DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

National coal exploration plan [Pakistan]

by

Geological Survey of Pakistan

and

U.S. Geological Survey

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This report is preliminary and has not been reviewed for conformity with
U.S. Geological Survey editorial standards and stratigraphic nomenclature.

1988

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PREFACE

Indigenous coal supplies about 7 percent of the commercial energy requirements of Pakistan. Oil, mostly imported, supplies about 40 percent, indigenous gas about 35 percent, hydropower about 17 percent, and the remaining 2 percent is supplied mainly by non-commercial fuels--such as fuelwood or cowdung. As the energy requirements of Pakistan increase, coal could and should be an increasingly larger portion of the energy-supply mix of the country.

In order for coal to be able to supply more of the needed energy, more coal exploration is required as the necessary prelude to its development and utilization. The National Coal Exploration Plan (NCEP) provides a framework for increased coal exploration in Pakistan. It is based on what is known or can be inferred about the coal-resource potential of the country, the possible forms of utilization of Pakistan's coal from geographic and quantitative and qualitative factors, and the perceived information requirements necessary to allow rational long-range planning for increased coal energy use. Program elements to meet basic data needs are summarized along with estimated funding requirements and timeframes.

Appendix A is a description of the coal classification system used by the U.S. Geological Survey. Appendix B is an introduction to coal exploration techniques for the benefit of the non-geologist. Appendix C provides acknowledgments to those involved in development of this plan.

The data herein is intended for use by planners as Pakistan's Seventh Five-Year Plan is prepared, and for early planning use by international assistance agencies. The report, of which this is the 4th version, is a joint effort of the Geological Survey of Pakistan (GSP) and the United States Geological Survey (USGS), under the auspices of the joint Government of Pakistan-United States Agency for International Development (USAID) Energy Planning and Development Project.

EXECUTIVE SUMMARY

Conclusions and Recommendations

An investment of small amounts of time, money and manpower in increased coal resource assessment and exploration can have a very large impact on the energy future of Pakistan. The present effort to assess the coal resources of Pakistan should be accelerated. A modern coal exploration program of the type needed in Pakistan will require funding support from both national and foreign sources. Exploration for coal should be started or accelerated in various parts of the South Sind coal area, and in the Khost-Sharig-Harnai, Sor Range-Daghari, and Salt Range coal fields as soon as possible so that the contribution of coal to the energy balance of Pakistan can be significantly increased in the near future. To assure sufficient production of coal to meet increased demands, leasing and licensing must follow practical guidelines that encourage the formation of efficient production units.

Recommended Coal Exploration by Priority and Area

A coal exploration strategy involves investigation of all sedimentary basins in order to delineate all major potential coal deposits and to evaluate the national resource base. Until this is done, it will be difficult to carry out rational energy planning for the country. Figure 1 shows location of Pakistan coal fields and table 1 lists summary information on known coal fields.

This NCEP describes individual local coal resource projects that are underway or proposed, and groups coal-bearing areas by priorities according to the perceived opportunity for economic exploitation. Detailed proposals for Geologic Assurance Programs (GAP) are presented for seven coal fields. Table 2 summarizes a few important factors about the GAP. **The total cost of exploration seems large but the cost benefits on a per-ton basis are extremely**

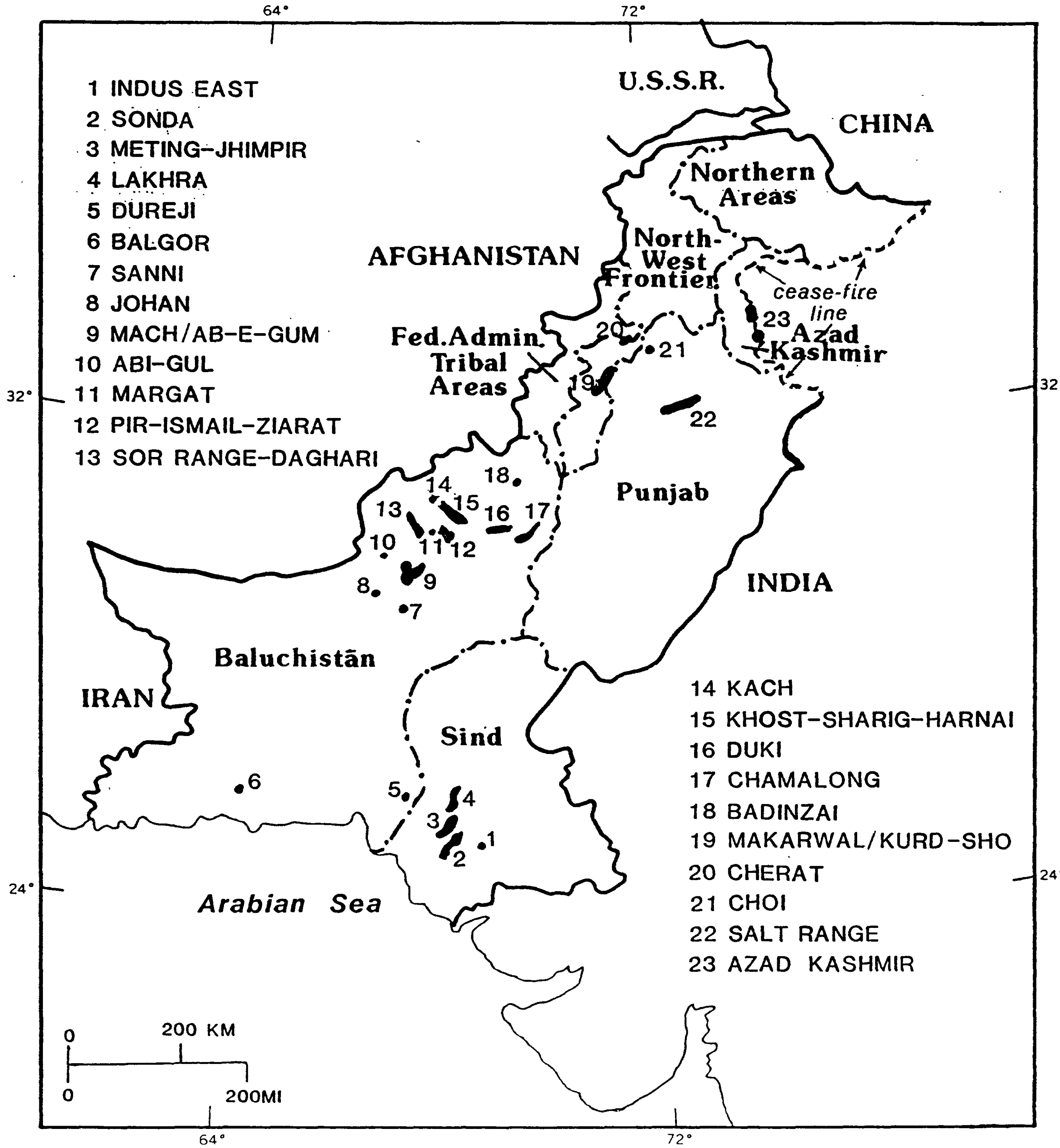


Figure 1. Location of Pakistan coal fields and occurrences

Table 1.--Summary information on known coal fields

Province and coal field	Area (sq. km)	Average mined thickness (m)	Demonstrated recoverable reserves (10^6 tons)	Inferred recoverable reserves (10^6 tons)	Total recoverable reserves (10^6 tons)	Coal rank[1/] (ASTM)	Average reported annual production (10^3 tons)
Sind							
Lakhra	200	1.5	100	200	300	ligA-subC	300
Meting-Jhimpir	90	.5	8	17	25	ligA-subC	40
Sonda	650	---	124	156	280	ligA-subB	---
Punjab (and NWFP)							
Makarwal	75	1.5	7	12	19[2/]	hvCb-hvBb	225
Salt Range	260	.75	17	58	75	hvCb	225
Baluchistan							
Sor Range-Daghari	50	1.25	18	16	34	subB-subA	460
Khost-Sharig-Harnai	200	.75	24	23	47	hvBb-hvAb	100
Mach	45	.75	9	6	15	subC-subB	125
Pir-Ismail-Ziarat	20	.5	6	5	11	hvCb	115
Duki	100	.5	8	5	13	subC-subA	250
Totals	1,690	---	321	498	819	---	1,840

1/ LigA = lignite A, subC = subbituminous C, subB = subbituminous B, subA = subbituminous A, hvCb = high volatile C bituminous, hvBb = high volatile B bituminous, hvAb = high volatile A bituminous (American Society for Testing and Materials, 1982).

2/ Includes Kurd-Sho area of NWFP.

Table 2.--Relationship between Geologic Assurance Programs

Coal field	GAP I (1 data point per 4 sq. km)			GAP II (1 data point per 2 sq. km)			GAP III (1 data point per 1 sq. km)		
	Exploration cost (10^6 Rs.)	Potential resources[1/] (10^6 tons)	Cost benefit (Rs./ton)	Exploration cost (10^6 Rs)	Potential resources[2/] (10^6 tons)	Cost benefit (Rs./ton)	Exploration cost (10^6 Rs.)	Potential resources[3/] (10^6 tons)	Cost benefit (Rs./ton)
Sonda	116.5	500	0.23	305	500	0.61	447	500	0.89
Lakhra	56.2	425	.13	160	425	.30	216	425	.51
Salt Range	34.5	75	.46	98	75	1.31	132	75	1.76
Khost-Sharig-Harnai	57.5	47	1.22	245	47	5.21	331	47	7.04
Sor Range-Daghari	43.7	35	1.25	128	35	3.66	173	35	4.94
Pir-Ismail-Ziarat	17.3	11	1.57	48	11	4.26	66	11	6
Mach-Ab-E-Gum	69	21	3.29	197	21	9.38	266	21	12.67
Totals	394.7	1,114	0.35	1,181	1,114	1.06	1,631	1,114	1.46

1/ Potential resources: 13 percent measured, 13 percent indicated, 74 percent inferred.

2/ Potential resources: 50 percent measured, 50 percent indicated.

3/ Potential resources: 100 percent measured.

favorable. There is a wide range of exploration costs per ton as a result of a wide range of differences in such factors as location, accessibility, and geologic setting of the coal-bearing rocks.

Priority I areas for exploration are those where present planning for utilization requires coal-resource information to establish the feasibility of supplying the necessary energy. The South Sind coal areas, the Khost-Sharig-Harnai and Sor Range-Daghari coal fields of Baluchistan, and the Salt Range coal field of Punjab are major Priority I.

The South Sind area has a large but unproven resource potential and encompasses the area considered as a site of future major electricity-generating installations that could supply a significant share of Pakistan's long-term energy needs. The presence and quality of large quantities of recoverable resources remains to be demonstrated. The GAP I would require about 173 million Rupees (Rs.) over a period of about 3.25 years.

The Khost-Sharig-Harnai coal fields have a railway line to Sind, and proposed segments of the national electricity grid are in and near the fields, with a 321-KV station tentatively proposed for construction near Sharig. The coal is of variable rank but is generally higher in rank than most coals of Pakistan, and some might be of value for blending with imported coal to make metallurgical coke for which higher rank coals are desirable. The fields never have been adequately mapped and explored, and a complete study of the geologic nature of the fields and the quantity and quality of coal should be initiated. The GAP I would cost about Rs. 57.5 million over a period of about 3 years.

Sor Range-Daghari is one of the most productive coal fields in the country. The extent of the field and quality of the coal are reasonably well known, but if the field is to remain productive, exploration is required to demonstrate the quantity of coal, particularly in the deeper parts of the field, that would be available for future recovery. The information will satisfy quantity and quality information needs and allow preliminary planning of realistic development and recovery programs. The GAP I would require a minimum of Rs. 43.7 million and about 2 years.

The Salt Range coal field is strategically located relative to the brick-making centers of Punjab Province and probably can continue to produce substantial quantities of coal for the short-term future. However, the large number of small mine operators will eventually recover the available coal reserves in the parts of the field near the outcrops where most present mine entries are located. Future mining by shafts, at greater depths, and by more efficient methods will be required. The information to guide future development and recovery activities and to justify required investment must be created by geologic study of the present mine areas and the available subsurface information, and by exploration drill holes. The GAP I would cost about Rs. 34.5 million and require 3 or more years.

Other areas of lesser priority also deserve exploration research, and some are now being studied or are scheduled for study in the near future. If the resource potential of an area improves, or if new utilization proposals are made, any area may advance to a higher priority.

Demand, Utilization, and Limitations

The annual coal production of Pakistan is now estimated to be as much as 2.3 million tons or more, and about 7 percent of the commercial energy used annually in Pakistan is contributed by coal. In contrast, coal production in 1947 was only about 350 thousand tons, but this amount supplied about 50 percent of the country's energy. Since then, the vastly increased energy demands of Pakistan have been satisfied by other energy sources, and the increased production of coal has been based on the increased demand for coal by the brick industry. The brick industry uses an estimated 80-90 percent of the annual coal production, and demand is expected to continue and increase at an annual rate of 2-5 percent as the economic development of the country continues. The projected growth in demand could be accomodated by an increase in annual coal production of 0.3 to 1 million tons by 1993 and 3 to 9 million tons by 2015.

The total electrical-generating capacity of the country is about 5,000 MW but only 15 MW is based on coal. As much as 9,000 MW electrical energy could be needed in Pakistan by the end of the Seventh Five Year Plan in 1993, and by 2015 the electrical energy needs of the country could approximate 20,000 MW per year. Domestic coal could supply the energy for 10 to 25 percent of such an increase in generating capacity if annual coal production increased by 2 to 6 million tons annually by the end of 1993 and 8 to 21 million tons by 2015.

Substitution of coal for other fuels in existing, and potential new, industrial applications has been studied and seems to be a viable option for such uses as briquetting and for process and industrial heat. Use in the cement industry is presently under study.

The following table summarizes coal demand projections through the year 2015 A.D. (also see details on table 3, page 17).

Coal Demand Projections

[millions of tons]

Year	Electricity	Cement	Bricks	Briquettes	Other	Total
1993	2.2-5.5	0.1-.3	1.9-3.1	0.005-.08	0.3-.6	5-9
2000	4.1-11	.4-.9	2.2-4.4	.1-.2	.5-1	8-17
2015	8.1-21	1.5-3.8	2.8-8.6	.3-.5	1-2	15-35
Total	120-310	16-39	65-140	3.5-6.8	16-32	240-510

Production of large quantities of coal of consistent quality is best accomplished from large, safe, efficient mines. Development of these mines will require large amounts of money, and the availability of funds is contingent upon demonstration of an adequate quantity and quality of coal that is producible over a specified period of time. These demonstrations are difficult to provide in the older coal fields of Pakistan because of the small areas (2 sq. km average) under a large number of license (500) and lease (240) tracts that are held by a large number of owners. A public sector company, Pakistan Mineral Development Corporation (PMDC), and only a few private companies are the only coal producers with reasonably large areas under license or lease. **The license and lease ownership problem must be solved if the coal productive capability of Pakistan is to substantially increase.**

The coal of Pakistan is largely lignite A to subbituminous C in rank, though small quantities reach a rank of high volatile A bituminous. The coals characteristically have high ash and sulfur contents. Beneficiation studies to date have not produced economically acceptable results. Combustion in fluidized beds is a relatively new technology that promises to allow use of such coals with no environmental or efficiency problems. **As long as the quality is usable, the significant future use for coal in Pakistan is as fuel for thermal-electric-power generation and brick-making. The large quantities of coal required for these purposes have not yet been demonstrated by exploration.**

Known Coal Resources of Pakistan

Coal is known in 23 different coal fields, areas, and occurrences in Pakistan (fig. 1). Some of the known coal fields have been exploited for more than 100 years, and some of the fields that are expected to be increasingly important in Pakistan's energy future are still in the early stages of exploration. The total potential coal resources of Pakistan are estimated as 1,000 to more than 2,000 million tons, and recoverable reserves as approximately 800 million tons (table 2). **Both estimates are conservative but cannot be significantly improved without large amounts of definitive information that can be created only by well planned exploration activities.**

INTRODUCTION

In the world as a whole, coal is second only to oil as a major energy source and supplies 28 percent of its needs. In Pakistan, however, coal furnishes only 7 percent of the commercial energy used by the country. Oil, most of it imported at a cost of about $1.4 billion in foreign exchange per year, supplies almost 40 percent of the nation's energy, and indigenous gas, a diminishing and subsidized resource, supplies about 35 percent. The energy requirements of the country are swiftly exceeding, by larger factors each year, the presently available energy supply. The energy future of Pakistan will be bleak and expensive unless the energy supply mix is changed.

Changes in the energy supply mix will have direct beneficial effects on Pakistan's economy. Decreasing the relative amount of energy supplied by imported oil (the cost of which is equivalent to half of the total export earnings of the country) while increasing the relative amount supplied by indigenous coal would favorably affect the country's foreign exchange and international loan situation while increasing employment and creating opportunities for business expansion in and near the nation's coal fields, which are widespread throughout the country and generally are not close to existing urban areas. Even at the present low production rate, as many as 40,000 people are directly employed in the coal-mining industry and as many as 200,000 people are indirectly benefitted.

Whether these changes take place or not is dependent on the Government of Pakistan's coal policy. Until the Sixth Five-Year Plan, no such policy existed. The Sixth Five-Year Plan expressed a national energy policy that included the objectives of arranging inter-fuel adjustments so as to minimize import dependence, preparing for growing self reliance in energy in the Seventh Five-Year Plan and beyond, developing indigenous resources of energy, intensifying the search for undiscovered resources, and evolving mechanisms for greater participation of the private sector in meeting the energy requirements of the nation. The Sixth Plan recognized that increased use of indigenous coal could assist in the attainment of these objectives. To date, these objectives have not been fulfilled, although advances have been made due to national awareness of the benefits of using indigenous coal. A consensus was recently reached at the First Pakistan National Coal Conference in Karachi (February 1986) to promulgate new legislation which would promote coal as a major energy source in Pakistan.

An impediment to utilization of coal is the absence of a reliable data base on the location, quantity, quality, and other factors of the indigenous coal resources. Further coal exploration is required to remedy this information deficiency, so that development and utilization of this vital energy source may proceed.

This report attempts to provide a framework for a national coal exploration plan. The broad objectives are:

1. Preliminary assessment, based on available information, of the geologic nature and economic potential of known coal areas of Pakistan with emphasis on determination of the amount, type, and distribution of information needed to allow planning for development and utilization.
2. Preparation of preliminary and/or detailed geologic exploration plans to remedy the identified data deficiencies. To the extent possible, plans will be proposed in the normal sequential exploration stages so that creation of information proceeds in an orderly manner with built-in review and decision points.
3. The exploration plans will include preliminary estimates of overall cost implications, manpower needs, and timeframes for the required investigations.

4. The plan will identify required needs in personnel training, institutional support, and governmental practices so the plan may produce the desired results.
5. Facets of coal-use planning that require further action or study beyond the scope of this document will be noted. Included are such problems as fragmented mineral rights and transportation needs.
6. The necessary divisions of responsibility for exploration and development activities between various types of organizations and agencies will be addressed. The necessary roles of basic and applied research in exploration activities will be described.
7. The plan will be presented in a format usable to those with responsibility for planning and managing the energy future of Pakistan.

Background Studies

Two major studies bearing on the expressed objectives of the national energy policy have recently been completed. Chemical Consultants (Pakistan) Limited of Lahore and Karachi completed a comprehensive "Feasibility study on the utilization of coal in substitution of other fuels" in January 1985 for the Ministry of Petroleum and Natural Resources, Government of Pakistan. The six-volume study included summary-type estimates of the theoretical and recoverable resources of the Pakistan coal fields, all based on existing information and not categorized by thickness or overburden except in a general way. The results of other studies, such as the potential for coal substitution in industry, the minability of the coal in different fields, coal beneficiation, analyses of samples collected during the investigation, and consideration of various utilization, storage, handling, and transport possibilities also were presented.

In February 1985, Energy Development International/Price Waterhouse completed a study of "The coal industry in Pakistan: requirements for growth." A wide range of considerations, from concerns about the state of resource knowledge and exploration activities to assessments of economic, technologic, and institutional factors, is addressed, and proposed actions to assist in solutions of the perceived problems are presented.

The Proceedings Volume of the First Pakistan National Coal Conference contains the texts of 52 formal papers and addresses, plus rapporteurs reports, that were presented during the meeting of February 22-26, 1986, in Karachi (see Khan and Pelofsky, 1986). This highly successful conference was attended by more than 600 people representing government, industry, and financial and educational institutions from 23 countries. Some of the individual contributions presented in the Proceedings Volume are subsequently cited in this report and the reader is urged to consult this relevant volume.

The three cited reports, plus many others that are available, address in depth coal-related considerations and problems that are only briefly addressed, summarized, or alluded to in this report, either because they are not within the direct scope of this report or because detailed discussion would be repetitive and redundant.

PAST AND FUTURE DEMAND AND UTILIZATION OF COAL

Past Demand and Uses of Coal

In 1947, when Pakistan became an independent nation, the annual coal production was about 350,000 tons. The main producing areas were the Makarwal, Salt Range, Sor Range-Daghari, Khost-Sharig-Harnai and Mach fields. Much of the coal produced today is still coming from the same fields but significant quantities are now also being produced in the Lakhra, Duki, Meting-Jhimpir, and Pir-Ismail-Ziarat fields.

Small shifts in utilization have occurred over the years. For example, 20 years ago coal was used to make fertilizer, and production of briquettes was about six times as large as today. However, the loss of these markets was probably scarcely felt because the brick-making industry has increased severalfold over that same timeframe and the demand for coal increased with that growth. Total coal production in Pakistan in fiscal year 1984-85 was estimated to be about 2 to 2.3 million tons. Brick-making presently uses 80 to 90 percent of the annual production. As much as 140 thousand tons of coal are supplied to railroads, 5 thousand tons or so are used to make briquettes, 30 to 40 thousand tons are used in the 15 MW electric-generating complex in Quetta, and the remainder is used for lime-burning and other process heat and domestic and industrial heating.

Future Demand and Potential Uses of Coal

The Sixth Five-Year Plan and many subsequent policy expressions stress the need to meet rapidly increasing energy requirements of the country and the need to satisfy the increased energy requirements from indigenous energy sources to the extent possible. Coal is recognized as an indigenous energy source that might meet some, or many, of the energy requirements of the near- and long-term future.

Table 3 presents projections of possible coal demands based upon forecasts and reasonable assumptions, which are discussed and described in following sections of this report. The basic assumptions used to create table 3 are believed to be realistic and the results are presented in ranges that should encompass the future coal requirements of the country. The table shows that generation of electricity could require half of the countries coal production by 1993 and for the foreseeable future beyond that, and that by 1993 Pakistan's coal demands could exceed the present annual production by 2.5 to 4 times.

Table 3.--Coal Demand Projections

[Millions of tons, summations affected by rounding]

Year	Electricity	Cement	Bricks	Briquettes	Other[1/]	Total[1/]
	Range	Range	Range	Range	Range	Range
1985	0.03-0.04	---	1.6-2.1	0.005-0.005	0.155-0.365	2.0-2.3
1986	.03-.04	---	1.6-2.2	.005-.005	.155-.365	2.0-2.4
1987	.03-.04	---	1.7-2.3	.005-.005	.155-.365	2.1-2.5
1988	.03-.04	---	1.7-2.4	.005-.005	.155-.365	2.1-2.6
1989	.03-.04	---	1.7-2.6	.005-.005	.155-.365	2.1-2.8
1990	.03-.04	0.03-0.06	1.8-2.7	.005-.02	.155-.365	2.2-3.0
1991	.6-1.4	.06-.13	1.8-2.8	.005-.4	.19-.43	2.9-4.6
1992	1.1-2.8	.09-.19	1.8-3.0	.005-.06	.22-.49	3.5-6.3
1993	2.2-5.5	.13-.25	1.9-3.1	.005-.08	.26-.56	4.8-9.2
1994	2.5-6.2	.15-.32	1.9-3.3	.018-.10	.29-.62	5.2-10
1995	2.7-6.9	.19-.40	2.0-3.4	.032-.12	.33-.68	5.6-11
1996	3.0-7.7	.22-.49	2.0-3.6	.045-.14	.36-.75	6.0-12
1997	3.3-8.4	.26-.59	2.0-3.8	.059-.16	.40-.81	6.4-13
1998	3.6-9.1	.30-.70	2.1-4.0	.072-.18	.43-.87	6.9-14
1999	3.8-9.8	.35-.81	2.1-4.2	.085-.20	.47-.94	7.3-15
2000	4.1-11	.40-.93	2.2-4.4	.10-.21	.50-1.0	7.8-17
2015	8.1-21.0	1.5-3.8	2.8-8.6	.30-.50	1.0-2.0	15-35
Total	120-310	16-39	65-140	3.5-6.8	16-32	240-510

[1/] Other derived by difference; thus year-totals reverse the Range of Other in annual summations.

Two other scenarios of coal demand in 1993 have been developed independently by the Task Force on Coal for the 7th Five Year Plan (written communication, March 1987). Comparison of the estimates for 1993 shown in table 3 and created by the Task Force show a general agreement on future total demand.

Comparison of 1993 coal demand projections

(thousands of tons)

	Task Force Scenario 1 (constrained)	Task Force Scenario 2 (recommended)	Table 3 Average
Electrical Power	1,365	2,157	3,850
Cement Manufacture	250	100	190
Brick Manufacture	4,445	5,434	2,500
Other uses	526	804	450
Total	6,586	8,495	7,000[1/]

[1/] Range 4,800-9,200.

The obvious differences are in projections for electrical power generation and brick manufacture but the totals are not significantly different.

Electric Power

Electrical energy need exceeds the available supply in some parts of Pakistan now, and "load shedding" with all its deleterious industrial and social effects is now a routine occurrence in those areas.

Table 3 assumes that the electrical generation capacity of Pakistan will increase from its present 5,000 MW to about 9,000 MW by the end of 1993, to about 12,500 MW by the year 2000, and to about 20,000 MW by 2015. It is further assumed that a 1,000 MW generating station requires about 5.5 million kilocalories of heat energy annually, and that 10 to 25 percent of the required heat energy will be supplied by indigenous coal after 1993. While these assumptions are deliberately crude, refinement would not significantly alter the basic relationships shown in table 3. Regardless of the exact magnitude of future thermal energy needs, it is inevitable that the electric generating capacity of the country must increase. If coal is to supply even as little as 10 percent of the future energy requirement, large sources of minable and usable coal will have to be identified by exploration activities prior to development and utilization.

Consequently, quantity of coal is the major consideration as long as the quality is acceptable and predictable. The average (presumably run-of-mine) coal quality predicted by Water and Power Development Authority for use in the proposed Lakhra power-plant complex is 32 percent moisture, 24.7 percent ash, 5 percent sulfur, and 5120 Btu/lb. If the Lakhra complex can operate successfully on coal of this quality, the basic quality factors for coal to be used in new steam-electric generating installations in Pakistan will have been established.

Bricks

There appears no reason to forecast a change in the energy needs of the brick industry. Coals of relatively poor quality (high ash and high sulfur, both in a wide range) can apparently be used successfully, and it is probable that the major requirement for this use is the need for the largest amount of lump coal possible. However, the brickmakers do recognize quality differences and the price they will pay for coal depends on the heating value, "age", and "source". According to Energy Development International/Price Waterhouse (1985), heating value is presumedly related directly to origin of the coal, with Baluchistan coal regarded as highest; "age" means time in stockpiles since mining, because low rank coals fall into small pieces and dust and may decrease in heating value; and "source" because coals from different areas produce differently colored bricks, and some particular colors may be required by a particular market. There is no obvious alternative fuel to coal even though small amounts of natural waste and other plant material are reportedly being used in some places where the economics allow such substitution.

In response to the general economic growth of the country, the demand for coal to make bricks is expected to continue to grow at a 2 to 5 percent annual rate over the foreseeable future. Based on this assumption, table 3 shows that the brick industry will continue to require a substantial portion, from 20 to 80 percent, of future coal production.

Cement

Most of the coals of Pakistan are of high sulfur content and much run-of-mine product has a high to very high ash content. Pakistan coal, from such disparate sources as the Sor Range and Salt Range coal fields, was used for cement manufacture in the past. With the present plants and requirements for high-quality cement, local coal would probably have to be blended with low-sulfur imported coal or oil in a ratio of 40 to 60 before it could be used in the cement industry (Nawaz, 1986) unless beneficiation of these coals becomes feasible and economical.

Table 3 embodies the following assumptions; the annual production of cement clinker will remain at about 5 million tons through the year 1993 and no coal will be used until 1990; cement clinker production will increase to about 10 million tons by the year 2004 and to about 15 million tons by about 2015; indigenous coal will supply about 10 to 20 percent of the required heat energy in 1993, 25 to 60 percent in 2004 and 40 to 100 percent in 2015; the heat energy required per ton of cement clinker is about one million kilocalories and the coal used has about 4 million kilocalories per ton. Table 3 shows that coal used for cement production could eventually comprise as much as 10 percent of annual production. The fact that the coal would be substituting for other fuels such as gas or oil is perhaps of more significant importance.

Qureshi and Rizvi (1986) list seven factors of prime importance to precede coal-firing in cement plants. The first three, which are directly dependent on the success of this exploration plan, are: at least 20 years reserves of the prospective coal, based on detailed geological exploration and assessment; assured, predictable quality with minimum variance in chemical and physical characteristics; and development of the mines needed to supply the additional coal.

Briquettes

Briquettes have been produced for over 40 years in a plant at Quetta, primarily for the use of the armed forces. Production has declined to approximately 5 thousand tons annually and the plant operates only a few months of the year. The coal used is from the Khost-Sharig-Harnai field, is weakly caking and is briquetted without binders using heat and pressure with the assistance of superheated steam. Tests show that other coals such as that from Lakhra can be used to make briquettes. Market and other potentials are being studied by PCSIR, PMDC, and private organizations (see Sabadell and others, 1986; Asifullah, 1986; and Ahmad and others, 1986).

Table 3 is based on the assumption that briquette production will not increase noticeably until 1990 or 1994 and that the coal required by the year 2015 will approximate 300 to 500 thousand tons annually.

Other Potential Uses

Other potential uses are as substitutes for gas as raw material and thermal energy in the fertilizer industry and for process heat in sugar mills and other such processing plants. A recent survey by Chemcon, Ltd. 1985, stated that coal cannot economically replace gas as a raw material but could be used in practically all process heat and direct industrial heat applications that were surveyed.

The amounts of coal used for "other", unspecified, purposes historically represent the difference between the total of specified uses (such as brick-making) and the estimated annual coal production. For the demand projections listed in table 3, it was assumed that unspecified uses would approximate 0.5 to 1 million tons in the year 2000 and 1 to 2 million tons in 2015, with no increase until the year 1991.

Because of the manner in which table 3 had to be created, the largest "other" coal demand estimate was combined with the smaller estimates of specified demand to derive the smaller estimated total annual production demand figures, and conversely.

Total Demand Projections

The total demand projections shown in table 3 include projected annual demand for every year between 1985 and 2015, even though not all years are listed individually in the table. Consequently, the totals shown for specified and other uses represent the amount of coal that would be required to satisfy the assumptions discussed in preceding parts of this report. The total/total shown, 240 to 510 million tons, represents a large part of the recoverable reserves that have been estimated to be present in Pakistan on the basis of incomplete coal resource investigations to date.

In general, because of the many limitations on minability and utilization, a large ratio of coal reserves to annual production is required. For example, the ratio of estimated identified reserve base tonnage to annual production in the United States is about 480 to 1. In Pakistan, if the recoverable reserves figure cited previously was completely equivalent (and it is not) to identified reserve base of the USA, the ratio would be less (350 to 400) with present-day producton and would be hopelessly inadequate to support a viable mining industry if the annual coal production of Pakistan is to increase by factors of 2 to 3 times by 1993 or 7 to 15 times by 2015.

Limitations on Utilization

Location

At present, coal from Baluchistan and Punjab is used mostly to supply the brick-making industry, which is largely centered in Punjab Province. Obviously, transportation is possible over the existing railroad and highway system. However, if the electric-generating needs of the country increase as predicted, the location of the required large coal sources relative to the point of utilization, such as a powerplant, becomes a major factor in evaluating the economics of proposed facilities. Though the electricity distribution gridwork of Pakistan can presumably allow establishment of generating stations at most places in the country for use nationwide, the desirable situation puts the large electric-generating plants near major use areas or adjacent to large capacity grid segments and as close as possible to the coal source to minimize the costs and problems of transport and storage.

In all other uses, the location of the coal supply relative to the utilization point will increase in importance as the quantity of coal required increases. The factor of location becomes particularly important as new utilization installations are planned.

Quantity

Total demand projections show that, regardless of the exact estimated quantities of demonstrated recoverable (reserve base) coal--and this is the part of estimated resources that is required for development and utilization planning and studies--the coal fields of Pakistan require much study to determine quantities of coal available to supply increasingly large quantities of coal required.

Quality

Quality factors for electric power generation and brick-making were briefly addressed in preceeding paragraphs. A search for coals of less sulfur content than is commonly present in most Pakistan coals might lead to identification of coals in certain areas, or coals in certain beds in certain areas, that could be selectively mined for use in such industries as cement-making or briquetting where the sulfur content is of extreme importance.

Beneficiation studies of Pakistan coals indicate that the ash and sulfur content cannot be reduced to desired levels without bringing about unacceptable low coal recovery rates. In general, plans should proceed on the basis of using the coal in the expected run-of-mine quality. Combustion in fluidized-bed furnaces seems to be a technology applicable to the high-ash and high-sulfur Pakistan coals because the fluidized bed functions with high-ash material and can be operated so as to retain most or all of the sulfur in the fluidized bed material instead of expelling it from the furnace as gases or very fine solids.

Ownership Limitations

The complicated interrelationships between the public- and private-sector financing, production, and marketing practices are addressed in the 1985 report by Energy Development International/Price Waterhouse. Many of the identified problems relate to the relative size of areas under prospecting license and mining leases. As pointed out in that report, 70 percent of the 242 coal mining leases in the country are less than 750 acres (3 sq. km) in size, averaging about 347 acres (1.4 sq. km). The situation for prospecting licenses (coal is produced in license areas as well as lease areas) is similar, with almost 73 percent of the 501 licenses being of less than 1,000 acres (4 sq. km) in size with an average of 600 acres (2.4 sq. km).

The following table shows the coal-bearing area required to supply various sized electric-generating plants. The assumptions are: coal with an average heating value of 5120 Btu/lb, so a 100 MW plant would require about 0.6 million tons per year; a recoverability ratio of 60 percent, so the in-place coal requirement would be about 1 million tons per year; a plant-life of 30 years; and a coal bed averaging 1 meter in thickness underlying 1 sq. km would have about 1 million tons of coal in-place.

Generating capacity (Megawatts)	Coal-bearing area (reserves) needed (square kilometers)		
	Average coal thickness mined		
	0.5 m	1.0 m	1.5 m
15	9	4.5	3
25	15	7.5	5
50	30	15	10
100	60	30	20
300	180	90	60

All of the assumptions are conservative; if the run-of-mine coal supplied to the powerplant has more heating value, the area required will be less; if recoverability is greater than 60 percent, the area required will be less; and so on. However, regardless of the exact assumptions, two facts are clearly shown: 1) mining leases and prospecting licenses of the average size (1.4 sq.

km and 2.4 sq. km) are too small to supply any but the smaller size electric-generating installations; and 2) blocks of identified resources of useful size should be preserved, and perhaps granted, as a single unit and not fragmented as in present leasing and licensing practice. **A system employing an approach like the "logical mining unit" concept used in the United States should be considered for future leasing in areas now undergoing exploration, such as Sonda, or to be explored, such as Indus East and parts of the Salt Range.**

The limitations placed upon "utilization potential" by the small size of lease range from inability to enter into long-term contracts, because of lack of resources, to the inability to justify the costs of improving mining methods and health and safety standards. **The problems caused by fragmented inefficient-size license and lease-holdings will increase in the future as the need grows for large assured quantities and qualities of coal for individual installations, such as powerplants.**

COAL RESOURCE EVALUATION

Coal resource evaluation goals are attained in a variety of ways. The necessity for reliable, credible, internationally acceptable overall resource evaluation is met with national summary assessment programs. The need for geologically coherent resource understanding of coal regions is met with regional syntheses that are based on available data supplemented by geologic studies. The need for local resource information for planning specific utilization projects is met by localized investigations that may start with geologic reconnaissance and proceed through a series of increasingly detailed exploration and development stages.

National Summary Assessment

Coal resource assessment has been defined as "A critical analysis based on integrating, synthesizing, evaluating, and interpreting all available data aimed at judgment of the geologic nature or economic potential of the coal resources and reserves of an area, field, district, basin, region, province, country, state, nation, continent, or the world. An assessment differs from an estimate, which is a determination of the amount of coal in an area. An estimate or estimates may be the principal data used to assess the coal resources and reserves of an area" (Wood and others, 1983).

The work plan for the Coal Resource Exploration and Assessment Program in Pakistan recognized the necessity for coal resource assessment in a national and international context by specifying that the principal goal of the exploration and assessment element of the program (see Work Plan) "...is a modern, comprehensive, internationally acceptable assessment of the coal resources of Pakistan." In addition, description of the proposed plan for a coal analytical system (See Work Plan) addresses the need to adhere to standards acceptable to international banks, donor organizations, and resource development entities and companies. In both cases, the expressed concerns reflect the need for coal resource assessments that are acceptable to planners and financial managers in Pakistan and in the international funding agencies.

A national summary assessment of the coal resources of Pakistan should be initiated as soon as possible. On a regional, field, and area basis all available information should be gathered, organized, synthesized, and summarized so as to allow systematic production of assessments (which usually include detailed resource/reserve base estimates) that would be comprehensive, detailed, and nationally and internationally comparable, and that were created using philosophy, methods, techniques, criteria, definitions, and parameters that are internationally understood, and accepted.

The summary assessment would be aided by up-to-date contributions from exploration projects underway or planned for the near future. However, initiation of a national summary assessment should not be dependent on completion of particular local exploration projects. The summary assessment would be as complete as possible as of a certain date and, like all progress reports, would be supplemented or succeeded by newer summary assessments at some future date.

A national summary assessment focuses on gathering, organizing, and synthesizing available data with the objective of producing a critical analysis--involving economic factors--leading to an understanding of the national resource/reserve base/reserve situation as of a certain date. As such, it ordinarily delineates poorly understood geologic relationships and identifies geologic problems that affect overall assessment. However, such studies generally cannot be designed to actively contribute to understanding of the relationships or solution of the problems they identify.

Regional Synthesis

Coal is found as a component of sedimentary rocks that accumulated as unconsolidated sediments on the surface of the earth under particular physical and chemical depositional conditions. The type of sedimentary rocks that contain coal are generally very thin compared to the length and breadth of the rock sequence. Consequently, areal considerations are pre-eminent and assessment activities are commonly generalized as national, regional, or local, depending on the size of the area and the scale and intensity of the proposed investigation.

A coal region may be defined as a geologically and/or geographically distinct area in which coal-bearing, or potentially coal-bearing, rocks are known or believed to be present. A region ordinarily includes two or more areally smaller entities that might be called areas or fields. To date, relative terminology for the different coal-bearing areas of Pakistan has not been standardized; most discussions are by fields, parts of fields, or undefined areas, and by national political subdivisions. As knowledge of

Pakistan's coal resources increases, it may be desirable to formalize an areal hierarchy to facilitate appreciation of the relations of national, regional, and local resource data.

Regional geologic studies are intended, and are so designed, to gather and integrate both existing and new information about the coal geology of a region so as to result in an increased understanding of the coal resource potential of the region and provide guidance for subsequent local exploration, development, and utilization activities.

Ideally, regional studies are done in accompaniment to local studies. Information produced by local exploration, development, and extraction activities is integrated with other local information, and continuing guidance, support, and active collaboration is provided by the regional study to the local investigations.

Our present understanding of the coal geology of Pakistan indicates that investigations of three coal regions should be initiated as soon as possible. These three regions are: 1) the part of southern Sind Province known or projected to be underlain by coal-bearing rocks of Paleocene or Eocene age, 2) the part of Baluchistan underlain by the coal-bearing Ghazij Formation of Eocene age, and 3) the part of the Punjab Plains that is potentially underlain by coal-bearing rocks of Permian age. Regional study of the large Salt Range coal field might be desirable as further exploration is proposed. In addition, regional study of the Makarwal field and Kurd-Sho area should be undertaken as soon as feasible.

The part of southern Sind Province that includes much of the Hyderabad Division is underlain by the coal-bearing Ranikot Group of Paleocene age and the Laki Formation of Eocene age. The distribution, both areally and stratigraphically, of the coal-bearing parts of these rock units is imperfectly known. Surface studies, particularly limited geologic mapping at large scales and stratigraphic section measurement, description, and interpretation with associated detailed paleontologic study, are needed over large areas west of the Indus River, and subsurface studies based on interpretation of samples and geophysical logs of coal-exploration drill holes and oil-and-gas exploration drill holes are needed in the part of the region east of the Indus River. The coal resource potential of this region is very large, and a regional understanding of the geologic history of the coal-bearing and associated rocks is necessary so that the resources of the region can be adequately assessed.

A very large area in Baluchistan is known to be underlain by coal-bearing rocks of the Ghazij Formation wherever the Ghazij has not been removed by erosion. The area extends westward from the Chamalong area through the Duki field and Kach-Khost-Sharig-Harnai fields to the Sor Range-Daghari field and then south through the Pir-Ismail-Ziarat and Mach and Ab-E-Gum fields through the small occurences at Abi-Gul and Margat to Johan. The known boundaries of the region containing coal are not well defined at present. A thorough integration and synthesis of existing information followed by surface and subsurface geological exploration might greatly increase the understanding of the distribution and internal character of the coal-bearing part of the Ghazij Formation and, more importantly, might allow guidance of local exploration activities to define areas of best resource potential for future utilization.

Parts of the Punjab Plains of eastern Pakistan (part of the Five Rivers area) are underlain by rocks of Permian age that may be coal bearing. The distribution and stratigraphic subsurface position of these rocks is poorly known from very widely spaced oil-and-gas exploration drill holes and the coal resource potential is particularly unknown. Information about the location and depth of possible exploration targets for drilling must be gathered and synthesized so that coal-exploration activities can be reliably planned. Geophysical studies must be the basis of the development of geologic understanding of the coal resource potential of this large strategically located region. A proposal for study of this area is included herein as a local resource project but could actually be viewed as a regional research project because of the breadth, depth, and scale of analysis involved.

The Salt Range coal field of Punjab should be regionally analyzed as information is obtained from proposed drill programs.

The important Makarwal coal field of Punjab and Northwest Frontier Provinces (NWFR) and its probable extension into the Kurd-Sho area of NWFP should be analyzed in a regional manner in conjunction with surface studies of critical areas and exploration drilling in areas where the potential coal-bearing rocks are covered by younger rocks.

These regional projects, each the responsibility of an experienced geologist in a GSP regional office, would be conducted concurrently with related local projects. In addition to the primary project chief, a number of other GSP earth scientists and specialists, as needed and available, would be required to accomplish the regional objectives.

Local Exploration Projects

Exploration has been defined as "searching through or into, penetrating or ranging over for discovery, examining thoroughly, striving to attain by search." In analogy with research, exploration may be basic with few or no preconceptions about that which may be found, or, more commonly, designed to yield information of certain types about particular subjects. In practice, exploration consists of a great number and variety of physical and mental activities conducted over a broad spectrum of data fields.

National resource assessment and regional synthesis are dependent on exploration to provide the data that is required. Exploration is the early part of a continuous sequence of activities that begins when the presence of coal is reported or believed geologically possible and extends through exploration, development, extraction, and utilization. Between these broad categories of related activities, the demarcation of exploration activities from development activities is sometimes difficult to define because in many cases the same methods, techniques, and equipment are used. In general, if the motive for the activity is geologic; that is, for example, to determine the extent of a coal field or an individual coal bed, to allow most estimated resources in the area to fall into the demonstrated (measured plus indicated) category, or to determine significant differences in coal quality related to location, the activity would be classed as exploration. If, however, the motive for the activity was to provide information needed for mine planning or for detailed economic analyses, or similar information needs that are necessary preludes to extraction, the activity would be classed as development. Obviously, data obtained an exploration reason can also be useful for development and extraction purposes.

Within the category of investigation designated here as "local exploration projects" there is much diversity in size of area and intensity of analysis.

The coal-bearing parts of Pakistan subsequently discussed as fields and areas range widely in size. Their distinguishing characteristic is their definition and distinction on the basis of geographic and/or geologic boundaries. In some cases, such as the Lakhra field, even those boundaries are not precise because of lack of information about the extent of the coal-bearing area, and the defined boundaries are subject to considerable change as exploration proceeds.

Intensity of analysis is judged on such parameters as scale of geologic mapping, and distribution and number of desired data points relative to the size of the area being studied. These factors are established by the amount and type of information required to satisfy a need for particular resource information. The range of information needs is broad--from "Is there coal present in the area?" to "How much of the coal of a particular quality is present in a particular category of bed thickness, overburden depth, and geologic assurance?"

Methods and techniques used to provide answers to such a wide range of questions necessarily are many and varied. The same technique, such as drilling coal-exploration holes, may be used in different analyses but the intensity of analysis--in this case the number and spacing of drill holes--can be very different.

Exploration activities are performed as parts of a continuous sequence of activities. For convenience, the continuum is commonly divided into a series of exploration steps or stages. One of the criteria for distinguishing the stages from each other is, commonly, the degree of geologic assurance about resource evaluation that is expected in each step.

Geologic Assurance is defined as "State of sureness, confidence, or certainty of the existence of a quantity of resources based on the distance from points where coal is measured or sampled and on the abundance and quality of geologic data as related to thickness of overburden, rank, quality, thickness of coal, areal extent, geologic history, structure, and correlations of coal beds and enclosing rocks. The degree of assurance increases as the nearness to points of control, abundance, and quality of geologic data increases" (Wood and others, 1983).

Though there is no universally recognized system of exploration steps or stages, a sequence such as described by Landis (1986) can be used in Pakistan. A three-tiered program based upon different degrees of geologic assurance of potential identified resources has been proposed by S.N. Khan and G. Abbas of GSP (Ahmed, 1986). The three sequential exploration programs, herein called Geologic Assurance Program (GAP) I, II, and III, differ in the number of data points required. GAP I calls for one data point for every 4 sq. km of the particular coal-bearing area, GAP II calls for one data point for every 2 sq. km of the coal area, and GAP III requires one data point for every 1 sq. km of the coal area. The data points would be almost completely exploration drill holes, though mine or outcrop measurements might be useful in some areas.

The GAPs are exercises in geologic and resource logic based on objective but conservative assumptions about the average thickness of coal beds in different fields and areas, the depth to which mining might be feasible now or in the near future, and experienced estimates about the costs and progress rates of exploratory drilling in the various parts of Pakistan.

In actual practice, GAP I would be completed, the data evaluated, resource estimates made, and an assessment made based on the available information. Decisions would then be made about the desirability of proceeding to GAP II and the possibility or necessity of modifying the GAP II in order to produce desired results more expeditiously and cost-effectively. The same procedure would be followed at the end of GAP II. The sequence has built-in stops and decision points. In addition, because all assumptions are conservative, in essence "worst case" situations, it is probable that the actual cost of proposed projects using the GAP system would be conducted at less expense than originally estimated.

Tables 4, 5, and 6 show the GAP I, II, and III, respectively, for different local exploration project areas in Pakistan. These data will be cited later in individual area discussions but are here summarized for comparison. All of the included assumptions are based on presently available knowledge--geologic, engineering, and fiscal--and could readily be modified as more, or newer, information becomes available.

In actual practice, organizations such as the Geological Survey of Pakistan (GSP) and the U.S. Geological Survey are responsible for the GAP I studies, are sometimes responsible for GAP II studies, but are rarely involved in GAP III studies. GAP II is commonly regarded as largely of benefit for development and mining feasibility studies and GAP III is definitely development and mine-planning studies. Ideally, GAP I would be conducted by GSP; GAP II by organizations like Pakistan Mineral Development Corporation (PMDC) or private parties and, in some cases, by GSP; and GAP III definitely by PMDC, other similar organizations, and private parties.

Two points are obvious. The total cost of comprehensive programs to produce results with a great degree of geologic assurance is fairly high. At the same time, the cost of such exploration evaluated on a per ton basis is very small.

Coal Resource Classification

The coal resources of Pakistan are unknown. Many resource estimates have been made of the quantity and quality of coal in specific parts of the country. However, because of differences in the philosophy and methodology of estimation and the resulting differences in systems of classification of resource estimates, there is little or no comparability between estimates in different areas. Summations of such data are almost meaningless.

In Pakistan, as in many other countries, resource classification terminology and methods are undefined and unspecified. It is possible that

Table 4.--Geologic Assurance Program I

[One data point per 4 sq km]

Province and coal field	Area (sq km)	Number of drill holes	Average depth (meters)	Total meterage	Cost per meter (Rs.)	Drilling cost (10^6 Rs.)	Geologic support cost (10^6 Rs)	Total cost (10^6 Rs.)
Sind								
Sonda	900	225	300	67,500	1,500	101.3	15.2	116.5
Lakhra	650	163	200	32,600	1,500	48.9	7.3	56.2
Punjab								
Salt Range	400	100	200	20,000	1,500	30.0	4.5	34.5
Baluchistan								
Khost-Sharig-Harnai	100	25	800	20,000	2,500	50.0	7.5	57.5
Sor Range-Daghari	50	13	1,000	13,000	3,000	38.0	5.7	43.7
Pir-Ismail-Ziarat	18	5	1,000	5,000	3,000	15.0	2.3	17.3
Mach/Ab-E-Gum	80	20	1,000	20,000	3,000	60.0	9.0	69.0

Table 4.--continued

Province and coal field	Potential identified resources (10^6 tons)				Time months/ No. of rigs	Cost benefit ratio (Rs. per ton)			
	Measured	Indicated	Inferred	Total		Measured	Indicated	Inferred	Total
Sind									
Sonda	65	65	370	500	26/8	1.79	1.79	0.31	0.23
Lakhra	55	55	315	425	13/8	1.02	1.02	.18	.13
Punjab									
Salt Range	10	10	55	75	36/2	3.45	3.45	.62	.46
Baluchistan									
Khost-Sharig-Harnai	6	6	35	47	36/2	9.58	9.58	1.64	1.22
Sor Range-Daghari	4.5	4.5	2.6	35	24/2	9.71	9.71	1.68	1.25
Pir-Ismail-Ziarat	1.5	1.5	8	11	10/2	11.53	11.53	2.16	1.57
Mach/Ab-E-Gum	2.5	2.5	16	21	34/2	27.6	27.6	4.31	3.29

Table 5.--Geologic Assurance Program II

[One data point per 2 sq km]

Province and coal field	Area (sq. km)	Number of drill holes	Average depth (meters)	Total meterage	Cost per meter (Rs.)	Drilling cost (10^6 Rs.)	Geologic support cost (10^6 Rs)	Total cost (10^6 Rs.)
Sind								
Sonda	900	589	300	176,700	1,500	265	40	305
Lakhra	650	464	200	92,800	1,500	139	21	160
Punjab								
Salt Range	400	284	200	56,800	1,500	85	13	98
Baluchistan								
Khost-Sharig-Harnai	100	71	1,000	71,000	3,000	213	32	245
Sor Range-Daghari	50	37	1,000	37,000	3,000	111	17	128
Pir-Ismail-Ziarat	18	14	1,000	14,000	3,000	42	6	48
Mach/Ab-E-Gum	80	57	1,000	57,000	3,000	171	26	197

Table 5.--continued

Province and coal field	Potential identified resources (10^6 tons)				Time months/ No. of rigs	Cost benefit ratio (Rs per ton)			
	Measured	Indicated	Inferred	Total		Measured	Indicated	Inferred	Total
Sind									
Sonda	250	250	---	500	18/10	1.22	1.22	---	0.61
Lakhra	212.5	212.5	---	425	9/10	.75	.75	---	.38
Punjab									
Salt Range	37.5	37.5	---	75	18/4	2.61	2.61	---	1.31
Baluchistan									
Khost-Sharig-Harnai	23.5	23.5	---	47	24/3	10.42	10.42	---	5.21
Sor Range-Daghari	17.5	17.5	---	35	12/3	7.31	7.31	---	3.66
Pir-Ismail-Ziarat.	5.5	5.5	---	11	12/1	8.73	8.73	---	4.36
Mach/Ab-E-Gum	10.5	10.5	---	21	3/4	18.76	18.76	---	9.38

Table 6.--Geologic Assurance Program III

[One data point per 1 sq. km]

Province and coal field	Area (sq km)	Number of drill holes	Average depth (meters)	Total meterage	Cost per meter (Rs.)	Drilling cost (10^6 Rs.)	Geologic support cost (10^6 Rs)	Total cost (10^6 Rs.)
Sind								
Sonda	900	864	300	259,200	1,500	389	58	447
Lakhra	650	627	200	125,400	1,500	188	28	216
Punjab								
Salt Range	400	384	200	76,800	1,500	115	17	132
Baluchistan								
Khost-Sharig-Harnai	100	96	1,000	96,000	3,000	288	43	331
Sor Range-Daghari	50	50	1,000	50,000	3,000	150	23	173
Pir-Ismail-Ziarat	18	19	1,000	19,000	3,000	57	9	66
Mach/Ab-E-Gum	80	77	1,000	77,000	3,000	231	35	266

Table 6.--continued

Province and coal field	Potential identified resources (10^6 tons)				Time months/ No. of rigs	Cost benefit ratio (Rs per ton)			
	Measured	Indicated	Inferred	Total		Measured	Indicated	Inferred	Total
Sind									
Sonda	500	---	---	500	24/10	0.89	---	---	0.89
Lakhra	425	---	---	425	12/10	.51	---	---	.51
Punjab									
Salt Range	75	---	---	75	18/4	1.76	---	---	1.76
Baluchistan									
Khost-Sharig-Harnai	47	---	---	47	18/4	7.04	---	---	7.04
Sor Range-Daghari	35	---	---	35	18/3	4.94	---	---	4.94
Pir-Ismail-Ziarat	11	---	---	11	9/2	6.00	---	---	6.00
Mach/Ab-E-Gum	21	---	---	21	27/3	12.67	---	---	12.67

estimates of "recoverable reserves" are largely in the reserve base category, but it is also certain that some estimates of "reserves" or "recoverable reserves" made in the past included some of the "reserve" category as economic producibility was perceived at the date of the estimate.

A modern detailed summary of known data and estimates of coal resources of Pakistan are needed for planning of the future energy budget of Pakistan. The USGS coal resource classification system, or one similar, should be applied so that the results are credible, comparable, and acceptable both nationally and internationally.

FUNDING, PERSONNEL, AND INSTITUTIONAL REQUIREMENTS

Funding

Exploration costs are insignificant compared to development, extraction, and utilization costs. For example, the proposed powerplant at Lakhra and the proposed mine to supply coal for the plant could cost as much as Rs. 30,000 million, whereas the exploration that justified planning for utilization cannot (no matter what range of costs are included) exceed more than about 0.5 percent of that total.

Cost-benefit ratios of this magnitude are not uncommon, but funding for exploration is not popular with the short-term viewer because of the long lead-time between exploration and utilization. The exploratory drill program that led to the realization that the Lakhra coal field contained a major portion of the identified coal resources of Pakistan was done in the early 1960s. Although coal has been produced from the field in increasing quantities since 1959, truly large-scale production from the field is still at least a few years away.

The Government of Pakistan has long known that indigenous coal could and should supply a larger portion of the energy needed for the country's growth. Pakistan's Sixth Five-Year Plan gave energy the highest priority among all sectors of the economy in terms of the budget allocations and stated that basic objectives of the plan included:

--preparation for increased self-reliance in energy in the Seventh Plan and beyond;

--development of indigenous resources of energy, intensification of the search for yet undiscovered resources, development of nuclear and renewable resources, and acquisition of technology relating to energy substitutes.

The plan recognized that coal should play an increasingly important role in meeting national energy needs, but both policy and funding support have lagged.

Under provisions of the joint GOP-USAID Energy Planning and Development Project, the Geological Survey of Pakistan was to be allocated Rs. 41 million for coal exploration during fiscal years 1986 through 1989. The exploration would be conducted in cooperation with the U.S. Geological Survey under a Work Plan that calls for assistance, technology transfer, training, and equipment acquisition under the auspices of--and with over $5 million funding support from--USAID. The funding supplied by GOP to GSP to date (February 1987) totals Rs. 5.1 million during 1986-87.

Personnel

Seventeen GSP earth scientists completed training in coal geology and resource assessment at Southern Illinois University (SIU) in June 1986. An additional 16 are scheduled to complete similar training in June 1987. This training is intended to provide a cadre of competent GSP personnel to work with USGS counterparts in the coal exploration program. Technology transfer between GSP personnel who have received training and other GSP personnel is very important. It is desirable for additional GSP personnel to receive this summary assessment and regional synthesis training. The need for familiarization in the use of new, unfamiliar exploration equipment or techniques will be identified as the program progresses.

Institutional Requirements

Even though the number of GSP personnel may be adequate for the planned coal resource program, and necessary specialized training is envisaged, other institutional and organizational changes may be desirable so the mandates of coal resource assessment may be accomplished in the most efficient, productive, and cost-effective manner.

The problem of funding is primary and cannot be rectified by GSP itself. Work plans and programs that have been prepared, evaluated, and approved at the highest management and planning levels can be effectively aborted by not allocating agreed-upon, necessary funding or by delaying allocation so late that necessary work, especially in the field, cannot be completed in required timeframes.

A major internal problem of GSP is the accelerated trend toward regionalization of the organization. The creation and staffing of regional offices for activities that can be most effectively carried on in a local context is a standard management approach with much to commend it. However, staffing of regional offices should be based on program needs, both in number of staff and mix of required expertise. Program needs change and personnel must be changed in response. In addition to flexibility in response to program needs, a system of planned rotation of personnel between different regional offices can result in well-rounded expertise. If personnel are assigned to dispersed offices for major portions of their careers, professional stagnation occurs, the national expertise of the agency depreciates, and effective management becomes extremely difficult.

A well-conceived program of on-the-job training, foreign fellowships, and long-term career planning is strongly recommended in scientific organizations such as the GSP. To be effective in their overall scientific mandate to serve their country in the broad, ever-expanding field of earth science, organizations such as GSP must be able to encourage, assist, and reward their personnel in continuing their education and increasing both the depth and variety of their expertise and management skills throughout their professional careers.

Training is a major element in the Coal Resource Exploration and Assessment Program, and a training program for GSP personnel in coal geology and resource assessment has been planned. In addition, several candidates will participate in a long-term training program leading to advancded degrees in earth sciences from U.S. universities. The program is open to all Pakistanis possessing a basic degree in earth or related science and having successfully passed the Graduate Record Examination and the Test of English as a Foreign Language. Candidates for this long-term training will be evaluated on the basis of selection criteria which include the candidate's demonstrated ability and apparent potential capability to improve Pakistani institutions upon completion of training.

EXPLORATION PROJECTS BY PRIORITY

The following discussions are arranged according to perceived priority or need. Future re-appraisal of this exploration plan will result in changes, additions, and deletions in the priorities.

Cost Estimates

The cost estimates presented herein are derived from the past experience of the GSP in conducting exploration projects. Obviously, the costs of the geologic assurance programs (GAPs) presented here are dependent on the costs of drilling and the geologic guidance and support necessary to achieve the exploration objectives.

A realistic sliding scale of drilling costs per meter is used. The changes in the scale are based on comparative average depths of bore holes in the different programs and experience in the relative costs incurred during actual drilling programs in the different coal fields of the country.

Costs of geologic guidance and support are expected to approximate 13 percent of the total estimated costs.

It is expected that actual costs in the future may change in presently unpredictable manners but the accompanying estimates are the best possible at this time.

Priority I Projects

This priority includes exploration plans for those areas where planning for utilization requires coal resource information to establish the feasibility of use for particular purposes. The South Sind coal area, the Khost-Sharig-Harnai and Sor Range-Daghari coal fields of the Baluchistan region, the Salt Range coal field of Punjab, and the Mackerwal/Kurd Sho field in Punjab/NWFP are in Priority I.

Table 7 summarizes pertinent information about the Priority I areas. Estimated exploration costs and time required are summarized in table 8.

Table 7.--Priority I Areas

[MT = million tons, m = meter, other as indicated]

	SOUTH SIND					BALUCHISTAN		PUNJAB	PUNJAB/NWFP
	Lakhra	Northwest Lakhra	Meting-Jhimpir	Sonda	Indus East	Khost-Sharig-Harnai	Sor Range-Daghari	Salt Range	Makerwal/Kurd-Sho
Estimated demonstrated recoverable reserves	100 MT	---	8 MT	124 MT	---	24 MT	18 MT	17 MT	7 MT
Depth of deepest reported coal	460 m	---	500 m	260 m	550 m	?	900+ m	?	?
Depth of present mines	<130 m	---	<150 m	---	---	250 m	650(?) m	<200 m	1,000(?) m
Average annual production	0.3 MT	---	0.4 MT	---	---	0.1 MT	0.46 MT	0.225 MT	0.260 MT
Coal Quality Range									
Moisture	13-39	---	27-37	9-40	---	1.7-11.4	5.1-21.2	3.2-10.8	2.8-6.0
Ash percent	7-25	---	8-17	5-39	---	9.3-38.0	2.7-14.3	12.3-44.2	6.4-30.8
Sulfur percent	2-6.5	---	3-5	0.4-5.6	---	1.4-9.4	0.4-5	2.6-10.7	2.8-6.3
Heat value - KC/Kg	2770-4200	---	3470-4260	3600-5700	---	4420-7000	4830-6060	3760-6170	5200-6780
Rank[1/]	ligA-subC	---	ligA-subC	ligA-subC	---	hvBb-hvAb	subB-subA	hvCb	hvCb-hvBb
Potential Utilization									
Electricity	Yes	---	Yes	Yes	---	Yes	Yes	Yes	Yes
Brick-making	Yes	---	Yes	Yes	---	Yes	Yes	Yes	Yes
Cement manufacture	?	---	?	?	---	?	?	?	?
Process and direct heat	Yes	---	Yes	Yes	---	Yes	Yes	Yes	Yes
Briquettes	Yes	---	?	?	---	Yes	Yes	?	?
Other conversions	?	---	?	?	---	?	?	?	?

1/ LigA = lignite A, subC = subbituminous C, subB = subbituminous B, subA = subbituminous A, hvCb = high volatile C bituminous, hvBb = high volatile B bituminous, hvAb = high volatile A bituminous (American Society for Testing and Materials, 1982).

Table 8.--Estimated exploration costs and time for GAP I in Priority I Areas (from table 4)

Area or field	Drilling costs (10^6 Rs.)	Geologic support costs (10^6 Rs.)	Total cost (10^6 Rs.)	Time (months)
South Sind				
Lakhra				
GAP I	48.9	7.3	56.2	13
Sonda				
GAP I	101.3	15.2	116.5	26
Indus East				
GAP I	?	?	?	?
Baluchistan				
Khost-Sharig-Harnai				
GAP I	50.0	7.5	57.5	36
Sor Range-Daghari				
GAP I	38.0	5.7	43.7	24
Punjab				
Salt Range				
GAP I	30.0	4.5	34.5	36
Punjab/NWFP				
Makerwal/Kurd-Sho				
GAP I	?	?	?	?

South Sind Coal Area

This large coal region in the Hyderabad Division of Sind Province should best be studied as a unit. The following area description is presented here to help define the relationship of the local resource areas subsequently discussed. The area is Priority I status because of the need for definitive information about the coal resource potential for supplying large electric generating complexes, some of which are in the planning stage. It is not known how much of the Hyderabad Division is underlain by potentially coal-bearing rocks. The Division includes almost 90,000 sq. km; if only one-quarter is underlain by rocks that contain coal, the potential tonnage is still large.

Two rock units are known to contain coal in the area--the Ranikot Group of Paleocene age and the Sunhari Member of the Laki Formation of Eocene age. The resource potential of the Ranikot Group is large because the unit is known to be present, and to contain coal, over very large areas. The Sunhari Member is known to contain coal only in the Meting-Jhimpir coal field though there are ambiguous indications that coal may also be present in the Sunhari or equivalent age units in other parts of the area.

The Ranikot Group is reportedly almost 1,000 m thick in an oil-exploration drill hole on the Lakhra anticline but is generally thinner elsewhere. The range in thickness is caused by differences in the original depositional thickness, erosion prior to the deposition of the overlying Sunhari Member, and erosion now and in the recent past. The Sunhari Member is reportedly only a few tens of meters thick in most of the area where it is present. The regional distribution and geologic history of the Sunhari are poorly understood and a regional study of the area would help understand the distribution of Eocene age coal in Sind.

The Ranikot Group is known to contain coal at depths as much as 550 m beneath the surface in the South Sind area. In the area where the Ranikot is being actively mined at present, seldom is mining done at more than 100-m depths. The Sunhari is also within 100 m of the surface in most or all of the area where it is now mined.

The perceived coal resource potential of the area is based on scant and very poorly distributed information. Much information has been developed for mine planning in one small part of the area. The remainder of the area is partly to very poorly explored and its total resource potential cannot yet be evaluated to the degree of assurance necessary for further utilization planning.

The quality of the coal in the area will probably be similar to that which is now mined in the Lakhra field, that is, lignite A to subbituminous C in rank, with high sulfur and medium to high ash contents. However, it is possible that in an area so large some coals might be of better quality, particularly in regard to sulfur content.

The area lies across the primary transportation artery of Pakistan, which extends northeast from Karachi along the Indus River and eventually to Lahore. Not only are the roads, railroads, people, irrigation systems, main industries, and light industries concentrated along this major artery which is a wide belt in the Five Rivers Area of eastern Punjab, but, of course, so are major parts of the national electrical grid (see Survey of Pakistan, 1985). The coal-bearing parts of the South Sind region potentially can supply the needed thermal energy for a major portion of the future electrical energy needs of the country. At this time, a project has been initiated to drill as many as 50 exploratory drill holes, spaced about 4.8 km apart, to 1) gather information about the extent and depositional setting of the known Lakhra coal field, 2) determine the relationship of the Lakhra and Sonda coal fields, and

3) extend the existing information about the Sonda coal field to the west and southwest of the known area. The proposed exploration would be conducted under the auspices and funding of the USAID by personnel of the Geological Survey of Pakistan, assisted by the U.S. Geological Survey. Also, GSP has extended exploration of the Sonda coal field into the Indus East Area by drilling two exploratory holes near the northeast corner of the area previously proposed as Phase II of the Sonda coal field exploration program. The holes have proved the existence of coal at depths of less than 150 m in the Indus East Area, and have provided the impetus for further exploration in the area.

Five parts of the South Sind coal region are believed to merit further exploration. The required data and exploration plans are discussed for each part of the South Sind area in the following section of this report. Estimated costs and time frames for planned and required exploration are presented in table 8.

Lakhra Coal Field.--The South Sind exploration program has been started, and includes the drilling of as many as 30 exploratory drill holes in the Lakhra field and is accompanied by limited surface studies of specific geologic problem areas. The drill program will be initiated during calendar year 1986 and a final report including detailed resource and reserve base estimates will be completed about 1 year after completion of the drilling program. Personnel involved are from the GSP, supported by GOP, and from the USGS, supported by USAID. The actual drilling is being done by a private Pakistani drilling contractor, and the geophysical logging is being done by a private USA contractor in cooperation with GSP and WAPDA personnel, using USAID equipment.

The drilling program will establish a loose grid, with about 4.8 km drill-hole spacing, from north to south along the length of the known Lakhra coal field and continue across the area between the Lakhra and Sonda coal fields. The program is intended to help delineate the boundaries of the known Lakhra and Sonda fields and identify those parts of the fields where coal is present in minable thicknesses at minable depths so that further exploration, development, and utilization studies may be considered.

The geologic assurance drilling program (GAP I) shown in table 4 would require 163 drill holes at a total cost of Rs. 56.2 million to put 26 percent of the potential identified resources in a demonstrated category. Thirteen months with eight drill rigs would be required. However, when plans were made for a GAP I program all the drilling up to that time would be considered, and the eventual GAP I might be shorter in time, require fewer rigs, and be less expensive.

Northwest Lakhra Coal Area.--The Northwest Lakhra coal area, which is presently undefined, adjoins the known and explored northern part of the Lakhra coal field. The area is separated from the main body of the field by geologic factors, such as poorly understood faulting, and by sheer shortage of information in the area compared to the adjoining part of Lakhra proper. The area has been geologically mapped at a scale of 1:50,000 but no exploratory holes have been drilled. Recently a mine, and perhaps more than one, has opened and may have found coal at unexpectedly shallow depths. Some preliminary site visits to parts of the area are needed as soon as possible to re-establish geologic interpretations in the area, to gain some idea of the extent of the area, and to examine those localities where coal has recently been reported. For example, Ansari and Abassi (1985), present an analysis of coal from a locality called Gaj and state that "Outcrops of coal have been seen in every nallah from Laki [near the Indus River north of Hyderabad-authors] to Ranikot [about 80 km northwest of Hyderabad]. There are coal seams in the Bara formation as well as the Khadro formation which are being worked by the private sector."

The exploration program now underway includes five exploratory drill holes that will contribute data about coal in the southeastern part of the Northwest Lakhra area. This information will be used for planning of further activities in the area. A GAP I program may eventually be required.

Meting-Jhimpir Coal Field.--The coal of the Meting-Jhimpir field occurs in the Sunhari Member, the basal unit of the Laki Formation. Generally only one minable bed is present, and it averages about 0.5 m thick and is seldom more than 1 m thick. Only about 40 thousand tons is produced in the field annually. If the approved exploration program shows that the coal in the Sunhari is persistent to the north and/or west of the present mining area, further exploration may be justified. Further efforts would certainly be planned if thicker coal is found at minable depths.

Sonda Coal Field.--This new and as yet unmined coal field has a large resource potential (Husain, 1985). The coal beds are in the same rock unit as the coals of the Lakhra field, and the 24-hole exploration program conducted over the last 5 years by the GSP shows that the Sonda field may eventually be at least as important in the energy future of Pakistan as the Lakhra field promises to be.

To date, all but two exploration drill holes have been west of the Indus River. Besides the 24 holes completed by GSP, an additional 20 drill holes are included in the underway exploration program already discussed. These additional points of information, plus the existing data, are expected to allow the selection of specific targets for further exploration, development and utilization studies. These targets should be selected following completion of the 20-hole program.

The GAP I would require 225 drill holes at a total cost of Rs. 116.5 million to put 26 percent of the potential identified resources in a demonstrated category (measured plus indicated).

Indus East Coal Area.--The Indus East coal area is here defined as the part of the South Sind coal area that is east of the Indus River and generally south of Hyderabad. As such, it includes the eastern extension of the Sonda coal field.

The area is covered by surficial materials--largely unconsolidated sands, silts, clays and gravels--deposited by the Indus River. Much of it is irrigated farm land, and, to the authors' knowledge, there are no prospecting licenses or coal mining leases in the area.

Approximately 60 oil-and-gas exploration and production wells have been drilled, most of them in the western part of the area. Figure 2 is based upon the stratigraphic records for 19 holes that were available in 1985. The records for an additional 21 holes have been made available recently but have not been synthesized and interpreted to date. This large area in which the coal-bearing Ranikot Group is at reasonable depths should be explored at an early date. GSP has completed two exploratory holes that have demonstrated the presence of coal in the area east of the river.

Baluchistan

The Ghazij Formation of Eocene age is present over a very large area in Baluchistan. Most of the unit is of marine origin and is non-coal-bearing. However, a middle unit of the Ghazij is a mixture of marine, non-marine, and transitional-environment rocks and does contain coal over a large, poorly defined area in northern and eastern Baluchistan. Regional study of this area is needed, as well as GAP I studies of two of the coal fields as Priority I projects.

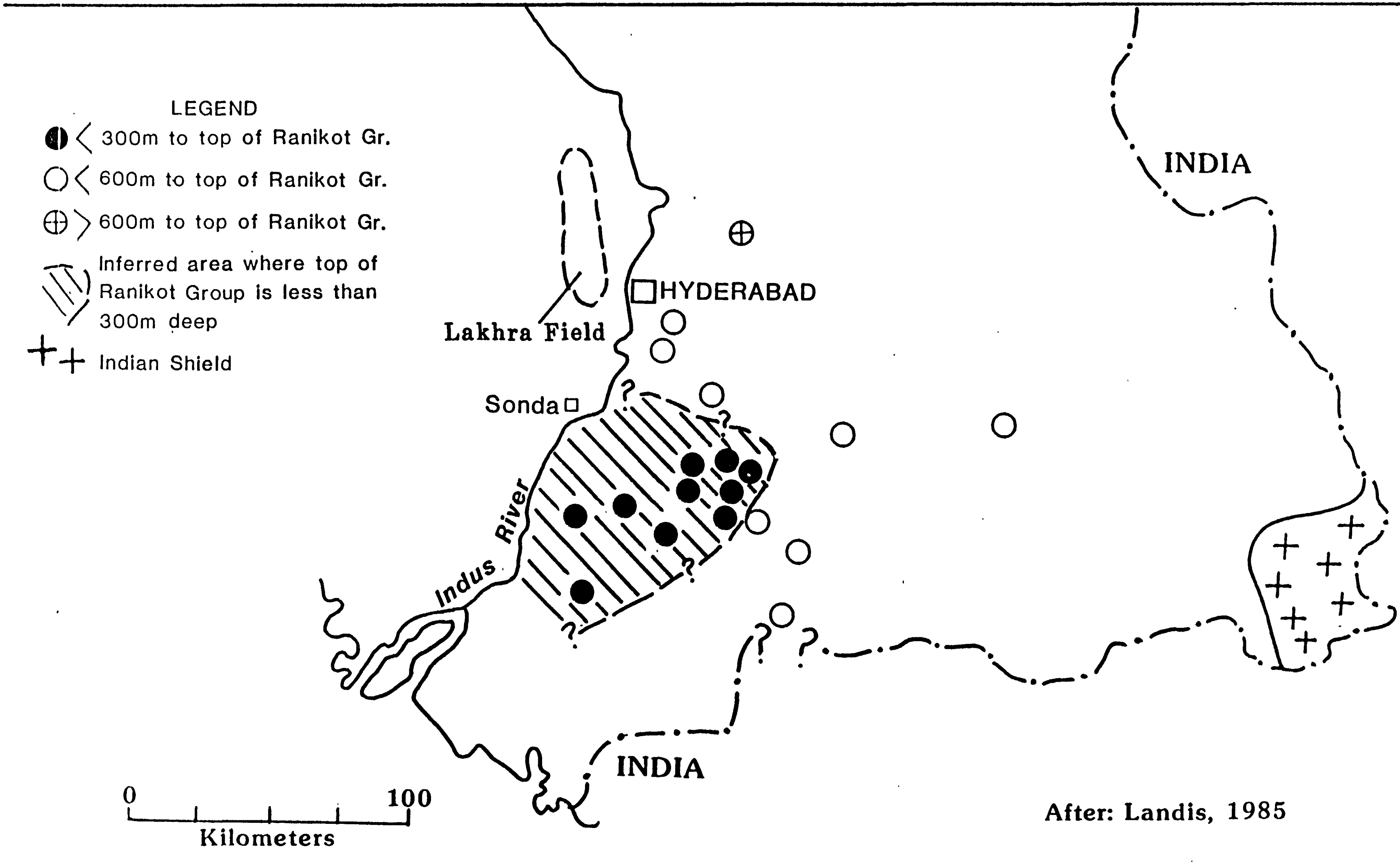


Figure 2. Indus East Coal Area.

Khost-Sharig-Harnai Coal Field.--This old coal field, with the highest rank coal in Pakistan, has never had a complete detailed geologic study designed to convert the potential resources of the field into demonstrated resources and reserve base.

The GAP I shown in table 4 would require about 25 drill holes, cost about Rs. 57.5 million, and take about 3 years.

Vertical aerial photography covering 2,750 sq. km, which the Baluchistan Government has agreed to obtain, will be of great value in the study of the region.

Sor Range-Daghari Coal Field.--This field is one of the most productive coal fields in Pakistan, with an average annual production of about 460 thousand tons. Exploration is needed to identify more resources within the depth range of currently operating mines and within the hypothesized depth range of future mines.

The bulk of the Sor Range-Daghari production now is used for brick making. However, serious consideration is being given to the possibility of erecting a privately financed 25 MW (and perhaps eventually a second) thermal powerplant to be fired by the Sor Range-Daghari coal. The known area of the coal field is only about 50 sq. km, and it is unlikely that the area will expand significantly even with diligent exploration. The exploration needs are: 1) information about the quantity of recoverable reserves in the part of the field that is accessible by present mining practice, 2) information about the quantity of recoverable reserves in deeper parts of the field, and 3) information concerning the quality of the coal.

The GAP I shown in table 4 would require about 13 drill holes averaging 1,000 m in depth, cost about Rs. 43.7 million, and take about 2 years time.

Punjab

Salt Range Coal Field.--The Salt Range coal field has been mined for many years and is still one of the most productive field in Pakistan. There is generally only one minable coal bed present and in places there is no coal. Nearly all mining to date has taken place near the outcrop much block faulting adversely affects mine planning and production. In addition, the past mining activity has removed most mineable coal from a belt generally about 350 m in from the outcrop and has rendered a large amount of coal unrecoverable in and near abandoned mines.

The above-listed problems are outweighed by the established tradition of coal mining in the field and, most importantly, by the field's location immediately adjacent to centers of brick manufacturing.

The coal needs of the brick-making industry wax and wane with the general economy of the nation but the overall trend is for increasing demand for coal for brick making. Forecasts of increases in demand are generally 2 to 5 percent a year. The strategic location of the field has been a large competitive advantage in the past but has also contributed to a continuation of now-inefficient mining and labor practices.

In the past, very little detailed exploration was done prior to or during mining and reliable quantification of recoverable reserves was seldom attempted. The field is almost completely a private sector enterprise with a large number of small operators.

The estimated recoverable reserves are large enough to allow a continuation of present practices for some time, but eventually the coal mines must be larger, more efficient, deeper (shafts instead of adits), and have reliable detailed reserve estimates to justify the costs of improving the mining methods, improving the health standardsfor the mine workers, and increasing mechanization.

The GAP I shown in table 4 would require about 100 drill holes at a total cost of Rs. 34.5 million to put 26 percent of the potential identified resources in a demonstrated category.

Punjab and Northwest Frontier

Makerwal/Kurd-Sho Area.--The demonstrated recoverable reserves of this field are on the order of 7 to 10 million tons. The present mines are getting deeper and, reportedly, considerable investment in further mine improvements may be required. Unless the resource and reserve position is improved, justification of costly improvements may not be possible in the future.

No geologic assurrance programs have been proposed for this area to date.

Priority II Areas

Information about the Priority II areas is summarized in table 9, and exploration costs and time are estimated in table 10.

These areas require exploration so the coal resources of Pakistan can be understood in its entirety, but exploration activity now cannot be justified. Certain areas may later merit a higher priority if new information is developed or if new demand arises.

Punjab

Punjab Plains Area.--An oil-and-gas exploration drill hole at Sarai Sidhu, about 60 km northeast of Multan, penetrated coal in rocks of Permian age at a depth of about 2,685 m. Subsequently, the GSP, on the basis of structural interpretation by geophysical methods, drilled an exploratory hole near Jhang that was intended to penetrate the coal-bearing interval at a depth of less than 1,000 m. However, the hole did not reach the target depth or the potential coal-bearing unit because of mechanical problems. Further investigations of this area could be considered a regional research project rather than a local resource project.

Table 9.--Priority II Areas

[MT = million tons, m = meters, others as indicated]

	PUNJAB	NORTHWEST FRONTIER	BALUCHISTAN			
	Punjab Plains	Cherat	Pir-Ismail-Ziarat	Mach and Ab-E-Gum	Chamalong	Duki
Estimated demonstrated recoverable reserves	---	0.010 MT	6 MT	9+ MT	5 MT	8 MT
Depth of deepest reported coal	1000 m (?)	70 m (?)	700+ m	?	?	?
Depth of present mines	---	20 m	200 m	425 m	?	365 m
Average annual production	---	0	0.115 MT	0.125+ MT	0.010 MT	0.250 MT
Coal Quality Range						
Moisture percent	---	0.5-15.5	5.2-10.0	7.1-12.0	7.9-11.8	4.8-9.2
Ash percent	---	5.8-62.4	13.3-34.2	9.6-20.3	1.6-29.2	2.7-22.3
Sulfur percent	---	2.3-5.0	---	3.2-7.4	3.3-4.5	2.7-7.7
Heat value - KC/Kg	---	2830-7560	5353-5939	5100-5730	?	4610-6380
Rank[1/]	---	subB(?)	hvCb	subC-subB	?	subC-subA(?)
Potential Utilization						
Electricity	?	Yes	Yes	Yes	Yes	Yes
Brick-making	?	Yes	Yes	Yes	Yes	Yes
Cement manufacture	?	?	?	?	?	?
Process and direct heat	?	Yes	Yes	Yes	Yes	Yes
Briquettes	?	?	?	?	?	?
Other conversions	?	?	?	?	?	?

[1/]LigA = lignite A, subC = subbituminous C, subB = subbituminous B, subA = subbituminous A, hvCb = high volatile C bituminous, hvBb = high volatile B bituminous, hvAb = high volatile A bituminous (American Society for Testing and Materials, 1982).

Table 10.--Estimated exploration costs and time in Priority II Areas

Area or field	General exploration costs[1/] (10^6 Rs.)	Specific exploration costs[2/] (10^6 Rs.)	Total costs (10^6 Rs.)	Time required (years)
Punjab				
Punjab Plains				
Proposed	2.45	7.05	9.5	3
Northwest Frontier				
Cherat				
Underway	.33	---	.33	.8
Baluchistan				
Pir-Ismail-Ziarat				
Proposed	---	---	---	---
GAP I	2.3	15.0	17.3	1
Mach and Ab-E-Gum				
Underway	1.0	---	1.0	2
GAP I	9.0	60.0	69.0	3
Chamalong				
Proposed	---	---	---	---
Duki				
Proposed	---	---	---	---

1/ Personnel, field expenses, travel, and administrative and technical support.

2/ Internal or contractual drilling programs.

Northwest Frontier

Cherat Area.--The coal occurrences of the Cherat area were first investigated by the GSP in 1952. Mining commenced soon after the discovery but ceased shortly thereafter because frequent collapse of roofs and sides of the mines was caused by the absence of overlying hard rocks and the presence of water seepage. In 1984, the Cherat Cement Co., while drilling for limestone, encountered coal in a faulted sequence with apparently better mine roof conditions. If this coal is persistent over a wider area, then there can be some hope for renewed mining activity. Mapping and detailed structural studies have been proposed by the GSP. Two geologists, plus support for a period of about 0.8 year, would be adequate for this preliminary study.

Baluchistan

Mach and Ab-E-Gum Coal Field.--Despite complicated structure and problems with water, this field continues to produce more than 125 thousand tons of coal per year. The field possesses a location advantage because it is very near the Sukkur-Quetta highway and railway line. Much of the production from the field is apparently used in brick-making in Sind or Punjab. Geologic mapping of the field has recently been completed and mine-site stratigraphic studies are underway. The proposed GAP I would require 20 drill holes averaging 1,000 m in depth, cost about Rs. 69 million, and take approximately 3 years (tables 4 and 10).

Pir-Ismail-Ziarat Coal Field.--Despite a disadvantage in location and a relatively low perceived resource potential, this isolated coal field has now reached an average annual production of 115 thousand tons. The area has received almost no organized or planned exploration, and the true resource potential will not be known until the needed studies are made. At this time, no studies are underway or planned.

The proposed GAP I would require five drill holes at a total cost of Rs. 17.3 million to put 26 percent of the potential identified resources in a demonstrated category. Drilling could be accomplished in 1 year.

Chamalong Area.--This large undefined coal-bearing area is one of the least explored, potentially large, producing coal fields in the country. Eventually, the field will require detailed exploration, but at this time no proposals for exploration have been submitted because of land-ownership problems.

Duki Coal Field.--Exploration activities in this field were concluded in 1985. An exploration program by GSP that started in 1980 resulted in an estimate of about 23 million tons of demonstrated remaining coal reserves. Most, or all, of this estimated reserve is in the area intensively mined by the private sector. Reportedly, there are insufficient resources in the public-sector part of the field to support a proposed 50-MW electric-generating powerplant in the area.

Neither proposed short-term programs nor the long-term resource requirements have been identified. Despite the lack of interest in the field for major new uses of coal, it is probable that 200 thousand tons or more will be produced for the brick industry every year.

Low Priority Areas

Areas such as Johan, Choi, Margat, Abi-Gul, Badinzai, and Balgor will not be considered for exploration unless some new information is obtained that requires reevaluation of their resource potential.

The Kach area is geologically part of the Khost-Sharig-Harnai field. The Sanni locality will remain unevaluated until an exploratory hole is drilled near the old oil-and-gas exploration hole in which coal was reported. It is possible that this reported coal was a coalified log, and the area would thus have no coal resource potential (G. Abbas, 1986, oral commun.). The coal occurrence near Dureji should be studied in reconnaissance to derive some idea about the geologic setting and possible extent of the coal bed that was sampled in Kirthar National Park.

SELECTED BIBLIOGRAPHY

Abbasi, F., Editor, 1985, Sind Coal Symposium, June 27-29, 1985: Proceedings Volume; Mehran University of Engineering and Technology, Jamshoro, 146 p.

Ahmad, N., Raza, M.Z., Shah, S.K., and Sibtain, F., 1986, Briquettability of coal with reference to Pakistan coals, in Khan and Pelofsky, 1986, Coal development potential in Pakistan, p. 473-483.

Ahmed, W.A., Husain, F., Khan, I.A., 1984, Geology and subsurface details of Sonda-Thatta coal field, Sind Pakistan: Geol. Survey Pakistan Geol. Map Series No. 12.

Ahmed, W., 1986, Coal resources of Pakistan, in Khan and Pelofsky, 1986, Coal development potential in Pakistan, p. 25-40.

Ahmed, W., Gauhar, S.H., Siddiqi, R.A., 1986, Coal resources of Pakistan: Geological Survey of Pakistan Records Volume XXIII, 55 p. and appendix.

American Society for Testing and Materials, 1982, Standard classification of coals by rank: ASTM Annual Book of ASTM Standards, pt. 26, D388-82, p. 238-242.

Ansari, B.A., and Abbasi, F., 1985, Problems of Sind coal utility, in Abbasi, 1985, Proc. Vol., Sind Coal Symposium, p. 136-140.

Asifullah, Kh., 1986, Pakistan experience in coal briquettes production, in Khan and Pelofsky, 1986, Coal development potential in Pakistan, p. 463-472.

Averitt, Paul, 1975, Coal resources of the United States, January 1974: U.S. Geological Survey Bull. 1412, 131 p.

Chao, E.C.T., MinKin, J.A., and Thompson, C.L., 1983, Recommended procedures and methodology of coal description: U.S. Geological Survey Circ. 894, 31 p.

Chemical Consultants (Pakistan) Limited, 1985, Feasibility study on the utilization of coal in substitution of other fuels: Vol. 1--Coal resources of Pakistan, 136 p.; Vol. II--Potential for coal substitution in industry, 139 p.; Vol. III--Mining of coal required for substitution of other fuels, 71 p.; Vol. IV--Coal beneficiation tests, 22 p.; Vol. V--Annexures Part I; Vol. VI--Annexures Part II; prepared for the Ministry Petroleum and Natural Resources, Government of Pakistan.

Energy Development International/Price Waterhouse, 1985, The coal industry in Pakistan: requirement for growth: Prepared under U.S. Agency for International Development IQC No. PDC-0001-I-06-313, W.O. No. 6, 168 p., 4 appendixes.

Geological Survey of Pakistan, 1985, PC-II Form and Scheme-Energy Planning and Development, Umbrella Project (Coal Resource Assessment) (1984-88), 25 p., 4 appendixes.

Geological Survey of Pakistan, U.S. Geological Survey, and U.S. Agency for International Development, 1985, Coal resource exploration and development programme, Component 2a, Energy Planning and Development Project (391-0478), 38 p.

Hobbs, R.G., 1979, Guidelines for logging, describing and sampling cores and cuttings of coal and associated rocks at the drill site: U.S. Geological Survey Open-File Report 79-1522, 23 p.

Husain, Farhat, 1986, Sonda, the future coal field of Pakistan, in Khan and Pelofsky, 1986, Coal development potential in Pakistan, p. 125-139.

Khan, M.N., and Pelofsky, A.H., Editors, 1986, Coal development potential in Pakistan: Proc. 1st Pakistan National Coal Conference, Feb. 22-26, 1986; sponsored by Ministry of Planning and Development and Ministry of Petroleum and Natural Resources in cooperation with U.S. Agency for International Development, 628 p.

Landis, E.R., 1986, Coal exploration techniques, in Khan and Pelofsky, 1986, Coal development potential in Pakistan, p. 117-123.

Landis, E.R., Reinemund, J.A., Cone, G.C., Schlick, D.P., and Kebblish, W., 1971, Analyses of Pakistan coals: U.S. Geological Survey Project Report PK-58; Open-File No. 8, April 1973, 71 p.

Little, A.D., Inc., 1985, Preliminary energy sector manpower needs assessment: Prepared for U.S. Agency for International Development and ENERPLAN, May 1985.

Mining Engineer Pakistan, 1985, Special Issue on Sind Coal Symposium 1985: Mining Engineer, Karachi, 79 p.

Nawaz, A.S., 1986, Use of Pakistan coals in industry, in Khan and Pelofsky, 1986, Coal development potential in Pakistan, p. 337-352.

Paracha, S.K., 1986, Private sector coal mining industry in Pakistan, in Khan and Pelofsky, 1986, Coal development potential in Pakistan, p. 529-542.

Reinemund, J.A., Landis, E.R., and Simon, F.O., 1982, Coal resources assessment: U.S. Geological Survey Project Report PK-66, 48 p., 5 attachments.

Sabadell, A., Sheldon, R., Stevenson, G., and Wilson, T., 1986, The application of smokeless briquettes in developing countries: the cases of Haiti and Pakistan, in Khan and Pelofsky, 1986, Coal development potential in Pakistan, p. 445-462.

Shah, S.M.I., Editor, 1977, Stratigraphy of Pakistan: Mem. Geological Survey Pakistan, vol. 12, 138 p.

Siemens Aktiengesellschaft, 1986, Coal fired powerplants at Quetta and Kakhra: Feasibility study sponsored by Habibullah Mines, 30 p.

Survey of Pakistan, 1985, Atlas of Pakistan: Director Map Publication, Survey of Pakisten, Rawalpindi, 129 p.

Swanson, V.E., and Huffman, Clande, 1976, Guidelines for sample collecting and analytical methods used in the U.S. Geological Survey for determining chemical composition of coal: U.S. Geological Survey Circ. 735, 11 p.

USAID and USGS, 1985, Energy Planning and Development Project, Coal Resource Assessment Component 2a: Participating Agency Service Agreement (PASA), IPK-0478-p-IC-5068-00.

U.S. Bureau of Mines and U.S. Geological Survey, 1980, Principles of a resource/reserve classification for minerals: U.S. Geological Survey Circ. 831, 5 p.

Wood, G.H., Jr., Kehn, T.M., Carter, M.D., and Culbertson, W.C., 1983, Coal resource classification system of the U.S. Geological Survey: U.S. Geological Survey Circ. 891, 65 p.

APPENDIXES A, B, AND C

NATIONAL COAL EXPLORATION PLAN

APPENDIX A

Coal Resource Classification

A detailed resource classification system should identify deposits of coal by areal location, distance from points of information, thicknesses of coal and overburden, quality, and estimates of quantity. Classes in the system, furthermore, should impart some idea as to economic, technologic, legal and environmental factors affecting the availability of coal (Wood and others, 1983).

The classification system used by the U.S. Geological Survey and U.S. Bureau of Mines provides a definitive coal resource classification system with standard definitions, criteria, guidelines, and methods to be used in estimating coal resources.

The following is extracted from USGS Circular 891, "Coal resource classification system of the U.S. Geological Survey" by Wood and others, 1983.

The classification system presented herein employs a concept by which coal is classified into resource/reserve base/reserve categories on the basis of the geologic assurance of the existence of those categories and on the economic feasibility of their recovery. Categories are also provided for resources/reserve base/reserves that are restricted because of legal, environmental, or technologic constraints. Geologic assurance is related to the distance from points where coal is measured or sampled; thicknesses of coal and overburden; knowledge of the rank, quality, depositional history, areal extent, and correlations of coal beds and enclosing strata; and knowledge of the geologic structure. Economic feasibility of recovery is affected not only by such physical and chemical factors as thicknesses of coal and overburden, quality of coal, and rank of coal, but also by economic variables - such as price of coal, cost of equipment, mining, labor, processing, transportation, taxes, and interest rates, demand for and supply of coal, and weather extremes - and by environmental laws, restrictions, and judicial rulings.

The classification system is designed to quantify the total amounts of coal in the ground before mining began (original resources) and after any mining (remaining resources). It is also designed to quantify the amounts of coal that are known (identified resources) and the amounts of coal that remain to be discovered (undiscovered resources). The system also provides for recognizing amounts of coal that are (1) standard distances from points of thickness measurements - measured, indicated, inferred, and hypothetical; (2) similar to coal currently being mined (reserve base and inferred reserve base); (3) economically recoverable currently (reserves and inferred reserves; (4) potentially recoverable with a favorable change in economics (marginal reserves and inferred marginal reserves); and (5) subeconomic because of being too thin, too deeply buried, or lost-in-mining. Finally, the system allows tabulation of coal amounts that are restricted from mining by regulation, law, or judicial ruling.

Two factors have created difficulties in categorizing resources and reserves in all classification systems. First, most geologists and engineers who classify resources and reserves are not experts in the economics of mining, transportation, processing, and marketing. Second, economic conditions change with time, so that the economic viability of coal is relatively fluid. For example, subeconomic resources of today can become reserves of tomorrow as the price of coal rises; conversely, reserves can become subeconomic resources as the price of coal drops. Finally, changing regulations, laws, and judicial rulings can affect mining, transportation, processing, and marketing, and thus the classification of coal resources. The concept of a reserve base was developed to alleviate these difficulties (U.S. Geological Survey, 1976, p. B2).

The reserve base is identified coal defined only by physical and chemical criteria such as thickness of coal and overburden, quality, heat value, rank, and distance from points of measurement. The criteria for thickness of coal and for overburden have been selected so that the reserve base includes some currently subeconomic coal. The concept of the reserve base is to define a quantity of in-place coal, any part of which is or may become economic depending upon the method of mining and the economic assumptions that are or will be used. An additional purpose is to aid in long-range public and commercial planning by identifying coal suitable for economic recovery.

Thus, resource specialists need not expend their time identifying the component part of coal deposits that are currently economically recoverable (reserves) because the reserve base category contains much of the coal that will be classed as reserves in the foreseeable future. Those required to classify coal as being economically recoverable, marginally recoverable, or subeconomic can examine reserve base estimates to locate such coal.

Figures 1 and 2 are conceptual diagrams modified from Circular 831 (U.S. Geological Survey, 1980) that show the relationships of the various classes of coal resources, the reserve base, and reserves. The classes are categorized in both figures according to their degree of geologic assurance (geologic assurance or proximity to points of control increases to the left), and according to their degree of economic feasibility of recovery (economic feasibility of mining increases upward). The resource/reserve base/reserve categories (classes) that can be used are not limited to those shown in figures 1 and 2 nor to the categories described in succeeding pages. For example, a particular bed of coal may be identified as being low-sulfur (0-1 percent), low-ash (0-8 percent), high-volatile A bituminous, and premium coking coal; other beds of coal may be identified as medium-sulfur (1.1-3.0 percent), high-ash (>15 percent), high-volatile bituminous, surface-minable

RESOURCES OF COAL

AREA: (MINE, DISTRICT, FIELD, STATE, ETC.) **UNITS:** (SHORT TONS)

CUMULATIVE PRODUCTION	IDENTIFIED RESOURCES			UNDISCOVERED RESOURCES	
	DEMONSTRATED		INFERRED	PROBABILITY RANGE (or)	
	MEASURED	INDICATED		HYPOTHETICAL	SPECULATIVE
ECONOMIC	RESERVES		INFERRED RESERVES		
MARGINALLY ECONOMIC	MARGINAL RESERVES		INFERRED MARGINAL RESERVES		
SUBECONOMIC	SUBECONOMIC RESOURCES		INFERRED SUBECONOMIC RESOURCES		

OTHER OCCURRENCES	INCLUDES NONCONVENTIONAL MATERIALS

BY: (AUTHOR) DATE:

A PORTION OF RESERVES OR ANY RESOURCE CATEGORY MAY BE RESTRICTED FROM EXTRACTION BY LAWS OR REGULATIONS.

FIGURE 1.—Format and classification of coal resources by reserves and subeconomic resources categories.

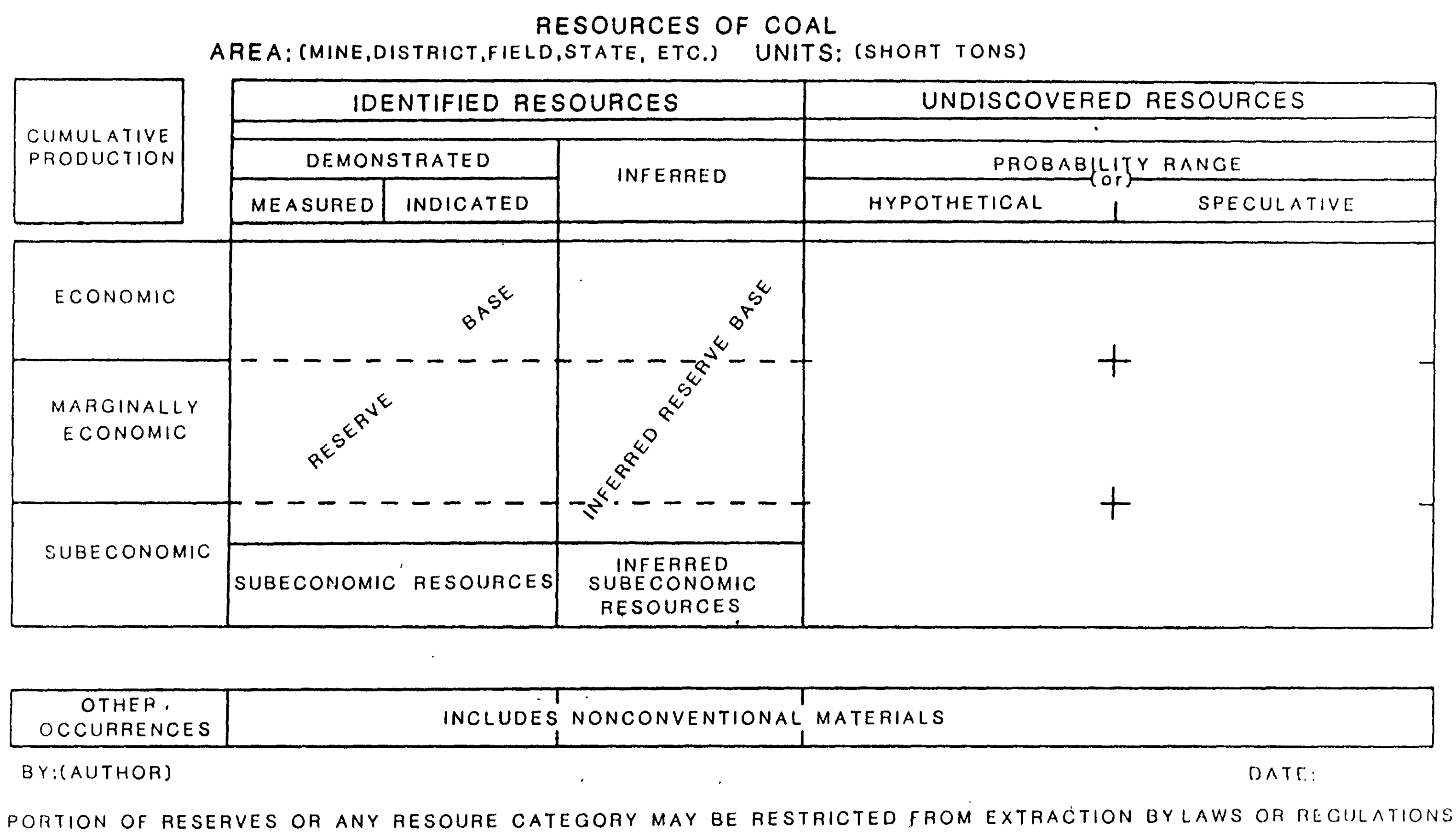


FIGURE 2.—Format and classification of coal resources by reserve and inferred reserve bases and subeconomic and inferred subeconomic resources categories

cannel coal, and so forth. The ability of the classification system to precisely describe the characteristics of a body of coal allows the coal resources of the United States to be divided into many hundred resource classes or categories.

The hierarchy of coal resources shown in figure 3 illustrates the conceptual relationships between the classes of resources as distinguished by their definitions and criteria. Examination of figures 1, 2 and 3 makes clear that each succeeding class in the hierarchy from original and remaining resources to reserves is included in the overlying classes. Original resources include remaining resources and cumulative depletion. Remaining resources include identified and undiscovered resources (divisible into hypothetical and speculative resources). Identified resources include measured, indicated, inferred, and demonstrated resources. Measured and indicated resources contain coal classed as reserve base, and inferred resources contain coal classed as inferred reserve base. Some measured, indicated, and inferred resources are subeconomic because they are too thin to mine or are buried too deeply to be mined by current extraction techniques; furthermore, parts of the reserve base and inferred reserve base are potentially subeconomic because they will be lost-in-mining. Reserves and inferred reserves are economically minable as of the time of classification. The reserve base and inferred reserve base also contain some coal that is believed to be potentially economic and which is classed as marginal and inferred marginal reserves.

Of particular importance is the resource/reserve base/reserve relationship.

HIERARCHY OF COAL RESOURCES[1]

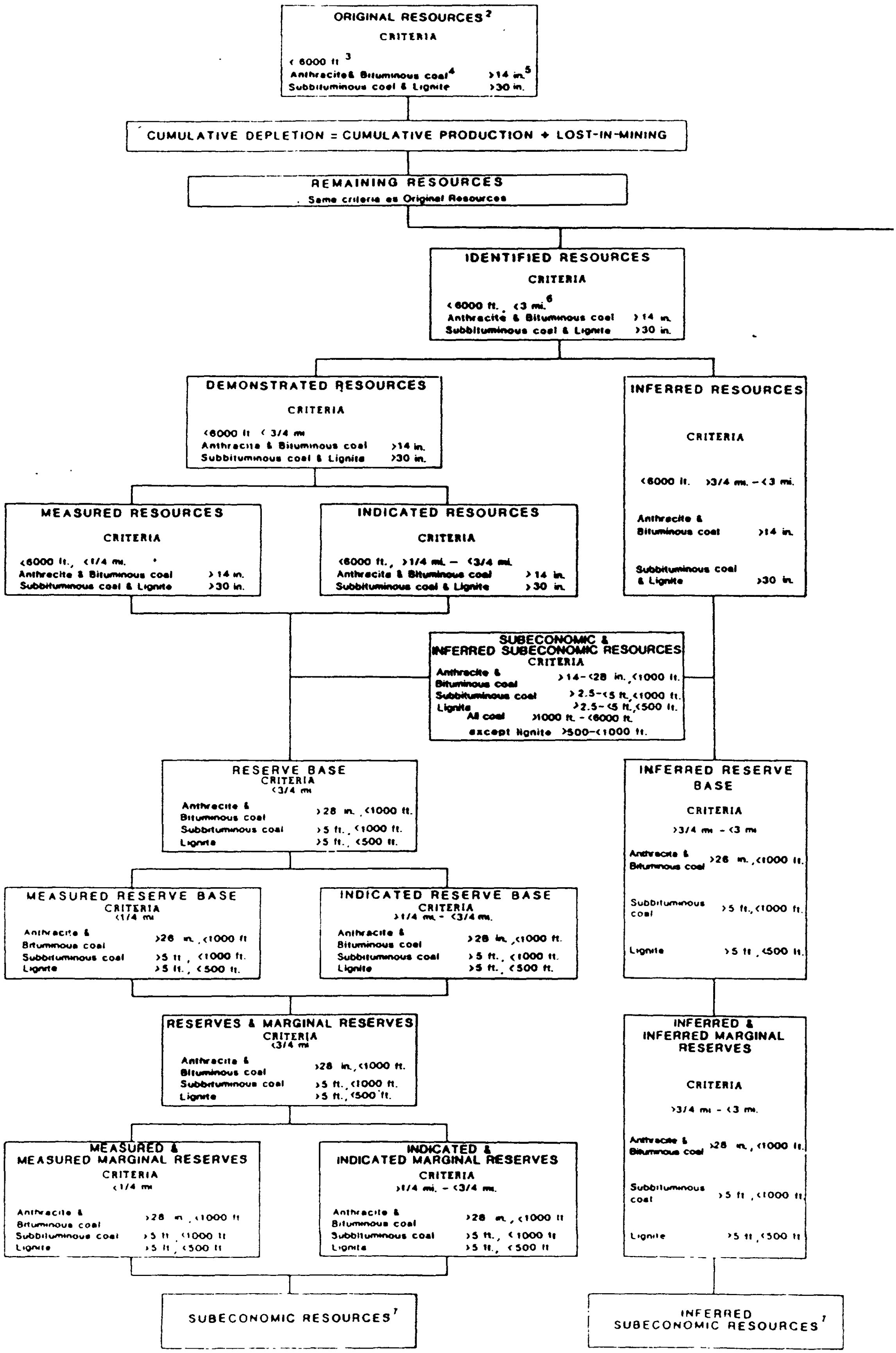
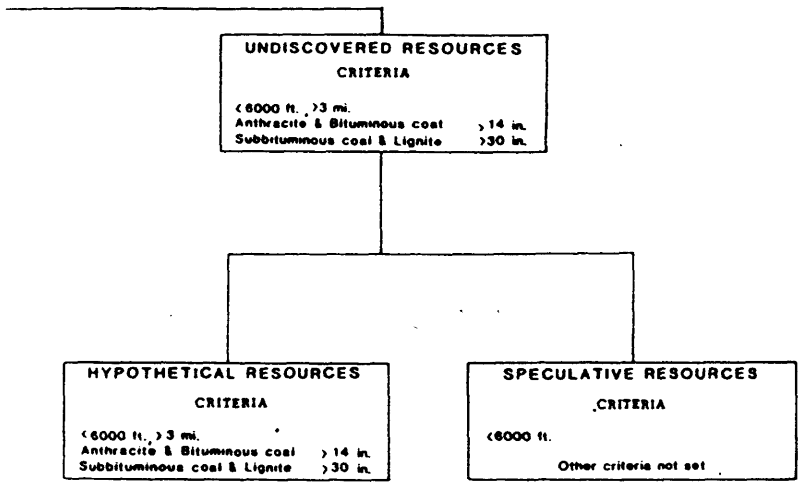


Figure 3. Heirarchy of coal resources and criteria for distinguishing resource categories.



1. Coal resource terms are defined in glossary.
2. Resources before mining.
3. 500 ft., 1000 ft., and 6000 ft. Depth of burial or overburden thickness.
4. Anthracite, bituminous, subbituminous, and lignite are ranks of coal. See Table 1
5. 14 in., 28 in., 30 in., and 5 ft. are minimum thicknesses of coal.
6. 1/4 mi., 3/4 mi., and 3 mi. are distances from points of measurement of coal thickness.
7. Includes coal left in room and pillar mining, in property barriers, coal too thick to be recovered completely by conventional mining, and mine and preparation plant waste.

NOTE

OTHER OCCURRENCES

Includes coal:

a) less than minimum thickness at any depth
b) containing more than 33 weight percent ash on dry basis
c) buried at depths of more than 6,000 feet

Estimated tonnage, where calculated, is to be reported as "Other Occurrences" and not as resources, unless mined. Where mined, tonnage quantity is included in reserve base and reserve estimates.

Figure 3. continued.

Resources are naturally occurring concentrations or deposits of coal in the Earth's crust, in such forms and amounts that economic extraction is currently or potentially feasible. It is the total quantity of coal in the ground within specified limits of bed thickness and overburden thickness (Averitt, 1975). In the United States, tonnage estimates by the USGS for coal resources are determined by summing the estimates for identified and undiscovered deposits of coal that are 14 inches (35 cm) or more thick for anthracite and bituminous coal and under less than 6,000 feet (1,800 m) of overburden, and 30 inches (75 cm) or more thick for lignite and subbituminous coal and under less than 6,000 feet (1,800 m) of overburden. The specified limits can be modified or amended for particular purposes. For example, in Pakistan it would be desirable to amend the lignite and subbituminous coal specific limits to include coal thinner than 30 inches (75 cm) because coal between 12 inches (30 cm) and 30 inches (75 cm) in thickness is mined in some areas.

Reserve base is those parts of the identified resources that meet specified minimum physical and chemical criteria related to current mining and production practices, including those for quality, depth, thickness, rank and distance from points of measurement. In the United States, the criteria used by the USGS for the reserve base include anthracite and bituminous coal 28 inches (70 cm) or more thick, subbituminous coal 5 feet (1.5 m) or more thick that occurs at depths to 1,000 feet (300 m), and lignite 5 feet (1.5 m) or more thick that occurs at depths to 500 feet (150 m). As mentioned previously, these specific criteria would need to be amended for Pakistan coals. Assignment of coal to a reserve base is controlled by physical and chemical criteria such as categories of reliability, thicknesses of coal and overburden, rank of coal, and knowledge of depositional patterns of coal beds, and associated structural features. Changing economic, technologic, and environmental considerations do not control assignment of coal to a reserve base (compare with following description of reserves).

Reserves (Wood and others, 1983) are the parts of a coal reserve base which could be economically extracted or produced at the time of determination considering environmental, legal, and technologic constraints. Reserves include only recoverable coal that is economically producible at the time of classification and the term need not signify that extraction facilities are in place or operative. Reserves can be categorized as measured and indicated, as underground or surface minable, by thickness of overburden, by thickness of coal in the bed, and by various quality factors. Reserves, which are derived from reserve base coal, exclude coal thinner or deeper than that classified as reserve base unless such coal is currently mined. Reserves are estimated by determining the amount of coal in each reserve base category that can be extracted at the time of classification. This amount plus the amount that will be lost-in-mining or is otherwise unrecoverable are equal to the reserve base.

Recovery factors are ideally determined and applied on a local basis considering what method or methods of mining have been or will be used and the legal or environmental factors that may affect recovery. For large areas, local recovery factors may not be applicable or known, and the USGS recommends applying a recovery factor of 50 percent to the reserve base.

In general, USGS estimates of resources and the derived reserve base are intended for use by local and national planners and for use in delineating further exploration, development and utilization activities. Resource and reserve base estimates are of long-term value and are generally only changed substantially by addition of new data.

In contrast, reserves are used primarily to determine economic feasibility and are subject to application of changing criteria. A reserve estimate may have little or no long-term credibility.

APPENDIX B

Coal Exploration Techniques

Exploration has been defined as "searching through or into, penetrating or ranging over for discovery, examining thoroughly, striving to attain by search." In analogy with research, exploration may be basic with few or no preconceptions about that which may be found, and is, designed to yield information of certain types about particular subjects. In practice, exploration consists of a great number and variety of physical and mental activities and involves a broad spectrum of information collection.

During the course of exploration, it almost always becomes necessary to develop subsurface information about the coal and coal-bearing rocks. In most parts of the world, subsurface information is most economically collected in a timely manner by drilling exploration boreholes. The classical form of borehole drilling is done with drill rigs designed to recover cores of the material penetrated by the borehole. Coring is commonly done from "the grass roots" to total depth. In relatively recent years, much exploratory drilling for coal has been done with rotary-type drill rigs designed to make a hole while also yielding rock cuttings as drilling progresses, but not to recover cores. In essence core drill rigs are designed to make a hole while recovering a core sample of the material penetrated.

However, to complicate matters, core drill rigs can drill open holes and not recover cores, and rotary drill rigs can recover cores. Both drill rigs do produce cuttings of materials penetrated regardless of whether they are coring or making open hole, and with both types of drilling, core-recovery is seldom 100 percent and may be much less (particularly in coal). Both types of drill rigs have advantages and disadvantages.

In modern practice, geophysical methods are used as supplements to both forms of drilling. Geophysical borehole logging provides much information about the rocks penetrated by the drill holes. For example, the geophysical log can often identify where loss of core has taken place and also what rocks were not recovered during coring. In rotary drilled open holes, the geophysical borehole log can establish the location and thickness of particular rocks in the sequence that was penetrated. Obviously, geophysical logs can be of crucial importance in activities such as coal exploration where "quantity" information--presence, depth, thickness--is vital. Geophysical logs also can be used for prediction of some "quality" factors such as ash content, and much research is underway for other applications. A great variety of geophysical methods have been employed in coal exploration. Electrical sounding and both high-resolution and conventional seismic methods are used to help define the stratigraphic and structural setting of coal beds, coal zones, and coal-bearing rocks. Magnetic methods have been applied with considerable regional and local success in areas where coal beds have burned in place, and both gravity and magnetic methods have been used to delineate intrusive rock masses and buried hills. Satellite imagery, particularly with computerized enhancement, has been widely used to determine the extent of coal-bearing and related rock units, and to locate faults and fracture systems that are not observable to their full extent in ground or lower-level photographic studies. New techniques such as side-looking airborne radar imagery may help in studies of structurally and stratigraphically complex areas.

APPENDIX C

Acknowledgments

The authors are deeply indebted to a large number of people who were consulted about all or parts of the NCEP. All the discussions were helpful. Much of what was learned is not directly mentioned or attributed in the report but forms part of the memory bank of background data that is of inestimable value in an endeavour of this kind.

The following listing of individuals and organizations is not complete but is presented to illustrate the breadth and depth of our interests in connection with development of the NCEP. The listing is chronological according to the sequence of interviews.

Pakistan Council of Scientific and Industrial Research (PCSIR):

Dr. Nisar Ahmed, Director of Fuel Research Center

Pakistan Mineral Development Corporation (PMDC):

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Siddique, Planning Assistant

Energy Planning and Development Project (ENERPLAN):

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A.M.I. Haque, Deputy Managing Director

I.A. Rizvani, Energy Specialist (Coal)

Ministry of Petroleum and Natural Resources:

M.N. Khan, Secretary, Mineral Coordination Board

M.S. Hasan, Deputy Secretary

Water and Power Development Authority (WAPDA):

G.M. Ilias, Chief Engineer, Coal Power Projects

Provincial Government of Punjab:

R.M. Sultan, Chief Inspector of Mines and President, Mining Engineers Association of Pakistan

State Cement Corporation of Pakistan, Ltd., (SCCP):

G.A. Qureshi, Director, Research and Development

Z.H. Rizvi, Deputy General Manager

Punjab Mineral Development Corporation (PUNJMIN):

B.A. Gill, General Manager (Planning and Operations)

Katha Collieries, Ltd.:

M.R. Ahmed, Managing Director and President All Pakistan Mine Owners Association

Punjab Directorate of Industrial and Mineral Development:

M.A. Beg, Joint Director (Mineral Development)

C.M. Naseeb, Director

I.V.H. Qureshi, Deputy Director

I.A. Khokhar, Deputy Director

Provincial Government of Baluchistan:

S.K. Paracha, Minister for Planning and Development Chairman, Private Mine Owners Association of Pakistan, and Manager, Habibullah Mining Limited

M. Afzal, Deputy Director, Mineral Development Cell, Directorate of Mineral Development

Oil and Gas Development Corporation of Pakistan (OGDC):

A. Kemal, General Manager

N. Qazi, Exploration Manager

S.H. Rizvi, Senior Test Geologist

A.S. Khan, Deputy Chief Geologist

M. Sultan, Deputy Chief Geologist

V.N. Quadri, Manager, Offshore Development

S.M. Shuaib, Geologist, Offshore Development

Provincial Government of Sind:

B.A. Ansari, Chief Inspector of Mines

Union Texas Petroleum (Union Texas Pakistan Incorporated):

F.A. Krieg, Exploration Manager

T. Hargreaves, Chief Geologist

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