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World Coal Exploration and Developments

by

Gordon H. Wood Jr.

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Gordon H. Wood, Jr.[2]

A distinct honor was conferred on me, when I was selected to deliver the keynote speech to this distinguished group of coal scientists. I sincerely hope that you will forgive my mispronunciations of the names of coalfields, cities, states, provinces, mines and localities in your own nations. At the time of preparing this speech, I did not know if there would be translation facilities or if each workshop participant would be left to their own devices to translate the best they could. Because of this uncertainty, I plan to speak clearly and slowly.

I feel that you should know something about me. I have worked for the U.S. Geological Survey since 1942. The first 6 years was spent in studying Paleozic, Mesozoic, and Tertiary sedimentary rocks in the mountain ranges of the western United States. These studies were based on the assumption that similar rocks in adjacent sedimentary and structural basins would be petroleum-bearing, and that the sedimentary characteristics observed in the mountains would aid the search in the basins for petroleum. The remaining 36 years of my almost 42 career have been spent on mapping coal-bearing rocks, in studying the structure of mountain ranges and coal fields, in understanding the vast subject of coal resource classification and estimation, and in analysing coal geology on a world basis.

During my career, I have managed geologists working in all phases of coal geology, including coal resource estimations, and studies of pollution

1 Keynote Address, Coal Geology Workshop, Southeast Regional Network of Geosciences, Seoul National University, Seoul, Korea, October 3-8, 1983.

2 Geologist, U.S. Geological Survey, Reston, VA 22092, USA

resulting from coal mining within the United States. Internationally, I have worked alongside geologic and engineering associates, and then assumed management of these associates for the World Coal Resources and Reserves Data Bank Service of the International energy Agency.

I feel competent in most fields of coal geology--but not as great competentence when chosen to speak in a combined sense on coal exploration and development. In explanation, I wish to emphasize my feeling of competency in problems related to exploring for, finding, and developing an understanding of the resources of coal at any place in the world. Such coal exploration, I prefer to think of as geologic exploration for coal in previously unknown or poorly known coal fields. Geologic exploration of this type is quite distinct from the engineering geologic exploration related to mine planning, development, and production.

Because of the two meanings implied by the title "coal exploration and development", this speech is divided into three parts. First, this speech is a recital of what I could learn from my associates and from the literature about mine planning, mine opening, projected production tonnage estimates, associated construction, and costs on a world-wide scale. Secondly, the speech is a recital of the geologic exploration by nations and companies for coal. And thirdly, it is a summary of geologic developments that I believe must take place on a world-wide scale, if we geologists are to contribute to the requirements of a growing world population.

1. Engineering - geologic coal exploration and developments.

Many billions of dollars are being spent annually by many nations in gathering geologic data related to individual mines and in gathering more general data needed for planning a mine or mining complex. Additional billions are being spent for drilling prospects, for opening mines, for constructing or modifying processing plants, for building railroads, for planning and constructing coal port terminals, for obtaining financing, for economic and engineering feasibility studies, and finally, for environmental studies about the effects of mining, processing, transportation, use of coal on atmospheric and water pollution.

Most of the money being spent is directed to developing mines or minng complexes, and to building ancillary facilities such as railroads and export terminals.

With this introduction, I will now proceed to describing the engineering, geologic coal exploration, and developments in individual nations.

Argentina

Adaro's Mineral Exploration Agency was awarded a contract by the Argentina government to further explore the Rio Turbo coal mining region of the state of Patagonia. The contract, financed by the World Bank, has a term of 4-years. The objectives of the contract are to increase production to 6 million metric tons per year, to build a railroad line to the port of Rio Galleos in Santa Cruz Province, and to improve the port so that 60,000 d.w.t. ships can be loaded and unloaded. Cost of the contract was not announced.

Australia

The coal industry of Australia produced 111 million metric tons in 1981 of which 51 million metric tons were exported. The tonnage produced in 1981 was an increase of 21 million metric tons over 1980. The production tonnage predicted for 1982 and 1983 indicates that each Australian state is expecting to produce less in 1981 as a result of the World recession. Furthermore, Japan has forced price reductions per ton of coal and the Australian mining industry is experiencing difficult times.

In New South Wales, the Brimestone No. 2 and Vally 2 coal mines have been closed, and the production at the Nattai Bulli mine has been cut by 50 percent. Pike Gully underground mine is being developed. The attitude in New South Wales, in general, is gloomy.

Queensland is apparently in better shape. The Tarong mine and power plant, a $252 million project, is to begin operation in July 1984 and to produce 66 million metric tons in the succeeding 10 years.

The Blair Athol mine, a $500 million surface mine projected to produce 5 million metric tons per year of steam coal, is progressing.

Consolidated Coal Company, U.S.A., purchased 49 percent of Gollin Wallsend Company in New South Wales, Austrailia. This purchase included the Gunnedah Mine, a 600 thousand metric ton per year operation, which produces steam and metallurgical coal and the Glennies Creek mine property, which is undeveloped, but which is capable of producing high-volatile coking and steam coal.

Austria

Austria has announced that it is building a 400-MW power plant to burn anthracite. It also announced plans that 2 smaller power plants are to be modified to burn anthracite, and plans for modifying 1 power plant to burn either lignite or anthracite, depending on the availablity of coal of both ranks.

Botswanna

The Moropule Mine is producing coal for the Botswana Power Corporation and for Botswana Copper Limited to be used in copper smelting. In 1982-83 production is projected to be 430 thousand metric tons. From 1983 to 1985 production is to be raised to 480 thousand metric tons and then to 600 thousand metric tons per year. Botswanna reserves are estimated at 3.5 billion metric tons, 56 percent of Africa's reported reserves. The Moropule mine, operated by the Anglo-American Company of South Africa, is underground mining the 30 foot Moropule coal bed using room-and-pillar extraction techniques.

Canada

Several new mines in British Columbia have been planned, contracted for, are being built, or are comming into production. Addtionally, several railroads are being constructed, and export terminals enlarged or built. Principal among these are the Green Hills mine, Quintette mines, Sage Creek mine, Willow Creek mine, Teck mine, and a 130 km railroad connecting the Quintatte mines and Ridgely Island terminal. The terminal, south of Prince Rupert, is being built to export 7.7 million metric tons per year and is capable of enlargement to 24 million metric tons per year. The Quintette Mines, the railroad, and the Ridgely Island terminal are projected to cost $2.2 billion. The Roberts Banks terminal, near Vancouver, British Columbia, is being enlarged from 14 million metric tons capacity per year to 25 million metric tons per year at a cost of $127 million. From the preceeding it should be evident that coal production increases are being implemented in Canada at a cost of several billion dollars.

Chile

The Packet coal project in the Straits of Magellan is planning and building a new surface mine with a capacity of 900 thousand metric tons per year that will be enlarged to 2.1 million metric tons per year later in the 1980's.

China

China appears to be undertaking a massive coal program to increase production. In 1982, China had 553 government mines that produced 385 million metric tons, and 18,500 local authority mines that produced 330 million metric tons. Total production was 715 million metric tons. By 2000 China hopes to increase production to 1.2 billion metric tons and to achieved a 1.3 billion metric ton capacity.

To achieve such a production increase China has inaugurated 10 coal projects to be completed by 1990. These projects are in Shanxi, Anhui, and Shandong provinces and in the Nei Mongol Autonomous Region. The resources in the 10 project areas are estimated at 4.5 billion metric tons, the currently proven reserves are 833 million metric tons. The cost of the 10 projects is estimated at $3.392 billion.

In addition, China is investigating the possibility of starting up 29 new mines, a power plant, and an 800 kilometer railroad in Zhanjigong and Guandong Provinces in southwest China. Barges are being built to move 1.2 million metric tons per year on the Yangtze River to stock a 1.5 million metric ton export terminal at Zhicheng in Hubei Province. Barge operations are to start in 1985. The Qiuhuandoa export terminal is to be in operation by January 1985. Capacity of this terminal is estimated to be 20 million metric tons per year. A 600 kilometer slurry pipeline is being built by Fluor Corporation from Shanxi Province to Shanghai.

About 66.7 billion tons of reserves are being opened for mining by the following surface mines: the Antaibo No. 1 of Island Creek Coal Company, No. 2 Jinning of Shell International Company, 3 open pits at Pingshou, Antaibo No. 2, Anjialing, Luan and Nincheng; and the following underground mines: Chengzhuong, Jincheng, Changchon-Luan, Sihe-Jincheng, and Tunlius-Luan. Production from these mines will be more than 50 million metric tons per year.

In the Nei Mongol Autononous region open pits are planned at Heidagou, Yagua, Panxie, and Yiminhe. These open pits will mine coal from deposits holding an estimate 15.8 billion metric tons of reserves. The estimated production from these open pits is project to be 89 million metric tons per year.

It can be seen from the preceding that China is assuring its ability to meet a production goal of 1.2 billion metric tons per year by 2000.

The proposed and actual mining activities heretofore described are in Carboniferous coal beds.

Six new mines are planned in Jurassic coal beds in the Huatong mining district where estimated coal reserves are 3.26 billion metric tons. When completed, the new mines are at Yanxio, Daxin, Chenjagou, Yangma, Baieagon, and Linjiaha are projected to produce 11.4 million metric tons per year.

Egypt

The Egyptian government is reopening the Maghora coal mine in the Sinai Peninsula with Babcock Contractors of the United Kingdom as operators. Production is projected at 710 thousand metric tons per year. The coal is suitable for steam purpose and for coke blending.

Hungary

Hungary is engaged in a minor expansion of production each year as evidenced by a small increase from 24.5 million metric tons produced in 1981 to 25 million metric tons produced in 1982. Despite this relatively small increase, Hungarian coal scientists are engaged in many studies to increase the efficiency of production, management of acid mine waters, and delineation prior to mining of coal bodies in highly complex tectonic settings. It is likely that many of their advances, if published, will benefit the coal industry world-wide.

India

India plans to increase coal production from 125 million metric tons per year in 1981 to 400 million metric tons by 2000. To accomplish this increase, surface mine production is to go from about 40 million metric tons per year per year to 200 million metric tons and underground production from about 77 million metric tons to about 180 million metric tons. Such an increase, obviously, will mean enlarging production from existing mines and the opening of many new mines. Currently, the Karanpura mines are to be developed at a cost of $885 million to $1.062 billion by the United Kingdom's National Coal Board. Various agencies of the Indian government and companies are engaged in many types of coal studies to improve efficency in mines, in the combustion of coal, in cleaning of coal, and in the finding or extending of coal fields. In order, to improve the safety of Indian mines, the government has ordered $654 million worth of gas detection equipment.

Indonesia

A contract for Tarahan coal terminal was awarded for $68 million. The terminal is to supply coal for Suratayo Power Station in Java and for export. The Indonesian government awarded a contract to P.T. Adaro for exploration and development of a 61,000 acre coal-bearing area in South Kalimanton.

Mozambique

Brazil's Companhai de Pesquisa de Recursos Minerals (CPRM) has completed a $5 million viability study for a 400 thousand metric ton per year mine a 540-kilometer railroad, and an expanded coal export terminal. The railroad is to connect the proposed mine with the port of Biera.

New Zealand

Plans call for replacement of the Morely and Beaumont mines by a new 200 thousand metric ton per year mine in Southland. The Warraki No. 6 mine has started a shaft sinking at a cost of $12,500,000 which is to be completed in mid 1984.

Pakistan

In 1983 production will be 1.3 million to 2.4 million metric tons, 90 percent will be used in brick kilns. This production will be derived from about 2,000 small mines.

Pakistan's known resources are between 500 and 600 million metric tons, and the reserve base is about 64 million tons. The government plans, if approval and financing can be obtained to increase production from 2.2 million metric tons to 5.4 million metric tons by 1988. It is also planning a 300-MW power plant at Lahkra which will be operational by 1988.

Philippines

Production in 1982 was predicted to rise about 400 percent from 359.3 thousand metric tons per year to 1.520 million metric tons in 1982 and to increase to 3.080 million metric tons in 1984. Plans call for development of coal mines on Semirara and Pollilo Islands at Surigao del Norte, Zombrango del Sur, and Cagayan Valley. In addition, eight export or inter-island terminals are to be constructed by 1987.

Romania

Currents plans are to increase production from 44 million metric tons per year to 96 million metric tons by 1985. Twenty percent of the increase is to be accomplished in 1982-1983.

Union of South Africa

Production in 1982 declined 6.3 percent from that of 1981. From 1983 to 1988 the South African coal mining industry plans to spend $3.3 billion for developing coal mines and ancillary facilities. In spending this amount of money the industry is anticipating creating 16,650 new jobs.

Two mines are to be developed to supply Escom's 2 power stations near Volksrust and Amersfoort in the Transvaal. The larger of the two, the Rand mine will be completed in 1988 and in full production by 1994, it will produce 15 million metric tons per year at an installation cost of $700 million.

Anglo-American Corporation plans to raise production from a current 40 million metric tons per year to 63 million metric tons by 1983. A part of this increase will be due to the Goedhoop mine which shipped its first coal in June, 1983. The Goedhoop mine is expected to produce 3 million metric tons per year when in full operation.

Union of Soviet Socialist Republics

The Soviet Union has announced that it is considering a development program in the Kansh-Atsckink lignite field of Siberia. The entire project is estimated at $16.34 million for construction of a large surface mine, several liquifaction plants, and a pipeline. Phase 1, presumably construction of the mine will cost $2,200,000,000 to $4.1 billion. Soviet mining officials have announced that the U.S.S.R. will not meet its 1983 production goal because of a continuation of a drop in the quality of coal being extracted from key regions.

United Kingdom

The United Kingdom is involved in discussions between the government and the mine workers union concerning the closing of unprofitable underground mines. Sixty-four mines have been closed since 1973, 15 more mines are scheduled to close in 1983/84. The mine workers have been offered jobs at other operating or new mines.

The Ashford mine in the Vale of Belvoir is planned to begin operation in the near future. It will open-up a 146 million metric ton body of very-deep reserves. Production is scheduled at 2.2 million metric tons per year. Opening of the mine will herald a new era in the United Kingdom's long-mining history.

Under the New Plan 2000 the National Coal Board proposes to expand underground productions to 165 million metric tons per year and surface production to 22 million metric tons. Currently the United Kingdom has an estimated reserve of 49 billion metric tons, recoverable by existing methods, sufficient for 300 years of mining at current rates.

United States

Production of coal in the United States from January 1, 1983 to July 23, 1983 was 373,885,038 metric tons as compared to 433.2 million metric tons for the same period in 1982. This 13.77 percent decrease in United States production has resulted in a slowing down of many coal industry plans and operations.

Exports of metallurgical coal in 1982 were 64,585,421 metric tons and of steam coal were 40,659,007. Total exports were 105,244,428 metric tons.

Many new mines are being constructed, railroads are being built, and local infrastructures are being planned and built. Typical of these are Caballo Rojo Mine of Mobil Oil, where 1.36 to 2.27 million metric tons will be produced in 1983 and whose annual production capacity will be 13.6 million metric tons. This mine is in the Powder River basin of Wyoming and is producing subbituminous C coal.

Numerous export terminals are being planned, built, enlarged, and put in operation. Among these are: 1) the Philadelphia coal terminal which is being enlarged from a capacity of 3.2 million metric tons per year to 10 million short tons. This terminal will be able to load 85,000 d.w.t. ships. Cost of the expansion is $25 million. 2) The Portland, Oregon export terminal began operation in July. Built at a cost of $60 million this terminal has a capacity of 10.9 million metric tons per year. And 3) the Sacramento, California terminal is being constructed at a cost of $25 million with a capacity of 2.7 million metric tons.

Philips Coal Company is working on a $4 billion Lurgi lignite gasification plant in Texas. Plant when completed will use 3.6 millon metric tons of lignite per year.

Costain Mining Company of the United Kingdom has plans to mine 2.3 million metric tons per year of lignite for the Devils Hill power plant of Louisiana. Utah Power and Light Company has opened a third 400-MW generator at the Hunter power station. Cost of the generator was $436 million.

Ashland Coal International has contracts to supply 410 thousand metric tons to the Energy Trady Company of Norway.

The Central Mine in Washington is conducting an experiment to burn in situ steeply dipping coal beds from a depth of 800 feet towards the surface. The experiments objective is gasification of the coal. Project's cost are estimated at $3 million.

The public in the United States is exceedingly interested in environmental preservation and protection of the atmosphere, land, and water resources, as well as protecting the fauna and the flora. Because of this interest mining companies, electric utilities, and industrial users are under close government and public scrutiny as to their activities. The agencies charged with government oversight and the U.S. Congress are also closely watched and advised by interested segments of the public. This interest by the public has greatly raised the costs of mining, governmental oversight, environmental protection, and use of coal.

Many computer companies in the United States have developed computer software programs for analysing geological, engineering, processing, waste disposal, and management problems, as well as for determinations of export potential, mine layout, and economics. A list of these companies can be obtained by reading the July 1983 issue of the U.S. publication Coal Age. Many other coal-related activities are underway in the United States concerning coal development. This speech only concerns a few highlights.

Colombia-Venezula

Exxon's El Cerrejon Mine in Colombia is purchasing railroad cars and in bringing a multibillion dollar project into full-production. The Colombia government is also actively interested in planning and bringing into operation many other mines. If El Cerrejon and the other mines are successful, Colombia will emerge as a major coal producer and exporter, capable of supplying coal to meet the requirements of its neighbors and other nations.

Venezula is planning and constructing the Mina Paso Diablo mine, scheduled to begin production at 1 million metric tons per year in 1986 - full production capacity of 6 million metric tons is scheduled for the mid-1990's. The coal is similiar in rank and quality to that of El Cerrejon Mine in Colombia; 7 coal beds, 1 to 12 meters thick, and dipping 5-14° east will be mined of Mina Paso Diablo. The No. IV coal bed is a metallurgical coal, beds beneath the No. IV are also metallurgical coal whereas the overlying beds are steam coal. The coal from this mine is dedicated for domestic use and will be used in a power plant to be completed in 1986 and in a steel mill projected for operation in 1987. When at full production, the Mina Paso Diablo mine will be the second largest in South America, exceeded only by the El Cerrejon Mine in Colombia.

Yugoslavia

In 1981 Yugoslavia produced 52 million metric tons of coal. Production is planned to increase to 85 million metric tons by an indefinite date during 1985-87. Achievement of this goal will be aided by the Kolubara Mining and Energy Company increasing production of lignite from 18 million metric tons (1981) to 40 million metric tons by 1985; by the Kovin mine, a 6 million metric tons lignite operation, being constructed to supply coal to a 600 MW power plant; by the Surudol lignite mine which has started operations; and by the Lukavic Mining Group increasing production from 3 million metric tons per year to 4.5 million metric tons.

Zimbabwe

The Wankie Colliery, Zimbabwe's only coal producer had a decrease in production from 2.38 million metric tons in the 1980-81 fiscal year to 1.982 million metric tons in the 1979-80 fiscal year. In addition to the loss in production the mine operated at a financial loss in 1980-81. Unsettled political conditions in Zimbabwe make it difficult to estimate production for 1983 and thereafter.

World Coal Trade

World coal trade in 1981 increased 7.2 percent to 275.805 million metric tons. Seven nations produced 95.3 percent of the exported coal. In order of decreasing tonnages the United States, Australia, South Africa, Soviet Union, West Germany, Canada, and Poland all exceeded 9 million metric tons of coal exports. Nations importing coal included Japan, France Canada, Italy, West Germany, Denmark, Belgium, South Korea, Spain, Taiwan, Netherlands, and East Germany in order of decreasing tonnages, each imported more than 6 million metric tons of coal for a total of 76.6 percent or 211.1 million metric tons of the 275.8 million metric tons exported.

In summary, coal developments during 1982-83 were numerous despite the world-financial depression, local political and union problems, and civil disorders at many places. Hundreds of mines, power plants, processing plants, railroads, pipelines, coal export terminals, and other coal-related facilities are being conceptualized, planned, and constructed in the larger and middle sized coal-producing nations. In the so-called underdeveloped nations, similiar activities are underway, largly depending on each individual nation's ability to obtain financing. The foregoing description of activities is a selected summary. Time does not allow me to talk more about many interesting coal developments.

2. Geologic Exploration for coal

Australia

Geologic exploration for coal is widespread in the sedimentary coal basins of Australia. This exploration is being conducted by geologists, drilling crews, and engineers in all provinces where sedimentary coal-bearing rocks crop out.

Although many of the persons engaged in exploration are employees of mining and industrial concerns, a large number work for provincial or national agencies charged with assessing the continent's natural resources. The exploration work is of the highest caliber utilizing geologists to do field mapping, to determine correlations and stratigraphic depositional patterns of individual coal beds, to do geochemical sampling, analysis and interpretations, and to supervise drilling and application of surface and subsurface geophysical techniques.

The success of Australian geologic exploration is attested to by discoveries in the Arckaringa basin of South Australia. There at location El 638, 3.1 billion metric tons of coal recently has been discovered and 1.3 billion metric tons is classed as indicated resources, and 1.8 billion metric tons as inferred resources. Similarly, at location El 736, 2.35 billion metric tons has been discovered of which 1.5 billion tons is inferred. In Western Australia 1 billion metric tons of high-salt coal has been discovered and is being evaluated by Western Collieries Ltd. Currently because of the high-salt content, the coal in this deposit is considered as usable only for on-site power generation. These recent coal field discoveries are only a few of those that took place in Australia in recent years. Continuation of high-caliber geologic exploration will undoubtedly result in many more coal fields being identified in the lesser known parts of Australia.

Argentina

Argentina is conducting a moderate-sized geologic exploration program to lessen the nation's reliance on foreign oil, gas, and coal imports.

Botswanna

Continuation of astute geological exploration in Botswana by governmental agencies and the mining industry seems likely to discover many coal fields beneath the sand dune fields of the nation. When fully explored, Botswanna appears likely to emerge in Africa as second only to South Africa in total coal resources much of which appears to be minable and usable, not only by Botswana, but also by neighboring countries.

Brazil

A recently discovered bituminous coal deposit in the state of Para is being actively investigated by Companhai de Pezquisa de Recursos Minerals (CPRM) in a drilling, geochemical, and petrographic program costing about $25,000,000. Other CPRM geologists are actively studying known and poorly known coal-bearing areas in Brazil in an effort to expand the energy base so that the nation will not be dependent on foreign energy.

Canada

In Canada, the governments of the coal-bearing provinces, the national government, and many industrial entities, both domestic and foreign, are conducting an intensive geologic exploration aimed at delineating the coal fields of the nation and at discerning minable resource bodies. These exploration efforts have been highly successful as measured by Canada's increase in identified resources and by the increase in exports.

China

China is emerging as the second or third most important coal-bearing nation in the world. A massive coal exploration and development program directed by many government agencies is being rewarded by the discovery of unknown coal fields and by expansion in size of and production from coal fields where coal has been mined for many years. Many Chinese geologists have been sent to other large coal-bearing nations where they have studied the techniques of coal scientists. This has resulted in a rapid transfer of the knowledge and methods used in other nations to the large number of coal scientists trained only in China. It seems likely that this rapid infusion of knowledge and methods will result in China's solidifying its recognition as a major exporter and user of coal, a discoverer of unknown coal fields, and a source of coal exploration data, both internally and foriegn.

Central America, North and Central Africa, and the Island Nations of the Caribbean Sea

Many underdeveloped nations of these parts of the world have deposits of coal, principally lignite. Most of these nations have not explored, studied, or developed their coal deposits, and as a result are largely or wholly dependent upon imports of oil, gas, and coal. Currently, many of these nations are entering, or are engaged in negotiating and/or contacting with multinational mining and energy companies, or with consulting firms to assess their coal resources as to quantity of coal and potential uses. In some underdeveloped nations, the World Bank, the mining companies, or the consulting firms are bearing much or all of the cost of exploration and assessment in the hope of developing their discoveries. Other wealthier underdeveloped nations are permitting concessions on coal-bearing lands or are themselves supporting the costs of exploration and assessment.

Pakistan

Pakistan is reportedly negotiating to conduct geologic exploration to increase knowledge of the nations coal resources and to provide fuel for the planned power plant at Lahhra.

Union of South Africa

Teams of geologists, geochemists, geophysicists, and coal scientists are actively exploring South Africa to better delineate the nations coal fields and to discover unknown fields.

Philippines

The Philippine government is reported to be engaged in a massive coal geology exploration program that is directed towards the discovery of coal fields on all islands that are believed to have had the requisite depositional environments for vegetable accumulations in swamps and burial conditions conducive to coalfication. The exploration program apparently is being highly successful. The government also is negotiating for foreign assistance in conducting additional geologic studies so the exploration program will more effectively delineate the nation's coal fields, increase knowledge concerning quantities and geochemical characteristics of the coal resources, and more efficently provide for an assessment of the the coal resources as related to potential uses.

Thailand

Dravo Engineers, a consulting firm, has been contracted by the government of Thailand to conduct a coal resource study for the Electrical Generating Authority.

Union of Soviet Socialist Republics

The Soviet Union purportedly is continuing long-term geologic exploration in the numerous coal fields of the nation. Past exploration has apparently been highly succesful, therefore, it seems likely that a continuation of highly sophisticated geologic exploration can only result in a better assessment Soviet coal resources which will ultimately result in a great expansion of the Soviet coal industry.

United States

The Federal government, the governments of each coal-bearing state, hundreds of coal mining companies, many universities, and numerous consulting geologists are engaged in geologic studies in the United States aimed at providing information about the nation's coal resources in known coal fields and in as yet undiscovered coal fields. Numerous publications describing the results of these studies are published each year and many other confidential company or consultant reports are prepared but not published. Advances in geologic coal exploration techniques and equipment are a frequent occurrence.

Despite these advances, an adequate geologic map is still the basic document guiding coal geologic exploration. In this respect the coal maps of the Federal and State governments are without question pre-eminent.

Currently, in the United States, highly sophisticated studies are being done in the correlating of coal beds, in determining the depositional patterns of coal beds in different depositional environments, in geochemical studies of sulfur, ash and mineral components of coal beds, in developing on-going coal resource techniques, in determining the geotectonics of individual coal beds, in the geostatistics of all facets of coal geology, and in geophysical studies of rocks encountered in drill holes, recovered in drill cores, and the coal underlying coal fields (reflection geophysics). It is becoming increasingly common to integrate, synthesize, and interpret all the various types of data resulting from the studies listed heretofore using computer techniques.

Considerable study is being conducted by geologists, geochemists, petrographers, and chemists to determine the sulfur cycle in coal at the time of deposition, during coalification, during combustion, and after combustion. At the time of preparing this speech, the many investigators appear to be reporting diverse and contradictory results.

Assessment of trends in coal exploration and development

An assessment of trends in coal exploration and developments as revealed by the literature, by conversations with associates, and by contacts with foreign coal scientists suggests that the coal industry and governments are hampered by many out-of-date adages, and concepts, and erroneous perceptions within industry, government, and the public. Additionally, discoveries of unknown coalfields, efficient production from known fields, and rapid dissemination of advances in the use of coal are being constrained by politics, competition between the various energy sources, competition between national governments, a lack of communication between the scientific, economic, and engineering disciplines, and failure of various levels of management to integrate work between individuals, organizations, companies, and governments.

In view of this personal assessment, I am using this opportunity to mention a series of suggestions that may aid in overcoming out-of-date perceptions and the constraints listed previously.

A. Geological Knowledge

Without doubt more geologic knowledge is required locally to regionally about geologic settings; about coal bed and associated rock stratigraphy; about penecontemporaneous, and post-deposiontal environments; about depositional features and structures; and operating geologic processes and phenomena. The required knowledge listed above can be largely obtained by preparation of adequate geologic maps and coal bed maps, by careful measurement of coal bed and associated rock stratigraphic sections; by proper collection of coal, fossil, and rock samples that are correctly located and recorded in the coal bed and stratigraphic sections; and by describing depositional features and structures in coal beds and associated rocks. The samples from coal beds and associated rocks will allow geochemical, petrographic, mineralogic, paleontologic, coking and other physical and chemical analyses and interpretations to be made with reference to three dimensional locations, which, in turn, will allow integration of these types of data into drilling programs, future mine planning, and extraction. The entry of these types of data into a formalized coal resource classification computerized system will make integration, synthesis and interpretation of derived results consistent and meaningful. As used by many industrial entities and some government agencies, computerization of geologic observations and analyses is making assessment of bodies of coal of suitable thickness, overburden, and quality much more reliable.

B. Geochemical understanding of coal

Until a few years ago understanding of the geochemistry of coal was poor and analytic data other than proximate and ultimate analyses were sparse. The common practice of chemically testing properly located and collected samples from individual coal beds in order to report ultimate and proximate analyses, individual trace element contents, and ash and coal mineralogies has enhanced the geologist's ability to more completely understand individual coal bed geochemistry. Interpretation of the geochemistry of individual coal beds by proper collection of sampels and modern analytic techniques should aid geologists in determining depositional environments, diagenetic changes, coalification processes, and degradation effects of diagenesis and coalification. Analytic data also are of basic importance in constructing isolines on coal bed maps of elemental, ash, and Btu or calorific contents; and of rank, cokability, and other analytically determined physical and chemical properties. Analytic data, when combined with geologic data on geologic and coal bed maps and with the data used to determine quantity of coal clearly depict in most places where the most geochemically suitable coal for various uses is located in relation to the most casily minable coal as defined by thickness of coal and depth of burial.

Before 1975 most geochemical analyses were made by coal companies and governments to determine the suitability of coal for specified end uses such as steam generation, cokability, non-ferrous metallurgy, steel making, home heating, transportation, blacksmithing, and other specialized uses. Today, geochemical analyses are also made specifically for determining the amount of pollution caused by coal to atmospheric, water, and land resources, as well as for determining potential health hazards to the public. Finally, many geologists and geochemists are beginning to use analytic data to correlate coal beds, to depict the chemistry of individual coal beds and/or coal zones. As mentioned before, computerization of geochemical data and geologic observations is allowing more efficient and effective decision making as to where to mine coal.

C. Integration of Tonnage estimates by using specific criteria

In order to use more efficiently their coal resources, mining companies and governments should be estimating availability of tonnages or quantities of coal according to standardized definitions and specific criteria established by a coal classification system. The system should categorize coal tonnages by location, thickness, quality of coal, thickness of overburden, rank, expected mining method, anticipated mining problems, and pollution potential. The results of such estimations should then be integrated into costs associated with mining, transportation, processing, and selling so as to allow comparison with coal and tonnages produced in other locales or with other energy sources.

D. Mining procedures must be developed for extracting coal from ultra-thin and ultra-thick coal beds.

Much of the coal in the earth's crust is in beds that are considered as either too thin or too thick for inexpensive, safe, efficient mining. In fact, it is posible that the quantity of coal in beds too thin to underground mine with today's equipment and too thick to mine underground without excessive danger to miners, to the land surface and to aquifers is greater than the quantity in the beds customarily mined. "Man can mine any deposit of any material" according to engineers. This statement, however, ignores whether it is economically feasable to mine the deposit or whether the resulting damage to the land surface and ground-water aquifers make the mining of each coal a detriment rather than an aid to man's existence.

Much coal is being either lost-in-mining or lost-to-mining by decisions of engineering or management personnel that mining will be uneconomic or hazardous because of thickness of coal beds.

Obviously, if equipment can be developed so as to mine effeciently exceedingly thin beds and ultra thick beds, large increases in coal resources will be added to national and world coal inventories. Such additions would result in some coal-poor nations becoming energy sufficient, and would probably extend the time before man becomes dependent on some other energy form.

E. Beneficiation, preparation, and combustion procdures must be developed to more effectively clean many types of impurities from coal.

Techniques for effectively and inexpensively cleaning all types of coal have not been developed that are certain of success when the techniques are transferred from processing plant to plant or from coal type to coal type. This lack of efficient widespread usability suggest: 1) the feedstock of coal from place to place is poorly understood as to its geochemistry and to its chemical and physical reactions. 2) Insufficient research was done to perfect the cleaning techniques. 3) The design and equipment used in the cleaning techniques are inadequate. And 4) combination of 1, 2, and 3 or none of the preceding. Projections of future coal use indicate that the future annual consumption of coal will increase several fold above current consumption. These projections of coal use can be used indirectly to project future exceedingly large-scale environmental pollution of the atmosphere, and water resources, and degradation of the land surface. Only the uninformed question the need for energy, be it coal or an alternative. Since coal is the only easily available abundant energy source, it behooves the governments and coal industry of the world to develop cheap effective coal cleaning techniques. If such techniques are not developed and used world wide, the efforts of individual nations to provide clean and livable environments by using such techniques will not be effective and the net result possibly would be a world population living in a CO_2, SO_2, NO_x, smog surrounded by polluted lakes, rivers, and oceans.

F. Informating the public and governments of coals importance, of possible consequences of increased coal usage, and of the possibility of centuries of plentiful energy

Geologists, mining engineers, economists, and industrialists have not been effective in informing the public and world governments about man's dependence on coal as the primary energy source of the future. In fact, many of those who should be knowledgable about coals importance appear to be unaware of this importance.

There is little doubt that with the international concern about nuclear energy, the growing scarcity of and the long-term high cost of petroleum, and the failure of alternative energy sources to emerge as large-scale replacements for petroleum, coal must be the primary energy source of the future.

The public and government officials must be persuaded that acceptance of coals's role will assure the long-term continuation of civilization. They must also be persuaded that coal can be used as a clean fuel if they will urge their scientists and engineers to develop inexpensive and effective techniques of cleaning and conversion. Also, government officials must urge the scientists and engineers to develop more efficient mining techniques that will be less destructive to ground water aquifers and that will minimize disruption of the land surface. The development of inexpensive, more efficient cleaning, conversion and mining techniques will minimize and perhaps largely prevent degradation of the environment.

Coal can provide energy for continued industrial development, for clean liquid and gaseous fuel to be used in domestic heating and transportation, and for long-term growth of the vital petrochemical industry. However, it can not provide these necessities in an atmosphere of public and governmental opposition. The many billions of dollars currently being invested by industry and the coal-bearing nations of the world clearly show that some governments and their coal industries are willing to gamble on a bright, glowing future based on centuries of plentiful energy from coal.

In conclusion, this workshop should provide a forum for instruction and the exchange of ideas that will aid each of us in resolving many of the problems related to the exploration and development of the world's coal resources. It will also help in promoting continuing cooperaton and in strengthening bonds between us and the countries we represent. It has been an honor to speak before you. I thank you.