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The Pennsylvania State University

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CLIMATIC CHANGE

by

H. A. PANOFSKY*

Introduction

Temperature, wind, rainfall, and other characteristics of the weather fluctuate on scales of time ranging from a fraction of a second to millions of years. We know a great deal about the variations on the smaller time scales, but human history is not long enough to permit us to be very certain about variations with periods of, say, 10,000 years. Fluctuations with periods of a second or so may be explained by "mechanical turbulence" produced by air flowing over rough ground. Wind gusts occurring approximately every minute are caused by heat convection; the regular diurnal variations of such things as temperature and wind are produced by the rotation of the earth. Weather changes also have periods of the order of a week, produced by cyclonic disturbances in the atmosphere in which the sun's heat is translated into air motion through the interaction of adjacent hot and cold air masses. In addition, there are slower variations with periods of the order of 3 weeks, the causes of which are not so well understood; they may reflect a natural oscillatory period of the earth's atmosphere or, possibly, a reaction to periodic changes in solar activity.

Next in order of scale are the annual variations, produced by the earth's revolution about the sun. Beyond these, the existence of irregular fluctuations has been suspected with periods of about 23, 90, 1000, 10,000, 250,000, 250,000,000 years, and many more.

The main point to be made here is that fluctuations presumably occur in all scales of time, and we know that those with short periods are not due to a single cause. It seems reasonable, therefore, that one should not necessarily attempt to explain the long-period fluctuations, the "climatic changes" by any single process.

There are many possible causes of climatic change and it is difficult to disprove the importance of any single effect, because the arguments must necessarily be qualitative. Weather processes are so complicated that physical theory and mathematics applied to them can solve only problems related to an unrealistically simplified atmosphere. Even qualitative reasoning runs into difficulties: an increasing intensity of sunlight has been claimed by some scientists to produce cooling on the earth; by others warming; both groups support their claims by reasonable physical arguments.

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H. A. Panofsky

The most important theories of climatic change can be classified as: (1) Earth's Crust; (2) Atmospheric; and (3) Astronomical. The following discussion will outline them further, with special emphasis on the astronomical theories. Figure 1 summarizes some of the important theories.

Earth's Crust Theories

The various theories involving the effects of changes in the earth's crust have one thing in common: the changes are slow. None of these theories could explain why, within the last million years or so, we had four successive and distinct advances of glaciers, with warm conditions in between. On the other hand, they cannot be rejected as explanations for the occurrence of long interglacial periods, perhaps 250,000,000 years long, which are interspersed by much shorter epochs, the length of which is only of the order of a million years, during which glaciation is possible.

Among the earth's crust theories, we might mention migration of the poles, mountain building, and volcanism. The first of these theories would assume that the north pole has taken different positions relative to the earth's crust. The main difficulty with the theory of polar shift is that it would produce glaciers in different regions at different times; the evidence is that at least the last major period of glaciation seems to have occurred simultaneously all over the earth.

Mountain building is quite possibly of major importance in the production of world-wide ice ages on the longest time scale. According to some geologists, there is an excellent correlation between the general periods of mountain building in the earth's history, and subsequent glaciation. On the other hand, some geophysicists believe that some mountain building has occurred somewhere at all times.

The effect of mountains is twofold: first, mountains reduce the free circulation between poles and equator, making the poles colder and the equator hotter. The cooling of the arctic regions then leads to increased glaciation, greater reflection of sunlight by the ice, and finally to colder climates throughout the world. Second, mountains are colder than the region near sea level and serve as a starting point for new glaciers. There is then both theoretical and empirical evidence that mountain building and glaciation are related; however, it is doubtful whether the glacial fluctuations with periods of 250,000 years or less can be explained in the same manner.

Along with mountain building, volcanism has been held responsible for climatic changes: volcanic dust would be blown into the high atmosphere, where it would scatter sunlight, thus reducing the radiation reaching the earth. In favor of this theory are the major volcanic explosions that, in historic times, have reduced solar radiation to an observable and, recently, measurable degree. Yet, severe objections can be made against the theory: that dust would settle too quickly (within a few years) to produce prolonged cold spells, unless it was suspended at extreme heights; that some periods of volcanism were not followed by periods of glaciation and vice versa. Yet, many of these objections can be overcome by postulating the right kind of volcanism at the right time; namely, explosions of such intensity that fine dust would be suspended in the upper atmosphere for very long periods.

Atmospheric Processes

In a way, the volcanism theory can be classified as a theory for ice ages caused by atmos-

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PENNSYLVANIA'S COLLEGE OF MINERAL INDUSTRIES

Dedicated to

Instruction and research in all fields of mineral discovery, extraction, and utilization to the end that true conservation—the efficient exploitation of known mineral deposits, the discovery of new deposits, and the development of new techniques for using mineral raw materials not now industrially employed—shall be achieved now and in the future.

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MINERAL TECHNOLOGY: Metallurgy, Ceramic Technology, and Fuel Technology.

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The Freshman Scholarship Program

The number of students being awarded B. S., M.S., and PhD. degrees in the mineral industries fields is far less than the country needs to maintain the pace of technological progress and the increasing standard of living which we have come to expect. Furthermore, from the standpoint of national defense a pessimistic picture develops when the number of science and engineering students being graduated in the United States is compared with the number in Russia. This latter is discussed at length in a Joint Committee Report of the 84th Congress just issued, entitled *Engineering and Scientific Manpower in the United States, Western Europe and Soviet Russia.* Of further and special interest to us is the fact that the College is not producing for our Pennsylvania industries the technically trained men needed for future leadership.

Despite the great and increasing demand for Mineral Industries graduates, the number has actually been falling off. This serious problem, along with one step toward a solution, was discussed in the January issue of MINERAL INDUSTRIES under "The Future Availability of Graduates in Fuel Technology." In order to have seniors there must be freshmen. The logical step to take, therefore, is to encourage the entrance of freshmen into the curricula, and the most immediately effective way to do this is with freshman scholarships, well publicized.

Our first scholarships on this program were three in Ceramic Technology, effective in the fall of 1954. The scholarships were donated by the Pfaudler Company, Garfield Refractories Company, and the O. Hommel Company. The publicity given the scholarships the preceding spring was sufficient to cause several first rate high school seniors to apply. Three were selected as recipients. They have done well. The scholarships were continued for a second year, and it is the intention of the donors to continue each for a third and fourth year as long as the boys continue to maintain satisfactory scholarship.

This past fall an additional six freshman scholarships in Ceramic Technology at $500 each were established, with the Harbison-Walker Refractories Company setting up two, and the following companies one each: National Refractories, Swindell-Dressler Foundation, North American Refractories, and Pittsburgh Plate Glass. An additional freshman scholarship was instituted by the Pennsylvania Ceramics Association.

Certainly the ceramics industry has moved in behind this program and is giving it fine support. New freshman scholarships in Ceramic Technology to start next fall are to date: one additional Harbison-Walker, a second Pfaudler, an additional Pittsburgh Plate Glass, an E. J. Lavino, and a Stackpole Carbon.

The fuels industry has been very active in instituting a series of freshman scholarships in the Department of Fuel Technology, effective next fall. The American Coal Sales Association Scholarship ($1,000 per year) was the first to be set up, followed shortly by Eastern Gas and Fuel Associates ($500) and by National Coal Association ($500). Publicity has now been issued on these three. Three additional $500 scholarships have just been subscribed, one by Bituminous Coal Research, Inc., the second by Pittsburgh Consolidation Coal Company, and the third by an anonymous donor. We have already (April 6) a good list of well-qualified applicants for the awards. Unquestionably the lone freshman in Fuel Technology will, when he is a sophomore, have strong backing from a good group of freshmen.

Another new addition is the E. J. Lavino and Company Scholarship in Mineral Economics ($500). This we hope is the beginning of a series of scholarships in this growing field where the demand for graduates is so much greater than the supply.

There is probably no better way for an industry to insure its future success than to make certain that well-trained, able college graduates are available for filling the many positions requiring these men. The efforts of the companies listed above are notable. More will no doubt join in this program. The College of Mineral Industries will welcome them.

E. F. Osborn

CLIMATE—

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pheric processes; other possibilities include the effect of increased carbon dioxide and increased cloudiness. The former is almost certainly quantitatively inadequate. Carbon dioxide absorbs radiation escaping from the earth, and reradiates part of this energy back to the earth, thus keeping the earth warmer than it would be otherwise. However, carbon dioxide is such a good absorber in a narrow band of the radiation spectrum, that neither a reduction nor an increase of the existing amount of carbon dioxide would have much effect on the radiation balance; the existing amount of carbon dioxide is already as effective as it ever could be. Further, if the carbon dioxide were greatly reduced, water vapor would still absorb and re-emit some of this same radiation.

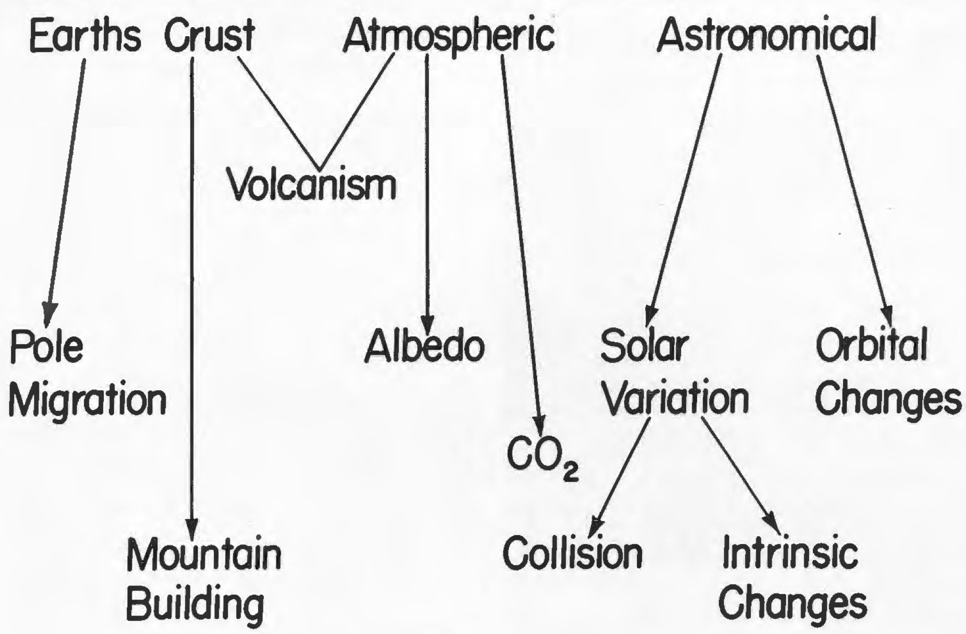
Clouds reflect, on the average, over 25% of the sun's radiation back into space. If the cloudiness increased, the ground would be heated less. Some meteorologists believe that weather changes are not produced by outside influences, but that the earth's atmosphere system is so complex that all sorts of possibilities occur more or less at random. In particular, a period of extended cloudiness over the globe might be produced in the normal course of events. Nevertheless, one of the difficulties with this theory is that, once a greater amount of sunlight is reflected into space, evaporation might be reduced, which in turn would decrease cloudiness. Whereas cloudiness is certainly a factor in climatic changes, it is not likely to be a primary cause, but rather a consequence of the changes.

Variations of Solar Activity

The astronomical theories of climatic changes rely either on changes of the characteristics of the sun itself, or on changes of the earth's orbit about the sun. Especially, the first of these theories is regarded quite favorably by many climatologists and astronomers in this country. In what way is the sun known to vary? The total visible radiation from the sun (as well as some of the near-infrared and near-ultraviolet portions) has been measured for many years. However, as instrumentation improved and as our knowledge of the effect of atmospheric interference increased, the variation of sunlight appeared to decrease until now it is recognized that any variation of total sunlight is smaller than what could be reliably measured.

Some astronomers have assumed that the sun may occasionally get brighter by collision with clouds of interstellar dust. Such collisions might occur at suitable intervals to explain climatic changes but this hypothesis seems to be quantitatively inadequate.

However, we know that some important changes occur on the sun, which have pronounced effects on the upper atmosphere, above 200,000 feet. Especially during periods of great sunspot activity, the upper atmosphere is bombarded by small particles from the sun, unusual amounts of light in the far ultraviolet, and X-rays. We know that these phenomena cause disruption of radio communication, aurorae, and irregular changes in the earth's magnetic field. But do they affect the weather? The difficulty is that only about 1/10,000 of the earth's atmosphere exists above 200,000 feet. If this part of the atmosphere is disturbed, it is not obvious that the much denser air near the ground would be affected. Possibly, the



Theories of Climatic Change

heated upper air could increase its radiation downward which would then give additional energy to the air at the lower levels.

There exist a number of statistical results indicating relations between solar activity and weather. Unfortunately, when one looks long enough for statistical relationship, one is likely to hit some spurious ones accidentally, particularly if there exists no physical theory to indicate what kind of relation to expect.

Nevertheless, it should be mentioned that apparently significant relations have been found among sunspots, air circulation, and temperature; between pressure patterns and index of magnetic storms (a good indicator of solar activity); and between sunspots and behavior of glaciers in Alaska. The reality of these relations is by no means taken for granted by all astronomers or meteorologists.

Solar activity has the well-known approximate periodicities of 11 and 23 years; periods of the order of 90 years are also suspected, but the record is too short to be reliable on this point. Whether there are any longer periods is not known.

Of course, one knows something about the characteristics of climatic change; so, one can simply postulate a variation of solar activity which agrees with the climatic change, without any fear of contradiction. Actually, it is not known what the effect of increased solar activity on climatic change would be. There are three rival theories. The most naive theory postulates that temperatures will go up when solar activity increases. This effect, then, is sure to dissolve any existing glaciers. The other two theories contradict this: if the temperature increases, the effect will be larger at the equator than at the poles. Thus, horizontal temperature differences are increased. This leads to increased circulation and, therefore, to increased evaporation. From this follows increased precipitation and increased formation of glaciers. Glaciers will reflect radiation in the arctic, further increase the temperature gradient, and, therefore, expand equatorward. The two remaining theories then differ on whether the sun will eventually become so active as to melt the precipitated ice and snow, or whether it will become less active and produce less precipitation.

Of course, it is difficult to see why solar activity should have been prominent in the last million years with a break in activity of 60,000,000 years preceding this period. Since little is known concerning long-range solar behavior, the sun could have been quiescent for 60,000,000 years. On the other hand, some scientists eliminate this difficulty by ascribing the fluctuations of climate with periods of a million years or less to solar activity, the long-period interglacials of much longer duration to lack of properly developed mountains.

Effect of Orbital Changes on Climate

The theory of climatic changes due to changes in the orbit of the earth has this immediate advantage over the others: we know from the principles of celestial mechanics how the earth's orbit has changed in the last million years or so, due to the influence of the moon and the planets. There exists three kinds of effects, all with different periods that interact with one another; two of them affect the northern and southern hemisphere in the same sense, the third in opposite sense so that, e.g., when the northern hemisphere gets warmer, the southern hemisphere gets colder.

1. The angle between the earth's orbit and the earth's equator, which is responsible for the seasons and is called the "obliquity of the ecliptic," has changed by about 2½°. The period of this variation is around 45,000 years. It has the same effect on both hemispheres: when the obliquity is large, the seasons are pronounced; furthermore, the pole-equator contrast in winter is enhanced.

2. The eccentricity of the earth's orbit has a period of about 90,000 years, and can become as large as .05 as compared to its present value of .016. In that case, the difference in radiation received from the sun at closest approach from that received at greatest distance is 20%; this is not at all negligible.

3. At present, the closest approach of the earth to the sun occurs in January; in 10,000 years it will occur in July, and in January again 21,000 years from now. This variation has opposite effects in the two hemispheres; for example, now the northern hemisphere has relatively mild seasons (compared to what will happen in 10,000 years). The reverse is true in the southern hemisphere.

None of the orbital changes affect the total yearly radiation from the sun significantly. However, Milankovitch, the principal exponent of the theory, points out that glaciers will expand if summers are cool (no matter how warm the winters) so that they do not melt in summer.

Milankovitch himself computed the orbital changes. (Recent recomputations by Yale astronomers added only small adjustments.) On the basis of these computations, he determined the periods at which cool summers would be produced in each hemisphere. He found that 4 such periods existed in the last 600,000 years. These periods he assumed to coincide with the 4 major advances of the glaciers during the last major ice age (in which we still find ourselves). He did not look into the possibility that increased obliquity might lead to increased temperature gradients, winds, evaporation, and therefore to ice ages.

At one time the orbital theory was so widely accepted by geologists that they used it to date events in the last million years. However, many objections have since been raised, which, in my opinion, can be overcome, although with some difficulty. Here are some objections and their refutations:

Objection 1: Effects would be different in the northern and southern hemispheres. Geologic evidence indicates glacial changes to be simultaneous around the earth. The evidence available during the last 80 years from climatic records also supports simultaneity.

Answer: The theory would make ice ages almost simultaneous, but out-of-step to 10,000 years. Geologic timing is not accurate enough to contradict this possibility. Short-period effects do not necessarily reflect long-period mechanisms.

Objection 2: Changes of orbital elements have occurred not merely in the last million years but at about the same rate for many millions of years. Yet, ice ages had a long break preceding the last million years.

Answer: Mountains of sufficient importance are needed to explain ice ages in addition to orbital changes.

Objection 3: The theory is quantitatively inadequate.

Answer: It is precarious to discuss effects quantitatively. The investigator principally responsible for this argument postulated that oceans would be affected less by changes in radiation than land. This is true, however, only when radiation fluctuates rapidly, with periods of a day or year. The ocean takes longer to absorb the radiation, but eventually will heat or cool as much as the land. With this correction, the theory appears quantitatively adequate.

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Dean Osborn and the Drake and Socony Mobile Scholarship Winners—Left to Right: Tom Turner, Jim Lander, Charles Bowman, Earl Hoyt, Dean E. F. Osborn, David Towell, Walter Hendricks, and J. T. Corless. Also Ken L. Harnden who is not shown.

Department of Meteorology

Dr. C. L. Hosler, associate professor of meteorology, presented a paper titled "Control of Ice Formation in Clouds to Produce Maximum Precipitation Growth" at an international conference on "The Scientific Basis of Weather Modification Studies," that was recently held at the Institute of Atmospheric Physics, University of Arizona.

Thirty-five scientists from 10 countries conferred on the present status and future outlook in the field of weather modification. Research in this field has been in progress at Penn State since 1949.

At the national meeting of the American Meteorological Society, held in Washington, D. C., April 30 to May 4, a joint paper was given by Hans Neuberger, head of the Department of Meteorology, and John Sherrod, Jr. entitled "Understanding Forecast Terms—Results of a Survey." At the same meeting, Dr. H. A. Panofsky, professor of meteorology, and Albert Miller, instructor in meteorology, present a joint paper on "Large Scale Vertical Velocities and Weather, January, 1953."

Department of Ceramic Technology

Thirteen ceramicists of the staff of the College of Mineral Industries presented papers at the 58th annual meeting of the American Ceramic Society in New York City, April 21 to April 28.

More than 2100 ceramic scientists, plant operators, engineers, designers and research men attended the sessions representing all parts of the United States and many foreign countries.

Penn State authors of papers were:

Malcolm C. McQuarrie, E. C. Subbarao and W. R. Buessem from the Department of Ceramic Technology; A. J. Majumdar, Rustum Roy, Elena C. Shafer, M. W. Shafer, and Cyrus Klingsberg, Department of Geophysics and Geochemistry; F. P. Glasser, E. F. Osborn, K. H. Gee, and M. E. Harnish, College of Mineral Industries; and Arnulf Muan, Department of Metallurgy.

Spicer Addresses Bituminous Coal Research

T. S. Spicer, professor of fuel technology, addressed executives of coal, railroad, and allied industries on "Future Availability of Fuel Engineers" at the Techno-Sales Conference of Bituminous Coal Research, Inc., in Columbus, Ohio, on April 18.

The objective of the Techno-Sales Conference is to help correlate the industry's research activities to coal's market-building efforts. This year's program was built around the general theme of "The Place of the Fuel Engineer in the Coal Industry."

In order to present this topic effectively, top leaders in industry and research discussed the responsibilities and opportunities for fuel engineers and engineering in coal sales work.

Highlighting the day's sessions was the luncheon address by Paul H. Robbins, executive director, National Society of Professional Engineers, on the "Professional Responsibilities of the Engineer."

Other speakers and their subjects were: E. C. Payne, consulting engineer, Pittsburgh Consolidation Coal Company, "Effective Fuel Engineering Practices for Coal Companies"; C. F. Hardy, director—sales engineering, National Coal Association, "Fuel Engineering Service by Coal Industry Associations"; R. S. Lane, Pocahontas Fuel Co., Inc., "The Relation of Fuel Engineering to Mining and Preparation"; W. W. Bayfield, executive vice president, American Coal Sales Association, "Coordination of Fuel Engineering with Coal Sales."

Completing the day's program were O. L. Scales, executive vice president, Enos Coal Mining Company, "The Fuel Engineer as Part of Management"; J. R. Garvey, BCR assistant director of research, "Combustion Engineers in the Coal Industry"; and Dr. A. A. Potter, president of BCR, "Essentials of Leadership."

Julius E. Tobey, president, Appalachian Coals, Inc., presided during the morning session and Carl R. Mabley, Jr., vice president, Island Creek Coal Sales Company, presided during the afternoon session.

CLIMATIC—

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Objection 4: Glaciers in equatorial regions also expand. The orbital theory produces no effect there.

Answer: The advance of glaciers in one hemisphere increases the reflecting power of the earth. This reduces the radiation generally, and cools the air. The air over the equator is mixed with the air over the rest of the earth by the circulation, so that equatorial regions also will experience cooling.

Objection 5: The time scale postulated by the theory of orbital changes is too short by geologic evidence.

Answer: Geologic dating is not sufficiently accurate.

Summary

It appears that many of the theories described can account for climatic changes. The theory of solar activity plus mountain building is the most popular in this country. I, personally, prefer the theory of climatic changes based on the earth's orbital changes plus mountain building, since the orbital changes must have taken place, whereas the long period variation of solar changes is still a matter of conjecture.

New Grants Established

A grant of $2,500 from Bird Well Surveys has been received by the University in support of research to be conducted in the Department of Geophysics and Geochemistry on the quantitative interpretation of electric logs. Dr. Benjamin F. Howell, Jr., professor of geophysics and head of the Department of Geophysics and Geochemistry, will direct the work.

The Jones and Laughlin Steel Corporation has established a graduate fellowship at the University with a $2,500 grant. The grant will support graduate training and research in the field of refractories in the Department of Ceramic Technology; the work will be directed by Dr. George W. Brindley, professor of solid state technology and head of the Department of Ceramic Technology.

Department of Fuel Technology

Dr. Howard Palmer, assistant professor of fuel technology, presented a paper entitled "Shock Tube Studies of High Temperature Fast Reactions," at the annual meeting of Project SQUID at Ann Arbor, Michigan, recently.

Department of Geophysics and Geochemistry

Dr. B. F. Howell, Jr., head of the Department of Geophysics and Geochemistry, attended the meeting of the American Institute of Mining and Metallurgical Engineers in New York recently, where he presented a paper entitled "Relationships between Science, Engineering, and Technology" before the Mineral Industries Education Divisions.

Bell Named Director of Experiment Station

Dr. Maurice E. Bell, formerly of Sylvania Electric Products, Inc., has taken office as director of the Mineral Industries Experiment Station and assistant dean for research in the College of Mineral Industries. His appointment became effective on May 1.

Dr. Bell fills the position vacated by Dr. John A. Hipple, who resigned, effective April 30, to become vice-president of the North American Philips Co. and director of the Philips Laboratories.

Maurice E. Bell

As manager of the solid state branch of the Physics Laboratory of Sylvania, Dr. Bell has been engaged in establishing a new semiconductor laboratory and expanding the research on electroluminescent phenomena and devices. He had previously been manager of the plans department in Sylvania's newly established Missile Systems Laboratory.

A native of Ohio, Dr. Bell received the bachelor of science degree with honors from Kenyon College, Gambier, Ohio, in 1932 and the doctor of philosophy degree in experimental physics in 1937 from the Massachusetts Institute of Technology.

During the academic year 1935-36 he held the Redfield Proctor travelling fellowship from M.I.T. at Trinity College, Cambridge, where he did research on the electron theory of metals.

For four years after leaving M.I.T. he was employed by the Westinghouse Electric and Manufacturing Co. in research on the electrical behavior of solid dielectrics and in development work on rotating-anode X-ray tubes. In the latter he made one of the first applications of molybdenite as a high-temperature, high-vacuum lubricant for bearings.

At the beginning of World War II, Dr. Bell joined the Harvard Underwater Sound Laboratory where he supervised studies of the radiation patterns of underwater transducers. He was one of the initial members of the Navy antisubmarine warfare operations research group organized by the NDRC in 1942, working with the Atlantic Fleet, the First Sea Search Attack Group, the Tenth Fleet, and later with the Seventh Fleet in the Southwest Pacific. For his work as a civilian scientist during World War II, he received the President's Certificate of Merit.

After the war, Dr. Bell became a member of the scientific staff of the London branch of the Office of Naval Research, carrying on liaison between European and American scientists at a time when, due to the war, publication backlogs were large and scientists in many European countries had lost touch. He became scientific director in 1951 and returned to this country at the end of 1953.

Dr. Bell's publications have been in the fields of gaseous electronics and electrical phenomena in solid dielectrics. He is a member of Phi Beta Kappa, the Scientific Research Society of America, the American Physical Society, and a fellow of the Operations Research Society of America and of the Physical Society (London). Dr. Bell was married in 1943 to Joan Ridley of Barrow-in-Furness, England, and they have one son.

Department of Geology

Dr. William J. Hoffmeister, paleontologist and geologist of the Tulsa Research Laboratories of the Carter Oil Company, recently discussed the use of some of the smaller microfossils in the modern search for petroleum with the graduate students of the Department of Geology in the Mineral Sciences Auditorium. Using colored lantern slides, he illustrated the manner in which fossil hystricospherids, spores, and pollen give indication of the direction toward the shallow water sand and reef sediments that provide the most important reservoirs for commercial occurrences of oil and natural gas.

Dr. Gerhard O. Kremp, research associate in geology, has been named senior research associate in geology, effective March 24. The title is a new one, established at the University for distinguished scholars employed by the University on other than University funds.

R. C. Neavel, R. R. Thompson, graduate students in the Department of Geology, and W. P. Schulhof, and F. Stanonis, graduate students in the Department of Mineralogy, were the principal speakers at the Henry Darwin Rogers Society Seminar held May 9 in the Mineral Sciences Auditorium. Their topic of discussion was "Diagenesis and Lithification of Sedimentary Rocks." On May 16, Professor Harold D. Wright, assistant professor of mineralogy, will speak on "Uranium Mineralization" at the final seminar for the spring semester sponsored by the Rogers Society.

Harold Davis Appointed Coal Age Managing Editor

Effective January 1, 1956, Harold Davis assumed the duties of managing editor of *Coal Age,* succeeding W. H. McNeal, who was recently promoted to the position of manager of research for *Coal Age* and *Engineering and Mining Journal.* Mr. Davis joined the editorial staff as assistant editor in August 1949 and was made associate editor in September 1953. Mr. Davis was formerly assistant supervisor of mining extension at Penn State and is a graduate of the University with a Bachelor of Science degree in mining engineering. He was employed by the Hudson Coal Co., Scranton, Pa., for three years before entering college.

Slobod Chosen as Head of Department of Petroleum and Natural Gas

Dr. Robert L. Slobod, formerly of the Research and Development Division, Atlantic Refining Co., Dallas, Texas, has been named head of the Department of Petroleum and Natural Gas.

His appointment became effective May 1. He succeeds Dr. John C. Calhoun, who resigned from the position September 1 to become dean of engineering at the Agricultural and Mechanical College of Texas.

Robert L. Slobod

Dr. Ralph F. Nielsen, associate professor of petroleum and natural gas engineering, has been acting head of the department since that time.

Dr. Slobod has been supervisor in charge of reservoir mechanics with the Atlantic Refining Co. since 1944. Prior to that time he was a member of the technical staff of the Bell Telephone Laboratories in New York, N.Y. His work there was in the field of microchemistry, oxide-coated cathodes, and radar developments.

Born in Pittsburgh in 1914, Dr. Slobod was reared in New York State. He received his undergraduate degree at Union College, Schenectady, N.Y., and in 1939 received his doctor of philosophy degree from Northwestern University at Evanston, Ill. His main research project at Northwestern dealt with the use of oxygen isotope ratios in geologic dating.

Of particular interest to the Pennsylvania area are Dr. Slobod's contributions in the field of water flooding dealing with displacement efficiency and areal sweepout. He is the author of 16 publications and holds several patents covering items of current interest in oil production work.

Dr. Slobod has been active in American Petroleum Institute sponsored research projects numbers 37 and 47, and for several years was chairman of their southwest committee on core analysis and well logging. In the American In-

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Mineral Industries 1946 to 1956

By John D. Ridge* and John J. Schanz, Jr.†

On May 10, 1946, the Board of Trustees approved the organization of a new curriculum in mineral economics—the first curriculum of its type in the United States. This action was the final step in a series of events which had begun with the offering of mineral economics subject matter under an advanced geology title in the 1941-42 academic year. When it was determined that this course was being accepted by the students, its title was changed to mineral economics in the 1942-43 academic year. This same course was offered on a regular basis until the formation of the new curriculum in 1946.

Now that 10 years has passed since the formation of the mineral economics curriculum, it is appropriate to review the results of this venture into a new field of applied economics. Penn State still remains as the only University offering mineral economics as an undergraduate curriculum, but it has been joined by several other institutions, such as Montana School of Mines and M. I. T., in presenting undergraduate courses in this field. Graduate programs in mineral economics at Wisconsin, Illinois, and Columbia have been offered for a number of years.

During its 10 years of existence the Department of Mineral Economics has encountered a normal amount of personnel turnover. Dr. W. M. Myers, who was the head of the department from its inception until his death in January 1951, was the only staff member during the first year. He was joined by Frank L. Fisher, assistant professor, for the 1947-48 school year. John J. Schanz, Jr., one of the first graduates of the curriculum, returned to the College with the rank of instructor to replace Fisher in August 1948.

Upon Dr. Myers death, Schanz served as acting head of the department until the appointment of John D. Ridge as permanent head on June 1, 1951. Dr. Ridge has remained as head of the department since that time and was named Assistant Dean for Instruction, in addition to his departmental duties, in October 1953. Other full-time members of the Mineral Economics staff have been John N. Hoffman, research associate from September 1952 until June 1955, and Louis T. Pugliese, research assistant from January 1953 until December 1954.

The curriculum has undergone a gradual process of evolution as experience has indicated where changes and improvement were needed. The first two years of the curriculum, which are common to all departments in the Division of Mineral Engineering, have had only minor revisions. The basic scientific background provided in these first two years has remained an essential foundation to a curriculum which emphasizes techno-economics.

*Professor and Head, Department of Mineral Economics.
†Assistant Professor of Mineral Economics.

Though the basic objectives which control the selection of courses for the last two years in mineral economics have not been altered, there has been a general tightening of course requirements over the years. The original curriculum specified 9 credits in general business, 23 credits in mineral science and technology, 13 credits in mineral economics, and 24 credits in electives. It was found that this program did not permit sufficient detailed coverage in mineral economics courses, omitted several important areas of mineral science and technology, and permitted somewhat too much latitude on electives.

The current curriculum calls for 12 credits in business, 27 credits in mineral science and technology, 21 credits in mineral economics, and 12 credits in electives. The major changes from the original program have been the addition of accounting, petroleum engineering, mineral preparation, and geophysics. In addition, the number of courses offered by the department itself has been expanded.

These additions were made by necessity at the expense of the total allowable elective credits. However, unlike other technical curriculums, mineral economics offers a broad education in its required courses. Consequently, 12 credits of electives offer the student sufficient opportunity for the introduction of further specialization or the addition of humanities courses as the student's personal requirements dictate. Though more specialized than is the case with a general business administration curriculum, mineral economics is not as specialized as most fields of work within the College of Mineral Industries. The problem is not to broaden the curriculum, but to prevent the student from diluting his program with too great a latitude in choice of electives. It is possible under these circumstances for the graduate to become a jack-of-all-trades, master of none.

The department offered six undergraduate and two graduate courses in its first year. In the next five years the number of undergraduate courses was increased to 12 by the addition of courses in conservation, a senior field trip, the mineral economy of the Soviet Union, petroleum and natural gas economics, mineral property valuation, and mineral data analysis. Since that time the course in conservation has been dropped. Currently eight courses are being offered once a year and three courses are being taught only when there is sufficient demand. The combined undergraduate and graduate courses are taught by the equivalent of one and a half full-time men.

The original two graduate courses were expanded to six by 1951, as it became necessary to provide for students progressing to the master's degree and the doctorate. At the present time, four graduate courses are being offered in mineral economics throughout the year, the other two having been discontinued. It is believed that the present graduate program is adequate to take care of students wishing to pursue work in mineral economics either on a major or a minor basis for either a master's or doctor's degree.

In 10 years the department has graduated 58 men and 2 women. There have been 50 bachelor's, 13 master's, and 1 doctor's degree granted to these 60 students. The variety of positions that have been open to mineral economics graduates is shown by the following table:

Type of Job	Number of Graduates
Government Services	11
Management and Administration	8
Engineering	8
Marketing	6
Teaching	4
Research	3
Banking and Investment	2
Graduate Study	2
Production	1
Purchasing	1
Technical Publishing	1
Armed Forces	6
Unclassified	7

Not only have a great variety of positions been open to graduates from mineral economics, but these positions are found in all parts of the mineral industries. Considering only those graduates who have entered industry, seven were employed by oil and gas companies, three were employed by coal companies, eight by metal companies, five by nonmetallic concerns, and eight are working with mineral industry service companies or manufacturing firms.

The fact that only three students out of 60 have been unsuccessful in obtaining a job commensurate with their training has substantiated the original belief that there is a place for a graduate with both technical and economic training in the mineral industries. Furthermore, in the three unsuccessful cases there is reason to believe that the training they received was not the real handicap. Also, experience seems to indicate that the mineral economics curriculum should not be so specialized as to train the student for only a single job classification with one type of mineral industry. If the student desires to point toward a job as specific as petroleum marketing, to the exclusion of other job opportunities, it is possible for him to do so through proper selection of electives.

In common with other lesser known curriculums in the College, mineral economics experienced a decline in enrollment from 1950 to 1954 which coincided with the unfortunate publicity given to a supposed (but nonexistent) surplus of engineers just before the Korean War. This decline affected all M. I. curriculums, but was most apparent in those fields of work which were unfamiliar to the recent high school graduate. The department had 11 students enrolled in its first semester in 1946. This figure reached a maximum of 21 in the fall of 1947 and held fairly constant during the peak years of veteran enrollment. Following this, enrollment declined steadily to a low of two students in the spring of 1954. With the upturn in M. I. enrollment, mineral economics enrollment has also started upward with five students enrolled in the current semester.

The average enrollment in mineral economics for 10 years has been 11 undergraduates, but the department has graduated an average of five bachelor's candidates per year. The disparity between enrollment and number graduating is the result of the concentration of enrollment in the junior and senior classes. This is to be expected, since the greatest source of students is by transfer. Only three students have enrolled in mineral economics as entering freshmen, none of whom survived the difficult first semester required of M. I. students.

The first graduate student in mineral economics enrolled in the Spring of 1947. Enrollment reached six by the Spring of 1950 and, unlike the undergraduate enrollment, has remained relatively constant since that time. Current graduate student enrollment in mineral economics is seven students.

It is obvious that the number of undergraduates enrolled in mineral economics as a major field does not justify the teaching of four undergraduate courses each semester. The reason the courses can be taught is that they are also service courses of interest and value to every student in the College. In 1946-47, the department offered three undergraduate courses to 97 students. This number increased to a peak load of 180 students in seven courses in 1949-50. Currently, the department is teaching six courses for 77 students. Over the 10-year period, the department has conducted 60 major course offerings for a total of 1,042 students. The average class size of slightly better than 17 students per class has proved to be a desirable balance between economy and optimum class size for teaching.

The greatest problem which faced the new Department of Mineral Economics in 1946 was to establish clearly the area of competence of this new field. Though mineral economics as a specific subject-matter field had appeared at least as early as the 1920's, its gradual evolution from the combined areas of economics, business administration, mineral engineering, industrial engineering, and economic geology had left the dividing line between mineral economics and these other areas quite obscure.

It would be erroneous to state that the definition of mineral economics is now complete. The boundaries are becoming more specific, but no field of work can ever become completely isolated from related areas. The mineral economist, like the agricultural economist, is more concerned with commodities than the economist who is mainly interested in functions. He is definitely more interested in management and economics than the mineral engineer. Though he shares an interest in management, operations, and economics with the industrial engineer and the business administration graduate, he confines himself to dealing with the peculiar economic problems associated with ore bodies and their exploitation and the extraction and primary utilization of their products.

Outside of the department itself, mineral economics has also become more clearly established. The formation of the Mineral Economics Division of the American Institute of Mining, Metallurgical, and Petroleum Engineers in 1948, and the current A.I.M.E. project of preparing a handbook of mineral economics has provided further professional status to the field. The appearance of textbooks in mineral economics, such as *Nonmetallic Minerals, Industrial Minerals and Rocks, Energy Sources—Wealth of the World, Petroleum Production Economics, Minerals in World Affairs,* and *Minerals in World Industry,* has provided a good beginning toward establishing a basic foundation of mineral economics literature. The *Resources for Freedom* report of the Presidents Material Policy Commission provided excellent examples of resource development problems, solutions of which are definitely within the competence of the mineral economist.

It has become possible over a number of years to develop a definite teaching program for the various courses offered by the department. In the first few years the subject matter presented in any given course would vary widely from semester to semester and from teacher to teacher. Today, though flexibility is still retained to allow for teacher preference and to keep courses contemporary, it is possible to state in broad terms what will, or will not, be included in any given course in mineral economics. Though it would be possible to further subdivide the subject matter of many of the courses offered, this would destroy their service value and lower enrollment to an uneconomic level.

Research has been an integral part of the department's work throughout its 10 years of existence. Three permanent State-supported projects have been in operation during the entire period: The Economics of the Mineral Industries of Pennsylvania, Depletion and Conservation of Pennsylvania's Mineral Resources, and Statistical Summary of the Mineral Production of Pennsylvania. Two major research projects were completed on external funds: Materials Survey—Tin, for the federal government; and A Study of Low Grade Manganese Deposits in Pennsylvania, for the Commonwealth. A few of the more important individual papers published by staff members have been: "The Role of Petroleum in the Economy of Western Pensylvania" by Dr. Myers, "The Pattern of International Trade in Metal Raw Materials" by Dr. Ridge, and "Reasons and Incentives for Pursuing a Career in the Mineral Industries" by Dr. Schanz. In addition to his papers, Dr. Myers was co-author of the book *Nonmetallic Minerals.*

A review of past achievements is a source of satisfaction, but establishing goals for the future is more rewarding. The research program of the past has been quite satisfactory for a new department with a small staff. However, in the future, the department must look to not only a continuation of its service to the Commonwealth through its permanent State projects but an increase in its externally financed projects. The number of areas of investigation for both government and industry which are open to the department are numerous. There is a more than adequate opportunity for the staff to contribute to knowledge, to serve the national economy, and to improve itself through research. There can be no justification for failing to capitalize on this opportunity.

Effort must be expended not only by members of the department, but also by people throughout the country who are primarily concerned with mineral economics, to continue the process of developing the fundamental concepts of mineral economics. An excellent start has been made in the span of a few years in defining the subject-matter field and providing an essential foundation of literature. This process must be continued to provide further definition and refinement.

For the department itself the current problem of greatest importance is that of enrollment. The 60 graduates who have gone on to industry, government, and teaching have established an excellent reputation and laid the groundwork for general recognition by employers. However, this will be of no avail if the growing demand, which has always exceeded the number of graduates, remains unsatisfied because there are only a few graduates available.

A start toward one possible solution to this problem was made this year by the establishment of a freshman scholarship in mineral economics by E. J. Lavino and Company. Additional scholarships would be desirable, at least in sufficient number to have one available each year for incoming freshmen and another one to reward particularly deserving upperclassmen. The value of scholarships is not only in gaining the student who is the recipient of the scholarship, but primarily because of the other students who become informed about the field of mineral economics as a result of their interest in the scholarship. In addition to the use of scholarships, every other possible effort must be made to inform high school students of the nature and opportunities in mineral economics work. Rejection of the curriculum by well-informed prospective students must be accepted, but lack of registrants due to ignorance of the field on their part can be overcome.

A similar program to strengthen enrollment in graduate training should also be begun. However, in the case of graduate students, fellowships will be utilized rather than scholarships. Though fellowships are available in the various fields of work in mineral science and technology, sufficient groundwork has not been done in developing similar opportunities for graduate students in mineral economics and the other departments in the Division of Mineral Engineering.

A strong feeling has developed on the part of many mineral economics alumni that prospective students and employers frequently disregard the curriculum because of its name. Though the term "mineral economics" has become well accepted over a number of years and is descriptive of the subject matter offered in the department's courses, it leaves something to be desired as a name for the curriculum itself. Perhaps this is a problem which will be solved in time merely by students and employers becoming more familiar with the curriculum. However, if this does not occur, it may become necessary to introduce a name which properly describes a man who has been trained in the technical and economic problems of the operation and management of all of the various mineral industries.

Finally, another goal of increased enrollment should be toward elevating the caliber of the students enrolled in and graduating from the department. A department depending to a great extent on transfer students unavoidably obtains a number of students who were not suited for the curriculum which was their original choice. The department has been fortunate in having a good many students who transferred to the department primarily because they wished to pursue a career in a field which was closely related to business and management as well as to science and engineering. Even those students that have transferred to mineral economics with the main objective of leaving a more technical curriculum to which they were not suited have been able to maintain an acceptable level of achievement in a curriculum which is primarily technical in nature.

Ideally, the mineral economics student should be one of the most versatile of all students entering the College of Mineral Industries. He must successfully complete the same rigorous first two years required of students majoring in mineral sciences or engineering. Thereafter, he is faced with courses in every department of the College as well as selected courses from the College of Business Administration. Under the circumstances, the ideal student for mineral economics must be one possessed of equal talents in science, engineering, and administration. Without these qualifications, the graduate will not achieve the high-level management positions in the mineral industries which are considered as the ultimate objective of training in the mineral economics curriculum.

SLOBOD—

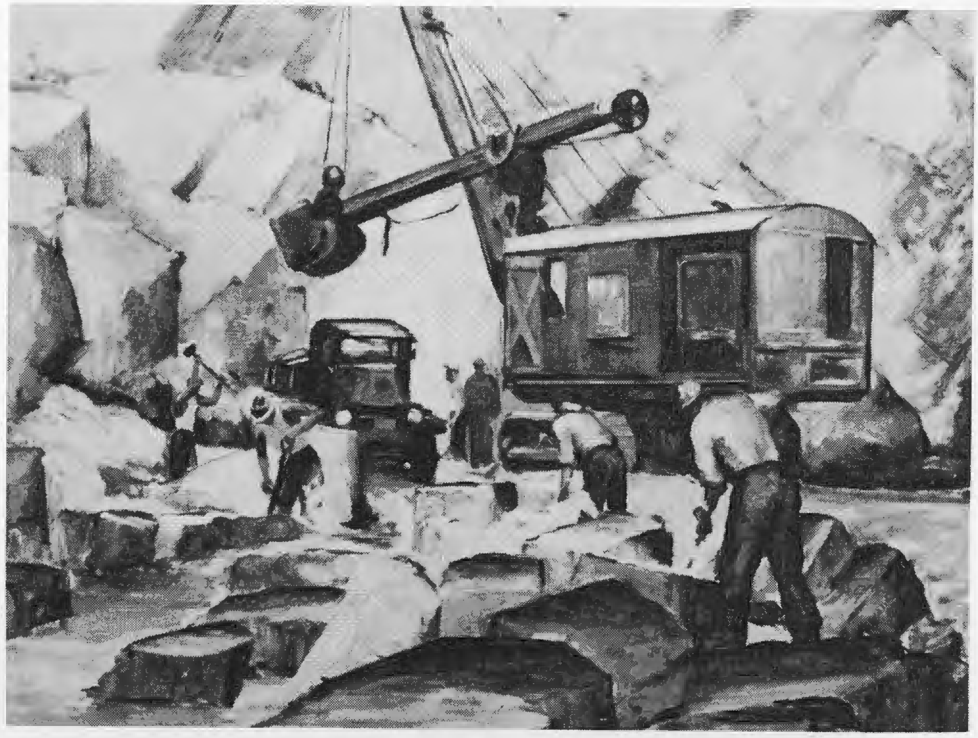
(Continued from page 5)

stitute of Mining and Metallurgical Engineers he has served on the Publications Committee and is at present a member of the Ferguson Award Committee. Earlier he took part in American Chemical Society local affairs and was editor of their journal, *The Southwest Retort*. He is also a member of Phi Beta Kappa, Society of the Sigma Xi, and Phi Lambda Upsilon.

Dr. and Mrs. Slobod have two children, Bobby, 10, and Meredith, 7.

Department of Mineral Economics

Dr. John J. Schanz, Jr., assistant professor of mineral economics, attended the New York meeting of the A.I.M.E. recently and presented a paper entitled "Measurement of Trends in the Mineral Industry" before the Mineral Economics Division. Dr. Schanz has also served in recent months on the Ad Hoc Synthetic Mica Panel of the Materials Advisory Board of the National Academy of Sciences. This panel has made five inspection trips to various companies interested in conducting research on the production of reconstituted sheet from synthetic mica. On March 29 the panel completed its review and analysis of the research proposals and has prepared its recommendations for the guidance of the federal government in negotiating contracts for the conduct of the research.



"The Quarry"—This Painting by Professor Floyd Gahman of the Ogontz Center is an Indefinite Loan to the M. I. Art Gallery.

Department of Mining

James I. Craig, Mining Engineering, '35, formerly chief of the Plant Department of the New Jersey Zinc Company's operations at Austinville, Virginia, has been appointed Superintendent of that company's Empire Zinc Division, Hanover, New Mexico.

Junior and senior students in mining engineering recently completed a five-day inspection trip through the mining fields of Western and Central Pennsylvania. Included in the trip were the Vesta coal mines and preparation plant and the Aliquippa works of the Jones and Laughlin Steel Corporation, the Annandale underground limestone mine of the Michigan Limestone Division of U. S. Steel Corporation, and the Mine No. 15 of Barnes and Tucker Company, Barnesboro, Pennsylvania. While in Pittsburgh, the group visited the U. S. Bureau of Mines and the plant of the Mine Safety Appliances Company. The trip was under the direction of Dr. Felix du Breuil and Dr. B. J. Kochanowsky of the Department of Mining.

Two German engineers, specialists in belt conveyor design and operation, were recent visitors at the College of Mineral Industries. They were H. P. Lachmann, Dr.-Ing., of the Franz Clouth Gumminwarenfabrik AG., an important manufacturer of conveyor belting, and R. Oettel, Dr.-Ing., of the Rheinische Braunkole AG., a large producer of brown coal, both located near Cologne in Germany. Accompanied by F. du Breuil of the Department of Mining, they visited the St. Nicholas Breaker of the Reading Anthracite Company, and the iron ore docks of the Pennsylvania Railroad in Philadelphia. Their trip continued through Ohio, Illinois and New York State before their return to Germany.

Department of Mineral Preparation

Junior and senior students majoring in mineral preparation visited two of the world's largest coal preparation plants during a recent field trip. These were the Vesta plant of the Jones and Laughlin Steel Corporation and the Robena plant of the U. S. Steel Corporation. In addition to visiting the plants the students went underground in the Vesta mines to see the actual mining operations. They also visited the Aliquippa works of the Jones and Laughlin Corporation to see the coal being converted into coke and coke being utilized to make iron and steel products. Other plants visited on the trip were the drycleaning coal preparation plant of the Barnes and Tucker Coal Company in Barnesboro, Pennsylvania, and the Cryolite Flotation plant of the Pennsylvania Salt Manufacturing Company in Natrona, Pennsylvania.

Department of Mineralogy

Dr. Roland Rynninger, in charge of chemical analytical work of the Atomic Energy Company of Sweden, visited the College recently to discuss problems of black shale minerals with Dr. T. F. Bates, professor of mineralogy, and other personnel conducting research on uraniferous shales. Dr. James Schopf and Dr. Ralph Gray of the U. S. Geological Survey Coal Petrology Laboratory of Columbus, Ohio, also visited the College of Mineral Industries to discuss similar problems with Dr. Bates, Dr. William Spackman, associate professor of paleobotany, and other staff members working on lignite and shale problems.