

Wanted

MINERAL INDUSTRIES COLLEGES

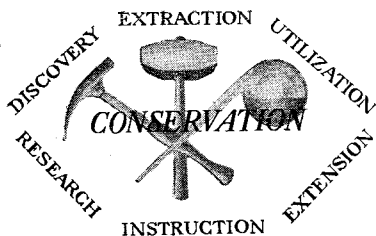
EDWARD STEIDLE



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Mineral Industries Experiment Station
SCHOOL OF MINERAL INDUSTRIES

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STATE COLLEGE, PENNSYLVANIA



WANTED: MINERAL INDUSTRIES COLLEGES

EDWARD STEIDLE

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P R E F A C E

*This circular is the third and last of a series. The first, Circular 31, **ROOTS OF HUMAN PROGRESS**, reflects on the generation of tomorrow whose general education will shape its destiny. Science has made such magical strides that the average citizen has developed an almost worshipful attitude toward it without really knowing its nature. Youth must not regard science as the be-all and end-all of education to the point where they neglect the Good Life and the acquisition of a knowledge of the principles of social and spiritual relationships. Progress does not automatically make people civilized; consequently, it is necessary that emphasis be placed on the importance of cultivating in young men of science warm convictions about liberty, a wise and understanding heart, and love for the humanities.*

*The second of the series, Circular 33, **A PHILOSOPHY FOR CONSERVATION**, attempts to explore basic principles in conservation of resources, human as well as natural. It points out the importance at this time of taking stock of where we stand on ten great issues: (1) ethical, human behavior, (2) fundamental education and research, (3) unity of purpose, (4) military manpower needs, (5) adequate stockpiles of minerals and metals, (6) inventory of mineral resources, (7) inventory of soils, (8) efficient use of soils, (9) national mineral policy, and (10) subsurface exploration.*

It is hoped that Circular 35 will provide stimulation of thought on the question, "What can be done about these needs in an emotional and irrational world?" Herein is disclosed the story behind Pennsylvania's School of Mineral Industries, the progress in shaping courses in mineral arts and sciences with the premise

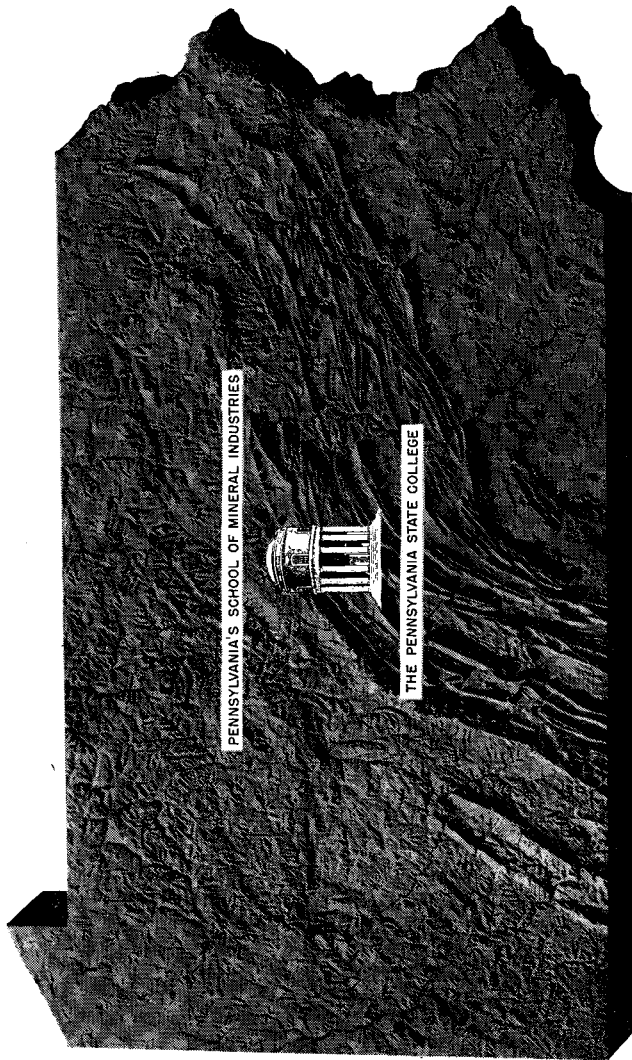


Figure 1. Potential primary mineral wealth in every hill and valley, surface and subsurface, awaits initiative, technologies, skills, teamwork—human resources.

that while there might be human progress without civilization, there can be no permanent civilization without conservation, and no conservation without education. It is hoped that the School's experiences will be of aid to mineral industries educators everywhere, especially in sister land-grant institutions where education in the mineral arts and sciences is a solemn obligation under the terms of the organic Land-Grant Act.

The co-operation, counsel, and help of the staff of the School of Mineral Industries is gratefully acknowledged.

*Edward Steidle, Dean
School of Mineral Industries*

January 1, 1950.

INTRODUCTION

Since the beginning of the 20th century the world has been trying to find a new political system, even as it did at the end of the 18th century. The French Revolution instigated the destruction of absolute monarchies when Napoleon unwittingly showed the masses the advantages of freedom, as opposed to the abuses of unlimited power by the imperialists.

In spite of advances in culture, science, and technology during the past 50 years, there is a hangover of laissez-faire economic principles. Failure to divert the trends of minority pressure groups has caused two world wars and is the basis for the current social unrest and turmoil. In the ebullition of ideas there have risen to the surface the dregs of ideas, old and new—Nazism, Fascism, Russian Communism—a hodgepodge of imperialistic, socialistic, communistic and capitalistic maneuverings where state monopoly of capital enables ruthless exploitation of the masses.

The United States owes much of its industrial greatness to the work of pioneers in the mineral industries. The task of the pioneer was to locate and develop in a rude way the mineral resources of the nation. Today, mineral industries leaders are still in great demand, but for a different purpose—to direct intelligent utilization of the limited, waning, submarginal mineral resources. Today the need is for trained earth scientists, mineral engineers, and mineral technologists rather than the unskilled prospectors of earlier days.

Some believe science and invention will take care of the problems of exhaustion, but it should be remembered that in a competitive world no industrial nation can exist using ersatz materials while other nations have stores of genuine raw materials. The mineral industries are in a stage of evolution. Invention, scientific dis-

covery, and research continuously present new problems; and great mineral industries colleges must be developed to prepare for these revolutionary ideas.

Everyone who can read and think should consider the needs of higher education of tomorrow—its scope, its aims, its values. Education has degenerated on all levels, and material and technical supremacy are accompanied by moral bankruptcy. Along with improved technical education there must be improved moral education. Man is not born human, he becomes so, and those responsible for the transformation are the teachers and parents. The real purpose of education is to overcome ignorance and prejudice and create an informed electorate. But all of the teaching and all of the books have not yet accomplished this.

For a short time, when we were in fear of losing the way of living which holds such strong appeal for us, we proved we could co-operate for the good of all, neglecting our own personal gains. And we accomplished so much in our concerted effort to destroy the enemy. Look! we shouted gleefully. We can make bigger and better airplanes so much faster. Look at all the guns and bullets and rockets and bombs. This war won't be so costly. There might be thousands of casualties, but with all our wonderful drugs and techniques, more men will be saved. And we indulged in mass masochism, bravely denying ourselves that little trip to the country or the vacation. We used just a cup of sugar in the cake, instead of a cup and a half. But we were becoming bored with this, and we were glad when the war ended and we could use all the gas and sugar and rubber we wished. The old car was really tired and it was about time we got a new one, and living in cramped quarters without any of the marvelous new gadgets had lost its glamour. So we called all our men home and set about working for our own selfish ends

once more. Let the politicians take care of world affairs—they know more about those things than we do and it's all too complicated for us to bother ourselves. And what if our oil and mineral reserves are getting low? The scientists will come up with something to replace them one of these days. Someone else is working on these problems: *we* should worry.

And that is just it. We *should* worry. The United States now imports from outside sources part or all of two-thirds of the different mineral varieties needed in war or peace. We must acquire a background that will enable us to cope with world politics, world economics, world-wide conservation, and world-wide use of those resources available to us. And the time to begin is now, with education. It is urgent that we check the onrush of degree-seekers in our colleges, that we contemplate our changing needs and set the sights for purer objectives modified by conditions in the world today and by the hoped-for conditions of the world tomorrow. We must cease to think of college as a pleasant but mildly stimulating way of spending the years between adolescence and adulthood. "College education" should mean thorough and serious preparation for taking one's place as a well-coordinated member of society.¹

We should begin thinking in terms of liberal education, the appreciation of all learning, no matter the professional training desired, be it in medicine, law, engineering, agriculture, or mineral industries. The scientist's approach to culture is of greater import than his ability to manipulate a microscope, compute an involved mathematical problem, or explain natural phenomena. His achievements are truly magnificent, but they can be dangerous, depending upon the theories

¹"Basic Trends in Mineral Industries Education," Edward Steidle, *Proceedings, American Institute of Mining and Metallurgical Engineers*, Vol. 9, No. 361, January 1937.

and interpretations and uses thereof. He has discovered the great possibilities of atomic fission but flounders trying to control and make this knowledge useful to the world.

We cannot expect bluntly to raise the moral level of humanity, but we can ponder seriously the implications of new discoveries. We cannot arrest material progress, we cannot swim against the stream of events, but we can hope that the moral education, more than the intellectual education, of youth will hold the attention of all schools, all universities, all nations.

Constant re-examination of pedagogy with a view to improvement is a task that must never end. In 1848 Lovett defined education as a "universal instrument for advancing the dignity of man and for gladdening his living." It is evident that mineral industries colleges must now begin to stress the intellectual education of the individual, training him to cope with moral and technical problems, laying the foundation for continued self-improvement; and before instituting such a program, mineral industries must be recognized as a great unified field encompassing many aspects pertinent to the well-being of the Commonwealth. What are some of the glaring defects, the absurdities, the paradoxes, the futilities, the problem encountered by the School of Mineral Industries at The Pennsylvania State College? Educators who have given any thought to the matter will undoubtedly come forth with individual suggestions for solution. It is hoped that this publication will provide stimulation of thought along these lines.

PORTAL TO THE PAST

Pennsylvania has been a leader in the pageant of industrial America because of her natural mineral resources, geographical location, and the ingenuity and

industry of her citizens. Brick and other clay products were manufactured in Philadelphia in William Penn's time. Ores of iron, zinc, lead, and copper were mined and smelted in eastern Pennsylvania long before the Revolution. Coal was mined on a commercial basis in the anthracite region as early as 1820 and in the bituminous fields in 1830. The first canals and railroads were constructed to transport minerals and mineral products. Oil was struck at Titusville in 1859.

A significant event occurred in 1855—the establishment of the Farmers' High School—Pennsylvania's first attempt to provide higher education for its youth. The Farmers' High School included instruction in geology, mineralogy, and assaying. In 1859 the laws of Pennsylvania transferred to the School the state geological and mineralogical collections formerly located in Harrisburg.

Well-informed people are familiar with the effects of the Land-Grant Act of 1862. With inspiring words it established state institutions of higher learning where "the leading object shall be, without excluding other scientific and classical studies . . . to teach such branches of learning as are related to agriculture and the mechanic arts . . . in order to promote the liberal and practical education of the industrial classes in the several pursuits and professions of life." The records reveal that the desire to develop the mineral resources constituted one of the strongest motivating forces leading to the acceptance of the terms of the organic Land-Grant Act in Pennsylvania in 1863.

Dr. Evan Pugh, the first president of what was then called Pennsylvania Agriculture College, was a great chemical mineralogist as well as a great agricultural chemist. He gave special attention to mineral industries education during his studies in Europe in 1859. He supervised three of the eleven theses of the first

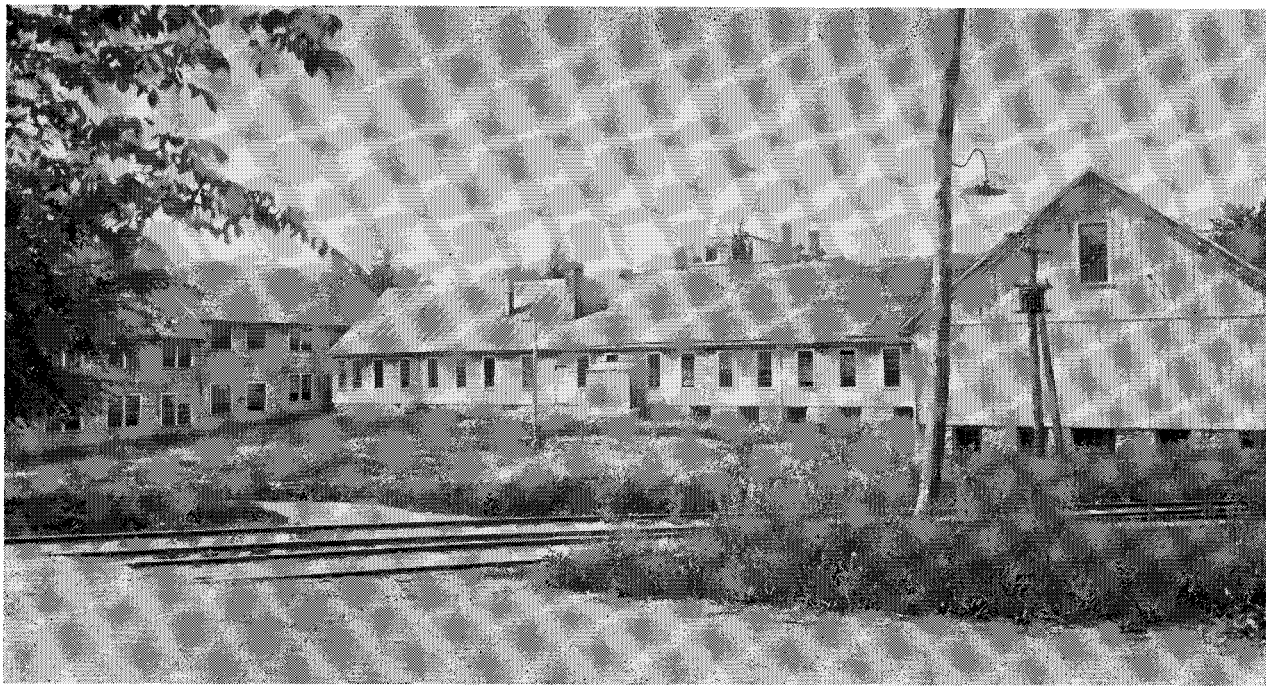


Figure 2. Home of mineral industries laboratories for thirty years.

graduating class of 1861 which related to iron smelting and fluxing materials. In 1864 he published a report on the organization of land-grant colleges in which he proposed several new professorships, including a professor of agricultural chemistry, and geology, and a professor of metallurgy, mining, and mineralogy. He also recommended that equipment be provided for instruction in the several mineral industries professions. The College Catalogue for 1867 outlined a course of study in metallurgy, mineralogy, and mining.

There is a gap in mineral industries work on the campus from President Pugh's death in 1864 to 1890 when the executive committee of the College established a curriculum in mining engineering. Pennsylvania's Land-Grant College had failed to keep pace with the State's mineral industrial progress. It is apparent that neglect was due to lack of understanding and of funds.

In 1891 the Legislature enacted laws for erecting and equipping a building for the mechanic arts, including mining engineering. In 1893 a special state appropriation provided for a department of mining engineering. But the work in mineral industries was relegated to an old wooden pumphouse (Fig. 2), roofed with tar paper, which had been moved to the site of the present power plant. In 1905 Andrew Carnegie donated \$5000 for a wooden addition to the pumphouse, the first recorded industrial grant to the College. Ten years later a special state appropriation of \$35,000 was made to construct one wing of a Mining Building—the building which now houses Textile Chemistry. The faculty struggled with these wholly unsatisfactory facilities until 1929.

Mining extension services began in 1893 and constituted what is believed to be the first formal vocational adult education work in the United States. From 1894-1899 twenty-seven extension bulletins were printed and

distributed free for the benefit of the mining industry. The records also show that a series of free lectures was delivered by a corps of teachers of the mining department "to the mine employees at their customary places of assembly upon matters of interest to them in their occupation." In 1899 legislative action cut the College appropriation for this type of education, but the faculty persisted on an unorganized basis. Organized effort was resumed in September 1919 through a small College appropriation and a grant-in-aid from the Central Pennsylvania Coal Producers Association. This program continued under the Smith-Hughes plan until July 1931 when College funds were made available for expanding extension activities into all subject-matter fields of the mineral industries in Pennsylvania.

Among the earliest technical publications of the College are four research bulletins covering brownstones, clays, and clay industries in various parts of Pennsylvania. Though these bulletins were published from 1896-1900, the Mineral Industries Experiment Station was not established until 1919. The bulletins were published only six years after the Agricultural Experiment Station was established, and the records show that they were the first technical publications published by the College relating to mechanic arts.

Penn State has been blessed by a number of excellent presidents. Three made School of Mineral Industries history. President Pugh inaugurated and directed the first program of instruction and research in the mineral industries. President Atherton, in the face of certain campus opposition, created the School of Mines when school units were first established on the campus in 1896. It remained for President Hetzel to pick up the reins of President Pugh, to keep faith with President Atherton's wisdom, and to make up for much lost time in developing Pennsylvania's School of Mineral Industries.

Efforts were made to sabotage the School of Mines and Metallurgy on two occasions, first in 1922, and later in 1928. The plan was to dismember the school and place the work under two other schools on the campus. The Board of Trustees countered the second time with a challenge—a leading School or nothing.

There were bitter pills to take. First, the School budget for the college year 1928-29 included \$60,040 for resident instruction, \$4,250 for extension training, and \$50 for research. It was soon discovered that some folks are great on co-operation if the other fellow does all of the co-operating. There were blueprints for another School building which included laboratories for graduate instruction and research in metallurgy and ceramics, including glass technology. One School did not consider Mineral Industries students qualified to take certain regular technical service courses. The School was advised without authority to restrict its extension activities to coal mining; and to let its Experiment Station die a natural death. Changes in personnel were required. There was a turn-over of five deans in the School from 1896-1928.

But a defensive operation never won a battle. And our battle was won, not by argument but by the product of better mineral industries education! The first move in 1928 was to change the name to the School of Mineral Industries, an all-inclusive, individual term, similar to agriculture, and true to the organic Land-Grant Act. In order to make a start with research, the administration endorsed a special appropriation in 1929-30 for petroleum research. This was the first research appropriation made by the General Assembly to the College for industrial research. The College Board of Trustees doubled its original estimate for a Mineral Industries building, constructed in 1929, and approved of the central wing, added in 1937 under the General State

Authority. The administration approved of working with mineral industries leaders in Harrisburg in 1931 to secure a larger appropriation for mineral industries extension and research. Governor Pinchot took over the program under the Greater Pennsylvania Council but agreed that the work in mineral industries should be carried on under the School. The Board then made funds available from the general maintenance appropriation on recommendation of the Appropriations Committee to employ a director of research, a director of extension, and a professor of geography. The Board approved wholeheartedly of a progressive school, including the present decentralized, unified plan of operation.

Too much credit cannot be given to the earlier faculties of the School who struggled against so many obstacles, the lack of public interest and support, and the lack of appreciation of the stupendous role which minerals would play in the development of national industry and its function in two international wars. But these few men saw the possibilities which lay ahead and they had the persistence to triumph over temporary disappointments. They laid the foundation upon which the School of Mineral Industries is built.

Thus, the story begins, a story which has much in common with those of many land-grant colleges and state universities.

THE LOST CHAPTER

In the fall of 1937, the Department of Mining at Penn State was being reorganized and the department records were moved to the Records Room of the School. An inventory of the contents of the vault disclosed six folders of records that had been forgotten for 27 years. These files, apparently preserved by former Dean W. R.

Crane, plus the recollections of several former members of the Association described below, unfolded the "lost chapter" in mineral industries education.¹

It was apparent at an early date in technical education that an association of mining schools with common interests and problems would have definite value. By 1902 sufficient interest had developed in this idea to cause the holding of a preliminary meeting for the purpose of organization. The first meeting was held at the Montana School of Mines on September 4, 1902. At that time, officers were elected and resolutions were adopted that there be formed an organization to be known as the National Association of State Mining Schools. The object and purpose of this Association was to advance the interests of state mining schools in every way, particularly by promoting legislation for the benefit of such schools.

The second meeting was held September 10, 1903, and a resolution was passed that the American Mining Congress petition the U. S. Congress to provide for the maintenance of one institution in each state, the purpose of which would be the giving of instruction in subjects related to mining and metallurgy and for carrying on investigations in these subjects. In addition to this, it was proposed that the American Mining Congress should petition the President to leave the collecting of mineral statistics to the U. S. Geological Survey where the work could be done by people familiar with mining.

After this session a successful attempt was made to enlarge membership by sending letters to various mining schools. As a result, the first annual meeting was held December 29, 1903, and a constitution was adopted. The object of the organization was stated in the constitution as follows: "The object of this Association shall

¹"The Lost Chapter in Mineral Industries Education," Edward Steidle and W. M. Myers, *Mineral Industries*, May 1942.

be to secure co-operation and united effort for the advancement of the interests of state mining schools in every possible way."

At the second annual meeting in November 1905 the Mondell Bill was endorsed. This bill provided for the payment of \$10,000 annually with an annual increase of \$1000 to a maximum of \$20,000 to schools of agriculture and mining. The appropriation was to be expended for instruction, research, and experiment in the fields of mining, metallurgy, geology, agriculture, forestry, irrigation, sciences, and conservation. The Association conducted a campaign for the passage of this bill, but little or no support was secured from other sources and no action was taken by Congress.

After this initial setback the activities of the Association began to bear fruit, and early in 1908 support for a school of mines bill became appreciable. Mr. Hoggot of Colorado introduced the Association's bill in Congress, Mr. Sturgis of West Virginia introduced another, and Mr. Foster of Illinois prepared a third. However, it was finally agreed that best results would be obtained if Mr. Foster were to draw up one bill incorporating the best features of all three bills.

This bill, S3764, accompanied by Report No. 583 of the 60th Congress, April 30, 1908, differed from the earlier Mondell Bill in that it requested aid for mining schools alone. In all other respects, financing and objectives, it was quite similar. The bill was endorsed by Mr. Dick from the Committee on Mines and Mining, by Charles D. Walcott, former Director of the U. S. Geological Survey, by the Association, by the American Mining Congress, by the Agricultural Association, and by the Association of State Universities. Further comment on Bill S3764 is contained in the Congressional Record, Vol. XLII, May 15, 1908.

In spite of the able manner in which the proposed

legislation was introduced and the validity of the arguments in its favor, it was not carried to successful completion. The Land-Grant colleges and mining schools were denied the opportunity of operating under its provisions. Recollections of former members of the Association indicate that a diversity of interests and a lack of local organizational support by the majority of the land-grant colleges contributed to the decline of active participation. Even today, mineral industries activities on many campuses are distributed without unified control. Naturally this leads to a certain amount of competition, and combined support becomes difficult to obtain. One member of the Association suggested that certain Washington officials took the stand that the Morrill Acts included mechanic arts and that the proration of the funds provided by the Acts was in the hands of the several states.

The caliber of the 48 men active in the Association was of the best and most of the leading educators and technical men of the day were included in this group. The Pennsylvania State College was represented by President G. W. Atherton, Dean M. E. Wadsworth, and W. R. Crane, the subsequent dean.

The Association called a meeting on December 11, 1909, for the purpose of determining what course to pursue relative to the passing of legislation in the coming session of Congress. Only six people were present. November 15, 1910, the secretary sent a letter to members requesting their opinion as to the advisability of making an active effort for the passage of a bill during the coming session of Congress, or postponing action until the organization of the next Congress. At this point the file closes.

NIGHTMARE

Mineral Industries education as an entity, again and again has sought recognition, always to be turned aside or ignored.¹ The incident mentioned in *Lost Chapter* was only the first of a series of disappointments.

The Land-Grant Act is camouflaged here and there in the name of progressive education. A new interpretation may be in the best interests of society in so far as the goose is not killed that lays the golden egg. The primary objective of the act is still "agriculture and mechanic arts" but mechanic arts is not alone mechanical arts or engineering. Mechanic arts was used in a broad sense as a symbol of creative effort in locating and winning the fundamentals of existence — plants, animals, and minerals — from Mother Earth, their primary processing and treatment into foodstuffs and raw materials of industry, their manufacture into useful articles of commerce, and, last, their distribution and utilization. Significantly the great agricultural industry is now at least half mechanic arts.

The Association of Land-Grant Colleges and Universities has neglected the mineral kingdom shamefully. The proceedings of the Association do not include any papers whatsoever on mineral industries or education in this distinct subject-matter field. There has been only one important office holder in the Association who can be identified as a mineral industries educator. The School of Mineral Industries has not had an opportunity to represent the great mineral industrial Commonwealth of Pennsylvania at a meeting of the Association since 1904. The Proceedings of the 61st annual convention, 1947, show a membership list of 425 members, two of

whom represent the mineral industries. Yet an examination of catalogues of Land-Grant Colleges and universities shows that 10 have schools of mines or colleges of mining, 6 of the schools of mines are in charge of deans and the balance in charge of directors. Four western states and one eastern state maintain independent schools of mines, but these now embrace other branches of engineering. Schools of mines are located also at four state universities and two privately endowed institutions.

Prior to World War II, it was love's labor lost to attempt action to better the situation. In January, 1941, President Hetzel addressed a letter to the Association proposing that the dean, the director of research, and the director of extension services of the School of Mineral Industries be included in the membership list of the Association. The acknowledgment indicated that "schools of this general character have not been previously listed . . . that there will be no possibility of listing the administrative staff of the School until action is taken by the Executive Committee (Association)" in spite of the fact that two deans of mineral industries schools were listed in the membership list, 1940 Proceedings, and the director of a third school of mines is included under the membership list, 1942 Proceedings.

President Hetzel addressed the Association again in March, 1944, proposing that a paper for the general session of the next annual meeting of the Association be on minerals and mineral industries implications in the war, and educational needs in these fields. The letter was referred to another officer of the Association who, in turn, advised the College in June 1944 that the "Program Committee . . . was unable to fit a discussion on mineral industries into one of the three general sessions of the forthcoming Chicago meeting." He proposed "that the discussion be fitted into some other portion of

¹"Are Mineral Industries Educators Rising to the National Emergency?" Edward Steidle, *The Compass*, Sigma Gamma Epsilon, November 1942.

the convention, for example, engineering section," a sad situation. There the matter rests.

In February 1930 the author suggested the formation of an Association of Mineral Industries Educators, and a letter containing a tentative plan was circulated among the leading educators of the day.¹ In the main, the plan embodied the policies and activities of the earlier National Association of State Mining Schools. Enough interest was aroused by this activity to result in the formation of the Mineral Industries Education Division in the American Institute of Mining and Metallurgical Engineers (AIME) on January 15, 1932. The activities of this division are probably familiar to many readers.

In the Institute there is a long list of diverse interests as indicated by the professional divisions and their committees. The concerns of education cross-section all these activities. It may be stated frankly that the Education Division is failing to live up to its mission. Its pattern of activity is too remote from the problems encountered on the campus, and the inclination is to discuss those subjects which most closely concern the members present. An academic discussion of teaching methods of technical subjects is desirable, but it fails completely to meet the fundamental problems of mineral industries schools.

Very few mineral industries educators joined the Society for the Promotion of Engineering Education (SPEE). Following the action establishing the Division of Mineral Industries Education of the AIME, SPEE formed a Division of Mineral Technology in June 1937 in order to attract a larger membership. A recent yearbook of SPEE lists 3269 individual members. Occupational distribution of membership classes 84 members, or 2.6 per cent of the membership under Mineral Tech-

¹"Mineral Industries Education Cannot Remain Static," Edward Steidle, *Mineral Industries*, February 1943.

nology. One-half of these are metallurgists. Examination of the officers since the start of the Society in 1894 naturally displays an overwhelming preponderance of engineering talent. Among all the officials the writer can recognize but one representative of the mineral industries. That the mineral industries should occupy an inferior position in the estimation of the public and even in treatment is an inevitable result. Mineral industries educators very definitely cannot stand on their own responsibility in this society, and once again mineral industries education was pushed aside.

The guidance booklet, *Engineering, A Career, A Culture*, published by the Engineering Foundation in 1932 is inadequate and unsatisfactory for the mineral industries and does some schools more harm than good. The chapter on mining is many years behind the times, especially as it concerns coal mining, and the great field of metallurgy was tacked on to mining, giving the idea that it is an optional course. The booklet did not give recognition to the other branches of the mineral industries in spite of the fact that the AIME is one of the sponsors. It has been explained that the mineral industries copy was dictated by the members of the committee whose major interests were not mineral industries. A high official of the AIME advised the author under date of August 26, 1942, that the booklet "is now dead," yet before the end of that year an institution of higher learning in Pennsylvania mailed a copy of the booklet, together with a letter, to every high school and preparatory school in this State.

The United States Employment Service, Department of Labor, has published National Rosters of Scientific and Specialized Personnel. Description of Professional Series Pamphlet No. 2, Engineering Science, includes ceramic engineers but not ceramists. It entirely neglects fuel technologists and fuels engineers, mineral prepar-

ation engineers, mineral economists, and geographers. Pamphlet No. 6, Physical Sciences, omits mineralogists and geologists.

Attention is called to (1) a Report to the Governor and the General Assembly of the Commonwealth of Pennsylvania from the Joint State Government Commission, under date of November 1948, on Findings and Recommendations of the Committee on Post-High School Education, and (2) Report of the Joint State Government Commission of the Commonwealth of Pennsylvania, on Post-High School Education in Pennsylvania under date of September 15, 1948. The State Legislature appropriated \$50,000 for the studies.

The studies were initiated by the Pennsylvania Association of College Presidents. It is significant that not one word appears in either report that can be identified specifically as mineral industries education. The word "coal" is not mentioned in either report. Page VI-5 of the latter report makes an excellent case for Pennsylvania's mineral industrial economy but ignores the type of education, research, and extension training that is so urgently needed in the search for minerals and in their extraction, beneficiation, processing, and utilization. The study reported favorably on so-called "technical institutes" actually started fifty years ago at two points in the anthracite region, which slowly died natural deaths. The man employed to head the study and who prepared the latter report stated that "time and money limited the scope of the study."

Carnegie's great fortune came from the mineral industries. About January 1, 1949, the Carnegie Foundation made a grant-in-aid for a 3-party extension study by the University of California, the University of Illinois, and The Pennsylvania State College. Mineral Industries Extension Services at Penn State gives extension aids to many mineral industries people in California

and Illinois, yet was not invited to take an active part in the study. Failure to include Penn State's 58-year-old, on-job vocational-technical, upgrading extension program directly connected with the mineral industries and the State Department of Public Instruction under the Smith-Hughes program, in the initial planning of the study is not in the best interests of adult education. This is one instance where valuable service made available by the School of Mineral Industries was forfeited by the lack of understanding on the part of those formulating the study.

Experiences during World War II teach us that there is urgent need for a unified scheme to concentrate this country's resources on military purposes immediately when the need arises. War III, if it comes, will undoubtedly require quick rigid control, restrictions on labor, wages, profits, material—a real war economy. Past inefficiencies, waste, the need and a proposed scheme for the economic mobilization of the extractive mineral industries are outlined clearly in *The Domestic Mining Industry of the United States in World War II*,¹ published recently by National Security Resources Board.

The U. S. Bureau of Mines advises that minerals furnish between 60 and 70 per cent of the primary national wealth, that mineral industries are of great economic importance in twenty-seven states. Why is there no Secretary in the cabinet of the President, no Department of Mineral Industries, to represent the second great industry? Agricultural interests are ably represented in the federal government by a department with a secretary in the Cabinet. Further, in the various states themselves, there are departments of agriculture co-operating with the agricultural schools, the Grange organizations, the 4-H clubs to promote interest in, and improvement of,

¹PhD dissertation, John D. Morgan Jr., School of Mineral Industries, The Pennsylvania State College, 1948.

farming and farming methods. The very great contributions made to the economic development and support of the country by agricultural organizations are due directly to this set-up.

Contrast the conditions surrounding the interests of the mineral industries. Activities related to the discovery, extraction, utilization, and conservation of the mineral industries are scattered throughout various bureaus in different departments of the federal government. In the mining states, there are departments of mines which usually confine their interests to the safety and health of the mine workers. Why are there no organizations similar to the Grange, 4-H Club, and Pennsylvania Farm Show, to promote interest in mineral discoveries, extraction, utilization, and conservation? A tree can be replaced, soil for farming can be revitalized, but an ore, once mined, can never be reintroduced.

And this is the past of mineral industries and mineral industries education—a series of oft-repeated attempts to find recognition and organization—attempts that were always repudiated.

OBSOLESCENT METHODS

The word “engineering” should not be considered as all-inclusive. Perhaps it should be redefined at this time.

Various fields of learning that are indispensable to the locating, beneficiating, processing and using of minerals cannot be classified properly as engineering. For example, in locating deposits, the sciences of paleontology, stratigraphy, mineralogy, petrology, petrography, geochemistry, economic geography, and mineral economics might be involved. Beneficiating, processing, and using go beyond the normal scope of engineering to include fuel technology, physical and organic chemistry, physical and atomic metallurgy, and ceramics.

Fifty-eight institutions of higher learning in the United States offer curricula in one or more subject-matter fields of the mineral arts and sciences. Thirty-four curricula are offered in mining; 42 in metallurgy; 17 in petroleum and natural gas; 13 in ceramics; 1 in fuel technology; 23 in geological engineering; 8 in geology; 4 in geophysics; 2 in mineral preparation; and 1 in mineral economics.¹ Under given conditions, some of these curricula probably could be eliminated without the slightest retardation in the rate of advancement of knowledge concerning the science of mineral discovery, extraction and utilization, but it is no credit to mineral industries colleges that five departments of mining perished in recent years. Some of these departments may have failed, one way or another, but it was not in the best interests of the nation to let them die without attempting their revival. The causes of failure lie deeper than any individual incompetency, they lie in the inadequacy of the whole outlook and the whole method of approach, the low caliber of instruction and research being dispensed at the institutions concerned, especially in ratio to the funds and efforts being invested.

To be brutally frank, few branches of mineral industries education have a very high standing in the engineering and scientific world, occupying a step-child position as they do. Some are considered a nuisance by college administrators and therefore are relegated to basement or attic space in old buildings on the campus. Values are based on enrollment rather than the peculiar services to be rendered by graduates; consequently, departments must take what they are offered or leave it.

In many colleges and universities, the work in mineral industries is dismembered and is under the leadership of deans whose chief interests are in other fields.

¹“Analysis of Mineral Industries Education in the Western Hemisphere,” Edward Steidle, *Mining and Metallurgy*, August 1948.

Many of these men would find it difficult to define a mineral or a rock, let alone a crystal. Geology and mineralogy may be found under the Liberal Arts division; mining, mineral preparation, and metallurgy, included in a single department under Engineering; ceramics, under Engineering; fuel technology processes split between Mechanical Engineering and Chemistry. Under organizations of this type, land-grant universities included, there can be no unity; department is against department on a "divide and conquer" basis, and the work is ineffective and uneconomical. And every bit of friction costs money.

Criticism frequently is leveled at teachers, by educators and students alike. In the first place, they seldom prepare themselves to become teachers. As the student is going through school, his curriculum is outlined with a view toward preparation for work in industry. And the factors upon which he bases final decision to teach usually are locale, security, better opportunity for research, and recognition of individual accomplishment—not love of teaching, itself. And so often comment is made on a professor that "he's brilliant all right, and he knows what he's talking about, but he can't teach." Conversely, there are frequent cases of a man's accepting a teaching job because he hasn't the drive or the desire to participate in a world of industrial competition; once accepted, he can expect to remain on a teaching staff as long as he wishes, providing he commits no startlingly bizarre act which might force his resignation.

How rare the professor who can really teach, who can impart enthusiasm for a subject to a group of apathetic individuals, who is genuinely interested in the progress of the students, who can command their respect while enjoying good fellowship, a personal student-teacher relationship. How rare indeed!

Once a student has decided to work in some phase of

mineral industries, somewhere along the way he should be shown the possibilities of the field, both in teaching and in industry. And in setting up a faculty, care should be taken that routine and teaching loads are held to a minimum, that there be produced an environment conducive to harmonious relations among teachers and between teachers and students. Further, means must be provided for continued training and instruction. "The teacher cannot only teach—he must be taught. He cannot always give out—he must himself take in. He must rejuvenate his jaded faculties with new contacts with the world about him. Research and study are the only avenues to this replenishment of his soul, and hence contact with scientific research and opportunity for study are the sine qua non for good teaching. They must be made not only possible, but necessary to a good teacher's environment." (Dr. Edward Orton Jr.)

Many mineral industries instructors are not adequately trained for the work ahead of them. This fact predisposes the need for sabbatical leaves for the purpose of doing graduate work or acquiring work experience in industry. Long vacation periods must not be wasted, but must be considered the opportunity for self-improvement, for expanding the limits of knowledge. The instructor must convince himself so that he can convince others, so that they can convince still others. Results will tell the story. More criticism is needed rather than less.

A glance at mineral industries curricula shows the need for more adequate practicum work, the elimination of antiquated methods. Laboratories should be of the small unit type, in order that students may work independently and that laboratory equipment may be maintained more easily and more economically. Reference texts should be kept at hand in order that the students may consult them and then work out their own pro-

cedures for conducting experiments. Thus, they develop the ability to analyze problems and work them out to their conclusions, and the instructor becomes a guide, a counselor, easily developing a close student-faculty relationship. Classroom training, supplemented by practice in the laboratory and in industry, must arouse sustained professional interest, must point the way to the solution of the more intricate problems of engineering and of management. The responsibility for laying a good technical foundation for these young men rests with the college—that of training them in plant practices and operations devolves upon industry.

More emphasis should be placed on a thorough knowledge of modern languages, especially at the graduate level. The language requirement for the Ph.D. at most colleges is a farce—the students often get a dictionary and a simple grammar, put in some rather hard study for six weeks, and take the examination. They pass. And they go into the world with a degree which signifies a knowledge of languages and philosophy and history and humanities. And actually they have acquired only a little more highly specialized knowledge in their own field. They do not realize how the subtle nuances found in a paper written in one language can be completely lost in translation by the layman.

Standards for the Ph.D. must be raised—in many instances established. In many cases, there are no written specific regulations for the degree. There is no outline of logical requirements—and too often the candidate must waste precious time learning some unrelated subject merely because one of the men on his board of examiners is interested in this subject. Requirements for the Ph.D. should be standardized and raised to a worthy level, or they will soon be a dime a dozen. And what then? Super-Ph.D.'s?

Too many educators attach importance to the num-

ber of students enrolled in a school, a curriculum, or a course, and allocating budget funds accordingly. Since many students seeking elective courses invariably crowd the bargain counters where high grades may be purchased with a minimum of study, there is a perfectly understandable tendency on the part of some educators to lower the caliber of service courses demanded of the students to a level whereby large enrollment is obtained. Such lowering of standards is a natural result of intense competition for funds.

Classroom standards in mineral industries schools can be raised by abandoning admiration for large numbers, by completely divorcing fiscal matters from enrollment, and by removing the uncodified but realistic pressure on deans, department heads, and professors to maintain student enrollment at the expense of quality. And if it is found that requirements cannot be met in the present 4-year college period, why not extend the time to five years? If all the colleges have a 5-year course, the students who wish to work in mineral industries will have to go to college for five years. There has long been a need for adjustment to a 5-year course in mineral industries—if *all* the schools change to such a system there will be no loss in enrollment in any of them.

There is concrete evidence that mineral industries leaders and educators believe that the most effective service can be rendered by unified, sectionalized schools. Certainly mineral states whose development has been based on this industry need great mineral industries schools. Lack of a truly fundamental attack upon the problem of minerals is indicated by the fact that of the 1400 known minerals, only 300 have been adapted successfully to the economic needs of the people. Man's mind has scarcely begun to grapple with the gigantic problems of employing Mother Earth's hidden potentialities to their fullest. Yet the time can already be

foreseen when certain resources will be exhausted. There must be more concentrated effort to produce men of high mental and moral caliber to utilize and conserve these resources and to explore and prepare them for the use of others. There must be a weeding out of obsolete ideas and precepts from the curricula, a gleanings of all pertinent facts in order that the time spent at college can be utilized to the greatest advantage.

Einstein exemplifies the value of a unified and basic understanding of science. He found that physics and mathematics were "split into many specialties, each of which could absorb the short lifetime granted us without having satisfied the hunger for deeper knowledge . . . I soon learned to scent out that which was able to lead to fundamentals and to turn aside from everything else, from the multitude of things which clutter up the mind and divert it from the essentials."

By unifying the several fields of mineral industries into one unadulterated school, much needless administrative distraction can be avoided and a coherent technology can be perfected. Such a unit school should practice a philosophy of administration that gives a meaning to the "why" as well as the "how." It must be an outpost against prejudice and popular pressure because suppressing and circumscribing education are the symptoms of a degenerating society. A unified school will enable students in the branches of mineral industries to acquire a picture of the inter-related fields and to use their time so effectively that it will be possible to include in their curricula humanistic subjects so sorely neglected in present day set-ups. The state will benefit, for it will receive into its communities skilled men who are not only competent in their professions but useful citizens who can participate intelligently in all activities.

Mineral industries education now must disregard precedent, must cease its inclusion as part of engineer-

ing curricula, and establish individuality. The big flood of postwar college graduates has begun. There is a bleak job outlook for graduates in many fields, and the mineral arts and sciences appears to be one of three big fields where job competition is not just around the corner. Now is the time for the establishment of mineral industries education as a pedagogic entity.

THE VISION

Today there is unparalleled opportunity for constructive effort in the national mineral economy on the part of the land-grant colleges and universities. The matter is too important to be pushed aside. It is inevitable that in the aftermath of World War II, conscientious Americans the country over should want to take stock of national resources. Attention is now centered, as never before, on our mineral potentialities.

Opportunities and responsibilities are unparalleled and a condition exists which will not occur for another generation. Mineral industries educators cannot provide the answer without taking stock of its component parts, organizing, planning, and taking action in a real dynamic sense. The services encompassed by the various fields of mineral industries must be utilized to help in the solution of problems provided by the international emergency, the country's needs, the people's needs.

Mineral industries colleges have a vital role in technical aid to backward countries through foreign student programs, especially in the Latin Americas.¹ By helping them to help themselves develop and utilize their resources to the fullest, we will be helping ourselves. One day they may be a Godsend in a solution of the American demographic problem. They may be prepared to

¹"Inter-American Educational Relations," Edward Steidle, *The Phi Kappa Journal*, December 1945.

absorb, substantially, the excess of the industrial production of the country, thus help to compensate the economy, to avoid the degrading spectacle of millions and millions of unemployed living by government subsidies of one kind or another. On the other hand, the backward countries must effect proper labor relations and work attitude, and understand that economic independence can lead to economic poverty¹. Assistance can best be provided by supplying personnel of a high technical level who are also trained in the problems peculiar to the area in which they will operate. And conservation must be developed on a world-wide scale.

The situation in our own backyard can be greatly improved by investigation and revision of some of the present laws of taxation with regard to mining properties. In the first place, ownership of minerals is complicated by the common separation between ownership of the land and ownership of the subsurface minerals—"the owner of the land owns only as far as the point of the plow." Determination of the value of the mineral deposit is extremely difficult because of peculiar geologic complications. Taxation of mineral deposits is carried to its greatest extreme in several iron ore mining states. In some states a mineral appraiser evaluates each deposit annually, and the facts are made public at an open meeting where any firm being taxed can protest. This procedure has had a totally unexpected result. Obviously, it is to the interest of the producing companies to have as small reserves as possible. Therefore, a company will do little to discover new deposits and will keep their reserve figures to a minimum. The result is that a great deal is heard about the exhaustion of first-grade iron ores in the United States; yet the picture may not be as bad as painted. Several states have recognized this ir-

regularity and have altered their tax laws to allow the development of information relative to reserves and beneficiation without penalization of the operating company.

A suggested tax reform, which would benefit the nation by removing the penalties and hazards of investing in mining properties, might include:

1. Increased recognition in the income tax law that dividends are, in part, a return of capital. Present recognition is not adequate. A man in a high-income tax bracket may have 90 per cent plus, of his income, taken by taxation. If a substantial part of this is dividends from mineral extraction, it is possible over the passage of years that he will lose most of his income and, in addition, most of his capital.

2. Lower the tax on net profits of corporations. Most mineral industries operate in corporate form and the percentage of net profit taken by the government immediately is very high and would not be tolerable except in prosperous years. It is obvious that taxes of all kinds, severance, benefits per ton of coal or otherwise, must be studied and revisions made where necessary. Mineral industries colleges have a stake in tax problems and must furnish basic information leading to equitable solutions.

And so, the mineral industries must seek recognition as a unit—first, providing representation and protection of their interests at the seat of government, and second, establishing their places in the educational world.

Mineral industries education must be considered on the broadest possible terms. Thinking must extend beyond the campus to the public, to governmental agencies whose influence is expanding, and to the industries themselves. Accept the challenge to meet the growing needs for co-ordinated action which must represent all the various units concerned with mineral industries edu-

¹"Some Practical Aspects of Mineral Industries Education in the Latin Americas," Edward Steidle, *Mining and Metallurgy*, October 1945.

cation. Establish a broad classification of mineral industries education on a basis of earth sciences, mineral engineering, and mineral technology. Revive the National Association of State Mining Schools under the name American Association of Schools of Mineral Industries, to include all of the schools in the Western Hemisphere. Advocate centralization and unification of mineral industries instruction and research at colleges and universities where such instruction and research is provided in order that the American Association of Schools of Mineral Industries shall not perish a second time. Urge the officers of the Association of Land-Grant Colleges and Universities to organize a Mineral Industries Section, and the member schools to undertake a plan of regional co-operative, technical, professional, and post graduate training to avoid wasteful duplication. Co-operate on an equal basis with any and all societies of engineering and science, including SPEE. Secure aid of public and preparatory school superintendents and high school principals on methods of educating promising boys into the mineral industries, especially in communities where the schools depend on the prosperity of the mineral industries. Request public school authorities to provide some elementary work as early as the sixth grade covering suitable information about the mineral industries; also instruction should be provided in the science courses in high and preparatory schools which will include some experiments in mineral industries subjects in order to make youth more mineral-conscious. Publish a monthly journal similar to the Chemistry Leaflet, or the Journal of Chemical Education, for secondary school consumption. Sponsor popular radio and television broadcasts. Urge the more than fifteen major institutes and societies representing the earth sciences, mineral engineering, and mineral technology to join on an equal status in a federation or

a council, perhaps a foundation, to ensure an overflowing measure of co-operation and unity of action on necessary problems of mutual interest. Foster a close bond between the Mineral Industries Federation (Council or Foundation) and the Engineering Foundation, the American Chemical Society, and any others. Urge proper representation of the American Association of Schools of Mineral Industries and the Mineral Industries Federation (Council or Foundation) in Washington. (The Committee for Economic Development, a private enterprise, was given offices in the Department of Commerce.) Give all-out support to the Pan American Institute of Mining Engineering and Geology, and subsequent meetings of the United Nations Scientific Conference on the Conservation and Utilization of Resources.

The place to start this ambitious program? With the student, the college freshman who shows promise and interest in the problems involving the mineral world of today.

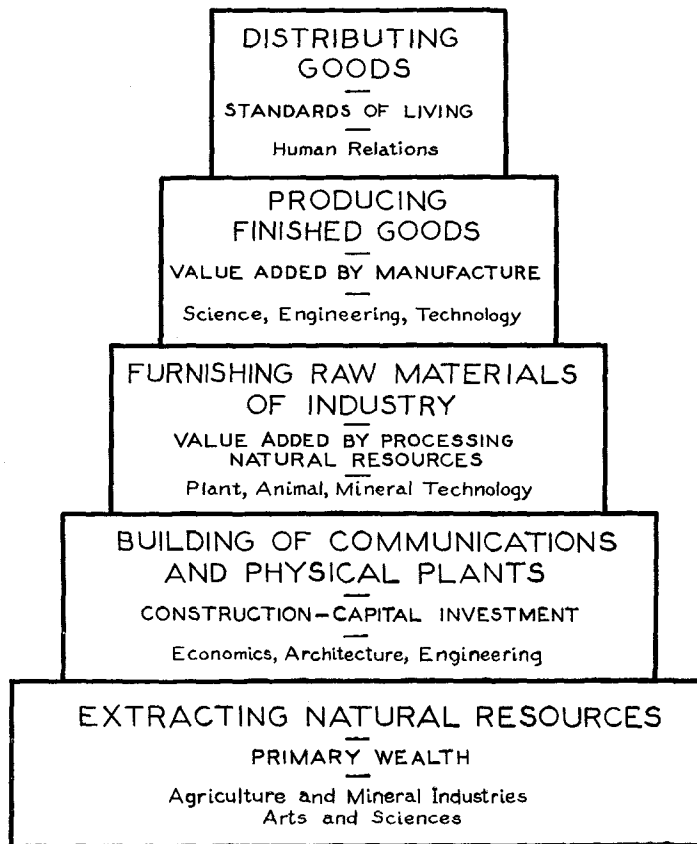


Figure 3. Human progress and the five stages of applied science, engineering, and technology.

Human progress has a visible material phase, easily discernible, that is expressed in the standard of living. This material phase, however, is only the outward expression of a spiritual or mental phase that acts as a driving force in making humanity improve both its outlook and its mode of living.

The instrument of progress is the human brain. Under the urge of spiritual drive, the brain acts as a focal point to utilize the forces of nature and put them to work for the benefit of mankind. Besides intelligence, which is an innate quality, the tools of the human brain are knowledge, experience, training, initiative, and skill. Given sufficient intelligence, the human brain can make an amazing amount of progress, provided it is supplied with an adequate spiritual and moral urge and a good technical background. It is the role of education to supply such a background.

The material phase of human progress proceeds on a series of parallel fronts, all of them interdependent to some extent (Fig 3). The rise of the standard of living, dependent as it is upon the manufacture and mass distribution of goods, is based essentially upon the development and utilization of the material resources of a country or land area. This development involves the extraction of mineral and organic products from Mother Earth, their transportation to manufacturing centers, their transformation into finished goods and their distribution to the people. All of these operations proceed continually and simultaneously on a parallel broad front, but each operation involves a series of stages, and each of these stages is conducted by human beings in whom qualities of intelligence, skill, and industry must be found in order to facilitate efficient consummation.

But the same kinds of intelligence and skill are not

necessarily required for each of the different operations. In manufacturing and distributing, two requirements are very important: (1) an intimate knowledge of machinery, its best uses, its potentialities; and (2) an understanding of human relations, personnel problems, and public relations.

In the stage of building and constructing the physical plants, and providing means of transportation and distribution, the problems are different. In this stage, the human equation is less of a problem than the conquest of hostile environments, the overcoming of natural obstructions.

In the basic stage of development of primary wealth in agriculture and mineral industries, man comes in closest and most direct contact with Nature. Nevertheless, the approaches to the problems in these two fields are different. In agriculture, each farmer traditionally has dealt with a single plot and the net result has been the accumulation of many thousands of individual efforts, each man working in his own way without much consideration of the result as a whole. However, in mineral industries, at least in the more modern aspect, the approach is different. In exploiting mineral resources, type, degree, intensity, and speed of operation have been dictated by national or international requirements. There are relatively few mines and oil fields and they are scattered throughout the globe. Their operation usually entails a struggle against natural difficulties and once exhausted, the supply is irreplaceable.

In order to be able to deal with the problems unique to their field, men training for mineral industries must have several basic qualities. They must have the ability to understand natural problems as a whole, the ability to interpret the functionings of the different fields in terms of national economy, the ability to solve problems which change from day to day, and a deep sense of ob-

ligation to exploit natural resources wisely and conserve them well. All this requires well-developed technical skills, the know-how of mechanical operations, as well as a strong, general scientific and cultural background.

How can mineral industries education best meet such difficult requirements? This function might well be compared with the natural process of the formation of a crystal. The high temperature solution, magma, from which igneous rocks originate, forms minerals by the process of crystallization. The quality of the finished mineral, its durability, its potential usefulness, will depend upon the chemical composition of the magma. By the same token the potentially highest level of mineral industries graduates depends upon the basic qualities of intelligence of the entering freshmen, a fact which should be remembered by those who are in charge of secondary education.

However, the high intelligence of a freshman class does not necessarily predicate the final achievement of the highest level of graduates. Nor does the correct concentration of a chemical solution insure the formation of a perfect crystal. There must be proper control of reactions taking place during crystallization. Temperature, pressure, and proper balance between physico-chemical fields must all be controlled for a definite period of time. Otherwise, a totally unexpected mineral may result; the crystal might be highly unstable, ready to invert and shatter as soon as pressure and temperature conditions change.

Similarly, well-rounded curricula must be provided and rigid standards maintained over an adequate period of time in order to produce a high-caliber graduate, a man well qualified to meet any exigency he might encounter. Otherwise, a mere automaton, a technician capable of only mechanical operations requiring no initiative, might result.

A comparison of the conditions governing the growth of a crystal from solution (the magma) and the development of a professional man from student material (the freshman) is given below:

<i>Crystal Growth</i>	<i>Student Development</i>
1. Proper concentration and physicochemical fields and phases (PH., etc.).	1. Adequate curricula and courses.
2. Proper intensity of crystallization (temperature and pressure).	2. Rigid standards.
3. Proper balance between various physicochemical processes going on in the solution and symetrically directed flow of nutrient solution toward crystal faces.	3. Teamwork between different divisions and curricula; co-operation between subjects; observance of prerequisites.
4. Adequate length of time for crystallization.	4. Sufficient length of education (4-year basic curriculum and at least one year of graduate work under traditional standards).

In order to obtain from a magma large and perfect crystals, without flaws, such as quartz, usable for exacting, technological purposes, it is necessary to have a slow period of crystallization. Too rapid crystallization either will produce many small and imperfect crystals, or large crystals which might be full of bubbles, flaws, inclusions, and impurities.

Similarly, the university training should be unhurried in order to obtain men of polished intellect and good judgment. Too rapid schooling produces men with little preparation, fit only for routine jobs, or men full of ill-digested knowledge who are incapable of applying their knowledge well.

Figures 4 and 5 show these factors and conditions,

both negative and positive, together with their effect as to growth of crystals from magma and the development of professional men from student material.

THE FORMULA

Assaying, mineralogy, and geology appear in ancient records as early as mathematics, physics, and chemistry. Agricola was the first author to unify the earth sciences, the mineral extractive industries and the mineral processing industries. His text, *De Re Metallica*, published in Latin in 1556, is recognized as the first technical literature.

In 1702 mining instruction was started at Freiberg, Germany. The purpose of this school was to train skilled workers, a program corresponding to present-day, on-job, vocational-technical, upgrading extension training. Formal instruction in mining engineering began at Schemnitz, Hungary, in 1763, at Freiberg, Germany, in 1766, and at St. Petersburg, Russia, in 1773. It is interesting to note that these three schools initiated instruction in mining engineering before formal instruction in civil engineering began at Paris, France, in 1775.

Early mining engineering, 1763-1900, was expected to cover all eventualities in the mineral industries. Optional curricula occurred early in the 20th Century but did not reach into all branches until after World War I. Specialization crystallized during World War II under three organic units: (1) Earth Sciences; (2) Mineral Engineering; (3) Mineral Technology, the three together constituting the mineral arts and sciences of the modern world (Fig 6).

The Earth Sciences are concerned with those divisions of natural science which relate specifically to the earth, its origin, constitution, and evolution. The term Earth Sciences is a direct translation of "geo-ology."

CRYSTAL GROWTH — — — — AND — — — — STUDENT DEVELOPMENT
UNDER NEGATIVE (UNFAVORABLE) CONDITIONS

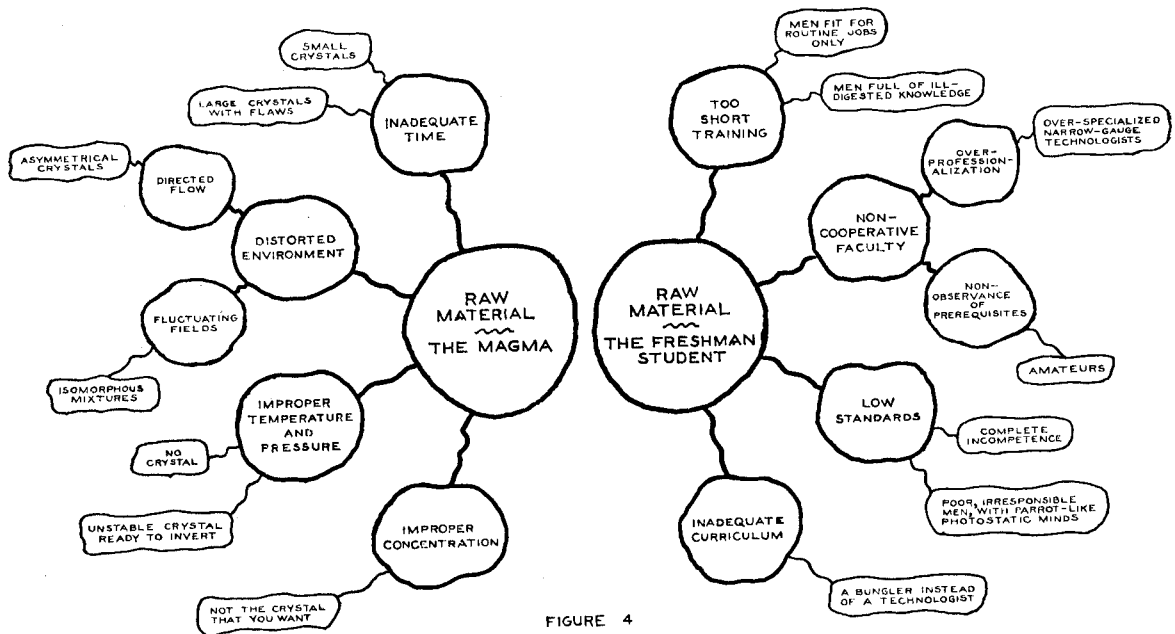


FIGURE 4

Figure 4. Crystal growth and student development under negative (unfavorable) conditions.

CRYSTAL GROWTH — — — — — AND — — — — STUDENT DEVELOPMENT
UNDER POSITIVE (FAVORABLE) CONDITIONS

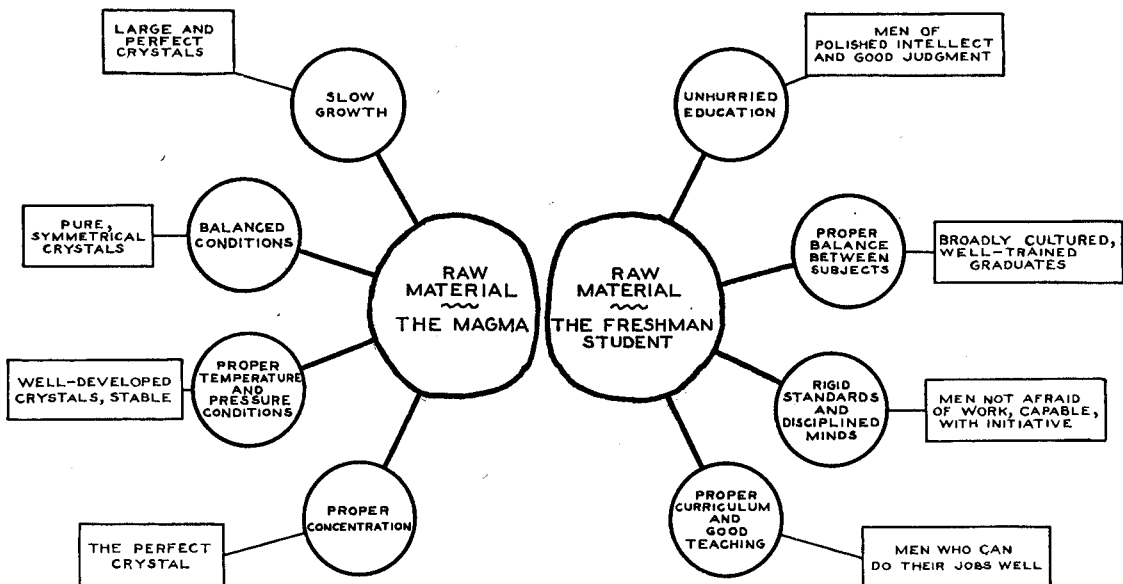


FIGURE 5

Figure 5. Crystal growth and student development under positive (favorable) conditions.

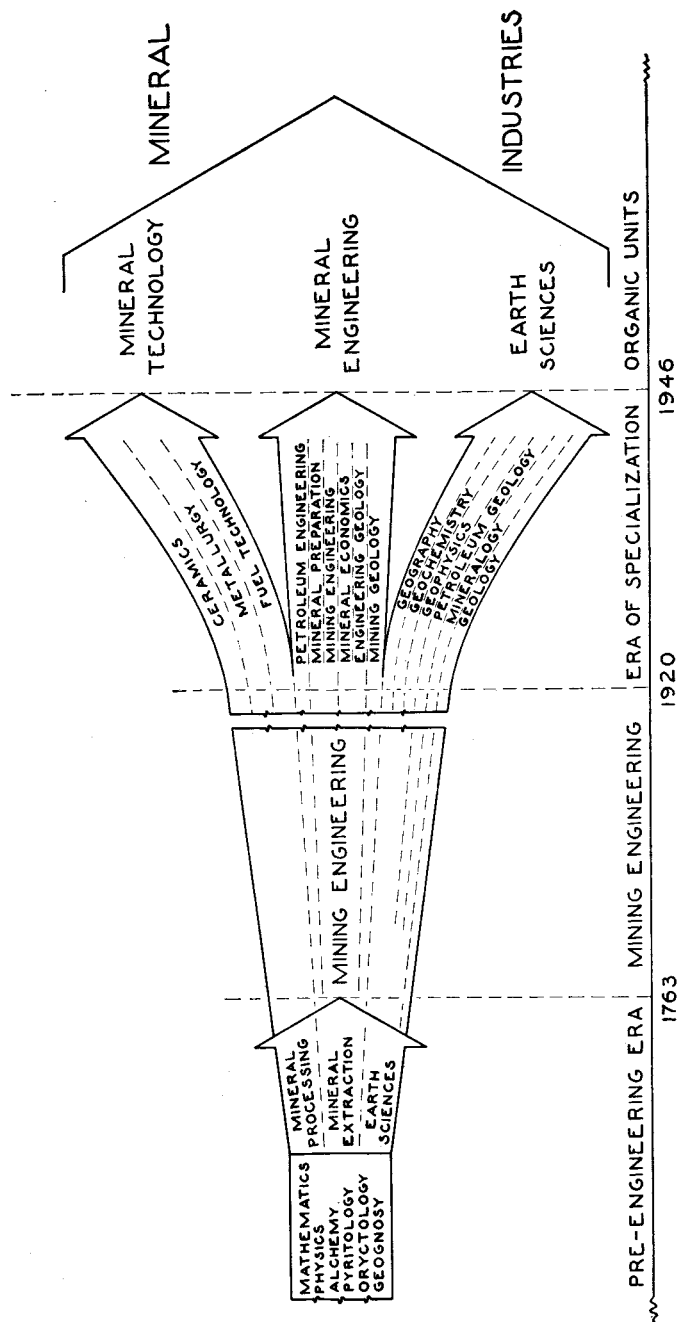


Figure 6. Evolution of mineral industries education, first unified by Agricola in 1556.

Mineral Engineering is concerned with extracting minerals from the earth and preparing them for use. In other words, it is the means by which mineral matter, including mineral fuels, is made available to man.

Mineral Technology is the applied systematic knowledge of primary methods of processing and treating mineral matter and directing its industrial utilization. It is concerned with those industrial arts and sciences which involve the transformation of mineral fuels into energy and the conversion of minerals of all classes into raw materials of industry or finished articles of commerce.

The word "geotechnology" was adopted by the School on July 15, 1942. The word is derived from the Greek geo, earth, technē, meaning art, and the suffix -ology, which denotes a science. Geotechnology signifies then the application of the arts and sciences to all those problems connected with the utilization of the natural constituents of the earth. The word has a familiar ring, but a diligent search in many dictionaries indicated that it is wholly new and unused prior to 1942.

Mineral industries curricula determine in broad outline the intellectual maturity of undergraduates. Too many schools today waste time and effort on specialized training at the expense of more basic studies. The result is a class of highly skilled graduate technicians that are so absorbed in the fascinating, labyrinthic intricacies of their own specialty that they become mental myopes, incapable of viewing their work in proper perspective to the total sum of scientific and cultural knowledge. Courses of study should provide assurance that the student has been exposed to the full complement of basic sciences and to the humanities, for only in this manner will the future mineral technologist acquire the ability to resolve problems in his special field into their basic physical and human components. In such fashion men will be developed who can make fundamental creative

contributions in several fields of basic mineral sciences, rather than in the applications of scientific principles discovered by leaders in other countries. No school can be equipped with staff and material to prepare its students for all possible fields of specialization in which they may engage for their life's work. Highly specialized preparation is more properly the duty of industry rather than of the school, and industry should foster the present trend of devoting a preliminary period to intensive training of its student recruits.

The layman does not appreciate the branches of science, engineering, and technology included in mineral industries curricula. A boy who is interested in engineering courses usually thinks in terms of popularized engineering courses. If a boy is interested in chemistry or physics, he usually thinks of courses covered under these captions. Attention is called to the fact, however, that these same interests may be preserved and cultivated in the mineral industries. The prospective technical student must weigh all of the facts carefully in order that his heart will be in his work.

The primary objective of the School of Mineral Industries is identical with that of The Pennsylvania State College as a whole—the good of the Commonwealth. Because the Commonwealth is not the State in the totalitarian sense, the School believes that “the worth of a State in the long run, is the worth of the individuals composing it.” The Commonwealth, in turn, is a member of the Federation composing the Nation. Loyalty to one does not compromise loyalty to the other, but rather the two are inextricably united. The School, therefore, is dedicated to the education of the citizenry and takes as its special province the search for, and dissemination of, the knowledge of Pennsylvania's mineral industries, especially the conservation of minerals.

A new plan of organization should be adopted by

Schools of Mineral Industries to meet future needs of the industries and of the people. The plan (Fig. 7) provides greater opportunity for unity in policy and purpose, more integration of programs, and greater application of democratic principles. The Executive Committee, composed of the Dean, Directors, and Chairmen, sets the course of the School. The Dean is responsible for the over-all school program, but concentrates on undergraduate resident instruction, a primary function. Directors co-ordinate extension training, and graduate instruction and research, respectively. Chairmen, for all practical purposes assistant deans, confer regularly and integrate divisional subject-matter fields. Heads of departments, key men, form the cutting edge of the over-all program, and give close attention to student personnel and guidance. Chairmen meet with respective heads of departments, and heads of departments with respective departmental staffs. General faculty meetings are held to a minimum. Budgets and records are simplified and centralized, faculty and physical plant are used with maximum efficiency, and research foundations and grants-in-aid are accommodated under the plan.

The new executive positions strengthen the organization. In selecting the personnel for these new positions, the traditional policy of advancement from within has been adhered to; personnel from the outside have been brought in only when the School ranks did not include someone with the peculiar qualifications for the position.

Unification in no sense overshadows the importance of each individual member of the staff of the School. Every man is essentially a key man in that the brilliance with which he engages in his own duties opens up and brings to maximum usefulness the knowledge being developed by the entire School. It is the duty of every executive officer to employ the finest talent available, and

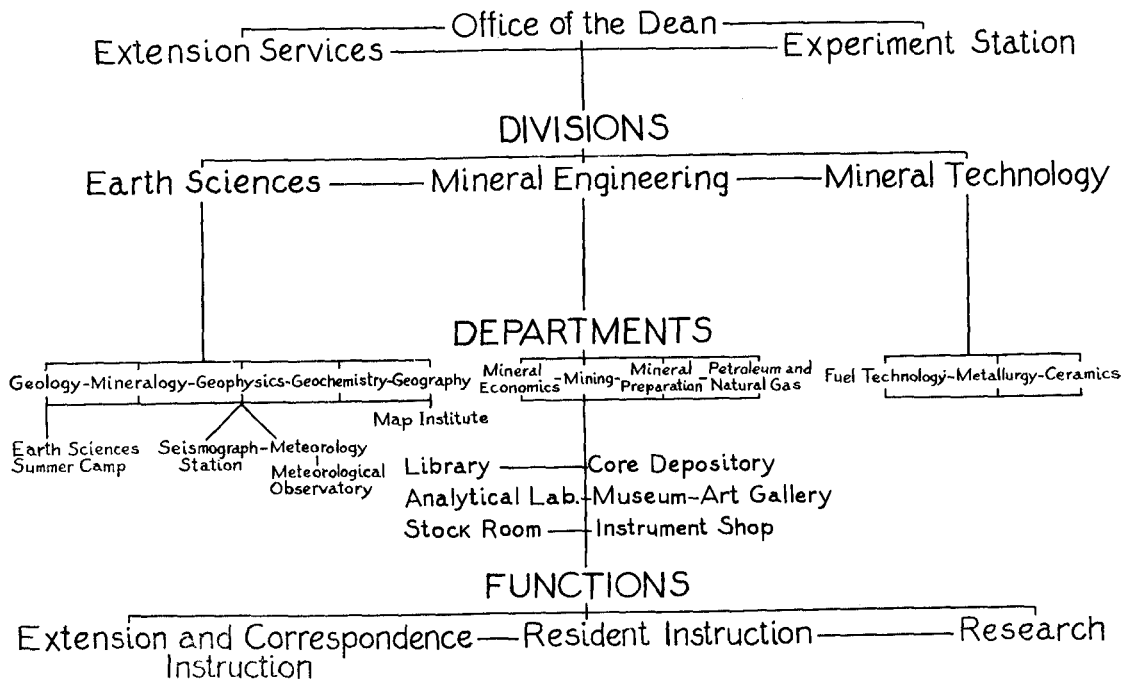


Figure 7. Progressive, decentralized, unified plan of operation for mineral industries colleges.

he must assume that some of these men may come in with a status above his own, for "he who surpasses me the furthest, loves me the most."

Reorganization without a purpose is more dangerous than no organization at all. It often takes much longer to plan a project than it does to build it; similarly, much longer to prepare a program than it does to put it into action. The success of the reorganization rests heavily on chairmen and heads of departments.

The attitude of the faculty must be positive. Leadership on the part of responsible officers renders it positive. Once leadership is withdrawn, the attitude inevitably becomes negative. If an officer slackens or fails, someone must be ready to assume leadership or the School will disintegrate as a functioning body. The net result is a weak spot that must be plugged with an interested, able man. Methods, too, can be improved again and again as human ingenuity and a fresh viewpoint are brought to bear upon them. Open minds are not in themselves sufficient. Initiative must be taken in originating projects if results are to be accomplished.

Mineral industries colleges must be equipped with specialized apparatus and trained personnel required to solve the educational and technological problems of commonwealths concerned with their mineral resources. Moreover, these colleges must offer all three functions of service, namely, resident instruction, research, and extension instruction, and must not differentiate among these functions. All are educational services that must be co-ordinated for effective application to progressive mineral industries. It takes a lot of hard work to build something worthwhile and then twice as much work to keep it moving progressively forward.

It will be remembered that a weaver uses a loom to unite many diverse strands into a useful and attractive cloth, a product far better than the warp and the woof

alone. Uniting all subject-matter fields in a mineral industries college accomplishes a like effect. The radar scanning screen and the television screen make visible energy waves through fluorescent excitation. A unified school effectively concentrates effort into one over-all profitable pattern. FM radio eliminates static, permitting clear reception. A unified school clears away much administrative static.

CURRICULA CLASSIFICATION

Earth Sciences: The standard of living of the world's people depends upon human initiative, investigation, and know-how in exploiting the earth's resources. The Earth Sciences—geology, mineralogy, geophysics and geochemistry, meteorology, geography—are basic sciences dealing with those problems concerning the origin, constitution, and utilization of the earth's materials. The development of these fields in one department provides the greatest opportunity for direct contact and stimulus for scientists and teachers working in related fields.

In the Earth Sciences, geology and mineralogy are obviously closely related. As rocks are the materials of which the earth is made, so in turn minerals are the constituents of the rocks. Conversely, a study of earth structures and the interplay of physical and chemical forces in the earth is necessary in order to understand the origin and source of minerals. Building on the basic core of knowledge of earth processes, earth structures, and earth history, the geologist will continue to push out the frontiers of stratigraphy, structural geology, paleobiology and petrology with growing insight into prin-

ciples that control surface and subsurface rock conditions.

As the field of geology has advanced, several lines of specialization have developed. The economic geologist is a specialist in mineral deposits and economics. His principal work is to study the occurrence and origin of metallic and nonmetallic minerals. The petroleum geologist is concerned with the discovery and exploration of oil and gas pools. The paleontologist, representing another branch of geology, is concerned with the study of ancient life, and paleontology is one of the few reliable methods of locating a layer of rock chronologically. In a mineral civilization such as the present, emphasis is placed on the economic aspects of geology, but back of all this there must be a sound foundation of research and instruction to discover the geologic facts and principles and to train men to use them.

As the geologist studies rocks, so in turn the mineralogist studies the constituents of the earth's minerals. The task of the mineralogist and petrologist is twofold: first, to obtain exact data as to the composition and properties of minerals and rocks by quantitative and precise methods of chemical and spectrographic analysis, manifold physical measurements, X-ray diffraction, and direct observation with the petrographic microscope with magnifications up to 2000 and the electron microscope up to 300,000; and second, to interpret and explain the behavior of minerals and rocks, partly in a direct way as components of a certain limited physicochemical system; and partly as members of larger and more complex dynamic natural systems, with many variables and elements. The mineralogists' methods include experimental laboratory work, statistical analysis, and the over-all guiding concept of a relativistic (Einsteinian) approach to the problem, an approach which during the past de-

cade has been rapidly replacing the absolute (Newtonian) approach.

While the geologists are in a position to surmise the existence of mineral deposits at shallow depths, when deep deposits are sought, methods are needed whereby the depth of investigation reached by the geologists' pick must be considerably lengthened. Geophysicists and geochemists have recently entered upon the scene. These scientists are concerned with the physical and chemical measurements of various earth characteristics, such as distances, masses, structures, forces, or chemical reactions. These fields are frequently divided into two parts: pure geophysics and geochemistry, having to do with physical measurements for their scientific value alone; and exploratory geophysics and geochemistry concerned with the search of minerals and ores of economic value. Airborne magnetometer and modern portable gravity meter surveys are under way in many sections of the country. In conjunction with these investigations, studies are needed on the distribution anomalies of the chemical elements of near-surface formations, and ground water and plants as possible leads to the existence of mineral deposits at depths. Since most of the surface mineral deposits have already been discovered, the work of geophysicists and geochemists will become increasingly important in the discovery of deep seated fuels and ore bodies.

While the possibility of human control of weather elements has been demonstrated recently by successful rain-making experiments, for a long time to come, agriculture, industry, and various other activities must rely on weather forecasting for economic planning and preparation against the adverse effects of the weather. There are many specialized problems, such as mine air-conditioning, safety, and smoke abatement. This, the principal work of meteorologists, deals with the inter-

pretation of atmospheric phenomena. Research which has been developed to the greatest extent in physical meteorology must be expanded in synoptic and applied meteorology and climatology. The profound influence of the weather on various aspects of our daily life must be more thoroughly investigated. The effect of weather on the behavior and functions of the human body is receiving increased recognition in therapeutics and preventive medicine. Studies of the relationship between climate, comfort, and efficiency will lead to greater human comfort. Some investigations have already crossed the borderline into psychophysics, and plans are being laid to explore the boundary where meteorology touches upon physiological and biological aspects. The increase of our knowledge of climate and weather is not only necessary for the present, but it builds a research foundation upon which future generations can rely to make increasing use of solar and wind energy. Meteorology is given equal status with other subject-matter fields at Penn State.

Geography is the science of the earth's surface and, thus, the work of geographers entails the systematic observation, description, analysis, and interpretation of the regions of the world as to their natural and cultural setting. As the demands for world resources grow, there is increasing need for an understanding of distant places and peoples. No nation can be self-sufficient under a complex industrial economy. This is particularly true of the mineral resources, since the geographic distribution of the individual minerals follows no regular pattern. One of the greatest contributions to geographic knowledge can be made by investigating the principal factors and problems affecting the distribution of the mineral industries, such as discovery of new minerals, depletion of known deposits, technological advancements, substitution of one mineral for another, and gov-

ernmental influence in mineral output. Geographers must further their studies of man's utilization of regions, developing such geographic aspects as accessibility, topographic setting, climatic conditions, hydrographic pattern, mode of transportation, number and distribution of people, stage of economic development, and political considerations.

Mineral Engineering: Mineral Engineering applies to those branches of the engineering profession concerned with the extraction of minerals from the earth, and with their primary preparation. It covers fields of work that are engineering in character. In the broad field of professional activity covered in the flow of products from the earth to their consumption by man, mineral engineering occupies a mid-position between the earth sciences and mineral technologies. There is no sharp line of demarcation between these fields. Each merges into the other so that some particular fields of activity embrace parts or all of the three major branches of activity.

Within the broad field of professional activity of those engaged in extracting minerals from the earth, a number of divisions with closely related aims, interests and training requirements have developed. Broad professional groups of the currently recognized mineral extractive industries, include mining geology, engineering geology, mining engineering, petroleum and natural gas engineering, mineral preparation (dressing) engineering, and mineral economics.

The mineral engineering profession can be divided into two fields based on function: (1) operating-management; and (2) research design. The first applies to the engineer who constructs and operates plants, who brings into relation the various parts of the enterprise,

and who correlates the work of the research specialists and the design engineer. This type engineer must have a broad technical knowledge, be versed in general business principles, and be able to cope with labor-management problems. The specialist research design engineer is needed to develop new methods, to improve existing methods and machines, to design plants and equipment, and to utilize the research method in solving the problems of industry. He must possess a keen mind, have a passion for detail, be imaginative, and have a flair for originality.

The divisions of mineral engineering are concerned: first, with extraction of minerals from the earth, (lithosphere, hydrosphere, atmosphere), whether by open pit, underground, bore hole or chemical method; second, with the treatment of those minerals to prepare them for processing or use; and third, with the general economics of the flow of mineral products into trade channels.

Mining engineering is the branch of engineering that applies science, machines, men, and money to win minerals from the earth. It is urgently necessary for mining engineers to effect complete extraction of minerals. With the constantly changing production picture, more thorough grounding in the fundamentals of mining engineering along the following lines is necessary. The relationship of sound principles of engineering to mining is a basic requirement for more advanced study. Ventilation, mechanization, and electrification have grown beyond the practical application stage and demand a more developed technological analysis. The technique of obtaining maximum yield with minimum effort must be studied and mastered. Unless there is anticipatory research along definite lines, there will be a serious lag in production. Limited reserves of high-quality metallurgical coals require a firm conservation policy with full-seam, complete extraction enforced. At

the present time lack of knowledge in the field of rock mechanics costs the industry millions of tons each year. Production of high-quality coals from thick seams under favorable mining conditions is declining, requiring more from thin, faulted, and banded seams with a subsequent loss in unit production, since suitable machinery and methods are unavailable. New concern must be given to coal as a chemical substance, as well as an energy substance. This also holds for mining with molecules; i.e., underground gasification of coal. Perhaps it is more difficult to waste natural resources than is generally realized. For example, raw materials extracted from the earth may eventually find their way to the sea from which it appears possible that many raw materials can be recovered, if necessary.

Pennsylvania has always been prominent in the petroleum industry, and petroleum and natural gas engineers find employment in designing, constructing, and operating equipment used in drilling and maintenance of wells, in transporting, producing, and certain phases of refining and marketing. There are many problems with which petroleum engineers must concern themselves. To devise methods that will economically remove the last remaining oil from the earth constitutes a challenge to the men of industry, government, and science. Practices must be adopted which will utilize to the fullest the forces of nature. Improved methods of secondary recovery must be studied in the laboratory and tested in the field. The development of tertiary methods must be pushed forward to recover that oil now locked in place by previous inefficient recovery methods.

The necessity for mining progressively poorer mineral deposits in the world has thrown a greater burden upon preparation, or mineral dressing, engineers, and has brought about a large demand for intensive research. In the future, this trend not only will be greatly

intensified but mineral preparation will develop into a highly scientific field. The older concept of considering ore concentration or coal preparation as a more or less crude mechanical art will completely vanish. There will be wide use of electronics, ultrasonics and various chemical treatments. Flotation of minerals will develop into a scientific process requiring thorough knowledge of organic and physical chemistry. Radioactive isotopes and the electron microscope will become common tools of the preparation research laboratories.

The rise of the mineral industries to their present status has created problems in correlating the various activities of mining, transportation, and use. Banks, investment houses, operating companies and governmental agencies require professional help in solving the special and general economic problems of the mineral extractive industries. This work is performed by mineral economists. Mineral economists must also evaluate production, consumption, value, and location of mineral deposits and their products in the light of changing technologies. The subject must extend far beyond the boundaries of ordinary economic studies and include two basic concepts of mineral use: transportation and marketing. There are some highly specialized problems of transportation in the mineral industries. Problems of consumption of mineral raw materials are on the increase; consequently, marketing will grow in importance with each succeeding year. Continuing shifts of population provoke some questions about the basic causes. A domestic viewpoint is not sufficient, and an international viewpoint must be adopted. The control of the world's minerals is an enormous problem for peace as well as for war. Assurance of equal access involves safeguarding supplies and preventing their use for war. Researchers must collect the data established by previous workers and provide the means by which this

information may be interpreted. The mineral industries of the future will be dependent upon the conservation of reserves now known. Study proves that the only effective conservation is research to explore new methods of discovery, economy in use, and the development of substitutes. Mineral economists are responsible for the attainment of these objectives.

Mineral Technology: The basic distinction between the methods and processes covered by Mineral Engineering and Mineral Technology is that, in general, in Mineral Engineering the mineralogical constituents of the raw materials are subject to no chemical alteration and limited mechanical alteration. They are extracted from the earth and concentrated by separation methods to yield marketable mineral products and waste minerals without destroying the physical and chemical identity of the minerals. In Mineral Technology, on the other hand, the principal objective is to produce a chemical alteration, starting with the mechanically concentrated material delivered by the mineral engineer.

Fuel technologists deal with the problems of origin, constitution, processing, and utilization of those materials which are useful for the production of heat energy and industrial raw materials. America, the most highly industrialized nation in the world, has a per capita coal, oil, and gas consumption equivalent to 250,000,000 B.t.u.'s and proved reserves of these fuels sufficient to last about 1000, 10, and 35 years, respectively. New oil and gas reserves will undoubtedly be discovered as a result of the extensive exploration now in progress, and more effective use is now being made of solar and hydro-energy. Nevertheless, the present wasteful practices of using quality fuels for inferior applications will have to be eliminated if this country is to remain self-sufficient.

Although now a technical reality, and an economic probability a few decades hence, nuclear fission for energy production is only a partial answer to the overall problem since mineral fuels also provide our major reserves of organic raw materials.

Because of the importance of mineral fuels in the present economy of the country, specialists in the technology of processing and utilizing these raw materials are urgently needed. To maintain the nation's industrial position it is becoming more and more apparent that intelligent conservation of our fuel resources must be practical, and a greater effort must be made to get more out of them than in years past. There will be a serious shortage of fuels to supply the energy requirements in the highly developed industrial East in another quarter century. Some of the most important research must be furthered in the field of coal processing. Uses must be found for wasted coal in silt and culm banks; ways must be found to improve the quality of poorer deposits and to mine the thinner seams. In addition, more efficient ways of converting coal into useful forms of energy must be found. New uses of coal, particularly its conversion to liquid fuels, are being developed which will have an important bearing on the future of the country. The turbine drive using powdered coal is a step forward, and every effort should be made to develop this and other means of improving the efficiency of the utilization of our irreplaceable mineral fuels. It is indeed tragic that at present only a fraction of the possible energy contained in a fuel is converted into useful work.

Smoke abatement regulations in cities and industrial areas have created new interest in methods for removing the smoke-producing constituents of bituminous coals and in mechanical equipment to burn these coals smokelessly. Stimulated by this interest, low tempera-

ture carbonization of Pennsylvania's coal for the production of domestic coke or char that burns readily but smokelessly is being developed by the industry. The utilization of special by-product tars constitutes an important problem that warrants detailed study.

Metallurgy may be divided roughly into two broad fields—chemical and physical. Under “chemical” may be included the science of extracting the metals from the ores through processes of pyrometallurgy, electrometallurgy, and hydrometallurgy. In pyrometallurgy, the metal is separated through bringing the ore to a high temperature, eliminating impurities until the pure metal is left. Hydrometallurgy is the method used in ore dressing or flotation, in which the ore is brought in contact with a liquid which will dissolve the valuable metal without attacking the associated materials. Electrometallurgy is the process of recovery of the metal from the solution by precipitation by electrolysis. Electroplating of metals in solution is also included in the broad term, electrometallurgy. Also under chemical metallurgy are included study of crystals and mineralogy, and thermodynamics.

Physical metallurgy is concerned with studies of the basic structures and properties of metals, the formation of alloys, the stretching and rupturing of metallic materials under stresses of temperatures and pressure, and the processes of forging, casting, and welding.

There remains much to be done in the field of metallurgical research. One of the big fields of study at present is that of corrosion, which causes losses on a world-wide scale amounting to billions of dollars every year. Another phase of great interest is the seeking of a suitable metal or alloy for atomic power plant construction, as well as metals or alloys which will withstand the peak temperature encountered in rocket and jet engines.

Fundamental investigation by metallurgists involves the use of the electron microscope, the spectograph, X-ray, and gamma ray in order to learn more about the structure of metals, the study and development of metals to resist high temperatures and high pressures, the physical properties of metals at both low and high temperatures, the fundamentals of metal conversion and the fundamentals of the reaction of the metals and their alloys toward heat treatment.

The word ceramics is used today to designate a branch of learning concerned with the manufacture of useful and artistical wares, generally with the aid of a high temperature operation, from the nonmetallic minerals. Raw materials used by the ceramic industries include practically every industrial mineral in the earth's crust except the fuels and the ores of metals. Manufactured objects and materials considered “ceramics” today include a wide diversity of products: glass of all kinds, vitreous enamel, fired clay wares of many types, heat resisting and insulating materials, and Portland cement. In the modern concept, ceramics is a field of basic science comprising essentially the high temperature chemistry of oxides, silicates, borates, phosphates, and the like. This involves both physical chemistry (rates of reactions) and stereo-chemistry (atomic configuration of the molecular groups involved in the reactions, or resulting from them).

Most ceramic raw materials are practically inexhaustible. The more they are used wisely to replace scarcer materials, the more effective is over-all conservation. Quality conservation should be practiced; that is, one should not use a raw material of higher quality than necessary for the specific purpose. Studies should be made to find means of producing technically satisfactory ceramic products from lower grades of raw materials. More effective utilization can be made of finished

ceramic products by learning to better control their properties. The outstanding problems facing the ceramic industries are the more efficient utilization of raw materials and fuels, and improved control of processes and products.

There is a feeling in some quarters that the Age of Steel is approaching its peak, but it is not clear whether this will be followed by the Age of Aluminum or the Age of Ceramics. Historical man started with stone tools, then worked the softer metals and finally the harder ones. Will man complete the cycle and revert to the use of the nonmetallic materials—this time, however, with superior properties, controlled to order by scientifically planned heat treatments?

FUNCTIONS OF SERVICE

A school grows big only as its usefulness increases and it will shrink rapidly if inefficient. Usefulness must be recorded in terms of service within the economic structure of the Commonwealth. Under this premise, modern mineral industries colleges must recognize and give equal significance to three interrelated, interdependent functions of service: namely, (1) resident instruction, on both the undergraduate and graduate levels; (2) research under an Experiment Station plan; and (3) extension training under three classifications, class instruction, correspondence instruction, and informal instruction. To train potential leaders for the mineral kingdom, to discover and teach new truths is only half of the job. Through extension training, equal attention must be given to the on-job, vocational-technical, upgrading of skilled workers on the production line. Similar to the School of Agriculture, the School of Mineral Industries is the only one in the Commonwealth offer-

ing the three functions of service in each of the subject-matter fields in mineral arts and sciences.

The functions of service must be based on the modern conception of mineral conservation (Fig. 8). Conservation of minerals differs from conservation of natural resources in general because man must find new mineral deposits and excel the geologic forces of nature in processes of concentration. True mineral conservation, therefore, may be defined as energetic discovery, complete extraction, and maximum utilization. Minerals are neutral material—not resources—until made useful. This utilization of mineral resources requires ingenuity, technology, skill, efficient management, and teamwork on the part of human resources (Fig. 9).

The torch of learning of the mineral arts and sciences must be placed solely in the hands of promising neophytes. Mediocrity among future mineral scientists can result only in failure to meet the challenge facing the field. It is imperative, therefore, that mineral industries colleges exercise judgment and restraint in the selection of students for admission. If the present policy of admitting virtually all comers is continued, in response to public demands for more and more education for more and more people, the end results can only be graduates on a mental par with the products of our mass-production system of high schools, where "education for all" is the keynote.

A properly selected freshman is like a rich ore body, waiting to be discovered and exploited. Each failure becomes an abandoned mine with all of the unused workings covered with the dusts and cobwebs of self-pity. The courses offered in resident instruction must be studied and the inessential, obsolete matters discarded in order to allow time for important factors, the ever-increasing and expanding knowledge of today. It is far more important that the metallurgy student know what

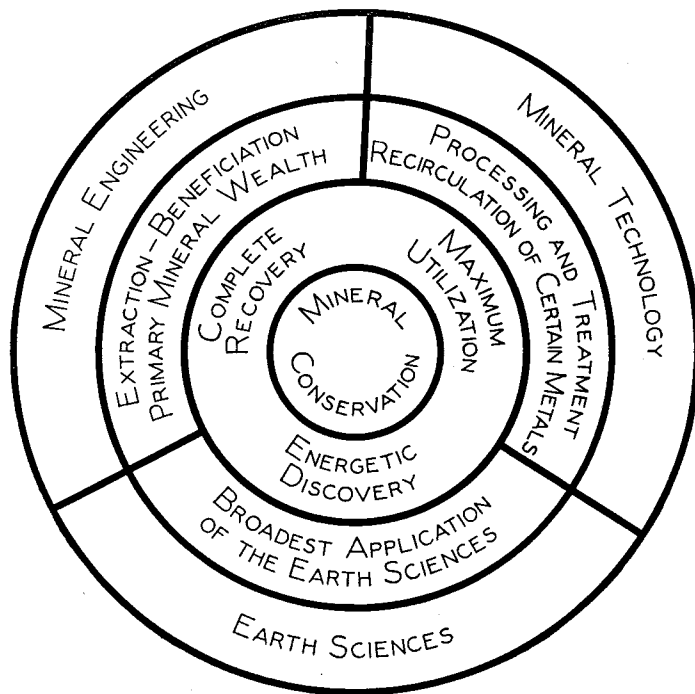


Figure 8. Modern conception of the development and conservation of irreplaceable minerals.

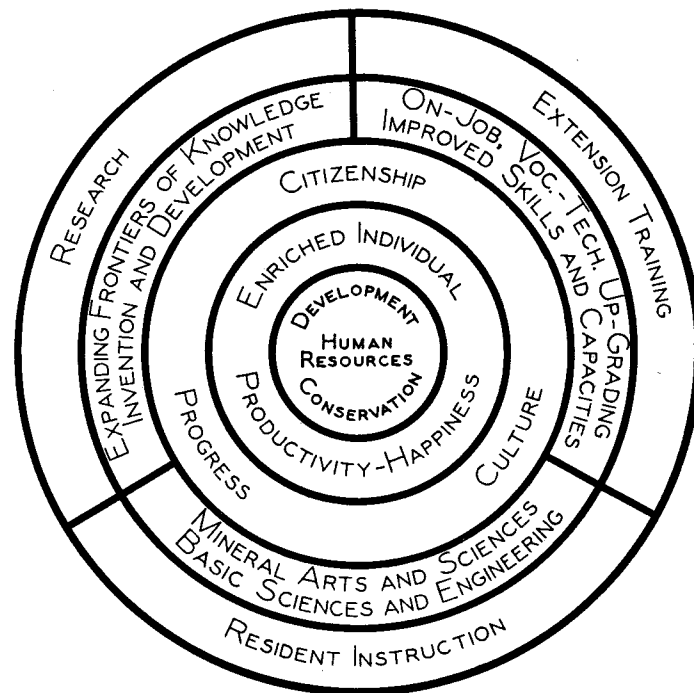


Figure 9. Modern conception of the development and conservation of human resources in the mineral industries.

goes on inside a piece of steel during heat treatment than that he know the dimensions of the biggest blast furnace. It is more important that a student know the why's and the how's of a reaction, rather than the time required for the reaction to take place. Above all, it is more important that he be able to *think* than that he know the characteristics of a variety of minerals.

Research, under an Experiment Station plan, provides the means for stimulating inquiries into matters of interest to the state, or to industry, or to the student himself. State funds are made available and these should be matched by industrial grants. The easy way is to have plenty of state money without strings attached as to its use, but this plan might defeat the very objectives of an institution of higher learning. Matching funds and independent grants-in-aid of all kinds require considerable administrative work, but the net result is that various state departments, industrial associations, and mineral industries companies, big and small, are educated in research and research processes and they actively take part in all three functions of service. Meanwhile, the colleges remain free institutions.

The education of better mineral technicians offers a fertile field for "taking the university to the masses," and is a solemn obligation of a state institution such as The Pennsylvania State College. The character of the mineral industries prevents a wholesale exodus into classrooms. The program of the School of Mineral Industries embraces a strong recognition of the value of extension service. Some of the extension classes are carried on under the Federal Smith-Hughes plan in co-operation with the Department of Public Instruction, Harrisburg.

The responsibilities of instructors do not end in the classroom, or when the student has received a degree. Graduates must feel free to call on their old teachers

for advice on various problems; personal, technical, or otherwise, especially during their apprenticeship period.

Students are urged to familiarize themselves with mining extension work to the extent that they can serve as instructors of night mineral industries classes and mine mechanics' training courses if called upon to do so. Experience has proved that extension teaching is good training and provides a seasoning process through contact and intimate acquaintance with the more ambitious mineral industries workers, and this is a field where the technically trained man can assume his rightful place as a leader and teacher, and be of valuable assistance to those less fortunate in the matter of formal education. Further, extension teaching will develop a recognition of the necessity for, and satisfaction or pride in, knowing accurately those things for which he has assumed responsibility.

Although the School of Mineral Industries at The Pennsylvania State College is constantly seeking improvement in its methods, it can show a good record of steady growth and development.

Since 1928 the number of undergraduate curricula has grown from 4 to 11, undergraduate enrollment from 144 to a top enrollment of 590, in spite of the fact that out-of-state enrollment for the entire college is limited to five per cent. Enrollment in service courses for students in other schools has grown from about 500 to 2000, and extension training has tripled, now averaging about 4000 each year. Graduate enrollment grew from 0 to 142; research from 0 to 100 projects supported by state, federal, and industrial grants. More than 75 agencies have made research grants-in-aid. And the staff of the School grew from 15 in 1928 to a maximum of 185 members in 1947.

The Experiment Station has published 35 circulars,

51 bulletins, and 160 technical papers, while Extension Services has published 16 bound texts and 15 sets of mimeographed terminal lesson material. Both Experiment Station and Extension Services publications have been requisitioned from all of the 48 states and 18 foreign countries.

Although extension service to the mineral industries was started as early as 1893, when staff members of the College traveled to the coal regions and gave lectures on mining practices, the work was not placed on an organized basis until 1931. During the period 1931 to 1949, the Extension Services provide training through classes for 50,776 workers employed by about 200 mineral industries companies in Pennsylvania, and through correspondence instruction for 1725 persons. In the Defense and War Training Programs given by the College under the sponsorship of the U. S. Office of Education, college-level training was provided during the 1941-44 period for 7138 persons. In the 1948-49 term the Extension Services enrolled 3587 students in extension classes and had 170 active correspondence students. The grand total of persons trained by the Extension Services since 1931 is 59,639, or an average of 3313 persons annually. The State coverage of the extension work is indicated by the results of a recent survey which shows that in the 1948-49 term classes were located in 94 centers in 39 counties, and that students from 573 communities attended these classes.

The directory reveals that there are 2003 graduates of the School, 1451 of whom have graduated since 1928. Little or no graduate work was carried by the School until 1928. Many Master of Science degrees, together with 37 Doctor of Philosophy degrees, have been awarded since 1928. Graduate students have come from 11 foreign countries. Graduates are employed in 39 states, the District of Columbia, and 19 foreign countries.

More than a quarter of the graduates are employed by steel companies in jobs ranging from observers to company presidents. Similarly, 10.6 per cent are working for petroleum and natural gas companies; 8.6 per cent for mining companies; 5.8 per cent for ceramic companies; 7.8 per cent in federal service; and 14 graduates are employed in Pennsylvania state departments. One hundred fifty-nine (159) graduates, mostly commissioned, served in the Army, 175 in the Navy, and 98 in the Marine Corps, during World War II.

It would be a boon to the industry to arouse the interest of promising high school boys in the possibilities of the mineral industries. This is being done by a few coal companies granting scholarships for the study of mining engineering. The postwar era definitely shows the need for much more of this progressive work. The inclusion of mineral industries vocational courses in high schools located in mineral industries communities will do much to direct promising boys towards careers in these industries.

The efficient carrying out of the functions of service demands a well-knit connection with the industries, and operation on a 12-months' basis, similar to schools of agriculture. Prospective employers of graduates may well be given a voice in the proper training of men. Industrial research projects are being offered to the College for solution, and an efficient extension service demands friends and advisers in industrial fields. In line with these functions of the School, numerous advisory boards and committees have been created. These boards and committees, as the names imply, are formed to act in an advisory capacity for the various departments. They are self-controlled, second-party units, and serve as contact agencies between the School, and industry and various State Departments in Harrisburg. Those chosen are prominent executives and scientists whose

advice and counsel are of greatest value. There are many more outstanding men whose membership is very much desired, but the need of a wide geographic distribution largely governed the selection.

The past twenty years have been marked by a fine spirit of co-operation between the College and the various mineral industries associations representing coal, oil, natural gas, steel, ceramics, and many individual companies. Industrial and research conferences are held each year and are made an integral part of the educational program of the School.

EFFECTIVE CRYSTALLIZATION

Resident Instruction: The character of an institution, the varying demands made upon it, its geographical location, its own internal organization, all are factors that predispose against rigid standards, curriculum-making, research programs, and extension services. Mineral industries educators must keep in mind that the undergraduate is the core of the college, a philosophy that implies a set of inviolable principles. They will want to turn out graduates with overwhelming talent in their field, together with incorruptible ethics, prepared to deal with people, as well as with theories and things.

Curriculum-making is a popular educational pastime. No course makes or breaks a curriculum. The particular qualifications and interests of individual students must find expression. However, selection must be made under guidance so that the student's individual needs are realized. In this way, specialization can be introduced into curricula previously conceived to be of general science or engineering nature only.

In its essence, formal education is society's endeavor

to put old heads on young shoulders, to implant the experience of centuries in the youthful generation. Seen in this light, it is evident that isolated facts have little place in formal education; that presentation of any subject without correlating it to other material, and to life itself, fails of its purpose. Undoubtedly some institutions have gone too far in providing diversissements to study, but experience in athletics, school politics, and other social activities at colleges are necessary to condition the young person for subsequent life in a more competitive and brutal society than that which exists on most campuses. Mineral industries colleges will experience the usual difficulty in seeking to strike a balance between liberal and professional subjects. Professional curricula can be presented in detail, but liberal subjects can be offered only in general outline. For one thing, the element of time is against their complete presentation. On the other hand, technical courses can be given a humane direction and inspiration. Under those circumstances technical education may also be labeled liberal education. After all, the best mineral engineers and technologists are those who know more than just science and engineering, just as the best lawyers are those who know more than the law.

This should be a challenge to the teachers of liberal arts subjects. Too many theorists in the field of the humanities live in a garden of highly cultivated illusions without a working knowledge of the sciences. Liberal arts teachers must find new ways to integrate their material, to weave individual subjects together in order to develop a perspective for the student. They must present the past so that it becomes vital today; they must link cause to effect through the ages; they must delineate the ends for which man struggled, the ideals which motivated him, the results he obtained, and show how all this affects the present. Certainly it is now ap-

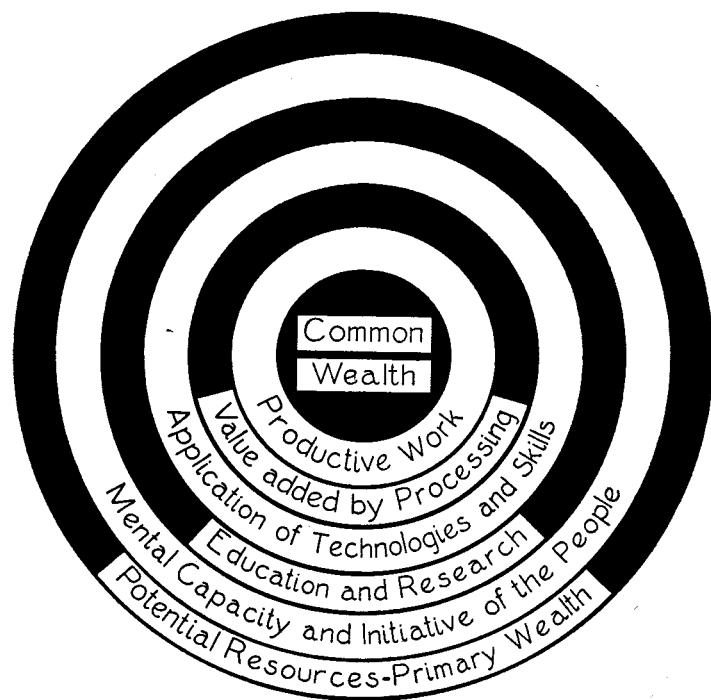


Figure 10. Mineral industries target, genuine commonwealth created only by co-operative human effort.

parent that the subjects of history, of democracy, and of American institutions have been neglected generally in the process of higher education.

Schools of mineral industries must give to undergraduate resident students as broad and general an education as is compatible with the period of their instruction and the character of their future work. Good citizenship must be stressed as a foundation for sound technical training. It is important also that students understand how free people under a free economy can participate in common wealth (Fig. 10).

It is a personal conviction that there should be no sectionalized curricula for the first two years of college work. These years should be confined to general, truly liberal education. The decision to enter the technical or nontechnical field could be made with some degree of reason at the end of two years. Properly qualified students should then spend three additional years in any one of the several mineral industries curricula leading to undergraduate degrees. All of this does not seem possible under present academic customs and egoisms, and mineral industries education cannot progress. Secondary schools would have to raise their standards under the plan. But, the day may come when the now lowly Bachelor will be able to hold up its head as a product of true accomplishment and bask in the educational sun.

Curricular generalities at Penn State's School of Mineral Industries will be presented in terms of the conventional four 2-semester years and Fig. 7. There is a fundamental freshman year, common to all departments and a fundamental sophomore year for each division. In reality, both freshman and sophomore years are, for all practical purposes, common to all undergraduates and provide an opportunity for students to transfer

within the School without serious loss of credit toward graduation.

Mineral Industries students can qualify during the freshman and sophomore years for any curriculum offered by the College without loss of credits or class standing.

Preliminary training in mathematics, chemistry, physics, English, drawing, geology, and mineralogy is given in the first two years. Engineering, technological, and introductory mineral industries professional courses are added as a superstructure in the upper years.

There are junior and senior years under each department embracing: (1) required fundamental subjects common to all divisions; (2) required professional subjects for departmental curricula; and (3) selected lists of humanistic, labor relations, and technical electives leading to Bachelor of Science degrees in Geology and Mineralogy, Geophysics and Geochemistry, Meteorology, Geography, Mineral Economics, Mining Engineering, Mineral Preparation Engineering, Petroleum and Natural Gas Engineering, Fuel Technology, Metallurgy, and Ceramics. The last three curricula emphasize scientific phases, as well as engineering applications. Students enrolled in Mining Engineering may elect options in Operating-Management or Design-Research.

On account of the growth of technical knowledge and the increasing need for specialists in many branches of the mineral industries, students showing outstanding analytical ability are encouraged to continue their studies by one to three years of specialized training at the graduate level under the Experiment Station plan. Graduate work is offered in each department leading to M.S. and Ph.D. degrees. Graduate work has increased tremendously; students from all over the world come

to the School for specialized training in the various branches of the mineral industries.

Refresher courses are available for veterans of the armed forces. Curricular adjustments are made for foreign students, especially Latin Americans. The human meaning of all phases of science, engineering, and technology is stressed under seminar plans. The objective, as a technical school, is to supply the type of earth scientists, mineral engineers, and mineral technologists on the undergraduate level that are required in the industries.

For those mineral industries in which there is a critical shortage of trained technical personnel, machinery has been set up for co-operative scholarships at the undergraduate level and co-operative fellowships at the graduate level.

Employers are willing and often anxious to discuss the subject of course material with the administration and instructional staff. Naturally these contacts should be encouraged. Subject matter should be under constant scrutiny and open to revision to keep abreast of the times, and to meet the changing needs of industry and of society in general.

Mineral industries colleges must include practice in English within the schools with multiple objectives: (1) to develop in the student the ability to use reference material with facility so that he learns to keep abreast of current developments, technical and humanistic; (2) to provide extensive practice in the writing of reports and papers of all kinds which are criticized in detail on the basis of both grammar and content; (3) to give experience in the preparation, organization, and oral presentation of reports and papers; and (4) to give practice in participation in formal sessions as speaker, chairman, or contributor to floor discussion. Compiling a technical report is not too difficult when the facts are

available. On the other hand, philosophical expression worth reading for its own sake is a laborious contrivance that can be accomplished only in rare moments of meditation. Excellence is something that counts; ability and facility to express an idea are almost as important as the idea itself.

The results of such English practice offered by Penn State's School of Mineral Industries are gratifying. By assigning or approving topics which are interesting, currently important in a technical and humanistic way, and often controversial, instructors arouse the enthusiasm of the student, and he will exert himself in a manner that is not likely to be found in English classes where the instructors do not have a technical background. Instructors are available for both technical and grammatical advice, and the resulting papers and talks are severely criticized from both aspects. The instructors try also to develop within the student the ability to criticize his own work, for until the student learns to do this he cannot hope to make much headway in improving his writing and speaking techniques. Through use of these methods, interest in the courses is held at a high level.

Although the instructors do not ordinarily participate actively in the class sessions at which oral presentations are given, they are always present to make notes on each student's performance. Each speaker is then given a private interview, his talk is criticized, and definite, specific suggestions are made for improvement. Care is taken to recognize improvement and to commend the student for his progress.

The price in terms of instructional time and energy is fairly high, but in view of the student response and the results accomplished, it is time and energy well spent. Not only does the student's writing and speaking ability improve remarkably in most cases, but his cultural background is immeasurably widened by the read-

ing and literature research which he must do in the course of preparing papers and talks. Such habits, formed early, enrich his professional and personal life.

Research—The Experiment Station: The word "research" has fallen prey to abominable misuse. Everyone is a scholar nowadays, a "researcher," the man of business, the historian, the scientist, the musician, even the man who feeds his chickens Indian maize resorts to experiments and statistics. Most present-day research is a dreary assemblage of facts wrapped in gaudy packaging. There is a startling demand "to know." To know what? Why everyone knows about Hooper ratings, batting averages, the speed of the newest jet planes, the number of books in the Bible, how long it takes to read the Constitution. But how many know the fundamentals of the movement of sound waves, or light waves, or the message of the Bible or the content of the Constitution? The titles incorporated in many annual reports on publication and research, even those found as research subjects for theses listed in Commencement programs, make highly humorous reading, some downright erudite inquiries on nonsensical matters. What travesties are made in the name of research!

Little thought is given to the social significance of research or its future. Organized research which emphasizes the practical application of new theories has been one of the greatest agencies in advancing the broad base of science. Organized research should be sustained on a continuing basis and should be devoted primarily to substantially increasing the reservoir of fundamental knowledge. From an historical view, war demands accentuate scientific developments which capture the headlines and obscure the fact that the accom-

plishments of scientists during a war are only a projection of their normal and far more important tasks—to contribute to human progress. Obviously, a vital task confronts research organizations; they must help to balance politico-social aspects of human behavior and scientific progress.

The Mineral Industries Experiment Station at Penn State is the organized expression of the research spirit of the School of Mineral Industries. Its objectives are to increase knowledge and to establish fundamental principles that will have wide practical application; to promote the most effective utilization of the products and productive capacity of the mineral industries of the Commonwealth by seeking new products, new uses and more efficient processes; to conserve natural resources; to train men for research work. All members of the School's faculty who are engaged in research are members of the Experiment Station staff. This makes possible teamwork which is essential where several specialists and much expensive equipment are needed on one project. No one in scholastic research preempts a field for his own exclusive use, for the net result of one man's work may be zero, whereas the cross-fertilization resulting from the contributions of two men may produce partial or complete results on a given problem. In mineral industries, it is important to hold to some well-conceived, long-range program on the discovery, extraction, treatment or processing of minerals, research that ties in with the economy of the Commonwealth.

Graduate study has gained in importance since the beginning of the 20th century until it is considered by some to be the heart of the university scheme of today. This is accomplished in two ways in the School: first, through scholarships, fellowships, and graduate assistantships which permit advanced training through which the graduate students develop a greater comprehension

of their chosen profession and greater capacity for achievement; and second, through research assistantships which enable young graduates to work under the guidance of experienced teachers and researchers. A scholar may not be a born teacher, but a promising teacher can be taught to teach.

The Experiment Station fosters and co-ordinates research in the several divisions of the School and supplements their efforts by enhancing basic library, shop, and laboratory facilities, furnishing special equipment and developing administrative relationships necessary to the successful conduct of research activities. The Station publishes the results of the investigations completed by the research staff and promptly distributes these publications to those interested in the work.

The research program of the Experiment Station which has been in active progress for almost twenty years has produced results that have repaid many-fold the limited funds expended for this purpose. The School has co-operated closely with industry, as well as with state and federal agencies. Approximately one hundred research projects are currently in progress in various divisions of the School, some supported by funds from departments, bureaus, or agencies of the state and federal government, and many by associations or individual companies producing, processing, or utilizing products of the mineral industries. Direct research contacts with industry are highly beneficial to both parties, for they foster a research attitude within the industries and give the college faculty a better knowledge of the industry's methods and problems, thus promoting mutual understanding and interest. Further contacts are made on an international scope through the training of foreign students on a graduate level and of Americans who are later employed abroad, providing a far-reaching interchange of ideas and techniques.

Today, more than ever before, the United States needs the results of research as well as the continuing stream of scholars and teachers who have had educational opportunities for advanced study. We must explore the frontiers of science because geographical frontiers have vanished. At the beginning of World War II there were only about a dozen strategic and critical minerals. The number has now multiplied five-fold and these are mined throughout the world. Development in this field must continue. To serve the State adequately in the solution of the many social and economic problems in mineral industries which are increasing in importance, the School must supply leadership in the solution of technical problems.

And the wheat must be separated from the chaff, the important, useful data culled from the obsolete, the defunct. Today, scholarship consists mostly of slugging through a jungle of books—what Oscar Wilde termed “mass plagiarism.” “We have felled the Canadian forests for paper to print on and we cannot see the truth for the woodpulp.” Evolution has surpassed itself in bestowing reproductive powers upon books. Today anything passes for research. Label a simple inquiry “research” and it acquires a mystic dignity. We must distinguish between investigation and research. Re-search into the postulates, theories, laws pertaining to the subject, careful scrutiny into the initial framework of the field of knowledge—such, in sum, represents the realm of research. All else is investigation. Einstein and classical physics, Lobachevsky and Euclidean geometry, Pasteur and medicine—all are representative of research of the highest and purest order, a thorough re-searching of the foundations in the respective fields of learning.

A deep appreciation of the functions and objectives of research adding to the ever-growing reservoir of knowledge should be encouraged by mineral industries

college personnel. This, or assuredly more Canadian spruce must meet an ignoble end!

Extension Training: Today the mineral industries worker is paid for his knowledge and skill, not his brawn. The Extension Services of the School of Mineral Industries provide the facilities whereby workers in the mineral industries of Pennsylvania can secure training courses that will be of aid in industrial advancement or will provide greater satisfaction in their jobs. The major part of the program consists of the establishment of training classes in communities where there are a sufficient number of industrial workers to support a class, or in locations that are central to areas from which students may be drawn. Correspondence instruction provides training service for persons unable to attend classes, and the field of this service extends beyond the boundaries of the Commonwealth to other states and foreign countries. This is truly a service extension program with a philosophy of providing educational aids for the 600,000 productive workers employed by the great, basic mineral industries of the State.

The plan of the Extension Services provides centralized control of state-wide training, yet permits localization of control for individual classes. A supervisor, corresponding to a department head, is responsible for the work in each of the extension programs. This work consists of the organization and supervision of classes, the development of text material for use in both class and correspondence instruction, and the handling of correspondence instruction.

Class instruction has been developed along three major lines. The initial type of program, and still the major activity of the department, is the on-job, vocational-

technical training of workers in order to upgrade them to a supervisory or equivalent technical level. The second type of program is designed for men on the supervisory level, and its general purpose is to develop their supervisory capacities in the technical phases of their work. The third type of program provides training of a specialized nature for technicians of a particular plant or of plants of similar nature in the same area.

Classes of the first type, for workers of less than supervisory grade, are organized largely under public school supervision and control, utilizing state and federal funds to reimburse local school districts for the instructional expense incurred. In this type of program, the training is free to students except for textbooks or incidental expense. This organization work is done with the approval of the State Department of Public Instruction, but the actual work is carried on in co-operation with local school officials. Classes are established where there is a demand by industrial workers, or by industrial management, or sometimes by local school officials, where investigation indicates that there are a sufficient number of persons interested to maintain a class. Local instructors, qualified by training and experience, are used exclusively, and the quality of the instructional work is controlled by visits and consultations between the supervisor and the instructors. This type of class instruction is of less than college grade.

Training programs of the second type, for men on a supervisory level, were developed at the request of industry which recognized the need of training for these men who are a part of neither labor nor management. Programs are not fixed but are planned according to the particular needs of the company served. Group conferences, limited to 12 to 15 supervisors from the same plant or company, under the guidance of a trained conference leader, examine supervisory problems that

have developed in the plant or company, and offer solutions that the company may follow. Conferences are planned in advance by a committee from management working with the conference leader, but initial plans may be altered as the results of the conferences indicate the need for further study of particular topics. At present the College furnishes the conference leaders, and companies bear the expense of operation. It is planned to develop local conference leaders who will work under the guidance of the Extension Services supervisors. Development of these supervisory training programs on a state-wide scale and in all of the mineral industries will contribute materially to the efficient operation of these industries.

Frequent requests for training of a specialized nature for technicians of a particular industry are answered through classes developed solely for the requesting group. These may be of less-than-college-level, of college grade, or of graduate level work. Local instructors are employed and the classes are operated on a fee basis, with either the students or the company bearing the expense. This type of program is not extensive but it is important in that it provides a service that is unobtainable through other educational services.

Correspondence instruction by the Extension Services consists of both college credit and less-than-college-level work. The college-credit courses are developed by resident instruction staff members who also grade the lessons submitted in these courses. The less-than-college-level work consists largely of courses developed by extension personnel from the material used in extension classes, and these supervisors act as instructors in conducting the correspondence courses.

The text material used in extension classes and correspondence work has been developed by respective supervisors. The close association of the extension per-

sonnel with the resident instruction and research staff has resulted in carry-over from the resident work of advanced theories and methods where such are applicable to the extension work. In addition, each supervisor makes frequent trips to mines, plants, or mills in his particular field of industry so that he will understand the problems of the industrial worker and evaluate the type of text material best fitted for class and correspondence work. The textbooks are written in simple language, readily understandable by workers, and have found wide application in both industrial and college classes. The list of texts available includes three books in ceramics, five in coal mining, five in petroleum and natural gas, and three in metallurgy. Each set of books provides the material to be used in a curriculum or series of integrated courses. Two of the mining books are used in related subject-matter courses.

From a selfish viewpoint, the extension training may be considered in the light of missionary work. Industry can place its thumb on some definite progress at the end of each year.

The present staff of the Extension Services consists of a director, a supervisor, and two assistant supervisors of mining extension, a supervisor and an assistant supervisor of metallurgy extension, a supervisor in each of the fields of ceramics, petroleum and natural gas, and fuel technology, a supervisor and an instructor in supervisory training, and four secretaries.

THE CATALYSTS

Teamwork: The famous first sentence of an essay entitled *Aphorisms*, by Hippocrates, is as follows: "Life is short, the Art long, opportunity fleeting, experience treacherous, judgment difficult." The future of science does not depend so much on the number of scientists or the number of colleges, but rather on the individual qualities and the degree of perfection of a limited group of leading scientists and colleges. These are individual factors which require inherent talent which in turn is a condition evolved after generations of culture. Thus, very elaborate higher education for indiscriminate masses of humanity or students may not necessarily show the expected results. In other words, it is possible that higher specialized education should be given only to the few talented individuals, and their capacity and worth should be judged by as highly qualified and talented teachers.

Quality is the greatest of all competitive aids. An essential qualification that must be possessed by a quality mineral industries college is a high caliber teaching staff, for the mineral sciences will advance in the coming years only if the leading minds of today are made available as the mental springboards for our scientists of tomorrow. Mineral industries schools are finding it increasingly difficult to maintain a high caliber staff of instructors and administrators in competition with private business and governmental demands for similar personnel. As a result, staff quality of many schools has been progressively declining during recent years.

In order to maintain a first-class staff, mineral industries schools first of all must attract competent personnel with financial remuneration that places academic employment on a monetary par with industrial and governmental employment. Mineral industries schools,

moreover, must not only recruit the best teaching personnel available, but they must jealously guard the opportunities for those individuals to engage in research and writing by limiting the burden of excessive teaching load, committee work, administrative duties, and other frequently unessential activities. No leader can long remain in the forefront of his field without adequate time for thought, reading, and travel, and the mental stimulus of direct contact with fellow workers. What we think expresses, in reality, what we are.

There is no better way to explain the character of a mineral industries college than to take a look at the faculty which is required to administer the three functions of service. The subject matter is interrelated, interdependent. No man is big enough to be independent of others because no man is perfect. Under these conditions a faculty can be efficient and successful only if all of its members, irrespective of rank, work together in a smoothly running team.

Manpower for a mineral industries college will depend somewhat on the state's needs. It is desirable to place in print for the first time a team of specialists that meets the needs of Pennsylvania.

Geology

1. Stratigraphic geologist and paleontologist: Mid-Paleozoic and older rock formations and key fossils
2. Stratigraphic geologist and paleontologist: Late Paleozoic and younger rocks and key fossils
3. Field geologist and Director of Summer Camp: principles and techniques of geologic mapping
4. Economic geologist: occurrence and origin of useful non-metallic mineral deposits
5. Economic geologist: occurrence and origin of metallic ores
6. Petroleum geologist: occurrence, origin and geologic methods of discovery of oil and gas
7. Engineering geologist: geologic problems of water supply, highway construction, dam sites

8. Structural geologist: rock structures due to mountain building and other deformation of earth's crust, that affect all problems of rock occurrence
9. Geomorphologist: form and origin of topographic features of earth's surface, and their use in reading earth history and earth structures

Mineralogy

10. Theoretical mineralogist: fundamental mineral structure
11. Igneous petrographer: basic high temperature natural and artificial mineral processes and their results
12. Sedimentary petrographer: basic low temperature natural and artificial mineral processes and their work
13. Sedimentary petrographer: applied studies of Pennsylvania, nonmetallic mineral deposits with emphasis on clays
14. Metamorphic petrographer: basic high pressure natural and artificial mineral processes and their results

Geophysics

15. Geophysicist: exploration for oil; emphasis on seismic and gravimetric prospecting, electro logging
16. Geophysicist: exploration for minerals (solid); emphasis on electrical and magnetic prospecting
17. Geophysicist: earth magnetism and atmospheric electricity
18. Seismologist: earthquakes and operation of seismic station

Geochemistry

19. Geochemist: geochemical exploration; emphasis on micro-analysis for traces of hydrocarbons and mineral elements in near-surface rocks, ground waters and plants
20. Crystal chemist: changes and transformation of solids. Physical chemistry of surfaces, crystallization and adhesion phenomena

Meteorology

21. Synoptic meteorologist: elements of meteorology, elementary and advanced weather analysis and forecasting
22. Theoretical physical meteorologist: thermodynamic and hydrodynamic aspects of the atmosphere, its optical, electrical and acoustical properties, and the structure of the upper atmosphere
23. Climatologist: regional distribution of, and physical causes for the various climates, the modern aspects of applied climatology, and the biological effects of climate on the living organism

24. Meteorological engineer: instrumental equipment used in modern meteorology (electronics), observational methods, control of indoor and outdoor climates, effect of weather and climate on business and industry, flood control, air pollution and mining operations
25. Observer and forecaster: observation schedule, evaluate all station records, keep record log up to date, and make two complete weather analyses daily for issuing general and specific (frost, etc.) forecasts

Geography

26. Economic geographer: basic problems in resources, transportation, industry, and commerce
27. Cultural and political geographer: fundamental problem in the political structure of nations, development of people
28. Physical geographer: basic problems in cartography, plant geography, physiography, soil geography, climatology
29. Regional geographer: region geography of North and South America, Europe, Asia, Africa, and Australia

Mineral Economics

30. Mineral taxations expert: examine the present status of taxation with regard to optimum operation of a mineral property, proper conservation of resources, and national well being
31. Financial expert: to trace the origin, path of travel and destination of the mineral dollar and the fortunes of the individual operating companies
32. Mineral statistician: diagnose statistical data and project conclusions into the future
33. Foreign mineral and tariff expert: establish a mineral policy on a global basis, for all nations

Mining

34. Mining engineer: layout, open pit and underground
35. Mine mechanization engineer: fundamental and advanced problems in mine mechanization
36. Mining physicist: problems in dust, gases, and ventilation
37. Mine efficiency expert: time and methods studies
38. Rock and earth mechanics expert: problems in roof support, subsidence, stresses in roof, effect of weathering on strength of rock, and various other problems in rock mechanics
39. Mining engineer: plant design, construction, and operation

Mineral Preparation

40. Mineral preparation physicochemist: chemical laws in froth flotation, agglomeration, flocculation, sedimentation, dispersion, and lexiviation processes of mineral dressing
41. Mineral preparation physicist: movement of solids in liquid and gaseous mediums as applied to gravity, electrostatic, and magnetic concentration processes
42. Mineral preparation engineer: design of flow arrangements and control of the unit processes of comminution, sizing, concentration, thickening, drying, filtration, and removal of fine solids from liquid and gaseous mediums, as applied to mineral preparation plants and problems
43. Mineral preparation engineer: plant design, construction, and operation

Petroleum and Natural Gas

44. Petroleum production engineer—natural production: supervise instruction in petroleum engineering involving natural production
45. Secondary recovery engineer: water flooding, gas drive, pressure maintenance, recycling, mining, and other techniques for stimulating natural production
46. Reservoir engineer: theory and application of fundamental laws to the operation of petroleum reservoirs
47. Natural gas engineer: production and transportation of natural gas
48. Petroleum processing engineer: processing and treatment of petroleum and natural gas
49. Petroleum engineer: plant design, construction, and operation
50. Fluid dynamicist: flow of single and multiplied fluids in porous media
51. Surface chemist: fundamentals of static and dynamic interactions between fluids and solid surfaces such as found in oil reservoirs

Fuel Technology

52. Fuel technologist: fuel testing and calorimetry
53. Carbonization engineer: thermal processing
54. Combustion engineer: combustion and combustion engineering
55. Gasification engineer: gasification
56. Synthesis and fuel processing technologist: chemical processing and synthetic liquid fuels
57. High polymer technologist: constitution of coal, tars, and related products

58. Mathematical chemist or physicist: thermodynamics, theoretical combustion, and research data
59. Fuels engineer: plant design, construction, and operation

Metallurgy

60. Chemical metallurgist: thermodynamics of metal and slag-metal systems
61. Electrometallurgist: applied electrochemistry with particular reference to electrolytic smelting and refining of metals, and the corrosion of metals
62. Foundry expert: foundry practice and metal casting problems
63. Metallurgist: mechanical behavior of metals and the theory thereof
64. Process metallurgist: iron and steel smelting and refining operations
65. Process metallurgist: nonferrous production metallurgy, particularly the light metals
66. Physical metallurgist: mechanisms and kinetics of high temperature chemical reactions involving slag metal and gas-metal systems
67. Metallurgist or physicist: kinetics and mechanisms of solid state transformations in metals
68. Metallurgist or physicist: advanced work in the theory of the solid state, as applied to metals
69. Structure expert: light and electron microscopy as applied to opaque materials and in the interpretation of X-ray diffraction phenomena
70. Metallurgical engineer: plant design, construction, and operation

Ceramics

71. Theoretical silicate chemist and ceramic petrographer: fundamentals of high temperature equilibria and their interpretation in the field of ceramics
72. Igneous physical chemist: thermodynamics and rates of reactions; artificial minerals produced by industrial reactions at high temperatures (pigments, fluorescent materials, and catalysts)
73. Ceramic technologist: colloid chemistry and high temperature chemistry in the various fields such as ceramic raw materials, refractories, whitewares, cements, etc.
74. Ceramic engineer: plant design, construction, and operation
75. Glass technologist: fundamental properties of the vitreous state, chemistry of colors in glass, and such problems as the chemistry of glass surfaces

76. Glass engineer: industrial trends, including current changes of glass batch composition for greater chemical resistivity, development of new products, and new processes
77. Ceramic artist: design and creation of ceramic objects of art

Tools: A final necessity essential to a quality mineral industries school, but absent in so many present-day institutions, is an adequate physical plant for faculty and students. Without proper buildings and modern equipment, there is lacking an appropriate environment both for teaching and research. Adequate facilities should include: (1) classrooms available in proper number and size, fully equipped to serve all needs; (2) appropriate laboratory facilities for instructional and research purposes; (3) ready reference library facilities; (4) an adequate instrument making and repair shop; (5) receiving and stock rooms; (6) museum and art gallery; and (7) sufficient individual laboratories for all key members of the staff. Likewise, there should be proper arrangement of offices, classrooms, and laboratories in order to provide the quiet and solitude so necessary for mental pioneering.

The Mineral Industries group of buildings at The Pennsylvania State College, i.e., Mineral Industries building, first unit, Mineral Sciences building, Coal Combustion Laboratory, Mineral Industries Summer Camp, (Figs. 11, 12, 13, 14, 15, 16) comprises one of the most modern physical plants anywhere devoted to mineral industries education. The buildings and the equipment, with few exceptions, have been acquired in the past eighteen years, and could not be duplicated for \$4,000,000. Mineral Industries and Mineral Sciences are connected on the ground floor and operate as one to insure physical plant efficiency. The buildings are planned to meet all foreseeable eventualities, whether

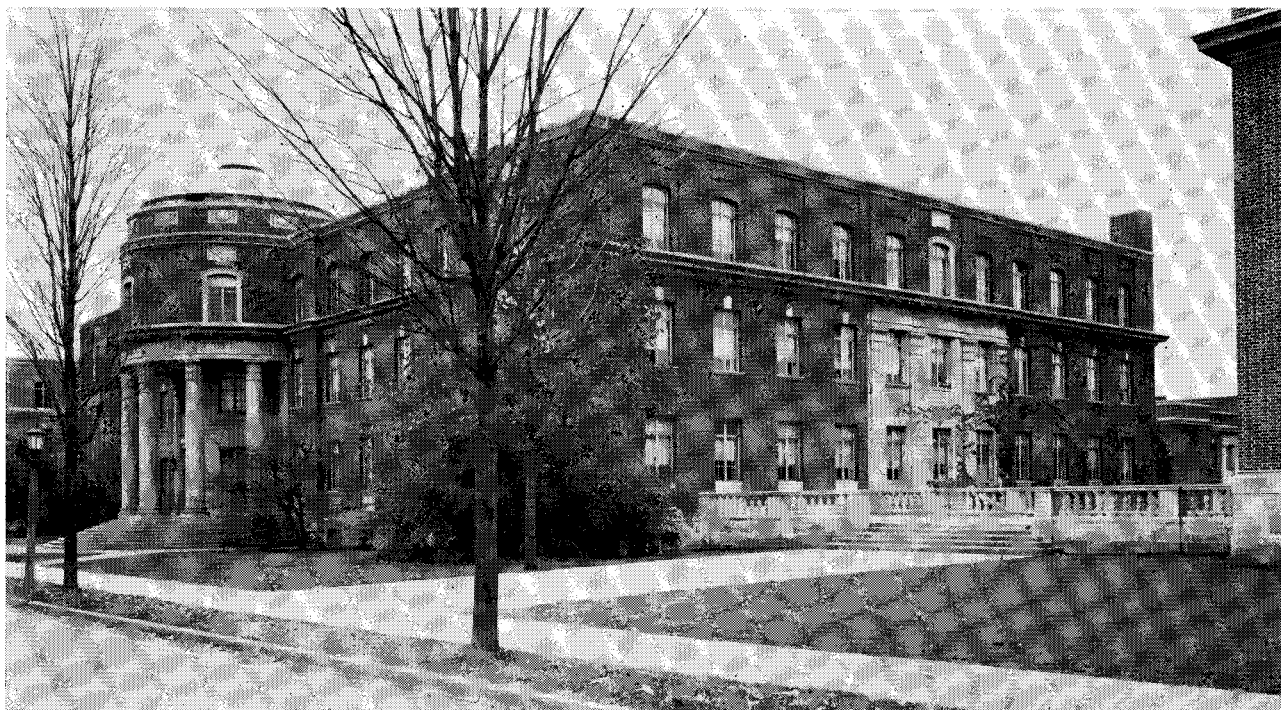


Figure 11. Mineral Industries building built in 1929, first step forward towards a comprehensive program of service.

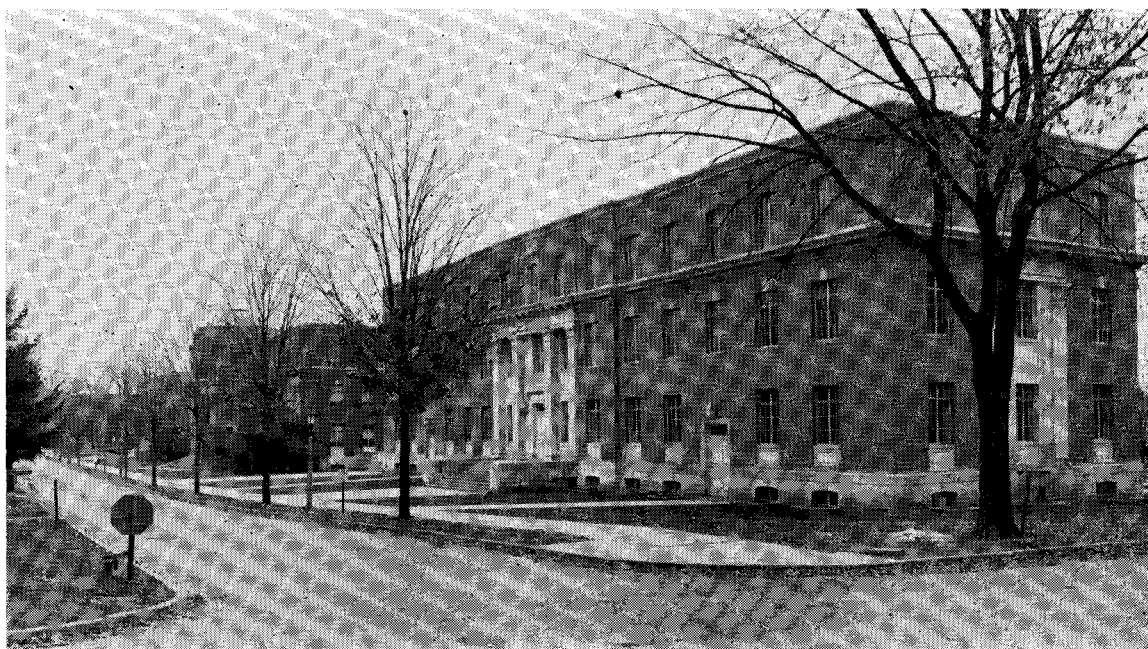


Figure 12. First unit, Mineral Sciences building, built in 1948 (see Figure 17). Mineral Industries building in background, followed by Willard Hall, the general classroom building.

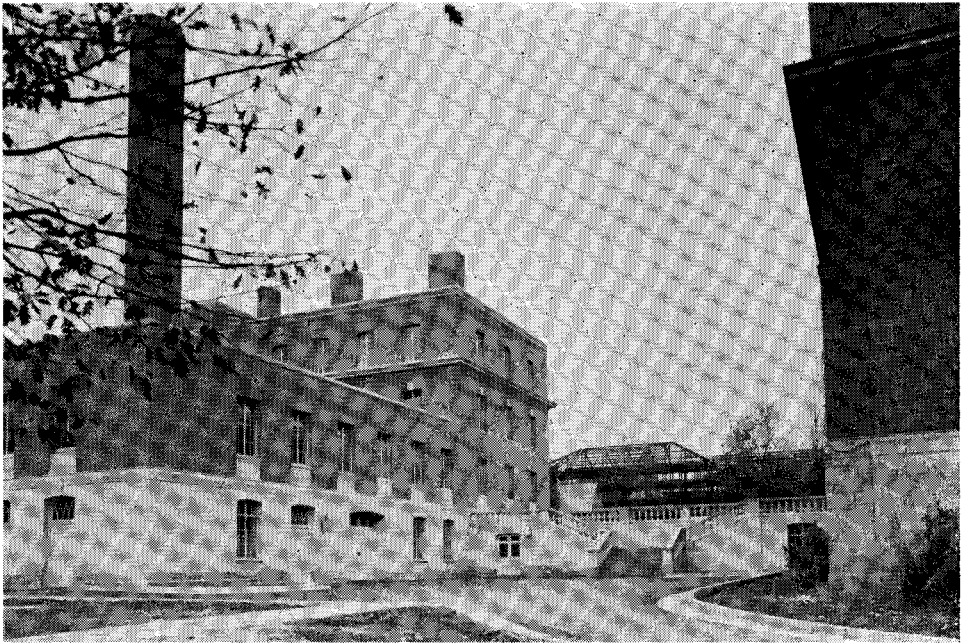


Figure 13. Rear view, mineral processing wing, new Mineral Sciences building, showing ground floor connecting unit, and new men's dormitories under construction in background.



Figure 14. Rear view, first unit, Mineral Sciences building, Mineral Industries building in background, followed by Willard Hall, the general classroom building.

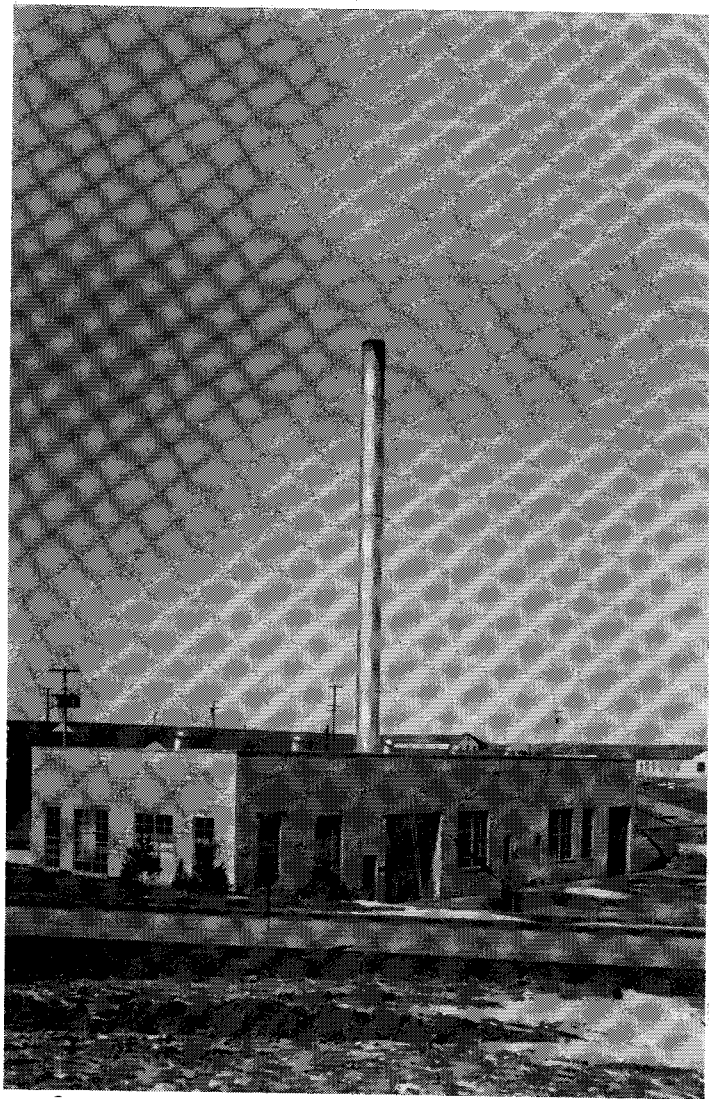


Figure 15. Coal Combustion Laboratory (and auxiliary heating plant) on east campus, built in 1948.

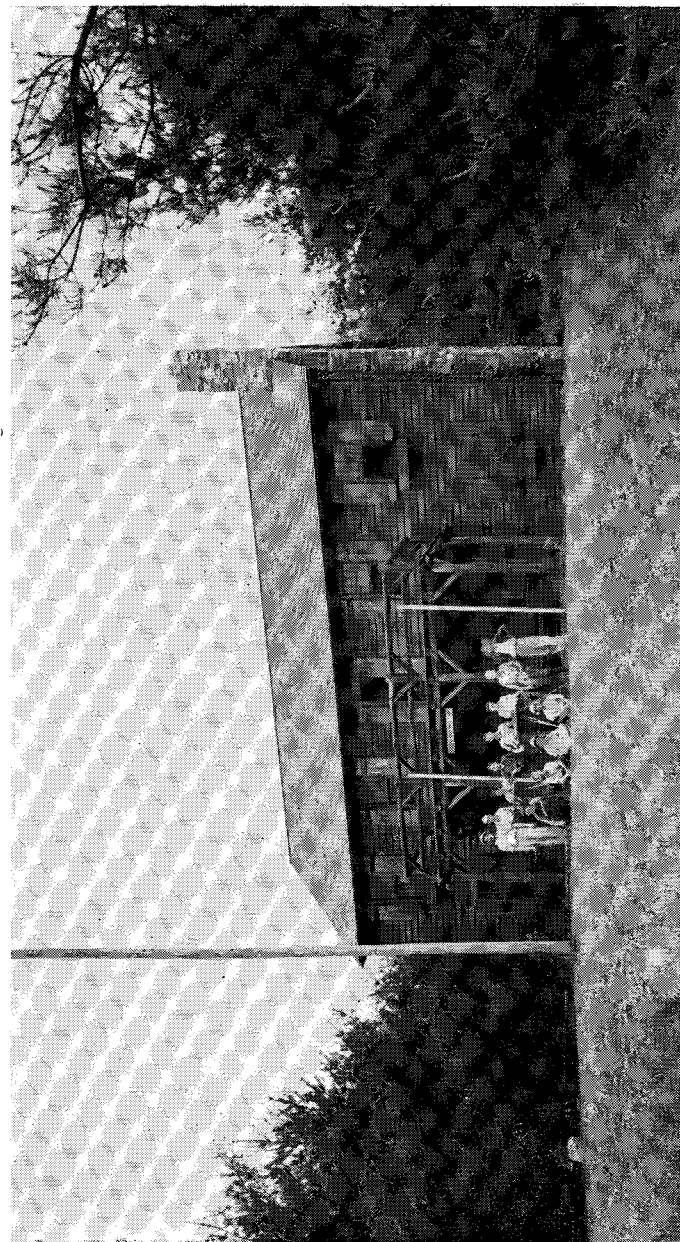


Figure 16. Mineral Industries Summer Camp in Stone Valley, built in 1937.

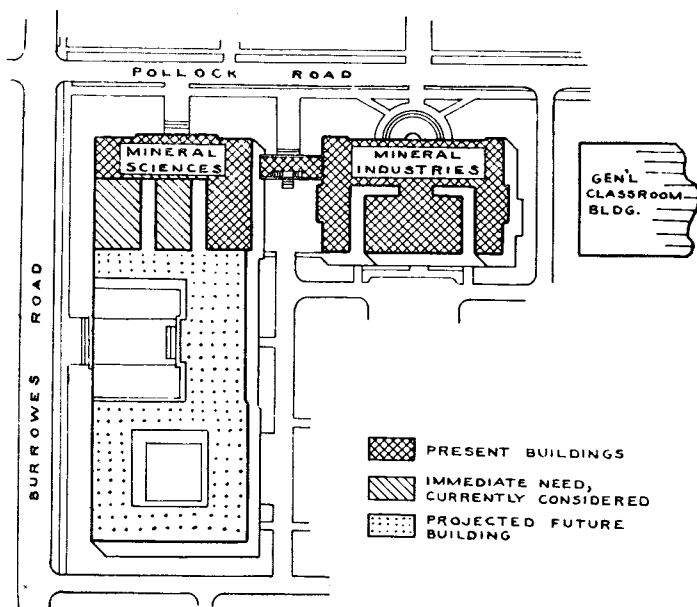


Figure 17. Greater physical plant facilities must be provided to compensate for the ever-increasing difficulties encountered in the conversion of minerals to common wealth.

instruction, research, or extension training in each of the subject-matter fields. Service suites of laboratories were established wherever possible, including crushing and screening, chemical analysis, physical testing, and mineralogical analysis. The latter service unit, for example, consists of laboratories for sample preparation, optical microscopy, X-ray diffraction and differential thermal analysis, spectroscopy and electron microscopy and diffraction. A large, fully-equipped dark room is operated in conjunction with the unit.

The original plans for the new Mineral Sciences building provided for the minimum current requirements of the School. In order to meet the limitations imposed by rising building costs these plans were cut down five times, eliminating elements as follows: the central wing, shrinkage of the front main section, the west wing, the third and fourth floors of the east wing, the sub-basement under the front main section.

The lost space (Fig. 17) included special facilities for beneficiation of coals, clays, iron ore, glass sand, and other submarginal mineral deposits of the Commonwealth; for development of new uses and new products in the nonmetallic mineral field—refractories, glass, cement, terra cotta, drain tile, face brick, enamel, white-ware, porcelain, abrasives, etc. (these give the best promise for new industrial expansion in Pennsylvania); for calibration of instruments and research requiring constant temperature, such as creep in metals, glasses, etc.; and also for the development of instruments for searching subsurface structures and paleobotanical studies in connection with Pennsylvania coals. The iron and steel business in Pennsylvania depends upon a continuing supply of quality coking coal and refractory flint clay, the first-grade resources of which are facing exhaustion (in the Commonwealth). The metals and alloys produced are indispensable in all our manufactur-

ing operations. Consequently, the lost space is directly connected with the economic structure of the Commonwealth and should be included in any new building program financed by public monies.

Adequate space has been provided for the Instrument Shop, which is responsible for the upkeep of equipment and the construction of special new equipment used in graduate instruction and research. The staff of the Instrument Shop at present consists of a head instrument maker and six thoroughly trained and experienced mechanics.

There is a receiving and shipping room and ample facilities for storing and dispensing supplies and accessory equipment. These activities are in charge of supply clerks.

The new Coal Combustion Laboratory is one of the most completely equipped and flexible laboratories in the country for combustion engineering research. The laboratory is adjacent to and interconnected with a small district heating plant servicing one of the College temporary dormitory developments. The equipment available permits a wide variety of operating conditions to be studied on units with burning ranges from 20 to 1000 pounds per hour, including twin 6' x 6' stokers firing twin 178 h.p. boilers so metered and instrumented that comparative performance can be observed and recorded when new developments are tried on one of the units.

The Mineral Industries Summer Camp, constructed by Farm Security Administration in 1937, is located in the heart of Pennsylvania, within the folded ridge and valley province of the Appalachian Mountains. It is ideally situated for the study of the great series of depositional and mountain-making events which culminated in one of the chief revolutions of geologic history,

the folding and uplifting of the Appalachians 200 million years ago.

In the mountainous area within a few miles of the camp site there are exposed a series of sediments totaling over twenty thousand feet in thickness, ranging in age from the Cambrian to Mississippian. These have been complexly folded and faulted, uplifted and eroded so that they now offer an exceptional opportunity for the development of the field techniques in studying and piecing together the past story of the earth as revealed in the rocks.

The camp is located 13 miles south of State College in wide, rolling Stone Valley, bounded on the north and south by Tussey and Stone Mountains. The main building consists of an attractive rustic hall combined with dining hall and living room, classrooms, recreation rooms, laboratory, drafting rooms, and offices. A total of 36 students and staff may be housed in 12 cabins furnished with steel cots, dressers, and electric lights. The camp has its own well and reservoir and modern sewage disposal plant. Outdoor recreational facilities are available at the camp and nearby recreational areas.

The Mineral Industries Museum is the only institution of its kind in Pennsylvania devoted exclusively to the mineral industries. The total length of museum display cases organized since 1930, exceeds a quarter mile, four shelves each, making a full mile of shelving. This is exclusive of cases used in the laboratories and classrooms. The material is carefully arranged adjacent to classrooms and laboratories in which instruction in a particular subject-matter field is given. One mineral collection is arranged according to the Dana classification. An exhibit of fluorescent mineral flowers is a never-ending source of wonder to visitors, as is the display of gem stone crystals and corresponding cut stones. A large room on the first floor off the lobby is devoted



Figure 18. Section of the Mineral Industries Art Gallery, a unique educational project.

to Pennsylvania minerals and mineral products. Large size geologic and geographic relief maps of Pennsylvania are displayed as background material. The museum is a repository for the Levi Smith Memorial Collection, which was awarded highest honors at the Columbian Exposition, 1892, and is exhibited through the courtesy of the Warren, Pennsylvania, High School.

The reference collections, which include the Frederick A. Genth Memorial Mineral Collection and the Krantz Rock and Thin Section Collection for research and advanced study, are among the prized items of the School.

The paleontological display is arranged in chronological order beginning with the earliest forms of life and carrying through prehistoric and modern man. There is an excellent representation of the various eras, the aim being directed to systematic study, rather than confusion for students in the earlier stages and for the general public. Behind the scenes the advanced student or research worker has thousands of specimens from which to draw.

There is not space to explain the displays in each subject-matter field. The mining phase is covered by items from those of historic interest to the most modern equipment, including that used for accident prevention and rescue work. The School is the fortunate recipient of the famous anthracite composite mine model, and the Foster collection of mine safety lamps, comprising the earliest types of mine lighting and gas detecting, together with their evolution to the later types.

Art has always grown out of life and life situations. There is an inner urge to create expression to meet the physical and spiritual demands of daily life. The Mineral Industries Art Gallery (Fig. 18), consisting of 165 original paintings and murals, was opened formally in 1942. The Gallery is a record of artists who have

found a congenial and fascinating subject. These are not dreary pictures of depressing scenes; they are vivid with scenic beauty, life, action, color, and drama. The Gallery is a fortunate opportunity for the vast army of young people who are led through progressive educational experiences to an eager interest in mining operations and the processing of minerals as well. They are fortunate to have these colorful visual aids to a better understanding of Pennsylvania's mineral industrial economy.

The 75 artists represented are not only recording the industrial scenes of today but are making a contribution as historians, having set down in many instances the passing scene in Pennsylvania for the information of future generations. The paintings include scenes in and around coal mines, in both the bituminous and anthracite fields; views painted in the scorching heat of the steel mills, pictures of towering oil and natural gas rigs and other general panoramas in the Pennsylvania oil fields; views of lime kilns, coke ovens, stone quarries, brick plants, glass works, and many other scenes of activities and objects. Virtually every section of Pennsylvania is represented. One is of the Diamond Colliery near Scranton, one of the oldest collieries in the anthracite region. Another shows one of the last bee-hive coke ovens to operate continuously in Pennsylvania. A painting made at Johnstown represents one of the first by-product coke plants installed in this country. Another is of the now dismantled Schollenberg rolling mill on the Monongahela River, Pittsburgh. The Lucy Furnace, one of the oldest iron blast furnaces on the Allegheny River, Pittsburgh, and a picture of a typical oil derrick at Titusville where oil was first discovered also are included.

The paintings, as well as the museum material, are gifts to the School by friends, alumni, and artists. The

Museum and Art Gallery have proved to be peculiarly worthy of an essential place in the over-all educational scheme, in order to make the citizenry more mineral-conscious. A full-time curator is in charge.

Library: Libraries and the advancement of civilization are closely allied. Technical libraries are of recent origin and are now recognized as essential elements in technical education. Technical literature in the mineral arts and sciences has progressed in much the same pattern as mineral production. The physical volume of publication since 1900 is probably greater than the combined production of the past. Technical librarians require a general knowledge of the sciences and technologies, as well as knowledge of languages and of library techniques.

The libraries may be considered as storehouses of scientific and technologic knowledge. But storehouses are, so to speak, locked, and a student must be taught to use the keys to them. The student must learn how to avail himself of the fund of information at his disposal and to use it efficiently. The keys are a card catalog. The catalog, however, is in reality only introductory. The student must familiarize himself with still other keys, such as indexes, abstracts, bibliographies of special fields, which open to him vistas of what has been published, even though his own library may not have it all on its shelves. Especially in the field of mineral industries, where no single comprehensive bibliographical guide has come into being, must he acquaint himself with abstracts in related fields. A student must have progressed beyond the textbook as his main source of information and be able to tap the primary sources which are recorded in the great mass of technical literature.

Lord Beaconsfield aptly stated: "The more extensive a man's knowledge of what has been done, the greater will be his power of knowing what to do." Research usually implies a laboratory with flasks, retorts, and delicate apparatus, all skillfully manipulated by a scientist. The technical library, the universal tool, must nowadays be included in the picture. Library research will prevent two serious mistakes often made by scientists: duplication of studies already made and failure to employ established methods and procedures. These observations also apply to the scientist working in the field. The individualized life of a scientist is a thing of the past, perhaps something to be fondly remembered. Today the scientist avails himself of the findings of scientists the world over through the printed word.

The need for a mineral industries branch library is readily apparent. In the past 16 years the combined original library of 1000 volumes has grown to a good working collection of over 15,000. These are devoted to the application of science in the fields of geology, mineralogy, geophysics (including meteorology), geochemistry, geography, mineral economics, mining, mineral preparation, petroleum and natural gas, fuel technology, metallurgy, ceramics, and closely allied subjects. The School may be considered one of the pioneers in the movement for the formation of specialized technical collections.

Journals in English, as well as other languages, constitute the greater part of the collection. More than 300 leading periodicals, not including transactions, proceedings, annuals, and monographs relating to the mineral industries, are currently received. Geological reports, bulletins, investigations, and circulars of the technical departments of state and federal governments, as well as those of foreign governments, bulk large, along with the publications of the professional societies, and of

institutions, both domestic and foreign, that are engaged in the same special phases of work as the School. No effort is spared to develop the collection systematically in respect to current literature; in fact, the work contemplated by the divisions and departments of the School is constantly kept in mind with a view to having on the shelves the required material when it is needed. To accomplish all this requires constantly a comprehension of the work being done by the School, a careful evaluation and selection of the printed material as it is published, and—imagination to keep within the limits of the budget.

Books also are necessary, even though their research value is of secondary importance to that of the journals. The value of sets of periodicals increases with the years, while that of books decreases. Authors frequently publish their findings in the former as soon as they arrive at safe conclusions, long before they are put into book form for the convenient use of students. Often, too, books are superseded in the course of six or seven years. There are, of course, exceptions to this rule as there are to any good rule; for example, the writings of scientists and engineers who have made significant and permanent contributions to mineral literature from the time of Agricola to the present.

For the effective use of the library, bibliographical tools, guides to the literature are indispensable. Without them there is no way of finding out what has already been done in a particular field. Of these guides some are of a comprehensive character; others are limited to special fields. Again, some of these guides appear at stated intervals, and others from time to time as the results of investigations become available. Governments, institutions, libraries, professional societies, all employing experts, contribute to the production of these highly exacting and valuable technical works.

Rarities already in the Mineral Industries Library include Agricola's *De Ortu & Causis Subterraneorum* (1546); *De Re Metallica* (1556, as well as the Hoover translation of 1912), and the German edition of the *Berckwerckbuch* (1580). Other pioneers represented in the collection are: Pettus' *Fleta Minor. The Laws of Art and Nature, in Knowing, Judging, Assaying, Fining, Refining and Inlarging the Bodies of Confin'd Metals* (1683), Schonberg's *Ausfuhrliche Berg-Information* (1693), Delius' *Anleitung zu der Bergbaukunst* (1773), de Saussure's *Essais sur L'hydrométrie* (1783), Mac-lure's *Observations of the Geology of the United States of America* (1817), Berzelius' *Nouveau Système de Minéralogie* (1819), Davy's *On the Safety Lamp for Preventing Explosions in Mines* (1825), Brongniart's *Traité des Arts Céramiques* (1854) and Wright's *The Oil Regions of Pennsylvania* (1865), to mention a few.

The Mineral Industries Library is a living organism, not a mere collection of journals and books. Forty-one thousand (41,000) persons have been served during the past year, including representatives of the industries, especially small industries throughout the State. This service included answering of individual reference questions, assisting in the preparation of bibliographies, and giving instruction in the use of the tools of the library. Since inquiries often must be pursued into other scientific fields, the library makes a point of procuring what is required either from other libraries on the campus, or through interlibrary loan, or, in lieu of the original materials, a photostat or microfilm. The library is in charge of a professional, technical librarian and two assistants.

MINERAL DOLLARS AND SENSE

Capital, as represented by mineral resources, is being exhausted rapidly without possibility of identical replacement. The public must be discouraged from thinking—why worry about the bank balance so long as there are plenty of blank checks? Instead of each man, woman, and child being owners of a mineral capital of \$89,000 as former Secretary Ickes once stated, they are really the guardians of a mineral reserve which, when harvested, cannot be reproduced. The proper use of this material is the basis of modern civilization and military power. The best American institutions cannot be maintained or transmitted to our children unless this trust is guarded.

It is unfortunate that more attention has not been focused on the fact that this country is headed for a have-not status in the family of great nations if something is not done to preserve its mineral heritage. It is the privilege of the United States now to champion and implement democracy because it is industrialized and can get at its raw materials. A high price is being paid every day in mineral depletion for the privilege. No one can eat his cake and have it too. The United States still must face world-wide economic competition and, perhaps, World War III.

In the final analysis all wealth comes from the ground, whether plant, animal, or mineral. Value is introduced by human effort, and neither the coal nor the petroleum of Pennsylvania is of value until extracted from the ground. Plants and animals follow the same pattern, and a tree growing in the forest or grain in the field is of little value until true utility is introduced by human hands. Therefore, it is of the greatest impor-

tance that the human element be trained to its highest efficiency and applied with the greatest intelligence. This is the objective of education. The concept of primary wealth may well be broadened to include the human mind as a third component, without which all else is valueless.

It is unnecessary to enlarge on the leadership of Pennsylvania as a producer and processor of minerals. However, certain elemental relationships between minerals and agriculture should be understood. The production of minerals varies with industrial activity and changes in the business cycle are reflected in an increase or decrease of mineral production. On the contrary, the volume of plants and animals progresses at a fairly even level and does not exhibit the wide swings recorded by mineral production. The demand is more constant and not subject to great variation, as food demands tend to remain level and, in general, follow population trends rather than industrial trends. Agricultural products are perishable and, therefore, cannot accumulate for many years or produce a permanent stockpile. However, they can be bred in successive generations, and the problems of conservation in agriculture are essentially those of management. With minerals, actual saving must be encouraged.

The service of agriculture in providing food and clothing cannot be overemphasized. It must be remembered that agriculture has changed within the present century from the family unit, operated by actual horse power, to the mechanized farm with its productivity multiplied many times by labor-saving machinery dependent upon steel, other metals, and petroleum. Similarly, the maintenance of soil fertility can be assured only by the use of mineral fertilizers supplying the necessary lime, phosphorous, potash, and nitrogen without which plant life cannot survive. In other words, the

free flow of plants and animals from the farm may be maintained and prolonged only by a free flow of minerals from the ground.

The only denominator common to agriculture and mining is the dollar. Using this yardstick of value we find that in Pennsylvania, minerals year after year account for two-thirds of the value of primary wealth, and agriculture for one-third. In other words, for one dollar produced by agriculture, two dollars are produced by extraction of minerals.

The value of minerals produced in Pennsylvania in one year frequently exceeds one billion dollars. This is primary wealth in the most elementary concept. It is the value of the minerals as removed from the mine, quarry, or oil well before conversion to heat, machines, structural members, fertilizers for the soil, or the thousand and one things in which minerals serve the people. The ultimate value of minerals in their role as a base of industry and the maintenance of present living standards is beyond calculation. In Pennsylvania it may be said to progress in a single year somewhat along the following pattern:

Value of minerals as recovered	
from the ground	\$1,000,000,000
Processed value	2,000,000,000
Final form as used by consumer	4,000,000,000
In support of all other industry	8,000,000,000
National defense and support	
of American democracy	Beyond calculation

Accurate figures are beyond acquisition, but the general geometric progression as indicated above is representative. Minerals are the base upon which industry rests and grows in constantly expanding ratios. Actually the dollar value does not represent the truth. The

truth lies in the fact that mineral products in their final form supply the foundation upon which American standards of living and national defense are dependent.

Mineral deposits are unusual freaks of nature and the result of a sequence of geologic events rarely repeated. There is a false sense of abundance because there have been consumed within a few years the accumulations of millions of years of geological time. The problem of conservation is one of acute importance at the present time. However, the exhaustion of minerals does not present as hopeless a picture as might be imagined. Man can constantly alter the grade of ore used, increase efficiency in use, and develop substitutes if research is planned to learn the necessary facts. An entirely new concept of mineral reserves may be developed in this manner, and this is the hope of the future.

As shown above, the value of minerals to civilization is beyond determination. However, a start can be made by taking the figure of \$1,000,000,000 as the value of mineral production in Pennsylvania for one year. To insure this flow of primary wealth, how much would a business man appropriate each year for two purposes: (1) to train the men to conduct the operations and to supply industry with research workers; and (2) to conduct such research in primary science as industry cannot do, or to use the unusual equipment in laboratory or scientific library as may be assembled in the School of Mineral Industries? One per cent of the annual sum would be \$10,000,000, and certainly this is no mean sum and actually so large as to be unnecessary. One tenth of one per cent, or \$1,000,000, would be more practical and well within the limits of possibility; likewise, a just use of taxpayers' money. The expenditure of such a sum in Pennsylvania's School of Mineral Industries is not to be regarded as patronage of education

or science but as investment which will pay large dividends in employment and security for the future.

The responsibility of directing the investment of such a sum would be great indeed. It should not be spent to design improvements on existing devices or in commercial testing or in engineering experimenting better done by commercial firms. It should be invested in the study of fundamentals. Fundamentals are concerned with the formation of minerals, how they may be discovered, how lower grade material may be used, how the submarginal minerals of Pennsylvania may be upgraded to commercial standards, how primary processes and treatment can be improved, and how intelligent use may preserve present reserves for the use of future generations and true conservation attained, thus pointing the way to new products, new uses, more jobs—individual participation in common wealth. Under these conditions the life of Pennsylvania will not slacken or fail in the competitive world of the future in which man will be forced constantly to do more and more with less and less.

CONCLUSIONS

"The earth is the Lord's and the fullness thereof." Science knows no national boundaries, knows no country. These views might be taken as premises for a discussion of the development of the mineral resources of the world. Yet how far man is removed from such broadminded ideals! In this day of jealousy and dread, of political machinations and statesmen's maneuverings, of rantings and crass ravings against fellow-beings, man's attitudes towards God's gifts are but the measure of the smallness of man.

That the exploitation of mineral wealth should be



Figure 19. Thirty-inch globe especially designed and constructed in the School to show the world-wide distribution of minerals and their flow to the processing industries of the United States.

for the common good, none will deny, but what is meant by "common"? Is it for the common good of The Pennsylvania State College, Pennsylvania, the United States of America, or the world? If man is big enough and honest enough to state categorically that by "common," as used in the context above, is meant that the utilization of the mineral wealth should be for the mutual benefit of all mankind, and that all concerned strive to see that such a viewpoint is executed, then there is brighter hope for the future.

It is to be hoped that the world may have at least a few years or possibly a generation of peace. What can be done in these years to work towards the ultimate goal of human improvement? The work of statesmen in the drafting of international agreements and the easing of small frictions which appear between nations, as they do between members of the same family, is beyond the scope of this discussion. The best contribution anyone can make lies in his own field with which he is best acquainted and in which he is in a position to effect some positive accomplishment. Therefore, mineral industries colleges are concerned with the adjustment of the mineral industries in a postwar world.

World War II proved that an uninterrupted flow of mineral supplies is a necessity for victory. The maintenance of peacetime industry at its present level is dependent upon the same movement (Fig. 19). And it is believed that the present level will not extend very far into the future. Man is faced with the problem of constantly acquiring an increasing tonnage of supplies in a geologic world in which the problem of discovery constantly increases. The adjustment of mineral industries to an ever-changing world presents certain difficulties which must be approached from the viewpoint of a practical solution if they are to be solved at all. Five basic considerations are:

1. The world and the public as a whole must be made more mineral-conscious. This is necessary if conservation is to be practiced in production and utilization which will become increasingly necessary as time goes on. It is necessary also to ponder seriously the implications of all new discoveries, and to insure the mineral industries the protection and support which are their just due.

2. Educate the trained man. There are not enough trained technologists or workers in the fields of discovery, production, and processing. The demand for such men will grow as industrialization spreads over greater areas of the earth's surface. The quality of training must improve to keep abreast of the advances of science and to apply these advances to the best interest of mankind.

3. Expand the knowledge of the fundamental properties of minerals. In spite of the centuries in which minerals have been used, and the immense advances made in the past 50 years, little is known about their fundamental properties or the manner and extent that such properties can be made serviceable to society.

4. Maintain the war-won knowledge that common hazards must be met with a common front. No man can live alone and no country can live alone. In the problems of the mineral industries a common front must be maintained for the mutual benefit of all.

5. Achieve greater understanding through congresses, technical conferences, exchange professors, exchange students, technologic aids; and aid in the training of skilled technicians.

Almost all nations have as much to lose as the next. But in these times of stress, if nationals can forget some of their selfish interests and learn to appreciate the particular capacities and skills of others, then nations can create a common ground of understanding and mutual

appreciation which can be extended and expanded in the future.

In summing up the characteristics that should be possessed by a *quality* mineral industries college, we can see that the following attributes are imperative:

1. *Entrance requirements* on a sufficiently high level to assure admission of superior students only.

2. *Courses of study* designed to prepare students to think in terms of (a) scientific fundamentals, and (b) human implications, rather than to prepare highly specialized technicians who are blind to the grand scheme of the world course of events.

3. *Classroom standards* of such high caliber as to avoid what has been so aptly designated as the "trained incapacity" of the current crop of graduates.

4. *Physical plants* containing every possible known tool that may be required in exposing the innermost secrets of the Mineral Kingdom, including technical library, instrument shop, museum, and art gallery.

5. *Faculty* composed of leaders in the respective fields of study, and cognizant that modern scientific progress is in a large part dependent on teamwork.

Now if all or most of the mineral industries colleges possess moral courage to succeed, in spite of opposition, and monetary wherewithall to meet the above described qualifications, what will be the future outlook for the mineral arts and sciences and for the people?

There will be witnessed:

1. A tremendous forward surge in the frontiers of *basic* mineral science, a movement, resulting from the correlation of minds skilled in the basic scientific concepts. This is a field long preempted by European scientists, where thorough training of the best minds in fundamental aspects of science has long been the commonly accepted educational procedure, rather than the typical

mass-education methods and applied scientific training so common heretofore in America. Thus, this country will move into the vanguard of fundamental mineral science knowledge and replace Europe in this traditional role.

2. Continued leadership in application of basic advances in mineral science to practical problems of industry, a field in which America has long held leadership.

3. A new generation of mineral scientists, schooled not only in the technical intricacies of their particular field, but also educated to recognize their responsibilities as citizens, to advance human welfare, to strengthen the economy of free enterprise, and to seek the ways of peace and harmony.

Obviously, a great deal depends upon how successfully the present generation of mineral industries educators will carry out their public trust. Let us not try to believe impossible things! Mineral industries colleges must face the challenge of the times and discharge their obligations to society effectively. The opportunities are great; the very fate of mankind may depend upon the adequacy with which the challenge is met.