VOLUME 46 NO. 2 NOVEMBER 1976

EARTH AND MINERAL SCIENCES

THE PENNSYLVANIA STATE UNIVERSITY, COLLEGE OF EARTH & MINERAL SCIENCES, UNIVERSITY PARK, PENNSYLVANIA

Caves: Underground Laboratories and Underground Wilderness

WILLIAM B. WHITE, *Professor of Geochemistry*

In the rolling farmlands of Penns Valley in central Pennsylvania, a farmer patiently removes a stone pile from his cornfield. Suddenly, with no warning, the earth crumbles beneath the front wheels of his tractor. In quick desperation, he slams the machine into reverse and hauls back the throttle. The big driving wheels churn in the loose soil and slowly the tractor pulls free as rock and soil cascade crashingly into the abyss. Nothing but blackness meets the gaze of the farmer as he peers gingerly over the edge once the uproar has subsided.

The year is 1958. A group of cave explorers from Penn State come across the gaping hole on the hilltop. On their reconnaissance descent, they find a vertical shaft, 20 feet in diameter and 80 feet deep. "Nothing but a pile of field stone at the bottom," reads their report.

1961. A more careful exploration team descends the shaft on the hilltop. A few feet above its bottom they find a recessed ledge. In the ceiling over the recess is a small hole opening into a cave passage above, one of a network of passages that wind and twist about the entrance pit and yet only twice intersect it. Beyond this small hole, the cave goes on and on. Word spreads rapidly over the grapevine and cavers flock in

The underground landscape – tubular conduit with stalagmites and column. (T.P. O'Holleran photo)

Continued on next page

Sun-powered Engines

HOWARD B. PALMER, *Professor of Fuel Science*

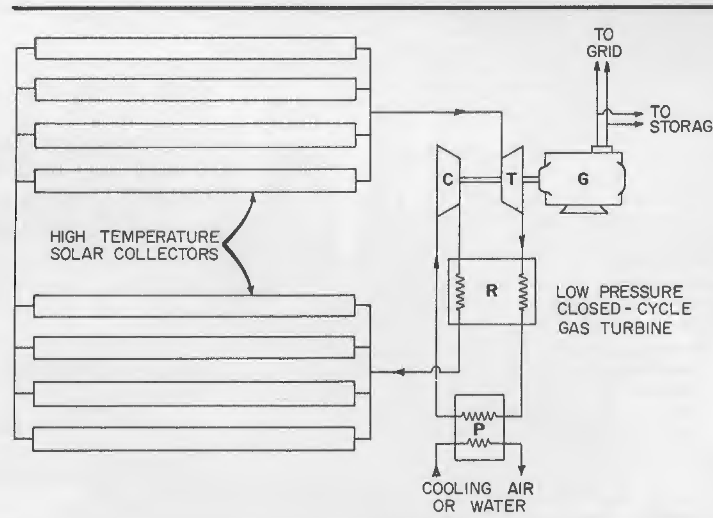
ZENEN ANTONIAK, *Fuel Science Graduate Assistant*

You must become an ignorant man again
And see the sun again with an ignorant eye
And see it clearly in the idea of it.

WALLACE STEVENS
"Notes Toward a Supreme Fiction"

In the spirit of the poet, solar energy researchers take the simple view that the enormous flux of energy from the sun striking the earth must offer an attractive possibility for meeting the future needs of mankind. But there are problems. Scientists and engineers have been trying (on a shoestring) for about a century to develop efficient, cost-competitive engines powered by the sun. The history of these efforts is interesting but rather discouraging.

In this bicentennial year, we might well try to imagine what our sources of energy will be in 2176 (or even 2076) and whether they can be developed to the level of perfection and in the quantity required by the society of that time. We should today be laying the foundations for that era.



Schematic diagram of a solar farm (not to scale) using a regenerative Brayton-cycle gas turbine. G – generator; T – turbine; C – compressor; R – regenerator; P – precooler.

Continued on page thirteen

Caves —

Continued from previous page

to see the spectacular new discovery.

1962. Exploration of the cave is largely completed and a survey is prepared. A geological reconnaissance is under way. Mineral investigations show aragonite and hydromagnesite in addition to the usual calcite speleothems. At the remote end of the cave is found a deposit of mammal bones that are proven by radiocarbon dating to have fallen into the cave about 9,000 years ago. They represent the first arrival of a modern fauna following the change from an arctic to a temperate climate.[1]

1963. With the cooperation of the landowner, a gate is placed over the entrance and the padlock snapped shut. Damage to the cave already has been extensive. Now traffic is closely controlled. Would-be visitors sign a log book and a release form, promising to stay on the trails, and not to leave trash, break speleothems, or scribble their names on the walls.

The discovery, exploration, survey, scientific reconnaissance, and ultimate gating and controlled access of the cave took place in only a few short years. The story is typical of cave exploration everywhere.

46th Year of Publication

EARTH AND MINERAL SCIENCES

Robert Stefanko, *Editorial Director*
Mary S. Neilly, *Editor*

THE COLLEGE OF EARTH AND MINERAL SCIENCES OF THE PENNSYLVANIA STATE UNIVERSITY

. . . dedicated to resident instruction, research and continuing education on the earth and its environments and the exploration, discovery, utilization, control, and conservation of the natural environment and the materials found therein.

Areas of Instruction and Research
Earth Sciences
Geosciences
  Geochemistry and Mineralogy
  Geology
  Geophysics
Geography
Material Sciences
  Carbon and Polymer Science
  Ceramic Science
  Fuel Science
  Metallurgy
  Mineral Processing
  Solid State Science
Meteorology
Mineral Economics
Mineral Engineering
  Mineral Engineering Management
  Mining Engineering
  Mining Technology
  Petroleum and Natural Gas Engineering

Published monthly from October to June inclusive by Earth & Mineral Sciences Continuing Education, 110 Mineral Sciences Building, University Park, Pennsylvania 16802. Second-class postage paid at State College, Pennsylvania 16801. Subscriptions available without cost upon written request. 77-293

Exploration and survey of caves are usually carried out by cave enthusiasts and represent one of the few remaining activities where useful contributions to geological knowledge can be made by nonprofessionals. But caving involves more than science and more than sport. In few areas of the earth sciences are there so many interweaving conflicts of value systems.

Caves have a scientific value as clues to the hydrology of carbonate terrains and as a special environment where unusual minerals are found, where archeological and paleoentological materials are preserved, and where a highly specialized fauna has evolved and now lives. In contrast, caves are a distinct hazard to land use. Reservoir and foundation engineering must deal with problems of subsidence, soil piping, and contamination of groundwater when construction is done in cavernous terrain.

Cave exploring is a popular outdoor activity particularly in the East where crowding and urban development severely limit the amount of land available for hiking, camping, and related activities. In a very real sense, caves offer a fragment of untouched wilderness, with strange beauties and bizarre landscapes that can be enjoyed as an esthetic experience. However, the damage to caves caused by hard usage for recreational or sport caving can decrease or destroy the esthetic or wilderness aspects of the underground experience.

The Occurrence of Caves

Most of the large caves of the world are formed in limestone, dolomite, or gypsum through the dissolving action of percolating groundwater and underground streams.

Groundwater is driven through joints, fractures, and bedding planes in rocks by the hydrostatic pressure difference between the water input areas of sinkholes and sinking streams and the water outlets at large springs. If the bedrock is limestone, the amount of calcium carbonate that can be dissolved increases rapidly as the carbonic acid content of the groundwater increases. Carbon dioxide to form the carbonic acid is obtained from the atmosphere, from the biological action of plants especially in the root zone, from decaying vegetable material in soils, and from organic material washed into the groundwater system by sinking streams. As the fractures enlarge, the flow tends to be concentrated in a few of them. These selected few enlarge still faster and ultimately become pipelike conduits carrying the bulk of the storm and snow melt runoff very rapidly through the aquifer to the springs. This integrated conduit system behaves more like a network of surface streams than like groundwater. The main difference is that water is driven through the conduit system by hydrostatic pressure as well as by gravity flow.

THE TEN LONGEST CAVES IN NORTH AMERICA

Cave Name	State	Length: Miles	Length: Kilometers
Flint Mammoth Cave System	KY	179.31	288.57
Jewel Cave	SD	54.7	88.0
Organ Cave System	WV	32	51.5
Wind Cave	SD	28	45
Cumberland Caverns	TN	24.63	39.64
Sloan's Valley Cave	KY	22.43	36.1
Crevice Cave	MO	22.37	35.99
Carlsbad Caverns	NM	20.62	33.18
Blue Spring Cave	IN	19.2	30.9
Binkley's Cave System	IN	19	30

Lengths current to early 1976. From compilation by Sprouse[2]

Caves are fragments of the underground conduit system, providing samples of the drainage network. Of the entire conduit system, some parts are below the water table and are not accessible to exploration, some parts are too small to enter, and some parts, although large and air-filled, are isolated segments with no connection to the outside world. Those few fragments that fortuitously connect with the surface make up the accessible population of caves.

Caves are explored by humans. If a fragment of a conduit is to be called a cave, it must be traversible by man and its length is determined by how far the human explorer can go.

Human explorers of caves are stopped by any one of a number of obstacles: sumps where the passage goes under water, chokes where mud and silt fill the passage to the ceiling, travertine blockades where secondary calcite deposition has sealed off the passage, and breakdown where rockfall has closed off the passage. The fundamental characteristics of caves are their length, the number of entrances (which may be zero), and the general pattern of their passages.

Most caves have only one entrance. A few have two entrances, and still fewer, three entrances. As the number of entrances increases, the probability of finding a cave with that number of entrances becomes smaller, but the caves with larger numbers of entrances that are found are larger.

If a list of caves is compiled in order of their length, it is found that most are small caves and that the number of caves with a given length decreases rapidly as the length increases. The lengths of caves follow approximately what statisticians call a Poisson distribution. The finding of an extremely large cave is a very unlikely event. The table on page 10 lists the ten largest caves in North America. Within the first ten, the length drops from 180 to 19 miles. The 40th largest cave is less than 8 miles long while most of the 20,000 or so caves in North America are much less than a mile long.

If cave entrances are formed by geologic accidents, such as roof collapse or the downward erosion of a surface valley to intersect a cave, then the probability of finding an entrance should be proportional to the length of the cave — the longer the cave, the more likely it is that something will happen to it to create an entrance. Curl[3] worked out a specific mathematical model for the distribution of lengths and entrances of limestone caves (see chart on page 12). The model contains the features already described. The chance of finding an exceptionally long cave is small. Caves with more than one entrance are, on the whole, longer than caves with only one entrance. But the model makes several interesting predictions. It predicts that there should exist a very large population of caves with no entrance at all — already implicit from the geological evidence — and that the entranceless caves should be small.

The largest cave in the world is the Flint Mammoth Cave System in Kentucky consisting of some 180 miles of interconnected passages. Its exploration required decades of intensive effort.[4] The largest cave in Pennsylvania is Laurel Caverns in Fayette County with more than two miles of passage. The second largest is Hosterman's Pit in Centre County, a little over a mile long, whose discovery was outlined at the beginning of this article. Hosterman's Pit was a large cave without an entrance, until the tractor almost fell into it. This chance discovery must be described as an extremely improbable event.

The Cave Environment

The cave environment may be described as dark, wet, neutral to mildly alkaline, and oxidizing.[5] The variations of these parameters are much less than the variations of similar parameters on the earth's surface.

Near the cave entrance is the twilight zone. Beyond is a middle zone of complete darkness but variable temperature, and finally there is an interior zone of absolute darkness and constant temperature. Relative humidity is near 100 percent. Flowing streams and standing pools of water are common. The pH of the underground waters is near neutrality, perhaps very slightly acid in the flowing streams and often mildly alkaline in dripping waters. The water contains dissolved oxygen, seldom less than that in surface streams, and can support aquatic life. The cave atmosphere may contain ten times as much carbon dioxide as does the surface atmosphere but truly foul air, choke damp, is uncommon. Both terrestrial and aquatic life-forms live in caves and the environment is often invigorating to human explorers.

Wet, very constant conditions make caves good depositional sites for minerals.

Calcite, a notoriously difficult material to grow in the laboratory, occurs in caves as spectacularly large crystals. Other unstable low-temperature minerals such as the magnesium carbonates, hydromagnesite, nesquehonite, and huntite are found in caves. Curiously, aragonite, a mineral stable only at pressures above 3,000 atmospheres is also commonly found in caves.

Sulfate minerals occur in caves in unusual hydration states because of the very constant water vapor content of the atmosphere.

Although a surprising variety of animal life occurs in caves, the populations are small because of the very sparse food supply. Caves act, therefore, as ecological laboratories where the interaction of organisms and their competition for available food can be easily studied.

The complete darkness and the constant environmental conditions of the cave lead to peculiar evolutionary pathways of the organisms. Features such as eyes and pigment which serve no purpose in the darkness of the cave are gradually lost. Adaptation for survival in a moderately hostile but fully predictable environment can be analyzed by comparing the cave species with their surface relatives.

Recreational Caving

Cave exploring for many is a sport or recreational activity. Cavers' motives

The underground landscape – calcite draperies and scuptured walls. (T.P. O'Holleran photo) are complex but at least two stand out: exploration of the unknown, and physical challenge.

There are those cavers whose whole effort is the discovery of new caves and exploration of the underground passages to the limit. Their objective is "virgin cave." In the underground, it is still possible, as it is nowhere else on earth except perhaps in the depths of the sea, to tread ground no man has trod before.

Caving is a goal-directed activity that has much in common with back-country hiking or mountain climbing. The objective is to enter the cave, traverse it to the end, and return to the surface. Very simple. Yet the accomplishment of this goal is a challenge requiring rope climbing, rock climbing, and the manipulation of one's body through low crawlways, up and down crevices, and through streams. It is strenuous and it requires physical skill and even courage.

Because of the darkness, the linear sequence of obstacles that separate the caver from the entrance, and the strange form of the underground landscape, the caver feels a sense of remoteness and accomplishment that is fully comparable with that of an alpinist on having climbed a mountain.[6]

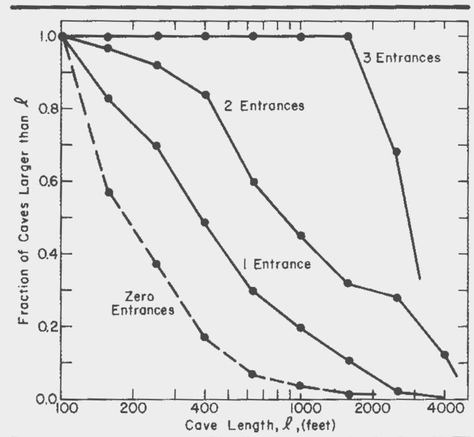
There is no doubt that recreational caving has a broad appeal. And because the available caves are limited in number, are mostly (at least in the East) on private land, and will tolerate only a small traffic without damage to their physical environments or their ecosystems, there is at present a considerable strain on cave resources.

The Underground Wilderness

The wilderness act of 1964 defines wilderness as "an area where the earth and its community of life are untrammeled by man, where man himself is a visitor who does not remain."

It has been argued[7] that although they may occur in the urbanized East, caves can be wilderness as much as empty expanses of mountain and forest miles from human civilization. This is, in part, because the underground landscape with its total darkness and unusual forms and shapes of rock and mineral deposits is so alien compared with the familiar surface landscape. Another reason is the remoteness of the cave.

The farthest reaches of the Flint Mammoth Cave System are only a mile or two from an entrance as the crow flies, and may be no more than ten or fifteen miles as the caver crawls. And, of course, the outside world is only a few hundred feet away through solid rock. However, reaching the far corners of the Flint Mammoth Cave System, doing a bit of surveying, a little exploring, or carrying out a scientific project, and then returning over those wearing, flesh-rending miles, requires 24 to 36 hours. In the same time one could have traveled comfortably across the continent on a jet plane, participated in a meeting in San Francisco or Seattle, returned home, and been clean and well rested to boot.



Distribution of cave length for all West Virginia caves more than 100 feet long as a function of the number of entrances (adapted from Curl[3]).

The cave, as was noted earlier, is remote. Its remoteness arises not from distance but from the time needed to traverse it, from the barriers that must be overcome along the way, and from the sense of the strange and the bizarre in the cave landscape, a landscape duplicated nowhere on the earth's surface.

A caver, resting a moment at the end of a cave, is as far away as if he were in another country or on the surface of the moon. The terrain is strange. No familiar sun or landmarks chart his way. Food, bath, and bed may be only hours away but he must get there under his own power. There are no jets, trains, or oxcarts. His emergence into the misty air under the bright stars of a summer's night is indeed the return from another world.

Caving, from this point of view, is truly an esthetic or wilderness experience. It requires solitude, a leisurely pace, and a sense of absorption into the environment just as does a wilderness experience on a mountain or in a forest. This experience is less easily achieved if the cave shows unmistakable wear and tear from the passing of previous multitudes of sport cavers.

The Pennsylvania Cave Survey

The primary output from the systematic discovery, cataloging, exploration, and mapping of caves is an inventory of resources known as a cave survey. Typical of such documents, which have been published for some 20 states, is the *Pennsylvania Cave Survey* now in its third major revision. Its object is to provide maps and brief descriptions of all known caves within the state. The first survey published in 1932 listed 80 caves, the second in 1953 listed 273 caves, and the third when complete will list more than 500 caves. But as the cave resources have grown, the statistical properties of the population remain the same. Most of the caves listed are very small, often less than 100 feet in length. The cave resources available for scientific study, recreational caving, and wilderness experience are always limited because the large and interesting caves make up such a small part of the whole cave population. This has been a source of conflict. Those who would conserve caves for their wilderness values are opposed even to the publication of the cave surveys since availability of the data spreads the recreational cavers over more of the cave populations.

In summary, caves, the mechanisms of their formation, and their hydrology and mineralogy are a subject within the scientific province of the earth scientist. Although the geological problems are interesting and much has been learned, it appears that the most valuable contribution of cave science in the past has been to provide a unique laboratory where the forces of adaptation, competition, and evolution can be observed in a less cluttered faunal community than exists on the surface. It appears that the value of caves in the future may be to the social sciences where human forces of competition for resources, debates on value systems, and response to wilderness situations are played out in a microcosm of the larger world outside.

References

1. J. E. Guilday, "The Climatic Significance of the Hosterman's Pit Local Fauna, Centre County, Pa.," *Amer. Antiquity* 32 (1967), pp. 231-232.
2. P. Sprouse, "Major Caves of the Western Hemisphere," *Inside Earth,* No. 4 (1976), pp. 14-15.
3. R. L. Curl, "A Statistical Theory of Cave Entrance Evolution," *Natl. Speleol. Soc. Bull.* 20 (1958), pp. 9-22.
4. R. W. Brucker and R. A. Watson, *The Longest Cave* (New York N.Y.: Knopf, 1976).
5. T. L. Poulson and W. B. White, "The Cave Environment," *Science* 165 (1969), pp. 971-981.
6. R. A. Watson, "Notes on the Philosophy of Caving," *Natl. Speleol. Soc. News* 24 (1966), pp. 54-58.
7. R. A. Watson and P. M. Smith, "Underground Wilderness, A Point of View," *Internatl. Jour. Environmental Studies* 2 (1971), pp. 217-220.

The Author

Dr. William B. White received a B.S. degree in chemistry from Juniata College in 1954 and a Ph.D. degree in geochemistry from Penn State in 1962. He has been on the University faculty since 1963 and currently holds a triple appointment in the Materials Research Laboratory, the Department of Geosciences, and the Department of Material Sciences. In 1974, he received the Wilson Outstanding Teaching Award of the College of Earth and Mineral Sciences. He has written many scientific papers on the hydrology, geomorphology, and mineralogy of carbonate rock terrains.

Sun-powered Engines —

Continued from first page

From current trends, one can predict that solar-heated homes and buildings will be common in 2176 and that other energy needs will mainly be met by electricity, with use of hydrogen as a gaseous fuel possibly being widespread, and with the source of specialized liquid fuels and chemical feedstocks likely to be coal conversion. If the electricity is to come from sunlight, efficient conversion processes must be found.

One strong possibility is photovoltaic convertors ("solar cells"), which even now are available with conversion efficiencies of the order of 20 percent. They are very expensive and delicate, but currently much effort is going toward making them economic and durable. If these problems are solved, there will be little reason to pursue other conversion methods unless they are substantially better on a cost-efficiency basis.

The principal alternatives all involve conversion of solar energy to mechanical energy which is then converted to electrical energy with a generator. Since the mechanical-to-electrical conversion is very efficient already, research centers on the solar-to-mechanical step. This article outlines some ~~of these efforts, including~~ work in progress at Penn State.

General Considerations

To achieve high efficiency, most engines operating on thermal cycles must be connected to a high-temperature (T_h) heat source. For example, modern steam-generating power plants operate with T_h values of the order of 800 degrees Kelvin. A solar energy collector can reach such temperatures only if the impinging solar flux is suitably concentrated by a mirror or lens. (For low-level solar heating of homes, swimming pools, and domestic hot water, concentration is unnecessary, which is why such applications are already widespread.) As the solar flux on a surface is increased by a concentrator, the energy input rate gains on the energy loss rate (i.e., losses to the surrounding environment) and the result is that the surface gets hotter, as anyone knows who has used a lens to focus the sun's image on a newspaper.

In order to maintain high temperature in a solar collector, the concentrator-collector system normally must track the sun accurately. The sun's image must be constantly focused on the collector. A few systems have been developed that employ non-tracking concentrators, but these cannot be expected to reach very high temperatures. However, they do have the advantage that they make some use of the *diffuse* radiation from the sun that results from scattering by molecules and larger particles or droplets in the atmosphere. Strongly concentrating solar devices can make use only of the *direct* (unscattered) component of solar radiation.

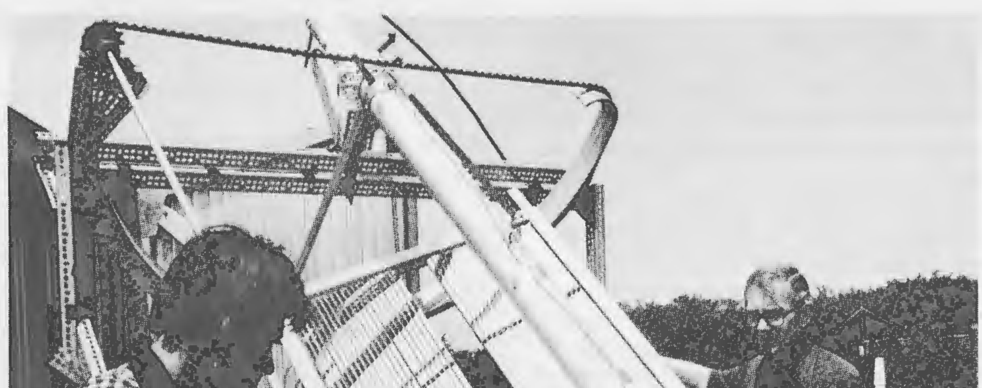
Concentrators, collectors, and engines are expensive, and thus solar-thermal power generation will be very capital-intensive (the fuel, of course, is free). Systems studies and pilot plant projects now in progress are aimed at achieving relative simplicity of system components in the hope of reducing capital costs.

The other large challenge in solar energy systems is storage of energy for use when the sun is not shining. In our judgment, the problem of developing an efficient, reliable, and not too costly concentrator-collector-convertor system has first priority. If that succeeds, adequate energy storage schemes will surely be forthcoming.

Specific Systems

There are two basic designs for large solar-thermal power installations — the "power tower" and the "solar farm." The former is essentially a very large vessel containing a heat-transfer fluid. It is mounted on a high tower surrounded on the ground by an array of many flat mirrors ("heliostats"). The heliostats are steerable and are programmed to continuously reflect the sun onto the receiver atop the tower. The heat-transfer liquid carries the absorbed energy down the tower to a power plant where it may, for example, be used to vaporize water to run steam turbogenerators. The single central receiver has advantages, but the tracking requirements for the heliostats are severe and the economics are unfavorable. Nevertheless, this concept is currently in the pilot plant stage at Albuquerque, New Mexico.

A solar farm (a term first used by the Meinels[1]) is the extension to large areas of a scheme employed in Egypt in 1913 to pump irrigation water using solar power. An array of long, trough-like, cylindrical-parabolic reflectors, each with a pipe running along the focal line, boiled water at a rate sufficient to run a steam engine that produced more than 50 horsepower. The modern version of the scheme would cover much larger areas, use advanced technologies such as special surfaces that can trap radiation (a solid-state "greenhouse") and better heat-transfer fluids, and generate much greater power. Possibly the parabolic reflector might be replaced with a long Fresnel lens. A schematic diagram (not to scale) of a possible solar farm is shown at the beginning of this article. The solar farm system, too, would be costly as presently envisioned. The economics are difficult to assess, but rough estimates suggest that electrical power from such an installation, if built now, might sell at about five to ten times current rates.



Mad dogs, Englishmen, and solar researchers go out in the midday sun. This is the Penn State 1/6th-scale Archimedes concentrator-collector located on the roof of the Mineral Industries Building. On the left is Zenen Antoniak, graduate assistant in fuel science, and, on the right, Dr. Howard B. Palmer, professor of fuel science, the authors.

Research at Penn State

Work at Penn State is aimed at developing a concentrator-collector of the solar farm type that is built of readily available materials, that is simple in its operation, and that will heat a gas to fairly high temperatures (800-850°K) so it can move directly into a gas turbine in a closed-cycle (Brayton) scheme. This will avoid many heat-transfer problems.

We have introduced an Archimedes mirror to replace the more complex parabolic trough, have investigated graphite as an efficient solar energy acceptor, have developed a design that avoids the complication of evacuated pipes produced by others, and are experimenting with an optical tracking mechanism in which the collector pipe remains fixed while the mirror rotates around it. The basic ideas were presented in papers published in 1973 and 1974[2,3] and we are now doing proof-of-concept experiments, together with careful computer-modeling of the system.

After encouraging results with a very small-scale version, we have now built a system for detailed study that is about 1/6th the scale (in lateral dimension) relative to the size envisioned for a practical power system. It is shown on page 13. The Archimedes mirror, an array of suitably tilted flat mirror strips, is evident, as is the central collector pipe (of high-temperature glass, insulated) and the tracking system. A slot window in the insulating jacket on the lower side of the pipe admits the solar radiation. The radiation strikes a graphite slab running the length of the pipe. As the mirror rotates around the pipe, the insulation is rotated so the window also rotates. Gas is circulated through the pipe.

We are mainly interested in the temperature rise of the gas as a function of gas flow rate as it moves from pipe inlet to outlet, and in the asymptotically limiting gas temperature that is achievable with a given solar flux. Both can be calculated if we know the properties of the materials used, so valid comparisons of mathematical model and experimental model can be made. If the results agree well, then extrapolation to a full-scale model can be performed with confidence.

Our preliminary estimate[3] of the attainable conversion efficiency in a full-scale version of this system (six times wider, and many times longer) is 12 to 14 percent, relative to the flux of light energy *entering the collector pipe.* That figure includes the efficiency of a regenerative Brayton-cycle gas turbine operating at inlet conditions of 7 atmospheres pressure and 825°K, with a pressure ratio across the turbine of 2. Losses of solar flux before it gets to the collector pipe reduce the efficiency to more like 6 percent relative to the flux at the top of the earth's atmosphere. If that figure seems low, as it does to us, we might recall that James Watt's 1770 steam engine had an efficiency of about 3 percent.

If the next 200 years of solar power development can bring improvement comparable to that in 200 years of steam engine development, citizens of the 22nd century need not run short of energy.

Acknowledgment

Support for this work has come from Penn State's Applied Research Laboratory and the U.S. Navy.

References

1. A. D. Meinel and M. P. Meinel, "Physics Looks at Solar Energy," *Physics Today* 25: 44-47 (1972).
2. H. B. Palmer, "Molecular Greenhouses for Solar Farms," *Proc. 8th Intersociety Energy Conversion Engineering Conf.,* 1973, pp. 366-371.
3. H. B. Palmer and S. C. Kuo, "Solar Farms Utilizing Low-Pressure Closed-Cycle Gas Turbines," *Proc. 9th Intersociety Energy Conversion Engineering Conf.,* 1974, pp. 264-270.

The Authors

Dr. Howard B. Palmer is professor of fuel science and chairman of the fuel science section in the Department of Material Sciences. He is best known for his work on combustion, fast gaseous reactions, and chemiluminescence in low-pressure flames. He began research on solar energy in 1973.

Zenen Antoniak is a graduate assistant in fuel science and a candidate for the Ph.D. degree. He obtained his B.S. and M.S. degrees in mechanical engineering and environmental engineering from Drexel University, and spent several years with the Environmental Protection Agency.

Abler Named to Head Geography Department

Dr. Ronald F. Abler, associate professor of geography and a member of the Penn State faculty since 1967, has been named head of the Department of Geography.

He succeeds Dr. Wilbur Zelinsky, professor and head of the department since 1970, who has stepped down in order to devote full time to teaching and research.

Dr. Ronald F. Abler is the new head of the Department of Geography.

Dr. Abler holds three degrees in geography from the University of Minnesota. He served as visiting associate professor of geography at the University of British Columbia in the fall of 1971. From 1972 to 1974, he was visiting associate professor of geography at the University of Minnesota where he also served as associate director and atlas editor for the Comparative Metropolitan Analysis Project, sponsored by the Association of American Geographers (AAG).

The atlas he edited for the AAG project, *Comparative Atlas of America's Twenty Largest Metropolitan Regions,* is scheduled to be published this fall. He is a co-author of another publication of that project, a monograph on *The Twin Cities of St. Paul and Minneapolis,* which was issued last summer.

He is also co-author of *Spatial Organization: The Geographer's View of the World,* published in 1971, and co-editor of *Human Geography in a Shrinking World,* published in 1974.

He originated a course on the geography of communications systems and also teaches courses in cartography, urban geography, the development of geographical thought, and the geography of the future. His major research interests are communications networks, urban geography, and the relationships between them.

35 E&MS Advanced Degrees Given in May

Thirty-five masters' and doctoral degrees were awarded to students in the College of Earth and Mineral Sciences at the University's spring term commencement in May. Following is a list of these degrees and the titles of the theses or papers prepared as partial requirements for them. Information on borrowing or purchasing copies of these papers or theses may be obtained by writing the editor of this publication.

Ceramic Science

Hiroshi Abe., Ph.D., *Instrumented Charpy Impact Testing of Silicon Carbide;* Binod Kumar, Ph.D., *Phase Separation Characteristics of Soda-Lime-Silica Glass as Related to Melting History;* Kelly David McHenry, M.S., *Crack Propagation in Silicon Carbide;* Thomas Michael Yonushonis, M.S., *Crack Propagation in Silicon Nitride Ceramics;* William Paul Minnear, M.S., *Subcritical Crack Growth of Glassy Carbon in Water.*

Earth Science

Edgar William Kreiger, Jr., D.Ed., *Geology and Petrology of the Two Buttes Intrusion.*

Fuel Science

Andrew Gregory Gargus, M.S., *Considerations of Energy Flow on Campus;* Swadesh Sharma Raj, Ph.D., *A Study of Some Chemical Structural Parameters of Coals;* Luiz Edmundo Bastos Soledade, M.S., *Reactivity of Coal Chars in Air.*

Geochemistry

Harry Joseph DiGiacomo, Jr., M.S., *Nonspecific*

Ion Exchange of Zn and Ca in a Ca-Montmorillonite; Constantine Christos Exharchos, Ph.D., *Studies of the Fate of Cell Wall Polymers of Higher Plants in Peat: A Contribution to the Geochemistry of Coal.*

Geochemistry-Mineralogy

Ralph Fidele D'Andrea, Jr., M.S., *Replacement of Marble by ZnS in Chloride Solutions;* Walter Arthur Schreifels, Ph.D., *Liquid-Solid Equilibria Involving Spinel, Ilmenite, and Ferropseudobrookite in the System Iron Oxide – Al_2O_3-TiO_2 with Implication for Lunar and Terrestrial Petrology.*

Geology

Edwin Scott Bair, M.S., *Permeability Distribution in Surficial Glacial Outwash Revealed by a Shallow Geothermal Prospecting Technique;* Charles Russell Faust, Ph.D., *Numerical Simulation of Fluid Flow and Energy Transport in Liquid- and Vapor-Dominated Hydrothermal Systems;* Shirley Smith Fonda, Ph.D., *Cheilostome Bryozoans in Modern Bermuda Reefs, Systematics and Ecology;* John Henry Guswa, Ph.D., *Numerical Simulation of the Multi-layered Aquifer System in the Coastal Plain Area, Southeastern Pennsylvania;* Robert Eric Mazurak, M.S., *Economic Geology of the Warm Spring Talc Deposits, Inyo County, California.*

Metallurgy

Daniel Robert Marx, M.S., *Interdiffusion of Electro-deposits with Basis Metals.*

Meteorology

Robert Granville Bachman, M.S., *On the Mirage: Imaging Through the Horizontally Homogeneous Atmospheric Lens;* Joseph Peter Bassi, M.S., *Low Latitude Middle Atmosphere Ionization Studies;* Albert Randall Boehm, M.S., *Climatologically Transnormalized Regression Probability;* Dean Peter Gulezian, M.S., *A New Verification Score to Evaluate Worded and Categorical Forecasts;* Barry Warren Halcrow, M.S., *F_2 Peak Electron Densities in the Main Trough Region of the Ionosphere;* Vance Askew Myers, Ph.D., *A Diagnostic Analysis of a Strong Sierra Nevada Lee wave.*

Mineral Economics

Stephen Darryl Baker, M.S., *An Examination of Published Data to Determine Possible Causes of Outages in Nuclear Electric Generating Facilities;* John Wilbur Whitney, Ph.D., *An Analysis of Copper Production, Processing, and Trade Patterns, 1950-1972.*

Mineral Engineering Management

Victor Tomas Burgos-Toro, M.E., *A Study of the Feasibility of Open Pit Anthracite Mining.*

Mineralogy and Petrology

Kenneth Earl Windom, Ph.D., *The Effect of Reduced Activity of Anorthite on the Reaction Grossular + Quartz = Anorthite + Wollastonite: A Model for Plagioclase in the Earth's Lower Crust and Upper Manite;* Shu-Cheng Yu, Ph.D., *The Crystal Chemistry of a Zn-Li Silicate and Defect Substructures of Augitic Pyroxenes and Their Implications.*

Petroleum and Natural Gas Engineering

Jose Miguel Figueroa, M.S., *Effectiveness of Emulsions and Sodium Hydroxide for the Recovery of a Canadian Heavy Oil.*

Petroleum and Natural Gas Engineering and Operations Research

Osborne Olumide Phillips, Ph.D., *Optimization Models for a Crude Oil Storage/Export System*

Solid State Science

Ming Keang Louie, M.S., *Differential Thermal Analysis of Poly(vinylidene chloride) Single Crystals;* Janice Braun Perison, Ph.D., *Crystal Chemistry of the Alkyl-Ammonium Halogen Metallates;* Donald Anthony Rogowski, Ph.D., *Synthesis, Characterization, and Superconducting Tc of RF Sputtered Nb-Ge Films.*

Dean's Proposal of New Method for Cooling and Recycling Power Plant Waste Water Studied

Build up a reservoir or pond of solid ice by spraying water during winter months in northern latitudes, then use this mass of ice — that could be made more than a hundred feet thick — to dissipate waste heat from a fossil-fuel or nuclear power plant — this relatively simple idea was originally conceived by Dr. C. L. Hosler, dean of the College of Earth and Mineral Sciences.

Now the engineering, climatic, and economic feasibility of the proposal is being investigated by a team of Penn State researchers who have already determined that it's technically possible to create a 275,000-acre-foot block of ice — 12 billion cubic feet. Currently, they're looking into the practicability of the idea.

Basically, the plan calls for spraying water into a valley during one winter in such a way that it will form a deep lake frozen solid behind a dam. Water heated in the process of cooling the power plant's condensers would be ejected into the upstream end of the lake at the bottom of this huge "ice cube." Once cooled by contact with the ice, the water would then be recycled back through the plant's condensers, along with melt water.

The ice mass would be made large enough the first winter to outlast the summer. From then on, it would merely be replenished each winter, never being allowed to melt completely. Solar radiation, the researchers say, would cause only slight melting.

The research team is made up of two civil engineering faculty members, Dr. Arthur C. Miller and Dr. Gert Aron, and two research associates, George Geisler in nuclear engineering, and Dr. Jorge Pena in meteorology. Dean Hosler and Dr. Warren Witzig, professor and head of the Department of Nuclear Engineering, are serving as consultants to the project.

The study is supported by three Pennsylvania utility companies — Pennsylvania Power and Light Company, Philadelphia Electric Company, and GPU Service Corporation.

It has been estimated that by 1980 approximately a fifth of the total runoff per year in the U.S. will be required for cooling power plants. The heated water that has been used to cool a plant's condensers, if dispersed directly into a creek, river, lake, or other body of water without previous cooling, raises the overall temperature of that body and thereby has an adverse effect on its ecology.

To alleviate this problem, a number of water-cooling methods such as cooling towers, spray ponds, and cooling reservoirs are currently used. However, all of these ultimately disperse the heat and large quantities of water vapor into the atmosphere where they may be responsible for altering local weather patterns.

With increased electrical consumption in this country, the environmental impact of the present cooling systems can only continue to grow unless other answers to waste heat disposal — such as the one this group is investigating — are found.

To get the massive "ice cube" started, the researchers explain, the weather must be cold enough and the sprayed water droplets small enough that they freeze in the air before they hit the warmer ground. Once the base of the ice mass is a few feet thick, the water droplets would not need to freeze until they hit the ice foundation. At this point, the pressure of the sprayers could be lowered, allowing the droplet size to increase and decreasing the amount of energy required to pump the water.

The cost of setting up this system and establishing the mass of ice, the researchers theorize, should be offset by the increased plant efficiency that would result from the cooler water supplied to the condensers.

Other advantages would include: greatly reduced environmental impact since cooling methods that disperse the waste heat into the atmosphere where it might effect local weather would not be needed: a significant reduction in total water requirements since most of the cooling water would be recycled; and overall lowered cooling costs.

College News Notes

Hold Faculty Senate Positions

Two members of the E&MS faculty are currently holding positions in the University Faculty Senate.

Dr. Lee Saperstein, chairman of the mining engineering section in the Department of Mineral Engineering, is 1976-77 secretary of the Senate.

Dr. John J. Cahir, associate professor meterology, is chairman of the Joint Presidential-Senate Commission to Study Remedial Education. Commission members, named by the Senate chairman and the University's president, have been charged with studying and proposing solutions to "the need by many students for instruction which is preparatory to college-level courses in areas of quantitative thought and articulation."

Article Reprints Available

Reprints of the following articles by E&MS faculty members may be obtained by writing to the first author listed at: Mail Room, Mineral Industries Bldg., University Park, Pa. 16802.

"Bubbles in Ceramic Systems" by Dr. W. O. Williamson, professor emeritus of ceramic science, in *Ceramurgia International*, 2 (1976): 1:3-12.

Two articles co-authored by Dr. Roy J. Greenfield, associate professor of geophysics, and C. H. Stoyer — "Errors in the Location of a Buried Electromagnetic Source Resulting from Lateral Changes in Ground Conductivity" in *IEEE Transactions on Geoscience Electronics*, April 1976, pp. 115-117; and "Monitoring Groundwater Contamination with Geophysical Methods" in *AIME Society of Mining Engineers Transactions*, 260:19-23.

"Ore Solution Chemistry V. Solubilities of Chalcopyrite and Chalcocite Assemblages in Hydrothermal Solution at 200° to 350°C" by Dr. H. L. Barnes, professor of geochemistry, and David A. Crerar in *Economic Geology*, 71:4 (June-July 1976).

"The Elastic Properties of an Almandine-Spessartine Garnet and Elasticity in the Garnet Solid Solution Series" by Dr. E.K. Graham, associate professor of geophysics, and Donald G. Isaak, geophysics graduate student, in *Journal of Geophysical Research*, 81:14 (May 10, 1976).

Co-editor of Book on Africa

Dr. C. Gregory Knight, associate professor of geography, is co-editor of a textbook, *Contemporary Africa: Geography and Change*, published recently by Prentice-Hall, Inc.

The book, whose other editor is Dr. James L. Newman of Syracuse University, examines seven major topics which are developed in chapters by two dozen different authors in addition to the editors. Two of the other authors are also Penn State geography faculty members — Dr. Peter Gould and Dr. A. V. Williams.

Dr. Knight wrote chapters on "Wildlife," and "Prospects for Peasant Agricultures," and is co-author with Dr. Newman of an introductory chapter on "Contemporary Africa." Dr. Gould wrote on "Tanzania, 1920-1963," and Dr. Williams' chapter is entitled "Tourism."

Heads Mining Safety Subcommittee

Dr. Lloyd A. Morley, associate professor of mining engineering, is the chairman of a new mining safety standards subcommittee of the Standards Committee of the Industry Applications Society of the Institute of Electrical and Electronics Engineers.

This subcommittee is to develop mining industry electrical safety standards to be used by the federal Mining Enforcement and Safety Administration which is responsible for safeguarding the health and safety of miners.

E&MS Datebook

For descriptive material and information on how to enroll in any of the following continuing education activities of the College of Earth and Mineral Sciences, write to: (Name of Activity), J. Orvis Keller Building, University Park, Pa. 16802.

Mining Economic Analysis and Cost Control Short Course, November 8-12.

Review for Mining Professional Engineering Examination, November 29-December 1.

Awards to mining engineering students – Left above: John C. Wilcox, center, who received his B.S. in mining engineering with highest distinction at the University's spring term commencement, is shown as he accepted the 1976 Watchman Award, presented annually by the Old Timers, a group of coal industry executives, to an outstanding mining engineering senior at Penn State. Making the award is Jesse F. Core, right, a 1937 Penn State mining graduate and coal consultant with U.S. Steel Corp. Looking on is Edward G. Fox, a 1925 mining graduate and retired president of the Philadelphia Reading Coal and Iron Co. Both Mr. Core and Mr. Fox are members of the Old Timers and both have received Penn State's Distinguished Alumnus Award. Right above: John K. Hollman, a senior in mining engineering, accepts the 1976 Howard N. Eavenson Scholarship of $500 from Mrs. Margaret Core, chairman of the scholarship committee of the Pennsylvania-Western Section of the Women's Auxiliary to the American Institute of Mining, Metallurgical, and Petroleum Engineers.

Heads International Association

Dr. John D. Ridge, professor emeritus of economic geology and mineral economics, was recently elected president of the International Association on the Genesis of Ore Deposits for a four-year term.

News of E&MS Alumni

(The editor would like to receive more news of alumni to report under this heading. Alumni are invited to send news of their professional activities and honors received to her at 110 Mineral Sciences Bldg, University Park, Pa. 16802.)

Former MinEc Graduate Students Meet

A dozen former graduate students in mineral economics returned to the University Park Campus for a reunion planned by the Department of Mineral Economics and held on a weekend last August.

The alumni attended an informal party on Friday night, a meeting with the faculty on Saturday morning where they heard reports on the current status of the department and its future orientation and goals, and a family picnic on Saturday afternoon and evening at Penns Cave.

Those who returned included: Asman Azis., M.S. — '67 and Ph.D. — '70, mineral economist, Department of Energy, Mines & Resources, Ottawa, Canada; Robert Bruneau, B.S. — '71 and M.S. — '75, planning manager — natural resources, FMC Corp., Philadelphia; Robert R. Czarick, B.S. — '71, M.S. — '75, Federal Power Commission, Washington, D.C.; Andre Dorr, Ph.D. — '75, Ministry of Natural Resources, Quebec, Canada; Dave Hubbard, B.S. — '71, M.S. — '75, U.S. Geological Survey, Reston, Va.; David Huttenlock, B.S. — '73, Division of Economic Analysis, Washington, D.C.

William Prast, Ph.D. — '64, assistant to vice president — Eastern Hemisphere, Continental Oil Co., Stamford, Conn.; John Schanz, B.S. — '48, M.S. — '50, Ph.D. — '54, Resources for the Future, Washington, D.C.; George Schenck, Ph.D. — '67, associate professor of mineral economics, Penn State; Glen Wittur, M.S. — '64, Ph.D. — '74, Mineral Research Branch, Ottawa, Canada; and Jan Zwartendyk, Ph.D. — '71, Department of Energy, Mines & Resources, Ottawa, Canada.

Named Aminoil Vice President

George E. Trimble, who received his B.S. in petroleum and natural gas engineering in 1942, is now executive vice president and a director of Aminoil USA.

This firm is a wholly-owned subsidiary of R. J. Reynolds Industries, Inc., the parent company of a number of firms including R. J. Reynolds Tobacco Co.

Now responsible for all operating activities of Aminoil USA, he has had broad experience in the oil industry. In 1954, he joined Creole Petroleum Corp., Exxon's Venezuelan affiliate. He served as executive vice president and a director of Esso Libya, beginning in 1967, and, in 1969, moved to Tehran, Iran, as deputy general managing director and a member of the boards of the Iranian Oil Exploration and Producing Company and the Iranian Oil Refining Company, operators for the Iranian Oil Consortium.

Receives Glass Research Award

Dr. John B. MacChesney, who received his Ph.D. in geochemistry in 1959, was a co-recipient of the 1976 George W. Morey Award presented to three ceramic scientists by the American Ceramic Society's Glass Division at its fall meeting at Bedford Springs.

A member of the technical staff at Bell Labs, Murray Hill, N.J., since 1959, he has done research there in single crystals and glasses of interest for their electrical, magnetic, or optical properties.

Alumnus is Dressler Vice President

Dr. Keshav Prabhu, who received his Ph.D. in ceramic science in 1950, was recently appointed commercial vice president of the Dressler Ceramic Group of Pullmann Swindell Division of Pullman, Inc., Pittsburgh.

A native of India, he received his B.S. from Madras University and his M.S. from Ohio State University. He joined Dressler in 1969 and had been director of international sales since 1974.