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Geology and Coal Resources of the Thar Coal Field
Sindh Province, Pakistan

by

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ABSTRACT

The Thar coal field is located in the Thar Desert of southeast Pakistan in eastern Sindh Province. The coal field area covers about 9,000 square kilometers with dimensions of 140 km (north-south) by 65 km (east-west); the field area is bounded by the Pakistan-India border to the north, east, and south. The field area is covered by northeast-trending longitudinal stabilized sand dunes with topographic relief of up to 100 m. The Thar is essentially roadless with tracks through the sand being the principal transportation routes mandating four-wheel drive vehicles. The Mirpur Khas - Khokhropar Branch Railroad traverses the desert just northwest of the field area. Total coal tonnage for the field is 78,196,555,800metric tons. The coal is lignite B in rank with an average as-received heating value of 5,333 Btu, as received sulfur percentage of 1.57, and as-received ash percentage of 8.83 percent. The average dry and ash-free heating value for the Thar coals is 12,322. Average as received moisture content is 48.57 percent. Nine drill holes in the south-central part of the field contain more than 24 m of total coal; six of these nine drill holes contain coal beds greater than 20 m thick. Drill hole TP-3 contains a bed of coal 27 m thick containing only three partings in its upper part measuring 1.05 m, .9 m, and .41 m thick. The shallowest coal in the field lies at a depth of 123 m; the deepest coal (depth to 1st coal bed) is at 245 m. The field contains 3,962,385,900metric tons of coal at a depth of less than 150 m. All of the drill holes in the field were located in interdune areas at the lowest elevation possible; because the surface relief of the sand dunes of the Thar Desert is as much as 100 m, the Thar coals between drill holes will probably be covered, on average by an additional tens of meters of dune sand.

A structural dome in the south-central part of the Thar coal field has elevated the thickest coals in the field closer to the surface. A north-easterly trending fault forms the boundary of the Thar field in the southeast part of the field area; east of this fault, the coal-bearing rocks were uplifted as much as 150 m and were probably eroded prior to deposition of the overlying alluvium. The Rann of Kutch fault zone probably represents the maximum southern extent of minable coal in the field area. Thar coals thin greatly northward, eastward, and westward in the northern half of the field area; to the south, relatively thick coals may be present west of the presently-drilled area. On the basis of paleontological information the Thar coals are Paleocene to Eocene in age; probably early Eocene. Available evidence indicates that the Thar coals may have been deposited in a raised-bog environment landward of a north-trending coastline of a sea to the west.

INTRODUCTION

The Thar coal field is located in the eastern part of Sindh Province, Pakistan in the Thar Desert (fig. 1). The discovery of this giant coal field was the culmination of a coal exploration and assessment program (COALREAP) involving the United States Geological Survey (USGS) and the Geological Survey of Pakistan (GSP). This program was carried out under the auspices of the United States Agency for International Development (USAID); the program began in 1985 and formally ended on June 30, 1993. The principal goals of the USGS/GSP program were to improve the professional

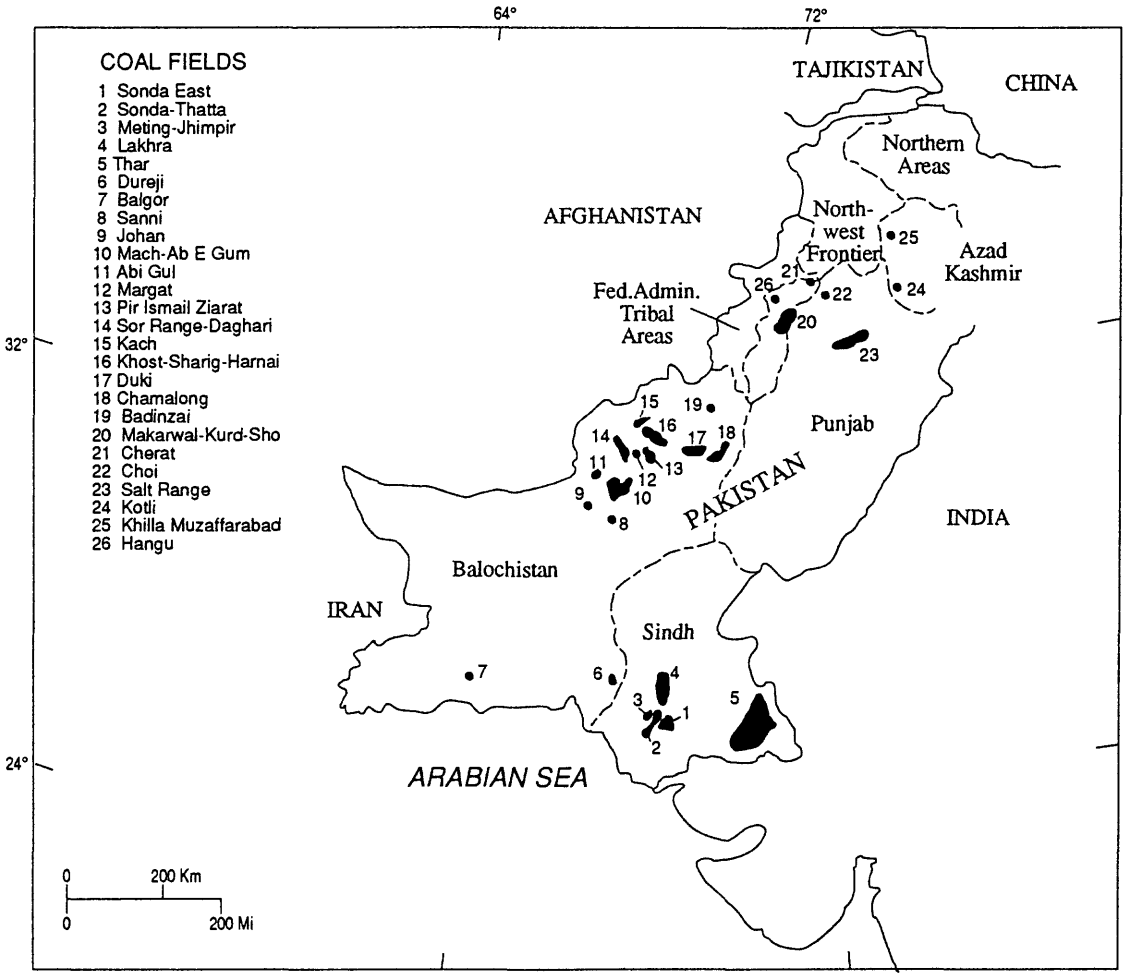

Figure 1. Map of Pakistan showing locations and names of coal fields and coal occurances; the Thar coal field area is shown at larger scale on figure 2 of this report.

capabilities of the GSP staff, particularly in the area of coal exploration and assessment, and to examine in detail the coal resource potential of Pakistan.

Discovery of the Thar Coal Field

The first tangible indication that coal was present beneath the sands of the Thar Desert came with the drilling of five water wells by the British Overseas Development Agency (ODA) in cooperation with the Sindh Arid Zone Development Authority (SAZDA). (This account of the discovery of coal in the Thar Desert is largely derived from a report by SanFilipo and others, 1992.) Water well ODA2 was drilled in 1988 near the village of Khario Ghulam Shah about 15 km east of Islamkot (fig. 2). The description of cuttings from this well noted "carbonaceous shale" (sic) between depths of 126.5 m and 129.5 m. In addition, the sample log gave the following description for the interval from 129.6 m and 132.0 m: "CARBONACEOUS SHALE very fine, dark but variably coloured, some resin and amber, some lignite, rare chalcopyrite". The interval from 129.6 m and 132.0 m in this well was cored. The core was examined in February 1989 by USGS and GSP geologists who determined that most of the cored interval was coal.

On the basis of the presence of coal in the ODA2 water well the USGS/GSP examined and described drill cuttings from other nearby SAZDA wells and in March 1989 geophysically logged water well TH-5 near Dhaklo (essentially the same location as TP-1 on fig. 2) and in July 1989 geophysically logged water well TH-6 near Chachro. On the basis of these geophysical logs it was estimated that the total coal present in well TH-5 was 19 m and in well TH-6 the total coal thickness was 16.1 m. (TH-6 is used as a control point in this report and its total coal thickness has been re-estimated to be 12.5 m.) The confirmation of the presence of very thick coal beds on geophysical logs in the Thar Desert ultimately led to a modest 4-hole coal test drilling program in the Thar that was conducted in February through July, 1992. This drilling confirmed the presence of the thickest coal beds yet found in Pakistan; test hole TP-3 penetrated nearly 30 m of coal and contained a bench of unbroken coal nearly 20 m thick.

Drilling-Exploration Program for the Thar Field

In October 1992, the GSP/USGS began a 21-hole exploration program to define the magnitude and geographic limits of the Thar coal field. The drilling plan was based on locating the 21 test holes over a more or less uniform grid covering that part of the desert thought to be underlain by significant coal resources. This drilling pattern resulted in a drill-hole spacing averaging about 22 km. (These 21 holes plus the initial 4 Thar Desert test holes have the prefix TP- in this report; "TP" stands for Thar Parker, and administrative district of Sindh Province.) This strategy proved to be quite successful in that it almost totally defined the limits of the field (with the exception of the southern boundary of the field which is as yet still not clearly defined). The 21-hole drilling program ended in mid-summer, 1993.

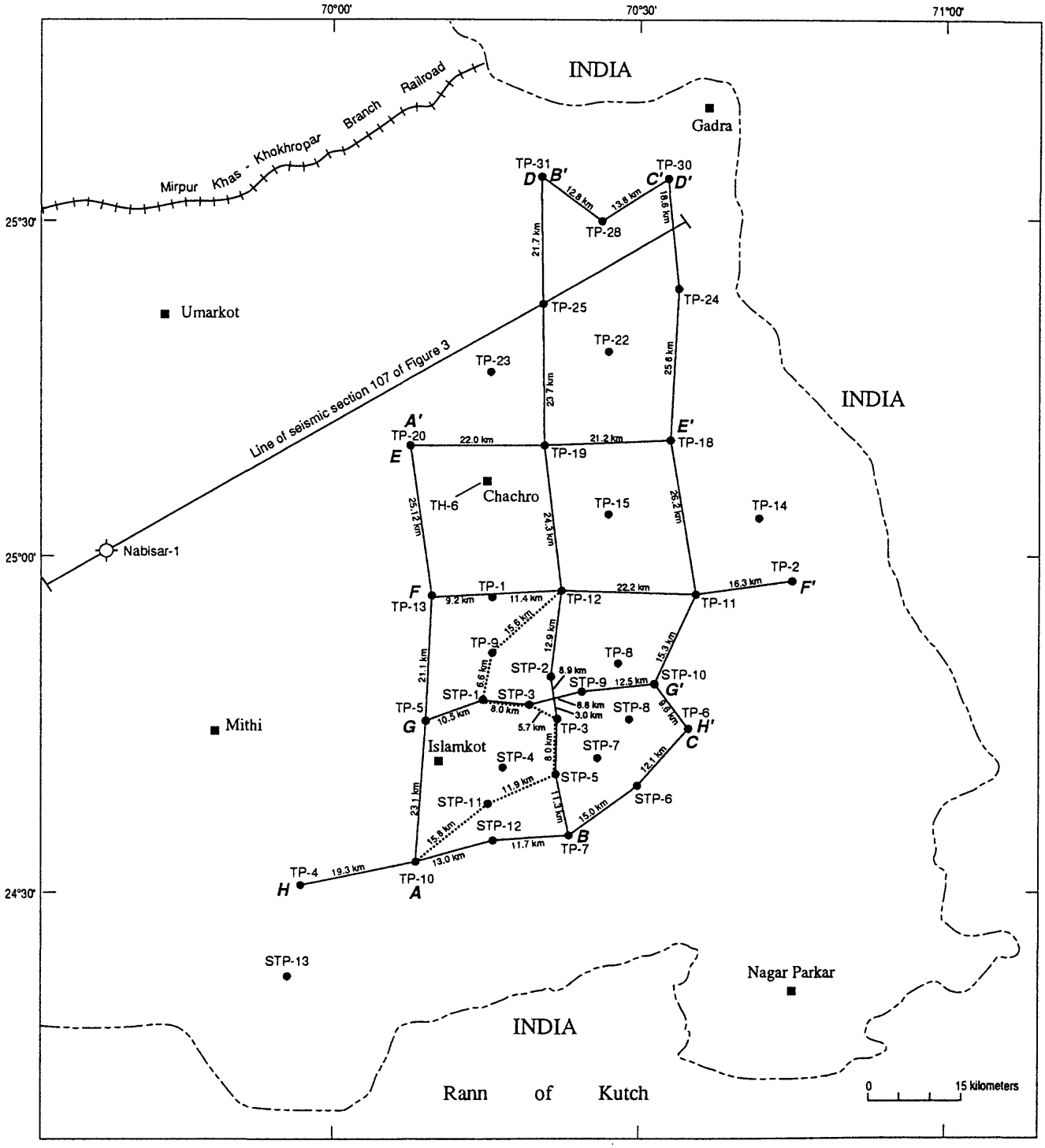

Figure 2. Index map of the Thar coal field area showing locations of all coal test holes plus water well TH-6 and lines of eight structural cross sections A-A' through H-H'. The dotted line beginning at drill hole TP-10 and ending at drill hole TP-12 is the line of the coal-correlation diagram (fig. 8). The line of seismic section 107 of figure 3 is also shown.

During the last quarter of 1993 an additional 10 test holes were drilled under a contract with the John T. Boyd Company under the auspices of USAID. The focus of this 10-hole drilling program was to conduct in-fill drilling in the south-central part of the field where the coal was known to be thickest and shallowest to gather data for a preliminary determination of the mining-engineering parameters of the Thar field. The Boyd drilling was completed in late December 1993. In January 1994 the GSP drilled 3 additional coal test holes under the auspices of USAID. (The 10 John T. Boyd holes and the three GSP holes have the prefix STP- in this report; "STP" stand for Sindh Thar Parker.)

Coal samples were collected for analysis by the USGS/GSP from the first 25 Thar coal field test holes and the results of those analyses are summarized in this report (table 2 and appendix 2). Coal samples were collected for analysis from the 10 John T. Boyd drill holes but the results of those analyses were not available at the time of writing of this report.

Purpose and Scope

The Thar field has enormous economic potential for Pakistan because it contains 78 billion metric tons of total coal in place; when this tonnage is added to Pakistan's previously known resource base of 9 billion metric tons, the total resources of 87 billion metric tons of total coal resources for Pakistan vaults the country to 11th place in a list of 12 countries in the world with the most reported estimated coal resources as shown on the following table (modified from Landis and Weaver, 1993); resources are in millions of metric tons:

1.	USSR (former)	4,405,900
2.	USA	1,570,262
3.	China	1,566,500
4.	Australia	785,226
5.	Germany	285,400
6.	Great Britain	190,000
7.	Poland	184,000
8.	South Africa	129,100
9.	India	115,402
10.	Botswana	107,000
11.	Pakistan	87,000
12.	Canada	63,000

Prior to the discovery of the Thar field Pakistan was not even in the top 20 countries with significant coal resources.

Because the economic potential of the Thar field is so significant for Pakistan, it is important to quickly make available the basic geologic facts of this deposit and that is the purpose of this report. These facts are presented herein primarily in the form of

figures and tables. A detailed discussion of the geologic setting of the Thar field within the tectonic and stratigraphic environs of Pakistan and South Asia is beyond the scope of this report.

Acknowledgments

The basic hard, dirty, and physically demanding work of gathering the data that this report is based on fell primarily on the shoulders of the GSP drilling crews, drill-site geologists, and geophysicists assigned to work on the Thar coal-drilling program. These personnel worked long hours in a very harsh environment in order to successfully complete the Thar Desert coal test drilling program. There is not space enough to list all of the many persons who participated in the discovery and definition of the Thar coal field but recognition must be given to the well-site geologists whose core descriptions form the basis for this report; they are, A. A. Shah, H. Chandio, M. D. Khan, S. A. Khan, Z. M. Khan, G. S. Lashari, A. R. Memon, and M. A. Tagar; the field geophysicists responsible for conducting the geophysical logging of the test holes are; Mehtab ur Rehman, Mujeeb Ahmad, and M.A. Nizmani. Five USGS geologists were involved in tours of duty on the Thar exploration program overseeing the drilling in the Thar Desert and making detailed core descriptions of the drill core; these persons were John SanFilipo, Peter Warwick, Bruce Wardlaw, Roger Thomas, and Ellie Brouwers. The true discoverer of the Thar coal field, USGS geologist John SanFilipo, deserves special recognition; it was John's perseverance and stubborn insistence on following up on the initial ODA coal discovery that ultimately led to the Thar coal test drilling program and the discovery and definition of the Thar coal field.

Upper-level management in the GSP were totally supportive of the Thar drilling program and their efforts contributed greatly to the success of the drilling program. We would especially like to thank Farhat Hussain who was Director General of the GSP during the time the Thar drilling program was conceived and executed; Dr. Hussain's patient and continuing support was invaluable in helping to resolve all of the many crises and problems that developed in the course of putting this drilling program together; without Dr. Hussain's strong and able leadership of the GSP during his tenure as Director General, the Thar drilling program and definition of the Thar coal field would probably not have occurred.

Geography

The Thar Desert of Pakistan is part of a much larger desert extending to the north and east into India. The Thar coal field is located in the Pakistan part of the Thar Desert in the eastern part of Sindh Province (fig. 1). The Thar Desert of Pakistan is bounded to the north, east, and south by the Indian border and on the west by the irrigated Indus River flood plain. The Indian border to the south follows the "shoreline" of the Great Rann of Kutch, a great, shallow arm of the Arabian Sea that is seasonally dry. The Thar

coal field, as presently defined, is about 140 km long (north trend) and about 65 km wide (east trend) covering an area of 9,100 square km.

The terrain is generally topographically higher in the northern and eastern parts of the field area with elevations ranging from near sea level in the south to more than 200 m above sea level in the northeast. Most of the sand dunes of the Thar are stabilized by scrub vegetation and grasses. The dunes are longitudinal with a northeast trend and have a relief ranging from tens of meters to 100 meters. There is no drainage system developed in the Thar coal field area. When the monsoon rains fall the water is immediately absorbed by the sand or rarely, during heavy downpours, flows very short distances down into the low-lying interdune areas where it is quickly absorbed.

Precipitation is seasonal coming normally during the monsoon months of June to September but drought years are not uncommon. For example, a seven-year drought was broken by very heavy rains in September 1992 as the 21-drill-hole program (holes TP-5 through TP-31) was just getting under way. Average annual rainfall ranges from 200 to 300 mm; the amount of average annual rainfall increases from northwest to southeast. Mean annual maximum and minimum temperatures range from 35°C to 19°C; maximum daily temperatures commonly exceed 45°C in April through June (Ploethner, 1992). The Thar Desert has been characterized as one of the most densely populated deserts in the world; the 1982 government census showed the population at nearly one million people.

The people of the Thar are primarily pastoral; livestock consists of cattle, sheep, goats, camels, horses, and donkeys, but the low-lying interdune areas are heavily farmed whenever the monsoon rains cooperate. The crops raised are primarily rapid-growing and maturing millets and pulses. The people of the Thar depend on dug wells as their primary source of water. The water is typically quite salty but potable. Immediately following the monsoon rains relatively shallow wells producing very fresh water are utilized in some of the broader low-lying interdune playa flats; these wells must obviously be producing from perched, ephemeral aquifers. A detailed study of the groundwater of the Thar Desert of Pakistan is available (Ploethner, 1992).

The only paved road in the Thar Desert extends from the town of Naukot located west of the Thar coal field on the eastern edge of the irrigated Indus plain to Mithi, west of the coal field area (fig. 2). The other roads of the Thar consist of deep ruts in the sand and four-wheel drive vehicles are a necessity to traverse these roads. Commercial transport into and out of the Thar Desert is provided by large, six-wheel drive trucks that serve as combination busses and goods carriers. Camels are the primary means of transport for the Thar people within the desert. The Mirpur Khas - Khokhropar Branch railroad traverses the northwestern part of the Thar coal field area (fig. 2).

GENERAL GEOLOGY

The geology of the Thar Desert of Pakistan has been poorly understood because the area is covered by dune sand to an average depth of approximately 80 m. The only outcropping bedrock in the Thar Desert of Pakistan is found at Nagar Parker (fig. 2) where the striking red-granite basement rocks tower above the surrounding dunes. (The basement rocks are not all granite, there are minor amounts of rhyolite and metamorphic rocks mixed in with the granite, but red granite seems to be the dominant lithology.) The Thar coal field rests upon a structural platform in the eastern part of the desert. This platform is underlain by relatively shallow granite basement rock. Figure 3, modified from a report by Ahmad and Zaigham (1993), provides a good representation of the subsurface geology of the Thar Desert area. This figure is a northeast-trending geologic cross section that is an interpretation of a geophysical seismic line that was run from the vicinity of the Nabisar 1 oil and gas test hole on the western edge of the desert nearly to the Pakistan-Indian border on the east. This cross section shows that the granite basement rock dives down abruptly beneath the western part of the Thar Desert and is there highly faulted. (Ahmad and Zaigham, 1993, interpret three other seismic lines in the Thar coal field area.)

At the Nabisar drill site the sedimentary rock sequence is nearly 4,000 m thick; drilled rocks at the Nabisar hole are 3,000 m thick and consist of Triassic, Jurassic, Cretaceous, Paleocene, Eocene, and post-Eocene age rocks (figure 4 is a stratigraphic column of the Nabisar hole). As this cross section shows, the sedimentary rock sequence thins markedly from west to east across the Thar Desert and in the Thar coal field area has an average thickness of about 250 m. The depth to granite basement rocks in the Thar coal field ranges from 1,530 m below sea level at drill site TP-20 to 66 m below sea level at TP-6 (fig. 5).

The available seismic records in the Thar coal field area were designed for oil and gas exploration purposes and hence designed to show stratigraphic relations at depth. For that reason, the definition of the stratigraphy of the upper few hundred meters on these seismic profiles is so poor as to be useless. For this reason, the Ahmad and Zaigham (1993) cross section on which figure 3 of this report is based is essentially blank above the granite on its eastern end where the sedimentary sequence is close to the surface. The interpretation of the subsurface relationships in the area of the Thar field (east of the point where the upper Jurassic carbonates of the Chiltan Formation are shown ending) on figure 3 is our modification of the original figure by Ahmad and Zaigham (1993). We here show an unconformity at the base of the Paleocene/Eocene sequence in the Thar field area truncating the underlying sedimentary rock sequence eastward to the point where the Paleocene/Eocene rocks rest directly on the basement granite.

Ahmad and Zaigham (1993) conclude in their report that the thickest coal in the Thar coal field is Jurassic in age based on the physical tracing of geologic contacts on seismic sections. Published palynological studies of cuttings samples, however, from two water

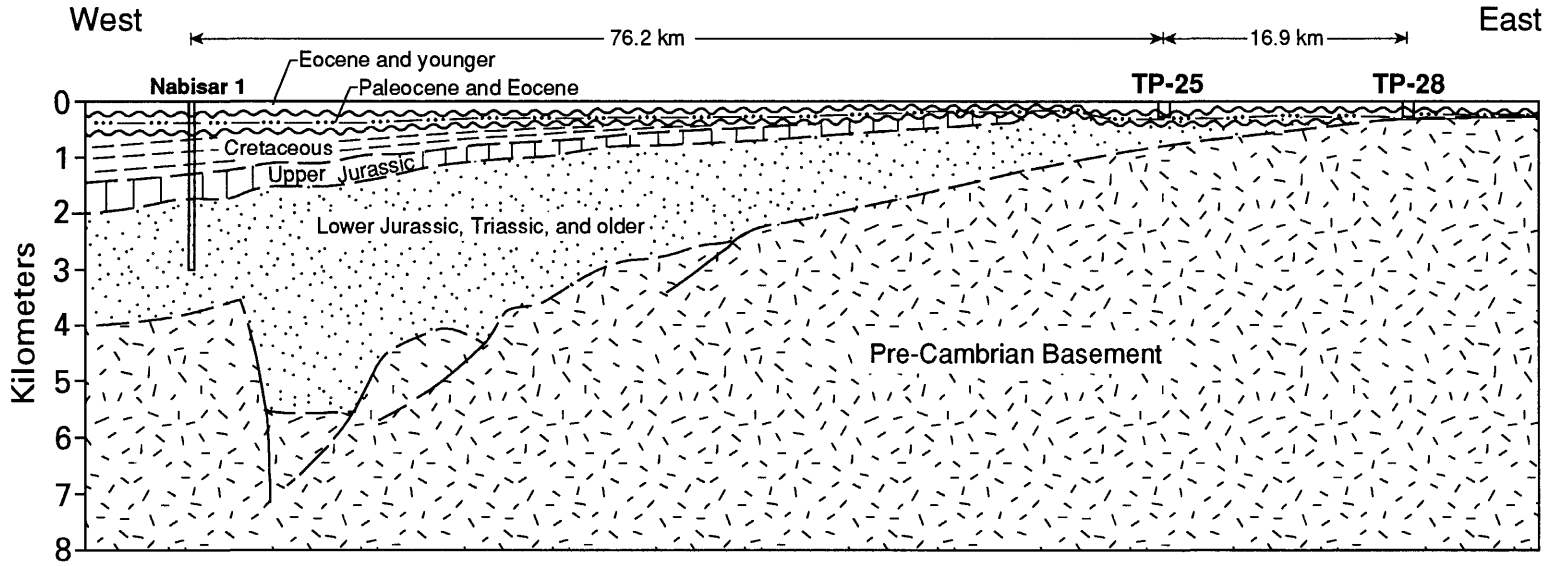

Figure 3. Structural cross section from Nabisar 1 oil and gas test hole through drill hole TP-25 and east of TP-28 showing the configuration of the basement granite and the distribution of the sedimentary rocks along the line of section. This figure is modified from figure 8 in Ahmad and others (1993) based on an oil and gas exploration seismic profile. The stratigraphic column for the Nabisar 1 drill hole is figure 4 of this report.

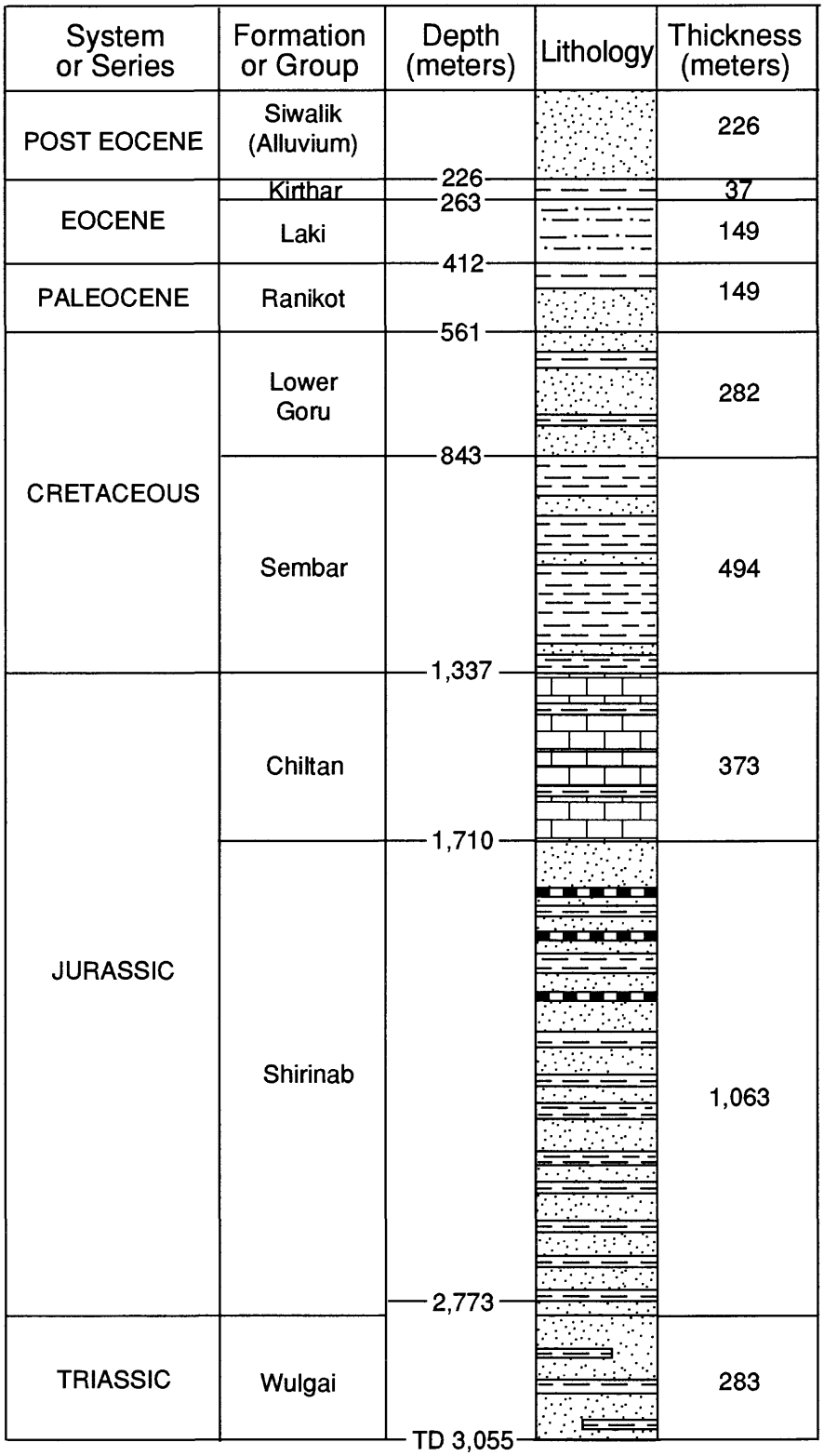

Figure 4. Stratigraphic column of the Nabisar 1 oil and gas test hole; location of this hole is shown on figure 2. This figure is adapted from the STANVAC interpretation report for the prospect of Nabisar, 1959.

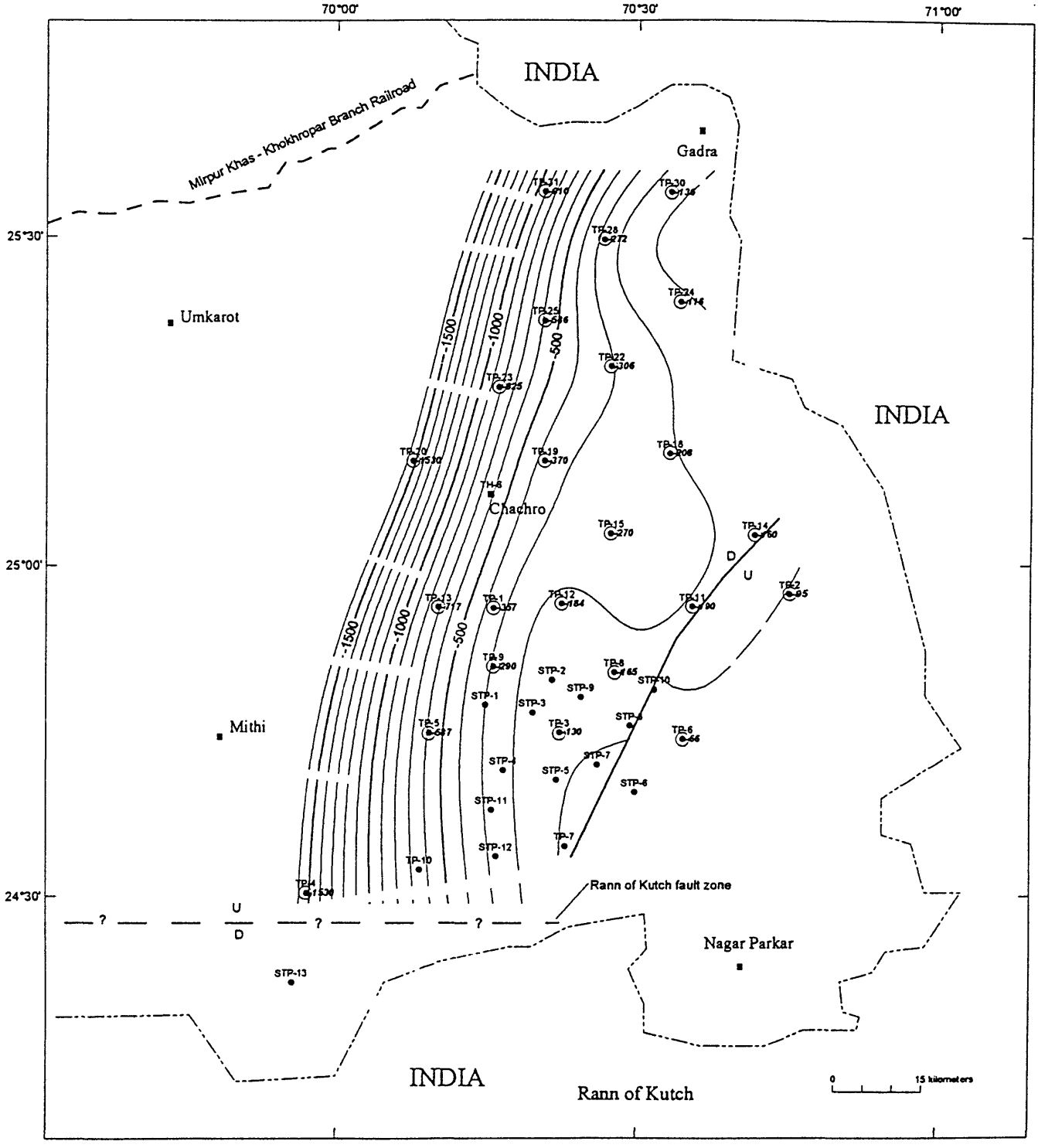

Figure 5. Structure contour map of the Thar coal field area contoured on the top of the granite basement rock. Drill sites used for control for this map are circled. Drill holes that actually penetrated the granite basement are TP-2, TP-3, TP-6, TP-8, TP-14, STP-5, STP-6, STP-8, and STP-10. (This map was generated using the computer-contouring program Surfer, manufactured by Golden Software.) Contour interval is 100 m.

wells from these same coal-bearing sequences in the vicinity of drill hole TP-1 and east of Islamkot clearly indicate that the coal-bearing strata are of late Paleocene to early Eocene age (see Report on Referred Fossils by Frederiksen, appendix 6 in SanFilipo and others, 1991). Frederiksen has subsequently examined rock samples collected from drill core from drill holes TP-1, TP-3, TP-4, TP-5, and TP-7 and he reports that: "... these samples undoubtedly come from close to the Paleocene-Eocene boundary, and the preponderance of evidence may favor an early Eocene age." (Frederiksen, written communication, 1993). On the basis of all available evidence, it is our opinion that the coal-bearing rocks of the Thar coal field are all late Paleocene to early Eocene in age. (This subject is discussed further in the "Geologic History" section of this report.)

The stratigraphic sequence in all of the Thar Desert coal test holes is essentially the same; in each drill hole there is an interval of dune sand ranging from 14 m to 93 m thick, followed by an interval of what is thought to be relatively recent Indus-valley alluvium, ranging from 11 m to 209 m thick, followed by the coal-bearing bedrock interval ranging from zero to 185 m thick. Nine of the test holes penetrated granite at or near their total depths (table 1 and fig. 5). Stratigraphic columns for the 38 coal test holes plus the water well TH-6 are in appendix 1 of this report.

No stratigraphic name is here given to the coal-bearing rocks of the Thar coal field; these strata are labeled "bedrock" on all of the stratigraphic diagrams in this report. As stated above these rocks are Paleocene to Eocene in age on the basis of palynological evidence. Additional studies of fossils from marine interbeds in the coal-bearing sequence from several test holes in the western part of the coal field are now in progress and it is hoped that those studies will more narrowly define the age of the coal-bearing rocks of the Thar coal field. The coal-bearing strata appear to be equivalent to the upper part of the Ranikot Group or more likely the lower part of the Laki Formation (fig. 4) but available evidence indicates that these coals are probably younger than the coals of the Indus valley coal fields to the west (fields 1-4 of figure 1). Coal-bearing rocks in coal fields of western India have been dated as Eocene and major Eocene-age Indian coal deposits in the Panandhro region, south of the Rann of Kutch and the Barmer region, due east of the Thar coal field (Gowrisankaran and others, 1987) provide evidence that coal occurrences in rocks of Eocene age are widespread south, east, and northeast of the Thar coal field area.

THAR COAL FIELD

The data on which this report is based were obtained by drilling 38 coal test holes in the Thar Desert. In addition, information about the Thar coal field was obtained from geophysical logs and sample descriptions from water well TH-6. The coal test drilling was conducted by the Geological Survey of Pakistan (GSP) drill crews using GSP drill rigs; geological work during the drilling program, including core description and coal-core sampling, was done principally by GSP geologists with some oversight and assistance provided by USGS geologists for the drill holes prefixed TP- and by John T. Boyd

Table 1. Locations and summary data for 39 Thar Desert drill holes

[Hole locations shown on figure 2, stratigraphic columns of drill holes in appendix 1, measurements in meters]

Hole No.	Latitude	Longitude	Elevation	Stratigraphic contacts (depths) Base of dune sand	Base of alluvium	to 1st coal bench	to thickest coal bench	Thickness of thickest coal bench	Total coal thickness	Total depth of hole
TP-1	24° 56.20'N	70° 15.56'E	78	66	125	144	164	4.7	20.8	253
TP-2	24° 57.42'N	70° 45.21'E	90	84	133	no coal	no coal	0.0	0.0	196[G]
TP-3	24° 44.92'N	70° 22.16'E	74	58	133	135	151	19.6	29.2	210[G]
TP-4	24° 30.32'N	69° 57.05'E	20	58	179	181	192	3.1	11.2	313
TP-5	24° 44.88'N	70° 09.19'E	63	43	135	155	166	3.3	14.6	274
TP-6	24° 44.31'N	70° 34.63'E	73	43	54	no coal	no coal	0.0	0.0	147[G]
TP-7	24° 34.56'N	70° 22.73'E	45	69	179	187	223	7.2	17.6	246
TP-8	24° 50.33'N	70° 27.69'E	90	41	118	158	158	7.0	17.2	268[G]
TP-9	24° 50.87'N	70° 15.55'E	110	82	123	148	212	5.7	29.3	308
TP-10	24° 32.41'N	70° 08.27'E	26	71	167	178	225	9.2	28.2	267
TP-11	24° 56.28'N	70° 35.57'E	100	21	230	233	236	1.8	4.6	249
TP-12	24° 56.58'N	70° 22.36'E	96	50	200	201	236	13.0	26.7	263
TP-13	24° 56.25'N	70° 10.08'E	73	60	142	177	202	5.5	14.8	301
TP-14	25° 02.79'N	70° 41.75'E	110	93	222	244	244	6.4	7.7	279[G]
TP-15	25° 02.96'N	70° 27.28'E	105	82	212	231	231	6.3	13.4	270
TP-18	25° 10.27'N	70° 33.23'E	137	66	224	230	230	0.6	0.6	288
TP-19	25° 09.62'N	70° 20.62'E	105	55	194	223	223	2.5	4.2	260
TP-20	25° 09.61'N	70° 07.50'E	70	63	208	244	258	2.7	5.64	311
TP-22	25° 18.24'N	70° 27.22'E	104	39	165	179	232	2.7	12.9	284
TP-23	25° 16.36'N	70° 16.00'E	75	23	188	206	206	1.3	2.0	246
TP-24	25° 24.05'N	70° 34.24'E	134	42	155	176	176	0.4	0.5	225
TP-25	25° 22.40'N	70° 20.57'E	114	44	175	189	206	1.0	2.1	276
TP-28	25° 29.78'N	70° 26.51'E	128	32	175	194	215	3.4	5.6	260
TP-30	25° 34.05'N	70° 33.30'E	139	15	99	123	131	0.9	1.5	163
TP-31	25° 34 12'N	70° 20.58'E	90	20	168	218	239	3.6	5.6	256
STP-1	24° 47.41'N	70° 14.75'E	91	78	118	136	144	10.3	30.6	237
STP-2	24° 49.66'N	70° 21.41'E	91	65	115	125	163	5.2	15.4	223
STP-3	24° 46.74'N	70° 19.46'E	70	65	107	128	153	11.0	26.9	215
STP-4	24° 41.52'N	70° 16.67'E	76	81	144	147	180	10.9	17.3	234
STP-5	24° 40.62'N	70° 21.85'E	53	62	127	142	169	11.5	28.8	231[G]
STP-6	24° 39.49'N	70° 29.77'E	46	14	94	no coal	no coal	0.0	0.0	112[G]
STP-7	24° 42.00'N	70° 26.01'E	92	44	135	145	190	4.0	24.1	224
STP-8	24° 45.52'N	70° 29.25'E	88	51	154	154	154	5.6	11.8	206[G]
STP-9	24° 48.12'N	70° 24.32'E	84	53	129	130	177	5.3	25.1	225
STP-10	24° 48.79'N	70° 31.74'E	91	62	151	no coal	no coal	0.0	0.0	175[G]
STP-11	24° 37.91'N	70° 15.41'E	45	54	138	143	171	15.5	28.7	231
STP-12	24° 33.65'N	70° 15.87'E	42	58	146	147	171	4.0	14.6	243
STP-13	24° 22.31'N	69° 55.59'E	30	63	147	no coal	no coal	0.0	0.0	249
TH-6	25° 06.55'N	70° 15.25'E	93	40	212	240	245	4.6	12.5	301

[G]Drill hole penetrated granite near total depth.

Company personnel for holes STP-1 through STP-10. The GSP selected the locations, drilled, and carried out the geologic work for holes STP-11 through STP-13 independently. The drill hole locations and summary data about each drill hole are in table 1 and the locations of the drill holes are shown on figure 2. The complete raw data set for the Thar test holes in the form of drill-site geologist's core descriptions and strip logs, copies of geophysical logs, and complete coal-analyses report sheets will be published separately; for TP-1 through TP-4 in SanFilipo and others (1994) and for TP-5 through TP-31 in Thomas and others, (1994).

Field Limits

An isopach map of the total coal thickness in the Thar coal field (fig. 6) shows that the field is defined quite sharply on its eastern side by the zero coal line in the north and by the northeast-trending fault to the south. This fault is upthrown on the east side and the coal-bearing strata that may once have been present east of the fault are no longer present due to their erosion. The coal-thickness pattern shown by the isopach map does seem to indicate that the coal is generally thinning eastward toward the fault but it is possible that a lobe of thicker coal may have extended further eastward prior to the time of faulting and erosion of the coal.

To the south the total-coal isopach lines do not close and the limit of the field in that direction is not presently known. Drill hole STP-13, the southernmost coal test hole, was drilled to a total depth of 249 meters and did not penetrate any coal beds. It is thought that this hole may be located south of a large east-trending fault that has down-dropped the coal-bearing strata and that coal may be present at the STP-13 drill site at greater depths. Such a fault or fault zone is tentatively shown on the Tectonic Map of Pakistan compiled by A. H. Kazmi and R. A. Rana (1982) and is thereon labeled the Rann of Kutch fault zone. Thus, the Thar field is probably limited to the south along an east-trending fault zone running between drill holes TP-4 and STP-13 that has dropped the coal down to great depths to the south (we have tentatively sketched in the Rann of Kutch fault zone on figure 6).

To the north and northwest the total coal is thin and the field is fairly well defined in those areas by the 1.5-meter isopach line. In the west central part of the field the isopachs do not close beyond the 12-meter coal-thickness line, thus the limits of the field in that direction are not known. The size of the field is thus roughly 9,100 square kilometers; about 140 km (north-south) and about 65 km (east-west).

Total Coal Thickness

Coal thickness measurements and methodology

The total coal thickness for the drill holes shown on figure 6 represents the sum of the thicknesses of the coal beds present in each drill hole. For the most part, these

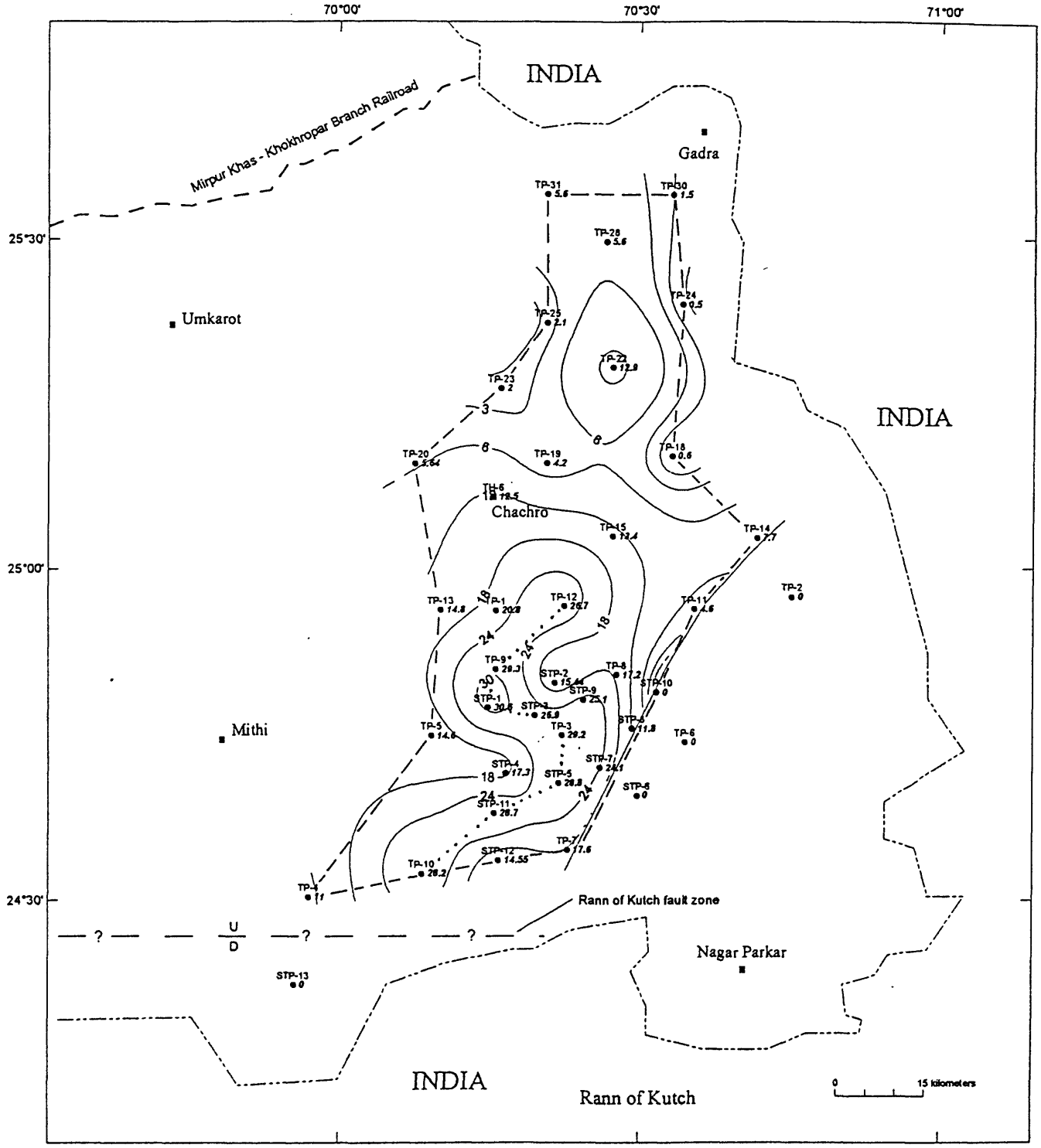

Figure 6. Isopach map of total coal in the Thar coal field. Coal-thickness values at each control point represent the sum of the thicknesses of all coal beds in each drill hole. The area bounded by the dashed line is the area for which coal resource calculations were made. The dotted line from TP-10 to TP-12 is the line of the coal correlation diagram on figure 8. (This map was generated using the computer program Surfer, manufactured by Golden Software; total coal resources for the Thar coal field were based on area-determinations for the various coal-thickness intervals shown on this map using the Surfer program.) Contour interval is variable, as shown.

thicknesses represent coal beds actually measured by the drill site geologist in drill core. (Drill hole TH-6 is the only drill hole that was not cored; coal thicknesses in this water well were determined from geophysical logs.) The tables accompanying the stratigraphic columns for each of the 39 drill holes in appendix 1 give the depths to the top and bottom of each coal bed and the bed thicknesses. For some of the drill holes there was core loss in coal beds (denoted by CLC on the table); in most instances the core loss in coal has been determined from the geophysical log for the hole, in a few rare cases where there was no geophysical log of the coal-bearing interval of the drill hole, the drill site geologist's notation that the lost core was "probably coal" has been accepted but this has only been done for relatively thin lost-core intervals within thicker coal beds.

The most serious question regarding whether lost core was coal or not arose with hole TP-7. There was extensive core loss in this drill hole that the drill site geologist noted as "probably coal" and there were no geophysical logs run in the coal-bearing part of this hole because of poor hole conditions. The total thickness of the probable-coal intervals in TP-7 was 20.7 m; because the total thickness of recovered coal from TP-7 was only 17.6 m we thought it prudent to not include the 20.7 m of probable coal in the total coal thickness for this drill hole. (If all of this lost core is coal, TP-7 has a total of 38.3 m of coal, by far the thickest total coal of any of the Thar Desert drill holes.)

All of the coal **benches** from which samples were collected for coal-quality analysis (drill holes with the TP- prefix) are numbered from the top down. The word **"bench"**is here used as defined in Wood and others (1983) as a layer of coal containing no partings of non-coal material greater than 1 cm in thickness. As can be seen on the stratigraphic columns in appendix 1, coal samples were not collected for analysis from some of the thinner coal benches in the TP- holes (usually benches less than .3 m thick); these benches are labeled NA. For the TH-6 hole and the holes with an STP- prefix all of the coal benches penetrated are numbered from the top down on the stratigraphic columns in appendix 1.

Coal **beds** are defined by Wood and others (1983) as intervals of mixed coal and noncoal layers in which the noncoal partings are less thick than overlying or underlying coal **benches**. The coal **beds** present in the Thar coal test holes are shown in brackets and are lettered alphabetically from the top down on the stratigraphic sections in appendix 1. Wood and others (1983) state that benches of "... lignite less than 75 cm thick are omitted from calculations [of reserves or resources] if they lie above or below partings that may deter their mining". Because the minability of these beds is presently unknown in the Thar Desert, in this report every measured coal bench, regardless of thickness, has been included in total coal thicknesses and consequently these thinner beds are included in the total coal tonnage resources numbers.

Coal distribution

Figure 6, the total-coal isopach map, shows the distribution of the coals in the Thar field. The area of thickest total coal is in the southern two-thirds of the field area; the area bounded by the 18-m isopach line has a somewhat sinuous northeasterly trend; within this thick-coal area total-coal thickness reaches its maximum value of 30.6 m at STP-1. There are ten drill holes within this thick-coal area that penetrated more than 24 m of total coal. The total coal thins away from the thick-coal area to the west, north, and east and to some extent to the south, although the total-coal thickness south of TP-10 (total-coal thickness of 28.2 m) is unknown because of lack of control south of that drill site. As discussed above, the Rann of Kutch fault zone (fig. 6) is probably located about 10 km or so south of drill site TP-10 and has probably dropped the coal-bearing rocks down to the south to great depths, hence regardless of the coal thicknesses south of TP-10, the area of potentially minable coal to the south is probably not large, in a relative sense.

With the exception of the 12.9 m of total coal found at TP-23, there is a marked thinning of total coal in the northern third of the Thar coal field but the northerly trend of the coal field is continued in this area. The width of the coal field is considerably narrower in its northern part.

Figure 7 is an isopach map of the thickest bench of coal present in each drill hole. The trends and patterns shown on this map are similar to those shown on the total-coal isopach map (fig. 6) with the thickest coal benches exhibiting a northerly trend. Drill hole TP-3 has the thickest coal bench at 19.6 m. Six drill holes contain coal benches more than 10 m thick; these drill holes are located on the same sinuous, northerly thick-coal trend seen on figure 6.

Coal Bench Correlation

A perusal of the stratigraphic columns in appendix 1 shows that the coal beds penetrated in the Thar Desert coal test holes are not easily correlated field-wide. However, a correlation diagram constructed along the sinuous thick coal trend portrayed on figure 6 shows that some coal-bench and coal-bed correlations are possible (fig. 8). Figure 8 is an 8-drill-hole correlation diagram on which the most probable coal-bench correlations are indicated (the line of this cross section is shown on figs. 2 and 6). (The suggested correlations are admittedly conservative, but we think, the most realistic given the relatively wide spacing of the drill holes.) This diagram shows that the coal benches in the southernmost 5 drill holes do seem to correlate quite nicely, especially the thicker coals in the lowermost coal bed. Coal-bench correlations from STP-3 to STP-1 and TP-9 are much less certain due to the spreading-out of the coals vertically in the last-mentioned two drill holes. It is interesting to note that TP-12 contains a thick coal bed at its base similar to the bed in the southernmost five holes but there is no apparent connection of these thick beds.

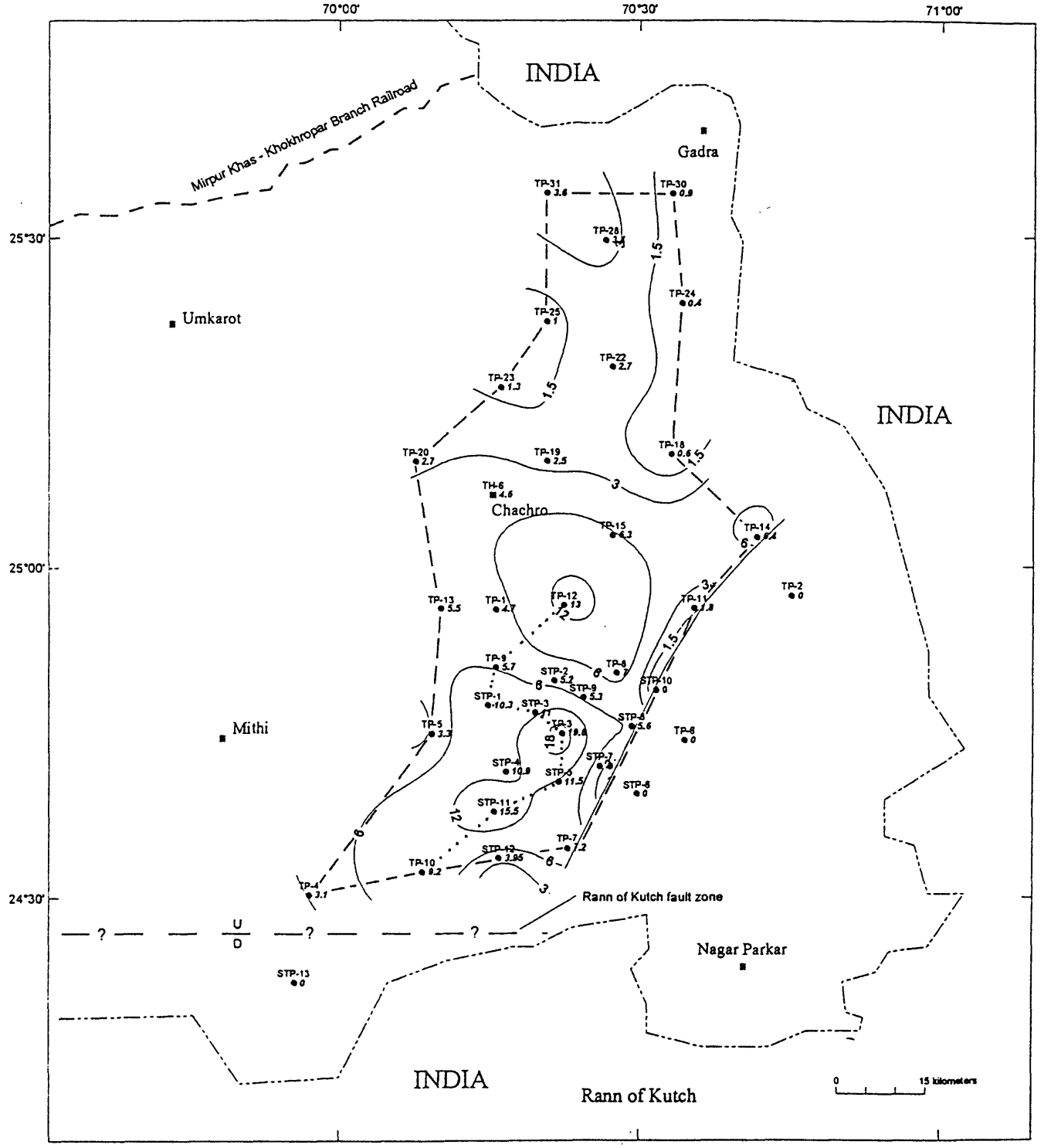

Figure 7. Isopach map of thickest coal bench in the Thar coal field. Coal-thickness values are the thickness of the thickest coal bench present in each drill hole. The area bounded by the dashed line is the area for which coal resource and reserve calculations were made. (This map was generated using the computer program Surfer, manufactured by Golden Software; the total coal resources for the Thar coal field were based on area-determinations for the various coal-thickness intervals shown on this map using the Surfer program.) Contour interval is variable, as shown.

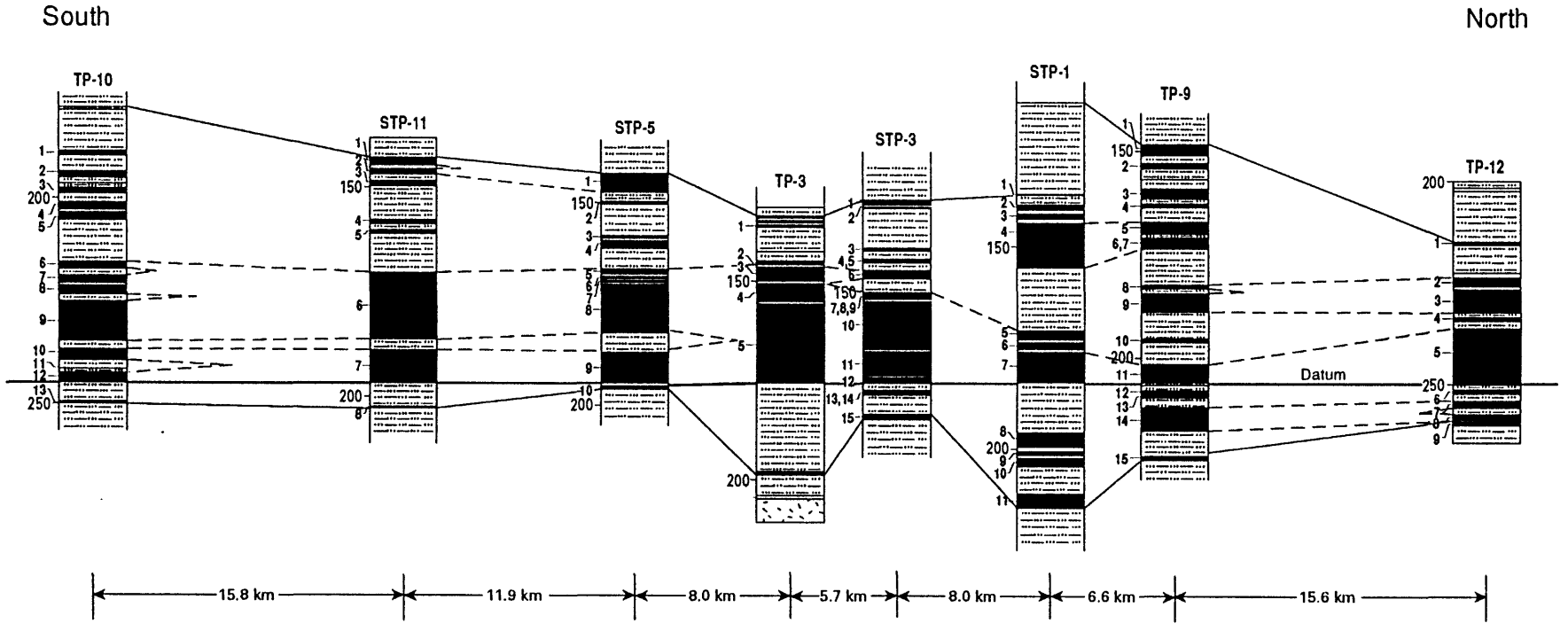

Figure 8. Coal-correlation diagram; line of section is through the thickest total-coal area on the total coal isopach map (fig. 6). The line of section is also shown on figure 2. Datum for this diagram is the base of the thickest coal bed for drill holes TP-10 through STP-3 and for TP-12; datum for STP-1 and TP-9 is a bit more subjective because of the wider vertical distribution of coals in these drill holes.

Coal Quality

Sample collection and analysis

Coal samples were collected from 22 of the 25 TP-series drill holes for analytical analysis; a total of 315 samples were analyzed. Sampled intervals varied from less than .2 m to more than 2 m but most sampled intervals were less than one-meter thick and averaged .74 m. Coal samples were collected at the drill site and for the most part, the utmost care was used to wrap the coal-core samples in waterproof plastic bags as soon as possible after the core was pulled and described. Procedures were as follows: as soon as the core was pulled and removed from the core barrel the core was washed and described and then double-wrapped in heavy plastic core-sample bags. If the coal core was left unwrapped for any length of time it was covered with water-soaked cloths. The only drill hole from which coal core apparently dried out prior to bagging was TP-1. The summary coal-analysis sheet for TP-1 (appendix 2) identifies those samples that probably dried prior to waterproof bagging.

Coal samples from the TP- drill holes were analyzed by three different laboratories; the Geochemical Testing laboratory in the United States, the Geological Survey of Pakistan laboratory in Karachi, Pakistan, and the Pakistan Council of Scientific and Industrial Research, Fuel Research Centre in Karachi, Pakistan. Table 2 summarizes the selected coal-analyses results for the TP-series drill holes and identifies the laboratory that performed the analyses.

Table 2. Selected coal-analyses values for 315 coal samples from 22 sampled coal test holes, Thar Desert, Sindh Province, Pakistan

[Coal analyses values shown are weighted averages for all samples analyzed from each coal test hole; GT, Geochemical Testing; GSP, Geological Survey of Pakistan; PCSIR, Pakistan Council of Scientific and Industrial Research, Fuel Research Centre; NA, not available; DAF, dry, ash free; MMM, moist, mineral matter; sampled coal thicknesses in meters]

Hole number	Sampled-coal thickness	Number of samples	Analytical laboratory	As received values-%			Heating values - Btu				Volatile matter (DAF-%)	Apparent specific gravity
				Total sulfur	Ash	Moisture	As received	Dry	DAF	MMM free		
TP-1[1]	18.86	24	GT	1.68	8.08	48.24	5,404	10,485	12,350	5,759	55.09	1.3
TP-3	27.22	36	GT	1.17	7.89	47.94	5,549	10,760	12,544	5,938	57.55	1.18
TP-4[2]	10.49	17	GSP	2.23	13.41	45.45	4,934	8,952	12,037	5,612	59.04	NA
TP-5	13.17	19	GT	1.11	10.16	48.48	5,185	10,144	12,496	5,701	56.97	1.19
TP-7	16.24	21	PCSIR	1.81	10.12	48.63	5,210	10,375	12,535	5,647	59.82	1.33
TP-8	16.89	18	PCSIR	1.2	7.6	49.4	5,276	10,465	12,230	5,625	60.09	1.29
TP-9	26.82	37	PCSIR	0.91	9.74	47.13	5,151	9,897	11,910	5,669	57	1.3
TP-10	25.09	33	PCSIR	1.4	8.68	47.21	5,453	10,417	12,322	5,869	61.2	1.38
TP-11	4.49	5	PCSIR	0.57	5.53	50.59	5,416	10,958	12,339	5,710	60.07	1.28
TP-12	25.09	32	PCSIR	1.27	6.99	48.11	5,400	10,470	12,043	5,715	60.53	1.45
TP-13	12.15	17	PCSIR	1.47	10.03	49.37	4,816	9,558	11,841	5,270	59.31	1.45
TP-14	4.75	5	PCSIR	2.56	8.54	47.36	5,253	10,072	11,906	5,752	58.16	1.3
TP-15	9.66	15	PCSIR	1.71	7.57	45.6	5,528	10,227	11,782	5,857	59.37	1.32
TP-18	0.6	1	PCSIR	0.8	8.46	44.72	5,659	10,236	12,084	6,154	63.62	2.1
TP-19	2.83	3	PCSIR	1.41	7.51	51.27	5,454	11,195	13,228	5,808	59.78	1.38
TP-20	2.35	3	PCSIR	1.54	9.19	49.5	5,071	10,070	12,271	5,490	60.09	1.36
TP-22	4.45	11	PCSIR	1.6	6.78	50.14	4,986	10,033	11,586	5,252	57.51	1.3
TP-23	2.35	2	PCSIR	2.4	17.13	44.05	4,414	7,894	11,349	5,174	61.31	1.35
TP-25	2.1	3	PCSIR	1.81	6.06	44.16	5,392	10,846	12,349	5,613	62.09	1.36
TP-28	4.49	6	PCSIR	2.18	5.71	51.85	4,936	10,305	11,638	5,123	57.67	1.27
TP-30	1.52	2	PCSIR	1.52	6.84	47.02	4,539	9,711	11,375	4,777	57.29	1.37
TP-31	4.49	5	PCSIR	3.6	9.58	47.95	4,886	9,438	11,455	5,109	56.62	1.68
		Arithmetic averages		1.63	8.71	47.92	5,178	10,114	12,076	5,574	59.1	1.32
		Weighted averages		1.57	8.83	48.57	5,333	10,356	12,322	5,747	58.72	1.33

[1] Weighted-average values do not include analyses values for some coal samples that dried out prior to sealing in plastic bags.

[2] Not all samples from this hole have Btu values, Btu averages are for 12 of the 17 samples.

Note.--To convert Btu (British thermal unit) heating values to kilogram-calories multiply by .556.

The majority of the coal samples were submitted to the testing laboratories for proximate and ultimate analysis, heating value, total sulfur and forms of sulfur, free swelling index, equilibrium moisture, apparent specific gravity, and Hardgrove grindability index determinations. All of these values are not summarized on the tables in this report; the values shown herein are: total sulfur, ash, moisture, and heating value on the as-received basis. Heating values are also given on the dry, dry and ash free, and moist, mineral-matter free basis. Volatile matter is presented on the dry and ash-free basis and apparent specific gravity is also given. Copies of the complete testing-laboratory analysis reports for each of the 315 samples will be published separately along with all other raw data acquired during the Thar Desert test drilling program; for TP-1 through TP-4 in SanFilipo and others (1994) and for TP-5 through TP-31 in Thomas and others, (1994). Heating values are shown as reported by each coal analysis testing laboratory in Btus (British thermal units). Even though all other measurements in this report are metric, coal heating values were not converted to kilogram-calories on the tables because of the difficulty this would have created for the reader wanting to compare values on the tables in this report with the values shown on the original laboratory analysis report sheets. Btu heating values can be converted to kilogram-calories by multiplying by 0.556.

We have created a detailed table for each of the drill holes from which samples were analyzed providing the above-listed values in three categories; by coal sample, by coal bench, and by coal bed. Coal bench and bed numbers on these tables are keyed to the numbered benches and beds shown on the stratigraphic columns shown in appendix 1 of this report. Composite-sample values for coal benches and beds are all weighted averages. The coal-analysis tables are in appendix 2 of this report. Table 2 presents the averages (arithmetic and weighted) of the analyses from each of the sampled drill holes.

Heating values

The over-all average analytical values for Thar Desert coals show that the coal is in the lignite B category because weighted-average MMF (moist, mineral matter free) heating values, are 5,747 Btu; below 6,300 Btu, the American Society for Testing and Materials (ASTM) threshold value between lignite B and lignite A. The highest average MMF heating value on table 2 is for TP-18 which had a value of 6,154 Btu; this value only represents a single coal sample from a coal bench .6-m thick and thus is not thought to be representative. The highest MMF heating value of 5,938 Btu for a drill hole with more than one sample came from drill hole TP-3 which had 36 samples from coals totaling 27.22-m thick (table 2). The lowest MMF heating value of 4,777 Btu came from TP-30 which only had two samples analyzed from two thin beds totaling 1.52-m thick and thus this average value cannot be considered to be representative.

A few thin coal benches from drill holes TP-4, TP-10, TP-12, and TP-22 had MMF heating values in excess of 6,300 Btu putting them in the lignite A range on the ASTM scale but these values appear to be anomalous. The highest MMF heating value for one

of the relatively thick coal benches found in the southern part of the coal field is from bench 9 of TP-10; this 8.93-m thick bench has an MMF heating value of 6,106 Btu. Bench 5 of TP-3, 19.58-m thick, has an MMF heating value of 6,043 Btu.

As received heating values are probably more important to consider in terms of the amount of heat that will be produced from the coal as it comes out of the ground. As received heating values were the only values from the coal analyses results for the TP-test holes that were susceptible to contouring; figure 9 is an iso-Btu map showing the distribution of the weighted-average, as-received heating values in the Thar coal field; these values are from table 2. The map shows that there is an area of heating values greater than 5,250 Btu that again shows the northeasterly trend first noted on the total-coal isopach map (fig. 6). Within the 5,250-Btu isopleth are two areas with heating values greater than 5,500 Btu. As figure 9 shows, TP-3 has one of the highest as-received heating values at 5,549 Btu; the thickest bench in TP-3, bench 5 (19.58-m thick) has an as-received heating value of 5,725.

Heating values for Thar coals are also given on the included tables in the standard categories of dry, and dry and ash free; these values are of interest in terms of providing some indication of what the heating value for the Thar coals would be if some of their moisture or ash content were to be removed. On the dry basis, with all of the coal's moisture removed, the weighted-average for all samples analyzed is 10,356 Btu; with all of the moisture and ash removed the heating value is 12,322 Btu.

Moisture

The weighted average for as-received moisture content for Thar coals is 48.57 percent (table 2); that is, nearly 50 percent of the coal's weight is in its contained moisture. The distribution of moisture-percentage values for the Thar coals appears to be random with no discernible pattern throughout the field area.

Sulfur

The weighted average for as-received sulfur percentage for all analyzed Thar coals (table 2) is 1.57 percent. The range of sulfur content for Thar coals is from .57 to 3.6 percent. The end members of this range are drill holes with relatively thin total coal and few samples. In drill holes from which more the 10 coal samples were analyzed, sulfur percentages range from .91 percent in TP-9 to 2.23 percent in TP-4. Sulfur percentages for the thicker (more than 6-m thick) coal benches in the field range from .8 percent in TP-3 for the 19.58-m thick bench 5, to 1.6 percent for the 6.65-m thick bench 8 in TP-8. The other coal bench over 10-m thick, the 12.67-m thick bench 5 in TP-12 has a sulfur value of .89 percent. The arithmetic average for sulfur for the six analyzed coal benches over 6-m thick is 1.1 percent. In a general sense, it is clear that the thickest coal benches in the Thar field have lower sulfur values than do the thinner benches. Sulfur

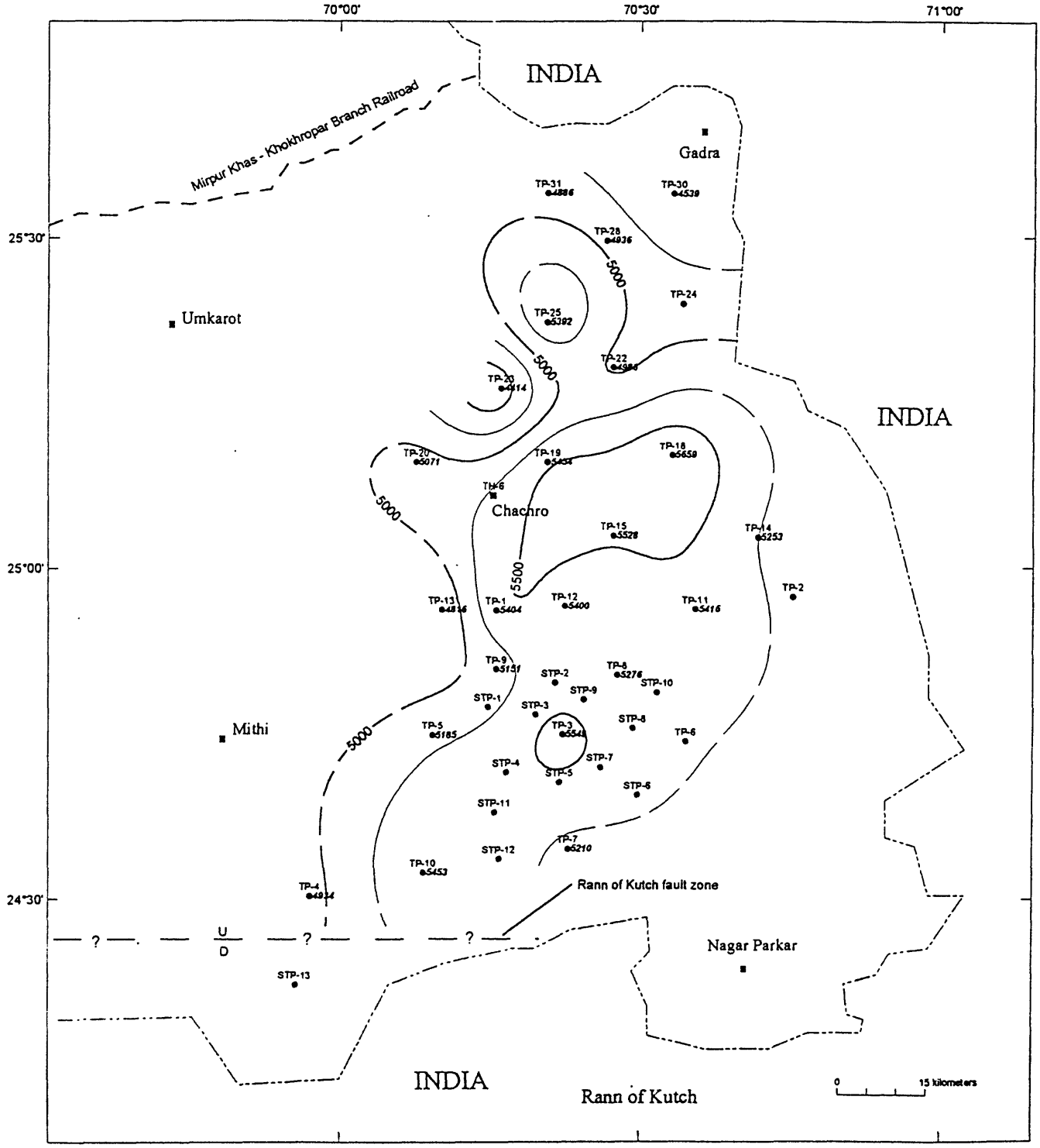

Figure 9. Isopleth map of as-received heating values for the Thar coal field. Heating values are given in Btu's (British thermal units); to convert Btu values to kilogram-calories, multiply by .556. Map constructed using the Surfer computer program. Contour interval is 250 Btu (as received).

percentages do not seem to have any specific geographic pattern throughout the Thar field.

Ash

The weighted average for as-received ash values for all the coals in the Thar field is 8.83 percent. The range for weighted-averaged ash values is from 5.53 percent in TP-11 to 17.13 percent in TP-23. As with the sulfur values these extremes are from drill holes with few samples and thin coals. Looking just at the ash values for drill holes with more than 10 samples analyzed, the range in ash content is 6.99 percent to 13.41 percent. For the thickest analyzed coal benches in the field the ash values range from 5.0 percent for the 12.67-m thick bench 5 in TP-12 to 10.28 percent for the 5.69-m thick bench 14 in TP-9. The thickest bench in the Thar field, bench 5 in TP-3 (19.58 m) has an as-received ash value of 6.21 percent. As with the sulfur values, the thickest coal benches tend to have the lowest percentage of ash values. Ash-percentage values seem to have a random geographic distribution throughout the field.

Overburden

The overburden in the Thar coal field consists of three kinds of material: dune sand, alluvium that was probably deposited by an ancestral Indus river system, and Paleocene to Eocene sedimentary rock. The dune-sand thickness throughout the field (at inter-dune drill sites) ranges from 14-m to 93-m thick and averages around 50-m thick; alluvium thicknesses range from 11-m to 209-m thick and average around 100-m thick. The Paleocene-Eocene bedrock interval above the first coal bed is normally quite thin with the first coals generally located less than 20 m beneath the alluvium-bedrock contact. In a few drill holes alluvium rests directly on the first coal bed.

It must be strongly emphasized at this point that in planning the coal test drilling program every effort was made to locate drill holes at the lowest possible elevation in the interdune areas. Thus, the average dune-sand thickness of 50 m is the average thickness of dune sand *beneath an imaginary plane connecting the surface elevations of all the drill sites*. Because the relief of the sand dunes at the surface in the Thar Desert exceeds 100 m in places, the average sand dune thickness overlying the alluvium layer probably averages more like 80 meters throughout the coal field; 50 m of dune sand below the low points where the test holes were sited plus an average of 30 m more represented by present dune topography. The "total overburden" isopach map (fig. 10) **does not** include the thickness of the dune sand above the imaginary plane referred to above. To compile an overburden map including the topography of the dunes between all of the test holes would have been an enormous undertaking far beyond the scope of this report. (If digitized large-scale topography were available throughout the Thar coal field area, such a map could be drawn quite easily using a computer-contouring program.) Figure 10 is thus a somewhat flawed total-overburden isopach map.

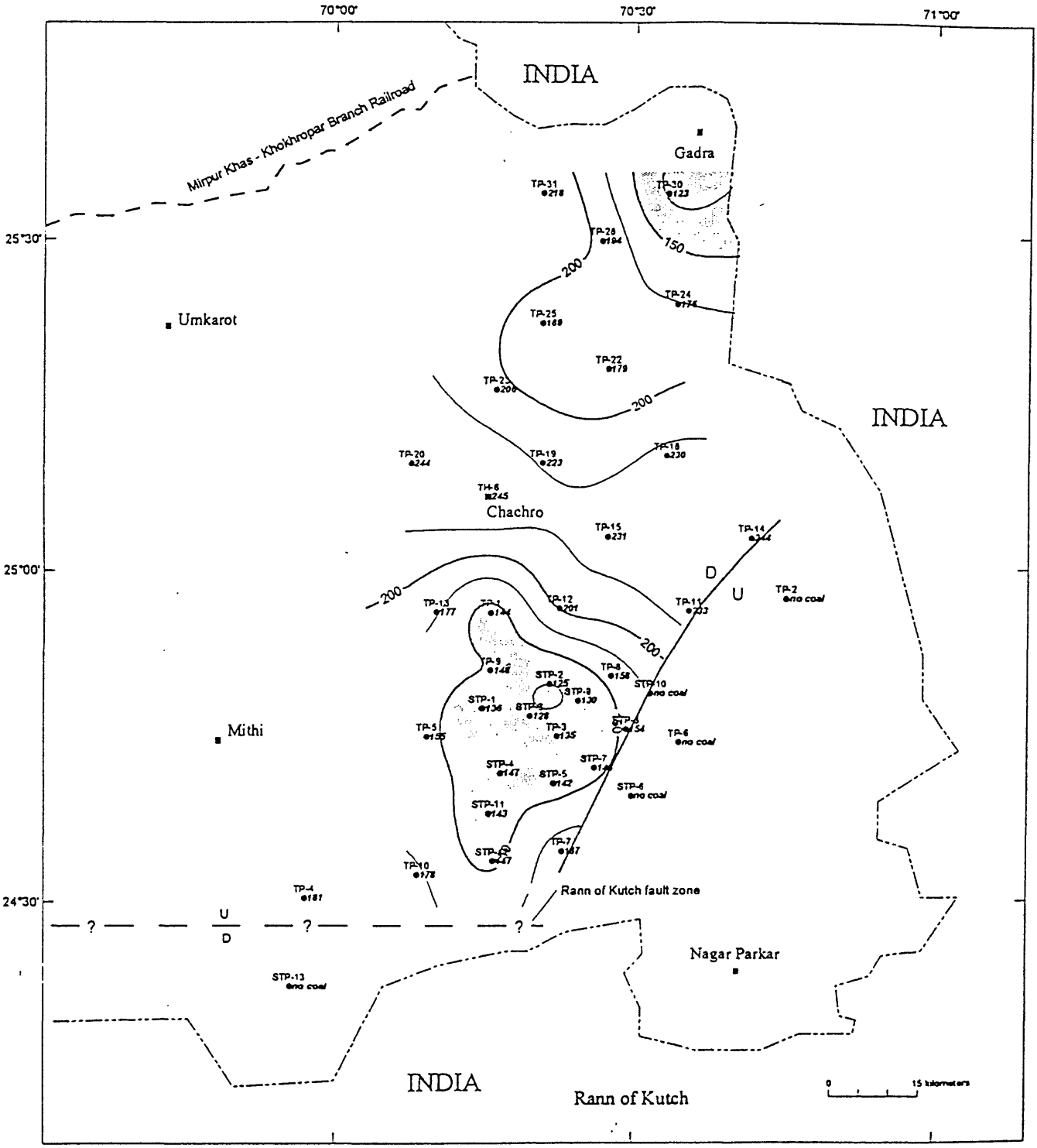

Figure 10. Total-overburden isopach map for the Thar coal field. Interval contoured is from the surface to the top of the first coal bed at each drill hole. Map constructed using the Surfer computer-contouring program. Contour interval is 25 m. Shaded areas are underlain by less than 150 m of overburden.

The values on figure 10 represent the interval from the ground surface to the top of the first coal bench penetrated. This map shows two areas of least (less than 150 m) overburden. The largest and most significant of these thinner-overburden areas is in the same part of the field where the thickest coals are found in the southern part of the field area. The area to the north where the overburden is less than 150-m thick is confined to a small region around TP-30 where the total coal is only 1.5-m thick. The thinnest overburden in the southern part of the field where the coals are thickest is 125 m at drill site STP-3. The area of thickest overburden (more than 225-m thick) is present along an east-trending band in the center of the coal field area.

The 150-m overburden isopach line is especially significant because lignite may be classified as coal reserves only where it is shallower than 150 m whereas lignite deeper than 150 m must be classified as resources (Wood and others, 1983). This subject will be discussed at greater length below in the "Coal Resources" section of this report.

Structure

The geologic structure throughout the Thar coal field is best seen on figure 11, a geologic structure map contoured on the top of the highest coal bed penetrated in each drill hole. The structure-contour values for all of the drill holes except one are below sea level; the exception is TP-30 where the top of the first coal is at 16 m above sea level. The major structural elements of the Thar field are the structural dome in the southern part with structural closure of 80 m, the structurally low saddle trending southeastward through the center of the field, the structural high in the northeast part of the field, and the uplifted fault block which sharply truncates the coal field in the southeast. The throw on this fault appears to be on the order of 150 m to the south decreasing to nearly zero at its northern end. There is a regional dip to the west indicated for the field area, however, if the structural and stratigraphic relationships inferred on the geologic cross section of figure 3 are correct there is the possibility, at least, of relatively shallow coal-bearing strata west of the Thar field.

To illustrate the structure of the coal field in another dimension, we have constructed a series of eight intersecting structural cross sections across the field. The lines of these cross sections are shown on figure 2; the cross sections are figures 3-1 through 3-5 in appendix 3 of this report. As shown on figure 2, three of the cross sections are north-trending and five are east-trending.

Structural cross section A-A' (fig. 3-1) trends north across the western part of the field and portrays the more gentle uplift of the structural dome along its western flank. There is slight thinning of the bedrock and alluvium intervals over the dome. There is little expression of the structural dome at the surface. The coal-bearing rocks have been brought closer to the surface over this structure. Cross section B-B' (fig. 3-2) crosses directly over the highest point of the structural dome and best shows the configuration of this structure in cross section. Bedrock does seem to thin over the dome and the

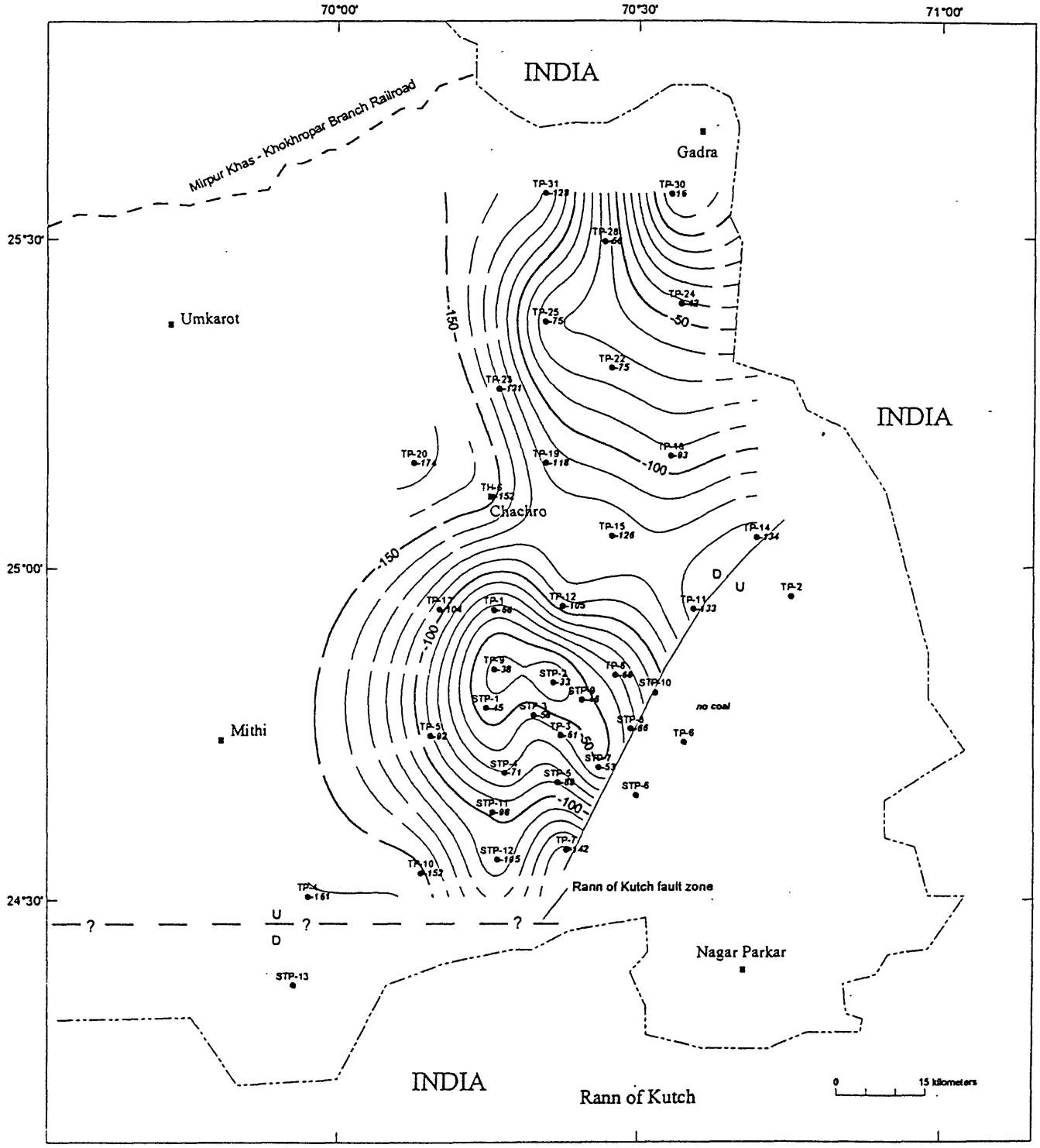

Figure 11. Structure map of the Thar coal field. Values contoured are depths to top of the stratigraphically highest coal bed adjusted to a sea-level datum. Contours were drawn by the Surfer computer-contouring program. Contour interval is 10 m.

alluvium thins dramatically over the structure. As on section A-A' the dome seems to have no surface expression. The very thick coals in TP-3 have been elevated closer to the surface over the dome. Section B-B' extends the entire length of the field and thus also shows the structural saddle between TP-12 and TP-25 and a small structural nose at TP-25.

The third north-trending cross section, C-C' (fig. 3-3), is east of the northeast-trending fault to the south and crosses the fault between drill holes STP-10 and TP-11. We have depicted the probable location and configuration of the fault on this cross section. As can be seen, the granite basement rock and the overlying bedrock have been offset by this fault about 100 m with the coal-bearing rocks apparently eroded off of the upthrown fault block to the south. The depths to the top of the granite basement at drill holes TP-11 and TP-18 are derived from the basement structure map (fig. 3) in Ahmad and others (1993). North of the fault, the bedrock rises steadily toward the surface. There seems to be no expression of the fault at the surface.

East-trending cross sections D-D' (fig. 3-1) and E-E' (fig. 3-4) cross the northernmost part of the Thar field and show the eastward-rising regional structural trend there; this eastward structural rise is mimicked by a topographic rise of the land surface. Section F-F' (fig. 3-4) crosses the north flank of the structural dome on its western end and crosses the fault at its eastern end. The estimated location of the fault is shown and apparently the coal-bearing rocks have been removed by erosion east of the fault where alluvium rests directly on the granite basement rock. The throw on the fault in this area is about 40 m. The depths to the top of the granite basement at drill holes TP-1, TP-12, and TP-11 are based on data on figure 3 in Ahmad and others (1993). Bedrock does not appear to thin over the dome on this cross section but the alluvium layer thins markedly over this structure. Again there is no expression of the fault or the structural dome at the surface.

Cross section G-G' (fig. 3-5) crosses nearly over the top of the structural dome and then crosses the fault at its eastern end. The throw on the fault between STP-9 and STP-10 is shown to be about 80 m but the depth to the granite basement rock is not know at drill site STP-10 so this is only an estimate. The depths to the top of the granite basement at drill holes STP-3, STP-1, and TP-5 are based on data in Ahmad and others (1993). Alluvium thins greatly over the dome whereas bedrock does not appear to thin appreciably. Again, neither the dome nor the fault show much expression at the surface. Cross section H-H' (fig. 3-5) is the southernmost of the east-trending cross sections and crosses the southernmost flank of the structural dome to the west before crossing the fault between TP-7 and STP-6. The throw on the fault here appears to be about 150 m. East of the fault at drill sites STP-6 and TP-6 the coal has apparently been eroded and alluvium rests directly on the granite basement.

Coal Resources

For coal resource calculations, the field was conservatively defined as being the area enclosed within a boundary line connecting the outermost coal test hole locations. The field area, so defined, is shown on figures 6 and 7 and it contains 4,320 square kilometers (431,900 hectares). Only coal resources within this boundary are included in the tables in this report (the exception is for measured and indicated resources for the edge-holes, those holes on the periphery of the field boundary; for these drill holes measured and indicated resources were included that fell within a .4 km and 1.2 km arc, respectively, outside the above-described field boundary.) There is undoubtedly additional coal to the south and west of the herein tightly-defined field area but additional test drilling in those areas will be required to quantify those resources.

The coal resources for the Thar coal field are herein given in the standard U.S. Geological Survey format as set forth in Wood and others (1983): coal quantities are presented in the measured, indicated, inferred, and hypothetical categories and in the thickness ranges recommended (in those few instances where U.S.G.S. standards were not strictly adhered to for calculation or presentation of coal resources, the reasons for so doing are clearly stated in the text). For coal resource determinations based on drill hole data, resource areas are defined by the U.S.G.S. as having radii (centered on the drill hole) of .4 km for measured, 1.2 km for indicated, and 4.8 km for inferred resources; beyond 4.8 km, resources are in the hypothetical category. Resource numbers are provided in three groupings; total coal, total coal with less than 150-m of overburden, and thickest coal bench. The total-coal resource determinations for each of the three groupings were made using a computer contouring program named Surfur, by Golden Software. Using that program, isopach maps were drawn for the three groupings listed above; these maps are shown on figures 6, 7, and 12 of this report. The areas for each thickness-range polygon on the three isopach maps were measured by the Surfer program in square kilometers. The coal tonnage was calculated by multiplying the area in square kilometers for each coal-thickness range polygon times the average thickness of coal for each area in meters and multiplying by 100 to obtain the volume of the coal in hectare-meters. The hectare-meter number was next multiplied by 13,200, the number of metric tons of coal per hectare-meter for coal of the specific gravity of the Thar field (Wood and others, 1983); as shown on table 2, the average specific gravity for Thar coal is 1.33.

The coal tonnages for the measured, indicated, and inferred categories were determined as follows: For measured resources the area of a circle with a radius of .4 kilometers was calculated (0.50 km^2) and this area was multiplied by the coal thickness value for that drill hole. The coal tonnage for that area was then determined by multiplying the area by 100 and then by 13,200, as described above. The coal tonnage thus determined was then assigned to the thickness-range category based on the thickness value for the test hole. Tonnage for the indicated-reserves category was calculated by determining the area of a circle with a 1.2 km radius (4.52 km^2) and this number was multiplied by an estimated thickness value. This estimated value was determined by observing the

thickness values of nearby drill holes and slightly modifying the value for the hole in question based on whether nearby holes had greater, lesser, or equivalent values than the drill hole in question. (For example, a drill hole with a total coal thickness of 20 m surrounded by drill holes with values of 10 m might be estimated to have a value of 19 m for calculating indicated resources.)

The procedure for determining inferred resources was to draw an arc around the drill hole on the isopach map with a radius of 4.8 km and then using a polar planimeter determine the areas of each thickness-range polygon within the area bounded by the arc. (In those cases where 4.8-km-radius arcs from nearby test holes intersected, areas for coal-thickness-range polygons within the larger area defined by the outer limit of 4.8-km arcs from two or more test holes were determined with a polar planimeter. In those instances where the 4.8 km arc intersected the boundary line of the field, coal resources were measured only for the area within the field boundary.) The coal tonnage for hypothetical resources was determined by subtracting the sum of tonnage for measured, indicated, and inferred resources from the total coal resources for the field for each of the three groupings.

The coal tonnages for the Thar field in the total-coal grouping is tabulated below; tonnages are based on the sum of the thicknesses of all of the coal benches identified in each of the Thar coal field test holes and contoured on figure 6; all coal benches, regardless how thin, are included in the total-coal-thickness values. Tonnages are presented in 8 thickness-range categories:

Geologic assurance category	Coal thickness ranges				
	0 to 1.5 m	1.5 to 3 m	3 to 6 m	6 to 12 m	12 to 18 m
Measured					
area km^2	1.5	1.5	2.5	1.5	5.0
metric tons	729,920	3,715,958	17,013,781	20,238,702	99,096,648
Indicated					
area km^2	12.0	12.0	20.1	12.0	40.2
metric tons	12,208,363	31,847,904	139,599,979	161,893,512	805,751,971
Inferred					
area km^2	20.4	109.9	210.8	217.8	171.7
metric tons	20,196,000	326,403,000	1,252,152,000	2,587,464,000	5,019,300,000
Hypothetical					
area km^2	22.8	92.5	648.1	720.9	544.6
metric tons	23,038,316	279,315,538	3,827,105,640	8,541,945,786	9,152,561,381
Totals (tons)	56,172,600	641,282,400	5,235,872,400	11,311,542,000	15,076,710,000

Geologic assurance category	Coal thickness ranges			
	18 to 24 m	24 to 30 m	>30 m	Totals
Measured				
area km^2	.5	4.5	.5	17.6
metric tons	13,802,131	163,900,308	20,305,058	338,802,507
Indicated				
area km^2	4.0	36.2	4.0	140.4
metric tons	1,179,434,045	1,308,948,854	153,931,536	115,419,988,886
Inferred				
area km^{25}	265.5	370.4	19	1,386
metric tons	7,359,660,000	15,000,876,000	752,400,000	32,318,451,000
Hypothetical				
area km^2	485.9	251.1	9.9	2,775.8
metric tons	13,469,957,002	7,126,370,038	394,419,406	42,814,714,106
Totals (tons)	20,953,825,200	23,600,095,200	1,321,056,000	78,196,555,800

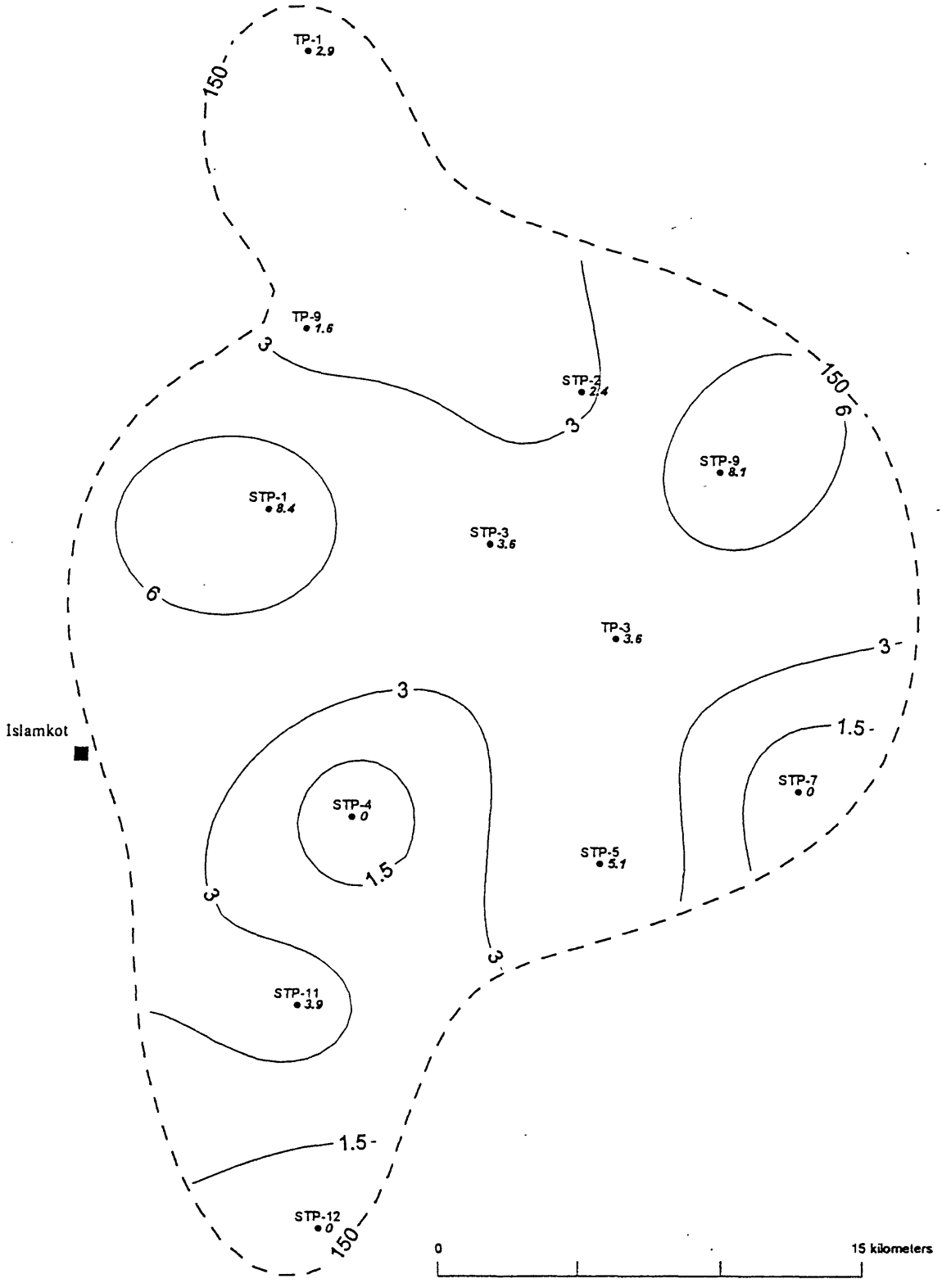

Figure 12. Isopach map showing distribution of coal thicknesses for coals shallower than 150 m. in the Thar coal field. Bounding line is 150-m thickness-of-overburden line from figure 10. Contours were drawn by Surfer computer-contouring program; areas for each coal-thickness range were measured by the Surfer program for coal-tonnage calculations. Contour interval is variable, as shown. Drill holes STP-4, STP-7, and STP-12 have values of zero because these holes do contain coal benches less than 150-m deep, but those benches are all less than .75-m thick and thus are not included in the coal totals for depths less than 150 m.

The coal tonnages for coals with total overburden thicknesses less than 150 m are tabulated below. Figure 12 is an isopach map of total-coal thicknesses at less than 150-m depth. The 150-m of overburden line shown on this map is from figure 10 of this report. The thickness of coal in each of the 12 drill holes containing coal at a depth less than 150 m (fig. 12) was measured down to the 150-m limit; in some drill holes a coal bench ranged from above 150 m to below 150 meters but only the coal above the 150 m line in such benches was included. In accordance with U.S.G.S. standards for coal-resource calculations (Wood and others, 1983), coal benches less than .75-m thick were not included. However, an artifact of the contouring of the coal thicknesses less than 150-m deep (some had zero values because they contained coal less than 150-m deep but the coal was in benches less than .75-m thick) resulted in areas on the isopach map of from 0 to 1.5 m in thickness; consequently those areas were measured, their coal tonnages were determined, and those areas and tonnages are shown on the table below. Tonnages are shown below in 4 thickness-ranges in the geologic assurance categories prescribed by the U.S.G.S.:

Geologic assurance category	Coal thickness ranges				Totals
	0 to 1.5 m	1.5 to 3.0 m	3.0 to 6.0 m	>6.0 m	
Measured					
area km^2	1.5	1	2	1	5.5
metric tons	0	4,578,592	10,749,737	10,948,806	26,277,134
Indicated					
area km^2	12	8	20.1	8	48.1
metric tons	8,758,174	50,425,848	82,804,550	79,619,760	221,608,332
Inferred					
area km^2	39.4	202.2	237.4	58.9	537.9
metric tons	39,006,000	600,534,000	1,410,156,000	515,691,000	2,565,387,000
Hypothetical					
area km^2	5.8	77.5	141	5.1	229.4
metric tons	10,368,626	195,812,060	874,487,513	68,445,234	1,149,113,434
Totals (tons)	58,132,800	851,350,500	2,378,197,800	674,704,800	3,962,385,900

The tonnages of coal calculated for the thickest coal bench present in each of the drill holes is tabulated below. These resource numbers provide a more realistic estimate of the number of tons of coal in the field that would be the primary target of mining. However, in many of the coal test holes there are several thick coal benches and thus the coal tonnage values for the thickest bench in each hole clearly under-represent the tonnage of potentially minable coal in the Thar field. The tonnages of coal in the thickest bench in each drill hole are shown below in 6 thickness-range columns:

Geologic assurance category	Coal thickness ranges				
	0 to 1.5 m	1.5 to 3 m	3 to 6 m	6 to 12 m	12 to 18 m
Measured					
area km^2	3.0	2.0	6.5	4.5	1.0
metric tons	2,786,969	6,436,571	38,486,712	52,952,407	18,911,574
Indicated					
area km^2	24.1	16.1	52.3	36.2	8.0
metric tons	26,539,920	52,018,243	308,393,870	428,354,309	143,315,568
Inferred					
area km^2	137.6	237	502.1	476	169.1
metric tons	136,224,000	729,696,000	2,900,277,600	5,617,920,000	3,251,160,000
Hypothetical					
area km^2	244.5	708.35	872.53	743.14	58.26
metric tons	239,557,111	2,073,295,686	5,267,416,018	8,867,672,484	1,266,540,858
Totals (tons)	405,108,000	2,861,446,500	8,514,574,200	14,966,899,200	4,679,928,000

(Table continued)

Geologic assurance category	Coal thickness range >18 m	Totals
Measured		
area km^2	.5	17.5
metric tons	13,005,854	132,580,087
Indicated		
area km^2	4.0	140
metric tons	98,197,704	1,056,819,614
Inferred		
area km^2	12.0	1,538
metric tons	297,792,000	12,933,069,600
Hypothetical		
area km^2	0.0	2,626,780
metric tons	0.0	17,714,482,157
Totals (tons)	408,622,500	31,836,578,400

Summary of Thar Coal Field Characteristics

The Thar coal field is located in the Thar Desert of southeastern Pakistan in eastern Sindh Province. The field area is about 9,100 square kilometers; the field dimensions are about 140 km (north-south) and about 65 km (east-west). The area of the field contained within a boundary drawn connecting the outermost drill holes contains 4,319 square kilometers (431,900 hectares). The dimensions of the field area so defined are about 115 km long (north-south) by about 40 km wide (east-west). Total coal tonnage for the field is 78,269,762,092metric tons. The coal is lignite B in rank with an as-received heating value of 5,333 Btu, as received sulfur percentage of 1.57, and as-received ash percentage of 8.83 percent. The dry and ash-free heating value for the Thar coals is 12,322 Btu. As received moisture content is 48.57 percent. Nine drill holes in the south-central part of the field contain more than 24 m of total coal; six of these nine drill holes contain coal beds greater than 20 m thick. Drill hole TP-3 contains a bed of coal 27 m thick containing only three partings 1.05 m, .9 m, and .41 m thick.

The shallowest coal in the field lies at a depth of 123 m (TP-30); the deepest coal (depth to 1st coal bed) is at 244 m (TP-14). The field contains 3,962,385,900metric tons of coal at a depth of less than 150 m. All of the drill holes in the field were located in interdune areas at the lowest elevation possible; because the surface relief of the sand dunes of the Thar Desert is as much as 100 m, the Thar coals between drill holes will probably be covered, on average by an additional tens of meters of dune sand.

A structural dome in the south-central part of the Thar coal field has elevated the thickest coals in the field closer to the surface. A north-easterly trending fault forms the boundary of the Thar field in the southeast part of the field area; east of this fault, the coal-bearing rocks were uplifted as much as 150 m and probably eroded prior to deposition of the overlying alluvium. The Rann of Kutch fault zone probably represents the maximum southern extent of minable coal in the field area. Thar coals thin greatly northward, eastward, and westward in the northern half of the field area; to the south, relatively thick coals may be present west of the presently-drilled area. On the basis of

paleontological information the Thar coals are Paleocene to Eocene in age; and are probably early Eocene.

COMPARISON WITH OTHER COAL FIELDS OF SOUTH ASIA

Warwick and Javed (1990) summarized the quality and characteristics of Pakistan coal and showed that the coals of northern and western Paksitan have the highest rank (bituminous) and the highest calorific value (10,000 to 13,000 Btu). The coals of Sindh Province, on the other hand, were shown to be lower in rank (lignite to subbituminous) with as-received Btu values ranging from 6,500 to nearly 7,000 Btu. The coals of northern Pakistan generally contained higher sulfur and ash values than the coals of Sindh, but all had sulfur values generally in excess of 3 percent. Ash percentages averaged in the mid-teens to the mid-twenties for all of the Pakistan coals. Most of the coals of the other fields of Pakistan are relatively thin and lens-shaped seldom reaching thicknesses in excess of a few meters. Total estimated resources for all of the coal fields of Pakistan prior to the Thar discovery were 9 billion tons (Kazmi, 1990).

Clearly, the low-sulfur, low-ash, very thick coals of the Thar coal field are nothing like the coals in the other fields of Pakistan. Coals with more resemblance to the Thar coals are present in the nearby west-central coal fields of India. The Panandhro lignite field 160 km southwest of the southwest corner of the Thar field is the third largest lignite field in India with reserves of 95-100 million metric tons. Coals in this deposit are contained in as many as five beds ranging in thickness from 10 cm to 10.5 m and are lower Eocene in age (Misra, B.K. 1992). The field is small covering an area of 8.3 square kilometers. Panandhro coals have moisture values of 35 percent and heating values of 6,800 Btu, (presumed to be as-received, but not specified), ash percentage is around 8 percent (Gowrisankaran and others, 1987).

In the Barmer basin of India, 85 km northeast of the northeastern corner of the Thar field, Eocene-age lignite beds as thick as 5 m are present, but on average coal-bed thicknesses for these lens-shaped coals are on the order of 1 to 2 m (Mukherjee and others, 1992). Moisture ranges from 41 to 50 percent, ash content is around 12 percent, and heating values average 4,500 Btu (Gowrisankaran and others, 1987). Reserves for the field are around 90 million metric tons.

In summary, the Thar coal field has more similarities to the coal fields of west-central India than to the coal fields of Pakistan. But when all of the characteristics of the Thar field such as thickness and continuity of beds, low ash, low sulfur, and total resources are considered there does not appear to be a direct counterpart to the Thar coal deposit anywhere in South Asia. It is hoped that more work on the Thar coal field will allow for the construction of more comprehensive models of coal deposition for this apparently unique deposit.

GEOLOGIC HISTORY

General

Figure 3, the regional geologic cross section from the Nabisar well through the northern part of the Thar coal field shows the present relationships of the sedimentary cover to the predominantly granite basement rocks. This figure indicates that a regional high existed in the Thar coal field area throughout the time that the 4,000 m of sedimentary rocks present at the Nabisar 1 hole were being deposited to the west. (The oldest rocks penetrated in the Nabisar 1 hole were Triassic in age, but Permian-age rocks are probably present below the total depth of this drill hole.) During Late Cretaceous time the entire area of figure 3 was uplifted and erosion of uppermost Cretaceous rocks took place; the Thar coal field area was most certainly uplifted higher than the area to the west resulting in the beveling by erosion of the older Paleozoic rocks so that the basement granites in the eastern parts of the Thar coal field were exposed.

Following this erosion cycle, the area again subsided and Paleocene and Eocene age rocks were deposited on top of the Cretaceous unconformity to the west. Because most if not all of the Paleocene is missing in the Thar field area, this area probably did not subside enough to begin accumulating sediments until late Paleocene to early Eocene time. During this time conditions became right for coal deposition and the Thar coals (and the lower Eocene coals of western India) began to form. Toward the end of the Eocene, the collision of the Indian sub-continent with the Asian mainland, which began around the beginning of the Eocene, began to buckle the rocks in what is now northern Pakistan and India resulting in a flood of coarse clastic rocks being carried south across the area west of the area here discussed; these are the post-Eocene Siwalik rocks of figure 4. During this post-Eocene episode of deposition the Thar coal field area apparently remained tectonically stable; not being elevated enough to cause erosion of the thin layer of Paleocene-Eocene coal-bearing rocks and not subsiding enough to be covered by any appreciable thickness of Siwalik rocks. Finally, during relatively recent times, the area was traversed by the ancestral Indus river system resulting in deposition of the alluvium layer present throughout the Thar coal field. The structural dome in the southern part of the Thar coal field must have been forming about this time because the alluvium thins over this structure. The fault in the southeast part of the field also probably formed at the same time resulting in the coals east of the fault probably being uplifted and removed by erosion. (Another, less favored hypothesis is that the fault was active during the time of coal deposition and the coals were not deposited on the upward-moving fault block.) The last chapter of the story occurred when the dunes of the Thar Desert began to form about 20,000 years ago (Margane, 1991).

Coal-Deposition Model

Available data is insufficient to establish a definitive coal-deposition model for the Thar Desert coals. Much closer-spaced test drilling will be required to provide detailed data on the geometry and continuity of the coal beds. However, the very low ash and sulfur content of the Thar coals would tend to indicate that the coals formed in raised peat

content of the Thar coals would tend to indicate that the coals formed in raised peat bogs rather than in low-lying swamp environments. Several of the test holes along the western edge of the field area contained marine-fossil-bearing strata interfingering with non-marine coal-bearing strata. This relationship clearly indicates that at the time the Thar coals were forming, the sea was to the west and the shoreline was transgressing and regressing across what is now the western edge of the Thar coal field area. The position of the very thick Thar coals east of the shoreline of the sea suggests that the coals may have formed shoreward of a stabilized and vertically upbuilding shoreline similar to the San Juan Basin (New Mexico and Colorado, USA) coal deposition model (Fassett and Hinds, 1973, Fassett, 1986). The north-trending sinuous trend of the thickest Thar coal beds lends credence to a coal-depositional model characterized by a backshore environment of deposition with peat bogs forming relatively near to a sinuous coastline to the west. It will be interesting to learn whether further drilling in the area will support this hypothesis.

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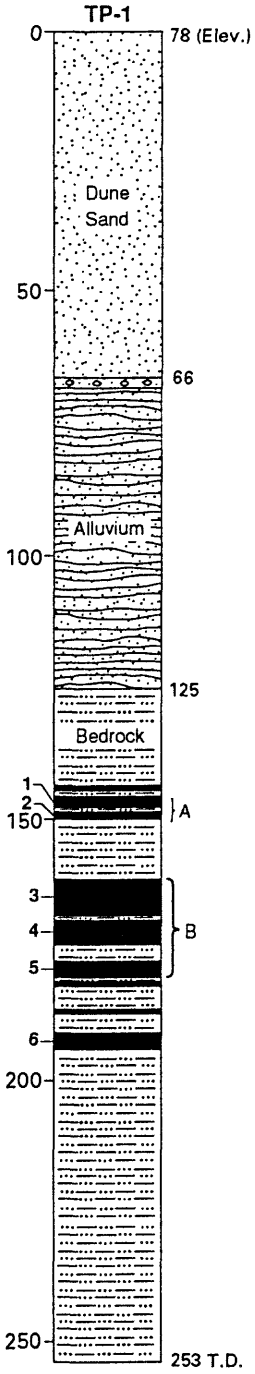
APPENDIX 1

Stratigraphic columns showing geologic data obtained from 39 Thar Desert drill holes, Sindh Province, Pakistan; coal samples from the 25 holes prefixed TP- were analyzed and coal bench and coal bed numbers shown on the TP- stratigraphic columns in this appendix are keyed to the coal analyses tables in appendix 2 of this report; coal samples were collected from the STP-drill holes but analyses results from those holes were not available at the time of publication of this report; drill hole TH-6 was a water well and no coal samples were collected from it for analysis.



Coal beds and benches; drill hole **TP-1**

[NA, not analyzed; CLC, core lost, coal]

Coal benches

Bench number	Top	Bottom	Coal thickness
NA	144.1	144.3	0.2
NA	145.7	145.78	0.08
1	146.38	147.8	1.42
CLC	147.8	147 98	0.18
2	148.7	150.22	1.52
3	162.11	163.83	1.72
CLC	163.83	164.13	0.3
3	164.13	168.02	3.89
4	169.17	173.87	4.7
5	177.39	180.47	3.08
NA	181.05	181.69	0.64
NA	186.35	186.9	0.55
6	190.47	193	2.53
		Total	20.81

Coal beds

Bed number	Top	Bottom	Coal thickness
A	146.38	147.8	2.94
B	162.11	180.47	13.69
		Total	16.63

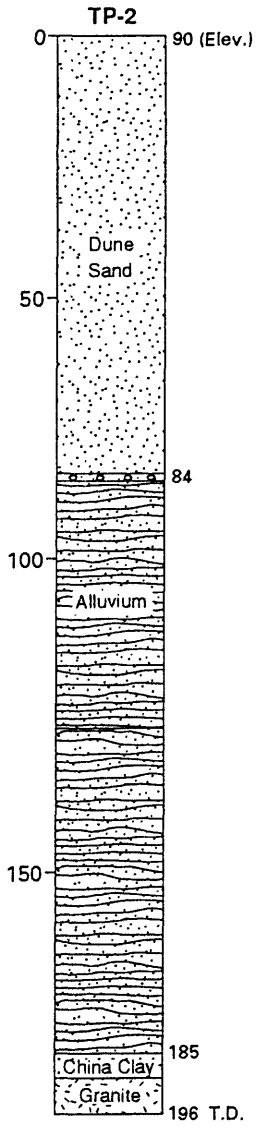
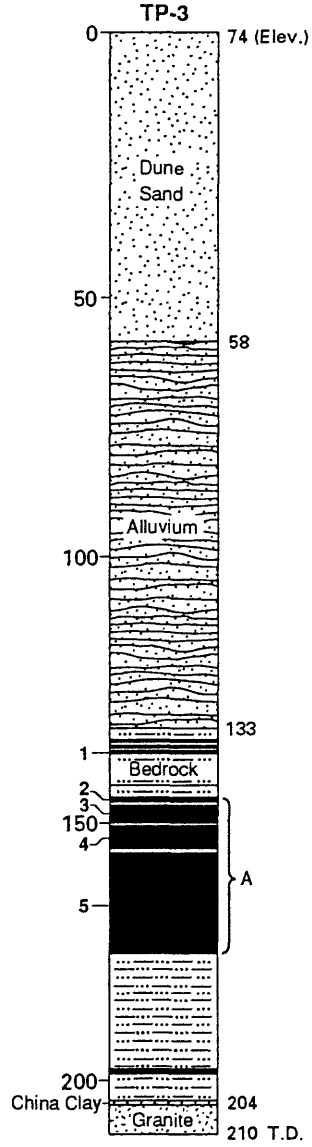


Figure 1-1. Stratigraphic columns of drill hole TP-1 and TP-2, Thar Desert, Sindh Province, Pakistan (drill hole locations are shown on figure 2). Coal bench numbers are shown on left side of column, coal bed letters are on right side of column; numbers and letters are keyed to coal-analyses tables in appendix 2.



Coal beds and benches; drill hole **TP-3**

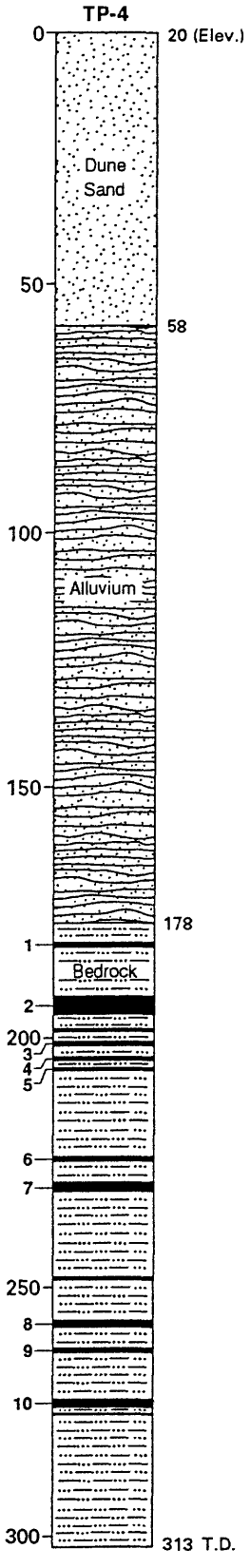
[NA, not analyzed; CLC, core lost, coal]

Coal benches

Bench number	Top	Bottom	Coal thickness
NA	134.87	135.07	0.2
CLC	136.02	136.25	0.23
NA	136.25	136.36	0.11
1	137.06	137.4	0.34
NA	143.54	143.83	0.29
2	145.96	146.78	0.82
3	147.19	147.74	0.55
CLC	147.74	147.82	0.08
3	147.82	150.12	2.3
4	151.17	154.8	3.63
5	155.7	175.28	19.58
NA	197.25	198.35	1.1
		Total	29.23

Coal beds

Bed number	Top	Bottom	Coal thickness
A	145.96	175.28	26.96



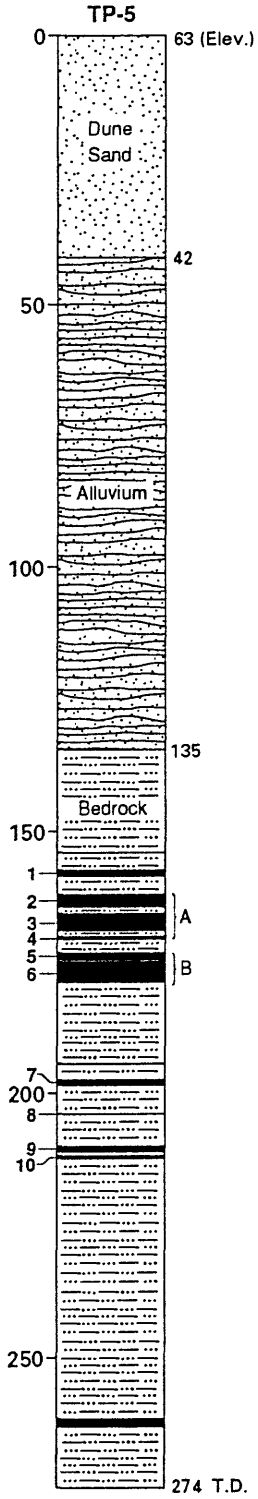
Coal beds and benches; drill hole **TP-4**

[NA, not analyzed; CLC, core lost, coal]

Coal benches

Bench number	Top	Bottom	Coal thickness
1	180 91	181.93	1.02
2	192.05	195.16	3.11
NA	198.05	198.2	0.15
3	200.68	201.12	0.44
4	203.45	203.75	0.3
5	205.73	206.08	0.35
6	223.78	224.66	0.88
7	229.01	230.73	1.72
NA	248.25	248.47	0.22
8	256.14	257.34	1.2
9	261.43	262.1	0.67
10	272.05	273.05	1
NA	274.45	274 58	0.13
		Total	11.19

Figure 1-2. Stratigraphic columns of drill hole TP-3 and TP-4, Thar Desert, Sindh Province, Pakistan (drill hole locations are shown on figure 2). Coal bench numbers are shown on left side of column, coal bed letters are on right side of column; numbers and letters are keyed to coal-analyses tables in appendix 2.



Coal beds and benches; drill hole **TP-5**

[NA, not analyzed; CLC, core lost, coal]

Coal benches

Bench number	Top	Bottom	Coal thickness
NA	154.71	154.84	0.13
1	158.18	159.23	1.05
2	162.4	164.35	1.95
3	166.3	169.55	3.25
4	170.4	170.95	0.55
CLC	173	174.15	1.15
5	175.45	177.72	2.27
6	178.09	179.09	1
NA	193.78	193.83	0.05
7	197.64	197.99	0.35
8	203.36	203.74	0.38
9	209.94	210.79	0.85
10	211.64	212.01	0.37
11	260.79	261.94	1.15
NA	261.94	262.05	0.11
		Total	14.61

Coal beds

Bed number	Top	Bottom	Coal thickness
A	162.4	170.95	5.75
B	173	177.72	3 42
		Total	9.17

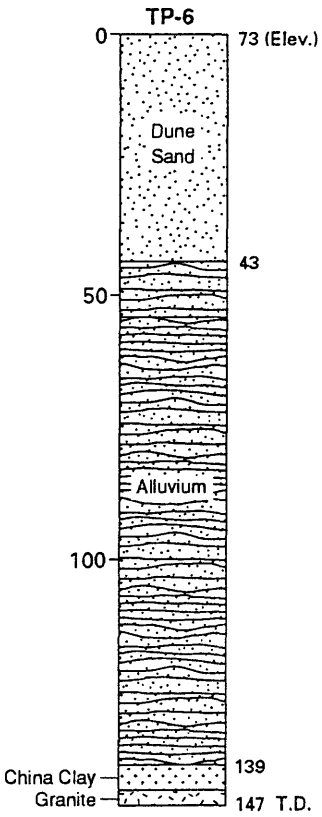
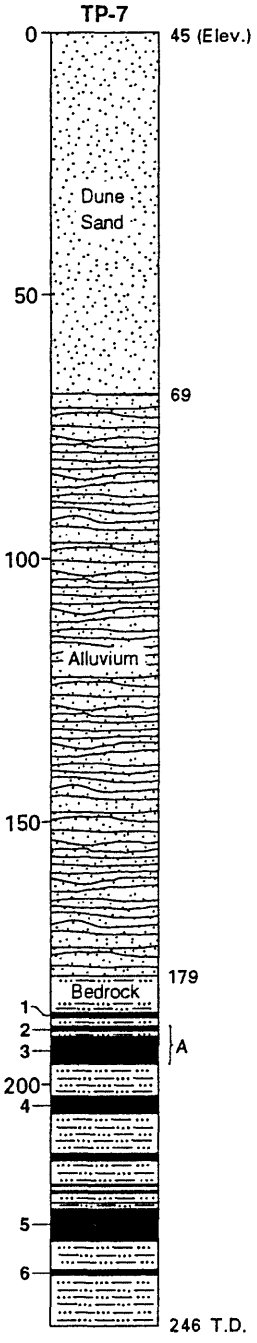


Figure 1-3. Stratigraphic columns of drill hole TP-5 and TP-6, Thar Desert, Sindh Province, Pakistan (drill hole locations are shown on figure 2). Coal bench numbers are shown on left side of column, coal bed letters are on right side of column; numbers and letters are keyed to coal-analyses tables in appendix 2.



Coal beds and benches; drill hole **TP-7**

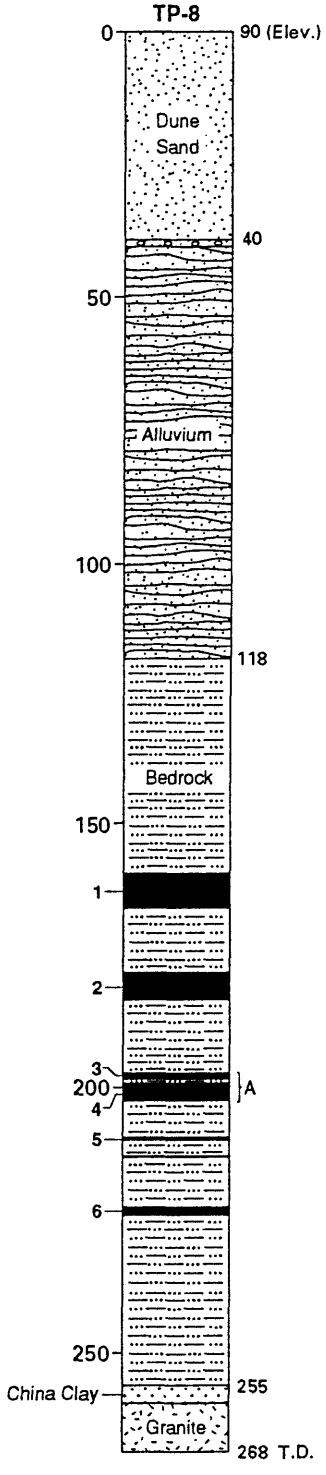
[NA, not analyzed; CLC, core lost, coal]

Coal benches

Bench number	Top	Bottom	Coal thickness
1	186.98	187.4	0.42
2	189.09	189.83	0.74
3	190.93	194.16	3.23
CLC	194.16	194.83	0.67
3	194.83	195.68	0.85
4	202.99	205.51	2.52
NA	214.35	214.55	0.2
NA	215 05	215.3	0.25
NA	221.15	221.35	0.2
5	223.27	230.5	7.23
NA	230.5	230.52	0.02
6	235.35	236 6	1.25
		Total	17.58

Coal beds

Bed number	Top	Bottom	Coal thickness
A	189.09	195.68	5.49



Coal beds and benches; drill hole **TP-8**

[NA, not analyzed; CLC, core lost, coal]

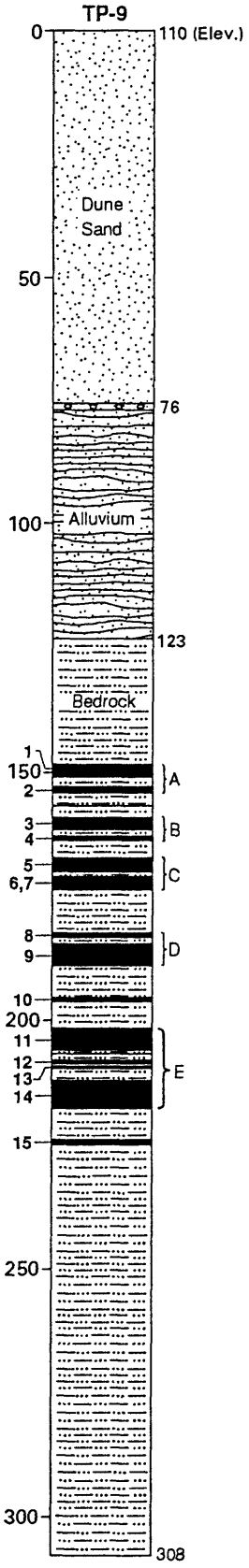
Coal benches

Bench number	Top	Bottom	Coal thickness
NA	158.8	159.03	0.23
1	159.03	165.68	6.65
2	178.28	183.13	4.85
3	196.98	197.95	0.97
4	198.91	201.8	2.89
NA	202.17	202.29	0.12
5	208.7	209.38	0.68
6	222.72	223.57	0.85
		Total	17.24

Coal beds

Bed number	Top	Bottom	Coal thickness
A	196.98	201.8	4.82

Figure 1-4. Stratigraphic columns of drill hole TP-7 and TP-8, Thar Desert, Sindh Province, Pakistan (drill hole locations are shown on figure 2). Coal bench numbers are shown on left side of column, coal bed letters are on right side of column; numbers and letters are keyed to coal-analyses tables in appendix 2.



Coal beds and benches; drill hole **TP-9**

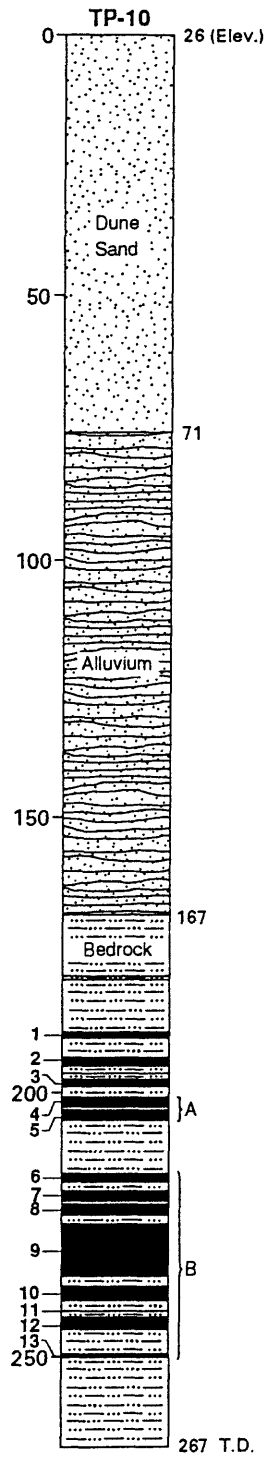
[NA, not analyzed; CLC, core lost, coal]

Coal benches

Bench number	Top	Bottom	Coal thickness
1	148.44	150.64	2.2
2	152.6	153.74	1.14
CLC	153.74	153.95	0.21
NA	156.45	156.65	0.2
3	158.97	160.02	1.05
CLC	160.02	160.77	0.75
3	161.07	161.57	0.5
4	163.1	163.82	0.72
5	167.36	170.06	2.7
6	170.86	171.51	0.65
7	171.81	173.56	1.75
8	182.69	183.47	0.78
9	184.74	188.68	3 94
CLC	188.68	188.99	0.31
10	195.13	195.83	0.7
11	201.5	205.1	3.6
NA	205.24	205.74	0.5
NA	206 35	206 45	0.1
12	207.65	208.05	0.4
13	208 6	209 05	0.45
14	211.8	217.49	5.69
CLC	223.64	224.04	0.4
15	224.09	224.64	0.55
		Total	29 29

Coal beds

Bed number	Top	Bottom	Coal thickness
A	148.44	153.74	3.34
B	158.97	163.82	3.02
C	167.36	173.56	5 1
D	182.69	188.68	4.72
E	201.5	217.49	10.14
		Total	26.32



Coal beds and benches; drill hole **TP-10**

[NA, not analyzed; CLC, core lost, coal]

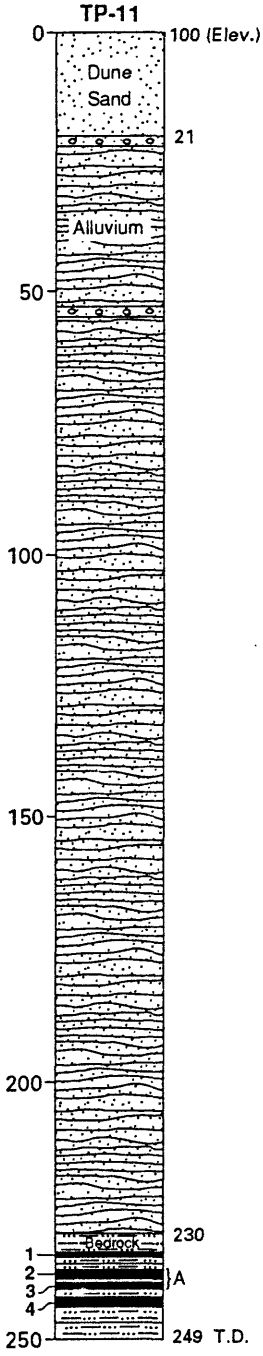
Coal benches

Bench number	Top	Bottom	Coal thickness
NA	178.33	178.48	0.15
NA	178.95	179.2	0.25
1	189.02	190.22	1.2
NA	193.35	193.5	0.15
2	194.92	196.24	1.32
3	197 97	198.77	0.8
4	201.02	202.57	1.55
5	203 4	205	1.6
NA	211.75	211.83	0.08
CLC	215 05	215.49	0.44
6	215 49	217.02	1.53
CLC	217.02	217.65	0.63
7A	219.39	219.71	0.32
7B	219.81	220.81	1
8	221.26	223.25	1.99
9	225.25	227.38	2.13
CLC	227.38	227.68	0.3
9	227.68	234.48	6.8
NA	234.65	234.87	0.22
10	236.83	239.43	2.6
CLC	239.43	240.03	0.6
11	241.38	241.83	0.45
NA	242.7	242.92	0.22
CLC	242.92	243.02	0.1
12	243.02	244.42	1.4
13	249.46	249 86	0.4
		Total	28 23

Coal beds

Bed number	Top	Bottom	Coal thickness
A	201 02	205	3.15
B	215.49	244.42	20.73
		Total	23.88

Figure 1-5. Stratigraphic columns of drill hole TP-9 and TP-10, Thar Desert, Sindh Province, Pakistan (drill hole locations are shown on figure 2). Coal bench numbers are shown on left side of column, coal bed letters are on right side of column; numbers and letters are keyed to coal-analyses tables in appendix 2.



Coal beds and benches; drill hole **TP-11**

[NA, not analyzed; CLC, core lost, coal]

Coal benches			
Bench number	Top	Bottom	Coal thickness
1	233.18	233.78	0.6
2	236.31	238.09	1.78
3	238.34	239.23	0.89
5	241.63	242.93	1.3
		Total	4.57

Coal beds			
Bed number	Top	Bottom	Coal thickness
A	236.31	239.23	2.92

Coal beds and benches; drill hole **TP-12**

[NA, not analyzed; CLC, core lost, coal]

Coal benches			
Bench number	Top	Bottom	Coal thickness
NA	201	201.06	0.06
NA	201.55	201.6	0.05
NA	201.85	201.9	0.05
NA	201.15	202.2	1.05
1	214.21	214.58	0.37
NA	221.4	221.47	0.07
2	222.62	224.54	1.92
3	225.8	231.2	5.4
4	232.59	233.49	0.9
5	235.5	242.48	6.98
CLC	242.48	242.77	0.29
5	242.77	248.46	5.69
6	250.15	250.95	0.8
7	253.31	254.33	1.02
8	256.11	257.2	1.09
9	257.69	258.61	0.92
		Total	26.66

Coal beds			
Bed number	Top	Bottom	Coal thickness
A	222.62	250.95	21.98
B	256.11	258.61	2.01
		Total	23.99

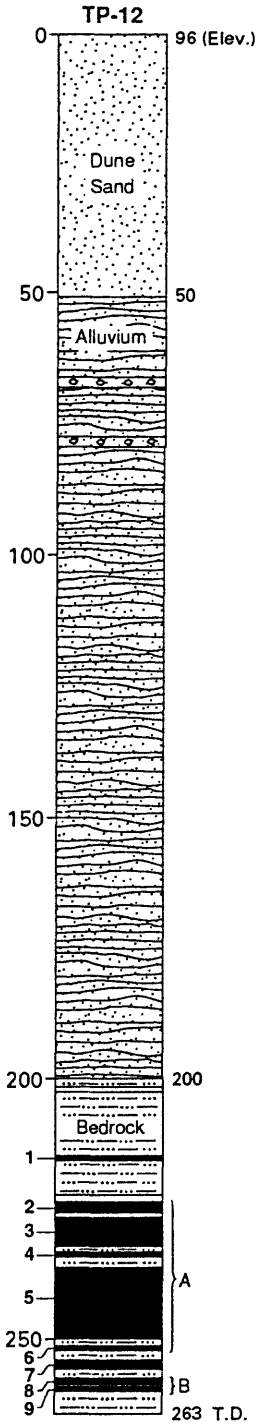
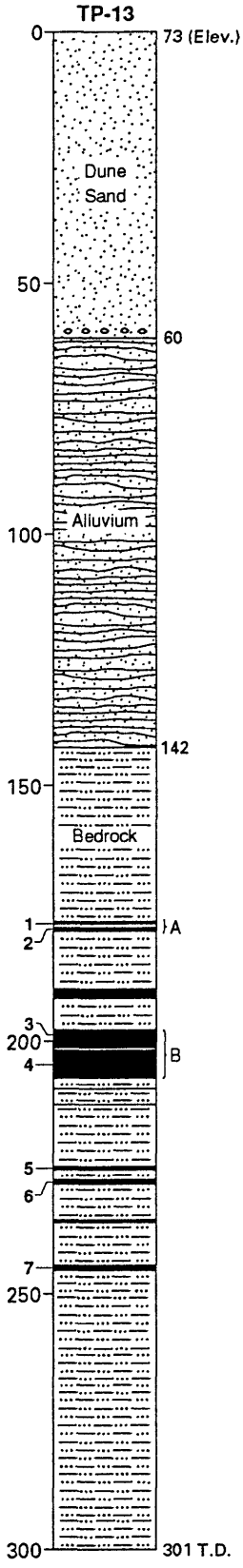


Figure 1-6. Stratigraphic columns of drill hole TP-11 and TP-12, Thar Desert, Sindh Province, Pakistan (drill hole locations are shown on figure 2). Coal bench numbers are shown on left side of column, coal bed letters are on right side of column; numbers and letters are keyed to coal-analyses tables in appendix 2.



Coal beds and benches; drill hole **TP-13**

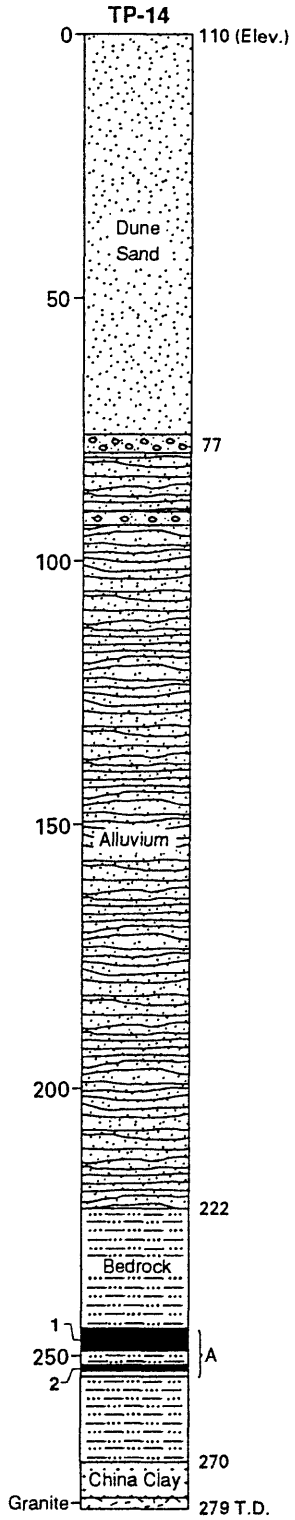
[NA, not analyzed; CLC, core lost, coal]

Coal benches

Bench number	Top	Bottom	Coal thickness
1	176.81	177.46	0.65
2	177.66	178.01	0.35
NA	178.01	178.46	0.45
2	178.46	178.84	0.38
CLC	190.35	191.1	0.75
3	197.86	201.3	3.44
4	201.75	202.75	1
CLC	202.75	202.94	0.19
4	202.94	207.29	4.35
NA	209.65	209.7	0.05
NA	212.62	212.67	0.05
CLC	224.75	225.25	0.5
5	225.25	225.9	0 65
6	227.7	228.18	0.48
CLC	228.18	228.3	0.12
NA	235.55	236.1	0.55
7	244.4	245.25	0.85
		Total	14.81

Coal beds

Bed number	Top	Bottom	Coal thickness
A	176.81	178.24	1.83
B	197.86	207.29	8 98
		Total	10.81



Coal beds and benches; drill hole **TP-14**

[NA, not analyzed; CLC, core lost, coal].

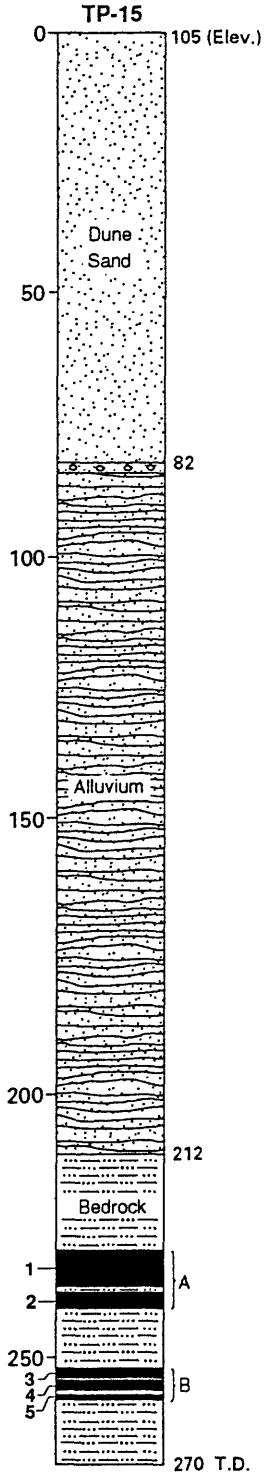
Coal benches

Bench number	Top	Bottom	Coal thickness
CLC	243.92	244.88	0.96
1	244.88	248.72	3.84
CLC	250.3	251.89	1.59
2	251.89	252.8	0.91
CLC	254.3	254.7	0.4
		Total	7.7

Coal beds

Bed number	Top	Bottom	Coal thickness
A	243.92	254.7	7.7

Figure 1-7. Stratigraphic columns of drill hole TP-13 and TP-14, Thar Desert, Sindh Province, Pakistan (drill hole locations are shown on figure 2). Coal bench numbers are shown on left side of column, coal bed letters are on right side of column; numbers and letters are keyed to coal-analyses tables in appendix 2.



Coal beds and benches; drill hole **TP-15**

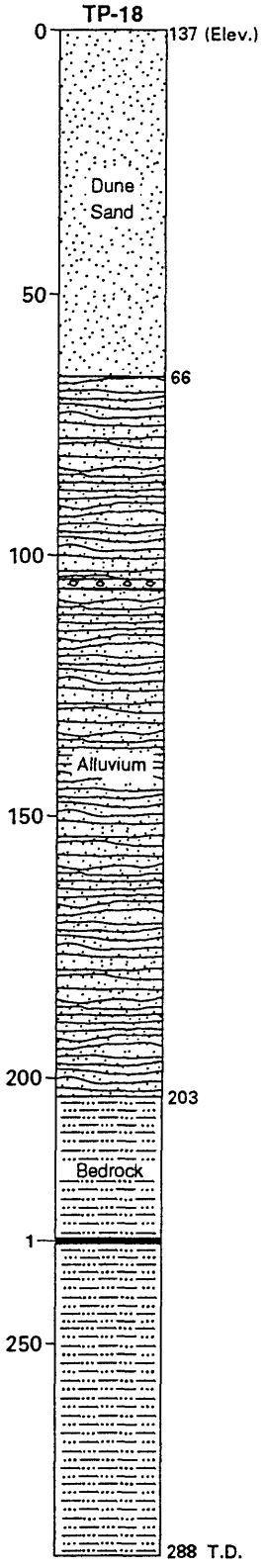
[NA, not analyzed; CLC, core lost, coal]

Coal benches

Bench number	Top	Bottom	Coal thickness
1	230.82	233.62	2.8
CLC	233.62	233.7	0.08
1	233.7	235.15	1.45
CLC	235.15	235.46	0.31
1	235.46	236.01	0.55
CLC	236.01	236.94	0.93
1	236.94	237.09	0.15
2	238.33	239.06	0.73
CLC	239.06	240	0 94
2	240	240.65	0.65
3	257.26	258.66	1.4
4	259.41	259.71	0.3
5	259.93	261.06	1.13
CLC	261.06	262.5	1.44
5	262.5	263	0.5
		Total	13.36

Coal beds

Bed number	Top	Bottom	Coal thickness
A	230.82	240.65	8.59
B	257.26	263	4.77



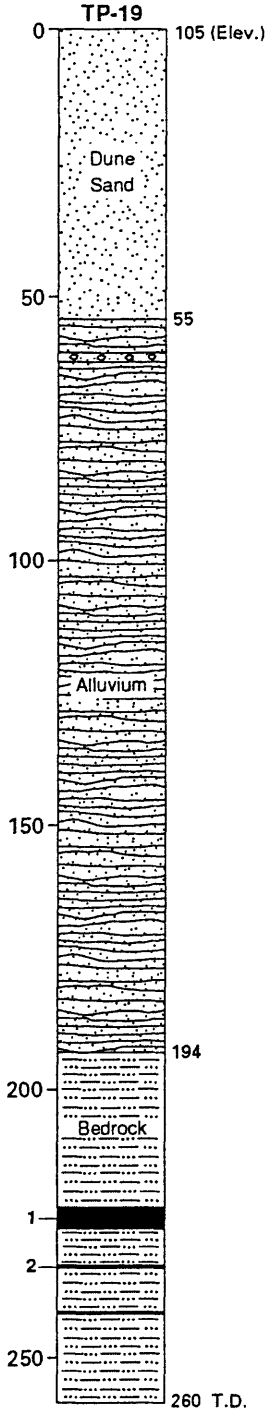
Coal beds and benches; drill hole **TP-18**

[NA, not analyzed; CLC, core lost, coal]

Coal benches

Bench number	Top	Bottom	Coal thickness
1	230.12	230.72	0.6

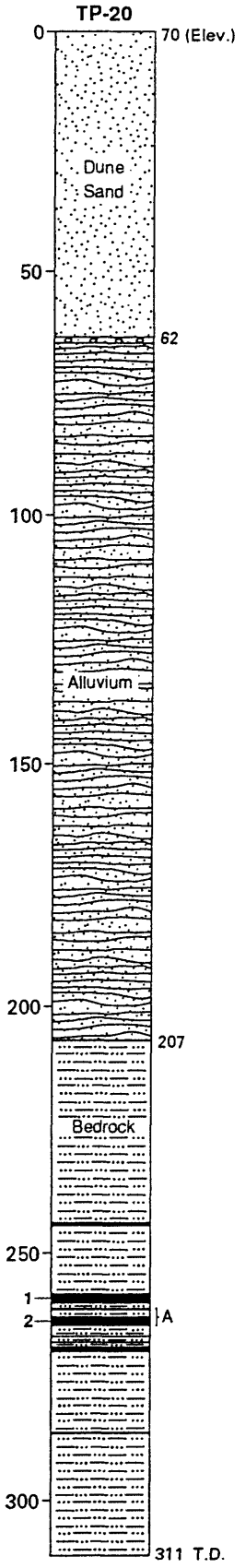
Figure 1-8. Stratigraphic columns of drill hole TP-16 and TP-18, Thar Desert, Sindh Province, Pakistan (drill hole locations are shown on figure 2). Coal bench numbers are shown on left side of column, coal bed letters are on right side of column; numbers and letters are keyed to coal-analyses tables in appendix 2.



Coal beds and benches; drill hole **TP-19**

[NA, not analyzed; CLC, core lost, coal]

Coal benches			
Bench number	Top	Bottom	Coal thickness
1	223.18	224.48	1.3
CLC	224.48	225.63	1.15
NA	225.63	225.68	0.05
2	225.8	227.03	1.23
3	233.88	234 18	0.3
NA	243.26	243.44	0.18
		Total	4.21



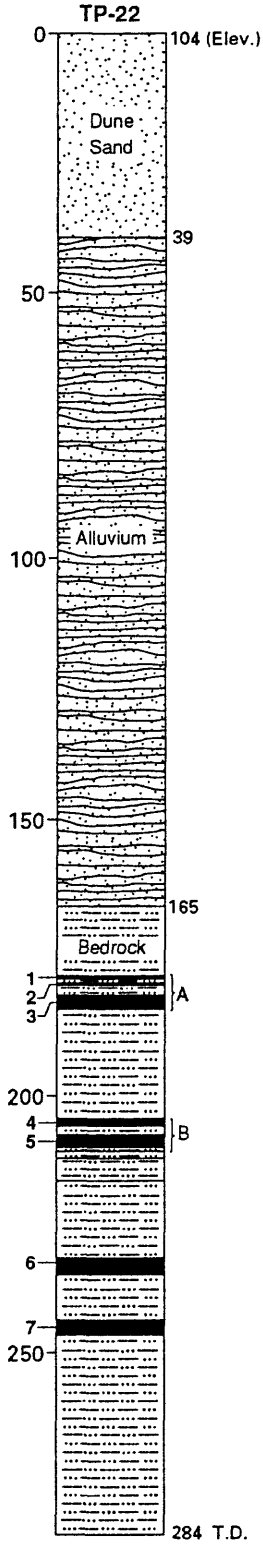
Coal beds and benches; drill hole **TP-20**

[NA, not analyzed; CLC, core lost, coal]

Coal benches			
Bench number	Top	Bottom	Coal thickness
NA	244.05	244.45	0.4
CLC	257.59	257.94	0.35
NA	257.94	259.44	1.5
1	259.44	260.24	0.8
NA	261.8	262.05	0.25
2	263.03	264.58	1.55
NA	264.58	264 63	0.05
NA	268.06	268.55	0.49
NA	285.83	286.08	0.25
		Total	5.64

Coal beds			
Bed number	Top	Bottom	Coal thickness
A	261.8	264.63	1.85

Figure 1-9. Stratigraphic columns of drill hole TP-19 and TP-20, Thar Desert, Sindh Province, Pakistan (drill hole locations are shown on figure 2). Coal bench numbers are shown on left side of column, coal bed letters are on right side of column; numbers and letters are keyed to coal-analyses tables in appendix 2.



Coal beds and benches; drill hole **TP-22**

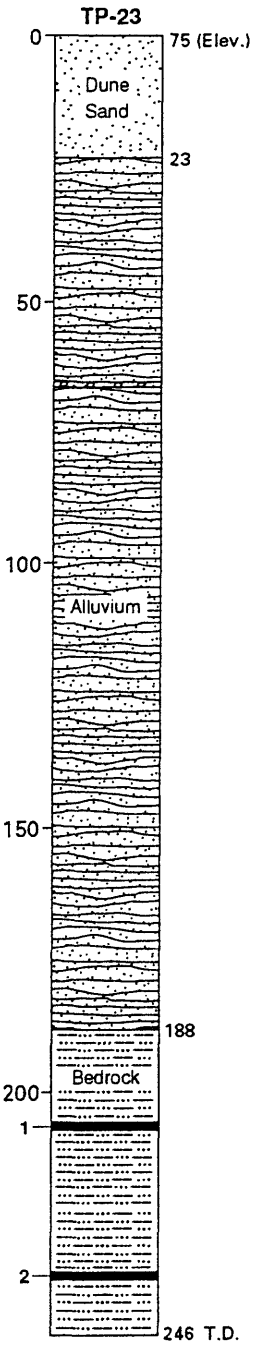
[NA, not analyzed; CLC, core lost, coal]

Coal benches

Bench number	Top	Bottom	Coal thickness
NA	178.91	178.96	0.05
1	178.96	179.61	0.65
NA	179.61	179.66	0.05
NA	179.86	180.41	0 55
2	180.41	180.81	0.4
CLC	180.81	181.14	0.33
NA	183.1	183.2	0.1
3	183.2	185.25	2.05
4	205.61	206.56	0.95
NA	206.56	206.61	0.05
5	208.25	210.25	2
NA	210.25	210.35	0.1
NA	211.3	211.55	0.25
NA	212.2	212.45	0.25
NA	216.41	216.46	0.05
6	231.55	232.8	1.25
CLC	232.8	233 98	1.18
6	233.98	234.28	0.3
NA	243.13	244 48	1.35
7	244.48	245 43	0.95
		Total	12.86

Coal beds

Bed number	Top	Bottom	Coal thickness
A	178.91	185.25	4.18
B	205 61	211.55	3.35
		Total	7.53



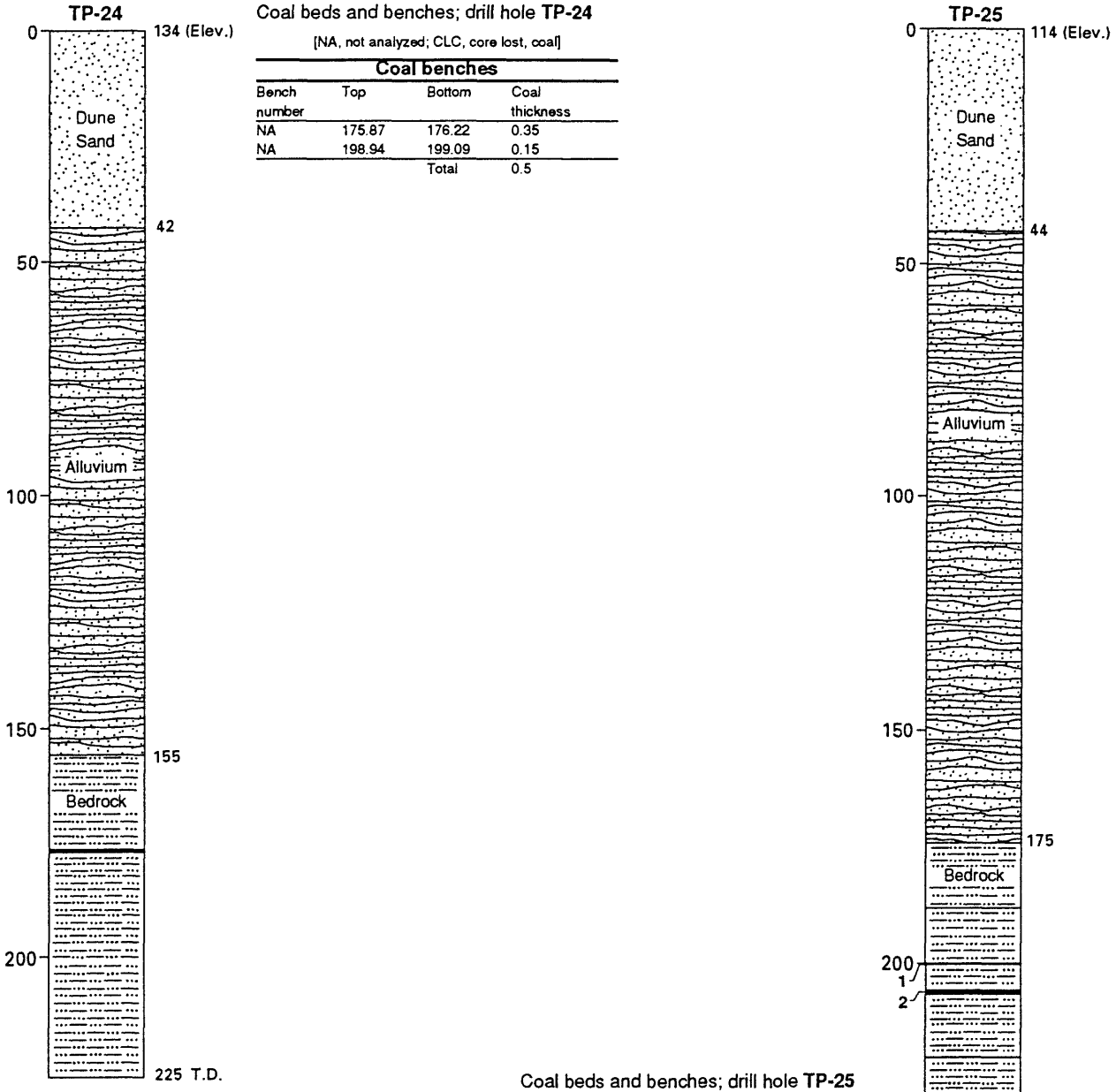
Coal beds and benches; drill hole **TP-23**

[NA, not analyzed; CLC, core lost, coal]

Coal benches

Bench number	Top	Bottom	Coal thickness
1	205.51	206.51	1
CLC	206.51	206.81	0.3
2	234.54	235.19	0.65
		Total	1.95

Figure 1-10. Stratigraphic columns of drill hole TP-22 and TP-23, Thar Desert, Sindh Province, Pakistan (drill hole locations are shown on figure 2). Coal bench numbers are shown on left side of column, coal bed letters are on right side of column; numbers and letters are keyed to coal-analyses tables in appendix 2.



Coal beds and benches; drill hole **TP-24**

[NA, not analyzed; CLC, core lost, coal]

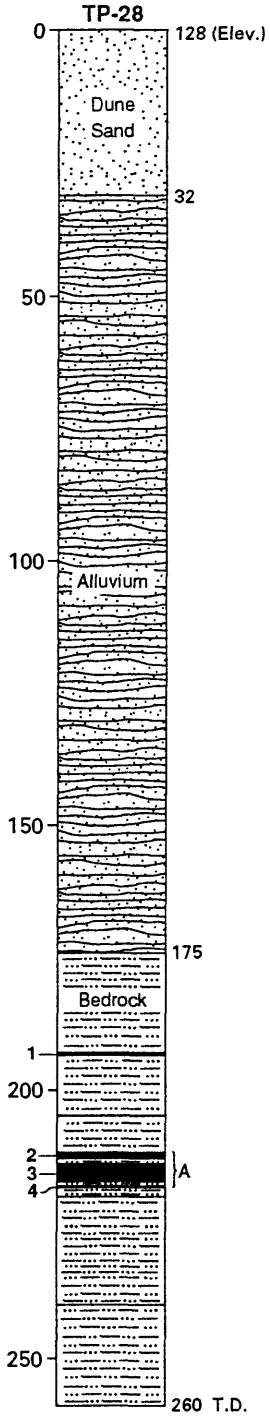
Coal benches			
Bench number	Top	Bottom	Coal thickness
NA	175.87	176.22	0.35
NA	198.94	199.09	0.15
		Total	0.5

Coal beds and benches; drill hole **TP-25**

[NA, not analyzed; CLC, core lost, coal]

Coal benches			
Bench number	Top	Bottom	Coal thickness
NA	189.03	189.28	0.25
1	200.22	200.62	0.4
2	206.38	207.38	1
NA	220.85	220.93	0.08
NA	236.15	236.25	0.1
3	236.25	236.55	0.3
		Total	2.13

Figure 1-11. Stratigraphic columns of drill hole TP-24 and TP-25 Coal beds and benches; drill hole **TP-22**, Thar Desert, Sindh Province, Pakistan (drill hole locations are shown on figure 2). Coal bench numbers are shown on left side of column, coal bed letters are on right side of column; numbers and letters are keyed to coal-analyses tables in appendix 2.



Coal beds and benches; drill hole **TP-28**

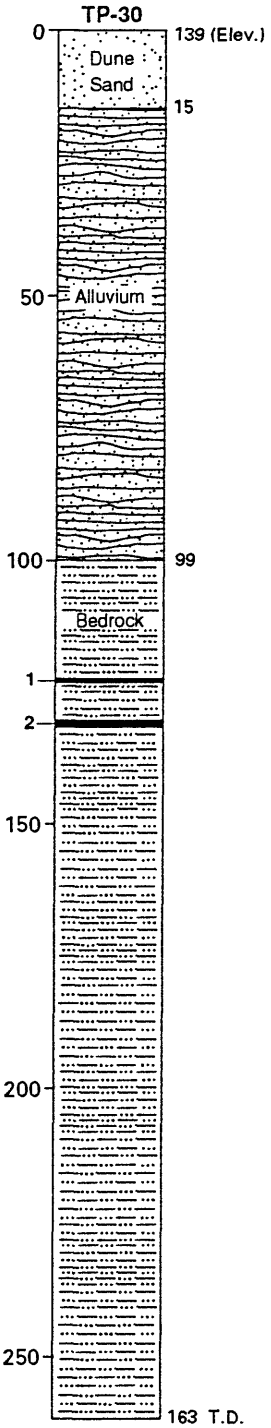
[NA, not analyzed; CLC, core lost, coal]

Coal benches

Bench number	Top	Bottom	Coal thickness
1	193.94	194.54	0.6
NA	205.89	205.99	0.1
NA	212.82	213.3	0.48
2	213.3	213.72	0.42
3	214.99	218.34	3.35
4	219.34	219.79	0.45
NA	221.29	221.34	0.05
NA	241.63	241.8	0.17
		Total	5.62

Coal beds

Bed number	Top	Bottom	Coal thickness
A	213.3	219.79	4.22



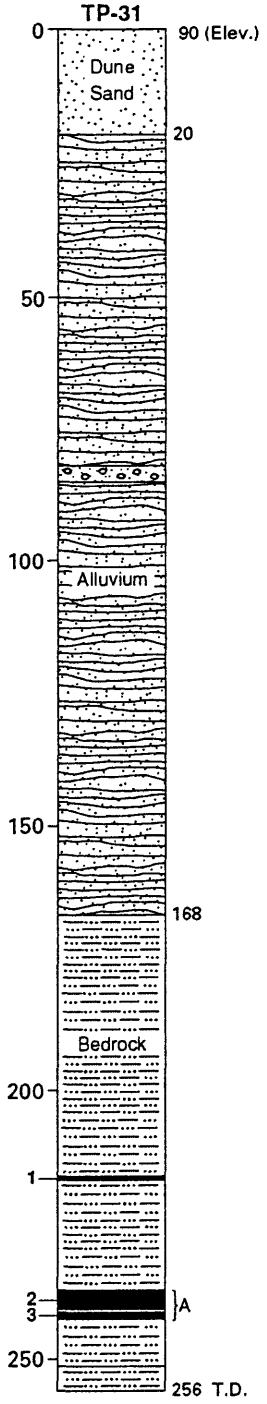
Coal beds and benches; drill hole **TP-30**

[NA, not analyzed; CLC, core lost, coal]

Coal benches

Bench number	Top	Bottom	Coal thickness
1	123.28	123.93	0.65
2	131.24	132.11	0.87
		Total	1.52

Figure 1-12. Stratigraphic columns of drill hole TP-28 and TP-30, Thar Desert, Sindh Province, Pakistan (drill hole locations are shown on figure 2). Coal bench numbers are shown on left side of column, coal bed letters are on right side of column; numbers and letters are keyed to coal-analyses tables in appendix 2.



Coal beds and benches; drill hole **TP-31**

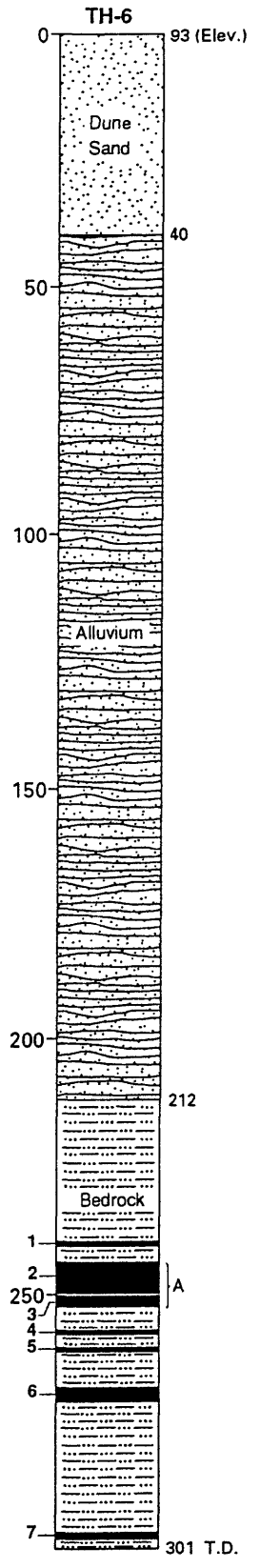
[NA, not analyzed; CLC, core lost, coal]

Coal benches

Bench number	Top	Bottom	Coal thickness
1	217.62	218.12	0.5
2	239.1	241.97	2.87
CLC	241.97	242.72	0.75
3	243.32	244.56	1.24
NA	253.27	253.53	0.26
		Total	5.62

Coal beds

Bed number	Top	Bottom	Coal thickness
A	239.1	244.56	4.86



Coal beds and benches; drill hole **TH-6**

[NA, not analyzed; CLC, core lost, coal]

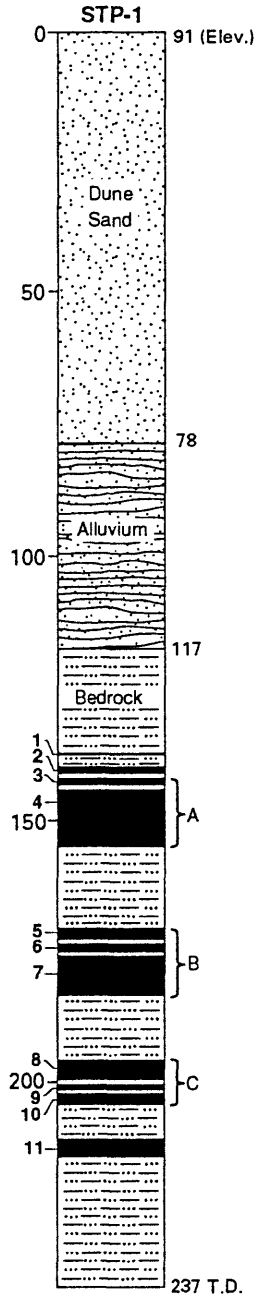
Coal benches

Bench number	Top	Bottom	Coal thickness
1	240.4	241	0.6
2	244.6	249.2	4.6
3	249.7	252.1	2.4
4	258	258.4	0.4
5	260.9	261.6	0.7
6	269.3	271.8	2.5
7.	297.5	298.8	1.3
		Total	12.5

Coal beds

Bed number	Top	Bottom	Coal thickness
A	244.6	252.1	7

Figure 1-13. Stratigraphic columns of drill hole TP-31 and TH-6, Thar Desert, Sindh Province, Pakistan (drill hole locations are shown on figure 2). Coal bench numbers are shown on left side of column, coal bed letters are on right side of column; numbers and letters are keyed to coal-analyses tables in appendix 2.



Coal beds and benches; drill hole **STP-1**

[NA, not analyzed; CLC, core lost, coal]

Coal benches

Bench number	Top	Bottom	Coal thickness
1	135.6	135.73	0.13
2	138.9	140.02	1.12
3	141.65	142.55	0.9
4	143.65	153.92	10.27
5	169.77	170.07	0.3
CLC	170.07	170.37	0.3
5	170.37	171.58	1.21
6	172.34	173.58	1.24
7	174.71	181.77	7.06
8	194.33	196.78	2.45
CLC	196.78	197.38	0.6
8	197.38	197.62	0.24
9	199.29	199.92	0.63
10	200.98	202.62	1.64
11	209.64	212.18	2.54
		Total	30.63

Coal beds

Bed number	Top	Bottom	Coal thickness
A	141.65	153.92	11.17
B	169.77	181.77	9.51
C	194.33	202.62	5.56
		Total	26.24

Coal beds and benches; drill hole **STP-2**

[NA, not analyzed; CLC, core lost, coal]

Coal benches

Bench number	Top	Bottom	Coal thickness
1	125.47	125.82	0.35
2	127.12	128.21	1.09
3	137.32	137.77	0.45
4	144.67	145.96	1.29
5	163.12	168.36	5.24
6	178.23	181.13	2.9
7	181.36	183.36	2
8	183.56	184.03	0.47
9	184.23	184.69	0.46
10	184.97	185.67	0.7
11	199.2	199.69	0.49
		Total	15.44

Coal beds

Bed number	Top	Bottom	Coal thickness
A	178.23	185.67	6.53

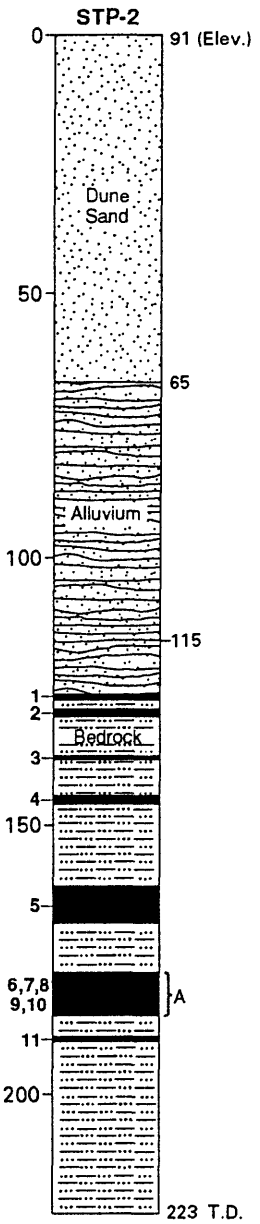
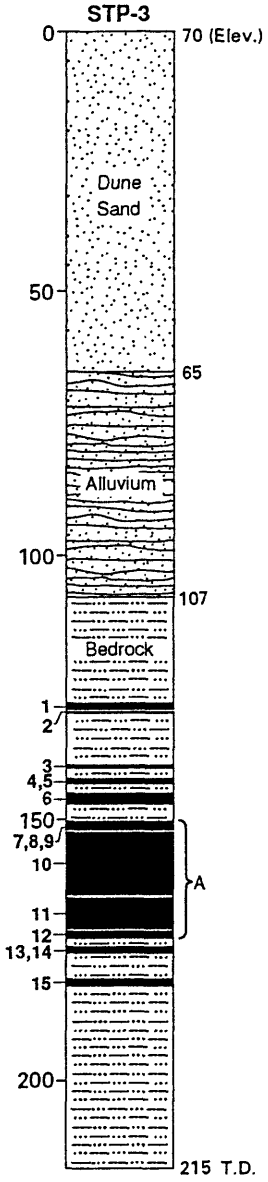


Figure 1-14. Stratigraphic columns of drill hole STP-1 and STP-2, Thar Desert, Sindh Province, Pakistan (drill hole locations are shown on figure 2). Coal bench numbers are shown on left side of column, coal bed letters are on right side of column.



Coal beds and benches; drill hole **STP-3**

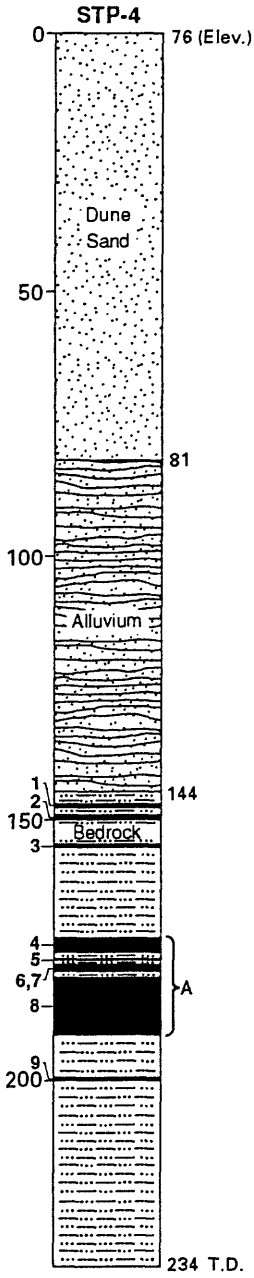
[NA, not analyzed; CLC, core lost, coal]

Coal benches

Bench number	Top	Bottom	Coal thickness
1	127.85	128.79	0.94
2	129.07	129.64	0.57
3	138.99	139.88	0.89
4	141.22	141.27	0.05
5	141.47	142.07	0.6
6	144.29	145.72	1.43
7	149.64	151.52	1.88
8	151.93	152.31	0.38
9	152.38	152.56	0.18
10	152.68	163.72	11.04
11	164.27	169.85	5.58
12	170.43	171.83	1.4
13	173.26	173.47	0.21
14	173.89	174.3	0.41
15	179.55	180.84	1.29
		Total	26.85

Coal beds

Bed number	Top	Bottom	Coal thickness
A	149.64	171.83	20.46



Coal beds and benches; drill hole **STP-4**

[NA, not analyzed; CLC, core lost, coal]

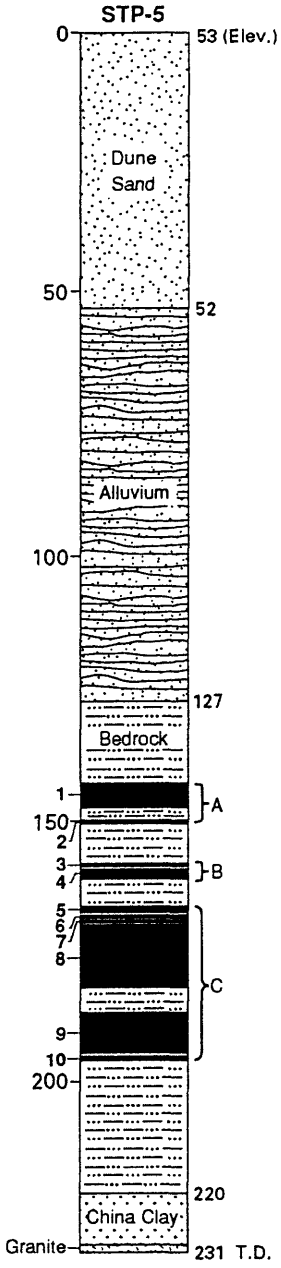
Coal benches

Bench number	Top	Bottom	Coal thickness
1	146.5	147.08	0.58
2	148.64	149.1	0.46
3	154.24	154.64	0.4
4	172.27	172.36	0.09
CLC	172.36	173	0.64
4	173	174.55	1.55
5	175.98	176.55	0.57
6	176.99	177.92	0.93
7	178.26	178.49	0.23
8	179.56	190.44	10.88
9	197.82	198.81	0.99
		Total	17.32

Coal beds

Bed number	Top	Bottom	Coal thickness
A	176.99	190.44	12.04

Figure 1-15. Stratigraphic columns of drill hole STP-3 and STP-4, Thar Desert, Sindh Province, Pakistan (drill hole locations are shown on figure 2). Coal bench numbers are shown on left side of column, coal bed letters are on right side of column.



Coal beds and benches; drill hole **STP-5**

[NA, not analyzed; CLC, core lost, coal]

Coal benches

Bench number	Top	Bottom	Coal thickness
1	142.04	146.38	4.34
CLC	146.38	146.73	0.35
2	149.22	149.64	0.42
3	157.5	158.81	1.31
4	158.91	160.03	1.12
5	165.62	166.96	1.34
6	167.49	167.82	0.33
7	168.11	168.52	0.41
8	169.23	174.26	5.03
CLC	174.26	174.52	0.26
8	174.52	179.49	4.97
CLC	179.49	180.12	0.63
8	180.12	180.72	0.6
9	185.91	191.2	5.29
CLC	191.2	191.29	0.09
9	191.29	193.18	1.89
10	193.93	194.33	0 4
		Total	28.78

Coal beds

Bed number	Top	Bottom	Coal thickness
A	142.04	149.64	5.11
B	157.5	160.03	2.43
C	165.62	194.33	21.24
		Total	28.78

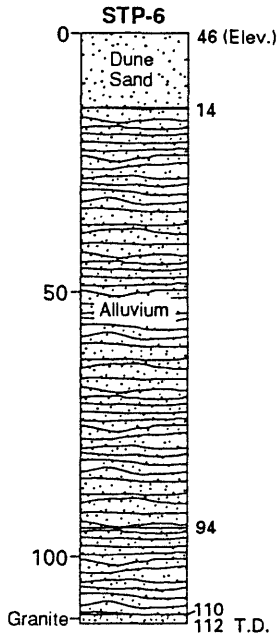
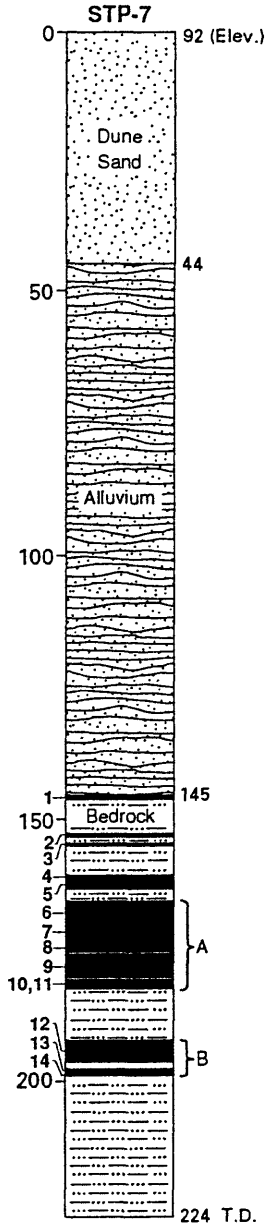


Figure 1-16. Stratigraphic columns of drill hole STP-5 and STP-6, Thar Desert, Sindh Province, Pakistan (drill hole locations are shown on figure 2). Coal bench numbers are shown on left side of column, coal bed letters are on right side of column.



Coal beds and benches; drill hole **STP-7**

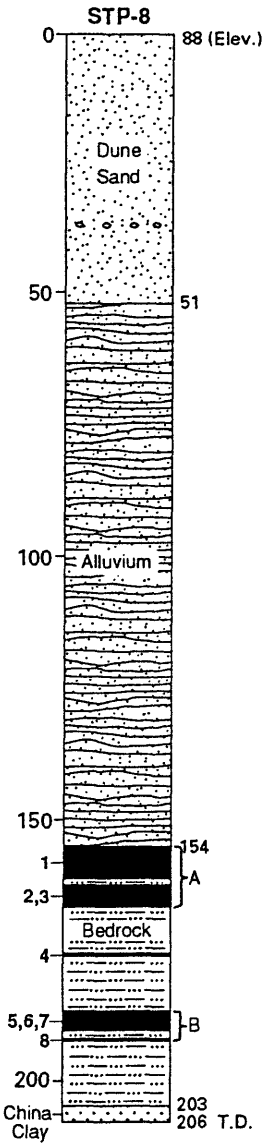
[NA, not analyzed; CLC, core lost, coal]

Coal benches

Bench number	Top	Bottom	Coal thickness
1	144.78	145.29	0.51
2	151.75	152.17	0.42
3	153.24	153.74	0.5
4	159.92	159.95	0.03
5	160	160.58	0.58
CLC	160.58	160.65	0.07
5	160.65	162.2	1.55
6	164.67	166.09	1.42
CLC	166.09	166.9	0.81
6	166.9	168	1.1
7	168.3	171.17	2.87
8	171.29	174.8	3.51
CLC	175.1	175.87	0.77
9	175.87	179	3.13
10	179.48	179.82	0.34
11	179.96	180.39	0.43
CLC	180.39	180.98	0.59
12	190.73	194.73	4
13	196.13	197.08	0.95
CLC	197.08	197.33	0.25
14	197.86	198.11	0.25
		Total	24.08

Coal beds

Bed number	Top	Bottom	Coal thickness
A	166.9	180.39	12.74
B	190.73	198.11	5.45
		Total	18.19



Coal beds and benches; drill hole **STP-8**

[NA, not analyzed; CLC, core lost, coal]

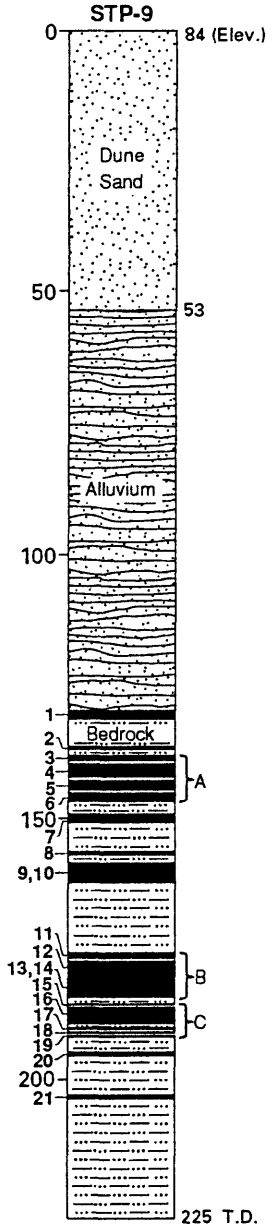
Coal benches

Bench number	Top	Bottom	Coal thickness
1	154.38	159.86	5.48
CLC	159.86	159.96	0.1
2	161.73	162.75	1.02
3	162.83	163.1	0.27
CLC	163.1	163.4	0.3
3	164.28	165.21	0.93
4	174.6	174.66	0.06
5	185.42	186.63	1.21
6	186.92	187.11	0.19
7	187.32	189.11	1.79
8	190.42	190.85	0.43
		Total	11.78

Coal beds

Bed number	Top	Bottom	Coal thickness
A	154.38	165.21	8.1
B	185.42	190.85	3.62
		Total	11.72

Figure 1-17. Stratigraphic columns of drill hole STP-7 and STP-8, Thar Desert, Sindh Province, Pakistan (drill hole locations are shown on figure 2). Coal bench numbers are shown on left side of column, coal bed letters are on right side of column.



Coal beds and benches; drill hole **STP-9**

[NA, not analyzed; CLC, core lost, coal]

Coal benches

Bench number	Top	Bottom	Coal thickness
1	129.48	130.21	0.73
CLC	130.21	130.55	0.34
1	130.55	130.87	0.32
2	136.04	136.39	0.35
3	138.05	138.79	0.74
4	139.09	141.07	1.98
5	141.98	142.14	0.16
CLC	142.14	143.01	0.87
5	143.01	144.03	1.02
6	144.43	145.98	1.55
7	148.76	149.89	1.13
8	155.52	155.6	0.08
9	157.38	159.87	2.49
CLC	159.87	160.43	0 56
9	160.43	160.83	0.4
10	160.87	161.11	0.24
11	174.84	175.71	0.87
12	176 54	177.56	1.02
CL	177.56	178.71	1.15
12	178.71	181.64	2.93
CL	181.64	181.76	0.12
12	181.76	181.85	0.09
13	181.99	182.34	0.35
14	182.52	183.12	0.6
15	184.81	184.95	0.14
16	185.26	188.01	2.75
17	188.87	189.37	0.5
18	189.75	190.14	0.39
19	190.44	191.19	0.75
20	193.45	193.65	0.2
21	202.01	202.24	0.23
		Total	25.05

Coal beds

Bed number	Top	Bottom	Coal thickness
A	138.05	145.98	6.32
B	174.84	181.85	6 18
C	184.81	191.19	4.53
		Total	17.03

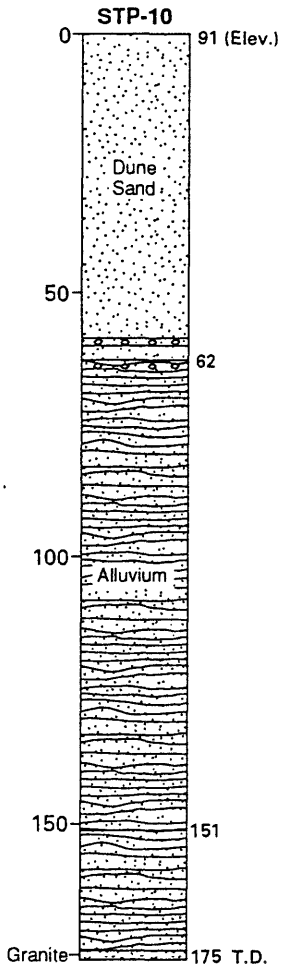
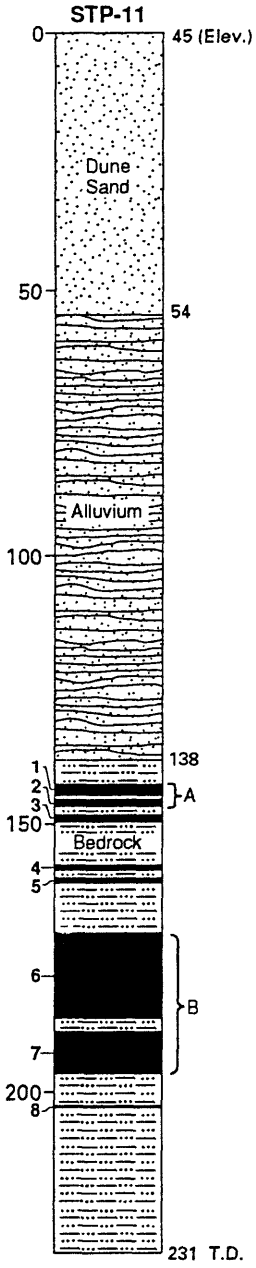


Figure 1-18. Stratigraphic columns of drill hole STP-9 and STP-10, Thar Desert, Sindh Province, Pakistan (drill hole locations are shown on figure 2). Coal bench numbers are shown on left side of column, coal bed letters are on right side of column.



Coal beds and benches; drill hole **STP-11**

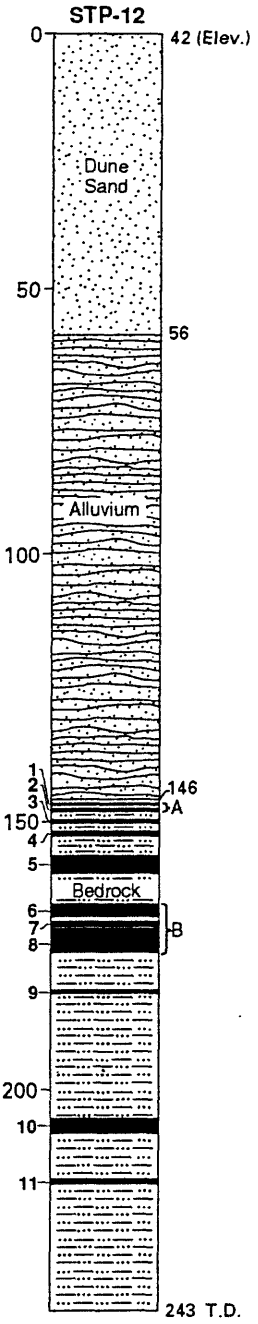
[NA, not analyzed; CLC, core lost, coal]

Coal benches

Bench number	Top	Bottom	Coal thickness
1	142.94	144.62	1.68
2	145.57	146.77	1.2
3	148.35	149.4	1.05
4	157.91	158.66	0 75
5	160.34	161.13	0.79
6	171.1	186.6	15.5
7	190.05	197.4	7.35
8	203.3	203.65	0.35
		Total	28.67

Coal beds

Bed number	Top	Bottom	Coal thickness
A	142.94	146.77	2.88
B	171.1	197 4	22.85
		Total	25.73



Coal beds and benches; drill hole **STP-12**

[NA, not analyzed; CLC, core lost, coal]

Coal benches

Bench number	Top	Bottom	Coal thickness
1	146.55	146.95	0.4
2	147.55	148.25	0.7
3	149.31	150	0.69
4	152.02	152.82	0.8
5	156.75	159.36	2.61
6	166.15	167.5	1.35
7	169.25	169.95	0.7
8	170.5	174.45	3.95
9	182.17	182.57	0.4
10	206.98	209.13	2.15
11	217.63	218.43	0.8
		Total	14.55

Coal beds

Bed number	Top	Bottom	Coal thickness
A	146.55	148.25	1.1
B	166.15	174.45	6
		Total	7.1

Figure 1-19. Stratigraphic columns of drill hole STP-11 and STP-12, Thar Desert, Sindh Province, Pakistan (drill hole locations are shown on figure 2). Coal bench numbers are shown on left side of column, coal bed letters are on right side of column.

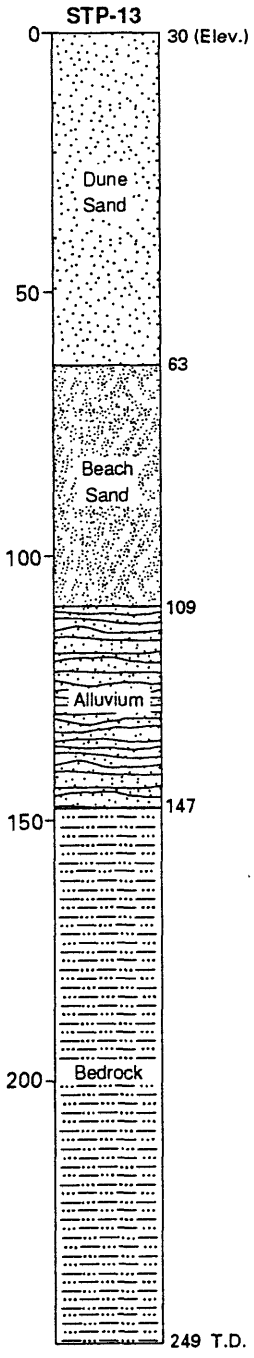


Figure 1-20. Stratigraphic columns of drill hole STP-13, Thar Desert, Sindh Province, Pakistan (drill hole locations are shown on figure 2). Coal bench numbers are shown on left side of column, coal bed letters are on right side of column.

APPENDIX 2

Coal-analyses tables for 22 coal test holes from the Thar Desert, Sindh Province, Pakistan; coal bench and coal bed numbers in these tables are keyed to the stratigraphic columns for these drill holes depicted in appendix 1 of this report.

Table 2-1. Selected coal-analyses values from drill hole TP-1, Thar Desert, Sindh Province, Pakistan

[Analyses of 24 coal samples by Geochemical Testing Laboratory, a Division of Energy Center, Inc., Somerset, Pennsylvania, USA; DAF, dry, ash free; MMM, moist, mineral matter, NA, not available; depths and thicknesses in meters, drill-hole locations are shown on figure 2]

Coal-sample analyses

Sample number	Sampled interval Top	Bottom	Coal thickness	As received values-% Total sulfur	Ash	Moisture	Heating values - Btu As received	Dry	DAF	MMM free	Volatile matter (DAF-%)	Apparent specific gravity
1.1	146.38	147.57	1.19	1.19	1.26	9.23	47.62	5,404	10,317	5,887	6,560	1.4
1.2	147.57	147.8	0.23	0.23	0.79	5.46	51.65	5,315	10,993	5,580	5,992	NA
2.1	148.7	149.54	0.84	0.84	0.63	5.21	50.12	5,495	11,017	5,768	6,137	NA
2.2	149.54	149.64	0.1	0.1	4.84	9.9	48.86	4,996	9,769	5,169	6,195	NA
2.3	149.64	150.22	0.58	0.58	1.27	12.21	48.62	4,580	8,913	5,161	6,007	1.39
7.1*	162.11	163.83	1.72	1.72	2.12	19.59	13.13	8,140	9,370	10,041	10,510	NA
3.1*	164.13	164.34	0.21	0.21	0.57	8.33	27.84	9,050	12,541	9,879	10,232	NA
3.2*	164.34	164.97	0.63	0.63	1.36	6.43	41.9	6,791	11,688	7,167	7,636	1.23
3.3*	164.97	166.3	1.33	1.33	0.31	4.36	44.92	6,567	11,923	6,863	7,132	1.26
3.4	166.3	166.59	0.29	0.29	1.28	6.15	45.44	6,105	11,189	6,422	6,881	NA
3.5*	166.59	167.43	0.84	0.84	0.44	4.84	40.09	7,222	12,054	7,578	7,856	1.21
3.6	167.43	168.02	0.59	0.59	1.66	6.61	44.56	6,127	11,052	6,445	6,957	1.36
4.1*	169.17	169.47	0.3	0.3	2.32	9.22	38.53	6,863	11,165	7,388	8,074	1.21
4.2	169.47	169.86	0.39	0.39	1.93	8.91	45.6	5,668	10,419	6,093	6,778	1.37
4.3	169.86	170.23	0.37	0.37	0.57	6.47	49.04	5,542	10,876	5,908	6,349	1.6
4.4	170.23	170.62	0.39	0.39	3.91	30.93	36.75	3,475	5,494	4,770	6,799	NA
4.5	170.62	171.35	0.73	0.73	3.1	8.22	46.97	5,546	10,459	5,808	6,563	1.33
4.6*	171.35	171.99	0.64	0.64	1.25	5.54	46.12	6,114	11,348	6,390	6,815	1.21
4.7*	171.99	172.88	0.89	0.89	1.52	5.61	43.55	6,653	11,786	6,939	7,387	1.25
4.8*	172.88	173.87	0.99	0.99	0.52	9.72	46.72	5,435	10,201	6,024	6,647	1.24
5.1	177.39	178.55	1.16	1.16	4.61	9.38	48.37	5,151	9,976	5,325	6,294	1.37
5A2	178.55	178.91	0.36	0.36	0.12	2.7	51.13	5,792	11,852	5,956	6,130	NA
5.2	178.91	180.47	1.56	1.56	1.42	5.62	49.45	5,729	11,333	5,974	6,446	1.3
6.1	190.47	193	2.53	2.53	0.72	6.51	49.87	5,396	10,763	5,741	6,201	1.28
		Total	18.86									
	Weighted averages			1.68	8.08	48.24	5,404	10,485	12,350	5,759	55.09	1.3

*These samples apparently dried out because of delays in wrapping them in plastic bags thus reducing their total moisture content; as a consequence, analyses values for these samples are skewed, values for these analyses were not used for determination of weighted averages

Coal-bench analyses

[Values are weighted averages for samples from each bench; in parentheses are numbers of samples in each bench]

Bench number	Composite interval Top	Bottom	Coal thickness	As received values-% Total sulfur	Ash	Moisture	Heating values - Btu As received	Dry	DAF	MMM free	Volatile matter (DAF-%)	Apparent specific gravity
1 (2)	146.38	147.8	1.42	1.18	8.62	48.27	5,390	10,426	12,502	5,837	56.23	1.17
2 (3)	148.7	150.22	1.52	1.15	8.19	49.46	5,113	10,132	12,057	5,497	53.8	NA
7 (1)*	162.11	163.83	1.72	2.12	19.59	13.13	8,140	9,370	12,099	10,041	55.1	NA
3 (6)*	164.13	168.02	3.89	0.8	5.49	42.45	6,778	11,760	12,996	7,133	58.88	NA
4 (8)*	169.17	173.87	4.7	1.73	9.54	44.82	5,732	10,440	12,495	6,193	58.72	NA
5 (3)	177.39	180.47	3.08	2.47	6.69	49.24	5,519	10,883	12,516	5,727	55.2	NA
6 (1)	190.47	193	2.53	0.72	6.51	49.87	5,396	10,763	12,370	5,741	53.66	1.28
		Total	18.86									
	Weighted averages			1.5	7.23	49.31	5,389	10,638	12,389	5,709	54.66	NA

*These benches contain samples with skewed analyses values due to drying out of samples prior to bagging, thus the values shown for these benches cannot be considered to be representative; values for these benches containing skewed analyses were not used to determine weighted averages

Coal-bed analyses

[Values are weighted averages of samples from each bed; in parentheses are coal-bench numbers included in beds]

Bed Number	Composite interval Top	Bottom	Coal thickness	As received values-% Total sulfur	Ash	Moisture	Heating values - Btu As received	Dry	DAF	MMM free	Volatile matter (DAF-%)	Apparent specific gravity
A (1,2)	146.38	150.22	2.94	1.17	8.4	48.89	5,247	10,274	12,272	5,661	54.97	NA
B (7,3-5)*	162.11	180.47	13.39	1.68	9	41.08	6,296	10,788	12,595	6,853	57	NA
		Total	16.33									

*This coal bed contains samples with skewed analyses values due to drying out of samples prior to bagging, thus the values shown for this bed cannot be considered to be representative

Note.--To convert Btu (British thermal unit) heating values to kilogram-calories multiply by .556.

Table 2-2. Selected coal-analyses values from drill hole TP-3, Thar Desert, Sindh Province, Pakista

[Analyses of 36 coal samples by Geochemical Testing Laboratory, a Division of Energy Center, Inc., Somerset, Pennsylvania, USA; DAF, dry, ash free; MMM, moist, mineral matter, NA, not available; depths and thicknesses in meters, drill-hole locations are shown on figure 2]

Coal-sample analyses

Sample number	Sampled interval Top	Bottom	Coal thickness	As received values-% Total sulfur	Ash	Moisture	Heating values - Btu As received	Dry	DAF	MMM free	Volatile matter (DAF-%)	Apparent specific gravity
1	137.06	137.4	0.34	1.1	6.04	55.32	4,667	10,446	12,078	4,902	53.1	NA
2A	145.96	146.78	0.82	1.53	9.21	49.7	4,998	9,936	12,164	5,415	54.17	1.25
2B	147.19	147.74	0.55	4.51	12.88	45.66	4,997	9,196	12,052	5,387	56.16	1.37
2C	147.82	148.64	0.82	2.09	6.3	46.9	6,266	11,801	13,389	6,531	63.08	1.09
2D	148.64	148.86	0.22	1.79	6.07	50.57	5,435	10,995	12,534	5,661	55.52	NA
2E	148.86	149.36	0.5	1.11	5.32	49.98	5,676	11,347	12,697	5,925	57.97	NA
2F	149.36	150.12	0.76	3.75	11.11	47.11	5,039	9,528	12,060	5,387	59.36	1.38
2G	151.17	151.74	0.57	1.61	7.41	49.56	5,334	10,575	12,397	5,415	54.37	1.14
2H	151.74	152.35	0.61	2.95	13.02	46.4	4,856	9,059	11,966	5,387	55.64	1.32
2I	152.35	153.28	0.93	0.47	12.25	45.4	5,252	9,620	12,401	6,531	59.95	1.13
2J	153.28	153.92	0.64	3.19	20.87	40.6	4,574	7,700	11,871	5,661	58.84	1.4
2K1	153.92	154.22	0.3	1.55	14.75	44.81	5,027	9,109	12,432	5,925	59.14	NA
2K2	154.22	154.8	0.58	1.43	30.33	36.98	3,781	6,000	11,567	5,387	66.02	1.69
2L	155.7	156.72	1.02	1.47	17.07	45.78	4,463	8,231	12,013	6,513	54.68	1.27
2M	156.72	156.97	0.25	0.41	8.07	47.04	5,746	10,849	12,800	6,257	59.67	NA
2N	156.97	157.64	0.67	0.77	5.08	49.67	5,840	11,604	12,905	6,111	59.49	0.97
2O	157.64	158.24	0.6	0.75	4.7	49.76	5,869	11,682	12,886	6,117	58.22	0.95
2P	158.24	158.94	0.7	1.86	9.42	46.12	5,556	10,311	12,497	6,013	59.64	1.1
2Q	158.94	160.02	1.08	0.77	5.12	48.73	5,826	11,364	12,625	6,099	55.47	1.02
2R	160.02	161.52	1.5	1.05	4.51	48.71	5,908	11,518	12,628	6,118	56.13	1.1
2S	161.52	162.42	0.9	2.35	6.15	47.17	6,111	11,567	13,090	6,332	62.13	1.06
2T	162.42	163.07	0.65	0.63	3.79	49.6	5,814	11,535	12,474	6,008	54.97	1.04
2U	163.07	164.3	1.23	0.37	3.08	48.98	6,091	11,938	12,705	6,268	55.99	1.02
2V	164.3	164.75	0.45	0.79	3.99	47.53	6,450	12,293	13,305	6,669	63.11	1
2W	164.75	165.52	0.77	0.66	3.62	50.43	5,803	11,706	12,629	5,982	55.6	1.13
2X	165.52	166.11	0.59	0.4	3.13	50.24	6,105	12,269	13,092	6,284	57.89	NA
2Y	166.11	167.66	1.55	0.47	3.47	48.91	6,282	12,295	13,191	6,485	58.91	0.94
2Z1	167.66	168.21	0.55	0.51	3.26	48.62	6,633	12,910	13,785	6,829	64.1	NA
2Z2	168.21	169.21	1	1.01	5.19	49.47	5,698	11,276	12,567	5,948	57.01	1.14
2AA	169.21	169.9	0.69	0.41	3.88	50.63	5,640	11,424	12,399	5,852	53.69	1.14
2AB	169.9	170.73	0.83	0.67	6.02	47.38	5,974	11,353	12,821	6,329	57.5	1.19
2AC	170.73	171.38	0.65	0.25	25.73	40.9	3,691	6,245	11,062	5,084	62.76	1.51
2AD	171.38	172.26	0.88	0.36	5.03	51.31	5,227	10,735	11,972	5,497	50.5	1.4
2AE	172.26	172.93	0.67	0.68	4.89	49.21	5,920	11,655	12,896	6,190	60.54	NA
2AF	172.93	173.83	0.9	0.53	4.2	49.89	5,873	11,719	12,791	6,106	57.99	1.1
2AG	173.83	175.28	1.45	0.38	5.35	51.33	5,314	10,918	12,265	5,607	53.24	1.32
		Total	27.22									
	Weighted averages			1.17	7.89	47.94	5,549	10,760	12,544	5,938	57.55	1.18

Coal-bench analyses

[Values are weighted averages for samples from each bench; in parentheses are numbers of samples in each bench]

Bench number	Composite interval Top	Bottom	Coal thickness	As received values-% Total sulfur	Ash	Moisture	Heating values - Btu As received	Dry	DAF	MMM free	Volatile matter (DAF-%)	Apparent specific gravity
1 (1)	137.06	137.4	0.34	1.1	6.04	55.32	4,667	10,446	12,078	4,902	53.1	NA
2 (1)	145.96	146.78	0.82	1.53	9.21	49.7	4,998	9,936	12,164	5,415	54.17	1.25
3 (5)[1]	147.19	150.12	2.85	2.8	8.66	47.54	5,526	10,550	12,589	5,832	59.27	1.27
4 (6)	151.17	154.8	3.63	1.79	16.23	43.98	4,825	8,717	12,103	5,666	59.06	1.32
5 (23)	155.7	175.28	19.58	0.8	6.21	49.46	5,725	11,209	12,644	6,043	57.24	1.14
		Total	27.22									
	Weighted averages			1.17	7.89	47.94	5,549	10,760	12,544	5,938	57.55	1.18

[1]This bench contains core loss in coal.

Coal-bed analyses

[Values are weighted averages for samples from each bed; in parentheses are coal-bench numbers included in beds]

Sample Number	Composite interval Top	Bottom	Coal thickness	As received values-% Total sulfur	Ash	Moisture	Heating values - Btu As received	Dry	DAF	MMM free	Volatile matter (DAF-%)	Apparent specific gravity
A (2-5)	145.96	175.28	26.88	1.17	7.92	48.53	5,560	10,764	12,550	5,951	57.61	1.18
		Total	27.22									
	Weighted averages			1.17	7.89	47.94	5,549	10,760	12,544	5,938	57.55	1.18

Note.--To convert Btu (British thermal unit) heating values to kilogram-calories multiply by .556.

Table 2-3. Selected coal-analyses values from drill hole TP-4, Thar Desert, Sindh Province, Pakistan

[Analyses of 17 coal samples; 14 by Geological Survey of Pakistan Karachi laboratory and 3 by Geochemical Testing Laboratory, a Division of Energy Center, Inc., Somerset, Pennsylvania, USA; DAF, dry, ash free; MMM, moist, mineral matter; NA, not available; depths and thicknesses in meters; drill-hole locations are shown on figure n] shown on figure 2]

Coal-sample analyses

Sample number	Sampled interval Top	Bottom	Coal thickness	As received values-% Total sulfur	Ash	Moisture	Heating values - Btu As received	Dry	DAF	MMM free	Volatile matter (DAF-%)	Apparent specific gravity
1A	180.91	181.25	0.34	2.45	13.22	48.23	NA	NA	NA	NA	59.51	NA
1B	181.25	181.6	0.35	3.4	32.82	39.31	2,730	4,498	9,797	3,854	66.22	NA
1C	181.6	181.93	0.33	0.11	25.93	41.06	2,689	4,562	8,146	3,724	68.56	NA
2A	192.05	193.02	0.97	5.92	14.15	43.35	5,545	9,788	13,048	5,967	57.38	NA
2B	193.02	193.58	0.56	0.1	12.95	44.91	4,840	8,786	11,486	5,618	60.11	NA
2C	193.58	194.31	0.73	1.08	8.33	48.11	NA	NA	NA	NA	56.17	NA
2D	194.51	195.16	0.65	9.85	18.18	40.08	5,742	9,583	13,757	6,119	61.44	NA
3	200.68	201.12	0.44	1.41	13.68	46.04	4,324	8,013	10,734	4,946	62.58	NA
4	203.45	203.75	0.3	2.63	8.82	48.9	NA	NA	NA	NA	58.08	NA
5	205.73	206.08	0.35	2.79	6.76	52.79	4,696	9,948	11,609	4,834	64.63	NA
6	223.78	224.66	0.88	0.14	3.95	48.13	6,525	12,579	13,617	6,804	63.79	NA
7A	229.01	229.71	0.7	1.84	7.66	48.37	NA	NA	NA	NA	57.38	NA
7B	229.71	230.18	0.47	0.24	4.41	48.06	6,269	12,071	13,192	6,561	59.47	NA
7C	230.18	230.73	0.55	2.74	7.76	48.76	NA	NA	NA	NA	54.65	NA
8*	256.14	257.34	1.2	0.39	18.67	41.81	4,855	8,344	12,285	6,041	60.03	1.46
9*	261.43	262.1	0.67	0.23	18.18	44.86	4,101	7,438	11,096	5,081	54.13	1.35
10*	272.05	273.05	1	2.27	16.46	45.45	4,356	7,986	11,436	5,083	52.86	1.54
		Total	10.49									
	Weighted averages			2.23	13.41	45.45	4,934	8,952	12,037	5,612	59.04	1.46

*Coal samples analyzed by Geochemical Testing, all other samples analyzed by Geological Survey of Pakistan

Coal-bench analyses

[Values are weighted averages for samples from each bench; in parentheses are numbers of samples in each bench]

Bench number	Composite interval Top	Bottom	Coal thickness	As received values-% Total sulfur	Ash	Moisture	Heating values - Btu As received	Dry	DAF	MMM free	Volatile matter (DAF-%)	Apparent specific gravity
1 (3)*	180.91	181.93	1.02	2.02	24.06	42.85	2,710	4,529	8,996	3,791	64.74	NA
2A (3)*	192.05	194.31	2.26	2.91	11.97	45.27	5,287	9,421	12,476	5,839	57.66	NA
2B (1)	194.51	195.16	0.65	1.08	8.33	48.11	NA	NA	NA	NA	56.17	NA
3 (1)	200.68	201.12	0.44	1.41	13.68	46.04	4,324	8,013	10,734	4,946	62.58	NA
4 (1)	203.45	203.75	0.3	2.63	8.82	48.9	NA	NA	NA	NA	58.08	NA
5 (1)	205.73	206.08	0.35	2.79	6.76	52.79	4,696	9,948	11,609	4,834	64.63	NA
6 (1)	223.78	224.66	0.88	0.14	3.95	48.13	6,525	12,579	13,617	6,804	63.79	NA
7 (3)*	229.01	230.73	1.72	1.69	6.8	48.41	6,269	12,071	13,192	6,561	57.08	NA
8 (1)	256.14	257.34	1.2	0.39	18.67	41.81	4,855	8,344	12,285	6,041	60.03	1.46
9 (1)	261.43	262.1	0.67	0.23	18.18	44.86	4,101	7,438	11,096	5,081	54.13	1.35
10 (1)	272.05	273.05	1	2.27	16.46	45.45	4,356	7,986	11,436	5,083	52.86	1.54
		Total	10.49									
	Weighted averages			2.23	13.41	45.45	4,861	8,896	11,882	5,566	59.04	1.46

*Heating values for these benches are weighted averages of the available Btu determinations; Btu values for some samples from these benches were not available

Coal-bed analyses

[Values are weighted averages of samples from each bed; in parentheses are coal-bench numbers included in beds]

Bed Number	Composite interval Top	Bottom	Coal thickness	As received values-% Total sulfur	Ash	Moisture	Heating values - Btu As received	Dry	DAF	MMM free	Volatile matter (DAF-%)	Apparent specific gravity
A (2A-2B)*	192.05	195.16	3.11	4.18	12.5	41.28	4,967	8,674	11,778	5,425	54.74	NA

*Heating values for this bed are weighted averages of the available Btu determinations; Btu values for some samples from this bed were not available

Note.--To convert Btu (British thermal unit) heating values to kilogram-calories multiply by .556.

Table 2-4. Selected coal-analyses values from drill hole TP-5, Thar Desert, Sindh Province, Pakistan

[Analyses of 19 coal samples by Geochemical Testing Laboratory, a Division of Energy Center, Inc., Somerset, Pennsylvania, USA; DAF, dry, ash free; MMM, moist, mineral matter, depths and thicknesses in meters, drill-hole locations are shown on figure 2]

Coal-sample analyses

Sample number	Sampled interval Top	Bottom	Coal thickness	As received values-% Total sulfur	Ash	Moisture	Heating values - Btu As received	Dry	DAF	MMM free	Volatile matter (DAF-%)	Apparent specific gravity
1	158.18	159.23	1.05	0.52	6.48	50.85	5,282	10,747	12,379	5,634	54.94	1.17
2A	162.4	163.15	0.75	1.04	6.63	51.06	5,374	10,981	12,703	5,697	57.12	1.04
2B	163.15	164.05	0.9	1.65	8.21	49.63	5,434	10,788	12,888	5,814	56.79	1.17
2C	164.05	164.35	0.3	0.24	17.9	46.04	4,361	8,081	12,093	5,382	58.12	1.26
3A	166.3	166.9	0.6	4.46	25	41.34	3,900	6,649	11,588	4,873	57.8	1.5
3B	166.9	167.7	0.8	0.75	6.59	52.71	5,010	10,594	12,308	5,330	52.72	0.97
3C	167.7	168.7	1	0.9	6.28	49.66	5,744	11,410	13,036	6,081	59.27	1.14
3D	168.7	169.55	0.85	0.46	8.86	48.56	5,598	10,883	13,149	6,148	61.52	0.97
4	170.4	170.95	0.55	1.07	9.33	47.83	5,619	10,771	13,166	6,149	60.6	0.98
5A	175.45	176.05	0.6	0.26	18.86	45.8	4,110	7,583	11,626	5,136	58.18	1.39
5B	176.05	177.03	0.98	0.27	9.49	47.67	5,373	10,268	12,542	5,962	58.27	1.18
5C	177.03	177.72	0.69	0.41	26.48	41.35	3,491	5,953	10,851	4,845	62.65	1.62
6	178.09	179.09	1	1	7.84	48.74	5,501	10,732	12,671	5,920	56.87	1.18
7	197.64	197.99	0.35	0.22	3.91	50.87	5,664	11,529	12,527	5,895	53.37	0.99
8	203.36	203.74	0.38	5.21	13.33	44.52	5,248	9,458	12,449	5,638	54.39	1.11
9	209.94	210.79	0.85	1.71	7.13	48.34	5,676	10,987	12,746	5,996	55.54	1.23
10	211.64	212.01	0.37	1.44	6.78	50.68	5,463	11,078	12,842	5,768	55.66	0.95
11A	260.79	261.39	0.6	0.94	4.28	51.84	5,611	11,651	12,788	5,802	52.27	0.98
11B	261.39	261.94	0.55	0.39	10.44	49.11	4,980	9,787	12,313	5,577	52.39	1.07
	Weighted averages	Total	13.17	1.11	10.16	48.48	5,185	10,144	12,496	5,701	56.97	1.16

Coal-bench analyses

[Values are weighted averages for samples from each bench; in parentheses are numbers of samples in each bench]

Bench number	Composite interval Top	Bottom	Coal thickness	As received values-% Total sulfur	Ash	Moisture	Heating values - Btu As received	Dry	DAF	MMM free	Volatile matter (DAF-%)	Apparent specific gravity
1 (1)	158.18	159.23	1.05	0.52	6.48	50.85	5,282	10,747	12,379	5,634	54.94	1.17
2 (3)	162.4	164.35	1.95	1.2	9.09	49.63	5,246	10,446	12,695	5,703	57.12	1.13
3 (4)	166.3	169.55	3.25	1.41	10.49	48.59	5,185	10,192	12,619	5,691	57.97	1.12
4 (1)	170.4	170.95	0.55	1.07	9.33	47.83	5,619	10,771	13,166	6,149	60.6	0.98
5 (3)	175.45	177.72	2.27	0.31	17.13	45.25	4,467	8,247	11,786	5,404	59.58	1.37
6 (1)	178.09	179.09	1	1	7.84	48.74	5,501	10,732	12,671	5,920	56.87	1.18
7 (1)	197.64	197.99	0.35	0.22	3.91	50.87	5,664	11,529	12,527	5,895	53.37	0.99
8 (1)	203.36	203.74	0.38	5.21	13.33	44.52	5,248	9,458	12,449	5,638	54.39	1.11
9 (1)	209.94	210.79	0.85	1.71	7.13	48.34	5,676	10,987	12,746	5,996	55.54	1.23
10 (1)	211.64	212.01	0.37	1.44	6.78	50.68	5,463	11,078	12,842	5,768	55.66	0.95
11 (2)	260.79	261.94	1.15	0.68	7.23	50.53	5,309	10,760	12,561	5,695	52.33	1.02
		Total Weighted Averages	13.17	1.11	10.16	48.48	5,185	10,144	12,496	5,701	56.97	1.16

Coal-bed analyses

[Values are weighted averages of samples from each bed; in parentheses are coal-bench numbers included in beds]

Bed Number	Composite interval Top	Bottom	Coal thickness	As received values-% Total sulfur	Ash	Moisture	Heating values - Btu As received	Dry	DAF	MMM free	Volatile matter (DAF-%)	Apparent specific gravity
A(2,3,4)	162.4	170.95	5.75	1.3	9.9	48.87	5,247	10,334	12,697	5,739	57.94	1.11

Note.--To convert Btu (British thermal unit) heating values to kilogram-calories multiply by .556.

Table 2-5. Selected coal-analyses values from drill hole TP-7, Thar Desert, Sindh Province, Pakistan

[Analyses of 21 coal samples by the Pakistan Council of Scientific and Industrial Research Fuel Research Centre, Karachi; NA, not available; DAF, dry, ash free; MMM, moist, mineral matter; depths and thicknesses in meters; drill-hole locations are shown on figure 2]

Coal-sample analyses

Sample number	Sampled interval Top	Bottom	Coal thickness	As received values-% Total sulfur	Ash	Moisture	Heating values - Btu As received	Dry	DAF	MMM free	Volatile matter (DAF-%)	Apparent specific gravity
1	186.98	187.4	0.42	4.13	18.28	46.34	4,028	7,507	11,385	4,631	58.43	1.62
2A	189.09	189.59	0.5	3.87	20.33	45.83	3,825	7,061	11,302	4,530	56.62	1.56
2B	189.59	189.83	0.24	0.49	12.02	54.18	3,866	8,437	11,436	4,401	55.15	1.26
3A	190.93	191.78	0.85	2.49	6.79	48.95	5,653	11,075	12,773	5,879	60.97	1.34
3B	191.78	192.71	0.93	2.41	7.59	44.71	6,106	11,044	12,802	6,428	60.89	1.21
3C	192.71	193.2	0.49	4.33	34.76	39.16	2,861	4,702	10,969	4,078	59.02	2.28
3D	193.2	194.16	0.96	2.25	5.99	57.51	4,532	10,666	12,415	4,664	57.19	1.62
3E	194.83	195.68	0.85	2.24	26.08	32.84	4,758	7,084	11,581	6,359	62.52	1.45
4A	202.99	203.69	0.7	2.59	8.93	47.56	5,612	10,702	12,900	5,974	63.56	1.28
4B	203.69	204.39	0.7	1.82	5.22	51.51	5,504	11,351	12,720	5,676	60.51	1.29
4C	204.39	205.51	1.12	1.52	5.03	57.15	4,692	10,951	12,409	4,839	56.89	1.1
5A	223.27	223.84	0.57	2.32	34.88	35.61	3,090	4,799	10,473	4,676	66.42	1.71
5B	223.84	224.41	0.57	1.92	32.65	36.84	3,324	5,262	10,893	4,906	65.85	1.66
5C	224.41	225.41	1	0.79	3.38	51.08	5,790	11,837	12,716	5,942	58.58	1.18
5D	225.41	226.41	1	0.52	2.84	51.32	5,845	12,008	12,750	5,985	57.54	1.13
5E	226.41	227.46	1.05	0.82	3.69	52.25	5,642	11,816	12,806	5,806	59.33	1.17
5F	227.46	228.46	1	0.75	3.17	52.16	5,620	11,748	12,581	5,756	57.6	1.18
5G	228.46	229.46	1	0.74	3.76	51.52	7,051	14,543	15,765	7,280	58.17	1.2
5H	229.46	230.5	1.04	3.28	6.88	50.54	5,412	10,943	12,712	5,561	57.91	1.1
6A	235.35	236.14	0.79	0.62	2.75	50.99	5,996	12,236	12,964	6,126	63.4	NA
6B	236.14	236.6	0.46	0.56	12.02	44.35	5,459	9,809	12,512	6,219	64.28	NA
		Total	16.24									
	Weighted averages			1.81	10.12	48.63	5,210	10,375	12,535	5,647	59.82	1.33

Coal-bench analyses

[Values are weighted averages for samples from each bench; in parentheses are numbers of samples in each bench]

Bench number	Composite interval Top	Bottom	Coal thickness	As received values-% Total sulfur	Ash	Moisture	Heating values - Btu As received	Dry	DAF	MMM free	Volatile matter (DAF-%)	Apparent specific gravity
1 (1)	186.98	187.4	0.42	4.13	18.28	46.34	4,028	7,507	11,385	4,631	58.43	1.62
2 (2)	189.09	189.83	0.74	2.66	17.43	48.55	3,862	7,505	11,350	4,512	61.32	1.46
3 (5)[1]	190.93	195.68	4.08	2.62	13.55	45.64	5,037	9,265	12,340	5,651	56.38	1.51
4 (3)	202.99	205.51	2.52	1.9	6.17	52.94	5,169	10,985	12,643	5,376	56.38	1.2
5 (8)	223.27	230.5	7.23	1.31	8.23	48.99	5,520	10,821	12,904	5,939	59.5	1.24
6 (2)	235.35	236.6	1.25	0.6	5.95	48.58	5,827	11,331	12,814	6,173	58.66	NA
		Total	16.24									
	Weighted averages			1.81	10.12	48.63	5,210	10,375	12,535	5,647	59.82	1.33

[1]This bench contains core loss in coal.

Coal-bed analyses

[Values are weighted averages of samples from each bed; in parentheses are coal-bench numbers included in beds]

Bed Number	Composite interval Top	Bottom	Coal thickness	As received values-% Total sulfur	Ash	Moisture	Heating values - Btu As received	Dry	DAF	MMM free	Volatile matter (DAF-%)	Apparent specific gravity
A (2,3)	189.09	195.68	4.82	2.63	14.69	46.08	4,797	9,088	12,094	5,431	59.54	1.5

Note.--To convert Btu (British thermal unit) heating values to kilogram-calories multiply by .556.

Table 2-6. Selected coal-analyses values from drill hole TP-8, Thar Desert, Sindh Province, Pakistan

[Analyses of 18 coal samples by the Pakistan Council of Scientific and Industrial Research Fuel Research Centre, Karachi; DAF, dry, ash free; MMM, moist, mineral matter; depths and thicknesses in meters; drill-hole locations are shown on figure 2]

Coal-sample analyses

Sample number	Sampled interval Top	Bottom	Coal thickness	As received values-% Total sulfur	Ash	Moisture	Heating values - Btu As received	Dry	DAF	MMM free	Volatile matter (DAF-%)	Apparent specific gravity
1A	159.03	160.03	1	2.07	6.05	50.1	5,583	11,187	12,730	5,792	59.61	1.22
1B	160.03	160.63	0.6	1.28	3.74	53.57	4,742	10,214	11,108	4,840	56.5	1.22
1C	160.63	161.63	1	0.38	4.53	48.2	5,643	10,893	11,937	5,901	54.19	1.26
1D	161.63	162.63	1	2.31	5.78	51.06	5,561	11,363	12,885	5,731	60.7	1.28
1E	162.63	163.63	1	3.18	6.34	48.19	6,144	11,860	13,513	6,306	66.15	1.24
1F	163.63	164.63	1	0.69	6.2	48.88	5,749	11,247	12,801	6,101	62.76	1.32
1G	164.63	165.68	1.05	1.22	14.65	46.27	4,472	8,323	11,441	5,199	57.17	1.36
2A	178.28	179.28	1	0.96	6.05	48.65	5,854	11,399	12,922	6,177	62.93	1.22
2B	179.28	180.28	1	0.67	3.25	51.63	5,774	11,938	12,798	5,926	61.6	1.23
2C	180.28	181.35	1.07	0.53	3.26	54.43	4,926	10,809	11,641	5,063	55.75	1.22
2D	181.35	182.35	1	1.45	10.11	49.8	4,030	8,028	10,053	4,403	78.69	1.27
2E	182.35	183.13	0.78	0.44	5.54	48.86	5,325	10,412	11,677	5,626	54.79	1.26
3	196.98	197.95	0.97	0.42	8.93	47.02	5,527	10,434	12,551	6,079	54.27	1.3
4A	198.91	199.95	1.04	1.12	5.28	48.35	6,032	11,679	13,008	6,296	62.21	1.24
4B	199.95	200.95	1	1.29	3.98	51.68	5,606	11,600	12,642	5,748	57.91	1.61
4C	200.95	201.8	0.85	0.99	5.12	51.49	5,406	11,143	12,459	5,637	57.68	1.26
5	208.7	209.38	0.68	0.88	17.92	45.55	4,292	7,883	11,750	5,236	59.05	1.45
6	222.72	223.57	0.85	1.6	23.41	45.22	3,598	6,569	11,472	4,654	55.9	1.37
		Total	16.89									
	Weighted averages			1.2	7.6	49.4	5,276	10,465	12,230	5,625	60.09	1.29

Coal-bench analyses

[Values are weighted averages for samples from each bench; in parentheses are numbers of samples in each bench]

Bench number	Sampled interval Top	Bottom	Coal thickness	As received values-% Total sulfur	Ash	Moisture	Heating values - Btu As received	Dry	DAF	MMM free	Volatile matter (DAF-%)	Apparent specific gravity
1 (7)	159.03	165.68	6.65	1.6	7	49.19	5,447	10,739	12,413	5,743	59.75	1.28
2 (5)	178.28	183.13	4.85	0.82	5.61	50.81	5,172	10,526	11,822	5,425	63.01	1.24
3 (1)	196.98	197.95	0.97	0.42	8.93	47.02	5,527	10,434	12,551	6,079	54.27	1.3
4 (3)	198.91	201.8	2.89	1.14	4.78	50.43	5,700	11,494	12,720	5,912	59.39	1.37
5 (1)	208.7	209.38	0.68	0.88	17.92	45.55	4,292	7,883	11,750	5,236	59.05	1.45
6 (1)	222.72	223.57	0.85	1.6	23.41	45.22	3,598	6,569	11,472	4,654	55.9	1.37
		Total	16.89									
	Weighted averages			1.2	7.6	49.4	5,276	10,465	12,230	5,625	60.09	1.29

Coal-bed analyses

[Values are weighted averages of samples from each bed; in parentheses are coal-bench numbers included in beds]

Bed number	Sampled interval Top	Bottom	Coal thickness	As received values-% Total sulfur	Ash	Moisture	Heating values - Btu As received	Dry	DAF	MMM free	Volatile matter (DAF-%)	Apparent specific gravity
A (3,4)	196.98	201.8	3.86	0.96	5.83	49.57	5,657	11,228	12,677	5,954	58.1	1.36

Note.--To convert Btu (British thermal unit) heating values to kilogram-calories multiply by .556.

Table 2-7. Selected coal-analyses values from drill hole TP-9, Thar Desert, Sindh Province, Pakistan

[Analyses of 37 coal samples by the Pakistan Council of Scientific and Industrial Research Fuel Research Centre, Karachi; DAF, dry, ash free; MMM, moist, mineral matter; depths and thicknesses in meters; drill-hole locations are shown on figure 2]

Coal-sample analyses

Sample number	Sampled interval Top	Bottom	Coal thickness	As received values-% Total sulfur	Ash	Moisture	Heating values - Btu As received	Dry	DAF	MMM free	Volatile matter (DAF-%)	Apparent specific gravity
1A	148.44	149.04	0.6	0.97	6.65	51.33	5,013	10,302	11,931	5,318	53.51	1.42
1B	149.04	149.69	0.65	1.33	10.08	45.44	5,776	10,587	12,987	6,355	63.32	1.39
1C	149.69	150.24	0.55	1.08	3.53	52.48	5,835	12,277	13,262	5,973	65.8	1.27
1D	150.24	150.64	0.4	1.9	8.56	44.78	6,178	11,188	13,240	6,627	65.12	1.37
2A	152.6	153.12	0.52	5	20.08	41.74	4,561	7,829	11,944	5,318	61.16	1.57
2B	153.12	153.74	0.62	0.39	6.41	50.68	5,414	10,977	12,617	5,783	60.72	1.36
3A	158.97	160.02	1.05	1.04	5.04	52.6	5,342	11,270	12,610	5,560	59.35	1.34
3B	161.07	161.57	0.5	0.33	7.72	49.28	5,253	10,355	12,215	5,701	57.02	1.39
4	163.1	163.82	0.72	0.3	6.55	51.86	4,809	9,991	11,563	5,150	51.46	1.41
5A	167.36	168.26	0.9	0.21	30.22	38.92	3,336	5,461	10,808	4,928	63.94	1.84
5B	168.26	169.16	0.9	0.74	17.16	44.52	4,303	7,757	11,232	5,211	59.43	1.63
5C	169.16	170.06	0.9	0.32	16.91	31.08	6,186	8,975	11,893	7,532	61.55	1.24
6	170.86	171.51	0.65	0.55	14.16	38.58	5,347	8,705	11,314	6,257	56.24	1.45
7A[1]	171.81	172.21	0.4	3.31	22.89	23.5	6,259	8,182	11,675	7,902	59.85	1.33
7B	172.21	172.91	0.7	0.39	7.33	35.99	6,648	10,386	11,729	7,181	53.37	1.21
7C	172.91	173.56	0.65	1.08	12.79	35.14	6,191	9,546	11,890	7,071	56.79	1.19
8	182.69	183.47	0.78	0.69	16.46	35.23	5,520	8,523	11,425	6,640	56.3	1.54
9A	184.74	185.44	0.7	0.58	6.13	51.08	5,505	11,254	12,866	5,844	58.84	1.17
9B	185.44	186.14	0.7	0.22	3.4	51.44	5,644	11,623	12,498	5,840	57.87	1.15
9C	186.14	186.84	0.7	0.96	4.7	53.24	5,155	11,024	12,257	5,350	55.66	1.2
9D	186.84	187.41	0.57	0.26	2.26	53.7	5,251	11,343	11,926	5,362	54.64	1.16
9E	187.41	187.98	0.57	0.2	2.22	54.06	5,210	11,340	11,915	5,321	53.2	1.19
9F	187.98	188.68	0.7	0.36	2.13	54.5	5,216	11,465	12,028	5,310	53.64	1.12
10	195.13	195.83	0.7	3.29	23.19	43.16	3,666	6,450	10,894	4,561	57.94	1.41
11A	201.5	202.4	0.9	1.2	4.14	51.75	5,470	11,337	12,400	5,624	54.65	1.15
11B	202.4	203.3	0.9	0.34	2.34	49.78	5,791	11,531	12,094	5,912	54.04	1.15
11C	203.3	204.2	0.9	1	3.86	55.76	5,002	11,308	12,389	5,138	51.93	1.22
11D	204.2	205.1	0.9	0.79	3.72	54.51	4,904	10,781	11,740	5,046	50.64	1.14
12	207.65	208.05	0.4	2.62	16.88	47.34	4,194	7,964	11,722	4,883	56.12	1.32
13	208.6	209.05	0.45	1.44	11.24	46.12	5,189	9,630	12,167	5,771	57.62	1.27
14A	211.8	212.44	0.64	0.37	2.73	49.53	5,888	11,666	12,332	6,035	56.02	1.14
14B	212.44	213.44	1	0.86	3.49	52.26	5,190	10,871	11,727	5,323	53.44	1.17
14C	213.44	214.44	1	1.05	7.95	49.43	5,079	10,044	11,916	5,464	55.4	1.21
14D	214.44	215.49	1.05	0.55	14.54	46.47	4,470	8,349	11,462	5,251	57.61	1.26
14E	215.49	216.49	1	0.8	26.99	39.25	3,491	5,747	10,340	4,841	63.28	1.35
14F	216.49	217.49	1	0.52	3.07	52.08	5,294	11,048	11,804	5,433	54.13	1.19
15	224.09	224.64	0.55	0.51	4.65	49.07	5,477	10,754	11,835	5,722	53.44	1.19
		Total	26.82									
	Weighted average			0.91	9.79	46.98	5,163	9,897	11,910	5,688	57	1.3

[1]Reported air dried moisture loss for this sample of 17.98 appeared to be anomalously low; consequently, this value was changed to 27.98.

Coal-bench analyses

[Values are weighted averages for samples from each bench; in parentheses are numbers of samples in each bench]

Sample number	Sampled interval Top	Bottom	Coal thickness	As received values-% Total sulfur	Ash	Moisture	Heating values - Btu As received	Dry	DAF	MMM free	Volatile matter (DAF-%)	Apparent specific gravity
1 (4)	148.44	150.64	2.2	1.27	7.23	48.69	5,656	11,041	12,814	6,026	61.59	1.36
2 (2)	152.6	153.74	1.14	2.49	12.65	46.65	5,025	9,541	12,310	5,571	60.92	1.46
3 (2)[1]	158.97	161.57	1.55	0.81	5.9	51.54	5,313	10,975	12,483	5,606	58.6	1.36
4 (1)	163.1	163.82	0.72	0.3	6.55	51.86	4,809	9,991	11,563	5,150	51.46	1.41
5 (3)	167.36	170.06	2.7	0.42	23.81	38.17	4,608	7,397	11,311	5,891	61.64	1.57
6 (1)	170.86	171.51	0.65	0.55	14.16	38.58	5,347	8,705	11,314	6,257	56.24	1.45
7 (3)	171.81	173.56	1.75	1.32	12.91	32.9	6,386	9,570	11,776	7,305	56.12	1.23
8 (1)	182.69	183.47	0.78	0.69	16.46	35.23	5,520	8,523	11,425	6,640	56.3	1.54
9 (6)	184.74	188.68	3.94	0.44	3.56	52.94	5,337	11,342	12,270	5,515	55.76	1.16
10 (1)	195.13	195.83	0.7	3.29	23.19	43.16	3,666	6,450	10,894	4,561	57.94	1.41
11 (4)	201.5	205.1	3.6	0.83	3.51	52.9	5,292	11,239	12,156	5,430	52.82	1.17
12 (1)	207.65	208.05	0.4	2.62	16.88	47.34	4,194	7,964	11,722	4,883	56.12	1.32
13 (1)	208.6	209.05	0.45	1.44	11.24	46.12	5,189	9,630	12,167	5,771	57.62	1.27
14 (6)	211.8	217.49	5.69	0.71	10.28	48.12	4,836	9,480	11,549	5,349	56.69	1.23
15 (1)	224.09	224.64	0.55	0.51	4.65	49.07	5,477	10,754	11,835	5,722	53.44	1.19
		Total	26.82									
	Weighted averages			0.91	9.78	46.99	5,162	9,897	11,910	5,687	57	1.3

[1]Interval includes core loss in coal; only thickness of analyzed coal samples is shown.

Table 2-7. Selected coal-analyses values from drill hole TP-9, Thar Desert, Sindh Province, Pakistan (Continued)

Coal-bed analyses

[Values are weighted averages of samples from each bed; in parentheses are coal-bench numbers included in beds]

Sample number	Sampled interval		Coal thick-ness	As received values-%			Heating values - Btu				Volatile matter (DAF-%)	Apparent specific gravity
	Top	Bottom		Total sulfur	Ash	Moisture	As received	Dry	DAF	MMM free		
A (1,2)	148.44	153.74	3.34	1.69	9.08	47.97	5,441	10,529	12,642	5,871	61.36	1.4
B (3,4)[1]	158.97	163.82	2.27	0.65	6.11	51.63	5,153	10,663	12,191	5,461	56.33	1.37
C (5-7)[2]	167.36	173.56	5.1	0.75	17.58	36.4	5,312	8,310	11,471	6,421	59.06	1.44
D (8,9)	182.69	188.68	4.72	0.49	5.69	50.02	5,367	10,876	12,131	5,701	55.85	1.23
E (11-14)[3]	201.5	217.49	10.14	0.86	8.18	49.69	4,988	10,051	11,799	5,378	55.34	1.21
		Total	25.57									
	Weighted averages			0.86	9.53	47.05	5,197	9,973	11,940	5,717	57.05	1.3

[1]Interval includes core loss in coal.
[2]MMM-free Btu (and other values) for this bed are probably too high because of low (incorrect) moisture value for sample 7A.
[3]This coal bed contains 2 thin unanalyzed coal benches.

Note.--To convert Btu (British thermal unit) heating values to kilogram-calories multiply by .556.

Table 2-8. Selected coal-analyses values from drill hole TP-10, Thar Desert, Sindh Province, Pakistan

[Analyses of 33 coal samples by the Pakistan Council of Scientific and Industrial Research Fuel Research Centre, Karachi; DAF, dry, ash free; MMM, moist, mineral matter; depths and thicknesses in meters; drill-hole locations are shown on figure 2]

Coal-sample analyses

Sample number	Sampled interval		Coal thick-ness	As received values-%			Heating values - Btu				Volatile matter (DAF-%)	Apparent specific gravity
	Top	Bottom		Total sulfur	Ash	Moisture	As received	Dry	DAF	MMM free		
1A	189.02	189.62	0.6	0.71	22.86	38.66	4,683	7,635	12,170	6,140	66.69	1.97
1B	189.62	190.22	0.6	0.32	30	38.57	3,144	5,118	10,002	4,615	64.88	1.57
2A	194.92	195.62	0.7	3.48	4.55	47.24	4,798	9,092	9,951	4,767	57.79	1.4
2B	195.62	196.24	0.62	2.13	12.18	49.15	4,336	8,527	11,212	4,805	56.67	1.43
3	197.97	198.77	0.8	4.95	20.61	43	4,049	7,103	11,126	4,724	58.24	1.52
4A	201.02	201.82	0.8	2.92	7.71	47.28	5,661	10,739	12,579	5,912	61.3	1.4
4B	201.82	202.57	0.75	2.77	8.51	49.21	5,153	10,147	12,189	5,431	57.04	1.38
5A	203.4	204.2	0.8	1.17	6.85	45.13	6,272	11,430	13,060	6,664	65.94	1.27
5B	204.2	205	0.8	1.18	5.02	49.04	6,024	11,821	13,112	6,264	57.97	1.46
6A	215.49	216.32	0.83	1.62	7.38	46.03	5,852	10,843	12,560	6,211	66.77	1.36
6B	216.32	217.02	0.7	0.4	5.33	48.72	5,390	10,512	11,731	5,685	59.32	1.32
7A	219.39	219.71	0.32	0.4	7.97	47.64	5,296	10,114	11,930	5,759	58.57	1.37
7B	219.81	220.81	1	2.36	27.06	38.66	3,742	6,100	10,915	5,029	64.84	1.87
7C	221.26	221.59	0.33	1	8.02	45.53	5,816	10,678	12,521	6,275	63.83	1.46
8A	221.59	222.45	0.86	0.96	7.11	48.94	5,663	11,090	12,883	6,047	61.93	1.32
8B	222.45	223.25	0.8	0.45	3.99	49.9	5,585	11,148	12,112	5,797	58.67	1.32
9A	225.25	225.96	0.71	4.04	9.79	43.37	6,062	10,704	12,942	6,394	62.93	1.67
9B	225.96	226.67	0.71	0.81	4.78	47.49	6,112	11,640	12,806	6,372	61.71	1.27
9C	226.67	227.38	0.71	1.81	5.73	47.98	5,909	11,359	12,766	6,138	61.92	1.3
10A	227.68	228.68	1	0.53	3.63	50.63	5,661	11,467	12,377	5,847	60.66	1.28
10B	228.68	229.68	1	1.02	5.13	49.76	5,641	11,228	12,505	5,882	59.05	1.31
10C	229.68	230.73	1.05	1.5	6.72	48.63	5,656	11,009	12,667	5,965	62.17	1.33
11A	230.73	231.73	1	0.81	4.01	49.11	5,831	11,458	12,437	6,025	59.3	1.34
11B	231.73	232.73	1	1.04	4.67	47.71	6,187	11,832	12,993	6,422	63.99	1.23
11C	232.73	233.78	1.05	1.21	14.48	45.88	5,523	10,206	13,936	6,424	62.78	1.32
12	233.78	234.48	0.7	0.44	3.11	51.65	5,446	11,262	12,036	5,599	55.44	1.32
13A	236.83	237.83	1	0.29	2.77	49.05	6,178	12,124	12,821	6,343	64.07	1.23
13B	237.83	238.83	1	1.28	4.86	48.73	6,043	11,787	13,021	6,264	62.74	1.24
13C	238.83	239.43	0.6	0.28	2.94	51.03	5,647	11,533	12,269	5,809	57.9	1.29
14	241.38	241.83	0.45	0.27	10.33	45.39	5,567	10,194	12,572	6,240	62.49	1.36
15A	243.02	243.72	0.7	0.22	2.81	50.84	5,842	11,882	12,602	6,006	60.58	1.25
15B	243.72	244.42	0.7	0.25	8.72	47.84	5,245	10,055	12,073	5,767	59.07	1.38
16	249.46	249.86	0.4	3.22	17.5	44.56	4,243	7,654	11,186	4,926	56.75	1.14
		Total	25.09									
	Weighted averages			1.4	8.68	47.21	5,453	10,417	12,322	5,869	61.2	1.38

Coal-bench analyses

[Values are weighted averages for samples from each bench; in parentheses are numbers of samples in each bench]

Bench number	Sampled interval		Coal thick-ness	As received values-%			Heating values - Btu				Volatile matter (DAF-%)	Apparent specific gravity
	Top	Bottom		Total sulfur	Ash	Moisture	As received	Dry	DAF	MMM free		
1 (2)	189.02	190.22	1.2	0.51	26.43	38.62	3,914	6,377	11,086	5,377	65.79	1.77
2 (2)	194.92	196.24	1.32	2.85	8.13	48.13	4,581	8,827	10,543	4,785	57.26	1.41
3 (1)	197.97	198.77	0.8	4.95	20.61	43	4,049	7,103	11,126	4,724	58.24	1.52
4 (2)	201.02	202.57	1.55	2.85	8.1	48.22	5,415	10,452	12,390	5,679	59.24	1.39
5 (2)	203.4	205	1.6	1.17	5.93	47.08	6,148	11,625	13,086	6,464	61.96	1.37
6 (2)	215.49	217.02	1.53	1.06	6.44	47.26	5,641	10,692	12,180	5,970	63.36	1.34
7 (2)[1]	219.39	220.81	1.32	1.88	24.44	52.22	5,573	9,743	14,291	6,774	79.28	2.11
8 (3)	221.26	223.25	1.99	0.76	4.67	41.21	4,692	9,274	10,437	4,944	50.35	1.1
9 (10)[2]	225.25	234.48	8.93	1.26	6.3	48.28	5,790	11,206	12,768	6,106	61.08	1.33
10 (3)	236.83	239.43	2.6	0.67	3.61	49.38	6,003	11,858	12,770	6,189	62.13	1.25
11 (1)	241.38	241.83	0.45	0.27	10.33	45.39	5,567	10,194	12,572	6,240	62.49	1.36
12 (2)	243.02	244.42	1.4	0.23	5.76	49.34	5,543	10,969	12,338	5,887	59.82	1.32
13 (1)	249.46	249.86	0.4	3.22	17.5	44.56	4,243	7,654	11,186	4,926	56.75	1.14
		Total	25.09									
	Weighted averages			1.4	8.68	47.21	5,453	10,417	12,322	5,869	61.2	1.38

[1]Contains .01-meter-thick unanalyzed carbonaceous mudstone parting.
[2]Contains core loss in coal.

Table 2-8. Selected coal-analyses values from drill hole TP-10, Thar Desert, Sindh Province, Pakistan (Continued)

Coal-bed analyses

[Values are weighted averages of samples from each bed; in parentheses are coal-bench numbers included in beds]

Bed number	Sampled interval Top	Bottom	Coal thickness	As received values-% Total sulfur	Ash	Moisture	Heating values - Btu As received	Dry	DAF	MMM free	Volatile matter (DAF-%)	Apparent specific gravity
A (4,5)	201.02	205	3.15	2	7	47.64	5,787	11,048	12,744	6,078	60.62	1.38
B (6-12)[1]	215.49	244.42	18.22	1.05	7.13	47.88	5,648	10,896	12,537	6,014	61.51	1.35
		Total	21.37									
	Weighted averages			1.19	7.11	47.84	5,669	10,918	12,567	6,024	61.38	1.35

[1]This bed contains 2 lost coal core intervals and 2 thin unanalyzed coal benches.

Note.--To convert Btu (British thermal unit) heating values to kilogram-calories multiply by .556.

Table 2-9. Selected coal-analyses values from drill hole TP-11, Thar Desert, Sindh Province, Pakistan

[Analyses of 5 coal samples by the Pakistan Council of Scientific and Industrial Research Fuel Research Centre, Karachi; DAF, dry, ash free; MMM, moist, mineral matter; depths and thicknesses in meters; drill-hole locations are shown on figure 2]

Coal-sample analyses

Sample number	Sampled interval Top	Bottom	Coal thickness	As received values-% Total sulfur	Ash	Moisture	Heating values - Btu As received	Dry	DAF	MMM free	Volatile matter (DAF-%)	Apparent specific gravity
1	233.18	233.78	0.6	1.14	6.3	50.54	5,496	11,112	12,734	5,797	62.78	1.3
2	236.31	236.83	0.52	0.58	5.65	54.43	4,763	10,453	11,933	5,025	57.81	1.1
3	236.83	238.09	1.26	0.6	5.47	48.61	5,765	11,217	12,554	6,073	61.97	1.32
4	238.34	239.23	0.89	0.44	8.39	49.84	5,152	10,271	12,333	5,626	62.65	1.41
5	241.63	242.93	1.3	0.42	3.27	51.52	5,488	11,318	12,137	5,654	56.28	1.23
		Total	4.57									
	Weighted averages			0.57	5.53	50.59	5,416	10,958	12,339	5,710	60.07	1.28

Coal-bench analyses

[Values are weighted averages for samples from each bench; in parentheses are numbers of samples in each bench]

Bench number	Sampled interval Top	Bottom	Coal thickness	As received values-% Total sulfur	Ash	Moisture	Heating values - Btu As received	Dry	DAF	MMM free	Volatile matter (DAF-%)	Apparent specific gravity
1 (1)	233.18	233.78	0.6	1.14	6.3	50.54	5,496	11,112	12,734	5,797	62.78	1.3
2 (2)	236.31	238.09	1.78	0.59	5.53	50.31	5,472	10,994	12,373	5,767	60.76	1.26
3 (1)	238.34	239.23	0.89	0.44	8.39	49.84	5,152	10,271	12,333	5,626	62.65	1.41
4 (1)	241.63	242.93	1.3	0.42	3.27	51.52	5,488	11,318	12,137	5,654	56.28	1.23
		Total	4.57									1.28
	Weighted averages			0.57	5.53	50.59	5,416	10,958	12,339	5,710	60.07	

Coal-bed analyses

[Values are weighted averages of samples from each bed; in parentheses are coal-bench numbers included in beds]

Bed number	Sampled interval Top	Bottom	Coal thickness	As received values-% Total sulfur	Ash	Moisture	Heating values - Btu As received	Dry	DAF	MMM free	Volatile matter (DAF-%)	Apparent specific gravity
A (2,3)	236.31	239.23	2.67	0.54	6.48	50.15	5,365	10,753	12,359	5,720	61.39	1.31

Note.--To convert Btu (British thermal unit) heating values to kilogram-calories multiply by .556.

Table 2-10. Selected coal-analyses values from drill hole TP-12, Thar Desert, Sindh Province, Pakistan

[Analyses of 32 coal samples by the Pakistan Council of Scientific and Industrial Research Fuel Research Centre, Karachi; DAF, dry, ash free; MMM, moist, mineral matter; depths and thicknesses in meters; drill-hole locations are shown on figure 2]

Coal-sample analyses

Sample number	Sampled interval Top	Bottom	Coal thickness	As received values-% Total sulfur	Ash	Moisture	Heating values - Btu As received	Dry	DAF	MMM free	Volatile matter (DAF-%)	Apparent specific gravity
1	214.21	214.58	0.37	2.85	12.79	44.27	5,134	9,213	11,957	5,688	57.55	1.44
2A	222.62	223.52	0.9	2.23	3.15	41.15	3,717	6,316	6,673	3,686	64.23	1.87
2B	223.52	224.54	1.02	0.84	5.89	48.71	4,841	9,439	10,663	5,099	61.88	1.45
3A	225.8	226.65	0.85	3.93	10.47	47.07	5,907	11,161	13,913	6,286	60.51	1.6
3B	226.65	227.53	0.88	1.15	5.7	47.42	3,227	6,136	6,882	3,355	61.67	1.42
4A	227.53	228.33	0.8	1.19	4.94	50.43	5,630	11,358	12,616	5,844	61.1	1.42
4B	228.33	229.13	0.8	1.64	5.66	48.46	5,911	11,469	12,884	6,149	62.87	1.43
4C	229.13	229.93	0.8	2.11	6.9	46.25	6,434	11,972	13,734	6,754	66.52	1.4
4D	229.93	230.58	0.65	1.17	5.92	43.54	7,135	12,638	14,118	7,508	73.47	1.19
5A	230.58	231.2	0.62	0.31	9.87	44.55	5,689	10,259	12,481	6,339	63.25	1.47
5B	232.59	233.49	0.9	0.36	9.54	44.46	5,903	10,628	12,833	6,547	64.82	1.42
6A	235.5	236.1	0.6	1.81	6.22	49.12	5,453	10,717	12,211	5,688	56.88	1.47
6B	236.1	236.67	0.57	3.24	7.96	48.41	5,300	10,273	12,146	5,514	54.9	1.57
7A	236.67	237.47	0.8	0.69	3.49	50.57	5,764	11,660	12,547	5,931	58.36	1.36
7B	237.47	238.27	0.8	0.59	4.5	49.07	5,670	11,132	12,211	5,908	58.06	1.37
7C	238.27	239.07	0.8	0.95	5.32	50.44	5,473	11,044	12,373	5,725	58.2	1.37
7D	239.07	239.72	0.65	1.42	18.74	44.08	4,283	7,660	11,519	5,229	61.14	1.96
8A	239.72	240.62	0.9	0.68	4.22	49.9	5,749	11,474	12,528	5,964	58.44	1.43
8B	240.62	241.52	0.9	1.09	5.62	50.74	5,297	10,752	12,136	5,546	56.51	1.45
8C	241.52	242.48	0.96	0.58	3.3	50.22	5,839	11,730	12,564	6,005	61.58	1.34
9A	242.77	243.57	0.8	0.76	3.76	48.62	6,072	11,817	12,749	6,262	61.97	1.36
9B	243.57	244.37	0.8	0.62	3.7	51.24	5,528	11,339	12,271	5,706	56.68	1.38
9C	244.37	245.17	0.8	0.25	2.5	48.62	6,457	12,568	13,211	6,614	65.85	1.22
9D	245.17	245.82	0.65	1.21	5.16	49.14	5,978	11,755	13,082	6,224	62.91	1.39
10A	245.82	246.72	0.9	0.45	3.23	50	5,984	11,969	12,795	6,161	60.11	1.41
10B	246.72	247.62	0.9	0.4	2.66	49.36	6,241	12,324	13,008	6,391	63.19	1.31
10C	247.62	248.46	0.84	0.75	4.32	49.31	5,933	11,704	12,793	6,156	60.94	1.33
11	250.15	250.95	0.8	0.34	5.41	51.11	5,291	10,823	12,169	5,591	56.54	1.28
12	253.31	254.33	1.02	1.18	14.99	49.11	4,282	8,413	11,925	5,000	53.34	1.54
13A	256.11	257.2	1.09	1.75	10.36	50.37	4,682	9,434	11,922	5,118	55.61	1.54
13B	257.69	258.01	0.32	1.82	7.83	49.58	4,989	9,895	11,713	5,292	55.65	1.44
14	258.01	258.61	0.6	5.07	30.94	37.01	3,049	4,841	9,513	4,030	61.54	1.97
		Total	25.09									
	Weighted averages			1.27	6.99	48.11	5,400	10,470	12,043	5,715	60.53	1.45

Coal-bench analyses

[Values are weighted averages for samples from each bench; in parentheses are numbers of samples in each bench]

Bench number	Sampled interval Top	Bottom	Coal thickness	As received values-% Total sulfur	Ash	Moisture	Heating values - Btu As received	Dry	DAF	MMM free	Volatile matter (DAF-%)	Apparent specific gravity
1 (1)	214.21	214.58	0.37	2.85	12.79	44.27	5,134	9,213	11,957	5,688	57.55	1.44
2 (2)	222.62	224.54	1.92	1.49	4.6	45.17	4,314	7,975	8,793	4,437	62.98	1.65
3 (7)	225.8	231.2	5.4	1.71	7.02	47	5,631	10,611	12,257	5,945	63.9	1.42
4 (1)	232.59	233.49	0.9	0.36	9.54	44.46	5,903	10,628	12,833	6,547	64.82	1.42
5 (16)[1]	235.5	248.46	12.67	0.89	5	49.42	5,720	11,327	12,530	5,960	59.83	1.41
6 (1)	250.15	250.95	0.8	0.34	5.41	51.11	5,291	10,823	12,169	5,591	56.54	1.28
7 (1)	253.31	254.33	1.02	1.18	14.99	49.11	4,282	8,413	11,925	5,000	53.34	1.54
8 (1)	256.11	257.2	1.09	1.75	10.36	50.37	4,682	9,434	11,922	5,118	55.61	1.54
9 (2)	257.69	258.61	0.92	3.94	22.9	41.38	3,724	6,599	10,278	4,469	59.49	1.79
		Total	25.09	1.27	6.99	48.11	5,400	10,470	12,043	5,715	60.53	1.45
	Weighted averages											

[1]This bed contains core loss in coal.

Coal-bed analyses

[Values are weighted averages of samples from each bed; in parentheses are coal-bench numbers included in beds]

Bed number	Sampled interval Top	Bottom	Coal thickness	As received values-% Total sulfur	Ash	Moisture	Heating values - Btu As received	Dry	DAF	MMM free	Volatile matter (DAF-%)	Apparent specific gravity
A (2-6)	222.62	250.95	21.69	1.11	5.67	48.3	5,565	10,805	12,131	5,832	61.21	1.43
B (8,9)	256.11	258.61	2.01	2.75	16.1	46.26	4243.45	8136.57	11169.96	4,821	57.39	1.65
		Total	23.7									
	Weighted Averages:			1.24	6.56	48.12	5,453	10,578	12,049	5,746	60.89	1.45

Note: Coal samples collected for analyses from this hole were not all correctly labeled by bench; bench 3 includes samples 3A-5A, bench 4 includes sample 5B, bench 5 includes samples 6A-10C; bench 6 includes sample 11; bench 7 includes sample 12; bench 8 includes sample 13A; and bench 9 includes samples 13B and 14; to convert Btu (British thermal unit) heating values to kilogram-calories multiply by .556.

Table 2-11. Selected coal-analyses values from drill hole TP-13, Thar Desert, Sindh Province, Pakistan

[Analyses of 17 coal samples by the Pakistan Council of Scientific and Industrial Research Fuel Research Centre, Karachi; DAF, dry, ash free; MMM, moist, mineral matter; depths and thicknesses in meters; drill-hole locations are shown on figure 2]

Coal-sample analyses

Sample number	Sampled interval		Coal thickness	As received values-%			Heating values - Btu				Volatile matter (DAF-%)	Apparent specific gravity
	Top	Bottom		Total sulfur	Ash	Moisture	As received	Dry	DAF	MMM free		
1A	176.81	177.46	0.65	2.4	11.67	48	4,917	9,456	12,192	5,408	59.97	1.54
1B	177.66	178.01	0.35	0.64	21.14	43.15	3,986	7,010	11,160	5,100	62.07	1.62
1C	178.46	178.84	0.38	8.21	17.16	47.86	4,129	7,919	11,803	4,324	58.49	1.79
2A	197.86	198.56	0.7	1.03	12.87	39.16	5,531	9,091	11,531	6,323	58.13	1.46
2B	198.56	199.21	0.65	0.56	3.87	50.38	5,326	10,732	11,641	5,511	56.5	1.4
2C	199.21	199.9	0.69	0.23	3.42	49.9	5,759	11,495	12,337	5,960	59.89	1.33
2D	199.9	200.6	0.7	0.29	3.91	50.86	5,391	10,972	11,920	5,605	56.96	1.36
2E	200.6	201.3	0.7	0.26	4.48	65.12	3,560	10,206	11,711	3,721	57.64	1.35
2F	201.75	202.75	1	0.72	8.01	47.12	5,117	9,677	11,405	5,538	60.78	1.38
2G	202.94	203.94	1	1.93	21.52	39.24	4,517	7,434	11,511	5,681	64.33	1.66
2H	203.94	204.99	1.05	1.93	11.53	61.74	3,107	8,120	11,621	3,397	59.75	1.62
2I	204.99	205.99	1	1.64	6.66	49.99	5,367	10,732	12,381	5,640	60.49	1.35
2J	205.99	206.99	1	2	7.62	47.57	5,568	10,619	12,426	5,888	59.93	1.33
2K	206.99	207.29	0.3	0.63	10.25	45.08	5,519	10,049	12,355	6,147	63.4	1.35
3	225.25	225.9	0.65	1.08	4.54	53.48	5,104	10,971	12,157	5,278	53.67	1.3
4	227.7	228.18	0.48	1.79	11.6	49.02	4,509	8,844	11,450	4,996	54.46	1.41
5	244.4	245.25	0.85	1.47	15.37	45.85	4,486	8,284	11,567	5,239	59.36	1.57
		Total	12.15									
	Weighted averages			1.47	10.03	49.37	4,816	9,558	11,841	5,270	59.31	1.45

Coal-bench analyses

[Values are weighted averages for samples from each bench; in parentheses are numbers of samples in each bench]

Bench number	Sampled interval		Coal thickness	As received values-%			Heating values - Btu				Volatile matter (DAF-%)	Apparent specific gravity
	Top	Bottom		Total sulfur	Ash	Moisture	As received	Dry	DAF	MMM free		
1 (1)	176.81	177.46	0.65	2.4	11.67	48	4,917	9,456	12,192	5,408	59.97	1.54
2 (1)	177.66	178.01	0.35	0.64	21.14	43.15	3,986	7,010	11,160	5,100	62.07	1.62
3 (1)	178.46	178.84	0.38	8.21	17.16	47.86	4,129	7,919	11,803	4,324	58.49	1.79
4 (5)	197.86	201.3	3.44	0.47	5.75	51.1	5,108	10,493	11,829	5,421	57.84	1.38
5 (6)[1]	201.75	207.29	5.35	1.59	11.03	49.02	4,764	9,346	11,894	5,263	61.18	1.46
6 (1)	225.25	225.9	0.65	1.08	4.54	53.48	5,104	10,971	12,157	5,278	53.67	1.3
7 (1)	227.7	228.18	0.48	1.79	11.6	49.02	4,509	8,844	11,450	4,996	54.46	1.41
8 (1)	244.4	245.25	0.85	1.47	15.37	45.85	4,486	8,284	11,567	5,239	59.36	1.57
		Total	12.15									
	Weighted averages			1.47	10.03	49.37	4,816	9,558	11,841	5,270	59.31	1.45

[1]Contains core loss in coal.

Coal-bed analyses

[Values are weighted averages of samples from each bed; in parentheses are coal-bench numbers included in beds]

Bed number	Sampled interval		Coal thickness	As received values-%			Heating values - Btu				Volatile matter (DAF-%)	Apparent specific gravity
	Top	Bottom		Total sulfur	Ash	Moisture	As received	Dry	DAF	MMM free		
A (1-3)	176.81	178.84	1.38	3.55	15.58	46.73	4,464	8,412	11,823	5,031	60.09	1.63
B (4,5)	197.86	207.29	8.79	1.15	8.96	49.83	4,899	9,795	11,869	5,325	59.87	1.43
		Total	10.17									
	Weighted averages			1.48	9.86	49.41	4,840	9,607	11,862	5,285	59.9	1.46

Note: Coal samples collected for analyses from this hole were not all correctly labled by bench; benchs 1-3 contain samples 1A-1C, respectively; bench 4 includes samples 2A-2E; bench 5 includes samples 2F-2K, benchs 6-8 contain samples 3-5, respectively; to convert Btu (British thermal unit) heating values to kilogram-calories multiply by .556.

Table 2-12. Selected coal-analyses values from drill hole TP-14, Thar Desert, Sindh Province, Pakistan

[Analyses of 5 coal samples by the Pakistan Council of Scientific and Industrial Research Fuel Research Centre, Karachi; DAF, dry, ash free; MMM, moist, mineral matter; depths and thicknesses in meters; drill-hole locations are shown on figure 2]

Coal-sample analyses

Sample number	Sampled interval Top	Bottom	Coal thickness	As received values-% Total sulfur	Ash	Moisture	Heating values - Btu As received	Dry	DAF	MMM free	Volatile matter (DAF-%)	Apparent specific gravity
1A	244.88	245.8	0.92	2.28	12.34	43.99	5,468	9,763	12,520	6,252	63.67	1.34
1B	245.8	246.47	0.67	0.44	3.28	52.44	5,228	10,994	11,807	5,390	56.34	1.33
1C	246.47	247.57	1.1	0.54	3.65	50.11	5,688	11,401	12,302	5,867	58.71	1.26
1D	247.57	248.72	1.15	0.4	5.64	51.07	4,928	10,071	11,384	5,192	53.9	1.08
2	251.89	252.8	0.91	9.56	18.16	39.02	4,941	8,103	11,539	6,083	58.63	1.5
		Total	4.75									
	Weighted averages			2.56	8.54	47.36	5,253	10,072	11,906	5,752	58.16	1.3

Coal-bench analyses

[Values are weighted averages for samples from each bench; in parentheses are numbers of samples in each bench]

Bench number	Sampled interval Top	Bottom	Coal thickness	As received values-% Total sulfur	Ash	Moisture	Heating values - Btu As received	Dry	DAF	MMM free	Volatile matter (DAF-%)	Apparent specific gravity
A (5)	244.88	252.8	0.91	7.92	18.16	39.02	4,941	8,103	11,539	6,083	58.63	1.5

Note.--To convert Btu (British thermal unit) heating values to kilogram-calories multiply by .556.

Table 2-13. Selected coal-analyses values from drill hole TP-15, Thar Desert, Sindh Province, Pakistar

[Analyses of 15 coal samples by the Pakistan Council of Scientific and Industrial Research Fuel Research Centre, Karachi; DAF, dry, ash free; MMM, moist, mineral matter; depths and thicknesses in meters; drill-hole locations are shown on figure 2]

Coal-sample analyses

Sample number	Sampled interval Top	Bottom	Coal thick-ness	As received values-% Total sulfur	Ash	Moisture	Heating values - Btu As received	Dry	DAF	MMM free	Volatile matter (DAF-%)	Apparent specific gravity
1A	230.82	231.82	1	4.61	12.95	40.5	5,734	9,637	12,317	6,214	62.86	1.26
1B	231.82	232.82	1	1.07	4.93	45.04	6,319	11,497	12,631	6,578	63.58	1.32
1C	232.82	233.62	0.8	1.67	6.04	46.06	5,466	10,135	11,414	5,703	57.8	1.21
1D	233.7	234.7	1	1.23	4.67	49.54	5,281	10,465	11,532	5,458	55.63	1.35
1E	234.7	235.15	0.45	0.38	2.93	47.51	5,724	10,906	11,550	5,879	56.36	1.24
1F	235.46	236.01	0.55	0.64	4.58	52.57	5,469	11,532	12,765	5,699	65.03	1.27
1G	236.94	237.09	0.15	2.53	11.47	51.14	4,145	8,483	11,084	4,515	56.3	1.46
2A	238.33	239.06	0.73	0.65	4.1	46.3	5,964	11,106	12,026	6,183	59.75	1.31
2B	240	240.65	0.65	0.42	7.59	45.2	5,355	9,772	11,343	5,795	58.12	1.39
3A	257.26	257.78	0.52	4.14	10.35	43.57	5,308	9,406	11,520	5,599	56.24	1.35
3B	257.78	258.01	0.23	4.47	35.19	31.65	2,989	4,372	9,014	4,290	64.29	1.77
3C	258.01	258.66	0.65	1.24	5.28	46.17	5,733	10,651	11,810	5,971	57.99	1.29
3D	259.41	259.71	0.3	2.25	16.55	35.02	5,284	8,132	10,912	6,204	58.33	1.43
3E	259.93	261.06	1.13	1.38	6.73	46.56	5,569	10,421	11,921	5,883	60.01	1.33
3F	262.5	263	0.5	0.74	5.58	48.63	5,210	10,142	11,379	5,481	54.38	1.29
		Total	9.66									
	Weighted averages			1.71	7.57	45.6	5,528	10,227	11,782	5,857	59.37	1.32

Coal-bench analyses

[Values are weighted averages for samples from each bench; in parentheses are numbers of samples in each bench]

Bench number	Sampled interval Top	Bottom	Coal thick-ness	As received values-% Total sulfur	Ash	Moisture	Heating values - Btu As received	Dry	DAF	MMM free	Volatile matter (DAF-%)	Apparent specific gravity
1 (7)[1]	230.82	237.09	4.95	1.85	6.65	46.44	5,639	10,551	12,019	5,913	60.18	1.29
2 (2)[1]	238.33	240.65	1.38	0.54	5.75	45.78	5,677	10,478	11,704	6,000	58.98	1.35
3 (3)	257.26	258.66	1.4	2.85	12.08	42.82	5,124	9,157	11,243	5,557	58.38	1.39
4 (1)	259.41	259.71	0.3	2.25	16.55	35.02	5,284	8,132	10,912	6,204	58.33	1.43
5 (2)[1]	259.93	263	1.63	1.35	7.96	45.3	5,432	9,993	11,624	5,828	58.29	1.34
		Total	9.66									
	Weighted averages			1.71	7.57	45.6	5,528	10,227	11,782	5,857	59.37	1.32

[1]Bench contains a lost-coal-core interval(s).

Coal-bed analyses

[Values are weighted averages of samples from each bed; in parentheses are coal-bench numbers included in beds]

Bed number	Sampled interval Top	Bottom	Coal thick-ness	As received values-% Total sulfur	Ash	Moisture	Heating values - Btu As received	Dry	DAF	MMM free	Volatile matter (DAF-%)	Apparent specific gravity
A (1,2)	230.82	240.65	6.33	1.56	6.46	46.3	5,647	10,535	11,950	5,932	59.92	1.3
B (3-5)	257.26	263	3.33	1.98	9.69	44.26	5,302	9,641	11,464	5,714	58.33	1.36
		Total	9.66									
	Weighted averages			1.71	7.57	45.6	5,528	10,227	11,782	5,857	59.37	1.32

Note: Coal samples collected for analyses from this hole were not all correctly labled by bench; bench 3 includes samples 3A-C, bench 4 is 3D, and bench 5 includes 3E,F; to convert Btu (British thermal unit) heating values to kilogram-calories multiply by .556.

Table 2-14. Selected coal-analyses values from drill hole TP-19, Thar Desert, Sindh Province, Pakistan

Karachi; DAF, dry, ash free; MMM, moist, mineral matter; depths and thicknesses in meters; drill-hole locations are shown on figure 2]

				Coal-sample analysis								
	Sampled interval		Coal	As received values-%			Heating values - Btu				Volatile	Apparent
Sample number	Top	Bottom	thick-ness	Total sulfur	Ash	Moisture	As received	Dry	DAF	MMM free	matter (DAF-%)	specific gravity
1	230.12	230.72	0.6	0.8	8.46	44.72	5,659	10,236	12,084	6,154	63.62	2.1

Note.--To convert Btu (British thermal unit) heating values to kilogram-calories multiply by .556.

Table 2-15. Selected coal-analyses values from drill hole TP-19, Thar Desert, Sindh Province, Pakistan

[Analyses of 3 coal samples by the Pakistan Council of Scientific and Industrial Research Fuel Research Centre, Karachi; DAF, dry, ash free; MMM, moist, mineral matter; depths and thicknesses in meters; drill-hole locations are shown on figure 2]

				Coal-sample analyses								
	Sampled interval		Coal	As received values-%			Heating values - Btu				Volatile	Apparent
Sample number	Top	Bottom	thick-ness	Total sulfur	Ash	Moisture	As received	Dry	DAF	MMM free	matter (DAF-%)	specific gravity
1A	223.18	224.48	1.3	2.09	7.78	51.14	5,682	11,628	13,831	6,013	54.61	1.4
1B	225.8	227.03	1.23	0.78	6.73	51.54	5,432	11,209	13,017	5,789	62.93	1.36
2	233.88	234.18	0.3	1.02	9.51	50.73	4,562	9,261	11,476	4,997	69.31	1.41
		Total	2.83									
	Weighted averages			1.41	7.51	51.27	5,454	11,195	13,228	5,808	59.78	1.38
Coal-bench analyses												
[Values are weighted averages for samples from each bench; in parentheses are numbers of samples in each bench]												
	Sampled interval		Coal	As received values-%			Heating values - Btu				Volatile	Apparent
Bench number	Top	Bottom	thick-ness	Total sulfur	Ash	Moisture	As received	Dry	DAF	MMM free	matter (DAF-%)	specific gravity
1 (2)[1]	223.18	227.03	1.3	2.09	7.78	51.14	5,682	11,628	13,831	6,013	54.61	1.4
2 (1)	233.88	234.18	0.3	1.02	9.51	50.73	4,562	9,261	11,476	4,997	69.31	1.41
		Total	2.83									
	Weighted averages			1.41	7.51	51.27	5,454	11,195	13,228	5,808	59.78	1.38

[1]Bench contains core loss in coal and unanalyzed coal sample intervals.

Note.--To convert Btu (British thermal unit) heating values to kilogram-calories multiply by .556.

Table 2-16. Selected coal-analyses values from drill hole TP-20, Thar Desert, Sindh Province, Pakistan

[Analyses of 3 coal samples by the Pakistan Council of Scientific and Industrial Research Fuel Research Centre, Karachi; DAF, dry, ash free; MMM, moist, mineral matter; depths and thicknesses in meters; drill-hole locations are shown on figure 2]

				Coal-sample analyses								
	Sampled interval		Coal	As received values-%			Heating values - Btu				Volatile	Apparent
Sample number	Top	Bottom	thick-ness	Total sulfur	Ash	Moisture	As received	Dry	DAF	MMM free	matter (DAF-%)	specific gravity
1	259.44	260.24	0.8	2.15	13.72	46.84	4,777	8,987	12,113	5,407	60.18	1.49
2A	263.03	264.03	1	1.37	7.23	51.07	5,127	10,476	12,294	5,442	60.86	1.3
2B	264.03	264.58	0.55	0.96	6.16	50.52	5,397	10,907	12,459	5,698	58.55	1.27
		Total	2.35									
	Weighted averages			1.54	9.19	49.5	5,071	10,070	12,271	5,490	60.09	1.36
Coal-bench analyses												
[Values are weighted averages for samples from each bench; in parentheses are numbers of samples in each bench]												
	Sampled interval		Coal	As received values-%			Heating values - Btu				Volatile	Apparent
Bench number	Top	Bottom	thick-ness	Total sulfur	Ash	Moisture	As received	Dry	DAF	MMM free	matter (DAF-%)	specific gravity
1 (1)	259.44	260.24	0.8	2.15	13.72	46.84	4,777	8,987	12,113	5,407	60.18	1.49
2 (2)	263.03	264.58	1.55	1.23	6.85	50.87	5,222	10,629	12,352	5,533	60.04	1.29
		Total	2.35									
	Weighted averages			1.54	9.19	49.5	5,071	10,070	12,271	5,490	60.09	1.36

Note.--To convert Btu (British thermal unit) heating values to kilogram-calories multiply by .556.

Table 2-17. Selected coal-analyses values from drill hole TP-22, Thar Desert, Sindh Province, Pakistan

[Analyses of 11 coal samples by the Pakistan Council of Scientific and Industrial Research Fuel Research Centre, Karachi; DAF, dry, ash free; MMM, moist, mineral matter; depths and thicknesses in meters; drill-hole locations are shown on figure 2]

Coal-sample analyses

Sample number	Sampled interval Top	Bottom	Coal thickness	As received values-% Total sulfur	Ash	Moisture	Heating values - Btu As received	Dry	DAF	MMM free	Volatile matter (DAF-%)	Apparent specific gravity
1A	178.96	179.61	0.65	2.54	9.63	47.18	5,024	9,511	11,633	5,382	58.56	1.35
1B	180.41	180.81	0.4	3.12	10.93	46.94	4,971	9,369	11,798	5,356	61.4	1.31
2A	183.2	183.9	0.7	1.76	6.67	49.51	5,234	10,367	11,944	5,488	59.69	1.32
2B	183.9	184.4	0.5	4.38	9.01	53.58	4,498	9,691	12,025	4,617	59.81	1.38
2C	184.4	185.25	0.85	0.83	4.73	52.6	4,936	10,413	11,569	5,133	59.74	1.24
3	205.61	206.56	0.95	1.53	10.77	38	5,725	9,234	11,175	6,332	56.53	1.33
4A	208.25	209.25	1	1.18	4.84	52.5	5,068	10,668	11,878	5,249	57.35	1.26
4B	209.25	210.25	1	1.89	5.08	54.19	4,661	10,175	11,444	4,779	58.38	1.26
5A	231.55	232.8	1.25	1.19	5.43	51.66	5,055	10,457	11,780	5,270	56.16	1.25
5B	233.98	234.28	0.3	0.83	5.94	54.52	4,542	9,988	11,489	4,786	54.6	1.34
6	244.48	245.43	0.95	0.39	5.73	52	4,656	9,701	11,018	4,931	53.26	1.4
		Total	4.45									
	Weighted averages			1.6	6.78	50.14	4,986	10,033	11,586	5,252	57.51	1.3

Coal-bench analyses

[Values are weighted averages for samples from each bench; in parentheses are numbers of samples in each bench]

Bench number	Sampled interval Top	Bottom	Coal thickness	As received values-% Total sulfur	Ash	Moisture	Heating values - Btu As received	Dry	DAF	MMM free	Volatile matter (DAF-%)	Apparent specific gravity
1 (1)	178.96	179.61	0.65	2.54	9.63	47.18	5,024	9,511	11,633	5,382	58.56	1.35
2 (1)	180.41	180.81	0.4	3.12	10.93	46.94	4,971	9,369	11,798	5,356	61.4	1.31
3 (3)	183.2	185.25	2.05	2.02	6.44	51.79	4,931	10,221	11,808	5,128	59.74	1.3
4 (1)	205.61	206.56	0.95	1.53	10.77	38	5,725	9,234	11,175	6,332	56.53	1.33
5 (2)	208.25	210.25	2	1.53	4.96	53.35	4,864	10,421	11,661	5,014	57.86	1.26
6 (2)[1]	231.55	234.28	1.55	1.12	5.53	52.22	4,956	10,367	11,724	5,176	55.86	1.27
7 (1)	244.48	245.43	0.95	0.39	5.73	52	4,656	9,701	11,018	4,931	53.26	1.4
		Total	9.66									
	Weighted averages			1.6	6.78	50.14	4,986	10,033	11,586	5,252	57.51	1.3

[1]Bench contains a lost-coal-core interval.

Coal-bed analyses

[Values are weighted averages of samples from each bed; in parentheses are coal-bench numbers included in beds]

Bed number	Sampled interval Top	Bottom	Coal thickness	As received values-% Total sulfur	Ash	Moisture	Heating values - Btu As received	Dry	DAF	MMM free	Volatile matter (DAF-%)	Apparent specific gravity
A (1,2)	178.96	180.81	1.05	2.76	10.13	47.09	5,004	9,457	11,696	5,372	59.64	1.33
B (4,5)	205.61	210.25	2.95	1.53	6.83	48.4	5,141	10,039	11,505	5,439	57.44	1.28
		Total	9.66									
	Weighted averages			1.85	7.7	48.06	5,105	9,886	11,555	5,421	58.02	1.3

Note: Coal samples collected for analyses from this hole were not all correctly labeled by bench: bench 2 is sample 1B, bench 3 contains samples 2A-C, bench 4 is sample 3, bench 5 contains samples 4A and 4B, bench 6 contains samples 5A and 5B, and bench 7 is sample 6; to convert Btu (British thermal unit) heating values to kilogram-calories multiply by .556.

Table 2-18. Selected coal-analyses values from drill hole TP-23, Thar Desert, Sindh Province, Pakistan

[Analyses of 2 coal samples by the Pakistan Council of Scientific and Industrial Research Fuel Research Centre, Karachi; DAF, dry, ash free; MMM, moist, mineral matter; depths and thicknesses in meters; drill-hole locations are shown on figure 2]

Coal-sample analyses

Sample number	Sampled interval Top	Bottom	Coal thickness	As received values-% Total sulfur	Ash	Moisture	Heating values - Btu As received	Dry	DAF	MMM free	Volatile matter (DAF-%)	Apparent specific gravity
1	205.51	206.51	1	2.11	19.44	43.77	4,080	7,257	11,092	4,958	62.42	1.37
2	234.54	235.19	0.65	2.84	13.57	44.47	4,928	8,875	11,746	5,507	59.59	1.31
		Total	2.35									
	Weighted averages			2.4	17.13	44.05	4,414	7,894	11,349	5,174	61.31	1.35

Coal-bench analyses

[Values are weighted averages for samples from each bench; in parentheses are numbers of samples in each bench]

Bench number	Sampled interval Top	Bottom	Coal thickness	As received values-% Total sulfur	Ash	Moisture	Heating values - Btu As received	Dry	DAF	MMM free	Volatile matter (DAF-%)	Apparent specific gravity
1 (1)	205.51	206.51	1	2.11	19.44	43.77	4,080	7,257	11,092	4,958	62.42	1.37
2 (1)	234.54	235.19	0.65	2.84	13.57	44.47	4,928	8,875	11,746	5,507	59.59	1.31
		Total	2.35									
	Weighted averages			2.4	17.13	44.05	4,414	7,894	11,349	5,174	61.31	1.35

Note.--To convert Btu (British thermal unit) heating values to kilogram-calories multiply by .556.

Table 2-19. Selected coal-analyses values from drill hole TP-25, Thar Desert, Sindh Province, Pakistan

[Analyses of 3 coal samples by the Pakistan Council of Scientific and Industrial Research Fuel Research Centre, Karachi; DAF, dry, ash free; MMM, moist, mineral matter; depths and thicknesses in meters; drill-hole locations are shown on figure 2]

Coal-sample analyses

Sample number	Sampled interval Top	Bottom	Coal thickness	As received values-% Total sulfur	Ash	Moisture	Heating values - Btu As received	Dry	DAF	MMM free	Volatile matter (DAF-%)	Apparent specific gravity
1	200.22	200.62	0.4	1.87	7.03	43.83	4,744	9,687	11,310	4,977	55.82	1.37
2	206.38	207.38	1	1.59	5.97	43.54	5,879	11,520	13,046	6,142	65.87	1.3
3	236.25	236.55	0.3	2.49	5.07	46.64	4,631	10,143	11,409	4,699	57.85	1.54
		Total	1.7									
	Weighted averages			1.81	6.06	44.16	5,392	10,846	12,349	5,613	62.09	1.36

[Values are weighted averages for samples from each bench; in parentheses are numbers of samples in each bench]

Bench number	Sampled interval Top	Bottom	Coal thickness	As received values-% Total sulfur	Ash	Moisture	Heating values - Btu As received	Dry	DAF	MMM free	Volatile matter (DAF-%)	Apparent specific gravity
1 (1)	200.22	200.62	0.4	1.87	7.03	43.83	4,744	9,687	11,310	4,977	55.82	1.37
2 (1)	206.38	207.38	1	1.59	5.97	43.54	5,879	11,520	13,046	6,142	65.87	1.3
3 (1)	236.25	236.55	0.3	2.49	5.07	46.64	4,631	10,143	11,409	4,699	57.85	1.54
		Total	1.7									
	Weighted averages			1.81	6.06	44.16	5,392	10,846	12,349	5,613	62.09	1.36

Note.--To convert Btu (British thermal unit) heating values to kilogram-calories multiply by .556.

Table 2-20. Selected coal-analyses values from drill hole TP-28, Thar Desert, Sindh Province, Pakistan

[Analyses of 6 coal samples by the Pakistan Council of Scientific and Industrial Research Fuel Research Centre, Karachi; DAF, dry, ash free; MMM, moist, mineral matter; depths and thicknesses in meters; drill-hole locations are shown on figure 2]

Coal-sample analyses

Sample number	Sampled interval Top	Bottom	Coal thickness	As received values-% Total sulfur	Ash	Moisture	Heating values - Btu As received	Dry	DAF	MMM free	Volatile matter (DAF-%)	Apparent specific gravity
1	193.94	194.54	0.6	4.74	10.87	46.92	4,403	8,294	10,431	4,584	55.91	1.37
2[1]	213.3	213.72	0.42	0.45	4.57	50.5	5,156	10,417	11,476	5,386	55.95	1.24
3A	214.99	216.09	1.1	2.64	5.05	51.7	5,039	10,432	11,651	5,111	57.29	1.23
3B	216.09	217.19	1.1	0.21	3.13	58.05	4,698	11,198	12,100	4,846	58.98	1.27
3C	217.19	218.34	1.15	1.52	5.61	50.5	5,182	10,468	11,805	5,387	57.68	1.3
4	219.34	219.79	0.45	0.12	8.06	48.35	5,148	9,969	11,813	5,629	59.3	1.2
		Total	4.49									
	Weighted averages			2.18	5.71	51.85	4,936	10,305	11,638	5,123	57.67	1.27

[1]Some values shown for this coal sample were affected by changing the air-drying moisture loss from 33.97 to 43.97 due to a presumed typographical error on the coal analysis sheet.

Coal-bench analyses

[Values are weighted averages for samples from each bench; in parentheses are numbers of samples in each bench]

Bench number	Sampled interval Top	Bottom	Coal thickness	As received values-% Total sulfur	Ash	Moisture	Heating values - Btu As received	Dry	DAF	MMM free	Volatile matter (DAF-%)	Apparent specific gravity
1 (1)	193.94	194.54	0.6	4.74	10.87	0.6	1	8,294	10,431	4,584	55.91	2.07
2 (1)	213.3	213.72	0.42	0.45	4.57	50.5	5,156	10,417	11,476	5,386	55.95	1.24
3 (3)	214.99	218.34	3.35	2.23	4.61	53.37	4,976	10,696	11,851	5,119	57.98	0.36
4 (1)	219.34	219.79	0.45	0.12	8.06	48.35	5,148	9,969	11,813	5,629	59.3	1.2
		Total	4.49									
	Weighted averages			2.18	5.71	51.85	4,936	10,305	11,638	5,123	57.67	1.27

Coal-bed analyses

[Values are weighted averages of samples from each bed; in parentheses are coal-bench numbers included in beds]

Bed number	Sampled interval Top	Bottom	Coal thickness	As received values-% Total sulfur	Ash	Moisture	Heating values - Btu As received	Dry	DAF	MMM free	Volatile matter (DAF-%)	Apparent specific gravity
A (2-4)	213.3	219.79	4.22	1.82	4.98	52.55	5,012	10,590	11,810	5,200	57.92	1.26

Note.--To convert Btu (British thermal unit) heating values to kilogram-calories multiply by .556.

Table 2-21. Selected coal-analyses values from drill hole TP-30, Thar Desert, Sindh Province, Pakistan

[Analyses of 2 coal samples by the Pakistan Council of Scientific and Industrial Research Fuel Research Centre, Karachi; DAF, dry, ash free; MMM, moist, mineral matter; depths and thicknesses in meters; drill-hole locations are shown on figure 2]

Coal-sample analyses

Sample number	Sampled interval Top	Bottom	Coal thickness	As received values-% Total sulfur	Ash	Moisture	Heating values - Btu As received	Dry	DAF	MMM free	Volatile matter (DAF-%)	Apparent specific gravity
1	123.28	123.93	0.65	1.31	7.17	46.01	4,615	9,665	11,373	4,893	58.59	1.39
2	131.24	132.11	0.87	1.68	6.6	47.77	4,483	9,745	11,376	4,690	56.32	1.35
		Total	1.52									
	Weighted averages			1.52	6.84	47.02	4,539	9,711	11,375	4,777	57.29	1.37

Coal-bench analyses

[Values are weighted averages for samples from each bench; in parentheses are numbers of samples in each bench]

Bench number	Sampled interval Top	Bottom	Coal thickness	As received values-% Total sulfur	Ash	Moisture	Heating values - Btu As received	Dry	DAF	MMM free	Volatile matter (DAF-%)	Apparent specific gravity
1 (1)	123.28	123.93	0.65	1.31	7.17	46.01	4,615	9,665	11,373	4,893	58.59	1.39
2 (1)	131.24	132.11	0.87	1.68	6.6	47.77	4,483	9,745	11,376	4,690	56.32	1.35
		Total	2.35									
	Weighted averages			1.52	6.84	47.02	4,539	9,711	11,375	4,777	57.29	1.37

Note.--To convert Btu (British thermal unit) heating values to kilogram-calories multiply by .556.

Table 2-22. Selected coal-analyses values from drill hole TP-31, Thar Desert, Sindh Province, Pakistan

[Analyses of 5 coal samples by the Pakistan Council of Scientific and Industrial Research Fuel Research Centre, Karachi; DAF, dry, ash free; MMM, moist, mineral matter; depths and thicknesses in meters; drill-hole locations are shown on figure 2]

Coal-sample analyses

Sample number	Sampled interval Top	Bottom	Coal thickness	As received values-% Total sulfur	Ash	Moisture	Heating values - Btu As received	Dry	DAF	MMM free	Volatile matter (DAF-%)	Apparent specific gravity
1	217.62	218.12	0.5	2.72	14.35	44.79	4,620	8,367	11,305	5,213	57.01	1.56
2A	239.1	240.1	1	2.65	7.96	47.05	5,334	10,073	11,856	5,602	56.2	1.29
2B	240.1	241.1	1	10.59	18.25	46.29	3,627	6,752	10,228	3,597	59.02	1.86
2C	241.1	241.97	0.87	1.23	5.2	52.4	5,265	11,059	12,417	5,473	56.33	1.34
3	243.32	244.56	1.24	0.73	5.05	48.17	5,383	10,386	11,508	5,632	55.08	2.13
		Total	4.49									
	Weighted averages			3.6	9.58	47.95	4,886	9,438	11,455	5,109	56.62	1.68

[Values are weighted averages for samples from each bench; in parentheses are numbers of samples in each bench]

Bench number	Sampled interval Top	Bottom	Coal thickness	As received values-% Total sulfur	Ash	Moisture	Heating values - Btu As received	Dry	DAF	MMM free	Volatile matter (DAF-%)	Apparent specific gravity
1 (1)	217.62	218.12	0.5	2.72	14.35	44.79	4,620	8,367	11,305	5,213	57.01	1.56
2 (3)	239.1	241.97	2.87	4.99	10.71	48.4	4,718	9,215	11,459	4,864	57.22	1.5
3 (1)	243.32	244.56	1.24	0.73	5.05	48.17	5,383	10,386	11,508	5,632	55.08	2.13
		Total	4.49									
	Weighted averages			3.6	9.58	47.95	4,886	9,438	11,455	5,109	56.62	1.68

[Values are weighted averages of samples from each bed; in parentheses are coal-bench numbers included in beds]

Bed number	Sampled interval Top	Bottom	Coal thickness	As received values-% Total sulfur	Ash	Moisture	Heating values - Btu As received	Dry	DAF	MMM free	Volatile matter (DAF-%)	Apparent specific gravity
A (2,3)	239.1	244.56	4.11	3.7	9	48.33	4,919	9,568	11,474	5,096	56.58	1.69

Note.--To convert Btu (British thermal unit) heating values to kilogram-calories multiply by .556.

APPENDIX 3

Structural cross sections A-A' through H-H' across the Thar coal field, Sindh Province, Pakistan. The eight cross sections are on five figures; figures 3-1 through 3-5. The datum is sea level for all cross sections.

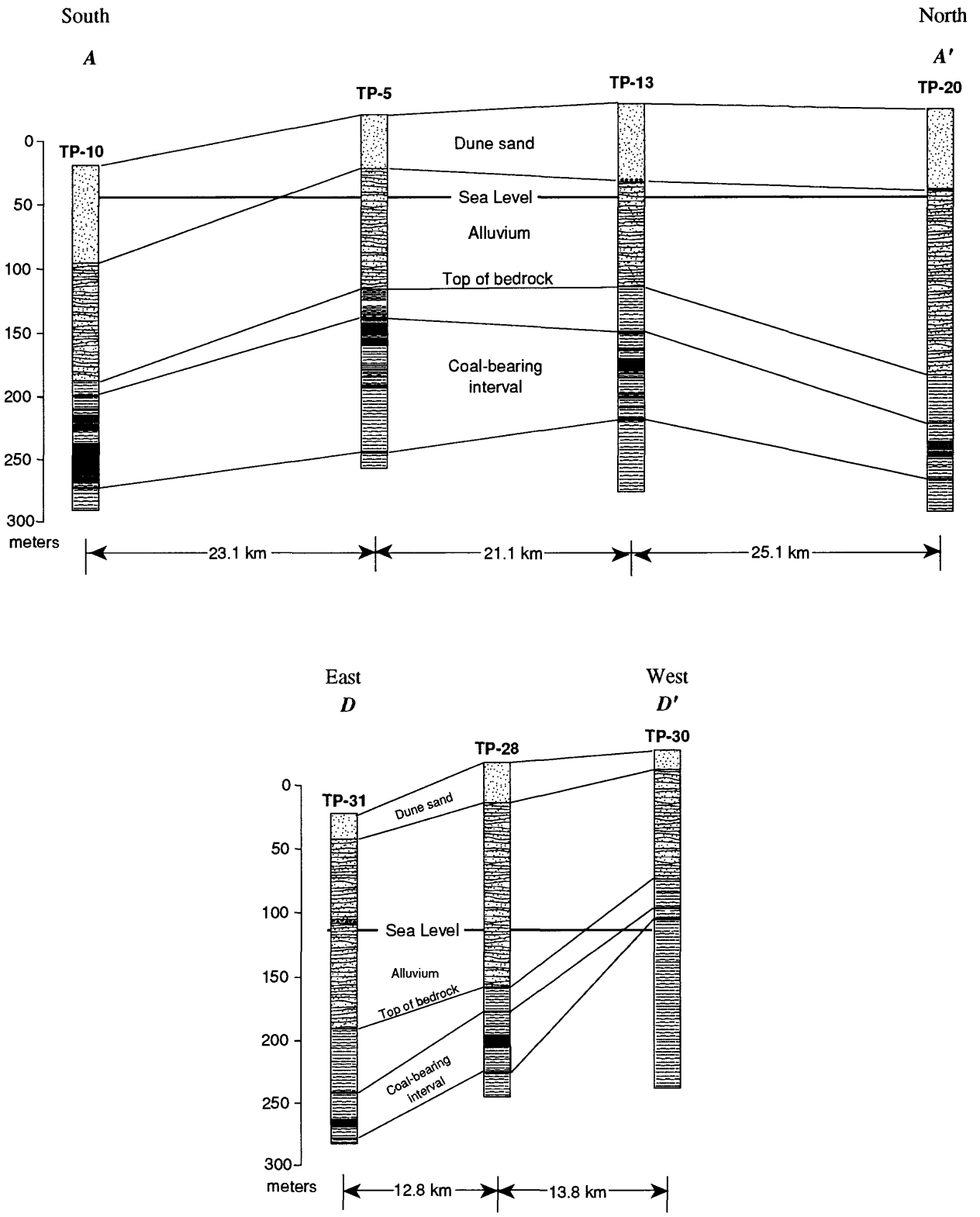


Figure 3-1. Structural cross sections A-A' and D-D'; lines of cross sections are shown on figure 2. Elevations, depths to geologic contacts and coal beds, and total depths of the drill holes shown may be found on the large-scale stratigraphic columns of these drill holes in appendix 1.

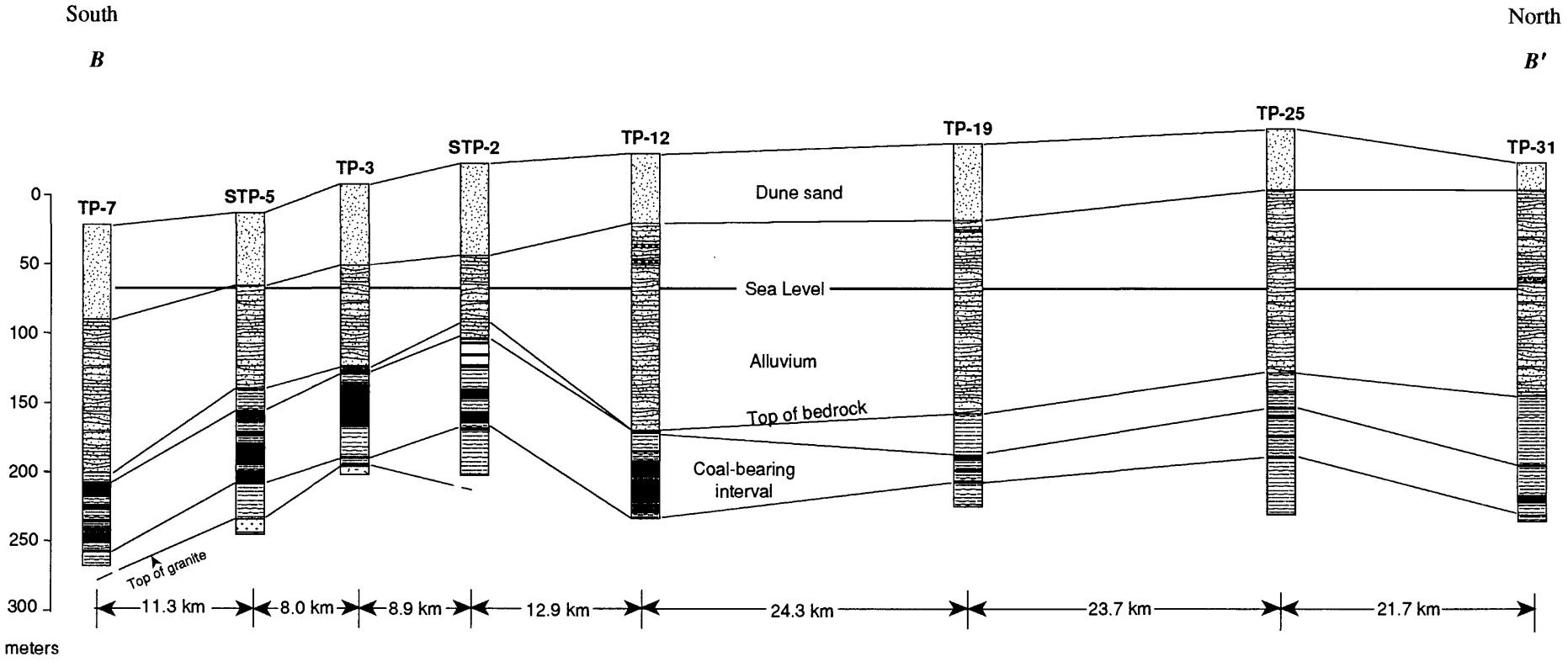


Figure 3-2. Structural cross section B-B'; line of cross section is shown on figure 2. Elevations, depths to geologic contacts and coal beds, and total depths of the drill holes shown may be found on the large-scale stratigraphic columns of these drill holes in appendix 1.

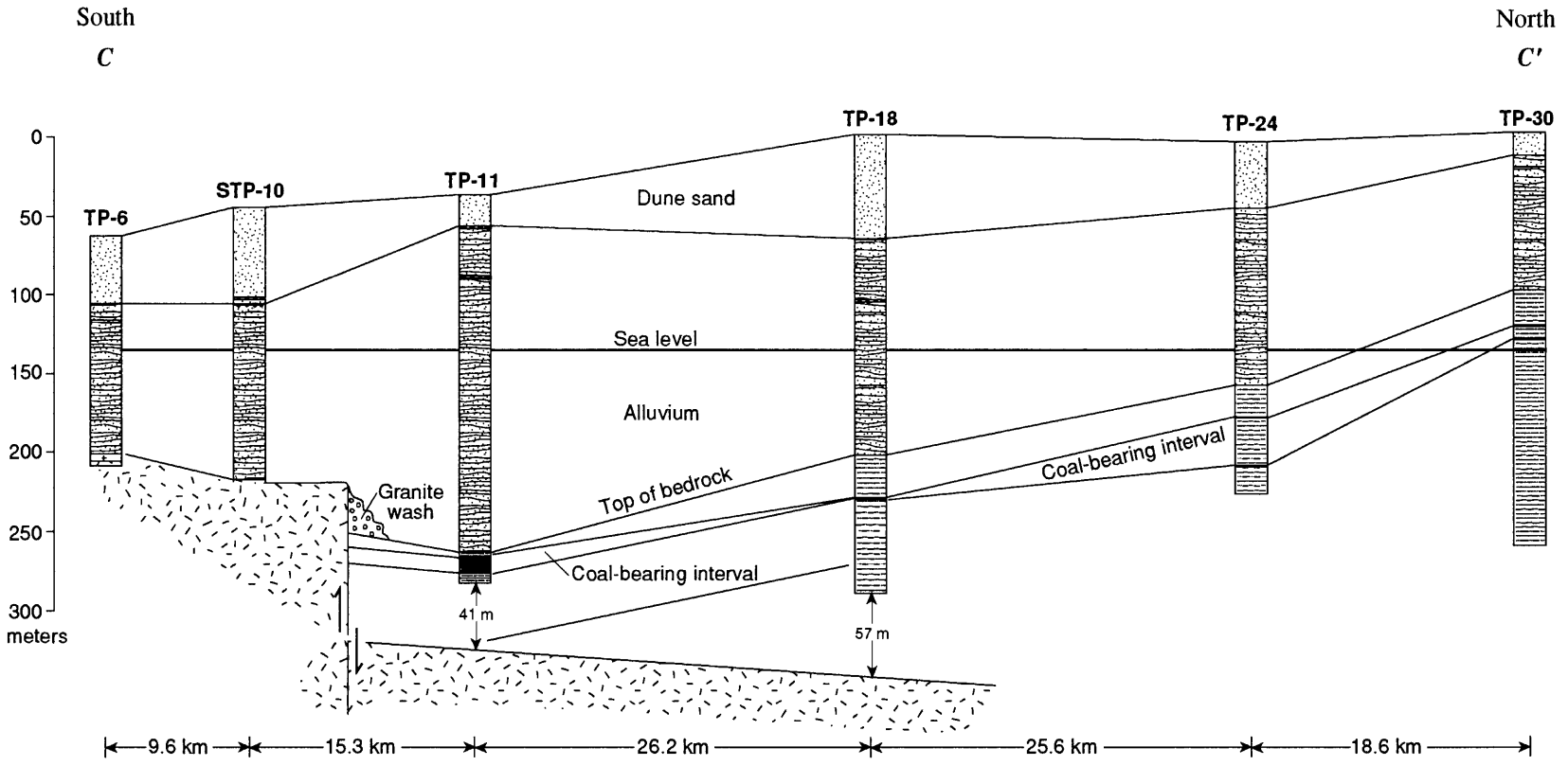


Figure 3-3. Structural cross section C-C'; line of cross section is shown on figure 2. Elevations, depths to geologic contacts and coal beds, and total depths of the drill holes shown may be found on the large-scale stratigraphic columns of these drill holes in appendix 1.

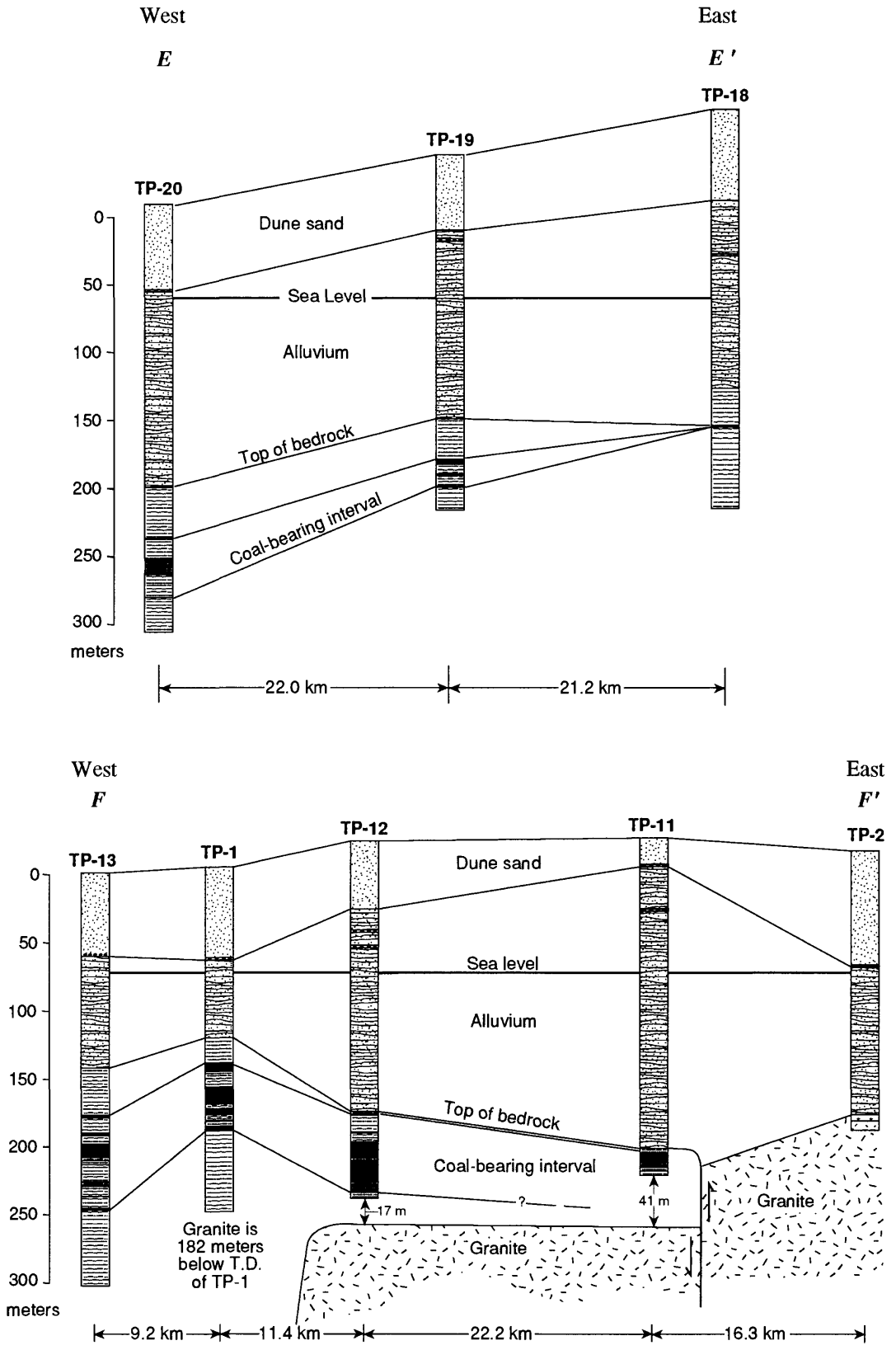


Figure 3-4. Structural cross sections E-E' and F-F'; lines of cross sections are shown on figure 2. Elevations, depths to geologic contacts and coal beds, and total depths of the drill holes shown may be found on the large-scale stratigraphic columns of these drill holes in appendix 1.

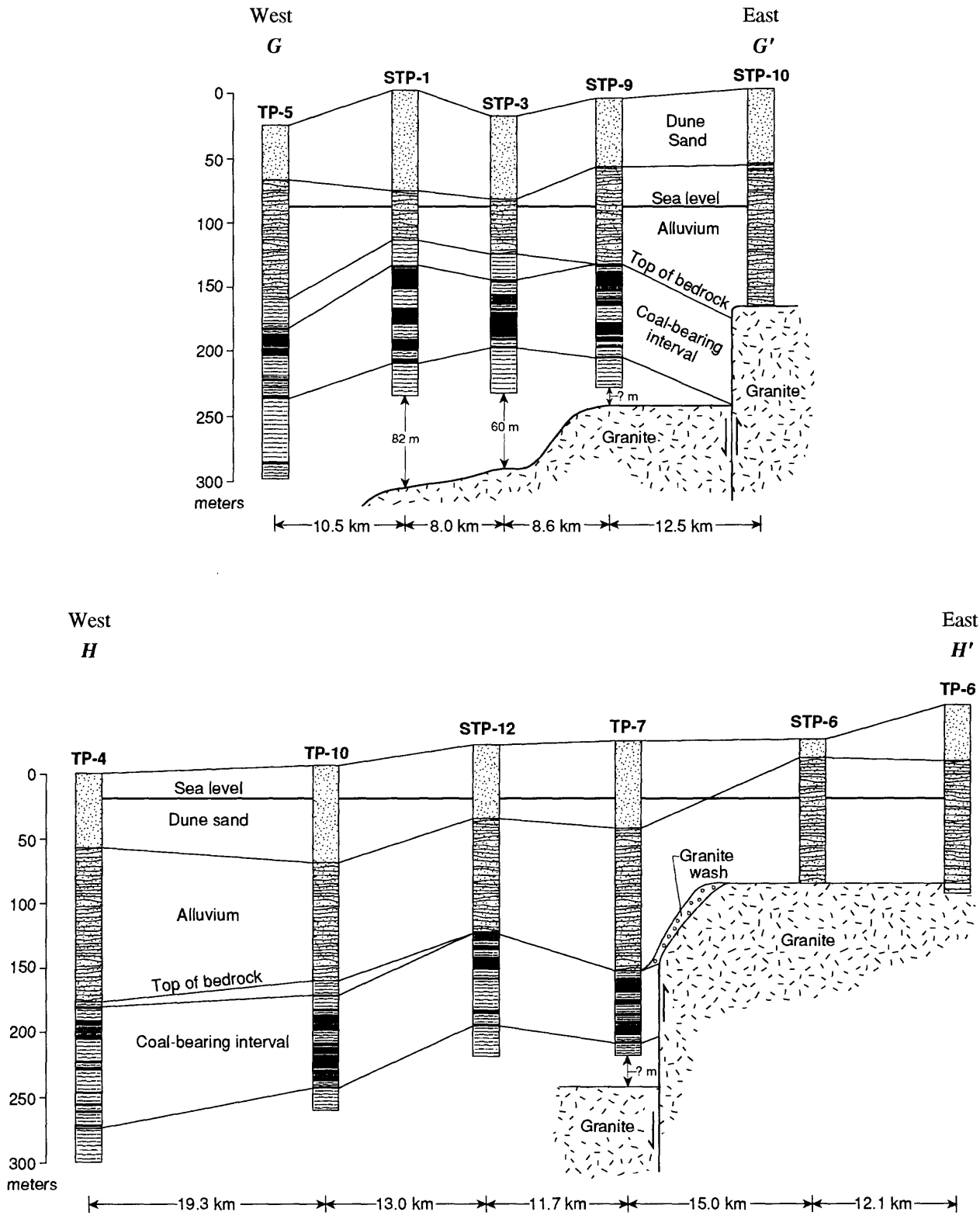


Figure 3-5. Structural cross sections G-G'and H-H'; lines of cross sections are shown on figure 2. Elevations, depths to geologic contacts and coal beds, and total depths of the drill holes shown may be found on the large-scale stratigraphic columns of these drill holes in appendix 1.