the future there will be an undersupply?

Dr. HIBBARD. At least in the beginning.

Senator FANNIN. And if we can project farther into the future, there will be an oversupply, will there not?

Dr. HIBBARD. It all depends on the supply and demand relationship, as you know. Prior to the strike on a worldwide basis there was a fairly good balance between supply and demand. And much of the copper that has come into this country during the strike has been drawn from the world supplies which would have gone otherwise to other countries. So I believe in the beginning there will be a shortage. But if the normal new starts which we foresee in the copper area take place, I think it will come into a balance sooner or later, and at some price level which I believe will be higher than the 38 cents which existed before the strike.

Senator FANNIN. Thank you.

Dr. HIBBARD. The other point, Mr. Zinner observes, is that the world requirements are going up faster than the U.S. requirements. And this is one of the complexities of the situation. They are not as large as the U.S. requirements, but they are accelerating faster.

Now, if I may go on, sir.

The reasons for this trend toward foreign investment are:

(1) Foreign ores and richer and new technology to mine and process them is not required.

(2) Foreign labor is cheaper.

(3) Many countries are making tax and other financial concessions.

(4) Foreign markets are growing faster than U.S. markets.

If these trends continue, our capability to produce minerals from domestic sources may not only remain static but in some cases disappear because they cannot be maintained in competition costwise with foreign production.

If these trends continue, we may be importing more and more of our requirements in many major tonnage items—for example, aluminum, copper, iron, and zinc, for which we have abundant resources which we should not permit to remain idle; as well as silver and gold where our resources are depleting; and chromium, tungsten, tin, mica, and asbestos where we have been traditionally deficient in economic ores.

If I may deviate a minute, our current studies are looking at this very question. We are looking at two extremes. One of them is, if we simply extrapolate the current trends or imports, what will our imports be by the year 2000?

And the second limit is what would happen if we retain the present ratio between domestic production and imports, what would happen by the year 2000.

Senator GRUENING. Dr. Hibbard, you say "We have abundant resources which we should not permit to remain idle." Why do these resources remain idle?

Dr. HIBBARD. If we go to importing, then our own resources are going to sit there unused.

Senator GRUENING. If new and efficient methods of exploration and development are devised, wouldn't some of these domestic resources be developed?

Dr. HIBBARD. If we do exploration and uncover resources that are competitive costwise with the foreign resources, then we will revive our own industry. But if these aren't competitive, the industry is going to those locations where they can make the most money.

Again, if I may deviate, the potash situation in New Mexico is exactly this. The U.S. resources for potash are relatively low grade. They have been depleting. Suddenly there is a discovery of new potash deposits in Saskatchewan, Canada. The grade of ore is much better than the grade of ore in New Mexico. Canada has a 5-year tax forgiveness. So the same companies that were operating in Carlsbad have picked up their chips, and they are putting their new money into Canada. And this is a straight business decision. You look at the two investment possibilities, and you will find that the investment is more profitable up north.

U.S. Borax has closed all its Carlsbad operations. Certain of the other companies are maintaining both for the moment. But if they continue to maintain both there is going to be a real overproduction, and then there will be a buyer's market, and the price will drop.

But this is a good example of decisionmaking—choosing between these two resources. The thing which bothers me personally about Carlsbad is that, if we had anticipated this, I believe there is technology that we could have brought to bear upon the Carlsbad deposits which might have kept them competitive. But the thing developed suddenly without any anticipation on our part, and therefore we did not have time to develop the necessary technology and get it in place. I believe this again illustrates that if you can foresee these problems soon enough and make an appraisal in depth of the specifics of these cases, there is technology which you can develop and put onstream which can make the domestic resources competitive.

The best example there is the Duval operation at Carlsbad, which has moved from one kind of ore to another. Duval is shipping right out of production. The rest of the companies are building up their stocks.

Senator GRUENING. Isn't it also a fact, as we discovered when we went to White Horse last summer, that there are matters of Federal Canadian policy, and of Provincial policy, which are much more incentive-producing? For instance, the Canadian Government not only paid two-thirds of the cost of the infrastructure, including transportation to harbors or airports, but in addition to that, they relieve a beginning enterprise of all Federal taxes. They have all that in Canada, and if we had the wisdom to adopt those policies in the United States, wouldn't that change the picture somewhat?

Dr. HIBBARD. If you compare the two policies, our tax structure is favorable toward mature operations. The Canadian policy is favorable toward new starts.

Senator GRUENING. In other words, they encourage exploration and development more than we do?

Dr. HIBBARD. Yes; our policy encourages the continuation of existing operations.

Senator FANNIN. Dr. Hibbard, at one of the previous hearings did you not give us information regarding the research that is being done in the search for gold ore? Weren't we talking about subsidies, and you explained the research and development program of the Geological Survey?

Dr. HIBBARD. Yes.

Senator FANNIN. What has resulted from that program today? Have we had any real success?

Dr. HIBBARD. I think that I can report great progress. Our search for new gold and new technology to support additional gold production is right on schedule. In my opinion we are going to achieve the goals of this program, I think by the year we suggested—it was 5 years from 1966—1971, that we will in fact have possibly increased the production fourfold.

Incidentally, I brought along a sample from one of the projects. This is a circuit board for a computer. This is now an out-of-date computer. And the circuit board has been thrown away. Most people don't realize it, but that circuitry is all gold. If you can see it from there, there is a lot of gold in it. We are finding, as I mentioned, that in recent years the electronic uses of gold have increased from something around 12 percent of our consumption to 27 percent. There are large amounts of gold going into electronics. We believe that we can recycle all this gold—we can recover it. But up until now people thought it was copper, and they haven't been collecting it.

Secondly, there are a number of new gold ores which have been developed and brought onstream. One of the most interesting ones is the "invisible" oxide ore in the Nevada district. Another interesting one is the carbon-bearing gold ore in the Idaho-Nevada-California belt. Both of these show great promise of substantial increases in production. The new production at Cortez has just been announced. And we have great prospects, I think, of bringing the domestic gold production from something like 1.8 million ounces, as it was in 1966, up to something like 5.5 million ounces or so by 1971 to 1973.

But that is not going to solve your problem, I am afraid.

Senator ALLOTT. I think you said before that our gold production is just one-fourth of our arts and industrial use now. So if we increase our gold or gold production fourfold between now and 1971, we will just have caught up with the present demand for the arts and industries use.

Dr. HIBBARD. The problem is not only that, but the growth in demand. We will have caught up with our arts uses today, but meanwhile our demands will be going up and will be much larger in 5 years than they are today.

Senator ALLOTT. That is the point I was making: the industrial and arts uses are increasing very rapidly. But the fourfold increase that you anticipate by 1971 will only catch up with present-day demand.

Senator FANNIN. I am wondering if this will be true worldwide. Will other countries be able to take advantage of the technology you are talking about and increase the production?

Dr. HIBBARD. In the case of the recycling of computer scrap, we have more computer scrap in this country than any other place in the world. And the same thing is true of these gold ores. These particular ores are peculiar to our western States. I don't believe that they are known any place else.

Senator FANNIN. So what you have done to date will not completely affect other world production?

Dr. HIBBARD. No, sir, they won't, as of this time at least.

Senator FANNIN. Thank you.

Senator ALLOTT. Let me ask one question.

I sat in on an institute meeting in the forepart of December, and there was one man there who had made considerable study of the subject who said that, had it not been for the great advances in technology in gold mining in South Africa, the gold situation in the world would not have remained stable as long as it has. Do you have knowledge of these advances in South Africa? Is this true? Not the conclusion of the statement, but is the fact of the increase in technology in South Africa true?

Dr. HIBBARD. The outlook for South African gold is not very bright. The projections that we foresee suggest that by the year 2000 South African annual production is going to be very small compared to what it is today. And this is because these are deep and difficult mines. They are the kind of mines that will have difficulty competing for investment capital, let's put it that way, in today's business world. And I think it is going to be very difficult. In fact, by the year 2000 it might even be that the U.S. production will be larger than the South African.

May I continue, sir.

Senator GRUENING. Yes; please do.

Dr. HIBBARD. We may then lose our market leadership with respect to this mineral production and possibly be obliged to pay world prices which are often controlled by the country of origin during periods of tight supply.

And I would point out that this future period is going to be a period of tight supply unless someone moves very fast to put in new production facilities.

Copper, before this strike, is a case in point. The world price was higher than the U.S. price by significantly more than transportation costs. Chile fixed the price of its copper exports at 4 cents higher than the U.S. price. Peru placed a 10-percent tax on all its exports.

Many of these supplier countries are trying to develop their economies by requiring that the refining be done before export at a higher value added and higher cost to the United States.

Venezuela want blast furnaces and steelmaking facilities.

Jamaica wants to export aluminum—not bauxite.

Peru wants to export copper wire, sheet, and tube—not copper concentrate. This is not bad. If I were in a country like Venezuela I would want to build my economy on my resources. Nevertheless, it has very significant implications.

All of these trends will lead to higher U.S. costs and greater uncertainties of supply because we will no longer dominate production and will be competing with other nations in a sellers market.

Senator GRUENING. Dr. Hibbard, isn't it true that during the past year the United States has subsidized industries in foreign countries which compete with ours? We have subsidized steel mills, and we have subsidized all kinds of manufacturing plants. Do you think that is a wise policy?

Dr. HIBBARD. I am not knowledgeable in this area, Senator. The developments that I am aware of have been privately financed.

Possibly people from the Department of Commerce could comment on that question.

Senator GRUENING. We would be very glad to have a comment.

Dr. HIBBARD. There has been a foreign aid program, but it has not concentrated in minerals, has it?

Senator GRUENING. We have here representatives of the Department of Commerce. We would like to know—this is one of the great concerns to us who are interested in the development of domestic mining—whether it is considered a wise policy for a foreign aid program to subsidize and build up and aid foreign countries to build manufacturing plants which process and refine their minerals in competition with ours? Our industries do not get any subsidies, they have to do it with their own private capital. And yet we are going throughout the world and building steel mills and other processing mineral plants to compete with ours. Is this a wise policy?

Dr. HIBBARD. My whole point in this presentation is that we have got to keep our domestic sources competitive, and anything that we do should, in my opinion, be aimed in that direction and not any others.

Senator GRUENING. I think the question should be raised from time to time. And we shall raise it again when the foreign aid program comes before the Congress.

Dr. HIBBARD. To continue, our studies also indicate two other important factors relative to this trend of the future.

Since the United States is the largest producer in the free world—a deterioration of U.S. production will affect world production. Mining is an economic base for total regional economies, such as the Southwest, the northern Rockies, and so forth. Our mineral production is 2.9 percent of the U.S. GNP but it has a direct impact on 40 percent of the U.S. GNP and an indirect impact on nearly 75 percent of the U.S. GNP. I would like to cite an example which I think you will find very interesting. If you take a $3,000 car, the value of the material in this car at the mine in the form of ore is $56. When you produce the metal it is worth about $446. And then this goes to make a $3,000 car. So it goes from $56 to $3,000. Then this car has an impact on $50,000 worth of economy. So we are going from $56 to a direct impact on $3,000 to an indirect impact on $50,000. And this again illustrates Senator Gruening's initial point, that it has a big effect on the economy.

It makes a dollar invested turn around several times. It makes resources grist for the economic mill. It contributes and must continue to contribute to the world supply.

The best answer to these trends—the ways and means of maintaining leadership in world mineral production—is clear from history; that is, the retention of world leadership in technology, the technology of exploration and discovery, extraction, processing, and use. That is, we can match technology against richer ores, lower labor costs, and tax concessions, and maybe balance these two things out.

The question arises: Why must the U.S. Government provide this technology? Let industry do it.

Well, industry is not doing it.

Industry is stimulated primarily by the profit motive. If investment climate and profit potential are more attractive for foreign ores—then they will understandably follow that attraction. Particularly if they cannot compete by means of domestic production.

That is one of the characteristics of the free enterprise system, of course.

Iron ore is a good example. We have plenty, yet 40 percent is imported because of its lower cost.

And the potash situation is the best example.

We also feel that the U.S. zinc production may disappear except for byproduct zinc by 2000, in spite of our reserves and potential resources, because U.S. costs are becoming higher and higher relative to foreign operations.

Thus, the U.S. mining industry is seeking lowest cost operations and thus trending to foreign ores. With a few exceptions, such as offshore oil and gas, its major expenses are increasingly directed toward foreign exploration and the development of foreign production facilities which are low risk because they use current and past technology. With few exceptions, they have no large programs aimed at new technology for improving domestic production.

And this again is the disadvantage of developing technology. It has a negative cash flow, a high initial cost, and it takes 5 to 10 years to get your money back in terms of the investment.

I mentioned earlier that it was possible to categorize the essential issues developed to date in the study. Nine such categories of common issues have in fact been clearly defined and I shall summarize them briefly.

I. MAINTAINING AN ADEQUATE MINERAL CAPABILITY

In notable instances, and particularly with respect to mineral commodities that are produced and consumed in large quantities, the United States will find it increasingly difficult during the next several decades to compete with higher grade, lower cost, and relatively abundant foreign sources.

Our estimates indicate that if you simply extrapolate today's trends, by the year 2000 I think we will be importing 98 percent of our iron. And we will be importing all of our lead and all of our zinc.

Now, simple extrapolation is a dangerous thing. But nevertheless, these are the trends.

It is obviously important that we find ways to minimize this difficulty, because of the inherent advantage in strategy, security, bargaining strength, economic gains and other benefits that go with an assurance that some appropriate proportion of the domestic need for primary mineral raw materials is satisfied from domestic sources.

The means of accomplishing this are limited and confined largely to alternative forms of protectionism or to competitive advantages gained through improvements in technology.

If the latter are achievable, they are much preferable to the former over the long term. In view of the outlook for increased competition for available world supplies of mineral raw materials the ultimate result of seeking to preserve a domestic productive capacity, that is not economically competitive with other sources, promises to be unfavorable to the United States. Aside from the retaliation engendered through such devices the ultimate outcome is certain to include further reductions in access to the lowest cost world sources of the materials we will need in growing quantities. In other words, with this approach the cost of raw materials to the United States will be higher than it is to other countries who don't follow this type of approach.

Protectionism measures promise only higher costs to the domestic processing industries, much higher prices to the consumer and a further deterioration in the capability of U.S. manufacturers to compete for foreign markets.

Technology, I am convinced, has the inherent power to improve the competitive position of domestic mineral sources. Energetically employed it will be the most powerful force we can exert. But we must not lose sight of the fact that technology is universally applicable. Consequently, if significant advantages are to be gained, they must be sought in areas where the technology will be immediately and particularly applicable to our domestic situation.

For example, the type of low-grade gold ores discussed a moment ago.

An unusual mineral aggregation would be another example. Or perhaps large concentrations of minor minerals, unusually favorable coproduct or byproduct relationships, ready accessibility, and source-to-market relationships that gain through transportation differentials or unusual use or marketing patterns.

Special emphasis will be needed on advancing the development of underground mining systems that will permit achieving costs at least comparable with those incurred in surface mining.

We have in our country very excellent underground mining equipment, the continuous mining equipment in the coal industry, in the potash industry, the tunnel borer.

But do you realize that continuous mining, if it is operating in a big coal mine, will operate only one-third of the time, because we don't have the capability in this system to take the material from the mine and bring it above ground on a continuous basis. So what we really need is a total mining system which will permit that continuous mining to operate around the clock. And this means a special system of removing the material, of providing roof support, of providing ventilation. And this is the controlling step in underground mining.

We can cut coal and we can cut potash and we can break rock an awful lot faster than we can handle it beyond that. And for some reason or other the equipment industry has concentrated on the speed of cutting and let the rest of the system go.

When I was up in Coeur d'Alene they were using one of these tremendous raise borers, and they could move through that hard rock tremendously fast. But they had to leave all the cuttings in the hole, because they couldn't remove them fast enough. And so all the economic advantages of this tremendous rock cutting device were lost.

So we need a total mining system. And this can be extremely effective.

Attention should be directed mostly to commodities mined in large volume, where reduction in extraction costs would measurably improve the capacity of domestic sources to compete commercially with sources abroad. I have in mind those operations that produce zinc, iron, copper, and the like; all of these commodities have large, deep resources, and can't be competitively handled today.

A new approach to underground rock breaking, initially tested on December 10, 1967, near Farmington, N. Mex., is the use of nuclear explosives to aid in the recovery and utilization of low-grade mineral resources heretofore uneconomic or impossible to exploit. Potential applications include in situ leaching of copper ore, natural gas stimulation, petroleum production, and the recovery of oil from oil shales.

Similarly, attention should be directed to those commodities where lower extraction costs would tend to improve the commercial significance of certain domestic sources or effect important savings when measured against projected demands.

Here, again, are uranium and gold—parenthetically, the gold chemistry is 50 years old. In the last 50 years there must have been some advances in chemistry which can be usefully applied to the gold industry. We have a study program on this at Reno, Nev., under Tom Henrie's direction, and we have found some of the most exciting new gold chemistry that you can imagine. If we can apply this to production it is going to have a tremendous effect.

Also included here are oil shale, most of the industrial minerals including limestone, the natural carbonates, salt and phosphate rock. Considering the future potential of clay as a source of aluminum and gypsum as a source of sulfur, perhaps these should be included, too.

Technical advances will be needed in separation practices, such as preparation, beneficiation, reduction, and smelting, where improved recoveries and cost reductions must be realized to prevent deterioration in the competitive position of domestic sources. Examples include zinc and its byproducts, with particular emphasis on retorting practices; beneficiation of iron ores, particularly flotation practices; copper and its coproducts and potassium in light of the decreasing grades of ore; and molybdenum, in regard to losses in processing, to name just a few.

Incidentally, molybdenum is going to be in trouble one of these days for that very reason. We have high production, but we have not achieved the necessary efficiency.

Senator ALLOTT. When you say efficiency in recovery, are you referring back to your remarks about mining a few moments ago, or the reduction processes?

Dr. HIBBARD. No, I am referring to the treatment of the ore.

Senator ALLOTT. You are talking about the treatment of the ore.

Dr. HIBBARD. Yes.

Senator ALLOTT. Thank you.

Dr. HIBBARD. Just how many of these situations that yield competitive superiority will develop during the remainder of this century depends on our willingness to make the research and development commitments necessary for the creation of new technology and also on our aggressiveness in applying that technology once it becomes available.

And, again, the must be done by industry, it is industry that produces the minerals, it isn't the Federal Government. And we must recognize that solutions to our problem require more time, money, and effort as the grade of domestic ore diminishes, mineralogy changes, and different types of mineral deposits are exploited. Also, we must develop the required technology on a timely basis to provide for an orderly adjustment of the economy to our changing needs.

Senator FANNIN. Before this we talked about processing. Do we really have a large-scale proven process for converting oil shale to petroleum? In other words, have we really realized any amount of product with any process we are using today?

Dr. HIBBARD. It is my opinion that the experiments which are done today would justify a scaling up to the point where this would be commercially feasible.

Senator FANNIN. Of course this always reminds me of what we have done on the desalting of water. We have shown how we accomplish it by slide rule but we don't have any water. Does that also apply to oil shale?

Dr. HIBBARD. We have gone through a demonstration stage, and it would be practical now to procede in an orderly manner to develop the processes to full-scale operation. But to answer your question, we do not have commercial-size oil shale retorting equipment.

Senator FANNIN. So today it is still theoretical to a certain extent?

Dr. HIBBARD. To a certain extent. But I believe the risk is low.

Senator FANNIN. Of course I know they are very competent in water desalination, also. But at the same time potable water is being produced at three to four times what they were predicting would take place, and I undersand that recently they have changed the figures and that the cost has gone up.

Dr. HIBBARD. You are entirely correct, we don't have the key to scaling yet which will make or break the process.

Senator FANNIN. Thank you very much, Doctor.

II. INSURING ESSENTIAL OVERSEAS SUPPLIES

Dr. HIBBARD. In common with other nations we are not presently, nor likely to become, self-sufficient in regard to the supply of mineral raw materials that are essential to our needs. Also, in some instances the outlook for obtaining even a small part of our need from domestic sources is remote.

Clearly, in the future even larger quantities of certain items will have to come from foreign sources if demand is to be satisfied without marked increases in cost. Included are tin, chromium, manganese, tantalum, columbium, cobalt, platinum, and others in various degrees.

There is no known mineral deposits in the United States which have any immediate hope of satisfying much of our needs for these types of materials. So we will continue to get these from overseas. It is very essential that the overseas trade with those countries producing these materials be maintained open and free.

Conversely, in important instances we produce surpluses that compete successfully for markets abroad. We should seek to retain and expand such markets and maintain trade balances favorable to the United States.

Coal is an example here.

Recognizing that resources, usable at any given time in terms of the prevailing economic and technologic constraints, are not now, nor likely to be in the future, present in nature in a system that conforms to any ethnical, political or continental pattern, access to world supply must continue to be sought through mutually advantageous agreements with friendly nations.

We are in the future going to be dependent to a large extent upon world resources, there is no way we can avoid it.

These foreign sources should be secured when significant savings, offsetting international relationships, or domestic investments in foreign ventures, favor reliance on foreign supplies for some appropriate share of our mineral requirements.

Toward these ends, we will require improved knowledge of foreign mineral production, consumption, and resources.

That is one of the weakest parts of the present study. We have got to know more about it. In fact, we should be able to obtain information on foreign developments that is fully comparable in quality and quantity with data on domestic mineral resources. Further, under certain circumstances, we should be prepared to provide technology to establish and insure foreign supplies which are essential to our resource base.

I emphasize here, I am not suggesting that we provide technology overseas to compete with domestic sources, but in those cases in which we are solely dependent upon the overseas imports we should be willing to provide the technology which will minimize the total cost to us.

Senator GRUENING. Dr. Hibbard, the State Department has various types of attachés and ambassadors. Couldn't the economic attachés be asked to supply this information concerning foreign mineral production?

Dr. HIBBARD. Yes, sir; that is possible. But it is my personal opinion—and this may not be the Department's view—that what is needed is a series of maybe eight or nine employees of the Bureau of Mines attached to the embassy in key foreign countries. What we require is not really an economic matter. You really need a mining man, somebody who knows geology, and who knows the minerals industry, who knows the technology of mining and mineral recovery. Without this kind of person we would have to accept at face value whatever we are told.

If we have eight or nine of these key people situated around the world who can not only collect the information but appraise it with relation to the United States, we will get the kind of information we really need. At the moment we only have a few minerals attachés anyway. They are becoming extinct.

Rising economic development throughout the world will inevitably stimulate demand for minerals in other countries, tending to limit the quantities available on world markets and to increase costs. Moreover, for some commodities most of the known reserves lie in Communist countries.

We know from past experience that, in times of national emergency when access to world sources is restricted, it is possible to work domestic deposits that otherwise are noncommercial. We also know that to do this requires vast standby or multipurpose investment and production capacity, which is expensive to acquire and difficult to encourage. The only alternative is to hope that such situations afford us sufficient leadtime, and that capital will materialize to support developments that have uncertain long term economic aspects.

If you look back at World War II we decided to produce aluminum from clay. We have plenty of clay. But if I recall the figures, we only produced about 50 tons of aluminum, and none of it was satisfactory.

In other words, the 4 years of World War II was too short a time to gear up for aluminum from clay production. And this is the problem. We can't suddenly switch from domestic production on an economic basis if our supplies are cut off; we have to have leadtime, 5 to 10 years. And if we don't have it, we are likely to face a crisis.

Senator ALLOTT. Along the lines of what you have been saying, Dr. Hibbard, this may not be true 100 percent of the time, but it would be true that in every instance that we have been caught in a national emergency, and have had to increase the supply of minerals from foreign countries, we have been caught in the box of higher prices, haven't we, almost entirely? There may be one or two exceptions, but this has been generally true.

Dr. HIBBARD. Yes; that is true. Shall I continue?

Senator GRUENING. Please continue.

Dr. HIBBARD. We understand the need for stockpiling as a security measure but we must not let our present favorable position in this regard obstruct our understanding of the significance of assured overseas supplied in meeting the growing domestic needs for many critical materials.

III. ACCOMMODATING TO CHANGING END-USE PATTERNS

The third important area is the accommodation to changing end-use patterns.

Those of us associated with the mineral industries must remain alert to the supply problems inherent in a continuous changing pattern of mineral demand. We must provide ourselves with techniques that can be applied to detect the imminence of change, to estimate its magnitude, and to reduce the potential hazards it represents to the nation's economy and security.

The demand for mineral raw materials is constantly shifting in terms of quantities, form, and substance, and the supply is subject to similar changes in quality, abundance, and source.

Reflect for a moment upon the dramatic examples of changes in the pattern of demand for mineral substances over the past few decades. At the beginning of this century we relied almost wholly upon coal to satisfy our energy needs. The significance of petroleum and natural gas as predominant energy sources has materialized subsequently over a very short time frame and the appearance of nuclear energy is so recent that its future in the total energy picture continues as a favorite subject for speculation. Similarly, a host of new minerals and metals have become important items of commerce only during very recent years, and even more dramatically, the way materials are used and synthesized has changed and progressed repeatedly. A few metals like iron, copper, lead, zinc, mercury, gold, and silver made up the basic items of commerce for centuries. But since 1900, the growth in significance of metals like aluminum and magnesium and the emergence of new substances like titanium and zirconium as common items of industry have greatly complicated supply-demand relationships. Certainly the suite of materials that will be in demand only a few years from now will be quite different than today.

We are aware that change is inevitable. We realize, too, how essential it is that we have leadtime if we are to solve the mineral-supply problems accompanying such change. Yet, we have failed thus far to develop fully effective techniques for recognizing the events that foretell significant changes in demand patterns.

This is the other weakness disclosed by our study.

Our appraisal of demand patterns is really not as good as it should be.

Demand forecasts still flounder in an atmosphere of vague generalities and seldom inspire the needed support for positive and timely action. This support in particularly difficult to generate during periods of prosperity. As humans, we tend to respond only when the house is on fire.

It is imperative that we work continuously to improve our capacity for isolating, appraising, analyzing, and correctly forecasting events that could significantly alter supply-demand patterns. Only in this way will we be in a position to initiate actions that can minimize the impact of change.

Our most critical analysis must be directed to situations where immediate changes in marketing specifications threaten to upset traditional supply-demand relationships. By way of current illustration, the impending changes in end-use patterns of fossil fuels dictated by a general concern with air-pollution problems promise significant changes in marketing patterns. The full impact of marketing constraints that might arise in the future must be clearly understood so as to minimize changes in traditional mineral supply-demand relationships that can threaten both economic stability and national security. And this cannot be accomplished without increased and continuing efforts to improve forecasting techniques and to provide basic planning data.

These first three are the major key items which worry me.

In addition, item 4 is diversifying primary supply patterns.

And in the interest of time, sir, may I just summarize these. They are fully described in the rest of my formal statement.

We are concerned here with being able to be flexible in supply to match the flexibility and demand. This means looking beyond conventional sources to low level concentrations of minerals and marginal and submarginal materials which have to be developed in the future.

Item 5 pertains to creating technology to minimize reliance on conventional resources.

If I could put this in the record too, I could summarize it by saying, the subject includes, for example, the possibility of recovering the minerals from the sea. There is a wide diversity of minerals there. And they are not proprietary to any country. So if we could develop the technology to do this, then our mineral supply problem would be considerably reduced. Or if by the use of nuclear fission, we could find inexpensive ways of treating minerals which are low in value, individual values, but cover a wide range. These, too, are the great hopes for this area.

I am not too optimistic about this. But this is one of these new possibilities, and, therefore, we can't ignore it.

Item 6 is stretching material supplies.

Actually this directs emphasis to the subject of recycling. If we could recycle all of the metals and minerals and commodities which we use only temporarily and then discard with obsolete equipment like old automobiles—or like this circuit board with its gold, for example—these items would constitute a substantial source of new supply. We don't really know much about the quantities involved. We are making studies right now to find out.

Senator ALLOTT. Could I ask you a question on that? You indicated, when you showed this scrap circuit board to us a few moments ago, that there were great numbers of these that are just having to be abandoned.

Dr. HIBBARD. You see, what happens, this circuit board is full of components, transistors and resistors, and so forth. This ends up in a surplus store. There is one in Washington, by the way. You can go down there and buy this plate for a quarter. The hams buy the plate and remove all the transistors and resistors, because there may be $20 worth of them on there. And this is what they want for their circuits. But they don't realize that there is more than a quarter's worth of gold in the board.

Senator ALLOTT. That is what I was going to ask.

Dr. HIBBARD. And so they normally abandon it, they throw it away. We are making a survey in the major cities right now, as part of our next step to find out just how much of this gold electronic scrap is available. It must be very large.

Then we will have to find out if there are ways and means of collecting it.

You know, some of this has shown up in the incinerator fly-ash. We had a study of fly-ash from seven incinerators in this area, and we found gold in that product. Somebody probably bought some of these plates and took off all the transistors and threw the rest in the wastebasket.

The other part of this subject has to do with the design of more durable goods. If we could double the lifespan of refrigerators or automobiles or the things that are made of minerals, this, of course, would measurably reduce our annual requirements for these commodities.

Or if we knew how to synthesize certain materials, we could reduce our concern for certain shortages. All of these approaches would stretch what we have, and make it last longer and go further.

Item 7—and, again, I would like to put the text in the record, but just summarize it by saying, this looks at certain resources that we have a lot of, but don't use extensively. Boron is an example. We have got lots of boron in the United States. If we could find some way of using boron more extensively, this would be an example of employing a good potential.

Oil shale is another one.

We have a superabundance of magnesium, silicon, and many of the common elements in the earth's crust. If we could learn how to use them, that would relieve the situation and provide a basis for vast new industries.

Going on to item 8—and, again, if I may put the text in the record, and summarize it—this pertains to resolving resource conflicts and the place of minerals in true multiple land use. We are more and more concerned about air pollution, water pollution, and mined land restoration. We have got to learn how to retrieve our minerals from nature, and at the same time restore the land so that it can be used for other purposes.

And this is going to add a cost to the mining operation. And, hopefully, that cost will be recovered by the subsequent values of the land.

And then item 9, which is extremely important—again, if I may put the full text in the record and summarize—item 9 is conserving manpower. There is a great shortage of mining engineers and mineral engineers and an uncertain supply of skilled labor and operators. If you will look at an increase of 50 percent in our requirements for minerals, this could mean at least an increase of 50 percent of our requirements for mining engineers. Our preliminary appraisals indicate that these people are not forthcoming. And, in addition, there are impending shortages of workers at the mine face and in the mills and smelters.

Somehow or other we are going to have to find ways and means for producing and attracting these people, or find ways and means of producing minerals without them, I don't know which, but it is a tremendously important area.

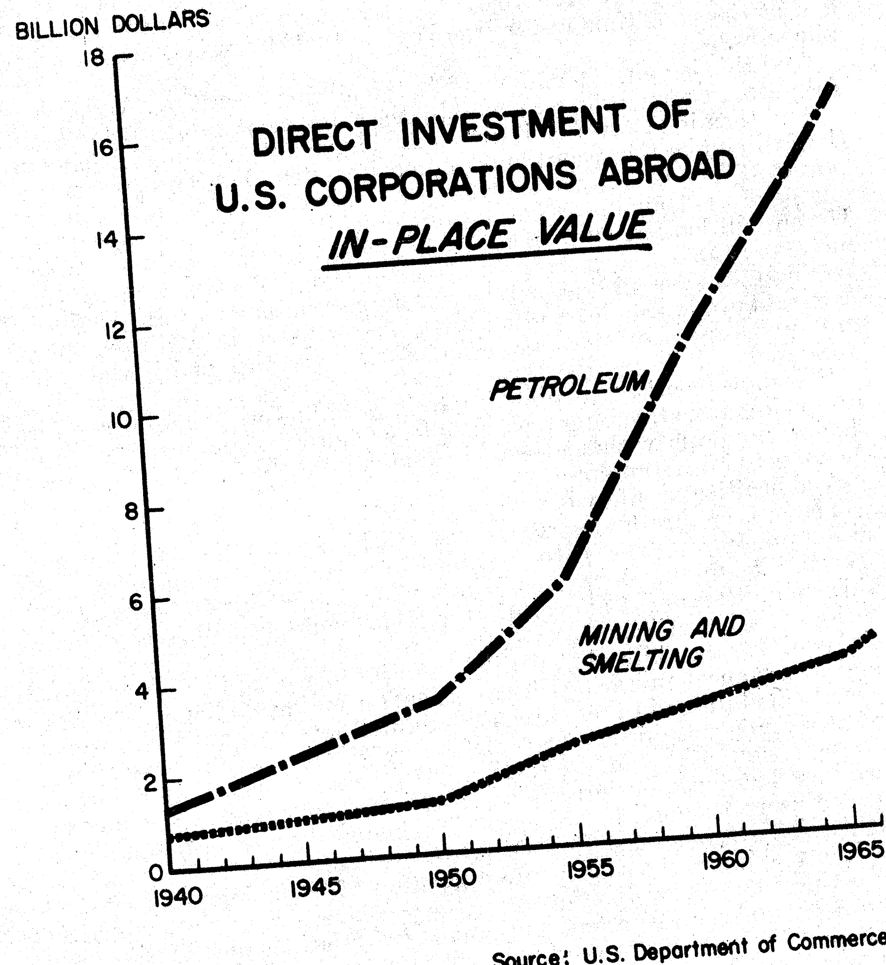
And health and safety is a major part of it.

These, then, are the emerging issues which merit the most serious attention. While some of these subjects are beyond the immediate responsibility of the Bureau of Mines, none are outside the interest of this committee, and I am certain these vital matters will receive your serious consideration.

Acquiring the skills that will be essential to accomplish the technological advances prescribed here presents a major challenge. Professional capabilities in these areas are limited now and are likely to be wholly inadequate in the future if an effective means of developing the necessary talent and attracting it to these problems is not forthcoming. The outlook suggests a critical need to increase the number of engineers, economists and executives knowledgeable in the mineral field and a way to attract their skills to these issues.

In my opinion, the successful application of technology to meet the mineral demands of the future is the most recurring theme in the appraisals of the projected supply-demand relationships. Until now, the industry's ability to keep pace with growing demand through the application of new and improved technology is impressive, indeed.

However, we now see two trends emerging which will have far-reaching implications for the future of our minerals policy. As shown in the chart, the minerals industry added, in 1966, another $1.3 billion of capital to the amount already invested in overseas ventures. Lately we have also been witnessing series of "marriages" within the minerals field. Several companies are diversifying and others are integrating their activities, both horizontally and vertically. The petroleum companies in particular are expanding into the total-energy-supply business as well as acquiring interests in nonfuel minerals. It is heartening to know that the potential for capital investment represented by the healthy financial condition and the earnings of the petroleum com-



panies is to become available for the advancement of other sectors of the mineral industries. However, two questions face us:

1. Will this potential be invested in advancing the urgently needed mineral technology?

2. What share of it will be invested in other countries?

I believe that these questions should be thoroughly examined if we are to chart a rational course for the future.

Incidentally, in the past couple of months the tendency toward merger has begun to disappear. There was an article in the Wall Street Journal this morning which noted that some of these proposed marriages just didn't occur. And this, they say, is an indication of times and caution.

We know, for example, that some minerals of current and foreseeable commercial significance are just not available from domestic sources and are not likely to be found here in any appreciable quantity. Moreover, assured access to developed sources of some of these minerals is at times questionable.

Also of significance to the solution of critical mineral-supply problems is leadtime. It often takes 5 to 10 years to bring a new mineral deposit into production. This is a factor that is well understood by those who work in the mineral industries, but too seldom appreciated elsewhere. Nevertheless, we know that mineral production cannot be turned on like a faucet and that substantial capital in the order of millions of dollars per venture is required.

We know also that we often lack the kind of information that is needed as the basis for mineral-development decisions. Knowing these things, we must move forward purposefully to devise new and more sophisticated procedures for acquiring and evaluating the information we need.

We must strive to improve the competitive position of domestic resources through the application of new and improved technology in extracting and processing. More efficient methods for mining ores and for upgrading them before smelting and refining can make the use of leaner substances technically and economically feasible. We must learn how to explore for minerals at depths, and to develop methods for finding and extracting minerals in the deeper layers of the earth's crust, and from under the sea.

Still another tremendous opportunity for easing our mineral-supply problems is offered through the improved recycling of scrap and waste. We must learn how to mine our scrap heaps and junkyards for the valuable metals that they contain. Substitution of abundant materials for those in short supply also can be practiced far more effectively as a means of stretching our supply of mineral raw materials.

These are but a few of the many ways in which we can and must act to insure an ability to meet our mineral demands in the years to come.

I am sure that my remarks have brought to mind some questions. In the time remaining, I will be glad to answer as many of them as possible.

(The complete text of items IV through IX of Mr. Hibbard's prepared statement follows:)

IV. DIVERSIFYING PRIMARY SUPPLY PATTERNS

Parallelling the need to forecast and understand the implication of changing demand patterns is a necessity for continuously redefining commercial ore reserves, from which primary supply must be derived at any given time. The heavy metals program we are currently pursuing is a case in point.

Although past improvements in extraction and processing technology have made it possible to recover and employ minerals from lower-grade and less accessible sources without significant increase in unit costs, the extent to which the traditional domestic sources can continue to satisfy increasing or changing demands in the future is questionable in many instances and will be determined largely by the size of our commitment to minerals research and development.

We must look beyond conventional sources to low-level concentrations of minerals and metals in marginal and submarginal materials, for these are what must be developed in the near future. I am referring to the known mineral aggregations which, because of technologic or other factors, have remained unexploited in favor of higher-grade, more accessible, or more profitable alternatives. There is little uncertainty with regard to the existence of substantial quantities of almost any given substance. But the uncertainty of increases substantially when one considers he mineral forms, or the associated products, and such factors as location, accessibility, and the costs of extraction and processing.

V. CREATING TECHNOLOGY TO MINIMIZE RELIANCE ON CONVENTIONAL RESOURCES

Instances are seen where advances in technology would significantly contribute to minimizing reliance on conventional raw material sources to which, because of political, geographic or physical factors, access in the future may be restricted, uncertain, unreliable or otherwise potentially inadequate.

Some observers have stated optimistically that with the advent of cheap nuclear energy, even common rocks, such as granite, would become "ore" and supply unlimited quantities of all metals needed by industry. And there are those who conclude that, because sea water contains virtually all the chemical elements, the oceans will at some future time become a cornucopia of metals.

I cannot embrace such optimism, even though I will admit that the solution of future mineral supply problems lies in devising a practical universal system for directly reducing any substance into its useful components at a very low cost. If this can be accomplished, our current definitions of "resources" will disappear. I am not greatly concerned, however, that we need to meddle with these definitions, at least for the remainder of this century. I say this because, as in the case of common rock as "ore," the appreciable differences in physical and chemical form of the compounds containing the low concentration of metals in these rocks would require a vastly new and complex technology to extract them. Consider also the huge quantities of unusable waste that would be generated for each unit of metal.

Nevertheless, the existence of these obstacles should not stand in the way of an aggressive quest for at least partial technological achievement in areas that are promising. Many common substances, low in mineral content but abundant in nature and broadly distributed, and environments not fully explored or hostile can be commercially exploited with only modest advances in established technology or with more ingenious application of known principles.

VI. STRETCHING MATERIAL SUPPLIES

We can expect, during the remainder of this century, to continue to meet our material needs in several ways: Through primary production of mineral raw materials, by recapturing secondary materials in reusable forms, and by extending the useful life spans of mineral based products, reducing dissipative uses and waste, using materials ever more efficiently throughout the production-consumption cycle.

To make meaningful progress in stretching our material supplies we must find new and better ways to minimize the need for primary materials through recycling; learn how synthesis, substitution, or conversion can reduce a drain on limited supplies or achieve greater economies; and identify more areas in which significant losses and wastes can be reduced or eliminated, or needs can be minimized, through improved constitution, fabrication, and design.

Vast tonnages of pure metals and alloys are trapped in manufactured products. Many of the ever-increasing variety of alloys that end up as scrap continue to accumulate in junk piles for lack of extractive methods to separate and reclaim the metals they contain. This problem is compounded by the fact that many of these alloys—some containing metals in critical supply—were developed to resist just such conditions as are used by the extractive metallurgist in making separations. That is, they are extremely refractory and corrosion resistant to most chemicals.

We will be able to stretch our resources much further when we can properly design systems that will extend the life of products; make easier their maintenance and repair, and/or simplify the salvage of metals. We must continue to improve our techniques of solid waste management. By this, I mean that through technology we must strive to achieve optimum recovery of all metal and mineral values during ore extraction and processing. The emphasis here is on saving the mineral values, thereby reducing the need for future retreatment of wastes. Material supplies can also be stretched by finding ways to use relatively abundant minerals, rather than relatively scarce ones, to meet our needs for a particular commodity.

The manufacture of usable minerals by artificially duplicating the conditions that result in their occurrence in nature is still another means of extending mineral supplies. We must also work harder to extend the useful life of the materials in which minerals are used. This will mean developing new substances or techniques that can reduce corrosion, oxidation, abrasion, and fatigue in mineral and metal products. Additional approaches to material supplies include using several different minerals to supply a particular commodity need, and improving materials engineering so as to provide new substances with unusual properties thereby reducing overall material requirements.

VII. EMPLOYING THE LATENT POTENTIAL

Many mineral-forming elements and aggregations occur in such abundance and are so readily accessible and widely distributed that regardless of demand they are essentially inexhaustible. Nevertheless, there are technologic problems or prevailing economic disadvantages that preclude their widespread industrial use as substitutes for mineral commodities in lesser abundance. Of equal significance are mineralized zones or sources which, like oil shale for example, are of such magnitude as to insure the accommodation of large-scale demands for a long time.

I am firmly convinced that the nation's industrial and resource base can be broadened with attendant economic, employment, and national-income benefits. This can be accomplished by directing appropriate technologic and economic investigations into the advantages to be derived through creating new demands or markets for materials in superabundance like magnesium, boron, and the more common elements in the earth's crust, or for byproducts that are surplus to current demands by virtue of their presence in substances processed primarily for other materials, like many of the rare-earth elements.

The research emphasis should be on new applications for these plentiful materials rather than on their utilization as substitutes in competition with traditional materials in established markets.

VIII. RESOLVING RESOURCE CONFLICTS

Accompanying the foreseeable demand for more minerals is an increasing recognition that these materials must be provided without destroying the environment of the society that needs them. As never before in the history of our country, people are becoming increasingly aware of the need for true multiple land use. As a nation, we have come to recognize the need to preserve the precarious balance between material requirements and natural resources, and at the same time, to improve the bountiful heritage of the land. This awareness includes, but also extends beyond, problems of surface disturbance, air and water pollution, and waste disposal that are common to the processes used in extracting minerals from the earth. And it poses a host of stimulating challenges in the minerals and fuels sector of our economy—challenges that must be met with an immensely improved minerals technology.

We must develop new techniques for the ultimate disposal of the mineral-based products that have no further value or are not otherwise recoverable for reuse. A better technology is needed for controlling the surface subsidence that can result from underground mining. We must develop suitable methods for eliminating stream pollution that is associated with mining activity and for restoring land that has been damaged by surface mining. Finally, we must improve mine-fire control technology to prevent the needless waste of coal resources, the destruction of property, and the formation of noxious gases that menace humans, animals, and plant life.

Attaining these objectives will not, of course, provide direct economic gains to industry. On the contrary, they will frequently add costs that will probably have to be passed on to consumers in one form or another. Nevertheless, the problems that arise in meeting the nation's demands for minerals and metals cannot be treated apart from environmental threats that stem from the mining, treatment, or use of any mineral substance and we must seek to minimize the cost of erasing such threats. For the remainder of this century, as never before, we must apply technology wisely and efficiently so that the mineral needs of our industrial economy can be supplied while maintaining the quality of our environment.

IX. CONSERVING MANPOWER

Aside from the universal problem of acquiring the scientific and technologic capabilities that are essential to all of the foregoing subjects, one of the key factors in providing the growing mineral needs of our nation in the years to come is the availability of manpower. The industry can meet these mineral needs only as rapidly and effectively as the men in it can produce the necessary raw materials. So, in a very real sense, adequate resources of skilled manpower are as essential as proved mineral reserves and the techniques to extend these reserves.

These manpower resources are limited today and all indications point to continued shortages, despite industry's recruiting efforts. It is evident, therefore, that we must conserve these human resources. And we can do this by strengthening our ability and intensifying our efforts to assure safe and healthful working conditions. In doing so, we will encourage those already employed to continue working, and at the same time we will provide incentive for promising young men to join the production team.

Through the combined efforts of industry, and the Federal and State Governments, notable achievements have been made in promoting safety and protection of workers. But we must never forget that this effective cooperation is only part of what is needed. Safe performance of a job, like efficient performance of a job, requires the energy, the conviction, and the wholehearted commitment of the individual worker. Moreover, safety demands continuous attention; constant cooperation by all concerned is essential to assure the protection of the man on the job. His well-being is the goal. He must share the responsibility, and the pride, in attaining it. We must work energetically and unremittingly to promote this responsibility and pride if we are to conserve the valuable human resource so necessary to the fulfillment of our mineral and metal needs.

Senator GRUENING. Dr. Hibbard, thank you for a very magnificent and comprehensive and important statement.

I have one or two questions I would like to ask you.

What is the role of Government vis-a-vis private industry in forecasting future needs?

Dr. HIBBARD. I think the Government has a major role, because industry forecasts generally are done on an individual commodity basis. And generally, they look at a specific, narrow area of the mineral economy. I think only the Government has the capability and the broad interest to do these broad types of forecasts.

Now, I think these forecasts should be made available to industry, and then they can use them as a basis for their more focused forecasts, which are concerned with the particular business which a given corporation is in. But I think the Government must provide the basic information.

Senator GRUENING. What more is needed than what is being done now to enable the Government to fulfill that role? It seems to me that if it is essentially the role of Government to open the doors of information and to explore the possibilities so that industry can take over, how much more should the Government be doing? Should there be a separate branch of the Bureau of Mines to do this, or should it be done by——

Dr. HIBBARD. We actually do have a separate branch in the Bureau of Mines to do this. But, sir, the problem is in two areas. First of all, we do not have the international capabilities. I think that the Bureau should be authorized to expand its data-gathering resources to overseas, at least to the key overseas mineral areas, so that we can have the same degree of accuracy, the same degree of detail, the same degree of sophistication with respect to our knowledge of world resources that we have with respect to our knowledge of U.S. resources.

The Bureau does not now have this kind of authority, in my opinion. And I believe this is very important. These people should be on the Bureau payroll, much as the agricultural people are around the world, and they should be stationed at key embassies.

Senator GRUENING. I wonder whether you would be willing to supply us with a little outline prospectus for such an agency. Then, we will see if we can get action on it.

Dr. HIBBARD. I would be very happy to supply it.

Senator GRUENING. We would like to have it so that we can get action in this Congress.

Dr. HIBBARD. The other area in data gathering where we are weak is in regard to end-use material patterns. We know in general that a given substance goes into, say, the transportation industry. But we must know more specifically how it is used so that we can project changes in end-use patterns.

For example to go into an area in which I am particulary acquainted, there is now a tendency to use fiberglas or reinforced plastic for automobile bodies. A typical question would be, What is the impact of this on the long-range requirements for glass and steel? You have to have a fairly sophisticated knowledge of a good many subjects in order to make these projections.

So we also need more capability in this end-use area.

Now, again we are talking about world end uses, not just United States, because this is a competitive matter. And while we have, I believe, the authority to look at this sort of thing, and we do this very closely with the Department of Commerce, the current system is not sophisticated enough to do it right. And we need additional resources here.

Senator GRUENING. Thank you. Senator Fannin?

Senator FANNIN. Thank you, Mr. Chairman.

Dr. Hibbard, I certainly want to commend you for a very fine statement, and also your fine responses to the questions.

Have you developed any type of a program for the study of the slag that develops over the years at different mines that have smelters? This has been quite a factor, I know, in my State of Arizona. And because of new technology, I wondered what has been done so far as the recovery of minerals from these wastes is concerned.

Dr. HIBBARD. We have done the following: We have a program where we are getting samples of all the large waste dumps and tailings piles in the United States. And we are analyzing these materials to see whether or not they might be reworked and disposed of that way. We are also analyzing them for other uses, like making brick. And then lastly, if we find that neither of these two will work, we are trying to find ways and means of growing vegetation on them. So that the program is progressing.

Incidentally, I always hark back to gold. We found in the Grass Valley area of California some tailings piles which have enough gold in them to make it worthwhile to rework them.

But this program in my opinion is not being carried on with the urgency it deserves. This is far more urgent in my opinion than the modest resources we have been able to bring to bear on it would infer.

Senator FANNIN. Thank you, Doctor. I do want to say that, as you know, the committee members were very elated when you came to the Department and when you took over the directorship of the Bureau of

Mines. And we are very sorry to see you leave. We hope you will continue to contribute to the work that is involved.

Dr. HIBBARD. I am really not leaving in spirit, and I will be glad to help in any way I can in the future.

Senator FANNIN. Thank you very much.

Senator GRUENING. Senator Hansen?

Senator HANSEN. Thank you, Mr. Chairman.

First of all, let me join with my colleagues, Dr. Hibbard, in congratulating you on an extremely important landmark statement. I just think it is extremely easy in this day of severe competition for headlines from the press and other news media to overlook really tremendously important statements. And I think you have made such a statement here this morning. We are going to have to take this statement—I am, certainly, going to take it back to my office and read it and reread it in order to get the full import of your many reflections on the sensitive and interrelated issues that concern our domestic minerals and fuel policies. They are related—you brought that out. And I can say that my great regret in your leaving the Bureau at this very critical time is certainly heightened by the fact that those of us who would like to help with the formulation of a policy, a Federal policy that will come to grips with these problems, are going to feel somewhat lonely by reason of your departure. And I hope that we can continue to have the great benefit of your observations as time moves along.

I don't mean to put any words into your mouth. But it seems to me that while you have given a very low-key and thoughtful presentation, there is throughout it the expression of a sense of considerable urgency about the future health of our domestic minerals and fuels industries. And this urgent need for better Government planning and understanding is, if I read your views correctly, certainly sharpened by our present balance-of-payments crisis. Would I be correct in assuming that you are telling us that we have not done very well in the past in creating an intelligent minerals policy for this country, and that our Government must act, and act quickly as well as intelligently, if we are to make up for this deficit with a meaningful policy that will give us the security, that will give us the economic viability, and that will give us the independence that I think we all cherish so much?

Dr. HIBBARD. I think, first of all, that in order to make intelligent policy you have to have a sound knowledge of the situation. And this is what this study has attempted to provide. I believe the kind of information needed to make policy has not been available. I think it is now available. And I think the situation is urgent. And I think we now have a basis of doing some things that need to be done and done promptly. And I would certainly recommend that a very high priority be given to looking at these problems in depth, and to determining what the policy should be.

With respect to the Bureau of Mines, I want to say that this is not a single man's effort. We have a tremendous team of people. These are two of my colleagues here. And here behind me are some more. This top management group is a management group in the same sense that industry has a management team. And these people are capable, they are knowledgeable, they are competent, and they have the desire to keep on following this approach to the Bureau's problems. And I think you are going to see a continuing emergence of the kind of information, the kind of presentation, the kind of advice that you will need to formulate sound legislative policies with respect to this area.

Senator HANSEN. Mr. Chairman, I would be presumptive in assuming that I could add anything to the great statement that has been delivered here. But if I could be permitted just a personal observation it would be to say that I think our country, with some 6 or 7 percent of the world's population, and using about roughly that same amount of the total land area, has indeed achieved a great deal. We produce at the present time roughly a third of the world's goods. We have the highest standard of living of any country in the world. And yet the cautions that Dr. Hibbard has called to our attention here this morning suggest to me that we must continue to press forward on all fronts. We need to investigate the technological improvements that must accompany any further activity in the mining industry. We have to stress research. And we must not forget leadtime. Even with our resources and reserves that do not have the highgrade deposits that we have been able to exploit in the past, we still have enough reserves in this country so that we can keep the kind of operation going in which Dr. Hibbard is so vitally interested. He has certainly given us a great valediction here this morning, and I compliment him very highly.

Senator GRUENING. I think that is a very excellent statement. I might add that we shouldn't get smug.

We have a couple of representatives here from the Department of Commerce who are kind enough to assist or listen in at this hearing. They are Anthony Bertsch, Assistant Administrator, Business and Defense Services Administration, and Henry Callaway, of the Office of Metals and Minerals. Would either of you like to make any comments?

Mr. BERTSCH. Mr. Chairman, we don't have any comments, except that I would like to join the committee in commending Dr. Hibbard for the excellence of his statement, and also, incidentally, to commend him and his staff for the kind of cooperation they give to the Department of Commerce.

Senator GRUENING. Thank you very much.

We will now stand adjourned.

(Whereupon, at 12:15 p.m., the subcommittee adjourned, subject to the call of the Chair.)

[illegible] Chairman, we don't have any comments except [illegible] the [illegible] Department of Commerce.

[illegible] Thank you very much.

[illegible]

APPENDIX

(The summary of the Bureau of Mines studies to which Director Hibbard referred in his oral presentation follows:)

ALUMINUM

Aluminum is the most abundant metallic element in the earth's crust and in this sense the resource is limited only by the price one is willing to pay for the metal. Current demand and technology limit the commercial reserves essentially to bauxite. Geographically, the majority of commercial bauxite reserves are in the less-industralized areas of the world far from the aluminum reduction and consumption centers. As a result, the availability and hence the consumption of bauxite is subject to any drastic changes in political climate. Power supply and costs influence the geography of reduction capacity. The present system through which aluminum is derived from bauxite is not likely to change in the immediate future, except for minor processes improvements and the further diversification of sources of bauxite supply. Competition within the industry, which is mainly vertically integrated and between aluminum and other metals, like copper, inspires innovation and research within the industry to improve operating techniques, lower labor and power requirements, and reduce costs.

The capital cost of an aluminum-producing facility, including bauxite, alumina, and power-producing facilities, is high, and the investment requirements make it difficult for a new company to enter the industry. Since most companies are vertically integrated, a new company which must purchase bauxite or alumina may be at a competitive disadvantage, especially in times of high demand for the metal. Local governments, through bond issues, help finance new plants and also make tax concessions.

Both domestically and abroad the ultimate alumina and aluminum resource is the nonbauxitic clays, mainly of the kaolin type (see section on clay). Probably, by 1985, a small but important percentage of new aluminum production will be derived from such material. Thereafter, dependence upon clays as the basic aluminum source should increase rapidly. The United States has large supplies of such clays. From this resource standpoint it could meet all or most of its raw material needs indefinitely. The employment, revenue, and other benefits from such a pattern would add substantially to the industrial strength of the country. Accordingly, any technologic advance that promises to improve upon the present technology of winning aluminum from clay and measurably reduce the economic disadvantages of presently known technology (about 25%) deserves a large measure of attention.

The Bayer process or modifications of it is the standard means used in the United States for reducing bauxite to alumina. Many small improvements have been made over the years until today there appear to be very few possibilities for improving the process except by modification of materials handling equipment and improved heat recovery. Similarly, in the production of metal from alumina, the few promising areas for further technological improvement are in lowered power consumption by additions of substances to the electrolyte, new direct reduction technologies, use of new cathode leads, new cell lining materials, and finding a substitute for petroleum coke that is commonly used for anodes in the reduction process. Carbon consumption varies, but in general it is an important cost element in the production of metal.

Most secondary aluminum is recovered as mill scrap where the composition is known and very little processing is required. Other aluminum secondary material such as scrap from automobiles and used equipment is melted down and made into aluminum silicon alloys for use in casting. Considerable quantities of aluminum are present in products that are scrapped, wasted, or discarded, only a portion of which are effectively recycled. In common with a variety of other metals, secondary recovery practices and techniques need improvement both from the conservation and waste disposal viewpoints.

Land-use conflicts would accompany any large-scale employment of domestic clays as a primary source of aluminum. Similarly, disposal of wastes that accumulate in quantity incidental to the production of alumina (red muds) pose a present problem that will become more critical with time.

ANTHRACITE

Anthracite is an energy source which had been used in great amounts. The high cost of mining due to unfavorable geologic conditions along with the availability and convenience of alternative fuels have substantially reduced the demand for anthracite. As production drops, mines close and become inundated, thereby increasing the cost of recovering anthracite left in the ground. Thus we have a dilemma for which there is no easy solution. Simply stated, there are sufficient anthracite resources to sustain a sizable production, but there is no demand for that production. If production does not occur, the coal remaining in the ground becomes more costly to recover. Yet anthracite is a low-sulfur, clean-burning fuel which may be in greater demand as air pollution restrictions become more widespread.

Essentially the emerging issues of the anthracite industry and region are social in nature. Streams polluted with acid mine water must be purified; spoil piles and culm banks must be eliminated; strip pits, crop falls and impoundments of acid mine water must be eliminated; subsiding land which ruins surface structures must be stabilized; and, fires in culm banks and coal seams which are hazardous to life, limb, and property must be quenched. The issues are here now and will remain until remedial action is taken. The urgency is that of nearly two million people living in a region with a sub-standard economy, yet a region which has much to offer the nation.

The production of anthracite is centered in a 10-county region of eastern Pennsylvania. The economy of this region had been heavily dependent on the mining of anthracite. As a result when the demand for anthracite faltered, the regional economy stagnated. Along with the drop in production, there was a reduction in the labor force. A stagnant economy coupled with fewer employment opportunities encouraged people to leave. For more than two decades, the population in the anthracite region has been declining while the surrounding counties have been gaining in population. Despite these trends, the anthracite area has great economic potential—it is close to large markets, has a surplus labor force, and possesses an ample supply of water. But before the full potential of this area can be realized, the residual effects of past mining practices must be nullified.

ANTIMONY

Major periodic variations in demand, uncertain foreign supply, the nature of deposition that limits the extent of reserves at single sites, and economics unfavorable to domestic production produce an uncertain primary supply picture. Defense requirements contribute to the fluctuating demand but are modified by management of the national stockpile. Also, secondary metal is important in meeting requirements with about 50 percent of the current demand being met from this source. Current domestic production of primary metal materializes as a byproduct in the refining of base metal and silver ores and adds a recognizable increment to the economics of the refining operations. Little opportunity is seen for improving upon current practices.

Secondary metal, already the source of much of the current requirement, is so important to the projected supply pattern that any improvement in the recapture and recycling of scrap merits attention.

There are many applications in which other metals substitute satisfactorily for antimony, the cost advantage together with minor inconveniences being the factors normally favoring employment of antimony. The technology and opportunity for such substitution are fairly well understood. Over the long term the availability and cost of the competing metals will strongly influence the antimony requirement and use pattern. This applies particularly to copper, mercury, titanium, lead, zinc, chromium, zirconium, calcium, bismuth, and various organic synthetics.

ARSENIC

The mineralogical association with copper, lead, cobalt, nickel, iron, gold, and silver relates the production potential for arsenic to the refining capacity for those metals. At present, and for the foreseeable future, this potential exceeds any anticipated requirement. Domestically, arsenic is treated more as a nuisance than an object for recovery in refining processes and only one firm presently produces it. Coincidentally, more than half of the United States demand is met through imoprts, some of which materializes in the domestic treatment of foreign base metal ores. The technology of recovering byproduct arsenic and its marketable compounds is complicated and relatively inefficient. Processing improvements probably could be made, but the low price and fluctuating market, coupled to the limited demand outlook, discourages investment in plant improvement and process development.

Because of its toxic properties, arsenic disposal practices deserve continuing attention. As one of the contaminants in smelter stack gases, improved control is a factor in the overall problem of minimizing air pollution and effecting better waste disposal systems.

Asbestos

The United States is the world's largest consumer but supplies only approximately 15 percent of its requirements from domestic sources. The term "asbestos" applies to a variety of natural occurring mineral fibers, some types of which have important defense and specialty characteristics. Complete dependence upon foreign supply for some types is minimized by adequate stockpiles but poses long-term concern. In view of past unsuccessful incentive programs designed to encourage domestic development of the more strategic grades of asbestos, the potential for such development seems poor.

Synthesis and substitution have been investigated as means of minimizing reliance upon uncertain supplies of selected grades, with an eye to the growing markets for asbestiform materials. Only a few substitutes are, at present, economically competitive. While considerable research has been directed to synthesizing fibers that have properties similar to the best natural substances, it has met with only limited success. The development of practicable technologic advances in this broad area would have substantial industry impact, both in regard to traditional use patterns and to the emergency of new applications and products.

Serious health hazards are present in the whole sequence of extracting, processing, and utilizing mineral fibers, and the expanding use of these substances directs attention to a need to better understand and manage the problem.

Barium

The United States is the world's largest consumer, and while it produces about a fourth of the world output, it is still a large importer. Barite ($BaSO_4$) is the mineral form most important in commerce. Consumption is a direct factor of the need for weighted muds in oil and gas well drilling, with over 70 percent of the demand stemming from those activities. Resources are abundant and widely distributed. Low cost of barite precludes the employment of substances that might otherwise be used as substitutes in the drilling mud market. The uses for which there are no practical substitutes are minor at present in terms of the abundance of the commodity. However, inquiry into the production of various barium compounds with properties that promise the possibility of future large-scale markets has some attraction because of the relative low cost and availability of barite. In particular, a potential exists for an appreciable use of barium chloride for water treatment and water pollution abatement if a lower cost method is developed for its manufacture.

Although ore reserves and processing technologies are adequate to insure ample supplies of barite, barium compounds, and chemicals for many years, increasing process efficiency and better beneficiation methods could improve recoveries and increase product quality.

Beryllium

Because of cost and technologic limitations, the only present commercial source of beryllium is beryl, hand-cobbed in a primitive fashion from certain pegmatites. Only a fraction of the domestic demand is derived from United States sources. World reserves of beryl are not thought to be very large, but other beryllium minerals and some fine-grained beryl occur in relatively large low-grade deposits both within the United States and abroad. Though the subject of considerable exploration and investigation, the commercial significance of such sources in the foreseeable future is uncertain despite past recurring extraordinary efforts to improve the domestic supply position. Some practicable means should be found for winning beryllium from such low-grade substances.

Beryllium and its compounds have certain unique properties which, irregardless of relatively high cost, promise a growing and diversified application in special and critical end uses. Presently, beryllium-copper alloys and beryllium metal are the principal use forms. A small quantity is employed in the ceramic and chemical industry. Periodically, real or imaginary promises of new volume uses spur unusual industry activity both in the quest for better sources and for methods of processing low-grade ores and ways of introducing a concentrated product to a trade geared traditionally to hand-cobbed beryl. These periods of interest have usually been of short duration and not very productive in advancing the status of the nontraditional sources of potential supply. A modest sustained interest would be more effective than the hot and cold approach of the past.

The high cost and some processing difficulties have limited the employment of beryllium and its compounds to the most obvious and demanding applications where its unique properties are important. Anything that would improve upon the processing and forming technology and reduce costs would measurably broaden the fields of application. To the engineer, designer, and user the properties of beryllium are ideal to many new product and use concepts.

The toxicity of beryllium complicates processing techniques and end use applications and adds substantially to costs.

Bismuth

Bismuth minerals rarely occur naturally in sufficient concentrations to permit commercial exploitation as a primary objective. They occur frequently in minor amounts in lead, copper, tungsten, and gold ores. Most domestic production results from the treatment of lead smelter products, and the rate of production is a factor of the smelting capacity. In recent years new uses have substantially increased demand for the metal and shortages have been avoided only by a drawdown on producers' stocks and through allocations. The byproduct bismuth is a measurable benefit in the economics of some smelter operations, and it is presumed that this provides sufficient incentive to promote effective recovery and efficient extraction. As a relatively high cost commodity with expanding applications and a supply not subject to much independent expansion, it would seem appropriate to seek instances where other commodities might satisfactorily substitute for bismuth.

Domestic supply could be adversely affected by the depletion of certain base metal deposits particularly rich in bismuth. Because of the mineralogical distribution, bismuth production is not necessarily a fixed ratio to the scale of smelter production. Presumably, the same conclusion applies to other world sources. In light of this eventuality, the bismuth content of ores likely to be commercially attractive in the future should be studied to gain better advanced knowledge of potential supply problems.

Better technological data are needed on the behavior of bismuth during lead and copper processing, on the bismuth content of various smelter fractions, and on the overall recoveries attendant with bismuth extraction.

Bituminous Coal and Lignite

Changing demand for bituminous coal had brought instability and economic hardship to the coal industry. Recently demand has exhibited moderate but consistent increases bringing a measure of stability and self-confidence to the industry. During the next decade coal consumption should continue to grow. But strong political and social forces working to reduce air pollution threaten this growth, thereby tending to discourage capital investment and to undermine confidence in the industry. Pending the successful introduction of economic methods for the removal of sulfur from coal or flue gases, the supply of low-sulfur coals will be relatively tight, and in most cases at higher costs than the conventional coals used for power generation. As a minimum, the drive to reduce pollution will disrupt some of the conventional supply-demand patterns by encouraging the production of low-sulfur coal. This is likely to increase the tendency towards larger mines and the consolidation of companies into relatively large groupings of mines. Further, there has been a trend in the affiliation of large coal companies with other energy-producing corporations. The increasing capital requirements of coal operations is likely to continue and even accelerate this trend.

Communities which rely on small mines for their livelihood will be faced with possible dislocation of job opportunities.

Other environmental factors, of less immediate concern but of long-range importance, include more stringent land reclamation laws, and laws restricting the discharge of acid-mine water. Research in the latter area may forestall or eliminate future problems.

The nuclear challenge to coal for the electric utility market should encourage a search for greater diversification in markets for coal. Possibly the natural gravitation to more flexible forms—liquid and gaseous—is the best way to achieve this diversification.

The changing nature of the bituminous coal industry will make it increasingly more challenging during the next decade to maintain safe and healthful working conditions. Mines will be getting larger, equipment will be more powerful, coal will be mined faster, and a greater number of new employees will enter the labor force.

During World War II the ready availability of strippable coal reserves for contour mining made possible the necessary rapid increase in coal production at that time. However, at the present time there is little specific information available on the extent and location of strippable coal reserves in the United States. Filling this gap is an area of major importance to the national interest.

As a result of improved transportation techniques, the competitive position of this industry has improved. Transportation of coal by unit trains has reduced costs. Successful development of extra high voltage transmission methods has made it possible to construct power plants at or near mine sites with the result that power, not coal, is transported economically.

Increasing demand for bituminous coal will not create any long-range supply problems, although at times the industry will have difficulty adjusting to changing conditions. For example, premium grade coking coal may be in short supply; production of low-sulfur coal may not keep up with demand; delays may occur in meeting contract commitments for export coal; miners, especially equipment operators, and skilled craftsmen may have to be recruited and trained; and, coal mining equipment manufacturers may fall behind schedule. None of these conditions appears serious although at times they could prove embarrassing to the industry as well as the nation. If these situations do occur, part of the reason lies in the slow response of the industry to increasing demand and part rests with the long lead-time needed to develop new mines.

The sulfur content of the majority of United States lignite reserves is low (0.7 percent), which indicates its value for fuel generation. However, the high moisture content and low-thermal value militates against its transportation over great distances. Since most reserves are far from major urban areas, there is a need to develop methods for upgrading the material. The utilization of lignite also depends upon overcoming severe ash fouling tendencies. Potential applications of lignite exist in the Minnesota iron ore industry for (1) production of prereduced pellets, (2) use of leonardite as a pellet binder, and (3) partial reduction of non-magnetic taconite to the magnetic form.

Approximately 40 percent of the bituminous coal consumption went to industrial uses, including coal carbonized for coke and for coal chemicals. The eastern, or Appalachian region, contains the largest reserve of high-quality, high-rank coals in the United States, and, in fact, in the world. While all the bituminous coals of the region have coking properties, not all are considered coking coals because some have ash and sulfur contents that exceed the normally accepted limits established for coking coals. In the midwest and western regions of the United States there are some reserves of coal suitable for coking purposes. In general these are not very large and the coal is often blended with higher-rank coals. There is a need to develop methods for wider use of such lower rank coals for coke production.

BORON

At present all of the United States supply and 70 percent of the world supply come from bedded deposits and lake brines in California. Reserves are abundant and seen as adequate to meet foreseeable demands. However, a significant factor in boron economics is the virtual world-wide monopoly held by a single foreign-based company.

Future world trade patterns may change somewhat and favor increased imports to the United States of certain mineral forms for special applications. Over the long-term, such competition will tend to stabilize or reduce prices rather than greatly affect production and consumption growth rates.

The possibility of employing boron and boron compounds as substitutes for other substances that are less abundant, more costly, or promise better performance has inspired much research both in the producing and potential consuming sectors. This interest is expected to be sustained without added incentives.

Turkey produces the boron-containing mineral colemanite which can be used by the glass industry without additional processing. As a result it is in a very favorable position to compete with domestic borax production. It is believed that domestic production from bedded deposits and from Searless Lake brines when coproducts are recovered will be able to compete successfully.

Bromine

World supply is, and will remain, a function of plant capacity and production economics. Brines and sea water promise a virtually inexhaustible supply. Desalinization plants promise a new commercial byproduct source of bromine incidental to the manufacture of potable water. In common with other substances, rejected in desalinization processes, potential markets for such byproducts materially affect the practicability of desalinization. Probably the processes for recovering commercial products from such rejects and, most significantly, finding ways to market them in presently satisfied trade patterns, merit increased attention—more from the standpoint of reducing desalinization costs than from the long-term mineral supply problem.

New or expanded volume uses of bromine would tend to facilitate the above relationship and the overall economics of operations where coproduct substances are affected (soda ash, salt cake, potash, borax, and lithium minerals).

The toxic properties of the element tend to restrain some potential volume applications and add to production, transportation and use costs. Among these the toxic aspects of emission traced to antiknock compounds in gasoline are not well understood.

Process wastes require extensive treatment prior to disposal, if pollution issues are to be avoided. Disposal practices have been improved but growing general concern with waste disposal and pollution practices may demand additional improvements and costs—unless new techniques are provided.

Cadmium

The mineralogical association with zinc makes cadmium resources a function of zinc resources and the rate of cadmium production a function of zinc production. Output would not respond to cadmium price changes but would vary with the output of zinc. Accordingly, cadmium supplies are a direct function of the price of zinc. Demand tends to exceed supply and in such instances increased cadmium prices tend to reduce some applications and restore a balance. The result is a cyclic pattern of rapid reversals in trends of consumption, industrial stocks, and foreign trade. In this relationship there is little logic in seeking new applications for the commodity.

Cadmium sales are a measurable increment in the economics of slab zinc production (4 to 10 percent of the value). Current technology removes 70 to 80 percent of the cadmium as recoverable fume during roasting and sintering. Most of the remaining cadmium reports with the zinc when reduction is affected by retorting, electrothermic furnaces or blast furnaces. Exploratory research indicates almost complete elimination of lead, cadmium and germanium if zinc concentrates are roasted in an oxygen deficient atmosphere.

As in the case of some other commodities (see section on bismuth) the cadmium content of zinc ores is not a constant ratio and future supply could vary as old zinc sources are depleted and new sources developed. In this light, the cadmium content of ores likely to be commercially attractive in the future should be periodically appraised to gain lead-time to accommodate potential supply problems.

Considering the average price of cadmium and the inflexibility in supply, improvement in secondary recovery techniques would have future significance.

Considering the uncertainty of future supply, it would seem that other more abundant or less costly commodities might find some application in the use areas traditionally or potentially occupied by cadmium. The whole issue of corrosion retardation, for example, demands attention both from the standpoint of materials and techniques. Similarly, speculative research directed to improving cadmium (nickel) batteries for large volume use could more profitably be oriented towards other substances.

Calcium

Sources are essentially unlimited and production capacity, demand, and costs alone will determine the volume of future production. Various compounds are employed in bulk quantities but the metal is produced only in small quantities. Future demands are uncertain but likely to expand in light of the metal's special properties and potential abundance. No particular issues attach to the commodity.

Carbon

The element, in a large variety of forms, is derived commercially from both mineral hydrocarbons and organic materials. Source and use-patterns are complicated and interrelated with energy aspects of coal, petroleum, gas, and the other naturally occurring substances. No basic raw material supply problem is probable in the foreseeable future. However, the endless variety of ways in which the element is derived and commercially employed in nonfuel applications are so critical to an industrialized economy that relatively minor improvements in use technology have, in the past, and will have, in the future, profound effects upon the nation's materials and industrial capabilities. The intricate use-pattern relationships that include carbon are not well understood and deserve more attention.

The significance of carbon in a mineral sense does not yield readily to appraisal but is seen in several broad characterizations.

a. In certain crystalline forms, like diamond and graphite, supply and use problems have received substantial attention and synthesis, substitution, and use technology have had, in notable instances, an impact from those problems. Elsewhere process and technologic improvements that effect cost reductions and provide materials with the exacting physical and chemical compositions demanded by many specialized applications would strengthen industrial capabilities in many sectors.

b. In other essentally pure forms largely derived from natural gas or petroleum, like carbon black and coke, supply is essentially a direct function of production capacity. Production techniques, costs, and substitution among the basic carbon sources (including products derived from coal and organic substances) suggest future use-pattern changes. Recovery of carbon black by the furnacing of oil and gas appear to be low and improved techniques are being sought.

c. As an alloying element as in the case of steel, various carbides and a host of intermediate metallurgical products, minor process improvements in controlling the carbon to other element ratios, and in understanding the effect of carbon in various alloys, promise important economic benefits and the evolvement of entirely new and useful materials.

d. As an adsorption medium or in catalysis, the present variety of applications are only a small measure of the potential diversity in form and volume to be ultimately demanded. Initially, new demands that would draw upon the solid fuels as the primary carbon source might have the most significant (domestic) economic, environmental and social impact.

e. Carbon is one of the essential building blocks and critical as an element or a medium for the production of various chemical substances. New products or uses derived through chemistry and opening large volume markets offer one means of moderating the impact of potential changes in the traditional use-patterns of the basis carbon sources—e.g., the relative share of the energy (fuel) market held by coal. Perhaps the role of carbon in the growing employment of plastics and, in turn, the potential interrelationship between plastics and metals in the materials picture, is one of the major uncertainties in predicting material requirements.

Digested, interchangeability among various primary carbon sources and in end-use applications presents unlimited opportunities for improving practices and strengthening the industrial economy. It also presents some problems, notably in instances where changing fuel demands on primary carbon sources might require nonfuel carbon requirements to shift to other sources.

While somewhat remote, carbon as a particulate matter in air pollution and as an element of certain gases (CO and CO_2) and compounds, and in certain solid wastes, has a significant role in the emerging environmental issue.

Cesium

Current supply is derived wholly from imports (contained in the mineral pollucite) although some small domestic resources are known. It is commonly associated with beryllium and lithium minerals, in pegmatites and is extracted by expense hand-cobbing and sorting procedures. It also covers in small quantities in certain brines and saline deposits. While cesium has a number of unique and potentially highly useful properties, present costs encourage the substitution of other materials for it wherever practicable. The element is not rare in nature and technologic improvements that would tend to reduce production costs would, in turn, promote further inquiry into new uses and some small industrial growth.

One specific property is significant in the development of ion propulsion rocket engines and certain thermic ionic devices. Recent research and development applications such as in advanced power and propulsion systems for space craft under study by NASA may develop sufficient new demand to provide industry with an incentive for developing large scale, efficient processing techniques and plants and for intensifying the search for and development of domestic sources of cesium.

Chromium

In common with most other major consuming countries, the United States relies, and will continue to rely, upon imports to meet its essential needs. The certainty of such supply in a number of instances is speculative. Supply and industry relationships and other aspects of the commodity are complicated and variable. The most urgent problem here attaches to establishing appropriate international relationships, with the situation in regard to this commodity specifically in mind. (Southern Rhodesia, Republic of South Africa, U.S.S.R.).

While the nature and extent of known domestic occurrences do not encourage much hope for the ultimate improvement of our resource position, the geologic probability of the presence of deep-seated deposits is not understood. Improvements in ore finding, including geophysical, techniques might eventually improve the domestic productive capacity.

In common with the other alloying elements, the evolvement of techniques permitting more flexibility in substitution would minimize supply crises in periods of emergency, tend to lower requirements, and possibly improve products. The broad subject of substitutability deserves attention now.

Evolving practices in the metallurgical industry infer radical changes in the chromium ferroalloy industry, the total demand for chromium, and an increased market for lower-grade chromite. The direct production of stainless steel from chromite and iron ore could radically change the entire chromium ferroalloy industry and result in a shift in demand from high cost metallurgical grade to lower cost chemical grade chromite. If this development does not take place, then changes can be anticipated for the chrome alloy processing industry as countries with chromite deposits become more industrialized and export chromium alloys and/or stainless steel products in place of chromite. Most chromite refractories are used in open hearth steel furnaces, but are not used in the growing basic oxygen furnace process. Consequently, as open hearth furnaces are phased out, the consumption of chromite refractories will decline.

Zinc oxide associated with some types of chromite is not recovered. Some shipments of Southern Rhodesia chromite contain 0.5 percent zinc.

In the production of chromium alloys the disposal of waste slag and air pollution from smelting operations pose environmental problems.

Technology for recovery of chromium from laterites could extend world resources by up to 50 million tons and spread the geographical supply base. This work would also expand cobalt and nickel resources. The problem is difficult, however, and will require long lead time (10–15 years) to resolve; delay until supply shortage is evident would negate effectiveness of this approach.

Clay

The term embraces a variety of substances with substantially different use-patterns and supply-demand relationships. Essentially they are bulk commodities that suport from local sources a variety of substantial industries that are vital in regional economies and important to the national economy. Anything that demonstrates the commercial feasibility of new industry based upon innovations that improve the quality of the raw material or permits the development of latent resources will have important economic and social benefits and should be pursued energetically. In a geographic sense, areas of low employment or below-average economies deserve a priority of attention.

(See section on aluminum.) The potential employment of clays as aluminum ores would completely alter traditional use-patterns and demand production of many millions of tons of clay (particularly kaolin and fireclay types) above presently projected totals. Aluminum (alumina) from this source is already the subject of substantial research effort and, in view of the impact upon supply-demand relationships for aluminum, deserves continued attention. In particular, more specific knowledge is required of the precise location of clay deposits that are of the required size and quality to support the production of alumina.

Most clays are produced from open-pits and the industry is particularly susceptible to increasing land-use conflicts. Zoning regulations, waste disposal and pollution factors will affect the economics of production in a growing number of instances. Devising practices that minimize the instances of such conflict demands immediate and concerted attention.

Price (cost) changes have substantial relationships to use of several of the clay types and, incidentally, to employment levels in the industry. Inquiries and innovations that would tend to reduce extraction (mining) costs would be particularly effective in this regard.

Cobalt

Occurring essentially as a coproduct in ores processed mainly for other metals—like copper, nickel and iron—the rate of cobalt production is a function of other commodity production. Only a small percentage of domestic needs are met from domestic sources, and this is likely to be the future pattern, too. The degree of reliability of major foreign sources is difficult to predict and in the case of this commodity, in particular, some improvement, however small, in the domestic productive capacity would tend to minimize future recurring supply problems. In particular, the development of new or better ways of concentrating, extracting, and producing metal from low-grade ores and cobalt-bearing scrap merits attention. Two major non-technical uncertainties affect producers and consumers alike and discourage development of alternate sources: the political instability of the Congo; and the surplus cobalt in United States Government stockpiles (5 years supply). The effect of recent sales from the stockpile has been to reduce imports by 50 percent over recent months.

On the world market cobalt supplies will tend to exceed requirements as production of copper and nickel increases and shifts to ores with higher cobalt content. Presuming that costs will concurrently decrease, the question of substitutability for other alloying metals deserves attention in the interest of minimizing reliance on the commodity for specialized uses, reducing requirements for other commodities with spot supply problems, and broadening use-patterns.

The opportunity to substitute advanced technology for reliance on the uncertainties of the geography of indigenous mineralogical occurrence is particularly attractive in this instance (see item 4, nickel). The marine environment promises a fairly universal source. While data are speculative, the apparent economic margin is such that relatively minor technological developments would permit commercial exploitation. Among all metallic commodities (not in solution) identified in the marine environment, cobalt would seem to deserve a priority of attention.

The association of nickel and cobalt continues to present either technologic or economic problems in effecting separation, and recovery of the latter is relatively poor. Moreover, the effective separation of cobalt from secondary sources, either for the purpose of winning the cobalt or eliminating it from other associated metals, is difficult and costly. Problems in this area will increase as cobalt use is diversified and as it finds its way into more end products. The problem of effectively separating closely associated metals, at costs that are commercially attractive, is general to the problem of recycling metals and minimizing waste. It deserves particular attention in this instance.

Technology for recovery of cobalt from laterites could extend and diversify world resources (see section on chromium).

Columbium

The recent evolvement of pyrochlore as a major source of columbium has substantially expanded the world reserve concepts and ultimate production patterns but the United States will continue to rely almost entirely upon imports for its primary supply. Coincidentally, the United States is the major world consumer of the metal. While the domestic potential resource position is not large in comparison to estimated world total, some means of employing these would tend to minimize future spot supply problems. Specifically, an appraisal of domestic pyrochlore resources and the practicability of extracting columbium from such substances deserve attention.

The close natural association of columbium and tantalum continues to present technologic and economic problems. Improvement in separation techniques would tend to reduce costs.

The broad field of interchangeability is, as in the case of other alloying elements, a factor in this instance. Costs influence, for example, the relationship between ferrovanadium and ferrocolumbium and, in turn, the design of structural members that employ either. Accordingly, innovations that effect cost reduction in either the manufacture of ferrocolumbium or high purity metal would tend to extend supplies or several commodities and broaden the uses of columbium in specialized applications.

Recovery from secondary sources includes technologic problems that will become magnified as the diversified application of columbium is increased and new alloys and applications affect the character of scrap and salvaged end products.

Copper

Installed productive capacity and the level of technologic development governs supply and, assuming the latter will be as energeticaly pursued and as effective as in the past, world supplies should be adequate to meet requirements projected over the next three or four decades. While the United States leads the world in both production and consumption, the extent to which it meets its future requirements from domestic sources is likely to decrease. As one of the key commodities in this industrial economy domestic copper production growth should be insured even recognizing that imports will have to supply an increased percentage of future United States demand. Cost reductions at every stage from exploration through fabrication will have to not only accomodate the continuously decreasing tenor of raw materials but permit effective competition of foreign operations. Any technologic advance that contributes to cost reduction is, in this instance, a subject for concerted attention.

The supply of a host of byproducts and coproducts depends upon the rate of copper production, processing and refining. The current annual value of these, recovered from the domestic processing of predominately copper ores, is more than $1.3 billion. Any innovation or technologic improvement that affects the recovery or use of the coproducts improves the overall economics of copper production, coincidental to the direct benefits to the coproduct, and thus merits attention.

Major opportunities for cost reduction are present in the initial extraction (mining) process. Attention to improvements in conventional systems as well as new approaches (in-situ-nuclear-leaching) is demanded. Large quantities of low-grade copper-containing waste are bypassed or moved in the mining operations. Further, large quantities of low tenor copper-containing waste are discharged from the concentrator. Such material represents a large copper loss which should be recovered, possibly by teaching.

Improved recovery of copper from the waste products of milling and refining would effect important additions to the domestic copper supply. By the same token, the ultimate disposal of the waste products from these operations is, as in the case of mining, a growing problem that promises increased processing costs if new concepts or practices are not developed.

Except for few dissipative uses much of the copper used adds to a "reserve" that is ultimately recoverable. At present this reserve supplies about a fifth of the domestic demand. From any standpoint—conservation, supply, economics, or other—improvements in the salvaging and processing systems for recovering and recycling the secondary metal (and its coproducts) merits immediate and intensive investigation.

The domestic extraction industry faces potentially critical land-use conflicts. Unless opposing views on surface restoration standards, waste disposal, and pollution issues are reconciled without excessive increases in operating costs the competitive position of United States supplies will deteriorate sharply. Current smelting practices generate sulfur-containing fumes, some of which exhaust into the atmosphere through high stacks. Such discharges represent both a serious air pollution problem and a loss of a valuable potential product—sulfur. This is a problem requiring immediate attention, and depending upon the stringency of air pollution laws, may require a major effort.

Conflicts are inherent in the emerging programs designed to protect natural endowments, to improve the Nation's environment and insure the welfare of its growing population. Specifically, the Wilderness program and public works designed to conserve essential land and water resources will increase confrontations with the industry and will present increasingly difficult problems for reconciliation. Yet it is essential in the public interest that such issues be equitably resolved. The subject deserves the highest order of priority. Because approximately 1 ton of makeup water is required per ton of ore processed in the concentrator, and with population increases and industry expansions, conflicts for sufficient water to process increasing amounts of ore can be anticipated in the Western States where much of the production is obtained. Decreased water requirements could result from research on the beneficiation step.

The copper stockpile has been drawn down deeply below the minimum level considered necessary for national security as a result of recent Government action in the form of releases to help control prices in an attempt to maintain adequate consumer supplies while accommodating large military requirements.

CORUNDUM

Domestic requirements are met from a single foreign source and are applied to essentially a single end-use, lens grinding. Moreover, that need could be accommodated with readily available substitute materials without significant economic impact.

Some emery (corundum and magnetite) is produced domestically and is employed in various abrasives. It, too, has a variety of substitutes and presents no pressing issue.

DIATOMITE

The United States can meet all of its requirements from domestic sources and, in addition, presently furnishes a large part of the world's supply. Diatomite has diversified industrial uses and is particularly important because of its unique filtration capability. Probably the substance would be in critical demand as a medium for the removal of radioactive particles from water supplies in a nuclear emergency. Except for a go or no-go trial procedure no effective testing process has been developed for determining if a deposit has useful properties. The development of such a test would diversify the source and probably improve the market potential.

In many applications other materials may substitute for diatomite (see perlite and vermiculite). Even sand, gravel, and coal can be substituted for some uses. Some inquiry into applications, where the unique properties of diatomite might enjoy some advantage over less effective substances, would tend to extend present utilization and marketing patterns.

Five Western States supply domestic production, and high transportation costs of this high bulk commodity, especially to eastern areas, encourage interest in beneficiating eastern deposits for commercial use.

All production is from surface workings and, as in the case of other bulk commodities, the problem of reconciling conflicting land-use problems is present.

FELDSPAR

Being among the most common of the rock-forming minerals, basic supply is no issue, but location of sources in regard to markets and certain sought-after properties, dictated by specialized applications, form the pattern of development. Like other bulk commodities, transportation costs limit marketing areas, but specific innovations that tend to lower production costs or improve the quality of the product can improve the economic advantage of one location over another. Efforts directed to improve the status of certain economically depressed regions should include this possibility in their consideration.

Technologic advances have provided for a healthy growth in the industry. First, the evolvement of beneficiation processes permitting the extraction of marketable products from feldspar-bearing rocks and sands has reduced the dependence upon hand-cobbed crystals from pegmatite deposits. Then the large-scale introduction of feldspar into the glassmaking industry vastly increased the market and helped evolve the disposable bottle. The latter commodity has become a villain in the emerging concern for the role of waste and litter in the environment. Thus the bottle could go, and much of the feldspar market, too. Scrap glass, along with other collected wastes or incinerator residues, could conceivably be a secondary source of pre-processed feldspathic material. Both as a waste disposal and conservation measure, and as the possible base for a new industry, some attention to the subject is warranted.

Current beneficiation processes require thorough desliming of the ore prior to processing and prior to each flotation stage. This action, in addition to loss of feldspar values in tailings, results in losses as high as 50 percent. Additional losses are encountered when the concentrate is treated to remove iron minerals.

Decreasing availability of high quality potash feldspar and increasing demands for this product (used for high tension porcelain insulators and TV picture tubes) may make necessary development of a method for separating the potash and sodium minerals.

In common with other commodities derived mainly from surface workings, conflicts in land-use are potentially present and will tend to reduce the economic feasibility of production in many areas unless means of reconciling the interests without excessive costs are devised.

Fluorine

The mineral fluorite is the common natural source of this commodity and the United States produces a quarter of its domestic demand for the mineral and consumes 35 percent of the world's supply. The domestic producing industry has exhibited considerable skill in surviving in a traditionally marginal economic atmosphere and the outlook for much growth in domestic fluorite production is not optimistic. While known world resources of fluorite are substantial, they are not sufficient to meet projected world demand. Thus, unless new discoveries are made or fluorine from materials other than the traditional fluorite ores (fluorspar) becomes competitive, world prices could rise. Therefore, some attention should be directed to opportunities for technologic improvement in the extraction and preparation of developed domestic fluorite sources and latent submarginal reserves.

Increased requirements for fluorspar flux in the basic oxygen steel furnaces, and rapidly expanded uses of fluorine in the uranium processing industry and the chemical industries will multiply the demand for fluorine by fourfold by the year 2000.

Large potential reserves of fluorine are present in phosphate rock. Approximately half of this is released in the manufacture of fertilizer and phosphoric acid. This has been considered a waste product and collected only for disposal purposes and to minimize air pollution. Some is now being recovered for commercial use. The extent of this resource and the interrelationship with other commodities, and the pollution issue in general, dictate that a priority should attach to more effective ways of extracting commercial fluorine products from ores likely to be mined primarily for another purpose.

Gallium

Compared to foreseeable needs both world and domestic resources are very large. Domestic production capability far exceeds demand. It is derived entirely in the processing of certain bauxites and zinc ores but trace quantities are also associated with coal. Quantities are so small that any conceivable increase in demand would have no effect on the extraction or processing cost of the primary substances or other coproducts. Gallium has some interesting and useful properties and research will broaden the areas of use for the metal and its compounds. The relative abundance of the element suggests that it might beneficially substitute for other substances of less abundance or higher cost in future use-patterns.

Garnet

Apparently the United States produces and consumes more than 90 percent of the world's supply. Domestic resources are very large. Except for minor problems stemming from the potential substitutability of and for other substances in abrasive applications, no aspect of the commodity demands particular attention.

The broad subject of abrasion, and the natural and synthetic substances that are employed in commercial applications of the property of abrasion, deserve attention from several aspects. For one thing, no good method for determining the effectiveness, acceptability, or relative performance of an abrasive exists and application develops only through service tests. For another, the devices, techniques and tools that apply abrasion have a low efficiency. More information on the theory and nature of abrasion might substantially alter traditional material concepts and, more significantly, improve the tools and techniques of applying abrasion. The benefits would accrue to the manufacturing sector through savings at time, labor, materials, and costs.

Germanium

Derived as a minor byproduct of ores mined primarily for copper or zinc the supply is wholly a factor of the production rate of those commodities. The element also occurs in trace amounts in some coals and other substances. A major current supply component is derived from recycled scrap from manufacturing processes. Current supply exceeds demand. Large stocks are accumulated in germanium-enriched refinery residues. Most of the consumption is in the electronics industry and there is strong competition from other substances tending to reduce the germanium share of the market. As in the case of the other minor coproducts of base metal ores, the sale of germanium has only a small effect upon the economics of extracting or producing the primary product. But the sale of refined germanium has been significant enough to occasion considerable industry inquiry into potential new uses and little additional emphasis on this subject is merited.

Gold

The national interest would be advanced through events that would permit increased domestic primary production of gold at the prevailing statutory price for the metal. Among other factors short-term foreign liabilities are reducing United States Treasury stocks at a rate that threatens statutory reserve requirements.

Because of its monetary relationship and the resulting fixed price and single legal domestic market for gold, the normal commodity supply-demand relationships do not apply. Price is not influenced by costs and, as a result, domestic production except that issuing as a byproduct has declined as costs have increased. Except in a few instances, technologic advances have not effected cost reductions to the extent necessary to permit continued commercial production. In view of the extent of the known resources that are presently non-commercial, the feasibility of new techniques, systems, or concepts that would permit profitable exploitation at the fixed price level invites attention.

Technologic advances in exploration have been effective in recent gold discoveries of commercial significance. In fact, the prospect of finding new sources of gold that will yield to present technology at present price levels is sufficiently attractive to merit a priority of attention. Similarly, such techniques are expected to disclose new large marginal gold sources that might be commercially attractive if modest advances in extraction and processing technology are realized.

Other factors which increase the uncertainty of gold supplies include the fact that gold production abroad was dominated by the Union of South Africa where 65 percent of world output was mined in 1966, but where some uncertainty attaches to future production rates. Although demand abroad for the arts and industry appears to have been relatively small compared with per capita consumption in the United States, there is an enormous but unmeasured disappearance of gold into foreign private hoards.

In the United States, copper and other base metal ores provide substantial amounts by byproduct gold. Byproduct silver is obtained from most gold ores and the recent increases in the price of silver have given some gold mine operators a small lift. Additional emphasis on byproduct production and the development of new techniques to base metal refinery slimes might result in some additions to supply.

Considerable gold is recovered from secondary sources, but the supply could be extended by improvements in salvage practices and techniques.

The marine environment promises a new dimension to source concepts if certain capabilities can be developed (see section on nickel).

New primary sources of gold are likely to be low in grade and, if commercially significant, likely to involve large volume mining and major surface disturbance. Major land-use conflicts must be expected and equitably resolved. For example, the importance of placer deposits as a source of production is decreasing because of competitive uses for suitable dredging land.

GRAPHITE

The bulk of the domestic needs are met through imports. Because of the limited resource outlook for some grades of graphite and economic factors in other instances it seems apparent that reliance on imports will continue in the foreseeable future. Dependence upon uncertain sources for certain high-quality types of graphite could be minimized by perfecting capabilities to substitute among the various types of graphite and among graphites of the same type from different sources. (See section on carbon).

Improvements in the technology of synthesizing acceptable graphite-type substances from other carbon forms would minimize the uncertain supply outlook. At the present state of the art manufactured graphite does not compete well with natural graphite in most end uses.

GYPSUM

Resources are, for all practical purposes, unlimited. Imports depend upon local transportation and economic advantages and have no bearing on availability. Demand relates directly to building and construction needs even though the commodity is employed in a variety of end-uses. The rate of growth in the gypsum industry would seem to rest upon the development of new gypsum-based products and the acceptance of such products by the building trades.

Byproduct gypsum discarded from the manufacture of phosphoric acid, presently a disposal problem, should find some utilization in gypsum-based products. Gypsum is seen as a potential commercial source of sulfur (sulfuric acid).

HAFNIUM

The primary supply of hafnium is wholly a function of zirconium with which it is geochemically related in nature in a ratio of about 1 to 50 (see section on zirconium). Hafnium was not discovered until 1922 and has been available commercially for only a few years. Consequently, its ultimate employment is speculative. The only significant current use is in control rods in nuclear reactors where it has a number of acceptable competitors. Only its appearance as a necessary reject in the production of hafnium-free zirconium permits its commercial recovery and employment. Possibly, the significance of hafnium as an alloying element has not been fully explored.

HELIUM

While traces of helium exist in the atmosphere and might be derived from other sources, these occurrences are academic and the only realistic resource is certain natural gases in which helium is present as a minor constituent. Much of the known helium-bearing gas is being marketed and, except for the helium extracted enroute, the contained helium is being depleted as an incident to the depletion of the natural gas. The prospect for discovering new resources of significant volume is not considered promising. Accordingly, attention is directed to the quantity of helium, that it would be practicable to recover with present technology, that is presently being wasted.

The Federal Government dominates the helium industry, although the private sector of the industry is growing and it is expected that private producers will aggressively seek to expand the uses for helium. The Federal Government agencies are also the dominant consumers in the United States and are required by law to obtain their major requirements from Government sources. The Government price is established to recover the costs of conserving some of the helium that would otherwise be wasted and, therefore, is higher than the price of helium from private sources. Some means of equalizing the cost of helium conservation programs between Federal and private sources deserves attention.

The technology of helium extraction is well advanced except that improvements in transportation methods promise a means of reducing costs at initial points of delivery. Also, ultimate supply can be extended by more efficient employment, recovery, and reuse practices in end-use applications.

Expanding and diversified uses for helium are probable. While the properties of helium preclude substitution by other gases in certain specialized applications, some large volume uses can be accommodated by other gases with minor inconveniences or cost differentials. However, because helium has been generally more expensive than the substitute materials, its use tends to be concentrated where technical or safety considerations dictate a preference. Lower helium prices would encourage less essential consumption and the need to conserve helium for essential applications will be a matter of increasing concern with time as the depletion of natural helium sources becomes more apparent.

INDIUM

Compared to foreseeable needs both world and domestic resources are very large. Domestic production capability is very large. Indium production results entirely from the treatment of flue dusts and residues issuing from the smelting of base metal ores (zinc). The value of indium output is neglible in relation to the principal products and neither indium price or demand advances would have any economic impact on overall operations. Indium is used in specialized electronic components and some alloys. The extent to which it might substitute for other elements or find new applications has not been exhaustively explored.

IODINE

World and domestic resources are large. Certain brines are the present source of domestic iodine (see section on bromine). Elsewhere it is produced as a byproduct in the production of nitrates, natural gas, and seaweed. Some new industrial employment of iodine shows promise of increasing the demand somewhat but no supply problem is foreseen.

IRON

Iron bearing substances are abundant and are widely distributed throughout the world. The degree to which these might be classified as ores, in a commercial sense, depends upon quality, in terms of prevailing technology; accessibility, in terms of competitive position with regard to other available sources; and security, in terms of the extent to which supplies are insured. The essentiality of iron to an industrialized economy provides a powerful incentive for any country to supply as much of its raw material needs from domestic sources as is possible at reasonable costs. Any advances in technology that tend to reduce domestic production costs, and permit the commercial employment of iron-bearing substances that are present in abundance, are in the national interest.

The essential need for iron is in the production of steel. The capacity of the domestic steel industry to compete effectively for domestic and world markets is, in turn, a function of cost reductions permitted by technologic advances, process perfection, and product improvement. The United States industry faces stiff competition in both the domestic and foreign markets. New and expanded steelmaking facilities have increased rapidly in many countries, and an overcapacity exists in the industry. Trade patterns are affected to some extent with governments, including the United States, exerting a strong influence on pricing policies.

The recycling of scrap is a major increment in the iron (steel) supply pattern and, in addition, substantial quantities of scrap are exported. Yet unreclaimed end products, largely composed of steel, are wasted in such quantities that visible accumulations are seen as a present and growing environmental problem. Means of commercially returning such wastes more effectively to the reuse cycle await development. The rapid trend to basic oxygen converter in steelmaking will continue and open hearths will have virtually disappeared by 2000. This process lowers the scrap to ore ratio. As a consequence, the problem of utilizing obsolete scrap will be multiplied.

It is significant that technological change has worked to the disadvantage of steel and to the advantage of labor and other metals. With respect to all kinds of durable equipment, advancing technology serves to deemphasize structure for more complicated, miniaturized, and electronified equipment requiring more assembly labor, more copper and aluminum, but rarely more steel. Growth in use of aluminum, plastics, and concrete substitutes has affected the growth of iron and steel compared with the overall economic growth.

Although most iron ore in this country has no important associated coproducts or byproducts, some iron production is the result of treating pyrites in the production of sulfuric acid and one iron ore beneficiation operation recovers apatite. However, concurrent with steel industry demand for iron is a demand for alloying materials in one form or another such as manganese, molybdenum, vanadium, titanium, tungsten, nickel, columbium, chromium, and a host of others as well as coal for coking, limestone, and fluorspar. The size of the steel industry greatly influences the demand and direct markets for many other substances.

Kyanite

The manufacture of mullite-type refractories accounts for most of the kyanite consumed, but nonrefractory uses are expanding. The production of synthetic mullite from aluminous and siliceous materials has substantially increased in recent years. Technologic changes in metallurgical practices have tended to increase demands for the more efficient and high-performance advantages that mullite has over lower cost refractory materials. End use applications favor the employment of kyanite-based refractories for special uses. The sources of domestic supply are remote from the growing market centers which occasions high transportation costs and the search for more diversified sources of appropriate quality.

Recovery of kyanite from its ores, at grades that are commercially acceptable, is relatively inefficient.

More diversified uses for kyanite that would tend to divorce demand from complete dependence on the refractory market would, in turn, encourage the development of more diversified sources of supply.

Lead

Spot shortages and long-term surpluses characterize the past and foreseeable future supply-demand relationship for lead. New world productive capacity and secondary output infer an atmosphere of surpluses and downward pressure on prices. Moreover, technological advancement has tended to curtail the growth in lead demand. The industry would welcome new large-volume applications for lead.

Lead production affects, and is in turn affected by, the demand for and the economic aspects of a variety of coproducts and byproducts. The relationship between zinc and lead is particularly significant.

Major changes in the demand pattern are possible, particularly in the largest end-use applications, storage batteries, and gasoline antiknock compounds. The latter is seen as a possible environmental problem.

Because of the local employment and tax revenue significance of lead extraction, production and use, Governmental action has frequently sought to protect the domestic elements of the industry through quotas and other devices. The factors that infer downward pressures on price, and dictate the capacity of the domestic industry to compete on the world market, will continue to attract legislative attention.

Lead (and zinc) is largely produced from deep sources. Technological advances in subsurface excavation, ground control and recovery, work to the advantage of the domestic competitive position. Similarly, more sophistication in exploration techniques will insure maintenance of a favorable domestic reserve position.

Transportation costs of bulk ore and concentrates to established mills or smelters are a limiting factor in exploitation of small lead deposits. To be commercially significant, such deposits would require development of a successful "mini-technology" for processing at the mine site.

Lithium

Domestic resources are in the form of mineral inclusions in pegmatites and as salts in certain brines. The former are large and the latter might be even larger. But both are commercially significant only when considered in terms of the coproduct values. World potential is unknown but considered large. Processing of brines tends to be a complex chemical problem and requires technologic improvement.

Both as a metal and in the compound form lithium is finding increased applications in the most advanced enterprises of technology. Price alone restrains a greatly increased consumption of the metal and infers a need for process improvement.

Magnesium

Magnesium is the third most abundant structural element in the earth's crust and is extracted commercially from such universal sources as sea water, well brines, and dolomite. It should find increasing commercial application as a metal and a variety of compounds. Because of the virtually unlimited nature of the presently commercial sources the advantages of substitution for less abundant commodities seem only partially realized. In structural application, for example, substitution for aluminum would increase if the price were reduced and many more uses would materialize.

The use of magnesium in refractories accounts for about half of the magnesium consumed in the United States; fluxes in the metallurgical industries for 40 percent; and the remaining 10 percent is divided about equally between the chemical industry and primary magnesium metal. Magnesium compounds are the lowest cost, high-temperature refractories available to the metallurgical industry and their use should increase in direct proportion to the production of iron and steel.

A number of opportunities for process improvement need exploration because of the potential benefits that are inferred both regionally and nationally. Among these are the possible commercial employment of Great Salt Lake brines, the development of methods to directly remove magnesium chloride from sea water, and a variety of improvements in current plant techniques.

Methods of reducing corrosion of the metal in finished forms would expand the number and volume of end-use applications.

MANGANESE

Possibly no other single commodity has received as much attention from the standpoint of trying to improve upon the capability to meet a larger share of the United States demand from domestic resources. These efforts have been essentially unsuccessful. Despite extensive low-grade occurrences, all processes and techniques investigated to date fail economically to promise products that compete effectively with the abundant foreign materials that are readily available under normal conditions. It can be expected that, under the pressure of gradually increasing demands and possibly higher prices, process development will continue to invite attention.

By comparison the demand for manganese in the production of steel far exceeds the sum of all other end-use applications. Steelmaking techniques have sought to minimize manganese requirements and it is possible that the quantity presently required could be reduced through new techniques. However, nothing is seen that would eliminate the need or reduce it very substantially.

The low manganese content of nodular substances on the ocean floors has excited interest as a possible future resource (see section on nickel), but the potential is essentially unexplored and no capability to exploit or use the resource is known.

MERCURY

With few exceptions the nature of mercury deposition is such that ultimate resources are difficult to appraise but the world potential is thought to be adequate to meet foreseeable demands. Supply has traditionally responded to sharp and rapid variations in price and it is generally assumed that any need will be met if costs is no object. Domestic sources are seen in the same light except that foreign sources respond more abundantly to price rises and it is likely that imports will continue to provide the major share of United States requirements. The opportunity to improve extraction and processing techniques to some advantage to domestic sources is not attractive. The possibility of discovering new domestic sources that could be commercially exploited at reasonable mercury price levels is not exhausted but is probably remote.

There are few satisfactory substitutes for mercury end uses where its combined high specific gravity, fluidity at normal temperatures, electrical conductivity and other properties find special application. Yet, the displacement of mercury in such applications as the manufacture of caustic soda and chlorine would substantially moderate future demands.

Transportation costs are a serious factor principally in Alaska, where the prospects of discovering significant new domestic resources are most probable.

Throughout the mining and processing of mercury ore, the health hazards due to salivation require the application of constant and careful safeguards.

MICA

Mica describes a variety of types and grades of material with widely different supply-demand relationships. Presently the United States is totally dependent upon imports for its sheet mica requirements, and essentially self-sufficient in flake and scrap. Over the long term suitable substitutes are expected to substantially reduce demands for high quality sheet mica. Towards that end the improvement of techniques for synthesizing mica, reconstituting flake, and exploring for types of plastics and ceramics that will comprise satisfactory substitutes deserve attention.

The manner in which sheet mica occurs in nature prevents the use of mass mining methods. The necessity of recovering undamaged books of mica and the softness of the material create special rock breaking problems. Domestic production of sheet mica is hampered by high extractive costs due primarily to the requirement of large amounts of costly hand labor. Imported mica can be delivered to a domestic consumer for about half the cost of domestic material. Attempts to replace natural sheet mica with synthetic flake have failed because of the lack of satisfactory bonding techniques.

The growing demand for ground mica has been accompanied by improvements in processing techniques resulting in improved products and lower costs. Also, processing improvements permit a variety of schists and other mica-bearing substances to be now considered as resources. Further development of these techniques promises lower costs and expanded markets.

Molybdenum

In regard to the ores mined primarily for molybdenum, as well as those containing molybdenum as a byproduct, grade tends to decrease and treatment complexity tends to increase with time. Thus mining and beneficiation, specifically flotation, technology will need improvement to preserve the present favorable commercial position of United States resources. Other countries, like Canada are emerging as major suppliers. It is debatable if the United States can retain its position as a net exporter after 1985 without substantial technologic advancement.

Supply presents no problem but recovery is poor (ranging from 40 to 90 percent) from the portion of total domestic production (20–30 percent) derived as a secondary product in the processing of porphyry copper ores.

The molybdenum-rhenium relationship is significant should the supply of the latter prove to be an issue. The only significant source of rhenium is as a coproduct of molybdenite existing, in turn, as a byproduct of selected porphry copper ores. The generally poor recovery of molybdenum from this source plus the fact that the rhenium is not presently recovered at all suggests that beneficiation techniques merit improvement. (See section on rhenium.)

There are essentially no competitive substitutes for molybdenum in its critical alloying applications, but it can substitute for other alloying elements—notably tungsten—to some extent. The relative abundance of molybdenum suggests that inquiries in the broad field of interchangeability among the ferroalloying elements would tend to reduce spot critical supply situations whenever use patterns change.

Reclamation of molybdenum from the increasing volume and more complex superalloys presents a growing problem of materials reuse and secondary metal recovery or disposal. The magnitude of the problem is not immediately measurable in terms of volume or urgency but in view of the technical uncertainties deserves modest attention at an early date.

Natural Gas

As in the case of petroleum, exploration and development activitiy has declined and the ratio of proved reserves to current consumption is trending downward. Improving the incentive for exploration, including cost-cutting technologic advancements, merits attention (see section on petroleum).

Also, as in the case of petroleum, Government policies and actions significantly influence the supply-demand pattern for natural gas.

The practicability of effectively employing gas from sources that have only marginal commercial significance at present deserves attention as a means of vastly improving the reserve position. Such potential sources include gas-bearing measures of low permeability and other formations that contain occluded gas but little or no petroleum.

Growing concern for atmospheric pollution stemming from the employment of high sulfur fuels, notably coal and oil, focuses attention on the relatively low sulfur content of the natural gases now marketed. While distribution limitations restrict imminent wholesale substitution of gas for other energy forms, it seems probable that some substitution may result, the probability and extent resting upon the degree of success realized in the removal or control of sulfur issuing from the other primary energy forms.

The rapid development of Western Canadian reserves and the geographical proximity of these reserves to major United States markets have resulted in continuing increases in natural gas imports from Canada. The quality is not of major importance but the reliance of certain regional markets is of concern because of foreign competition and control over future supplies.

Increasing storage capacity near large industrial centers has been largely responsible for a decline in low price "interruptible" gas available during the off-heating season. These storage systems include some that store liquefied natural gas near highly populated urban areas. Shipment of liquefied natural gas by refrigerated tankers is technically feasible and is becoming economic.

Nickel

The United States is not likely to ever accommodate much of its demand for primary nickel from domestic sources, but there should be no particular problem in gaining requirements for the immediate future from relatively secure and diversified foreign sources at reasonable costs. Yet the apparent vast world resources are real only if substantial technologic advances are realized in the extraction of nickel from low-grade substances and from the lateritic type materials at realistic costs. Even though the majority of such sources are abroad, the advancement of such technology would serve the interests of the United States in assuring adequate future supplies, and the subject deserves immediate attention.

In common with the other alloying elements—particularly tungsten, molybdenum, and vanadium—advances in techniques of interchangeability would tend to minimize instances where spot supply problems might restrict critical production or upset traditional use-patterns.

Reclamation of nickel from secondary sources must receive increased attention, not only as a conservation and economic measure designed to minimize requirements of primary metal, but because of the accumulating detrimental effect nickel presents in the effective reuse of other secondary materials with which it is associated. This detrimental effect is pronounced in the reprocessing of ferrous scrap. The subject deserves substantial and immediate emphasis (see section on iron).

The marine environment promises a new and universal source of nickel which, if exploitable, would minimize the uncertainties that are always present where essential and rapidly expanding requirements are met mostly from foreign sources. Such development, if proven practicable, would introduce a new concept in material supply. Specifically, it would relate supply to technologic capability rather than idigenous mineralogical occurrences. The concept applies to certain other commodities as well. The probability of successfully achieving nickel production from this source soon is low and our present capability is unknown but seen as wholly undeveloped. But achievement of production promises such large dividends that energetic inquiry seems fully justified. Urgency attaches wholly to the complex technology involved and the extremely long lead-time certain to elapse before production from this medium might be practicable even if the inquiry is pursued with vigor.

Nitrogen

The extent to which the compounds of nitrogen might substitute for other substances in critical applications where supply or economic problems might be present, or where new or expanded applications that would materially increase the demand for conventional products—and thus the size of the industry—warrants some attention (the evolvement of ammonium nitrate as a practical explosive is an example).

Ammonia is the basic compound from which most nitrogenous materials are manufactured, and it is derived from air and a hydrogen source such as natural gas, refinery gas, naptha, fuel oil or electrolysis. Hydrogen is the significant economic variable in the manufacturing process. As long as natural gas is abundant and cheap, new ammonia capacity is likely to be established in that vicinity and the world production patterns may tend to shift away from domestic sites. While not a matter of great urgency, the use of domestic coals as a source of cheap hydrogen deserves some attention.

Nitrogen supply is essentially a function of manufacturing capacity and is independent of any important resource limitation. Reduction in production costs has been achieved by effective research and the competitive nature of the industry would seem to assure adequate future supply. Ultimately production costs may warrant some attention in the interest of maintaining the domestic share of the world's production capacity, but the critical period is some years hence and the subject deserves observation rather than direct attention during the next 5 or 10 years. The rapid projected world demand may result in over-capacity of production plants in the early 1970's. In spite of this, shipping and distribution problems may cause deficits in certain geographic areas.

Oil Shale

It has been repeatedly demonstrated that liquid and gaseous fuel products may be derived from oil shale. But there remains uncertainty as to whether the present technology and concepts are basically those that will ultimately be employed commercially, and a wide diversity of opinion as to when a combination of circumstances will encourage and demand large-scale domestic commercial exploitation of oil shale. (Present concern attaches almost entirely to the shales of the Green River formation and the production of liquid fuels substitutable for those commonly derived from petroleum).

Despite the technologic and economic uncertainties, the issues that immediately beset the embryonic shale-oil industry center initially on legal, social, and environmental issues. The fact that much of the oil shale is in public ownership complicated by unsettled disputes over the validity of private claims (to sodium and aluminum minerals in addition to the shale) and the absence of a perfected leasing system that would insure protection of the public's interest, tends to depress active development but not exhaustive, and largely unproductive, debate.

Aside from the legalistic issues, the emergence of a significant commercial shale-oil industry would be more apparent in the presence of further advancements in extraction and processing technology. Specially, the practical employment of in-situ extraction processes has been only partially explored, the extent to which conventional mining costs might be reduced is speculative, the present retorting concepts have certain shortcomings, the real significance of the mineral substance associated in the oil shale is wholly unknown, and, the disposal of waste products that might issue in the exploitation of oil shale under presently conceived processes or those that might be discovered in the future is seen as an impending environmental problem. Paradoxically, much of the uncertainty that complicates the legalistic and economic aspects of oil shale stems from these technologic gaps.

The commercial development of oil shale depends not only on developing an economic process to compete with petroleum but also is vulnerable to the development of a technology to liquefy coal or to the increased availability of oil produced from the Athabasca tar sand deposit in Alberta, Canada.

The environmental problem resulting from the large scale processing of oil shale and the generation of 1 to 2 million tons of solid waste per day will have to be solved before oil shale operations begin on any scale. Associated with the solid waste generation are also air and water pollution, damage to vegetation and other ecological factors. The problem of adequate water supply as well as its unpolluted disposal is involved. This subject requires intensive study and has a high priority for attention.

Peat

While peat is significant as a fuel in certain areas of the world, it cannot, in the foreseeable future, compete as a significant source of energy in the United States. Virtually all peat consumed in the United States is used for agricultural and horticultural purposes, and the demand for these purposes is expected to grow. Domestic resources are large and widely distributed, but about 90 percent of the total reserve occurs in four states. Locally, the prospect of increasing employment and introducing new businesses periodically encourages efforts to employ peat for generating electric power, beneficiating (iron) ores, producing chemical raw materials, or expanding the agricultural output. Except in the latter instance, such attempts have not, and are not likely to be, successful.

Perlite

The term identifies a form of amorphous aluminum silicate of igneous origin that, upon expansion, finds a variety of industrial and construction applications. No immediate raw material source problem is seen and growth in consumption is likely to be proportional to the rate of building construction. Except for certain inadequacies in the employment of the fines produced during processing operations, present technology seems adequate to current and foreseeable needs. However, precise knowledge of the technology is lacking and, if gained, might disclose ways in which the industry might enjoy an unusual growth rate.

While domestic processing of perlite to local requirements is fairly well distributed, the source of raw material is restricted to a few western states. Transportation costs are a factor in limiting the cost of the commodity in its conventional bulk-type, low-cost applications. Some inquiry into new applications where the special properties of the processed product might enjoy an advantage over other substances might tend to broaden the utilization pattern and the size of the industry.

Petroleum

Opinion and estimates of the ultimate world and domestic petroleum resources vary widely and are of less significance than the manner in which commercial reserves are established or the technologic and economic factors that attach to exploration, production, and use of petroleum and its products. Certainly domestic resources remain large and ample for projected demands for many years. The significance of this resource potential rests upon such issues as the presence or absence of incentives to explore for and develop new reserves and for the investment required to economically develop and produce from domestic sources while abundant low-cost supplies are present on the world market. Presently domestic exploration (drilling) has declined and established reserves are lower than traditionally maintained to support future domestic production. Improving the incentives for exploration, including cost-cutting technologic advancement, demands serious concern.

Because of the significance of petroleum to the whole economy, Government policies and actions influence, and in a sense determine, the domestic supply-demand relationship. Typical of these are the nature of import controls, maintenance of price and wage structures, provisions in the tax structure, regulatory provisions, leasing policies, and the like. The announced national objectives subscribe to the maintenance of adequate supplies of low-cost energy, diverse in form and geographic source but "drawn largely from domestic sources," etc. The factual base for the type of action necessary to achieve this objective is not adequate. Specifically, better knowledge of the extent, distribution, and character of potential resources and the problems that attach to exploiting them are essential to effective Governmental action and national policy.

Only about a third of the developed petroleum reserves is recovered in current practices.

Environmental and pollution problems attach to all sectors of the industry as well as to the employment of the products of petroleum. The problem of solving these without significant added cost to the producer or consumer presents a growing challenge.

Potential substitutes derived from other hydrocarbon energy forms (liquid fuels and chemicals from coal, gas, shale, etc.) are seen as supplements rather than competitors of petroleum. Their advent should tend to minimize overall petroleum costs by deferring needs to exploit specific high cost products until, in turn, technology and time permit effective future employment of such marginal resources.

Major oil companies in recent years have adopted the concept of "total" energy. Some oil companies have purchased or merged with coal companies and others have uranium interests. Some are involved in research on gasification and liquefaction of coal and others are studying the mining and retorting of oil shale. The extent to which this trend aids or inhibits the public interest deserves constant attention.

Phosphorus

Domestically, sources are in four geographic groupings. The nature of mineralization and consequently extraction and processing techniques are different in each instance. Within several decades the two most productive areas (Florida and Tennessee) will be largely depleted and demands upon other sites, notably the western sources, will be large. The western sources have certain inherent disadvantages that cloud economic as well as technologic speculation. These include location, transportation, grade, depth, and a variety of other factors. Currently only selected high-grade zones can be mined. Technologic advances that promise to reduce both extraction and processing costs would have immediate as well as long-term benefits.

Recovery is poor in the Florida area and involves waste disposal as well as conservation problems. A better means should be developed for reducing the volume of phosphate slimes, through improved dewatering systems to reduce the volume, by decreasing drying time of impoundments and by recovery of the lost phosphate. Improvements in recovery will extend the life of the area. The subject deserves immediate attention.

All areas share a common problem in that low-grade ores are difficult or uneconomic to treat, and high losses are present in discarded fractions. Common solutions are not applicable to every area but the problem merits individual attention as both a conservation and a waste disposal issue.

Similarly, the extraction or disposal of associated elements presents a general problem. These in some instances detract from the commercial value of the phosphorus product and in others would, if effectively recovered, add to the economic feasibility of production or satisfy some demand for the other elements. In the former case lowering the iron and alumina content of all beneficiated phosphate rock would improve marketability and extend the resource base. On the other hand, recovery of uranium, vanadium, and rare earths dissolved during acidulation of phosphate ore should receive attention from a supply standpoint. Technological problems such as the production of large amounts of impure gypsum byproduct (see section on sulfur) and the release of a large tonnage of fluorine (see section on fluorine) in the wet process of producing phosphoric acid, and the recovery of lost mineral values, exist.

The marine environment is an attractive potential source of phosphorus to meet future requirements at home and abroad. Except for the notion that phosphorus minerals occur in some abundance in relatively shallow locations, little is known as to the actual dimensions and nothing is known about how these might be commercially extracted. Considering the presently inadequate state of the art, the subject deserves early and concerted attention.

The electric furnace production of phosphorus depends on eastern coke (mainly coke breeze). Transportation adds considerably to the cost and a satisfactory method of making the reductant from western coals would lower the cost of the process and benefit both the western phosphate interests and the coal producers.

Platinum

The United States is not likely to ever supply much of its requirements for platinum or the associated metals from domestic sources. However, world resources are large and sufficiently distributed so as to minimize long-term dependence upon any single source. The changing use pattern suggests that improving recovery from secondary sources deserves attention but because of the high unit values involved it is expected that the trade will react appropriately.

Advances in refining and separation techniques might serve to reduce the traditionally high cost of the platinum group of metals. Present technology is complex and elaborate and, incidentally, highly efficient. Accordingly, improvements in technology would not affect supply, only costs, and the subject does not claim a high priority for attention.

A continued rising demand is expected because of increasing use as petroleum processing catalysts and as materials to withstand severe heat and corrosion environments. The degree to which other more plentiful substances might replace platinum in these growing applications is not well understood.

Potassium

The industry is, for the time being, over-expanded. The development of new sources in Canada together with expanded capacity in other potash areas of the world spells a world surplus at least through 1971. The result is increased competition effecting a lowering in price, expansion of normal consumption rates because of the price situation, and a shifting of supply patterns to the benefit of the richer and lower cost areas. Domestic sources, which have already lost some of the domestic market, stand to have their percentage of the domestic market further reduced. Much of the industry has foreign as well as domestic holdings and is expected to operate where the profit margin is most favorable. Much of the domestic production comes from New Mexico and the decrease in domestic production will be felt in that locality. As a sociological rather than a supply problem, some means of deferring, delaying, or minimizing the termination of the New Mexico operations should receive immediate attention.

Further, the commercial grades of ore in the bedded-type deposits of New Mexico (90 percent of the total domestic output) will be depleted in 20 or 25 years. Lower grade ores would be significant only if new ways of producing or treating them can be developed. In particular, the improvement of flotation practices to treat ores with a high clay content deserves investigation.

Solution mining is being practiced by one Canadian firm. The system, which has been experimented with only in a half-hearted manner on occasions in the United States, deserves a thorough investigation in the interest of not only extending the productive life of the established domestic mining areas but with the prospect of developing new areas. Very deep but rich deposits are inferred in Montana and North Dakota (where such developments would have a particularly beneficial effect on the regional economy).

Means of treating non-conventional domestic potassium-bearing substances merit attention from a long-term resource position standpoint.

Theoretically, potassium is available in almost unlimited quantities from brines and saline waters. Processes, like ion-exchange or others, that promise a practicable way to recover potassium salts or compounds without having to resort to evaporation or other costly devices, would have an important impact on future desalinization development as well as on the long-term supply outlook.

Pumice

The term identifies a rock of igneous origin that is resistant to chemical and physical destruction. The principal domestic source is in the western states. No foreseeable supply problem is present. Growth in demand is linked to the rate of construction and is expected to be large in spite of the transportation costs that limit bulk commodity movement and competition from other commodities. As a light-weight aggregate, the opportunity for new applications in pre-cast and other structural applications are unlimited. Studies relating transportation limitations to new end uses could disclose new markets for the commodity and encourage an expansion of the industry. Regional benefits would be realized.

Land-use conflicts face some sectors of the production side of the industry. Being a low-cost bulk product, relatively small changes in land values directly affect the economics of production. Zoning changes, waste disposal and other environmental conflicts will tend to constrain operations in a number of instances. In common with a number of other commodities mined in bulk from surface workings, the reconciliation of such conflicts through enlightened operational practices demands increased attention.

As a filtering medium, pumice might find a growing demand in sewage disposal and other applications arising from a general concern for the quality of water in the nation's streams and rivers.

Radium

Except in certain foreign areas that do not have facilities for or access to secondary radium or a source of radioisotopes, most of the important uses for radium have been or are being occupied by the radioactive isotopes. Where radium is preferred, the demand is satisfied from secondary sources and appreciable stocks, but these instances are seen as decreasing. Nothing is foreseen that merits concern for supply or demand for the element.

Domestically, as a coproduct of uranium, radium has been discarded and resides in the solid wastes issuing from the processing of uranium ores. At certain western sites these are seen as potential sources of water pollution and a health hazard.

The decay products of radium are seen as an occupational hazard in uranium mining.

Rare Earths

The phrase usually identifies the naturally occurring compounds of the elements numbered 57 through 71 of the periodic table. The United States became self-sufficient in the commercially significant elements of the group with the development of a single source of the mineral bastnaesite in California. The mineral monozite previously was the principal source of the rare earth minerals and also the principal ore mineral of thorium. Rare earth production is still gained from that source incidental to the production of titanium and zirconium materials and some is recovered as a byproduct of molybdenum production.

Large, presently non-commercial, resources are known both within and outside of the United States. Because present commercial interest focuses upon selected elements and because the elements do not occur in the same fixed ratio at every source, large surpluses of some elements develop incidental to production of others.

The rare earth elements while closely associated in nature have a variety of useful properties unique to each. The technology of efficiently separating the elements into essentially pure forms has received much attention but is not well developed and is complicated and costly. More effective separation techniques would permit fuller use of the elements and help balance their use pattern.

All of the useful properties of each of the rare earths are not well understood. Their potential as alloying elements and a variety of other applications is not developed. An improved understanding of these properties would open a large area of new application and product development and might demonstrate how singly or in some combination the elements might substitute for other materials that are in less abundance or are more costly.

Secondary recovery, presently receiving some attention, will become increasingly significant as the employment of the rare earth expands.

RHENIUM

Production rate is wholly dependent upon the recovery of molybdenum, with which it is associated in nature (see section on molybdenum). Recovery is relatively inefficient (about 35 percent), and much of the rhenium escapes to the atmosphere in the present sequence of operations. Increased demand would probably encourage an improvement in recovery but present technology suggests that it would be very costly and an immediate incentive (market) is lacking. Because the future demand is promising and for the sake of conserving a limited commodity, some means of limiting this loss should be developed.

The properties that rhenium imparts to superalloys and refractory metal alloys are the subject of considerable ongoing research. For the moment designers tend to design around rhenium to avoid its high cost.

RUBIDIUM

All current domestic supplies are derived from residues remaining from a plant that formerly processed lepidolite for lithium compounds. Elsewhere rubidium issues as a byproduct in the processing of pollucite for cesium. Other potential sources are thought to exist but are of little immediate commercial significance. Costly extraction techniques limit uses. Moreover, in most current applications other elements, like cesium, can be substituted with minor inconveniences. For the immediate future, the element would be classified as a subject for laboratory rather than significant commercial concern. Its properties merit study.

SAND AND GRAVEL

Sand and gravel resources of the United States and the world are, in a sense, inexhaustible. However, from a practical standpoint the geographic distribution and quality often do not match well with market patterns or requirements and promises to match even less well in the future. These are large volume commodities of low unit cost. Local demand is proportional to local construction activity and unrelated to national patterns. Transportation is a significant incremental element in costs. Land-use conflicts are pronounced in the industry and promise to increase. Major markets are in metropolitan areas and the sources of the products are feeling the impact from adverse zoning and regulations against noise, dust, unsightliness, and pollution.

Water supplies present a problem with the increased demand for washed aggregate. Adequate supplies are no longer assured and, in addition, the accompanying problem of waste water disposal is raised.

SCANDIUM

The present knowledge of primary scandium sources indicates that if the demand increased to the pound lot level, from the present gram lot level, no means of meeting that demand is foreseen. While the element occurs in trace amounts with a number of other substances of commercial interest, no important single source of scandium is known. Coincidentally, no important demand has inspired much concern for the poor resource outlook.

Apparently research on potential uses does not always proceed in full appreciation of supply limitations. A large potential market for scandium in the illumination field has been sought which, in turn, has concentrated some attention on developing low-cost separation and purification techniques.

Selenium

While distributed widely in nature, the mineralogical association of selenium with sulfide minerals of copper, iron, lead, and other metals provides the significant source. At present it is derived domestically as a byproduct of electrolytic copper refining. Demand has not been such as to encourage special efforts toward optimum recovery and less than 60 percent of the selenium available to the United States refiners is recovered. Foreign practice approximately parallels this situation. Given a sustained larger demand and higher prices the losses would be reduced. Also, other potential sources of selenium are present in materials that have not been exploited, such as flue dusts from lead smelters and sulfuric acid plants. While the new uses have significantly increased interest in selenium, particularly in electrical and xerox-type copying devices, potential supply seems adequate to accommodate foreseeable demands. As a relatively plentiful byproduct with useful properties, the opportunities for devising new uses or for substitution for less abundant commodities have not been fully exploited.

Silicon

The element is practically limitless and supply is wholly a function of production capacity. The end-use applications of commercial importance attached to the production of ferrosilicon or silicon metal. The demand is governed mostly by the requirement of the ferroalloy and steel industries. Relatively small but important uses have developed in the production of silicone and in the electronic industries. The industries engaged with the production and use of silicon are the largest and most advanced of all, and no particular issues are foreseen in either the supply or the development of new application from the element.

As an abundant, potentially low-cost, commodity, the opportunity for substitution for less abundant or most costly substances is present.

Silicon is consumed in large quantities in the form of silica sand for the manufacture of flat glass, tube glass, optical glass and glass products, foundry sand, plaster sand, and for filter beds in municipal water plants. Produced mainly from sand pits, quartzite and sandstone quarries, the industry is plagued by the same conflict of land use, water and air pollution environmental issues affecting sand and gravel production (see section on sand and gravel).

Silver

Major transitions presently upset traditional supply-demand relationships both in the United States and abroad. Ultimate price levels are the subject of speculation and a variety of conclusions. The majority of interests anticipate that both price and demands will move upward over the short-term occasioning a reappraisal of submarginal sources for commercial feasibility.

A large part of the domestic demand has been accommodated through drafts from U.S. Treasury stocks and metal reclaimed from secondary sources. Primary output from domestic mines, while expanding, satisfied only a fraction of the demand. Only a third of the new silver produced domestically is presently derived from predominantly silver ores; the remainder is recovered incidental to the production of copper, lead-zinc, and other mixed ores. The latter relationship is of considerable importance in the overall cost of production and should direct attention to the potential commercial feasibility of a variety of marginal substances in which silver occurs in any significant quantity.

Except within selected ore bodies silver does not occur in mixed ores in any fixed ratio to the predominant metals. As present byproduct sources of silver are depleted, there is no assurance that the ratio of silver to other metals will improve or be maintained, even though the production of those metals (e.g., lead-zinc) is greatly expanded. The byproduct silver potential of ores likely to be of commercial interest in the future should be understood in terms of the impact various silver (and other coproduct metals) price levels might have on the feasibility of production.

than offset by new and expanded applications.

Advances in exploration techniques and instrumentation are expected to lead to new sources, some part of which might be commercially exploited with present technology. Much larger potential sources will be established only if improved extraction and processing techniques, permitting their exploitation at reasonable cost, are devised. Most of the silver in the world is recovered from vein deposits and associated with other valuable materials. The improvement of underground mining methods appears to offer an opportunity for improving resource development and submarginal ore extraction.

Secondary silver has in recent years supplied much of the demand. Photography, arts and jewelry, electronics, special alloys, and users of in-plant scrap provided the source of this silver. The growing use of industrial silver, particularly in electronics, is likely to be a significant source of secondary silver. Only a fraction of the complex electronic scrap is presently collected and reprocessed. In view of the quantities now involved (30 million ounces of silver annually) in this application, the subject merits early attention. A similar observation is applicable to gold, platinum, and copper.

Some land-use conflicts attributed mostly to the disposal of extraction and processing wastes have been experienced and promise to become more frequent.

Anticipated increases in demand are not likely to be greatly moderated by modest increases in price. Substantial price increases would significantly affect use-patterns but might have only a minor influence on the overall demand. In many present and foreseeable uses, silver comprises a relatively small part of the substance of the manufactured product and substitution is not likely even at much higher prices. Even in photography, the principal consumer of silver, intensive research has failed to develop a practicable substitute. Should such be discovered, a reduction in demand by 25 or 30 percent would result. In the other major use categories, minor saving through substitution will be more

SODIUM

Salt is the principal natural source of sodium. Native (rock) salt is so abundant in the United States that the foreseeable supply to meet any demand may be considered unlimited. In addition, lakes, brines and the seas provide a truly unlimited source of various compounds. The gigantic chemicals and manufacturing complex of the United States both consumes and produces vast quantities of sodium compounds incidental to a variety of other substances and foresees no supply problems save only the inconveniences of distances between sources and some points of consumption, changing use-patterns and technology that affect manufacturing practices rather than occasion concern for supply.

Essentially all of the chlorine in addition to most of the sodium used in the United States is derived from salt. The demand for chlorine (as well as other substances) is subject to changing use-patterns and its relative availability and price have a bearing upon the economics (and technology) of a variety of mineral and metal processes where it serves as a reagent, solvent, or other processing medium.

(Special note: The interrelationship between a given mineral or metal and all of the materials and substance consumed directly or indirectly in bringing it to some usable form is, at best, a complex system for total analysis. Thus, the economic margin favoring the production of some metal or mineral may disappear, or be substantially improved, with minor changes in the projected availability and cost of a variety of seemingly unrelated substances. The evolvement of a realistic means of measuring such margins deserves special study.)

The opportunity of substitution between sodium compounds and those of other elements is always present. Similarly the potential employment of sodium in large volume applications traditionally occupied by other substances (like sodium for copper in the transmission of electricity) has startling possibilities deserving thorough investigation.

The presence of large salt sources in relatively depressed economic or low employment regions provides a basis for speculation on the feasibility of establishing new industries that draw upon such local resources.

Some land-use conflicts and the effects of urbanization may necessitate that the pattern of raw material sources in the future change somewhat from that of the present (e.g., solar evaporation is particularly susceptible).

Stone

As in the case of sand and gravel, stone resources of the United States and the world are, in a sense, inexhaustible. However, exacting specifications determine the marketability of stone in important instances and sources adequate for such needs at reasonable costs are not unlimited. One example is seen in the production of limestone for chemical and metallurgical purposes, where new sources with suitable specifications and reasonably located in regard to established or contemplated markets are matters of some concern.

Because of the variety of industrial uses the local availability of stone that will meet specifications of local markets influences the industrial and economic development potential of an area.

Land-use conflicts are present and will tend to increase. Markets for major products of the stone industry are close to expanding metropolitan areas and will feel the impact of zoning and other regulations. These factors, and others, may dictate that an increased share of commercial stone will be derived from underground sites in the future.

Large tonnages of low cost and high quality limestone and lime products are available in easily mined and widely distributed deposits close to consumers. Limestone fines, waste residues and sludges present a pollution threat to air and water. However, in the future these materials might be used as an aid to controlling pollution such as neutralizing toxic gases and acid wastes, and as soil stabilizers and conditioners for the revegetation of other types of waste dumps. The subject deserves attention.

Strontium

The United States consumes about half of the world's production but produces none. Domestic resources are substantial but of a grade that precludes competition with imported material. Nothing is foreseen that will alter the pattern.

No satisfactory substitutes are known for the major uses of strontium compounds in pyrotechnics and tracer ammunition. Stockpiling effectively accommodates increased demands during periods of national emergency.

Sulfur

At once the subject of abundance, as an unwelcome coproduct of other materials, and of frequent scarcity, in regard to primary commercial supply, sulfur supply, use and disposal present problems of growing significance. Because sulfur is employed in large quantities throughout the industrial complex, continued domestic commercial abundance at reasonable costs is desirable. Present major commercial sources (Frasch), though large, are insignificant in comparison to the potential sulfur resource contained in nonelemental forms. Means of diversifying commercial supplies through improvement of processes for sulfur recovery from non-elemental sources would profoundly affect future industry practices and expansion.

The capture of sulfur from solid, liquid or gaseous effluents and wastes, seen now as essentially a health and environmental necessity, can be most effectively accomplished in the presence of economic incentives to the producers of such effluents. Such incentives are possible only with the discovery and development of devices or techniques permitting the recovery of sulfur in some usable form at costs that compete effectively with other sources of sulfur. Conversely, the absence of such devices or techniques will not deter the demand for restricting sulfur in effluents for health and environmental reasons without economic benefits. Accordingly, absence of technologic achievements in this area will cause a variety of disruption throughout the extraction, processing and utilization sectors of many industries and widely influence consumer costs.

The fertilizer industry consumes almost half of the commercial sulfur in the United States. Some substitution for sulfur in this application is possible, and probable if sulfur prices should rise sharply. The effect of such reductions in use seems small in comparison to an inevitable increase in demand brought on by new and expanding needs elsewhere. However, the variety of ways through which other products (like hydrochloric acid) might be substituted for sulfur products (see section on sodium) deserves attention in research directed to new processes development or the economics of local use-patterns.

The cost of disposing of sulfur or acquiring it for processing needs affects the real value of a variety of commodities in both the fuel and metal categories. Anything that would tend to affect such costs when translated, to raw materials like submarginal sulfide ores or high sulfur coals or, to processes like the pickling of steel, can have a profound influence on future materials supply. Such relationships deserve continuous reappraisal.

Talc

Talc, and a variety of mineral substances with essentially identical properties, occurs in sufficient abundance, both within the United States and abroad, to eliminate any concern for supply in the foreseeable future. A variety of exacting specifications related to particular end-uses dictate the industry pattern and the degree of reliance upon imports. Successful research has substantially reduced the latter. Improvements in beneficiation methods would permit potential domestic sources to meet competition from abroad for markets demanding more exacting specifications.

Minor land-use conflicts complicate the extraction and processing of talc. However, atmospheric contamination (silicate dust) attributed to some mills has demanded special control practices.

Tantalum

A major increase in demand for tantalum is expected because of its electronic and chemical properties that are not closely approached by other metals. Development of plutonium fueled atomic reactors could cause a significant rise in tantalum structural and cladding material.

The tantalum resource base is small and is probably inadequate to meet world demand for very long. Moreover, the reliability of important foreign sources is open to speculation. Estimates based on fragmentary resource data indicate that total reserves and resources will be exhausted by 1986. Subsequent to that time a price increase can be expected. Particular long-term benefits are seen in any technologic advance that would permit extraction from submarginal sources or the discovery of new sources.

(See section on columbium.) While there is a close mineralogical relationship to columbium the movement toward pyrochlore as a source of that element extends the potential reserves of columbium but does not improve the position of tantalum. Currently a significant amount of tantalum is irretrievably lost by the use of raw columbite and pyrochlore in the preparation of ferrocolumbium. The use of pyrochlore (1 to 1.5 percent Ta_2O_5) is extensive in the United States and the loss of tantalum is therefore relatively minor. The rest of the world, however, generally uses columbite (5 to 20 percent Ta_2O_5) and hence represents a major loss of tantalum.

As a coproduct of columbium which, in turn, materializes in a substantial degree as a byproduct of tin mining, the supply pattern is related to the production of those commodities. Small amounts of tantalum report in tin smelter slags and with columbium consumed in ferroalloys. Practical methods for commercially recovering these losses would lessen the problem of primary tantalum supplies.

A low-cost method for separating tantalum from columbium in Malaysian and Nigerian columbite would at least double known tantalum reserves.

Cost problems have prevented Malaysian columbite (12–20 percent tantalite content) and Nigerian columbite (5–8 percent tantalite) from entering the present market. Large quantities of this material entered the stockpile under the Government purchase program however. These ores, being leaner than those currently used by processing plants might require more plant capacity and probably result in higher recovery costs but consideration should be given to such an undertaking before this material is disposed of as columbite ore.

Recovery from secondary sources includes problems that will be multiplied as the diversification in use evolves.

Tellurium

Tellurium is distributed widely in nature but its occasional mineralogical association with copper, lead, and other metals provides the significant source. At present it is derived as a byproduct in the refining of those metals. While some search for new applications has met with limited success, the apparent and projected supply far exceeds any potential demand (see section on selenium).

Thallium

Present technology limits thallium supply to quantities present in certain base metal ores, notably zinc. Commercial supply is derived wholly from processing selected smelter flue dusts. Thallium association with certain gold, potash, and other deposits are of academic interest only. Although only a fraction of total contained thallium currently is recovered, dispersal of thallium into various smelter products not amenable to economic separation militates against marked improvement in recovery. Consumption of thallium is so much below supply that thallium-bearing residues at the plant of the one thallium producer reportedly have become a burdensome quantity. It is estimated that the thallium containing residues are generated at three times the rate of consumption.

The dominant consumption until 1965 was as a rodenticide. This was sharply curtailed because of Government action, which encouraged substitution of alpha-naphythyl thiorurea or other chemicals less toxic to humans. However, the market loss was compensated for by increased use of thallium in solder and fusible alloys. Only modest increases in demand are expected.

Thorium

Domestic supply exceeds the demand. Except during a short period when traditional foreign sources were being nationalized and a stockpile was being acquired, world supply usually included surpluses. Thorium is a product of monazite which, in turn, is a byproduct from the production of titanium and zirconium minerals from beach sands. While a small growth in demand for illumination and alloying purposes is foreseen, the possible employment of thorium in breeder-type nuclear applications continues to be the basis for speculation on ultimate needs (see sections on titanium and zirconium).

If consumption should increase substantially as a result of successful development of thorium-fueled breeder reactors the demand could be met by production from the relatively high grade thorite deposit of Idaho and Montana. Research has demonstrated the feasibility of treating the thorite ore if it is needed.

Recovery of monazite from beach properties may conflict with urban and recreational development in some areas. Some monazite sands have already been lost to beach development. On the other hand, some dredging operations on both river and beach placers have established models for mined land reclamation.

Tin

The United States is the major consumer of both primary and secondary tin and uses about 40 percent of the world's supply. Domestic production and foreseeable potential are negligible. A unique international agreement among several producer and consumer nations that seeks to stabilize supplies and prices has been only partially successful in its objectives. Rising prices and uncertainty in regard to future supply provide incentives for finding substitutes for tin in the major end-use applications.

In the concentration of tin ores from both placer and lode deposits, there is evidence that as much as 30 or 40 percent of the tin mined is lost in the slimes. In addition, the presence of impurity metals in the concentrate requires complex metallurgical processing resulting in further losses.

Considerable work has been done on volatilization processes for the removal of tin from low-grade ores but the method is seldom used except in special cases where fuel, volatilization agent and raw materials are available at low cost. The current economic situation has stimulated a renewed appraisal of the potential of sulfide volatilization for Bolivian ores. It is unlikely, even if the study is successful, that output of tin from Bolivia will increase significantly during the next five or ten years. Technical assistance to Bolivia by the United States has become traditional and additional cooperation is likely to be called for in the foreseeable future.

Titanium

Present technology dictates distinct end-use patterns for the two principal mineral sources, ilmenite and rutile. The United States is a major source of the former but not the latter. In fact, long term adequate world supply of titanium will depend to a large extent on successful development of an increased capability to use ilmenite instead of rutile. A variety of submarginal occurrences of titanium minerals are known both domestically and abroad. Domestic occurrences promise abundant supply if technologic improvements in extraction and processing can overcome certain economic disadvantages.

In a major end-use application, pigments, numerous substances vigorously compete with titanium for present and foreseeable expanding markets. Process improvements that promise cost advantages or product improvement would tend to insure a share of this market for titanium pigments. Adoption of a hydrochloric acid method for pigment production by all newly constructed titania plants, coupled with steadily increasing demand for titanium metals, has created unprecedented demands for rutile (TiO_2).

The unique properties of the metal foretell expanding and diversified use. Such expansion will be magnified by technologic improvements that affect cost reduction in metal production, forming or fabrication.

Secondary recovery from nondissipative forms is, at present, accomplished effectively. However, diversified uses and volume will present future problems in handling and processing scrap and alloys.

The known occurrences of commercial deposits of ilmenite and rutile in beach sands suggests that additional resources of titanium minerals may be found offshore and conceivably may be commercially workable. It also seems likely that rutile in significant quantities may occur both on and offshore along beaches in many countries and new discoveries of workable deposits, especially in Africa, appear probable.

Only about 2 percent of the material mined from sand deposits for titanium minerals is recovered, the remainder being mud and slimes consisting of silica, kaolin and organic matter. Some 11-acre feet of this waste material are generated each month in Florida and impounded in large mud lakes. Hence, it seems certain that the potential for expanding operations in Florida because of solid waste and land use conflicts will soon become severely limited.

Tungsten

Except for production as a coproduct of molybdenum, and an instance or two where tungsten is produced as a primary objective, known domestic sources do not compete effectively with foreign sources in normal domestic or world markets. Moreover, known domestic resources are not large in comparison to present or projected demands. With the exception of the resources of China and certain other locations presently not considered available the extent of known world resources available at reasonable costs in relation to projected requirements is uncomfortably small. Improvments in extraction and processing techniques that offer cost reductions in the employment of low grade ores would permit some expansion in domestic production. The specter of a potential flood of low cost tungsten from China tends to discourage investment in the development of higher cost sources.

The real domestic resources position is not fully understood. Under government incentive programs in the mid-1950's, approximately 750 mines produced tungsten in the United States. The exact circumstances under which any of these or others could again become productive is subject to considerable speculation.

The unique properties of tungsten promise increased demand in all of the three predominant end-use forms; alloys, carbides, and metal. Substitution, even at increased price levels, is not likely to modify the demand to any substantial degree. However, advancement in the procedures and technology for recovering tungsten from scrap, worn out end products and other secondary sources would substantially extend supplies.

The marine environment offers some potential for diversifying sources of supply (see section on nickel). Similarly, minute quantities known to be present in certain brines would, if shown to be commercially recoverable, improve the long-term supply outlook.

Processes that depart from traditional extraction through utilization squences might, if shown to be technologically feasible, minimize certain economic advantages presently attaching to low grade occurrences. Specifically, advances made in producing metal or carbide directly from concentrates or impure compounds promise much if the metals associated with the tungsten can be simultaneously recovered.

Better ways of reducing oxidation of tungsten at elevated temperatures would extend the end-use life, and indirectly the supply, of the commodity. Similarly, means of accommodating to the absence of ductility at normal temperatures would improve efficiencies in consumption.

Uranium

With the emergence of applied nuclear phenomenology and until very recently the uranium supply-demand cost relationship has been precisely programed and controlled. Relaxation of some controls plus added emphasis on commercial aspects of nuclear energy with the attendant cost-supply and related economic implications pose uncertainties as to future supplies of uranium at various price levels and, indirectly, the relative economics of nuclear power in comparison to traditional (essentially fossil fuel) sources. Incremental savings in mining and milling costs will have to be realized.

While present reactors require a large quantity of uranium for the initial fuel charge, little is actually consumed annually, and most of the uranium will eventially reappear in fuel reprocessing or whenever a reactor is dismantled. Thus, practically all the uranium procured to date is still extant in one form or another. The advent of the breeder reactor would cut U.S. uranium demand to about 2 percent of the demand estimated for 1985 because of the huge accumulations of depleted uranium available and would stretch the uranium resources of the world tremendously. The AEC in extending its domestic purchasing (stretchout program) from 1966 through 1970 admittedly has contracted for more uranium than is necessary for defense needs. Such a surplus is a safeguard to the reactor operators, but it is also a potential threat to the domestic uranium mining industry.

The coproduct relationship with vanadium in domestic ores relates the value and economics of two commodities at the source that have no relationship in end-use applications. The previous surplus of one in the production of the other has been reversed in the past. More recently vanadium has been readily marketable. However, new (non-uranium associated) sources of vanadium are being developed that might affect the commercial value of the uranium ores. Similarly, moybdenum as well as vanadium are present with the uranium sought in certain domestic lignites.

Small quantities of uranium are known in the waste liquors and products that issue from the treatment of other ores, notably copper. If shown to be recoverable substantial amounts of the future uranium requirements could be met from these sources.

A variety of environmental and health problems are inherent in all aspects of the uranium and related industries, from initial extraction to the ultimate disposal of final waste products. All of these promise to become more severe and demand more stringent (more costly) control practices in the future. The health problem associated with the mining of uranium ores or other substances, for that matter, where radiation in some form is present, has been singled out for special attention. However, in the longterm the disposal of wastes incidental to nuclear power generation is likely to have the most serious economic and social implications.

Present technology provides quantities of depleted uranium which awaits eventual application through development of a practicable breeder reactor system or some other useful application. Attempts to find other uses have been largely unsuccessful. Moreover, a system employing a thorium cycle is seen in some quarters as eventually offering commercial advantages (see section on thorium).

Vanadium

A long period during which vanadium supply exceeded requirements has closed and supply and demand is in approximate balance. Domestically the relationship with uranium contributed to the imbalance (see section on uranium). New primary domestic sources, not associated with uranium, are being developed or are known. World resources are large. A variety of new and expanded uses are developing. The mineralogical phenomena that associates vanadium in nature with elements that are only remotely related to it in end-use applications demands continuous reappraisal of potential resources when the need, price or supply of any one of the associated substances changes (see section on phosphorus).

In common with other alloying elements, improvements in techniques that permit more flexibility in substitution would minimize periods of supply inadequaces, tend to lower or stabilize requirements, and possibly improve products. Cost is important factor with regard to vanadium's competitive position with other alloying elements, particularly molybdenum and columbium. The potential of high purity vanadium for use as fuel envelopes in fast breeder atomic reactors may significantly increase demand.

Like tungsten, oxidation problems at elevated temperatures tend to restrict application. Improvements in technology would tend to broaden the scope of potential end-uses.

Most of the vanadium produced in the U.S. and overseas is obtained by salt roasting vanadium ores or intermediate products. In general, the current technology of salt roasting of low grade vanadiferous raw materials is a complex, sensitive and relatively inefficient and costly unit operation.

VERMICULITE

The United States dominates world production and resources are thought to be adequate to meet any foreseeable need. However, definitive data are lacking concerning their true extent or availability at specific price levels.

Demand growth rate is closely related to the volume of building and construction at any given time. However, its use faces competition from other low cost products (see perlite and pumice) including clay, slate, shale, and other substances from which lightweight aggregates may be manufactured. Transportation costs from the source to exfoliation plants, near the points of end use, limit the size of marketing areas as well as the competitive position with regard to other commodities. Improvement in practices that would minimize the treatment losses in fine fractions or provide a market for fine-size vermiculite would improve the competitive position of vermiculite.

YTTRIUM

Yttrium exists in minor amounts at many locations and is closely associated in occurrence, properties, and end-use application with the rare earth elements. Supply is not seen as any foreseeable problem, in terms of presently conceivable needs. It also occurs with other substances but in insignificant quantities so that the commercial significance of such association would hardly be altered by unforeseen major demand or price changes. Yttrium and other heavy rare earth oxides occur in phosphoric acid made from phosphate rocks. Technologic investigation, and development of processes suitable for increasing production from these sources would assure future supplies. (See sections on phosphorus and rare earths). Present uses relate to electronics (television) and to a lesser extent certain alloying applications. In the latter case the properties unique to yttrium are not fully understood but the prospect for new and important uses in this field seems promising.

Yttrium costs may be reduced through demand for the other elements with which it occurs and through improvements in separation techniques. A variety of applications would develop in this eventuality.

ZINC

About a third of the domestic demand is derived from domestic sources and this ratio is likely to persist in the demand-supply relationship of the immediate future. However, unless a means of commercially exploiting sources that are presently classed as submarginal evolves in the interim, the apparent domestic reserves will have been largely exhausted by 2000. Reduction of costs in each of the incremental industry sectors, from exploration through refining, is seen as the principal means of deferring depletion.

Zinc production affects, and in turn is affected by, the demand for and the economic aspects of a variety of coproducts and byproducts. The relationship between lead and zinc is particularly significant.

Much of the industry is organized internationally and responds to economic advantages that one location might offer over another at any given time. Governmental action has frequently sought to protect the domestic zinc (and lead) industry through the imposition of quotas and other protective devices. Zinc is mined in 20 states, milled and refined in 12, and initially consumed in 7. It is expected that the welfare of the industry will continue to be the object of increased legislative and executive attention as competition from foreign sources increases. The potential effect of proposed actions demands a detailed understanding of world industry, economic and resource structures.

Most zinc mines are underground operations so improved efficiency in underground mining methods would significantly effect cost reduction.

Horizontal retort reduction is relatively inefficient metallurgically and very inefficient from a manpower standpoint. Several of the newer systems of metal recovery show potential of increased efficiency and probable increased recovery of byproducts. (See section on cadmium).

Zinc competes with many alternate materials, principally aluminum and plastics, for major uses. In die-casting applications zinc is apparently on the defensive because aluminum and plastics are in good supply and price trends seem to favor such substitution.

Recycled scrap furnishes about 20 percent of domestic requirements. However, secondary recovery from some nondissipative end uses could be improved, notably in the die-casting area and specifically in such end-use items as appliances, automobiles, and industrial machinery.

Although zinc generally is mined from underground operations and there is no stripping waste problem, the solid waste and tailings piles represent a land use conflict problem in some of the more heavily populated areas in common with other mining operations for other commodities. Electrolytic zinc refineries present no solid waste problems since slimes are usually shipped to lead or copper smelters for further processing. Retort plants produce residues which require disposal, however, and plant stacks can give off heavy sulfur and other fumes which can add to the air pollution of urban areas. In common with other mining operations, the effects of mine subsidence is becoming of increasing concern to the public especially in view of the recent disaster in the Tri-State area.

At present there are few manufacturing facilities permitting galvanizing of large structural members, like bridge trusses, even though economic benefits through more effective corrosion resistance might result from such practice. The relative roles of zinc and other metals and coatings as corrosion inhibitors are not well established. Theoretically, major reductions in material demands should be realized through extending the useful life of end products before effective means of inhibiting corrosion is seen as an effective way to extend mineral supplies.

Zirconium

Zircon is the only zirconium mineral of commercial significance. At present it is imported in substantial quantities to accommodate U.S. demands. Domestic submarginal resources are very large. The coproduct relationship with titanium is important in the current economics of primary production of zircon. Development of techniques for selectively extracting zircon commercially without economic dependence on coproduct values or demand would improve the supply outlook.

The major use of zircon is in foundry sands where costs control the degree of competition from acceptable substitutes. Refractories also employ the mineral in specialized applications. A method for satisfactorily reusing zircon in foundry molding would ease need for increasing imports.

Zirconium metal attracts a majority of attention because of its relative recent emergence as a product of commerce and because of its properties, its high unit value and speculative significance in nuclear power applications. In this connection the mineralogical association of zirconium and hafnium in zircon is significant to the different supply-demand relationships of the two metals. Improvement in separation techniques would effect important cost reductions.

In almost every presently known end-use application substitutes may be employed with minor inconvenience or quality sacrifices. Accordingly, price will affect demand for any of the commercial forms—metal, hafnium-free metal, oxide or mineral. Process improvements that tend to reduce costs at any production stage from extraction through forming will significantly influence future demand and application. Conversely, zirconium may substitute for other substances (see section on tantalum) in less abundant supply, or find a variety of expanded applications where oxidation and corrosion resistance, low-neutron absorption and other properties may be significant.

Recovery from nondissipative end-use applications will demand attention in the future. Recycling of impure zirconium metal and alloy scrap presently is handled by retreatment through the chlorination, separation, reduction and melting stages. Pure hand sorted material is simply remelted with virgin sponge. If large quantities of material containing nuclear impurities become available less costly recycle methods probably will be required.

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