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Coal Geology and the Future— Symposium Abstracts and Selected References

Coal Geology and the Future— Symposium Abstracts and Selected References

Edited by C. R. Meissner, Jr., C. B. Cecil, and G. D. Stricker

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Abstracts presented at a symposium sponsored by the U.S. Geological Survey, September 27–28, 1976 in Reston, Va.

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PREFACE

A symposium titled "Coal Geology and the Future," sponsored by the U.S. Geological Survey, was held in Reston, Va., September 27–28, 1976. The primary purpose of this meeting was to identify present and future geological research requirements in coal exploration, mining, and utilization in response to the ever-expanding demand for coal to meet the Nation's energy needs. In order to accomplish this objective, leading research scientists from State and Federal agencies, industry, and universities were invited to present results of their investigations emphasizing problem areas and further research needs. The abstracts, with selected references, included in this circular should serve as a valuable summary and reference source for those who wish to pursue any or all facets of the topics covered.

The program was structured to encompass both theoretical and applied geological research from the origin of coal to ultimate utilization. The first technical session considered the general geology of coal from the peat-forming environment through the genesis of bituminous and anthracite coal. The second session was devoted to geology as applied to coal exploration, coal mining, and reclamation of mined land. Geological science as applied to utilization of coal in the generation of electricity, coke manufacture, gasification, and liquefaction was the focus of the third session. Finally, the various programs in coal geology of the U.S. Geological Survey (U.S.G.S.) were considered. The abstracts and selected references which follow are in the order in which they were presented during the symposium and represent the views of the individual speakers. Panel discussions related to the four technical sessions were then held in order that participants could comment and question speakers and panelists.

The 2-day meeting was of international interest and was well received. The abstracts and selected references indicate the breadth of ideas presented and exchanged as well as the integration of various geologic and related scientific and engineering disciplines.

C. R. Meissner, Jr.
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Editors

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COAL ENVIRONMENTS

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ABSTRACT

Organic materials are buried as peat deposits in coastal plains and deltaic settings that span the climatic regions of the globe. Upon burial, diagenesis, and passage of geologic time, peat is converted to coal and lignite, and an understanding of the environments of deposition in which peat accumulates is critical in order to exploit existing coal reserves efficiently. Floristic composition, peat geochemistry, lateral and vertical geometry of peats, and the relationships of the peat deposits to nonorganic sediments are functions of depositional conditions such as climate, tectonics of the depositional basin, sediment yield and dispersal patterns, and riverine and nearshore coastal dynamic processes. Depositional models are produced in which deposits rich in organic material form a significant part of the sediments and have distinct vertical and lateral interfingering relationships with the coastal plain deposits.

In arctic settings (North Slope, Alaska), peats are composed primarily of sedges, grasses, and mosses and form thick deposits that cap channel and beach sands and interfinger laterally with lagoon and lacustrine silts and clays rich in organic material. Supratidal sediments, evaporites, and sandy channel deposits interfinger with erratically distributed woody peat layers in the arid deltaic setting of northeast Australia. Deposits rich in organic material accumulate in saline mangrove environments, and often, a wide variety of early diagenetic products is formed in underlying deposits.

In the temperate climate of the Mississippi River Delta, peat deposits are highly variable in thickness and have a wide range of floristic composition and organic content. Fresh-water peat in the alluvial valley is normally thick (2-5 m) and woody and has low lateral continuity. Pyrite and vivianite are common inclusions in the peat, and iron and calcium carbonate are diagenetically produced in the underlying clay. Brackish and saline coastal peat is normally thin (<2 m), but each bed has wide lateral continuity. Marshy nonwoody components contribute significantly to total organic content, and early diagenetic products are common within and beneath the peat layers.

In the tropical Klang River Delta, thick widespread peat deposits (5-15 m thick) overlie lower deltaic silty and clayey tidal-flat deposits, and the peat interfingers laterally with river-channel sand. Early cementation of the peat is common; excessive leaching of the underlying clay is often present.

Thick fresh- and saline-water peats accumulate in a large (60,000 km^2) coastal plain of Surinam and the Guianas, along the northern coast of South America. Many peat deposits exceed 40 m in thickness and interfinger locally with sandy beach deposits. Sand bound by organic matter (humate) is abundant, and diagenetic components are common both within the peat and in adjacent deposits.

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STRATIGRAPHY AND TECTONICS OF WESTERN COALS

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ABSTRACT

The Cretaceous and Tertiary strata of the Rocky Mountain region contain extensive coal deposits that accumulated in coastal-plain and alluvial environments. The common swamp and marsh environments of "in situ" coal are channel-margin swamps, coastal marshes, and channel-fill swamps. Channel-margin coal environments are of two general types: (1) areally restricted back-levee swamps which parallel channels and are also the site of deposition of light-colored leached kaolinitic claystone; and (2) more extensive flood-basin swamps which are commonly associated with lacustrine deposits. Thin lenticular coals, derived from the accumulation of transported organic material, can be found in both nonmarine and shallow marine environments.

The critical factors necessary for the formation of commercial thicknesses of coal are: (1) fresh clear water, (2) accumulation of land-derived organic material only, (3) balance between ground-water table and depositional interface, (4) favorable climate, and (5) persistence of conditions in time and space and a favorable basin-wide and (or) local tectonic influence on sedimentation. These conditions are most commonly found in alluvial- and delta-plain depositional environments.

The occurrence of penecontemporaneous (growth) faults may influence swamp environments and control the thickness of peat accumulation. Detailed geological and geophysical investigations along the west margin of the Denver basin indicate that two types of growth faults are present in an Upper Cretaceous deltaic sequence: (1) deep-seated basement faults, and (2) shallow listric normal faults. The latter type was a primary control on sedimentation in the coal-bearing Laramie Formation and determined whether or not the coal beds are of commercial thickness. The lateral continuity of coal in the Laramie is interrupted by growth faults; most of the minable thicknesses of coal are found only in graben structures.

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GEOLOGY AND EASTERN COAL

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ABSTRACT

Most coal resources in the eastern half of the United States are found in strata of Pennsylvania age. The complex stratigraphy resulting from depositional environments that were dominated by deltaic sedimentation and influenced by many marine incursions needs to be known in detail for the mapping of coal resources and reserves, particularly for coal at great depths and in less well known areas. Geologic study methods (including geophysical techniques) that are similar in character to those used to locate oil and gas are now receiving much attention in the search for new coal resources and the tracing of regional trends of coal quality.

The important minable coals in the Eastern United States range in rank from high-volatile C bituminous to anthracite. Studies of geologic controls on the regional distribution and mineral form of coal and on the composition of mineral constituents in coal are becoming of great interest as coal is increasingly viewed as a raw feed for various chemical processes, including liquefaction and gasification.

Application of geology to the mining of coal is of special significance in the Eastern United States where most past mining has been underground and where future significant increases in coal production must take place. Development of much new mining technology, as well as improvements in existing technology to increase productivity, will require a particularly detailed knowledge of the rock materials of mine roof and floor.

Geology also has increasing applications in coal utilization, particularly in eastern areas where the major coal deposits have a broad range of coal characteristics. The higher ranks

of coal close to major markets will be in greater demand not only for generation of electric energy but also for other chemical and physical conversion processes. Knowledge of chemical and physical properties of coal, including those discovered by coal-petrology techniques, will find wide application in the utilization of eastern coals.

Land-use problems associated with mining also require wise use of available geologic data.

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COALIFICATION

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ABSTRACT

Coalification denotes the transformation of plant debris under reducing conditions into a continuous series of products having increasing percentages of carbon and diminishing percentages of oxygen and hydrogen. Initial conversions, those from peat through subbituminous or high-volatile bituminous coal, are essentially biochemical and chemical, require minimal input of energy, an involve the elimination of carbon dioxide and water. Subsequent changes, from medium-volatile bituminous coal to anthracite and ultimately to material approaching graphite, are both physical and chemical and require more intense sources of energy, such as may be provided by moderate increase in temperature or by shear. These transformations are accompanied by elimination of methane and gaseous hydrogen. The chemical and physical properties of a coal at any particular stage of coalification are defined by the rank of the coal.

Coalification may be described geochemically as: (1) microbiological degradation of cellulose of the initial plant material, (2) conversion of lignin of the plants into humic substances, and (3) condensation of these humic substances into larger coal molecules. As they increase in size, these coal molecules assume the properties of a thermoplastic resin, at which point they melt and decompose when heated. At this stage coals assume coking properties. As coalification continues, the coal molecules become so large that they no longer melt before decomposing.

Unbiased data are needed to determine the fate of certain organically bound elements and minerals as coalification advances. Such information, soon to be available through the National Coal Resources Data System (a computerized information file being prepared by the U.S. Geological Survey), may serve as a guide in the search for high-quality coals. Also, intensive investigations for more than half a century have failed to yield a clear picture of the chemical structure of coal. Imaginative, but not necessarily sophisticated, studies are needed to obtain structural information basic to the conversion of coals to synthetic fuels. From a geochemical point of view, information on the distribution of forms of organically bound sulfur in coals from a particular basin may serve as an indicator of sedimentological conditions that prevailed in the early stages of coalification and may direct attention to coals of highest quality.

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EXPANDING HORIZONS IN COAL PETROLOGY

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ABSTRACT

Eight facets of the science of coal petrology will, or should, change significantly in the immediate future.

1. The limited scope of concerns that is currently associated with the science must be expanded. The petrologist concerned with igneous or sedimentary rocks is not solely concerned with the proportions of minerals in his granite or limestone. Instead, he has found it essential to be concerned with the full gamut of physical properties and chemical characteristics of rocks; he uses these properties and characteristics as the basis for understanding a rock's origin, evolution, and behavior in the situations in which man uses it. For the same reasons, the coal petrographer must, and will, be concerned with the complete task of characterizing the properties and composition of the rock called coal.

2. Our concept of coal composition also must expand. In particular, fluorescence microscopy must become a routinely used analytical tool. Failure to use fluorescence microscopy gives inaccurate compositional data on the hydrogen-rich macerals.

3. Because of vastly increased interest, we need to expand our concepts and analytical procedures relating to low-rank coal. The simple extension of the descriptive procedures used for bituminous and anthracite coal to subbituminous coal and lignite will be inadequate for the practical application of petrography in coal utilization.

4. Coal petrography must be used in connection with coal-conversion technology, especially in the field of coal cleaning, preparation, and beneficiation, where management of feedstock composition will become increasingly important.

5. The increased practical use of petrographic data will result in the increased automation of analytical methods. Systems are now being devised that can rapidly assess the mode of occurrence of pyrite as a means of evaluating sulfur reduction problems; still other systems are being devised as industrial tools to monitor feedstock compositions on a routine basis.

6. The possibility of predicting coal liquefaction yields and product qualities was revealed decades ago through the work of the U.S. Bureau of Mines, and the prospects for making such predictions are excellent.

7. The application of the petrographer's techniques to the study of liquefaction residues is providing considerable insight into the effects of varying process conditions and into the compositions of both normal and abnormal residues.

8. The field of coal carbonization can similarly benefit from the application of petrographic techniques to the carbonaceous residue as it is produced in the coke oven. Coke microscopy is actively pursued in some steel industry laboratories, and recognition of its merits will result in expanded use.

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MAJOR, MINOR, AND TRACE ELEMENTS IN U.S. COAL

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ABSTRACT

The current coal geochemistry program of the U.S. Geological Survey is a cooperative effort involving Federal and State agencies, university groups, and private companies. It encompasses all coal-bearing States and coal provinces, and, in many regions, each of the many major coal beds. A major goal of the program is to quantify those quality parameters needed for resource assessment as relates to technology, environmental, byproduct, and chemical usages.

Started in 1971, the program has been responsible for complete chemical analysis of more than 3,200 channel or borehole samples of coal and associated rock. The analyses include quantitative determinations of the amounts of 24 major, minor, and trace elements (including Al, As, Cd, Cu, F, Hg, Mn, Na, Pb, Se, U, and Zn) and semiquantitative determinations of the concentration of 15 to 20 additional trace elements (including B, Be, Cr, Ge, Mo, Ni, and V). In addition, the U.S. Bureau of Mines provides proximate and ultimate analyses, Btu and forms-of-sulfur determinations, and the ash fusibility and free-swelling index on the coal samples.

Statistical summaries of analyses for 799 samples completed in 1975 (Swanson and others, 1976) indicate that the average coal in the United States contains 11.3 percent ash, 10.0 percent moisture, and 2.0 percent sulfur, and has 11,180 Btu per pound on an as-received basis. Of the 10 major oxides determined on the 525°C ash, the SiO_2 concentration is 38 percent; Al_2O_3, 20 percent; and Na_2O, 0.67 percent. The average Cd content is 7.3 ppm (range <1 to 580 ppm); Pb, 114 ppm (range 13 to 2,700 ppm); and Zn, 151 ppm (range 1 ppm to 6.0 percent). As determined on the raw coal, the average Hg content is 0.18 ppm (range <0.01 to 3.3 ppm), Se content, 4.1 ppm (range <0.1 to 150 ppm); and U content, 1.8 ppm (range <0.2 to 42.9 ppm).

Other components of the coal-composition program to date include detailed coal petrography and mineralogy studies of selected samples derived from economically important Appalachian and interior provinces coal beds. All of these geochemical, coal-petrographic, and mineralogical data aid in the evaluation of coal resources for environmental implications, technological and chemical resource assessments, byproduct recovery feasibility, and the definition of geologic factors that control the differences in, and permit a prediction of, the variable chemical and physical properties of coal.

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COAL-MINING GEOLOGY

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ABSTRACT

Coal-mining geology, or more properly geotechnology, differs from the geology of coal fields and the geologic aspects of coal-science, both in its primary purpose, to serve the objectives of coal undertakings, and also in being in a "downstream" but complementary position relative to the other geologic sciences. In Great Britain, the year 1947 brought to a head misunderstandings due to the differences in primary objectives between what was then the Geological Survey of Great Britain and the British coal-mining industry. Wartime overall undercapitalizations of what had always been a highly competitive multicorporation coal industry, still enjoying a twofold price advantage over oil, combined with its critical position underpinning all future plans for peace-time economic growth, enforced nationalization of the industry and the formation of the National Coal Board.

Since then, what is now coal-mining geology has emerged through the process of training geological scientists to get inside the mind of the coal-mining engineer and to identify the significant aspects of their geology from his standpoint, and with what would be his priorities in mind, in any mining situation. In Britain, because outcrop coal has been worked from Roman times onwards, recently 85 to 90 percent of the 130 million-180 million tons/yr. output has had to be from deep mines rather than from surface mines.

In modern highly capitalized deep mining, the vast bulk of the revenue from the day to day output of the coal mine is required to offset labor costs and fixed capital and interest charges. Any profit comes from the total revenue obtained from the marginal output above a high "break-even" figure. Any form of unexpected natural (rather than induced) geologic disturbance to the planned continuity of production, such as a change within the sedimentary framework or the tectonic setting of the coal seam being worked, has an effect on profit in proportion to the proceeds per ton lost from the planned production.

In these circumstances, apart from being what underpins rarely occurring decisions involved in choosing the best seams to work first, and starting to mine in the best direction, the geological conditions are solely the "unexpected geological disturbances" (to the planned continuity of mining).

Geology is considered part of the mining condition. Efficient exploration is that part of the mining undertakings' total activity that contributes to finding "disturbances," and other changes in the geologic conditions, in just sufficient time to provide the replacement capacity necessary to preserve continuity of planned output (i.e. within the minimum response time of the local system to change).

At the single-mine level, exploration by productive methods must commonly play a greater part in achieving an efficient balance of mining effort than the familiar nonproductive methods of exploration (drilling, mapping, geophysical surveying). More knowledge of the sedimentary framework and tectonic setting of the seam can be achieved by altering the pattern and degree of costly dispersion (or departure from the cheapest, most concentrated layout) and the degree of costly development to be created and maintained in advance of (assumed uninterrupted) production needs. A hand simulation and gaming method is used to test the best balance between (1) the cost of any exploration (productive and nonproductive); (2) the insurance costs, partly in the form of spare shift capacity, for geologic

phenomena that cannot be proved within the exploration costs; and (3) the costs of residual "unexpected" geologic disturbance whose presence and pattern of occurrence can be extrapolated and interpolated although the actual locations of the elements constituting the pattern cannot be inferred.

At the multimine level, if the definition of the reserves is productivity sensitive and the reserves of the year are equivalent to the sum of the annual outputs, then if overall conditions remain unchanged, the trend shown by annual reserves assessment performs the same function as does productive exploration assessment at the single-mine level in the mining industry. Both can be used by the geologist to find the appropriate level of nonproductive exploration necessary for minimum annual cost and maximum annual proceeds at any level in any particluar mining and geological circumstances. The latter (multimine) method stems from its place in balancing exploration for more reserves, current reserves trend, current capacity, and the market outlook (within the response time of the undertaking to market change) and the time necessary to find and to bring on to "full-stream" a new mine, or to close the least profitable existing mine.

None of these techniques for matching the needs of the coal mining industry to the geological conditions under which it must, perforce, operate, could have been developed solely from the principles of either geological science or mining engineering. The new geological discipline of coal-mining geology is halfway between the two and depends on both.

IMPROVED MINING TECHNIQUES AS RELATED TO GEOLOGY

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ABSTRACT

The U.S. Bureau of Mines has two major goals relative to coal mining; the maximization of coal production, and the maintenance and upgrading of health and safety conditions during the mining operation. The role of applied geology in our research program differs from the usual geological investigations because we are concerned with the engineering aspects of the resource. The definition of geologic features as they relate to the coal-mining process and of their potential hazards forms the basis of the Bureau's geologic investigations, both in-house and contractual. The major program areas using applied geology information are: (1) Advanced Mining System Development, where premining geologic conditions regulate the type and method of extraction technology; (2) Ground Control, where the potential hazards of the structural geologic features are identified and corrective measures are applied to insure safe production environments; (3) Subsidence Program, which involves the prediction of ground movement response from the geologic conditions; and (4) Methane Control, where geologic information is used for planning mine layouts to minimize outflow and outburst phenomena. Specific geologic features under study by the Bureau include premining definition of sand channels and want areas by geophysical and sedimentological studies, prediction of roof-fall areas by geologic prediction models, and cataloging of known potential hazardous features for each major coal seam in the United States.

THE ROLE OF GEOLOGY IN COAL MINING

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ABSTRACT

Geology plays an important role in both underground and surface coal mining. In underground mining, the lithology, structure, and ground-water conditions of rocks above and below the coal affect the behavior of these rocks in response to mining in three important ways: First, structure and lithology control the rate and direction of erosion, which, in turn, govern the thickness, depth, and configuration of the overburden and consequently control those stress conditions in the coal, roof rock, and floor rock that are related to topography. Faults, joints, and ground water tend to weaken rocks above the coal and to increase the rate and amount of subsidence above mine

workings. Second, any active orogenic stresses can change the magnitudes and directions of the stresses produced by topography. Third, the lithology and the primary and secondary structures—such as bedding, crossbedding, organic structures, channel sandstones, dikes, joints, and faults—in the rocks above and below the coal influence stability of the mine roof and floor in various ways. Knowledge of the ways in which these structures affect the stability of mine roofs is very important, because statistics indicate that roof falls are the primary hazard to coal miners.

Short- and long-term stability of highwalls and spoil piles in surface-mining operations also is controlled by the structure and lithology of the bedrock, by local surface-water and ground-water conditions, and by climatic conditions. The depth limit and benching requirements for stripping overburden, for example, are governed to a large extent by the short-term strength of the unweathered bedrock, which is in turn controlled both by its structure and lithology and by the local distribution of surface and ground water. Final grading specifications for the last cut on the highwall of a surface mine depend upon the long-term slope stability of the weathered bedrock. Chemical weathering and leaching of spoil piles, as well as the stability of the slopes and the settlement characteristics of the regraded materials, also are affected by the lithology and structure of the unweathered and undisturbed bedrock or surficial material, as well as the climatic conditions in the mining area. These factors, therefore, are important to well-planned and efficient mining and surface-restoration operations.

Basic geologic studies are important to planning mining activities from resource assessment through the mine-development and land-restoration stages. The map products from these studies should be at scales ranging from a national scale, to a coal-field scale, to perhaps even a local area scale, because various aspects of planning and implementation of mining projects by private companies or by government agencies commonly are conducted on national, regional, and areal scales. Maps at several scales are needed for evaluating the environmental effects as well as for analyzing and appraising the resource.

Types of maps that show geologic features that are important to planning and implementing mining activities from resource appraisal to restoration are listed below at suggested scales:

1. National Overview Series; scale 1:5,000,000 to 1:7,500,000; for use in determining target coal field and appropriate mining method within selected coal fields; a series of maps is recommended, showing:
   a. Location, coal thickness, and tonnage of coal deposits that can be mined by (1) surface and (2) underground methods.
   b. Coal rank and type, sulfur and ash content, and abundance of trace elements.
   c. Other economic deposits that may be affected by coal mining activities.
   d. Surface relief; surface drainage and lakes, subsurface water quantity and quality.
   e. Overburden thickness, type, lithology, strength, and structure; tectonic framework.
   f. Surface and underground land use and ownership.
   g. Areas previously mined by (1) underground and (2) surface methods; effects of past mining.
2. Coal Field Series; scale 1:50,000 to 1:500,000, depending on areal extent of coal field; for use in appraising coal resources, in planning general drilling programs, and in determining best mining sites, mining procedures, general environmental effects of mining. Maps should show same elements as in National Overview Series but should be more specific and more detailed.
3. Mining Area Series; scale 1:2,500 to 1:25,000, depending on size of mine area and detail needed; maps for use in (a) resource appraisal; (b) design of mining operations; (c) analyses of effects on the ground surface, ground water, and surface water; (d) design of drilling studies; and (e) restoration of mined lands. The maps in this series commonly would be compiled by private companies and would portray the same features as the National Overview Series,

except in much greater detail. Other special-use maps, such as forecast maps of mining conditions for underground mining activities, probably will be needed.

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GEOPHYSICS IN COAL EXPLORATION AND DEVELOPMENT

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ABSTRACT

Geophysical methods have wide technical application in almost every phase of coal mining—from exploration within large structural basins for potential coal deposits to prediction of rock conditions only a few meters ahead of the continuous-mining machine. However, only in recent years, spurred by the rapid increase in coal demand and coupled with the steady rise in labor and exploratory drilling costs, has coal geophysics become economically attractive. Its principal applications today are in borehole logging for determining the depth and thickness of seams and for obtaining a measure of coal quality, in high-resolution seismic prospecting for isolating tectonically disturbed areas within which mechanized mining would be unprofitable or unsafe, in seismic seam-wave probing for certifying seam continuity and for detecting minor faulting, and in gravity and magnetic surveys for delimiting coal resources. These successful demonstrations of the cost effectiveness of coal geophysics will accelerate the application of existing methods and motivate the development of new techniques, a trend already evident in the amount and variety of ongoing research.

In addition to refining proven techniques, research is being directed to the following problem areas: (1) delineation of old, inaccessible underground workings, (2) location of very old mine shafts, (3) determination of the continuity of coal beds, (4) prediction of ground conditions immediately ahead of the advancing longwall, (5) detection of lenticular coal deposits at strippable depths, (6) mapping of channel cutouts, (7) development of borehole assaying methods for sulfur, (8) location of igneous dikes and clay seams within coal measures, (9) determination of overburden and roof-rock strengths, and (10) improvement in the safety of mining operations.

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HYDROLOGIC ASPECTS OF THE REHABILITATION POTENTIAL OF SURFACE-MINABLE COAL LANDS IN THE WEST

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ABSTRACT

Climate, topography, and geology are the three major factors that cause variations in the vegetation, soils, and hydrology of coal lands in the Western United States. Therefore, each is

among the important factors that determine the rehabilitation potential of any specific area where mining is proposed.

Rehabilitation potential is the probability for returning the land to a usable form and maximum feasible productivity by applying reasonable procedures in conformance with a land use plan. The goals of rehabilitation are to develop a stable ecology, to minimize environmental deterioration, and to provide consistence with surrounding aesthetic values.

In order to evaluate rehabilitation potential more accurately, we need research on several formidable problems associated with surface mining of western coal lands:

(1) The effects of changing land use after mining and changes caused by construction of transportation corridors and urban and recreational areas need to be defined. Potential effects include changes in (a) annual volume of runoff water, (b) frequency and magnitude of peak flows, (c) soil erosion, (d) chemical and biological quality and sediment loads of streamflows, and (e) ground-water recharge and discharge. (2) Alternative procedures designed to preserve the forage-production capability and water-quality values of alluvial valleys need to be intensively evaluated. (a) Technology exists for stabilization of highwalls or other knick points where they intersect stream channels, but specific applications need to be designed. (b) Methods of backfilling that minimize compaction or means for draining ground water through compacted fill need to be devised to prevent the mixing of good-quality surface water with poorer quality ground water. (3) The effects of closed depressions in the postmining topography on the regional hydrology in areas of thick coal beds need investigation, and plans for rerouting, regrading, and maintaining the flows of through-flowing streams must be designed. (4) Additional knowledge is required about the effects on the quality of ground water and surface water of vertical leaching and horizontal flushing of backfill materials.

In addition, long-term (perhaps two decades or more) monitoring or applied research is needed to determine how long it takes for the soil to reaggregate, for vegetation to reach equilibrium, and for ground-water levels and ground-water quality to stabilize after mining and rehabilitation.

Research is progressing in other aspects of rehabilitation that have influences on the hydrology of mining areas such as: (1) determination of overburden members that are suitable for vegetation growth media in areas of thin or unsuitable topsoil; (2) depth of topsoil or growth media needed for given surface materials, subsurface materials, adapted vegetation, climate, and topography; (3) need for temporary irrigation to expedite vegetation establishment and the programming of the irrigation; (4) adaptation of vegetation species and planting methods; (5) mechanical treatments to rehabilitated surfaces to promote vegetation growth and minimize erosion; and (6) disposal of refuse including potentially toxic substances.

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RECLAMATION OF EASTERN SURFACE MINES

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ABSTRACT

The mountains of southern Appalachia contain some of our Nation's most valuable surface minable coal, but the area is one of the most difficult to reclaim properly after mining. Steep slopes, thick overburden, generally poor soils, highly variable rainfall, and extreme winter temperatures provide a constant challenge.

In recent years, tremendous progress has been made by State enforcement agencies and the surface-mining industry in planning, mining, and reclaiming, and in utilizing reclaimed areas. This presentation describes these facets of the coal surface-mining industry in southwest Virginia. The problems encountered and the solutions are, however, typical of those in several other southern Appalachian States.

In a region where the average slope of areas being mined exceeds 25°, even getting equipment to the job site posses special problems. Water control and management take on special significance.

During the entire mining operation, the ultimate reclamation of the site must be an overriding consideration. Material management is critical. The operator must be sure that he has available enough suitable material to sustain vegetation and that he can physically stabilize the area.

His choice of seed, fertilizer, mulch, and application methods will also be extremely important. Soil types and available plant nutrients vary widely, and occasional problems with acidity increase chances of unsatisfactory reclamation results unless every action is carefully planned and executed.

With better reclamation has come an increased public awareness of the great potential of reclaimed surface mines. Already, these areas are being used for recreation, airports, shopping centers, housing developments, school sites, and agriculture.

In addition to these factors, this presentation covers the effects of existing surface-mining legislation, the probable effects of certain pending bills, and the outlook for Appalachian coal surface mining.

TECHNICAL SESSION III—UTILIZATION OF COAL: SYNFUELS, PETROCHEMICALS, METALLURGICAL COKE, ELECTRICITY GENERATION

CHARACTERISTICS OF COAL RELATIVE TO SYNFUELS

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ABSTRACT

Various degrees of coalification and the accompanying chemical and physical changes result in the formation of coals of different characteristics. These characteristics influence the chemical processes used to convert coal to synthetic gaseous and liquid fuels. Various conversion processes exist—pyrolysis, solvent extraction, catalytic hydroliquefaction, gasification. Consequently, although certain general and specific properties of coal have been identified that bear on the suitability of coals for synthetic fuels, no single set of suitability criteria has been found.

Coal rank is based mainly on volatile content, which is related to elemental composition. Geologically younger coals generally are more chemically reactive than older coals, and vitrain is known to be more reactive than fusain. High hydrogen content is desirable in coal to be used in synfuels production, but oxygen, sulfur, and nitrogen are not desirable and must be removed. Caking tendencies of coal cause operating problems in the preheaters and reactors of synfuels processors.

The petrography and mineral matter of coal have been identified as factors affecting synfuels processes. Many chemical elements in the mineral matter are active catalysts in the hydroliquefaction and gasification of coals. Specifically, iron compounds catalytically accelerate hydroliquefaction, whereas sodium speeds up gasification. Ash from the mineral matter left after the chemical reaction taking place during the production of synfuels is responsible for problems in the solid separation of the heavy residue produced by coal hydroliquefaction. In the synfuels production methods, ash causes difficulties in slag removal and in other operations in the large-scale coal-combustion equipment and slagging-type coal gasifiers. Complete removal of mineral matter in the feed for synfuels processes is not economically feasible nor, in certain processes, desirable.

Successful in-situ gasification depends on the nature of the local coal deposits, on an adequate water supply, and on an appropriate local topography.

Research is needed to establish relationships among characteristics of coal, its petrographic components, the synfuels processes, and the quality of products. Research is also needed to study kinetics of gasification and hydroliquefaction of petrographic components; to clarify the mechanisms of synfuels conversion with relation to the chemical structure of coal (including forms of sulfur, oxygen, and nitrogen, and mineral water) and to its petrographic components; and possibly also to devise methods for large-scale treatment of petrographic components for synfuels production.

Recent highlights of the ERDA program in studying characteristics of coals relative to synfuels conversion are summarized.

COAL SCIENCE RELATED TO UTILIZATION

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ABSTRACT

Coal can be defined succinctly as a sedimentary rock that is composed principally of macerals and subordinately of minerals and that contains water in submicroscopic pores. Coals originated as peat deposits formed in swamps through the accumulation of physically discrete

and chemically distinctive plant substances (and minor proportions of inorganic substances). The distinctive organic components of peat were converted (metamorphosed) to distinctive coal constituents (macerals) (1) by compaction beneath subsequently deposited detrital sediments and (2) by heat from subterranean sources.

Wood was the dominant plant material in typical peat swamps; therefore, typical coals consist predominantly of the wood-derived maceral vitrinite. All coals can be ranked by measuring one or more of the vitrinite properties (i.e., carbon content, volatile matter) that reflect the severity of the metamorphic processes that affected the region containing the coals. Identification of the rank of a coal provides a key, through established correlations, to many of the physical and chemical properties of the vitrinite. Characterization of the coal type according to its content of nonvitrinitic macerals and minerals provides insight into the expectable deviations of whole-coal properties from the properties of vitrinite of that rank.

Thus, to compare and to contrast (that is, to classify) coals optimally, both the *coal rank*, reflecting the stage of metamorphic alteration, and the *coal type*, reflecting the heterogeneity inherited from the diverse source materials, must be recognized.

The utility (grade) of coal for any use is reduced in direct proportion to its content of included impurities (moisture and ash-forming inorganic material). Additionally, for each process in which coal is used, specific criteria (other than purity) exist by which the coal is valued or graded. As shown in the table below, each of these grade criteria is affected directly by (1) the rank, (2) the type (petrographic constitution), or (3) both rank and type.

I estimate that about 75–85 percent of the variability in coal properties critical to grade (other than content of nonorganic impurities) is attributable to variations in rank. This is largely due to the fact that, because most coals are vitrinite rich, the metamorphically induced vitrinite properties dominate. However, as shown in the table, variations attributable to depositionally related coal-type factors can influence coal grade. For some applications, even where the rank is right, the type may preclude the use of a coal completely.

Process	Principal grade criteria	Controlling fundamental coal property (1, dominant; 2, secondary) Rank	Type
Mining, preparation.	Grindability, hardness, abrasiveness	1	2
	Formation of unique particles		1
Combustion	Calorific	1	
	Combustibility, swelling	1	2
	Ash properties		1
Pyrolysis (exmetcoke)	Yield structure	1	2
	Agglomeration	1	2
Metcoke	Coke strength	1	2
	Coke yield	1	
	Contraction, pressure	1	
	Impurities in coke		1
Liquefaction	Gas + liquids yield	1	2
	Gas/liquids ratio	1	
	Liquid properties	1	
	Autocatalysis, exchanged ions	1	
	Autocatalysis, minerals		1
Gasification	Reactivity	1	
	Autocatalysis, exchanged ions	1	

On the bases of the foregoing, I conclude that planning for the optimal use of our Nation's coals requires that:

1. Our Nation's coals be defined adequately in terms of their rank *and* type (petrographic constitution).
2. Research programs be instigated that quantify the specific correlations between the principal grade criteria (especially for synthetic fuels uses) and the fundamental properties that define rank and type.

COAL AS A CHEMICAL RESOURCE

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ABSTRACT

Originally the base for many organic chemicals (from "coal tar"), coal has almost ceased to be a chemical raw material because of the availability of low-cost hydrocarbons from natural gas and petroleum sources. However, the large U.S. coal resource base and its likely long-term cost relative to that of petroleum are causing government and industry to project a resurgence of chemicals production from coal before the end of the century.

Chemicals that can be made from coal by developing technologies include olefins, aro-

matics, oxygenated intermediates, and ammonia. The effect of coal rank and characteristics and of various gasifier or liquefaction technologies on light-hydrocarbon and chemical yields are discussed. Economics for production of certain chemicals from coal are covered in a general manner.

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SELECTION OF COALS FOR COKE MAKING

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ABSTRACT

Coke making is one of the oldest coal-conversion processes. Some coals, heated in the absence of air, produce a porous carbon residue called coke. As the demands for charcoal for the blast furnace depleted the forests, these coals were substituted for wood in the charcoal oven, and the coking industry was born. The dome-shape beehive oven was one of the earliest permanent structures used for coke making. Late in the 19th century, the Europeans developed byproduct ovens which, for the first time, enabled collection of the valuable distillation products. The byproduct oven is the dominant type used today; however, an effort to commercialize continuous coking is growing.

Coking coals are loosely defined as those producing acceptable coke. However, coking coals possess the unique property of softening, fusing, and resolidifying to form a porous carbon structure when carbonized. When coking coals are heated, the complex organic molecules break down into simpler primary volatile gaseous and liquid compounds. Some primary products react to form secondary products. The solid residue is coke and the gas, light oil, tars, and ammonium are by-products.

Coke for the blast furnace must be strong and low in impurities that could adversely affect performance or metal quality. Coke strength is measured by the amount of degradation induced by shatter or tumbling tests, and purity is measured in terms of volatile matter, ash, sulfur, phosphorous, and alkalies.

To meet coke quality specifications, the proper coals must be selected. A narrow group of coals in the lignite-to-anthracite series possesses properties that distinguish them as coking coals. These coals are called bituminous and consist of high, medium, and low volatile bituminous. Medium volatile coals are the best coking. The tests used to select coking coals measure chemical, rheological, petrographic, and carbonization properties. The most common chemical analyses are proximate and sulfur; however, phosphorous, alkali, and chlorine content are frequently determined. Commonly used rheological tests are Gieseler plastometer and free-swelling index. Petrographic analysis measures maceral composition and vitrinoid reflectance which serve to define coal type and rank, and these data can be used in predicting carbonization characteristics. Carbonization tests measure pressure and volume change and produce a coke that is tested for strength such as hardness and stability. Carbonization variables that affect strength are coal pulverization level, heating rate, and bulk density.

Most coking coals contain 15–40 percent volatile matter, 4–7 percent ashes, and 0.6–1.0 percent sulfurs. Alkali, phosphorous, and chlorine content should be as low as possible. Gieseler fluidity should be on the high end of the range for each of the coal ranks considered. The free-swelling index should be a minimum of 4. Ash softening temperature should be greater than 2500° F. On the basis of petrography, the vitrinoids should have reflectances between 0.7 and 1.8 percent, and a large amount of reactive macerals is desirable. Better coking coals are in the middle of the reflectance range: a blend reflectance of 1.1 to 1.2 percent is desir-

able when more than one coal is blended for making coke. The coal or coal blends must not produce pressures in excess of 2 pounds per square inch on oven walls, contraction should be 8 percent or more, and the coke should have a stability of 50 or greater. Small blast furnaces can use weaker coke than large furnaces. A stability of 58 or more is required for large blast furnaces. Limited availability of better coking coals necessitates blending of coals to obtain high-strength coke.

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ELECTRIC UTILITY INDUSTRY STRATEGY FOR RESEARCH IN COAL GEOLOGY

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ABSTRACT

The electric utility industry is the largest single consumer of U.S. coal; it uses roughly two-thirds of total annual production. In the future, coal will continue to be an essential fuel in existing utility facilities, in those converted from fluid hydrocarbon fuels, and in new power plants.

For the most part, particularly for the remainder of the 20th century, coal will be burned to raise steam for power generation. Accordingly, the electric utility industry's objectives for research on coal concern all factors pertaining to coal utilization.

Coal-fired electric-power generating facilities may require about 820 million tons of coal in 1985 and roughly 1600 million tons in the year 2000. Although the United States is endowed with substantial coal resources, not all these resources constitute reserves, and not all reserves can be recovered for use. The remaining measured and indicated recoverable reserves are estimated to be only about 8 percent of the total National coal resource.

Cumulative coal-production statistics are assumed to represent recoverable reserves that have already been recovered. Together with estimated remaining recoverable reserves, these data permit an estimate of the stage of coal development by State. Extensive coal mining has taken place in the Appalachian region; only about one-third of the measured and indicated recoverable reserves remain in Alabama and Tennessee, and only about half these reserves remain in Pennsylvania, Maryand, and Virginia. In contrast, the remaining recoverable reserves from measured and indicated deposits in the States west of the Mississippi River are essentially intact. The estimate of remaining recoverable reserves is increased by inclusion of less well known 'inferred" deposits; their inclusion extends the estimated reserve lifetime, especially at the higher production levels projected for 1985.

Electric utilities are concerned with the quantity of recoverable coal reserves, their quality in various utilization systems, and environmental effects of production and consumption. Historically, utilities could concentrate on the engineering aspects of individual coals in specific facilities for optimum power generation, and a wealth of empirical data was acquired. The present situation, in which concern over environmental pollutants influences coal selec-

tion and utilization, creates an opportunity for placing unprecedented emphasis on the availability of comprehensive geological data on coal properties and characteristics to guide engineering efforts for pollution control while maintaining operational efficiency. Considerable effort will be required to place present engineering data about coal use on a firm theoretical base that will enable performance assessments to be prepared in advance of utilization.

Research on coal geology needs to be directed toward obtaining information to guide resource conservation and characterization of coal properties for efficient utilization. Goals for research on coal geology in the remaining years of the 1970's and beyond are suggested, as follows:

1. Before the end of the 1970's, compile and analyze data on coal deposits for the remaining States according to a computer procedure similar to that developed by the Illinois State Geological Survey (ILLIMAP).
2. Before the end of the 1970's, perfect and deploy a means for rapid nondestructive comprehensive analysis of representative coal samples as an integral part of production, preparation, and utilization operations.
3. Before the end of the 1970's, establish and utilize a means of correlating coal properties and utilization conditions so as to facilitate beneficiation/blending to meet performance requirements within pollution-control limits.
4. By 1980, rejuvenate curricula and instructional materials on coal geology at both undergraduate and graduate levels.
5. Within the next decade, pursue the integration of results in coal geology research with those from other sectors of the earth sciences to contribute to a better understanding of the evolution of the earth and its environment.

Specific research activities directed toward attainment of these goals include:

a. Compilation of available data on coal reresource and recoverable reserves,
b. Investigation of inferred resources,
c. In-mine geological mapping,
d. Determination of properties of associated strata,
e. Resource exploration,
f. Perfecting a means for rapid non-destructive analysis of coal,
g. Determination of engineering properties of coal,
h. Basic research on coal characteristics and origin, and
i. Rejuvenation of curricula and instructional materials related to coal geology.

Geologists who are knowledgeable about coal must become more involved in planning and implementing coal research and development if the nation is to derive full advantage from its deposits.

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THE NATIONAL COAL RESOURCES DATA SYSTEM

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ABSTRACT

A computer-based coal-resource data system has been developed by the U.S. Geological Survey (U.S.G.S.). This interactive conversational query system allows access to the data by any interested party, either by request through the Geological Survey or by independent remote access through any standard computer terminal. Development of the system has been in two phases to accommodate the availability and complexity of the data.

Phase I, which is currently available but for which data entry is not yet complete, contains published resource and chemical data on an areal basis, such as State, county, township, or field. The user can retrieve and tabulate aggregated coal-resource-related data from the area file to compile local, regional, or national summary reports.

Phase II will store, retrieve, and manipulate basic point-source coal data from, for example, field observations and drill-hole logs. The data will include geodetic location; bed thickness; depth of burial; moisture, ash, sulfur, major-, minor-, and trace-element content; heat value; and characteristics of overburden, roof, and floor rocks. The computer system may be used interactively to generate structure-contour, isopach, or isoline maps of the physical and chemical characteristics of a coal bed or to calculate coal resources.

Coal-resource-related data from ongoing U.S.G.S. programs, as well as from other Federal, State, university, and industrial groups, will be entered into the system to provide comprehensive national coverage.

All data should be available to all users of the system. However, where essential, confidentiality will be preserved, and the general user will be provided with aggregated data only.

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U.S. GEOLOGICAL SURVEY PROJECTS IN WESTERN COAL GEOLOGY

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ABSTRACT

The present work of about 150 U.S. Geological Survey geologists, hydrologists, geophysicists, chemists, and engineers is devoted to studies of Western U.S. coal geology, including geologic mapping, stratigraphic studies, mineral classification, coal resource evaluation, geochemical studies, and coal hydrology. Programs dealing with these topics are largely concentrated in the Rocky Mountain and Great Plains States of North Dakota, Montana, Wyoming, Colorado, Utah, and New Mexico. For the six-State region, ownership of coal lands and coal rights by the Federal Government ranges from an estimated 82 percent of the total coal lands and coal rights in Utah to 25 percent in North Dakota; it is about 60 percent for the region as a whole.

Priority areas of investigation are the lignite area of western North Dakota, subbituminous coal areas of the eastern and northern Powder River Basin of Montana and Wyoming, and subbituminous and bituminous coal areas of the Yampa River and Danforth Hills fields of northwest Colorado, the Hanna Basin and Rock Springs uplift of southern Wyoming, and the Wasatch Plateau of central Utah. Exploratory drilling is being done in most areas being studied. About 1,000 holes, totalling about 415,000 feet, will be drilled in 1975–76.

Objectives of the work of the U.S. Geological Survey are to determine the continuity of the coal beds, refine coal-bed correlations, locate more accurately the position of coal beds that were originally mapped on inadequate base maps, determine the locations and tonnages of coal in thick beds under shallow cover, and establish regional and local geochemical variations in surficial deposits, coal-bearing rocks, and selected vegetation types in selected coal basins additional objectives are to provide estimates of water availability and water quality from streamflow and ground water; this information will be used to help plan for increased coal production and related developments such as coal-slurry pipelines. Studies have been designed for selected small stream basins to determine, in detail, the relations of the coal beds to the hydrologic system and the hydrologic effects of coal mining and land reclamation.

Site-specific evaluations are being undertaken in cooperation with the U.S. Bureau of Land Management at several localities in the Western States in a coordinated approach to analysis and interpretation of soil, water, overburden, and coal-resource data in prospective mining areas.

Geochemical studies include work on chemical variations in soils and on variability of selected elements in stream sediments in the Northern Great Plains, mineralogic and chemical variations in overburden rocks in the Fort Union Formation, and element concentrations in soils and vegetation near certain power plants and on reclaimed soils in the Great Plains region.

Studies in the Western U.S. coal fields are providing information needed to regulate the leasing and mining of Federally owned coal; they provide information useful for classifying coal resources in greater detail than has been done before; they enhance our ability to predict and monitor the geologic effects of coal mining; and, finally, they provide a better understanding of the coal-forming processes and coal-forming environments in Cretaceous and early Tertiary time in the Western Interior region.

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U.S. GEOLOGICAL SURVEY PROJECTS IN COAL GEOLOGY OF THE EASTERN UNITED STATES

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ABSTRACT

The geologic aspects of Eastern United States coal deposits are covered by research projects ranging from studies of the initial accumulation of organic matter in modern swamp environments, through various phases of coal-resource mapping and assessment, to the investigation of the characteristics and compositions of ash and other emissions in the final utilization of the coal.

Modern swamp studies are focused primarily on the Everglade basin, Florida, where geologic mapping, coring, and geochemical analysis are in progress to investigate the genesis of coal and the geologic controls on coal deposition. Because of the demand for low-sulfur coal, Virginia, West Virginia, and eastern Kentucky are priority areas for assessing the magnitude and quality of coal deposits. These studies involve geologic mapping, core drilling, sampling, petrographic description, and depositional-environment determinations. A complementary project—the Pennsylvanian System Stratotype Study—is a stratigraphic and paleontologic effort to establish a standard section for the Pennsylvania System, so that regional and worldwide correlations may be made of these economically important coal-bearing rocks. Possible environmental effects from the consumption of eastern coals and trace-element concentrations are being investigated by the detailed sampling and analysis of in-place coal, cleaned and blended coal, and the ash and flue gases resulting from the commercial utilization of coal.

Newly acquired data from the ongoing projects, as well as currently avaliable information on Eastern U.S. coal beds, are being computerized for the National Coal Resources Data System, which is being prepared by the U.S. Geological Survey.

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