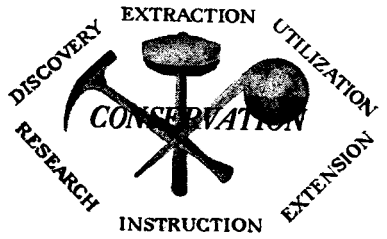
The Pennsylvania State College Bulletin



SERVICE to
the COMMONWEALTH through

Mineral Industries Research

CIRCULAR 36

SCHOOL OF MINERAL INDUSTRIES
THE PENNSYLVANIA STATE COLLEGE
STATE COLLEGE, PENNSYLVANIA

Pennsylvania's School of Mineral Industries

Dedicated to education in mineral conservation and research by which the means may be found to make conservation effective. This includes diligent search for mineral truths and the energetic discovery, maximum recovery, and complete utilization of irreplaceable mineral resources.

FIELDS OF WORK

Earth Sciences: Geology, Mineralogy, Geophysics, Geochemistry, Meterology, and Geography.
Mineral Engineering: Mineral Economics, Mining, Mineral Preparation, and Petroleum and Natural Gas.
Mineral Technology: Fuel Technology, Metallurgy and Ceramics.

DIVISIONS OF SERVICE

Resident Instruction, Extension and Correspondence Instruction, Mineral Industries Research.

RESEARCH: A FUNCTION OF THE COLLEGE

The foundations of The Pennsylvania State College are the Morrill Land-Grant Act of Congress signed by Lincoln in 1862 and the 1863 act of the Pennsylvania Legislature implementing the federal legislation and designating this institution as the instrument of the Commonwealth in carrying out the terms of the federal act.

The spirit of research which permeates the College is in keeping with the purposes of the Land-Grant Act in bringing the methods and procedures of modern science into relation with the agricultural and industrial pursuits of the nation.

The mineral resources of Pennsylvania have always dominated its economy. The advanced stage of their development has brought problems that must be solved if the Commonwealth is to retain her position of economic leadership. In the solution of these problems another resource, scientific and technologic research, is necessary. One of the important functions of Pennsylvania's School of Mineral Industries and Experiment Station is to develop this great resource—research—by educating leaders in technology through graduate instruction and by aiding in the solution of technical problems.

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STATE COLLEGE, PENNSYLVANIA

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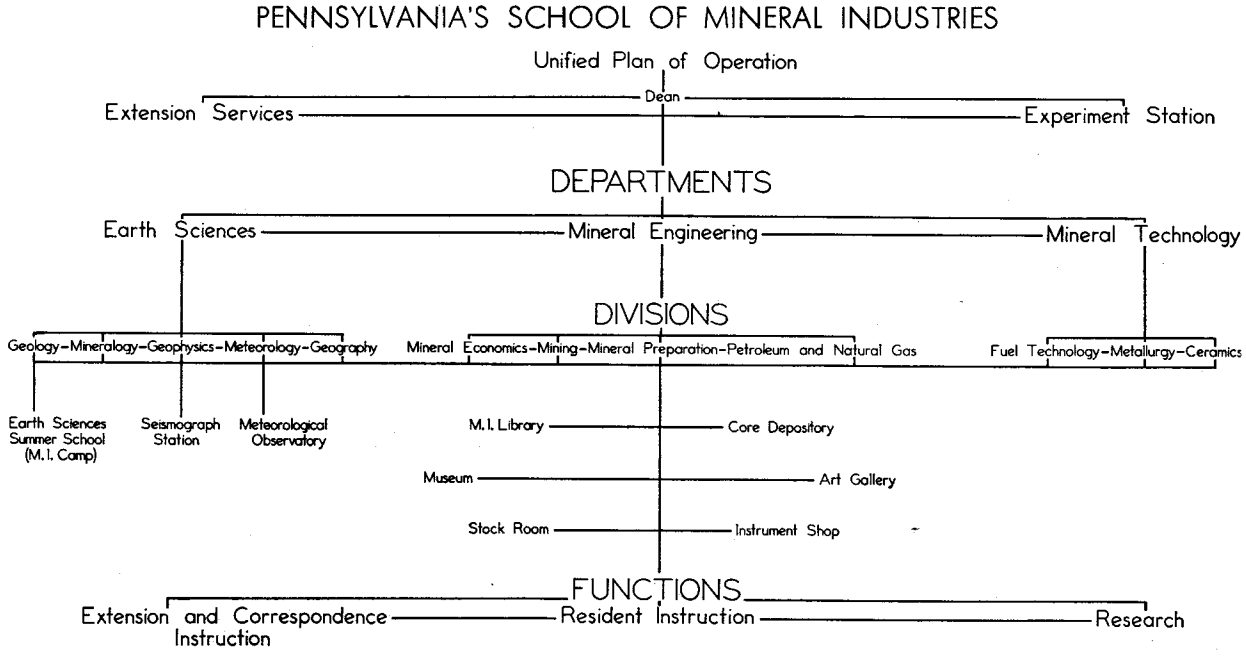


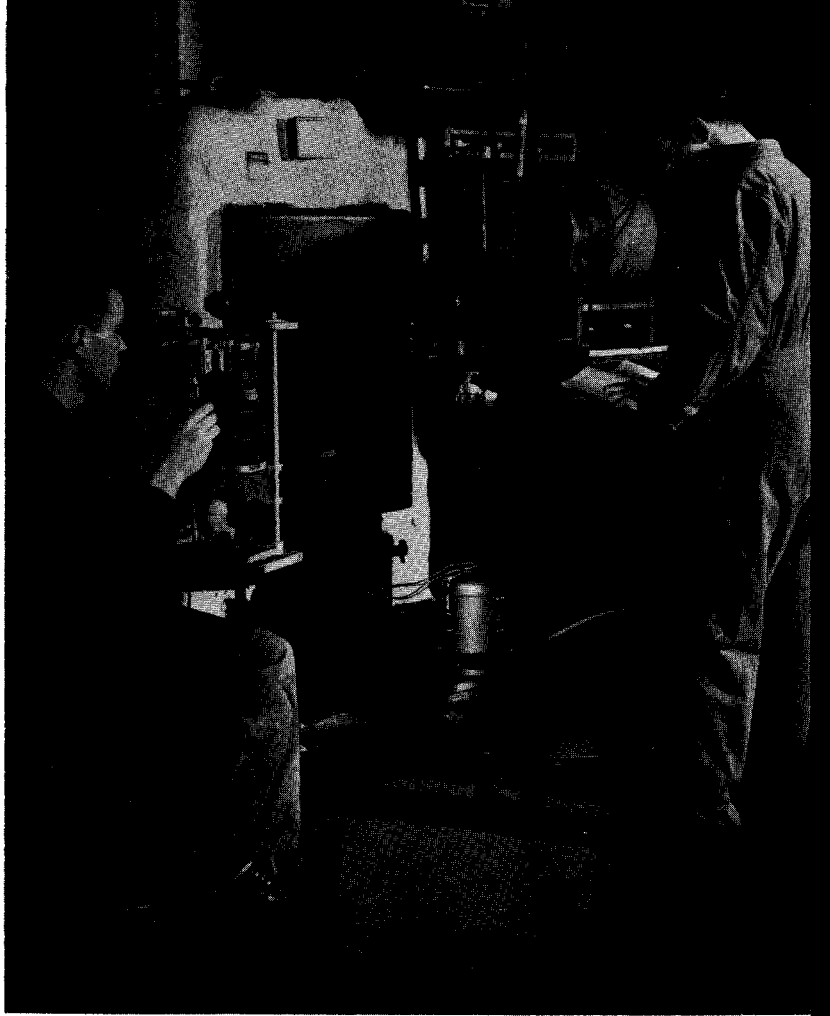
Foreword

The School of Mineral Industries of The Pennsylvania State College is organized into three Departments which encompass all phases of exploration, development, exploitation, primary processing and utilization of natural mineral resources. These Departments are: (1) *Earth Sciences, including the Divisions of Geography, Geology, Geophysics and Geochemistry, Meteorology, and Mineralogy,* (2) *Mineral Engineering, including the Divisions of Mineral Economics, Mining, Mineral Preparation and Petroleum and Natural Gas Engineering, and* (3) *Mineral Technology, including the Divisions of Ceramics, Fuel Technology and Metallurgy.*

In the discharge of its obligations to the Commonwealth the School of Mineral Industries has three functions, namely, resident instruction, extension and correspondence instruction, and research. In the field of the mineral industries these three functions are particularly important in the program of The Pennsylvania State College which is the Land Grant College of the Commonwealth. For it is in this particular field that Pennsylvania has excelled in the past, and it is on the mineral industries that the future of Pennsylvania must rest.

Of the three functional divisions, research finds expression through the Experiment Station, which is not set up as a separate department but is the organized expression of the research spirit of the School. All members of the School faculty who are engaged in any research are members of the Experiment Station staff.

Organized in 1919, *the Station has demonstrated its usefulness in advancing the effectiveness of higher education in the Mineral Industries, and in promoting the economic development of the Commonwealth. For the past* 21 *years its program has received the support of the Commonwealth through special legislative appropriations; in addition, hundreds of researches have been underwritten by the federal government and by industry.*



Students test performance of oil-fired furnace for thesis work.

The objectives of the Station are to seek fundamental knowledge and to establish physical laws that will have wide application; to promote the full and most effective utilization of the productive capacity of the mineral industries; to train men for research work through graduate instruction; to conserve natural resources; to improve undergraduate instruction; and to enhance the value of extension instruction.

This Circular describes briefly the fields of research and the research facilities in the School of Mineral Industries.

Significance of the Mineral Industries in the Economy of Pennsylvania

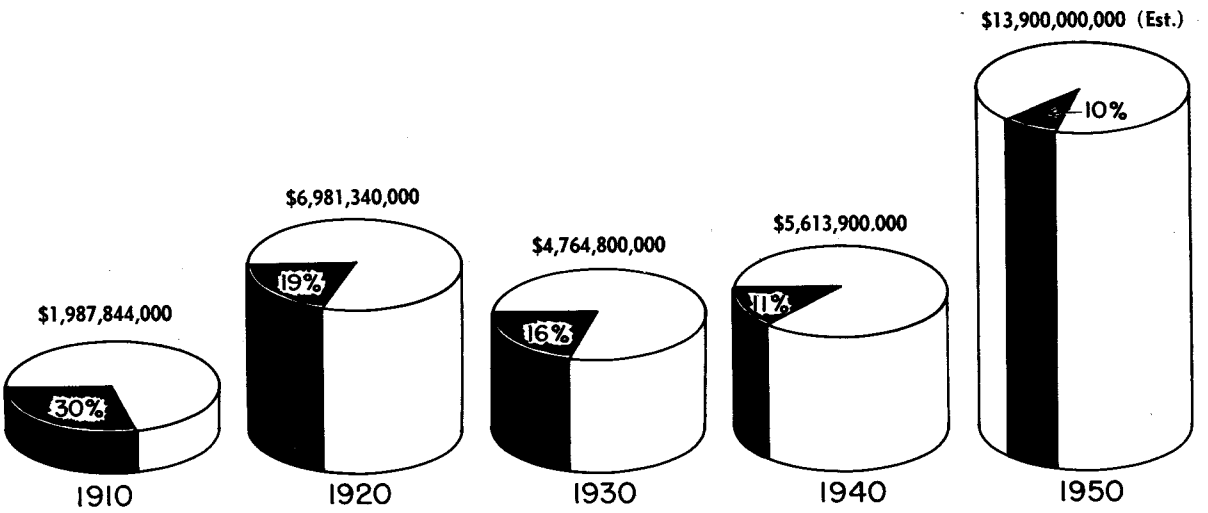
ALMOST FROM THE TIME OF WILLIAM Penn the people of Pennsylvania have pioneered in the discovery, development, and utilization of mineral resources. Coal, iron ore, and limestone played an important role in the war for independence, many charcoal iron furnaces supplying munitions of war. Numerous great industries have thus arisen within the borders of the State—the arts, skills, and technology of which have been carried to all parts of the earth.

The early industrial development of Pennsylvania can be traced directly to the bountiful supply and extraordinary diversity of its mineral wealth, and its present pre-eminent position as an industrial State depends in no small measure upon the extraction and processing of mineral resources.

Pennsylvania produces over 10 per cent of the total value of the mineral production of the United States, and some 67 per cent of the primary wealth of the Commonwealth derives from this source. Over 300,000 workers are directly employed in the mining and extraction of minerals, and approximately 40 per cent of the Commonwealth revenue is attained from the mineral industries. These figures, however, tell but a small part of the story, for there is a complex flow of mineral products into the State from all parts of the world. The processing of these minerals, whereby wealth is added through manufacture, is an important activity and source of employment for the people of the State. Thus, the resourcefulness, ingenuity, and enterprise of its people have been responsible for an industrial development which takes advantage of its native mineral resources, its geographic position, and its transportation system to bring raw materials from many areas and to process them in Pennsylvania.

Directly or indirectly the products of the mineral industries are interwoven into our daily living to such an extent that it is difficult to conceive of civilized existence without the availabiiity and use of such materials.

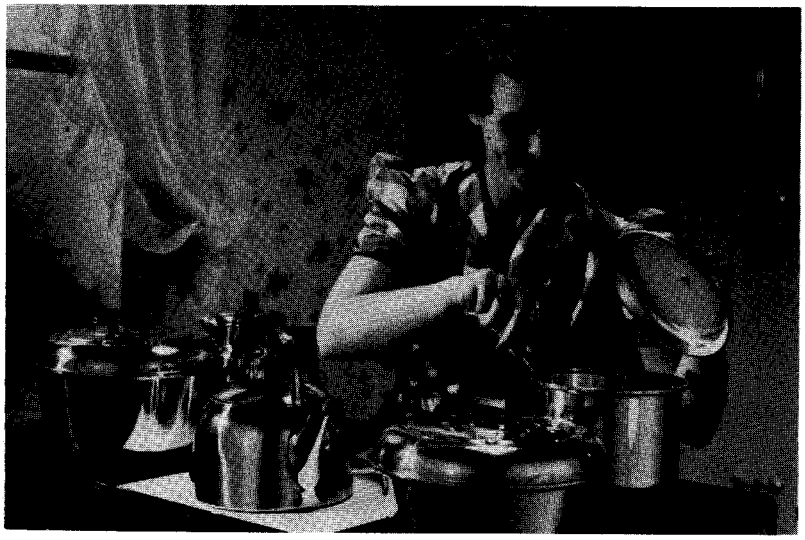
Pennsylvania's share (shown in black) of the total mineral production in the United States has steadily declined.



Mineral Industries Serve Agriculture Manufacturing and Transportation

Farming is a mechanized industry requiring machinery, fuel, lubricants, fertilizers—All products of the Mineral Industries.

Courtesy School of Agriculture.



Household utensils, war materiel, transportation and construction equipment are manufactured from aluminum processed from ore brought in from without the State.

Courtesy of Aluminum Company.

40 per cent of the revenue of railroads in Pennsylvania is derived from freight consisting of products of the mines.

Courtesy of Pennsylvania Railroad.

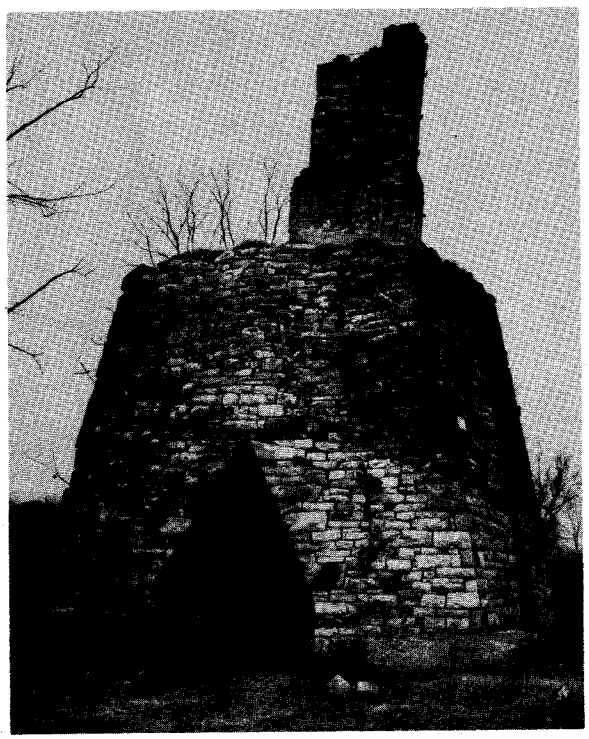
Pennsylvania Needs a Mineral Industries Experiment Station

UNLIKE THE PRODUCTS OF THE FARMS, forests, and waters, the products of the mines cannot be replaced; when once used up or destroyed they are gone forever. The history of the development of industries based upon natural mineral resources follows a similar pattern the world over. The richer and more accessible deposits are exploited first. As these are exhausted, operations are transferred to the poorer and less accessible reserves. Physical conditions become more difficult, and more intelligence and technologic skill become necessary to overcome the growing difficulties of nature. The rate of production and use of minerals increased enormously during the past decade, and the cycle of mineral exploitation has been accelerated greatly.

Pennsylvania's technologic problems are a direct consequence of the advanced stage of the cycle of mineral industrial development. The "cream of the crop" is exhausted, and the industry is faced with natural conditions of increasing difficulty. Intelligent research in mineral technology is necessary if Pennsylvania is to maintain her position of leadership in productive industry.

Three general types of problems face the Commonwealth. These are the improvement of lower quality resources by beneficiation, the development of new products from known resources, and the discovery of ways of utilizing minerals available in large quantities but of no commercial usefulness at the present time.

It is in the solution of technologic problems that the Mineral Industries Experiment Station fulfills an obligation to the Commonwealth.

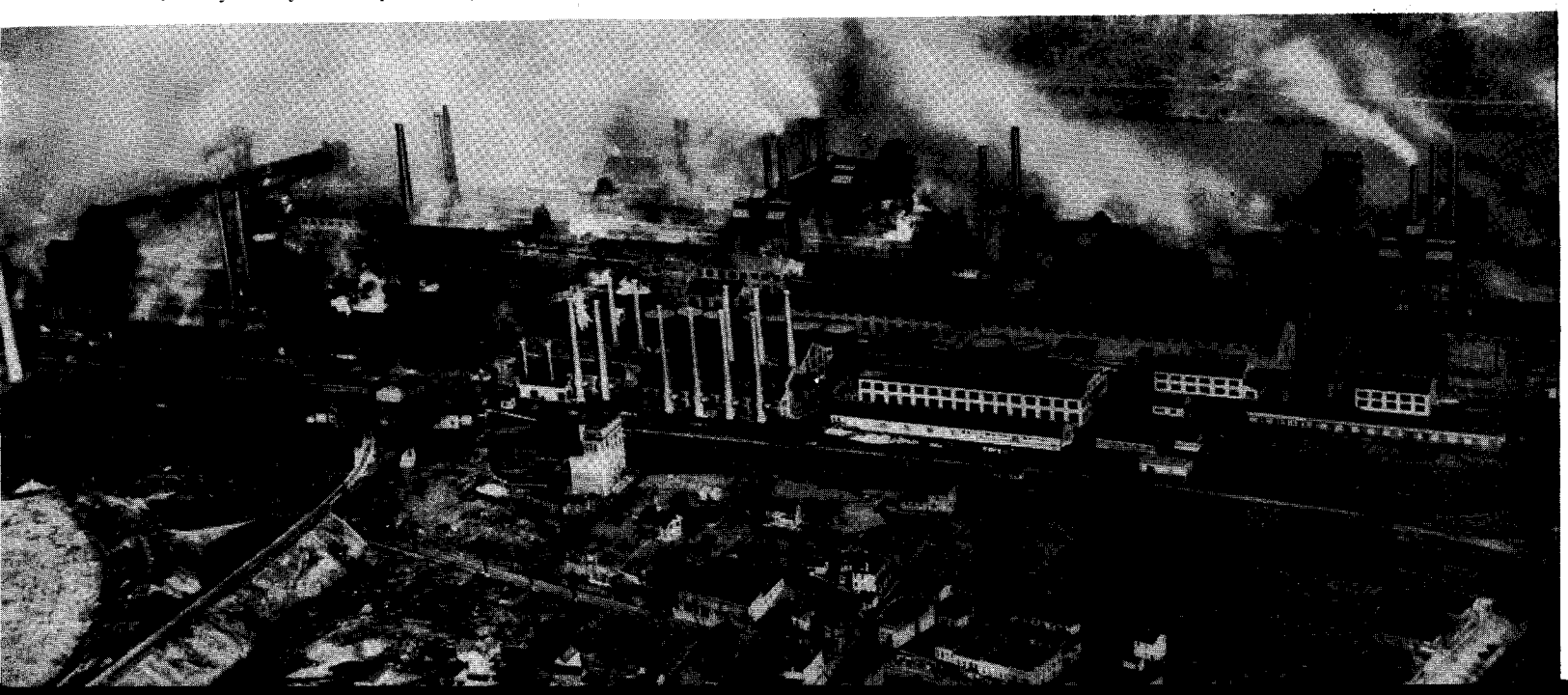


Curtin charcoal iron furnace near Bellefonte—Many such furnaces in Pennsylvania were forerunners of the giant steel industry shown below.

Courtesy William Sieg.

"Steel Valley" Pittsburgh.

Courtesy Pennsylvania Department of Commerce.



Research an Essential Feature of the Educational Program

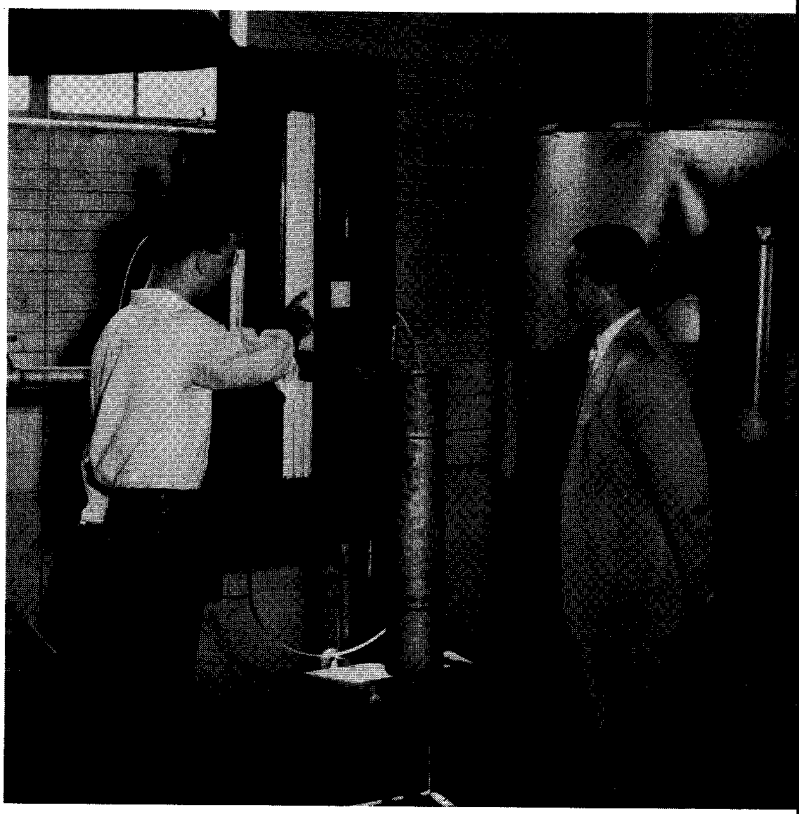
THE EXPERIMENT STATION ALWAYS has fostered advanced training by providing qualified young men with opportunities for experience in research and with financial assistance in the form of scholarships, fellowships, and graduate assistantships. Such young men work under the direction of mature and experienced research men and have the benefit of advice and counsel of experts in fields related to their own specialty.

This plan trains men who later can develop into positions of leadership in their respective chosen fields and supplies new fundamental knowledge for the use of the industries. The importance of these two functions, advanced training and fundamental research, must not be underestimated, for it is only by continual growth in new knowledge and in numbers of trained personnel that the Commonwealth can maintain its position of industrial leadership.

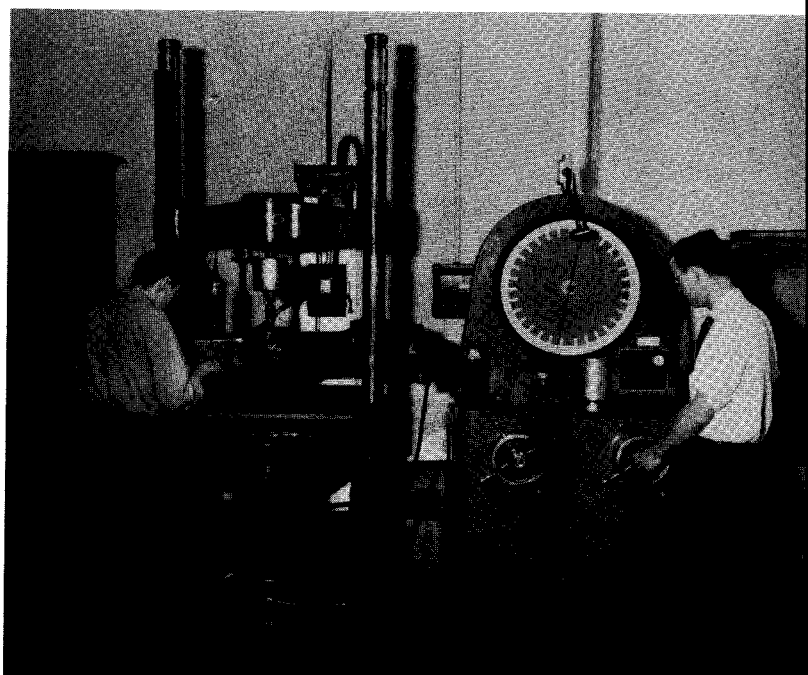
An active research program is also important in undergraduate instruction. It keeps the instruction up-to-date and enlivens the class room with curiosity and zest for discovery. Frequently, opportunity is provided for properly qualified undergraduate students to devote part of their time to working on research projects, and all may have some contact with original endeavor.

The Experiment Station also works closely with the Mineral Industries Extension Services, whose function it is to provide a program of adult education for workers in the mineral industries in Pennsylvania. The extension staff presents the results of research to the workers in such a manner that they are informed as to progress and, therefore, are more effective in their employment.

Modern higher education must include a research program to attain its highest level of effectiveness.



Graduate students are in close contact with faculty advisers.

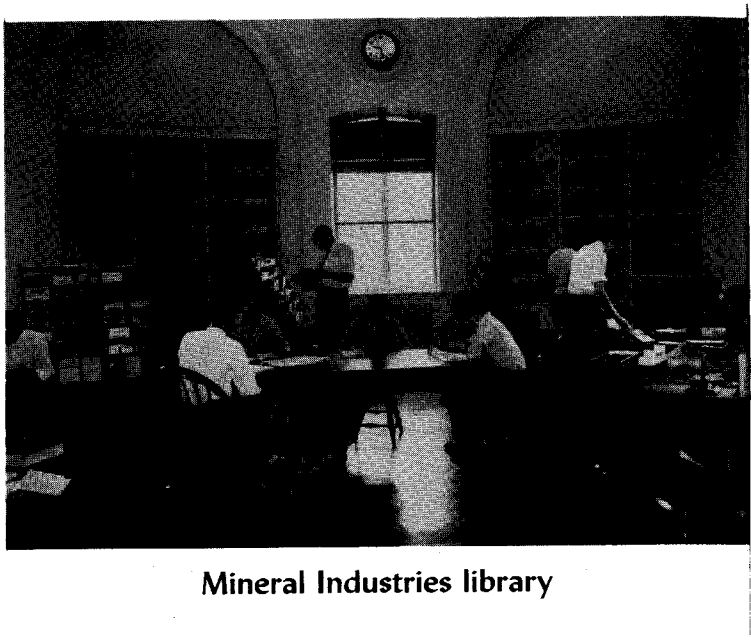


The physical properties—strength, ductility, toughness, and hardness of metals —are tested in order to determine their adaptation for use.

Staff and Facilities

STAFF. THE ACCOMPLISHMENTS OF any organization are in direct proportion to the caliber of its staff. The Experiment Station has excellent leaders in every division of the mineral industries—geology, mineralogy, geophysics, geochemistry, geography, meteorology, mineral economics, mining, mineral preparation, petroleum and natural gas engineering, ceramics, fuel technology, and metallurgy. In addition, chemists, physicists, and other technically trained men working on specific projects are available for consultation on any researches where they can be of assistance.

The staff of the School presents an unusual diversity of talent; the members have in fact been selected so that the Experiment Station can bring to bear on any problem the advice and counsel of men experienced and expert in many fields of knowledge. The abilities of many of these men have been recognized in this country and abroad. Many have served and are serving as officers of national, technological, scientific, and engineering societies. Frequent contributions are made to the technical literature; many have been called on to render service to national and state governments; and some have received grants-in-aid of research from organizations such as the National Research Council, and the Geological Society of America.



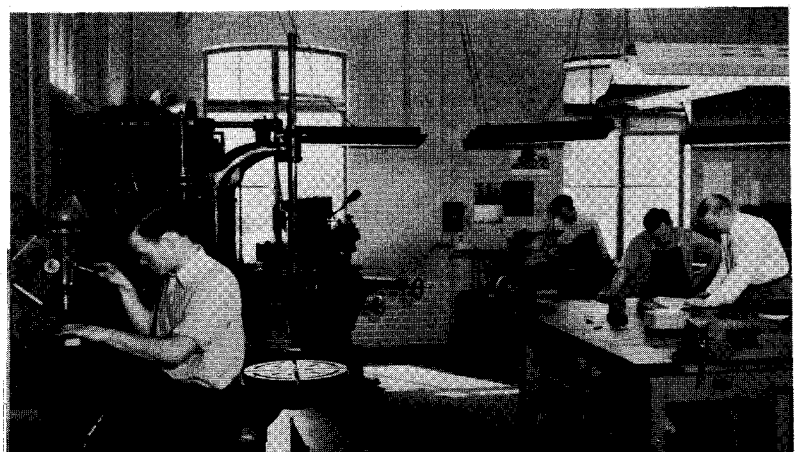
Mineral Industries library

FACILITIES. The physical resources of the School, including library, instrument shop, and the various laboratories and equipment necessary for a well-rounded program of research and instruction, are housed in two buildings provided by the Commonwealth in 1929 and 1949 respectively. In 1948 a Coal Combustion Laboratory financed jointly by the College and coal industry of Pennsylvania was placed in service. This unit of the Mineral Industries Experiment Station is the most completely equipped research laboratory in the country for work on stokers. Boilers and stokers in size ranges from domestic units to the 178 HP boiler fired with a 6′ x 6′ underfeed stoker are so interconnected that any one may be operated under special test conditions or under the normal operating conditions of supplying steam for use in the College heating system.

The well-stocked library is in charge of competent librarians who render valuable service to the staff by preparing bibliographies and keeping the staff informed of newly published material bearing on the work of the Station.

A fully equipped shop staffed by expert mechanics is available for construction and repair of apparatus and equipment. Much of the specialized apparatus required in the research is constructed in this shop.

A modern analytical laboratory staffed by graduate chemists and equipped with a variety of apparatus for routine and specialized testing of minerals and mineral products performs an important function in the research program.



Corner of Mineral Industries shop

Research Program

THE PROGRAM OF THE MINERAL INdustries Experiment Station embraces both pure and applied research. In fact, it is not always possible to differentiate between these two types. Some investigations which seem, at the start, to yield little promise of practical results eventually prove to be of greatest practical value.

In general, the problems selected are of the long-range type looking forward to the future progress of the Commonwealth, rather than the immediate or "trouble-shooting type" met with in the course of daily industrial operation. Selection of problems, the solution of which fits in with the objectives of the Mineral Industries Experiment Station, requires careful planning based upon the economic needs of the Commonwealth.

Studies of the trends in these industries are constantly being made by the Division of Mineral Economics. The results of several such studies have already been published, the most recent having been incorporated in a cooperative publication of the Pennsylvania Department of Internal Affairs entitled *Pennsylvania's Mineral Heritage.*

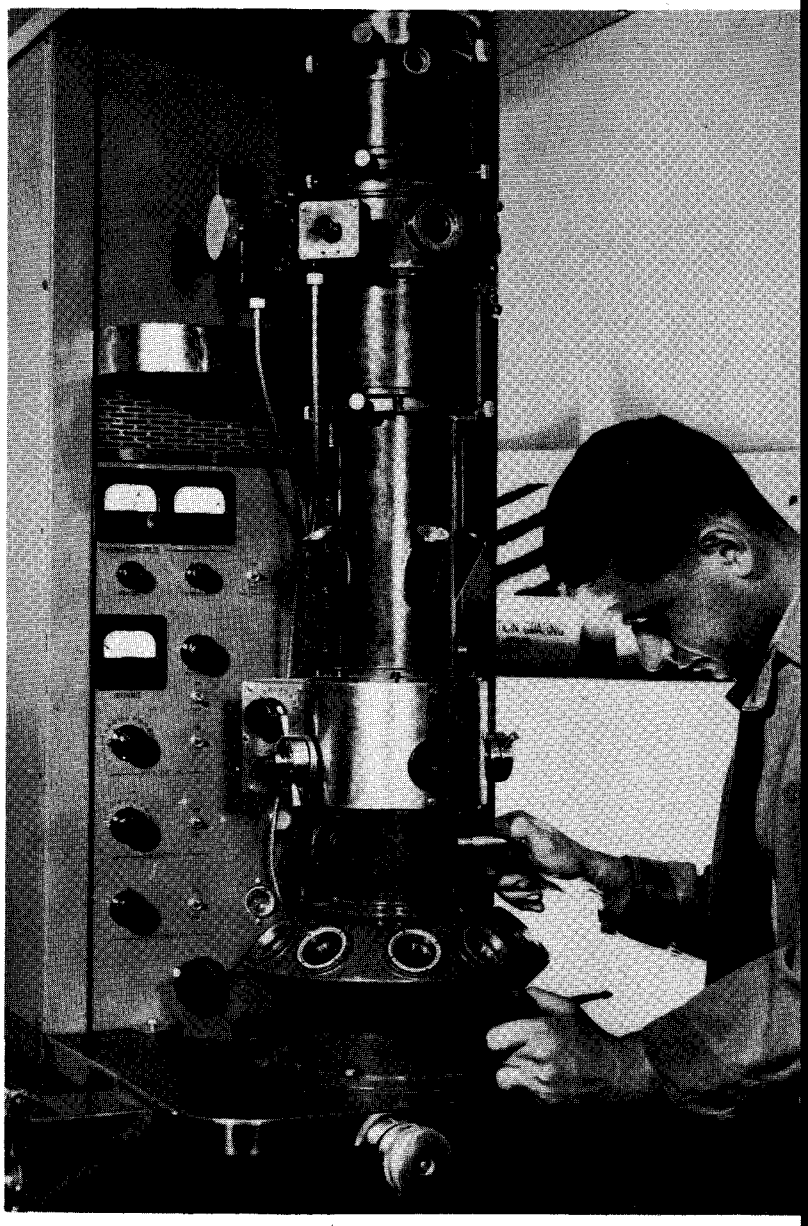
Whenever any research supported wholly by College funds leads to discoveries of patentable nature, the College reserves the right to require the patenting of such discoveries and assignment of such patents to the College. This recognizes the principle that the results of experimental work carried on by members of the College staff, and having the expense thereof paid from public funds, belong to the College and should be used and controlled in ways that will bring the maximum benefit to the public.

The research service of the College should be available to all the industries and occupations of the State. However, the limited public funds for research make this impossible. It is the policy of the College to use the funds available for research that will be of wide application and benefit.

Requests are frequently received for routine tests varying from simple analysis of minerals to elaborate firing tests on clays or coals. In general such testing is undertaken only when the results will contribute to the general good and where the Station will not be competing with existing commercial laboratories.

Testing for other departments of the Commonwealth, or for other public agencies which do not have laboratories, will be undertaken by special agreement.

All inquiries regarding routine tests and cooperative projects should be addressed to the Director of the Mineral Industries Experiment Station; a fee will be charged to cover the cost of the service rendered, including the purchase of special apparatus, all supplies and materials used, the wear and tear on equipment, and the employment of assistants.



The electron microscope reveals the secret of the crystal structure.

Cooperative Research with Industry

IN ORDER TO EXTEND THE USEFULness of the research facilities of the Mineral Industries Experiment Station, and thus be of greatest possible service to the Commonwealth, the School will accept funds from private sources for cooperative research in accordance with the spirit of the Regulations of the Council on Research as adopted by the Board of Trustees in 1940.

Such cooperation between the School and the industries that it serves establishes a relationship which is mutually advantageous. It fosters a research attitude within the industries, gives the College faculty better knowledge of the industries and their problems and, in general, promotes a mutual understanding.

The Board of Trustees of the College has adopted a definite policy with reference to cooperative research. Certain broad lines of procedure have been adopted in carrying out this policy. In general, the cooperative nature of each project is recognized by an equitable understanding or contract between the College and the cooperating party or parties which specifies the respective financial obligations of the College and the cooperators, the conditions under which the research will be conducted, and the policy that will be followed in the publication or application of the results.

In the case of investigations financed wholly by an organization of industrial, or other character, or by individuals not connected with the College, the agreement may provide for publication of the results by the cooperating agency with the consent of the College and in such form as the College may approve.

A field test of smokes developed in the laboratory for plugging loose streaks in recovery of oil by air drive is one phase of cooperation with the Pennsylvania Grade Crude Oil Association.

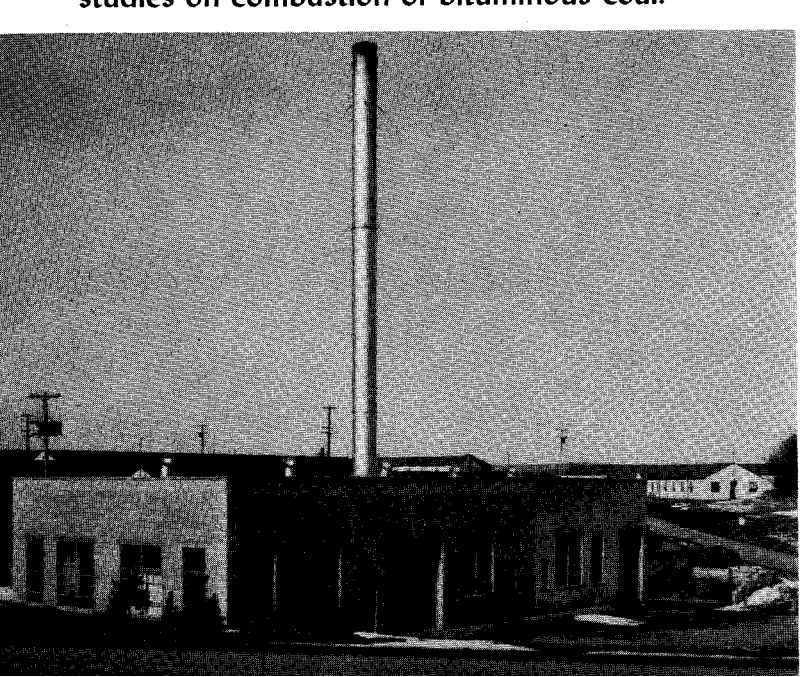
Similarly, provision can be made in the agreement for ownership by the donor of any patents which may result from the cooperative research.

In cooperative investigations, the Mineral Industries Experiment Station provides a high quality of creative and administrative ability to exercise general direction of the investigation. It furnishes, in addition, the use of its facilities, including laboratories and equipment. The cooperating agency provides such funds as are necessary to pay the salaries of the special investigators working under the direction of the Experiment Station staff members, exclusively in the conduct of the particular research undertaken on a cooperative basis; for the purchase of materials and special apparatus; and for other pertinent expenses.

Ordinarily the cooperating agency provides for the appointment of a competent Research Committee, which assists the officers of the Experiment Station in outlining the program for the investigation, and represents the cooperating agency. By means of discussions of the work at meetings of the research men and the Committee, more efficient progress and greater assurance of results of practical value are attained.

Arrangements for cooperative research should be made with the Director of the Mineral Industries Experiment Station, The Pennsylvania State College, State College, Pennsylvania.

Combustion laboratory built with the aid of a grant from the Central and Western Pennsylvania coal industry is used for cooperative studies on combustion of bituminous coal.



Cooperative Research with Public Agencies

AS A STATE INSTITUTION THE MINERal Industries Experiment Station naturally is prepared to cooperate fully with all other agencies of the Commonwealth. Pursuant to this policy the College has had a cooperative agreement with the State Topographic and Geologic Survey of the Department of Internal Affairs for the past 14 years, whereby certain functions are performed by the Experiment Station.

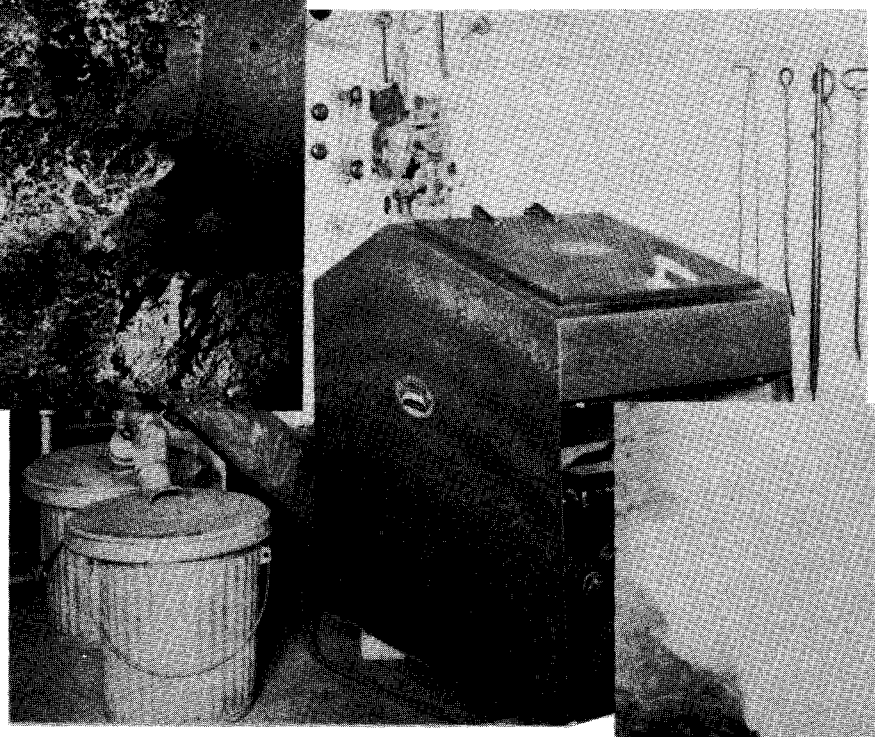
Since 1939 a program of research on anthracite and bituminous coal has been under way in the Experiment Station under the supervision of the Secretary of Mines. This is a cooperative program in which the cost is borne jointly by the Commonwealth, the Anthracite Institute, the Western Pennsylvania Coal Operators Association, and the Central Pennsylvania Coal Producers Association.

The Division of Meteorology cooperates with the Department of Forests and Waters in daily weather observations.

From time to time the Experiment Station is called upon to conduct researches for various agencies of the federal government. Such studies cover the entire scope of the mineral industries including, among others, studies of the environmental conditions in selected areas of the North American Arctic region by the Division of Geography and investigations in metallurgy for the United States Army, fundamental researches in mineralogy and glass technology for the Office of Naval Research, and studies on high temperature ceramics bodies for the United States Air Force.

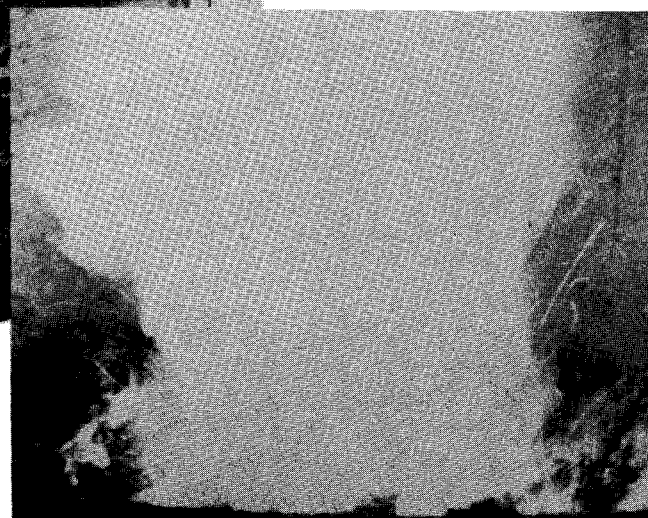
A new principle of firing developed in cooperation with the bituminous coal industry of Pennsylvania and the Department of Mines resulted in a stoker which eliminates the formation of coke trees.

The Problem



The Solution

The Result

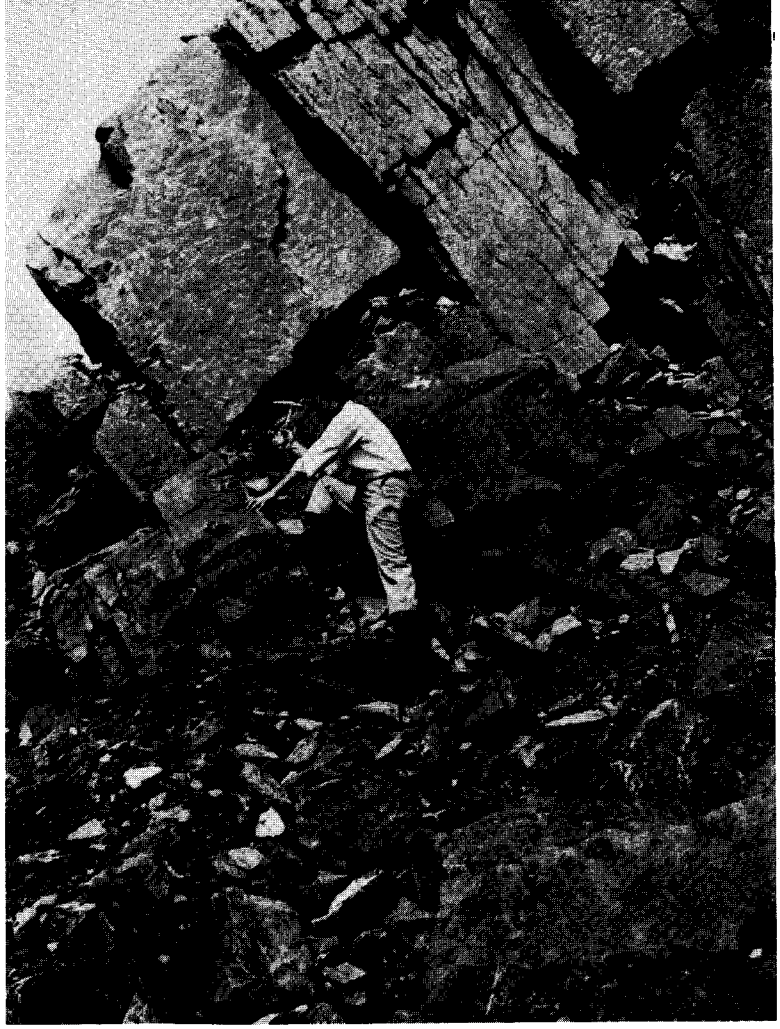


Earth Sciences

EARTH SCIENCES CONSTITUTE THE basic body of knowledge on which the mineral industries are founded. The discovery and identification of minerals, determination of extent of reserves and quality of deposits must precede any development. Since the Experiment Station staff includes members skilled in all branches of the mineral industries, the Station is prepared to render a high quality of service to the Commonwealth.

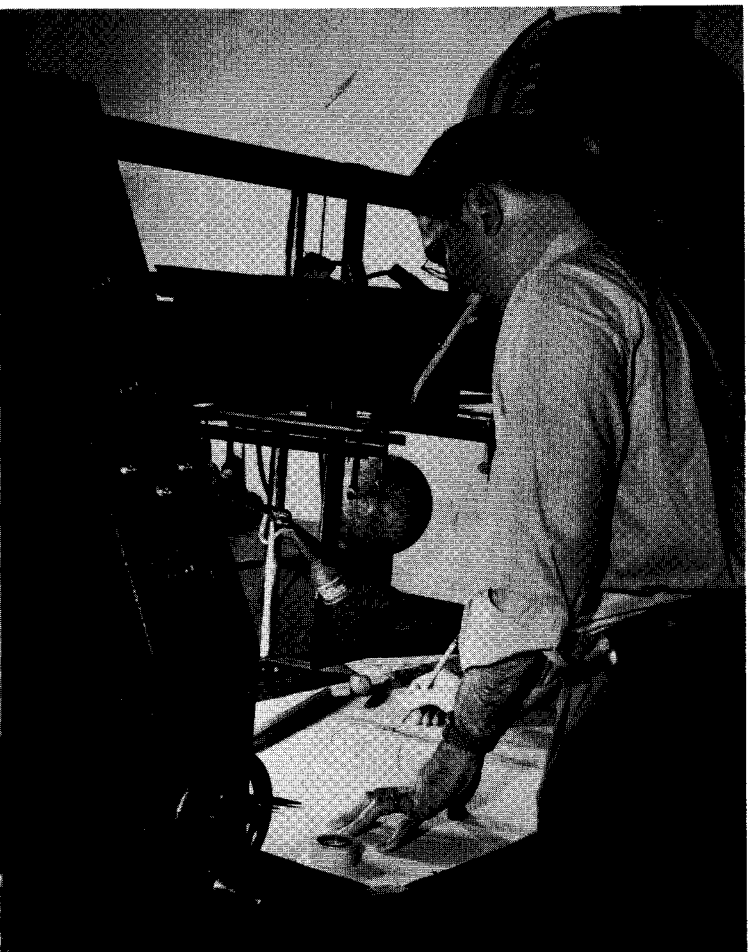
Geology

By trained and penetrating analysis of rocks and their minerals and fossils in both the field and laboratory, geology investigates and interprets the structure, composition, and history of the features of the earth's crust. It thus gives to our modern civilization insight into natural phenomena, so that we can understand the forces and processes of weathering, of erosion and sedimentation by rivers, glaciers, and oceans, of mountain-making and of earthquake and volcanic activities. It places in perspective the history of living things including man himself. In the economic realm, it makes major contributions since it provides knowledge of the origin, characters, occurrence and extent of the metallic ores, of the limestones and ceramic raw materials, of the mineral sources of heat and energy, of the soils from which we grow our foods and the waters that we gather in our reservoirs.



Study of outcrops of strata enable the geologist to visualize the underground structures and locate mineral deposits.

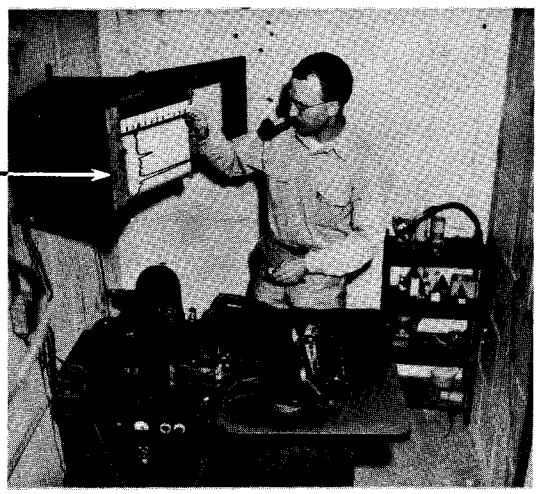
Land utilization maps are prepared by plotting data from aerial photographs by using a multiscope.



Geography

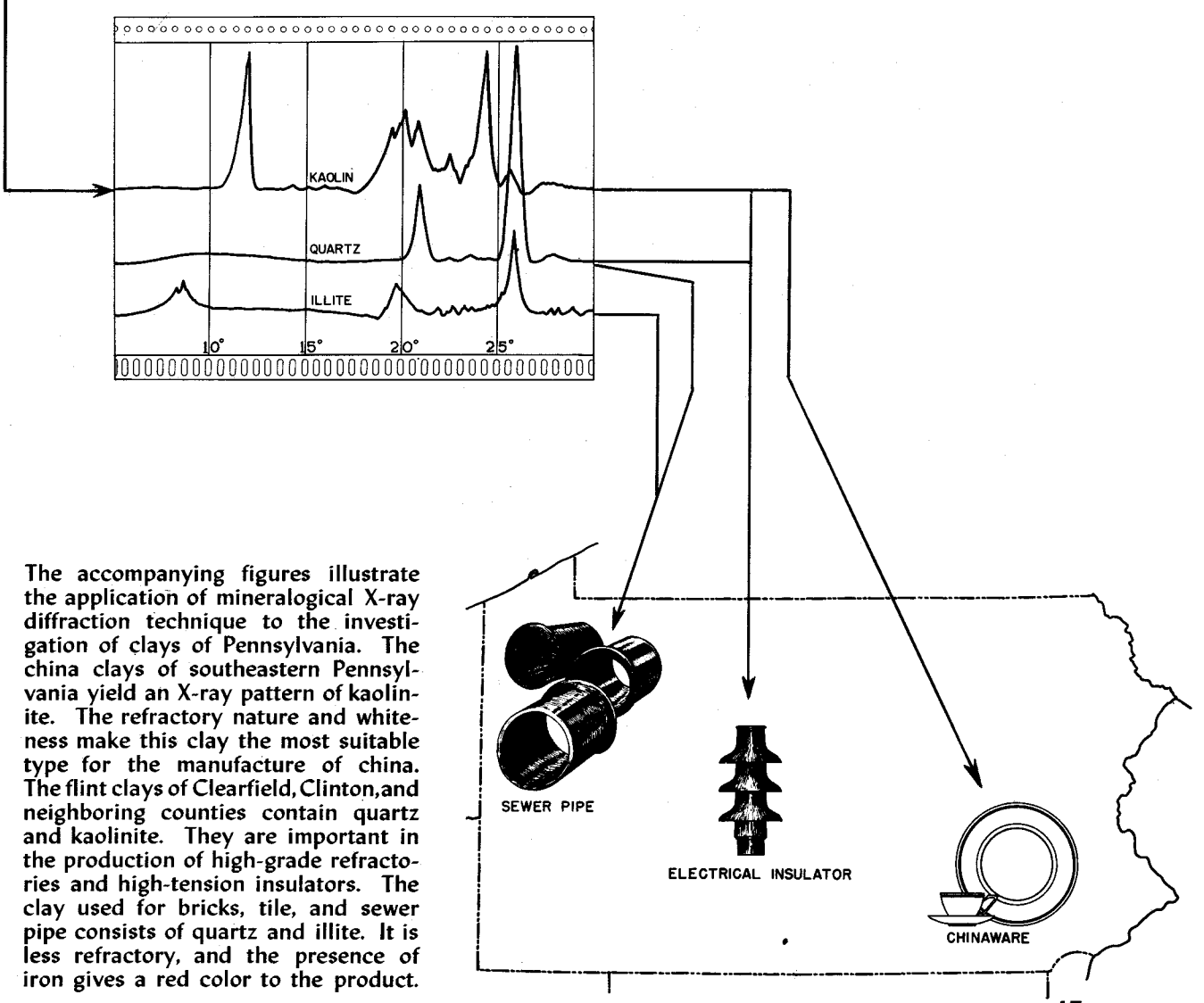
The practical applications of geography have developed greatly in the past decade. It is the job of the geographer to present the patterns of man's activities on the earth. The geographer must first deal with the physical background, which includes topography; climate; mineral resources; natural vegetation; and soils. With the natural setting as a basis he explains man's activities in utilizing the wealth of regions; why he is so distributed and occupied; and the problems and potentialities of each area. These are practical items of knowledge. They are especially significant now in the modern intensified search for the raw material of industry which must be extended to every region of the earth.

Mineralogy and Petrology



RESEARCH IN THE DIVISION OF MINeralogy covers the fields of clay mineralogy, origin of sedimentary rocks, composition and behavior of oil reservoir rocks, and high temperature investigations of natural and artificial silicates.

The Division has been first in the country to apply high magnification electron microscope methods to geological problems; to devise a new and effective classification scheme of sedimentary rocks; to discover the essentials of oil accumulation in different sandstone types; and one of the few to perform hydrothermal synthesis of minerals under independently varied temperature and pressure conditions and determine phase equilibria in fluoride systems.

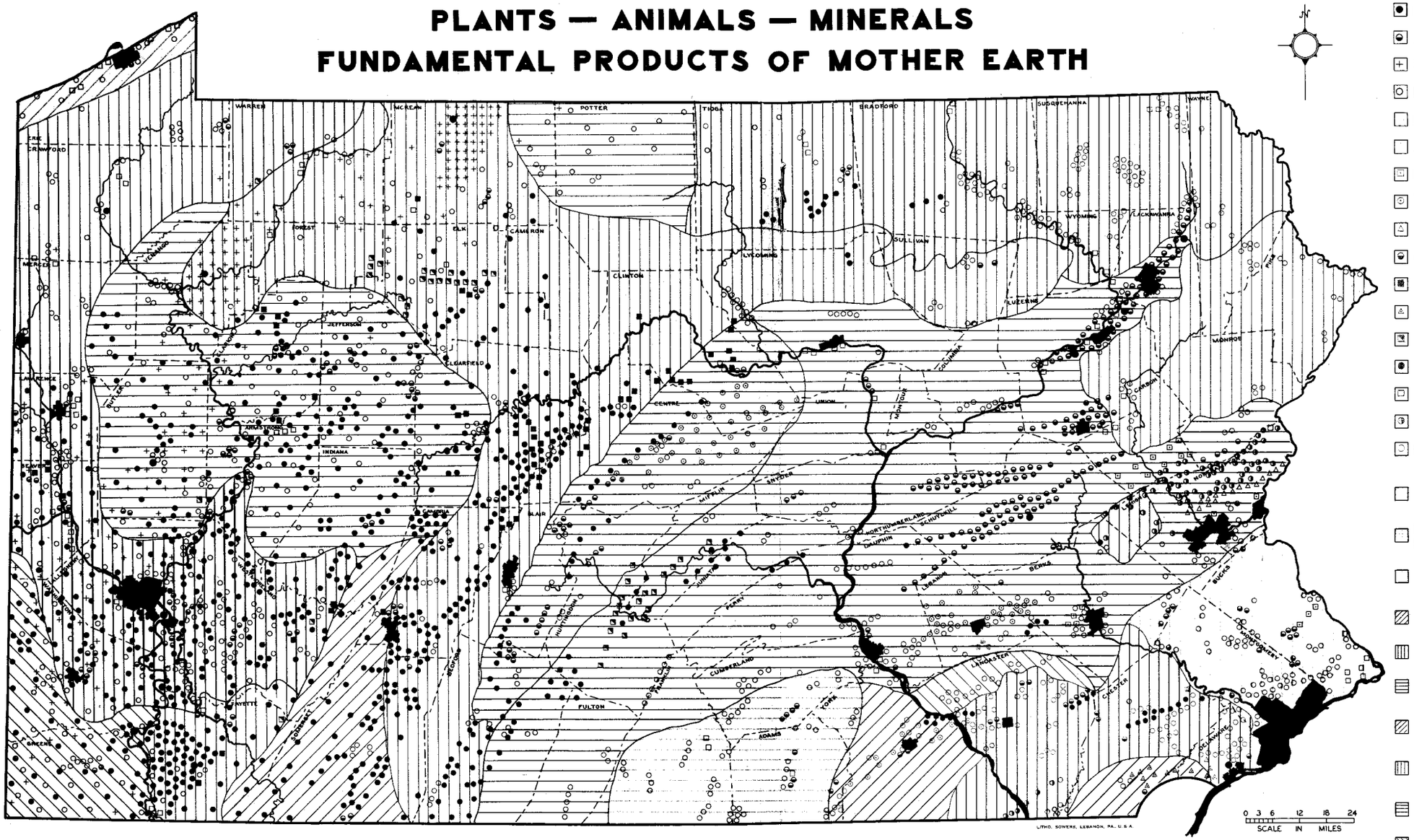


The accompanying figures illustrate the application of mineralogical X-ray diffraction technique to the investigation of clays of Pennsylvania. The china clays of southeastern Pennsylvania yield an X-ray pattern of kaolinite. The refractory nature and whiteness make this clay the most suitable type for the manufacture of china. The flint clays of Clearfield, Clinton, and neighboring counties contain quartz and kaolinite. They are important in the production of high-grade refractories and high-tension insulators. The clay used for bricks, tile, and sewer pipe consists of quartz and illite. It is less refractory, and the presence of iron gives a red color to the product.

KNOWN SOURCES OF PRIMARY WEALTH

PLANTS — ANIMALS — MINERALS

FUNDAMENTAL PRODUCTS OF MOTHER EARTH



LEGEND

- BITUMINOUS COAL
- ANTHRACITE
- PETROLEUM
- NATURAL GAS
- IRON ORE
- ZINC ORE
- MIN. PIGMENTS
- CHEM. LIMESTONE, DOLOMITE
- CEMENT ROCK
- CERAMIC CLAYS
- FIRE CLAY
- FELDSPAR
- GLASS SAND
- GANISTER
- SAND AND GRAVEL
- SLATE
- BUILDING STONE

- VEGET., POULTRY, DAIRY FARM., FRUIT
- POULTRY, FRUIT, DAIRY FARMING
- POULTRY, DAIRY, TRUCK FARMING
- DAIRY FARMING, POULT., VEGET.
- DAIRY FARMING
- DAIRY FARMING AND FOREST
- GENERAL FARMING AND FOREST
- PART-TIME FARM. AND FOREST
- POTATO AND DAIRY FARMING
- TOBACCO
- GENERAL FARMING
- POTATOES
- MUSHROOMS
- SHEEP RAISING

SMALL, DIVERSIFIED, COMMERCIAL MINERAL DEPOSITS ARE NOT INDICATED. THE ATMOSPHERE AND UNDERGROUND WATER SUPPLY ARE PRECIOUS MINERAL RESOURCES.

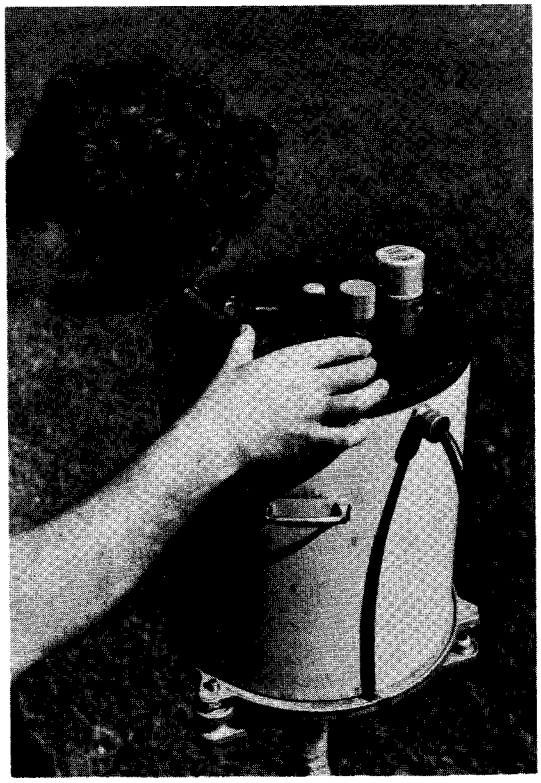
MINING, A BASIC INDUSTRY, FURNISHES IRREPLACEABLE FUELS AND INDUSTRIAL RAW MATERIALS. MINES FURNISH 67 PER CENT OF PRIMARY WEALTH, FREQUENTLY EXCEEDING A BILLION DOLLARS A YEAR. THIS IS OVER 10 PER CENT OF THE VALUE OF MINERAL PRODUCTION IN THE UNITED STATES. AGRICULTURE, A BASIC INDUSTRY, FURNISHES FOOD, AND FARM CASH INCOME TOTALLED $750,000,000 IN 1946. MINERAL INDUSTRIES WORKERS FORM A LARGE PART OF THE RURAL POPULATION AND ARE AN IMPORTANT MARKET FOR AGRICULTURAL PRODUCTS. FAVORABLE CLIMATE AND SOIL CONSERVATION INSURE CONTINUED PRODUCTIVITY

COMMONWEALTH OF PENNSYLVANIA

Geophysics and Geochemistry

BY GEOPHYSICAL MEASUREMENTS man seeks to map the distribution of the rocks buried beneath the surface. Study of the nature and occurrence of earthquakes and the transmission of seismic waves yields information on the deep interior of the earth. Study of the variation of the acceleration of gravity and of the earth's magnetic field at the surface helps to map the distribution of the rocks which constitute the basement underlying all parts of the earth.

Geochemistry is concerned with the amount and distribution of elements in the earth and the causes of this distribution. Chemical and spectroscopic analyses are made of minerals, rocks, and vegetation to find the quantity and distribution of elements, especially the trace elements. These data are useful in the search for ore, for the presence of certain trace elements has in some cases indicated near-by ore bodies. Geochemical research at high pressures and temperatures is being conducted in order to find the conditions under which metamorphic minerals have formed from clays and calcareous deposits.



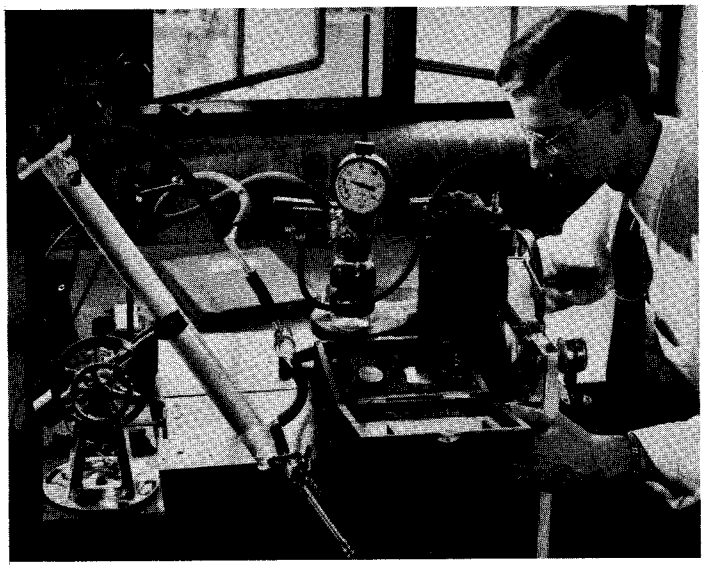
The gravitymeter shown above is used to study the distribution of the denser rocks which everywhere lie buried beneath the surface veneer of soil and sediments.

Meteorology

RESEARCH IN METEOROLOGY IS AIMED at the broadening of our knowledge of fundamental atmospheric processes and the improvement of weather forecasts. The results of such research are applied in many fields of human endeavor. Although most applications require a knowledge of weather processes in order to best cope with the natural weather conditions, recent experiments in cloud physics have spurred hopes of actually bringing about artificial modifications of the weather over small areas.

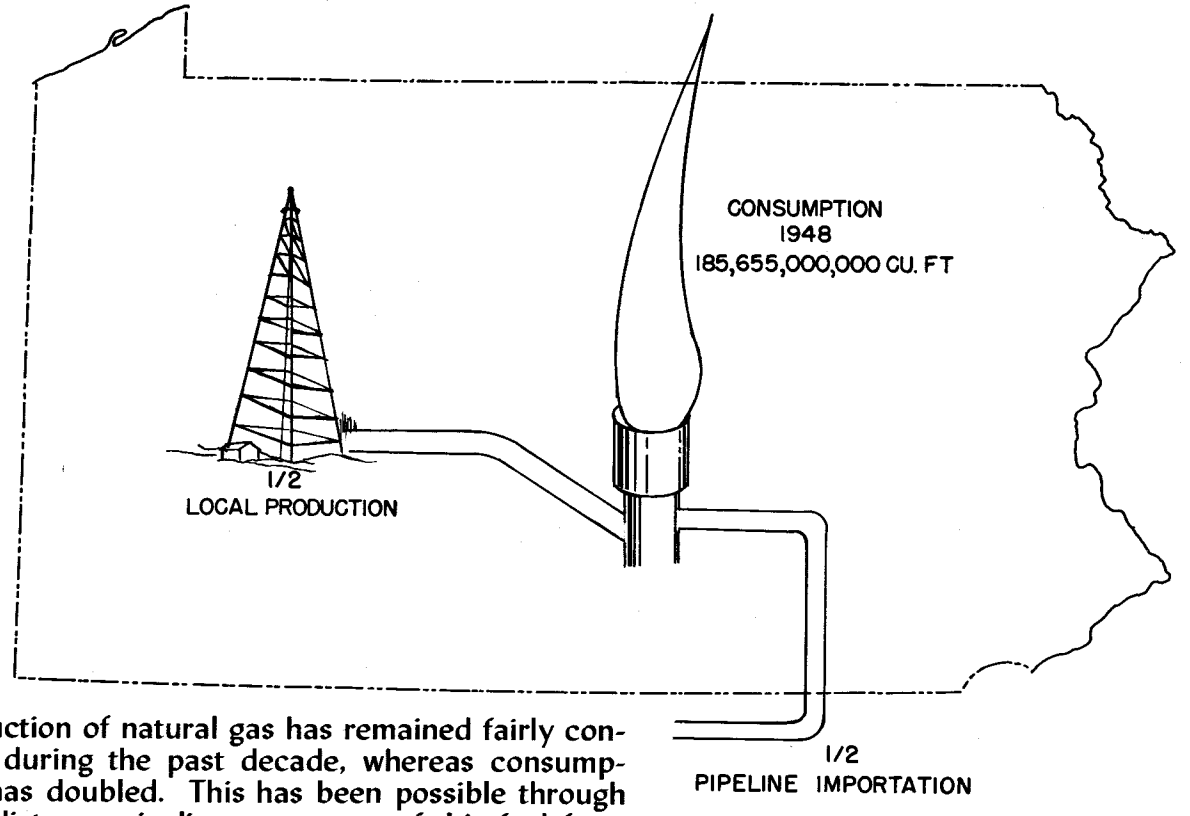
The wide expanse of the atmosphere is the meteorologist's main laboratory.

Properties of city "smog" are being studied in controlled laboratory experiments as pictured below.



Mineral Engineering

MINERAL ENGINEERING INCLUDES 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 final use by man, Mineral Engineering occupies a mid-position between the Earth Sciences—mineralogy, geology, etc.—on the one hand, and the Mineral Technologies—metallurgy, ceramics, fuel technology—on the other. There is no sharp line of demarcation between these three major fields; each merges into the other, with the consequence that some particular fields of professional activity may embrace parts or all of two fields, and in certain instances cover all three.



Production of natural gas has remained fairly constant during the past decade, whereas consumption has doubled. This has been possible through long-distance pipeline movement of this fuel from the Southwest.

Mineral Economics

MINERAL ECONOMICS IS CONCERNED with the interrelated fields of technology and economics. Studies have been made of trends of the mineral producing and processing industries in Pennsylvania. These studies are being expanded to include the important field of marketing which deals with the final and most important action of all; the conversion of goods into dollars. Such studies supply a basis for the planning of long-range research programs of the Experiment Station. There is a growing tendency in industry to examine economic factors, including supplies of raw materials, transportation and competition in markets in the guidance of established business and before engaging in new production. In addition to cooperating with other divisions on their programs, the Division of Mineral Economics makes special studies in its field. Statistics are the history of business and the yardstick by which accomplishment is measured. Their interpretation requires special skills. These are possessed by the Experiment Station's Mineral Economics staff and can be made available to the industries of Pennsylvania.

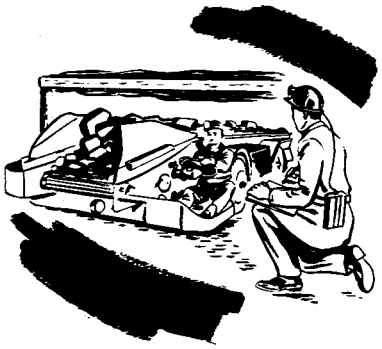
Mining

ENGINEERING PROBLEMS IN THE MINing industry are becoming more complex each year. Many of our thick, high-grade deposits are being depleted at a rapid rate, and it is necessary that new and more efficient methods be developed for mining low-grade deposits. In addition to new methods, new machinery must be developed if we are to maintain our present output. As the methods and machinery become more complex the problems of planning also become more complex, requiring specialists in the various steps in the mining operation. The mining staff is active in working with industry, in devising ways of increasing the productivity of mechanical equipment, determining new fields of use for existing types of machinery, and studying the possibility of redesigning machines to fit particular mining conditions.

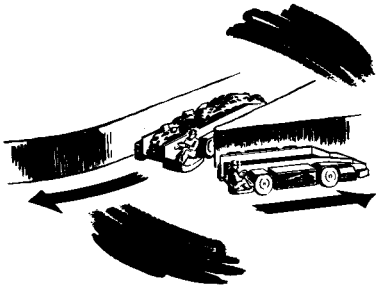
An efficient system of making time, motion, and production studies of mining equipment has been developed. Methods of rating and evaluating mechanical loading machine performance and trackless haulage equipment have been developed and put into use. At least six papers have been published on time and method studies and machine evaluation. Representatives of operating companies have consulted with the Division of Mining on how their operations might be improved by use of rating methods developed here. As mining operations become more complex, requests from industry for aid in improving the efficiency of mining operations are likely to increase.

In addition, a study is being made of the problems of mining thin coal beds, the goal being to develop methods and equipment so that production will be comparable with that in the thicker, more easily mined deposits.

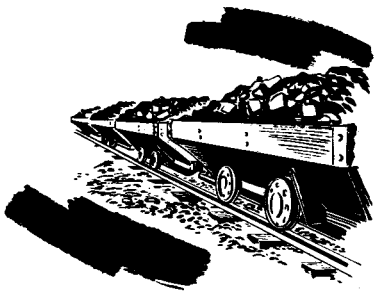
A system of Time & Method study



developed by the Mining Division



has led to increased production of coal at lower cost.



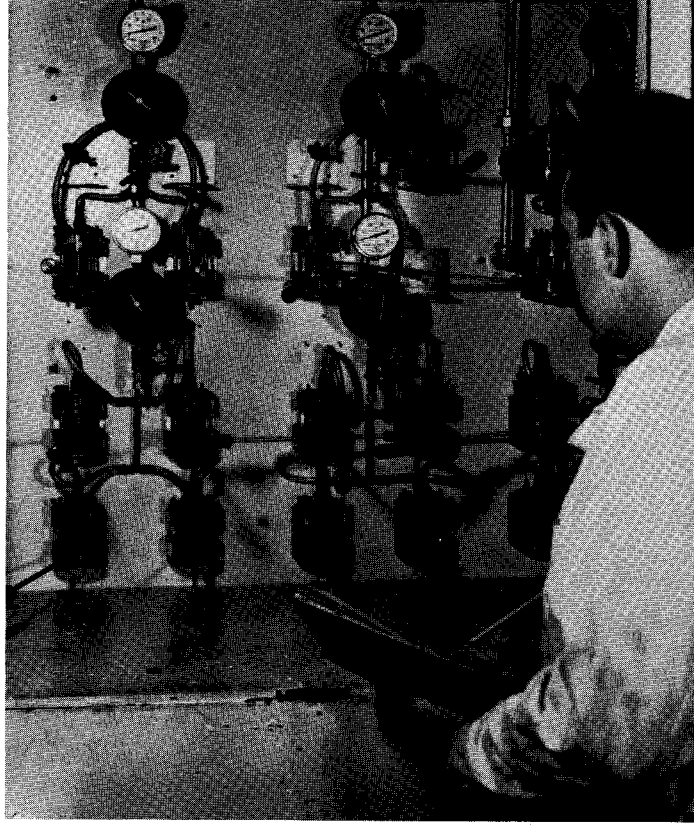
Mineral Preparation

FEW MINERALS IN OUR WORLD TODAY are so concentrated in their natural state that they can be used directly as they are mined. A vital and increasingly important step is necessary between the actual mining of the ore and the use of the mineral or minerals by industry. That step is called mineral preparation, beneficiation, or ore dressing. With the rapid depletion of the world's rich mineral deposits it has become necessary to progressively mine the poorer deposits of minerals, including coal, with the result that more intensive research has been directed to methods and processes of mineral preparation.

The Division of Mineral Preparation has an active and aggressive research program designed to meet these growing demands. Some of the more important investigations include: a comprehensive study of coal washing processes leading to improvements in efficiencies and quality of product; the froth flotation of fine coal to recover what was in the past wasted in refuse piles or turned into the streams and rivers causing pollution of the country's water supply; the chemical aspects and physical phenomena surrounding the flotation of minerals; the magnetic concentration of converted iron ore; and the application of ultrasonics for purposes of mineral concentration and the sedimentation of finely divided minerals in water or other fluids; fundamental studies on the mechanism of flotation of minerals and a method for measuring the effectiveness of reagents and the carrying power of froth which have led to development of new theories and commercial applications; and the development of a new method for the analysis of mineral suspensions utilizing high frequency electrical measurements.

Petroleum

THE BIRTH OF OUR GREAT PETROleum industry took place near Titusville, Pennsylvania, in 1859 with the drilling of the famous Drake well, and since that time Pennsylvania has pioneered many phases of the industry. From flush natural production techniques to secondary recovery operations this State has furnished leadership in both men and methods. For 21 years a research program has been under way in the Mineral Industries Experiment Station for improving the recovery of petroleum from the reservoir rock. At the present time a residual of as high as 40 per cent of the original oil will remain in the formation even when applying the most efficient methods known today. This challenge to our research and engineering skill is being met by a study of the fundamentals underlying the recovery process resulting in the development of new concepts and techniques in primary production and secondary recovery by water flooding and air-gas drive which have been generally accepted by the industry. It is now possible to recover more oil from a given reservoir with greater efficiency than was possible prior to such studies.



Complex apparatus shown on this page is used in the laboratory for study of the movement of oil, gas, and water through oilbearing sandstone. From such studies fundamental knowledge is gained which has increased the economic recovery of petroleum.

Natural Gas

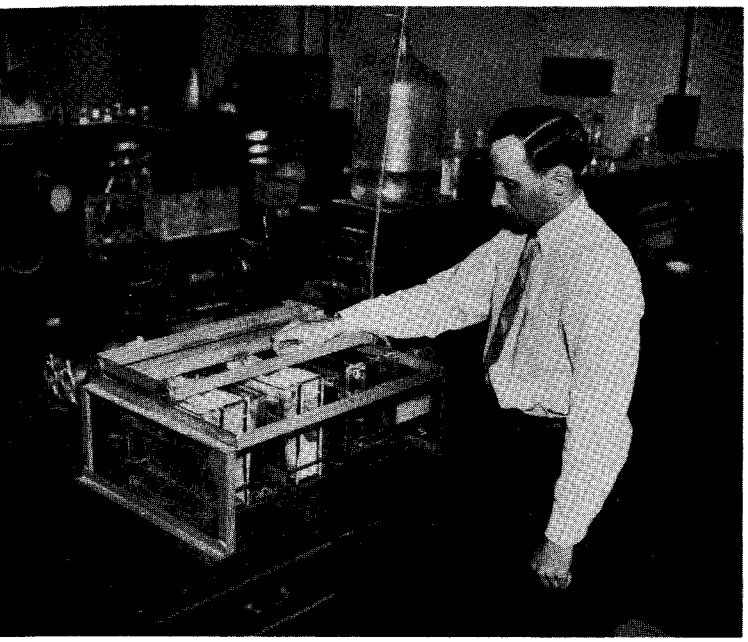
NATURAL GAS IS ONE OF THE MOST convenient of modern fuels and for many purposes is almost ideal. More recently it has become the source of numerous pure chemicals, solvents, plastics, and gasoline. The Experiment Station has carried out investigations both on production and utilization of natural gas, in part in cooperation with the industry. One of these investigations has led to the development of a new type of household incinerator which eliminates many of the disadvantages of the older types. For example, the disagreeable odors usually produced in the combustion process have been eliminated by a special surface combustion zone in the stack.

Mineral Technology

MINERAL TECHNOLOGY comprises the divisions of *Fuel Technology, Metallurgy* and *Ceramics*. The integration of the activities in these three fields into a single closely knit department has many advantages, resulting in improved effectiveness in the handling of research problems. For instance, there are many problems in the steel industries which are as much fuel and ceramic problems as problems in metallurgy. The iron blast furnace is in some respects best considered as a problem in fuel technology and in other respects best considered as a problem in metallurgy, so that a research project dealing with the over-all improvement of blast furnace operations should benefit by being placed in a department wherein exists close cooperation among specialists in these two fields. This applies equally well to almost any other pyrometallurgical process, including open-hearth steel making. All such processes pose problems in ceramics, not only because of the importance of the refractories with which the vessels are lined, but because ceramists are well qualified to handle many slag problems. The interactions between refractories and slags, and between slags and molten metals require treatment by teams comprising both ceramists and metallurgists.

Demonstrating new principle of odorless gas-fired incineration.

Ceramics



THE CERAMIC INDUSTRIES OF PENNsylvania provide the bulk of the refractories used in the East. Silica rock is converted into heat-resisting bricks for steel furnaces, glass melting tanks, and coke ovens; it is also crushed to produce a high-quality sand for the extensive glass industries of the State. Raw materials for the production of fireclay bricks used in many industrial furnaces, and for the manufacture of porcelain, china, and household bricks, come from the clay mines of Pennsylvania. As modern industry sets higher and higher goals of quality and production, the ceramic producer must turn to research to obtain information on the treatment of his materials and products in order to meet specifications. As the best of the raw materials are consumed, ceramic research also points the way to the beneficiation of low-grade rocks and ores into suitable material.

The School is also well known for its fundamental researches in glass technology. In particular the studies on glass surfaces have led to theoretical conclusions that are finding application in many other fields of science.

Equipment for measuring the electrical conductivity of refractories at 1500°C.

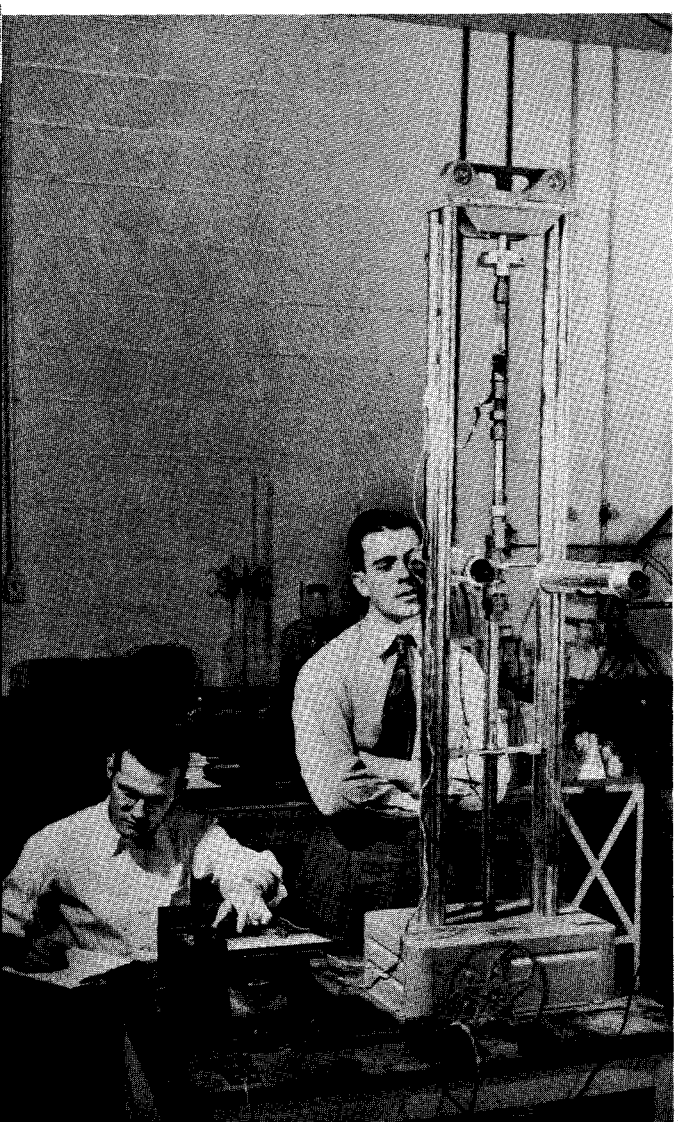
Student in picture below observes ceramic reactions at high temperature.

Metallurgy

THE DIVISION OF METALLURGY PROvides the nucleus and incentive for research and research training, both in metal science and industry. Practical industrial types of research are promoted and encouraged as well as fundamental studies concerning the electronic structure and properties, ductility and cohesion, mechanical, electrical, and chemical properties of metals.

The metallurgical laboratories are equipped for advanced research in theoretical, physical, and chemical metallurgy. X-ray and electron diffraction equipment, optical and mechanical dilatometers, the latest of metallographs, several types of electric furnaces with automatic temperature control, and various electrical instruments including oscilloscopes are available. Equipment for hot and cold working of metals, mechanical testing of all types, and precision measuring devices find continual use. Apparatus is available for the heat treatment of metals under controlled conditions, for the study of rates of reaction in solid and liquid alloys, and for electroplating and corrosion studies.

The structure of metals is examined under the microscope with a metallograph.



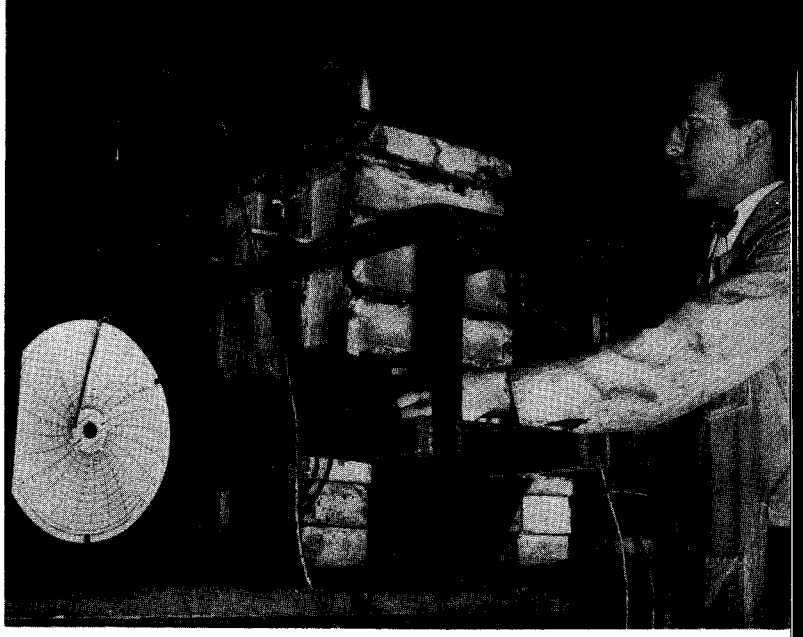
Graduate student in picture at lower left determines the tensile strength of small gage steel wires.

Fuel Technology

RESEARCH ACTIVITIES OF THE DIVISION of Fuel Technology include projects on anthracite and bituminous coal and tars, ranging from purely theoretical studies to plant scale application of research developments.

The anthracite program has included projects on the physics and chemistry of the combustion reactions; the flow of gases through fuel bed; the mechanism of volatile matter release; the manufacture of water-gas and producer gas; the oxygen gasification of anthracite to produce synthesis gas; the combustion of anthracite-bituminous coal blends; the use of anthracite as cupola fuel; methods of recovery and beneficiation of silt; the utilization of anthracite fines in the preparation of activated carbon, in pelletized fuel, and in by-product coke manufacture.

The bitumious program has included projects on comfort heating such as the development of the pre-oxidation principles of the Pennsylvania stoker, on the development of single retort underfeed industrial stokers to burn strongly caking slack coals and the application of suspended arches to improve combustion performance with existing units; on organic fertilizers from nitrohumic acids (a means of utilizing fines); on fundamental aspects of ash fusion, and the determination of fusain; on the liquefaction and hydrogenolysis of coals and related compounds; and on the constitution of humic acids and of coal.



Graduate student studies the behavior of coal in a small coking oven designed in the Experiment Station.

The program on tars has included the development of a system for characterizing water-gas tar; the fine fractionation, solvent extraction, chemical separation and identification of tar constituents; the aging properties under the action of heat; and methods of dewatering tar emulsions.

Fundamental studies on burning of individual pieces of solid fuel in this test furnace pictured at the right lead to a clearer understanding of what is occurring in fuel beds.

PUBLICATIONS OF THE SCHOOL OF MINERAL INDUSTRIES

RESEARCH RESULTS ARE DISSEMINATED THROUGH publications, lectures, correspondence, resident instruction, inspection by visitors, presentation of papers before scientific societies, and other means. Three types of publications are issued by the Experiment Station:

1. Bulletins. The bulletins present the proceedings of technical conferences and the detailed results of experimental studies of a problem which may be more comprehensive than a single project.

2. Information Circulars. Information circulars present in more or less non-technical language the results of studies which are given in greater detail in other publications. They may also present statistical data or information gathered from other sources which, it is felt, should be given wide dissemination within the State.

3. Technical Papers. Technical papers consist of bound copies of papers published in scientific journals (reprints), of progress reports, and of results of experimental studies which represent isolated phases of research and which will be summated later in bulletin form.

Following is a list of the publications of the School. Those that are still available may be obtained from the Director of the Mineral Industries Experiment Station, The Pennsylvania State College, State College, Pa., at the price stated:

The Building Materials of Pennsylvania. I. Brownstones, by Thomas C. Hopkins. 1896. *Free.*

Clays and Clay Industries of Pennsylvania. I. Clays of Western Pennsylvania (In Part), by Thomas C. Hopkins. 1898. *Free.*

Clays and Clay Industries of Pennsylvania. II. Clays of Southeastern Pennsylvania (In Part), by Thomas C. Hopkins. 1899. *Free.*

*Clays and Clay Industries of Pennsylvania. III. Clays of the Great Valley and South Mountain Areas, by Thomas C. Hopkins. 1900. *Free.*

The Rifling of Diamond Drill Cores, by W. R. Crane; The Formation and Decomposition of Sulphate During Roasting, by Boyd Dudley, Jr. 1917. *Free.*

Thermal Conductivity of Refractories, by Boyd Dudley, Jr. 1917. *Free.*

EXPERIMENT STATION

Bulletin 40. Progress in Research for Biennium 1943-45. 1945. *Free.*

Bulletin 46. Progress in Research for Biennium 1945-47. 1947. *Free.*

Bulletin 53. Progress in Research for Biennium 1947-49. 1949. *Free.*

EARTH SCIENCES

Geology Mineralogy Geophysics Geochemistry Meteorology Geography

BULLETINS

Bulletin 2. Petrography of the Mica Peridotite Dike at Dixonville, Pennsylvania, by Arthur P. Honess and Charles K. Graeber. 1926. *Free.*

*Bulletin 3. The Theory of Crystal Etching and its Significance in the Classification of Crystals, by Arthur P. Honess. 1929. *Price:* 15¢.

*Bulletin 4. The Helderberg Group from Central Pennsylvania to Southwestern Virginia, by Frank McKim Swartz. 1929. *Price:* 25¢.

*Bulletin 5. Bentonite in Pennsylvania, by C. A. Bonine and Arthur P. Honess. 1929. *Price:* 10¢.

*Bulletin 13. The Geography of Johnstown, Pennsylvania, an Industrial Center, by Raymond E. Murphy. 1934. *Price:* 50¢.

Bulletin 17. The Economic Geography of York, Pennsylvania, A City of Diversified Industries, by Raymond E. Murphy. 1935. *Free.*

Bulletin 24. Petrology of the Bradford Sand of the Kane District, by Allen W. Waldo. 1938. *Price:* 50¢.

*Bulletin 29. Petrology and Genesis of the Third Bradford Sand, by P. D. Krynine. 1940. *Price:* 50¢.

Bulletin 43. Geology and Economic Aspects of the More Important High-Calcium Limestone Deposits in Pennsylvania, by F. M. Swain, in cooperation with The Pennsylvania Railroad. 1946. *Price:* 50¢.

TECHNICAL PAPERS

*T. Paper 3. Revision of the Ostracode Family Thlipsuridae, with Descriptions of New Species from the Lower Devonian of Pennsylvania, by Frank McKim Swartz. 1932. *Free.*

*T. Paper 6. Dimorphism and Orientation in Ostracodes of the Family Kloedenellidae from the Silurian of Pennsylvania, by Frank McKim Swartz. 1933. *Price:* 25¢.

T. Paper 9. Silurian Sections Near Mount Union, Central Pennsylvania, by Frank McKim Swartz. 1934. *Price:* 25¢.

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T. Paper 32. Revision of the Primitiidae and Beyrichiidae, with New Ostracoda from the Lower Devonian of Pennsylvania, by Frank McKim Swartz. 1936. *Price:* 50¢.

T. Paper 35. Etch Figure Investigations with Optically Active Solvents, by Arthur P. Honess and J. Robert Jones. 1937. *Price:* 75¢.

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On the Estimation of Focal Depth from Macroseismic Data, by H. Neuberger. 1938. *Price:* 25¢.

T. Paper 51. A New Mastodon Locality at Saltillo, Hunting-

* Out of Print.

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don County, Pennsylvania, by C. W. Robinson and P. D. Krynine.

Mineralogy of the Mapleton Glass Sand, by P. D. Krynine, M. R. Klepper and M. Glasser. 1940. *Price:* 25¢.

T. Paper 53. Authigenic Albite from the Lowville Limestone at Bellefonte, Pennsylvania, by A. P. Honess and C. D. Jeffries. 1940. *Price:* 25¢.

T. Paper 61. Radioactivity Tests of Rock Samples for the Correlation of Sedimentary Horizons.

Measurements of Radioactivity for Stratigraphic Studies, by H. Landsberg and M. R. Klepper. 1940. *Price:* 10¢.

*T. Paper 63. Paleozoic Heavy Minerals from Central Pennsylvania and Their Relation to Appalachian Structure, by P. D. Krynine.

Heavy Minerals of the Ordovician-Silurian Boundary in Central Pennsylvania, by O. F. Tuttle. 1940. *Price:* 10¢.

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T. Paper 71. Early Devonian and Late Silurian Formations of Southeastern Pennsylvania, by Charles K. Swartz and Frederick M. Swartz. 1941. *Price:* 50¢.

T. Paper 76. Silurian and Early Devonian Studies in the Middle Appalachians, by Frank M. Swartz. 1942. *Price:* 50¢.

*T. Paper 97. On the Measurement and Frequency of Traces of Precipitation, by H. Neuberger. 1944. *Price:* 10¢.

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MINERAL ENGINEERING

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*Bulletin 6. Production Data on Appalachian Oil Fields, by Clark F. Barb and Paul G. Shelley. 1930. *Free.*

Bulletin 8. Oil-Field Waters of Pennsylvania, by Clark F. Barb. 1931. *Free.*

*Bulletin 9. Proceedings of the First Petroleum and Natural Gas Conference, held at The Pennsylvania State College, October 24-25, 1930. *Free.*

*Bulletin 10. A Method for Determining the Effective Porosity of a Reservoir-Rock, by Kenneth B. Barnes. 1931. *Free.*

Bulletin 11. Proceedings of the Second Petroleum and Natural Gas Conference held at The Pennsylvania State College, May 20-21, 1932. *Free.*

*Bulletin 12. Proceedings of the Third Pennsylvania Mineral Industries Conference, *Petroleum and Natural Gas Section,* held at The Pennsylvania State College, May 5-6, 1933. *Price:* $1.00.

*Bulletin 16. Proceedings of the Spring Meeting, American Petroleum Institute, *Division of Production,* Eastern District, held at The Pennsylvania State College, April 6-7, 1934. *Price:* 50¢.

*Bulletin 19. Proceedings of the Fifth Pennsylvania Mineral Industries Conference, *Petroleum and Natural Gas Section,* held at The Pennsylvania State College, April 26-27, 1935. *Price:* 50¢.

*Bulletin 20. Proceedings of the Sixth Pennsylvania Mineral Industries Conference, *Petroleum and Natural Gas Section,* in cooperation with the Pennsylvania Natural Gas Men's Associa-

BULLETINS

tion, held at The Pennsylvania State College, April 24-25, 1936. *Price:* 50¢.

*Bulletin 21. Proceedings of the Seventh Pennsylvania Mineral Industries Conference, *Petroleum and Natural Gas Section,* in cooperation with the Pennsylvania Natural Gas Men's Association, held at The Pennsylvania State College, April 30-May 1, 1937. *Price:* $1.00.

Bulletin 25. Proceedings of the Eighth Pennsylvania Mineral Industries Conference, *Petroleum and Natural Gas Section,* in cooperation with the Pennsylvania Natural Gas Men's Association, The Pennsylvania Grade Crude Oil Association, The Bradford District Pennsylvania Oil Producer's Association, held at The Pennsylvania State College, May 27-28, 1938. *Price:* $1.00.

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