Circular 39

Mineral Forecast 2000 A.D.

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STATE COLLEGE, PENNSYLVANIA

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PREFACE

This circular completes a series of five companion circulars. Circulars 31, “Roots of Human Progress”; 33, “A Philosophy for Conservation”; and 35, “Wanted: Mineral Industries Colleges”; were designed to explain some of the philosophies of Pennsylvania’s School of Mineral Industries and some of the obligations of the College in the mineral field under the terms of the organic Land-Grant Act.

The need for Circular 37, “Minerals and Posterity,” presented itself when we entered the war in Korea. It seemed desirable to review our utter dependence on outside sources for various strategic and critical mineral supplies during World War II, together with the necessity for down-to-earth mineral policies.

The Korean War is seriously depleting our limited mineral resources, and preparedness and foreign aids of many kinds will be with us for another generation. Stockpiling of mineral supplies from overseas has become a part of our daily life, and cannot be completed, nor the future assured, under present conditions.

The Pennsylvania State College will celebrate its one hundredth anniversary in 1955. At the time of the Land-Grant Act, 1863, the Commonwealth of Pennsylvania was emerging busily from a predominantly agrarian economy into an industrial economy, based primarily on mineral industries. The rapidly growing utilization of the State's mineral resources—for example, slate, clay, coal, iron ore, petroleum, the coming of the railroads, the presence of the short-lived canals, and the appearance of many new inventions—played a part in this period in making Pennsylvania the nation’s workshop.

The iron masters who operated charcoal iron furnaces in Central Pennsylvania actually initiated reforestation—conservation—in this country nearly 100 years ago. These reliant individualists worked out a plan to perpetuate their fuel reserves which was designated “30-year cutting.”

Even agriculture was in a period of transition in 1863. Midwestern farmers were beginning to grow wheat on a larger scale than could be done here; consequently, Pennsylvania farmers turned to more extensive dairying, livestock farming, and vegetable growing, all of which found a ready market in the industrial centers that were springing up around them.

An equally dramatic shift of economy is taking place today and we can see reasonably well into future needs, especially with regard to the mineral industries. Unlimited horizontal expansion is no longer a possibility in the United States. Pennsylvania, secure in its natural wealth, is mature in the development of its natural resources, and in its established industries. Intensive development of every possibility inherent in our manpower and raw materials poses many problems that will have to occupy our attention as a Land-Grant college. The intent of this circular is to show how education and research can constantly point out new directions of ef-
fort and prove that what we lack in quality resources can be offset by better brains and skills. The circular establishes a long-range goal toward which the activities of Pennsylvania's School of Mineral Industries can be directed.

The confidence, counsel, and help of the staff of the School of Mineral Industries; of various Pennsylvania State Departments; of the great, diversified mineral industries of the Commonwealth; and of the alumni of the School are gratefully acknowledged.

Edward Steidle, Dean
School of Mineral Industries

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INTRODUCTION

In looking ahead 50 years we must assume that our present civilization will have met and satisfactorily solved the two dilemmas now facing us: on the one hand, decimation through atomic, supersonic missiles, bacteria, or other totally destructive warfare; on the other hand, deterioration through overpopulation.

In 1952 we are hounded by the urgency of preventing the Great Holocaust; the threat of total destruction is ever present. We are heedful of Einstein's horrible prediction that the fourth world war will be fought with clubs. Mineral technologists are well aware that with widespread use of atomic eruptions, there will be little of our machine age left for salvage and development. We must assume that the great effort to arm against and prove the futility of attack will pave the way for the intelligent, unharassed pursuit of happiness.

However, little thought is being given to the grim warnings of the geneticists. In looking ahead to the year 2000 we must hope that the world population increase has leveled off instead of increasing by one-half the present population, as now predicted. We must hope that chemists have produced large quantities of nutritious food from yeasts and bacteria, that water from the oceans is utilized for irrigation purposes and the production of many metals. We must hope that
arable land has been made available for the 68,000 hu-
man beings now being born every 24 hours, and, above
all, that quality with regard to intelligence and health
has been kept at a high level. And, we must have
brought about acceptance of American political morali-
ty and responsibility instead of the imported kind of
materialism composed of political expediency and doc-
trinaire economic manipulations. Whatever the out-
come, we may be assured that nature, the one truly in-
destructible force, will seek its own balance, a balance
which we have upset with our vast improvements which
not only increase life expectancy, but also the live birth
rate. We can expect to develop the great potentialities
which we know to exist, only by assisting nature to seek
such balance.

In the past 50 years there has been spectacular indus-
trial progress. The use of electricity for light, power,
and communication; the automobile, airplane, and now
the jet-propelled plane to speed our missions of peace
and war; and the approaching control of nuclear power
for some industrial uses have all been part of this ad-
vance. Much of the raw and processed material and
some of the human ingenuity that produced such
changes in half a century have been supplied by the
mineral industries; they are prepared to continue in
this work which will certainly bring even greater
changes by 2000 A.D.

The industrial future can be predicted with some
assurance if our world problems of human relations can
be solved. We must now prepare for the certain demand
for improvement in the quality and quantity of our raw
minerals and processed materials, because the known

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Figure 1. Schematic presentation of comparative rates of personnel training and research in some basic American industries.
reserves of many of the first quality deposits are vanishing at the very time when the need for them is rapidly increasing. Prospecting for new deposits, the upgrading of second quality minerals and ores, the synthesis of desired materials, and the design of more efficient manufacturing processes, as well as the systematic development of new products with specified properties, are all under way. These trends provide a lookout tower from which to glimpse the future.

The potential demand for minerals and mineral products is staggering! For the first time in our history there apparently is a permanent need for war industries, and the requirements that these make, together with those for housing and related facilities of our ever-increasing population, make it necessary to study intensively our mineral resources. Fifty years ago the United States had a population of 76 million people; today it has 151 million and in 1960 it will have about 170 million. At this rate of growth, or even at a somewhat slower one, we would have a population of over 200 million people by 2000 A.D. This would require much greater consumption of raw materials than at present in order to fill the needs of the people and maintain our industrial economy. The United States may have to become self-sufficient in supplying many of the strategic minerals or find substitutes for them. The first World War resulted in the creation of our vast chemical industries, and the second emphasized the need for developing and conserving native strategic minerals and metals as well as stockpiling imported ones (Fig. 1).

MINERAL REALISM

It is a known fact that the United States possesses seven per cent of the world's population and five per cent of its land area. With this small fraction of the world's population and area, how long can the United States expect to continue producing 34 per cent and consuming 50 per cent of the world's mineral production? We are perhaps fortunate to be able to consume thirteen times as much mineral wealth per capita as the rest of the world. However, do we realize the implications of having to produce ten times as much per unit area, plus depending on the rest of the world for one third of our mineral supplies? Obviously, the question of how long we can continue cannot be answered specifically, but it is evident that we may, sooner or later, find foreign ores no longer available to us and will be faced with an even more rapid depletion of our domestic high-grade ores.

It would be unrealistic to expect that the people of the world will continue to be satisfied with a lower standard of living while the citizens of the United States enjoy the fruits of both domestic and foreign irreplaceable mineral resources. We must be prepared for growing opposition on the part of the various nations to shipping their mineral raw materials to the United States. We must expect the eventual necessity of having
to compete, not for foreign ore, but for the limited supply of more costly foreign fabricated goods.

These difficulties in procuring foreign materials will come at a time when the United States is facing the depletion of her own high-grade domestic resources. Exploration and technology have just not been able to keep up with the rapid utilization of our mineral reserves. American industry will be faced not only with a lack of raw materials at home, but also with the difficulty of obtaining supplies abroad. This could mean that the United States will eventually fall from its imminent position in world affairs, as this position has been maintained primarily by our outstanding productive capacity. The American consumer may be faced with the shocking necessity of having to be satisfied with only an average share of the world's mineral wealth instead of thirteen times as much as anyone else. The political and economic implications of these possibilities are disturbing. The present difficulties being encountered by Great Britain, although mostly of politico-sociological origin, are thought-provoking previews of the mineral impoverishment that may be in store for the United States.

Yet are we irrevocably destined for such a future in this country? Must we resign ourselves to a gradual loss of the good things of the past? No, there remains one hope, one weapon, to fight economic decline, and that is technology. Granted, it is not a magic wand which will create wealth out of nothing. It is not even a predictable tool; its progress is erratic and undependable. But it is the only way to answer depletion and maintain domestic self-sufficiency. Technology, alone, finds new mineral deposits, develops methods of using lower-grade mineral deposits, increases the efficiency and lowers the costs in our extractive industries. This is the only truly acceptable and enduring solution to the problem of depletion. In the future, if we set our sights high enough, technology could conceivably provide a high standard of living for all the population of the world. Perhaps a more permanent world peace could be derived in such an environment of prosperity for all instead of for just the favored nations.

A far greater effort must be made in the future than in the past, if we are to accomplish these vital things with technology. We must realize the necessity for an accelerated program of research now while we have the economic well-being and the material resources to finance an all-out effort. To get the answers from technology we must invest the time, the money, and the effort while we yet have them to expend. When the last of the cream of our mineral resources has been skimmed off, it may be too late; we may no longer have the time, the money, and the physical resources. Once retrogression sets in, we may have to devote all our efforts to mere survival.

We of the United States mention with pride the spirit and resourcefulness of the people of our nation that have raised the country from a wilderness to the world's most prosperous land in the short interval of a few hundred years. We live confidently in the reflected glory of past victories in war, social, and economic struggles. Yet we are faced with a much greater battle in the future, the battle of survival of not only our nation, but of our civilization.
This difficulty is a new one in the history of mankind. Great civilizations of the past have collapsed due to internal corruption, loss of moral fiber, and similar causes which make them easy prey to the more virile conquerors from outside. But exhaustion of natural resources was not a major, or even contributory, cause to the decline of such civilization in the past, since these civilizations were agricultural or mercantile, and the level of their technologies was primitive.

Not so at present. Our twentieth century American civilization as we know it is totally founded upon technology, which in its turn is entirely based upon natural resources, mineral resources above all.

This is new and disturbing. In the past moral stamina could accomplish wonders with limited resources. Not any more. We must have tools and arms forged out of many metals, and these metals threaten to evaporate in our very hands. To survive we must have them.

The question we are faced with is, do we have the intelligence to survive? Do we have the foresight to sacrifice some of the material comforts of today and invest them in the development of physical resources for generations to come? We must expend our time, money, and effort wisely. Do we have the intelligence to do it and survive?

The long struggle ahead against depletion must be fought with future progress in technology, but the more immediate threat of world communism must be fought for the most part with the resources and technology immediately available to us. Though the United States may in the future find foreign mineral raw materials difficult to procure, it is now necessary that the free na-
growing weak. We would also be better off in two additional ferro-alloying elements, tungsten and nickel. Other commodities that the western nations as a group could provide are antimony, graphite, platinum, quartz crystals, beryllium, and asbestos. Though there would be improvements over the position of the United States alone, the hemisphere would still have some deficiency in tin, fluorspar, mercury, industrial diamonds, manganese, and mica. Hardly any improvement would be found in chromite, cobalt, columbium, kyanite, and tantalum.

However, to date the United States has not restricted herself to the protection of the western hemisphere alone but has cast her lot with the Atlantic Pact nations. Though it would seem logical that the South American nations would be a part of any defense effort in case of actual war, what is the mineral position of the Atlantic Pact nations standing alone? In addition to the nine mineral commodities in which the United States has adequate supplies, the other nations in the North Atlantic group could contribute sufficient aluminum, asbestos, copper, fluorspar, lead, nickel, platinum, and zinc. If Turkey is eventually added to this group, then important supplies of chromite could be added to this list. There would then remain deficiencies in antimony, beryllium, cobalt, columbium, graphite, kyanite, manganese, mercury, mica, quartz, tantalum, tin, and tungsten. These would, without a doubt, be critical shortages for waging a war; but on the other hand the Atlantic Pact group has a tremendous advantage in supplies of the absolutely essential heavy raw materials, such as petroleum, coal, iron ore, and the important nonferrous metals. The real strength of the North Atlantic nations lies in their unequaled productive capacity. Here we find two-thirds of the world's heavy industrial capacity, while the communist group controls only about one-fifth.

The greatest possible strength, of course, lies in a union of all the free nations of the world. The democracies of North America, South America, Africa, Europe, and Asia would be self-sufficient in all mineral raw materials and would have the productive capacity to use them to full advantage. The mineral commodities not found in either South America or the North Atlantic regions are available in the other free nations. From Africa and Asia would come the cobalt, columbium, kyanite, mercury, mica, tantalum, tin, industrial diamonds, and manganese that we lack. Though perhaps the lands behind the Iron Curtain possess greater reserves in some of these minerals they do not have the immediate ability in all cases to produce them in comparable quantities.

The above has shown conclusively that individually the democracies are far from self-sufficient; collectively they possess great material strength. The frequently heard words “united we stand, divided we fall” could never be truer. It is encouraging to see a practical acceptance of this interrelationship in the recent allocation of tungsten and molybdenum among eleven producers and consumer nations of the world. A continuation of such international voluntary co-operation will bring about a highly productive, efficient, and realistic defense effort among the democracies.
Such international co-operation should not stop at the allocation of materials for defense. For the democracies to survive in the long pull there should be progress in both productivity and human welfare among all the nations. The Point IV program is one example of potential achievement in this sphere of international responsibility.

The objectives of the Point IV program are to improve the natural resources, increase productivity, and raise the standards of living of economically undeveloped regions outside the Soviet orbit. In this free world there live 1,150,000,000 people. Work of this character was initiated many years ago by our progressive mining and petroleum companies operating overseas. It is evident that food supply cannot be increased, or health, labor, and education facilities improved, without simultaneously building up roads, railroads, docks, power plants, and industries. Therefore, in propagating programs of American democracy and technical know-how, it will be important to maintain a happy balance between "industrialization" and the rural type of programs that the Technical Cooperation Administration is now implementing.

THE JOB AHEAD

Since the establishment of The Pennsylvania State College in 1855, profound changes have taken place in science and technology and in their applications to the professions, industry and the mechanic arts, and agriculture. These changes have been, first of all, based upon so-called pure or basic research. This research has introduced entirely new concepts: for instance, the principles of relativity, radioactivity, thermodynamics, and physical chemistry, the bacterial concept of infectious diseases, and so forth. All of this research has been done to a very large extent under so-called ivory tower conditions. Without this research, none of the technological progress that followed could have been possible. This should be emphasized and brought forcibly to the attention of our people and our political leaders.

This pure or basic research has provided a reservoir of knowledge that has fed so-called applied research. This applied research has transformed these basic and pure scientific concepts into forms susceptible of utilization by industry. For instance, the basic concepts mentioned above have resulted in applied phase rule in high temperature technology, in atomic chain reactions and utilization of fissionable materials, and in principles of immunization and the bacteria-static utilization of such items as antibiotics.
These applied phases of science in their terms have resulted in the gigantic series of manufacturing developments that have led to the present position of the chemical and manufacturing industries, to all of the various progresses in agriculture, and to the visible expression of a mineral civilization as we know it today.

These changes have been fairly rapid and somewhat asymptotic in nature with a tendency toward acceleration with time. However, as a whole, in all of the industrial fields outside of the mineral industries, technological progress did follow gradually the development of applied science, and applied science followed equally the gradual development of pure or basic science. If no development in pure science was forthcoming, then that particular industrial field stagnated and failed to develop; it lost to more progressive and more competitive fields. However, there was no inherent cause for self-destruction in any one of these fields if they were not sparked by scientific progress.

This generalization of easy-going progress does not hold true any longer in the field of mineral industries. During the first 50 years, or possibly 70 years of the life of the College, i.e., up to 1910 or 1920, progress in mineral industries followed the same pattern as in other technological branches: discoveries in pure science, followed by discoveries in applied science and finally by technological application, with no particular debacle threatening anybody outside of the expected lack of progress if the necessary discoveries failed to arrive. Furthermore, the field of mineral sciences, arts, and industries up to that time (1910-1920) was well equipped to take care of demands from other technological and industrial fields just by expanding production, because up to that time the specified technological requirements of industry were reasonably simple.

The situation has completely changed during the last 30 years. Due to enormous technological advances in other industrial fields which require both ultraspecialized raw materials and also enormous amounts of more conventional raw materials, mineral industries had to provide an undreamed-of effort. The pace of technological acceleration in mineral sciences and industries really began only 30 years ago and is developing at an enormously faster pace than in other fields. The reason for this is twofold: (1) the exhaustion of many of our natural resources and the absolute necessity to replace them immediately by others, and (2) the necessity of discovering entirely new types of raw materials to handle the demands of other technological fields.

This means that whereas in other fields both pure and applied research can operate on a relatively short-range base without fear of a complete breakdown and debacle (at worst only stagnation may result), in the field of mineral industries even relatively short-range research must produce results which in other fields would be considered long-range. Indeed, certain fields of the mineral industries have changed practically overnight and completely in a period of five years or less, and such abrupt and phenomenally rapid short-range changes are the rule rather than the exception. In other industries, the type of change that takes place in the mineral industries would be considered long-range indeed and would require from 20 to 40 years, but in the mineral
industries field such changes may be completely abrupt and take place in a matter of a few years at most.

Mineral industries must have at their beck and call at all times not only a well-supplied reservoir of applied research, but an even more impressive pool of pure, basic so-called "useless" scientific research. Unfortunately, both the applied and particularly the pure research approaches for developing mineral industries are of somewhat specialized types. They depend, among others, on such subjects as mineralogy and geology, in which research is limited and is not carried on along such a broad front as, for example, chemistry and physics.

Hence, mineral industries have less chance to utilize pure (or even applied) research done outside of its own field. Basic discoveries in physics and chemistry are immediately adapted, but this is not enough. Furthermore, the peculiar problem of mineral industries makes it necessary, as soon as you pass from pure to applied science, to carry research of an even more self-contained and specialized aspect. In those applied fields mineral industries can hardly depend upon outside help.

This means that, as contrasted with other industries (such as manufacturing), the mineral sciences and arts depend much less upon outside help from classical ivory-tower institutions or upon research in adjacent fields, but must depend very much more upon themselves. Furthermore, what would be very long-range research in other fields is really short-range research in the mineral industries. This means that planning ahead must be much greater in the mineral industries, and the future must be anticipated on a much expanded scale and in a much more detailed way than in other fields.

All of these requirements spell one thing. The development and coordination of mineral industries activities on a much larger scale and under one "roof" is a crying necessity, because otherwise results may fail to forthcoming rapidly enough. And if those results should fail to materialize, and since the mineral industries are the primary source of a multiplicity of material upon which the very existence of our technological civilization depends, then indeed such a failure may produce deep and utterly deplorable repercussions throughout our entire economy.

The extraordinary speed-up of the scientific development of mineral industries, and the need to carry on this speed-up in such a way as to have a background of ideas for the future, is requiring the training of a type of personnel that is different from that in other scientific and technological fields. This personnel must be extremely progressive, imbued with the research spirit, self-reliant and, to a large extent, self-contained and not dependent upon spoon-feeding from outside.

Furthermore, subprofessional technological personnel at the lower levels must be periodically rejuvenated mentally by incessant on-the-job training. It is the nature of mineral industries that they change with extraordinary rapidity, and fossilization of the personnel on the job must be avoided at all costs, because otherwise it will lead to greater calamities than in any other branch of modern industrial technology.

This means that the School of Mineral Industries, in addition to a stupendous research job, has ahead of it an equally stupendous teaching job, a job of instruction which in complexity and in the type of demands that
it makes upon the staff of the School is doubtless greater than in other similar branches of instruction. Again this means planning for the future, for a long-range future on a short-range basis. Education in the mineral industries must be ready considerably ahead of time for any potential change or emergency, because these changes take place in the mineral industries with kaleidoscopic rapidity and, unless promptly met, threaten it with a greater collapse than could be possible in other industrial fields. It seems necessary now to forecast⁴ the supplies of mineral fuels, metallic minerals, and nonmetallic minerals, together with their use and some of their technological implications.

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"Mineral Forecast," Edward Steidle, Engineering Experiment Station News, Ohio State University, October 1951.

MINERAL FUELS

Much has been written concerning reserves and consumption trends of the individual mineral fuels, and a few excellent articles have appeared on over-all energy trends and future requirements. The purpose of this discussion is to correlate and integrate the material available with a view to defining more clearly the fields of research and development in which we of the mineral industries should provide leadership to the nation in order to insure adequate energy supplies for future generations. In order to arrive at any logical conclusion, it is necessary to extrapolate past experience and trends into the future—always a questionable policy. However, an educated guess is better than no guess at all. If it serves to focus attention on the basic energy problem facing the nation and stimulates long-range planning by those now charged with the initiation and direction of research programs, a contribution will have been made. It seemed best to emphasize the energy problem rather than by-product technologies at this time. Petroleum, for example, is one of the most important factors in the final determination of whether this and other governments of free people will survive.

At the present time, America produces and consumes a little more than one-half of the total world energy requirements. In view of the marked trend toward
industrialization of many less technically advanced nations, it is highly probable that world energy consumption will rise at an even more rapid rate than that of our own nation. The significance of this trend is that foreign needs for energy may be expected to force upon us an even greater degree of self-sufficiency than currently exists. If not from foreign sources, where then are we to find our tremendous energy requirements of the future? Based upon long-range trends and our current consumption of approximately 12 trillion horse-power hours per year, it can be reliably predicted that our probable needs will be about 19 trillion by 1975 and about 27 trillion by 2000 A.D. Such requirements are cause for serious thought even to a nation as richly endowed with mineral fuel resources as is our nation.

The potential energy sources to meet such a demand may be broadly classified into two groups: one, continuous sources such as solar, water, wind, or tidal energy and vegetation; the other, irreplaceable sources such as the fossil fuels and atomic energy.

At the present time, continuous sources furnish roughly one-seventh of our energy requirements, primarily in the form of water power and vegetation. Potentially the continuous sources, especially solar energy, could produce many times our current or predicted requirements. However, the geographic distribution and the technical problems associated with the collection and storage of solar energy are serious limitations to present use.

Of the irreplaceable energy sources, natural gas, petroleum and coal currently furnish six-sevenths of our total requirements. Atomic energy has been widely pub-

licized in recent years as the energy source of the future. Possibly this will occur as the result of our rapidly increasing knowledge of fissionable processes. However, the supplies of uranium and thorium are by no means extensive. Even using the breeder reactor, which would permit conversion of all our uranium and thorium into fissionable material, it has been reliably estimated that our known reserves of uranium and thorium would just about equal in energy release that of our known reserves of petroleum. For specialized uses—especially those of a military character—atomic energy will undoubtedly find application, but as a major energy source, the present status of known reserves and applicability suggests limited use. It thus appears probable that the fossil fuels will have to carry a substantial share of the burden of our energy production for many years to come.

Estimates of the reserves and availability of all the mineral fuels have been the subject of considerable controversy in recent years. This has proved highly beneficial as it has led to an extensive and critical re-examination of our reserves at a time when such information is sorely needed. If we are ever to develop an intelligent national fuel policy, accurate information on reserves is essential. Although there is disagreement among the "experts," the following are probably as accurate as can be determined at present.

Natural Gas—The present proved reserves of natural gas are estimated at 185 trillion cubic feet and have shown a progressive increase in recent years despite increasing production. Many geologists predict that the ultimate reserves will prove to be considerably higher—figures between 200 and 400 trillion have been suggested.
Future discoveries cannot be reliably estimated, but an examination of recent trends is helpful in predictions of what may be expected. Although proved reserves have continued to increase in recent years, the increases are due largely to re-evaluation of previous estimates for existing fields rather than to new discoveries. In 1949 and 1950, new discoveries added respectively 1.9 and 4.1 trillion cubic feet less than was consumed.

In recent years, production and consumption trends have been sharply upward and may be expected to reach about 10 trillion cubic feet within the next few years unless regulatory bodies impose restrictions limiting production. This figure will closely approach the 10.6 trillion cubic feet availability in 1955 estimated by the National Petroleum Council Committee on Oil and Gas Availability on the basis of current gas industry expansion programs. On a short term basis, availability can no doubt be increased somewhat beyond this figure, but unless new discoveries, even beyond the most optimistic predictions, add materially to present reserves, it is apparent that availability will reach a peak within the next 10 to 20 years and will decrease progressively thereafter. It is probable that economics will play a major role in increasing our natural gas supplies beyond present proved reserves. As consumption approaches availability, the price of natural gas may be expected to rise sharply and the increased revenue will permit more exploration and deeper drilling which should in turn result in new discoveries.

It may be concluded, therefore, that although natural gas will undoubtedly be produced 50 years hence, the amount available will probably be substantially less than at the present time and will not represent a very significant portion of our energy requirements. In fact, its value as a chemical raw material is such that its use as an energy source may become uneconomic as early as 1975.

Petroleum Liquids—Estimates of proved reserves of crude oil are currently placed at 25.3 billion barrels and of natural gas liquids at 4.3 billion barrels. As with natural gas, the proved reserve figure has been increasing each year and again the increase has been due largely to re-evaluation of recoverable oil in known fields. The quantity of petroleum resulting from new discoveries has been tending downward for several years, and although the number of new fields discovered has increased, all but a few of these have been relatively small and have not significantly altered the total proved reserve figure.

The history of discovery and production trends both abroad and for many of our oil-producing states shows that the production peak is attained several years after the corresponding peak in discovery. Whether or not we have actually passed the discovery peak is a debatable question that will not be definitely settled for a few years, but indications certainly point strongly to this conclusion. If this is true, we may expect the peak in the production to be attained in the relatively near future—probably between 1955 and 1960.

The National Petroleum Council Committee on Oil and Gas Availability has estimated current availability of petroleum liquids at 2.7 billion barrels as compared to actual production of 2.2 billion barrels. Based on current expansion plans of the petroleum industry, an
availability of about 3.0 billion barrels is predicted for 1955. Unless a number of major discoveries are made in the very near future, this may well be our peak availability. It appears unlikely, therefore, that domestic petroleum products will be a major factor in the overall energy supply 50 years hence or even 25 years hence. This does not imply that no domestic oil will be produced at that time, but rather that production will have dropped to a point where it can no longer supply a major fraction of the country's energy needs.

If domestic petroleum supplies fall off, can we logically expect to import adequate supplies? This question is almost as controversial as that of reserves. At present the major proved reserves exist in the Middle East, although many geologists believe that Russia will eventually prove to have the world's largest deposits. In times of national emergency it would seem politically unwise to place much dependence on the importation of oil from Asia. Undoubtedly South America will be in a position to furnish substantial quantities of petroleum for many years to come, but again reliance upon importation for a major portion of our energy requirements is a dubious policy.

Coal—The coal reserves of the United States have for years been considered virtually inexhaustible with estimates ranging upward to nearly 3 trillion tons. Recent estimates by the National Coal Association have reduced this figure to about 1.6 trillion tons, while Mr. Andrew B. Crichton, who is largely responsible for initiating the current re-evaluation of coal reserves, places economically recoverable reserves at 0.224 trillion tons. Whether one accepts the high or the low estimate, the inescapable fact remains that a large percentage of this coal is located in the far west and is low-rank lignite and sub-bituminous coal. The quality coking coals of the Appalachian area, which have in the past furnished about 85 per cent of our coal requirements, have been seriously depleted. The latest state surveys for Pennsylvania, Ohio, and West Virginia report reserves of 44, 10, and 116 billion tons, respectively. Mr. Crichton's estimates for the same states are 10, 6, and 18 billion tons of economically recoverable coal.

Such drastic downward revisions in our estimated reserves must of necessity alter our thinking with respect to sources of the nation's energy requirements. Annual coal production has been ranging between 550 and 600 million tons in recent years. Even assuming no increase in per capita consumption as a result of diminishing supplies of the other fossil fuels, the expected population growth over the next 50 years would increase production requirements to over 850 million tons per year. A synthetic liquid fuel program, based on coal, to furnish the major portion of our liquid and gaseous fuels, would nearly triple this requirement. Most mining engineers, however, doubt that such production rates could be attained.

Oil Shale—Reserves of oil shale are probably less accurately known than are those of any of the other mineral fuels. The most recent estimates place the reserves at about 345 billion barrels of shale oil. The economic limit below which it is impractical to process the shale is not yet known, but at present it is believed that but a small fraction, possibly 10 or 15 per cent, could be processed economically at anywhere near the
current price of crude oil. There is also considerable doubt as to whether the shale oil thus produced has a value comparable to that of crude petroleum. Moreover, the physical and technical problems of mining and retorting the billions of tons of shale necessary to produce even a major portion of our current petroleum needs are fantastic to contemplate, to say nothing of the problem of disposing of an equivalent tonnage of waste material.

Use Value and Interchangeability—In the foregoing discussion, no consideration has been given to use requirements and trends nor to the interchangeability of the various fuels for specific energy-producing purposes. There are three major energy uses, each accounting for some 25 to 30 per cent of our total energy consumption. These are transportation, space heating, and manufacturing. For transportation purposes liquid fuels have unquestionable advantages and may be expected to remain the dominant energy source as long as available. For space heating, coal is still the dominant fuel, but only because of lack of availability of gas and oil, especially the former. Consumers' demand for completely trouble-free and automatic space heating has been most nearly satisfied by natural gas, and the trend toward use of gas for this purpose has been especially pronounced in recent years. For manufacturing purposes coal is still the dominant fuel, but again the current trend is toward the use of oil and gas. As with space heating, the trend rises from the demand for more automatic operation that will reduce labor costs. The latter has become a significant item in energy costs at many plants. The over-all cost of delivered energy, rather than of the relative cost of the potential energy in the fuel, is the controlling factor in most manufacturing uses.

From these trends it is apparent that unless major natural gas and oil discoveries alter the reserve and availability figures, we will soon be faced with a demand for these products far in excess of their availability. The question of interchangeability of energy sources will then become critical.

Interchangeability may be accomplished in two ways, either by the transformation of one fuel into another, or by modification of the methods of energy use so that other fuels can be used. In view of the fact that liquid or gaseous fuels are the preferred form for many present-day applications, the problem resolves itself into one of converting coal into liquid and gaseous fuels or of developing new methods of application for coal to meet the requirements of the energy use. At present our government research efforts appear to be concentrated principally on coal hydrogenation and synthesis processes for the conversion of coal into liquid fuels. These processes are being vigorously investigated and considerable technical advance has been made. Under present conditions, the economics of such transformation is unfavorable. From a conservation viewpoint these processes are decidedly unsound, since some 50 to 60 per cent of the thermal energy of the coal is lost in the conversion process.

Up to the present, only limited effort has been made toward the adaptation of coal to meet the requirements of modern energy uses. The coal-gas-turbine for railroad locomotive power is a significant effort in this di-
rection as is the use of the heat pump for space heating. As diminishing supplies of gas and oil limit availability of these fuels, the use of coal will become more attractive. This should lead to intensification of research and developments on applications of use interchangeability.

Conservation and Research—Our mineral fuel resources can be extended very materially by the application of modern scientific knowledge to the discovery, extraction, processing, and utilization of the mineral fuels. Current economics are such that in many cases industry cannot justify the application of such information and processes. Any definite indication of potential scarcity will rapidly alter this situation, however, and conservation practices undoubtedly will be adopted, thus extending our available supplies of the mineral fuels. Examples of a few such practices that may be expected are more extensive application of secondary and tertiary recovery method in oil production, hydrogenation of petroleum to increase the yield of distillate fuels, improved recovery in both coal mining and cleaning operations, and more efficient utilization of all fuels in improved energy conversion equipment.

Research can and should be extended on new methods for locating gas and oil deposits, on improved methods of recovery of all the mineral fuels, on improved methods of processing to decrease energy consumption and losses, and most of all, on the application of new methods of utilization, to permit utilization, especially of coal, without the tremendous energy losses involved in conversion to liquid fuels and synthetic natural gas. Comprehensive research and development programs along these lines would materially improve our over-all energy situation for generations to come. It seems unlikely, however, that even the extensive application of research and conservation will enable the mineral fuels to supply the enormously increased energy requirements of the future.

Within the next 25 to 50 years other energy sources will have to be utilized to an increasingly greater extent. Undoubtedly, some temporary easing of the situation can be attained from the application of atomic energy in very specialized cases. Extended use of water power can also assist. It seems probable, however, that eventually we will have to rely more and more upon solar energy. For several important energy applications, such as space heating and certain manufacturing processes, solar energy could be used much more effectively even today, and further research on methods of collecting and storing solar energy undoubtedly will be developed as the need arises.

It is logical to believe, therefore, that the transition from a mineral fuel energy economy to one relying upon other sources will be a gradual process occurring in an orderly fashion over the next hundred years, as a result of technical developments and economic pressure. One of the principal contributions the leaders in the mineral industries can make is to provide the research leadership in improved exploration, production, processing, and utilization practices, and in the conservation of the mineral fuels so that maximum energy production and interchangeability can be attained. Such contributions will not only insure orderly transitions, but will benefit the nation through more efficient and effective use of all available energy sources.
METALLIC MINERALS

Assuming that the year 2000 will find us still in a state of progress rather than pandemonium, we will find the metallurgist enjoying a place of eminence. He will be working in co-operation with other physical scientists to bring about the adjustments made necessary by the crowded conditions of the earth’s area. He will have developed substitute alloys and processes to compensate for the accelerated depletion of the high-grade metal deposits which has occurred during the twentieth century and upon which our economy is dependent. In atomic energy development, the metallurgist already is the indispensable man of 1952.

Ferrous—Steel, that industrial giant of today, will have lost little of its importance to man’s present or his future. The United States Bureau of Mines estimates that there are upwards of 75 billion tons of potential iron ore in the United States, and that this should be sufficient for the next 76 years. The existence of such a supply of iron ore does not imply that the steel industry has reached a static state. Iron and steel will not have been replaced by other metals, at times referred to as “wonder metals,” to the degree predicted by the promoters of these wonder metals. True, we will no longer have the immense deposits of rich iron ore to satisfy our ever-increasing demands, but these demands will be sat-

ished by our low-grade deposits, especially taconite. Our mineral preparation engineers, confronted with the many problems in the beneficiation of these ores, will have developed processes by which iron is produced in great quantity and at low cost. Furthermore, high-grade iron ore will be available to the United States from South America and Canada. Advances in quick-smelting processes and the ever-increasing demand for high alloy steel in more and more quantity may push the more prosaic methods of steel refining to the background and make the electric furnace our standard steel-refining furnace. Another factor in the almost worldwide use of electric furnaces for steel production is the convenience, low cost, and efficiency of electric power. No longer will we be dependent upon coal or water power to generate all of our electricity. Solar energy will supplement the mineral fuels so that these extremely important resources can be utilized for the production of synthetic resins and other essential by-products. Our experience and improved technology in coal and carbonaceous fuel research has pointedly demonstrated that to use these vital resources totally as a source of heat and power is extremely wasteful of their important energy and chemical potentialities.

Domestic resources of the principal alloying elements in steel production will have reached a state of serious near-depletion in another 50 years, with the exception of silicon and molybdenum. Finding ourselves dependent on foreign supplies of manganese, chromium, nickel, vanadium, and tungsten, we will be forced to develop alloys with similar properties and containing smaller amounts of these metals. It will be necessary to investi-
gate the influence of all possible alloying elements on the properties of steel. Improved methods will have been developed for the production of rare-earth metals, and many unusual properties will be developed by alloying these metals with base metals. Electron bombardment of metals will have produced extremely interesting results and unheralded properties. Nuclear reactors will be common and radio-isotopes will be used in many aspects of metallurgy by 2000 A.D.

**Nonferrous**—Scarcities are developing already in the supplies of nonferrous metals. Conservation and substitution of new materials are foreseen as keynotes in this field. Recovery of secondary copper, equal at the present time to production of virgin metal, will be a chief source of supply. Secondary zinc and lead also will be of primary importance, and the pattern of secondary recovery will have increased in importance throughout the industry.

Aluminum and magnesium will be very important metals as materials of construction and for use where strength-to-weight ratio is critical. Immense tonnages of magnesium will be produced from our sea-water plants and at surprisingly low cost. Since the development of aluminum production from native clays will have been attained, we will not be dependent upon imports of bauxite. Tin, a once necessary metal for corrosion protection, will have been replaced by more accessible metals, possibly aluminum and magnesium, or even by plastics.

A great expansion in the use of the refractory metals, tungsten, molybdenum, tantalum, and zirconium, will have indicated the importance of these metals for high temperature use. Molybdenum, with its high melting point and good mechanical properties, possesses many of the necessary characteristics of high-temperature structural material and will find widespread use since processes will have been developed to improve its resistance to oxidation. Zirconium will prove to be of great interest because of its resistance to corrosion and will be used to replace scarce platinum metals in most instances. The need for materials to withstand the high temperatures and pressures which will exist in space vehicles and machines will have necessitated the development and improvement of these metals, as well as those of “cermets” or metal-ceramics. Improved methods of coating high-strength alloys with corrosion and heat-resistant ceramics will have increased the efficiency of these vehicles and machines considerably, but much will remain to be accomplished in this field.

Efficient production methods will be developed for titanium, tantalum, zirconium, molybdenum, and cobalt, and these metals will be used in enormous quantities. Titanium will be produced at a cost and in such quantity that it will be in strong competition with iron and steel.

Engineering materials and development will still remain our chief bottleneck in securing the ultimate in distance and speed as predicted by our scientists; stronger, yet no heavier, structural materials will be needed.

**Planning**—Such is an idealized picture of the metal situation in the year 2000 A.D. It must be emphasized, however, that much remains to be done before this picture can become a reality and the time available is not infinitely long. Not only are some of these goals desir-
able, but they have become a prime necessity because of the supply situation in some of the metallic ore minerals. The present known reserves of several metals vitally important in our industrial economy are small—copper, lead, zinc, and tin reserves are estimated to be enough, at present rates of consumption, for no more than 40 years. While further discoveries of ores of these metals undoubtedly will be made, the life expectancies of the base metals are short in comparison with those of iron, the light metals (aluminum, magnesium, and titanium), and manganese. This means that within the next 150 years, the supplies of these base metals will be essentially exhausted and their places must be taken by the relatively much more abundant light metals. For the tremendous amount of advance planning that this changeover in most of our industrial processes will require, 150 years is none too long.

Were the light metals, iron and manganese present in the earth’s crust in no greater amounts than the base metals (they are among the nine most abundant elements, except for manganese which is twelfth), the situation in the not too distant future would be serious indeed. Fortunately, however, the reserves of now mineable ores of the light metals, iron, and manganese are relatively large, ranging from 200 years in the case of iron and aluminum, to 250 for manganese and even more for titanium and magnesium. Even this situation would be far from favorable were it not for the high grade of the ores of these metals now being mined. This means that the high-grade ores currently being exploited are the rich cream and huge amounts of, metallurgically speaking, light cream and good whole milk remain to be taken from the earth when the problems of beneficiation and metallurgy necessary to make them ore have been solved. On the other hand, the base metals now being mined are skim milk ore deposits and, as regards the porphyry coppers at least, they have been highly watered by nature as well. In short, the grade of copper, zinc, lead, and tin ores that are being worked today is so low that refinements in the techniques of beneficiation and metallurgy would add relatively little to the world’s reserves of these metals.

Thus, planning for the future must be done longrange; first, 50 to 150 years, and second, for an indefinite period beyond that limit. Planning for the first of these two periods must be aimed primarily at: (a) prolonging the useful industrial life of the base metals by the discovery of new, mineable deposits; and (b) increasing the supplies of the light metals, iron, and manganese so that they will be able, gradually, to assume the added burden to be placed on them. Both of these requirements can be met only by large exploration programs which probably cannot be carried out in more than small part by private capital unless the present federal tax laws that relate to mine exploration are revised. Even if the present penalties on unsuccessful exploration are removed, much of the prospecting will have to be done by the federal government on a sounder basis, it is to be hoped, than that which was done during World War II and immediately thereafter.

Planning for the period beyond the next 50 to 150 years when the light metals, iron, and manganese will be the main support of our industrial economy must be aimed mainly at reducing the grades and changing the
types of the ores of iron, aluminum, and manganese in particular, and perhaps those of titanium and to a lesser extent, of magnesium as well. In the case of iron, the first step must be to turn the now marginal taconites of the Lake Superior district into ore which requires no more than putting into large scale operation methods now used on a small or pilot plant scale. Even the supplies of taconite are not inexhaustible, however, so that new methods of beneficiation and metallurgical practice must be developed to recover iron from iron-bearing rocks of considerable (10 to 20%) iron content that are now submarginal, both as to grade and mineral content.

As for aluminum, the reserves of bauxite will not last nearly so long as those of taconite; and new methods of beneficiation and metallurgy must be found to convert to ore such aluminum-bearing materials as clays, shales, and high alumina igneous rocks. Similar problems for which solutions must be found also exist for titanium and manganese, but the ocean probably will meet even greatly accelerated demands for magnesium for a very long period.

Another problem for the relatively distant future is what to substitute for the ferro-alloying elements now used to change iron into the wide varieties of steel which our industries demand. Of the currently important ferro-alloy metals, nickel and chromium, tungsten and molybdenum, vanadium and cobalt, only molybdenum appears to be available in quantities sufficient for its inclusion in long-range planning. Serious thought and study must be given to this problem because inexhaustible iron reserves are useless unless the necessary minor constituents are available to make them into steel. It is probable that this will be a more difficult obstacle to surmount than any or all of the difficulties connected with the production of the abundant metals, but fortunately molybdenum seems to be the most versatile of the ferro-alloys.
NONMETALLIC MINERALS

As a nation we have been extravagantly wasteful of most of our natural resources, but we are now beginning to see the urgent need of practicing strict conservation of these assets. We have learned to extract elements and minerals from deposits in which they occur in too small a concentration to make their extraction economically feasible at present. They may be recovered not only from clays, sands, rocks, and ocean floor deposits, but also from slags and other industrial wastes which harbor many important trace elements. The improved methods of mining and mineral preparation that will make this possible will be based on a more profound understanding of the variation in chemical composition of these deposits than we possess today and upon the new knowledge being accumulated in mineral technology.

Ceramic—Clay, sand, and limestone will continue to be basic raw materials for ceramic bodies, glass, and cement. They will be needed in tremendous quantities for the building trades, where they will often replace metals. The clays will be freed of mineral impurities and will be chemically treated, possibly with improved ion-exchange resins, so that their colloidal properties, which greatly affect the plasticity, shrinkage, and strength of the bodies in which they are used, can be precisely controlled. The grain size of the clay particles in the subsieve range will be carefully regulated, and treated clays will be blended according to specifications. Sands, too, will be controlled in grain size and purity, but the most important improvement may be in the treatment they receive to make the surfaces of the grains more quickly reactive in fired bodies and in cements. Limestones will be more selectively used in terms of their lime and magnesia content and the major impurities present, in order to develop the most desirable products. The degree of calcination and sintering of limestone and dolomite will be more accurately limited so that the most desirable amount of surface will be developed, and the degree of hydration or reaction will be better controlled in preparing cements. Practical means of inhibiting the hydration of calcined dolomite and lime are being perfected so that these very abundant oxides will be much more widely used in the refractories industry of the future.

Widespread deposits of gypsum, calcium sulfate, are found in many parts of the world. This mineral will gain in economic importance as a source of sulphur and sulphuric acid, as well as of lime. New methods of calcining the gypsum, probably in a vertical shaft furnace or in a Dorr fluidized bed furnace, will increase the efficiency of the operation. The great gypsum deposits of the Middle East may help in solving the economic difficulties of that region.

Most industrial minerals, even the more common ones, will have to be beneficiated in increasingly larger amounts as the first quality deposits are progressively depleted. Feldspar, for example, will be extracted from granites, of which there is an almost inexhaustible
supply; other rocks such as nepheline syenite and aplite which yield feldspars and feldspathoids will be blended for uniform chemical composition. Long ere 2000 A.D., our large deposits of phosphate rock will be processed before being used as fertilizers so that much of the fluorine will be extracted for industrial use, a necessary step because the fluor spar deposits will be greatly depleted. Talc is being used in electrical insulator and other ceramic bodies. The widespread deposits of talc and of serpentine will have a great variety of new uses when cheaper methods of using them are developed.

Some sources of nonmetallic materials will be more intensively used. Slags from open hearths and blast furnaces, and ashes from steam boilers, contain significant amounts of rare elements that will be reclaimed when economical processes for doing so are perfected. Many elements that at present vanish in the smoke from industrial chimneys will be collected and purified. Sands can yield significant amounts of valuable minerals when the techniques for extracting them have been improved.

Synthetic—When new deposits are sought but not found, or beneficiation of known supplies is unsatisfactory, desired minerals will be manufactured! The synthesis of many nonmetallic compounds is an accomplished fact, and progress is being made continually. The growth of large single crystals, from solutions or melts, is only one aspect of this. The production of crystal aggregates from solid state reactions is already an everyday activity of the ceramic technologist.

There seems little doubt that natural long-fiber asbestos will be rare in the industrial world of 2000, but synthetic asbestos will have arrived to join other inorganic, manufactured fibers like fiber glass for the production of heat-resistant and chemically resistant textiles.

Mica ceramics, almost entirely from synthetic material, will be increasingly important. The micas will be synthesized with a wide variety of electrical characteristics, and will be machined to precise dimensions. Deposits of vermiculite mica, used in the expanded form for heat insulation, probably will be exhausted soon, but lower grade micas should respond to methods of treatment to give them the characteristic properties of vermiculite.

The synthesis of numerous other compounds has been achieved in the past decade, including many that were previously unknown. Some possess properties that make them particularly desirable for specialized refractory uses at very high temperatures; others have highly developed, specific chemical or physical characteristics. Together the field of synthetic minerals of the carbides, borides, nitrides, or hydrides of tantalum, titanium, and molybdenum, to name but a few, offer tremendous possibilities to be thoroughly exploited in the next 50 years. Oxides may be replaced by other compounds as the building units of new ceramic bodies. The field of nonmetallic synthesis would appear to be one of the most promising fields of development. Is an age of oxides, silicates, carbides, nitrides, etc., just over the horizon, preparing to follow the present age of metals? The extraction of salts from sea water will supply many scarce items. Magnesium is commercially produced now from sea water, but many other elements can be obtained
if the demand for them is sufficient. Sea water and the atmosphere are our two relatively untapped natural resources that will be far more exploited in the future.

Bailar, possibly in a somewhat long-range prophetic mood, said recently: “Iron obtained from the earth’s core will require no furnace treatment. Atomic bombardment will yield stainless steels of any desired composition and nickel, cobalt, vanadium, chromium. Chemists will transmute the silicon of aluminum-bearing clays to obtain aluminum oxide, directly reducible to metallic aluminum, while different bombardments will convert aluminosilicates to phosphorus, and potassium feldspar directly to potassium phosphate fertilizer.” Yes, perhaps by 2100 A.D.

High Temperature—The new products that will appear in the field of nonmetallic minerals may not differ spectacularly in appearance from the present ones, but they will be greatly improved in quality. The superrefractories will make it possible to operate furnaces at higher temperatures for longer periods of time without replacements, thus greatly increasing production. Many of these refractories will be formed from prefire material to eliminate shrinkage and some chemical reactions. More and more of the brick will be installed in furnaces as chemically bonded unfired units, more economical to produce and showing greater volume stability at high temperatures than the present product. The annealing of brick will be better understood, and prestressed products will have special uses.

The field of high temperature technology is potentially one of great developments that can be foreseen. With the new synthetic minerals that have already been mentioned, it will be possible to build refractory containers that will not react with the materials being melted. The melting of metals, glasses, and other compounds at high temperatures will be revolutionized through controlled pressures and controlled composition of atmospheres in the furnace. Furnace design is an important phase of this development.

The abrasive industry will continue its rapid development of hard synthetic grains, but annealing of these grains as well as better control of crystal orientation, grinding media, and temperature of operation, will greatly advance this industry. Surface phenomena will play an important role in the development and use of new abrasives.

New glasses for special purposes are developing at such a rate that it is safe to predict that in 50 years there will be many radical changes in glass formulations, particularly when it is possible to protect the exposed surfaces from weathering. The present-day types of glass will continue to have an expanded market. If the supplies of decolorizers such as selenium, cobalt, and nickel become more critical, it may be necessary to develop new decolorizers or convince the buyer that a slight greenish-blue color does not impair the quality of the glass. Glass as a building material, and prestressed glass objects, as well as those with electrically conducting and luminescent surfaces, will increase in importance.

Many new products combining materials from different fields will appear. At present “cermets” are advancing because they are more refractory than metals and less brittle than straight ceramic bodies. This field has
been barely touched. The combination of plastics with glass, metals, and aluminosilicates is another field of rapid development.

The greatest changes in the next 50 years may not be in specific products but in the processes used. For example, increased knowledge of the phenomenon of sintering will make unnecessary the conventional and limiting process of bonding crystalline phases with a glass. Many of the new bodies will be self-bonded. The fields of surface control and of catalysis offer great hope for process and product development.

Recently, it was reported that television has been used in industrial research in following combustion reactions within a boiler in order to eliminate smoke and inefficient firing when they first occur, not when the products escape from the chimney. Similar applications of television, radar, and other war-accelerated developments will greatly aid precise process control.

Energizers—Problems of energy supply and power production probably will still be with us in the year 2000. It has been suggested repeatedly that, from a standpoint of conservation, coal, oil, and gas should be more widely used as a starting point for organic synthesis than for fuel. For unusually high temperatures, the burning of metals in oxygen, developing temperatures in the order of 5800 to 7200°F., and releasing heat at the rate of approximately 1 million Btu's per hour per cubic foot, is already possible. If the use of metals as fuels were to expand, there would be still further increased consumption of their ores, as well as of fuel or energy to produce the metal from the ores.

Regardless of how it is produced, the chances are that electricity will be the “fuel” used in much ceramic firing and glass melting in 2000 A.D.

There are possibilities of atomic energy, although Conant has predicted that the harnessing of solar energy will be of far greater economic importance than atomic energy. Any widespread use of atomic power will bring new problems in refractories, and thus new demands for minerals for these, as well as demands for additional sources of fissionable material.

Truly, we will be living for the next 50 years in a highly complicated and delicately balanced mineral economy. It will be, however, one that will offer a most wonderful and intriguing challenge to men of foresight, courage, adaptability, and inventiveness!
GEOLOGY GROUP

The mineral industries are in turn vitally dependent upon the geologic sciences for discovery and understanding of the mineral resources that are being consumed in ever-increasing amounts. In accord with this basic dependence upon geologic concepts and methods, the School of Mineral Industries puts emphasis upon both instruction and research in the fields of geology, mineralogy, petrology, geophysics, and geochemistry. The geologic sciences in turn benefit from the added recognition they receive for their partnership in the discovery, exploitation and processing of mineral wealth. Funds and facilities are more readily forthcoming for their work. Interchange of ideas is facilitated with men who apply to mineral problems highly varied and diverse techniques and methods of thought. Modern chemical, spectrographic, X-ray and electron microscope laboratories are made available because of values in many fields of mineral studies. The association mutually benefits the programs in the geologic sciences and in mineral engineering and mineral technology, with resultant economies in both faculty and physical plant.

Let us review briefly, for the geology group of fields, the areas of progress, and then extrapolate this progress. Of course, it must be borne in mind that in predicting developments it is possible to miss completely because a new tool or idea may come along accidentally or unexpectedly and change the whole course of development. The developments in geochemistry, for example, were almost entirely due to the introduction of new tools which were not in use before 1900.

Geology—Geology, proper, today stands at the crossroads. Unlike its relatives—mineralogy, petrology, geochemistry, and geophysics—it has not yet incorporated unto itself the newest developments of chemistry and physics of the past 50 years. The quantitative aspects that have revolutionized biometrics have not reached as yet into the geologic profession. Hence, potentially, geology is capable of enormous progress, but it is difficult to predict which way geology may develop, if and when such advances finally get under way.

In the meantime, pending the opening of such vertical frontiers, geology is developing horizontally, very much as geography did in the past, by mapping and describing more and more of the earth’s surface by the tried and true methods now long in existence. In any event stratigraphy, structural geology, and economic geology are in their infancy and training in these fields is necessary to solve the urgent problems of mineral supply.

Progress has been slow, from a practical viewpoint, in the last 50 years on the geology of Pennsylvania. Geologic maps are available for only a minute part of the Commonwealth. New larger scale topographic maps show the surface with greater reality and make possible improved geologic maps that will aid in the search for mineral resources, both surface and subsurface. The
new magnetite and gas strikes may arouse a little interest in geologic studies, but some group has to push the program, perhaps the Mineral Industries Advisory Committee. Perhaps the work of the United States and State Geological Surveys and of the School of Mineral Industries should be more closely integrated under current co-operative agreements. An adequately manned Survey group working closely with the School and using students for summer geologic mapping could, by 2000 A.D., map most of the State and learn what we have in the way of resources—where it is and how much. Naturally, should geologic practice show the progress that is to be hoped for, then the program indeed may have great possibilities.

Meteorites are the only objects that did not originate on earth. The science of meteoritics has been experiencing a remarkable upsurge in recent years. Rocket experiments, ballistics advances, and the preparation for interplanetary travel have placed a new emphasis on the study of material which comes to us from space. Never has the importance of meteoritics as a linking science between geology and astronomy been so strongly recognized.

Paleobotany and coal geology constitute areas of research in which rapid strides have been made in recent years. A fact which must be emphasized is that the amount of coal formed in a hundred years, or a thousand years, is negligible in terms of present-day usage. This fuel represents the product of hundreds of millions of years and at the present rate of extraction, what was done in this vast period of time will be undone in a matter of centuries. In the light of this information, it behooves us to learn as much as possible about this material in order to utilize it best.

Research into the nature of coal and the mode of occurrence of this critical substance is important. Coals well suited for coking or other purposes are becoming more and more difficult to find. A more adequate picture is urgently needed of what is still available and where it is to be found. This means that detailed geologic mapping in coal areas should be stimulated. A problem immediately arising in such work is the proper correlation of the rock units that comprise the coal measures. Some of the important tools of correlation are the paleobotany of the coal horizons, spore analyses, heavy minerals, trace elements, petrographic studies, and cyclothemic criteria. A better understanding of the geology of the coal measures will bring a better estimate of reserves, including quantity and distribution of such special types as the coking and steam coals. In addition, research into the characteristics of the rocks associated with the coals will undoubtedly pave the way for improved mining practices.

The physical and chemical nature of coal and the process of “coalification” need much more research. Coal’s innermost secrets remain to be revealed. This is an area of study in which co-operative endeavor is at a premium for there are few individual scientists who can qualify as botanists, geologists, physicists, and organic chemists and, in addition, profess an interest in coal. Much of the work in the past reflects the lack of co-operation by individuals in these different disciplines. The coal petrographer, the coal technologist, the coal geologist, and the coal botanist will have to get
together and examine this complex substance through their collective eyes. Through such an approach the concept of the so-called “coal molecule” can be clarified, additional light can be shed on the processes involved in coal metamorphosis, and the role of the coal ingredients in the coking process may be further elucidated.

The importance of paleobotanical research seems only too obvious. It is most encouraging that the last few years have seen a worth-while strengthening in this area.

There is increasing appreciation that the work of the agronomist, who deals with soil fertility, soil types and their distribution, etc. can be valuably augmented by investigation of soils from the mineralogical, geological, and geochemical viewpoint. Such studies will contribute materially to the knowledge of: (1) characteristics of bedrock that influence soil properties; (2) past climatic and topographic conditions that have affected soil development; and (3) relations of geologic processes to the physics and chemistry of soil genesis.

Survey of the literature shows conclusively that these are aspects of soil development that up to the present time have not been investigated adequately by petrographers, geologists, and agronomists. Research along such lines will contribute significantly to understanding the nature and potentialities of soils and will help also to provide a foundation on which to base soil conservation policies.

A rapidly growing need for engineering geologists has come with the rise of large-scale engineering projects undertaken by several branches of the federal government and private industry. Successful projects carried out by such agencies as the Corps of Engineers, Bureau of Reclamation, and the Tennessee Valley Authority, which to date have mostly involved flood control, irrigation, and soil erosion control, have proved the dependence of engineering on geological information. During and since World War II, building of structures and supply lines for the Armed Forces has brought renewed impetus to study of geological processes as related to engineering practice. Also, ever-increasing numbers of private and municipal projects are enlisting the services of geologists.

Geologic problems arise in nearly all civil engineering operations. The success or failure of an undertaking depends largely upon the natural physical conditions, which fall within the realm of geology, and upon the ability of the engineer to correctly design and soundly build his structure.

Although engineers with training in geology should be able to solve simple geological problems, it becomes increasingly apparent that engineering projects involving complex geological conditions require the consultation of professional engineering geologists.

Specific problems which will require better understanding during the next half century include: (1) engineering properties of stratified rocks as interpreted from borings; (2) subsurface analysis of rocks by new inexpensive techniques, such as seismic and resistivity; (3) techniques for evaluating ground water potential and availability; (4) information for predicting the expansive character of rocks in tunnels; (5) more thorough understanding of soil and slope stability as determined by soil characteristics, degree of water satur-
ation, effect of frost action, etc.; (6) data for predicting durability of reinforced concrete structures, based on mineralogic-chemical study of aggregates; and (7) new information on engineering properties of soil materials under Arctic conditions, especially in the "perma-frost" areas.

**Mineralogy**—Mineralogy is becoming a fantastic field. The amazing advances in the past 40 years, due largely to crystal structure research, make it possible now to synthesize a mica crystal with properties made to order, or to introduce an element into a submicroscopic tube of synthetic asbestos and cause a plate to grow instead of a tube.

By the year 2000, undoubtedly we will be able to synthesize any mineral with the possible exception of the diamond, and even this may be possible. But it is not just in the synthesis of minerals that mineralogy is important. In order to upgrade or improve the quality of a clay, for example, mineralogic research on clay minerals is essential. As high-grade clay deposits are exhausted in Pennsylvania, it is only the ignorant that feel that an industry will be lost. A wise research program will point the way for the beneficiation of low-grade clays, and the mineralogic research on clay minerals at the School of Mineral Industries will be the starting point.

The black shales, together with certain types of phosphate rock, are of major importance as a potential source of uranium in case large quantities are required, especially if we are compelled to rely upon sources within the confines of the United States. Black shales are a very low-grade ore. Therefore, basic research of a very detailed and comprehensive mineralogical nature has been initiated and geological studies of occurrence and resources are in progress. The program now being undertaken is an excellent example of applying, in a constructive manner, long-range, fundamental, high-powered scientific research to meet a problem which is likely to arise in 1975.

We should make every effort to get industrial and State funds for basic mineralogic work directed specifically toward Pennsylvania rocks instead of depending on federal monies, as at present is the case for practically all mineralogical, geochemical, and geophysical research.

**Petrology**—The study of rocks was largely a matter of description, 50 years ago. Like shell collectors, petrologists looked for new types of rocks, named and classified them. Due to extensive laboratory work and some careful field work, a fairly clear picture of the complex geotectonism, physical chemistry, and crystal chemistry involved in the formation of igneous, sedimentary and metamorphic rocks has evolved. Just as many new problems have arisen as have been solved, but this is a sign of progress.

By the year 2000 we will have a clear picture of the manner of formation of granite batholiths and possibly of the origin of basaltic lava, just as we have in the past 40 years unraveled the mysteries of the crystallization and differentiation of basaltic magmas. In the field of metamorphic petrology, high pressure-temperature laboratory studies are pointing the way to answers on problems of origin. In the field of sedimentary petrology we can expect enormous studies. It is safe to say that funds spent in the support of research in sedi-
mentary petrology at Penn State means money well spent for oil exploration, among other things. Careful laboratory studies of sediments cannot help but tell us eventually why oil is where it is.

Laboratory studies of sediments and of metamorphic rocks are closely allied fields in Pennsylvania, because as we move from west to east the sediments, in general, show a greater degree of metamorphism. This whole problem of the change of sedimentary rocks as a function of determining background should be a number one problem of research. We must understand our rocks if we are to find and to make better use of our mineral resources.

*Geochemistry*—Advances in geochemistry have been spectacular in the past 40 years, due largely to X-ray and spectroscopic techniques. We know at least in a general way for all elements: (a) in what environment each occurs (type of rock, ocean, atmosphere, etc.); (b) the amount of each element in the outer part of the earth; and (c) the reasons why each element occurs where it does and in the amount it does. Research in this field has indicated what elements should be associated under a given set of conditions, why some elements are segregated and concentrated and why others are dispersed. These principles are being used in geochemical exploration.

By the year 2000, we will not be wasting our coal ash, in which geochemists have shown there is a notable concentration of rare elements, such as germanium and rare earths. We will be recovering these elements, which by then will be critical materials in our economy. The same is true of waste gases, now being dispersed in the atmosphere. Prospecting for minerals will be largely in the hands of geochemists, who will probably have simplified, accurate field kits for making quantitative trace element analyses, differential thermal analyses, radioactive measurements, and possibly X-ray analyses on the spot. Trace element studies of ground water, plants, soil, and "barren" rock will undoubtedly lead to the discovery of important ore bodies. Drilling will be much more extensive in exploratory work with far more significant data being obtained from the cores as modern techniques of trace element and structural analysis are used. The extended use and comprehension of the significance of isotope ratios in rocks will permit more accurate age determinations of rocks and may supply quantitative data on temperature and pressure conditions during formation. Phase equilibrium studies of metamorphic mineral systems, now in their beginning, will give us the information necessary to estimate depth and temperature at which our rocks formed. As we can better reconstruct the history of rocks of the crust, the better we can estimate what is now hidden below us—our future mineral resources. By the year 2000, geochemical research will play an important role in all fields of the mineral sciences, because this approach is the basic approach where minerals and rocks, whether natural or synthetic, are concerned.

If we compare geology to a growing crystal which is enlarging rapidly along certain preferred directions or on certain faces, but growing slowly or virtually not at all on other faces, geochemistry is one of those faces which is pushing out rapidly and adding to and carrying classical geology along with it. To maintain leadership
in the field and to insure future discovery and development of new resources, we need to push what we are doing in high pressure, high temperature, and high magnification, but in addition develop: (1) a trace element laboratory; (2) what we might call a “magnetomineral” laboratory; and (3) a physical measurements laboratory for measuring piezoelectric, thermoelectric, and other properties of minerals.

Geophysics—Like geochemistry, the progress in geophysics during the past half century has been phenomenal. To detail the progress would take too long, but the development of the aerial magnetometer, already a highly successful exploratory instrument, might be mentioned. By 2000 this instrument will seem very crude and elementary.

The Commonwealth would be wise to expend considerable sums on a long-range program of research and exploration, especially in the field of geophysics. The Office of Naval Research has considered it worth while to support geophysical research in the School of Mineral Industries, in addition to supplying a field truck. If the Commonwealth would finance a similar project each year on geophysical research on Pennsylvania rocks, it would pay off immeasurably by 2000 A.D. For our future development, we must know what rock structures and types underly the surface to a depth of several miles. This we can find out with the laying out and execution of a wise and broad research program in geophysics. During the course of the program new techniques would inevitably be developed to accelerate the work. By the year 2000, extensive geophysical work will have been done in Pennsylvania if we do what a progressive state should do. We will know the extent of water-bearing gravel deposits in the northern part of the State, the location of possible buried ore deposits, and the location of deep structures which may contain oil and gas. It must be remembered that we have just been pecking around on the accessible surface. A forward-looking program will begin exploring the subsurface, and geophysical techniques are available to do this.

Some real impetus should be put behind the ground magnetometer surveys, but perhaps of even more importance is a seismic exploration program. Every summer we should have a seismic party out shooting profiles to determine the deep structures. With the truck the O.N.R. loaned us, a small start is being made.

Geophysics and geochemistry are dominated by new emphasis. The cost of producing petroleum will rise until it becomes stabilized by competition with synthetic oil produced from coal. Electrical studies will be used widely in mapping shallow coal deposits and measuring their thickness, by 2000.

The most sought after mineral resource is water, which is in short supply in most of our large cities. The new steel plant being built at Yardley, Pennsylvania, was made possible by the location of a good aquifer by geophysical means. In the near future prospecting will be dominated by the electrical resistivity method. In every state there will be a geophysical survey under either the Geologic Survey or that department having responsibility for the state’s water supply. Private contracting firms will be active throughout the country locating aquifers, and what is equally important, finding
storage reservoirs underground, for surface storage has too great an evaporation loss. Thus New York City today would help its water shortage if it could store water with less loss. This special demand on electrical methods will have a stimulating effect on their use in mining work, where they will be used particularly in locating sulfide deposits, especially those of copper, lead, and zinc.

Geochemical and biogeochemical exploration will be important also in the tropics where heavy rainfall causes deep weathering of surface rocks and leaves few outcrops for the prospector’s inspection. Among the elements sought by these methods we may expect to find beryllium, boron, antimony, tin, mercury, the rare earths, and ferro-alloys.

The widespread use of nuclear reactors as a source of energy will impose some special problems on the science. To the geophysicist and geologist will fall the task of planning disposal of dangerous radioactive wastes in large quantities in such a manner that underground water supplies are not polluted and streams are not poisoned. Disposal areas, largely buried, must be continually monitored by geophysical apparatus to make sure poisonous by-products of disintegration are not escaping in dangerous quantities.

Detailed geophysical mapping of the gravitative and magnetic fields of the earth will have reached the stage of development in which topographic mapping finds itself to day. The whole of the United States will have been covered by the airborne magnetometer. The whole of Indiana has already been mapped. From such surveys will be located not only new iron deposits, such as that recently found at Morgantown, Pennsylvania, but probably also ferro-titanium deposits, such as those in Quebec. These are needed to supply the increasing demand for titanium by the aircraft industry. Airborne Geiger counter surveys will be used to locate radioactive ores of uranium and thorium needed by industries related to nuclear energy processes.

Modern geologic and geophysical prospecting techniques have been conspicuously successful in the search for oil and gas, because it is relatively easy to identify some of the large sedimentary structures covering at least major fractions of a mile in extent and identifiable over broad horizons. In searching for petroleum and natural gas, one is usually looking for a feature covering a square mile or more in area and being a minimum of a foot in thickness. The discovery and identification of such a body is frequently within the possibilities of present instrumentation. Moreover, the petroleum or natural gas is a fluid, and thus one is searching for a material having markedly different properties than the rocks which contain it. In contrast, metallic and other mineral deposits are surrounded by other solid materials, many of whose properties differ but little from the ore being sought. Consequently, it is far more difficult to locate a vein of copper-bearing material that may be only a few inches thick, a few feet wide, and at most, a few hundred yards long, buried only a quarter of a mile underground. Another factor which has made possible the application on a wide basis of geology and geophysics to the search of petroleum products is the large amounts of money and manpower being expended by the petroleum industry for research in this direction.
In proportion to its economic importance, much less effort has been made along these lines by mining interests. Obviously, solution of these problems will cut across all subject-matter fields in the geology group, and the studies must show some practical application long ere 1975.

In general, the demand for mineral materials will be so great by 2000 that it will be necessary to search everywhere for more ores. Today we search only where prospects are excellent; tomorrow we will search wherever there is any possibility of finding ores. Copper is an example of this search. For years its cost has climbed steadily; more and more marginal deposits are being utilized. Because copper is indispensable to the electrical industries, geophysicists today are searching for it throughout the world with resistivity, potential, electromagnetic, microchemical, and other exploration methods.

**METEOROLOGY**

It appears that in appraising the possible development of meteorology, we must distinguish two separate phases: (1) the advance of knowledge pertaining to the properties of and processes in the atmosphere; and (2) the practical application of such knowledge to weather forecasting and weather control. As in any other scientific field, the first phase will always be ahead of the second phase. In meteorology, judging from the progress made during the past 50 years, progress in the applied phase will lag behind the "pure" phase by a considerable margin, chiefly because the weather services the world over rely on international agreements and cooperation. As a consequence, the systems employed in the collection, dissemination, and usage of weather information are conservative, i.e., radical changes are unlikely to be made, if not impossible. Improvements in weather forecasting, in turn, are handicapped by the limitations imposed by the weather data collected, which are mainly confined to the thermodynamic properties of the lower atmosphere, omitting entirely the physical and chemical aspects, such as electric properties and the aerosol, as well as the behavior of the upper stratosphere and ionosphere.

By 1975, the theory of the circulation of the atmosphere will have made sufficient progress to include the
jet stream, a narrow air current of the upper troposphere in middle latitudes of very high velocity, discovered during the last war. Great strides will have been taken in cloud physics; in particular, the processes that lead to formation of precipitation from clouds and the cause of thunderstorm electricity will be known. There will be theories of hurricanes and tornadoes available that not only will fit the known structure of these storms better than do current hypotheses, but will also enable more accurate forecasting of these meteorological events. An increased network of aerological stations will furnish us better and more adequate data of the variations in temperature, humidity, pressure, and wind in the troposphere and stratosphere. For probing the ionosphere, a network of radio stations will have been established, and systematic observations of the various ionized layers will have given us a better knowledge of the variations in temperature, ion density, and currents in these rarified realms of the atmosphere.

On the practical side, radar will have become a general tool at all major weather stations for tracking hurricanes, air-mass thunderstorms, and fronts, so that accurate short-term forecasting of these features will be routine. On the other hand, long-range forecasting will have made only slight progress because of the lack of data on the variations of energy from the sun and the lack of knowledge of the probably subtle trigger effect of solar activity on atmospheric circulation. The recently revived fad of rainmaking will again have subsided as it did 20 years ago; but instead of being forgotten, it will have given way to more serious and more scientific, controlled experiments in cloud physics, provided that premature state and federal legislation on weather control does not squelch scientific interest simultaneously with commercial interest in this field.

Regular long-distance flights of jet-propelled airliners will require better determinations of wind direction, velocity, and turbulence in the tropopause and lower stratosphere. This will be facilitated by a denser network of radar-wind observing stations, at which more frequent observations will be made than today. Information on the middle and upper stratosphere will occasionally come from manned and guided rocket planes. But systematic gathering of observational material from these heights will still be a goal to be reached by future developments.

By the year 2000, the balloon as a vehicle for radiosondes will be obsolete and will have been replaced by rockets, and systematic upper air soundings into the ionosphere will be made on a routine basis. Levels of flight forecasting will have risen as long-distance rocket-powered airliners will seek increasingly higher altitudes. Close collaboration between geophysicists, electrical engineers, solar physicists, and meteorologists will be necessary to solve communication and navigation problems of ionospheric flights.

Agricultural planning will be greatly facilitated by vastly improved long-range forecasting, the improvement stemming from the better understanding of the interaction between the various layers of the atmosphere and between solar activity and atmospheric circulation. Advances in cloud physics will be reflected, not only in greatly improved short-term forecasts, but also in the extensive regional control of precipitation with respect
to timing, distribution, and intensity of rain and snowfalls. In the main, however, the progressive shortage of agricultural, industrial, and domestic water will have to be relieved by vast irrigation projects involving the conversion of sea water, the damming of all major river arteries, and the tapping of underground water reservoirs.

The numerous atomic power plants will be among the vastly enlarged circle of industrial users of meteorological information. Similarly, all color-television networks will adjust their transmissions according to the expected atmospheric conditions. The increased problem of air pollution by the expansion of the chemical and mineral industries will be solved partially by the recovery of the effluent material at the source. However, the radioactive waste products of atomic energy plants will require a network of monitoring stations, as well as meteorologists who specialize in forecasting of the trajectories and diffusion properties of air currents.

By 2000 A.D., the subprofessional grade of meteorologist will be on its way out. Most weather observers will have been replaced by automatic weather stations, which, however, will require the servicing of electronic specialists. At the several weather central stations, weather analysis and prognostic mapping will be done chiefly by electronic computers, and dissemination of weather information will be by wireless facsimile printing and television.

GEOGRAPHY

One of the major objectives of the Division of Geography in the School of Mineral Industries is the training of professional mineral geographers. We are ideally situated to perform this function. Experts from allied sciences are available in the School for discussions of all problems. We are also located in the heart of one of the greatest mining regions in the world. The possibility of geographical specialization in the mineral industries is unexcelled, and an enviable reputation in this field is established. The need for geographic planning is being recognized by the large mineral companies; and our graduates are now being employed by the large coal, coke, and steel corporations.

The geographer is fundamentally interested in the study of earth patterns and their differentiation from place to place. Thus the economic geographer working in the field of minerals has as his objective the description and explanation of the patterns of the world's mineral production. Since the search for minerals is becoming increasingly intensive, mineral geography is essentially dynamic in character. Industries are now planning on a world basis in order to secure their raw materials. The understanding of physical, economic, and cultural special relationships in mineral exploitation is necessary to a sound mineral economy which is based on world resources.
Along with vast strides in the physical sciences and technological fields of knowledge that are to be expected during the next half century, there must develop equivalent or superior advancements in the understanding of how these new techniques and discoveries will affect man and his economic, social, and political institutions. For technical progress, without matching strides in our appreciation of its complex influence upon man, could well lead to the decline of this nation, the eclipse of democracy, and conceivably to the decimation of our people if an unfriendly foreign power excelled us in the understanding of the human repercussions of scientific advances. Since the study of geography, with its emphasis upon correlations and interrelationships between the physical and cultural aspects of the world, is the intellectual bridge or catalyst between technical earth studies and human institutions, it becomes imperative that continued advancements be made both in the field of geographic research and in the field of mass dissemination of geographic knowledge through our institutions of higher learning.

Examples of the ways in which technological progress might conceivably remake the geography of the world by the year 2000, and rend asunder existing patterns of human institutions, are fantastic in their potentialities. It is well within the range of possibility that the end of this century will witness, not the evolution of an "atomic age," but instead the full-blown blossoming of a "solar age" in which energy derived from the sun will be the overwhelmingly dominant source of industrial power. The human implications of such a development will be cataclysmic and will ramify through every facet of every individual’s life. The seats of world power will shift from the present coal-rich, middle-latitude nations, like the United States and the Soviet Union, to sun-rich tropical lands. Industrial pygmies, such as the Sahara and Australian deserts, may well evolve into the gigantic workshops of a nearby tomorrow. Solar power might well be so cheap, universally available, and non-cyclical seasonally in tropical desert lands that virtually unlimited quantities of sea water will be converted into fresh water to change now-barren wastes into the most productive and prosperous gardenlands of the world. If and when such events come about, titanic struggles will occur among the people of the earth for control of these new seats of power and wealth, as has been the case throughout the history of the world.

Or, again, it is not unreasonable to assume that the next half century will witness development of low-priced and effective antifertility compounds which could be distributed among, and accepted by, the overpopulated and undernourished people of eastern and southern Asia. Once the problem of contant pressure of population on resources is solved in these lands, it will be within the bounds of probability that a new and mighty Asia will evolve, peopled moderately by virile and well-fed races whose time and energy would be devoted to cultural and scientific progress rather than the present problems of simply remaining alive. What effects would such an antifertility compound have upon the geography of the world? Would Asiatic lands regain the intellectual dominance they so long possessed during the "golden age" of Chinese history? Or would the resurgent yellow race seek to replace the white man as
leaders by power and brute force? These are questions and potentialities that require most careful consideration, for their implications of changes in the present structure of the world are tremendous.

It behooves the educational and political leaders of our nation to ponder long and well the possibilities of economic, social, and political repercussions to its technological advances, and to engage the most competent personnel available to analyze and predict the effects upon the future geography of the world of probable advancements in the physical sciences, so that this country may foresee and plan for such contingencies long in advance of possible adversaries dedicated to a way of life inimicable to the democratic tradition. Furthermore, instruction of the masses of the people, in both the present and possible future geography of the world, is essential in order to obtain an intellectually alert and receptive citizenry who will understand and support social, industrial, and political policies that will enable our nation, our way of life, and our very people themselves to exist and thrive in a rapidly changing world.

MINERAL ECONOMICS

Essentially, the future will show the adaptation of new and feasible technologies to a background of economic realities. Hence, although such economic realities are discussed elsewhere in this study in connection with the treatment of specific technologies, it is vitally important to restate the entire problem primarily in terms of mineral economics. The tremendous scope of the economic problems in mineral supply is clearly outlined by the following example.

When one of our soldiers in Korea swings the sights of an anti-aircraft gun on an approaching plane, the world's most spectacular example of co-operation will begin to function. The firing pin, a steel alloy made from iron from Minnesota containing chromium from Turkey, nickel from Canada, molybdenum from Colorado, machined with tool steel containing tungsten from Spain, or industrial diamonds from Belgian Congo or Brazil, will fall on a detonator containing mercury from Mexico. The resulting explosion of materials originating in nitro bodies recovered from the atmosphere of the United States will drive out a steel shell manufactured in Pennsylvania from Venezuelan iron ores with Connellsville coke alloyed with manganese from India, Africa, or Brazil. This steel will have been produced in furnaces using refractory brick made from
clay in Clearfield County, Pennsylvania, smelted with the aid of fluor spar from Illinois, and cast with the assistance of graphite from Madagascar or Ceylon. The flights of the shell will be controlled by a rotating band of copper from Arizona, Montana, Utah, Peru, or Chile. Upon the arrival of the shell at its destination, the detonator containing mercury from California or Texas will again release the forces of destruction. The whole operation will be carried out by a gun containing steel from the mills of Pennsylvania with alloy elements from Peru and Turkey, mounted on bearings containing tin from Bolivia, copper from Chile or the west, and lubricated with Pennsylvania petroleum. Firing orders will arrive on a communication system whose operation is dependent upon mica from India and aluminum from Arkansas or Dutch Guiana, cryolite from Greenland, and quartz crystals from Brazil.

The maintenance of this cooperative enterprise in the face of a disturbed international trade system is taxing the ingenuity of earth scientists, mineral engineers, and mineral technologists to the limit. Nevertheless, the job is being done at the expenditure of sweat and mental effort, and the final issue will be decided in a substantial manner by the growth and strength of mineral industries education.

As our mineral economy grows progressively complex, the need for the mineral economist becomes apparent. The necessity for understanding technologic-economic relationships is being recognized by both industry and government. Exactly where will mineral economics fit into the struggle against depletion as it becomes more critical in the next 50 years?

Foremost among the contributions to be made by the mineral economist is the formulation of a sound, workable mineral policy for the nation. The direction of our mineral future will naturally fall under the supervision of the federal government, since it has the centralized authority to direct a program to assure the country of adequate mineral supplies. However, the government is helpless and ineffective if it is not following some long-range plan of action. Our facilities must be directed along the most fruitful paths if we are to succeed in time. Therein lies the task of the mineral economists in the universities, in industry, and in government. By both independent and cooperative research the mineral economist can develop a mineral policy that is economically feasible, technically practical, and fully cognizant of the peculiar nature of mineral resources.

The development of such a policy cannot rest on a few applicable generalizations. It must be specific enough to be workable, but yet flexible enough to meet changing conditions. This can be accomplished only by the efforts of large staffs of trained mineral economists. Before an actual policy can be formulated, it will be essential to make a detailed survey of the origin, magnitude, and flow of both the world’s and domestic mineral resources. Analysis and interpretation of the information gained by such an exhaustive study of the world’s mineral wealth should lead to the eventual writing of a long-range national mineral policy. However, before this policy can be realized, the time, facilities, and personnel must be made available.
It has been claimed by some that national planning should be accomplished on the basis of doubled “gross national product” by 1975. Doubled GNP by 1975 does not seem reasonable, particularly on the basis of domestic mineral production. GNP could double in dollar value but not in terms of actual physical production or “real” dollars. If we assume that doubled GNP requires a doubling of mineral production, we will have to expand our mineral industries much faster than we have in the past 25 years. The physical volume index of mineral production was 90 in 1925 and 150 in 1950, an increase of 60; doubled GNP might require an index of 300 by 1975 or an increase of 150. In view of the fact that our iron, copper, zinc, lead, and other mineral resources no longer seem adequate to approach past peaks in production, that petroleum has limitations in reserves, and that coal no longer has tremendous reserves of high-grade material and unused capacity, it does not seem wise to assume that domestic mineral production could double in the next 25 years. Perhaps a doubled GNP could be derived on a basis of mineral imports, but even this seems dubious in consideration of increasing world competition for irreplaceable mineral supplies.

It does not seem logical that GNP can grow any faster than in the last 25 years, if domestic mineral production can be considered an accurate criterion of the potential of the nation. This would mean a maximum GNP in 1975, or 40 per cent greater than at present. In light of the gradual shifting of the United States population center westward and the depletion of the East’s older mineral deposits, it seems logical that perhaps the rate of expansion in Pennsylvania will be less than in the western areas.

Expansion in Pennsylvania will probably be through additions to present plants to handle the normal increase in demand created by the gradual growth of population. However, there are two exceptions to this general trend in Pennsylvania. One exception is the development of new industries brought about by the shipment of foreign ores into the Eastern Seaboard ports (e.g., the new steel center in the Philadelphia area to handle Venezuelan iron ore). The other is the potential development of many of Pennsylvania’s heretofore unexploited vast nonmetallic mineral deposits.

Probably the greatest factor in retarding industrial expansion in the Pennsylvania area would be a continued decline in the per capita requirement for coal by the nation. Coal has always been the backbone of Pennsylvania economy, but it has suffered from competing fuels, as well as from the gradual decline of coal as the deciding factor in the location of industry. Another retarding factor, as mentioned previously, could be a continued downward trend in Pennsylvania’s relative population growth.

The things which would do most to promote Pennsylvania’s growth would be: a favorable industrial environment developed and maintained by the people and the State government; development and discovery of unexploited mineral resources; and an increasing need for processing of foreign minerals in the East Coast area.

Though the development of a national mineral policy is probably the most essential program for the mineral economist, it is not the only one of value. Another area
requiring trained mineral economists, provided with adequate facilities, will be investigations of the economic effects of using substitutes for presently critical minerals and also of using high-cost materials from our own mines instead of cheaper foreign materials. The world’s reserves of practically all metals are, if equitably apportioned among the industrial nations of the world, adequate for the next 50 to 150 years. These reserves, however, are not distributed evenly in the earth’s crust but are often found in areas far removed from the large industries which need them and many times are under the control of nations whose present policy is to withhold them from us and our allies. This condition makes more immediate the need of rapidly reducing our consumption of such elements as chromium, tungsten, and tin by substituting for them metals which we have in larger supply ourselves or which we still can get from our friends. Even such a policy of retrenchment, however, well might be disastrous in time of war were an enemy able to sever our sea connections with our present suppliers in Africa, India, or Southeast Asia. The degree, then, to which we are to encourage trade in critical materials as opposed to the amount of encouragement which we are to give to our high-cost producers of these metals at home must be carefully reappraised at short intervals to insure that no future change from uneasy peace to all-out war will find us woefully deficient in something we must have to defend ourselves.

Studies on the economic factors which influence the search for new mineral wealth are far from complete. These factors must be given serious consideration if we are not to find ourselves with our reserves of the base metals exhausted, insufficient supplies of the light metals available, and our economy incompletely or not at all converted to the era of light metals which such an exhaustion ultimately will force upon us. Such factors include not only the expenses of exploration, mining, beneficiation, smelting, and refining, but also the costs of taxes, labor, and the replacement of obsolescent and worn-out equipment.

Taxation has become a particularly acute problem, and there is urgent need for the development of a sensible tax program. The United States is probably the only major nation in the world where individual ownership of the subsurface mineral rights is the rule rather than the exception and where, until recently, private capital and initiative were free to exploit metal and mineral deposits on the basis of the prospects of making a fair profit on the activity. Government planners did not make out long-range supply requirements balance sheets before our steel, aluminum, copper, lead, zinc, coal, petroleum, etc., industries were started. Government attempts at long-range planning cannot offset the value of private initiative doing the job. Under present tax policies, however, the incentive for mineral expansion is not so great as formerly, and the government will either have to modify tax policies to permit the private investor to realize the fruits of his investment in mineral expansion, or else the government will have to make broad general purchase guarantees which underwrite mineral production by establishing long-range floor price and government purchase programs. For example, under authority of the Defense
Production Act of 1950, as amended, we have recently guaranteed to buy all of the tungsten produced in the United States over the next five years at a price of $63 a short ton unit. This has been done to encourage private business to expand tungsten production despite the fluctuating requirements for tungsten that have been caused by government uncertainty in the defense program. It may well be that the broad guarantees of this type covering almost every metal and mineral and extending for far longer periods of time than five years will be necessary to insure mineral production.

Other subjects to be delved into are the practical application of conservation to mineral resources, solutions to the economic problems of specific mineral industries, and plant location studies.

One matter which will have an important bearing on the success or failure of our long-range program for mineral use is the education of the young mineral economists. Graduates must have a broad grounding in mathematics, chemistry and physics, and the various fields of mineral engineering and mineral technology, as well as the earth sciences. It can be seen also that the problem for planning future mineral economics research is definitely not one of what to study, but rather one of trying to decide what to do first and whether the necessary facilities are available to accomplish the task.

**MINERAL EXTRACTION**

There will be revolutionary changes in methods of working mineral deposits under the impact of new knowledge, new machines, and new demands before 1975. These changes will point to more efficient production at lower costs, and better management-labor relations. This study will have to be confined largely to coal, petroleum, and natural gas with due regard to Pennsylvania.

*Coal*—Five hundred thousand (500,000) miners now produce about 500,000,000 tons of coal annually in the United States. It is reasonable to predict that 350,000 miners will have to produce upwards of one billion tons of coal annually in the United States by 1975; likewise, that 300,000 miners will have to produce well over one billion tons of coal annually in the United States by 2000 A.D.

The mining industry has always lagged behind other modern industrial operations in efficiency mainly because mine labor, until recently, was cheap and non-fluid. Since labor was not costly, mines could spend it freely. Efficiency was not needed. Recent advances in mine wages make it increasingly difficult to find plenty

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of cheap mine labor. Modernization must follow; and as history has shown, the new operations and the virgin mineral areas receive priority with regard to the most recent developments. It is not considered economical to frequently revamp an old, existing operation. Pennsylvania, being one of the oldest mining areas, produces less tons of coal for each man-shift expended.

Heretofore, empirical methods have dictated the innovations in mining equipment and methods. The field of application has been the giant laboratory of trial and error. Empirical methods are slow and wasteful. They have not yet proved a single mine-loading machine absolutely better than the age-old manual type of loading, except in tonnage loaded.

With the emphasis on scarcer raw materials the mineral-producing industries must necessarily keep pace with ever-increasing efficiency of manufacturing and distribution industries.

Theoretical research is vitally needed in the mining industry from the standpoint of profitable operations and from the standpoint of both National and Commonwealth mineral conservation. The research should be divided into (1) environmental, (2) operational, and (3) servicing.

By the environmental aspect of mine research we mean the study of protective measures taken to facilitate the other two divisions of mine research. Included in this category would be mining tectonics, the study of controlling the walls and roofs of the mines, removing the water influx, physics of mining or mine air conditioning. Thirty years hence, we should expect the treatment and control of the adjoining country rock (i.e., adjacent rock which has no mineral value) to be advanced to such a degree that the present need for elaborate roof and wall supporting structures would be eliminated. Rock mechanics is fast approaching the exactness of structural mechanics.

The operational phase of mining research includes the loosening and breaking of the mineral from its solid position in the bowels of the earth. By 2000 A.D., the extraction of minerals from the solid should have progressed to the point that no machine or no worker should occasion even a momentary interruption. This indicates that mining place operations will become much more concentrated and continuous. It is a far cry from the 50 per cent productive time which is normally experienced today.

The phase of servicing involves the increasingly important technology of materials handling and transportation. Much of the equipment used in the mineral bulk handling has been borrowed from other industries; a few have recently been developed specifically for mining. One of these, the shuttle car, has been a great asset to mine materials handling. Another innovation developed for other industries has had much less success. The functions and capabilities of the conveyor have not been understood for adaptation to mining. Handling equipment should be designed for proper economy. It should have the exact continuous capacity as the extraction equipment so that it will seldom be idle. This cannot be accomplished today because present practice is empirical, not based upon fundamental research.
Carrying the whole phase of mining into the quarter-century future, one might expect that these three divisions of mine research will amalgamate to approach even greater efficiency. For example, the beneficiation of minerals, which is now done in surface plants, might more cheaply be done at the very point of extraction. Thus, transportation of the useless reject mineral would be saved. It might be incorporated with the fixation of the adjacent rock masses and impurities. On the other hand, should the materials handling and transportation phase of mining be developed by research to the highest state of efficiency, it might be rather more economical to further centralize beneficiation processes.

Much of our future coal lies in thin seams, seams containing thick bands of impure coal and heavy rock-partings, and in seams overlain by soft friable draw slate. It is in the seams with maximum working height that we can expect the most rapid strides in development. To work these seams economically and efficiently, a full-scale mechanical system must be developed to mine the coal and the impurities selectively, to dispose of the waste material underground in the working section, and to prevent surface subsidence. Sufficient experimental work has been carried out to prove that properly designed equipment and good supervision will do a highly successful job under extremely difficult conditions.

Petroleum and Natural Gas—In order to foresee the future in education and research in petroleum and natural gas engineering one must appreciate the distinctive features of the profession. These features may not be clear at present because the name does not cor-
rectly fit the profession. Petroleum and natural gas engineering as it is now conceived and taught covers only a fraction of its logical scope.

Petroleum and natural gas engineering is that technology which deals with the procurement, production, injection, replacement and transfer of fluids from and within the confines of the earth. At present these fluids happen to be primarily oil and gas because the commercial procurement of these fluids has demanded the development of a technology. The same environment, physical laws and technology apply, however, to water as one of these fluids. That petroleum engineering has not been understood to include this fluid results only from the fact that handling of the fluid has not been sufficiently commercial to demand a technology. Hence, its procurement has remained an art.

The end uses to which procurement, injection, replacement, and transfer of fluids will apply are many. First, there is the procurement of raw minerals, such as petroleum and natural gas at present. This will include water also, not only that from the normally conceived water zone but from deep-lying strata where reservoirs of tremendous capacity exist. This must be followed by the replacement of these raw minerals. They cannot be taken from their natural rock storage unless they are replaced by another fluid. Replacement of a raw material, such as oil, by a cheaper material, such as water, or replacement of a water resource by air are examples. Then there is the storage of fluids. It is commercially advantageous now to store natural gas, artificial gases, and gasolines in rock strata. The storage of other gases and liquids is also possible and will be
commerically enticing as the technology is developed. Disposal of waste fluids underground is a resulting problem. This operation in connection with a replacement of underground fluids is also possible. Underground disposal of brines is practiced already in the petroleum industry and in a few other instances. Underground disposal of radioactive materials is a definite commerical possibility. A more widespread disposal of waste fluids from industry into underground reservoirs either as a storage disposal or as a replacement disposal into reservoirs from which other fluids are being drawn will follow as the technology develops. Another problem is the possible purification of fluids by underground transfers. Natural reservoirs contain an enormous amount of solid-fluid surface contact. In this respect they make excellent absorbers for certain types of ionic and non-ionic materials. The purification of water by flowing through an underground reservoir is known to occur in some present operations. The development of this end use is a distinct possibility. And finally, there is the underground heat reservoir to be utilized. This can be done only by the production, injection, or transfer of fluids. The same technology which applies to the handling of the fluids themselves must apply to the handling of the heat as a fluid. Commerical uses of the earth heat reservoir are limited now but will develop.

The imagination can realize that other commercial uses of underground fluid reservoirs in place would be possible and that those cited will be developed faster as means of fluid control underground are improved. Furthermore, it is evident that economic use of these processes depends somewhat on the ease with which a well may be drilled. Research in the future must, therefore, be directed along these two avenues.

Basic to the use of a rock bed either as a storage, transfer, replacement, or purification unit must be an understanding of the complete physical laws governing these processes. Thus, research must also be directed to the laws of fluid flow, replacement, ionic transfer, and heat transfer within natural porous media.

How these specific problems may be tackled and in what direction they would take the engineer remain to be seen. Fracturing of rocks for drilling and fluid control by electrical impulses is already being considered. Drilling by arcs and by sonic impulses are current research programs. The future drilling may call upon many other technologies.

The replacement of underground fluids is being attempted already by solvent extraction, by burning, and by bacteria. Replacement at extremely high pressures has some advantages and, therefore, research at high pressure is a must.

The importance of research in secondary and in tertiary recovery cannot be overemphasized. What was good secondary recovery practice in 1940 is now good primary practice. The techniques developed in our laboratories have spread to the entire industry and are now utilized while it is still early enough to better conserve the oil reserve. It is safe to assume that the ideas of tertiary recovery which are now being worked upon will be the best accepted methods of secondary recovery long ere 1975.
Thus, the future in research and education in petroleum and natural gas engineering will go far afield from the petroleum and natural gas industries. The nucleus of this technological expansion is held, however, by the petroleum engineers and is the single distinctive feature of the profession. Perhaps a more descriptive name for this subdivision of engineering should be adopted.

Manpower—Manpower will continue to be the controlling factor in mineral extraction. The handling of mine labor is a science in itself. Some men are naturally endowed with this trait, while others must acquire it by observation and study. It is an unwise policy to put a green and untried man, especially one not familiar with the handling of labor, in charge of a coal mine or a section of a mine simply because he possesses a certificate of competency as mine foreman or fire boss. Such a course is unfair to the man himself, to the mine employees, to the company, and to the public. These men should be compelled to serve an apprenticeship or attend classes embodying short courses concerned with labor and management relationships, organization, cost control, accident prevention, mechanical mining methods, and others.

It is imperative that top executive positions in the coal industry be filled by well-trained technical men who have the best interests of both labor and management at heart. Very few individuals recognize the need for training or will do much about it if left to their own free choice. Such has been the lot of the coal industry, but this tendency must disappear. Young men with the proper technical and practical background should be

spotted and placed as understudies for the various executive positions. Only in this way will whole-hearted support of policies for the training of mine officials and mine labor, and a general betterment of the industry result. The training of men below the rank of mine officials will be a tremendous task. No thorough training job can be accomplished in a year or even in several years, but if we are faithful to these concepts and ideals we will slowly, but progressively, attain the much desired happy relationship between labor and management in the coal industry long before 1975.

Taxation and Finance—Certain items of importance in the future of the mineral extractive industries cannot be predicted with any assurance. One of these is the nature of future government policies, particularly as related to taxation. The trend has been for government to become progressively more important in its effect on business management and for taxation to become more burdensome as the years go by. The degree of taxation that we can expect in the future is dependent upon many variables, the particular administration in power, the political philosophies of that administration, the occurrence of wars, the National Defense efforts, and so on. With so many unknowns, one dare not even hazard a guess.

However, it appears that there is a saturation point beyond which taxes may not go. This saturation point is reached when further taxes will so weaken the industries involved that their progress and profits begin to decline. This results in a short-lived increase in tax income, but an eventual loss in tax money because of lowered income by the companies effected. Naturally, there
is much disagreement as to the location of this level of maximum taxation. The leading members of mineral industries management are firmly convinced that we have already reached it.

Thus the mineral industries must guard against strangulation by taxation in the next 50 years. It is to be expected that certain groups who have attempted to lower the percentage depletion allowance for the mineral industries will try again. Fortunately, Congress has refused to be misled by these arguments in the past and, in the Revenue Act of 1951, went so far as to raise the depletion allowance from five to ten per cent for coal, and provided percentage depletion for various additional nonmetallic minerals. However, ill-considered taxation policies will remain a constant peril.

Problems of taxation and finance have brought about seemingly contradictory activity in mineral industry organization. The high level of taxation has resulted in attempts by various companies to break down their organization among smaller individual corporations so that the profit structure of the individual corporations will be small and incur a lower amount of taxation per dollar of income. On the other hand, modern mining with its mechanization, high labor cost, and high property cost, are beyond the capital reserves of the smaller mining company. This has brought about the growth of large corporations with tremendous resources in capital and technical skills. For example, the steel industry today incorporates iron ore mines, coal mines, transportation facilities, blast furnaces, open hearth furnaces, and fabricating plants.

We can expect in the next 50 years a continuation of the past trend of decline in the number of small mining ventures and gradual growth in the size of the major mining corporations. At the same time there will perhaps be a reorganization and decentralization of the corporate structure of these gigantic companies into a form which will bring about the lowest possible tax burden.

Great progress in the extractive industries is certainly forthcoming. Whether Penn State and Pennsylvania have the vision to be associates or even leaders of such progress is a question that must be answered today.
SAFETY AND HEALTH

The coal industry pioneered the safety movement in this country. No matter what yardstick is used, it is apparent that the coal industry has made greater effort and far more progress than the country has made as a whole.

Perhaps the first organized effort of coal mine safety was the enactment of inspection codes in Pennsylvania in 1870, followed by the inauguration of first aid to the injured in the Anthracite Region in 1899. Our precious memories go back to the days when the life of a miner was not worth much more than a mule, when some of us risked our lives with negative pressure helmets, the days of the open light and black powder, when flame safety lamps and canary birds were supreme in testing for mine gases. Milestones were the establishment of the Pennsylvania Department of Mines, U. S. Bureau of Mines, Experimental Mine, American Mine Safety Association, Mine Safety Appliances Company, the advent of permissible electrical equipment, and the first laws to combat the coal dust hazard. Likewise, the electric cap lamp, permissible explosives, scientifically controlled ventilation and mechanization, all have contributed in making the miners job consistently safer.

Wars always have been great catalysts and social and scientific advancements mature under military stimulus in a fraction of the time normally consumed. World War I produced Hopcalite and the All-Service Gas Mask. Rock dusting, continuous carbon monoxide and methane recorders, portable gas testing equipment, McCaa self-contained oxygen breathing apparatus, convergence recorders, hard hats, goggles, safety shoes, protective clothing of all kinds, National Mine Rescue Association, Joseph A. Holmes' Mine Safety Association, the Federal Coal Mine Inspection Act, and finally The John T. Ryan Memorial Laboratory, followed in a progressive safety movement.

In spite of deeper mines, and increased uses of mechanical equipment and electric power underground, fatalities have decreased from 5.32 per million tons in 1910 to 1.07 (tentative) in 1950. There has been a parallel lowering of non-fatal accident rates and their frequency is less than half of what it was 20 years ago. The future injury rate should drop from our present 30,000 to about 5000 per year with a comparable lowering of the fatality rate to 0.1 per million tons. The horror aspect of a mine disaster, in the past, has tended to obscure real achievement of the mining industry in making the worker's job safer. Headlines are made by the infrequent mine explosions rather than the notable records of steady improvement. Mine explosions are now known by their absence as they were known by their regularity 30 years ago.

Bitter past experience has shown that safety and public relations cannot be kicked around until they become lost, and no longer are they neglected by the
mining industry. It is seldom known that coal mining is a safer occupation than plumbing, building construction, street and road construction, or working in machine shops, and that mining has been safer than these and some other industries for the last decade or more.

The great bulk of mining accidents are the result of human failure, in turn a lack of worker and management education. These accidents occur, one or two at a time, to men working in confined areas. Stemming from top management, excellent progress is being made in engineering studies of equipment and methods of working. It is a little known fact that the coal mining industry pioneered many safety features and appliances for machines later adopted in other industries.

But what are the future possibilities of safety in bituminous coal mining? Mining equipment developments are in the offing that will tend to revolutionize methods of working, and various new scientific discoveries will find ready application in mine safety. More efficient methods of safety control will be based on sound principles of engineering. Research laboratories will find the answers.

Safety in the mineral extractive industries must be unified under State Departments of Mines and Minerals. Lessons learned through experience in coal mine safety can be applied to the other mineral extractive industries; they will receive the benefits of years of trial and error, as it often had to be applied. Inspection agencies should have real authority to crack down on violators for failure to enforce even elementary safety regulations. Like other important developments, good safety records will not come easily and will cost money. But once attained, the original expenditure will be repaid many times by the saving of life and limb, by fewer lost-time accidents, as well as in good will and improved public relations.

Methods of bituminous coal dust control in working areas must be made more effective. Use of plastic sprays which would render the material not only inert but incapable of movement show much promise. The general use of conveyor haulage should reduce transportation accidents. Conveyor belting of fire-resistant or fire-proof materials are capable of development. Fluid flow transportation of coal from the face areas through pipe lines will be developed. New, safer, more efficient methods will be devised to break down coal, applying principles based on chemical and physical laws.

Respiratory diseases incurred by mine workers must be eliminated through preventive measures applied at the face. Dust collecting devices for rock drilling are even now in a remarkable stage of development. Others, perhaps utilizing ultra-sonic and electrical precipitation principles, could wipe out silicosis and other similar diseases in anthracite and hard-rock mining.

New accurate types of electric methane detectors will be developed to replace the flame safety lamp which requires so much training to use correctly. It is not inconceivable that methane alarms can be designed that will be sufficiently rugged, simple, and inexpensive to justify their widespread adoption and use in every working place in gaseous mines. The use of drill holes
in the mine or on the surface to bleed off methane will become common in some regions.

It is natural also that we should look forward to improvements in the design of mine rescue apparatus. Though some of our mine rescue work is carried on today with the use of gas masks, self-contained breathing apparatus would be more widely used if the equipment were lighter in weight, simpler and more rugged in construction, and did not require so much training to use with comfort and security. And, a way will be found to make the Self-Rescuer practicable.

Based on progress made to date, it is not out of line to assume that our entire future coal requirements will be satisfied by less workers with greater productivity. Thus 300,000 workers can produce a billion tons of coal per year by working 200 days and mining at the rate of 15 tons per man shift. Of the total employed, a far smaller proportion will actually be needed at the face. To reduce accident possibilities of these exposed men, strong shields to protect them from falls of rock and coal may be in the offing. This hazard still accounts for the majority of all coal mine accidents.

Remote control equipment based on electronic principles will be a big factor in further reducing the number of face men. Space illumination for all areas in the mine will be made more efficient so as to make its use more the rule than the exception. This will practically eliminate the stumbling hazard, looking for tools, and man output efficiency certainly will increase. It follows from this that accident frequency will become lower.

Mine ventilation will become more positive and efficient through fluid flow studies utilizing radioactive tracers. Axial-flow type mine fans will be supplemented with bore hole installation of turbo blowers designed for mine ventilation characteristics. Sprayed plastics for sealing ventilation construction, plastic cloth for curtains and line brattice will be in common use. There will be a more general application of mine roof sealing to prevent rock falls and improve ventilation.

It is not too much to expect that "rule of thumb" will give way to practices based on scientific principles in the control of mine strata, thereby practically eliminating unexpected falls of roof and coal. Mining systems will be conceived whereby the removal of material will not cause critically induced stress concentrations in the working place. The application of mining tectonics and geophysical principles will be common in the establishment of rock strata failure criteria.

Instruments will be developed that will give continuous records of rock stresses and roof movements which will permit long-range forecasting of break line falls. Convergence and deflection testing devices will be available for use at the working face. Portable subsonic equipment with micro-timers will be perfected to test for loose coal and roof rock. Electrical resistivity analogies will be used to correlate stress-strain determinations in the immediate stratum. The future cost of drill holes will be such that pre-grouting of expected bad top areas in the mine can be accomplished. Thus
water seals and consolidation of wash and old stream bed material are good possibilities.

There is no need for a widespread mine disaster in any American coal mine, and they will be unheard of in the not too distant future. The "if" will go out of safety and only the human equation will remain. The human equation in turn will be licked by education, and processes are outlined in other parts of this discussion.

MINERAL PREPARATION

One of the most crucial problems before the nation is that of upgrading many of its remaining mineral supplies. Obviously, the problem is directly related to conservation of minerals.

Hulin pointed out in 1947 that based upon the prewar rate of consumption the commercial reserves of medium and high-grade ores of iron, copper, zinc, lead, and mercury in the United States are sufficient for 22, 34, 15, 12, and 3 years, respectively. In regard to aluminum, the available data indicate that at the present rate of consumption, 900,000 tons per year, the high-grade bauxite in Arkansas and Alabama may be exhausted within the next 10 years. In the case of tungsten, manganese, tin and antimony, the ore deposits are not only small in quantity but also poor in grade. The situation of the rapid depletion of high-grade resources is further enhanced by the fact that in the past decade the discovery of new ore deposits admittedly has been low. Large deposits of high-grade ores, conspicuously exposed at the surface, are now largely a thing of the past. Future discovery may deal mostly with lower-grade ores.

Modern civilization depends on minerals so greatly that it is difficult to imagine what our surroundings would be if minerals in common use were virtually
unavailable. Do these ominous statements mean that civilization shortly will be forced to alter its way profoundly? Must we in a few generations return to horse-drawn vehicles, candlelight and handicraft industry? The answer to the question posed is that in the year 2000 there need be no shortage of minerals and we will have substitutes for most of the scarcer minerals. By then the physicists will use solar energy as a cheap, inexhaustible source of power to augment the mineral fuels. The chemists will have invented synthetic plastics to replace some metals in some places. The metallurgists will be able to produce aluminum and steel from clayey materials at low cost. The geochemists will make more synthetic minerals, and will recover radium from running brooks and germanium from coal ash. The geophysicists will discover new ore deposits from many unexpected sources. Finally, the engineers of mineral preparation will invent new processes for the concentration of lean ores, and for the reclamation of tailing-piles and minedumps of old properties.

The present assembled facts indicate that in the field of mineral preparation there is a new vigor and emphasis on the research of beneficiation of low-grade ores. Before the century is over, most of the currently practiced processes of mineral preparation will become obsolete. The new methods will utilize gamma ray, ultraviolet light, high frequency sound, and high voltage electricity. Machines for flotation and gravity concentration will be improved greatly by the adoption of ultrasonics, electronic equipment, radioactive devices, photoelectric apparatus, thermal regulators, and automatic controls. As a result, the engineers of mineral preparation will be able to recover minerals from the low-grade ores at reasonable costs. The enormous amounts of minerals in the low-grade ores will not be exhausted in the year 2000, as can be visualized from the following illustrations.

Coal—Fifty years hence high-grade coal for coking purposes will be exhausted, necessitating the use of coals of high impurity content and coals having inferior coking properties. Processes will be developed and preparation plants designed to not only remove deleterious impurities, but in the case of the low-rank coals to separate the mineralogical constituents of the coal substance from each other. This will permit the use of the mineralogical constituents suitable for coking in the metallurgical industries.

Many of the currently practiced processes for the concentration of minerals are inefficient, and the amount of valuable minerals lost in tailings and mine dumps is alarmingly large. For example, it is not uncommon in coal washing for the rejects to run as high as 30 or 40 per cent of the input feed. Based on the conservative estimation that the loss of coal rejected per ton of feed coal is 8 per cent and that the current average amount of clean coal produced from mechanical cleaning plants is 150 million tons per year, then the loss of coal to the reject per year can be calculated as 12 million tons.

In the coal industry, millions of tons of fine coal have been wasted in the tailing piles and mine dumps, and some of it has found its way into the stream beds. The coal content of these accumulated tailing piles may run from 10 to 20 per cent and can be recovered by
means of froth flotation. The Lehigh Navigation Coal Company has been reclaiming coal lost in wash water at a rate of about 2350 tons per day since 1942. The Pennsylvania Water and Power Company at Holtwood is recovering the coal on the stream bed of the Susquehanna River by means of the hydro-concentrator, tabling, and froth flotation. The Hudson Coal Company at Scranton, Pennsylvania, is treating its anthracite silt from both the silt bank and the breaker wash water for boiler fuel by means of Humphrey’s spirals. The M. A. Hanna Company at Nanticoke, Pennsylvania, has been working on its fine coal from the breaker waste by means of froth flotation since 1947.

**Metallic minerals**—Those who have concern for the future of the iron ore industry may be relieved to know that the beneficiation of low-grade iron ores is now well in progress. The reserve of the low-grade iron ores in the Lake Superior region, including the intermediate type and the taconites, is estimated to be more than 60 billion tons with an average of 25 to 35 per cent metallic iron. The sub-marginal iron ores in Pennsylvania and many other states will soon become valuable resources through the advance of mineral preparation.

The average annual production of iron ore through the period of 1943 to 1946 is roughly 100 million tons, of which approximately 36 per cent had to be concentrated before shipping to consumers. Iron ore beneficiation efficiency is low. Based on the average of 10 per cent iron unit rejected as tailing, the annual loss of iron unit is calculated to be more than 3 million tons.

The low-grade tin ores in Bolivia, on which the United States depends greatly for its tin resources, have always been considered waste because they have never been able to be successfully concentrated. Research work has made it possible for the concentration of tin ores containing as low as 1 per cent tin. Hence, the low-grade tin ores and tailing piles in Bolivia, Malaya, and the Dutch East Indies can be concentrated into high-grade tin ores. The research on the concentration of an extremely low-grade wolframite ore here may point to a method that will help to make the United States reasonably self-sufficient in tungsten.

In the case of copper, lead, and zinc, not only the vast amount of low-grade ores, but also the oxidized ores can be concentrated into high-grade ores. Recently, a large copper mill has been successful in treating ore carrying only 6 pounds of copper per ton. The St. Anthony Mining and Developing Company proved that oxidized lead ore can be concentrated successfully by means of froth flotation.

Broadly speaking, the recovery of coal, iron ore, phosphate rock, bauxite rock, and barite in the current practice of beneficiation ranges from 60 to 93 and averages at about 85 per cent. The total losses of these five minerals in their tailings are estimated to be more than 16 million tons per year. The total losses of copper, lead, and zinc ores per year are estimated to be around 970,000 tons. The content of valuable minerals in the old tailing piles and mine dumps is much higher than that of the current tailings. The reclamation of the unlimited amount of valuable minerals from the old tailing ponds and mine dumps has long been a matter of academic interest but now is being proved metallurgically successful by means of flotation, though the
problem of cost remains. In the future it will be possible to re-treat, at a profit, all the tailings and mine dumps. The result is that an enormous amount of valuable minerals will be at our disposal in the near future.

Attention has been focused recently on the reclamation of tailings and mine dumps, but the surface of the field has hardly been scratched. In World War II, more than 5 million tons of tailings and mine dumps of silver-lead-zinc ores left from the old mill in the Coeur d’Alene district of northern Idaho have been reworked. The metallic content in these tailings are 5,090,000 ounces of silver, 86,988 tons of lead, and 77,678 tons of zinc. It has been proved by laboratory experiments that, when the current gravity concentration of tin ores in Bolivia is replaced with a new process of flotation and leaching, not only the recovery of the tin ores can be increased from 50 to 85 per cent, but also the accumulated mill tailings assayed as low as 1.0 per cent tin can be reworked.

With respect to strategic minerals and rare elements, titanium ores can be obtained from many sources, such as the beach sands of Florida, the low-grade ilmenite deposits in Virginia, and the low-grade titaniferous iron ores in New York State. Manganese and tungsten minerals will be concentrated from the low-grade ores in Colorado and other states. The advance of mineral preparation may eventually lead us to concentrate aluminum minerals from clay, and to concentrate zirconium, lithium, uranium, titanium, phosphorous, beryllium, tantalum, and magnesium from ordinary rocks.

Nonmetallic minerals—In regard to ceramic minerals, flint clay, a valuable raw material for making refractory fire bricks, is rapidly diminishing in Pennsylvania. The practical remedy is to obtain flint clay from fire clays by means of feasible concentrating process. The amount of low-grade fire clays in Pennsylvania and in the embayment area is almost inexhaustible. The supply of ganister rock for the making of silica brick can be assured through the removal of iron from the unlimited amount of low-grade quartz rock. Glass sand can be continually supplied by finding a simple method to remove the impurities from the low-grade quartzite and New Jersey sand. Cement rock can be concentrated from the inexhaustible amount of low-grade limestones and rocks.

In regard to phosphate rock beneficiation, the recovery of phosphate in a modern plant is 90 per cent. This is, of course, higher than that of the phosphate plants using washing, tabling, or hydroseparator processes. Based on the 1946 annual production of 7,168,839 long tons and the average reject of 10 per cent, the loss of phosphate in tailing is calculated to be approximately 500,000 long tons per year. In a similar way, the loss of bauxite, copper, lead, and zinc ores in tailings can be estimated roughly, on the basis of their 1946 capacity of production, as 100,000, 800,000, 50,000, and 120,000 tons per year, respectively.

The world’s need for sulphur continues to grow. At present approximately 5,000,000 tons yearly of sulphur in the form of pyrite is being wasted to bituminous coal mine refuse dumps. At present prices this represents an annual $100,000,000 loss of a valuable natural
asset. In the year 2000 this sulphur will be recovered in preparation plants and converted into elemental sulphur or sulphuric acid as required for the manufacture of sulphur compounds for industry and agriculture.

In the year 2000 the industries of the world need not be suffering from too drastic a shortage of minerals. Before the high-grade ores are completely exhausted, the technique of mineral preparation will be so advanced that many minerals can be concentrated easily from the vast amount of low-grade ores, tailing piles, and mine dumps. It is also possible that high-grade iron and aluminum ores can be processed from clay, and many rare elements and ceramic materials can be concentrated from ordinary rock. With the new techniques, the strategic minerals such as manganese, tungsten, tin, and titanium can be obtained from the unlimited amount of low-grade ores. The low-grade coals will suffice until a new source of power, probably solar energy, is adopted.

It is expected also that before the century is over, the natural resources of minerals will be greatly supplemented by the presence of many synthetic minerals, as well as many substitutes for the scarcer minerals. This trend can be illustrated by the fact that more than two million pounds of metallic copper is being saved annually by substitution of organic chemical compounds, the dithiocarbarnates, for copper formerly used as an insecticide for orchard sprays. These same chemicals are also saving four to seven pounds of sulphur for every 100 gallons of insecticidal spray. It is a well-known fact that the research on synthetic minerals is well in progress. Scientists may eventually learn to prepare synthetic minerals and metallic substances from the disintegrated elements of scrap piles, and the process will be repeated. The rapid advance of science and technology not only can assure the continual supply of minerals in the year 2000, but also may make the United States self-sufficient in minerals.
WATER SUPPLIES

Water, characteristically a mineral in its natural occurrence and its definite and inorganic composition, is one of man's especially precious resources. It forms one of the primary factors that govern his distribution on the earth and will continue to mold his history.

In arid regions, man has necessarily recognized that water is vital for his existence. In humid areas, modern civilization increases the problems of water supply, due to concentration of population in urban centers, increased personal use of water favored by modern plumbing, and rapid expansion of industrial requirements. In the year 2000 water supply increasingly will be a major factor affecting population and industrial growth. The water problems can, however, be met in part by improvements in water procurement and utilization.

In modern residential communities, water consumption seemingly has leveled off at about 90 gallons per person per day. Industrial use has greatly increased in the past few decades, so that in Chicago, for example, the residential plus industrial consumption raises the total to about 300 gallons per person per day. Increased industrial use, as well as increased population, rather than lowered water supply, largely are responsible for recent water difficulties in New York City.

In the United States, the population is growing, and larger proportions of the people will tend to gravitate to industrial communities. Industrialization already is at high levels, but must continue to expand. Limitations inherent in water conditions today are recognized, not only in low rainfall areas of the southwest, but also in well-watered portions of the country. In parts of Ohio, Indiana, and Illinois, for example, water supply already is a critical factor affecting introduction of new industries. In the Commonwealth of Pennsylvania, water problems are now less severe, but by the year 2000, they will be definitely serious in many areas, due to growth of population. There is urgent need for present studies that will help us meet the water problems that inexorably will multiply in coming years.

The water of the Commonwealth of Pennsylvania is finite in volume, though self-renewing from year to year. Its availability for human use can, however, be modified and much increased by human ingenuity. There first must be new and continued investigation of water volume, manner of occurrence, and quality. New possibilities must be sought for both surface and subsurface water storage. New methods must be found for purification of human and industrial wastes, so that their waters can safely be returned to available supplies. New ideas must be developed for artificial augmentation of natural waters, for example, "mining" ocean waters to yield potable supplies.

In Pennsylvania alone, some 30,000 billion gallons of water fall to the ground each year as rain and snow. It is this water that feeds our streams and rivers, that seeps into soil and bedrock to maintain underground
water reserves, that supports our crops and other vegetation, and that is essential for our human and animal populations.

This very great volume of water, if it all could be so used, would provide for the water systems of modern industrial cities having a total of nearly a billion inhabitants, or for residential communities of more than two billion citizens. In fact, it cannot support more than a fraction of such numbers. Large proportions of the rainfall are returned to the atmosphere, in part by direct evaporation, in part by the respiration of animals, and more especially by the transpiration of plants. Much water is carried away by stream and river runoff during periods of high water. Part of the water seeps underground to maintain supplies in crevices in the soil and rock mantle and in shallower portions of the bedrock, rising again to be used by plants or to feed springs of the head-waters and channels of streams and rivers. In land areas, lake and subsurface waters represent a reserve, changing from season to season; fundamentally, the water input from rain and snow is balanced by water outflow through evaporation and runoff.

The ability to modify nature's water budget for man's benefit will be enhanced by better understanding of its details. Much information is available about precipitation of rain and snow, about volume of stream runoff, about water qualities, and about plant transpiration. This information from the meteorologist, the hydrologist, and the forester needs to be brought together and reinterpreted with special respect to relationship with local and regional water conditions. Continued augmentation of such data will be required to keep them up to date. New studies of the volume and occurrence of ground water are needed, and also of the fashion in which such water seeps into the soil and bedrock and moves through underground crevices. These studies are geological and geophysical in character.

It is an essential feature of the water supply problem that precipitation varies greatly from day to day, and that water use often increases during periods of drought. Nature provides reserves for the drier periods in the form of lakes and underground water. Man has supplemented these natural reserves by some man-made reservoirs. Loss of water by river runoff, especially during floods, is a measure of the inadequacy of present reservoir systems. Hydrological, geological, and geophysical studies are needed to plan for future expansion of surface reservoirs, and to increase subsurface storage as far as effectively can be done. Subsurface as compared to surface storage reduces loss by evaporation and does not limit surface use of the land. Today it is being practiced to only a limited extent and probably can be much expanded, on the same general basis that various commercial companies are pumping natural gas into subsurface, porous rocks during times their supply exceeds demand, to extract it again when demand increases. To increase subsurface water supply, however, modifications of natural surface conditions can profitably increase seepage into subsurface reservoirs, although direct pumping during periods of high water is found desirable in some instances.

Great progress has been made in recent years by sewage and chemical engineers in purification of human and industrial wastes, so that their waters can be re-
turned to general water supplies. Further improvements can be expected; the need is obvious to any observer of the streams and rivers of heavily populated and industrialized regions.

Development of new surface and subsurface water storage facilities, and of new purification techniques, will represent improvements of water control methods that already are in operation. We can expect that by 2000, various new ideas will be developed that will modify present practices.

With the development by the year 2000, and perhaps even by 1975, of some cheap nonmineral fuel energy, ocean waters can be treated commercially to recover the many valuable mineral materials of the sea and simultaneously to produce potable water. Thus New York City may be supplied wholly from adjacent seas, and fresh waters may be piped inland to new large communities, in place of the present condition under which New York drains from large areas the waters that might make possible expanded human occupation.

The coming half-century will see new adaptations also for direct use of solar energy that likewise may completely modify present techniques of water use.

**Atomic Energy**

While the material for these pages was being assembled, it was announced, in August 1951, that the United States Navy had arranged for the construction of a submarine to be driven by a machine energized by nuclear fission. This official disclosure was promptly followed by rumors that the undersea ship was already well on the way toward completion, that it would be more than twice the size of previous submarines and would have twice their submerged speed, and that the craft would shortly be given its trial run. Speculations on the nature of the power plant to be used in this ship have been exceeded only by extravagant contemporary predictions about the imminence of a widespread development of industrial power from the energy of nuclear processes.

It is true that power plants energized by nuclear fission are already technologically possible. Such an installation might take the form of a reactor-heating plant through which a liquid metal could be circulated and delivered to a heat exchanger (as has been widely proposed) to generate steam for turbines; or a metal might be vaporized within the reactor, to be used directly in turbines, and possibly to make steam secondarily.
But questions fundamentally more difficult than these technological ones are those of (1) economic feasibility, (2) military sagacity, and (3) hygienic manageability. First, can we afford the cost of the elaborate installations and of the fabulous raw material, even if the proposed “breeder” reactor is successful? Is there, in all the accessible earth, enough recoverable fissionable material to supply the reactors necessary to provide the power for the industrial world? Shall we discard the energy reserve of the fossil fuels with which that world was built? Those who calculate a small productivity differential (1.0 per cent or so) in the favor of the nuclear reactors apparently assume that the manner in which coal is now consumed and the efficiency with which it is utilized in power plants will remain unchanged “throughout all generations.” That assumption disregards the virtue of recent and current research on fuels and overlooks the potential advantages of the liquid and gaseous fuels that, even now, can be made from coal. Who can say what the relative costs of power from coal and from nuclear reactors will be 20 years from now? Moreover, the advocates of industrial application of atomic energy appear to ignore the vast potential of the solar energy which is delivered in bountiful continuity to this restless planet. Thus far, attempts to garner and apply this energy have seemed both sporadic and puny. One may conservatively estimate that if one per cent of the sum thus far expended in the discovery of the control of fission and in the acquisition of its raw materials had been applied toward the mastery of the sun’s rays, we should now be well on the way toward the adoption of solar energy as an important supplement of our fossil fuels.

In the improbable event that the economic balance should some day come to lie on the side of the reactors, we still should have to decide whether our nation, or any nation, could dare to divert its available nuclear fuel to the peaceful production of industrial power while potential adversaries consistently applied their supplies of fissionable metals to military purposes. The enormous power of the fission bomb has been well demonstrated, and the adaptation of nuclear explosives to other weapons is doubtless already accomplished. The superiority of nuclear fuel over liquid fuels for submarines is hardly open to doubt; perhaps nuclear power offers a similar advantage to surface ships of combat, and possibly to certain types of military aircraft. Could we allow our enemies these advantages while we spent our fissionable treasure in ephemeral industrial prodigality?

Even if the questions of economy and defense were answered favorably, we should face the prodigious problem of disposal of the dangerously radioactive wastes from reactors. With only the plants of the Atomic Energy Commission operating, the matter of disposal is already a problem of considerable magnitude and has been the cause of some public expressions of anxiety. As our population grows, an already numerous people cannot comfortably look forward to a nationwide multiplication of these centers of sinister effluvia, making dangerous our rivers and bays and the food they bear, and polluting the atmosphere with ingredients of debilitation and death.
In the famous Smyth report on "Atomic Energy for Military Purposes," 1945, the author states that "the technological gap between producing a controlled chain reaction and using it as a large-scale power source... is comparable to the gap between the discovery of fire and the manufacture of a steam locomotive." Such a statement from one of the highest scientific authorities on atomic energy should temper enthusiasm for immediate industrial application of this energy source. Yet speculations, rational, fanciful, and fantastic, continue to fill the popular press. But Wall Street has shown no panic: securities of coal companies, metal industries, and utilities move with the general trend of the stock exchange. Petroleum companies are numbered among our richest and most progressive corporations. The railroads continue to haul coal and oil, and it looks as if people will continue to drive gasoline-powered automobiles for some time.

Existing industries are unlikely to compete wildly for the first atomic power plants that may become feasible. Industry must be assured of an ample supply of this (or any other) new energy source before investing large sums of money in installations for its utilization. The natural radioactive elements from which atomic energy can be obtained are not abundant substances. Indeed, the necessary nuclear decompositions are limited to a few isotopes of elements of very low and very high atomic number. At best, the presently known supplies could provide the world's power requirement for but a limited time—not long enough to justify any long-range planning. Even if industrial atomic energy were being utilized, there would always remain the threat that, in time of war, government would commandeer all supplies of nuclear fuel. It appears, therefore, that sources of the raw materials of atomic energy are too limited and continuity of supply too unreliable for dependence for industrial energy. Rather, in the light of present knowledge, it appears that our present sources of energy will continue to be utilized for the next few centuries, probably increasingly augmented by a growing use of solar energy.

Finally, little cause has arisen to alter an opinion expressed by the author and published in the press on August 9, 1945, the next day after the explosion of the A-bomb over Hiroshima. That opinion follows:

"A limited practical application of atomic energy is likely within the next 10 to 20 years. However, the uranium-containing minerals are relatively rare on the earth. No important sources are generally known within the confines of the United States.

"Approximately one pound of the rare isotope U-235 is equivalent to 1000 to 2000 tons of coal. On this basis, it would take about 1,100,000 pounds of the rare isotope to replace the energy supplied annually in the United States by all the coal, petroleum, natural gas and hydroelectric power. This would require an annual production of 100,000 tons of the highest grade concentrated uranium ore.

"At best, the presently known uranium deposits could only supply the world's energy needs for but a limited time, certainly not in terms of years. Possibly other elements more abundant and more easily obtained than uranium will prove better suited for the commercial production of atomic power. In spite of atom-splittin
possibilities, there is no prospect of the organic mineral fuels going out of business."

MINERAL INDUSTRIES
EDUCATION

There is uniform agreement among men concerned with national defense that technological education and research must be kept at a high level in order to maintain our strength.

Instruction—In the field of mineral industries education the emphasis on the fundamentals of mineral technology—geology, mineralogy, chemistry, physics, and mathematics—will continue, but more selectivity in the materials presented will be necessary because of the vast amount of training and information that must be crammed into a 4-year college course. Mineral industries curricula will be lengthened to five years long before 1975. Certain phases of physical chemistry are of special importance to a student of the mineral industries, and the same is true of the other basic fields. Selective scientific fundamental training is essential, but greater emphasis will have to be placed on training the students in the techniques of reasoning and application of information—the integration of knowledge. A man working in the field of the mineral industries cannot be successful in our present and future activities on a world basis unless he has some training in the field of geography and of human relations and develops an
understanding of the needs and attitudes of the people with whom he works, both here and in foreign countries. Irrational human behavior will not work under any system of government. And there must be a balance between human and intellectual aptitudes. Human relations are at least as important a subject-matter field as are the fundamentals of science, and greater emphasis must be placed on them than at present (Fig. 2).

The Air Force has selected our School, one of seven institutions of higher learning, to give special meteorological training to Air Force men. The Air Force sent us the first group of 35 graduate students in meteorology last September, and a second group is planned for September, 1952.

A very fundamental reason for requiring that each student take the rather heavy loads involved in mineral industries curricula is the necessity of training technical students to work at a high level of pressure and accomplishment. The pace of present-day industrial research, development, and production requires that the technical man who is to succeed must devote his entire attention to his daily tasks and problems. We deem it advisable, in fact necessary, to train our students to meet high demands on their energies and attainments in college in order that the training will carry over in industrial activities. The wisdom of this procedure has been amply proved by the gratifying reports which we have from our graduates. They have regularly reported that the training received has fitted them, not only technically for the work which they have undertaken, but in the habits of intensive study and work and discipline engendered by our intensive curricula and
standards. We must set our sights high in mineral industries education in order to interest students of superior intellect and ambition, and to create an atmosphere of accomplishment which will serve as a stimulant to students of lesser capabilities.

Conventional 8-semester curricula have outlived their usefulness in the mineral arts and sciences. Students in these fields must be exposed to new and expanded technologies with each succeeding year, and they must not be graduated blind to the grand scheme of the world course of events.¹ It is clear that nonsectionalized curricula are in the offing for the first two years of college work and that properly qualified students will spend three additional years in any one of the several mineral industries curricula leading to undergraduate degrees, long ere 1975.

Research—One very essential condition for maintaining our national strength, whether for peace or for war, is that research in the mineral arts and sciences, which is basic to all technological progress, be kept at a high level. In fulfilling this condition, we must maintain a continuing supply of fundamental knowledge and assure a continuing flow of competent young earth scientists, mineral engineers, and mineral technologists into industry, university, government, and the armed forces. This will be accomplished by continued and strong support of basic mineral research, suitable for


the training of graduate students, and an expanded program of so-called applied research.

The School of Mineral Industries is uniquely fitted to engage in research in the minerals field. There are on our staff internationally known authorities in each of the subject-matter fields. No research program can ever be successful without trained specialists who are enthusiastic in solving the problems of the times. The co-ordination of the work of the Departments of Earth Sciences, Mineral Engineering, and Mineral Technology make possible an integrated research program that has no equal in the country.

The physical facilities for research are being improved continually within the School. While the present laboratories and workrooms are well equipped, there is a rising need for additional space and special facilities to carry out new mineral research programs. As the easily accessible and richer deposits are depleted, the ability to utilize the lower-grade deposits will depend on the strength of the country’s research programs.

Other research advantages should be stressed besides those which are available on the campus. Pennsylvania is one of the oldest and most important mineral-producing states. In most years minerals make up about two-thirds of the primary wealth produced. There is every type of mineral development in Pennsylvania which can be found anywhere in the world. Type studies of every conceivable mineral problem can be made within 200 miles of State College. No research center could be more advantageously located.

Extension Training—Any estimate of the types of training that Mineral Industries Extension Services will
provide in 1975 and 2000—both for the mineral industries workers of the Commonwealth and for other individuals, agencies, etc., both within and outside of Pennsylvania—must necessarily be purely speculative. Nevertheless, there are certain basic premises, predicated on the continuance of present trends, that will affect both extension and correspondence training in those years.

In regard to the mineral industries of the Commonwealth, the following conditions will exist:

First—all mineral industries will be highly mechanized, and completely technical—which will mean fewer workers possessed of superior skill. These workers will require training in mechanical electrical principles, as well as in technical and operational procedures. By 1975, this trend will be well developed in the petroleum refining industry, partially developed in the coal mining and metallurgy industries, and will be in the beginning stages in the ceramics industry. By 2000, all of the mineral industries should be well developed in this respect.

Second—only intelligent, competent and responsible workers will be permitted to serve in positions of importance, for example, in control jobs. All such workmen will be high school graduates or better. This trend is becoming more pronounced, and it should be well developed in all industries by 1975.

Third—a high quality of supervision will be required; primarily, because of the highly technical-mechanical types of operational methods in use; and, secondarily, because of the high quality of workers to be supervised. Supervisors will be either college-trained or high school graduates with “know-how” developed through years of experience. The degree to which the quality of supervision will have advanced in each of the mineral industries by 1975 and 2000 will be dependent on the degree of technical and mechanical advancement attained.

Worker training programs will be largely of the “specific application” type; for example, single-course applications for specific job phases, with prerequisite training where necessary. All job phases of each mineral industry will be studied, and courses will be devised for those phases that lend themselves to our type of training. This study and course development should be completed for all of the mineral industries and be operative by 1975. A succession of specific application courses will take the place of our present 3-course curricular training in certain fields. The academic level of the course work will be higher than at present—on a level with the needs of the specific jobs.

Supervisory training programs will be developed to a high degree, chiefly because of the need for high-grade supervision. By 1975 many companies, and by 2000 every company of any size, will have a supervisory training program with a definite plan of progression for each supervisor, both new and experienced. In this respect, the term “supervisor” applies to department heads as well as to operation supervisors. These programs will be of the continuing type, to be taken by a supervisor throughout his entire supervisory career, with lapses each year for vacations and for periods of application of those supervisory principles developed in the training program.
Application of extension classes will be either through state-aided programs in centers where employees of many companies will attend, or through company-sponsored programs restricted to employees of the sponsoring company. The latter type may well predominate by 1975 as consultation service is provided whereby training plans for all employees of a company, both of worker and supervisory capacity, are worked out between College staff members and company officials.

Training work conducted in co-operation with state and local educational agencies—that is, area centers serving many companies—will still be offered in 1975 and 2000 on an invitational basis to workers, in their home localities, without pressure to attend, provided that state and federal legislations do not impose controls which will disturb such "free enterprise" education. The extent to which such service can be provided will depend on the continued support by the College of our type of extension training. Where limited numbers prevent utilization of state aid, small-fee classes may be operated.

Company-sponsored programs, both for workers and supervisors, will continue to grow in number and importance, and these will be fee training programs, with staff members added to take care of additional programs as these are developed. By 1975 "partial coverage" of the mineral industries in the State by this method should be possible; by 2000 "almost complete coverage" should be the status. Again, limitations imposed by government regulations may affect adversely the proposed operation of these college-industry training programs.

In regard to other individuals, agencies, etc., both within and outside of Pennsylvania, certain trends are evident:

First—there is a growing awareness on the part of educators of the need for more thorough training in our public school systems of certain mineral industries subjects, chiefly geography, but also geology, which subject is included now in secondary education in England. Training of teachers who lack the qualifications to teach these subjects will be done in extension classes serving areas or by correspondence study. Both of these methods are operative now, and will probably continue to grow until the maximum need is satisfied, possibly in advance of 1975. Whether this trend will include adult groups not associated with public school systems is not evident at present, but such interest could well develop as the general public becomes aware of the value of such knowledge in everyday life.

Second—the mineral economics field with its correlation of engineering, technology, and economics can be of great value to mineral industries supervisors. A start has been made on the development of this extension service, and by 1975 an aggressive program, organized through the consultation service for companies, should be in operation in many places throughout Pennsylvania. The offering of this program by correspondence to individuals or company groups outside of Pennsylvania will parallel the extension class development within the State but will, naturally, involve fewer students.
Third—governmental agencies, of states, the federal government, or of foreign countries will be served in increasing amount through correspondence study in those mineral industries subjects of particular value to the agency employees. An example is the service that is now provided 450 employees of the United States Weather Bureau in meteorology studies. There is no other particular course field that would appear at present to be comparable in value to meteorology for such agencies, but the development of such service for other course fields will follow the appearance of any demand.

Fourth—service to the armed forces, defense, and security groups of the state and federal government can be developed in a parallel manner to that described under the third trend above. At present we have had no specific group call for training service, although many individuals in the United States Armed Forces take correspondence courses in a wide variety of subjects.

Library—Scientific progress is not spontaneous; it develops organically from the combined efforts of generations of scientists of the past. The basic tool of research is communication, that is, the printed accounts of previous research. Without thorough knowledge of the literature, researchers will increasingly waste efforts in duplication of previous work and in retracing dead-end roads explored by others in the past.

Thorough knowledge of existing literature becomes increasingly difficult in view of the vastly increased productivity of scientists, and the large number of researchers in each and every field of intellectual endeavor. The rate of future progress will be some sort of equilibrium between the productive life span of scientists and the amount of time spent in preparative learning necessary for new discoveries.

In order to facilitate literature surveys by 2000 A.D., all publications will be issued as microprints combined with automatic, punch-card cataloging. Library services will be to a great extent automatic, so that the user can dial a specific subject number, whereupon he will receive through a conveyor system a pack of cards with all the pertinent literature on them. Thereby, the time-consuming job of searching through volumes of dozens of journals will be eliminated. Moreover, an enormous amount of space will be saved in libraries, as well as sorting and general handling, binding, repair of books and bound journals.
MINERAL POLICIES

At present the United States does not have an overall, co-ordinated, long-range plan of mineral development and mineral use. If we are to maintain a strong economy we must be aware of the extent of our existing resources and the demands the future will place on them. Such an awareness necessitates a survey of the world’s mineral resources; we cannot confine our efforts to this country alone, for no country is self-sufficient in its mineral needs. Our way of life is based on a mineral economy; we can maintain our high standards of living and a strong world position only if our use of the non-renewable mineral resources is consistently maintained at a high level. Such a sound utilization of mineral resources can be achieved only if we know, for a period of many years, how much of each resource we can obtain in this country and how much must come from abroad. This knowledge can come only from a national mineral policy based on complete understanding of the world’s mineral resources.

Minerals are a vital part of our way of life. The vast industrial expansion of modern times would not have been possible without a corresponding increase in the output of minerals. Mineral production has been increasing rapidly for a hundred years, and there is no indication that a peak in mineral consumption has yet been reached; the great danger is not a lessening of the demand for minerals, but rather a lessening of the supply. Modern mineral exploitation began and has developed most rapidly in eight industrialized countries—the United States, Great Britain, Russia, Belgium, France, Germany, Italy, and Japan. The industrial and military strength of the countries of the world and their development of a higher standard of living is increasingly dependent on a growing development of the world’s mineral resources and their availability to the world’s industrial nations.

Endowed with a rich heritage of mineral wealth, the United States has for decades led the world in the production and consumption of fuels, metals, and non-metallic minerals. Without this mineral wealth, native and imported, the United States could not be one of the leading nations today, nor could the citizens of our country have attained the highest standard of living achieved anywhere in the world. We must remember, however, that our own resources are being diminished at a constantly increasing rate, and that we have never had some of these resources in anything like the quantities we have used and will use. We must constantly expand our search for minerals both at home and abroad. The importance of minerals to the nation and to the world is recognized in the Point IV program through which plans are being formulated to give technical assistance in finding and developing the mineral resources of the world.

Minerals are fundamental to the world’s economy; all phases of our society depend on them. Agriculture has passed from organic fertilizer and animal power to
mineral fertilizers and metal machines, powered with mineral fuels. The machinery and products of industry are mainly made of metals derived from minerals. We are truly living in an age dependent on a constant and balanced supply of minerals.

Mineral depletion is a modern dilemma. The problem of supplying the world's industries in minerals is becoming acute. The industrialized countries of the world are not self-sufficient and must import minerals from distant lands. This has produced an intense worldwide interest in minerals, an international competition for mineral raw materials not anticipated a generation ago. The seriousness of the depletion of our resources becomes more apparent daily and increases constantly with the growth of world population. This situation is bad enough in times of peace, but it becomes far more grave with the realization that successful preparation for defense or conduct of war depends on the full functioning of industries based on mineral use. The people of this country and of the free nations of the world now find themselves in an emergency of unknown duration, the successful outcome of which depends largely on their possession and utilization of adequate mineral resources.

Mineral industries are dynamic complexes; this produces many problems which affect the stability of nations and of national and international economies. For example, today we hear much discussion that steel production must be increased to 120-130 million tons a year in our country. However, the magnitude of such an undertaking in utilizing the world's resources, the number of people involved, and the changes in our economy and those of the nations from which we do or will obtain raw materials are essentially never discussed in even the most elementary fashion. To produce a ton of steel requires more than a ton of iron ore, nearly two-thirds of a ton of coke, a third of a ton of limestone, precious flint clay refractories, half a ton of scrap steel, and smaller but significant quantities of the ferro-alloys. To expand steel production 20 to 30 per cent requires a corresponding increase in the production of every one of these vital raw materials. This will involve, directly or indirectly, nearly everyone in our country, as well as many people in foreign lands.

As new mineral areas are developed here or overseas, such factors as accessibility, topographic setting, climatic conditions, transportation patterns, distribution of people, regional economic characteristics, and political factors affecting areal relationships are of as great importance as the availability of the mineral resources themselves. Mineral depletion causes an unfavorable change in the economic life of the community. This produces major social and economic problems. In the past, such depletion has developed too many "ghost towns" such as Tonopah-Goldfield and the Comstock Lode in economically distressed areas in which complete disruption of normal living conditions has taken place. We must be certain that our way of life will not be destroyed, locally or on a national scale, as we deplete our non-renewable mineral resources. If our society is to continue its prosperity and to develop further in the future, there is essentially nothing so vital to us as an accurate appraisal of the nature, quantity, and distribution of our own and the world's mineral resources. The utiliza-
tion of minerals to satisfy our basic human wants is now a matter of national and international concern and must be guided by a sound and timely national mineral policy.

A U. S. Department of Mineral Industries—The development of a sound national and international mineral policy will depend largely on the establishment of a sound governmental organization. This governmental organization should be independent and centralized in scope. This means a United States Department of Mineral Industries with a Secretary of Cabinet rank. Only if a strong policy group is developed can a wise utilization of minerals follow. At present there is a growing multitude of agencies, each trying to secure minerals and develop and control mineral regions, mineral research, and mineral utilization, which means that we did not benefit from our devastating experiences in handling minerals in World Wars I and II as well as the peace efforts following these wars. There is a continual grouping and regrouping of organizations in Washington so that no one of them has a clear concept of duties and responsibilities. The recent establishment of the Defense Materials Procurement Administration (a temporary agency) may have helped a little but is certainly far short of an answer to the problem.

Mineral Policy Researches—There is urgent need for a national mineral policy. A sound policy must be based on facts. Some of these facts are now available; others will have to be secured by field studies and interpretation of existing data. The following points are basic to the establishment of a sound mineral policy for the nations of the world.

Phase one:

1. A survey of the world's mineral resources.
2. A survey of the world's mineral demands, including an estimate of future demands.
   a. Change of the mineral position of creditor mineral nations to debtor mineral nations.
   b. Migration of mineral exploitation in the world and its effect on the stability of national and international economies.
   c. Effects on the economy of a region or nation in the development of a new mineral or in the new application of a known mineral.
   d. Distribution of mineral resources as a factor in industrial location.
   e. Area studies of problem mineral regions, such as the declining Bradford Oil Field of Pennsylvania.
3. An evaluation of national and international demands for minerals in relation to existing resources and the economic and political structure under which they are developed.
   a. Effects of wars on the rate of depletion of the world's mineral resources.
   b. Effects of a growing world population on demands for mineral resources.
   c. Conservation as a factor in mineral resources exploitation.
   d. Effects of programs of nationalization of natural resources on mineral exploitation and exploration.
e. Analysis of needs for technical education in foreign lands if our Point IV program is to be successful.

4. Establishment of a United States Department of Mineral Industries with a Secretary of Cabinet rank.

5. The development of state, national, and international mineral policies.

Phase two:

1. Implementation of the proposed mineral policy. The goal of the individual studies is in phase two in which the recommended mineral policies are applied on a state, national, and international basis to create a sound mineral economy in the world.

It is now generally understood that minerals are dominating influences in the conduct of modern warfare, that they control military strategy, are decisive factors in victory, and will be the basis of a lasting peace. Since minerals play so vital a role in the economy of nations, there must be developed a body of knowledge on which a sound mineral policy can be formulated. The necessary raw statistics are available in greater amounts than for any other class of earth resource. At the present time, the analyzing and interpreting of these data for the welfare of mankind is in an elementary stage of development. We are at the most dangerous period of our national history. If we lose the struggle, the world will have lost its most precious rights and freedoms. We must rely on more than our technical know-how. Emphasis must be placed also on the human problems of utilizing the world’s resources. Only when these aspects are evaluated can a sound economy for the future be developed.

Possibly there is nothing so necessary to the future welfare of America and the whole world than to have an accurate understanding of the nature, distribution, and quantity of the mineral resources essential to the continuing existence of mankind in a world society. The accumulation and interpretation of mineral data can make available new knowledge that will aid in the over-all development of our society. In the past, our attitude has been that our mineral resources are essentially inexhaustible. The United States has reached a point now in its mineral exploitation that we are no longer a creditor nation in many basic minerals but a debtor nation. As a result of this factor, our whole trend of thinking must change to meet the changed conditions. A new set of attitudes toward our irreplaceable resources is a very fundamental consideration if we are to maintain a strong nation and a high standard of living for our people. We also must develop a new set of criteria, acceptable both to us and the rest of the world, for utilizing the world’s minerals if we are to continue to import from distant regions the minerals which are vital to our economy.

Regional economies, based on mineral exploitation, have had in the past long periods of decline with resultant economic depression for those areas. The solving of the social problems of these areas has seldom gone beyond the giving of temporary relief funds by governments. Frequently this type of aid has perpetuated a depressed economic region. There are many
examples of this situation throughout the world, such as the coal mining regions of England, the Anthracite areas of Pennsylvania, the Joplin-Galena area of the Tristate District, the Mother Lode, the Keweenaw Peninsula, Colorado Frontal Range Complex, and others. The understanding of how a sound economy can be developed in a minerals region is one of our fundamental social and economic problems today. Working principles can be evolved by studying these mineral areas that will guide regions in the development of a permanently sound economy.

As an example, the Anthracite region of Pennsylvania, while it contains one of the most valuable fuels, has been in a depressed condition for more than three decades. The original economy of this area was based predominantly on the exploitation of anthracite. Since about 1920 the demand for this fuel has been declining. Production today is about one half that of 30 years ago. This has resulted in a loss of income for the region. Plans to develop other industries in the region have been sporadic. This area continues to be one of the economic trouble spots in the State; unemployment is essentially always highest in this area. Economic opportunities are lacking in the region; the area is losing population by having the young people migrate to other areas of greater opportunities. Unless the present problems are solved, the area will continue to decline and so affect the entire economic stability of the State.

In the bituminous coal province of Pennsylvania, the Connellsville-Uniontown Beehive Coke Region illustrates an area of declining prosperity as a result of a technological change. Connellsville was once the greatest area of coke production in the world when the beehive ovens were used. The use of the beehive oven is one of the most flagrant examples of waste in the mineral industries. With the introduction of the by-product oven about 1910 the coke industry largely moved to the areas of steel production where the coal tars and gases could be utilized. As a consequence, thousands of workers have been stranded in the Connellsville-Uniontown area. Other industries have not found the small coke towns attractive places to develop. Unemployment has been high here for the last 35 years. Mining slum areas have developed in spots. If these areas grow in number and size, the economy of the country will not remain strong.

Mineral planning is world-wide. The development of the studies to aid in the creation of a sound National Mineral Policy will involve local, national, and international aspects of mineral exploration, exploitation, and use. No policy can be sound which ignores any of these three levels of operation. For example, local problems of mineral depletion can influence greatly the developments on a national or international scale. On the other hand, our consumption of minerals is so great in both variety of needs and quality that our demands greatly influence the location and scale of mineral development. Only after a sound mineral economy is established on a working basis, can the resources of the world be made available to all of the people.
CONCLUSIONS

And so we have made a few allusions to the mineral industries problems we must overcome before the year 2000 A.D. Generally speaking, we hope that the new millenium finds that more good than evil will have prevailed; that the capitals of the world will stand undamaged by any enemy action since World War II; that by then there still will be many different national dogmas, but that their fundamental differences will seem a bit modified and of less importance; that we will have found a way out of the overpopulation menace, dictated by common sense and necessity; that we will find many changes have taken place in the past 50 years, but that they have been for the better.

But if we are to realize these hopes, we must recognize today that the United States is seriously involved economically, politically, and socially in world affairs, actually committed to near limit of national endurance. It means that if all of the economically prostrated and undeveloped nations are to have more, the United States is to have less, including raw mineral materials and foreign markets under normal economies. And are we sure that our people will have the spirit and courage to sacrifice some of our present standards of living without anarchy? The acid test will come before 2000 A.D.
Figure 3. The crucial links between nature and civilization.
The mineral industries can be an important factor in the promotion of world peace and prosperity under some definite mineral policies.\(^1\) It is up to us to co-operate with our colleagues in other countries in the development of new products and processes, but it is equally important that we aid some of the less developed countries in the use of their natural resources under the Point IV program. It is hoped that we will have progressed materially toward this goal by 1975.

The general problems of mineral industries reviewed in this circular are brought to particularly acute focus in Pennsylvania, since the Commonwealth to a large extent has to depend upon relatively low-grade natural resources and must be extremely alert to meet all the rapidly changing technological demands of our present-day civilization. It is more difficult to meet these demands in Pennsylvania than in other states, since our industrial manufacturing requirements are enormous; our mineral resources are particularly difficult to utilize without considerable work; considerable research must be accomplished ahead of this work; and quality personnel, undergraduate, graduate, and skilled labor, must be developed in advance. It means that the School of Mineral Industries has indeed a big job. It provides under one roof both pure and basic research without much reliance on other sources; it translates this pure research into applied principles; and it carries these applied principles to the industry of the Commonwealth.


Professional men in the links between nature and civilization must be *whole men* with an all embracing approach covering most fields of basic human endeavor, ranging from rough pioneering to the most sophisticated scientific and economic aspects. The training of these men is *unique development*, tending towards the integrated viewpoint necessary to meet unusual challenges (Fig. 3).

Mineral industries subject matter ranges from the Earth Sciences (geology, mineralogy, geophysics, geochemistry, meteorology, geography), through Mineral Engineering (mineral economics, mining, mineral preparation, petroleum and natural gas), and into Mineral Technology (fuel technology, metallurgy, ceramics). They are individual, interdependent, mutually supporting, and must be taught as one series of integrated curricula. The training of mineral industries practitioners of the future can never be developed piecemeal otherwise.

Thus, from the viewpoint of effectiveness, there can be no question that operation under one roof, in one School, is the best way, nay the only practicable way to turn out good professional men in the mineral industries. But it is also the cheapest way, since otherwise overlapping and duplication of courses, taught by unrelated and rival departments in different Schools, and also duplication of faculty and expensive equipment is sure to follow. Furthermore, such duplication, resulting in unnecessary frills and added useless expense, frequently leads—since money is not inexhaustible—to the unwise elimination of really necessary subject matter, the importance of which is not realized by unrelated
and far-flung departments. The service laboratories of the School, particularly the Mineral Radiation and High Magnification Laboratories, are a prime example of economical, non-duplicating, high-grade, modern instructional, and research enterprises.

In terms of wealth produced, the mineral industries are far ahead of any other source of income in Pennsylvania. To a large extent, mineral industries must depend upon themselves to provide their own backlog of applied research and, what is much worse, their own backlog of pure research. They must have a particularly specialized and competent type of personnel. Much of this is self-contained, and little help comes from other scientific or professional sources. It is necessary for them to anticipate radical and profound short-range changes and to have at all times a long-range research program on tap, which is vastly more ambitious than that required by any other industry. Finally, the tempo of development of the mineral industries is not only asymptotic, like other scientific and technological developments of the last century, but it is proceeding now at a much faster pace than recent progress in other technological fields.

This study accepts the idea of an ever-expanding United States economy during the next 50 years. However, the same minerals and more were in the United States in the period 1929 to 1940, during most of which the economy was not expanded, and it is the lack of faith on the part of many in the ever-expanding economy that inhibits the investment of private funds in long-range mineral development programs. For example, almost all of the big domestic copper expansion projects are requesting government assistance with accelerated tax amortization as a minimum form of assistance, and several firms are requesting long-range purchase contracts.

It is always difficult to estimate the cost of instruction per student. Strictly, mineral industries instruction cost well under $500 per student during the college year 1950-51, including 562 undergraduate and 145 graduate students. The staff that gave this instruction to regular students also gave instruction to about 3000 students enrolled in other Schools last year. The cost of this instruction, together with the extra cost of carrying a large graduate enrollment, would greatly lower the cost per mineral industries student. In any event the cost per student can be considered as frugal in the field of technical education.

About 8 per cent of the State appropriation from College maintenance was invested strictly in the School of Mineral Industries during the College year 1950-51. At the present writing the School receives research grants-in-aid, matching monies, and sponsored fellowships that total nearly a half million dollars, considerably in excess of the total amount of State maintenance money budgeted to all three functions of service of the School. Included in the lists are the Anthracite Institute, Central Pennsylvania Coal Producers Association, Western Pennsylvania Coal Operators Association, Pennsylvania Grade Crude Oil Association, and Pennsylvania Natural Gas Men's Association, which insures that the School touches practically every county of the Commonwealth and every extractive mineral industry, small and large alike. Grants are made by United States


Undergraduate scholarships in the School are: William Grundy Haven Memorial Scholarships, Jerome N. Behrmann Scholarships, Edwin L. Drake Memorial Scholarships, Philadelphia and Reading Coal and Iron Company Scholarships, Pittsburgh Consolidation Coal Company Scholarships, Imperial Coal Company Scholarships, Johnstown Coal and Coke Company Scholarships, American Smelting and Refining Company Scholarships, E. W. Rugh Scholarship Fund, as well as various awards of the American Institute of Mining and Metallurgical Engineers, including the L. E. Young and Coal Division awards.

Our faculty at the moment consists of 165 teachers and researchers, 3 analysts, 6 mechanics, and 12 extension supervisors. An effort was made in building a faculty to include representatives of leading universities in the United States and Europe. Public documents will show that a majority of our faculty enjoys international reputation in respective fields. It is clear that the total potentialities of our faculty cannot be realized in the national defense effort unless they have the proper space and facilities to carry on their highly technical and diversified fields of work.
Since 1928 the College, realizing the importance of unifying its program in the mineral arts and sciences, has been developing a modern physical plant for the School. The first units of the Mineral Industries building were completed in 1930, and the central wing was added in 1938. The Geology Summer Camp was built in 1937; the Coal Combustion Laboratory and the first units of the Mineral Sciences building were built in 1948. The General State Authority is currently completing the Mineral Sciences building as originally planned. Among other things, the new addition will provide for effective instruction and research in mineral beneficiation, including pilot plant units necessary to bridge the gap between laboratory and full scale operation. A third building, which will be designated Mineral Arts, is included in the long-range College building plans and will be connected to the Mineral Sciences building in due time. The Mineral Arts building will complete the Mineral Industries group as now conceived and will provide adequate space for the Mineral Industries branch library, the instrument and repair shop, mineral industries equipment demonstration and maintenance laboratories, instrument calibration, mineral industries instrumentation, constant temperature, rare elements, trace elements, physical measurements, and “magneto-mineral” laboratories, as well as some badly needed space for every subject-matter field of the School, whose service to the Commonwealth is restricted only by facilities, including physical plant. Preliminary plans for the building are on file in the Office of the Dean.

The author has visited personally nearly every college and university offering mineral industries work in the Western Hemisphere and in 13 countries in Europe and the Mediterranean Area. About 75 foreign mineral industries leaders have visited our School since World War II, as well as special missions from Russia, Argentina, Chile, Brazil, Mexico, Union of South Africa, England, Japan, and France.

Members of the faculty have first-hand contact with the industries throughout the State. The School is hypostatically united with various units of State government, the mineral industries of the Commonwealth, and the alumni body. The co-operation and aid of these various bodies is adequate testimony as to the merits of the case; furthermore, representatives of these bodies have reaffirmed their faith in, and endorsement of the current program of the School in recent weeks. These leaders have indicated time and again that the industries have a high stake in our program, that they cannot neglect this enterprise which widens their markets and increases productivity. They ponder the reasons for the fall of the mineral industries studies initiated in 1863, their rebirth in 1896, finally vitalizing in 1928, and always with the firm conviction that the program of 1951 should have materialized in 1900. In any event, the progressive, unified, decentralized program of 1951 is the best that can be conceived, and is prosecuted with efficiency and economy.

The story of Pennsylvania’s School of Mineral Industries, including its long-range objectives, is now in black and white, simple, direct, coldly factual as possible for the good of the people. It has not been based on class-
room theories or empire building, but rather on logic and common sense, in turn based on the needs of the Commonwealth in keeping with the organic Land-Grant Act. The study extended over a period of nearly 24 years, and we have learned that progressing satisfactorily is only a happy circumstance.

It seems to be reasonable that in order to meet all of its responsibilities, Pennsylvania’s School of Mineral Industries must redouble its efforts and must increase not only the quality, but the quantity of its work. If it wants to point to the problems of the year 2000 it must be ready to crystallize its ideas as to how to meet these problems in advance of 1955, the beginning of the second hundred years of The Pennsylvania State College. The challenge must be met with glorious vision.