Principles of Mineral Conservation

By W.M. Myers

The Pennsylvania State College
School of Mineral Industries
State College, Pennsylvania
1946
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INTRODUCTION

ONE OF THE GREATEST LESSONS learned in the war is that national existence is dependent upon an uninterrupted flow of diverse mineral products. There is nothing new in the recognition of this fact. The important part of the lesson is that it has been learned by millions of people. The public of the United States is now mineral conscious to a degree unparalleled in the past. The role of minerals in national defense, the international complications involved in procuring adequate supplies, and the realization that no nation is entirely self-sufficient are now matters of widespread knowledge. The social-economic problems associated with these factors are common to all people; and their solution, as difficult as it may be, is necessary if we are to advance toward any state of international amity. Minerals and their products dominate the present industrial age. They differ from other natural resources in one outstanding characteristic, they cannot be replaced when exhausted. For this reason their conservation is of vital importance.

Any long range program for the support and maintenance of the economic life of Pennsylvania must be concerned with mineral conservation. The leadership of the State as a producer and processor of minerals is still unchallenged. It can be maintained only by a wise use of our own resources and an assured supply of those materials which cannot be produced locally. The most recent published inventory indicates that the Commonwealth still possesses a tremendous reserve of those minerals upon which industrial supremacy rests.¹ The efficient and conservative use of this great natural resource is a matter of economic significance to every resident of the State.

WHAT IS MINERAL CONSERVATION?

Mineral conservation has been defined recently by C. K. Leith as, "efficient extraction and use, not hoarding." If carried to the highest state of efficiency undoubtedly this is true. However, it seems inescapable that some element of preservation and actual saving should be emphasized. Our present resources are adequate in nearly all types for one more generation of the most profligate use and abuse, and fortunately some of them exist in tonnages sufficient for many generations. Higher efficiency in production and use will prolong the period. The author prefers to define mineral conservation as the intelligent utilization of mineral resources plus a proper regard for the rights of coming generations. Certainly the future is entitled to some equity in our national inheritance. Mineral conservation is concerned with the preservation of this inheritance and the peculiar problems involved in the immediate free use of minerals by industry.

CHARACTERISTICS OF MINERAL PRODUCTION

The frequently quoted statement that more mineral wealth has been produced since 1900 than the combined production of all previous time is well known. It is less commonly recognized that during the same interval there has been a corresponding increase in the accumulation of scientific knowledge. The application of these scientific principles to the production and utilization of minerals has become the foundation of this acceleration in output as well as producing those economies necessary for the maintenance of prices permitting the extensive use of mineral products.

Among the contributions of science the development of high explosives dating from the invention of dynamite in 1866, the development of the air drill about 1904, the establishment of the flotation process about the same year, and the constantly expanding application of the principles of chemical engineering to oil refining and mechanization of all mineral production have been outstanding. Although some of these items are ancient in origin, they are essentially modern in their relationship to the mineral industries and became of controlling importance only after the turn of the century.

A contemporaneous development of specialized carriers such as the iron-ore cargo ship on the Great Lakes, the pipe line, and the petroleum tanker on the ocean together with a general expansion in railroads, highways, and marine transportation stimulated production everywhere. Each increase in radius of economic haulage has permitted the exploitation of mineral resources in a new circle of activity. These circles now overlap and cover the earth.

The size of the United States, with its millions of consumers and the presence of forty-eight states existing without tariff walls, has permitted the development of that extraordinary American phenomenon, mass production. Its development in its highest state has occurred in the manufacturing industries. Concentrations of large tonnages of ore are amenable to a similar technique, particularly if they can be worked by open cut methods. Such operations have been successful in the porphyry coppers and in certain iron ore mines and limestone quarries. The economies of operation are such that they have contributed enormous tonnages of material to industry at low cost.

Domestic mineral production reflects changes in activity in the business cycle with a small time lag. In times of depression it drops rapidly to low levels. In periods of inflation it climbs rapidly to great peaks. In part this is due to the comparatively small amount of material in storage. Most of this material is either in transit or in process. The capital investment involved in the storage of large tonnages of raw materials or finished goods is such that it is avoided and the processor and fabricator adjusts his raw material orders to the market for his wares. Seasonal interference with shipment interferes with this procedure, and there are certain outstanding exceptions to this practice, such as the movement of iron ores on the Great Lakes, which must be completed during the months when navigation is possible. Storage of ore at the Lake ports or steel mills is therefore necessary to supply the demands of the winter months.
The population of the United States has almost doubled since 1900. This increase created markets which strained the productive capacity of the country. The principal problem of industry during part of this time was one of production and not distribution. Efficient recovery of mineral raw materials frequently was sacrificed for speed and profit. Many wasteful processes were ignored or tolerated to the detriment of conservation. The first change in the production-distribution pattern was noted after the close of World War I when the excess capacity, originating in wartime expansion, produced more goods than the market could absorb. The problem was one of over-capacity to produce rather than actual over-production. This condition was partially obscured during the rising tide of prosperity in the 1920’s and did not become prominent until the depression years. World War II again utilized all the country’s capacity to produce and actually expanded it. Events indicate that certain problems associated with over-production will again be present in the postwar years of economic adjustment.

Mineral production increases at a far more rapid rate than population growth. This is shown by the remarkable increase in the value of mineral wealth produced per capita. In 1900 this amounted to $14.50; in 1945 it was $62.50. In part this reflects an increase in price as well as in production. There is no reason to doubt that this expansion in production will continue for an indeterminate period in the future, provided the mineral resources exist in adequate tonnage to support such a productive flow. They will not exist unless proper measures are devised and applied to increase the efficiency of mineral utilization and the conservation of our mineral reserves.

CHARACTERISTICS OF MINERAL CONSUMPTION

About one hundred species of minerals supply the fundamentals upon which our present industrialization rests. However, this number tends to expand continually, and one of the marked characteristics of the consumption pattern of the past few decades has been a constant addition of new minerals to the list of those of industrial significance. More and more materials become useful as research discloses their properties and their relationship to industrial processes. Many of these minerals possess an importance out of all proportion to their value or tonnage. That is, they perform services which cannot be duplicated by any other material and these services are indispensable in industries of major importance.

The consumption of minerals has expanded to all types of human activity, and their continued existence is dependent upon an unfailing supply. This is illustrated by agriculture. Soil productiveness can be maintained only by the application of mineral fertilizers. No other supply exists in adequate tonnages. The mechanization of the farm requires machines and the mineral fuels to operate them to the extent that food production is dependent upon the mineral industries. The rise of the chemical industries during the present century has been one of the most outstanding events in our economic development. As stated by the U. S. Bureau of Mines, “The chemical industries depend upon minerals for a substantial part of their essential raw materials. Sulfur, salt, and lime are outstanding examples of well-known mineral substances employed in enormous quantities either for active reagents or as components of finished products. Chemical processes form the backbone of industrialization. In no nation or community can diversified manufacturing and processing industries become dominant unless chemical raw materials are available in adequate quantities at moderate prices. The United States has been richly endowed with most of these essential commodities, and their abundance and availability have been decisive factors in the enormous growth of the chemical industries that has marked the past 30 years.”

The alteration of the original mineral raw materials by chemical processes is so great that frequently the final product displays no resemblance to the minerals from which it has been derived. Therefore, there is a hidden consumption of mineral products

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not easily recognized. Nylon and other related plastics of mineral origin resemble organic products so closely and compete so directly with them that their connection with the mineral kingdom is obscured.

The trend of per capita mineral consumption, with one outstanding exception, has been upward. Actually the tremendous increase in per capita consumption has been the cause of the depletion of mineral resources to a degree unpredictable in the past. There is no evidence of any marked decline in this trend. Predictions as to the future life of reserves at the present rate of consumption are likely to be of limited value or seriously in error. The consumption will be greater than anticipated, and unless conservative measures are applied the demands of the future cannot be met.

Figure 1 illustrates the per capita consumption of coal, petroleum, and steel—the three great fundamentals of modern industry. Steel and petroleum exhibit a spectacular increase; coal has declined since 1920. Why has coal declined? In part this is answered by the rise in petroleum, which as a competitive fuel has displaced coal as a space heater and as an industrial fuel. It is also due to increased efficiency in combustion among such large consumers as the railroads, steel mills, and public utility power plants. A decline in per capita consumption of a mineral commodity of primary importance may serve as a clue to an increased efficiency in use.

THE RELATIVE NEED OF CONSERVATION

The proportion of the original mineral resources of the United States remaining for future use as estimated by Pehrson4 is shown in Figure 2. The greatest exhaustion of our original resources is shown by the nonferrous metals extending from mercury to antimony. Among these are those extraordinarily useful metals, copper, lead, and zinc. The United States has led the world in the


production of these three metals for many years. It is essential that the reserves remaining be employed so efficiently as to postpone the date of ultimate exhaustion to as remote a period as possible.

A representation of the total reserve remaining presents information which can be misleading and too reassuring. The place value of minerals cannot be overlooked for low-priced commodities which are forced to move in a short competitive radius. This is particularly true of coal, and the coal which will count in maintenance of Pennsylvania's prosperity is that which can be mined within the Commonwealth or introduced from immediately adjacent areas. The great tonnages available in distant areas will be of
limited value. The history of mineral industry development has shown that raw materials move toward the fuels wherever possible. And such a movement is accompanied by a shift in population and the establishment of industrialization in a new area. The preservation of the major industries of Pennsylvania is dependent upon the preservation of its fuels.

![Figure 2. Proportion of Mineral Reserve Remaining in the United States](image)

**TABLE 1**

<table>
<thead>
<tr>
<th>Practice of Conservation</th>
<th>Fuels</th>
<th>Metals</th>
<th>Nonmetals</th>
</tr>
</thead>
<tbody>
<tr>
<td>More efficient recovery</td>
<td>X</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Use of lower grade material</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Economy in transportation and storage</td>
<td>x</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>More efficient use</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Use of substitutes</td>
<td>O</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Re-use</td>
<td>O</td>
<td>x</td>
<td>x</td>
</tr>
</tbody>
</table>

X = A reasonably large opportunity.  
X = A small opportunity.  
O = Practically nil.

**FUELS**

Energy resources are closely allied with national policy and have been discussed as such.\(^5\) Briefly the situation is as follows: The percentage of loss in the production of fuels is notoriously high. In coal mining an average of 35 per cent of the original resource is commonly lost and left in unrecoverable form. In a year of normal production this amounts to over 200,000,000 tons. Possibly one-half of this is avoidable. In the production of petroleum the loss is as high or frequently greater, depending upon the amount of reservoir engineering applied in the early stages of operations, and possibilities of later secondary recovery

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through water flooding or air drive. The fugitive nature of natural gas has baffled the best intended efforts directed toward its recovery. Its collection and introduction into the ground in oil fields to increase the efficiency of oil recovery, its collection and distribution through pipe lines, and its storage underground in geologic structures have resulted in substantial savings; but great loss still continues. Some economies in transportation and reduction of loss by volatilization are possible and desirable.

Great advances have been made in the increase of efficiency in the combustion of fuels as noted with regard to the decline in per capita coal consumption. Similar advances have been made in the processing of petroleum. Coal, petroleum, and natural gas yield approximately 90 per cent of the total energy supply of the country. The possibility of expanding water power, the contributor of the remaining 10 per cent, beyond its present status is dependent upon large governmental expenditures and then can develop an energy supply in localized areas only. The nebulous state of atomic energy and the extraordinary difficulties associated with its industrial application do not indicate any competition from this source in the foreseeable future. The complete destruction of fuels associated with their utilization does not permit reuse.

The recovery of by-products during the manufacture of coke introduces a desirable phase of conservation in that much of the original fuel value is retained in addition to a series of useful and valuable products. This process has introduced the first important non-fuel use of coal. These uses for coal, petroleum, and natural gas are now rapidly increasing under the impetus of research. These natural resources are becoming the fundamental raw materials of great chemical industries employing thousands of people and producing thousands of products. A great expansion in this industrial use of the fuels is inevitable. Their efficient use as fuels and their conservation as the raw materials for the support of the future industries of Pennsylvania is a necessity.

The problems of coal conservation have been summarized by Rice, Fieldner, and Tryon in an outstanding contribution from which the following is quoted: "The central problem in conservation of coal resources is not absolute exhaustion in the remote future but a relatively early increase in cost through depletion of the richer and more accessible deposits. The anthracite deposits of Pennsylvania are 29 per cent exhausted, and the anthracite industry has already entered the stage of increasing costs. In the bituminous fields the life of certain of the finest seams of the Appalachians is limited to 50 to 100 years at 1929 production. Resort to thinner or less accessible beds, of which large reserves are available, will increase the difficulties of mining, and under really difficult conditions the labor required per ton may be doubled or quadrupled. . . . While wastes in mining have shown little sign of abatement in recent years, great progress has been made in reducing wastes in consumption through the advance of fuel technology."

METALS

The necessity for the economic use of our shrinking reserve of metals has been noted. Actually the shortage has become so acute that it is a matter of grave concern to those charged with the problems of supply for national defense. More efficient recovery of some ores is certainly possible. However, the greatest advances have been made in lowering the grade of material which constitutes ore. As stated by Corry and Kiesling "Grade tends to vary inversely with tonnage." The large tonnage producers of gold, copper, and iron ores have been able to effect such economies in operation that the grade of ore which could be termed commercial constantly dropped. This has added millions of tons to the reserves and has served as an agent of conservation.

Little opportunity exists for conservation of the metallic ores or metals in transportation or storage other than normal protection from loss or corrosion. Some saving can be produced in use by employing the lowest grade of metal or alloy which will serve

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satisfactorily and metallurgists have already effected great savings in devising alloys of minimum rare metal content. The uses of metals exhibit such variation that in some fields a degree of substitution is possible, although this has little effect on tonnage consumption.

The greatest opportunity for the conservation of metals lies in their re-use. This is controlled by the value of the material, its properties, or how it is employed. Gold, silver, platinum, and other precious metals are protected from loss and pass through many cycles of utilization which is justified by their value. Metals which resist corrosion may be exposed for long periods of time with little loss and later used again. Copper and lead belong to this class and may be exposed for years with little change other than the development of a surface coating of oxidation products which protects the metal from further attack. Unfortunately the great problem of rust protection for ordinary steel is yet to be solved. Lead used in the storage battery or in the form of cable can be recovered and recycled many times. The same metal employed as a pigment in paint is lost beyond recovery which is true for zinc whether used in paint or as a metallic coating on galvanized steel. A large percentage of tin used in tinplate is also lost. The consumption of lead in tetraethyl lead is also final and without possibility of recovery. It is regrettable that so much of the consumption of lead and zinc should be final and lost beyond recovery.

The collection of scrap metal has become a well-organized industry. During the war it has functioned to the great advantage of national defense. The collection of scrap has become a familiar sight in many communities. This is conservation of the best type. A ton of steel scrap represents two tons of iron ore and 2600 pounds of coke, as well as a substantial amount of fluxing stone. Therefore the savings produced by the use of this material affect many operations. In 1942 and 1943 ferrous scrap supplied the raw material for slightly over one half of the total steel production of the country.

The tonnage of the nonferrous metals produced in the United States in 1944 and the amount of secondary metal recovered and its value is shown in Table 2.

<table>
<thead>
<tr>
<th>Table 2</th>
<th>NONFERROUS METALS IN THE UNITED STATES IN 1944</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tons Produced</td>
</tr>
<tr>
<td>Aluminum</td>
<td>778,446</td>
</tr>
<tr>
<td>Antimony</td>
<td>4,755</td>
</tr>
<tr>
<td>Copper</td>
<td>1,098,090</td>
</tr>
<tr>
<td>Lead</td>
<td>394,443</td>
</tr>
<tr>
<td>Magnesium</td>
<td>157,100</td>
</tr>
<tr>
<td>Nickel</td>
<td>988</td>
</tr>
<tr>
<td>Tin</td>
<td>6</td>
</tr>
<tr>
<td>Zinc</td>
<td>574,453</td>
</tr>
</tbody>
</table>


The recovery of tin and nickel in amounts greater than production is due to the importation of material from foreign sources.

THE NONMETALLICS

The nonmetallic minerals contain the basic raw materials consumed by the building, ceramic, chemical, and fertilizer industries. The tonnage available for future use is still very large as is indicated by Figure 2. In addition, there are very large reserves of clays, building sand, glass sand, and building stone. In general these commodities do not command high prices and are sold within a local market of small radius. Certain high-valued minerals such as mica, asbestos, and quartz crystals are also included in this group. These minerals exhibit peculiar physical properties which have made them of special value to industry, and the economic considerations controlling their production and use are far different.

Opportunities for an increase in the efficiency of recovery are restricted. The possibilities for the use of lower grade material are almost unlimited. In many cases this is highly desirable not so much as a matter of conservation of material as a conservation of transportation cost. The place value of a noncommercial mineral can be enhanced enormously by the application of the proper technology to convert it to commercial grade. The actual increase
in value represents the freight saving which can be derived from
the operation of a satisfactory source of supply within a few miles
of the consuming industries as contrasted with an equally satis-
factory source hundreds of miles away. An increase in the efficiency
of use or the development of substitutes for most nonmetallic min-
erals is not promising.

Many nonmetallic mineral products are destroyed by utilization
or so converted into other products that there is little possibility
for re-use. The most important exceptions are the recovery of
brick and building stone from razed structures and their use in
new construction, and the collection of broken glass, known as
cullet, and its remelting in the glass furnace. The use of cullet has
been credited with speeding up the melting of the batch, increasing
the capacity of the furnace and conserving raw materials and fuels.
Its use from 20 to 50 per cent by weight of the batch is possible in
the production of some glasses. At present there are some differences
of opinion among operators as to the efficacy of use of cullet. Lime
is used in large tonnages by sugar refineries and paper mills, and
in water purification. The calcium carbonate produced by the re-
action has been recovered in some instances and calcined again
for re-use. The recovery of water in arid localities where its value
is high is commonly practiced, particularly by mining companies
engaged in the concentration of minerals.

TECHNOLOGY THE GREAT CONSERVER

Technology depends upon research to discover scientific truths.
The application of these truths to the problems of mineral indus-
tries increases the productive capacity of the worker, produces new
and better goods, reduces costs, and prevents waste. This is con-
servation in its most desired form. And it is the only type of con-
servation which can be applied. There is no other choice. Waste has
been defined by Rockefeller as follows: "Whenever the word is
used thoughtfully, 'waste' denotes an unfavorable comparison be-
tween an actual situation and another possible or ideal situation.
Quantitative measures of waste must necessarily be expressed as
ratios of the actual compared with the possible or the ideal. Waste
is a degree, not a magnitude."8

The reduction of waste to a minimum magnitude is the goal of
research in the mineral industries.

The contributions of technology to the present status of the
mineral industries are innumerable. They have been discussed in
detail elsewhere.9 New exploration techniques have been developed,
and their precision has been increased. Most ore deposits that crop
out and most oil structures that can be recognized easily have been
found. The acquisition of reserves for the future, which is part of
the conservation problem, is now dependent upon an increased
knowledge of the sub-surface. This can be obtained through the
sciences of geology and geophysics. Knowledge of the earth is still
only skin deep in spite of the fact that improved methods have
permitted mining to 7000 feet and oil-well drilling beyond 16,000
feet. The ultimate depth at which minerals may be recovered is
controlled by economic factors. These may be changed by the pro-
duction of new methods through research.

The crust of the earth is no longer capable of satisfying all the
demands of industry, and the extraction of minerals from the at-
mosphere and from the ocean has given rise to great industries.
These developments have changed completely all ideas as to the
amount of mineral resources available for future use and have
opened reserves in tonnages undreamed of in the past. This de-
velopment has accomplished another feat of the greatest economic
and political importance. It has altered the international pattern of
mineral reserves. Among these reserves the most important is ni-
trogen. The monopoly formerly controlled by Chile through the
ownership of the world's only known supplies of nitrates has been
shattered by fixation of nitrogen in the atmosphere, and any nation
with the necessary technical skill may become self-sufficient. Ni-
trogen is essential for plant growth, and great tonnages are con-
sumed by agriculture. A far more spectacular and socially signifi-

8 Unused Resources and Economic Waste. David Rockefeller. The University of Chicago
cant use is its employment in explosives. Until the development of the atomic bomb practically all explosives were nitro-bodies. Ability to wage war has been dependent upon control of nitrogen, and the development of a new technology has not only conserved the natural supply but it has also altered the balance of international power.

The development of the cracking process in the petroleum refining industry is an outstanding example of conservation of raw materials by the use of a new method of processing. The use of this process has saved billions of barrels of crude oil. The savings for 1940, the last year for which data are available, are shown in Table 3.

<table>
<thead>
<tr>
<th>TABLE 3</th>
<th>CRUDE OIL CONSERVED BY CRACKING</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield of</td>
<td>Total</td>
</tr>
<tr>
<td>Straight-run</td>
<td>Quantity of</td>
</tr>
<tr>
<td>Gasoline from Production</td>
<td>Gasoline Required</td>
</tr>
<tr>
<td>Crude Oil (Per cent)</td>
<td>Crude Oil Cracking</td>
</tr>
<tr>
<td>1940</td>
<td>20.37</td>
</tr>
</tbody>
</table>

Data: American Petroleum Institute.

**ACTION IN CONSERVATION**

*Fact Finding.* Intelligent action can be based only on facts. All the facts concerned with the relationship of reserves to production and consumption must be assembled. Production data are relatively abundant and reasonably accurate. Data dealing with consumption are incomplete and do not supply the information necessary for the solution of the closely associated problems of marketing. The interpretation of the extraordinary effects of technological developments on the economic structure will be possible only when factual data are assembled.

*Research.* Research is the foundation of technical advancement. The increased utilization of minerals requires an expansion in the knowledge of their basic properties. The development of new methods of exploration by which supplies may be increased and new technologies by which savings in production, processing, and use may be effected is the only road to true conservation. Research has been termed a national resource, and its application to the problems of conservation of natural resources is the only means of their solution.

*Quality Conservation.* Quality conservation implies the use of the lowest grade material that can be used satisfactorily and the saving of superior materials for such uses as can benefit by superior quality. Low-sulphur coking coals are at a premium as fuel in the metallurgical industries, and the tonnage reserves are rapidly dwindling. The use of such material for ordinary heating where lower grade fuels would suffice is an unnecessary waste of quality.

*Increase in Saving Habits.* The American public has been wasteful in the use and disposal of all mineral products. This attitude is due in part to the abundance of material that has been produced at low cost. Scarcity of metals during the war has demonstrated that large tonnages can be collected for re-use. The collection of scrap iron, tin cans, and tooth paste tubes permitted a recirculation of metal in substantial amounts and has schooled the public in the value of such materials. The provision of proper facilities for the collection of metal waste could continue to expand the recovery and secondary use of such important metals as iron, lead, copper, tin, and zinc.

*Reduction in Consumable Uses.* Substitution of other more plentiful materials is desirable where the loss in utilization is complete without hope of recovery. In many cases no substitution is possible. In others there is a reasonable expectancy of developing substitutes. The loss of metals in surface coating and in paints is complete and final, and the development of alternative materials will be necessary eventually.

*Governmental Policies.* The basic problems of conservation are so universal in distribution and so closely associated with the well-being of the country that they can be solved only on a national
basis. Unfortunately no unified national policy has been formulated and those activities connected with exploration, production, processing, and conservation are scattered in many agencies. Certain problems within the sphere of governmental action are outstanding.

The strategic minerals are those that are not produced within the country in quantities adequate for industrial consumption. Tin, chromium, and manganese are among the most important. In normal times imports from foreign sources are readily obtained. The difficulties associated with supply increase in war to the extent that the procurement of tonnage adequate for the production of armament becomes a military problem of first rank. The proper management of our inadequate supplies to insure a maximum length of life and existence in times of emergency is necessary in any plan for national security.

The discovery and operation of mineral deposits and oil fields in many foreign countries together with the establishment of proper transportation systems has created an intricate international flow of mineral raw materials on a global basis. Entry of materials of foreign origin in the United States is controlled in part by the extent to which similar materials are produced domestically. Little opposition exists to the introduction of materials which we do not produce. Those which compete with domestic production create an economic problem concerned with the differential in wage rates which exists between the United States and foreign countries. The solution and control of this problem is attempted by means of import tariffs. A re-examination of the relationship of present domestic reserves and future consumption to foreign supplies should develop data which should permit the establishment of tariffs that would serve to conserve any resource showing signs of dangerous depletion.

In an aging mineral economy the situation develops frequently in which the limit of economic operation is attained. That is, the oil well or mine ceases to produce profit dollars although the mineral resource itself is by no means exhausted. Further operation is dependent upon a price in excess of that current in the market. Should such properties be abandoned with the probable complete loss of the reserves remaining or should their life be prolonged so that the maximum in total mineral recovery be obtained? Prolongation is dependent upon a compensatory payment or bonus which in effect serves to subsidize production and insure the recovery of material which otherwise would be wasted.

A satisfactory program for the taxation of natural resources has never been evolved. The fact that mineral resources are wasting assets in which production consists of a liquidation of capital presents a situation not encountered in normal industry. The tax structure is now complex and extends from federal acts to those of the local community. Excessive taxation favors rapid and wasteful exploitation. A comprehensive study and possible reorganization of the regulations controlling mineral taxation possesses possibilities for an increase in conservative action.

**Time for Action.** The time for action is not after the inroads of use and waste have reduced the national mineral heritage to the vanishing point. The time is while reserves still exist which if wisely conserved will suffice for many years. That time is now.

### SUMMARY

The present century has been marked by an unparalleled increase in the consumption of minerals. This trend increases at a rate greater than the growth of population. The industries of the nation are dependent upon an unfailing supply of mineral products for their continued existence. This condition is developed to its highest state in Pennsylvania because the Commonwealth leads in the production and processing of such products. The problem of supply increase with time. To insure supply for the future a better and more efficient use must be found for our reserves. This cannot be accomplished by hoarding or miserly use. It can be attained only by the invention of new techniques of discovery, greater economy in recovery, and more efficiency in use. This requires an expansion in the fundamental knowledge of all minerals. This is true conservation.
PUBLICATIONS OF THE MINERAL INDUSTRIES EXPERIMENT STATION

Research results of the Experiment Station are disseminated through the following publications: (1) Bulletins which present the proceedings of technical conferences and the detailed results of the experimental studies of the problem which may be more comprehensive than a single project. (2) Information Circulars which present in non-technical language the results of studies which are given in greater detail in other publications, statistical data or pertinent information gathered from other sources. (3) Technical Papers consisting of bound copies of papers published in scientific journals (reprints), of progress reports, and of results of experimental studies which represent isolated phases of research and which will be summated later in bulletin form.

A few of the publications are listed below. These may be obtained from the Director of the Mineral Industries Experiment Station, The Pennsylvania State College, State College, Pennsylvania.

Bulletins


Circulars