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Iowa State Mining and Mineral Resources Research Institute

ANNUAL REPORT

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Iowa State University
Ames, Iowa

ANNUAL REPORT

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Ray W. Fisher, Director

Mining and Mineral Resources Research Institute
Iowa State University
Ames, Iowa

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ABSTRACT

Education and research programs are being developed at Iowa State University to strengthen graduate education and research training of scientists and engineers for work in the field of mining and mineral resources. A need for this development was first recognized by Congress when the Title III program, the establishment of state Mining and Mineral Resources Research Institutes, was incorporated into the Surface Mining Control and Reclamation Act of 1977 (Public Law #95-87). As a consequence of this Act, 31 Institutes including Iowa State University have been established at a corresponding number of educational institutions. While the Iowa State Mining and Mineral Resources Research Institute will provide increased opportunities for research in the field of mining and mineral resources, the full potential for education and training is being realized through this Institute's graduate education and research programs. The major elements of the Institute's overall program are 1) education and training; 2) mineral-related research and experiments; and 3) technical information dissemination. The educational program is intimately tied to the research program through an interdepartmental minor offered by the Graduate College. This minor includes a special curriculum and courses to address the unique problems related to the development of our mineral resources. The Institute research effort not only draws from a large continuing base research program at the University but focuses on three research areas: mineral characterization, mineral processing, and reclamation of surface-mined areas. The objectives set by this Institute have tied together various disciplines needed to cope with the complex problems of extracting and processing fossil fuels and minerals.

SECTION I. GOALS AND OBJECTIVES OF THE INSTITUTE

The Iowa State Mineral Resources Research Institute conducts technical projects of a substantive nature which are directed at the near, intermediate, and long term problems limiting the development of mineral extraction, characterization, and processing. These projects will continue to be carried out by competent researchers in consultation with representatives from industry and government.

The Institute goals, aimed at addressing mineral resource problems, are classified into three major groups: 1) education and training; 2) research and experiments; and 3) technical information dissemination.

Education and Training

A high priority goal of the Institute is to enhance and expand graduate degree programs designed to educate scientists and engineers in mineral science and technology. Education of individuals to fill immediate scientific and managerial gaps in both government and industry is particularly important. Current and future degree programs will be modified to meet changing requirements in the nationwide Mineral Research Institute program.

The Institute's intended training program, i.e. special conferences, seminars, and short courses, provides an opportunity for current mineral scientists and engineers to be updated on new technologies and research.

Research and Experiments

In the near and intermediate term, technical projects focused at identifying mineral extraction and characterization techniques will be pursued. Several of our current projects addressing reclamation impacts have drawn to a close in the past months as final data have been compiled and analyzed. The most promising current projects address better ways to characterize mineral structure during analysis and to predict mineral behavior during processing. In the long term, several projects addressing improved mineral processing techniques will be emphasized.

Methods of characterization and processing have been tested in laboratory-scale experiments. Further experiments will be conducted to verify and expand our current data bank.

Information Dissemination

As verifiable results are obtained from the Institute's research and experiments, technical information will be transferred to other researchers and to public policy makers at the local, state, and federal levels via seminars and educational programs. Specialized information will also be provided to various mineral-related industries.

ADMINISTRATIVE STRUCTURE

During the first year of its initial performance period, the Iowa Mineral Research Institute implemented its administrative and scientific operations as is shown in the Table of Organization, Figure 1. Throughout the first two years and during the start of its third year, the following administrative structure has overseen Institute operations.

Executive Committee

Important to the operation of the Institute was the creation of the Executive Committee, composed of the Director of the Energy and Mineral Resources Research Institute, Robert S. Hansen; Iowa State University Vice-President for Research and Dean of the Graduate College, Daniel J. Zaffarano; and the Director of the Iowa State Mining and Mineral Resources Research Institute, Ray W. Fisher.

The Executive Committee represents the policy-making body of the Institute and as such is responsible for all institutional decisions. In order to maintain effectiveness, the membership of the Executive Committee is deliberately limited to a close-knit administrative unit which oversees the whole of Institute operations. In addition, the committee reviews the technical merits of the Institute's research programs prior to implementation. The committee meets on an as-needed basis to coordinate mining and minerals research for the Institute and approve allocation of funds made available to the Institute.

Specifically, the responsibilities of the Executive Committee have been to:

1. Develop Institute priorities and establish an overall research program to carry out these priorities;

2. Authorize disbursement of funds to Institute budgets based upon documented recommendations provided to the Institute Director;

3. Appoint an Academic Advisory Committee to advise the Executive Committee on expedition of the Institute's Allotment Grant Program, Fellowship Grant Program, Research Grant Program, and additional research programs, as deemed appropriate and necessary by the Executive Committee in accordance with Title III requirements;

4. Solicit proposals in the interest of the Institute;

5. Act on specific proposals solicited by the Institute;

6. Accept unsolicited proposals for pursuit in the interest of the Institute at the discretion of the Executive Committee.

IOWA STATE MINING AND MINERAL RESOURCES RESEARCH INSTITUTE

TABLE OF ORGANIZATION

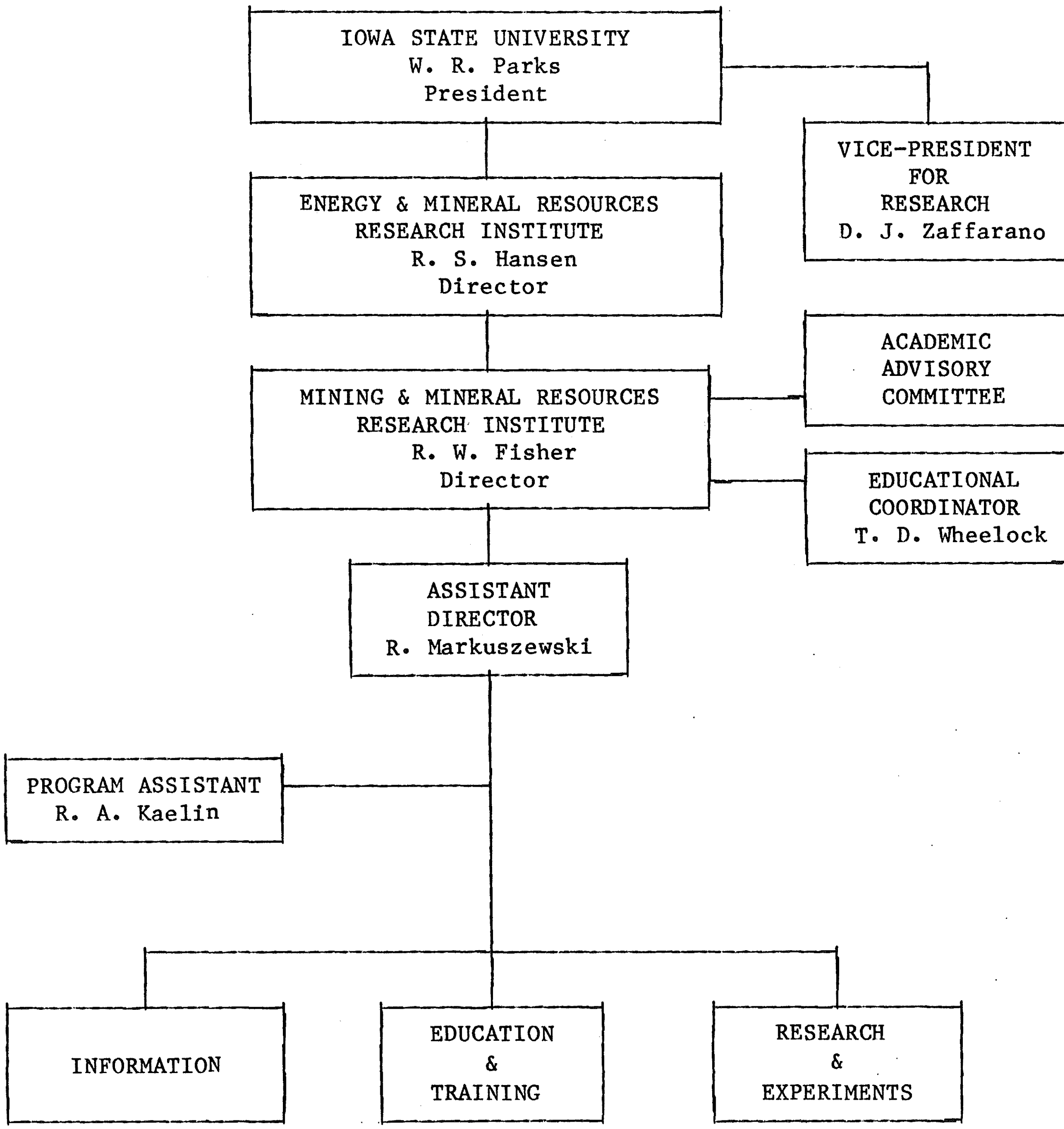

Figure 1

Academic Advisory Committee

Another important aspect in the administration of the Mineral Institute program at Iowa State University was the formation of the Academic Advisory Committee. This particular committee is composed of representatives of some of the departments participating in the Institute's research programs:

Carl E. Anderson	Associate Professor of Agricultural Engineering
Renato G. Bautista	Professor of Chemical Engineering
Ray W. Fisher	Institute Director (ex-officio member)
Raymond T. Greer	Professor of Engineering Science and Humanities
Richard L. Handy	Professor of Civil Engineering
Stanley J. Henning	Associate Professor of Agronomy
Bert E. Nordlie	Professor of Geology and Chairman of Earth Sciences Department
Ruth Swenson	Assistant Dean of Science and Humanities
Thomas Wheelock	Professor of Chemical Engineering and Committee Chairman
David Wilder	Professor of Material Science and Engineering and Chairman of Department

Specifically, this committee:

1. Advises the Institute Director on the Assistantship Grants Program's viability;

2. Makes recommendations to the Director on use of funds for broadening the scope of Institute programs;

3. Evaluates proposals submitted by potential graduate and faculty researchers in mining- and mineral resource-related projects sponsored by the Institute.

This latter function became all important in subsequent actions as the Academic Advisory Committee screened and selected graduate students from various disciplines to participate in an emerging interdepartmental program of mineral-related research. (See Section III of this report for a more complete listing of active projects currently sponsored by the Institute).

Institute Officers

Adherence to the philosophy of the Mineral Research Institute Program was ensured through the efforts of our committees to establish on campus the academic research programs which would produce scientists and engineers well-grounded in aspects of mining engineering, mineral resource identification and management, and mineral processing. Putting this philosophy into daily practice has been the duty of the Institute's administrative officers. Again, the Institute's Executive Committee saw the need to keep the administrative structure streamlined in order to ensure efficiency in operation.

The responsibilities of the Institute's daily operations were divided among a cohesive infrastructure which assured a smooth transfer of information on decisions of policy, priority, and budget:

Ray W. Fisher, Institute Director

The Institute Director has the responsibility to operate the Institute and act as executive secretary to the Executive Committee. Funds allocated to the Institute are under the budgetary control of the Director with approval of the Executive Committee. The Director is advised by the Assistant Director and the Educational Coordinator, and interacts with the Academic Advisory Committee in an ex-officio capacity.

Richard Markuszewski, Assistant Director

The Assistant Director has the responsibility to help organize new research at the University through the Institute and to identify possible outside sources for research work, relating this type of work to the direction of the Institute's operation. The Assistant Director reviews the scientific progress of all research projects and functions for the Institute Director in his absence.

Thomas D. Wheelock, Educational Coordinator

The Educational Coordinator chairs the Academic Advisory Committee and has the responsibility to coordinate graduate student activities of Institute programs, assure information transfer between committees, and coordinate applicable University-wide education programs with developing Institute research programs.

Roy A. Kaelin, Jr., Program Assistant

The Program Assistant has the responsibility of coordinating day to day research efforts as they apply to research budgets; to organize the operation of specific projects, work for others, and various Institute programs; to help develop new programs in cooperation with the Educational Coordinator, and Assistant Director; and, to prepare technical progress reports.

SECTION II. EDUCATION AND TRAINING PROGRAM

With the infrastructure developed and put into place early in the first year of its operation, the Institute implemented in its subsequent years a comprehensive research program, interdisciplinary in nature, yet highlighting department-specific research related to the philosophy and intent of the nationwide Title III program. The overall Institute research effort has involved an organization of scientists and engineers working on specific projects in each of three programs outlined in the Title III program. Allotment, fellowship, and research grants support faculty to train and educate students in mineral-related research.

INTERDISCIPLINARY MINOR IN MINERAL RESOURCES

During the first and second years of its operation, the Iowa Mineral Research Institute chronicled several achievements in the education and training program funded by the Allotment Grant. Significant among the Institute's achievements was the establishment of an interdepartmental minor in Mineral Resources. Proposed by the Graduate College, the minor involves these departments: agricultural engineering, agronomy, animal ecology, botany, chemical engineering, civil engineering, earth sciences, engineering science and mechanics, industrial engineering, materials science and engineering, nuclear engineering, political science, sociology and anthropology.

Since its inception, the minor has strengthened the graduate education and research training of scientists and engineers for work in the field of mining and mineral resources. The minor in its program of courses makes use of the Energy and Mineral Resources Research Institute (EMRRI) already established at Iowa State. The program has tied together various disciplines needed to cope with the complex problems of extracting and processing fossil fuels and minerals. Nearly 80% of the students who have participated in this program have found greater employment opportunities as trained personnel in the mining and mineral industry. The remaining 20% of participating students are pursuing further graduate study in their chosen field. Of those 20%, nearly 75% are participating in ISMMRRI's graduate program.

The objectives of the minor have been to provide students with a basic understanding of the nature of mineral resources, of mining methods, of mineral processing techniques, and of related social, legal, economic, and environmental aspects of mining and mineral extraction operations. The minor has also provided students with training in the application of the techniques of their major field to the solution of coal and mineral resource problems.

Students who have chosen to minor in mineral resources are required to take a series of courses which will acquaint them with the field and to conduct research on a topic of importance to the field. The requirement for the minor at the master's degree level is the completion of a thesis in the major field. This thesis subject deals with a coal or mineral resource problem and is based on a minimum of six semester credits of research. The requirement for the minor at the doctorate degree level includes the completion of a two-semester (6-credit) course sequence in mineral resources, completion of two additional graduate courses dealing with a coal or mineral resource problem and is based on a minimum of 14 semester credits of research. (See Appendix A for a synopsis of available courses comprising the minor in Mineral Resources.)

While the present staff is capable of teaching many of the topics which will be included in the mineral resources courses, additional faculty members from various participating departments teach the two new interdisciplinary graduate courses, Mineral Resources I and II.

The first of these courses, Mineral Resources I, focuses on mining coal and mineral deposits and associated aspects of locating and evaluating such deposits, mineral production, and land management and restoration. It is taught by a team selected principally from the Departments of Civil Engineering, Earth Sciences, Agronomy and Agricultural Engineering. The second course, Mineral Resources II, focuses on properties, characterization, separation, and processing of the minerals following mining. It is taught by a team selected principally from the Chemical Engineering, Materials Science and Engineering, Engineering Science and Mechanics, and Earth Sciences Departments. Faculty from other participating departments are called on to discuss the related social, legal, economic, and environmental aspects of mining and mineral production.

Sources of Potential Students

In order to ensure active participation, those students awarded research assistantships through the Fellowship Grant are required to enroll in the mineral resources educational program supported by the Allotment Grant.

Graduate students majoring in any of the fields represented by the departments participating in the interdepartmental program are a potential source of students for the Institute's educational program. Students working on coal and mineral-related research topics are the most likely to choose the mineral resources minor. The following estimate of the number of students who may minor in mineral resources in any given year was made by consulting various faculty representatives from the participating departments:

Departments	Students
Agricultural Engineering	4
Agronomy	5
Animal Ecology	2
Botany	2
Chemical Engineering	5
Civil Engineering	5
Earth Sciences	12
Engineering Science and Mechanics	2
Industrial Engineering	2
Materials Science Engineering	3
Nuclear Engineering	2
Political Science	2
Sociology and Anthropology	2

Comparison of Programs

This educational program, while similar to the Water Resources Research Institute program at Iowa State University, is a non-traditional program and therefore unlike established disciplines at most other colleges and universities. Of the current 31 institutes in the Title III program, the traditional programs are usually undergraduate courses which provide specialized training in mining engineering (16 schools), petroleum engineering (17 schools), metallurgical engineering (31 schools), geological engineering (11 schools), ceramic engineering (11 schools), mineral engineering (2 schools), and mineral processing (1 school)*. Relatively few schools have significant graduate programs in mining engineering; fewer than 10 doctorate degrees have been granted annually in the United States in the field of mining engineering alone. Other schools, the University of California at Berkeley and the Massachusetts Institute of Technology, for example, recently instituted interdisciplinary graduate programs similar to the one described here.

There are no other comparable programs in Iowa. In adjacent states the University of Missouri at Rolla offers both undergraduate and graduate degrees in mining engineering and geological engineering; the University of Minnesota offers undergraduate and graduate degrees in geological and mineral engineering; the University of Wisconsin at Platteville offers an undergraduate degree in mining engineering; and Southern Illinois University offers a bachelor's degree in mining technology and a master's degree in mining engineering. None of these programs is of the same interdepartmental nature as the Institute's current program; hence, the need exists for this type of program at Iowa State University which is situated amid abundant deposits of coal, limestone, and gypsum.

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*The number of schools offering these programs was reported for the year 1981 by the Engineers Council for Professional Development.

SECTION III. FACULTY AND GRADUATE RESEARCH PROGRAM

Many of these researchers have on-going mineral research projects; others are developing projects. An integral part of the Institute's successful operation is the interaction of faculty and students in research. Faculty and staff are the key to both the research and education program.

ACTIVE INSTITUTE PROJECTS

Graduate student research has continued throughout the Institute's first and second year and is now in the third year of operation. Students awarded research assistantships through the Fellowship Grant were also allocated funds to purchase supplies in connection with their research. This method of allocating seed funds from the Allotment Grant allows the Institute to maintain flexibility in its program from that conducted through the Fellowship Grant. Items purchased from the Allotment Grant can be utilized by the department in which the student conducts his research and still be made available as needed to other disciplines participating in the Institute's overall research effort.

Currently, the Allotment and Fellowship Grants support graduate students in the following categories of mineral-related research.

CATEGORY	COMPLETED DEGREES	PRESENT DEGREE CANDIDATES
Mineral Characterization	Robert Dawson-Summer '82 Roger Kocken-Summer '82	Curtis Lindsay-Spring '83 Kyle Hansen-Summer '84 Barbara Wheeler-Fall '83
Mineral Processing	Charles Allen-Summer '82 Michael Dobbins-Summer '82 David Felker-Summer '82 Leon Heath-Fall '82 Michael Stephenson-Spring '82	Bruce Kreischer-Summer '84 Michael Dobbins-Summer '83 David Felker-Summer '83 Leon Heath-Summer '83 Lawrence Wu-Spring '83
Mining Engineering		John Rohde-Summer '83 Loras Klostermann-Summer'83
Geology (Mining)	Joseph Klingshirn-Spring '82	Kathleen Galloway-Fall '82 Jerold Herwehe-Fall '82 Robert Osolin-Summer '83
Land Reclamation	Terrence Hingtgen-Summer '82 Scott Killpack-Spring '82 George Peregrim-Summer '82	John Kean-Summer '84

On the following pages is a synopsis of each student's objectives, approach, results to date, and projected schedule of accomplishment. The Allotment and Fellowship Grants have supported the research of eleven graduate students. The abstract of each student's thesis appears after the listing of active Institute projects.

ACTIVE MINERAL INSTITUTE PROJECT SUMMARY

Summarized below are research projects currently sponsored by the Iowa State Mining and Mineral Resources Research Institute. The detailed description of each project is given in the following pages.

MINERAL CHARACTERIZATION

Topic: THERMAL BEHAVIOR ON MINERALS COMMON IN LOW TEMPERATURE ASH CONCENTRATES FROM COALS.
Student: Curtis Lindsay
Advisor: Donald L. Biggs
Professor of Earth Sciences

Topic: GEOCHEMICAL STUDY OF EVAPORITE DEPOSITS IN IOWA.
Student: Kyle S. Hansen
Advisor: Steven M. Richardson
Assistant Professor of Earth Sciences

Topic: RAPID DISSOLUTION OF COAL AND MINERALS FOR ANALYSIS.
Student: Barbara Wheeler
Advisor: Richard Markuszewski
Assistant Director, ISMMRRI

MINERAL PROCESSING

Topic: RECOVERY OF SULFUR AND LIME FROM WASTE GYPSUM.
Student: Bruce E. Kreischer
Advisor: Thomas D. Wheelock
Professor of Chemical Engineering

Topic: RECOVERY OF MINERALS FROM POWER PLANT FLY ASH BY HIGH TEMPERATURE CHLORINATION.
Student: Michael S. Dobbins
Advisor: George Burnet
Distinguished Professor of Nuclear Engineering

Topic: ELECTROWINNING OF COPPER USING A FLUIDIZED BED ELECTROCHEMICAL REACTOR.
Student: David L. Felker
Advisor: Renato G. Bautista
Professor of Chemical Engineering

Topic: DEWATERING OF COAL SLUDGE BY PRESSURIZED ELECTROOSMOSIS.
Student: Leon W. Heath
Advisor: Turgut Demirel
Professor of Civil Engineering

Topic: INFLUENCE OF FINE PYRITE ENRICHMENT IN COAL WASHING EFFECTIVENESS.
Student: Lawrence Wu
Advisor: Donald L. Biggs
Professor of Earth Sciences

MINING ENGINEERING

Topic: DEVELOPMENT OF APPARATUS FOR DIRECT SHEAR TESTS ON THE WALLS OF MINING BOREHOLES.
Student: John R. Rohde
Advisor: Richard L. Handy
Professor of Civil Engineering

Topic: LOAD-INDUCED ULTRASONIC TESTING OF IN-SITU STRESS OF UNDERGROUND MINES.
Student: Loras Klostermann
Advisor: Richard L. Handy
Professor of Civil Engineering

GEOLOGY (MINING)

Topic: GROUND WATER QUALITY OF RECLAIMED MINE SITES.
Student: Kathleen E. Galloway
Advisor: John Lemish
Professor of Earth Sciences

Topic: TRANSPORT OF FUGITIVE DUST FROM A SURFACE MINE ENVIRONMENT.
Student: Jerold A. Herwehe
Advisor: Eugene E. Takle
Associate Professor of Earth Sciences

Topic: GROUND WATER QUALITY OF MUNICIPAL AQUIFERS DOWNSTREAM FROM A COAL PREPARATION PLANT.
Student: Robert Osolin
Advisor: John Lemish
Professor of Earth Sciences

LAND RECLAMATION

Topic: EFFECT OF NITROGEN-FIXING GROWTH ON RESTORED COAL SPOIL BANKS.
Student: John Kean
Advisor: Richard C. Schultz
Associate Professor of Forestry

MINERAL CHARACTERIZATION

THERMAL BEHAVIOR OF MINERALS COMMON IN LOW TEMPERATURE ASH CONCENTRATES FROM COALS

Graduate Student: Curtis G. Lindsay

Faculty Advisor: Donald L. Biggs
Professor in Earth Sciences

Background: The contribution of the mineral suite present in a coal to fouling and slagging in furnaces is not well understood, but the facts of fouling and slagging and their deleterious effects are well known.

Objective(s): This research will monitor the phase changes in the low temperature ash concentrates of eight coals (and selected blends between the eight coals) with increasing temperature under carefully controlled conditions using an inert atmosphere or vacuum. Products of these reactions will be determined on both a quantitative and qualitative basis.

Approach: Because of the known difficulty of forming crystalline products in silicate systems, the most significant measurements are expected to be observed during heating of the sample. Some phases may crystallize, however, more rapidly than anticipated. Therefore, in some experiments the cooling time will be varied.

Results: Phase changes in silicate systems have been observed during heating of the samples. Cooling times have been varied in some of the experiments and the results are being analyzed by x-ray diffraction techniques.

Schedule Projections: From these experiments we will learn what phases can be expected to form during heating of the mineral matter present in coal and blends of coal in an inert atmosphere. Although this will not be the same set of phases as encountered in actual furnace experiments, the data obtained will be very useful. It is hoped that this knowledge will give us a better theoretical framework to account for the thermal behavior of minerals during the coal combustion process.

MINERAL CHARACTERIZATION

GEOCHEMICAL STUDY OF EVAPORITE DEPOSITS IN IOWA

Graduate Student: Kyle S. Hansen

Faculty Advisor: Steven M. Richardson
Assistant Professor of Earth Sciences

Background: Much attention has been given to structural, stratigraphic, and lithologic features of Iowa evaporites in earlier studes; however, to date, no systematic baseline survey of the chemistry of these evaporites has been conducted. Such a survey would be used as an exploratory tool and a means of interpreting the depositional paleoenvironment of the region.

Objective(s): 1) Define the environment of deposition. 2) Define the geochemical signature of the evaporites obtained for the study. 3) Provide a means to trace hydrocarbon-bearing horizons that are associated with evaporite deposits, e.g. the Wapsipinicon Formation.

Approach: To define the paleoenvironment, concentrations of stable isotopes of oxygen and sulfur will be analyzed in evaporite samples in order to obtain the relative influences of marine and fresh water and of biochemical reactions.

Results: Results of this research will help support a study being conducted at Northern Illinois University to determine the nature and movements of Illinois groundwater in equilibrium with evaporites.

Schedule Projections: Recognition of the geochemical signatures of evaporites will aid in correlating contemporaneous evaporite horizons with those horizons that are not physically continuous. Also, identifying more than one cycle of evaporite deposition involving organic-rich carbonate marls or muds will help determine which current evaporite deposits effectively act as a stratigraphic trap for hydrocarbons generated during pre-evaporite sedimentation.

MINERAL CHARACTERIZATION

RAPID DISSOLUTION OF COAL AND MINERALS FOR ANALYSIS

Graduate Student: Barbara C. Wheeler

Faculty Advisor: Richard Markuszewski
Assistant Program Director, ISMMRRI

Background: For many of the analytical methods employed for the determination of major, minor, and trace constituents in coal, the sample has to be first dissolved by a convenient and reliable method. Most dissolution methods are tedious and require unusual procedures.

Objective(s): A rapid method for dissolving coal will be developed, based on digestion of a small coal sample with an acid mixture consisting of concentrated nitric, perchloric, and phosphoric acids. The resulting solution will be used for analyses by conventional spectrophotometric or other methods.

Approach: By using a simple digestion apparatus, the entire coal sample can be dissolved in 20-45 minutes, but the actual labor required is approximately 5 minutes per sample. Completion of the digestion yields a clear digest, leaving silica in a pure form for subsequent determination by filtration, ignition, and weighing as SiO_2. Aliquots of the clear solution from the filtrate are used to determine total sulfur by a turbidimetric measurement of the precipitated $BaSO_4$ and to determine iron by a spectrophotometric method.

Results: For eight subbituminous and bituminous coals containing 0.41-4.20% sulfur, the results agreed fairly well with those obtained by using a Fisher Sulfur Analyzer, based on combustion followed by automatic iodometric titration of the evolved sulfur dioxide.

Other aliquots of the same filtrate were used for the spectrophotometric determination of total iron using FerroZine as the reagent. For an iron range of 0.113-1.762%, the standard deviations were 0.001-0.050.

Schedule Projections:

The clear digest can be also used for the determination of calcium, magnesium, aluminum, copper, manganese, and other elements by spectrophotometric or atomic absorption procedures.

If precautions are taken to prevent the escape of volatile components (by the introduction of a reflux condenser or by using a Bethge apparatus for the digestions), many other elements can be determined by conventional procedures. The digests are also suitable for multi-element analyses by inductively coupled plasma-atomic emission spectrometry.

MINERAL PROCESSING

RECOVERY OF SULFUR AND LIME FROM WASTE GYPSUM

Graduate Student: Bruce Kreischer

Faculty Advisor: Thomas D. Wheelock
Professor of Chemical Engineering

Background: Waste gypsum is produced by various industries at a prodigious rate and presents a serious waste disposal problem. A process which may alleviate this problem has been demonstrated at Iowa State University. This process would not only reduce the magnitude of the waste disposal problem but would also recover sulfur from the gypsum in a form which is easily convertible into sulfuric acid, one of the principal raw materials of the fertilizer industry.

Objective(s): Develop a promising industrial process for decomposing waste gypsum at high temperature.

Approach: The basic characteristics of the process must be fully explored and engineering data accumulated for the design of a larger reaction system. To accomplish the desired objective, various flow models of the reaction system will be studied. These models will include cold models as well as hot working models. Cold models constructed of plexiglass are not only more convenient, but also more revealing of flow patterns. Such models can be used to study fluidization and mixing characteristics, particle entrainment rates, and effects of various gas distribution methods. Also, hot models are required for studying reaction kinetics. Physical modeling of the reaction system will be accompanied by mathematical modeling where possible.

Results: This is a new research project, and results will be available in the near future.

Schedule Projections: While the process has been demonstrated in a continuous flow system involving a six-inch diameter fluidized bed reactor, further demonstrations on a pilot plant or industrial scale will require using reactors which are many times larger and more costly. Therefore, the design of larger systems should be based on sound engineering principles and a thorough understanding of the process.

MINERAL PROCESSING

RECOVERY OF MINERALS FROM POWER PLANT FLY ASH BY HIGH TEMPERATURE CHLORINATION.

Graduate Student: Michael S. Dobbins

Faculty Advisor: George Burnet
Distinguished Professor of Nuclear Engineering

Background: An important mineral resources problem which deals with the recovery of aluminum and titanium compounds from power plant fly ash by high temperature chlorination is being solved. Alternate sources for these minerals are essential to permit our country to reduce its dependency upon imports and to improve its balance of payments.

Objective(s): Investigate a new concept for carrying out the production in a fused salt reactor.

Approach: It is known that the reaction to recover certain metals from fly ash occurs in a temperature range from 600°C to 850°C, when chlorine gas is brought into contact with fly ash in the presence of a reductant. The gaseous metal chlorides formed are condensed and separated to give the desired products.

Results: The reactor concept under investigation-chlorination in a fused salt bath-enhances control of the reaction and minimizes problems of corrosion. The fused salt to be used has been identified, the reaction chemistry has been studied, and design of a test reactor system has been initiated.

Schedule Projections: Work is continuing toward a workable solution on recovery of particular strategic minerals from fly ash.

MINERAL PROCESSING

ELECTROWINNING OF COPPER USING FLUIDIZED BED ELECTROCHEMICAL REACTOR

Graduate Student: David L. Felker

Faculty Advisor: Renato G. Bautista
Professor of Chemical Engineering

Background: The conventional electrowinning of cathode copper is by use of planar electrodes. The recently developed fluidized bed electrochemical (FBE) reactor uses an agitated medium of conducting particles as its electrodepositional surface.

A FBE reactor has considerably more electrode surface area compared to a conventional plate electrodeposition cell occupying the same reactor volume. Because of the large surface area of the particulate cathode, the FBE reactor can be operated at large overall currents (thus high rates of deposition) but small cathode current densities. This enables metals to be removed from solutions containing 10-1000 ppm metal and do so at very high current efficiency. A FBE reactor can be used to produce cathode copper from dilute leach solutions. Its ability to handle low metal concentration solution can be effectively used to remove heavy metals present in 0-50 ppm concentrations in industrial waste effluents.

Objective(s): Develop a correlation to relate mass transport of copper in a FBE reactor to bed particle shape and ionic impurities.

Approach: The system under study is a dilute solution of $H_2SO_4/CuSO_4$ containing other metal impurities. The H_2SO_4 concentration ranges from 100 to 200 g/1 and the copper concentration ranges from 0.1 to 10 g/1. Metal ions are added in concentrations of 10-100 ppm. A 3 1/2" O.D. side-by-side cylindrical FBE reactor is used with different types of copper particulates: irregularly shaped copper powder with diameters up to 300 μm and a surface area of about 0.5 m^2/g, and spherical copper shot with a surface area of about 0.03 m^2/g.

Results: Simplified correlations have been made between the mass transfer of copper and the FBE reactor operating parameters, e.g. bed expansion, electrolyte conductivity, electrolyte flow rate, copper concentration, current density, viscosity, and particle size.

Schedule Projections: Metal contaminants such as iron, lead, aluminum, silicon, manganese, cobalt, and chromium were investigated. An automatic sampler was designed to monitor various ion concentrations at very short time intervals. In order to monitor the effect of mass transfer on the system, all experiments were run very close to the limiting current density of copper so that the concentration driving force would approach the value of the bulk concentration.

MINERAL PROCESSING

DEWATERING OF COAL SLUDGE BY PRESSURIZED ELECTROOSMOSIS

Graduate Student: Leon W. Heath

Faculty Advisor: Turgut Demirel

Background: Extraction of minerals by direct means or by secondary recovery methods leaves in its wake saturated wastes which must be properly handled, and stored, and disposed. Disposal of waterlogged mineral wastes can be both expensive and time-consuming. In additon to proper disposal of mineral wastes, beneficiation of coal and other minerals can leave the final product in a saturated state which may complicate transportation of the product. A method of dewatering both mineral wastes and cleaned coal products is being explored which can significantly reduce the moisture content of these materials.

Objective(s): 1) Determine that electroosmosis is a viable means for dewatering coal sludge and mineral fines; 2) sufficiently develop the method as a possible circuit to run in a beneficiation scheme.

Approach: Bench-scale apparatus for dewatering by gravity and electroosmosis have been set up to compare the two methods. The final moisture levels of the two dewatering schemes have been evaluated with respect to time, bed depth, sludge composition, electric power settings, electrodes, and other parameters.

Results: To date, the method works on a limited basis to desaturate coal sludge in experimental tanks set at varying currents. Further tests have been carried out on fines at various levels of saturation. Pressure enhancement has also been carried out to improve the dewatering. The water run-off from the two dewatering schemes has been analyzed and the properties of the residue have been evaluated.

Schedule Projections:

Work to further refine the electroosmotic process to dewater coal slurries has commenced and will be the focus of his dissertation.

MINERAL PROCESSING

INFLUENCE OF FINE PYRITE ENRICHMENT ON COAL WASHING EFFECTIVENESS

Graduate Student: Lawrence Wu

Faculty Advisor: Donald L. Biggs
Professor in Earth Sciences

Background: During flotation experiments with coal from the Dietz seam (Decker, Montana), anomalous behavior of finely ground coal was observed. Most of the sample appeared in the sink fraction of the 1.4 flotation experiment. Microscopic examination gave the first impression that the behavior was due to a significant enrichment in finely divided pyrite in the size range less than one micrometer.

Objectives(s): This work, to be conducted on -60 and -200 mesh mounts of pyrite and pyrite-bearing coal, should provide data for the determination of actual size distribution of ground pyrite. These techniques will then be applied to the float and sink fractions of washed coals.

Approach: Particle-size distribution determination using random counting techniques proved to be inadequate to properly assess the contribution of finely divided iron sulfide to the behavior. A technique was devised using counting of contiguous particles, but again the results were inconclusive.

Results: Use of the scanning electron microscope image analyzer pointed out the difficulty of measuring all particles of pyrite in a polished mount. Therefore the decision was made to model the actual particle size distribution with equivalent random area measurements at 50, 100, 200 and 400 diameters to complement the 400 diameter magnification at which the light microscopy if performed.

Schedule Projections: Associated with this work is the testing of the hypothesis that finely divided pyrite, by simply adhering to the fine coal particles, may play a significant role in the float/sink characteristics of washed coals. If testing this hypothesis has a positive result, efforts to inhibit this sort of surficial interaction can be taken and thus improve the yield of coal washing techniques in some instances.

MINING ENGINEERING

DEVELOPMENT OF APPARATUS FOR DIRECT SHEAR TESTS ON THE WALLS OF MINING BOREHOLES

Graduate Student: John R. Rohde

Faculty Advisor: Richard L. Handy
Professor of Civil Engineering

Background: Widespread application of rock mechanics to design of underground mines is hindered by a lack of adequate means to determine rock strength in response to present and anticipated stresses. Until recently, rock strength was usually evaluated from direct shear tests of core samples; however, coring the soft to moderately hard rocks almost always introduces bias due to incomplete core recovery. Research performed at ISU between 1970 and 1976 produced a good solution to the problem in the development of a device that performs direct shear tests on the walls of a borehole. As the device has performed admirably since its invention, it can be improved for more efficient operation under actual mine conditions.

Objective(s): Develop and evaluate a faster operating and inexpensive borehole shear tester which functions in standard size boreholes.

Approach: The device should be compatible with existing mining operations in order to analyze rock strength for roof, pillar, and floor support.

Results: A comprehensive series of tests has been completed in a laboratory environment comparing the shear tester with existing methods for measuring rock strength from core samples. Under laboratory conditions, the test device shows superior performance over existing methods of shear testing.

Schedule Projections: Further research will include design, statistical validation, and field testing in as many surface and underground mines as possible.

MINING ENGINEERING

LOAD-INDUCED ULTRASONIC TESTING OF IN-SITU STRESS OF UNDERGROUND MINES

Graduate Student: Loras A. Klostermann

Faculty Advisor: Richard L. Handy
Professor of Civil Engineering

Background: Knowledge of in-situ stresses occurring near underground mine openings is a prerequisite to the design and analysis for nearly any facet of underground design. Computations are usually used to evaluate stress fields but are frequently inconsistent with actual field measurements. This may be due to the inability of theory to account for residual tectonic stresses and complex opening configurations normally associated with mining operations. Thus techniques have been developed to provide a direct measure of in-situ stress.

Objective(s): Develop a simple, utilitarian method to evaluate in-situ stress.

Approach: Ultrasonic pulse velocities are monitored across a zone of rock upon which increasing tensile stress is induced. When large flaws develop at tensile failure, a change in pulse velocity should be observed; the corresponding force producing this failure can be related to the combined components consisting of cohesion and the in-situ stress component in the direction of tensile stress.

Results: It has been possible to measure in-situ stress by repeating the process as the cohesion component is destroyed. Also, it has been found that the basic process of in-situ testing serves as an additional method to measure the modulus of elasticity in a zone of rock.

Schedule Projections: A portable apparatus capable of functioning in a working mine environment has been developed. Tensile stresses are induced with a pair of hand-operated, hydraulic borehole jacks designed to operate in a 1 5/8 inch diameter hole (as this is a common size used for roof bolts). With such an apparatus, it is possible to evaluate rapidly the stress field occurring in the plane of any exposed underground surface, e.g. roof, floor, pillar. Tests are being performed in an underground mine as the apparatus has proved functional.

GEOLOGY (MINING)

GROUND WATER QUALITY OF RECLAIMED MINE SITES.

Graduate Student: Kathleen Galloway

Faculty Advisor: John Lemish
Professor of Earth Sciences

Background: The contamination of surface and ground waters by acid mine drainage is one of the major environmental problems associated with coal mining. Acid mine drainage may be inhibited by rapid burial of spoil beneath a nonacid forming cover. Although rapid burial is a common procedure, little research has been completed to verify its effectiveness. In Mahaska County, three contiguous mines were reclaimed at different times and to different stages of completion. The Iowa Coal Project Demonstration Mine (ICPDM) was immediately reclaimed to the best possible standards. The adjacent Star Mine was immediately reclaimed to earlier, more lenient state standards. Another adjacent tract was belatedly reclaimed to the same earlier standards after aging four years. Spoil was cast by dragline in all but the ICPDM.

Objective(s): 1) Investigate the degree to which contamination has occurred in abandoned spoil and reclaimed soil; 2) compare the ground water quality between the three mines to evaluate the effects of different reclamation standards, procedures, and spoil age.

Approach: The ground water borehole network at the ICPDM site is being used to monitor water quality on a monthly basis. Standard analytical procedures are used to test for particular ions in water samples drawn from the network.

Results: The network has been extended to the adjacent mines as an additional check on changes in water quality over time. Correlations have been made between the existing ICPDM borehole network and the more recently drilled boreholes on the adjacent mines. A hydrologic pattern among all mines has been developed. Correlations will be made between the existing ICPDM borehole network and the more recently drilled boreholes on the adjacent mines.

Schedule Projections: A hydrologic pattern among all mines will be developed once the extent of potential contamination has been established through continued sampling. This pattern will be used to predict potential contamination in effluent from reclaimed and abandoned mine lands.

GEOLOGY (MINING)

TRANSPORT OF FUGITIVE DUST FROM A SURFACE MINE ENVIRONMENT

Graduate Student: Jerold A. Herwehe

Faculty Advisor: Eugene S. Takle
Associate Professor of Earth Sciences

Background: Surface mining of mineral resources generates fugitive dust in the extraction, hauling, and processing stages that can potentially create both short and long term environmental problems. In the short term, atmospheric particulate loading may exceed federal clean air standards and present a health hazard to mining personnel. In the long term, subsurface materials may become widely dispersed into the surface environment near and far downwind of the mine site. The extent of the particulate dispersal and potential for disturbance of the natural environment depend on the spectrum of particulate sizes generated, the chemical composition of the fugitive material, atmospheric transport processes, and the orographic and vegetative features of the mine environment.

Objective(s): Apply a currently operational two-dimensional finite-element numerical advection diffusion model to simulate transport of fugitive dust from a surface mine environment.

Approach: An ensemble of experiments of increasing complexity has been performed using (as input) idealized orography, e.g., a v-shaped or square-shaped mine cross-section, and idealized turbulent flow patterns based on results of wind tunnel studies, to calculate particulate deposition patterns.

Results: Vegetation canopy flow models have been used to specify advective and turbulent diffusive characteristics of the flow in the deposition zone. Results of deposition studies performed under the Iowa Coal Project have been used to characterize the deposition dependence on atmospheric stability.

Schedule Projections: The resulting simulations have provided estimates of the fugitive dust loading in the mine atmosphere and particulate deposition in the mine environment caused by various dust source strengths and various idealized mine configurations.

Mr. Herwehe will complete his master's thesis in the coming months. Several papers are planned from his work.

GEOLOGY (MINING)

GROUND WATER QUALITY OF MUNICIPAL AQUIFERS DOWNSTREAM FROM A COAL PREPARATION PLANT.

Graduate Student: Robert L. Osolin

Faculty Advisor: John Lemish
Professor in Earth Sciences

Background: The Iowa Coal Project gave rise to the construction of a coal beneficiation facility complete with a cleaning plant housing beneficiating circuits and ancillary equipment. One of the potentially detrimental effects of such a plant is possible contamination of nearby water resources from effluent discharged on or near the plant's premises. To ascertain this, the possibility of contamination should be monitored.

Objective(s): Determine the effects of a coal beneficiation plant's highly mineralized effluent on municipal aquifers.

Approach: Sampling was first completed in December of 1975 to establish the initial ground water quality in the beneficiation plant impact area on the campus of Iowa State University. Since that time the monitoring network, a series of 14 wells sunk to varying depths, has been expanded to include the coal storage pile of the ISU Physical Plant. Ground water samples have been collected approximately every month for the past several years. (The Institute has since taken over responsibility for the sampling work.)

Two municipal aquifers were intercepted at depth, allowing any contamination from the site to be detected. Shallower wells were dug to monitor infiltration of any contamination from surface run-off. All well samples are tested for specific conductivity, pH, alkalinity, and concentrations of iron, manganese, chlorine, calcium, magnesium, sulfate, and nitrate.

Results: To date, analyses of collected samples show increased concentrations of sulfate, calcium, iron, and manganese near the beneficiation plant as compared to those found during the original baseline study. Currently, these increases are confined to the shallow ground water beneath the site and have not extended much either laterally or vertically. Monitoring also indicates that the water quality has been nearly stable for the past two years, demonstrating no progressive deterioration. The concentration of contaminants found in the ground water at the site is low as compared to the ranges reported for similar coal storage sites throughout the nation. Analysis of surface water samples also indicates that the receiving streams are able to dilute the surface run-off from the beneficiation plant area to acceptable levels.

Schedule Projections: The data will be collected for another several months until another year's worth of data is obtained. Seasonal fluctuations of temperature and underground flow rates will be taken into account before data analysis is complete. Data will be analyzed for evidence of possible contamination to determine if the water quality in the City of Ames has deteriorated as a result of the coal preparation plant operation.

LAND RECLAMATION

EFFECT OF NITROGEN-FIXING GROWTH ON RESTORED COAL SPOIL BANKS

Graduate Student: John N. Kean

Faculty Advisor: Richard C. Schultz
Associate Professor of Forestry

Background: Mine reclamation sites, with their "rebuilt" soils, pose a real problem to the rooting ability of seedlings. The layer nature of the soil produces many discontinuities that roots must penetrate. Because of the varying conditions of the roots of the various kinds of tree stock, different abilities of establishment for a species exist. In addition, different species have different expressions of root form that are genetically controlled. It is therefore important to determine the ability of the various kinds of stock of different species to become established on mine reclamation sites.

Objective(s): Test the establishment potential of bare-root tree stock, containerized stock, and hardwood cuttings on a coal mine site that has been mined and restored under the most recent reclamation practices.

Approach: Inoculation with mycorrhizal fungi has been shown to improve the establishment of seedlings. This hypothesis will be tested with various kinds of stock by inoculating half of them and leaving the other uninoculated. If natural inoculum exists on the site all seedlings should eventually become mycorrhizal but those that become infected earliest should have greater survival and growth advantage.

Results: Results will be reported as this new project will be developed in the future.

Schedule Projections: Since the initial survival is dependent to a large extent on the timing of new root growth and top growth, phenological measurements will be made at regular intervals during the first two growing seasons. Roots systems will be excavated and root development will be related to soil profile characteristics.

COMPLETED MINERAL INSTITUTE PROJECTS

Summarized below are research projects completed under the sponsorship of the Iowa State Mining and Mineral Resources Research Institute. The detailed description of each project is given in the following pages.

MINERAL CHARACTERIZATION

Topic: TRACE ELEMENT DISTRIBUTION AND MINERAL ASSOCIATIONS IN IOWA COALS.
Graduate Student: M. Robert Dawson, M.S., 1982
Faculty Advisor: Karl E. Seifert
Professor of Earth Sciences

Topic: PETROGRAPHIC AND MINERALOGIC ANALYSIS OF CHANNEL SAMPLES FROM KENTUCKY #9 AND BROOKVILLE COAL SEAMS.
Graduate Student: Roger Kocken, M.S., 1982
Faculty Advisor: Donald L. Biggs
Professor of Earth Sciences

MINERAL PROCESSING

Title: PARTIAL EQUILIBRIUM MODEL ON THE KINETICS OF DISSOLUTION OF URANIUM AND PYRITE.
Graduate Student: Charles E. Allen, M.S., 1982
Faculty Advisor: Renato G. Bautista
Professor of Chemical Engineering

Title: PRODUCTION OF AN IRON CONCENTRATE BY CAUSTIC DIGESTION OF POWER PLANT FLY ASH.
Graduate Student: Michael S. Dobbins, M.S., 1982
Faculty Advisor: George Burnet
Distinguished Professor of Nuclear Engineering

Title: DEWATERING OF COAL SLUDGE BY PRESSURIZED ELECTROOSMOSIS.
Graduate Student: Leon Heath, M.S., 1982
Faculty Advisor: Turgut Demirel

Title: ELECTROWINNING OF COPPER USING A FLUIDIZED BED ELECTROCHEMICAL REACTOR.
Graduate Student: David L. Felker, M.S., 1982
Faculty Advisor: Renato G. Bautista
Professor of Chemical Engineering

Title: SOLUBLE SULFUR SPECIES EXTRACTED FROM COAL BY CHEMICAL LEACHING
Graduate Student: Michael D. Stephenson, M.S., 1982
Faculty Advisor: Thomas D. Wheelock
Professor of Chemical Engineering

GEOLOGY (MINING)

Title: GEOLOGY OF GROUND WATER IN RECLAIMED AND UNRECLAIMED SPOIL
Graduate Student: Joseph A. Klingshirn, M.S., 1982
Faculty Advisor: John Lemish
Professor of Earth Sciences

LAND RECLAMATION

Title: SMALL MAMMALS AND THEIR IMPACT ON RECLAIMED LAND IN THE NORTHERN GREAT PLAINS.
Graduate Student: Terrence Hingtgen, M.S., 1982
Faculty Advisor: William R. Clark
Assistant Professor of Animal Ecology

Title: SOIL PROFILE CHARACTERISTICS OF RESTORED SOILS AT A SURFACE COAL MINE.
Graduate Student: Scott C. Killpack, M.S., 1982
Faculty Advisor: Gerald A. Miller
Associate Professor of Agronomy

Title: ROOT DEPTH AND CORN YIELD RESPONSE TO TILLAGE ON RECLAIMED SURFACE-MINED LAND.
Graduate Student: George Peregrim, M.S., 1982
Faculty Advisor: Stanley J. Henning
Assistant Professor of Agronomy

MINERAL CHARACTERIZATION

Trace element distributions and mineral associations in Iowa coal

Malcolm Robert Dawson II
M. S., 1982
Under the supervision of Karl E. Seifert
From the Department of Earth Sciences
Iowa State University

Channel cut sections were collected from four active coal mines in Iowa. From these sections 23 raw coal samples were analyzed using instrumental neutron activation analysis (INAA) for the following trace elements: La, Ce, Sm, Eu, Tb, Lu, Sc, Cr, Co, As, Rb, Sr, Cs, Hf, Ta, Th, and U.

To determine how these elements are associated with the coal, three techniques were used: 1) Pyrite and calcite cleat fillings were hand separated from the coal and directly analyzed using INAA. 2) Eleven samples were taken from the channel cut sections and were separated by float-sink methods. High temperature ashes (HTA) were made of both the whole coal samples and the float, which were analyzed using INAA and atomic absorption spectroscopy (AA). From the float-sink study the organic and inorganic associations of these trace elements were determined. The percent of HTA for each sample was also correlated with the elemental composition of the raw coal to determine elemental association with the mineral portion of the coal. 3) A microscopic study of pyrite and calcite was used to determine the abundance and occurrence of these minerals. This information was correlated to the elemental concentrations in the raw coal.

The effects of cleaning and combustion on trace element abundances were observed in the float-sink study and the ashing process.

The examination of the concentrations of trace elements in Iowa coals found abundances to be, in most cases, consistent with a trend of decreasing element concentration from east to west across the United States. The elements that conformed to this trend are: Sc, Cr, Rb, Cs, Ta, Th, and As. In these cases, Iowa coals displayed concentrations comparable or lower than Illinois coals.

Most of the trace elements demonstrated inorganic tendencies. These elements include: Rare earth elements (REE), Co, As, Cs, Hf, Ta, Th, and U. Cr and Rb show organic associations and were also found in authigenic minerals. Sr association has some organic qualities, and Sc has an intermediate association.

Analyses of mineral separates showed Sc, Cr, As, Co, Rb, Th, and REE to be incorporated into pyrite cleat fillings, with As specifically showing a strong correlation to framboidal pyrite. Sc, Cr, Co, U, and REE were found in calcite cleat fillings. Evidence also indicates that calcite plays in important role in the occurrence of Sc.

MINERAL CHARACTERIZATION

Petrographic and mineralogic analysis of channel samples from Kentucky #9 and Brookville coal seams

Roger James Kocken
M.S., 1982
Under the supervision of Donald L. Biggs
from the Department of Earth Sciences
Iowa State University

The Kentucky #9 coal seam in Muhlenburg County, Kentucky, is a high volatile C bituminous coal. The 136.2 cm thick seam can be divided into three sections by different maceral content. The upper 30 cm and bottom 10 cm have a detrital appearance with small pieces (less than 50 microns in diameter) of inertinites and exinites in a groundmass of desmocollinite. These two sections were deposited in a reed-marsh environment that was affected by marine waters. The middle section of the seam is composed mainly of pure bands of collinite with a few bands of fusinite and semifusinite.

The minerals identified in the low temperature ash (LTA) concentrates from the Kentucky #9 coal were illite, kaolinite, gypsum, quartz, pyrite, marcasite, and calcite. The most abundant minerals are illite, kaolinite, quartz, and pyrite. The shales that surround the coal seam contain more illite, kaolinite, and quartz and less pyrite than LTA concentrates from the seam. The LTA concentrates from the middle of the seam contain more clay than those from the top and bottom.

It was necessary to etch the pyrite to make all the textures visible. The pyrite was described as framboids, colloform, dendritic, massive crystals, cleat-filling, cell-filling, isolated euhedral crystals, and blebs. Massive crystals and dendritic pyrite account for 75 percent of the total pyrite. Marcasite represents a small amount of the total iron sulfides and is mainly associated with the colloform and dendritic pyrite. A general paragenesis was established with framboids forming as the earliest pyrite followed by later intergrowth of colloform and dendritic pyrite. Massive crystals represent the youngest pyrite. Cleat-filling pyrite may have formed at any time after the development of cleats and cell-filling pyrite after the formation of the fusinite. Epigenetic pyrite is common in the Kentucky #9 coal.

The chemical analysis of the shales compared to the chemical analysis of the LTA concentrates showed that the shales contained more SiO_2, MgO, K_2O, Na_2O, Rb, and Cu. However, the LTA concentrates contained more iron and TiO_2 than was shown in the chemical analysis of the shales. The increased illite content of the shales is reflected in the higher K_2O, Na_2O, and Rb contents. The higher SiO_2 content of the shales relates to increased quartz content. The high pyrite content of the LTA concentrates results in higher iron amounts than is found in the shales.

The Brookville coal seam from Somerset County, Pennsylvania, is a medium volatile bituminous coal. The main minerals identified in the LTA concentrates from the seam were illite, quartz, kaolinite, and pyrite. Illite is found only in the thin coal layers and carbonaceous shales that separate the coal layers at the top of the seam. Kaolinite was the only clay mineral to occur in the main coal layers at the bottom of the seam. The kaolinite reflects the strongly reducing and acidic conditions in the peat swamp. Under these conditions, illite and its precursors would dissolve and kaolinite would form. Pyrite and marcasite are more abundant in the main coal layer.

Most of the LTA samples from the carbonaceous shales and thin coal layers have a chemical composition close to that of an average kaolinite. The amount of K_2O and Rb follow the occurrence of illite in the samples. The average Al_2O_3 content for the LTA samples from the coal seam is 28.53 percent and the average SiO_2 content is 38.06 percent. This reflects the dominance of clay minerals in the coal. Cu is concentrated at the upper and lower contents of the coal seam. Strontium is concentrated in the coal-rich layers, possibly showing that the strontium is either associated with calcite or it is being organically bonded to the coal.

The majority of the pyrite and marcasite are associated with inertinites in the Brookville coal. Etching of the pyrite made possible the recognition of three different types of pyrite. Based on etching color, the three types were defined as brown, yellow-brown, and yellow pyrite. Brown pyrite, yellow-brown pyrite, and maracasite were seen in areas resembling cell lumens. Yellow pyrite is seen cutting and replacing the earlier pyrite and marcasite.

MINERAL PROCESSING

A partial equilibrium model based on the kinetics of dissolution and equilibrium in solution of the UO_2-FeS_2-$Fe_2(SO_4)_3$-H_2SO_4 system

Charles Christopher Allen
M.S., 1982
Under the supervision of Renato G. Bautista
from the Department of Chemical Engineering
Iowa State University

A mathematical model for determining the concentration changes in solution during the dissolution of a uranium dioxide-pyrite mixture has been developed using a $Fe(SO_4)_3$-H_2SO_4 lixiviant. When modeling such a leaching process, two different types of reactions must be considered: heterogeneous dissolution reactions and homogeneous solution reactions. The dissolution reactions occur at kinetically limited reaction rates which are slow enough so that the rapid solution reactions can be assumed to be a continual equilibrium. This situation allows for the partial equilibrium approach to be utilized to model the overall leaching process.

In setting up the model, the major solution reactions and aqueous species present during the dissolution process were identified. The initial equilibrium concentration for each of these aqueous species is then determined for a given lixiviant. The modeling process then determines the equilibrium changes for each of these aqueous species for every increment of solid dissolution, with the relative amount of uranium dioxide to pyrite reacting based on the experimentally determined rate expressions. The calculated concentration changes are obtained from simultaneously solving a series of linear equations arising from each equilibrium reaction, a charge balance, and material balances for Fe(III), Fe(II), UO_2^{2+}, and SO_4^{2-}. A computer model was written to perform this iterative process.

Results from the model for the dissolution of a uranium dioxide and pyrite mixture were found to agree with the experimental results obtained for similar leach conditions. The $Fe_2(SO_4)_3$-H_2SO_4 solution was found to be an effective lixiviant, provided leaching conditions were adjusted for the selective leaching of uranium dioxide. These conditions correspond to a solution with a low ferric:ferrous ratio, with the concentration of ferric ion limited by the solubility of $Fe(OH)_3$. This solubility limit is increased with increasing H_2SO_4 concentration.

MINERAL PROCESSING

Production of iron concentrate by caustic digestion of power plant fly ash

Michael Sean Dobbins
M.S., 1982
Under the supervision of George Burnet
from the Department of Chemical Engineering
Iowa State University

Fly ash from coal fired power plants was examined as a potential source of iron. Magnetic separation of high-iron ashes produce a concentrate containing 40-50 wt% iron. Further processing is required to produce a concentrate acceptable in the current world iron-ore market. Both physical and chemical beneficiation methods were examined and caustic extraction of the gangue was deemed most feasible. The effect of caustic strength, extraction temperature and time, and solid-liquid ratio on the extraction product were investigated. Trial extractions indicated that concentrates containing approximately 62 wt% Fe, 2% silica and 4% alumina could be produced by treating the magnetic ash with a solution of 30 wt% NaOH at 200 C for 0.25 hours. At solid-liquid ratios greater than 70 g/l, the iron content of the concentrate was reduced. The reduced iron content was shown by SEM methods and chemical analysis to be caused by the formation of a sodium aluminosilicate precipitate formed during extraction. By using an acid wash to remove the precipitate the ash could be successfully treated at solid-liquid ratios as high as 140 g/l. The operation of the moving field magnetic separator was also reviewed.

MINERAL PROCESSING

The study of the electrowinning of copper using a fluidized bed electrochemical reactor

David Lloyd Felker
M.S., 1982
Under the supervision of Renato G. Bautista
From the Department of Chemical Engineering
Iowa State University

A study was done on the use of a fluidized bed electrochemical reactor for the recovery of copper from aqueous solutions. Electrolyte solutions containing 0-8 g/l copper, 0-8 g/l iron, and 200 g/l sulfuric acid were used. Porous diaphragms made of plastic, ceramic or glass were used to separate the cathode and anode regions. The size range of diaphragms resulted in fluidized bed widths between 1.2 and 2.7 cm. The glass diaphragms were sufficiently nonporous that catholyte and anolyte solutions could be physically separated (electrical contact was still maintained).

The current efficiency, energy consumption rate, and volumetric reaction rate were calculated for the variety of experimental conditions mentioned above. Results indicated that when the catholyte and anolyte are circulated from a common reservoir and iron(II) is present in the electrolyte, the energy consumption rate exhibits a minimum value of about 1.5 kWh/lb Cu at a volumetric reaction rate of about 100 lb Cu/m^3 hr. When the anolyte and catholyte are separated, the energy consumption rate rises linearly with volumetric reaction rate, being about 1 kWh/lb Cu at 100 lb Cu/m^3 hr (roughly two times the volumetric reaction rate of a conventional electrowinning cell). Under the conditions of the study done, the optimum bed width in the direction of current flow was about 2 cm.

A mathematical model which takes into account the dissolution of copper by ferric ion and oxygen is shown to explain the changes in the current efficiency and the volumetric reaction rate with current density seen in most of the experiments. Results indicate that separation of the catholyte and anolyte is imperative. Experiments showed that this can be accomplished using a porous Vycor glass diaphragm. In addition, use of the porous Vycor glass diaphragms eliminated the problem with copper dendrites growing through the diaphragm (a problem that was present when ceramic or plastic diaphragms were used).

MINERAL PROCESSING

Dewatering of coal sludge by pressurized electroosmosis

Leon W. Heath
M.S., 1982
Under the supervision of Turgut Demirel
From the Department of Civil Engineering
Iowa State University

It was found that electroosmosis can be successfully used to enhance the dewatering of coal sludge. In general, high voltage gradients led to lower final moisture contents in a shorter time, but at the expense of higher energy consumption. In addition, lower initial moisture contents produced sludges with lower final moisture contents independently of the voltage gradient. In dewatering coal sludge solely by electroosmosis, it was found that the sludge failed to consolidate continually, causing an unsaturated state to develop in which heating subsequently occurred. In addition to heating, energy was consumed by electrochemical reactions apparent by the precipitation of calcite in the removed water.

The investigation also showed that by combining electrical and hydraulic gradients, lower final moisture contents were obtainable in a much shorter time and that the final moisture content produced by combined gradients was lower than that produced by the gradients individualistically. It was found that when combined, hydraulic dewatering predominated initially and once ceased, electroosmosis continued to dewater the coal sludge. Also, due to the shorter time and higher degree of consolidation produced by the combined gradients, heating and electrochemical reactions were not as significant.

The results of this study indicate that high voltage gradients and pressures should be used in further study to determine an optimization. Also, it was found that heat evolution and electrochemical aspects of electroosmotic dewatering should be investigated quantitatively in more depth. Since the coal sludges used in this study were not altered physically or chemically upon receipt, further study should be undertaken to determine the effects of pretreatments such as grinding to optimize the particle size distribution and chemical additives to optimize the zeta potential. On the basis of other research, it is recommended that further study be conducted into current reversal or interruption to determine the effects on combined gradient dewatering.

As a result of this research, this dewatering method is applicable not only to coal sludge, but also to coal suspensions, sewage sludges, mill tailings, slimies, pulps, and other materials which are difficult to dewater.

MINERAL PROCESSING

Soluble sulfur species extracted from coal by chemical leaching

Michael David Stephenson
M.S., 1982
Under the supervision of Thomas D. Wheelock
From the Department of Chemical Engineering
Iowa State University

The nature of the soluble sulfur-containing reaction products from the desulfurization of pyrite was studied. Two varieties of pyrite were used: mineral grade pyrite from the Foote Mineral Company and coal-derived pyrite from the refuse produced in cleaning coal from the Childers site adjacent to the Iowa State University demonstration mine in Mahaska County, Iowa. Desulfurization experiments were carried out in a fixed bed tubular reactor, 1.0 liter and 300 ml autoclaves, and a 1000 ml three-neck Pyrex flask. The rate of oxydesulfurization of the two varieties of pyrite was studied under the leaching conditions of the Ames process. Concentrations of soluble sulfur species were determined not only for oxydesulfurization using leach solutions of sodium carbonate, sodium bicarbonate, distilled water, and dilute sulfuric acid, but also for alkaline leaching without oxygen using sodium carbonate.

Mineral grade pyrite was found to be much less reactive towards oxydesulfurization than coal-derived pyrite. Although the sulfur conversion was always lower with mineral grade pyrite, the mechanism of sulfur removal was apparently the same. The shrinking unreacted core model agreed well with the experimental data with diffusion through the product shell controlling the overall rate of reaction.

The sulfur-containing products of oxydesulfurization were found to be thiosulfate, sulfite, and sulfate for alkaline leach solutions, and elemental sulfur and sulfuric acid when neutral or acidic solutions were used. For the Ames process, thiosulfate was usually the major sulfur-containing product, although some oxidation to sulfite and sulfate was found to take place. Oxidation of thiosulfate did not occur with oxygen alone, but did occur in the presence of oxygen and partially reacted pyrite. Higher temperatures and higher oxygen partial pressures favored formation of sulfate at the expense of both thiosulfate and sulfite. With neutral and acidic leach solutions, sulfuric acid accounted for most of the sulfur, although measurable quantities of elemental sulfur were present. Higher oxygen partial pressures and higher temperatures favored the formation of sulfuric acid at the expense of elemental sulfur. Pyrite oxidized faster under alkaline conditions than under neutral or acidic conditions.

Pyrite was also leached at high temperatures in a sodium carbonate solution in the absence of oxygen. Most of the extracted sulfur was present as soluble sulfides (60-90%), although measurable amounts of sulfate were detected. The intense green color of the solutions was presumed due to the soluble iron(II)-sulfide species, $Fe_2S_3^{2-}$, although the amount of sulfur in this form was extremely small.

GEOLOGY (MINING)

Geology of ground water in reclaimed and unreclaimed coal spoil, Mahaska County, Iowa

Joseph Klingshirn
M.S., 1982
Under the supervision of John Lemish
From the Department of Earth Sciences
Iowa State University

The ground water, surface water, and spoil properties of three contiguous areas of coal surface mine spoil were studied to determine the effects of reclamation methods, spoil age, and time between mining and reclamation on water quality and distribution. Water and spoil samples were collected from the Mich site and the reclaimed and unreclaimed Hull sites, located in Mahaska County, Iowa. The data were statistically analyzed to determine differences among the sites.

In general, ground and surface water and spoil leachate from the Mich site are less mineralized than water and leachate from the Hull sites, due primarily to difference in reclamation methods, spoil age, and surface materials. Similarities in spoil material and age contribute to similarities in chemical properties of water and spoil from the reclaimed and unreclaimed Hull sites. Reclamation appears to have had little effect on water and spoil quality on the reclaimed Hull site.

Hydraulic conductivity is generally higher on the reclaimed Hull site than on the Mich and unreclaimed Hull sites. Differences in hydraulic conductivity and time available for resaturation on the sites have resulted in different water table shapes. Perched water tables are present on the reclaimed Hull site and seem to be related to the buried pre-reclamation surface. Moisture content in the unsaturated portion of the Mich spoil is lower than that in the spoil on the Hull sites. Moisture content increases slightly with depth on the Mich site and decreases with depth on the Hull sites, with the difference between the sites due primarily to a difference in reclamation methods.

LAND RECLAMATION

Small mammals and their impact on reclaimed land in the Northern Great Plains

Terrence Hingtgen
M.S., 1982
Under the supervision of William R. Clark
From the Department of Animal Ecology
Iowa State University

Small mammal populations were studied on reclaimed strip mine land as part of a study of their impact on vegetation. Two- to five-year-old reclaimed areas were categorized as young and established areas. Eight species of small mamals were present on the established reclaimed areas compared to six on young reclaimed areas. The masked shrew (*Sorex cinereus*) and northern grasshopper mouse (*Onychomys leucogaster*) were captured almost exclusively on the established areas. Deer mice (*Peromyscus maniculatus*) dominated populations on all reclaimed areas both in terms of individuals (13.8$\pm$1.2 animals/ha) and biomass (240.1 109.1 g/ha). They comprised 90.6% of all individuals captured on young reclaimed areas, and 81.9% of individuals captured on established areas. Densities of deer mice, proportions of reproductively active males and females, survival rates, and average adult male weights were not different on reclaimed areas of different ages. Proportion of females captured was significantly lower, and proportion of juveniles higher on the established areas. It is concluded that deer mice populations peak within 2 years after reclamation. Vegetational changes after 2 years produce habitats that supports a smaller adult population of deer mice, and is more favorable for other small mammal species.

LAND RECLAMATION

Soil profile characteristics and variability of restored soils at a surface coal mine, Mahaska County, Iowa

Scott Collin Killpack
M.S., 1982
Under the supervision of Gerald A. Miller
From the Department of Agronomy
Iowa State University

The Iowa Coal Project is a 16 ha reclaimed surface coal mine in Mahaska County, Iowa. This reclaimed site is unique because soil horizons and parent materials were removed, separately stockpiled, and subsequently replaced prior to the federal reclamation act of 1977. Operations at the Iowa Coal Project began July 1975 and ended November 1977 with the removal of 108,000 tons of coal. Replacement and subsequent reclamation of soil materials were done with earthscrapers and dozers. Soil properties present in the soil profile are different from those properties existing prior to disturbance. The major emphasis of this study was to determine to what degree soil properties were changed as a result of reclamation and to characterize the distribution of these properties in the constructed soil profile. In addition, the magnitude of variability resulting from reclamation was also investigated. The objectives of this study are summarized as follows:

(1) To determine select physical and chemical properties of restored soil materials at the Iowa Coal Project and to provide baseline data for future study of the changes in those properties.

(2) To quantify variability of the soil materials at the Iowa Coal Project and the magnitude of change in soil characteristics resulting from the mining and reclamation operations.

To achieve the objectives of this study, soil samples were collected from two sampling areas of unequal size (0.98 ha and 0.028 ha). All sampling was done on one of four terraces, terrace 2, which is representative of soil materials at the Iowa Coal Project. A total of 480 soil samples from 60 soil profiles in increments to a depth of 150 cm were collected for this study. Soils collected for comparison to the Iowa Coal Project were selected from undisturbed sites on landscapes similar to the Iowa Coal Project prior to mining.

The objectives stated were chosen because an evaluation of resulting reclamation cannot be complete without an investigation and analysis of the restored soil. An investigation of the restored soil is important if the land is to be reclaimed for crop production. The soil characteristics will be the major controlling factor in the success of crop production yield levels. The information obtained in this study can serve as a basis for post-reclamation management of the soil.

SECTION IV. EXISTING RESOURCES AVAILABLE TO THE INSTITUTE

The problems limiting the development of minerals in this region of the country, particularly in the state of Iowa, are complex and will require a systematic long-term research effort to be resolved. To help solve these problems, certain University research facilities have been dedicated to Institute research.

Research Facilities

The research facilities of the participating departments which are presently dedicated to research on coal and other mineral resources have been made available for both the Institute's research and educational programs. These facilities include the Geotechnical Engineering Research Group in the Civil Engineering Department, the Coal and Mineral Processing Facilities of the Chemical Engineering Department, and the Coal Microcharacterization Laboratory of the Engineering Science and Mechanics Department.

In addition, many of the research facilities of the Energy and Mineral Resources Research Institute including the Coal Preparation Plant, the Engineering Research Institute, and the Agricultural Experiment Station, are available to students and faculty participating in our current research program. Also, the site of the former Iowa Coal Project Demonstration Mine has been utilized extensively for post-mining research. Table 1 (p. 42) and Appendix B (pp. 74-76) describe the capabilities of our available research facilities in greater detail. Figures 2 and 3 (p. 42 and 43, respectively) depict two of these facilities.

To add to its research capabilities, the Institute has expanded its own library with a comprehensive collection of books and serials dealing with most aspects of mining and mineral resources. The present library budget should provide for continued growth of this collection. In addition to the Iowa State University Library, the Physical Sciences Reading Room and the Ames Laboratory Document Library also contain applicable reference collections.

Equipment

The following is a list of equipment approved by the Office of Surface Mining, Division of Technical Services, and purchased by the Iowa Mineral Research Institute.

- Scintillation counter
- Sonicator cell disruptor
- Sulfur analyzer
- Polarographic analyzer
- Image dissector camera
- Color display monitor
- Graph plotter
- Ultrasonic velocity meter
- Transducers for the velocity meter
- Computer video terminal
- Computer keyboard terminal
- Seismograph
- X-ray spectroscopy amplifier
- Thin sectioning equipment
- Laboratory ovens
- Magnetometers

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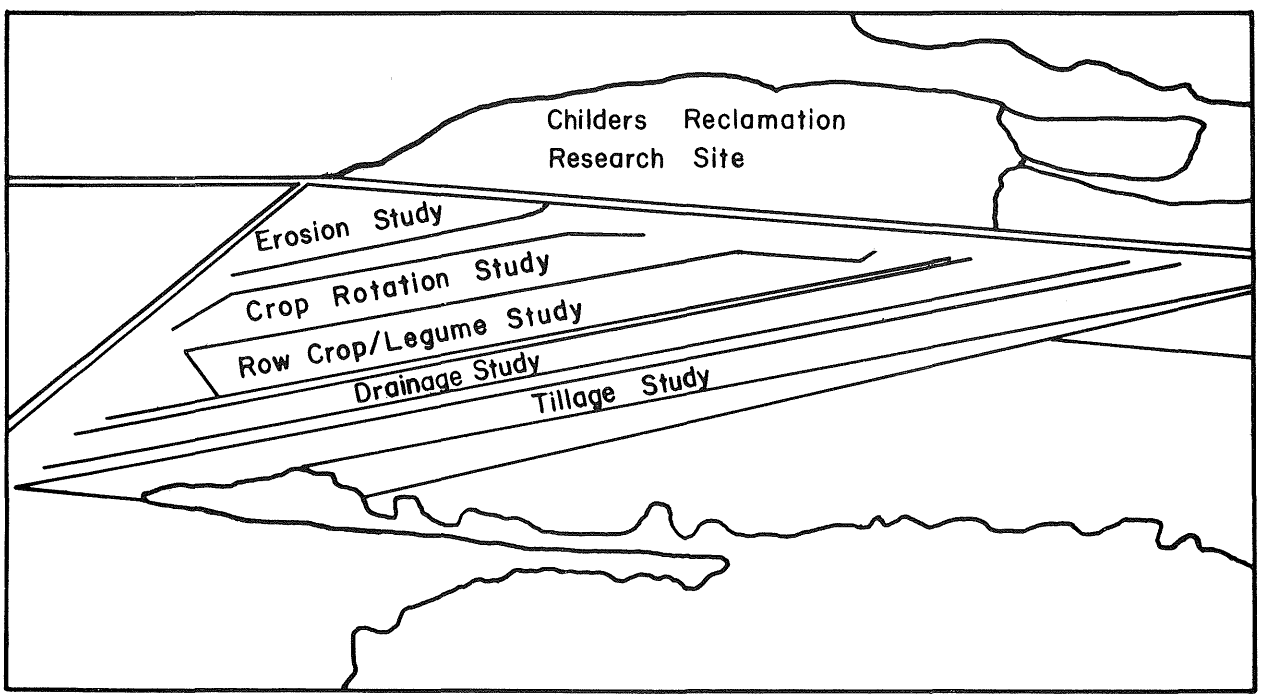
TABLE 1. Research Facilities Available to the Iowa Mineral Research Institute

Research Facility	Capability	Major Equipment
Coal Preparation Research Facility	Multi-Stream Coal Processing Plant	20 to 70 TPH Full Scale Heavy Media Cleaning Plant; 0.5 TPH Advanced Physical Coal Cleaning Pilot Plant
Organosulfur Studies Lab	Structural Identification and Component Separation of Organosulfur in Coal	Spectrophotometric and Chromatographic Equipment; Balances
Petrographic Laboratory	Coal Petrography, Coal Blending Studies	Optical Microscope; Furnaces for Low Temperature Ashing; Polishing and Grinding Equipment
Coal Characterization Support	Inductively Coupled Plasma-Atomic Emission Spectrometry; X-ray Excited Optical Luminescence Spectroscopy; Laser Techniques	ESCA; SIMS; Auger; Moessbauer; NMR; X-ray Fluorescence; Atomic Absorption; and Mass Spectrometry
Coal Microstructure Lab	Microstructural Analysis	Scanning Electron Microscope, Electron Microscope X-ray Analysis; Scanning Transmission Electron Microscope; Automated Image Analysis
X-Ray Characterization	X-Ray Analysis	EXAFS (Extended X-Ray Absorption Absorption for Fine Structure); X-ray Diffraction
Materials Analysis Lab	Development of New Materials for Coal Conversion Processes	Transmission Electron Microscope; Scanning Electron Microscope Electron Microphobe; X-ray Diffractometer; Thermal Analyses
Mineral and Coal Preparation Research Laboratory	Oxydesulfurization, Froth Flotation, Oil Agglomeration, Pelletization, Briquetting	Autoclaves; Balances; Comminution and Classification; Pelletizing; Briquetting
Iowa Coal Project Demonstration Mine #1	Coal Mining, Restoration, and Management Demonstration Site	45 Acre Site
Childers Reclamation Research Site	Management and Maintenance of Reclamation Projects	27 Acre Site
University Library	1,400,000 Volumes; 17,600 Journals; 1,200,00 Microforms; 84,000 Maps and Photographs	
Computation Center	Data Processing and Computer Serv.	IBM 360-65; ITEL AS/6; VAX 11/780

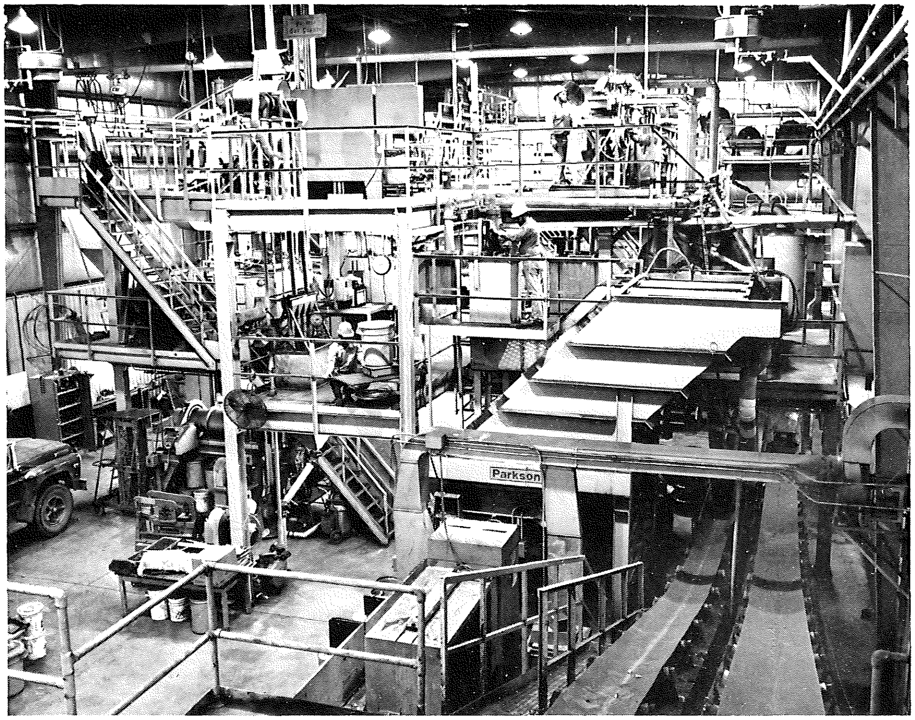
Figure 2

Aerial view of restored ICP Demonstration Mine reclaimed Childers site.

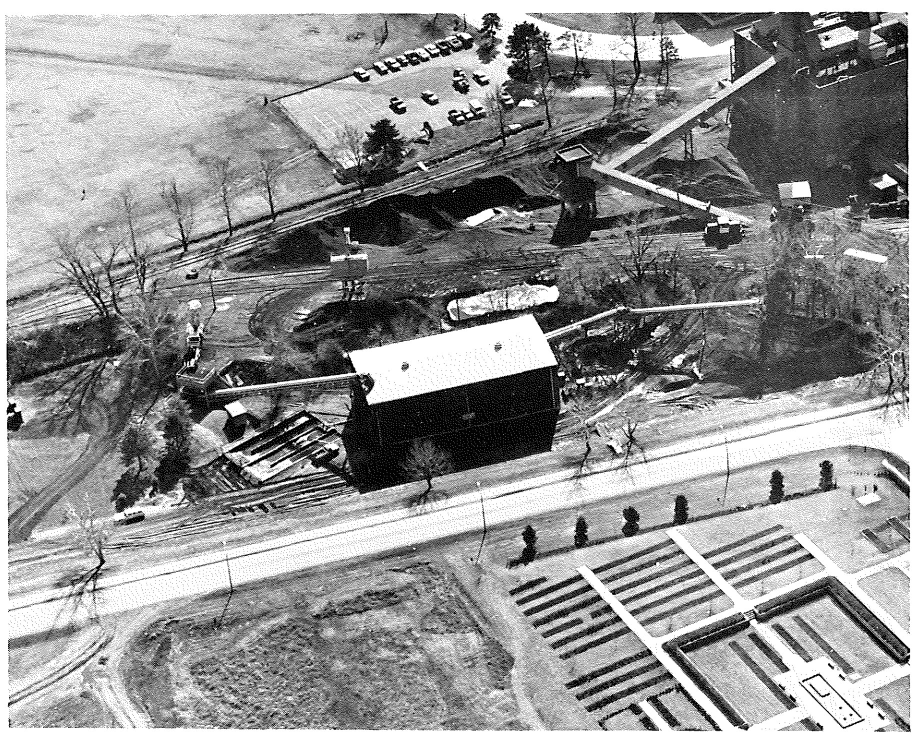


This graphical representation of the restored mine site locates the long-term agronomic studies that are being conducted.

Figure 3



Interior view of Iowa Coal Project Preparation Plant.
This experimental coal processing plant has a 25-70 tph capacity.



Exterior view of the Iowa Coal Project Preparation Plant.

The image dissector camera, approved and purchased from the Institute's original allotment grant, has been coupled with an automated image analysis system from LeMont Scientific Company*. Mineral processing studies have been initiated in order to produce samples for rapid characterization. Characterization involves the quantitative measurement of size, shape, orientation, porosity, and relative fractions of mineral phases and microstructural mineral features in sufficiently large numbers to assure reliable information in an extremely short time. Current work includes study of the effectiveness of separation of inorganic (mineral) phases from such materials as coal which are subjected to various surface treatments. These experiments are being conducted to evaluate systematically potential new mineral processing techniques using modifications of froth flotation or agglomeration methods. The availability of this particular device has enhanced the Institute's mineral characterization ability resulting in a broader base and interdisciplinary interaction within the University.

The portable proton magnetometer, approved and purchased from the Institute's first allotment grant, will be complemented in the coming quarters by the acquisition of an additional magnetometer as part of an accurate mineral resource assessment being conducted in the State on a limited basis. In addition, the device will enhance the current field monitoring and survey requirements of the Earth Sciences Department.

The equipment purchased under the Institute's first and subsequent allotment grants has effectively extended the current grant's aim to develop economic mineral resource assessment techniques:

1) In past quarters the scintillation counter has greatly enhanced our ability to investigate physical and chemical properties of mineral species with application to further studies in mining and engineering.
2) The sonicator cell disruptor has improved the characteristic rate of mineral analyses at various stages of processing.
3) The sulfur analyzer has given our graduate researchers the capability of rapid, direct determination of total sulfur in coal and gypsum, two of Iowa's most abundant mineral resources.
4) The polarographic analyzer has allowed our researchers to monitor organic and inorganic sulfur species in liquids found in coal and coal-derived liquids. Once mineral species and their constituents, e.g., trace metals, sulfates, and particulates, are identified, better data on the effectiveness of extractive techniques in mineral processing can be obtained.

*Mention of a particular brand or company does not constitute an endorsement of that particular brand or company.

SECTION V. INTERACTION WITH INDUSTRY OF COAL- AND MINERAL-RELATED RESEARCH AT IOWA STATE UNIVERSITY

Several projects dealing with coal- and mineral-related research at Iowa State University enjoy the cooperation of industries with interest in the studies. Although the summaries below are not complete, they are illustrative of industry-sponsored collaboration which address one of the goals of the mineral research institutes.

Coal-Fired Combustor Furnace for Corn Drying

Versatile Products, Inc. has supplied to the Institute a coal fired furnace to conduct research on grain drying. As a result of this acquisition, the Institute was awarded a research grant from the Iowa Energy Policy Council.

The furnace has been equipped with monitoring instrumentation and was operated to produce: 1) refined estimates on efficient combustion of raw, cleaned, or processed Iowa coals (including pelletized forms); 2) better understanding of mineral matter loading in such coals; and 3) estimates of waste heat recovery for agricultural use, particularly in drying corn prior to shipment.

Desulfurization of Waste Gypsum

A process for decomposing waste gypsum discarded by the phosphate fertilizer industry is under development. This process converts calcium sulfate, the principal component of the waste, into sulfur dioxide and calcium oxide by high temperature calcination in a two-zone fluidized bed reactor. As the solid particles move about in this reactor they are exposed alternately to reducing and oxidizing conditions which are created by controlling the air-to-fuel ratio in the different zones. The process has been demonstrated using natural gas as the fuel. The process is now being adapted to use coal in place of natural gas. The work is being supported by the phosphate fertilizer industry which could benefit greatly from a process that would recover sulfur dioxide from the waste produced by the industry. The sulfur dioxide could be converted into sulfuric acid which is one of the principal raw materials for the industry.

Rapid Dissolution of Coal and Minerals for Analysis

In most analytical procedures, dissolution of the sample is required prior to any instrumental measurements. An acid-dissolution technique for coal and minerals has been under study at Iowa State University. The Hach Chemical Company, known worldwide in the area of water analysis, has donated a spectrophotometer, a dc recorder, a digestor, and other associated equipment and supplies to pursue these studies further. Preliminary results for total sulfur, iron, and nitrogen content look encouraging, and benefits to coal and mineral analysis appear promising.

Statewide Mining Activities

The Institute also interacts with the mining industry in the state and has sponsored field trips for both graduates and undergraduates to mines in southern Iowa as part of our interdepartmental education program. In addition, the Institute has attracted the interest of other institutions and subsequently hosted the 1981 conference of the American Council for Reclamation Research at which two papers were presented by Institute graduate students. Listed below are the titles and authors of the papers.

Scott Killpack and Gerald A. Miller
Department of Agronomy, Iowa State University
"Variability of Soil Physics and Chemical Properties at a Reclaimed Surface Coal Mine, Mahaska County, Iowa."

Joseph A. Klingshirn
Earth Science Department, Iowa State University
"Characteristics of Water Associated with Coal Spoil."

IOWA COAL UTILIZATION ADVISORY COMMITTEE

Representatives from the private and public sectors have been called together by the Institute to form an advisory board external to the Institute's operations. The Iowa Coal Utilization Advisory Committee meets on a monthly basis to discuss and promote sound means to increase the extraction, processing, and use of Iowa's coal and mineral resources. Working relationships have been established with prominent coal- and mineral-related industries in Iowa, with appropriate State agencies, and with legislators from the General Assembly who serve on its Energy Committee. Listed below are the state agencies and private businesses holding membership in the committee.

State Agencies

Iowa Commerce Commission
Iowa Development Commission
Iowa Energy Policy Council
Iowa Geological Survey
Iowa Department of Environmental Quality
Iowa Department of Soil Conservation

Private Industry

Brown Engineering Company
Cargill Company, Milling Division
Central States Warehouse Company
City of Ames Electric Utility
Archer Daniels Midland, Clinton Processing Company
Corn Belt Power Cooperative
Iowa Power and Light Company
Iowa Fuel and Minerals Company
Iowa Coal Sales
Star Coal Company
University Avenue Coal Company

APPENDIX A

OUTLINE OF COURSES AND SEMINARS IN MINERAL RESOURCES MINOR

APPENDIX A

Outline of courses and seminars for the program includes:

a. Prerequisites for prospective students in the proposed program.

A successful applicant must meet the normal qualifications established by the Graduate College and academic department responsible for the student's major field of study. In addition, the successful applicant should have a minimum of 15 semester credits of undergraduate courses in the natural sciences and mathematics including chemistry (6 credits) and physics (4 credits).

b. Implications of the program for undergraduate work and related areas within the University.

Although an undergraduate program is not envisioned at this time, qualified undergraduates may enroll in the proposed courses in Mineral Resources. Also undergraduate students with an interest in this field should be encouraged to enroll in appropriate courses in the natural sciences and mathematics including geology, chemistry, physics and biology.

c. Listing of courses and seminars presently available in the co-operating departments or related departments which may be taken to satisfy program requirements.

CH.E. 515. Coal Science and Technology (3 credits)
Geol. 582. Advanced Economic Geology (3 credits)
MSE. 513. Advanced Extractive Metallurgy (2 credits)

d. Proposed new courses.

(1) Mineral Resources I. (3 credits)

Prereq: Chem. 164 or 178, Phys. 111 or 221.
Coal and mineral deposits, rock mechanics, underground and surface mining, land use planning and restoration, and related social, legal, economic and environmental aspects of mining operations.

(2) Mineral Resources II. (3 credits)

Prereq: Chem. 164 or 178, Phys. 111 or 221.
Mineralogy, coal petrography, mineral processing, coal preparation, extractive metallurgy, and related social, legal, economic and environmental aspects of mineral processing operations.

Appendix A (cont'd)

(3) Mineral Engineering (3 credits)

Prereq: EM 324 or 325, Mineral Resources I.
Underground and surface mining methods, rock mechanics, production economics.

(4) Mineral Processing (3 credits)

Prereq: Chem. 321, Mineral Resources II
Principles of mineral processing operations including size reduction and particle classification, separation, sedimentation, filtration, and drying.

(5) Special Topics (var. credits)

Prereq: Permission of instructor.

(6) Seminar in Mineral Resources (1 credit)

Prereq: Permission of Mineral Resources Supervisory Committee.

APPENDIX B

ON-CAMPUS RESOURCES AVAILABLE TO THE INSTITUTE

APPENDIX B
COMPLETED ON-CAMPUS RESOURCES AVAILABLE TO THE INSTITUTE

This Appendix contains expanded descriptions of coal- and mineral-related facilities listed in Section IV, "Existing Resources Available to the Institute".

Iowa State University (ISU)

Coal Preparation Research Facility. The Energy and Mineral Resources Research Institute is in the unique position of having operational responsibility for a 25-70 ton per hour multi-stream experimental coal processing plant in which research can be conducted. The plant is three years old, designed with adequate space for expansion, and has experienced operators.

Coal Preparation Research Laboratory. This laboratory is equipped with autoclaves, balances, pelletizing equipment, and other items which are necessary to perform laboratory research in oxydesulfurization, froth flotation, oil agglomeration, pelletization, and briquetting.

Organosulfur Studies Laboratory. This is a well-equipped laboratory with a full complement of spectrophotometric and chromatographic equipment, balances, and other items necessary to perform structural identification and component separation.

Petrographic Laboratory. Equipment items include a hot stage petrographic microscope, optical microscopes and three furnaces for providing low temperature ash specimens. Grinding and polishing equipment necessary to the preparation of polished coal and mineral specimens is also available.

Microstructure Laboratory. This laboratory is well-equipped with an automaged image analysis system tied to scanning electron and scanning transmission electron microscopes. Energy- and wavelength-dispersive x-ray analysis information can be gathered by a computer-controlled electron microprobe and analyzed by state-of-the-art support software.

Chemical Analysis Laboratory. This laboratory is equipped to perform analyses of coal and mineral samples according to ASTM and other classical techniques.

Instrumental Analysis Facilities. The Iowa Mineral Research Institute has access to the Ames Laboratory's unique capabilities in chemical analysis. The laboratory's energy research and technology work has resulted in the development of ultrasensitive analytical techniques, including inductively coupled plasma - atomic emission spectrometry and various laser techniques. Other analytical techniques include x-ray fluorescence and spark source mass spectrometry.

X-ray Characterization Laboratory. This facility is equipped to characterize minerals in single crystal and powdered forms, using single-crystal diffractometers, powder diffractometers, and the newly acquired EXAFS unit (Extended X-Ray Absorption for Fine Structure). The equipment is interfaced with computers for automated operation. In addition, an on-line x-ray diffractometer for monitoring pyrite and other minerals in coal is being developed.

Material Analysis Laboratory. One of the major support facilities for engineering research at Iowa State University is the Material Analysis Laboratory (MAL) of the Engineering Research Institute. Major facilities include a scanning transmission electron microscope, a scanning electron microscope, an electron microprobe, an x-ray diffractometer, and a thermal analyzer.

Iowa Coal Project Demonstration Mine #1. Coal mining and restoration activities have been completed at this research facility. During the course of operations 110,000 tons of coal were mined from this 40-acre site. Land that was originally pasture of marginal value has been reclaimed to topography of bench terraces suitable for intensive agricultural use. The mining method featured the use of rubber-tired scrapers to remove top soil, till, and shale overburden in a modified haul-back manner. The different overburden types were segregated during mining which enabled them to be replaced in their original order during reclamation. Therefore, the site is representative of "new law reclamation" and features five feet or more of non-toxic overburden, including topsoil, over the entire site. The demonstration mine site exists for continuing agronomic and hydrologic research.

Childers Reclamation Research Site. As part of mining operations, the Iowa Coal Project reclaimed 27 acres of abandoned mine lands to a field potentially valuable for hay or forage production. The area is now available as an environnmental demonstration site to re-examine the effective time on reclamation projects.

Iowa State University Library. The University library collections now total more than 1,400,000 volumes, 17,600 current journals and serials, 1,200,000 microforms, 84,000 maps and photographs, as well as manuscripts and archival materials. The library is particularly strong in the basic and applied fields of the biological and physical sciences and engineering. Iowa State's scientific serial collection in the fields of science and technology is one of the best in the nation.

Iowa State University Computation Center. The Iowa State University Computation Center provides complete data processing and computer services. The main digital computer system is built around a central processor, the NAS AS/6, running under OS/SVS, which makes it an IBM 370/168 equivalent. The AS/6 has four million bytes of real storage. Direct storage, floppy disks, magnetic tapes, readers, printers, and incremental plotters are all available on the system. A large-scale analog computer, the EII 8112, is also available. In addition, the Computation Center has recently installed three VAX 11/780 computers each with four million bytes of real storage for instructional purposes.