CHAPTER FOUR

SONDA COALFIELD

INTRODUCTION

Sonda coalfield was discovered in 1981 by Geological Survey of Pakistan, in a small village Sonda, located in the deltaic area of lower Indus, on the National Highway 40 kms from Thatta and 130 kms from Karachi towards Hyderabad. The region includes plains, mostly overlain by old and new alluvium. The relief is generally low with southwesterly landforms controlled by active fluviatile processes. This coalfield lies in the east and northeast of Keejhar Lake in District Thatta and falls in toposheet No. 40 D/1 and 40 C/4. It extends from Jherruck to Thatta in northeast and southeast direction and Jhimpir to Sujawal in north-south direction covering an area of 1500 sq. Km (Fig. 4.1). More than 29 coal seams of varying thickness and continuity occur at different horizons in Sonda coalfield, the maximum thickness of one coal seam is 6.2 meters. The total reserves have been estimated as over 295 million tones (Waheeduddin et al., 1992).

The area is part of tropical coastland dominated by sea breezes. The mean annual temperature is generally over 90^{O}F, humidity exceeds 50% through out the year. The average annual rainfall is between 7 to 15 inches. Natural vegetation comprises forests, shrubs, herbs, and grasses. Tidal forests of mangrove occur in the eastern part of the area (Khan, 2003).

GENERAL GEOLOGY

The general stratigraphic units in and around Sonda range in age from Paleocene/Cenozoic to Recent/Holocene. The oldest unit of the Cenozoic age is the upper part of the Bara Formation, Lakhra Formation, and Laki Formation, while the youngest units include the surficial parts of Holocene alluvium of the Indus river flood plain. Coal seams occur in two major formations, i.e. Bara Formation of Paleocene and Laki Formation of Eocene age. The generalized stratigraphic sequence exposed in the area is described below.

Bara Formation

The unit is composed predominantly of sandstone and subordinate amounts of claystone or shale, siltstone and coal. The unweathered sandstone is light grey, grey, white and greenish grey, but weathers into various shades of yellow red and brown. It is coarse to fine-grained, mostly subangular and poorly sorted, cross-bedded, massive, friable, loosely cemented. The claystone or shale and sandstone are light-grey to grey, pyritic, sandy and gypsiferous, associated with irregularly distributed coalyphile and range from non-laminated to poorly laminated. Its upper contact with the Lakhra Formation is conformable (Fig. 4.2).The generalized stratigraphy of the rocks exposed in Sonda-Thatta-Jharruck area is given in Table 4.1. An Early to Middle Paleocene age (Domian to Montian) may be assigned to Bara Formation (Thomas et al., 1993).

The strata are exposed along a very narrow strip of right bank of River Indus at Dhaduri ridge, at Sonda, where it directly underlies the alluvium cover. The subsurface contact of Bara Formation and overlying Lakhra Formation is exposed along the River Indus at many places (Waheeduddin et al., 1988).

Lakhra Formation

This name has been proposed by Ahmed and Ghani (1967) after the village Lakhra (a type locality) in Dadu District for the Upper part of the Rani Kot Formation of Vredenburg (1906). Lakhra Formation consists of sandstone, limestone, claystone or shale and siltstone. Sandstone is dominant in the basal beds whereas limestone is dominant in the upper part and alternates with sandstone and claystone. The sandstone is thin to thick-bedded, light-grey, dark-brown/chocolate, yellow - brown and red in colour. It is fine to coarse grained in texture with subangular to subrounded grain, fossiliferous in certain layers and calcareous, at places grades into sandy limestone. It is hard and resistant when calcareous and fossiliferous (Thomas and Khan., 1989) .

The limestone is light grey, weathered to yellow and brown, sandy, fossiliferous and in places grades with coquina. It is typically thick bedded to massive and resistant. The shale or claystone and siltstone are light grey, stained

yellow and brown, soft and slope forming. This Formation conformably overlies the Bara Formation but unconformably underlies the Laki Formation. At places the Laki Formation is missing and Manchar Formation overlies the Lakhra Formation. The unit is of variable thickness because of post Lakhra erosion (Thomas et al., 1993).

The thickness of this formation increases from northeast to southwest and the total thickness recorded in a section is about 113 meters. The age assigned to this formation is Middle to Late Paleocene. The base of Lakhra Formation is exposed only along a narrow strip below Dadhuri ridge near Sonda. The rocks of Lakhra Formation crops out along the right bank of river Indus, on both sides of the National Highway. In Lakhra Formation, four prominent, continuous, limestone beds are noted which alternate with sandstone, shale and marl (SanFillipo et al., 1990).

Laki Formation

Laki Formation is the term used for the "Laki Group" of Hunting Survey Corporation (1960) which was earlier "Laki Series" of Noetling (1903). The name Laki is derived from the Laki Hill range and village in the western part of Hyderabad Division. The formation consists of finely crystalline limestone, lateritic claystone, siltstone and shale. This formation is best developed in the

southern part of Kirthar Province. It attains a thickness of 55 meters near Thatta. The lower contact of the formation is unconformable with Lakhra Formation and is marked by Sonhari member. This is divided into members namely Sonhari bed member, Meting limestone and shale member and Laki limestone member (Schweinfurth & Hussain, 1988).

Sonhari bed Member

The Sonhari Member comprises of lateritic clays, sandstone and gypsiferous shales. Clays are of various colors ranging from violet to reddish-brown, yellowish-brown, bluish-grey, off white, grey-brown, and buff and are silty, sandy and highly ferruginous with local patches of fire clay and lenticular lignite beds ranging in thickness from 0.30 to 0.75meters. Sandstones are yellowish-brown to light-brown and dark-gray in color, fine to coarse-grained and even gritty at places with rounded and subrounded grains and are ferruginous and calcareous. Friable silica sand bands occur in sandstone with variable thickness which gradually passes into buff, reddish, ferruginous sand (Wnuk et al., 1991).

Shales are found in various colors, like blackish-grey and dirty-brown, containing carbonaceous shale with poorly developed lignitic material and pyrite crystals. Small bands of laterite occur on the middle part of the beds. Sonhari member varies in thickness from 10 to 30 meters (Thomas and Khan., 1990).

Meting Limestone and shale Member

It consists mainly of creamy white nodular limestone with subordinate sandstone in the upper part. The shale is grey, greenish-yellow, weathering dark rusty brown, ferruginous and gypsiferous. The limestone is thin bedded and arenaceous where as the sandstone is commonly ferruginous. The Meting Member is about 70 meters thick at the type locality (Waheeduddin et al., 1988).

Laki limestone member

The limestone is light yellowish grey, white and light-grey, stained yellow to brown and weathers to light grey. It is nodular, hard, resistant and massive and forms cliff containing foraminfera in abundance and mega fauna mostly in upper part. It is characterized by steep scarps.

Coal beds and zones

Sonda coal beds are commonly lenticular, partly as a result of original lenticular deposition and partly as result of post deposition erosion, folding and faulting during which coal beds are squeezed and broken into complex, distorted, discrete lenses and isolated patches. The thickness of the coal bed ranges from a couple of centimeters to 2.45 meters in various places. Pinching and swelling of

lensoid coal beds are pronounced which makes the correlation of seams difficult. The coal beds are almost horizontal; slightly dipping towards west. In general the number of coal seams are classified in three different coal zones including upper, middle and lower on the basis of their position in geologic/stratigraphic columns. The main middle coal seam is termed "Sonda Seam" which is considered to have reasonable consistency in its extension, although it could be discontinuous and may change to carbonaceous shale. The coal seam in the upper zone and above Sonda seam in the geologic column are termed as "Dadhuri Seam" where as the name "Jherruck" is assigned to the coal seams falling in the lower coal zone below the Sonda Seam. Three other coal seams encountered only above the Sonda Coal Seam and falling in middle coal zone are named as "Enayatabad Seams". Waheeduddin et al. (1988) have divided Sonda coalfield into the following coal zones:

Dadhuri Coal Zone or Zone–I: It is the top coal zone lying between stratigraphic interval from the top of Bara Formation to the base of the lowermost fossiliferous limestone bed ('A' Bed) of Lakhra Formation. It contains two to three coal beds in stratigraphic column varying in thickness from 0.10 to 0.75 meters associated with highly carbonaceous clays on top and bottom which vary in thickness from 0.10 to 0.6 0 meters. The roof of this zone is sandy claystone with sandstone at places, while the floor rocks are claystone and carbonaceous claystone (Waheeduddin et al., 1988).

Generally coal is brownish-black to greyish-brown, dull laminated, brittle,

conchoidal to uneven fracture with silty and clayey inclusions. This zone consists of claystone with interbedded sandstone carrying, clayey laminae, that posses calcitic, pyritic and sideritic nodules.

Sonda coal zone or zone-II: This is the main and middle coal zone which lies in a stratigraphic interval varying from a depth of 150 meters from top of Bara formation. It contains four to five coal beds in statigraphic column alternating with claystone and carbonaceous shale but at places these coal beds lie very close to each other, where they range in thickness from 0.30 to 2.50 meters and are associated with highly carbonaceous shale (0.20 to 1.50 meters) on top and bottom. The coal is brownish black to black, dull to sub-vitreous, laminated, brittle and unevenly to conchoidaly fracture. The zone consists of claystone, siltstone with interbedded sandstone and carbonaceous shale carrying pyritic and calcareous siderite nodules (Thomas et al., 1990).

The coal bed throughout in its extent consists of claystone and carbonaceous claystone as roof and floor. This claystone is olive grey, dark grey and light bluish-grey to greenish grey. It is hard, compact, non-calcareous and silty at places. The carbonaceous shale is dark grey to brownish black, brittle, compact, pyritic and non calcareous (Thomas et al., 1990).

Jherruk Zone or Zone-III: The lower most coal zone lies between stratigraphic intervals 170 to 220 meters from the top of Bara formation or from the base of lowest limestone bed (Bed 'A') of Lakhra formation and contains two to three coal

beds in stratigraphic column. These coal beds vary in thickness from 0.30 to 0.80 meters and are associated with grey carbonaceous clays on top and bottom (Thomas et al., 1988).

Coal is generally brownish black to black, brittle, pyritic, dull, laminated with uneven to conchoidal fractures. This zone consists of sandstone (Silica 85%), siltstone, sandy claystone and interbedded claystone. Generally roof rock is siltstone of dark grey to olive grey, hard, compact, sandy, with clayey laminations and pyritic. While the floor rocks are underclays that are light bluish grey, compact, fissile at places and interbedded with brownish black, laminated carbonaceous claystone (San Filipo et al., 1990).

HEAVY, TRACE AND LIGHT ELEMENTS IN SONDA COAL

Eleven representative samples were collected from various localities at Sonda coalfield, and these samples have been analyzed for Pb, Zn, Cu, Ni, Cr, Co Cd, As, Fe, Mn, Sb, U, Ca, Mg, Na, and K by using atomic absorption technique (see Appendix-I). The data have been given in Table 4.2 and graphically presented in Figures 4.3 and 4.4.

It is clear from the Table 4.2 and Figures 4.3a&b that among the heavy and trace metals of the Sonda coals Copper is ranging from 6 ppm to 32 ppm (average

= 14 ppm), Lead from 8 ppm to 28 ppm (average= 17 ppm), Zinc from 9 ppm to 75 ppm (average= 44 ppm), Nickel from 14 ppm to 46 ppm (average= 34 ppm), Chromium from 7 ppm to 18ppm (average= 11 ppm), Cadmium from 0.10 ppm to 0.4 ppm (average= 0.19 ppm), Iron from 891 ppm to 8421 ppm (average= 5867 ppm), cobalt from 2ppm to 4ppm (average= 2.91 ppm) and Manganese from 0.14 ppm to 0.42 ppm (average= 0.27 ppm).

Among the light elements in Sonda coal, Magnesium varies from 28ppm to 68ppm (average= 43 ppm), Calcium from 85 ppm to 512 ppm (average= 203 ppm), Sodium from 370 ppm to 438 ppm and Potassium from 218 ppm to 340 ppm (average= 289 ppm).

By comparing the heavy and trace elements concentration in the Sonda coals (Fig. 4.4a), it is clear that the iron has the highest concentration with gradual decreasing trend towards Cd (i.e., Fe>Ni>Cu>Pb>Cr>Co>Mn> Cd). While among the light elements in the Sonda coals, sodium has the highest concentration with gradual decreasing trend towards magnesium (i.e., Na>K>Ca> Mg) (Fig. 4.3b) (Fig. 4.4b).

PROXIMATE ANALYSIS OF SONDA COAL

Among the proximate constituents of the Sond coalfield, fixed carbon and ash contents were determined and the results are given in Table 4.3. It is clear from

this table that the fixed carbon varies from 39.34 to 44.78% with an average amount of 41.20% whereas the ash contents varies from 9.5 to 12.68% with an average amount of 11.55%.

ULTIMATE ANALYSIS OF SONDA COAL

Among the ultimate constituents of Sonda coalfield, hydrogen, carbon, nitrogen and sulfur contents have been determined and the results are presented in Table 4.3. It is clear from this table that hydrogen is ranging from 5.88 to 7.3% (average = 6.90%), carbon is ranging from 54.78 to 67.45% (average = 61.43%), nitrogen is ranging from 0.23 to 0.40% (average = 0.31%) and sulfur is ranging from 2.00 to 7.00% (average = 4.33%) in the Sonda coals. The Sonda coals are having three times higher amount of sulfur as compare to Thar coals.

COMBUSTION PROPERTIES OF SOND COAL

The calorific values (CV) of the Sonda coals were determined and the results are given in Table 4.3. It is clear from this table that the calorific values of Sonda coals are ranging from 9835 to 11195 btu/lb with an average value of 10301 btu/lb.

Table.4.1 Stratigraphic sequence of exposed rocks in Sonda area (after Thomas et al., 1993).

Age	Unit	Thickness	Lithology
Recent	Alluvium	---- ? ----	Unconsolidated strata, alluvial and Aeolian Deposits of sandstone, siltstone and claystone with limestone and sandstone and pebbles beds
	---------- unconformity ----------		
Eocene	Laki Formation (Laki limestone, Meting shale, Meting limestone. sonhari beds).	125 meters	Limestone, Clays, Sandstone, Marl, Lateritic clays and Lenticular coal in the Basal part.
	---------- unconformity ----------		
Paleocene	Lakhra Formation (Upper part of the Ranikot Formation)	100 meters	
Paleocene	Mountain to Landimian	125 meters	Fossiliferous, Limestone, Sandstone, Clay Stone or Shale.
	Bara Formation (lower part of Rani kot Formation)	100 meters	
Domain to Mountain ?		5 meters	Sandstone, shale or Claystone, Coal, devoid of mega fauna.

Table 4.2 Heavy, trace and light elements (in ppm) in Sonda coalfield.

Sample No.	Pb	Zn	Cu	Ni	Cr	Co	Cd	As	Fe	Mn	Sb	U	Ca	Mg	Na	K
SND-1	28	18	32	26	10	3	0.40	1.2	7845	0.23	0.8	2.8	315	68	412	21
SND-2	21	28	31	14	18	2	0.40	1.7	7321	0.14	1.2	3.4	238	60	418	24
SND-3	25	70	9	34	8	2	0.10	1.3	4385	0.24	1.7	3.9	145	30	438	29
SND-4	19	9	18	28	9	4	0.20	1.9	5786	0.31	1.8	2.8	512	38	430	31
SND-5	12	75	12	35	12	3	0.10	1.3	5423	0.41	0.9	2.9	195	41	421	32
SND-6	11	71	8	38	16	3	0.10	0.9	4976	0.22	0.8	4.1	191	43	419	30
SND-7	17	72	6	36	9	3	0.10	0.7	5314	0.31	1.4	3.8	175	39	418	34
SND-8	14	51	9	40	7	3	0.10	1.4	7856	0.25	1.8	2.8	185	31	398	29
SND-9	8	37	8	46	15	4	0.30	2.3	8421	0.42	2.1	3.2	90	62	432	27
SND-10	12	40	12	42	8	2	0.10	1.4	6314	0.18	0.9	4.1	102	28	370	24
SND-11	24	10	11	35	7	3	0.20	1.9	891	0.21	1.7	3.2	85	38	395	33
Average	**17**	**44**	**14**	**34**	**11**	**3**	**0.19**	**1.45**	**5867**	**0.27**	**1.37**	**3.36**	**203**	**43**	**414**	**28**

Table 4.3. Mean values of various proximate and ultimate analysis (in percent) and calorific values (btu/lb) of the Sonda coalfield.

S.No.	Fixed Carbon	Ash	Hydrogen	Carbon	Nitrogen	Sulfur	Calorific value
SND-1	40.32	5.76	7.22	63.23	0.36	4.00	10102
SND-2	41.34	5.23	6.34	64.12	0.32	3.80	10335
SND-3	39.34	6.34	7.02	56.78	0.23	7.00	9835
SND-4	44.78	5.98	7.45	67.45	0.40	4.20	11195
SND-5	39.45	6.34	6.98	61.54	0.28	3.00	9863
SND-6	40.98	5.78	7.11	58.23	0.36	6.40	10245
SND-7	40.12	5.78	7.23	62.59	0.27	2.00	10030
SND-8	39.56	5.12	6.13	54.78	0.31	2.30	9890
SND-9	41.32	6.31	7.23	64.46	0.30	3.00	10330
SND-10	43.78	6.12	7.34	64.23	0.29	5.40	10945
SND-11	42.17	4.76	5.85	58.34	0.29	6.50	10543
Average	**41.20**	**5.77**	**6.90**	**61.43**	**0.31**	**4.33**	**10301**

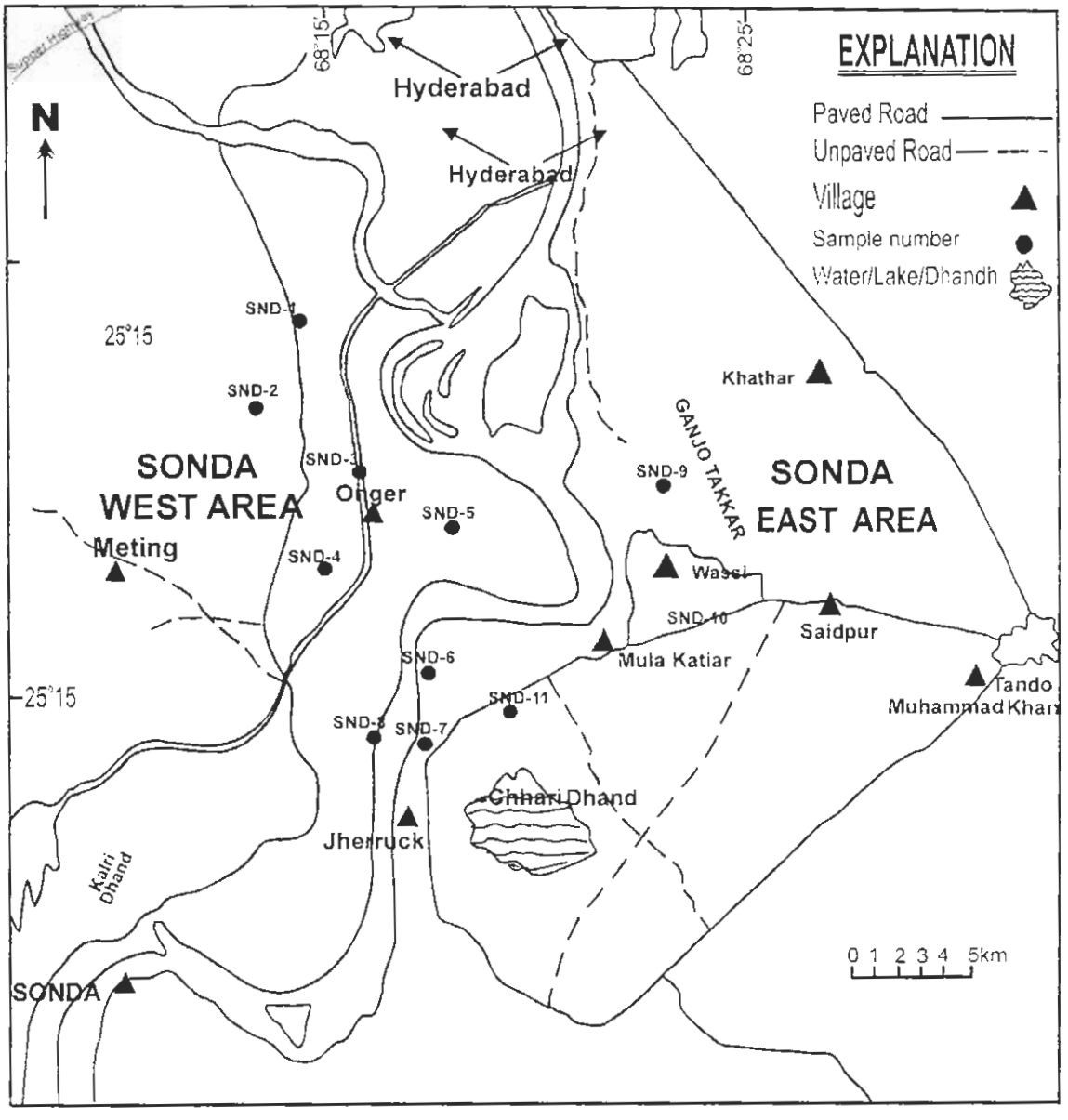

Figure 4.1 Map showing location of Sonda coalfield and the sampling location (Thomas and Khan., 1992).

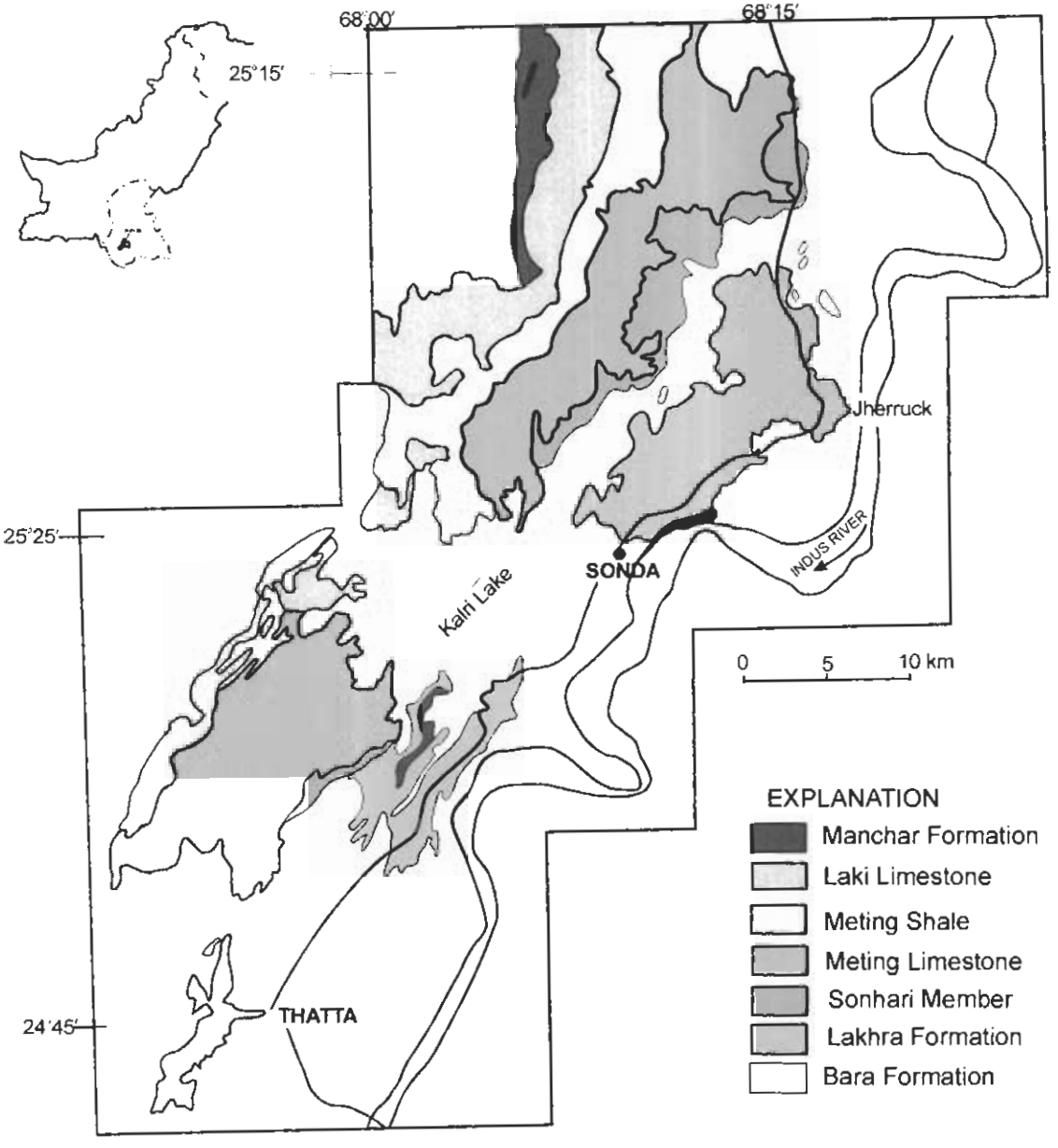

Fig. 4.2 Geological Map of Sonda coalfield (Ahmed et al., 1986).

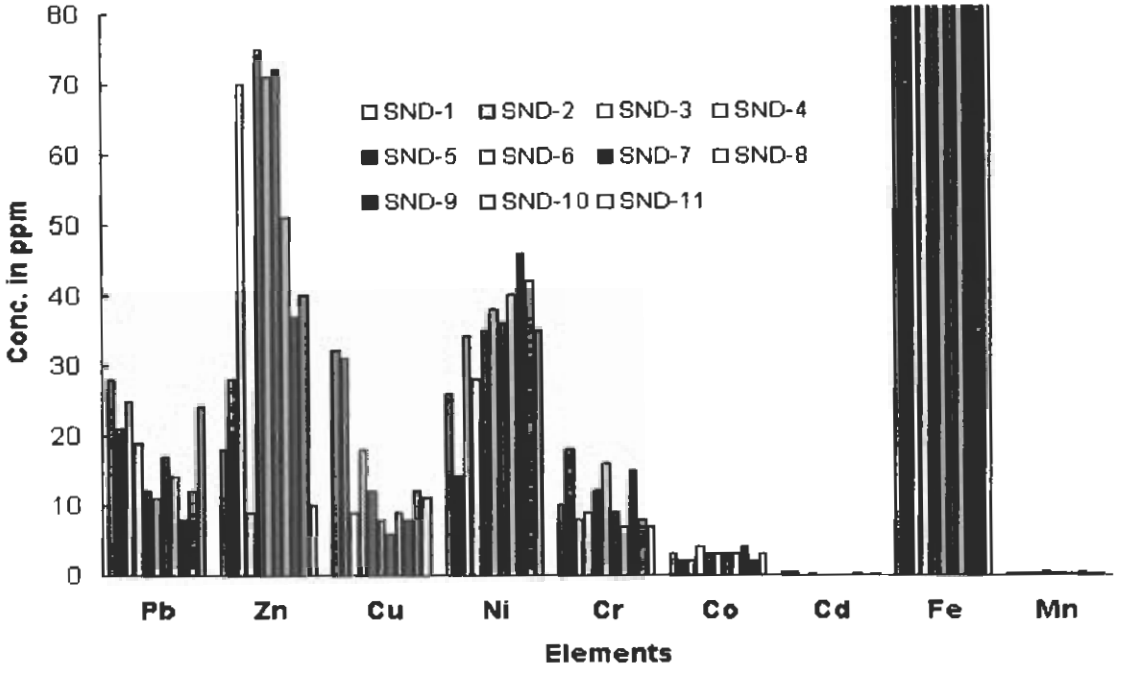

Fig. 4.3a Variation of various heavy and trace elements in the Sonda Coals.

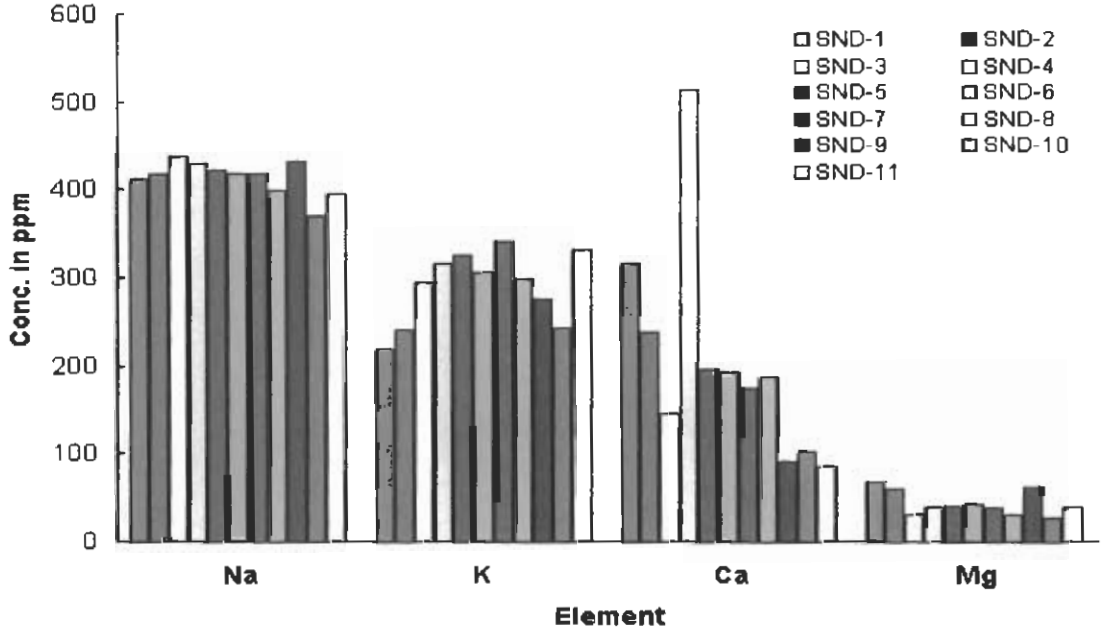

Fig. 4.3b. Variation of various light elements in the Sonda Coals.

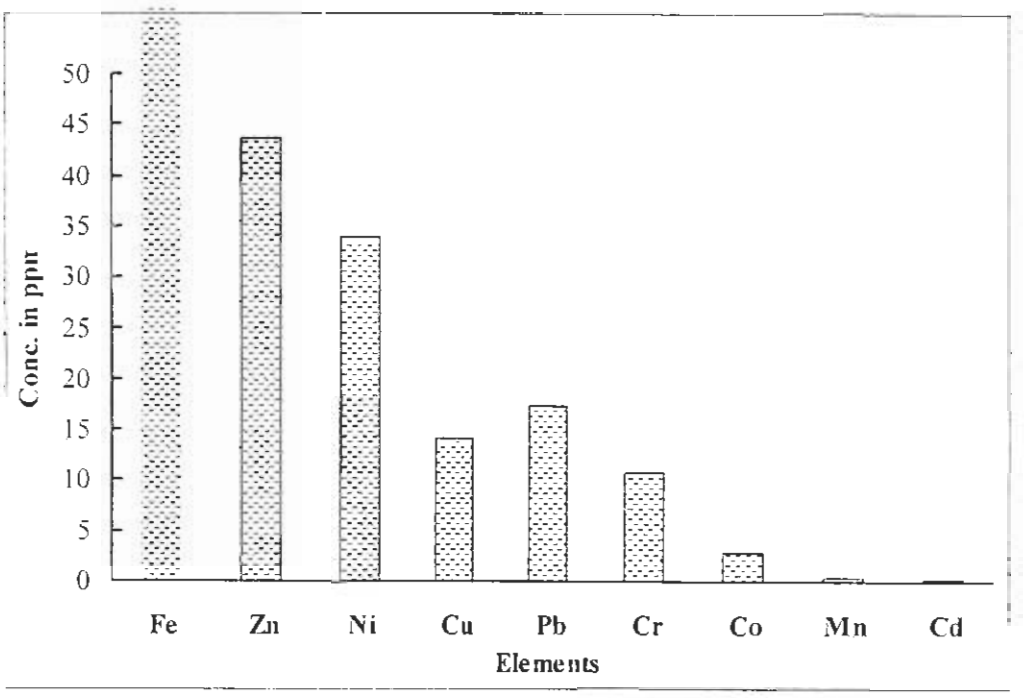

Fig. 4.4a. Inter-elemental comparison of heavy and trace elements in the Sonda caol.

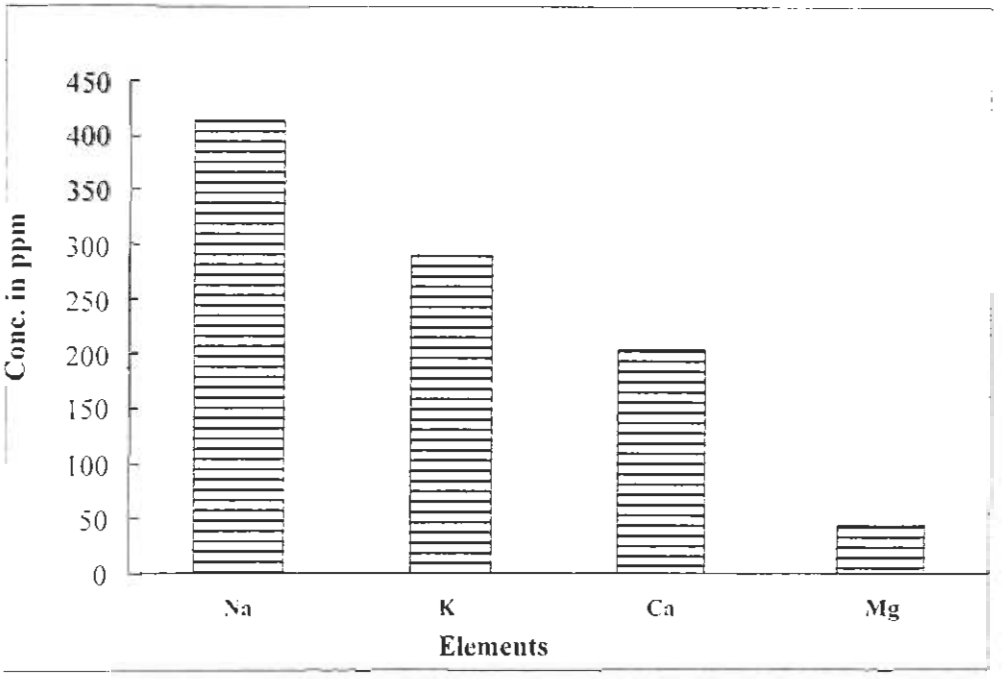

Fig. 4.4b. Inter-elemental comparison of light and trace elements in the Sonda caol.