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Estimation of Potential Mineral Reserves, and Public Policy

Results of resource assessment methods are so imprecise that a policy based on them may be worse than a policy that recognizes our complete ignorance of potential reserves.

WILLIAM A. VOGELY, *Professor and Head, Department of Mineral Economics*

The question of the future availability of mineral resources is one that has puzzled society since the industrial revolution. Fear that the stock of minerals in the ground is being used up so that future generations will be doomed to poverty is a current theme in both popular and serious scientific literature.

The mineral shortages and the energy situation in the early 1970s led to a great deal of effort to understand our resource base. As mineral production comes from mineral reserves, estimates of potential reserves—that is, the ultimate amount of minerals that can be produced over time—are necessary to address the issue of resource depletion. The need for this information was increased because of public policy dealing with federal lands.

To make good land-use decisions, the alternative values of the land under dif-

Continued on next page

Private Support of College Up 56%

Greater response than ever before from private donors is being received this year to appeals of the College of Earth and Mineral Sciences for financial support for its programs.

As of January 31, gifts to the college and its various programs totaled $1,007,054 — 56 percent more than the amount that had been received by the same time last year.

Contributions from alumni of the college showed a dramatic increase. A total of $75,950 from 718 graduates had been received by January 31 — an increase over the previous year of almost 89 percent in dollars and 64 percent in the number of donors. Gifts from corporations, associations, and foundations totaled $925,554, while $5,550 had been received from friends.

In a letter sent to all college alumni last December, Dean C. L. Hosler pointed out that financial aid from private sources is becoming essential for the college if it is to maintain, in the face of decreasing support from traditional sources, the standards of excellence it has set for

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Polymer Alloys—Materials with a Bright Future

The development of polymer blends—mixtures of two or more polymers to form materials with properties unobtainable from any one polymer—is still in its infancy.

JAMES P. RUNT, *Assistant Professor of Polymer Science*

The term "alloy" has been used for many years by materials scientists to identify mixtures of two or more metals or mixtures of metals with other nonmetallic elements such as carbon and phosphorus. In the past 35 years, and especially in the last decade, "alloy" has made its way into the vocabulary of synthetic polymer physicists and chemists.

Polymer alloys or the more commonly used term, "polymer blends," are analogous to their metallic counterparts. They are the result of physically mixing two or more polymers to form materials exhibiting combinations of properties that cannot be obtained from any one polymer. To understand the rationale for the current interest in these mixtures, we need to examine briefly the historical development of synthetic polymer science.

In the formative period of polymer science and technology as we know it today (the early and mid-1900s), much effort

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Metallurgy to Observe 75th Anniversary

Alumni of Penn State's Metallurgy Program are being invited to attend a program of special activities, April 29 and 30, planned in observance of the 75th anniversary of the establishment of metallurgy as a separate course of instruction at the University.

Although metallurgical engineering had been inaugurated in 1893 as an option in the mining curriculum at what was then called The Pennsylvania State College, it was not until the 1907-08 academic year that a separate Department of Metallurgical Engineering was set up.

Metallurgy is now a program within the Department of Materials Science and Engineering in the College of Earth and Mineral Sciences.

The 75th anniversary program will begin with an open house in the Metallurgy Program's laboratories and other facilities in Steidle Building on Friday afternoon, April 29, and Saturday morning, April 30. At these times, visitors will have opportunities to meet and talk with faculty and students.

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Mineral Resources—

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ferent uses must be understood. Thus the pressure to withdraw large areas of land for wilderness use has generated the need for potential reserve estimates in the western states and Alaska. Leasing programs on the outer continental shelf rest upon ideas about how much oil and gas will be discovered. Large synthetic fuels research programs are justified on the basis that conventional sources of oil and gas are depleting.

Most important of all, our conceptions about future economic growth and current consumption reduction so as to conserve for the future can have significant implications for the quality of life. So estimates of potential reserves of minerals and fuels play an important role in public policy, and can make a real difference in our welfare.

Are the estimates of potential reserves available today good enough to carry the weight of those important public decisions where they are used? My answer is no! To understand why this is so, the nature of primary mineral supply must be understood.

Minerals can only be produced from deposits existing in the earth that have been discovered. To estimate how much will ultimately be produced, the resource endowment must be described and a discovery function developed. As neither of these elements can be determined from the current state of scientific knowledge, indirect methodologies are used for potential reserve estimation. These methodologies are evaluated below.

Resource Estimation Methodologies

The usual way that resources are classified is by geologic knowledge of their existence and the economic feasibility of their production. Reserves are those resources that are fully demonstrated to exist and are economic to mine under current price/cost conditions. Other groups are marginal and sub-marginal known resources, inferred economic resources, and undiscovered resources of all economic classes. Estimates of potential reserves—those resources that will be economic to produce when they are discovered—are at issue here.

The major methods used for potential reserve estimation are analogies, both geographic and geologic; time rate analysis; crustal abundance models; and subjective probability analysis.

Geographic Analogy. There are two major applications of this technique. One uses the known resources of a well-explored area for a mineral that occurs in several geologic environments, such as uranium, and applies the volume of discovered resources per unit of area to unexplored regions. This provides an estimate of the total amount of a specific mineral to be found. The second method uses the total real value of mineral production in dollars per unit of area in a fully developed region as the basis for estimation of the potential value to be discovered in a less developed region. This second method is not mineral-specific as only total values are estimated, not specific mineral values. These methods are geographic since they are based upon land area.

Geologic Analogy. Here the mineral production and reserves of a geologic environment that has been fully explored and developed are applied to similar environments in undeveloped regions. The most common examples are those which use the oil-in-place and recoverable oil volumes determined for a fully developed sedimentary basin on a cubic-volume-of-sediments basis to estimate the oil potential of undeveloped basins. In more complex analogies, the deposit size distributions and discovery rates of the developed areas are being used to estimate potential reserves in unexplored areas in the United States for oil, natural gas, and the major metals. These methods are based upon specific geological formations, not surface area, and use more information than the geographic methods.

Time Rate Analysis. This method enjoyed much popularity about ten years ago. It is based upon the observation that a mineral deposit usually shows a normal bell-shaped function for production over the life of the deposit. If the bell-shaped function is assumed for production of mineral from all deposits taken togeth[er], the time series of production compared to the time series of discoveries will show when production becomes greater than discoveries; the mathematics of a bell-shaped function can then be used to predict the inflection point of the production curve, which in turn allows the calculation of lifetime production.

King Hubbert of the U.S. Geological Survey, using this method, predicted that oil production in the United States would peak in 1970; the prediction was made in the mid 1950s and was statistically correct. The method was considered proven, and the results of its application were widely used for policy purposes.

However, flaws in the logic of the argument were pointed out, and now the method is not widely used for resource assessments. These flaws involved the generalization to all deposits of the behavior of a single deposit, and the great sensitivity of the estimate to the precise determination of the inflection point of the production curve.

Crustal Abundance Models. This class of techniques relates the crustal abundance of a mineral—that is, the average amount of the mineral contained in a cubic mile [of] the earth's crust—to the ultimate recovery of that mineral. Using the cumulative production plus reserves for lead, a mineral that has been sought for centuries,

Dr. W. David Kingery, second from left, professor of ceramics at the Massachusetts Institute of Technology, internationally known for his work in ceramic science and education, served as the 1982 Nelson W. Taylor Lecturer in Materials Science last December. During a reception in his honor in the Earth and Mineral Sciences Museum, he spent most of the time talking with students who brought him their copies of his textbook, Introduction to Ceramics *to be autographed. Here he talks with Pamela Peacock, left, and Bruce Kschinka, third from left; waiting in line at right is Stephen Bentley; all three students are 10th-term ceramic science and engineering majors.*

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and its crustal abundance as the basis, a relationship between potential reserves and crustal abundance is determined. Using this relationship, the potential reserves for any mineral in a large cubic volume of the earth's crust can be estimated. The problems of this method center on the nature of the relationship between potential reserves and crustal abundance, which is assumed to be linear when expressed in logarithms, but this form may not be universal; and on the difficulty of estimation of crustal abundance itself.

Subjective Probability Analysis. This is now the most widely used method for resource assessment. Stated simply, the judgments of geologists familiar with the mineral occurrence in a geologic region are sought, interaction between the experts is assured, and an estimate of potential economic resources for a mineral by region is prepared. A probability range around the estimate, based, it must be assumed, upon the variability of the expert opinion, is determined. Perhaps the most fully developed application of this methodology are the frequent assessments of the remaining petroleum to be discovered in the United States done by the U.S. Geological Survey.

It is obvious that all of these indirect methodologies have shortcomings. Each method applies some kind of historical data to an assumed fundamental relationship. The first step in the production of a mineral is the existence of the ore body. Geological science cannot predict the resource endowment of the earth because the state of the science does not permit it. The second step necessary for producing a mineral is the discovery of an existing ore deposit. Exploration and discovery are not well understood as economic processes.

Because of the state of our understanding of ore endowment and the process of ore discovery, we are driven to use of the indirect methods described above. So long as these methods are not firmly tied to scientifically determined resource endowment data and a well-understood discovery process, the potential reserve estimates are no more than guesses with an unknown but very large variance. Evaluations of these methodologies by statisticians reveal that the data do not support the conclusions. The wide variance among estimates of the same thing made by different methods indicates that there is a problem. We are truly ignorant of our mineral resource potential, and, unfortunately, these potential reserve estimates may make us believe we know something we do not know. That can be dangerous.

Conclusions

The evaluation of resource assessment methodologies has identified a serious issue. Their results are so imprecise that a policy based upon them may be worse than a policy that recognizes our complete ignorance of potential reserves. For example, United States energy legislation in the mid-1970s mandated consumption shifts away from natural gas and continuation of price controls on it because the resource assessments indicated only a small amount of potential reserves remained; the issue was the allocation of this fixed total supply. Had this policy not been changed, it would have been self-fulfilling in that the search for natural gas would have stopped and the existing potential reserves, such as those in the over-thrust belt in the west and in the deep basins of the southwest, would not have been discovered. A policy that preserved the process of search on the grounds that the amount to be discovered is truly unknown would have been wiser as indicated by the results of our policy change.

But all is not lost! True ignorance is a function of geologic knowledge, and increasing knowledge reduces ignorance. For resource estimates in areas where there is information such as geologic maps, geophysical and geochemical surveys and other data, analogies become more applicable. For many purposes, estimations of resource potentials according to quality ranges are quite sufficient for policy decisions such as those related to federal coal leasing in the west. We can use what we do know to guide these kinds of policy decisions. But we may impose large

Working in the Remote Sensing Laboratory of the Department of Geography, Todd Bacastow, standing left, geography graduate student, uses a coordinate digitizer to produce computer maps. Seated at the computer console is Kenneth Beck, while Brian Kloo looks over his shoulder; both are seniors in geography. This laboratory is part of the newly designated George F. Deasy Laboratory of GeoGraphics.

Deasy Laboratory of GeoGraphics Honors Memory of Distinguished Teacher of Cartography

The George F. Deasy Laboratory of GeoGraphics has been established in the Department of Geography to honor the memory of a distinguished member of the geography faculty who served from 1946 until his retirement in 1973, and died in 1977.

The laboratory includes already existing facilities for cartography, remote sensing, and computer modeling of earth science data that are used for instruction and research.

Cartographic facilities include 20 work stations, a fully equipped darkroom, a 20-by-24-inch copy camera, and a reflecting projector. Equipment available for both optical and digital analysis of aircraft and satellite images includes a graphic digitizer with microprocessor, color compositing systems, computer terminals, and a number of teaching and interpretation stations. Activities of the Deasy Laboratory, which works with, and complements the facilities of, the University's Office for Remote Sensing of Earth Resources (ORSER), include instruction in cartography, graphics production, cartographic research, and computer mapping.

Dr. Deasy is described as a rare combination of inspiring teacher and outstanding research scholar. He was a pioneer in the field of aerial photo interpretation, and, in 1947, established one of the first geography courses in remote sensing in the U.S. He also taught cartography to several generations of geographers who are now involved in various professions including university teaching. His basic physical geography courses regularly attracted from 250 to 300 students.

Last among the more than 20 graduate students he advised was Dr. Mark Monmonier ('67 M.S., '69 Ph.D.), now professor of geography at Syracuse University, who dedicated his book, *Computer-Assisted Cartography* to Dr. Deasy.

Dr. Deasy served as treasurer of the American Society of Professional Geographers and the Association of American Geographers; president of the Pennsylvania Academy of Sciences; and editor of *The Professional Geographer.*

costs upon society if we adopt in other areas policies that are correct only if the estimates of resource potentials for those areas are correct. In such areas, it is much wiser to adopt actions that are compatible with high or low potentials and can be adjusted as the truth emerges over time. The point is that it is a mistake to believe that society knows more than it really does.

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The Author

Dr. William A. Vogely has more than 30 years of experience in the minerals field including 22 years as a senior civil servant with the U.S. government, where he held such positions as assistant director—mineral resources evaluation with the U.S. Bureau of Mines, adviser to the Departments of State and Commerce on negotiations of many mineral matters, and assistant secretary—energy and minerals in the Department of the Interior. He joined the Penn State faculty in 1974 and became head of the Department of Mineral Economics in 1975. He has supervised and conducted research in mineral investments, mineral market behavior, and mineral policy analysis.

Untreated Natural Water Sources: How Safe Are They?

Eight rustic sites in Blair County, Pennsylvania, from which water is often obtained for domestic use, were monitored in this study.

GARRY L. BURKLE, *Instructor in Environmental Sciences*
JOHN E. LENNOX, *Assistant Professor of Microbiology*

Water used for domestic purposes in the United States, whether it comes directly from natural sources or from municipal supplies, must comply with quality standards that have been established by the federal Environmental Protection Agency (EPA).

The EPA standards, which were last revised in 1977, set maximum allowable amounts of inorganic and organic chemicals, pesticides, and microbiological contaminants that may be present in water if that water is to be considered safe for human consumption.

Municipal and private water suppliers must frequently test to make sure their water conforms to the standards.

But what about the temptingly clear water frequently found flowing gently down mountainsides, or trickling from pipes that extend from hillsides along country roads? Is it safe to drink? People often drive many miles to obtain water from a natural site, assuming that, since it is found in a natural setting, the water must be pure. In reality, such sources are seldom if ever checked for purity.

Our interest in the microbiological contamination of water from natural sources was stimulated by two findings. First, the level of fecal coliform bacteria in water taken from a spring near The Pennsylvania State University campus at Altoona, located in Blair County in central Pennsylvania, exceeded the EPA standards for water considered safe to drink without treatment. The second finding was that many people used water from this spring for domestic purposes.

To learn if water is microbiologically contaminated, tests are performed to determine the presence of fecal-coliform-type and fecal-streptococcus-type bacteria. These bacteria are found almost exclusively in the intestinal tract of warm-blooded animals and are easy to detect. Their presence is, therefore, used as an indication that the water in which they are found has been contaminated with fecal waste and should be considered unsafe for human consumption. While fecal coliforms and fecal streptococci themselves are not pathogenic, the concern is that other intestinal bacteria that are pathogens may be present in water that has received fecal pollution.

It is generally assumed that waterborne disease is no longer a problem in this country. However annual reports summarizing waterborne diseases that are published by the Public Health Service's Center for Disease Control indicate otherwise. The latest summary, that for 1980, appears in the January 1, 1982, edition of *Morbidity and Mortality Weekly Reports.*

Fifty outbreaks of acute water-related disease associated with domestic water use and affecting 20,008 people are reported. As has frequently been the case, Pennsylvania led the nation with 20 percent of all outbreaks. At least a portion of this large number is due to a well-developed statewide surveillance system. Among the illnesses reported were amebiasis, giardiasis, hepititis, salmonellosis, shigellosis, and typhoid fever.

Natural Water Sources: Blair County

Traveling through the countryside of central Pennsylvania, one cannot help but notice numerous natural sources of water, primarily streams and springs. In Blair County, we easily identified more than a dozen sites that, by our own observations and information from a variety of sources, we knew were frequently used to obtain water for domestic use. From these twelve sites, we chose eight to sample regularly (Figure 1), basing our selection on their location, accessibility to users, and site characteristics. The bedrock at all the sites is sandstone.

The sites were categorized into three groups according to their degree of improvement. The Lock Mountain and Blue Knob sites were considered to be improved sites. At each of these locations someone has built stonework to enclose a water delivery pipe (Figure 2). The sites at Bellwood, Frankstown, Juniata Gap, Reservoir Road, and Skelp were classified as unimproved. At each of these locations, the water delivery system is simply a pipe which has been driven into a rock layer, or laid into a surface flow (Figure 3). The remaining site at Horseshoe Curve was classed as surface water. At this location, water is dipped directly from the stream (Figure 4).

Sampling Procedures

Sampling took place over a period of one and a half years. Samples of 350 milliliters (ml) of water were aseptically collected at a frequency of about one sample per week per site. At the time of collection, the water temperature at each site was taken, and the flow rate from the particular delivery system was measured. Samples were returned to the laboratory within two hours after collection. In the laboratory, the pH of each sample was determined, and samples from each site were vacuum-filtered through sterile 0.7-micrometer HC Millipore filters to determine the number of fecal coliform and fecal streptococci bacteria present.

After filtration, duplicate membrane filters are placed on M-FC Broth and KF Streptococcus Agar. These are bac-

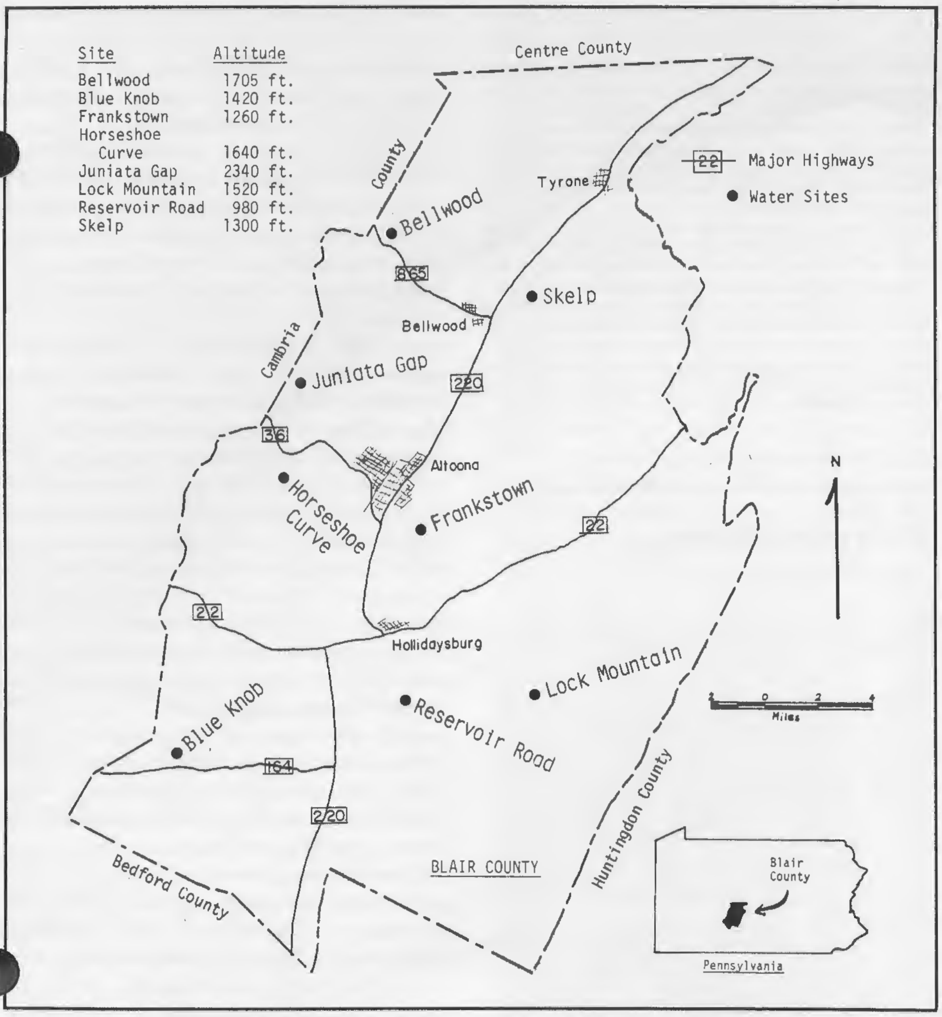

Figure 1. Blair County, Pennsylvania, showing the locations of the natural water sources monitored by the authors over a period of one and a half years.

teriological media that selectively support the growth of fecal coliforms and fecal streptococci, respectively, while inhibiting the growth of all other organisms. The M-FC Broth is placed in a water-bath incubator at a temperature of 44.5°C ±0.2°C for a period of 22 ±2 hours. KF Streptococcus Agar is incubated in a waterbath incubator at a temperature of 35°C ±0.5°C for a period of 48 hours. Following incubation, colonies appearing on each of the types of selective media are counted.

Findings

According to EPA standards water is unsafe to drink if untreated when the arithmetic mean for all samples collected during a month exceeds a coliform density of 1 per 100 ml of water, or, if, in any one sample, densities exceed 4 per 100 ml of water, when fewer than 20 samples per month are taken.

After several weeks of sampling, it was apparent that all the sites were contaminated to some degree. We roughly grouped them into three categories according to their contamination levels. We found that two sites, Lock Mountain and Bellwood, virtually always met EPA standards. When we did find some contamination at these sites, it was usually at low levels. We classed the Juniata Gap and Horseshoe Curve sites as conditionally unacceptable. There were times when they met EPA standards, and times when they did not. The remaining four sites, Blue Knob, Frankstown, Reservoir Road, and Skelp, showed great variability in coliform counts, but virtually never met EPA standards.

The last two groups are interesting because of the variability in their levels of contamination. To attempt to determine if this variability could be related to precipitation, we plotted coliform counts against flow rate, which can be used as an indirect measure of precipitation.

Three general situations were found. First, there were sites where the flow rate remained relatively constant, while coliform counts varied widely. For instance, at the Frankstown Road site, flow rates varied from a low of 5 liters per minute to a high of 40 liters per minute. However, coliform counts varied from a low of 10 per 100 ml of water to a high of 2,465 per 100 ml of water. We decided that at this site the source of contamination must be variable, and the level of contamination not related to precipitation, as high and low coliform counts are recorded at low as well as high flow rates.

The second situation is best illustrated by the Blue Knob site, where, with an increase in flow rate, there is an associated increase in coliform count. At low flow rates of 5 liters per minute, coliform counts were commonly in the range of 20 to 25 per 100 ml of water. As the flow rate increased to 20, 50, and 90 liters per minute, coliform counts increased to 100, 550, and 1,428, respectively. This situation may indicate the influence of considerable amounts of surface runoff that enters the delivery system during times of heavy rainfall.

The Juniata Gap site is an example of the third situation where flow rate is variable while contamination levels remain relatively constant. The flow rate varied from 15 to 55 liters per minute, while coliform counts ranged from 0 to 5 per 100 ml of water. This situation seems to indicate that there is a relatively constant source of contaminants more or less continuously supplied.

The ratio of fecal coliforms (FC) to fecal streptococci (FS) can be used to determine whether the fecal contamination is more likely to have come from human or animal sources. FC/FS ratios of 2 or more are indications that the major source of contamination is most likely human. The Blue Knob, Frankstown, and Juniata Gap sites all had ratios of 2 or more on at least one occasion, with Blue Knob recording four such readings. Ratios of from 1 to 2 are considered a gray area, and interpretation is difficult. However, these same three sites recorded eight readings in this range. Therefore, we feel confident that at least on some occasions, these sites are contaminated with human waste.

FC/FS ratios of 1 or less are indications that the source of contamination is most

Figure 2. This natural water source on the side of Lock Mountain is one of the two sites monitored that were considered to be improved. Here someone has built stonework to enclose a water delivery pipe.

Figure 3. This water source near Frankstown is one of five that the investigators classified as unimproved. It is simply a pipe coming out of a hillside spring.

likely waste from animals, wild or domestic. Our study indicates that without question, the dominant source of fecal contamination at the eight sites is animal.

Summary

Our research has clearly documented contamination by fecal material in water from natural sites in Blair County, Pennsylvania. The levels of contamination in most of our samples far exceeds the EPA standards for water considered to be safe to consume without treatment. The fact that Pennsylvania leads the nation in reported outbreaks of waterborne diseases indicates the problem of contaminated water is not limited to Blair County. In fact, reports from the Center For Disease Control indicate the problem is nationwide. Therefore, we can only conclude that people who consume water from untreated sources are exposing themselves to a potential, unnecessary health risk.

The Authors

Garry L. Burkle received his B.S. in 1964 and his M.S. in 1970, both at Illinois State University. He did postgraduate work in physical geography at Michigan State University before joining the faculty of Western Michigan University in 1971. In 1974, he joined Penn State's College of Earth and Mineral Sciences as a member of the environmental sciences faculty at the University's Altoona Campus, teaching courses in geography, geology, and meteorology. He is currently studying for a doctorate in geography at Penn State and assisting the college's associate dean for resident instruction. His research interests are in the area of man-environment relations.

Dr. John E. Lennox received his B.S. in biology in 1963 at Indiana University of Pennsylvania and his M.S. in 1965 and his Ph.D. in 1968 in botany at the University of Chicago. In 1968, he joined Penn State's College of Science as a member of the microbiology faculty at the University's Altoona Campus where he has taught courses in biology, microbiology, and genetics. His research interests include environmental microbiology and the genetics of toxin production by a variety of molds.

Figure 4. This natural water source near the Horseshoe Curve of the Conrail Railroad not far from Altoona was classified as surface water.

Polymer Alloys—

Continued from first page

was put into synthesizing and characterizing the molecular structure of homopolymers. Homopolymers are simply very large chain-like molecules consisting of a single chemical unit that repeats along the chain. Polyethylene and poly (vinyl chloride) are two common examples. A great many homopolymers have been synthesized over the past 70 years and many possess unique and useful properties.

Advances in synthetic techniques then paved the way for the development of new groups of polymers known as copolymers. In a sense, copolymers are like alloys; they consist of two or more different chemical repeating units and possess properties that are some combination of the properties associated with each of the chemical units.

The first copolymers prepared were called random copolymers. In 1920, during the search for a replacement for natural rubber, isoprene and dimethylbutadiene (both low-molecular-weight liquids) were mixed and polymerized. Characterization of the resulting polymer showed that isoprene and dimethylbutadiene structures were both present in a given polymer chain, and their placement within the chain was random. Hence the name random copolymer.

Whole families of synthetic random copolymers are available today and form a significant portion of commercially available polymers. For instance, Saran Wrap, a product of Dow Chemical Company, is a random copolymer of vinylidene chloride and vinyl chloride. The homopolymer of vinylidene chloride exhibits excellent resistance to diffusion of oxygen and water, but can be processed only with great difficulty. A small amount of vinyl chloride is added into the vinylidene chloride chain structure to function as a processing aid, yet the barrier properties of the parent vinylidene chloride homopolymer are retained. Polymers found in nature such as proteins and DNA are also random copolymers but are far more complex than their synthetic counterparts.

Graft copolymers were discovered in 1933, but the principle of grafting was not disclosed until 1952. As the name implies, graft copolymers are prepared by attaching or grafting a homopolymer to the backbone of a second homopolymer. Block copolymers, first prepared in 1960, are similar to graft materials but the individual components (or blocks) are joined at their ends. Unlike random copolymers, the different chemical repeat units in block and graft copolymers are separated within a given molecule. This usually results in segregation of the chemically different portions of block and graft copolymers into regions of the material (phases or domains) which differ from one another in chemical composition. For instance, in a block copolymer consisting of two different repeating units, one of the components forms separate domains which are dispersed in a matrix of the other component. The domains can be spherical, cylindrical, or lamellar in shape depending on the composition of the block or graft copolymer and the processing conditions. Note that, in these systems, the phases are connected by covalent linkages since a portion of each copolymer molecule resides in two separate phases.

Polymer Alloys

The next development in polymeric materials, polymer alloys, was stimulated by the need for higher-performance materials, and, to some degree, by economic considerations. It is usually less expensive to blend two or more existing polymers to obtain a new material than to develop a new homopolymer or copolymer from scratch.

Polymer alloys can be defined as physical mixtures of two or more different homopolymers and/or copolymers with no covalent bonds between the different molecules (Figure 1). Thirty-five years ago, Grotenhuis found that a rubber with excellent flexibility and abrasion resistance could be obtained by mixing a hard unmasticated rubber with an elastic rubber. It was recognized at this stage that this mixture was heterogeneous. In other words, like most block and graft copolymers, the two polymers exist in their own separate phases. Blends that result in multiphase systems are generally referred to as incompatible or immiscible blends; the different polymers do not mix on a molecular level but prefer to remain with molecules of their own kind.

The first commercial polymer blends were incompatible systems and were introduced in 1948. One of these, known as high-impact polystyrene (HIPS), is a blend of polystyrene (a rigid plastic), polybutadiene (a rubber), and a styrene-butadiene graft copolymer. The graft copolymer is added since it would be expected to reside at the interface between phases and provide the interfacial adhesion necessary for useful properties. The so-called ABS (acrylonitrile-sytrene-butadiene) alloys were also introduced in the late 1940s. Typically, these are mixtures of a glassy styrene-acrylonitrile copolymer with a copolymer of butadiene and acrylonitrile. Again, some graft material is usually present in the mixture to provide good interfacial characteristics. The multiphase character of these systems is illustrated in Figure 2 for HIPS containing 6% polybutadiene. Note particularly in this photograph that a significant portion of the polystyrene is occluded within the domains.

Approximately 90 percent of all polymer alloys that have been studied exhibit a multiphase structure. The remaining 10 percent are known as compatible or miscible alloys. Here the polymers are thought to be mixed on the molecular level and one expects to obtain system properties that are roughly an average of those of the constituent polymers. However, it is possible to obtain synergistic behavior in certain compatible blends. For instance, Figure 3 shows the variation in tensile and flexural strength as a function of blend composition for the compatible poly(methyl methacrylate)/poly(alpha-methyl styrene-methyl methacrylate-acrylonitrile) copolymer blend. The copolymer in this system is composed of three chemical units and is conventionally referred to as a terpolymer. Note that the strength of the blend can be significantly higher than that of either constituent material alone.

How can one distinguish between compatible and incompatible alloys? Since incompatible blends form multiphase systems, they would be expected to yield opaque materials, whereas single-phase compatible alloys would be expected to be clear. This distinction can be used successfully in some cases but there are some troublesome complications. As an alternative, a technique such as differential scanning calorimetry or differential thermal analysis may be used to explore the thermal behavior of a system. In a binary blend, the existence of a single glass transition temperature (Tg) that is between the Tg's of the constituent polymers would be used as evidence of compatibility. If the individual Tg's of the component polymers are observed, then the system is classified as incompatible. Of course, there are examples which do not fit neatly into either of these classifications; these are often referred to as being "semi-compatible."

In the last five to ten years, considerable interest has arisen in a group of blends in which at least one of the blend components is crystallizable and the crystalline regions are phase-separated from a miscible amorphous matrix. These systems should not be considered strictly as compatible since crystallization (phase separation) does occur, but the portion of the crystallizable polymer which does not crystallize is believed to be intimately mixed with the second component. For lack of a better name, we have termed such systems "crystalline/compatible" alloys. Interest in these materials has grown at least partially because roughly a half to two-thirds of all useful polymers are crystalline or crystallizable.

Compatibilty

What controls whether a polymer alloy is compatible or incompatible? Clearly, the systems studied have shown the general trend to be toward incompatibility. From a very simplistic point of view, this can be understood by looking at basic thermodynamics. The free energy of mixing (ΔG_M) can be represented as a function of the enthalpy and entropy of mixing (ΔH_M and ΔS_M, respectively):

$$\Delta G_M = \Delta H_M - T\Delta S_M$$

where T is the temperature. For miscibility to occur, the free energy of mixing must be zero or negative. For low-molecular-weight solvent/solvent mixtures and even for solvent/polymer mixtures, the entropy of mixing is normally large and positive and promotes mixing. However, it is known to be a very small positive value for polymer/polymer mixtures. Therefore, polymer/polymer miscibility is inhibited and should occur only in those mixtures which exhibit very small positive or negative enthalpy changes on mixing. The heat of mixing is primarily dependent on the energy change associated with changes in nearest neighbor contacts during mixing, and most polymers only weakly interact to give positive heats of mixing.

Even though there is still considerable controversy, it appears that only those polymer mixtures in which dissimilar chains can form relatively strong intermolecular interactions result in miscible systems. This concept of "complementary dissimilarity" supposes that two chemically-unlike polymers interact to form hydrogen bonds or relatively strong dipolar interactions. In fact, such interactions have been observed in a number of miscible polymer pairs. It is important to realize that the usual concept of "like dissolves like" does not necessarily hold for polymer/polymer mixtures.

One of the first things that a materials scientist would like to know about an alloy is its phase diagram (a map which shows which phases are present and their relative amounts in a material as a function of temperature, pressure, and overall com-

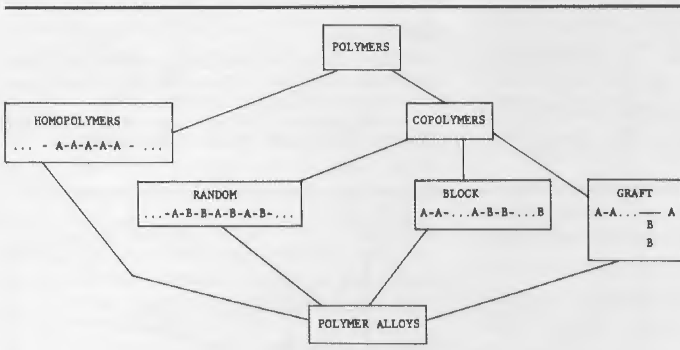

Figure 1 (above). Possible routes to the formation of polymer alloys.

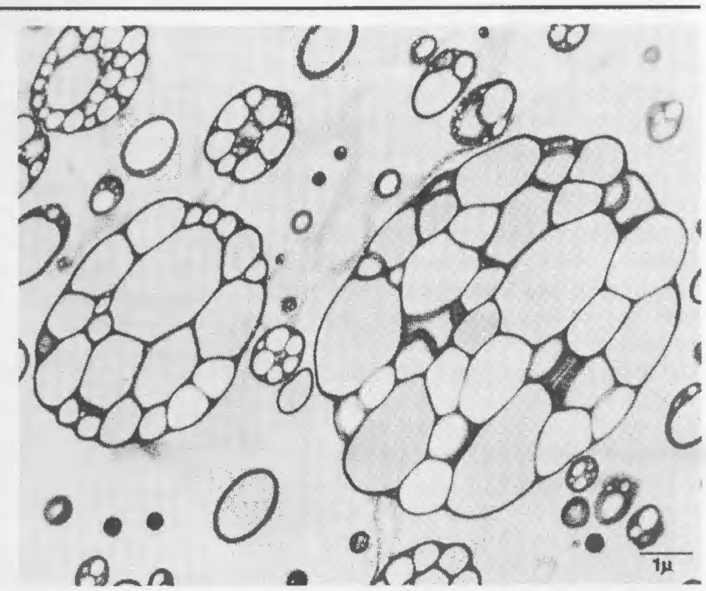

Figure 2 (right). Structure of high-impact polystyrene containing 6 percent polybutadiene. (Reprinted by permission from Rubber Chemistry & Technology *43 [1970]:1129)* position). However, little attention has been paid to polymeric phase diagrams until recently. Early theoretical treatments predicted that polymer mixtures should be more compatible at higher temperatures and exhibit upper critical solution temperatures (Figure 4). Note that the upper critical solution temperature (UCST) is not fixed but varies with alloy composition. At temperatures above the UCST, the mixture should form a one-phase system, and, below the UCST, a two-phase material. However, UCSTs are only observed for materials of rather low molecular weight. High-molecular-weight compatible polymer alloys are *less* compatible at high temperatures and can exhibit lower critical solution temperatures (LCST). At temperatures above the LCST, the alloy forms a two-phase system, and below the LCST, a miscible one-phase system.

A miscible alloy in which one of the components is crystallizable will exhibit a more complicated phase behavior. For the sake of simplicity, we will consider a system which is completely miscible (exhibits no LCST over the temperature range of interest). Such alloys will exhibit a single Tg that will be a strong function of blend composition (Figure 4). Below Tg, the crystallites will be embedded in a glassy miscible matrix, and, above Tg, in a rubbery (melt) material. As temperature is increased, the crystals will melt and a compatible polymer liquid will result. The melting point will also be a function of blend composition, but, in general, will not be nearly as sensitive to composition as Tg. Interesting phase behavior can result when the concept of LCST is superimposed on the Tg and melting point.

Some Selected Commerical Alloys

Incompatible Alloys. Many of the commodity polymers lack the mechanical toughness needed for various applications. One way around this problem is essentially to disperse rubber particles in a matrix of the commodity material as in the high-impact polystyrene and ABS incompatible blends. Depending on the size and concentration of the particles, the toughness of the material can be increased by a factor of 10 or more. Much work has gone into understanding the mechanism of this rubber-toughening phenomena, and it appears that the rubber particles act as strong stress concentrators and initiate crazing in the matrix. Unlike true cracks, the formation and propagation of crazes is a major energy-absorbing mechanism in many so-called engineering plastics.

Other incompatible alloys are also used commercially. For some time, the textile industry has employed the concept of alloying various fiber types, such as polyester and cotton, to form fabrics. Incompatible rubber/rubber blends are also used extensively, particularly in the construction of automobile tires. Rubber-toughened alloys can themselves be blended with other polymers to enhance mechanical performance as is done in ABS/polycarbonate mixtures.

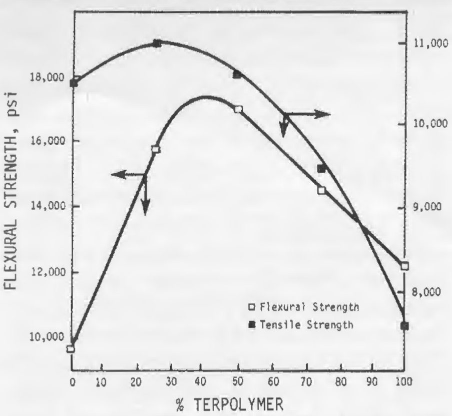

Figure 3. Composition dependence of the flexural and tensile strengths for the compatible polymer alloy of poly(methyl metacrylate)/poly (alpha-methyl styrene-methyl methacrylate-acrylonitrile) terpolymer. (Reprinted by permission from Advances in Chemistry Series *176, Ch. 29, 1979)*

Compatible Alloys. As one might expect from the earlier discussion, commercial compatible alloys are much rarer than incompatible ones. However, several have made significant impacts in the marketplace. Poly(vinyl chloride) (PVC) is a rigid polymer which depends upon the addition of plasticizers for some of its useful properties. Conventionally, plasticizers are low-molecular-weight organic liquids that soften—or plasticize—the polymer. Liquid plasticizers offer many advantages such as low cost, efficiency of plasticization, and ease of processing. However, for many of today's more demanding applications, these low-molecular-weight liquids cannot be readily used since they have inferior chemical resistance and will leach out of the parent material over time, rendering it rigid and brittle. To avoid these difficulties, PVC may be permanently plasticized by forming an alloy with a low-glass-temperature compatible polymer. The most widely used macromolecular plasticizer for PVC is nitrile rubber; a blend of these is used for wire and cable insulation and in the food packaging industry.

Probably the most widely recognized compatible blend used commercially today is Noryl, produced by General Electric. Commerical interest in this material involves the concepts of property combination and cost dilution. Poly(phenylene oxide) (PPO) has excellent thermal stability, but is quite difficult to process and relatively expensive. Polystyrene, on the other hand, is moderately priced and more easily processed, but has poorer high-temperature properties. By forming a compatible alloy of PPO and polystyrene (Noryl), a material with favorable processability, cost considerations, and high-temperature properties (though not as favorable as PPO alone) is produced. One of the major advantages of Noryl, as well as of other incompatible and compatible alloys, is versatility. An entire family of products with various physical properties can be produced from a single system by simply changing the blend composition. Noryl has proved useful in the manufacture of such products as electronic components, appliance housings, and automobile dashboards.

Summary

In comparison to other branches of materials science, the development of polymer alloys is still in its infancy. There is much we do not know about the influence of phase structure and compatibility on material performance. A considerable amount of research is going on in these areas, and there can be little doubt that the future of these new materials is exceedingly bright.

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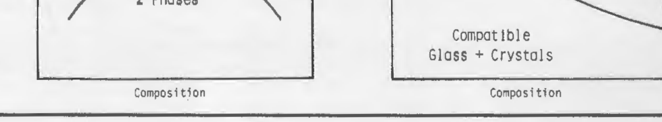


Figure 4. Phase behavior of polymer blends.

3. O. Olabisi, L. M. Robeson, and M. T. Shaw, *Polymer-Polymer Miscibility* (New York: Academic Press, 1979).
4. O. Olabisi, "Interpretations of Polymer-Polymer Miscibility," *J. Chem. Ed.* 58 (1981): 944.

Author

Dr. James P. Runt received both his B.S. and Ph.D. in polymer science from Penn State, and joined the faculty in 1979. His current research interests include studies on the crystallinity and compatibility in polymer alloys, piezoelectric polymer/ceramic composites, and the relationship between polymer morphology and mechanical properties.

Geography Doctoral Program Rates High

In a recent assessment of doctoral programs in geography at U.S. colleges and universities, the Ph.D. program of Penn State's Department of Geography was rated second in the nation with regard to the scholarly competence and achievements of its faculty, and third in its effectiveness in educating research scholars and scientists.

The assessment was conducted by a committee named by the Conference Board of Associated Research Councils which includes the American Council of Learned Societies, the American Council on Education, the National Research Council, and the Social Science Research Council.

Rated first in the nation with regard to the achievements of its geography faculty was the University of Minnesota. Its department head is Dr. John Adams, who served as a member of the Penn State geography faculty from 1966 to 1970. The two institutions whose geography doctoral programs were judged better than Penn State's in the area of effectiveness of educating research scholars were the University of Wisconsin at Madison and the University of California at Berkeley. Head of the Berkeley department is a Penn State geography alumnus, Dr. Allan Pred ('59 M.S.).

In a similar assessment made for geosciences doctoral programs by the same committee, Penn State's doctoral program in geochemistry and mineralogy was rated among the top ten in the nation with respect to faculty competence and effectiveness in educating research scholars.

C. L. Hosler Elected Chairman of UCAR

Dr. Charles L. Hosler, professor of meteorology and dean of the College of Earth and Mineral Sciences, was recently elected chairman for 1983 of the board of trustees of the University Corporation for Atmospheric Research.

The corporation (UCAR), founded in 1960, is a consortium of 48 educational institutions with doctoral programs in the atmospheric sciences and two research organizations—Scripps Institution of Oceanography and Woods Hole Oceanographic Institution. Penn State was one of the founding universities.

With offices in Boulder, Colorado, and Washington, D.C., UCAR operates the National Center for Atmospheric Research in Boulder under contract with the National Science Foundation, and the National Scientific Balloon Facility in Palestine, Texas, under contract with the National Aeronautics and Space Administration. The combined facilities have a staff of 700 and a budget of more than $70 million. UCAR also serves as host to a number of other university consortia such as the Consortium on Energy Impacts and the Computer Science Network.

Dean Hosler also recently was an invited participant in the Symposium on Education and Training in Meteorology with Emphasis on Climatic Change and Variability, held in San Jose, Costa Rica, under sponsorship of the World Meteorological Organization.

He served as chairman of a session and presented a paper, "The Place of Correspondence Instruction (Distance Learning) in the Training of Meteorological Personnel."

He is a member of the Executive Committee Panel of Experts on Education and Training in the World Meteorological Organization.

316 Degrees Granted in May; Thesis Titles Listed

A total of 316 degrees were granted by the College of Earth and Mineral Sciences at the University's 1982 Spring term commencement last May.

Two hundred fifty-nine bachelor of science degrees, 25 associate degrees, and 32 advanced degrees were awarded.

Following is a list of the 32 advanced degree recipients and the titles of their theses or reports. Requests to borrow these are to be made through the borrower's community, company, or university library. Libraries should address requests to: Interlibrary Loan Service, Pattee Library, The Pennsylvania State University, University Park, Pennsylvania 16802.

Ceramic Science—Adam Jan Gesing, Ph.D., *Fracture Properties of Polycrystalline Ceramic: The Effect of Microstructure and Temperature on Slow Crack Growth in Alumina;* Edward Joseph Koval, M.S., *Effects of Fe_2O_3 Additions on the Sintering of Dolomite (CaMg $(CO_3)_2$).*

Earth Science—Joseph James Gerencher, Jr., Ph.D., *Multivariate Study of the Interrelationships Among Selected Variables of the Organic Fraction of Samples of United States' Coals.*

Fuel Science—Joseph Michael Lambert, Jr., Ph.D., *Transformation of Pyrite to Pyrrhotite and its Implications in Coal Conversion Processes;* Alan Arthur Leff, Ph.D., *Evolution and Yield of Products from Coals Under Rapid Pyrolysis Conditions;* Eugene Nnaji Ogu, M.S., *Design and Construction of an Isothermal High-Temperature Plug-Flow Reactor for Studies of Soot Formation;* Yoshinobu Otake, M.S., *Volatile Matter Release During Pyrolysis of Demineralized and Metal Cation Loaded Lignites;* Timothy Joseph Peters, M.S., *The Carbonization and Graphitization of Phenanthrene;* Shyam Narayan Singh, M.S., *Technique for the Study of Slag Deposits in a Laboratory Pulverized-Coal-Fired Furnace.*

Geochemistry and Mineralogy—Melissa Jean Mathews, M.S., *The Formation of Sulfides in Coastal Marine Sediments;* Bennetta Lee Schmidt, M.S., *A Study of the X-ray Diffraction and Thermodynamic Properties of Synthetic, Binary Nepheline-Kalsilite Crystalline Solutions.*

Geography—Edward Thomas Blair, M.S., *The Microcomputer as an Instructional Tool in Geography;* James Anderson Hargan, M.S., *Evaluating a Neighborhood-based Project: A Case Study in Traffic Law Enforcement, and the Sequence of Development of a Tampa Suburb, 1900-1978;* Vivian Ruth Levensohn, M.S., *Appalachia and the American Mind;* E. William Slentz, M.S., *Historic Preservation in Pennsylvania as Measured by The National Register of Historic Places.*

Geology—Robert Mark Cohen, M.S., *Pollution of Landfill Leachate by Spray Irrigation in a Northeastern Forested Karst Terrain;* Leslie Eugene Erwin, M.S., *Recognition of Tin-bearing Granites by Multivariate Statistical Analysis, Pikes Peak Batholith, Colorado;* Eason Hong, M.S., *Petrographic Evidence on the Paleoclimate and Provenance of the Catskill, Pocono, and Pottsville Formations, Southeastern Pennsylvania.*

Geophysics—Walter Allen Arnold, M.S., *Dipping Slab Effects on Seismic Source Mechanisms at Subduction Zones;* Dennis Alan Sienko, M.S., *Crustal Structure of South-Central Pennsylvania Determined from Wide-Angle Reflections and Refractions.*

Meteorology—Gilbert Randy Jersey, M.S., *Incorporation of a Simple Evapotranspiration Parameterization in an Efficient Model of the Atmospheric Boundary Layer;* Rich Neil Soucy, M.S., *Vertical Cross-Spectra of Winds Below 150 Meters at the Boulder Atmospheric Observatory.*

Mineral Economics—William Robert Behling, M.S., *An Economic Evaluation of Coal Slurry Pipelines;* Gary Allen Campbell, Ph.D., *Disequilibrium Effects on the Estimation of Metal Demand: A Study of Copper and Cobalt;* Dennis Frank Kelter, M.S., *Efficiency of Fuel Consumption in the U.S. Transportation Sector 1960-1977;* Jan Marie Maiale, M.S., *Deepening Harbors to Enhance U.S. Coal Export Potential–A Cost-Benefit Analysis.*

Mineral Processing—David John Chaiko, M.S., *Micellar Catalysis in the Liquid Membrane Extraction of Cobalt;* Frank Maimillian Smaila, M.S., *An Investigation of the Kinetics of Dry Batch Ball Milling.*

Mining Engineering—Frank Anthony Camilli, M.Eng., *Reserve Estimation and Siting of an Open-Pit Anthracite Mine Utilizing Computer Models.*

Polymer Science—Michael Edward Starsinic, M.S., *The Application of FTIR Spectroscopy to the Measurement of Oxygen-Containing Functional Groups in Coal and Carbonaceous Polymers.*

Solid State Science—Akram Abdel-Majeed Rousan, Ph.D., *A Methodology for Thermal Characterization of Cementitious Materials;* Xi Yao, Ph.D., *Dielectric and Piezoelectric Behavior of Lithium Niobate Bicrystals and Polycrystal Ceramics.*

Enrollment Still Rising

Enrollment in the College of Earth and Mineral Sciences registered another all-time high last fall, increasing 1.5 percent over the 1981 fall term total.

Last fall's enrollment was 2,511. Included in that total were 1,913 B.S. candidates, 518 graduate students, and 80 associate-degree candidates. The college enrollment has risen 98.9 percent since

1973 and the beginning of the so-called "energy crisis." Women now comprise 17 percent of the college student body.

The University's overall enrollment last fall was 63,271, contrasted with 61,800 in the 1981 fall term. Here at the University Park Campus, the enrollment last fall was 34,342, down from 34,693 in 1981—a decrease that was planned because of housing shortage problems in 1981.

College News Notes

Jenkins Heads Fuel Science

Dr. Robert G. Jenkins, associate professor of fuel science, has been appointed chairman of the Fuel Science Program in the Department of Materials Science and Engineering.

He succeeds Dr. Philip L. Walker, Jr., Evan Pugh Professor of Materials Science, who retired in January (see story on page 24).

Dr. Jenkins received both his B.Sc. and Ph.D. in fuel science at the University of Leeds in England. He first joined the Penn State staff as a research associate in fuel science in 1970, continuing until 1973 when he returned to England as a research assistant in physical chemistry at the Imperial College of Science and Technology of London.

In 1975, he returned to Penn State as senior research associate in fuel science and was named to the faculty as assistant professor of fuel science and acting director of the Fuels and Combustion Laboratory in 1978; he served as director of the laboratory in 1981-82. His research interests are in coal characterization, coal conversion chemistry, small-angle X-ray scattering, and zoelite chemistry.

Two Former Faculty Members Die

Dr. Frank M. Swartz, research professor emeritus of paleontology, died December 2, 1982, in Tucson, Arizona, at the age of 83. He joined the Penn State faculty in 1925 and served as head of the then Department of Geology from 1945 to 1961. He retired in 1964. He had a B.A. in chemistry and a Ph.D. in geology from The Johns Hopkins University, and served as national president of the Paleontological Society in 1958.

O. Allen Knight, who served as a member of the metallurgy faculty from 1919 until 1935 when he resigned as associate professor, died January 23, 1983, at Roulette, Pennsylvania, at the age of 89. He later worked as a metallurgical engineer for the federal goverment. He had a bachelor's degree in chemistry from Ohio University, and received an M.S. in metallurgy in 1925 and the degree of Metallurgical Engineer in 1928, both from Penn State.

Microcomputers in Mining Symposium

A Symposium on the Applications of Microcomputers in the Mining Industry will be held at Penn State's University Park Campus, March 28-30, as a continuing education service of the Mining Engineering Section of the Department of Mineral Engineering. University faculty members will be joined by speakers from industry to present the program which is designed to bring together manufacturers, researchers, mine operators, and other specialists for presentations and workshops devoted to exploring the use of microcomputers in the mining industry. Further information may be obtained from Dr. Christopher Bise, assistant professor of mining engineering, 123 Mineral Sciences Building, University Park, Pennsylvania 16802; (814) 863-1644.

Two Labs to Get New Facilities

Two laboratories in the College of Earth and Mineral Sciences—the Mine Electrical Research Laboratory and the Fuels and Combustion Laboratory—will be relocated in new facilities in an academic activities building to be constructed on the University Park Campus.

The new structure will be built at Bigler and Hastings Roads, near the present Fuels and Combustion Laboratory which occupies a building that was originally the heating plant for some buildings in that area. The Mine Electrical Research Laboratory has been occupying a rented building off the campus in State College.

Dr. L. A. Morley, professor of mining engineering, directs the Mine Electrical Research Laboratory, while Dr. James J. Reuther, assistant professor of fuel science, directs the Fuels and Combustion Laboratory.

Weather Association Meets Here

More than 100 weather experts from all over the U.S. attended the 1982 meeting of the National Weather Association held at Penn State last fall under the auspices of the Department of Meteorology. General chairman for the meeting was Dr. John Cahir, professor of meteorology and associate dean for resident instruction in the college, who had served as president of the association for the past year.

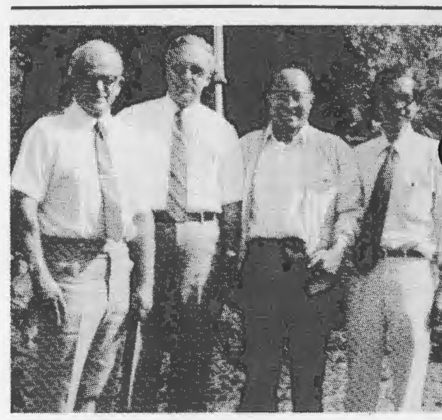
Among those who presented parts of the program was John Coleman, weatherman on ABC Network's *Good Morning, America* TV program. He employs a number of Penn State meteorology graduates for a 24-hour weather TV channel that he makes available to TV cable companies.

E&MS Students Honored

Joseph Sottile, a 9th-term honor student in the mining engineering major, has received the 1982 $1,000 national merit scholarship of the Society of Mining Engineers of the American Institute of Mining, Metallurgical, and Petroleum Engineers. He was selected in competition with students from all over the U.S.

Richard Sweigard, Ph.D. candidate in mining engineering has received a $3,000 scholarship for the 1982-83 academic year from the Henry DeWitt Smith Scholarship Trust of the American Institute of Mining, Metallurgical, and Petroleum Engineers. He received his B.S. in civil engineering at Drexel University and his M.S. here at Penn State in geology in 1979.

Dennis C. O'Neill, M.S. candidate in geophysics, received the "Best Student Paper" award inaugurated at last September's Seis-



When a delegation of scientists and engineers from the National Cheng Kung University in Taiwan visited the University of Alaska at Fairbanks, last summer, acquaintances were renewed and four Penn State graduates posed for this picture at the Usibelli Coal Mine at Healy, Alaska. Left to right are: Donald J. Cook ('58 B.S., '61 Ph.D., MinPrep), professor emeritus of mineral beneficiation at the University of Alaska, and visiting professor at National Cheng Kung University; David R. Maneval ('61 Ph.D., MinPrep), acting dean, School of Mineral Industry, University of Alaska; Su-Yen Chain ('65 M.S., PNGE), vice president, Chinese Petroleum Corporation, Taipei, Taiwan, and H. S. Liu ('63 M.S., '68 Ph.D., MinPrep), director of graduate school, mining, metallurgy and materials science, National Cheng Kung University.

Hal Harman '56 to Receive McFarland Award

Hal Harman, who received his B.S. in metallurgy in 1956 at Penn State, has been selected to receive the 1983 David Ford McFarland Award of the Penn State Society of the American Chapter for Metals.

Mr. Harman is group vice president—metal casting divisions, Interlake, Inc. Presentation of the award will be made at the 75th anniversary dinner of the Metallurgy Program at the Penn State Sheraton, Saturday, April 30. (See story beginning on first page.)

Hal Harman, 1983 McFarland Award Recipient.

The McFarland Award, now in its 35th year, recognizes outstanding achievements by Penn State metallurgy alumni and honors the memory of Dr. McFarland who was professor and head of the then Department of Metallurgy from 1920 to 1945.

After receiving his B.S. in metallurgy at Penn State, Mr. Harman went on to earn his M.S. in the same field at Massachusetts Institute of Technology in 1957. He is a registered professional engineer in Pennsylvania and Illinois.

He first worked for U.S. Steel Corp. at its Homestead Works where he advanced to the position of chief control metallurgist. In 1962, he joined Interlake, Inc., as chief metallurgist at its Riverdale steel plant. He eventually became manager of this plant before being named president of Arwood Corporation, a subsidiary of Interlake, Inc. In his present position as group vice president, the divisions he heads include the investment casting and die casting groups of Arwood Corporation, Rockleigh, N.J., and the investment casting air foil operation of Duradyne Technologies, Mentor, Ohio.

Chairman of the board of Interlake, Inc., is Frederick C. Langenberg ('55 Ph.D.), who received the McFarland Award in 1973.

mological Society of America Eastern Section meeting. Title of his paper, written with Dr. Shelton Alexander, professor of geophysics, was "Crustal Structure Beneath Parts of Eastern North America from P-SV Conversions." He received his B.S. in geosciences here in 1980.

Faculty Briefs

Dr. Howard B. Palmer, professor of energy science, participated in the 19th International Symposium on Combustion held recently at the Technion-Israel Institute of Technology, Haifa, Israel. He served as chairman of a technical session on flame chemistry and also of a meeting of the editorial board of *Combustion and Flame,* the journal of the Combustion Institute, of which he is editor.

Dr. Z. T. Bieniawski, professor of mineral engineering, has been appointed by the U.S. Department of Energy to the Overview Committee for the Basalt Nuclear Waste Isolation Project in Richland, Washington. The committee reviews the work of Rockwell International, primary contractor for the project, in the areas of repository performance assessment, siting and licensing, waste package, rock mechanics and engineering, and ecology. Dr. Bieniawski also heads the Overview Committee's subcommittee on rock mechanics and engineering.

Dr. L. A. Morley, professor of mining engineering, was recently elected chairman of the Standards Department of the Industrial Applications Society of the Institute of Electrical and Electronics Engineers for 1983. This department is responsible for all standards activity for the society, including most IEEE and ANSI (American National Standards Institute) standards for industrial electrical systems. Dr. Morley reports that mining industry electrical standards are being developed now, covering underground gassy and nongassy mines, surface mines, and preparation plants and related operations. He is the first university faculty member to head the Standards Department, all former chairman having come from industry.

Dr. Peter Gould, professor of geography, was awarded the honorary degree, *Docteur Honoris Causa,* last December, by the Louis Pasteur University in Strasbourg, France. He was cited as a researcher, author, and teacher "whose pioneer research on the perception of space, mastery of a variety of applications of contemporary numerical methods, and remarkable qualities as a teacher have inspired a generation of geographers in the United States and foreign countries to the renewal of their discipline."

Dr. H. R. Hardy, Jr., professor of mining engineering and director of the Penn State Rock Mechanics Laboratory, was an invited participant last fall in the International Society for Rock Mechanics Symposium on Seismicity in Mines at Johannesburg, South Africa, presenting a paper entitled "Stability Monitoring of Underground Structures Using Acoustic Emission Techniques." He also took part in a post-conference discussion on rockburst location and prediction techniques and visited a number of South African gold mines. His visit was sponsored by the South African National Group on Rock Mechanics and the Western Deep Levels Mining Company.

Dr. Peter Thrower, associate professor of materials science, became editor-in-chief of *Carbon, An International Journal,* in January. He was formerly an associate editor of the publication which is a bimonthly sponsored by the American Carbon Society.

Dr. Richard C. Bradt, professor of ceramic science and engineering and head of the Department of Materials Science and Engineering, spent a month in China last fall at the invitation of the Chinese Society of Astronautics. He lectured on fracture of ceramics and refractories at a number of research institutes and universities in several cities. His host and interpreter was Jiaxiang Zhao, vice director of the nonmetallic materials department at Beijing Research Institute of Materials Technology. Dr. Zhao was the first citizen of the PRC to come to Penn State in recent years for study and research and spent two years here.

News of Alumni Needed

To E&MS alumni: You can help to make the alumni news section of this bulletin more interesting by sending news of your activities to the Bulletin Editor, 116 Deike Bldg., University Park, PA 16802.

News of E&MS Alumni

Wainerdi Heads Gulf R&D

Dr. Richard E. Wainerdi ('55 M.S., '58 Ph.D., PNGE) recently joined Gulf Oil Corporation as president of Gulf Research and Development Company.

He was previously a member of the board of directors, senior vice president, and director of research and development for 3D/International of Houston, Texas, an engineering and design firm with worldwide activities.

Richard E. Wainerdi, president of Gulf Research and Development Co.

Before joining 3D/International, Dr. Wainerdi spent 20 years with Texas A&M University as a leader in research and academic affairs. He founded the University's Nuclear Science Center, Radioactivation Analysis Research Laboratory, German Synfuels Technology Retrieval Program, and Center for Energy and Mineral Resources. He was professor of chemical engineering, and also served as associate dean of engineering, and as both assistant and associate vice president for academic affairs.

Myers Honored by Ogontz Campus

Dr. Joel N. Myers ('61 B.S., '63 M.S., '71 Ph.D., Meteo), was honored last spring as an outstanding alumnus of Penn State's Ogontz Campus at Abington, Pennsylvania. He spent his first two years at Penn State at the Ogontz Campus in 1957-59. He is president and chairman of the board of Accu-Weather, a weather consulting service in State College, Pennsylvania, which he began in 1962. The firm now serves 450 clients across the U.S. In 1981, he was elected by Penn State alumni to serve as a member of the University's board of trustees.

Alumni Briefs

Carl P. Giardini ('57 B.S., PNGE) is deputy project manager, Brae Field Development, with Marathon Oil, U.K., Ltd., in London, England.

Thomas H. Parker ('71 M.E., MinEngMgt) recently joined Nevada Molybdenum Co., Tonopah, Nevada, as general manager.

Dr. Dana L. Hankey ('80 Ph.D., Solid State Science) is now a member of the technical staff at Cermalloy, Inc., West Conshohocken, Pennsylvania. He was formerly with Sandia National Laboratories.

Alumni Obituaries

Dr. John H. Hoffman ('43 B.S., '48 M.S., Mining; '61 Ph.D., MinEcon), curator of mining and mineral technology at the National Museum of American History, Smithsonian Institution, Washington, D.C., died July 7, 1982. He served on the Penn State faculty from 1956 to 1960 as instructor and research assistant in mineral economics, and was also an instructor in Mineral Industries Extension.

Thomas J. Crocker ('47 B.S., Mining Engineering), of Bethlehem, Pennsylvania, died June 11, 1982.

Richard M. Niedbala ('54 B.S., PNGE), of Monroe, Michigan, died July 30, 1982.

Private Support—

Continued from first page

its programs. Only 21 percent of the college's 1981-82 operating budget came from the Commonwealth of Pennsylvania.

Dean Hosler noted special need now for funds for new equipment and instrumentation in light of the fact that two of the college's laboratories—Fuels and Combustion and Mine Electrical Research—are to have new quarters in a building to be constructed soon on the eastern end of the University Park Campus; and Steidle and Mineral Sciences Buildings are scheduled for renovation with funds specially appropriated by the state legislature. Much of the equipment now in Steidle (constructed in 1930) and Mineral Sciences (built in 1948) is outmoded and badly needs to be replaced.

Other areas for which the dean is seeking

E&MS Calendar

Folders describing the following continuing education offerings of the College of Earth and Mineral Sciences at Penn State's University Park Campus may be obtained by writing (Name of Program), Keller Building, University Park, PA 16802; or by phoning 814-865-7557.

Management of Mine Cost Analysis and Control, March 21-23.
Symposium on the Applications of Microcomputers in the Mining Industry, March 28-30.
Fundamentals of Surface Mining for Nonmining Personnel, April 12-14.
Elements of Underground Coal Mining, April 25-27. (Also offered October 24-26)
Hydrological Design for Surface Coal Mining, May 2-4.
Lime Manufacturing Technology, May 4-6.
Mine Ventilation Analysis, May 9-13.
Elements of Coal Preparation, May 18-20. (Also offered November 14-16)
Underground Mining Analysis, June 13-17.
Mining Professional Engineering Exam Review, June 27-July 1.
Technical Elements of Surface Coal Mining and Land Reclamation, August 2-4.
Coal Mine Electrical Systems, August 8-11.
10th Annual Training Resources Applied to Mining Conference, August 14-17.
Fundamentals of Rock Mechanics, September 26-28.

support include scholarships for undergraduates, many of whom are finding it financially difficult to stay in school; additional computer equipment and facilities for use in all of the college's disciplines; the Edward Steidle Fund whose goal is an endowed sum of $1 million from which the income would be used to enrich the student experience in various ways and help in attracting, retaining, and rewarding valued faculty members; and specific needs within each of the college's areas of teaching and research.

Students Conduct Phonathon

More than $22,300 in pledges were solicited from E&MS alumni by some 60 of the college's undergraduates who participated in the 1983 Winter Phonathon of Penn State's Office of Gifts and Endowments. Using 30 phones on

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The Honorary Dean's List

Alumni and friends of the College of Earth and Mineral Sciences who contribute at least $500 in any one year to the college are accorded the honor of being listed in the Honorary Dean's List in the college's annual report issue of this bulletin published each fall.

Twenty names appeared on the first Honorary Dean's List printed in 1981; in 1982, the list contained 40 names; this fall, it is expected to be much larger.

The first time an individual's name appears on the list, he or she receives an engraved plaque decorated with a medallion of the college seal. For each successive year, that an individual qualifies for the list, a small plate engraved with the year is provided for the plaque.

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each of two successive evenings in early February, the students called graduates of their respective disciplines, who live throughout the contiguous 48 states, telling them of the needs of their disciplines and seeking their financial assistance.

Last year, the E&MS student phoners achieved a pledge total of just under $10,000.

Appeals from Program Areas

In March and April 1983, E&MS alumni will receive letters from the department heads or chairmen of their areas of study that will bring them up to date with activities and news of those areas and seek their support for needs of the programs.

Special efforts are under way this year for the Robert Stefanko Memorial Scholarship Fund which will honor and aid outstanding mining engineering undergraduates; the Hans A. Panofsky Scholarship Fund, which will recognize deserving students in meteorology; and the Benjamin F. Howell, Jr., Award Fund which will provide an award each year in recognition of the most outstanding professional contribution by a geophysics student.

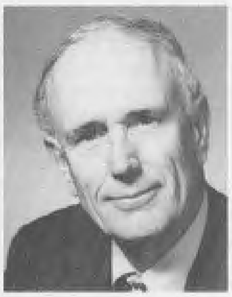
Goal of the Stefanko fund is an endowed fund of at least $45,000. More than $20,000 has already been received.

Where to Send Gifts

Gifts designated to the college or any of its program areas may be sent at any time to: Penn State Office of Gifts and Endowments, 100 Old Main, University Park, PA 16802. Checks are to be made payable to The Pennsylvania State University.

Dr. Philip L. Walker, Jr., Retires after 30 Years

Dr. Philip L. Walker, Jr., chairman of the Fuel Science Program in the Department of Materials Science and Engineering, retired in January as Evan Pugh Professor Emeritus of



Dr. P. L. Walker has retired as professor emeritus.

Materials Science after serving more than 30 years on the Penn State faculty.

He joined the faculty in 1950 as instructor in fuel technology, and, by 1955, had advanced to full professor. He was named an Evan Pugh Professor by the University in 1974 in recognition of his research and teaching achievements.

He served as head of the Department of Fuel Technology from 1955 to 1959, as chairman of the Mineral Technology Division from 1959 to 1964, as head of the Department of Material Sciences from 1967 to 1978, as chairman of t[he] Polymer Science Section from 1972 to 197[?], and as chairman of the Fuel Science Program since 1977.

In September, he was awarded a citation by the British Joint Carbon Committee during its international conference in London, acknowledging his fundamental contributions to carbon science made over many years. In 1969, he received the American Chemical Society's Storch Award for distinguished contributions to the science and utilization of coal, and, in 1971, that society's Skakel Award for contributions to the science and technology of carbon materials. He has served as a national lecturer for Sigma Xi, a distinguished speaker for the American Ceramic Society, and as George Graffin Memorial Lecturer for the American Carbon Society. He received his B.S. and M.S. from The Johns Hopkins University and, in 1952, his Ph.D. in Fuel Technology from Penn State.

His research interests include coal conversion processes; physical and chemical properties of coal; and formation, structure, and reactions of carbons. He plans to continue close association with his colleagues and the University.

Metallurgy—

Continued from first page

Also on Saturday morning, a bronze plaque on which names of the recipients of the Robert Lindsay Award in Metallurgy will be listed will be unveiled in the foyer of Steidle Building. This award has been established by colleagues and friends of Dr. Lindsay, professor emeritus of metallurgy, to honor students who do outstanding work in courses in physical metallurgy and alloy systems. Dr. Lindsay, who served on the faculty from 1943 to 1957 and 1959 until his retirement in 1972, headed the then Department of Metallurgy from 1960 to 1969.

Metallurgy Alumni Take Part

The Saturday afternoon program will open with a talk on problems facing the metals industries in the 1980s given by Hal Harman (B.S., '56), 1983 recipient of the David Ford McFarland Award of the Penn State Chapter of the American Society for Metals (see page 22). Following his talk, a panel of other distinguished metallurgy alumni will discuss possible solutions to the metals industries' problems.

The 75th anniversary dinner will be held Saturday evening at the Penn State Sheraton in downtown State College. The program will include presentation of the McFarland Award [to] Mr. Harman.

Two Booklets To Be Published

As part of the anniversary observance, two booklets are being published. The first will be a general overview of metallurgy at Penn State past and present, including descriptions of the present graduate and undergraduate curricula and listing of the faculty and their interests. The second booklet will be made up of descriptions of the various research projects currently being carried on under the direction of the faculty. Both booklets will be made available to alumni later this year.

A letter will be sent in early April to all metallurgy alumni, listing the final program details and inviting them to make reservations for the anniversary dinner. In the meantime, further information may be obtained from Dr. John Hoke, chairman of the Metallurgy Program, 208 Steidle Building, University Park, Pennsylvania 16802; phone (814) 865-5446.

EARTH AND MINERAL SCIENCES
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