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COAL FIRED POWER GENERATION POTENTIAL OF BALOCHISTAN

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Abstract

Socio-Economic development in Balochistan has always been stressed due to the lack of an adequate and dependable electricity supply. To meet the needs for power generation not only over burden that existing infra-structure but also put pressure on oil and gas resources. The share of coal in the power generation of Pakistan is merely 1%. The unexploited coal resources of Pakistan may generate more than 100 GW of electricity for the next 30 years by converting coal to a clean gas, which can then be burned like natural gas with combined-cycle turbine. Balochistan coal reserves are 217 MT including 32 MT mineable, of sub-bituminous to bituminous rank, heating value ranges from 9,637 to 15,499 Btu/lb, coal seam thickness ranges from 0.3 to 2.3 meter. It contains low ash and high sulfur and considered suitable for power generation. Small power plants up to 25 MW can be setup in each coalfield.

Key words: Coal Resources; Pulverized Coal Steam generator ; Power Generation; Balochistan.

1. Introduction

Pakistan is known as a land of natural beauty, grandeur and is the home of a culture as ancient, complex and striking as many in the world. The landscape varies from lofty Karakoram and Himalaya mountains to the famous desert of Thar and includes fertile plains of the river Indus [1].

Pakistan is one of the developing countries with very low energy consumption, high population growth rate and managing to improve its living standards by increasing its energy production for the development of industrial base country [2]. The consumption of energy is one of the critical indicators of the level of development of any country. Despite enormous potential of energy resources, the country remains energy deficient and has to rely heavily on imports to meet its requirement [3].

Electricity is playing a vital role in prosperity and economical development of any country. Demand of electricity is increasing day by day; today 60% population of Pakistan has access to electricity [4]. The role of renewable energy resources has been negligible in the total energy picture of Pakistan. Previous research in renewable sources of energy were not believed to be fruitful due to lack of understanding and handling of technologies [5].

In 2002, demand and supply projection indicates that power shortage will appear in 2006 and reaches to 5,500MW in 2010 [3,6]. The importance of coal in Pakistan is now realized because of Hydel Power declination; high oil prices and NG depletion [7]. Solution for the energy crises in Pakistan could be defended by the utilization of 175.5 million tons of Thar coal, discovered in 1992 by Sindh Arid Zone Development Authority (SAZDA) with collaboration of British Overseas Development Agency (ODA) [4]. Pakistan's coal resources may generate more than 100 GW of electricity for the next 30 years [4], unfortunately 150 MW power plants has been installed [8-13].

2. Coal Resources of Pakistan

In Pakistan, coal deposits presence was known before of independence. Its economic value was highlighted in the late 80's, when large reserves of coal were discovered in the

Lakhra and Sonda area of Sindh. In 1992 deposits of 175.5 Billion tones was discovered in an area of 9000 sq. km in Tharparkar Desert [3, 4]. Coal reserves exits in Sindh, Balochistan, Punjab, Khyber Paktun Khuwa (formerly known as NWPF) and Azad Jamu Kashmir, estimated about 185.5 billion tons of Lignite to sub-bituminous ranks details are shown in Table 1 [3].

The importance of coal as industrial fuel is well known in the industrialists, because of its low price and good heating value, but the high emission of the coal flame is a distinct advantage. Initially coal was not used as fuel in the cement plants, now cement industry realized the importance of Coal as a fuel and started using the coal [3]. It is used for direct firing in the manufacture of cement, bricks, pipes, glass tanks and metal smelting, and as boiler fuel for the supply of steam to process plant in the paper, chemical and food processing industries. In the brick kiln, it is estimated that one ton of coal have same energy potential as of one tone oil. Pakistan coal consumption by industrial sector wise is given in Fig. 1[3].

Table 1. Coal Reserves of Pakistan (MT)[3]

S. No	Province	Coal Resources
1	Sindh	184,623
2	Balochistan	217
3	Punjab	235
4	Kyber Pkhtun Khuwa	91
5	Azad Jamu Kashmir	9
Total		185,175

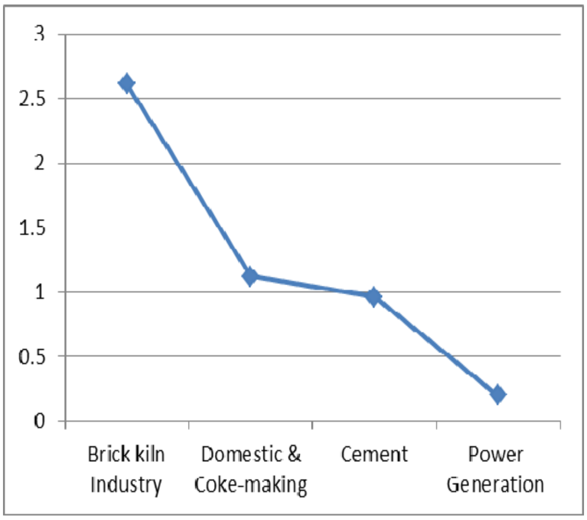

Fig. 1 Coal Consumption by sector wise in Pakistan (MT)

3. Balochistan Coal Resources, Accessibility and Quality

Balochistan have five coal areas where mining activities are in progress, these are Dukki, Khost-Harnai, Sor Range-Deghari Pir Ismail Ziyarat and Mach as shown in Fig. 2, producing about 50% of the total coal production of Pakistan. Coal reserves of Balochistan in different fields are shown in Fig. 3. The present status of the coal potential of the province stands mostly on the work done in the previous years. However, Dukki coal field has been explored and assessed to an initial level with maximum collection of data on proper scientific formats [14].

3.1. Dukki Coal Field

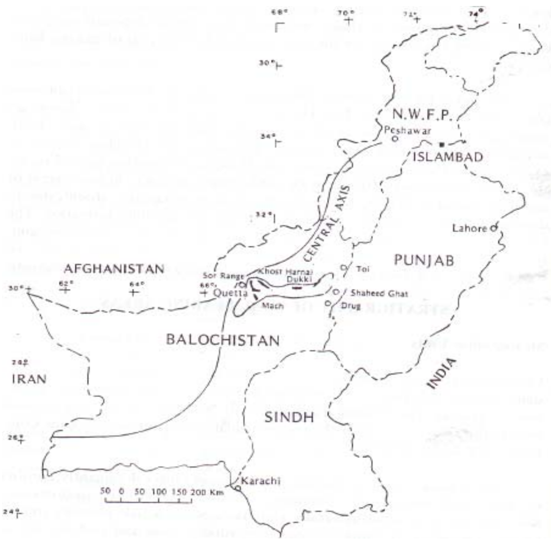

Fig. 2 Locations of Coal Fields in Balochistan

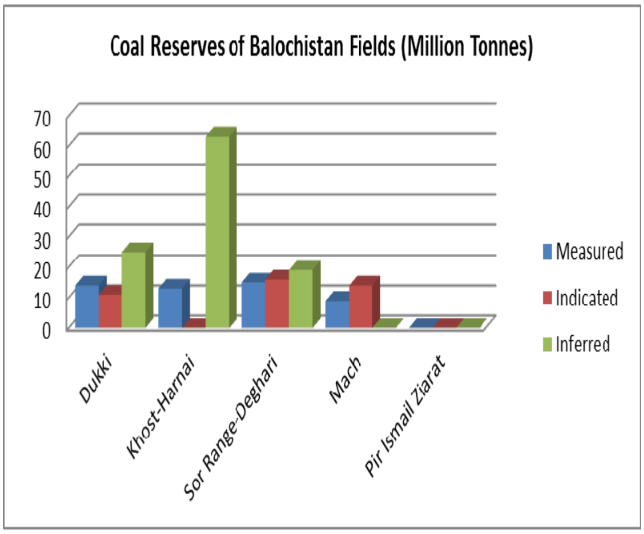

Fig. 3 Coal Reserves of Balochistan in different Fields (MT)

Dukki field lies in Pakistan topographic sheet Nos. 39 B/8,12 and 16 and 39 C/5,9 and 13, between 29°45' to 30°15' and 68°15' to 69°0'on Latitude and Longitude respectively. Dukki is about 320 km from Quetta in the east, forms the center of activities from where the entire mining area is approachable by fair weather roads. Geological investigation has been conducted by Geological Survey of Pakistan (GSP) with the support of the Water and Power development Authority (WAPDA). The investigation includes geological mapping on the scale of 1:50,000, followed by the detailed mapping on the scale of 1:25,000 of selected areas and the collection of the data on coal seams on the scale of 1:1000, have been done as shown in Fig. 4 [14].

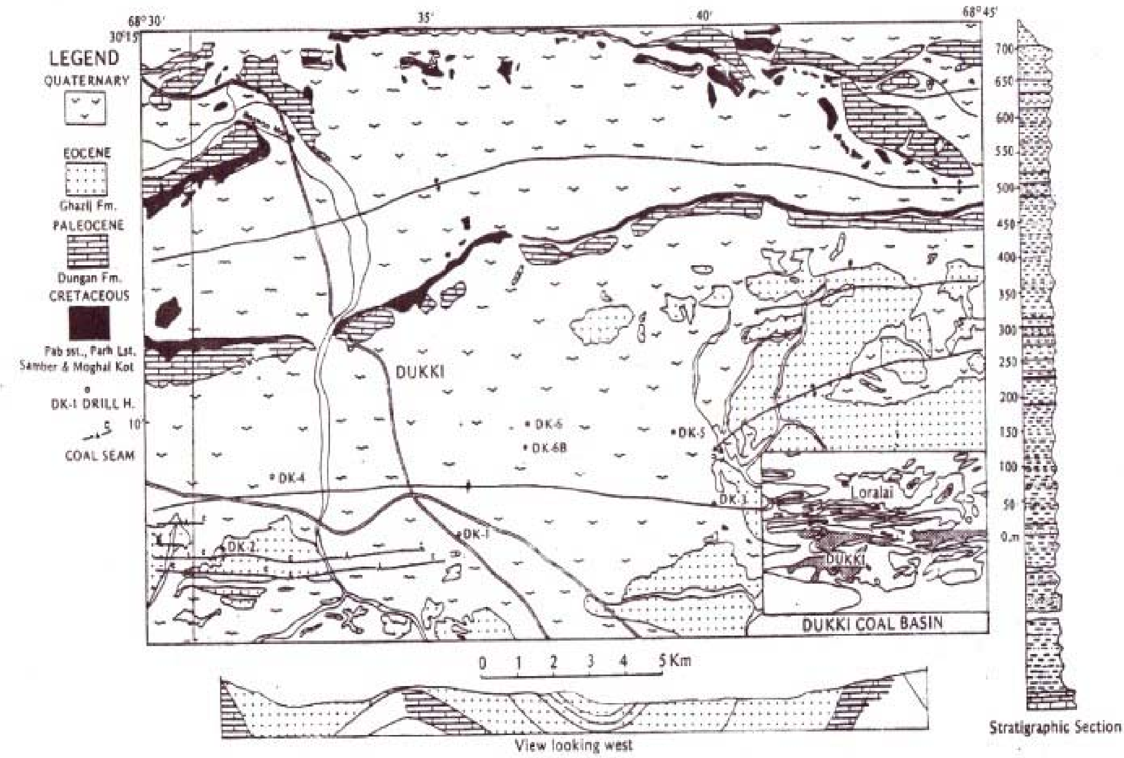

Fig. 4 Geological map of Dukki coal field, Balochistan [14]

The Dukki coal field contents maximum number of coal seams as compare to the other coal fields of Balochistan. The coal seams range in thickness from 0.15 to 2.30 m. A 1,080 m thick coal-bearing horizon contains four separate coal zones of 15, 22, 36 and 92 m thickness [14]. Coal of this filed is black, brownish black as well as fissile to laminated at places. The roof and floor of the coal seams is claystone, with variation of sandstone at a few places. Average BTU values of most coal beds in Dukki range in rank from sub-bituminous B to C with a few exceptions of sub-bituminous A and some beds are lignite [14-18].

Calorific values per pound of coal determined on air dried basis range between 9500 to 14515 BTU/lb. However, the general range is between 10,131 to 14,164 BTU/lb. calorific value of is more reliable for 19 to 27 MW small power plant [3]. Dukki coal quality is shown in Table 2 [3].

3.2 Khost-Harnai Coal Field

This in one of the oldest coal field of Indo-Pakistan. Coal filed lies on topo Sheet Nos. 34 N/12 and 34 N/16, located about 200km in southeast of Quetta, connected with Quetta by part metalled and a long distance fair weather, Shingle road, Hernia, Shahrig and Khost towns are connected by railway line with Sibi. The area has been mapped by the GSP on 1: 250,000 and 1:50,000 scale and coverage of 1000 sq. km has been done 1:25,000 scales Fig. 5 [14]. The coal bearing zone of the formation is about 120 m thick and contains several coal seams, varying in thickness from a few cms to 1.3 m. In general the thickness of the coal seam ranges between 0.5 to 0.9 m, the maximum thickness attained by coal seam is much as 3.5m. Geology of Khost-Harnai is composed of clay stone, silt stone and sand stone of similar colors [14-18].

Quality of Sor-range -Deghari has been classified between sub-bituminous, with calorific value of 11,245 to 13,900 BTU/lb, which can be considered suitable for power generation of capacity ranging between 21 to 26 MW [3].The coal quality of field is highlighted in Table 2 [3].

The Khost-Harnai ranges in rank from Lignite to Bituminous B, the average rank of coal range between sub-bituminous C to A. Analysis of coal sample shows the calorific value from 9,637 to 15499 BTU/lb on as received basis, 18-29 MW small power plant may be operated on this filed [3]. Coal quality of field is shown in Table 2 [3].

3.3. Pir Ismail Ziarat Coal Field

The Pir Ismail-Ziarat coal field lies in topo sheet Nos. 34 N/8 and 34 O/5, about 96 km in south of Quetta, having almost equal distance from Quetta and Spezent railway station and this filed connected with the fair weather road to the Sor-range and Deghari area [14].

Pir Ismail Ziarat coal filed is the newest and the smallest coal field of Balochistan. GSP has geological mapped part of the area on the scale of 1:250,000. Coal is found in the Toi Formation in which 3 to 4 coal seams are reported from this coal field. The thickness of the upper seams ranges from 0.6 to 0.7 m and that of the lower from 0.4 to 0.45 m as shown in Fig. 6 [14].The coal quality differs at various places with in the field. It is mostly brownish black while bright black coal is common. Analysis of coal sample shows the calorific value ranges from 8006 to 10940 BTU/lb on as received basis, 15 to 20 MW small power plants may be operated on this filed [3]. Coal quality of field is shown in Table 2 [3].

3.4. Sor Range Deghari Coal Field

The Sor-range Deghari coal field has been in operation for the past one hundred years, field lies on topo sheet Nos. 34 N/4 and 34 N/5 and covers an area of 230 km in Quetta and Kalat districts. Metaled road encircles the entire coal field with centers of active mining at Deghari Sinjidi, Good Hope and Sor-range areas. For the Sor-range coal field, Quetta is the nearest station [14].

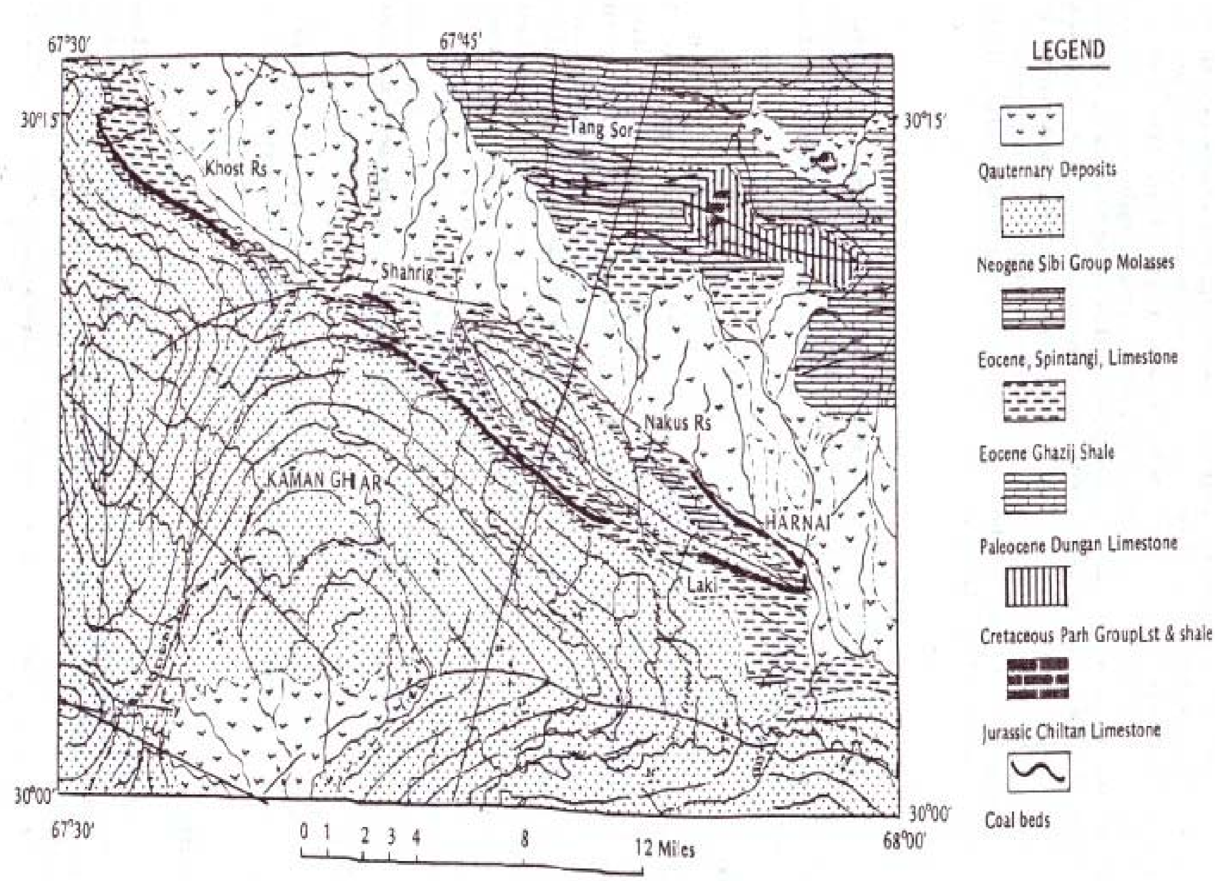

Fig. 5 Geological map of Khost-Shahrig-Harnai coal field, Balochistan [14]

The thickness of the coal bed ranges from 0.3 - 1.3 meters. Detailed topo and geologic maps were prepared and preliminary assessment of coal resources was been made as shown in Fig. 7[14]. The composition of the coal bearing horizon is mainly clay stone of bluish, grey, reddish grey, pale yellowish grey and maroon color with a few beds of sand

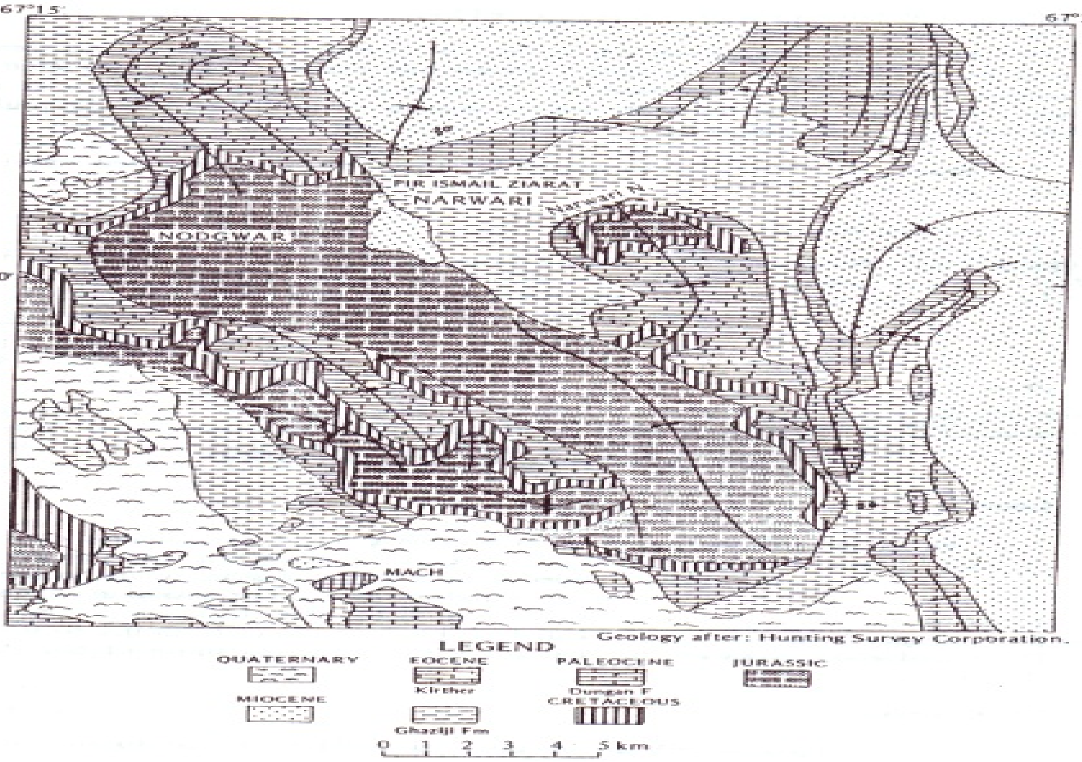

Fig. 6 Generalized geological map of Pir Ismail Ziarat coal field, Balochistan[14]

stone of grey shades [14-18].

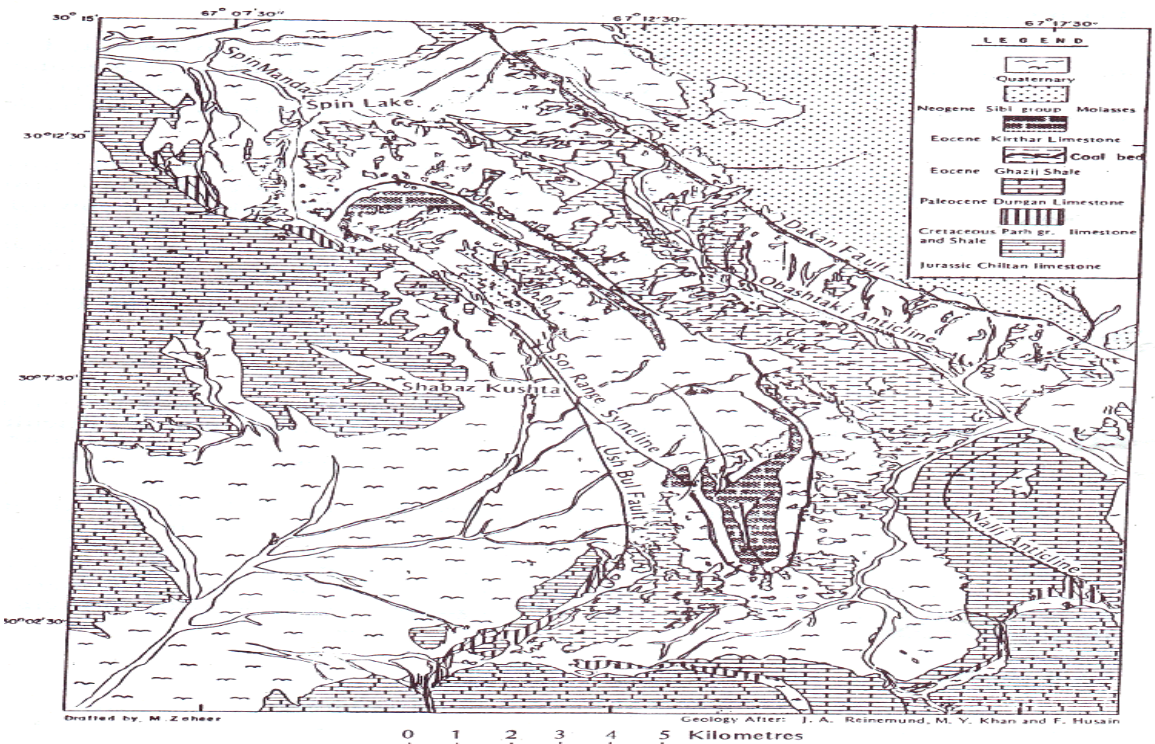

Fig. 7 Geological map of Sor Range-Deghari Coal field, Balochistan [14]

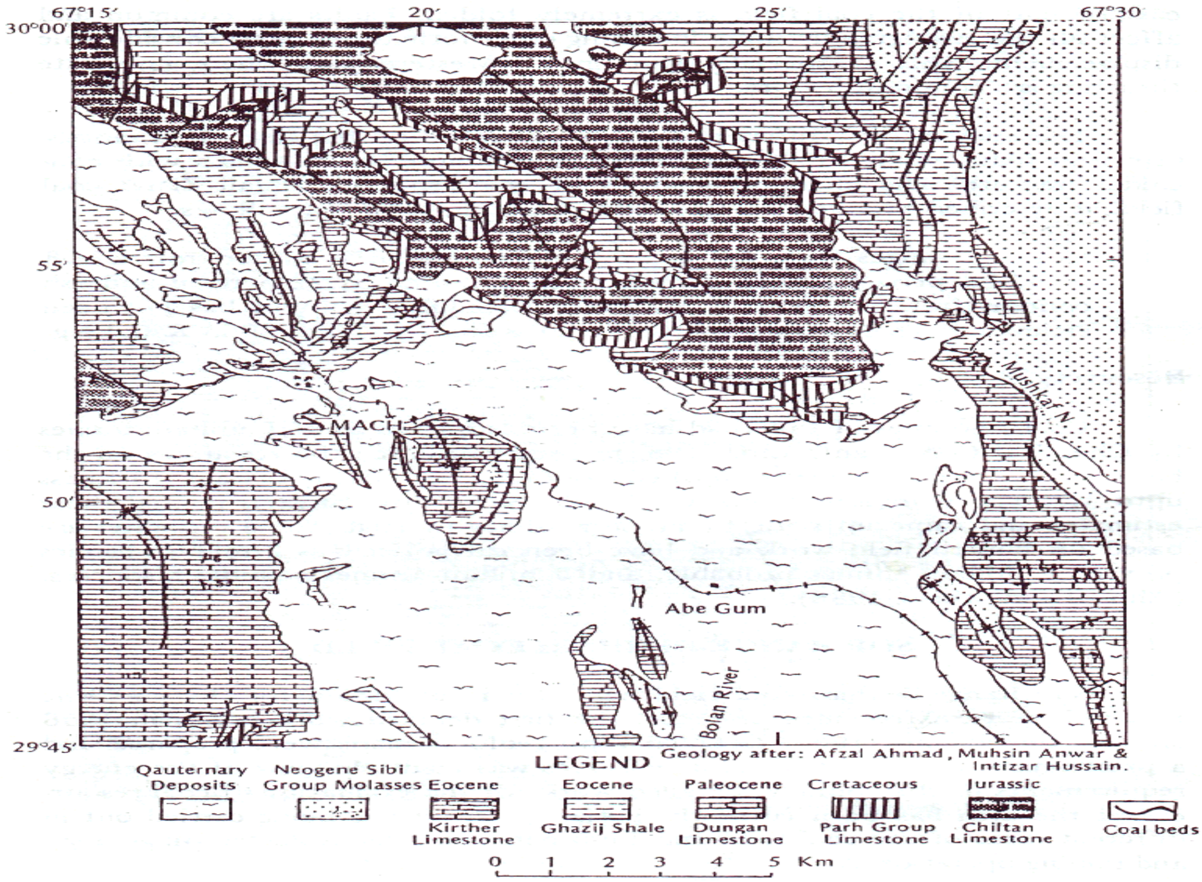

Fig. 8 Geological map of Mach Coal field, Balochistan [14]

3.5.Mach Coal Field

Mach coal field lies in topo sheet No. 34 O/5 within a few kilometer radius of Mach railway station in Kachhi and Kalat Districts, having about 50 sq. km. of presently know coal field area. The station is situated 65 km from Quetta of Sibi-Quetta rail road which passes through the historic Bolan Pass. Coal in Mach area has been known since pre-partition times. The area has been mapped on 1:50,000 and 1: 25, 0000 scales are available as shown in Fig. 8 [14].

Several coal seems are present in ranging in thickness from 0.3 m – 1.5 m but only 3 beds with an average thickness of 0.75 m are commercially workable. The quality of coal is sub bituminous [14-18]. The coal can be subjected to spontaneous combustion and is suitable for power generation of 21 to 24 MW [3]. The coal quality analysis is given at Table 2 [3].

Table 2 Coal Quality of different fields of Balochistan [3]

Parameters	Coal Fields				
	Dukki Coal	*Khost-Harnai*	*Pir Ismail Ziyarat*	Sor Range Deghari	Mach
Moisture (%)	03.50-11.50	01.70-11.20	05.2 – 10.0	03.90 – 18.90	07.10 – 12.00
Ash (%)	05.00-38.00	09.30-34.00	13.36 – 43.47	04.90 – 17.20	09.6 – 20.30
Volatile Matter (%)	32.00-50.00	09.30-45.30	27.08 – 41.56	20.70 – 37.50	34.20 – 43.00
Fixed Carbon (%)	28.00-42.00	25.50-43.80	21.96 – 37.22	41.0 – 50.80	32.40 – 41.50
Sulfur (%)	04.00-06.00	03.50-09.55	NA	0.60 – 05.50	03.20 – 07.40
Calorific Value (BTU/lb)	10,131-14,164	9,637-15,499	8,006 – 10,940	11,245 – 13,900	11,110 – 12,370

4. Characteristic and Utilization of Balochistan Coal

Coal can be classified in many ways but the classification by rank that is, by the degree of metamorphism of the coal- is the most commonly used system classification by the type of plant material, and by type and quantity of impurities (grade) is also used [14-18].

The position of a coal within the metamorphic series which begins with peat and ends with graphite. The increase in rank of coal, is indicated by in its constituents- the higher rank coals have more carbon and less hydrogen and oxygen than lower rank coal [14]. To two forms of analyses- the proximate and the ultimate analysis are used to determine the rank of coal [14].

The ASTM “apparent” rank classification of Balochistan coal are given in the Table 3. Although the ASTM classification does not include coals with less than 48 percent dry, mineral-mater-free fixed carbon, the samples of that type of coal have been used in the rank determination shown in Table 3 [14].

Lurgi *et al.* conducted extensive research on 57 tons of coal to produce lump coke [14]. The research has shown that,

1. The Shahrig coal was found unsuitable for making a metallurgical grade product
2. The Sor Range coal produced a metallurgical grade coke under closely controlled and high selective conditions
3. The Deghari coal by itself was found unsuitable but could be used when mixed with the Sor range coal provided sulfur content of the mixture was carefully controlled and processed under high selective conditions
4. The sulfur contents of the coals were not appreciably moved during the entire process.

The solvent extraction tests on hand-picked samples from the Shahrig and Mach coal fields gave the following results in Table 4 [14]. The gray-kiln assay measures the quantity and type of solid, liquid and gaseous products obtained on carbonization of coal at 600 to 900^{o}C. Results of these tests are given in Table 5 [14].

Various methods of de sulfurization, such as by oxidation in various aqueous media by low temperature of carbonization, and by gravity separation were tried [19-21]. By the first method, a small reduction of approximately 0.02 % in the sulfur content of the coals resulted. Trial by the second method was also unsuccessful. In last, desulfurization by gravity separation was successful only on selected coals [19-21].

Wash ability tests result varied even in case of coals from the same bed, but that all the coals could be washed with the reasonable degree of success. Through wash ability test it is determined that the quality of the Sor Range Deghari coal is such that washing was not considered necessary [14].

Table 3 Apparent rank classification of Coals from major Balochistan Coal Fields [14]

Coal Fields	No. of samples	Apparent rank, and number of samples in parenthesis
Sor Range-Deghari	22	Sub A(19), and Sub B (3)
Khost-Shahrig-Harnai	26	hvBb (14), hv (7), and hvCb (5)
Mach	6	hvCb

High volatile A bituminous (hvAb), high volatile B bituminous (hvBb), high volatile C bituminous (hvCB), sub-bituminous A (sub A), sub-bituminous B (sub B), sub-bituminous C (sub C), lignite A (lig A), and lignite B (lig B)

Table 4. Results of Solvent extraction tests on Balochistan Coal [14]

Coal Field	Solvent	Extraction Time Hours	Percent extract	Gray-kiln tar yield in percent
Shahrig	Pyridine-chloroform	90	6.47	16.5
Mach	Pyridine-chloroform	70	3.91	10.5

5. Clean Coal Utilization

There are four different ways of using coal namely, combustion, carbonization, gasification and hydrogenation. Combustion or burning to produce thermal energy is playing the largest role. Carbonization or the destructive distillation of coal by heating it in the absence of air is important in iron and steel producing countries because this is the process by which the metallurgical coke and other products are made. Gasification of coal, or the conversion of solid organic constituents of coal to gases by combining with steam, air or oxygen, produces gas that can be use as a source of many organic chemicals synthetic liquid fuels, gases for heating in many industrial processes. Hydrogenation or the breaking of complex organic chemical compounds in coal to simpler or desirable forms by treatment with hydrogen under high temperature and pressure has been used to produce synthetic liquid fuels, natural gas constituents and a large variety of organic chemicals [22].

For power generation on a scale of over about 25 MW, the acceptable practice for coal generation in a steam generator has been suspension firing in the free volume of the boiler furnace that is pulverized coal combustion. The steam under high pressure and at super heated temperature followed by expansion of the steam in rotating turbines to drive electric generators is almost used exclusively throughout the world [22].

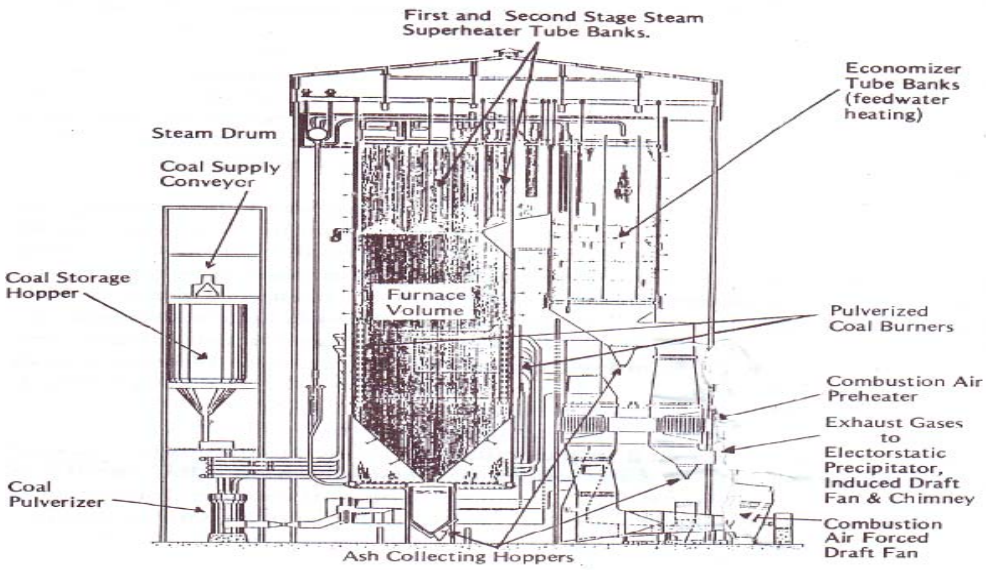

Fig.9 Pulverized, utility-scale steam generator[22]

Fig. 9 is a representation of emission control with respect to particulates by utilizing scale generator designed for pulverized coal firing [22].

Complete combustion of combustibles in the coal in order to raise fuel efficiency to the maximum. The answer is high furnace temperatures: precisely what is not needed if the formation of nitrogen oxide is to be suppressed. High temperatures are needed, too, to promote high rate of heat transfer in the furnace to the boiling water, so that the size of furnace, and the cost of equipment can be reduces [22].

With respect to Pakistani coals, compatibility of Lakhra coal in particulate, the mineral composition is such that the melting point of ash achieved during combustion or at low temperature so that ash melting or slaging occurs. The tube furnaces are fouled, heat transfer is lost, and equipment must be frequently shutdown for claim. This phenomenon occurs in Quetta [22].

Pulverized steam generator Fig. 9 provides no provision for suppression of the sulfur oxide during combustion. Steam generations in existing stations have been reterofitted with equipment which can mitigate sulfur dioxide by lime in order to abolish environmental degradation problems [22].

Fig. 10 shows a modern pulverized coal power generation cycle having capacity of repression of SO_X. The NO_X and SO_X emitting form the chimney will reduce to 10% by installing the flue gas desulfurization (FGD) scrubber. FGD equipment increases the capital cost of the entire power plant by 25 to 50 % [22].

The solution for Pakistan is fluidized bed combustion of coal. The transfer and adaptation of this technology is the wave of the future for the coal utilization for achieving National goals for increase in power generation. Fluidized bed combustion addresses the goals of emission of three pollutants and provides the means to suppress their emission in one equipment package. It does this at lower lost in location where strike environmental control exists and at competitive costs [22].

Fig.11 represents four modes of making contact between solid particles and gases in order to promote chemical reaction for combustions. The mode differs in the average velocity of upward moving gases. At about 4 feet per second, the upward impact of the gas stream begun to lift the particles, which then floats in the gas stream. As such, the entire mass, or bed, takes the shape of the container which is the characters of the fluids, if the solids are a solid fuel and the gas is air, and the temperature are high enough, combustion occurs and we have bubbling type fluidized bed combustion (FBC). The smallest diameter particles tend to leave with the gas and these are captured and returned to permit the reactions to go to the reaction [22].

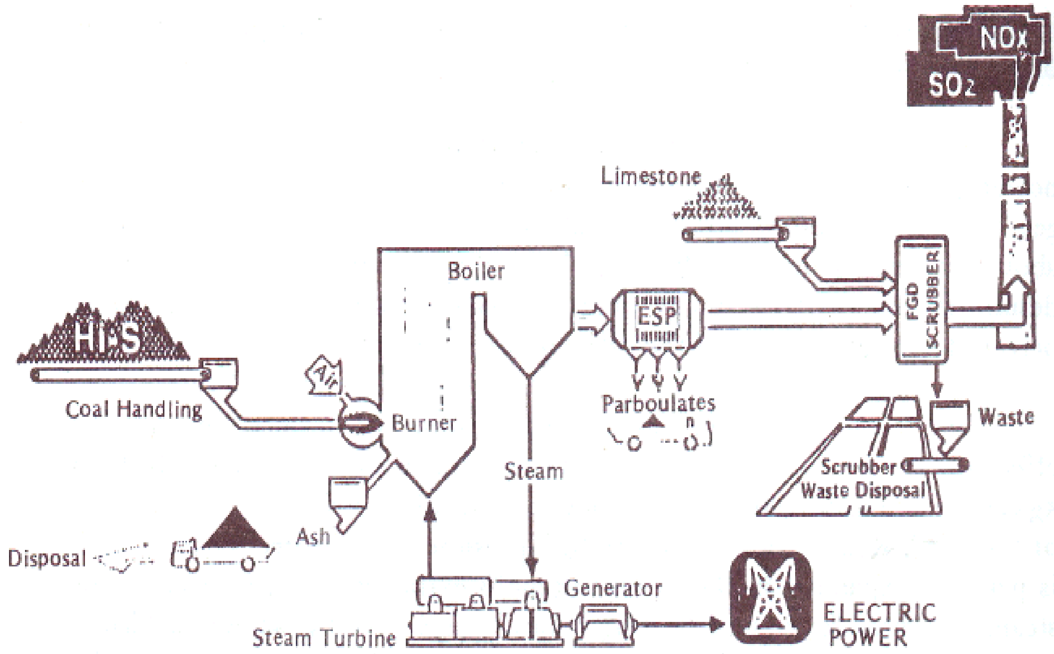

Fig.10 Schematic representation of a modern, pulverized-coal electricity generation unit [22]

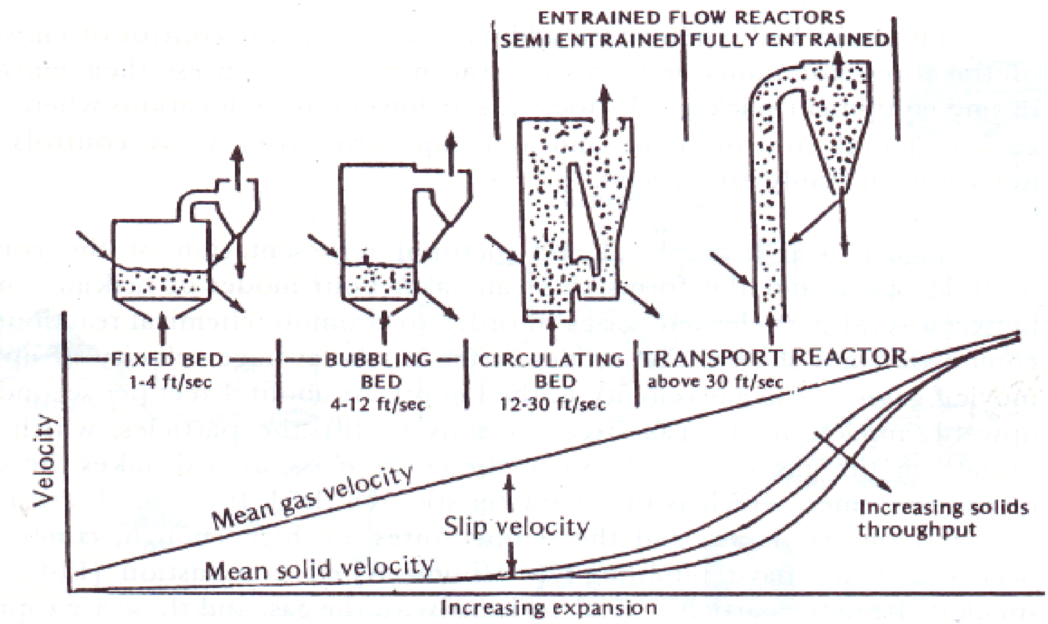

Fig. 11 Fluidized concepts and forms [22]

When upward velocities reached about 12 feet per second, most of the particles travel upward with the gas stream. In order to maintain combustion reaction to completion, these entrained particles must be captured and returned to the bed. This mode is circulating fluidized bed combustion (CFBC) [22].

A lime stone is introduced into the bed along with the fresh coal in measure proportion to the sulfur content of the coal. The bed is maintained about 1600^{o}F under these conditions, the lime stone decomposes to lime or calcium oxide. The calcium oxide combines with the sulfur dioxide from the combustion of coal in the presence of oxygen to a mixture of calcium sulfite and calcium sulfate. These solid products leave with the excess ash from the fluidized bed where they can be readily disposed off. The temperature in fluidized bed is considerably lower than that of pulverized coal combustion. The reaction rate between nitrogen and oxygen are dramatically lower that those for the temperatures of pulverized coal combustion and nitrogen oxide formation drops usually to below the level sets for environmental control [22].

Finally removal of most of the sulfur oxides of the combustion gases serves to reduce the electrical conductivity of particulates to level where the performance of electrical precipitators is no longer acceptable. Particulate control is therefore accomplished through filtration in close-mesh bags assembled in bughouses, a more costly alternative. [22].

6. Conclusion

Balochistan is rich in Coal resources. Coal quality of Balochistan is adequate for power generation through small power plants of 25 MW. Modern, pulverized-coal electricity generation unit can be operated for power generation and, it has provision to mitigate H_2S and emission of SOx, NOx can be abridged to 10% from chimney or flare. Role of Natural gas, oil and other resources of energy is more than 99% for power generation and coal has contributed merely less than 1%.Reservoirs of conventional natural gas are depleting which are raising question for availability of energy for power generation. Compatibility of Coal can justify Underground Coal gasification technique for gasification and its utilization in Combined Cycle Station for power generation. Large portion Balochistan, yet not be explored for coal resources. Solution to the energy crisis can combated by sustainable energy system which can attained by effective utilization of Coal.

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