John Carih Succeeds E. W. Miller as College's Associate Dean for Resident Instruction

Dr. John Carih, associate professor of meteorology, has been named associate dean for resident instruction in the College of Earth and Mineral Sciences, effective July 1.

He succeeds Dr. E. Willard Miller, professor of geography, who is retiring in June with emeritus rank after serving 55 years on the Penn State faculty.

Dr. Carih, who received his B.S. in 1961 and his Ph.D. in 1971, both in meteorology from Penn State, joined the University faculty in 1965. He teaches courses in the areas of synoptic meteorology, climatology, and applications of satellites.

His research interests include application of micrometeorological analysis methods to short-range weather forecasting, effects of cloudiness on the earth's radiation balance, and structure of small-scale circulations that produce thunderstorms. In 1971, Dr. Carih received the American Meteorological Society's Award of Appreciation for Television Weather Forecasting; and last year, he received the Award for Outstanding Contributions to Applied Meteorology made annually by the National Weather Association.

He is the author of an additional 35 papers, 13 of them published in refereed journals.

Elected UCAR Vice Chairman

Dr. John A. Dutton, professor of meteorology, was recently elected by the University Corporation for Atmospheric Research (UCAR) to serve as vice chairman.

UCAR is a consortium of 49 North American universities and research institutes with active research programs in atmospheric science. Penn State was one of the founding universities and Dr. Dutton was appointed to the Board of Trustees.

Dr. Dutton has served on the UCAR Board of Trustees since 1973 and has been both secretary and treasurer of the corporation. He continues to serve as a member of the corporation's executive committee and budget and program committees of the board of trustees, in addition to serving as UCAR's representative on the budget and program management of the corporation and the center.

Refractory Technology Short Course

Trends in refractory use and research will be reviewed by experts in this field during a short course entitled "Fundamentals of Refractory Technology," being offered June 30-July 9 as part of the National Exhibition of Materials and Science Engineering, is director of the course which will cover such topics as mechanical properties of refractories, the application of refractories to the steel industry, slag attack on refractories, laboratory tests for refractories, and carbon and graphite as refractories.

Further information may be obtained from

Dr. Stobbs, 328 Stroud Building, University Park, PA 16802.

Palygysolinos Incorrectly Listed

The report on the 12th annual meeting of the American Association of Strategic Palygysolinos in the last issue of this bulletin had an error in one case. The additive correctly listed, Douglas J. Nichols, Ph.D., '70, was invited panel on a featured discussion (the is AAP newsletter editor). Arthur D. Colb, Ph.D., '68, also presented a paper, as did Funk, 328 N.S., B.S., '73, Robert E. Deny, Ph.D., '72, was chairman of a session.

E&M Short Courses

For additional information on continuing education offerings of the College of Earth and Mineral Sciences at Penn State's University Park Camp may be obtained by sale of the College of Earth and Mineral Sciences, 305 Foundry Hall, University Park, PA 16802.

Each year, the nations consuming 20 billion dollars worth of mineral raw materials that are neither fuels nor any building materials such as stone or concrete. These valuable mineral materials are primarily metals that are supplied by various kinds of ore deposits.

Some of these deposits—such as iron—accumulated as sediments in ancient seas or lakes; some—such as bauxite—resulted from rock weathering; and still others—such as nickel and platinum group metals—were formed by the segregation of immiscible magmas during earth's evolution. Some percent of all metals consumed each year by the United States is supplied by mineral deposits formed by a fourth mechanism—metal precipitation from hot aqueous solutions. Economic geologists refer to these as hydrothermal ore deposits—that is, they were deposited through the action of hot water.

Hydrothermal ore deposits have presumably been studied by a very necessary operation, not only to create new sources of energy, but also to remove environmental problems.

Continued on next page

College News Notes

Three New Faculty Members Named

Three new faculty members joined the staff of the College of Earth and Mineral Sciences recently. They are: Dr. Craig E. Devey, professor of meteorology; Dr. Tanasek Deb, assistant professor of geology; and Dr. Gary L. Messing, assistant professor of ceramic science.

Dr. Devey received a B.S. in mechanical engineering from San Jose State University in 1969, and an M.S. in nuclear engineering in 1966, and a Ph.D. in nuclear physics in 1973 from the University of Texas at Austin.

Dr. Devey received his B.S. degree from D. P. in materials science at the University of Florida in 1971. For the last two years, he was a research assistant at Barne Memorial Institute, Columbus, Ohio.

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EDITORIAL BOARD

PETER T. LUCKIE, Chairman, Mineral Processing Section

Our nation is built upon a mineral-based economy. Consequently, we have a large industry involved in the extraction of minerals and their subsequent utilization or conversion.

A good example is the steel industry where iron ore is extracted—mined—from the earth and converted into various grades of steel. Over time, the quality, or grade, of the extracted minerals has declined while the need for higher and higher grades of minerals for utilitarian conversion has increased. Bridging this ever widening gap between the quality of ores mined and the quality needed is an engineering discipline known as mineral processing.

The mineral processing engineer is responsible for upgrading the mineral extracted to a marketable product. As one might suggest, this involves the processing of particles. Particle processing is a very necessary operation, not only to create new sources of energy, but also to remove environmental problems.

Continued on next page

Modeling Hydrothermal Ore Deposit Genesis

WILLIAM C. CATHES III

Laurence A. Profile Assistant of Geosciences

Continued on next page

Combustion of Alternative Natural and Synthetic Fuels

JAMES E. REUTHER, Assistant Professor of Fuel Science

For strategic, economical, and national security reasons, but not necessarily environmental or technical ones, the United States is expected to place a greater reliance on the utilization of coal, the most abundant and available fossil fuel, in order to meet short- and long-range energy needs.

Simultaneous to the recognition of an "energy crisis" during the last decade came the enactment of regulations for combustion-generated air pollutants. Because of these dual developments, combustors and combustion research in the 1980s will focus on the discovery of ways to utilize domestic coal in an ecologically and technologically acceptable manner.

When burning coal directly, it is often impossible to satisfy both ecological and technological criteria simultaneously.

A comprehensive and systematic study in progress at the College's Fuels and Combustion Laboratory is attempting to achieve an understanding of both the combustion properties of natural and synthetic, fossil and non-fossil fuels relate to their combustion behavior. The fundamental data resulting from this research allows us to develop alternative fuels and energy systems.
Bridging the Gap—
Continued from page 1

pollutants. This does not mean that min-
neral processing is a new discipline, but rather that its impact is expanding rapidly.

Mineral processing traces its origins back to medieval and early Renaissance practices. As Gaudin pointed out in "Prin-
ciples of Mineral Dressing," "information con-
cerning the operations of the past is so full as might be wished... largely because educated Athenians and Romans alike would not lower themselves to such com-
munitas' as are implied in technological description or discussion." Consequently, most of the descriptions of very early prac-
tices in mining and mineral processing appear in De Re Metallica by Georgius Agricola, published in 1556. This book, which details the state of the art in Europe at the time of the Renaissance, was trans-
lated from Latin to English by Herbert Hoover (later to become president of the United States) in 1912, and published in 1912 by The Mining Magazine, London. In 1950, a new edition was issued by Dover Publications, Inc., New York, N.Y.

In his introduction to Chapter VIII in De Re Metallica, Agricola says, "...I will explain the methods of preparing the ores, for since Nature usually creates metals in an impure state, mixed with earth, stones, and solidified juices, it is necessary to separate most of these impurities from the ores as far as can be, before they are smelted, and therefore I will now describe the methods by which the ores are sorted, broken with hammers, burnt, with starch with ground into powder, sifted, washed, roasted, and calcined."

Agricola's book is profusely illustrated with drawings showing in great detail the various steps in mining and mineral pro-
cessing as it was done more than four cen-
turies ago. One of these illustrations is re-
produced on this page.

Hand-sorting—picking out the valuable lumps of ore from the worthless lumps—must be the oldest of all mineral processing unit operations. This technique is sometimes practiced today, except that now the large worthless lumps are picked out so that they will not damage any of the processing equipment. Old re-
mains indicate that the washing of ore to remove fine particles was practiced cen-
turies before the Christian era.

Size reduction to break worthless mate-
rial from valuable material was also prac-
ticed early, and washing units extended to gravity concentration. In the ruins of the Athenian silver mines in At-
ica were found stone tables, set at an

angle that were used to concentrate heavy particles. In the Harz mountains of Ger-
many, jigging particles placed on a screen that was submerged in water developed into the jigging process of today in which heavy particles migrate to the bottom of a bed.

From medieval and early Renaissance times to the present, the importance of being able to process fine particles has be-
come increasingly evident. Particle prop-
erties other than specific gravity have been explored to bring about separations, for instance, those caused by magnetism and surface chemistry. Perhaps the easiest way to explain what mineral processing is all about is to examine the evolution in our country of the processing of a mineral of which everyone is currently very much aware—gold.

Gold as an Example of Mineral Processing

The first producers of gold had a rather easy job in that it could be found in stream beds and simply picked up. In this case, nature had already ex-
racted the gold from the orogenic process of it. All that remained was the hand-sorting of the desired mineral from the sands of the stream bed.

fuels appear to have innate clean-burning compositions. However, further inves-
tigation reveals that potential environmental advantages of firing these alternates may be offset by technological problems—clean-burning substitute fuels may not have ignition and burnout characteristics as favorable as those of the dirty fuels they are replacing.

Coal conversion technology, with its manifold process variations, can either re-
constitute, liquefy, or gasify coal. Reconsti-
tuted solid coal (SRC-1) has lower sulfur and ash than the parent coal, but also has more nitrogen and is more difficult to burn than the feedstock coal. The nitrogen-concentration problem exists, too, in the production of coal liquids, which also have higher aromatics than petroleum-derived liquids, making them more prone to produce smoke upon rich combustion. This situation creates a di-
lemma: NOX production can be con-
trolled by performing combustion in two stages, with the first stage operating at a rich, Hence, staged combustion of nitrogen-rich fuels having high aromatics may result in increased smoke production while achieving the de-
sired NOX reduction; one pollutant is traded for another.

Coal-derived syntheses, though low in pollutant precursor concentrations, con-
tain inert gases (CO2 and H2O) along with combustible gases (CH4, H2, and CO). Carbon monoxide knowledge of known flame extinguishers, and their presence in syngas makes this fuel burn less readily.

Fuels and Combustion Lab Research

Clearly, advanced concepts are needed if the nation is to extract energy from coal in a clean and efficient manner. One ad-
vanced concept being explored is the combustion of blends of different fuels. A hybrid mixture of a clean, but difficult to burn fuel and a dirty, but easy to burn fuel may prove overall combustion char-
acteristics that are superior to any single fuel because of synergistic effects.

The approach taken in research at the Penn State Fuel and Combustion Laboratory is to combust, in a test rig, and analyze a variety of fuels under standardized, well-controlled, well-defined conditions in the combustors shown in the pictures ac-
companying this article. The goal is to achieve a better understanding of the fundamental process of combustion. Once this is properly understood, ways to burn available fuels in an environmentally and technologically acceptable manner can be developed.

The research discussed here is currently funded by the Department of Energy, the Petroleum Research Foundation of the American Chemical Society, the Penn State Co-operative Program in Coal Research, and the Penn State Faculty Re-
search Fund.

The Author

James J. Beuther obtained a B.A. in chemistry from the State University College of Ontario, New York, in 1975, an M.A. in combustion and flame from the State University of New York at Binghamton in 1978, and a Ph.D. in fuel science from Penn State in 1981. He was appointed an assistant professor of fuel science at Penn State in 1981.

He is a member of the American Chemical Society and the Combustion Institute. His primary research field is fundamental and alternative fuel combustion research at the Fuels and Combustion Laboratory. Dr. Beuther is conducting research in the chemical and physical inhibition of emissions by solid, liquid, and gaseous agents, in visco- elastomeric joint metal atomization reactions, and in soot for-

MATHEMATICAL INEQUALITIES

Alumni Are Urged to Return Questionnaires for New Directory to Be Published in Fall

Gathering up-to-date information on alumni of the College of Earth and Mineral Sciences for the new alumni directory to be printed this fall got under way in March with the mail-
ing of questions to alumni from the ques-
tionnaire (see above). A second set of questionnaires went to all alumni in mid-May. If you are an alumnus of the College and have not yet returned one of these two questionnaires, please return one at once. There is no need to return more than one.

If an alumnus does not wish his name listed in the new directory, he should indicate on the ques-
tionnaire and return it.

The directory will be both home and business addresses for each alumnus of the college. Names of deceased alumni and those for whom no addresses are available will not be included.

Compilation, printing, and marketing of the directory is being done by Bernard C. Harris Company, Inc., White Plains, N.Y., under con-
tract with the university, and at very little ex-
pense to the college.

The college will not benefit financially from the sale of the directory, but both the college and alumni deserve substantial ben-
fit from the comprehensive updating of alumni records that will result from the Harris effort.

Beginning in late summer, Harris personnel will call on alumni to verify the informa-
tion received or solicit information if it has not been sent in. During this phone call, the alumni will also be invited to purchase a copy of the directory. Only enough directories to fill the prepublication orders will be printed and circu-
lated will be carefully restricted to alumni.

50 EARTH AND MINERAL SCIENCES

TABLE I. TYPICAL COMPOSITION OF CONVENTIONAL AND ALTERNATIVE FUELS

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Ultimate Analysis</th>
<th>Proximate Analysis</th>
<th>Ash Analysis</th>
<th>Sulfur Content</th>
<th>Nitrogen Content</th>
<th>Coal</th>
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Coal
- Lignite
- Bituminous
- anthracite
- Anthracite
- lignite
- Oil Shale
- Gas

Combustion characteristics obviously play a crucial role in fuel selection. To some extent, the physical ignition, burnout rates and chemical (air-pollution emissions) combustion behavior of a fuel can be anticipated by its composition. The atomic hydrogen-to-atomatic carbon ratio (H/C) is an informative parameter since it can be used to characterize a fuel's ease of burning. Ease of burning can be expressed by three interrelated phenomena: ignition, reaction, and completion. As the H/C ratio decreases, the ease of burning decreases—ignition becomes more difficult, reaction slows, and burnout is delayed. Fuel flame behavior according to the H/C ratio also indicates, in part, the reason why natural gases and oils have recently become endangered fossil fuel species.

Coal: A Solution

With continued widespread use of petroleum and natural gas no longer possible, some of the coal combuslers will have to be retrofit to fire coal. The coal combusler is considered to be bituminous because it is easier to burn than coals of other ranks. The ease of ignition and burnout are functions of a powdered fuel's density. To a limited extent, the combustibility of a powdered fuel is affected by the presence, in significant quantity of its volatile matter and carbon content. Broadly speaking, the higher the percentage of volatile matter and the lower the percentage of carbon, the more readily the coal will ignite and burn out.

Bituminous coal usage, however, is not a panacea for the current energy availability crisis. First, not all combustors can be retrofitted to fire coal; because of size limitations, some combustors can only burn oil or gas, which generate shorter flames. Eventually, the presence of stringent environmental performance standards, fuels must not only be easy to burn but also slow to burn. An evaluation of a fuel's combustion-generated air-pollution potential should also be made. Inspection of its chemical composition: the higher the percentage of nitrogen (N), sulfur (S), and ash (A), the more air pollution (correspondingly, the higher the atmosphericity), the greater the tendency for the combustion of the fuel to result in the formation of nitrogen oxides (NOX), sulfur oxides (SOX), particulate (ROX) and smoke, pollution, respectively.

The bituminous coal composition given in Table 1 is a good estimate of the average composition of all known reserves of coal of this rank. With these high precursor-to-polutant ratios, the bituminous fuels have the known reserves of bituminous coal, when fired directly, can simultaneously comply with NOX and NOX emission standards, and none with NOX standards alone, unless expensive air pollution control techniques are implemented.

Alternative Energy Scenarios

The latter situation has caused several alternative coal-utilization strategies to be developed. These strategies include: a) a switch to solid fuels that are naturally cleaner burning, e.g., anthracite coal, wood; b) a switch to alternative sources of liquid fuel, e.g., tar sand, oil shales; or c) the removal of the elemental precursors to pollutants, e.g., the synthesis of SOX (SRC), liquid (SRC-I), and gas (syngas) coal derived.

Table II shows a comparison between the combustion characteristics of conventional and alternative fuels. In the inspection, several natural and synthetic phases of fossil fuels, respectively. This preference for readily combustible fuel is primarily why natural gases and oils have recently become endangered fossil fuel species.

However, it was not long before these types of nuggets were depleted, and the gold producer had to find other sources. Close examination of the stream-bed sands revealed small pieces of gold mixed in with the larger quantity of stream-bed material. In this case, nature had extracted the mineral, but had not processed it. By carefully panning the bed material, that is, washing it, a riveting action that removed the gold between, leaving behind the heavier gold particles, the old prospector could obtain gold dust. When the quantity of gold particles in the stream-bed material was too small to make panning profitable, this process was replaced by another known as sluicing. A wooden trough—the sluice—was constructed and a flowing stream of water was directed into it. The materials in the water stratified into layers due to their different specific gravities so that the heavier particles were trapped behind riffles in the bottom of the sluice. In this wooden trough, the prospectors had basically reproduced the action of natural wind and water and concentrated the gold particles in the stream in the first place. The sluice was operated for a time and then the gold particles were removed. Although such concentrating of an ore is one only one phase of mineral processing, it is the heart of the problem.

Eventually, the sources of gold that could be recovered by sluicing declined, and the many of the old methods of concentrating and other minerals that are much more important to gold in our everyday lives. This means that the demand for mineral processing engineers continues to increase as solutions to the problems of concentrating low-grade ores into high-grade concentrates are sought.

The Steps in Mineral Processing

The procedures employed in mineral processing can be condensed into four steps: characterization, liberation, sorting, and mixing.

Disposal: Characterization is the examination of the ore to determine its makeup and the amount of mineral and gangue material in it. Many times, there are several desirable minerals in one ore, making the concentrating more challenging.

Liberation involves the creation of particles whose content of the desirable mineral is very high and of other particles with a high content of undesirable gangue. Creating only two types of particles would be the ideal situation, but, in reality, particles of various concentrations of the desirable mineral are created. Liberation is achieved by size reduction—crushing and grinding of run-of-mine ore, sometimes reducing it down to particles of 50 microns or less in size. Sorting is the separation of the liberated ore into concentrates—mineral containing particles with a high concentration of the desirable mineral—and tailings—material containing very low concentrations of the desirable mineral. During the process, material known as middlings which contains intermediate concentrations of the desirable mineral, can be produced. The sorting is done physically by utilizing differences in such particle characteristics as size, shape, specific gravity, and magnetic susceptibility. Physical differences cannot be successfully exploited, chemicals are used to alter the physical properties of each ore to create size differences by attracting some particles to the gangue while others to the desirable mineral. This means that the demand for mineral processing engineers continues to increase as solutions to the problems of concentrating low-grade ores into high-grade concentrates are sought.
Where Mineral Processing Engineers Work

Mineral processing engineers work for companies that process ores, such as coal, iron, phosphate, copper, uranium, aluminum, titanium, and cement. Within such companies, these engineers are involved in planning, engineering, operations, and research. For example, consider the positions of several of our Penn State mineral processing students. Dale Augsburger (B.S., 1971; Ph.D. ‘74) is supervisor of operations for K & J Coal Co. Ed Martinec (M.S. ’50) is a superintendent in the central research laboratory of ASARCO. Al Tercich (B.S. ’86) supervises research for U.S. Steel. Dave Irons (B.S. ’82; M.S. ’86) supervises research for Bethlehem Steel; Elliott Spearman (B.S. ’69; M.S. ’71) conducts research for Inland Steel.

Mineral processing engineers also work for universities doing basic research and research the systems used to produce minerals, and for companies that manufacture the equipment, unit operations, and supplies, such as chemicals, that are used to prepare and concentrate the ore. For example, Dick Wesner (M.S. ’48), the first Penne State graduate in mineral processing, is president of Kennedy Van Saun Corporation. Jim Patterson (B.S. ’58; M.S. ’62) is with Long-Airdorf Construction Company, and in his capacity as technical manager for John Hely and Patterson Company. Dick Boris (B.S. ’61; M.S. ’70) manages research for Combustion Engineering. Larry Halvorsen (B.S. ’55; M.S. ’60) manages research for the Folco Corporation. Bob Dwyer (B.S. ’65; M.S. ’66) directs research for Envirotech. Jim Kindig (M.S. ’61; Ph.D. ’66) is ice chemistry professor at the University of Minnesota.

Mineral processing engineers are employed, too, in government and universities, consulting companies, formulations, and policy, and engineering systems to clean up our environment because the techniques used in concentrating minerals can also be used to remove many pollutants from our atmosphere. Dr. Dave Maneval (Ph.D. ’61), formerly the Appalachian Regional Commission, is now at the University of Utah. Joe Leonard (M.S. ’58) is dean of the College of Mineral and Energy Resources at West Virginia University; Bill Foreman (Ph.D. ’60), a professor at Virginia Polytechnic and State University. Still, other mineral processing graduates end up doing their own mining. Sam Weir (M.S. ’65) and his wife, Mary, are helping to improve the environment by buying a restored, and selling old houses. Recently interviewed on the NBC Today Show, they have written a book about their experiences.

Mineral Processing at Penn State

Mineral Processing at Penn State first received recognition as a separate discipline when, in 1955, a student organization, the Metal Processing Section of the Materials Science and Engineering Society, was established as one of six divisions in the Department of Mineral Engineering. However, courses in coal washing and ore dressing had been offered within the mining curriculum as early as the 1930’s. The Repton of the Pennsylvania State College for 1894, in the section on mining engineering, there is a report on instruction offered in “The Mechanical Treatment of Ores.” Students learned in part from working with models of a coal washer, an ore-dressing mill, and a coal breaker.

The first degree in mineral preparation was granted in 1948. Since then, more than 250 B.S., about 80 M.S., and over 25 Ph.D. degrees have been awarded. In 1950, the division became part of the Mineral Department within the Division of Mineral Engineering, and, in 1962, its head, Dr. H. L. Barmherz, was appointed Pennsylvania’s secretary of mines. Dr. H. L. Locell became acting head, serving until 1968 when Dr. Frank F. Aplan was named head. In 1971, the department became the Mineral Processing Section within the Department of Material Sciences, and the undergraduate degree was dropped and replaced by an extractive metallurgy option within the metallurgy B.S. program. In 1979, the section became a part of the Department of Mineral Engineering, which is where it began more than three decades ago, and the undergraduate program is now offered as an option in the mining engineering program. In 1978, the author of this article was named chairman of the section.

In addition to the usual engineering background courses in mathematics, chemistry, physics, mechanics, and computer science, the undergraduate in mineral processing also takes basic courses in mining and mineral processing and then studies operations analysis, electrical power, computer science, and physical concentration, and design. Courses in particle characteristic, hydrometallurgy, and pollution control may also be elected.

The Graduate Programs

At the graduate level, the mineral processing courses fulfill the M.S. and Ph.D. degree requirements. These courses of study are oriented toward specialized knowledge in the fundamental principles steadily operate, but, at depths where petroleum is near, thermal circulations become predominant due to warming of the initially cold overlying strata. However, this is not sufficient to cause significant mineral precipitation. We are thus forced to look to other precipita- tion agencies, and other solid deposits are fluid condensation or boiling, and we are now directing our efforts to- wards these mechanisms into this process.

Other Aspects of Hydrothermal Activity Investigated by Modeling

Situation of interest to those studying the hydrothermal alteration of ore deposits is controlled by computer modeling. Nearly con- tinuous intrusive activity near the world’s major mineral deposits at the rate of to 2 to 15 centimeters a year and causes substantial hydrothermal circulation. It is estimated by various techniques that the entire mass of water in the world’s oceans is convectively circu- lated through Earth’s crust in 1 to 30 million years. For comparison it takes the discharge from rivers about 180,000 years to replace the mass of water in the oceans. Hydrothermal circulation near ocean ridges is, therefore, of potential impor- tance to the global chemical balances that control the chemical composition of ocean water.

Massive sulfide ore deposits are as- sociated with this mechanism. Recent studies have suggested that the large-scale sulfide deposits have been formed by hydrothermal circulation, and magnetic anomalies are useful in con- straining the hydrodynamic processes in such ore bodies because methods have been developed to predict what anomalies will be produced by bodies of various types. A great deal more information will certainly be obtainable from the often very regularly zoned alteration and mineral deposits ob- served near and in hydrothermal ore de- posits once the methodologies required to predict the alteration and mineral deposit- ion processes are established. The first testing area for the methodologies de- veloped here, at Penn State will be the Korokoko deposits of Japan that are known as Koro- koko deposits is being carried out here at Penn State as part of a research program led by Dr. Robert Ohmoto, professor of geochemistry. This project is described in a recent issue of this bulletin in which Dr. A. L. Gobert, associate professor of geology, discusses one aspect of the research being done.

Plans for Future Work

The most exciting activity for the future in our work is a tighter joining of chemistry and the fluid-flow models already de- veloped. We have just begun this process.

Ultimately, we must make it evident how processes of fundamental importance to natural processes, such as the solubility of sulfides in the oceans, can be predicted on the basis of fundamental knowledge of the chemical and physical processes in the ocean. The processes we have been studying have been studied by others. It is expected, too, that much will be learned from modeling geochemical al- terations from the metalliferous deep sea floor spreading. Recently, a massive sul- fide deposit has been found in the process of being formed on the deep-sea floor off the coast of Baja California, 8,200 feet below the ocean’s surface.

Here, pipe-like structures protruding up- ward from the ocean floor resemble black-bellied factory smokestacks. Solu- tions venting from the structures appear as- dark-colored smoke because of the pre- cipitation of iron(II) hydroxides and copper sulfides disseminated in them. Temperatures of these “plumes,” it was determined, are more that 300°F. Spectacular pictures of this phenomenon appear in a recent issue of National Geographic. Two of these pic- tures were from the Woods Hole Oceanographic Institute, are re- presented in this article.

The Menlo model has proven useful in helping to define the kinds of hydrothermal circulation that can be expected to form mineral deposits.

Intriguing but unusual still will very low-grade radiogenic mineral con- tent be observed off the coast of Cominco Gran- ite in New Hampshire, and the foliage maintain temperature contrasts of about 130°F between the hot hydrothermal circu- lation and the rock at an equivalent depth outside. Observations of such processes, as they could not be developed, causing hydrothermal fluid circulation whenever tectonic forces fracture the intrusive and its surroundings. It has been hypothesized that this situation could be a real potential for the formation of daughter intrusions that are much younger than the parent intrusive. Such daughter intrusions are known to be ob- served in several areas.

Modeling of the genesis of a large area of altered country in the northern part of Mi- norum Japan that are known as Korokoko de- posits is being carried out here at Penn State as part of a project led by Dr. Robert Ohmoto, professor of geochemistry. This project is described in a recent issue of this bulletin in which Dr. A. L. Gobert, associate professor of geology, discusses one aspect of the research being done.

References
of comminution, classification, physical and nonphysical concentration, hydro- 
metallurgy, flotation, solid-liquid separations, and agglomeration.

A major aspect of the graduate program is research oriented toward analysis and 
modeling of grinding circuits, flotation, classification, and mixing/transport; col-
loidal behavior of particles in liquid media; solid-liquid interfaces; influence of 
poles defects in the structures of material on its separation behavior; the 
rheology of particulate systems; sulfur and ash re-
moval from coal; and treatment of process 
water.

Primary Areas of Research

The mineral processing faculty members have sold backgrounds in both industrial and 
academic areas. In addition to offering a

A process of ore formation was actually seen for the first time when "shimmering" 
opposing Machiavel, liquid hot water on the sea floor was discovered last 
year by a camera replacing at depths of more than 5,000 fathoms in the ocean 
ridge off the Baja California. Sulfides of copper, iron, and zinc precipitated instantly as fine 
particles when the heated seawater solution hit the surrounding, much colder 
water, and formed mounds around what the scientists called "black smokers." Two 
of these hot, metallic-rich pools found deep in the sea are shown here in photos taken by 
Wood Hole Oceanographic Institution scientists. (Left photo by Dudley Foster; right 
photo by Robert Ballard.)

sured in terms of the grams of fluid that 
will pass through a one-centimeter-square unit area per second to the flow direc-
tion in some unit of time. The maximum mass flux rate shown in the figure occurs 
about 5,000 years after intrusion and above the center of the intrusive. The rate of 
flow is 17 grams of fluid per square centimeter per year—hardly a very rapid 
circulation, but one which, nonetheless, has a major impact on the rate and manner 
of the cooling of the intrusive.

The diagrams also show contours of constant temperature (color lines) and 
fluid pressure (dot-dash lines). The initial intrusion is shaded as is the zone in which 
the pore fluids consist of steam rather than 
water. Above the cross-sectional depiction of temperature, fluid pressure, and 
fluid circulation in each of the diagrams is a graph showing the surface heat flow in 
HFU (1 HFU = 1 x 10^18 calories per 
per square centimeter per second).

It can be seen from the diagrams that fluid circulation causes the heat anomaly 
initially associated with the intrusive to lift 
it off like a hot-air balloon and rise upward till it cools on the surface. At this time, very high surface heat flows are produced. For a permeability of 0.25 m/h, the heat flow is the same on the sur-
face after about 7,000 years, and, 7,750 years after intrusion, surface heat flow

measurabilities of at least a few millidarcies. With such permeabilities, intrusions will 
cool very rapidly and, consequently, modeling suggests intrusive activity must have 
occurred within the last few thousand 
years in order for an exploitable geother-
mal system to have survived till the present. Furthermore, the most economically 
attractive (i.e., steam-dominated or hot-
test) systems are likely to be those that have yet to manifest spectacular surface, hot-
spring activities. By the time such surface 
manifestations are produced, the geother-

mechanics of the glassy crust extends from a laboratory fresh flotation miner. In this flotation testing, he is 
augmented by adding water and various types of minerals in order to improve the recovery and grade of the minerals.

Grinding laboratory studies (left) are geared toward reducing the energy consumed during grinding and producing desired size distribution. A typical grinding circuit consists of a series of steps: 
Richard Perry, another graduate student, sorts ferrous containing the desired
of particle processing problems facing the mineral industries. As our mineral resources are depleted, efficient and economical mineral processing becomes of ever greater importance for the future wellbeing and security of our nation.

The Method of Modeling

The method of modeling is conceptually simple and exactly analogous to the kinds of numerical modeling of petroleum reservoirs

Chinese Geology, Vol. 1, No. 1, 1970, pp. 5-10. The model of ore deposits is in a much earlier stage of development than that of petroleum res-

Ore Deposit Genesis—Continued from page 5

since the beginning of the Cambrian age, and efforts to explore for them have been guided—or misled—from the start, by the concepts of how they were formed and the environments that they were formed in. Because the concepts deve-

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matured for about 150 million years. Since then, the deposits have been re-

The Method of Modeling

The method of modeling is conceptually simple and exactly analogous to the kinds of numerical modeling of petroleum reservoirs.

Considerable attention has been directed toward the study of the genesis—formation—particularly of hydrothermal ore deposits, as well as de-

The ore deposits being considered are those that are formed by hydrothermal processes. Hydrothermal processes are those in which hot

**The Chinese Geologic Society, 542-546**

H. C. Heidrick, Jr., left, door of the college. The move is right for Yau-Ling Chao, graduate student in meteorology. Yau-Ling Chao, visiting scientist in fuel science, Feng Zhu, visiting scientist in the Department of Geosciences, Chih-Shih Chen, assistant professor of meteorology, and Mrs. Yu-Fang Li, research assistant in meteorology.

Five members of the faculty of Chinese education institutions and a graduate student are currently studying and doing research at the college of Earth and Mineral Sciences faculty members.

One of them, Jia Xiang Zhao, vice director of the geochemistry department at Be-

Jing (Peking) Institute of Materials and Technology, came to Penn State last fall and is working as a visiting scientist in fuel science in the Department of Materials Science and Engineering.

The others arrived on campus early this year. Three are working in the Depart-

ment of Meteorology. They are Mrs. Yu-Fang Li, a lecturer in meteorology at the University of Hong Kong, who is a research assistant in meteorology here; Chih-Shih Chen, an assistant professor of geophysics at Beijing University, who is

Mrs. Li is the second generation of her family to study at Penn State. Her father, Dr. Lai Yong Li, received his Ph.D. in botan-

ography here in 1941. He is now professor and president emeritus of Fujien Agricul-

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