UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

National Coal Resource investigations of the United States Geological Survey

Open-file report 77-763
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Gordon H. Wood, Jr., Compiler

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CECIL D. ANDRUS, *Secretary*

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V. E. McKelvey, *Director*

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I PREFACE

The objective of this report is to provide a record of some of the goals and accomplishments of the coal resource investigations of the U. S. Geological Survey for 1977. Successful completion of these goals will aid the Nation in the years ahead because proper usage of coal resource data may lessen economic displacements resulting from the energy shortage.

This report is concerned only with one mineral fuel -- coal -- and only with coal resource investigations in the Geologic Division of the U. S. Geological Survey. Other divisions involved with coal or coal-related work are the Conservation, Water Resources, and Topographic Divisions. It is one of a series of reports on the energy resource studies conducted by the Geological Survey that provide a public record of the objectives, activities, and accomplishments of these programs. Similar reports have been prepared on oil and gas, oil shale, uranium, thorium, and energy-related industrial minerals.

This report includes descriptions of the program, each sub-element of the program, individual projects, and a selected list of program publications from 1970-76. It also describes how the program is responsive to Presidential pronouncements and Congressional mandates. The program is cooperative with several Federal bureaus, many state agencies, universities, and industry. This coordination assures that the program supplements the work of these interested groups and is not duplicative.

A scientific program such as the coal resource investigations is difficult for the non-involved person to understand solely from the existing reports on various studies made in the program. This report provides an explanation that the scientist, decision maker, personnel of other government agencies, and the layman can use to relate various activities and to gain a better understanding of the relation of coal to the Nation's requirements for energy and of the importance of a carefully planned program on this energy resource.

II INTRODUCTION

The coal resource investigations of the U.S. Geological Survey are directed towards the mission of helping alleviate the energy crisis by developing information immediately usable by the government, industry, and the public. Individually and collectively, the investigations are aimed at assessing the location, size, quantity, and quality of the coal deposits of the Nation (see Fig. 1) so that the proper coal can be mined at the most effective locality for the correct usage. In support of this assessment some of the investigations are directed to developing data on the origin of coal, the phenomena and processes that controlled coal accumulation, and the chemical and physical characteristics of regional and local coal deposits so that the location and distribution of undiscovered deposits may be predicted; to developing and maintaining a computerized data system capable of assessing and updating estimates of the Nation's coal resources; and to developing the scientific ability to predict geologically pertinent facts concerning coal with a minimum of exploratory effort.

The description of the Geological Survey's coal resource investigations is presented in this report in the context of the underlying socio-economic problem of expanding the domestic production of coal while maintaining acceptable environmental standards. This orientation toward a national mission characterizes each segment of the Survey's energy resources and marine geology programs. Readers who want information about the individual projects that constitute the coal resources program will find it in the appendices, which also include a bibliography and appropriate fiscal data, and an outline of procedures involved in a coal resource study.

A. Rationale of Program

Even though most people know that coal provided the bulk of the energy that fueled the Industrial Revolution, few realize that coal was the dominant energy source until World War II, and fewer still realize that it is an important ingredient in our current energy mix for manufacturing and is the principal fuel for electric power generation. As a result of this unawareness, coal investigations by scientists employed by government agencies, universities and industry were nearly non-existent from the late 1920's to 1970. The prospect of an energy shortage that would begin to materialize in the 1970's was forecast by some scientists, engineers, and economists as early as the 1950's. This warning was generally ignored.

The decade of the 1970's so far has been marked by a sharply increased dependence by the United States on foreign sources of energy. Although this dependence had been growing for the previous 15 years, it was made clearly visible, as forecast, to the American public by the Arab oil embargo of 1973. Since then, energy has remained a topic of public discussion and concern, and many different strategies have been proposed to solve the "energy crisis of shortage".

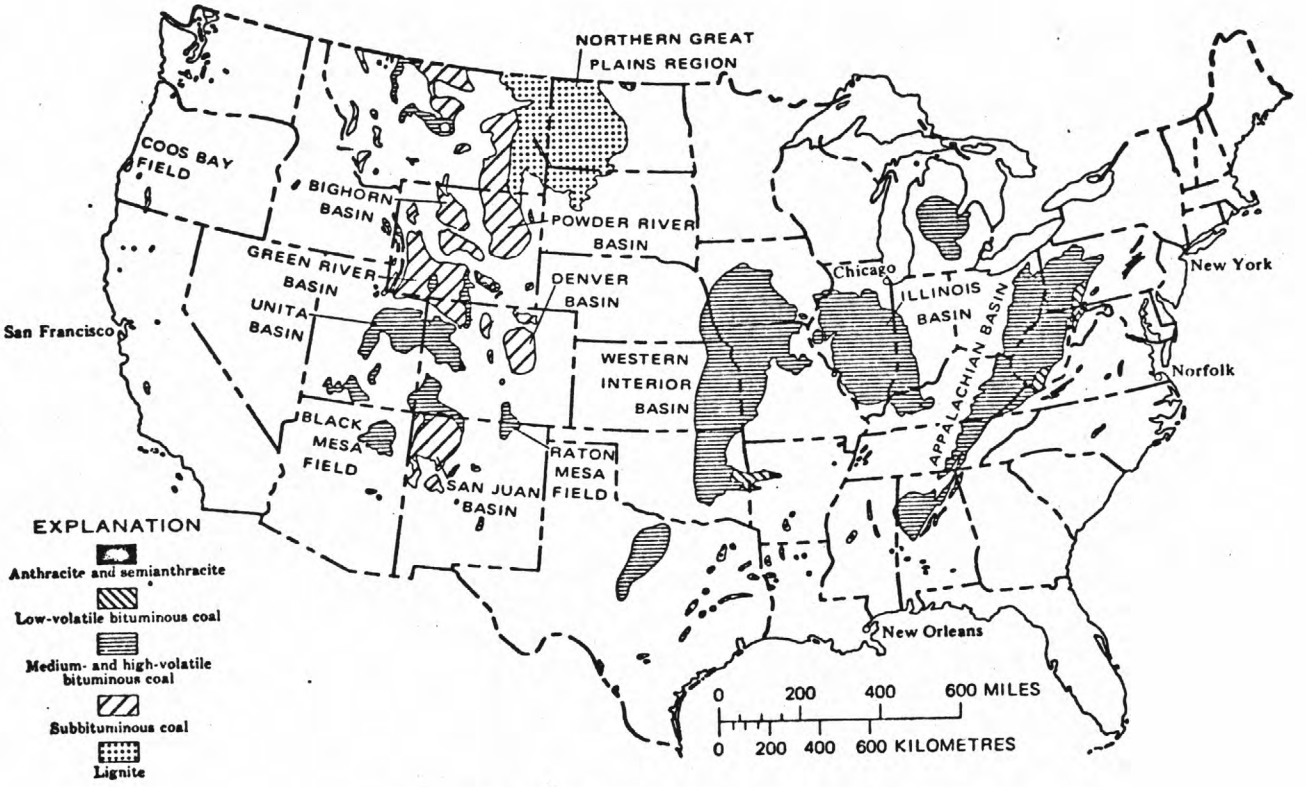

FIGURE 1.—Coal fields of the conterminous United States.

The current balance between U.S. energy supply and demand and the generally recognized need to increase the domestic production of energy make it appropriate to review our present knowledge of U. S. coal resources, which resource base provided in 1975 about 20 percent of the energy produced in the United States. These conditions also warrant a description of some of the research that is being done to improve our understanding of this resource.

At present the Nation is undergoing local to regional energy shortages because large scale sources of energy, such as coal, are not adequately developed to supplement oil and gas and are poorly located with reference to usage.

B. Federal Authorization for the program

The basic mandate for this program is the Organic Act that established the Geological Survey in 1879. This Act (43 U.S.C. 31 (a)) authorized the Survey to examine "the geological structure, mineral resources, and products of the national domain." More recent authorizations permit the Geological Survey to "conduct geological and geophysical exploration in the Outer Continental Shelf" (43 U.S.C. 1340) and in areas outside the National domain "where determined by the Secretary (of the Interior) to be in the national interest" (43 U.S.C. 31 (b)).

Several reports commissioned by the President have given impetus to an expanded national program of energy resource assessment. In December 1973, Dixie Lee Ray, then Chairman of the Atomic Energy Commission, submitted to President Nixon a report entitled "The Nation's energy future." One of the recommendations in this report calls for "enlarging the qualitative and quantitative inventory of domestic resources as rapidly as possible by improving the knowledge level of domestic resources and economically available reserves of oil and gas, both onshore and offshore," "the knowledge level of domestic resources . . . of uranium and thorium," the assessment of the "quality, regional distribution, and recoverability" of the Nation's coal resources, and the "information base on the distribution and quality of oil shales and tar sands" (page 98). The Project Independence report of November 1974, also commissioned by President Nixon, does not recommend specific policy actions concerning energy but does note that "all the new oil production is forecast from frontier areas in Alaska, from the Atlantic OCS or from improved tertiary recovery techniques. Each of these requires further exploration or new technology" (page 42). Elsewhere in the Project Independence report (page 114), the current level of uranium resources and exploratory activities to find them are recognized as constraints to the potential expansion of nuclear power. These reports have undoubtedly played a significant role in influencing the Congress to appropriate increased funds for fuels resource investigations under existing statutory authority.

Recently the Federal Coal Leasing Amendments Act of 1975 was passed by the Congress. In Section 8a the Secretary of the Department of the Interior is authorized to conduct an exploratory program designed to evaluate the extent, location, and the potential for developing the known recoverable coal resources on Federal coal lands. He is also to develop a "comprehensive land use plan." Section 8b states that the Secretary, through the U. S. G. S., is to conduct or contract for the results of seismic, geophysical, geochemical, or stratigraphic drilling

and to make public all data, information, maps, interpretations, and surveys that are obtained directly or under contract. The Secretary is also directed to prepare, publish, and keep current a series of geological and geophysical maps and reports concerning all coal lands to be offered for leasing under the Act. The program described herein, in coordination with other Geological Survey program elements, meets the requirements of this legislation.

III COAL RESOURCE INVESTIGATIONS OF THE GEOLOGICAL SURVEY

A. History

Coal studies of the Geological Survey commenced shortly after the founding of the agency in 1879. These studies were carried out with great vigor until about World War I and were expanded again in the early 1920's. In the late 1920's work began to taper off, probably as a by-product of the impending Great Depression. In the sense of modern coal studies these early investigations, with few exceptions, would be classified as reconnaissance in nature. Much valuable information was collected but by modern standards it is not adequate to meet today's requirements.

Coal work was increased to a moderately sized program after World War II. This level of activity, which lasted from about 1948 to 1958, was marked by the initiation of many projects, but the scientists involved gradually completed their assignments and new work was not scheduled. This gradual cessation of activity was due to a temporary decreasing importance of coal as an energy source to the Nation. During 1970, work was again expanded and in June of 1972 the Branch of Coal Resources was activated and the modern program of investigations initiated. This program has steadily increased in scope and number of investigations.

B. Present Status of Coal Resource Knowledge

On a nationwide basis there are thousands of maps, reports, and tables that can be used to varying extents to compile an inventory of U.S. coal resources. However, many of these contain data that are not compatible. For example, over the past 100 years many different authors have used individual systems for classifying coal bed thickness, overburden, method of reporting chemical analyses, petrographic examinations, reliability of data, bed correlations, rank and quality determinations, and location. This varied reporting of resource data has made it extremely difficult to relate the work of many individuals and groups into a coherent national assessment. Currently, no coal-bearing area in the U. S. has been adequately inventoried because of the varied classification and reporting preferences of the investigating scientists and agencies and because responsible authorities did not view assessment as necessary considering the magnitude of the resource and the commonly accepted belief that coal's day was over.

The same type of situation exists as regards scientific research into coal resource subjects such as coal chemistry and geochemistry, petrography, genesis of coal, effect of geologic phenomena and processes on mining, geophysical techniques usable for coal exploration and chemistry, and the development of reliable, integrated, cohesive data systems.

Work during the last few years has shown that the coal deposits of the Nation are: 1) varied as to the quality of coal they contain; 2) classifiable as to many quality and quantity parameters; 3) divisible into mappable classified parameters that can be used to predict specific qualities, tonnages, and mining conditions; and 4) are for the first time in many places amenable to matching quality requirements with resources in the ground.

Using all available data, Averitt (1975) estimated that the coal resources remaining in the ground on January 1, 1974 totaled 3,968 billion tons, distributed in several major categories, as shown below:

Table 1. -- Estimated remaining coal resources of the United States, January 1, 1974
[Figures are for resources remaining in the ground]

Category	Billions (10^9) of short tons
1. Identified resources:	
A. Reserve base	424
B. Additional identified resources	1,307
C. Total identified resources	1,731
2. Hypothetical resources:	
A. 0-3,000 ft overburden	1,849
B. 3,000-6,000 ft overburden	388
C. Total hypothetical resources	2,237
3. Total remaining resources	3,968

The following, which is quoted from Averitt (1975), succinctly explains the meaning of the estimate as regards the amount of resources, how the resources are classified, the position of the United States with reference to world estimates of coal, and relates coal to other energy sources:

"The new United States estimate is a 23-percent increase over previous estimates (Averitt, 1969, 1973), made possible by an increased program of geologic mapping, exploration, and study during the past few years by Federal and State agencies and by private industry. The new estimate is based on detailed published estimates of identified resources in individual States and on generalized estimates of additional hypothetical resources for unmapped and unexplored areas in these States.

The identified tonnage has been classified in all States according to rank. It has also been classified by thickness of overburden, degree of reliability of estimates, and thickness of beds in 21 States. Coal thus classified is well distributed in all coal provinces and represents about 60 percent of the total identified tonnage. This large classified tonnage is, therefore, reasonable representative of the total identified resources. The distribution of the classified tonnage in several meaningful categories, each expressed as a percentage of the total, is as follows: (1) 91 percent is 1,000 feet or less below the surface, (2) 43 percent is bituminous coal, (3) 33 percent is in thick beds, and (4) 24 percent is in the reserve base.

The United States contains about 25 percent of the world's identified coal resources and about 20 percent of the world's estimated total coal resources. In 1972 the United States accounted for about 19 percent of the total world production. Between 75 and 80 percent of the United States production is obtained from 23 thick, continuous beds.

A comparison on a uniform Btu basis of resources of coal and other fossil fuels in the United States shows that coal constitutes 69 percent of the total estimated recoverable resources of fossil fuel, whereas petroleum and natural gas together constitute only 7 percent, and oil in oil shale - which is not currently used as a fuel -- constitutes only 23 percent. The disparity between the large resources of coal and the small resources of petroleum and natural gas is sharply emphasized by the fact that in 1973 the combined production of petroleum and natural gas in the United States was 3 times that of coal."

Many thousand pieces of coal resource information, both old and new, were utilized by Averitt in reaching the estimate and the conclusions stated. Despite this vast amount of data, the estimate is inadequate for today's needs because of the increasing needs for sophisticated geochemical data, the intermixture of old, new, good, and bad data, the failure of early geologists and engineers to adequately document their data, and the failure of many reports to define the parameters used in deriving an estimate. As an example, Averitt's statement does not mention that the resources could not be classified on a modern chemical basis, and so industry cannot match quality with tonnage, costs of mining, transportation, environmental problems, type of mining, market, and usability.

C. Scientific and Technical Problems Under Investigation

The coal resources program of the Geological Survey is designed to address the following issues:

1. Resource Investigations. Many of the Nation's coal deposits are not precisely located and are inadequately classified and assessed

as to resources and reserves, depth of burial, status of ownership, and reliability of tonnage estimates. These factors must be better known.

2. Coal quality. Gaps in knowledge exist that prevent a modern assessment of the geochemistry, petrography, and quality of coal deposits on national, regional, and local bases. A sophisticated assessment should be made that would provide future decision makers with sufficient data so that preliminary plans for coal mining, utilization, and waste disposal can be based on scientific and engineering facts.

3. Origin of coal. The physical and chemical processes and phenomena that controlled the original extent of coal deposits, their physical and chemical characteristics, diagenesis, and timing of coalification are poorly understood. This lack of knowledge limits the ability to predict coal occurrences as to extent, quality, usability, and minability. Studies of the origin of coal are, therefore, exceedingly important if exploration, development, environmental, and mining problems are to be minimized.

4. Geophysics. Existing exploration for coal is largely guided by surface exposures and drilling. The development of more efficient surface and borehole geophysical techniques could result in large time and monetary savings.

5. Coal Geology and Mining. Coal mining has not been adequately studied with reference to the geologic phenomena and processes that prevail in the subsurface. The development of new techniques and equipment for high speed, large-scale mining should be guided by a knowledge of the geology of each major coal deposit because otherwise technologies costing large sums of money may be developed and never amortized if sufficient resources suitable for extraction by a particular technique are not available. Some technologies also might prove to be unsafe to use under the geologic conditions as some localities.

6. Data Handling. The volume of coal data is increasing rapidly and is too large for efficient non-computer handling. The National Coal Resource Data System has been developed to keep track of the enormous volume of information.

D. Summary Description and Current Status of Program

The problems being studied by the coal resource investigations program are divided into four subprograms, each directed to addressing a particular set of problems (see the organization chart on page 48). The interrelations of subprograms and projects are described below.

1. Resource Investigations. Quantitative resource assessment is being attacked by several areal studies. In the West, quantitative studies at present include several large detailed mapping and stratigraphic projects in Montana, Wyoming, Utah, Colorado, Arizona, and New Mexico. The objectives of these projects are in response to the Federal Coal Leasing Amendments Act of 1975.

These large detailed mapping and stratigraphic projects in the West are contributing regionally scaled information filling gaps in data required to determine the existence of commercial quantities and the delineation of deep and/or surface recoverable coal resources in coal fields encompassing significant Federal coal. These results can be usefully shown at a map scale of 1:100,000. More detailed and specific information, including that from mapping, drilling, geophysical, and geochemical studies, will be analyzed in order to determine; (1) the geographic extent and subsurface makeup of coal fields which contain considerable amounts of Federal coal and (2) make assessments of the amount of coal recoverable by deep and surface mining methods. For these purposes, the results will generally be shown on maps at a scale of 1:24,000.

Resource investigations in the East include similar mapping and stratigraphic projects in Virginia, West Virginia, Kentucky, and Pennsylvania. Although federal lands do not make up a large portion of the coal-bearing areas in the East, the objectives of the eastern projects are much the same as those of the western ones -- to quantitatively assess National coal resources.

National coal quality projects operating in close coordination with the eastern and western mapping and stratigraphic projects are designed to qualitatively assess the geochemistry and petrology of the Nation's resources. These projects collect, sample, and provide analyses of coal beds throughout the nation. Data from these projects complement those from the mapping and stratigraphic studies by providing detailed information on the composition and quality of coals, which is needed to determine the best uses of various coals and tonnages of coals with specific parameters.

2. Assessment Research. Several topical studies are grouped into the Assessment Research subprogram.

Basic knowledge of coal quality is being gathered and evaluated by several chemical, geochemical, petrographic and mineral-matter topical studies in the assessment research subprogram. In addition, data on sulfur, trace elements, and contaminants as related to mining, usage, disposal, and by-products is being collected and studied by several projects.

The studies are examining the geology, sedimentology, stratigraphy, geochemistry, paleontology and physical and chemical characteristics of modern peat deposits in Florida, North Carolina, and Louisiana to better understand the genesis of ancient coal deposits. These projects are also charged with determining the fate of each element, compound, maceral (unit of organic material), and the changes in organic geochemistry as swamp vegetation is converted to peat; and the processes of degradation of vegetable matter and coalification.

Increased use of geophysical equipment, improvements in technology, and developments in exploration are being investigated by cooperative projects sponsored by the Branch of Coal Resources in the Branches of Isotope Geology and Petrophysics and Remote Sensing. A bore-hole sonde (measuring device) is being constructed to determine the chemistry of overburden and coal irradiation. Approximately ten chemical tests can be made by the sonde in a borehole with results that compare favorably with laboratory analyses of samples. Unfortunately the diameter of the sonde at present is slightly too large for NX coreholes. It is hoped that the diameter problem can be solved as the technology of component miniaturization advances.

Sonar, seismic, gravity, and magnetic geophysical equipment and techniques are being investigated to develop better methods of tracing individual coal beds, channel sandstones, and other pertinent geologic features in the subsurface.

A combined geophysical and geochemical study is directed to developing strains of microorganisms which will neutralize acidic mine waters, develop electricity, purify the water, and precipitate mineral or elemental by-products. Waters containing nuclear wastes such as tritium are also being innoculated with the organisims to determine if the radioactive contaminants can be removed. If successful, the microorganism research on coal wastes will benefit the nuclear industry.

The U. S. Geological Survey and the Polish Geological Institute are cooperating to compare the relatively small and well known Polish coal basins with the geologically similar but larger and more poorly known U. S. bituminous coal basins. Such comparison should result in recognition of characteristics that are common to all coal basins and in the U. S. coal basins being explored and mined in view of these characteristics.

3. Coal Geology and Mining. The usage of geologic data by the mining industry and the government is being actively investigated. Studies are being made in two areas of Federal Land selected by the Bureau of Land Management to determine the best methods of using geologic data to aid in selecting future mine sites. These studies are part of an overall investigation to assure that the best coal underlying Federal lands is mined at suitable localities for the best usage, either on site or off-site, and with the least detriment to the environment of a mine area. Cooperative studies with the Bureau of Mines by Geological Survey personnel are attempting to develop geological analyses that will be more useful to the mining engineer. Five areas in the West, already

geologically mapped are being reexamined by a team of geologists who are devising new types of maps, illustrative material, and reporting methods so that more useful products can be prepared for use by mining and planning personnel. New types of maps and reports, if properly accepted by mining engineers, could influence the development of high speed, high capacity, and advanced mining equipment and practices because the engineers would be more aware of the amount, quality, and geologic problems associated with the extraction of coal.

4. National Coal Resource Data System. The problem of handling the increasing volume of coal data is being investigated in a subprogram that is cooperative with the Geological Surveys of most of the coal-bearing states and several foreign nations.

The sub-program is designing, planning, developing, and maintaining the computerized National Coal Resource Data System (NCRDS). The NCRDS was established to store, retrieve, manipulate, integrate, synthesize, and summarize all existing and future coal resource data as rapidly as possible. It has been developed in two phases -- Phase I, a series of areal summary data files for the coals in each state, portraying the best available resource information by reliability category, rank, quality, and past mining. The data has been assembled wherever possible by county, 7 1/2' quadrangle, and township. Phase II, a series of point-source basic data files on the coal beds of the Nation that will contain geologic, geochemical, engineering, environmental, topographic, and miscellaneous information which can be used to compute local, regional, and national coal resources. The system is designed so that by using basic data located geodetically and three-dimensionally in the earth's crust, charts, tables, maps, and other illustrative matter can be constructed by the computer. As designed and developed, many different types of point source data can be entered, stored, retrieved, manipulated, integrated, analysed, and synthesized by the computer. The Phase II files will be used to update and validate the Phase I files, and as sufficient data develops to calculate coal tonnages in any area with reference to coal quality and to discriminate reserves and resources by categories of overburden, reliability, thickness, physical and chemical parameters, private and public ownership, and institutional restrictions. In addition, the computers of the system will be able to prepare maps, charts, and tables that can be published with minimal revision and editing. This capability will be the focal point of the government's data on coal resource availabilities, because the computer files constitute the only source where publicaly available data will be continuously updated for appropriate users.

The NCRDS is developing as parts of its file system a series of banks that will be maintained for the International Energy Agency's (IEA) assessment of international resources. These banks will contain data supplied by member countries of the IEA. The Geological Survey will supply the NCRDS computer capability for the IEA assessment. When fully operative, the data system will interrelate the coal investigations of the Geological Survey, cooperating state and federal agencies, industrial concerns, and cooperating foreign nations. This interrelation will enable the U. S. Government, industry, and the public for the first time to gain

an insight into the coal resources of the United States, other nations, and the World from the viewpoint of modern scientific data. It will also allow decision makers -- public and private, miner and conservationist, and user and environmentalist to intelligently assess utilization of coal as a partial answer to the energy crisis.

A Coal Resources Assessment Group (CRAG) has been established to standardize and monitor the reporting of coal resource data within the Geological Survey and to promote the use of acceptable standards in other agencies and organizations engaged in coal assessments. The methodology of making resource assessments has not been uniform in the past; standardizing procedures and terminology will allow maximum benefit to be derived from the computerization of coal resource information, and will minimize the cost and time involved in any type of resource calculations.

Methods of producing better, more illustrative, and more easily understood geologic and coal resource maps are also being probed in the National Coal Resources subprogram. It is expected that improved maps may be made more rapidly and cheaply through the use of digitized computer-graphics data. Use of continually updated information stored in the NCRDS will permit rapid revision of computer-graphic maps, in formats acceptable for open-file or preliminary report publication without any manual compilation or drafting.

E. Future Direction of the Program -- Unsolved Problems

Many problems concerning coal resources, geochemistry, standardization of reporting methods, data collection techniques, fate of chemical elements and compounds during coalification, and methods of publicly reporting coal information remain to be solved and/or improved. Each of these problems must be investigated and either partly or wholly solved so that sounder scientific and engineering advice can be given to the decision makers who are charged with proper utilization of the Nation's coal resources.

At present, industrial decisions concerning coal mining and utilization are largely governed by economic considerations. Little industrial attention is directed to localities where coal of similar or better quality is available simply because data has not been collected, collated, and disseminated. More data are needed about coal resources in all the Nation's coal fields; these data should be of equal caliber and publicly available.

Efforts in these areas should help provide the data:

1. Continue and improve mapping, stratigraphic, sedimentologic, depositional, geochemical, and drilling studies to better assess the quantity and quality of coal resources.

2. Continue and improve data collecting and utilizing techniques so that NCRDS can work to highest efficiency.

3. Augment effectiveness of topical studies investigating the geologic phenomena and processes that control mining, the chemical changes that take place as coal increases in rank, Btu value, etc., and as various elements are added, subtracted, or recombined as a coal deposit is subjected to natural events through time.

4. Through developing new software and programs, enhance the ability of the NCRDS to manipulate coal data so that sound decisions are made more easily and quickly.

5. Devise new and improved methods of standardization of data so that state, National, and international resource assessments can be compared with assurance.

6. Broaden cooperative work between Federal and state agencies, universities, and foreign nations so that the time necessary to achieve validated data can be shortened.

7. Develop methods of information dissemination that are more effective, efficient, less costly, less time and manpower consuming, and more reliable.

8. Develop additional techniques that will, with minimum data, more efficiently predict coal thickness trends, quality trends, and usability.

Fulfillment of these 8 items will allow the Nation to use its coal resources more efficiently with minimum degradation of the environment and with proper regard to all data instead of economic factors being the only considerations.

F. Relation of Program to Other Groups

The coal resource investigation program is deeply involved with other groups, including both those that simply use the data and information as generated in the program and groups that both use it and provide feedback of information generated in their own related studies.

1. User Groups. Major federal agencies relying on Survey programs as a source for the information needed in planning and implementing certain aspects of their work are the Bureau of Indian Affairs, the Federal Power Commission, and the Federal Energy Administration. Numerous other federal agencies request information from time to time. The Survey has conducted several investigations on coal in areas being considered for Wilderness and Primitive areas. Other direct users of the data include industry, parts of state and local governments, and the general public. Cooperative work, however, in which information between user groups and the Survey is shared and mutually complementary, is very widespread.

2. Cooperating Groups. There are several groups within the U. S. Geological Survey that are concerned with various aspects of the Nation's coal resources. The Coal Resources Investigations program of the Geologic Division works closely with all of these groups. The Central Region Energy Liason Committee functions as the focal point or coordinating work on Federal Coal Lands; administrative personnel in Washington and Denver overview cooperation on private and state lands. Thus exchanges of information are routine among personnel involved in geologic, geochemical, geophysical, and mineral resource studies in the Geologic Division, and with personnel in the Conservation, Water Resources, and Topographic Divisions of the Geological Survey.

The U. S. Geological Survey is the leader in the United States in promoting cooperation on coal resources investigations among federal and state agencies, industry, universities, private individuals and international groups. Cooperative studies are carefully monitored and nurtured so that any duplication of work will be kept to a minimum and worthwhile research will be increased.

The U. S. Geological Survey is cooperating on coal resource investigations with the Bureau of Land Management in conducting research on geologic models of coal mine sites and in determining the best methods of presenting information to users. It is cooperating with the Bureau of Mines to define categories of geologic data that are more useful to mining engineers and to determine better ways of communicating geological information to engineers. The Environmental Protection Agency is sponsoring research on contaminants in coal as related to depositional environments, diagenesis, and geologic history so as to aid coal mine planning, coal preparation, cleaning and waste disposal, and reclamation of mined areas. The Energy Research and Development Administration is cooperating on studies of waters polluted by acid and tritium and on a program of collecting, analyzing, and evaluating samples of coal from throughout the United States to elucidate the composition, geochemical variables, quality parameters, predictability, and resource potential of U. S. Coal. The U. S. Bureau of Mines routinely performs proximate and ultimate analyses on coal samples collected by Branch of Coal Resources projects.

Most of the Nation's coal-bearing states are cooperating with the U. S. Geological Survey through their State Geological Surveys or the appropriate responsible state agency in collecting and analyzing coal samples and in building the National Coal Resource Data System (NCRDS). This cooperation is funded by small grants or contracts with some states; with other states the Geological Survey has agreed to perform chemical analyses and make the results available to the State agencies. It has also agreed to enter any State's data into the NCRDS and to provide them access to the computer based file at cost on a time-sharing basis.

The Geological Survey is cooperating with the Coastal Studies Institute of Louisiana State University in studying the peat deposits of the Mississippi River Delta. Informal cooperation is carried on with the Pennsylvania State University by exchanging analytical data and by entering coal data from that university in the NCRDS.

Internationally, the Geological Survey is cooperating with the United Kingdom, Canada, the Federal Republic of Germany, Belgium, and Italy in developing and maintaining a World Coal Resources and Reserves Service. These nations have agreed to finance the service through the International Energy Agency (IEA). The NCRDS of the Geological Survey is functioning as the computer agency for the service. The National Coal Board of the United Kingdom is operating a clearinghouse that supplies data categorized for the computer and handles all requests for information from the member nations. It is anticipated that the IEA World Coal Resources and Reserves Service will become the principal source for worldwide data on coal within the next five years.

The Geological Survey is also working with the Polish Geological Institute, Warsaw on two cooperative projects that are designed to analyze in detail the small, compact, well-known Polish coal fields, with the anticipation that the results can be applied to the large, less well-known U. S. fields. If successful, the ability to predict coal trends and geochemistry in the U. S. may be greatly enhanced.

G. Geographic Distribution of Coal Investigations

The coal investigation projects of the Geological Survey are directed to (1) nationwide topical or resource problems and (2) local and regional geologic problems. The geographic distribution of effort is controlled by the sulfur content of coal and whether the coal is owned by the Federal government (these factors being part of the basis for possible leasing priorities) or by states and private interests.

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Geologic mapping and geochemical investigations of high rank, high-to-low-sulfur special purpose (including metallurgical), coals (see Fig. 2), in parts of Pennsylvania, Kentucky, Virginia, and West Virginia is being conducted by several projects. Figure 2 also shows the location of peat investigations in Florida; the distribution of sulfur and trace elements in peat, is of particular interest in these studies. Many other projects are working on the low sulfur, subbituminous and bituminous coals and lignites on or near federally owned coal in the western United States (see Fig. 2), including the subbituminous coals of the Powder River Basin of Montana and Wyoming, the lignites of North Dakota, bituminous and subbituminous coals in the Rock Springs uplift of Wyoming, the Hams Fork area of Wyoming and Utah, and in central Utah. Mine site selection studies with the Bureau of Land Management are taking place at localities in Wyoming, Montana, North Dakota, New Mexico, Colorado, and Utah. These studies are designed to develop geologic, geochemical, resources, land use, and environmental parameters that can be used along with other parameters to guide decisions resulting in the better usage of federal coal with minimum degradation of the natural environment and maximum socio-economic benefits.

The remaining projects of the Geological Survey coal investigations are topical or are directed to regional and national problems.

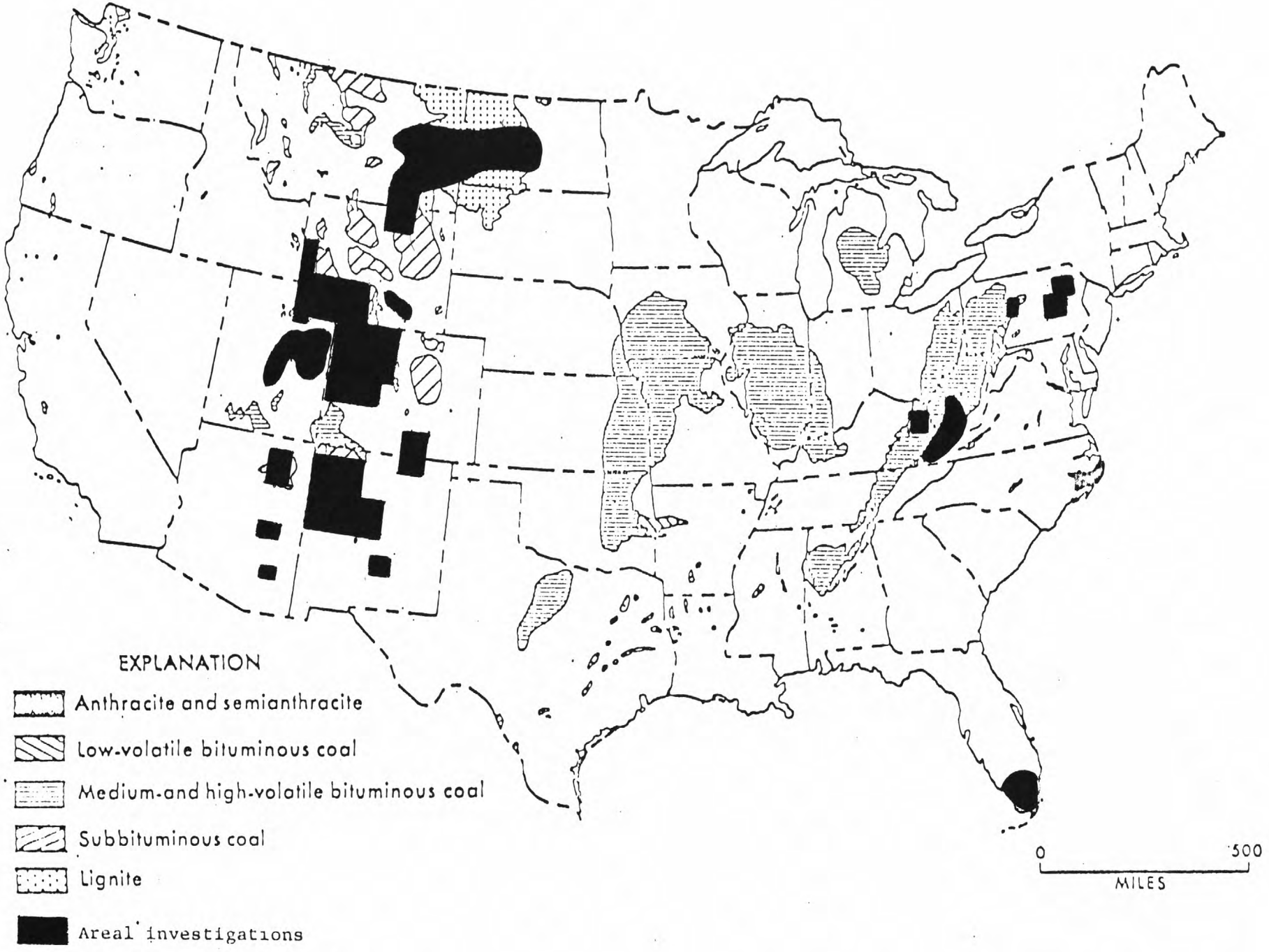

Figure 2.-- Branch of Coal Resources areal investigations in coal fields and peat deposits of the conterminous United States.

H. Program Products

The techniques used by the Branch of Coal Resources to transfer investigatory results from scientist to scientist and to the public, Congress, industry, and other government agencies are generally by reports and maps published in Bulletins, Professional Papers, Geologic Quadrangle and Miscellaneous Investigation Maps, professional and trade journals, and circulars. In addition, many speeches and accompanying abstracts for professional meetings are made each year. All of these techniques have been followed by Branch personnel during the last few years. In order to supplement these techniques and to further dissemination of data, the Branch conducted a 3-day seminar on coal geology and mining in September, 1976. This meeting was attended by about 325 coal scientists from several countries and was an effective method of data exchange. Within the next year or so another seminar will be held to continue this method of exchange of ideas, research results, and problems. The National Coal Resource studies subprogram is conducting research into methods that could be utilized to prepare computerized reports, maps, and other illustrations for public distribution. It seems likely that computerized reports can be prepared more cheaply, efficiently, and rapidly than standard printed publications.

I. Summary of Program Accomplishments in FY 1976 and FY 1977

1. Research results.

A scientific breakthrough occurred through the development of techniques for determining with a magnetometer the underground margins of burned coal in the Powder River Basin of Wyoming. This breakthrough, if fully utilized will guide drilling of exploratory boreholes in areas already burned and allow much greater precision in computing coal resources.

Coal and coal-related geologic data derived from all investigations of the Branch of Coal Resources, the Bureau of Mines, and several State Geological Surveys are being entered at an increasing rate into the computerized National Coal Resource Data System. Approximately 80,000 records were entered by mid-summer FY 1977.

A symposium titled "Coal Geology and the Future" sponsored by the Geological Survey was held in Reston, Va., September 27-28, 1976. Twenty-three leading research scientists from State and Federal agencies, industry, and universities discussed present and future research requirements in coal exploration, mining, and utilization. In their opinions these requirements must be fulfilled in order to satisfy the ever-expanding demand for coal to meet the Nation's energy needs. About 325 scientists from throughout the Nation and from many foreign nations attended the symposium.

In FY 1976 about 3,800 square kilometers were mapped and assessed geologically for their coal resources. Approximately 2,600 square kilometers of this was in low-sulfur coal lands of Wyoming, Montana, Colorado, and 1,300 square kilometers in similar coal lands of Kentucky, West Virginia,

and Virginia. Results from FY 1977 show that 1,800 square kilometers were mapped as of August, 1977 in the same states and that 2,300 square kilometers of Federally owned coal resources were re-evaluated in Montana and Wyoming.

During FY's 1976 and 1977 2,250 and 1,300 samples of coal and related rocks were collected with the cooperation of State Geological Surveys. These samples are being analyzed for 60 major, minor, and trace elements in addition to their Btu content and the normal ultimate and proximate analyses. As of August 1977 approximately 5,000 samples had been analyzed by modern methods during the preceding several years. Results of these analyses indicate that coals in the Western and Eastern Interior Coal Basins contain higher than normal amounts of zinc and cadmium and coals in the Eastern Interior Basin also contain higher than normal amounts of cobalt, chromium, nickel, and vanadium.

Geologic mapping during FY's 1976 and 1977 and coal resource calculations during FY 1977 indicate that about 130 million tonnes of bituminous coal remain in 13 beds in the 356 square kilometer area proposed for a National Park along the New River Gorge in West Virginia. Approximately 60 million tonnes of coal remain in 12 beds in the less extensive 238 square kilometer area proposed as the wild and scenic river in the gorge.

Sixteen potential coal mine sites on Federal land were geologically investigated and their resources of coal estimated during FY 1976 (12 sites) and FY 1977 (4 sites) in cooperation with the Bureau of Land Management and the Bureau of Reclamation.

During FY 1977 four comprehensive regional reports containing descriptions of geology, coal resources, mining methods, potential developments, and environmental hazards were prepared for areas where production of Federally owned coal is anticipated and Environmental Impact statements will be required.

The coal resource classification systems of the Geological Survey and the Bureau of Mines were standardized in FY 1976 when the Directors of the two agencies authorized publication of U. S. Geological Survey Bulletin 1450-B entitled "Coal Resource Classification System of the U. S. Bureau of Mines and U. S. Geological Survey."

Sixty-nine reports were published and open-filed by personnel of the Branch of Coal Resources during FY 1976. These reports detail the mapping of many coal-bearing areas, the collection and chemical analyses of many coal and coal-related samples, and many diverse results of topical studies. Each report is listed in the references.

About 80 reports and/or maps will be published or open-filed by personnel of the Branch of Coal Resources during FY 1977. These reports are not listed in the references because many remain to be printed and their full citations are not yet available.

2. Personnel Additions

Eight professionals were assigned to the Branch of Coal Resources during FY 1977, a 17 percent increase in the size of the scientific staff.

3. Facilities

Forty-seven of the eighty-seven employees of the Branch of Coal Resources employees are housed in offices and laboratories at the U. S. Geological Survey's National Center in Reston, Va. Thirty-nine employees are in offices and laboratories in Denver, Colorado. One employee is located at Charleston, West Virginia.

Trace element analyses and scanning electron microscope examinations are performed by Geological Survey Analytical Laboratory personnel in laboratories in Denver and Reston. Peat and some sulfur analyses are made in Branch laboratories.

During FY 1976 the program was enhanced by development of a reflected light petrographic laboratory at Reston. Also the program opened a facility at Reston where more than 20,000 coal thin sections of many of the world's coal beds can be examined by government, private, and industrial scientists. This collection of thin sections will allow petrographic comparisons of coals to be made on a worldwide basis.

A fine-particle coal petrochemistry laboratory was activated at Reston during FY 1977. This laboratory will be used to study organic and inorganic components of coal by transmitted and reflected light microscopy and to correlate the optic and other physical and chemical properties.

IV OPPORTUNITIES FOR EXTERNAL PARTICIPATION

To help attain the objectives of its various programs, the Geological Survey is authorized by Public Law 85-934 to spend funds through grants for the support of scientific research and for other purposes. Grants may be awarded only to colleges and universities, other non-profit organizations, and State and local governments. They are based on unsolicited research proposals submitted by investigators who believe that they can contribute to an ongoing scientific program conducted by the Geological Survey. Research proposals may be submitted to the Survey at any time, but some programs will consider only those proposals submitted in response to a public announcement of a project to be carried out partly or exclusively through research grants.

Opportunities for grant supported research projects related to the coal resources investigations program depend on the nature and scope of the proposed work, its importance to the program, and the availability of funds. Proposals that complement, rather than duplicate or overlap, existing or planned Survey conducted projects on coal resources have a better chance of receiving support. A prospective grantee may discuss his proposal with appropriate staff members in the Branch of Coal Resources before formally submitting it to the Geological Survey.

Detailed information about the procedures for applying for a research grant are contained in a Geological Survey pamphlet entitled "Grants for scientific research,". Copies of this publication may be obtained from any Survey office.

The Geological Survey may award a research contract, as opposed to a grant, to any individual or group, including for profit organizations, that has the capability to deliver the required product, such as a map, a report, rock or mineral samples, analytical data, or a scientific instrument. A contract usually is awarded in response to a Request for Proposals (RFP), which the Geological Survey issues whenever it requires the services of a private organization. The Survey may send copies of an RFP to known potential contractors, and the RFP also is published in "Commerce Business Daily." However, in some circumstances a contract may also be awarded on the basis of unsolicited proposals.

Further information about grants or contracts related to the Coal Resources Investigation program may be obtained from the Branch of Coal Resources, U. S. Geological Survey, National Center, Reston, Virginia, 22092.

Appendix I

Current research projects of the Geological Survey arranged by subprogram and project number. Includes project leader's name and official duty station.

Annotated List of Projects in The Branch of Coal Resources

RESOURCE INVESTIGATIONS

Eastern Geologic and Stratigraphic Studies

Project No.

9420-00136 Pennsylvanian System Stratotype
K. J. Englund, Project Chief, Reston, Virginia

Objectives: To determine an acceptable top and base for the Pennsylvanian System in the U. S. after critical study of type strata and their floral and faunal content; to establish a stratotype section for the System, one of two systems named in the United States.

9420-00148 Southern Anthracite Field, Pennsylvania
G. H. Wood, Jr., Project Chief, Reston, Virginia

Objectives: To compile and interpret through geologic mapping information on the depth, structure, thickness, resources, mining, and continuity of anthracite coal beds, as well as detailed stratigraphic information on the carboniferous coal measures and older rocks.

9420-00150 Northern Anthracite Field, Pennsylvania
M. J. Bergin, Project Chief, Reston, Virginia

Objectives: Same as for project no. 9420-00148

Considerable reserves of anthracite may lie beneath thrust plates in this coal field.

9420-01080 Geology and coal resources of the Central Appalachians
K. J. Englund, Project Chief, Reston, Virginia

Objectives: To determine the availability and quality of coal resources in West Virginia and Virginia through geologic mapping and collection of all available surface and subsurface data; to establish the areal extent, thickness, chemical composition, trace element, ash, and sulfur contents, coal rank, and lateral changes in the coal deposits; to study the effects of stratigraphic and structural features on the exploration and development of coal resources.

9420-01344 Coal resources of Kentucky
P. T. Hayes, Project Chief, Denver, Colorado

Objectives: To make geologic maps of selected quadrangles, and to assemble all geologic data including deep core samples in order to define and characterize coal seams in the region; to delimit low sulfur coals and to make recommendations for reclamation procedures.

Western Geologic and Stratigraphic Studies

Project No.

9420-01079 Coal resources of the Northern Powder River Basin, Wyoming and Montana
W. J. Mapel, Project Chief, Denver, Colorado

Objectives: To provide geologic maps and compilations showing the extent, thickness, composition, and chemical and physical characteristics of coal beds and other key beds in the Wasatch and Fort Union Formations for coal resource calculations in this vast low sulfur coal field.

9420-01091 Coal resources of the Rock Springs uplift, Wyoming and Colorado
H. W. Roehler, Project Chief, Denver, Colorado

Objectives: To determine rank, grade, thickness, sulfur and trace element content, and extent of coal reserves in the area; to provide maps and cross sections showing stratigraphic and structural relations and to computerize resource data.

9420-01825 Depositional studies of selected coal beds of central Utah
P. T. Hayes, Project Chief, Denver, Colorado

Objectives: To provide geologic maps; to determine the stratigraphy and sedimentology and then to establish models relating the variability in sulfur and ash content, coking qualities, and other characteristics of certain coal beds to their original depositional environments. The principals developed in establishing the models should help in exploration, reserve calculations, and development of coal throughout the western U. S.

9420-01977 Environments of coal deposition in the U. S. Western Interior Coal Basins
R. M. Flores, Project Chief, Denver, Colorado

Objectives: To make detailed studies of environments of deposition of coal beds and associated sedimentary rocks in tectonically contrasting basins in the Western Interior. To provide depositional models that could form foundations for exploration and economic development, and help in evaluating resource potential of major coal fields.

Projects 9420-01981, 01984, 01985, and 01986 have similar objectives and differ only as to the area studied. The objectives for each of these projects can be determined from the description of 01981.

Project No.

9420-01981 Coal Geology, Hanna and Rock Creek Coal Fields, Wyoming
D. Hansen, Project Chief, Denver, Colorado

Objectives: To prepare geologic, coal occurrence, and coal quality maps on a regional scale for the Hanna and Rock Creek coal fields; to refine basinwide stratigraphic correlations of the coals and associated rocks; to determine the relations of depositional environments, paleogeography, and structure to the shape, thickness trends, areal extent, and variations in rank of the major coal beds, and to refine estimates of the coal resources. This work will help fill a need for updated coal resource estimates in the Hanna and Rock Creek fields, which together comprise one of the important coal producing areas in the Rocky Mountain Region.

9420-01982 Coal Geology of the central Colorado Coal Fields
V. L. Freeman, Project Chief, Denver, Colorado

Objectives: Same objectives as project 9420-01981 in the Tonque Mesa, Grand Mesa, Somerset and Carbondale coal fields. Particular emphasis will be given to determining the occurrence of coking coal. This is a priority area in the Departmental Coal Exploratory Program, and in the BLM schedule of lease sales.

9420-01983 Coal Geology of the west-central New Mexico and Arizona Region
E. R. Landis, Project Chief, Denver, Colorado

Objectives: To prepare geologic, coal occurrence, and coal quality maps of the coal-bearing areas in west-central New Mexico and eastern Arizona, and to determine the relations of regional geologic history to the stratigraphic position, thickness trends, areal extent, and variations in quality of the coal beds. The information is needed for a preliminary analysis of coal potential and as a guide in the lease-tract selection process.

9420-01984 Coal Geology of the Raton Mesa Coal Field, New Mexico and Colorado
W. Danilchik, Project Chief, Denver, Colorado

Objectives: Same objectives as project 9420-01981. This coal field is on the priority schedule of the Departmental Coal Exploratory Program, and in the BLM schedule of lease sales.

9420-01985 Coal Geology of the Hams Fork Region, Utah-Wyoming
J. W. M'Gonigle, Project Chief, Denver, Colorado

Objectives: Same objectives as project 9420-01981. This is a priority area on the schedule of the Departmental Coal Exploratory Program, and in the BLM Schedule of lease sales.

Project No.

9420-01986 Coal Geology of the Book Cliffs Coal Field, Utah
J. L. Gualtieri, Project Chief, Denver, Colorado

Objectives: Same objectives as project 9420-01918. The area has a high priority in the Departmental Coal Exploratory Program, and in the BLM schedule of lease sales.

9420-01987 Coal Geology of the Southern Part of the San Juan River Coal Region, New Mexico
J. W. Mytton, Denver, Colorado

Objectives: To prepare geologic, coal-occurrence, and coal quality maps on a regional scale for the southern parts of the San Juan River coal region, with particular attention to coals in rocks of Late Cretaceous age; to refine coal bed and coal zone correlations; to determine the relations of depositional environments, paleogeography, and structure to the shape, thickness trends, areal extent, and variations in rank of the major coal beds, and to refine estimates of the coal resources. This area has a high priority in the Departmental Coal Exploratory Program, and in the BLM schedule of lease sales.

National Coal Quality Studies

9420-00106 Geology and geochemistry of coal
V. E. Swanson, Project Chief, Denver Colorado

Objectives: To accumulate, assess, summarize, and interpret the geochemical data on the quality of coal in the United States. The data, which consist of chemical analyses for 45 to 60 major, minor and trace elements, will be summarized statistically to establish norms and ranges by coal rank, age of coal, and U. S. coal resources. The mineralogic, petrographic, and/or organic associations of individual elements and, particularly, suites of metals, will be determined, and their stratigraphic and regional distribution analyzed for genetic interpretations.

9420-01979 Chemical analysis and geologic evaluation of coal from Eastern U. S. (Cooperative with the Energy Research and Development Administration.)
J. H. Medlin, Project Chief, Reston, Virginia

This project, which is a corollary to the Geology and geochemistry of coal project and to the Chemical analysis and geologic evaluation of coal in the Western U.S. project, has the following objectives:

Project No.

1) to develop and test models for predicting geochemical, mineralogic and petrographic trends, both stratigraphically and laterally, within coal beds and basins of Eastern U. S.;

2) to elucidate those geochemical variables that are meaningful and useful for predicting quantitative chemical and mineralogical changes in coal beds and basins of the Eastern U. S.;

3) to quantify those coal quality parameters needed for resource assessment as relates to technological, environmental, byproduct and chemical usages;

4) to statistically define the variability of sodium, potassium, magnesium, calcium, strontium, and barium in coal; and

5) to determine mineralogical form, mineralogical variability and relative time and processes of emplacement in coal.

9420-01980 Chemical analysis and geologic evaluation of coal in the Western U. S. (Cooperative with the Energy Research and Development Administration.)
J. R. Hatch, Project Chief, Denver, Colorado

The objectives of this project are like those of the corollary project for the coal of the Eastern U. S., except that objective number 4 will define the variability of zinc, cadmium, lead, nickel and cobalt in coals instead of sodium, potassium, magnesium, calcium, strontium, and berium.

9420-01866 Petrology of North American Coals
R. W. Stanton, Project Chief, Reston, Virginia

Objectives: To perform optical analysis of selected U. S. coal beds and to relate coal characteristics to depositional environments and geologic history. This information will aid in selecting suitable coals for various metallurgical, power, petrochemical, and conversion uses, and will be computerized to supplement other recorded coal analytical data.

ASSESSMENT RESEARCH

Origin of Coal

Project No.

9420-01388 Genesis of low-sulfur coal
Z. S. Altschuler, Project Chief, Reston, Virginia

Objectives: To develop the ability to predict areas of low sulfur coal through studies of peat formation in the Everglades and other coastal swamps; to establish geologic and hydrologic controls in accumulations of various kinds of peat, the geochemical features and variations in peat, and the importance of various forms of sulfur and the variations in trace element content in different kinds of peat as peat is transformed into lignite and coal.

9420-01865 Experimental diagenesis of organic matter
C. B. Cecil, Project Chief, Reston, Virginia

Objectives: To simulate experimentally the effects of depth of burial on organic materials, including hydrocarbon generation and diagenesis of complex organic molecules, introduction of contaminants, changes in maceral content, compaction ratios of peat to various ranks of coal, and coal rank change with pressure and temperature. Such information will increase the accuracy of predicting the petroleum floor and the rank of coal.

9420-01374 Core Sound, North Carolina
E. R. Landis, Project Chief, Denver, Colorado

Objectives: To determine kinds and distribution of organic matter in bottom sediments and buried peat deposits; to find interrelationships of sulfur, trace elements, and organic matter with depositional environment, source and type of sediment, and depth of burial; to relate these data to coal genesis and distribution of elements in coal formed along coasts.

Coal Quality Studies

9420-01092 Sulfur in coal and lignite
A. J. Bodenlos, Project Chief, Reston, Virginia

Objectives: To establish the geologic and geochemical parameters governing the accumulation of sulfur-bearing organic compounds and minerals in present and ancient swamps as an aid in the search for low sulfur coals.

9420-01536 Trace element geochemistry related to coal mining, usage, and disposal
P. Zubovic, Project Chief, Reston, Virginia

Project No.

Objectives: To document the distribution, concentration,and geochemical relations of trace elements in coal basins, in power and conversion plant effluents and the fallout patterns of these elements around power plants. This should aid in the initial selection of coals which will have the least adverse environmental impact.

9420-01525 Organic geochemistry of coal
I. A. Breger, Project Chief, Reston, Virginia

Objectives: To study the degradation of plant material as peat and lignite are formed, to discuss how organically bound elements are introduced and behave during coalification, and to understand the chemical structure of lignites. These data will help in the search for coal with certain desired characteristics.

9420-01824 Mineral matter in western coal
B. F. Bohor, Project Chief, Denver, Colorado

Objectives: To make mineralogical and geochemical analyses of coal ash and partings and to relate variations in mineral matter to distributions in coal beds, to coal age, rank, trace element content and other geological variables. These data can help in mine planning and in the design of boilers, precipitators, and gasification, liquification, desulfurization processes.

9420-01848 Geology of contaminants in coal (Cooperative with Environmental Protection Agency)
C. B. Cecil, Project Chief, Reston, Virginia

Objectives: To determine and characterize the contaminants in U. S. coals, especially as a function of coal depositional environments, diagenesis, and geologic history. This information will be valuable in planning coal mining, preparation, cleaning, waste disposal, and in planning the reclamation of mine areas.

9420-02006 Coal Petrochemistry and related investigations
E. C. T. Chao, Project Chief, Reston, Virginia

Objectives: To determine, measure, and correlate detailed and systematic mineralogic, petrologic, and chemical data (mostly from Electron Microprobe) on coal and related samples. Unlike current research approaches, this project employs both reflected and transmitted light microscopy on polished thin sections of coal and related samples. Project will provide basic parameters suited for description of stratigraphic and lateral variations in coal beds and basins, so that correlations with specific geologic settings based on field research can be made.

Foreign Coal Basin Studies

Project No.

9420-01902 Comparative research on characteristics of coal basins
(Cooperative with the Polish Geological Institute)
K. J. Englund, Project Chief, Reston, Virginia

Objectives: To study the geology of the Lower and Upper Silesian Polish coal basins, compact areas in which much can be learned about the depositional characteristics of coal, factors controlling coal quality, correlation of coal beds, and other aspects of coal geology; to enhance exploration and the establishment of coal resources through development of improved geologic models of coal basins by comparative studies of the geology of Polish and U. S. coal fields.

9420-01903 Geochemistry of coal and computerization of coal data
(Cooperative with the Polish Geological Institute)
V. E. Swanson, Project Chief, Denver, Colorado

Objectives: To conduct research on the rank, heating value, and the chemical composition of Polish coals, establishing the ranges and variations in these characteristics within each individual coal basin, and to develop a system for computerization of coal data comparable with one currently being developed in the USGS. As data accumulate it will be possible to manipulate the information to analyze and evaluate those factors affecting the quality and potential uses of bituminous coals in both Poland and the U.S.

Geophysical Studies

9420-01380 Borehole neutron activation analysis -- coal
F. E. Senftle, Project Chief, Reston, Virginia

Objectives: To develop methods for determining location and thickness of coal seams, partings in a seam, major and minor elements present, high and low sulfur and ash contents, ratio of organic to inorganic sulfur, and relative leaching of a coal bed by ground water.

9730-01527 Geophysics of coal
W. P. Hasbrouck, Project Chief, Denver, Colorado

Objectives: To study coal beds by geophysical means to determine their continuity, lateral extent, and physical properties; to investigate particularly the use of seismic seam waves, develop specialized well logging techniques, and the use of gravity and magnetic exploration methods.

Project No.

9420-21363 Bioenergetics treatment of acid mine water
(Cooperative with the Energy Research and Development Administration)
F. E. Senftle, Project Chief, Reston, Virginia

Objectives: To study the feasibility of using microorganisms to convert high sulfur acid mine water into useful energy, purer water, and other by-products; to study use of microorganisms in liquifying low-grade coal and tar sands in situ, and as an aid in the secondary recovery of fossil fuels.

NATIONAL COAL RESOURCE STUDIES

9420-01367 National coal resources data system
M. D. Carter, Project Chief, Reston, Virginia

Objectives: To computerize coal data, replacing and greatly enlarging the present manual coal resource inventory. National Coal Data System will have two interactive parts: a) the Coal Resource Analysis Bank, derived from existing resources inventories by county, date, and coal field, and b) the National Coal Data Bank, based on point resource and reserve data on individual coal beds; several hundred different criteria could be entered at any given point of observation.

9420-00156 Coal resources of the United States
P. Averitt, Project Chief, Denver, Colorado

Objectives: To provide a continuing appraisal and review of data on U. S. and world coal resources. Products include summary reports and maps on resources in the U. S., topical reports, progress reports, and specialized bibliographics.

9420-02000 Coal resource assessment group
G. H. Wood, Jr., Project Chief, Reston, Virginia

Objectives: To develop a standardized methodology and criteria for coal resource assessment for use by all workers in the profession. To develop a methodology for validating and certifying estimates of coal resources made throughout the U. S. and internationally. To provide the NCRDS with validated data for entry into the computer.

Project No.

9420-01978 Investigation of techniques for preparation of geologic and resource maps
M. J. Bergin and G. D. Stricker, Project Chiefs, Reston, Virginia

Objectives: To produce more illustrative, more useful, and more easily understood geologic and mineral resource maps; to produce such maps rapidly by computer graphics from digitized computer data, particularly data in the NCRDS. Hopefully the development of computer graphics will allow periodic and rapid production of updated maps and displays in a format acceptable for public release without further compilation or drafting.

COAL GEOLOGY AND MINING

9420-01390 Geologic analysis of coal model areas
(Cooperative with the Bureau of Land Management)
E. R. Landis, Project Chief, Denver, Colorado

Objectives of these projects are: to conduct research into the acquisition and evaluation of geologically significant information about areas that are geological models of coal mine sites, and to determine the best ways to present the information to potential users.

9420-21879 Advanced mining technology (Cooperative with the Bureau of Mines)
H. H. Arndt and B. H. Kent, Project Chiefs, Denver, Colorado

Objectives: To develop categories of geologic information useful in improving techniques of surface and underground mining; to develop and test information on physical and engineering properties relevant to mining; to computerize and intermanipulate such information with other types of data.

Appendix II

Coal resource publications of the U. S. Geological Survey and Grantees financed by the Geological Survey for FY 1976. Listed by subprogram, arranged alphabetically by author. Several pre-1976 publications are listed if of major importance to coal resources.

RESOURCE ASSESSMENT

Eastern Geologic and Stratigraphic Studies

Bergin, M. J., 1976, Bedrock geologic map of the anthracite-bearing rocks of the Wilkes-Barre West quadrangle, Luzerne County, Pennsylvania: U. S. Geol. Survey Misc. Inv. Map I-838, scale 1:12,000

Englund, K. J., 1976a, Geologic map of the Grahn quadrangle, Carter County, Kentucky: U. S. Geol. Survey Geol. Quad. Map GQ-1262. scale 1:24,000

_____1976, U. S. Geological Survey projects in coal geology in eastern United States (abs.), in Coal geology and the future -- Symposium, Reston, Virginia, September 1976: Reston, Va. U. S. Geol. Survey, [n.p.].

Englund, K. J., Cecil, C. B., Stricker, G. D., and Warlow, R. C., 1976, Carboniferous stratigraphy of southwestern Virginia and southern West Virginia: Geol. Soc. America Field Trip Guidebook no. 3, March 1976, 40 p., illus.

Gillespie, W. H., and Pfferkorn, H. W., 1976, Early and Middle Pennsylvanian plant fossils, in Englund and others, Carboniferous stratigraphy of southwestern Virginia and southern West Virginia: Geol. Soc. America Field Trip Guidebook no. 3, March 1976, p. 6-10.

Henry, T. W., 1976, Late Mississippian and Early Pennsylvanian faunas, in Englund and others, Carboniferous stratigraphy of southwestern Virginia and southern West Virginia: Geol. Soc. America Field Trip Guidebook no. 3, March 1976, p. 11-14.

Meissner, C. R., 1976, Preliminary geologic map of the Duty quadrangle, Virginia: U. S. Geol. Survey open-file rept. 76-161, scale 1:24,000.

Schweinfurth, S. P., 1976, Geologic map of the Avella quadrangle and part of the Steubenville East quadrangle, Washington County, Pennsylvania: U. S. Geol. Survey Misc. Inv. Series Map I-908, scale 1:24,000.

Schweinfurth, S. P , Arndt, H. H., and Englund, K. J., 1976, Description of core from three U. S. Geological Survey core holes in the Carboniferous rocks of West Virginia: U. S. Geol. Survey open-file rept. 76-159, 61 p.

Western Geologic and Stratigraphic Studies

Culbertson, W. C., 1976a, Preliminary geologic map of the Jones Draw quadrangle, Sheridan County, Wyoming: U.S. Geol. Survey Misc. Field Studies Map MF-726, scale 1:24,000, 2 sheets.

_____1976b, Thick coal beds in the Wasatch Formation, western Powder River Basin, Wyoming (abs.): Am. Assoc. Petroleum Geologists Bull., v. 60, no. 8, p. 1395.

Culbertson, W. C., and Mapel, W. J., 1976, Coal in the Wasatch Formation, northwest part of the Powder River Basin near Sheridan County, Wyoming: Wyoming Geol. Assoc. Guidebook, 28th Ann. Field Conf., p. 193-202.

Hayes, P. T., Ryer, T. A., Kitley, L. W., and Hatch, J. R., 1976, Geology and mineral resources of east-central Utah, Pt. A, in Summary of the geology, mineral resources, landscape geochemistry, and engineering geology characteristics of east-central Utah: U.S. Geol. Survey Administrative Report, 112 p., illus., tables.

Kent, B. H., 1976a, Geologic map and coal sections of the Recluse quadrangle, Campbell County, Wyoming: U. S. Geol. Survey Misc. Field Studies Map MF-732, scale 1:24,000, 2 sheets.

_____1976b, Geologic map and coal sections of the Wildcat quadrangle, Campbell County, Wyoming: U.S. Geol. Survey Misc. Field Studies Map MF-735, scale 1:24,000, 2 sheets.

Landis, E. R., and Cone, G. C., 1971, Coal reserves of Colorado tabulated by bed: U. S. Geol. Survey open-file rept., 3p., 515 tables.

Mapel, W. J., 1976a, Geologic map and coal sections of the Bar N Draw quadrangle, Wyoming and Montana: U.S. Geol. Survey Misc. Field Studies Map MF-763, scale 1:24,000, 2 sheets.

_____1976b, Geologic map and coal sections of the Birney quadrangle, Rosebud County, Montana: U. S. Geol. Survey Misc. Field Studies Map MF-813, scale 1:24,000, 2 sheets.

_____1976c, U. S. Geological Survey projects in western coal geology (abs.), in Coal geology and the future -- Symposium, Reston, Virginia, September, 1976: Reston, Va., U. S. Geol. Survey, [n.p.].

Mapel, W. J., and Dean, B. W., 1976a, Preliminary geologic map and coal sections of the Ulm quadrangle, Sheridan County, Wyoming: U. S. Geol. Survey Misc. Field Studies Map MF-731, scale 1:24,000, 2 sheets.

_____1976b, Geologic map and coal sections of the Verona quadrangle, Sheridan County, Wyoming: U. S. Geol. Survey Misc. Field Studies Map MF-762, scale 1:24,000, 2 sheets.

Mapel, W. J., and Malahy, M. D., 1976, Geologic map and coal sections of the Buffalo Run Creek, quadrangle, Sheridan County, Wyoming: U. S. Geol. Survey Misc. Field Studies Map MF-792, scale 1:24,000.

Mapel, W. J., Swanson, V. E., Conner, J. J., and Malde, H. W., 1976, Summary of the geology, mineral resources, and engineering geologic characteristics of the northern Powder River Basin coal region, Montana, Pt. A, Geology and mineral resources: U. S. Geol. Survey Administrative Report.

McKay, E. J., 1976a, Preliminary geologic map and coal sections of the Willow Crossing quadrangle, Rosebud and Powder River Counties, Montana: U. S. Geol. Survey Misc. Field Studies Map MF-802, scale: 1:24,000.

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Appendix III

Program funding in 1977, application of resources by program, and recent funding and personnel trends.

The President's budget, as submitted to Congress each year, recommends an amount of money to be appropriated to support the Survey's coal resource investigations. The budget explanation describes the program and states the type and amount of work that is to be accomplished with the appropriated funds. For fiscal year 1977, the coal resource investigations program is generating field and laboratory determinations of the physical and chemical characteristics of coal, based on the analysis of coal samples for major, minor, and trace elements, sulfur and ash content, moisture, and heating value. A cooperative program with the State geological surveys is providing additional samples and data. Related geologic investigations, including surface mapping and core drilling, help determine the thickness, areal extent and depth of burial of coal beds. Geophysical techniques are being developed to help expedite coal bed sampling and correlation, and other studies are determining the geologic factors critical in the selection of mine sites. The data derived from all these investigations are entered in the National Coal Resources Data System for rapid processing and retrieval.

The work being carried out in fiscal year 1977, as reported in the budget explanation, includes geologic mapping and resource assessment of low-sulfur coal deposits in parts of Pennsylvania, Virginia, West Virginia, Kentucky, North Dakota, Montana and Wyoming, totaling about 12,000 square miles. Up to 10,000 feet of core drilling is being done in the central Appalachian basin and in Montana and Wyoming. About 2,100 coal samples obtained from this drilling and from the State geological surveys will be analyzed, with each analysis representing up to 100 chemical determinations. The results of these analyses, together with related geologic and geophysical data, will be processed for storage in the National Coal Resources Data System.

Figure three shows the percentage application of personnel and funds in FY 1977 to various elements in the Branch of Coal Resources program, and figure four shows historic trends in funding and personnel in the Branch.

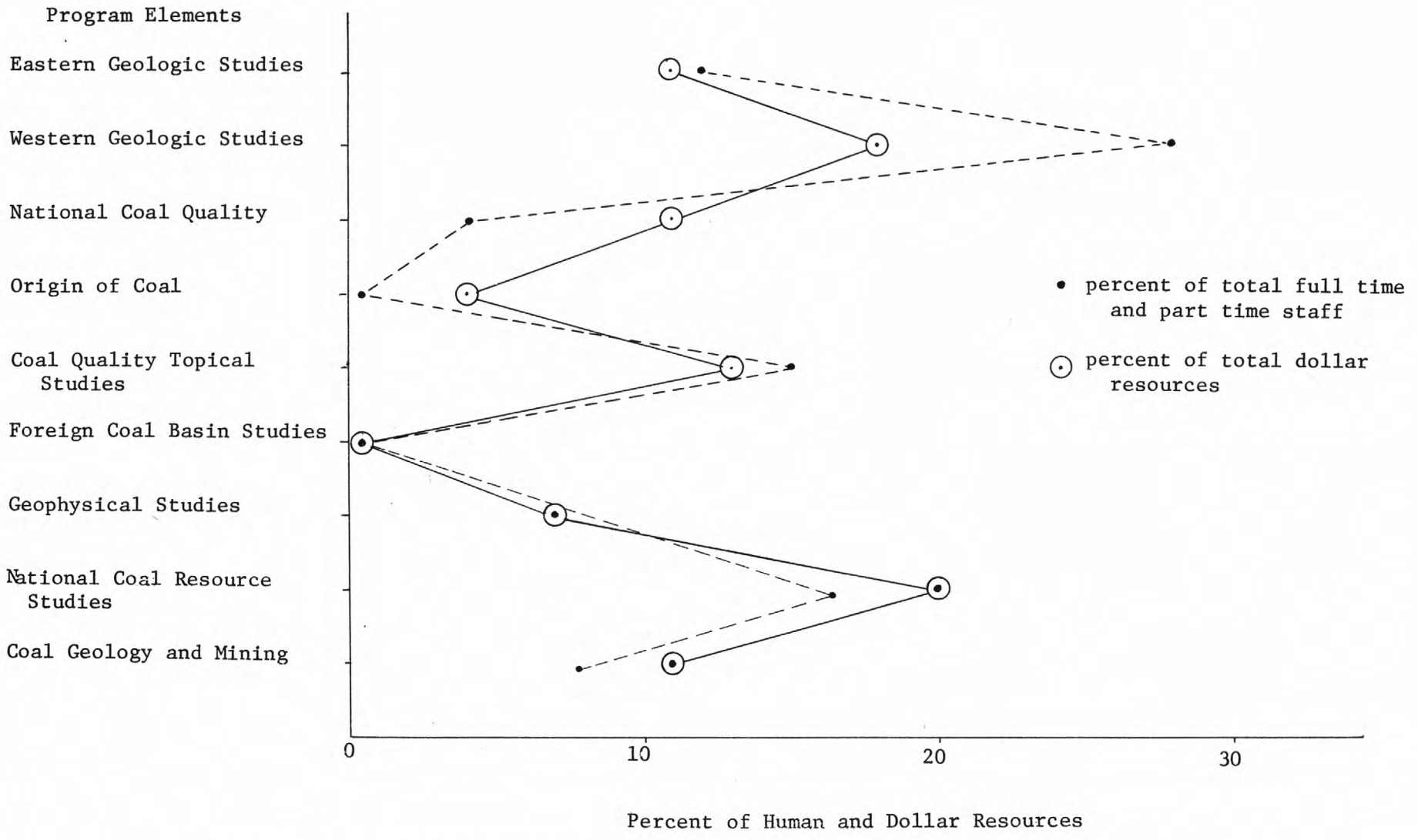


Figure 3. -- Application of Resources by Program in the Branch of Coal Resources

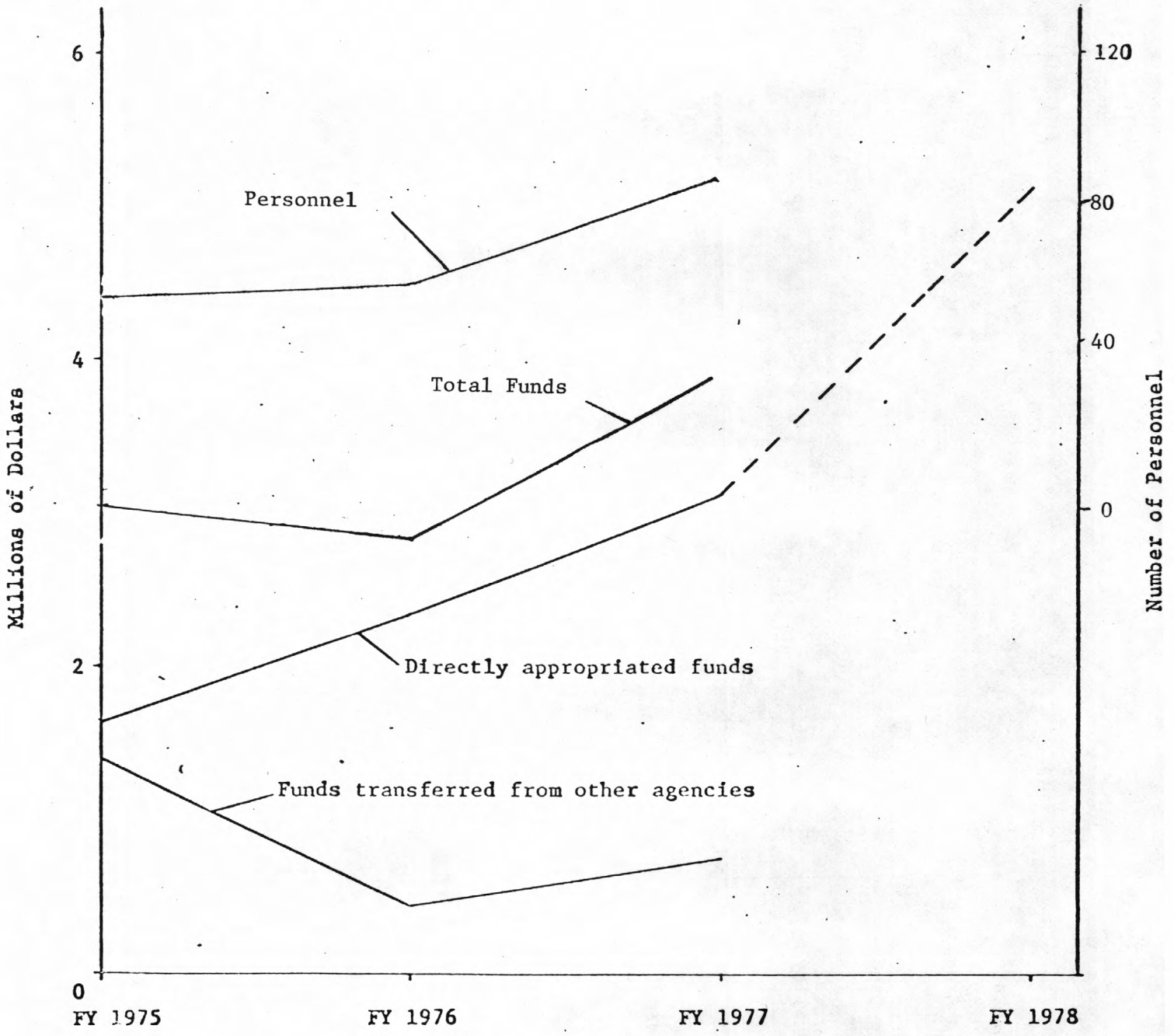
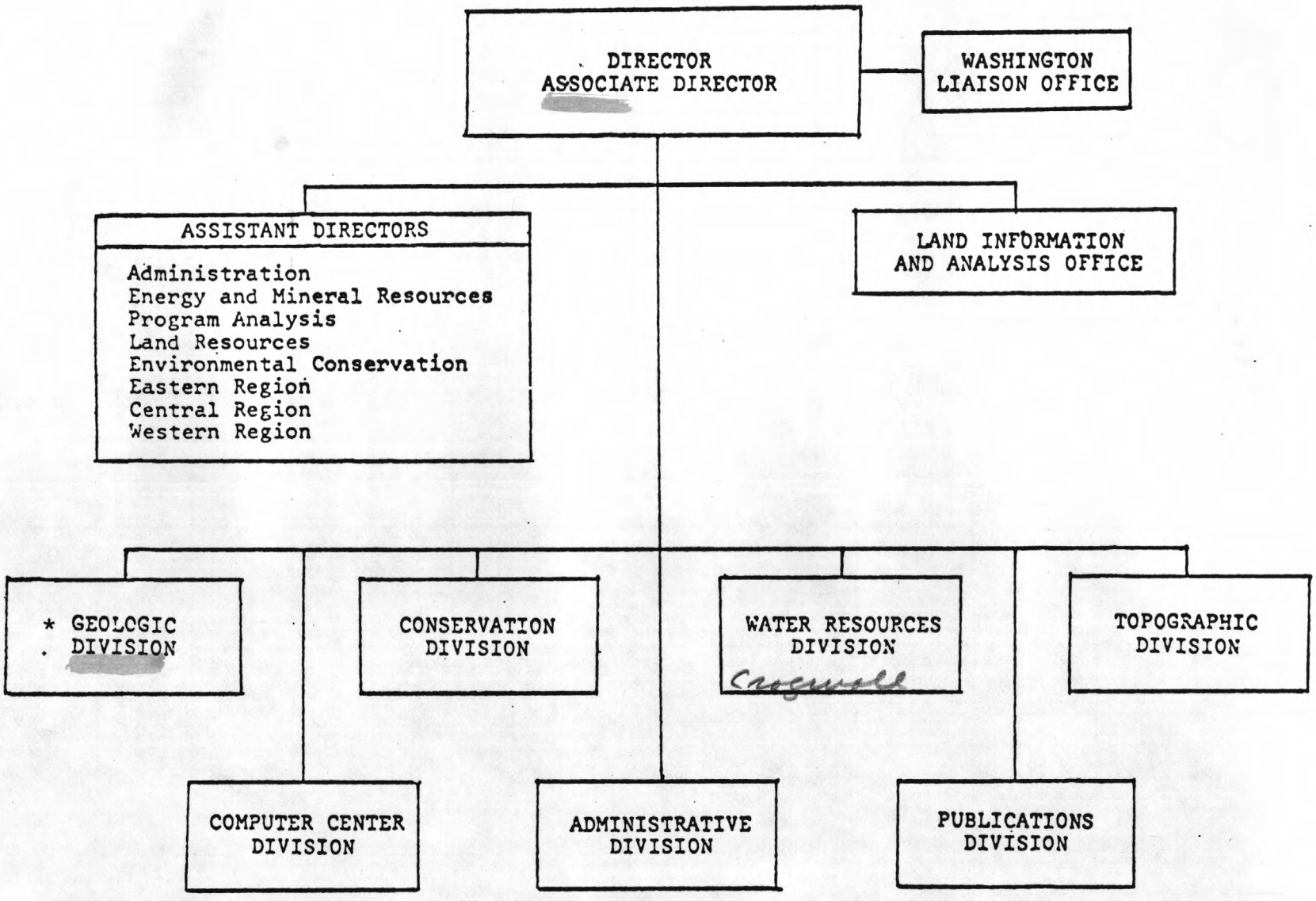


Figure 4.-- Recent Funding and Personnel Trends in the Branch of Coal Resources

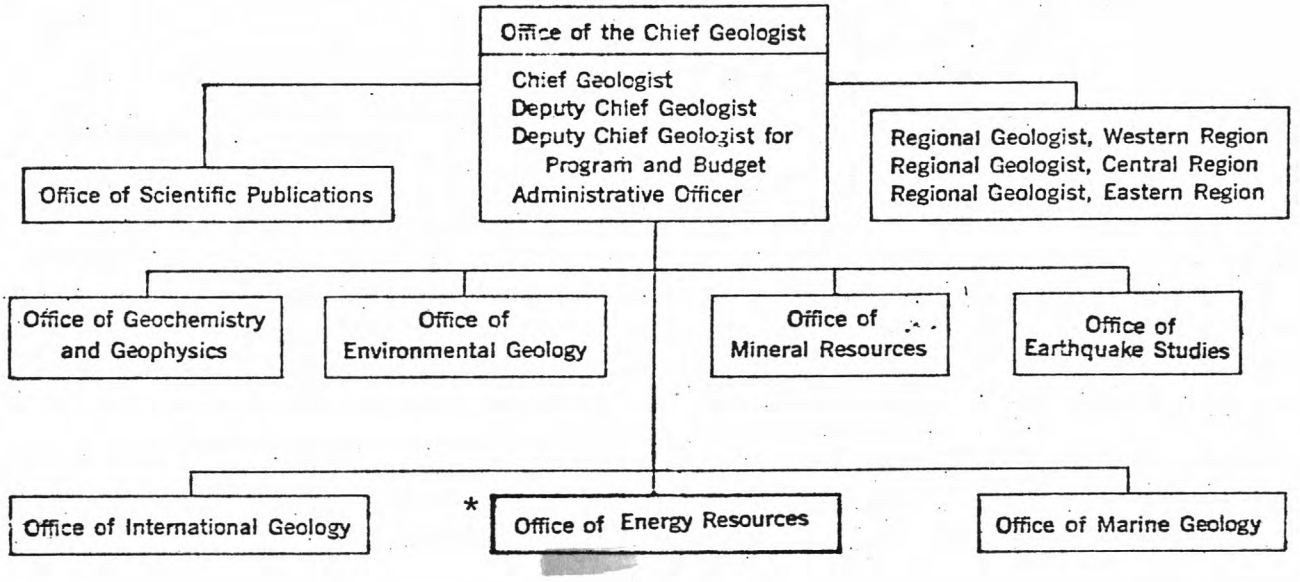
Appendix IV

Organization Charts

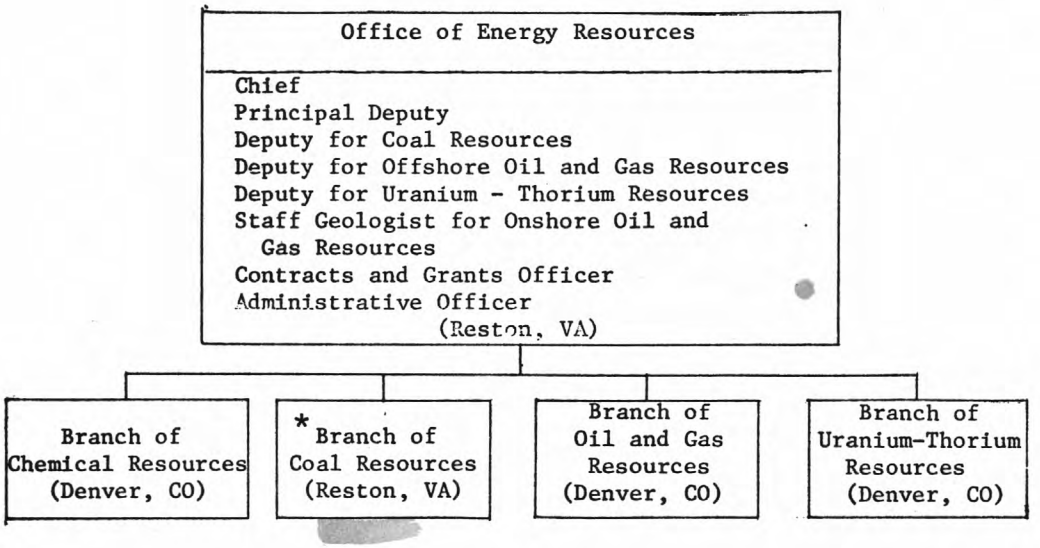
U.S. Department of the Interior
GEOLOGICAL SURVEY

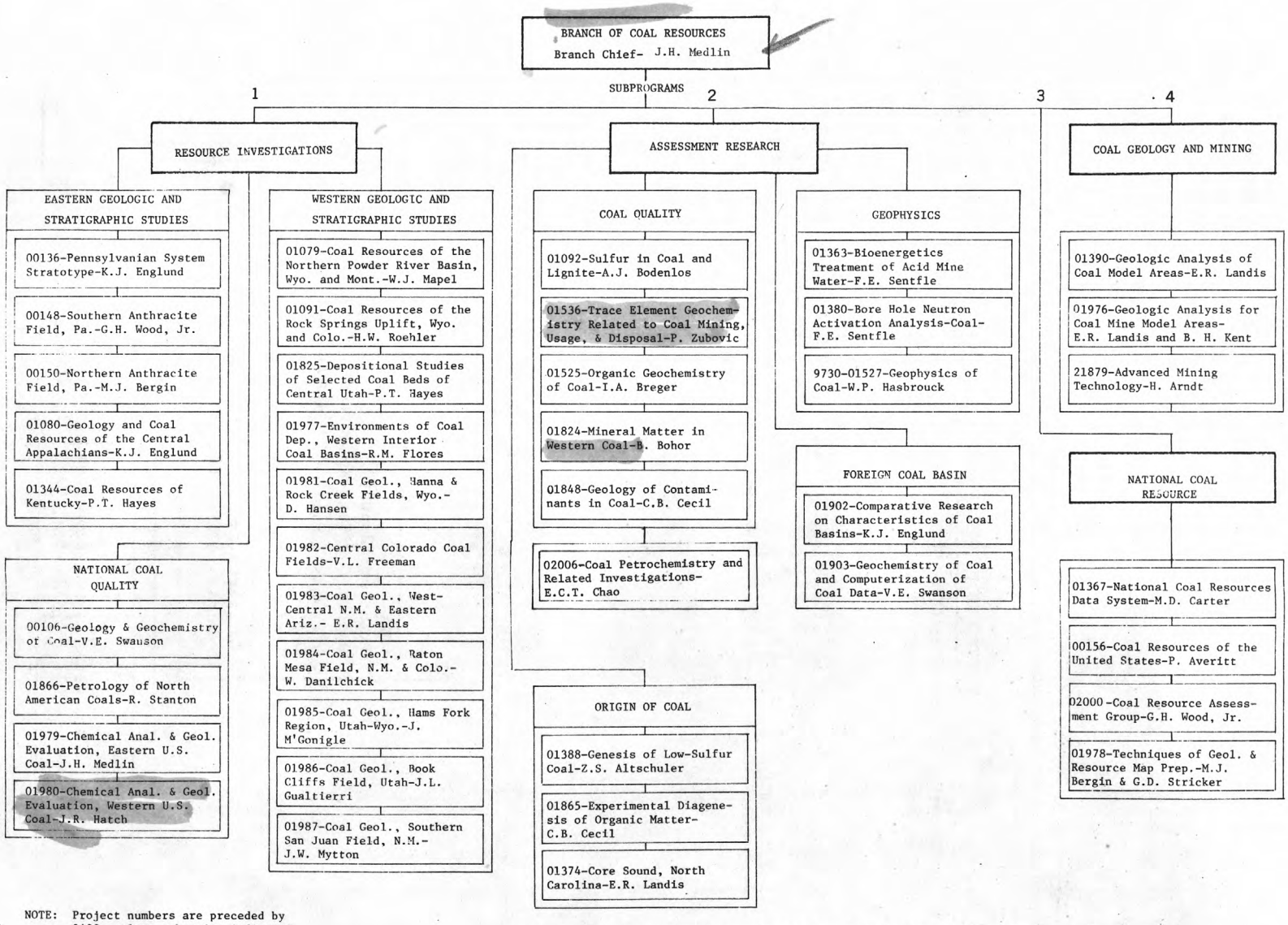


ORGANIZATION OF THE GEOLOGIC DIVISION



ORGANIZATION OF THE OFFICE OF ENERGY RESOURCES





NOTE: Project numbers are preceded by 9420- unless otherwise indicated.

ORGANIZATION OF SUBPROGRAMS AND PROJECTS IN THE BRANCH OF COAL RESOURCES

Appendix V

An outline of procedures involved in a Coal Resource study

A. Initial Phase. A coal resource study begins with a review by the Geological Survey's management of the evidence that coal exists in the area proposed for study and that the probable amount of coal resources warrants the investment of funds and manpower required for a complete investigation. If the review is favorable, the area to be studied is placed in a priority list with other such areas. After an area is selected for a coal resource study the following steps are implemented successively:

1) A qualified project leader is appointed. Generally, this leader is familiar with nearby coal fields or basins.

2) The leader then personally conducts a search for all preexisting literature, records, and borehole data in the files of the Geological Survey and the Bureau of Mines. He contacts the State Geological Survey or Surveys in which the study area lies, and asks them to search their files for data.

3) When the leader is satisfied that the search has been adequate, he informs the management of the Survey whether the existing data is adequate or inadequate for a reassessment, and asks for appropriate personnel to be assigned to him to carry out either a first-time assessment or a reassessment. It is extremely rare that there is sufficient preexisting data to perform a reassessment that will be adequate in terms of modern needs.

B. Assessment work. If it is decided that there is insufficient data on hand, assessment work commences. The project leader and his staff locate the preexisting data, including sites of all boreholes on maps, determine where additional subsurface data are needed, compile a list of desired core holes, and ask a contracting officer to advertize for these holes to be drilled at selected localities to specified depths. All pertinent equipment is assembled and the field personnel proceed to the area to perform a field survey.

1. Main field survey. The field survey has many facets, including the following:

a) Mapping the surface traces of all exposed coal beds and pertinent coal related data between exposures

b) Measuring the thickness of all rocks including the coal beds at many surface localities. During these stratigraphic and coal bed measurements, rock types are described and samples collected; folds and faults are identified and their effects determined.

c) The rocks are classified as to their original depositional environments so that coal-bearing sequences can be identified in areas where coal is not exposed.

d) Samples of coal and of all associated rocks are collected from surface exposures and the cores of the drill holes so that geochemical analyses can be performed. These analyses are necessary to determine the in-place quality of the coal, potential best uses of the coal, potential by-products, and possible environmental problems that may result from coal mining.

e) Entry of data of various types gathered in the course of the field studies into the National Coal Resources Data System (NCRDS) is initiated. During the remainder of the assessment work other information obtained from analyses, field studies, and interpretation of results is also entered into the NCRDS. From this point on during the course of a coal resource study the speed, accuracy, and precision of the computer system is utilized when possible in computations, compilations, and decision making.

2. Initial analyses and compilation of results

In the laboratory the coal samples are analyzed to determine the quality of the coal, including its heating value, moisture and ash content, sulfur content, and for as many as 60 minor and trace elements. In the office, a large part of the geologic analysis is directed toward determining the three dimensional configuration of the coal beds from geologic and structural maps. These are constructed by utilizing all pertinent thickness, stratigraphic, bed altitudes, geophysical, and drill data. In some areas the configuration of the coal beds cannot be accurately determined without the aid of geophysical surveys and additional drill holes. By this stage in the study, the Survey team can also usually determine if additional core holes will be necessary to properly calculate tonnages and determine the quality of the coal resources. The project chief and his staff then select the locations of a minimum number of additional core holes that can be utilized to determine the structure, tonnage, and quality of the coal beds being studied.

3. Secondary field surveys

Additional field data are gathered where information is needed to more accurately interpret the geology and coal occurrences. The additional core holes are drilled during this phase of the work; samples are collected and the coal beds and associated rocks are then correlated as carefully as possible on the basis of the new data, which includes additional analyses of the samples collected from the cores and from other follow up field studies.

C. Compilation. The samples collected during the second phase of field work are analyzed and the team begins to assemble a series of final maps, stratigraphic and drill-hole sections, and the results of all chemical analyses. A geologic map is prepared that shows all commercial coal

beds, formations, members, faults, folds, preexisting and existing mines, drill holes, sample collection and thickness measuring points, and any other pertinent information such as bed attitudes, joints, ancient stream channels.

Final correlation diagrams showing the lithologies in boreholes and stratigraphic sections are compiled. Coal bed correlation diagrams showing all coal measurements are prepared showing roof and floor rocks. All pertinent geochemical analyses are compiled in a series of charts and tables and related to the geologic maps, stratigraphic diagrams and coal bed diagrams.

D. Determination of Coal Resources

The actual determination of coal resources and reserves begins with a classification of the coal according to several factors: a) its depth of occurrence (strippable, 0-1000 feet, 1000-2000 feet, 2000-3000 feet, and more than 3000 feet); b) its rank, heat value, ash, trace element, and sulfur content; and c) the reliability of data on quantity and quality (measured, indicated, inferred, hypothetical, and speculative categories). Other factors to be considered are ownership of the land surface and subsurface minerals (private, state, Indian, public), Federal, State, and local laws and regulations, any specific requirements imposed by Departmental or Survey management, and environmental rulings imposed by courts.

The calculation of tonnages of coal in the various categories is made by computer from the data previously entered into the NCRDS. The computer not only can determine the amount of coal in a specific area and for a specific category, but it can also generate coal bed maps for all these categories.

The numerous coal bed maps, charts, tables, geologic maps, and stratigraphic diagrams are then assembled, together with a written report, into a folio, which is made publicly available. This folio constitutes a compiled record of all known coal and coal related information on the study area as of the date of the release. The folio concept when combined with the National Coal Resources Data System is planned so that updates of individual maps, charts, diagrams, and tables can be inserted as additional information flows into the Survey.

The procedure described previously is generally followed for all areas investigated, whether they are public, private, or state lands. With reference to the recently enacted Federal Coal Leasing Amendments Act the procedure has been slightly modified. On Federal Lands that may be leased the Geological Division of the Survey will prepare a folio for each 1/100,000 quadrangle that lies within a KRCRA. This folio will contain all data described but the objective will be to classify the coal only to the inferred category rather than to the measured and indicated categories. This folio will direct the attention of the Conservation Division to areas within the KRCRA's

that merit additional Federal expenditures for evaluation and leasing. It is anticipated that an overview of each 1/100,000 quadrangle will isolate areas of richer coal and will result in considerable saving of money by the Federal Government as only the richer areas will then be fully examined and leased. Identification of the richer coal-bearing areas by overview studies will ease the task of other Federal agencies that are examining the environmental, transportation, socio-economic, and energy requirements of localities, regions, and the Nation, as their attention can be directed to relatively small areas.

☆ U.S. Government Printing Office: 1977—261-221/135