Mine Drainage
Part II: The Hydrogeologic Setting

RUSSELL R. DUTCHER; E. BRUCE JONES; HAROLD L. LOVELL; RICHARD PARIZEK; ROBERT STEFANKO

The Watershed

A knowledge of watershed characteristics and the hydrogeological and geochemical setting should afford a new vantage point from which to consider mine drainage problems. This is appropriate since the drainage basin represents the basic planning, development, and management unit in hydrology. This approach permits mine drainage problems in Pennsylvania to be given a broad overview appraisal in terms of seriousness, unique or general character, and location. Defining regions as to the present and potential future economic impact of mine drainage on Pennsylvania and adjacent states is necessary if we are to be able to select areas where treatment will result in the greatest benefits for the lowest cost. Problem areas may be divided into two categories: first, where management will reclaim or protect watersheds for the least cost, stretching existing reclamation dollars to achieve rapid results; and second, where maximum involvement will be required on a continuous basis involving a far greater cost. Although one might think that such a classification has already been made in detail, the seasonal and daily variation of water quality in relation to stream flow has not yet been established on a watershed to watershed basis. This type of information is necessary when one realizes that the absence of certain aquatic species in a given reach of river may equally result from either water quality exceeding the toxic limit for only one hour during a year or for the entire year. If water quality management requires a design to protect against an occasional pollution event it is an entirely different problem from that needed to provide for continuous treatment. Water quality frequency graphs showing percent of time various quality levels are likely to be equalled or exceeded for each station would indicate the seriousness of pollution observed during the period of record and would aid in making decisions for water management.

Recently the United States Geological Survey and United States Public Health Service have established continuous water quality monitoring stations in cooperation with various state and other federal agencies. Together with existing stream gauging stations, these represent inroads on the problem; nevertheless, these observations will have to be broadened to include other basins and existing gauged basins will have to be subdivided into working sub-units. These sub-units should include drainage areas with common hydrological and geochemical characteristics relevant to mine drainage pollution. The extent and nature of mine drainage pollution must be outlined for each, as well as extent of mining, date mined, mine practice, number and location of strip and deep mines, and future mining potential.

Continuous flow and water quality measurement stations will have to be established for each drainage unit to define the hydrological and chemical regime of the watershed. In many cases, this will mean that new basic data collection stations would have to be established at selected sites. An appreciation of the detail required may be gained by reviewing the Pennsylvania Department of Health's study on Slippery Rock Creek, Pennsylvania.
Before new and costly management schemes are initiated, over and beyond present legal requirements, water quality indices might well vary regionally as a result of local demands and problems. These may include biological requirements, quality requirements for industrial, municipal and recreational uses, and esthetic values. A watershed must serve all of these uses, then quality requirements to achieve the lowest tolerance limits must be selected. This is not as simple as it seems. For example, quality requirements for fish may depend more upon the tolerance limits of elements in their food chain rather than upon the fish themselves or their tolerance at various stages in their life cycle. More basic research will be required to find definitive answers to such problems.

As indices are being established, and as drainage units are defined, available and new methods of controlling, abating, preventing, and disposing of mine drainage must be considered within the context of their effectiveness and cost. The unique geohydrological and geochemical setting of one region may favor methods of watershed management which differ from those used in an adjoining watershed. Once technological alternatives best suited to each region have been determined, quality standards established, and benefits evaluated, engineering cost estimates can be made for the design, construction, maintenance, and operation of such management works.

MINERAL INDUSTRIES

John J. Schanz, Jr., Editorial Director
Pamela L. Slingluff, Editor

The College of Earth & Mineral Sciences of The Pennsylvania State University

... dedicated to resident education, research, and continuing education in all fields of mineral discovery, investigation, extraction, and utilization to the end that true conversation—the efficient exchange of ideas—shall be achieved now and in the future.

Departments of Instruction and Research

Ceramic Science
Geochemistry and Mineralogy
Geography
Geology and Geophysics
Metallurgy
Meteorology
Mineral Economics
Mineral Preparation
Mining
Petroleum and Natural Gas

Published monthly from October to June inclusive by Mineral Industries Continuing Education 104 Education Building, University Park, Pennsylvania 16802. Second-class postage paid at State College, Pennsylvania, 16801.

STATEMENT OF OWNERSHIP: In compliance with U.S. Post Office regulations, the following statement of ownership and management is published.


EDITORIAL STAFF: John J. Schanz, Jr.; Pamela L. Slingluff.

Vol. 48, No. 6, June 1967

To select proper alternatives sociological and political factors as well as costs and technological advances must be considered. Mine drainage problems in Pennsylvania are far from simple. For example, they include: (1) defining and demonstrating methods of controlling mine drainage from both active and abandoned strip and deep mines; (2) evaluating the success or failure of earlier attempts to do the same; (3) determining the social, economic, political, educational, and technical problems associated with mine drainage, and (4) appraising gaps in knowledge gained from previous work, and any resultant shortcomings.

Regardless of available manpower and funds, research interests, equipment, organizational responsibilities that influence group research, and the relevance of work completed to date, we have reached a time when more research effort must be applied to the overall problem. This research effort must be expanded to the field scale, and adequate instrumentation and control must be provided to evaluate the success or failure of these demonstration studies. Aside from the previous work of the U.S. Bureau of Mines, Bituminous Coal Research, Inc., Department of Health of the Commonwealth of Pennsylvania, National Coal Association, Mellon Institute, Ohio Department of Health, private consultants, various coal companies, universities and other governmental groups cited in Part I of this article, represent examples of field oriented demonstration projects. Other important broad scale field investigations include the study of the influence of strip mining on the hydrological environment of parts of Beaver Creek Basin, Kentucky, and the joint federal-state control program in the Pennsylvania anthracite region.

More demonstration projects beyond the pilot plant stage must be established to test the validity of existing corrective measures or to develop new ones, not only to solve problems in previously mined areas, but also at active mines. As of January 1, 1967, legislation in Pennsylvania demands that active coal companies dispose of or treat their mine drainage to meet specified water quality requirements. Hopefully, methodology will be available to these operators by this date to enable them to cope with their problems even though pollution by mine drainage will still result from abandoned mines.

The demonstration projects should be selected to represent the end member conditions to be expected under various geohydrological settings. Each demonstration project must have a preconceived research design aimed at isolating variables and testing concepts and hypotheses selected for evaluation. Many conclusions drawn from previous work should be further tested and proven prior to their forming the sole basis for the expenditure of vast sums of money. The pattern, nature and frequency of measurement comprising the monitoring network must be worked out to determine whether or not a remedial measure has in fact had the predicted result. This point cannot be overemphasized. Perhaps this is true about the cause and effect relationships where remedial measures have been applied at the field scale.

It has been said that most problems are of an economic nature. Perhaps this is true in the case of treating polluted mine drainage. In looking to the future the economics of the problem must not be minimized. The watershed can serve a very useful purpose in approaching this overall question of acid mine drainage; however, it does not help particularly to view the difficulties solely from a legal, social or economic angle. These elements do not necessarily follow watershed boundaries. Thus, in the overall approach, watersheds may well be the basic physical planning units, but when the social and legal sciences are to be included then planning units may have different boundaries.

Management of Mine Drainage and the Geological Setting

Little has been written concerning the roles of the soil profile, the soil moisture and groundwater.
water reservoirs in the formation of acidic type waters, which influence water quality during its migration from recharge areas to areas of ground water discharge. The importance of dilution and neutralization reactions between mine drainage and native ground water or the interaction between mine drainage and aquifer and non-aquifer materials is not fully understood. Mine drainage eventually becomes neutralized as it is mixed with surface water down watershed. However, this fact offers little consolation to those who live along polluted reaches of the same watershed. Bienecker and George (9) concluded from their work that the mixture of alkaline streams with mine drainage waters eventually neutralizes all acid streams in the Appalachia region. As an example they cite the badly polluted upper Ohio River drainage basin above and below the confluence of the Allegheny River. The addition of Allegheny water, together with other more alkaline tributaries downstream, accounts for improved water quality. This is not surprising in view of the hydrogeologic and geochemical conditions found in various drainage basins. Figure 1, from Bienecker and George (9), shows areas where the bicarbonate concentration of surface water exceeds, or is less than, 50 parts per million. Again this shows the somewhat regional nature of the problem. Superimposed on these sampling points on the geologic map of Pennsylvania, they fall in areas where CaCO₃ in the form of limestone, limestone and dolomite pebbles and rock flour contained in glacial till, lake sediments and outwash deposits, and CaCO₃ contained in calcareous shales and as cement in sandstones is at least present near the land surface. With further review these regions may be correlated in part to outline areas where Pennsylvanian age rocks were deposited in marine, brackish, and fresh water environments. This is especially important since acid forming minerals are generally more abundant in marine and brackish sediments associated with coal beds rather than in fresh water sediments. Also CaCO₃ concentrations are generally higher in fresh water sediments, (excluding marine limestones).

Williams and Keith (25) attempted to relate total sulfur distribution in coal to geologic facies on a regional level. They showed that the Lower Kittanning coal exhibits regional variations in sulfur content which are statistically related to regional changes in overburden, areas of marine overburden being higher in sulfur than continental areas, (Figure 2). The Upper Freeport coal, overlain entirely by continental beds, showed no significant regional variation (Figure 3). If acid potential or acid formation derived from these areas increases with some aspects of sulfur distribution, environmental mapping will prove highly significant. Williams (24) has shown that shales above the Mercer, Lower Clarion, Upper Clarion and Middle Kittanning coals are of both marine and continental origin. As a major start on the problem Williams has provided maps that show the regional distribution of environmental rock types above each of the major coal beds in western Pennsylvania.

From the work already completed it may be possible to predict areas of relatively high and low sulfur concentration in coals and roof rocks and as a result also indicate areas of high or low acid potential. In addition, detailed mapping may be warranted to define variations in sulfur distribution, and in particular, indicate which sulfur is responsible for the acid and iron content of mine drainage. Reidenouer (18) investigated factors influencing the total sulfur variation in three selected coal seams and related it to the physical and chemical conditions of the original peat swamp. His study, confined to outcrops of 1000 feet or less in length, was of the Clarion coal at the Krebs Mine near Clearfield, Pennsylvania, and two benches of the Lower Kittanning coal in a railroad cut near Curwensville, Pennsylvania. A close correlation was found between sulfur distribution and the porosity of the coal and using paleo-magnetic lows in the coal swamp floor. In two cases the highest sulfur values were related to channels where coal deposition was influenced by paleotopography.

Dr. Muan's abiding interest, however, is his work on studies of the culmination of many years of hard work when the Addison-Wesley Publishing Company brought out *Phase Equilibria among Oxides in Steelmaking*, a book he co-authored with Dr. E. F. Osborn, professor of geochemistry and vice president for research at the University. The book treats in detail an important aspect of oxide phases in steelmaking, namely equilibrium relations. Neither a textbook on phase equilibrium theory, nor a mere compilation of phase diagrams, it represents an attempt on the part of the authors to bridge the gap between theory and practice by critically reviewing the available diagrams and demonstrating a practical method of applying these diagrams to actual steelmaking problems. As a result, the book constitutes a useful guide to the treatment of high-temperature heterogeneous equilibrium problems for those interested in the interdisciplinary fields of metallurgy, ceramics, materials science, and geosciences.

In 1948, when Dr. Muan left the University of Trondheim to study high temperature chemistry on a Norwegian Government Fellowship and a Fullbright Travel Grant, he elected to come to Penn State where he has been a member of the faculty since 1952, having been progressively research associate in geochemistry, assistant, associate and professor of metallurgy. On December 1, 1966, he became professor of mineral sciences and head of the department of geochemistry and mineralogy.

Dr. Muan devotes the majority of his leisure hours to his family. His children, aged 2 and 4, have already had their first skiing lessons. Family swimming is a common evening activity during the summer months, and the bouncing of a soccer ball is often heard around the Muan property on weekends. The garden shows distinct signs of the expert care of soil chemists and that of his family — although he did graciously consent to have the above photograph published in *Mineral Industries*.

Current work being conducted under the sponsorship of the Coal Research Board of Pennsylvania Contract Number CR-66 confirms that sulfur concentrations are highly variable both vertically and horizontally in other areas, and that a carefully selected sampling plan will have to be followed to estimate the pollution potential of unmined strata. The significance of a stratigraphic approach to define acid potential was given by Hanna and Brant. (13) That the variability in sulfur distribution may be predictable once the paleoenvironment in which it was formed is understood was shown by Reidenouer. (18) However, detailed studies of other settings will be required to establish widespread application of this and similar work. Therefore, studies of the character and distribution of sulfur bearing minerals, in particular, pyrite variations in sulfur distribution, and in particular, indicate which sulfur is responsible for the acid and iron content of mine drainage. Reidenouer (18) investigated factors influencing the total sulfur variation in three selected coal seams and related it to the physical and chemical conditions of the original peat swamp. His study, confined to outcrops of 1000 feet or less in length, was of the Clarion coal at the Krebs Mine near Clearfield, Pennsylvania, and two benches of the Lower Kittanning coal in a railroad cut near Curwensville, Pennsylvania. A close correlation was found between sulfur distribution and the porosity of the coal and using paleo-magnetic lows in the coal swamp floor. In two cases the highest sulfur values were related to channels where coal deposition was influenced by paleotopography.

Dr. Muan has also long been interested in photography, particularly in taking nature pictures and family portraits. However, he stresses this is a pastime strictly for his own pleasure and that of his family — although he did graciously consent to have the above photograph published in *Mineral Industries*.
and marcasite, must be continued on a regional and local scale, coal measures by coal measure, because vertical and horizontal distribution of sediments accompanied changes in environments of deposition which varied in time and space. Knowledge of these depositional environments and mapping of the distribution and acid potential of coal and associated strata will allow for the geochemical classification of mining regions referred to earlier. To establish the criteria for such mapping is one of the objects of the study above mentioned, i.e. the Pennsylvania Coal Research Board Contract CR-66.

Knowledge of the distribution of sulfur bearing minerals in advance of mining may dictate an alteration of the mining methods to minimize pollution problems. Selective stripping, removal, and safe burial of high sulfur materials should be possible under certain schemes of mining.

In areas where alkaline surface and ground waters are present, there is hope that mine drainage can be treated and neutralized by water resources management. This would include regulating the flows of either mine waters or impounded alkaline waters to achieve the desired quality of water in regions where the chemical characteristics of mine drainage and receiving waters indicate that such action would offer a reasonable alternative.

The dilution and buffering potential of acid water by waters containing various concentrations of \( \text{HCO}_3^- \) has been discussed by Barnes and Romberger. They show, for example, that 100,000 gallons of bicarbonate free water with pH of 7 would be required to dilute 1000 gallons of mine drainage with a pH of 3 to achieve a final pH of 5. They present equations which may be used to determine the amount of diluent necessary for neutralization to take place where various amounts of bicarbonate are present. A series of seven diagrams have been prepared using different concentrations of bicarbonate which give the initial and final pH relations as a function of dilution.

Although alkaline waters are not always available in mining regions, this management scheme can be applied in the lower reaches of a watershed when all other possibilities of solving the mine applied impractical. Thus, water quality in the lower Susquehanna River could undoubtedly be improved by manipulating the alkaline tributaries upstream, such as Bald Eagle and Spring Creeks. Dams to impound alkaline waters need not be built exclusively to store surface water. Larger volumes of water can be stored behind smaller dams when both ground water and surface water are impounded. A rise in lake level at the outlet of a carbonate valley, for example, will raise the adjacent regional water table, and hence store billions of gallons of water within previously unsaturated rocks. These dams would flood limited surface areas with low evapotranspiration losses and could be readily recharged because of the high recharge potential of carbonate rocks.

It is not uncommon to see an alkaline bank and a mine drainage polluted bank along a reach of the same river. This condition affords a barrier to aquatic life well below a point where favorable quality would be achieved if both waters were mixed. Engineering works could be designed, however, to achieve mixing just below the confluence where mine drainage enters alkaline rivers, such as that along the Susquehanna. Constructing these works in the form of concrete baffles and raceways, would represent a legitimate use of water resources management funds once the decision was made to use existing and future engineering works for mine drainage control as well as for recreation, flood control, and water supply. This would require that the location and character of such works take into consideration control of mine drainage from abandoned mines as one justification for the project in advance of its design and construction.

In view of the potential value of watershed management techniques in controlling water that may ultimately become mine drainage, this type of preventive measure should not be neglected in basin planning where it will serve to increase the multipurpose objectives of such projects. Existing engineering works should also be reviewed to determine whether or not modifications can be made in structures. This, in turn, must be weighed against the long term benefits that would accompany the correction of pollution.

In other instances mine drainage bypasses strata which might alter the composition of wastes under natural conditions if given the opportunity to do so. Ground water runoff and surface discharge are limited by precipitation, evapotranspiration losses, ground water recharge, surface drainage characteristics, and the storage and transmissive character of rock strata. On the other hand, a variety of engineering pursuits, including mining operations, can greatly alter the surface water and ground water recharge and runoff characteristics of drainage basins, often allowing mine drainage to bypass the available treatment media. Outlets to deep mines such as shafts, haulage ways, and collapsed overburden constitute zones of increased or nearly infinite permeability when compared to original strata. There is neither time nor opportunity for neutralization reactions when mine waters escape from free drains. Availability, amount, and distribution of neutralizing strata should be considered in the geohydrological and geochemical classification cited earlier. Where they are present, surface waters can be brought into contact with these strata by discharging them into abandoned mines which discharge alkaline waters (such a project is underway at the Barnes and Tucker mine near Barnesboro, Pennsylvania). Other possibilities are to divert surface water to appropriate strip mines, inject waters to deeper aquifers by wells and shafts and even irrigate adjacent uplands. This is the reverse of hauling tons of limestone to the neutralization site. Neither the available sites where these methods can be tried nor the problems associated with this method of treatment have been outlined or investigated in detail. The near surface Vanport limestone of Western Pennsylvania may offer such neutralization sites (Fig. 4).

Aside from establishing methods of evaluating the probable quality of mine drainage in advance of mining, the magnitude of the overall future problem must be reviewed. In some cases, this may discourage mining in certain areas in view of the long term responsibility the miner now has as a result of recent legislation. Kinney(14) has shown the influence of mine drainage pollution on fish habitats in Pennsylvania and West Virginia. Biesecker and George(9) indicate that there is a striking relationship between Kinney's data and coal.
production by each state in Appalachia. A rough approximation of the mine drainage problem by 1980 might be obtained in a similar manner by comparing past coal production and present quality of surface and ground waters against projected future coal production and potential water quality. This should be done to insure that regional abatement facilities are not under-designed for the problem that may arise if other abatement measures fail. Interim solutions may be acceptable by water resource planners so long as they are part of a long-range program and have not become obsolete for other reasons.

Knowledge of the geohydrologic setting within each drainage unit would be particularly useful when considering the ground water reservoir's role in transporting and neutralizing mine drainage after it has penetrated the ground water reservoir, and also in accounting for the source of high alkalinity in some streams. The relative position of sources of alkalinity and mine drainage within the ground water flow regime should be of importance in assessing ground water pollution by mine drainage and in establishing the role of the ground water reservoir as a potential treatment media. If CaCO₃ occurs in the direction of ground water flow and ground water has already become contaminated, the neutralization media may become coated with basic hydrated oxides of iron, hydrated ferric sulfate, or calcium sulfate which eventually may armor the media and either stop or retard neutralization. On the other hand, if the ground water has attained sufficient alkalinity ahead of the pollution site, the neutralization process can continue. Barnes and Romberger(6) indicate that this same principle may be used to treat water in advance of its inflow to a mine. They state that where the hydrologic system is simple, inflow may be treated with limestone or, preferably, dolomite to establish a buffering capacity to counteract acid while reducing the rate of acid formation since catalyzing bacteria do not thrive at near neutral pH's. Under favorable conditions the bicarbonate content for limestone or dolomite saturated water may be 500 ppm with a pH of above 8, which would afford a considerable buffering capacity.

These considerations should be helpful in locating disposal sites for waste materials associated with coal, since tailings are generally high in pyritic sulfur.

More can be achieved during the mining operation to minimize or prevent acid production by directing waters from pyritic-bearing deposits. Diversion trenches, hedge hopping ravines to convey surface water away from mine sites, drainage ditches, etc., have been described by Lorenz.(15) In some cases dewatering in advance of mining may provide water of suitable quality to meet municipal and industrial water requirements. Ground water development must exceed the recharge rate if dewatering is to be successful and for associated strata to be dewatered by removing water from storage.

With appropriate geologic and hydrologic information, the number and spacing of wells, the amount of water to be pumped, and the time necessary to achieve dewatering can be predicted in advance of mining. To accomplish this the following information should be obtained: thickness, distribution, and geometry of all aquifer and non-aquifer units, coefficients of vertical and horizontal permeability and storage capacity of all rock units in and adjacent to coal beds, distribution and character of recharging and "no flow" hydraulic boundaries such as rivers, fault-zones, stratigraphic pinch outs, etc., hydraulic potential distribution between and among aquifer and non-aquifer units, and the area to be mined. These data can be obtained from the initial boring program used to delineate the coal resource and from relatively few additional borings. Where numerous hydrologic units are present and where beds are heterogeneous in character, electrical analog models can be used to predict the time rate of water level decline as a function of time, pumping rate, as well as the number and spacing of wells throughout the mine district. The cost of constituting these models will probably be small in comparison with the benefits derived (Walton and Prickett.(53)

At the end of mining, two alternatives are available: the dewatering process can be continued as long as there is a use for the water, or the mine can be allowed to flood. This latter may or may not prevent the oxidation process, and this should be established in advance of abandoning the mine, otherwise dewatering will provide only a temporary solution during mining. Where two or more levels are mined, water quality derived from each may vary. Under ideal field conditions, such as at the mines at Barnesboro, Pennsylvania, acid water and alkaline water mix naturally underground so that the final drainage is satisfactory. This might not have been the case had the two waters been discharged separately to the land surface.

Finally, mined regions should be reviewed carefully to determine the potential uses of a new resource, namely, the scarred landscape. To produce features such as contour trenches, deep shafts and vast underground openings would be prohibitively expensive were it not for the coal extracted. What new uses can be made of these features? Many shallow strip mines occur in areas where mine drainage is not a problem, and many mines make excellent reservoirs when excavated below the water table. These can be used for boating, fishing, swimming, or fish propagation. They could also be exploited as tourist attractions, and as building sites for homes. Although Pennsylvania has an abundance of scenic countryside, reservoirs are few and far between. In glaciated areas of the midwest, even the rough land created by mining pro-
vides a relief from the monotonous flatlands. In some regions these areas are being exploited in their present form. Existing legislation in Pennsylvania should be made more flexible to allow for new and beneficial uses of abandoned mines.

Abandoned strip and deep mines should be considered a potential new resource. Where they are adjacent to rail lines or major highways they can be used to store or dispose of liquid wastes which accumulate in urban areas and, with proper shipping incentives, sites distant from population centers might be used for this purpose. Strip mines in uplands could be sealed to store vast quantities of municipal water supplies for towns in adjacent valleys, thus eliminating the need for costly storage tanks. Since existing laws do not allow for such variances, they may well be competitive. Deep mine waters of favorable quality, or waters that are treated to meet quality standards, may be pumped to augment low flows of nearby rivers. Billions of gallons of water are presently available in existing abandoned deep mines.

Aside from water quality, mining has had a significant influence on the regional hydrology of many watersheds. In retrospect, surface runoff should be less because of infiltration and ground water storage capacities, which are increased through mining. When settlement is completed collapsed roof rock will alter the permeabilities and porosities in deep strata and the recharge potential to these strata.

Conclusion

Many ideas have been incorporated herein, some already confirmed by considerable research, while others are rather unconventional, and even preliminary work on them has not yet been done. Many statements will arouse controversy among workers in the field; and, in fact, they have already done so among the present authors reflecting their own divergent opinions about some of the ideas set forth in this article. This reflects the fact that there are two basic approaches necessary to alleviate water pollution. These are first, the implementation of procedures presently available, although they are perhaps not completely satisfactory, and second, a continued effort to arrive at more permanent solutions. Thus, if some of the ideas that have been stated here stimulate thinking along pioneering lines, then the goals of the authors have been achieved. It is recognized that controversy exists and that this is a healthy situation so long as we direct our arguments toward ultimate solutions rather than merely indulging in criticism.

The advent of new laws in many states which dictate, or soon will, water quality standards, has imposed upon all citizens the responsibility of caring for one of the most valuable resources any nation can have — water. Like any abundant resource, the seemingly endless supply of water has led to abuses. We are now paying for these abuses in both hardships and in dollars. It is, therefore, imperative that the present generation, including lawmakers, industries, cities, the scientific community, and the general citizenry, pay heed to past mistakes, learn from them, and act cooperatively so that future generations will not inherit an even greater problem than that facing much of the country today.

References


About the Authors

Dr. Russell R. Dutcher, associate professor of geology, received the B.A. degree from the University of Connecticut in 1951, the M.S. degree in 1953 from the University of Massachusetts and the Ph.D. degree from Penn State in 1960. All these degrees were in the field of geology. He joined the Penn State faculty in 1963 and presently serves also as Assistant Director of the Coal Research Section.

Dr. Dutcher's principal research interests are in the fields of coal composition, the mineral matter content of coal and coal stratigraphy.

He is a member of GSA, AAPG, and AIME.

Dr. E. Bruce Jones, assistant professor of meteorology, is also assistant director of the Institute for Research on Land and Water Resources and as such he is in charge of the Water Resources Center. He was born in Fort Collins, Colorado, and received the B.S. degree in 1955 in civil engineering from the University of Wyoming, the M.S. degree from Penn State in meteorology in 1959, and the Ph.D. degree in watershed management in 1964 from Colorado State University. He joined the faculty at Penn State in 1965.

Dr. Jones's major areas of research are water resource management and hydrology, and he holds membership in the AGU, ASCE, and the AMS.

Dr. Richard R. Parizek, Staff Geologist of the Mineral Conservation Section at Penn State, serves also as associate professor of hydrogeology in the department of geology and geophysics. He received the B.A. degree from the University of Connecticut in 1956 and the M.S. and Ph.D. degrees from the University of Illinois in 1960 and 1961 respectively, all in the field of geology.

Dr. Parizek's research has been principally in the areas involving the distribution and movement of ground water in glacial and carbonate areas, and he is presently directing a research project which is evaluating ground water reservoirs associated with coal-bearing strata. He has contributed to the National Symposium on Acid Mine Drainage.

Dr. Robert Stefanko, professor of mining engineering, has been head of the department of mining since 1964. He joined the faculty in 1957 as an instructor, having been a graduate assistant from 1955. He holds the B.S. degree in Naval Science from the University of Virginia, and the B.S., M.S, and Ph.D. degrees in mining engineering from Penn State.

In 1948 he joined the Western Pennsylvania Mining Company, and until 1955 served in several capacities, including mine engineer, assistant mine foreman, and purchasing agent.

At Penn State he was responsible for the establishment of the rock mechanics laboratory in the department of mining. He has been active on rock mechanics committees in both the AIME and ASTM, and is presently chairman of the scholarship committee, Coal Division, SME-AIME.

J. L. Mauthe Dies

J. Lester "Pete" Mauthe, retired president and board chairman of the Youngstown Sheet and Tube Company, a distinguished alumnus of the University which he served as a trustee for nearly 30 years, died January 1st at his home in Poland, Ohio.

Mr. Mauthe received the B.S. degree in metallurgy at Penn State in 1913 and in 1948 he was awarded the degree of metallurgical engineer. In 1951 in recognition of his achievements in metallurgy he was awarded the David Ford McFarland Award by the Penn State Chapter of the American Society for Metals.

As Penn State's first football great, Mr. Mauthe was not only chosen an All-American, but he became the only Penn State player to win College Football's highest honor election to the National Football Hall of Fame.

Widely known in the steel industry, Mr. Mauthe was a member of the Association of the Iron and Steel Engineers, a director and member of the executive committee of the American Iron and Steel Institute and a lifetime member of the American Society for Metals.
Recent publications of the College of Earth & Mineral Sciences are listed below. Those desiring reprints should address their request to the senior author, 5 Mineral Industries Building, University Park, Pennsylvania, 16802.


Recent publications of the College of Earth & Mineral Sciences are listed below. Those desiring reprints should address their request to the senior author, 5 Mineral Industries Building, University Park, Pennsylvania, 16802.

As a direct result of a visit by Mr. Thomas C. Petty, President of the Hauck Manufacturing Company of Lebanon, Pennsylvania, to the department of fuel science recently a scholarship fund in the initial sum of $1,000 for undergraduates majoring in fuel science has been established.

It is proposed that awards will be made by the department within the procedures laid down by the Committee on Scholarships, and the department is to have the responsibility of selecting properly qualified recipients and of deciding what value should be assigned to individual scholarships according to the scholastic ability and financial needs of applicants. The award will be known as the Hauck Scholarship.

College News Notes

Dr. Philip L. Walker, Jr., professor of fuel science, is the editor of a series of advances, Volume 2, Chemistry and Physics of Carbon, which has just been published by Marcel Dekker, Inc., New York.

Peter H. Given, head of the department of fuel science, attended the Third International Meeting on Organic Geochemistry held in London, September 26-28, 1966, at which he presented two papers. While in England, Dr. Given also visited two newly created organic geochemistry units at the Universities of Glasgow and Newcastle.

Dr. Hans A. Panofsky, professor of meteorology, addressed a meeting on "Spectrum Analysis" at Madison, Wisconsin, on October 3-5, sponsored by the Mathematics Laboratory of the U.S. Army on "Cross Spectrum Analysis in Meteorology."

George W. Birchley, professor of geochemistry and mineralogy, attended the Clay Minerals Conference in Pittsburgh on October 10-13 as program chairman and member of the council of the Clay Minerals Society. He presented a paper jointly with Monsieur J. Mering of Paris entitled "X-ray Diffraction Band Profiles of Montmorillonite and the Interlayer Organization."

B. F. Howell, Jr., professor of geophysics, attended the annual meeting of the Eastern Section of the Seismological Society of America in Ottawa, Canada, on October 6-7, where he served on the Resolutions Committee and presented three papers: "Scale-Model Study of Refraction along an Irregular Interface" (with T. G. Baybrook); "Scale-Model Study of Refraction Arrivals in a Three-Layered Structure" (with D. A. Siskind); and "Method for Recognizing Repeated Pulse Sequences in a Seismogram" (with P. M. Lavin, R. J. Watson, Y. Y. Cheng, and J. L. Lin).

John D. Ridge, head of the department of mineral economics, has been appointed to serve on a panel of the National Academy of Science on Mineral Economics and Resources under the Chairmanship of Dr. John D. Morgan, a graduate of the College. The panel is charged with studying the status of the mineral resources of this country, both now and in the future, and its relationship to foreign sources of supply, as well as the status of mineral economics education in this country. The representative of the National Academy on the panel, Dr. Cyrus Kingsberg, is also a graduate of the College. The panel, which met in Washington, D.C. on December 12, will meet again in mid-January.

R. B. Hewes, professor of mining engineering, presented a paper entitled "Recruitment and Training of Mine Maintenance Personnel" at the 14th Annual Meeting of the Mining Electro-Mechanical Maintenance Association in Greensburg, Pa. Professor Hewes is president of the National Advisory Council for MEMMA.