Lithofacies and Palynostratigraphy of Some Cretaceous and Paleocene Rocks, Surghar and Salt Range Coal Fields, Northern Pakistan

U.S. GEOLOGICAL SURVEY BULLETIN 2096

Prepared in cooperation with the Geological Survey of Pakistan, under the auspices of the Agency for International Development, U.S. Department of State, and the government of Pakistan

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This report includes discussions on the lithofacies, depositional environments, palynobiostratigraphy, coal quality, and measured sections of Cretaceous and Paleocene strata of northern Pakistan

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Lithofacies and Palynostratigraphy of Some Cretaceous and Paleocene Rocks, Surghar and Salt Range Coal Fields, Northern Pakistan

By Peter D. Warwick,[1] Shahid Javed,[2] S. Tahir A. Mashhadi,[2] Tariq Shakoor,[2] Asrar M. Khan,[3] and A. Latif Khan[2]

ABSTRACT

The stratigraphic relation between the Cretaceous generally noncoal-bearing Lumshiwal Formation (64 to 150 m thick) and the Paleocene coal-bearing Hangu Formation (5 to 50 m thick) in the Surghar Range of north-central Pakistan is complex. Both formations contain remarkably similar lithofacies: one or two types of sandstone lithofacies; a combined lithofacies of mudstone, claystone, carbonaceous shale, and coal beds; and a rare carbonate lithofacies. An analysis of pollen data from rock samples collected from various stratigraphic positions indicates that the formations are separated by a disconformity and that the age of the Lumshiwal Formation is Early Cretaceous and the age of the Hangu is Paleocene. Previous workers had suggested that the age of the Lumshiwal is Late Cretaceous.

An analysis of sedimentologic, stratigraphic, and paleontologic data indicates that both the Lumshiwal and Hangu Formations probably were deposited in shallow-marine and deltaic environments. The rocks of the Lumshiwal become more terrestrial in origin upward, whereas the rocks of the Hangu become more marine in origin upward. The contact between the two formations is associated with a laterally discontinuous lateritic paleosol (assigned to the Hangu Formation) that is commonly overlain by the economically important Makarwal coal bed. This coal bed averages 1.2 m in thickness. No other coal beds in the Surghar Range are as thick or as laterally continuous as the Makarwal coal bed.

Analytical data from the Makarwal and one other Hangu coal bed indicate that Surghar Range coal beds range from high-volatile B to high-volatile C bituminous in apparent rank. Averaged, as-received results of proximate and ultimate analyses of coal samples are (1) moisture content, 5.4 percent; (2) ash yield, 12.5 percent; (3) total sulfur content, 5 percent; and (4) calorific value, 11034 Btu/lb (British thermal units per pound). Minor- and trace-element analyses indicate that these coals contain relatively high concentrations of the environmentally sensitive element selenium (average 13.4 ppm (parts per million)), compared to concentrations from United States coals of similar rank.

The Makarwal coal bed represents a paleopeat that formed during changing relative ground-water base levels. Relatively low base levels were associated with periods of slow clastic deposition and lateritic paleosol development, followed by relatively high base levels that coincided with increased runoff, marine flooding, and clastic sedimentation that buried the paleopeat of the Makarwal. These environments formed along the northwestern margin of the Indian subcontinent as it drifted northward through equatorial latitudes in the Tethys Sea. The Makarwal coal bed is thin or absent in the northern part of the range where the Lumshiwal and Hangu Formations are the thinnest. Such rapid lateral changes (over about 25 km) in formation thickness and the apparent change in relative ground-water base level indicate that tectonically induced subsidence rates varied across the Surghar Range and influenced the deposition of the rocks that compose the two formations.

INTRODUCTION

Indigenous coal has been a minor part of Pakistan's energy budget since the late 19th century, but as modern, large, coal-fired electric-power generation facilities are brought online, coal will become an important component of Pakistan's energy budget. Consequently, detailed geologic studies such as this report on a coal-bearing area in northern Pakistan are warranted. This report reviews the coal-bearing Cretaceous Lumshiwal and Paleocene Hangu Formations of the Surghar Range and of the western part of the Salt Range in north-central Pakistan (figs. 1, 2). The paper defines the stratigraphic relation between the

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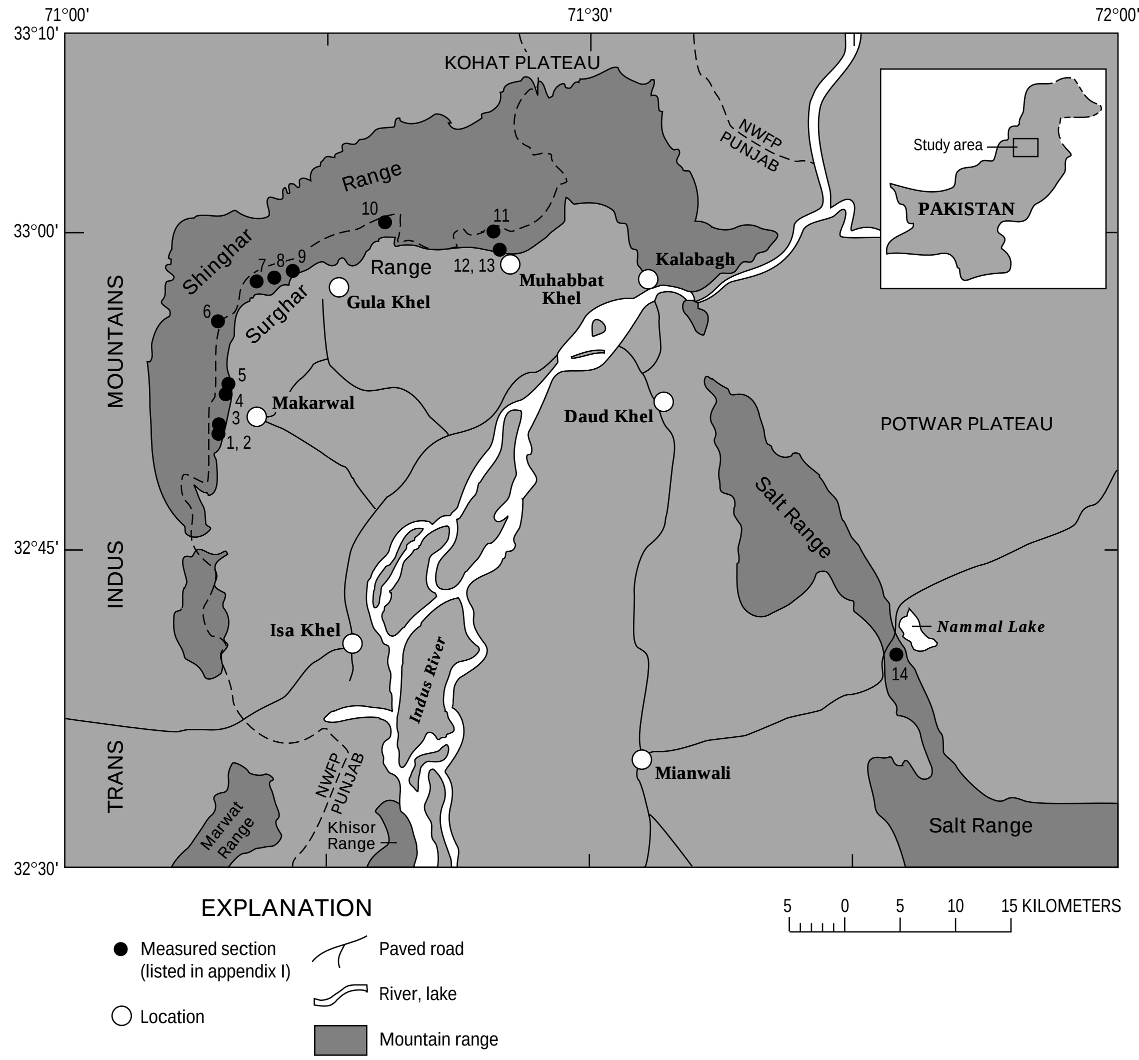


Figure 1. Part of northern Pakistan showing the study area. Numbered solid dots indicate location of mine and outcrop measured sections in appendix I. Pollen samples (fig. 4, table 1, appendix III) were collected at sections 1, 2, 4, 6, 11, and 14. Coal samples (appendixes I, II) were collected at sections 2, 5, 7, 9, and 13. Dashed line indicates the provincial border between the Punjab and the North-West Frontier Province (NWFP).

Lumshiwal (and its minor coal occurrences) and the Hangu (and its economically important coal deposits). The various lithologies within the Lumshiwal and Hangu and associated palynological data are discussed, along with the chemical and physical characteristics of Hangu coal samples. The report also includes interpretations of the depositional environments of the Lumshiwal and Hangu rocks.

GEOLOGIC SETTING

The Shinghar and Surghar Ranges constitute the northernmost part of the Trans Indus Mountains (fig. 1). The Makarwal Gula Khel coal field, as described by Ahmed and others (1986), is located in the north-trending southern part of the Surghar Range and lies along the border of the Punjab and the North-West Frontier Province (NWFP). The coal-mining town of Makarwal is the center of mining activities. The Kurd coal field (Ahmed and others, 1986) is located in the east-trending part of the Surghar Range west of Kalabagh and south of the Kohat Plateau (fig. 1). In this report, the Makarwal-Gula Khel and Kurd coal fields are referred to as the Surghar Range coal fields.

The rocks exposed in the Surghar Range vary in age from Triassic(?) to Quaternary (fig. 2). The stratigraphic relation between the Hangu and the underlying Lumshiwal Formation is not clear, and in outcrop the contact is difficult to define. The upper part of the Lumshiwal and the lower part of the Hangu are dominated by sandstone, and both formations contain carbonaceous shale and coal beds. Danilchik and Shah (1987) define the contact between the formations as occurring at the base of a prominent coal bed that is developed in the southern part of the field. Where the

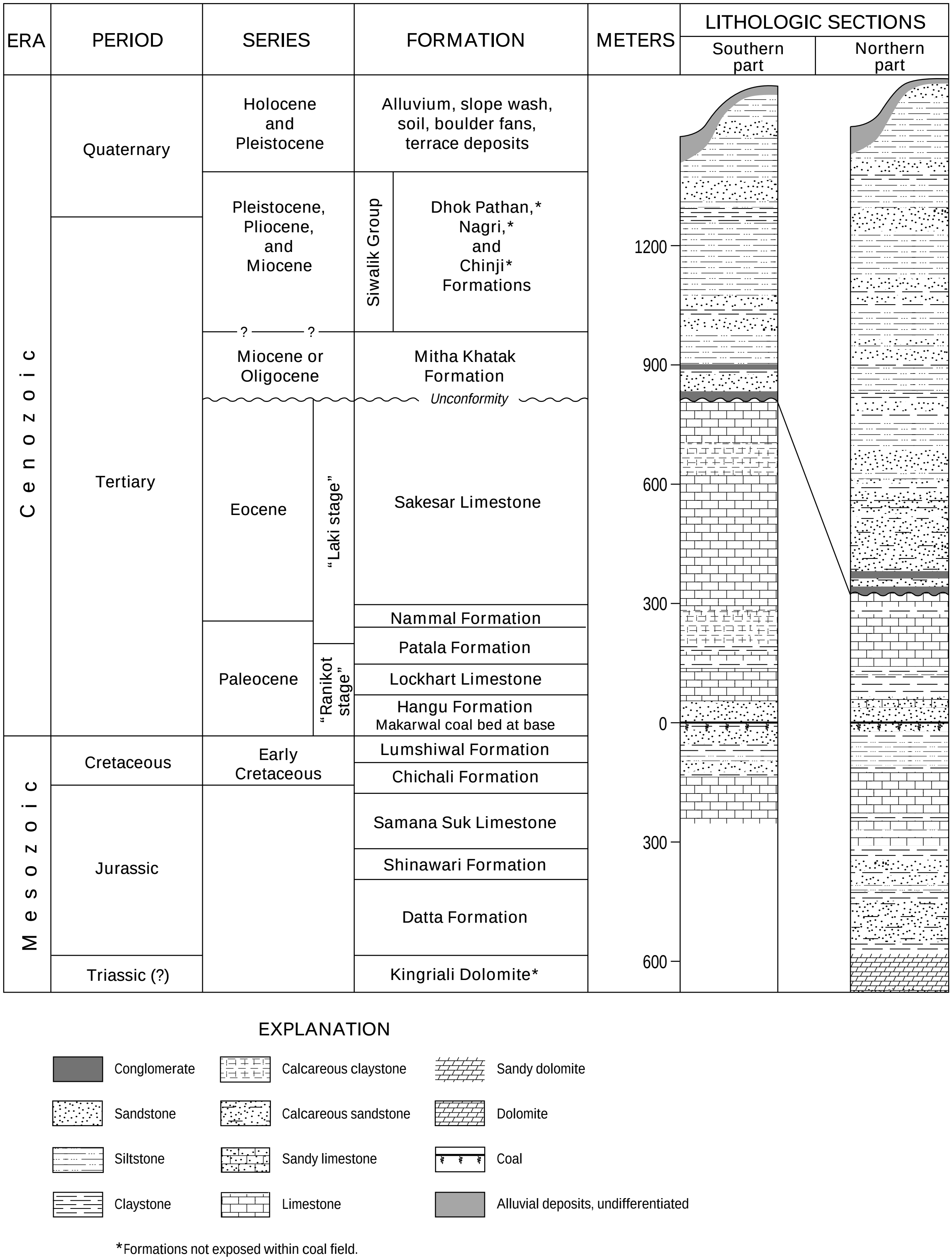
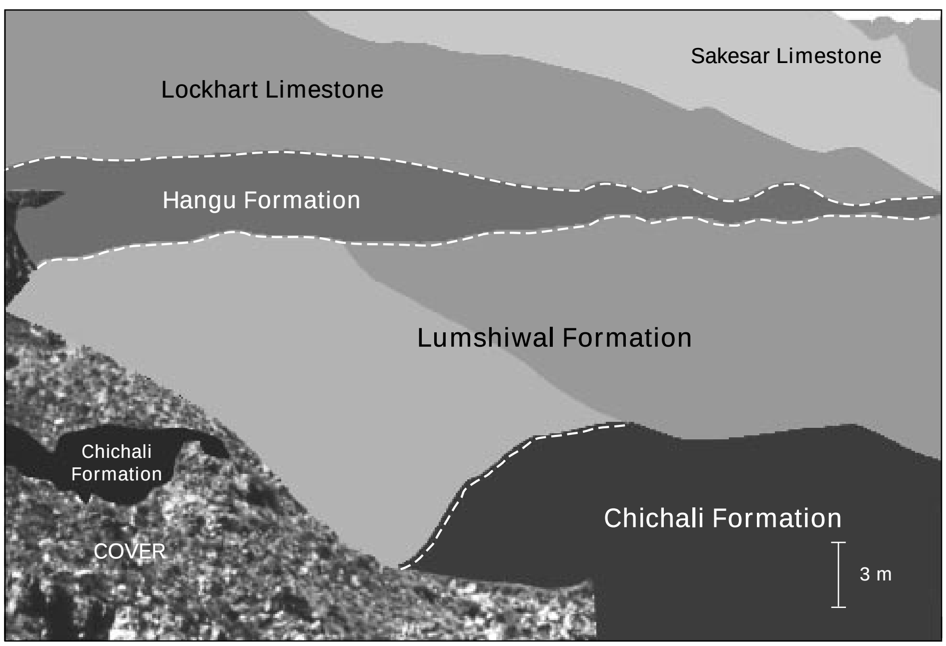
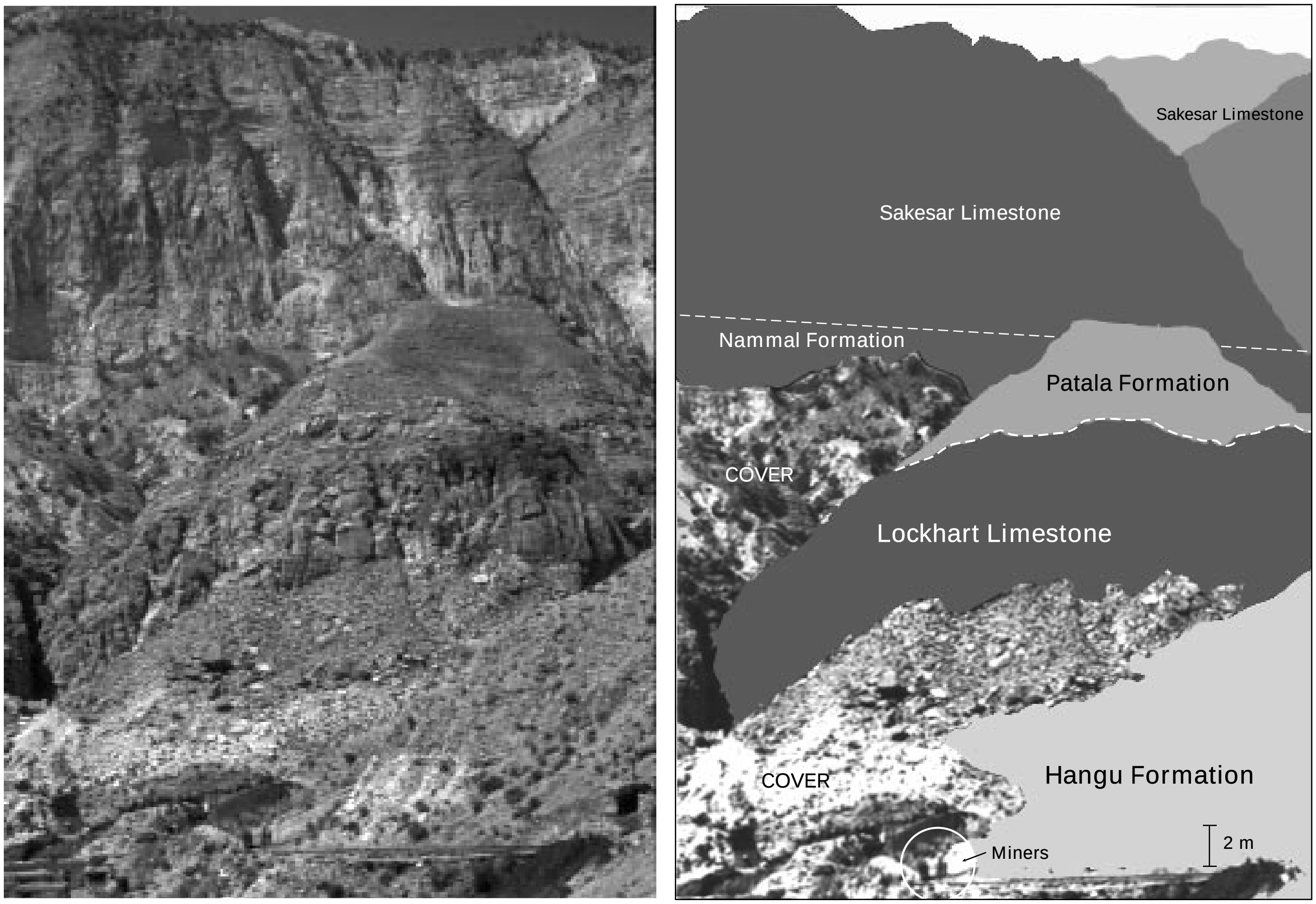


Figure 2. Generalized stratigraphic section of the rocks exposed in the Surghar Range study area (modified from Danilchik and Shah, 1987).



A. Photograph and schematic diagram showing general view of the Cretaceous Chichali and Lumshiwal Formations and the Paleocene Hangu Formation and Lockhart Limestone. Note that the Lumshiwal Formation becomes more thickly bedded upward. The Eocene Sakesar Limestone is in the background. The Chichali Formation through Lockhart Limestone section shown is approximately 300 m thick.

Figure 3. EXPOSED CRETACEOUS AND PALEOCENE ROCKS IN THE SURGHAR RANGE NEAR MEASURED SECTIONS 1 AND 3 (fig. 1; appendix I).



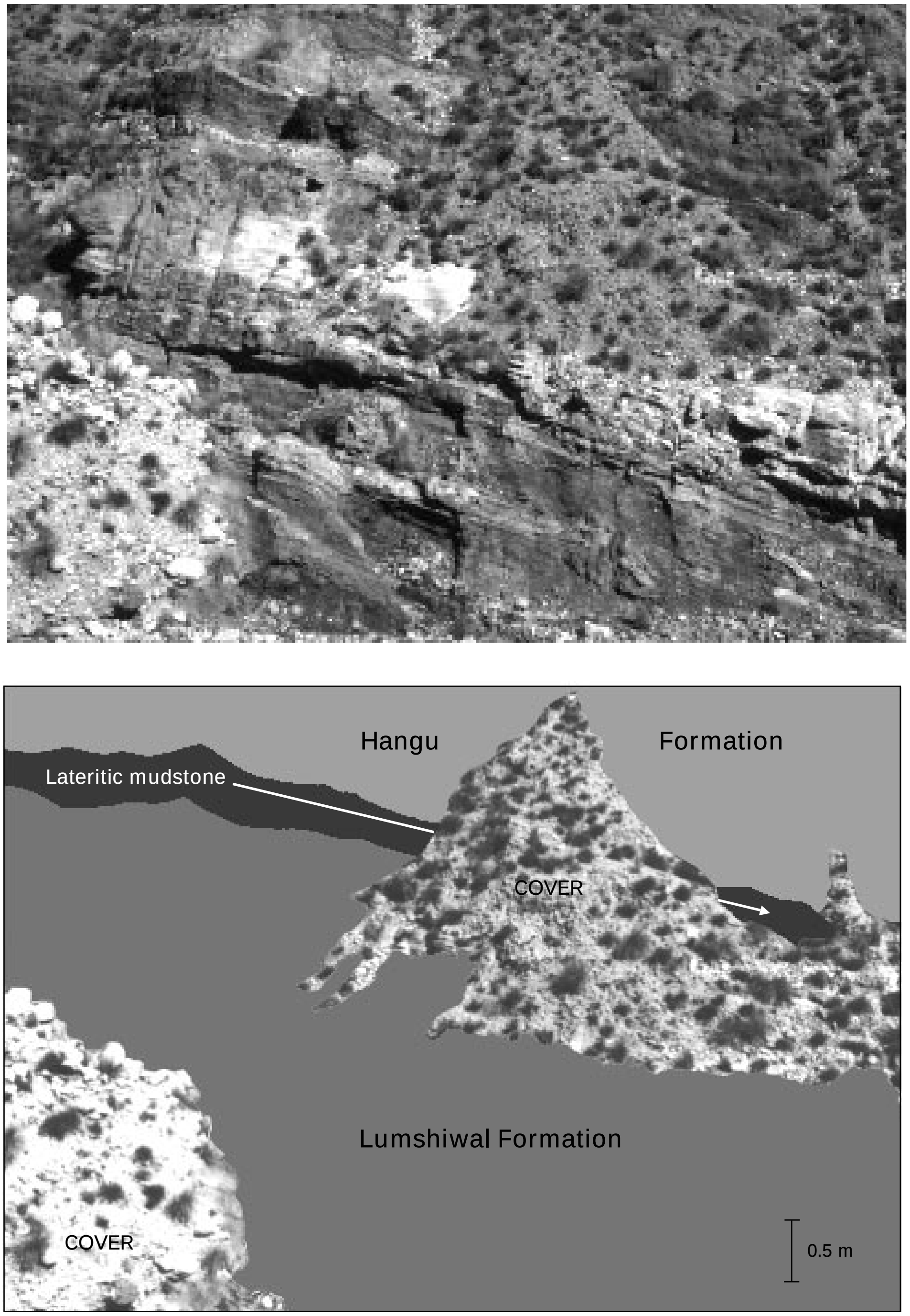
B. Photograph and schematic diagram showing general view of the Paleocene Hangu Formation, Lockhart Limestone, and Patala Formation. Note coal miners and coal-mine spoil piles from the Makarwal coal bed in the lower part of the photograph. The cliff face in the background is composed of the Eocene Nammal Formation and Sakesar Limestone.

coal bed is absent, the contact has been placed at the base of a thin lateritic mudstone that Danilchik and Shah (1987) interpreted to represent the base of the Paleocene. Studies in the Salt Range, located southeast of the Surghar Range (fig. 1), by Warwick and Shakoor (1988; in press) reported that such lateritic beds do not represent major disconformities and are common in the lower part of the Hangu in that area. These stratigraphic problems led us to collect a series of stratigraphic samples for paleontologic analysis. The results of these paleontological studies, along with measured stratigraphic sections through the Lumshiwal and the Hangu Formations and coal quality data, are presented and discussed in this paper.

The strata in the Surghar Range are deformed by folds and faults and commonly dip 30° or more to the west or northwest (fig. 3*A*, *B*). The structural setting of the Surghar Range and the >750 m of overburden above the Hangu Formation (fig. 3) have prevented the extensive exploration drilling programs that normally precede coal-field development. The Makarwal coal bed and a few other minor coal beds crop out along the cliff face of the Surghar Range (figs. 2, 3). The Makarwal coal bed is the primary bed mined in the area; however, near the town of Makarwal, a second bed, called the upper coal, is also mined. In the western part of the Salt Range, the Lumshiwal and Hangu Formations are very thin or absent, and only the Hangu has a few minor carbonaceous shale beds.

PREVIOUS INVESTIGATIONS

The regional characteristics of the Lumshiwal and Hangu Formations have been reviewed by Fatmi (1973), Shah (1977), and Wells (1984). Earlier workers who described the occurrences of coal in the Surghar Range include Wynne (1880), Simpson (1904), Gee (1938, 1941, 1948, 1949), Khan (1949), and Warwick and Husain (1990). Landis and others (1971) described the chemical and physical characteristics of nine coal samples collected from four different mines of, presumably, the Makarwal coal bed of



C. Photograph and schematic diagram showing iron-stained, lateritic mudstone bed overlying the upper part of the Lumshiwal Formation. This mudstone bed is about 1 m thick and probably represents paleosol development on the surface of the Lumshiwal Formation prior to the formation of the Makarwal coal bed (not shown). Lithologies exposed in the Lumshiwal include thin-bedded sandstone and mudstone. Photograph courtesy of E.A. Johnson.

the Surghar Range. Their study reported that this coal bed ranges in apparent rank from high-volatile B to high-volatile C bituminous. Warwick and Javed (1990) described the geochemical characteristics of various Pakistani coals, including those from the Surghar Range. Detailed investigations were undertaken by Danilchik and Shah (1987) to map the structure and geology of the Makarwal-Gula Khel coal field at 1:50,000 and 1:6,000 scales. Faruqi (1980, 1983) also worked on the structural details of the mining area. Ghaznavi (1988) described the petrographic characteristics and geologic setting of the Surghar Range coal deposits. Davies and Pinfold (1937), Haque (1956), Fatmi (1972), Köthe (1988), Frederiksen (1992), and Frederiksen and others (in press) have provided paleontological age determinations for the Lumshiwal and Hangu Formations.

A detailed assessment of the coal resources of the Hangu, defining reserve categories such as measured, indicated, and inferred, was not undertaken in this study because such estimates have been presented in Ahmed and others (1986) and Danilchik and Shah (1987). These authors suggest that the coal reserves of the Surghar Range are 16 million to 19 million tons of coal.

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We are thankful to the Pakistan Mineral Development Corporation (PMDC) for providing some of the data that were used in this study and for providing access to their mines in the Surghar Range. We are also grateful to the many privately owned mining companies in the Surghar Range who provided coal thickness data and access to their mines for sampling.

We acknowledge Patricia A. Hawk for her help in retyping appendix III.

METHODS

Fieldwork was done between 1989 and 1991. Thirteen stratigraphic sections were measured in the Surghar Range, and one in the western part of the Salt Range (fig. 1; appendix I). Sections 6 and 11 (fig. 1; appendix I) contain complete sections through the Lumshiwal and Hangu Formations. Two bench (MK–HT–2, MK–HT–3) and four whole-coal (MKCT–6, MKD3–7, MK–NCN–4, MKE 3–5) samples of the Makarwal coal bed and one whole-coal sample (MK–HT–1) of the upper coal bed (appendix II, table II–1) were collected from five working mines (fig. 1; appendix I,) following guidelines for channel samples by ASTM (1986) and Golightly and Simon (1989). The results of the chemical and physical analyses of the coal samples are presented in appendix II (table II–2). Laboratory results from four additional whole-coal samples of the Makarwal coal bed from the Makarwal area, collected by M.I. Ghaznavi (1986–87) (appendix II, table II–1, 85-series field numbers), were incorporated into the coal sample data set for this study. Three of the four additional samples were previously described by Ghaznavi (1988).

Thirty-two claystone and mudstone samples were collected for pollen analysis (table 1). The results of palynological studies conducted by Khan are presented in appendix III. Palynological results from Frederiksen (1992) and Frederiksen and others (in press) also are summarized in table 1.

A generalized cross section of the Lumshiwal and Hangu interval is shown on figure 4. Stratigraphic correlations between the sections were made by using the best-fit method; the lower coal zone in the Hangu Formation served as a datum.

LITHOFACIES OF THE LUMSHIWAL FORMATION

The general description of the Lumshiwal Formation by Danilchik and Shah (1987) provides a review of the previous literature and presents a good description of the basic characteristics of the unit. Detailed descriptions of the various lithologies composing the formation are provided in the measured sections (appendix 1). Three major lithofacies were identified in the Lumshiwal Formation: two types of sandstone (sandstone lithofacies A and B) and a combined facies consisting of mudstone, claystone, carbonaceous shale, and coal beds (combined lithofacies). There is also a minor carbonate lithofacies composed of arenaceous limestone.

The Lumshiwal Formation is dominated by the two sandstone lithofacies. These lithofacies generally are defined on the basis of grain size, clay content, and depositional bedding characteristics. Sandstone lithofacies A is composed of pale-yellowish-brown, yellowish-gray, and olive-gray, fine- to coarse-grained sandstone that is commonly burrowed, sometimes intensely. Bedding types include massive or parallel, and bed thicknesses are commonly greater than 1 m. Small, <0.5-m-thick, tabular cross-bed sets may be present. Carbonaceous debris is common along the bedding planes. Ironstone nodules several centimeters in diameter are commonly found throughout the lithofacies. Red-iron-oxide stains are commonly present along fractures, and glauconite and carbonate cements are common, especially in the lower part of the Lumshiwal. Red-iron-oxide staining of the sandstone lithofacies is more common in the upper part of the formation. Quartz content of lithofacies A ranges from 80 to 90 percent, based on hand sample observations. Lithofacies A may grade vertically or laterally into the combined lithofacies and, in places, may be interbedded with the combined lithofacies. Sandstone lithofacies A commonly coarsens upward in grain size and is most common in the lower part of the Lumshiwal Formation (fig. 4).

Sandstone lithofacies B generally resembles lithofacies A. Lithofacies B differs, however, by containing fewer claystone interbeds and much more medium- to coarse-grained

Table 1. Summary of palynological data from Surghar and Salt Range pollen samples.

[Location data refer to stratigraphic sections in appendix I. S., section; U., unit]

Sample No.	Age		Location
Pollen samples analyzed by Khan (unpub. data; see appendix III)			
T–SH–2	Early Cretaceous		S. 1, U. 6
T–SH–3	Early Cretaceous		S. 4, U. 25
K–SH–1	Late Jurassic to Early Cretaceous		S. 1, U. 2
K–SH–2	Paleocene		S. 4, U. 11
K–SH–3	Barren		S. 4, U. 16
K–SH–4	Barren		S. 4, U. 19
K–SH–5	Late Jurassic to Early Cretaceous		S. 6, U. 8
K–SH–6	Early Cretaceous		S. 11, U. 6
SH–MK–HT–1	Paleocene		S. 2, U. 1B
SH–MK–HT–2	Barren		S. 2, U. 3A
Pollen samples analyzed by Khan (unpub. data; see appendix III) and Frederiksen (1992)			
	Khan	*Frederiksen*	
PW–90–1	Early Cretaceous	Early Cretaceous	S. 1, U. 2
PW–90–2	Barren	Barren	S. 1, U. 6
PW–90–3	Paleocene	middle Paleocene	S. 1, U. 8
PW–90–4	Barren	middle Paleocene	S. 1, U. 11
PW–90–5	Barren	middle Paleocene	S. 1, U. 17
PW–90–6	Barren	Barren	S. 6, U. 10
PW–90–7	Barren	Barren	S. 6, U. 11
PW–90–8	Barren	middle Paleocene	S. 6, U. 13
Pollen samples from the Nammal Pass section analyzed by Frederiksen (1992)			
PW–90–9	Jurassic or Early to mid-Cretaceous		S. 14, U. 2
PW–90–10	Cretaceous, Aptian		S. 14, U. 10
PW–90–11	Barren		S. 14, U. 13
PW–90–12	Barren		S. 14, U. 15
PW–90–13	Barren		S. 14, U. 17
Pollen samples analyzed by Frederiksen and others (in press)			
NF89P–1	Late Jurassic–Early Cretaceous		S. 1, U. 2
NF89P–2	Rare pollen, no date		S. 1, U. 6
NF89P–3	Cretaceous, Aptian–Albian(?)		S. 1, U. 7
NF89P–4	Barren		S. 1, U. 16?
NF89P–5	Paleocene		S. 1, U. 20
NF89P–8	Rare palynomorphs, no date		S. 11, U. 6
NF89P–9	Rare palynomorphs, no date		S. 11, U. 6
NF89P–10	Paleocene		S. 14, U. 17
NF89P–11	Paleocene		S. 14, U. 17

sandstone characterized by large tabular and trough crossbedding. The individual crossbed sets are >1 m thick. Broad, low-angle crossbedding is rare. Lithofacies B is composed of individual units as much as 10 m thick that are separated by basal scours that extend laterally across the outcrop for many tens of meters. Individual beds tend to thicken upward (fig. 3*A*). Although individual beds within lithofacies B commonly have a scoured base, the base of lithofacies B is transitional with lithofacies A or the combined lithofacies. Sandstone constituting lithofacies B is very quartzose in hand specimen; quartz content ranges from 80 to 90 percent. Coarse- to granule-size sandstone and pebbly bands up to 0.5 m thick are commonly interbedded within lithofacies B. The pebbles are composed exclusively of quartz (fig. 4). Red-iron-oxide staining is very common in lithofacies B, especially in the uppermost part of the formation.

The combined lithofacies consists of mudstone, claystone, carbonaceous shale, and coal beds. This lithofacies generally is restricted to the upper part of the Lumshiwal Formation (fig. 4). The color of the mudstone ranges from medium-reddish brown, to reddish brown, to black, and the mudstone is commonly carbonaceous, burrowed, and (or) rooted. Mudstone also occurs as thin (<0.5-m-thick) interbeds within the sandstone lithofacies in the upper half of the formation. In the uppermost part of the formation, the mudstone is interbedded and gradational with thin claystone, carbonaceous shale, and coal beds that are <0.3 m thick and

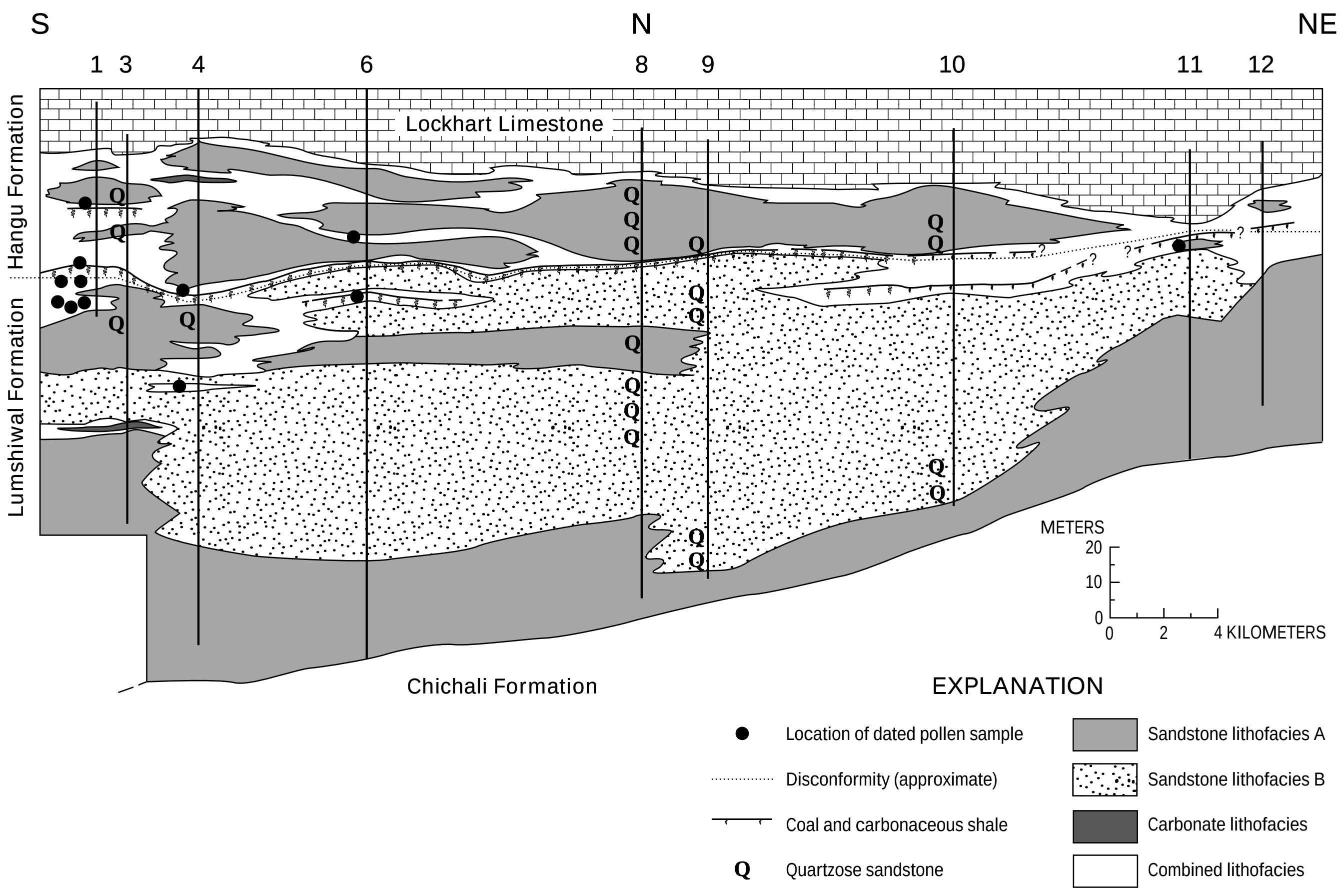

Figure 4. Cross section showing stratigraphic relation of exposed Upper Cretaceous and lower Paleocene rocks in the Surghar Range. Measured sections (indicated by numerals) are described in appendix I. Locations of the measured sections are shown on figure 1. Vertical exaggeration is 1:77.

laterally discontinuous. The claystone is carbonaceous, is often rooted, and commonly comprises underclay that is gradational with the carbonaceous shale and coal beds.

The minor carbonate lithofacies is rare in the Lumshiwal Formation. A single limestone bed (unit 6 in section 3, appendix 1; fig. 4), which is 1.22 m thick, is the only occurrence in these measured sections. This facies consists of arenaceous limestone that is medium-light to light gray and glauconitic. Quartz grains and a few ironstone concretions occur within the carbonate matrix.

LATERAL AND VERTICAL VARIATIONS OF LITHOFACIES OF THE LUMSHIWAL FORMATION

In the Surghar Range, the Lumshiwal Formation generally consists of sandstone lithofacies A units overlain by stacked, coarsening-upward lithofacies B sandstone units that are monolithologic for as much as 85 m (section 4, Charles mine, appendix I; fig. 4). Lithofacies B sandstone decreases in abundance toward the north and toward the south, as is illustrated on the cross section (fig. 4). The combined lithofacies, which contains a few thin coal beds, is generally discontinuous and is restricted to the upper part of the formation (fig. 4).

As noted by Danilchik and Shah (1987), the Lumshiwal Formation in the Surghar Range decreases in thickness from south to north. The thickest part of the formation is at the PMDC central tunnel (section 5 is between sections 4 and 6, on fig. 4), where it is greater than 150 m thick. The thickness of the formation decreases northward to about 64 m at Chichali Pass (section 11, appendix I; fig. 4). In the western part of the Salt Range at the Nammal Pass (section 14, appendix I), the unit is very thin, if present at all. At Nammal Pass, the rocks below the Hangu Formation, constituting the Jurassic Datta Formation and possibly the Lumshiwal Formation, are indistinguishable. Danilchik and Shah (1987) also observed this identification problem.

DEPOSITIONAL ENVIRONMENTS OF THE LUMSHIWAL FORMATION

Danilchik and Shah (1987) suggested that the Lumshiwal Formation of the Surghar Range was deposited under terrestrial conditions, presumably because of the scattered coal and carbonaceous beds found in the upper part of the formation. Although the identifications of depositional environments are preliminary in the present study, the most gross probable environments of deposition for the Lumshiwal Formation are shallow marine in the lower part of the formation and deltaic in the upper part of the formation. This interpretation is based on the predominance of lithofacies A sandstone in the lower part of the formation. Lithofacies A is transitional with the underlying marine Chichali Formation, which is rich in belemnites and coiled ammonites (Fatmi, 1972; Danilchik and Shah, 1987) and Early Cretaceous marine fossils from the lower part of the Lumshiwal described by Fatmi (1972). The lithofacies A sandstone, which has a clay matrix with glauconite, intense burrowing in places, generally thick bedding, and increasing grain size upward, was probably deposited in shallow-marine, prodeltaic environments. The glauconite probably represents mineralized fecal pellets of burrowing organisms. Characteristics similar to those described for the lower part of the formation also have been attributed to shallow-marine and deltaic depositional sequences in numerous other rock records (Galloway and Hobday, 1983).

The upper part of the Lumshiwal Formation, dominated by lithofacies B sandstone, is more complex than the lower part. The mix of primary bedding structures and various grain sizes present, the scattered occurrence of carbonaceous and coaly beds, and the abundance of quartzose sandstone indicate that a dynamic mix of depositional environments was probably responsible for the character of this unit. The large lithofacies B sandstone bodies probably resulted from an array of deltaic and nearshore marine processes that gave way to the development of small peat mires. The abundant quartzose sandstone may represent deposits that were enriched in their quartz content by reworking associated with nearshore processes. Frederiksen (1992) suggested a brackish-to-marine environment of deposition for the upper part of the Lumshiwal on the basis of the presence of the acritarch *Veryhachium* sp. Petrographic study of the major Lumshiwal rock types, detailed outcrop study of primary bedding structures, and three-dimensional stratigraphic control are needed for a better definition of the relative depositional environments of the formation.

Local tectonic subsidence contemporaneous with deposition most probably played a role in defining the character of the Lumshiwal Formation. Danilchik and Shah (1987) noted that the formation thins to the north. This thinning is evident on the cross section of the Surghar Range (fig. 4). The thicker part of the Lumshiwal, composed primarily of sandstone lithofacies B, indicates that the southern part of the range had a relative subsidence rate that was greater than that of the northern part of the range. McDougall and Khan (1990) have shown that a major, modern strike-slip fault extends along the western part of the Salt Range. These authors also point out that the strike-slip fault overlies a deep (5 km) basement ridge that probably is of basement-fault origin. Movement may have occurred along these or similar basement features during the Cretaceous, thus influencing the distribution of depocenters, and so may have contributed to the variation in Lumshiwal Formation thickness. Indeed, during the Late Cretaceous, the area that is now the Surghar Range ceased to be a depocenter, became subaerial, and experienced erosion or nondeposition. This change is evidenced by the lack of Upper Cretaceous strata in the area. Such patterns in deposition may have been structurally influenced.

Without a regional stratigraphic data set that can be used to map sequence boundaries and parasequence packages, fitting the observed changes in Lumshiwal stratigraphy to Mesozoic sea-level curves such as those discussed by Haq and others (1988) is difficult. Undoubtably, sea-level and climatic changes affected the deposition of the Lumshiwal. The disconformable surface at the top of the Lumshiwal may be a sequence boundary, but the lateral variations of stratigraphic thickness of the Lumshiwal appear to be influenced primarily by the tectonics of the area.

AGE OF THE LUMSHIWAL FORMATION

The disconformable relation between the Lumshiwal and Hangu Formations is quite enigmatic, because the contact is very difficult to define. Wynne (1880) first described the rocks of the Trans Indus Mountains and classified some of the rocks as Cretaceous in age. Gee (1945) later named some of these rocks the Lumshiwal Formation. Fatmi (1972), on the basis of fossils including *Gryphaea* and *Hibolithes* collected from the basal 3 m of the Lumshiwal Formation in Baroch Nala (section 6, appendix I), suggested that the lower part of the formation was probably Aptian(?) to middle Albian in age. The pollen samples collected from the upper part of the Lumshiwal during the current study and described by Khan (appendix III), Frederiksen (1992), and Frederiksen and others (in press) indicate a broader age range for the Lumshiwal—from Late Jurassic to Early Cretaceous. One sample (NF89P–3, table 1; section 1, appendix I), however, collected and described by Frederiksen and others (in press), correlates with the age given by Fatmi (1972). Dates obtained from this sample suggest that the upper part of the Lumshiwal is Aptian to Albian(?) in age. The location of dated pollen samples collected from the Surghar Range are plotted on the cross section (fig. 4), and the position of the difficult-to-define disconformable surface is approximately marked on the cross section.

Although Danilchick and Shah (1987) describe an Aptian to Albian(?) age for the Lumshiwal in their text, it is not clear why figures 3 and 5 of their report show the age of the formation to be Late Cretaceous. If the age of all the Lumshiwal is Aptian to Albian(?), then there is a substantial age difference (roughly 30 million years) between the upper part of the Lumshiwal and the overlying Paleocene Hangu

Formation. Danilchik and Shah (1987, p. 18) addressed the situation as follows: “In the Trans-Indus Mountains the [Lumshiwal] formation apparently disconformably underlies, but is lithologically gradational with, a fossiliferous formation known to be of Paleocene age.” Presumably the lithologically gradational nature of the Lumshiwal and Hangu contact led Danilchick and Shah to suggest that the upper part of the Lumshiwal may be Late Cretaceous in age.

LITHOFACIES OF THE HANGU FORMATION

The Hangu Formation of the Surghar Range is remarkably similar lithologically to the underlying Lumshiwal Formation, and on first inspection one would believe that the two units are part of the same stratigraphic sequence. Like the Lumshiwal, the Hangu is composed mostly of sandstone, with minor amounts of mudstone and claystone, carbonaceous shale, coal beds, and a few intercalations of limestone. Because the two formations are so similar, the same lithofacies terminology is used for both. Two major lithofacies are identified in both the Lumshiwal and Hangu Formations—(1) one type of sandstone (sandstone lithofacies A) and (2) a combined facies consisting of mudstone, claystone, carbonaceous shale, and coal beds (combined lithofacies). There is also a minor carbonate lithofacies that is composed of arenaceous limestone. Detailed descriptions of the various lithologies composing the formation are provided in the measured sections (appendix 1).

Although the two formations are similar, there are some differences. Unlike the Lumshiwal, lithofacies B is absent from the Hangu Formation. Instead, the Hangu is dominated by sandstone lithofacies A, which accounts for approximately two-thirds of the total formation; the combined lithofacies accounts for approximately one-third of the formation (fig. 4). Intense burrowing is an overwhelming characteristic of Hangu sandstone lithofacies A, and so the primary bedding features are generally obscured. Burrowed and sometimes rooted mudstone interbeds, generally <1 m thick, are commonly gradational with the sandstone lithofacies A. In some places, the Hangu sandstone lithofacies is quartzose, such as at section 8 (appendix I; fig. 4), and small crossbeds (sets <1 m thick) are common. The crossbeds are not as large as those observed in the sandstone lithofacies B of the Lumshiwal; therefore, all sandstone in the Hangu Formation is included within sandstone lithofacies A. Grain size is commonly fine to medium, but in the quartzose zones (fig. 4), grain size is normally graded from coarse at the base to fine at the top of the unit. Glauconite is less common than in the Lumshiwal, and dispersed carbonaceous material is abundant.

The combined lithofacies of the Hangu Formation, as in the Lumshiwal Formation, contains mudstone, claystone, carbonaceous shale, and coal beds. The primary difference between the two formations is that the Hangu contains the thick (commonly <2-m-thick), widespread Makarwal coal bed. Below the Makarwal coal bed is a laterally discontinuous, iron-stained, lateritic, pyrite-rich, and contorted mudstone deposit (fig. 3*C*). The red mudstone is not always present, as indicated in those sections measured in the northernmost part of the Surghar Range (sections 8–10, appendix I). In these places, the Makarwal coal bed overlies gray, rooted mudstone. No age for the red mudstones has been obtained, and so the deposits have been included in the Hangu Formation, with the Makarwal coal bed. In some places, a pisolitic structure is developed within the claystone (section 6, appendix 1). In section 14, at Nammal Pass, in the Salt Range, a thick (>7-m-thick), bauxitic claystone near the base of the Hangu is probably correlative to the red mudstone zone of the Surghar Range. The red mudstone deposits are similar to those described in the eastern part of the Salt Range by Warwick and Shakoor (in press) and probably represent paleosol horizons. Danilchik and Shah (1987), Shah (1984), and Whitney and others (1990) described these red deposits as laterites.

The combined lithofacies in the upper part of the Hangu Formation is calcareous and contains terrestrial plant and marine animal fossils. These units are gradational with the minor carbonate lithofacies and with the overlying Lockhart Limestone. The carbonate lithofacies of the Hangu is less arenaceous than that found in the Lumshiwal and is nodular and muddy (sections 4, 8, 12, appendix I; fig. 4).

COAL CHARACTERISTICS OF THE HANGU FORMATION

Danilchick and Shah (1987) estimated that the remaining minable coal reserves of the Hangu Formation of the Surghar Range are about 16.6 million tons. These reserves are contained in a single coal bed, the Makarwal coal bed, which dips to the west at about 30° and ranges between 0.6 and 3.0 m in thickness (average, 1.2 m). Near the middle of the formation in the southern part of the range, a thin coal bed (<0.6 m thick) is locally referred to as the upper coal bed and is not part of this reserve estimate. Five in-mine sections measured in the Surghar Range (sections 2, 5, 7, 9, 13, appendix I) describe the physical characteristics of the Makarwal coal bed. The coal bed is commonly bright, sometimes banded, resinous, pyritic, and cleated. Gypsum occurs along some of the cleats. Sandy or muddy partings or stringers are common. Roof rock ranges from carbonaceous shale to mudstone or sandstone that is rooted or burrowed. Floor rock includes lateritic mudstone, rooted claystone, mudstone, and fine-grained sandstone that is commonly pyritic and carbonaceous.

Ghaznavi (1988) described the megascopic and petrographic characteristics of the Makarwal coal bed. He

Table 2. Descriptive summary of Surghar and Salt Range coal samples.

[Location data refer to stratigraphic sections in appendix I. S., section; U., unit. n.a., not available; Do. (do.), ditto]

Sample No.	Source	Location	Coal bed; sample type
85–MK–004	Ghaznavi, 1986	n.a.	Makarwal, whole coal.
85–MK–005	do.	n.a.	Do.
85–MKGL–006	do.	n.a.	Do.
85MIG123	Ghaznavi, 1987	n.a.	Do.
D–91602	Landis and others, 1971	Godarmal mine	Do.
D–91603	do.	Charles mine	Do.
D–91604	do.	do.	Do.
D–91605	do.	Omparkash mine	Do.
D–91606	do.	do.	Do.
D–91607	do.	do.	Do.
D–91608	do.	Landoo mine	Do.
D–91609	do.	do.	Do.
D–91611	do.	mine-run composite	Do.
MK–HT–3	Warwick, this study	S. 2, U. 4A	Makarwal; upper bench.
MK–HT–2	do.	S. 2, U. 2A	Makarwal; lower bench.
MK–HT–1	do.	S. 2, U. 2B	upper; whole coal.
MKCT–6	Javed, this study	S. 5, U. 2	Makarwal; whole coal.
MK–NCN–4	do.	S. 9, U. 16	Do.
MKE 3–5	do.	S. 13, U. 2, 4.	Do.
MKD3–7	do.	S. 7, U. 2	Do.

reported that the coal bed was resin rich and variable in thickness. Petrographic study of three Makarwal coal-bed samples from the Surghar Range indicates that they are vitrinite rich; their average vitrinite content is 71.8 percent. Inertinite macerals averaged 18.4 percent, and liptinite macerals averaged 9.8 percent.

Landis and others (1971) and Danilchik and Shah (1987) described and collected eight mine samples and one mine-run composite sample from the Makarwal coal bed of the Surghar Range. During the present study, one coal sample from the upper coal bed and six from the Makarwal coal bed were collected for chemical and physical characterization. In addition, M.I. Ghaznavi collected four samples of the Makarwal coal bed. Descriptions of the coal samples are summarized in table 2, and the results of coal-sample analyses are summarized in table 3 and collated in appendix II.

As reported by Landis and others (1971) and Danilchik and Shah (1987), the apparent rank of the Makarwal coal bed ranges from high-volatile B to high-volatile C bituminous. Averaged, nonweighted results from the samples described in Landis and others (1971) and the present study indicate that some of the averaged, as-received characteristics of the Makarwal and upper beds are (1) moisture content is 5.4 percent; (2) ash yield is 12.5 percent; (3) total sulfur content is 5.0 percent; and (4) calorific value is 11034 Btu/lb (table 3).

Four coal samples of the Makarwal coal bed were analyzed for various major, minor, and trace elements. The results of these tests are presented in appendix II (table II–3). The arithmetic means and standard deviations of these analyses are presented in table 3. For general comparison, data for selected elements from the medium-volatile Upper Freeport coal bed of Pennsylvania are also given (table 3). The Upper Freeport data set was selected for comparison with the Makarwal coal bed because both beds are bituminous and the chemical characteristics of the Upper Freeport coal bed are well documented (Cecil and others, 1981).

Trace elements such as arsenic (As) and selenium (Se) are sometimes environmental pollutants if their concentrations are greater than those found in the Earth's crust (NRC, 1980). The arithmetic mean for As in the Makarwal coal bed samples is 5.88 ppm and does not appear to pose a threat. This concentration is less than the mean of samples from the Upper Freeport coal bed (24 ppm) and is comparable to the overall range of As concentrations for all Western United States coals (0.34–9.8 ppm; Gluskoter and others, 1977). Selenium, however, is a different story. The mean for Se concentration for all United States coals is 4.1 ppm (Swanson and others, 1976). The mean for Se concentrations for Western United States coals is 1.4 ppm (Gluskoter and others, 1977) and for the Upper Freeport coal bed is 2.96 ppm (table 3). For the Surghar Range, the mean Se concentration is 13.4 ppm. Warwick and others (1990) found Se concentrations in coal samples from the Salt Range to average 11.48 ppm. Large-scale use of coal having very high concentrations of Se can cause unacceptable concentrations of Se from fly ash to accumulate in Pakistan's semiarid environment. Therefore, any plans to use Surghar Range coals for electric-powerplant feedstocks must take the concentration of Se into consideration.

Table 3. Averaged selected analytical results from Surghar Range coal samples.

[Complete analytical results are given in appendix II. Data from the Upper Freeport coal bed, Pennsylvania, are listed for comparison (from Cecil and others, 1981). *N*, number of samples; avg., arithmetic mean; s.d., standard deviation. All values as-received, except thickness; trace- and minor-element data on whole-coal basis in parts per million. Thickness data from Danilchik and Shah (1987)]

Characteristic or composition	Surghar Range, Pakistan			Upper Freeport coal bed, Eastern United States		
	N	avg.	s.d.	*N*	avg.	s.d.
Coal bed thickness (m)		1.20			2.78	
Moisture (percent)	20	5.42	1.04	21	1.05	0.25
Ash yield (percent)	20	12.52	5.36	21	14.95	4.55
Volatile matter (percent)	20	41.21	3.38	21	25.34	2.44
Fixed carbon (percent)	20	40.84	3.06	21	58.66	3.14
Carbon (percent)	20	60.05	4.32	21	72.70	4.05
Hydrogen (percent)	20	5.25	.29	21	4.50	.27
Nitrogen (percent)	20	.80	.24	21	1.23	.10
Total sulfur (percent)	20	4.98	.89	21	2.06	.75
Pyritic sulfur (percent)	9	1.65	1.17	21	1.42	.74
Organic sulfur (percent)	9	2.83	.45	21	.56	.10
Sulfate sulfur (percent)	9	.35	.26	21	1.42	.74
Oxygen (percent)	20	16.38	2.84	21	4.58	.62
Calorific value (Btu/lb)	20	11,034	761	21	12,861	751
Trace- and minor-element data						
Ag	4	0.05	0.005	19	0.05	0.04
As	4	5.88	2.44	21	24.00	17.38
B	4	77.26	18.70	21	13.50	6.30
Ba	4	16.44	5.61	20	47.91	18.96
Be	4	3.35	2.39	21	1.52	.51
Br	4	6.36	5.96	21	9.17	3.03
Cd	4	.38	.15	21	.18	.21
Ce	4	11.00	9.40	21	25.90	15.25
Cl	1	150.00				
Co	4	2.75	1.37	21	5.40	1.95
Cr	4	20.67	11.23	21	22.24	6.44
Cs	2	.42	.40	21	1.65	.50
Cu	4	110.70	34.20	21	19.14	8.94
Eu	4	.32	.09	21	.48	.32
F	3	56.67	23.09	20	101.20	49.20
Ga	2	5.42	.66	21	7.12	1.98
Ge	2	25.74	23.42	20	1.98	1.41
Hf	4	1.22	.69	21	1.01	.52
Hg	1	.05		21	.41	.16
La	4	35.25	57.26	21	13.62	7.30
Li	4	160.00	31.60	21	20.94	9.65
Lu	3	.09	.02	21	.18	.11
Mn	4	104.00	77.00	21	22.76	9.13
Mo	2	20.55	5.13	20	1.89	.69
Nb	2	6.85	1.80	21	2.25	1.50
Nd	4	10.24	4.91	13	12.58	6.37
Ni	4	9.92	5.00	21	14.41	7.13
Pb	4	69.00	40.10	21	.81	1.22
Pr	1	1.08				
Sb	4	.33	.20	21	.81	1.22
Sc	4	3.15	.93	21	4.65	1.91
Se	4	13.40	4.78	20	2.96	2.73
Sm	4	1.54	.40	21	2.25	1.32
Sn	2	3.73	.83	3	1.93	2.90
Sr	4	157.40	80.30	21	77.44	43.06
Ta	4	.39	.22			
Tb	4	.21	.07	20	.39	.27
Th	4	3.18	1.27	7	4.57	1.92
U	4	4.60	6.10	21	1.73	.74
V	4	25.70	18.50	21	22.31	6.57

Table 3. Averaged selected analytical results from Surghar Range coal samples—Continued.

Characteristic or composition	Surghar Range, Pakistan			Upper Freeport coal bed, Eastern United States		
	N	avg.	s.d.	*N*	avg.	s.d.
Trace- and minor-element data						
W	4	.60	.20			
Y	1	6.93		20	6.57	3.92
Yb	4	.71	.31	21	.98	.54
Zn	4	130.00	63.00	21	26.11	17.72
Zr	4	27.74	8.58	21	17.14	8.75

LATERAL AND VERTICAL VARIATIONS OF THE LITHOFACIES OF THE HANGU FORMATION

The thickness of the Hangu Formation ranges from 4.88 m at the Chichali Pass section in the northern part of the Surghar Range (section 11, appendix I; fig. 4) to 49.23 m at the Charles mine section (section 4, appendix I; fig. 4) in the southern part of the range. The Charles mine section contains the thickest part of the formation and the greatest amount of sandstone (fig. 4). Along strike, the thickness of the sandstone gradually decreases northward and rapidly decreases southward. In the northern part of the study area at the Chichali Pass section (section 11, appendix I), no sandstone is found in the Hangu, but farther east, in the western part of the Salt Range, sandstone beds in the Hangu are more than 10 m thick (Nammal Pass, section 14, appendix I).

The significant differences between the Hangu and the Lumshiwal Formations are that the Hangu contains a minable coal bed in its lower part and that the upper part of the Hangu becomes less sandy and grades into the overlying Lockhart Limestone. This sequence is the reverse of the sequence observed in the Lumshiwal Formation. The lower part of the Lumshiwal is finer grained and more calcareous than the upper part of the Lumshiwal.

DEPOSITIONAL ENVIRONMENTS OF THE HANGU FORMATION

Danilchik and Shah (1987, p. 18) suggested that the lower part of the Hangu Formation of the Surghar Range was “wholly of terrestrial origin,” and that the upper part was transitional with the overlying marine Lockhart Limestone. Although the definition of depositional environments of the Lumshiwal and Hangu Formations is preliminary in this study, the most probable environment of deposition for the lower part of the Hangu is similar to that of the upper part of the Lumshiwal Formation—shallow marine and deltaic. This environment of deposition is suggested by the abundance of burrowing found in the sandstone of the Hangu, the frequent mudstone intercalations in the formation, and the presence of marine fossils in the Hangu (Davies and Pinfold, 1937; Haque, 1956). Frederiksen and others (in press) and Khan (appendix III) reported that rock samples from the Hangu of the Surghar Range contain pollen of the brackish-water palm of the genus *Spinizonocolpites*.

The Makarwal coal bed is unique because it represents a transition of environments of deposition from those initially associated with subaerial exposure and lateritic paleosol development to those associated with mire development and subsequent marine and deltaic environments in the upper part of the Hangu. A rise in relative ground-water base level may have triggered mire formation to spread over lateritic paleosol deposits that formed on weathered paleosurfaces of the Lumshiwal Formation. As the relative base level rose, the mires were flooded by shallow-marine water and buried by clastic deposits probably derived from local Paleocene deltas. Only brief periods of peat accumulation occurred after the formation of the Makarwal coal bed. The thin, laterally discontinuous carbonaceous shale and coal beds in the lower and middle parts of the Hangu probably represent short-lived periods of peat accumulation in the Paleocene coastal area. Warwick and Shakoor (in press) have shown that, during the deposition of the Paleocene Patala Formation in the Salt Range, about 75 km southeast of the Surghar Range, the shoreline was roughly oriented north-south and the Tethys Sea lay generally to the west.

In terms of sequence stratigraphy, the disconformity between the upper part of the Lumshiwal Formation and the base of the Hangu (fig. 3*C*) is a possible sequence boundary. The lower part of the Hangu Formation of the Surghar Range, above the Makarwal coal, probably contains several marine-flooding surfaces, as suggested by the upward decreasing abundance of terrestrially related lithologies (such as coal beds) and the increasing presence of limestone beds having foraminifera. The flooding surfaces cannot be mapped without detailed local and regional stratigraphic control, and it may be difficult to distinguish eustatic flooding surfaces from flooding surfaces caused by shifts in the local subsidence rate or autocyclic environmental shifting. The transgressive deposits of the Hangu Formation in the Surghar Range appear, however, to be associated with the Paleocene transgressive-regressive sequences preserved in the Salt Range and across northern Pakistan (Warwick and

Wardlaw, 1992). Additional fieldwork is needed to address these problems.

As in the Lumshiwal, local contemporaneous subsidence rates driven by tectonics probably influenced the deposition of the Hangu as much as, or even more than, eustatic or climatic variations influenced the deposition. As noted by Danilchik and Shah (1987) and as evident on the cross section of the area (fig. 4), the Hangu thins rapidly to the north. Similar variations of formation thicknesses have been described by Fatmi and Haydri (1986) for Mesozoic sedimentary rocks southeast of the Surghar Range in the Salt Range. These differences in formation thicknesses may be attributed to local or regional basement faults that may have been active during Lumshiwal and Hangu deposition. Warwick and Shakoor (in press) and Drewes and others (in press) suggest that offsets of basement rocks in the Salt Range and Potwar Plateau, east and northeast of the Surghar Range, influenced thickness of the Paleocene formations in those areas. Influence from basement faults, which also probably affected Lumshiwal deposition, is suggested for the Hangu Formation. Likewise, tectonic controls, probably combined with eustatic and climatic controls, influenced the development of the laterites in the Surghar Range. Shah (1984) also argued for a dominate tectonic influence on various other lateritic deposits at different stratigraphic positions across Pakistan.

As pointed out by McCabe (1991), tectonics play an important role in peat accumulation. The Paleocene paleopeat of the Makarwal coal bed accumulated very close to a disconformable surface that was exposed or experienced nondeposition for approximately 30 million years during the Late Cretaceous. The reasons for the formation of this erosion surface are debatable, but the depositional influences of eustacy and climate change on these rocks were probably overprinted by tectonic forces. A relatively high base level is theorized for the upper part of the Hangu and is indicated by the increasing abundance of marine rocks above the Makarwal coal bed. Tectonic mechanisms, such as active basement faults, probably influenced sediment supply and subsidence rates and caused the rapid change in lithologies and formation thicknesses observed in the Surghar Range.

AGE OF THE HANGU FORMATION

Studies of marine fossils collected from the Hangu Formation (or the Dhak Pass beds, as it was previously known) by Davies and Pinfold (1937) and Haque (1956) have indicated a Paleocene age for the formation. Köthe (1988), on the basis of a regional study of nannofossils and dinoflagellates, gave the Hangu Formation a middle to late Paleocene age. These age ranges are confirmed by the results from pollen samples collected during this study (table 1; appendix III).

CONCLUSIONS

The Lumshiwal and Hangu Formations of the Surghar Range of north-central Pakistan are lithologically similar and were deposited in what we interpret to have been similar depositional environments of shallow-marine and deltaic settings. The two formations are separated by a disconformity and possible sequence boundary that represent a hiatus of approximately 30 million years (from Aptian or Albian to Paleocene). Palynological data (Frederiksen and others, in press; Khan, appendix III) indicate that the age of the Lumshiwal is Early Cretaceous, not Late Cretaceous as previously reported by Danilchick and Shah (1987). A middle Paleocene age is confirmed in this study for the Hangu Formation. The contact between the formations is commonly associated with possibly Paleocene lateritic paleosols that developed on exposed Early Cretaceous Lumshiwal rocks. This disconformity, which has been defined stratigraphically by palynological studies, is graphically displayed on a cross section of the Surghar Range (fig. 4). The peat deposits that later formed the Makarwal coal bed (average thickness 1.2 m) developed on these lateritic deposits probably in response to a rise in the relative ground-water base level. The rise in base level probably was driven by tectonic influences, but climatic and eustatic influences are not excluded. The Makarwal coal bed represents a transitional lithology that formed in a depositional setting that changed from laterite formation associated with the unconformity to mires associated with deltaic environments of the Hangu Formation. The upper part of the Hangu Formation and the Lockhart Limestone represent the culmination of marine transgression. The rapid change in the thickness of the Lumshiwal and Hangu Formations, over a distance of about 20 km, suggests that tectonic forces such as active basement faulting may have influenced deposition of both formations.

Analytical data from the Makarwal coal bed indicate that the apparent rank of the coal bed ranges from high-volatile B to high-volatile C bituminous (Landis and others, 1971). Averaged, as-received results from analytical tests indicate that Hangu coal deposits in the Surghar Range contain 5.4 percent moisture, 12.5 percent ash, and 5 percent total sulfur and have an average calorific value of 11034 Btu/lb. Trace-element analyses indicate that Hangu Formation coal beds contain concentrations of the environmentally sensitive element selenium (average 13.4 ppm); these concentrations are relatively high when compared to concentrations from similar United States coals. Structural complications and a significant overburden have prevented major development of the coal deposits and have limited mining to the outcrop area of the Hangu in the Surghar Range.

REFERENCES CITED

Ahmed, W., Gauhar, S.H., and Siddiqi, R.A., 1986, Coal resources of Pakistan: Records of the Geological Survey of Pakistan, v. 73, 55 p.

American Society for Testing and Materials [ASTM], 1986, Annual book of ASTM standards; sec. 5, Petroleum products, lubricants, and fossil fuels: Gaseous fuels; Coals and coke, v. 5.05, 565 p.

Cecil, C.B., Stanton, R.W., and Dulong, F.T., 1981, Geology of contaminants in coal; Phase I, Report of investigations [chap. A] and Appendixes [chap. B]: U.S. Geological Survey Open-File Report 81–953, chap. A, 101 p.; chap. B, 218 p.

Danilchik, Walter, and Shah, S.M.I., 1987, Stratigraphy and coal resources of the Makarwal area, Trans-Indus Mountains, Mianwali District, Pakistan: U.S. Geological Survey Professional Paper 1341, 38 p., 4 pls.

Davies, L.M., and Pinfold, E.S., 1937, The Eocene beds of the Punjab Salt Range: Memoirs of the Geological Survey of India, v. 24, no. 1, 79 p.

Drewes, Harald, Ahmad, Zaki, and Khan, Rafiullah, in press, Resource evaluation of selected minerals and industrial commodities of the Potwar Plateau area, northern Pakistan, *in* Warwick, P.D., and Wardlaw, B.R., eds., Regional studies of the Potwar Plateau area, northern Pakistan: U.S. Geological Survey Bulletin 2078, chap. H.

Faruqi, S.H., 1980, A critical study of Makarwal collieries development operations and proposals for improvement: unpub. Pakistan Mineral Development Corporation report, 27 p.

———1983, Special features of the geology of Makarwal coal fields: Proceedings of the National Seminar on Development of Mineral Resources, 2d, May 21–24, 1983, Peshawar, Pakistan, p. 21–24.

Fatmi, A.N., 1972, Stratigraphy of the Jurassic and Lower Cretaceous rocks and Jurassic ammonites from northern areas of West Pakistan: Bulletin of the British Museum (Natural History) Geology, v. 20, no. 7, p. 297–380.

———1973, Lithostratigraphic units of the Kohat-Potwar Province, Indus Basin, Pakistan: Geological Survey of Pakistan Memoirs, v. 10, 80 p.

Fatmi, A.N., and Haydri, I.H., 1986, Disappearance and reappearance of some Mesozoic units in Lalumi section, western Salt Range—A stratigraphic riddle: Acta Mineralogica Pakistanica, v. 2, p. 53–59.

Ferm, J.C., Smith, G.C., Weisenfluh, G.A., and DuBois, S.B., 1985, Cored rocks in the Rocky Mountain and High Plains coal fields: Department of Geology, University of Kentucky, Lexington, 90 p.

Frederiksen, N.O., 1992, Palynology of Mesozoic and lower Tertiary samples from northern, central, and southern Pakistan: U.S. Geological Survey Open-File Report 92–215, 11 p.

Frederiksen, N.O., Sheehan, T.P., and Andrle, V.A.S., in press, Spore-pollen biostratigraphy and paleoecology of Mesozoic and lower Tertiary samples from the Surghar and Salt Ranges, northern Pakistan, *in* Warwick, P.D., and Wardlaw, B.R., eds., Regional studies of the Potwar Plateau area, northern Pakistan: U.S. Geological Survey Bulletin 2078, chap. D.

Galloway, W.E., and Hobday, D.K., 1983, Terrigenous clastic depositional systems: New York, Springer-Verlag, 423 p.

Gee, E.R., 1938, The economic geology of the northern Punjab, with notes on adjoining portions of the North-West Frontier Province: India Mining Geology and Metallic Institute Transaction, v. 33, pt. 3, p. 263–350.

———1941, A study of certain Indian coals: Records of the Geological Survey of India, Professional Paper 11, v. 75, 41 p.

———1945, The age of the Saline Series of the Punjab and of Kohat: India National Academy of Sciences Proceedings, v. 16, pt. (2–4), p. 95–154.

———1948, Coal: Records of the Geological Survey of India, Bulletin of Economic Minerals, v. 76, no. 16, 147 p.

———1949, The mineral resources of north western India: Geological Survey of Pakistan Records, v. 1, pt. 1, 25 p.

Ghaznavi, M.I., 1988, The petrographic properties of the coals of Pakistan: Carbondale, Ill., Southern Illinois University, M.S. thesis, 175 p.

Gluskoter, H.J., Ruch, R.R., Miller, W.G., Cahill R.A., Dreher, G.B., and Kuhn, J.K., 1977, Trace elements in coal—Occurrence and distribution: Illinois State Geological Survey Circular 499, 154 p.

Golightly, D.W., and Simon, F.O., eds., 1989, Methods for sampling and inorganic analysis of coal: U.S. Geological Survey Bulletin 1823, 72 p.

Haq, B.U., Hardenbol, J., and Vail, P.R., 1988, Mesozoic and Cenozoic chronostratigraphy and cycles of sea-level change, *in* Wilgus, C.K., Posamentier, H.W., Ross, C.A., and Kendal, C.G.St., eds., Sea-level changes—An integrated approach: Society of Economic Paleontologists and Mineralogists Special Publication 42, p. 72–108.

Haque, A.F.M.M., 1956, The foraminifera of the Ranikot and Laki of Nammal Gorge, Salt Range: Geological Survey of Pakistan Memoirs, v. 1, 300 p.

Khan, N.M., 1949, A survey of coal resources of Pakistan: Geological Survey of Pakistan Records, v. 2, pt. 2, p. 1–11.

Köthe, Angelika, 1988, Biostratigraphy of the Surghar Range, Salt Range, Sulaiman Range and the Kohat area, Pakistan, according to Jurassic through Paleogene calcareous nannofossils and Paleogene dinoflagellates: Geologisches Jahrbuch, ser. B, no. 71, p. 3–87.

Landis, E.R., Reinemund, J.A., Cone, G.C., Schick, D.P., and Kebblish, W., 1971, Analyses of Pakistan coals: U.S. Geological Survey Project Report, (IR) PK–58, 71 p.

McCabe, P.J., 1991, Tectonic controls on coal accumulation: Bulletin de la Société Géologique de France, v. 162, no. 2, p. 277–282.

McDougall, J.W., and Khan, S.H., 1990, Strike-slip faulting in a foreland fold-thrust belt—The Kalabagh fault and western Salt Range, Pakistan: Tectonics, v. 9, no. 5, p. 1061–1075.

National Research Council [NRC], Panel on the Trace Element Geochemistry of Coal Resource Development Related Health, 1980, Trace element geochemistry of coal resource development related to environmental quality and health: Washington, D.C., National Academy Press, 153 p.

Shah, S.H.A., 1984, Stratigraphic observations of laterites in Pakistan and oscillation and movement of the Eurasian and Indian blocks: Geological Bulletin of the University of Peshawar, v. 17, p. 101–108.

Shah, S.M.I., 1977, Stratigraphy of Pakistan: Memoirs of the Geological Survey of Pakistan, v. 12, 138 p.

Simpson, R.R., 1904, Report on the coal deposits of Isa Khel, Mianwali, Punjab: Geological Survey of India Records, v. 31, pt. 1, p. 9–34.

Swanson, V.E., Medlin, J.H., Hatch, J.R., Coleman, S.L., Wood, G.H., Jr., Woodruff, S.D., and Hildebrand, R.T., 1976, Collection, chemical analysis, and evaluation of coal samples in 1975: U.S. Geological Survey Open-File Report 76–468, 503 p.

Warwick, P.D., and Husain, Farhat, 1990, Coal fields of Punjab and North-West Frontier Provinces, and Azad Kashmir, Pakistan, *in* Kazmi, A.H., and Siddiqi, R.A., eds., Significance of the coal resources of Pakistan: Geological Survey of Pakistan, Quetta, p. 15–26.

Warwick, P.D., and Javed, S., 1990, Quality and character of Pakistan coal, *in* Kazmi, A.H., and Siddiqi, R.A., eds., Significance of the coal resources of Pakistan: Geological Survey of Pakistan, Quetta, p. 127–135.

Warwick, P.D., and Shakoor, Tariq, 1988, Preliminary report on the coal characteristics in the Salt Range area of north-central Pakistan: U.S. Geological Survey Open-File Report 88–637, 333 p.

———in press, Lithofacies and depositional environments of the coal-bearing Paleocene Patala Formation, Salt Range coal field, northern Pakistan, *in* Warwick, P.D., and Wardlaw, B.R., eds., Regional studies of the Potwar Plateau area, northern Pakistan: U.S. Geological Survey Bulletin 2078, chap. I.

Warwick, P.D., Shakoor, Tariq, Javed, Shahid, Mashhadi, S.T.A., and Ghaznavi, M.I., 1990, Chemical and physical characteristics of coal and carbonaceous shale samples from the Salt Range coal field, Punjab Province, Pakistan: U.S. Geological Survey Open-File Report 90–524, 44 p.

Warwick, P.D., and Wardlaw, B.R., 1992, Paleocene-Eocene stratigraphy in northern Pakistan—Depositional and structural implications [abs.]: Himalaya-Karakoram-Tibet Workshop Programme and Abstracts, 7th, Department of Earth Sciences, Oxford University, U.K., p. 97.

Wells, N.A., 1984, Marine and continental sedimentation in the early Cenozoic Kohat Basin and adjacent northwestern Indo-Pakistan: Ann Arbor, University of Michigan, Ph.D. dissertation, 465 p.

Whitney, Gene, Abbas, S.Q., and Esposito, Kenneth, 1990, Mineralogy and thermal properties of clay deposits in the Salt Range and Kala Chitta Range, Punjab Province, Pakistan: U.S. Geological Survey Open-File Report 90–657, 114 p.

Wynne, A.B., 1880, On the Trans-Indus extension of the Punjab Salt Range: Geological Survey of India Memoir, v. 17, pt. 2, 95 p.

APPENDIX I. MEASURED SECTIONS AND SAMPLE LOCATIONS FROM THE SURGHAR AND SALT RANGE COAL FIELDS, NORTHERN PAKISTAN

[Note: All sections were measured with a Jacob's staff where possible or were measured on a cliff face with a 30-m measuring tape. Thicknesses shown are true thicknesses. Numerical rock codes (numerals in parentheses following rock type) follow Ferm and others (1985). Designations in bold are sample numbers. See text-table 1 for analyst, age, and location data for samples]

SECTION 1. SECTION OF CRETACEOUS AND PALEOCENE ROCKS IN THE SURGHAR RANGE, LOWER LUMSHIWAL NALA

[The section is in the downfaulted block of the Lumshiwal and Hangu Formations below working coal mines. Samples were collected for pollen analysis. The approximate location is lat 32°51' N., long 71°08'45" E. on Survey of Pakistan 1:50,000-scale topographic sheet 38 P/1. Measured by Peter D. Warwick and Tariq Shakoor on October 20, 1990 (revised from unpublished notes of Shahid Javed, S. Tahir A. Mashhadi, and A. Latif Khan, Geological Survey of Pakistan, 1989)]

		Thickness (meters)
Lockhart Limestone (lowermost part):		
27.	Limestone (890), nodular, fossiliferous with foraminifers	Not measured
Hangu Formation:		
26.	Covered (000), thickness estimated	1.83
25.	Sandstone (543), light-gray, with gray claystone interbeds, quartzose interbeds, flat-bedded, thickness estimated	4.57
24.	Mudstone (320/120), dark-gray, thickness approximate	1.52
23.	Sandstone (543), light-gray, with gray claystone interbeds, more shaly at places	1.98
22.	Claystone (120), dark-gray, mostly covered	.30
21.	Mudstone (332), light-gray, gray claystone layers, burrows, sandy in places	.61
20.	Carbonaceous shale (123/023) with coaly streaks, weathered, possible upper coal bed locally mined (see section 2, units 1B and 2B, for description and location of upper coal bed samples); same interval as **SAMPLE NF89P–5**	.52
19.	Mudstone (323), dark-gray, clay streaks, rooted, burrowed	.46
18.	Sandstone (543), light-gray, clay interbeds, flat-bedded, fine-grained, burrows	2.44
17.	Carbonaceous shale (123), dark-gray, sandy streaks, burrows, **SAMPLE PW–90–5**	1.52
16.	Mudstone (332), light-gray, claystone streaks, burrows, **SAMPLE NF89P–4**	.91
15.	Sandstone (540), light-gray, massive to flat-bedded, fine-grained	.61
14.	Mudstone (332), light-gray, sandy in places, burrows, thin carbonaceous shale layers	1.68
13.	Claystone (124), dark-gray, massive	.15
12.	Mudstone (332), light-gray, with coal streaks, burrowed, flat-bedded	2.13
Section moves laterally west, up the canyon to better exposures		
11.	Carbonaceous shale (123), coaly, **SAMPLE PW–90–4**	.61
10.	Mudstone (332), light-gray, iron-stained, coarsens upward into sandstone	4.57
9.	Carbonaceous shale (123/022) with coaly layers, weathered, should be lower coal bed locally mined (see section 2, unit 2A, 3A, and 4A for description and location of samples from lower seam)	.46
8.	Claystone (120), dark-gray, carbonaceous, fissile, flat-bedded, **SAMPLE PW–90–3**	.76
	Total Hangu Formation	27.63
Lumshiwal Formation (upper part):		
7.	Sandstone (540), light-gray, medium-grained, fining upward, coaly spars, and rooted, fractured, fewer iron stains than below (lower part is probable interval of **SAMPLE NF89P–3**)	2.29
6.	Claystone (123), brownish-black (5*YR* 2/1), carbonaceous, coaly streaks with resins, **SAMPLE PW–90–2** (same interval as **SAMPLE T–SH–2** and probable interval of **SAMPLE NF89P–2**	.30
5.	Mudstone (332), medium-reddish-brown, mottled, burrows in places, upper 0.30 m rooted	2.29
4.	Sandstone (543), thin claystone interbeds, moderate-reddish-brown (10*R* 4/6), coarse-grained at base, mottled throughout, beds about 15 cm thick	1.37
3.	Sandstone (544), light-gray, fine- to medium-grained, quartzose, mottled, upper part burrowed, iron-stained in cracks	1.52
2.	Mudstone (322), medium-gray (*N* 4), clayey in places with carbonaceous and coaly streaks, ironstone nodules, **SAMPLE PW–90–1** (same interval as **SAMPLE K–SH–1** and probable interval of **NF89P–1**	.70
1.	Sandstone (544), quartzose, fine- to medium-grained, flat bedded to low-angle cross beds	+6.00
Section starts near the base of the Lumshiwal Formation		

SECTION 2. MINE SECTION OF PALEOCENE ROCKS IN THE SURGHAR RANGE, LUMSHIWAL NALA MINE, MAKARWAL

[Mine section from Pakistan Mineral Development Corporation (PMDC) mine, Haq tunnel 1, Maadan-e-Haq, at Lumshiwal Nala. The Makarwal coal bed is about 18 m below the upper coal bed, according to Mr. Haq, PMDC

Chief Geologist (Makarwal Operations). The approximate location is lat 32°51' N., long 71°08'45" E. on Survey of Pakistan 1:50,000-scale topographic sheet 38 P/1. The section was measured by Shahid Javed, Peter D. Warwick, S. Tahir A. Mashhadi, and A. Latif Khan on April 2, 1989. The coal samples were collected by Peter D. Warwick on Oct. 30, 1989. Samples also were collected for pollen analysis]

Unit	Description	*Thickness (meters)*
	Hangu Formation (in part):	
	Upper coal bed:	
3B.	Mudstone (327), carbonaceous, sandy, pyritic, rooted, resins	0.30
2B.	Coal (020), bright, resins, cleats, gypsum along fractures, thin clayey stringers scattered throughout, **SAMPLE MK–HT–1**	.6
1B.	Claystone (124), dark-gray (*N* 3), carbonaceous, tiny sand inclusions, pyritic, **SAMPLE SH–MK–HT–1**	.15
	Makarwal coal bed:	
4A.	Coal (020), bright, resins, pyritic in veins, banded, **SAMPLE MK–HT–3**. About 0.30 m of coal at base is not exposed or sampled	1.46
3A.	Claystone (124), dark-gray (*N* 3), massive, coal streaks, **SAMPLE SH–MK–HT–2**	.30
2A.	Coal (020), bright, resinous, **SAMPLE MK–HT–2**	.76
1A.	Claystone (123), dark-gray (*N* 3), carbonaceous, abundant coal stringers, resins	.30

SECTION 3. SECTION OF CRETACEOUS AND PALEOCENE ROCKS IN THE SURGHAR RANGE, UPPER LUMSHIWAL NALA

[The section is located in the Surghar Range, Lumshiwal Nala, adjacent to and above working mine facilities. Mined coal beds are not well exposed in outcrop. The approximate location is lat 32°51' N., long 71°08'45" E. on Survey of Pakistan 1:50,000-scale topographic sheet 38 P/1. Measured by Shahid Javed, Peter D. Warwick, S. Tahir A. Mashhadi, and A. Latif Khan on April 2, 1989]

Unit	Description	*Thickness (meters)*
	Lockhart Limestone (lower part):	
25.	Limestone (990), pale-yellowish-brown (10*YR* 6/2), fossiliferous with pelecypods	Not measured
	Hangu Formation:	
24.	Mudstone (400), light-brownish-gray, slightly calcareous	3.05
23.	Covered (000), probably mudstone, slightly calcareous	4.57
22.	Sandstone (541), grayish yellow (5*Y* 8/4), fine- to medium-grained, quartzose, soft, friable, iron-stained, burrowed, low-angle crossbeds, black metallic minerals	7.01
21.	Mudstone (333), light-brownish-gray, carbonaceous	5.18
20.	Sandstone (541), pinkish-gray (5*YR* 8/1), quartzose, coarse-grained, rounded grains, some black metallic minerals, scoured base, sharp contact, burrowed, crossbedded	3.50
19.	Mudstone (338), light-brownish-gray, burrowed, iron-stained, plant material	1.68
18.	Sandstone (548), moderate-greenish-yellow (10*Y* 7/4), fine-grained, burrowed, ferruginous at places, massive	.91
17.	Mudstone (333), light-brownish-gray, burrowed, iron-stained, fine mica specks	4.57
16.	Mudstone (137), light-brownish-gray, carbonaceous matter	1.52
15.	Claystone/ironstone (124), moderate-reddish-brown (10*R* 4/6), iron nodules	1.07
14.	Carbonaceous shale (123), light-olive-gray, sand and silt intermixed	.61
	Total Hangu Formation	33.67
	Lumshiwal Formation (in part):	
13.	Sandstone (548), yellowish-gray (5*Y* 7/2), fine- to coarse-grained, medium-bedded, burrowed, iron-stained, massive	4.94
12.	Mudstone (330), light-gray, carbonaceous matter, iron staining	.15
11.	Sandstone (548), fine-grained, more burrowed than below	1.68
10.	Sandstone (540), very light-gray (*N* 8), coarse-grained, quartzose, rounded grains, iron-stained, some black minerals (may be ilmenite), low-angle flat beds, burrowed, small scours, possibly beach facies	7.92
9.	Sandstone (541), same as unit 7, more massive	3.81
8.	Sandstone (541), same as unit 7	6.71
7.	Sandstone (541), grayish-pink (5*R* 8/2), coarse-grained interbeds, crossbedded, large tabular crossbeds, iron staining, ferruginous, friable, calcareous, iron nodules, coal specks, coarsening-upward sequence, upper part becoming trough crossbedded. Paleocurrent direction is N. 80° E. or S. 80° W., as indicated by small-scale trough crossbeds 0.35 m wide and 8 cm high	16.46
6.	Arenacious limestone (800), light-gray (*N* 7) to medium-light-gray (*N* 6), glauconitic, coarse quartz grains, ironstone concretions	1.22
5.	Sandstone (540), pale-yellowish-brown, coarse-grained, quartz pebbles	.21
4.	Sandstone (548), pale-yellowish-brown, fine-grained, thick-bedded, burrowed, iron-stained	8.84
3.	Sandstone (540), pale-yellowish-brown, coarse-grained, massive quartz pebbles up to 2 mm, sharp contact with the lower strata	.46
2.	Sandstone (548), same as unit 1	10.97
1.	Sandstone (548), pale yellowish-brown (10*YR* 6/2), fine-grained, burrowed, flat-and thick-bedded, carbonaceous streaks, iron-stained along fractures, ferruginous in places, friable	10.36

Section starts in the lower part of the Lumshiwal Formation.

SECTION 4. SECTION OF CRETACEOUS AND PALEOCENE ROCKS IN THE SURGHAR RANGE, CHARLES MINE, SIDDIQUI NALA, NORTH MAKARWAL

[The section is located in the Surghar Range, Siddiqui Nala, at the abandoned Charles mine workings that are above the Pakistan Mineral Development Corporation central tunnel and were described by Danilchik and Shah (1987). Samples were collected for pollen analysis. Dip ranges from 26° W. to 45° W. Measurements were made to approximate true thicknesses. The approximate location is lat 32°47'30" N., long 71°08'45" E. on Survey of Pakistan 1:50,000-scale topographic sheet 38 P/1. Measured by Shahid Javed, Peter D. Warwick, S. Tahir A. Mashhadi, and A. Latif Khan on April 3, 1989]

	Thickness (meters)
Lockhart Limestone (lower part):	
39. Limestone (996), light-gray (*N* 7), nodular	Not measured
Hangu Formation:	
38. Claystone (423) with limestone interbeds, transitional with overlying limestone	0.91
37. Sandstone (548), same as unit 36	4.57
36. Sandstone (548), yellowish-gray, fine-grained, burrowed, iron-stained, carbonaceous matter	4.88
35. Mudstone (333), yellowish-gray, burrowed, carbonaceous streaks, iron-stained, flat-bedded	1.83
34. Limestone (996), light-gray, fossiliferous (foraminifers), nodular	1.37
33. Mudstone (330), light-gray (*N* 7)	4.57
32. Limestone (800), very light-gray, silty	.36
31. Sandstone (748), yellowish-gray, fine-grained, abundant coal streaks and carbonaceous matter	2.44
30. Carbonaceous shale (123), dusky-brown (5*YR* 2/2), carbonaceous	.30
29. Sandstone (548), yellowish-gray, fine- to medium-grained, calcite cement, iron-stained, upper part contains carbonaceous matter, coal streaks, burrowed, rooted	5.18
28. Sandstone (548), yellowish-gray, fine- to medium-grained, burrowed, iron-stained at places, upper part contains lime cement	16.76
27. Sandstone (543), yellowish-gray, fine- to medium-grained, carbonaceous matter, interbedded with subordinate mudstone and carbonaceous shale beds, burrowed	2.29
26. Sandstone (540), dark-yellowish-orange (10*YR* 6/6), coarse-grained, coal streaks	.76
25. Coal (020), weathered, **SAMPLE T–SH–3**	1.83
24. Mudstone (133), brownish-gray (5*YR* 4/1), carbonaceous, burrowed	.91
23. Claystone (132), light-brownish-gray, carbonaceous	.27
Total Hangu Formation	49.23
Lumshiwal Formation (in part) (the contact with the Hangu Formation is not clear):	
22. Sandstone (544), olive-gray (5*Y* 4/1), fine-grained, abundant carbonaceous matter	0.36
21. Claystone (133), light-brownish-gray, carbonaceous	.30
20. Sandstone (548), same as unit 18, upper few centimeters are more ferruginous	7.62
19. Coal (020), weathered, powdery, has been mined, **SAMPLE K–SH–4**	.06
18. Sandstone (548), white (*N* 9) to very light-gray, quartzose, fine-grained, loose, friable, sugary, some black minerals, burrowed; in places, bands of rounded coarse sandstone nodules that are calcite cemented and ferruginous; upper part fine- to coarse-grained with some carbonaceous matter	3.96
17. Sandstone (548), yellowish-gray, (5*Y* 7/2), fine-grained, massive, burrowed, iron-stained, local dip is 26° W.	1.22
16. Mudstone (338), yellowish-gray (5*Y* 7/2), thin-bedded, carbonaceous, burrowed, **SAMPLE K–SH–3**	1.07
15. Sandstone (548), yellowish-gray (5*Y* 7/2), fine-grained, massive, burrowed, iron-stained	2.13
14. Mudstone (334), grayish-orange to light-brownish-gray (5*YR* 6/1), carbonaceous material, thin-bedded, burrowed	6.40
13. Sandstone (640), medium- to coarse-grained, calcareous cement, ferruginous-rich iron bands, glauconitic	.76
12. Sandstone (548), medium-light-gray (*N* 6), fine-grained, argillaceous, burrowed, iron-stained, iron concretions	1.83
11. Mudstone/sandstone (328), dark-gray (*N* 3), carbonaceous, burrowed, iron-stained, **SAMPLE K–SH–2**	.61
10. Sandstone (541), same as unit 6	4.11
9. Claystone (124), dark-gray, carbonaceous	.15
8. Sandstone (541), same as unit 6, coarse-grained, large tabular crossbeds	11.58
7. Sandstone (541), same as unit 6	14.33
6. Sandstone (541), white (*N* 9) to light-gray, quartzose, coarse- to fine-grained, loose, friable, large-scale crossbeds, iron-stained, black minerals, thick-bedded to massive, rounded coarse sandstone nodules with calcareous cement in the upper part	11.89
5. Sandstone (541), yellowish-gray (5*Y* 7/2), very fine-grained, quartzose, large crossbeds in the upper part, burrowed, iron concretions	7.62
4. Sandstone (548), yellowish-gray (5*Y* 7/2), very fine-grained, argillaceous, abundant carbonaceous streaks, burrowed, iron-stained, massive	7.92
3. Sandstone (541), covered, same as unit 1	9.75
2. Sandstone (541), mostly covered, same as unit 1	15.54
1. Sandstone (541), very light-gray (*N* B), quartzose, very coarse-grained, soft, friable, iron-stained and concretions, burrowed, massive- to thick-bedded, occasionally crossbedded, occasional coarse to pebbly quartz bands	6.71

Section starts in the lower part of the Lumshiwal Formation.

SECTION 5. MINE SECTION OF PAKISTAN MINERAL DEVELOPMENT CORPORATION CENTRAL TUNNEL, NORTH MAKARWAL

[Because the main mine area was under repair, a coal channel sample was collected from a part of the coal bed left in a mined-out area. The roof had fallen at various places, and the coal face was inaccessible. A coal bed approximately 2.4 m thick was visible on one of the mine sides, but it was difficult to sample because of poor wall supports. Coal-bed thickness generally varies between 0.61 and 1.07 m. The maximum length of the mine is about 3,350 m, and the bed at the active mine face is about 1.37 m thick. The mine-mouth location is approximately lat 32°52'39" N., long 71°09'30" E. on Survey of Pakistan 1:50,000-scale topographic sheet 38 P/1. The section was measured, and the coal sample collected, by Shahid Javed and S. Tahir A. Mashhadi on April 9, 1989]

	Thickness (meters)
Hangu Formation (in part):	
3. Sandstone (550), very light-gray, quartzose, fine-grained, coal specks, iron-stained	+0.30
2. Coal (020), bright, vitreous, **SAMPLE MKCT–6**	.49
1. Sandstone (550), fine-grained, quartzose, iron-stained, carbonaceous matter	+.30

SECTION 6. SECTION OF CRETACEOUS AND PALEOCENE ROCKS IN THE SURGHAR RANGE, BAROCH NALA

[The section is located in the Surghar Range, Baroch Nala, north of Haji Maula Khan and Akhbar Badshah coal mines. Dip at the base of the section in the Lumshiwal Formation is about 52° NW., and strike is N. 28° E. Samples were collected for pollen analysis. The approximate location of the section is lat 32°55'35" N., long 71°08'50" E. on Survey of Pakistan 1:50,000-scale topographic sheet 38 P/1. The section was measured by Peter D. Warwick, Shahid Javed, and S. Tahir A. Mashhadi on April 4, 1989. The section was revisited and resampled by Peter D. Warwick, Tariq Shakoor, Edward Johnson, Edward Landis, James Fassett, and Shaukat Qureshi on October 20, 1990]

	Thickness (meters)
Lockhart Limestone (lower part):	
19. Limestone (890), light-gray, nodular, fossiliferous	Not measured
Hangu Formation:	
18. Sandstone (548), light-gray (*N* 7), very fine-grained, calcite cement, heavily burrowed, burrows occasionally filled with ferruginous material, thick-bedded to massive	8.23
17. Mudstone (118), black, carbonaceous, resins, heavily burrowed in the upper part where burrows are filled with sand, silty stringers throughout	1.83
16. Sandstone (548), yellowish-gray (5*Y* 8/1) to olive-gray (5*Y* 4/1), fine-grained, burrowed, flat-bedded, lower part friable	10.36
15. Mudstone (328), brownish-gray, carbonaceous material, burrowed, flat-bedded	1.22
14. Sandstone (548), yellowish-gray, fine-grained, abundant carbonaceous matter, heavily burrowed, iron-stained.	3.20
13. Carbonaceous shale (123), thickens across canyon where miners have tried excavations for coal, **SAMPLE PW–90–8**	.15
12. Sandstone (548), yellowish-gray, fine-grained, abundant carbonaceous matter, heavily burrowed, iron-stained..	4.57
11. Coal (022), black, sand-filled burrows in top of bed, sandy inclusions, several mines active, thickness varies, sampled thickness is 0.33 m thick, **SAMPLE PW–90–7**; see section 7........	.61
10. Claystone (124), light-olive-gray (5*Y* 4/4), iron-stained, pisolitic, spheres up to 5 cm in diameter, fractured, pyritic, possible paleosol, **SAMPLE PW–90–6**........	.91
Total Hangu Formation........	31.08
Lumshiwal Formation:	
9. Sandstone (541), very light-gray (*N* 8) to grayish-orange (10*YR* 7/4), coarse-grained, heavily burrowed, tabular crossbed sets, iron-stained	6.10
8. Claystone (123), dark-gray (*N* 3), carbonaceous, sandy, **SAMPLE K–SH–5**	1.04
7. Sandstone (541), white, quartzose, hard, friable, fine-grained, medium- and flat-bedded, small-scale tabular crossbeds, burrowed, iron-stained........	11.58
6. Sandstone (543) with claystone interbeds; sandstone is yellowish gray, fine grained, very thin bedded; claystone is interbedded with carbonaceous material, brownish-gray	9.14
5. Sandstone (541), generally yellowish-gray to dark-yellowish-orange, fine- to coarse-grained, burrowed, large tabular crossbed sets; mixed with dark-yellowish-brown sandstone that is quartzose and coarse grained, friable, iron stained, with thin carbonaceous claystone beds in the lower horizons........	15.24
4. Sandstone (540), dark-gray (*N* 3), sandy nodules, pyritic, coal specks, highly carbonaceous, burrowed, local diggings for possible coal in this unit........	.91
3. Sandstone (541), very light-gray to dark-yellowish-orange (10*YR* 6/6), coarse-grained, large tabular crossbeds, quartzose, friable, iron-stained, burrowed, carbonaceous matter........	19.81
2. Sandstone (541), very light-gray to dark-yellowish, quartzose, burrowed, thick-bedded, carbonaceous matter, iron-stained, coal streaks, coarse-grained, medium-bedded, crossbedded, with coarse quartz bands in the upper part, crossbed sets up to 1.2 m thick, tabular crossbeds, ferruginous bands	24.38
1. Sandstone (540), grayish-orange (10*YR* 7/4) to yellowish-gray (5*Y* 7/2) and grayish-yellow (5*Y* 8/4), fine-grained, iron-stained in bands, carbonaceous matter, massive- to very thick-bedded, Fatmi (1972) collected the fossils *Gryphaea* and *Hibolithes* from the basal 3m of this unit	30.48
Total Lumshiwal Formation........	118.68

Section starts at the base of the Lumshiwal Formation.

SECTION 7. MINE SECTION OF PALEOCENE ROCKS IN THE SURGHAR RANGE, MALLAR KHEL

[Mine section from the Pakistan Mineral Development Corporation Sardar Wilayat Shah mine, north incline, level No. 1. Dip of the rocks is about 49° N. The approximate location of the mine mouth is lat 32°55'35" N., long 71°8'50" E. on Survey of Pakistan 1:50,000-scale topographic sheet 38 P/1. The section was measured by Shahid Javed and S. Tahir A. Mashhadi on April 10, 1989. A channel sample of coal from the working face was collected by Shahid Javed on Oct. 30, 1989, for chemical and physical characterization]

	Thickness (meters)
Hangu Formation (in part):	
3. Claystone (133), medium-gray to medium-light-gray, coaly specks, claystone has a plastic and swelling behavior at the coal contact........	+0.30
2. Coal (020), bright, vitreous, top of bed heavily burrowed, **SAMPLE MKD3–7**. Coal thickness laterally swells and pinches; about 9.0 m south from the sample location, the bed is 1.50 m thick along a length of about 9.0 m, then farther south the bed thickness increases to 0.36 m and in places becomes 0.24 m........	.94
1. Sandstone (748), medium-gray (*N* 5), fine grained, coal streaks, carbonaceous matter........	+.30

SECTION 8. SECTION OF CRETACEOUS AND PALEOCENE ROCKS IN THE SURGHAR RANGE, LANDA PUSHA CANYON

[The section is located in the Landa Pusha stream canyon, north of the villages of Banda Girdhari and Doya. The base of the section is approximately located at lat 32°58'24" N., long 71°11'54" E. on Survey of Pakistan 1:50,000-scale topographic map 38 P/1. The section was measured by Shahid Javed and S. Tahir A. Mashhadi on April 6, 1989]

	Thickness (meters)
Lockhart Limestone (lower part):	
28. Limestone (996), fossiliferous, nodular	+15.00
Hangu Formation:	
27. Sandstone (643), same as unit 26, interbedded with limestone, light-gray (*N* 7)	3.05
26. Sandstone (558), white to yellowish-gray (5*Y* 7/2), fine-grained, some black minerals, quartzose, burrowed, iron-stained at places, carbonaceous material, medium-bedded	3.05
25. Sandstone (558), white to yellowish-gray (5*Y* 7/2), fine- to coarse-grained, some black minerals, quartzose, burrowed, calcareous cement in places, fine-grained in the upper part, iron-stained, carbonaceous material in places	14.33
24. Sandstone (551), very light-gray (*N* 8), medium- to coarse-grained, quartzose, hard, carbonaceous material, small crossbed sets, burrowed, medium- to thick-bedded	7.47
23. Coal (020), black (*N* 1), resin, sandy layers, bright, burrowed at top, burrows filled with sand, coal bed thickness ranges from 0.15 to 0.38 m	.38
22. Mudstone (137), brownish-gray, abundant carbonaceous matter, sandstone bands, rooted	.49
Total Hangu Formation	28.77
Lumshiwal Formation (in part):	
21. Sandstone (551), very light-gray (*N* 8), quartzose, fine-grained, friable, hard, iron-stained, carbonaceous material, flat- to crossbedded, some black minerals	16.76
20. Sandstone (548), pale-greenish-yellow (10*Y* 8/2), very fine-grained, burrowed, interbedded with claystone, brownish-gray (5*YR* 4/1) to dark-gray (*N* 3), carbonaceous	5.49
19. Sandstone (548), very light-gray (*N* 8), quartzose, fine-grained, burrowed, iron-stained, medium-bedded	1.83
18. Mudstone (113), black (*N* 1), carbonaceous, sandy	.12
17. Sandstone (548), very light-gray (*N* 8) to very pale-orange, burrowed, iron-stained	2.74
16. Claystone (113), carbonaceous, black (*N* 1)	1.22
15. Sandstone (558), very light-gray (*N* 8), fine-grained, quartzose, friable, burrowed, iron-stained, abundant carbonaceous matter	1.37
14. Mudstone (113), carbonaceous, black (*N* 1), sandy	.15
13. Sandstone (558), very light-gray (*N* 8), quartzose, coarse-grained, burrowed, carbonaceous material, friable, iron-stained, thick-bedded	2.29
12. Sandstone (551), black (*N* 1), clayey, carbonaceous	.30
11. Sandstone (551), same as unit 9	6.10
10. Sandstone (551), same as unit 9	13.41
9. Sandstone (551), very light-gray (*N* 8) to pale-yellowish-orange (10*YR* 8/6), quartzose, coarse-grained, iron-stained, bands of coarse quartz grains at intervals, iron-stained in places, flat-bedded	7.62
8. Sandstone (551), white to very light-gray (*N* 8), quartzose, friable, some black minerals, fine- to medium-grained, crossbedded, burrowed, iron-stained, coarse quartz bands at places	5.79
7. Sandstone (551), same as unit 6	5.18
6. Sandstone (551), very light-gray (*N* 8) to yellowish gray (5*Y* 7/2), quartzose, very fine-grained, friable, burrowed, bands of very coarse quartz grains in places, small tabular crossbed sets, iron-stained, medium- to thick-bedded, carbonaceous matter	4.57
5. Sandstone (543), same as unit 1	3.05
4. Sandstone (543), same as unit 1	7.01
3. Sandstone (543), same as unit 1, contains sandstone nodules (3.5-cm diameter) filled with ferruginous matter	10.06
2. Sandstone (543), same as unit 1	3.66
1. Sandstone (543), yellowish-gray (5*Y* 7/2), very fine-grained, argillaceous, burrowed, burrows filled with ferruginous matter, thick- to massive-bedded, calcite veins in places	9.14

Section starts in the lower part of the Lumshiwal Formation.

SECTION 9. MINE SECTION OF CRETACEOUS AND PALEOCENE ROCKS IN THE SURGHAR RANGE, GULA KHEL AREA

[The section is located in the large canyon north of the villages of Gula Khel and Narmia in the northeastern part of the Surghar Range. Along the line of section is the Makarwal New C Narmia mine where a coal sample was collected. The approximate location of the base of the section is lat 32°58'54" N., long 71°13'23" E. on Survey of Pakistan 1:50,000-scale topographic sheet 38 P/1. The section was measured by Shahid Javed and S. Tahir A. Mashhadi on April 5, 1989. One coal sample was collected by Shahid Javed on Oct. 30, 1989, for coal chemistry and physical characteristics]

	Thickness (meters)
Lockhart Limestone (lower part):	
23. Limestone (906), nodular	+15.24
Hangu Formation:	
22. Sandstone (548), yellowish-gray (5*Y* 7/2), fine- to medium-grained, medium- to thick-bedded, burrowed, iron-stained	9.14
21. Sandstone (543), very light-gray (*N* 8) to dark-gray, carbonaceous, fine-grained, burrowed, thin- to medium-bedded	.55
20. Sandstone (548), very light-gray (*N* 8) to yellowish-gray (5*Y* 7/2), fine-grained, ferruginous, burrowed	1.37
19. Claystone (123), dark-gray, carbonaceous	1.07
18. Sandstone (553), same as unit 17	.76
17. Sandstone (553), very light-gray (*N* 8) to yellowish-gray, fine-grained, quartzose, burrowed, flat-bedded, carbonaceous material, iron-stained, thin beds of carbonaceous shale in the lower part, some black minerals	6.10
16. Coal (020), black, weathered, pinches to 6 cm laterally, **SAMPLE MK–NCN–4**	.30
15. Mudstone (123), brownish-gray (5*YR* 4/1), silty carbonaceous matter, pyritic	.30
Total Hangu Formation	19.59
Lumshiwal Formation(?) (in part):	
14. Sandstone (748), very light-gray (*N* 8) to yellowish-gray (5*Y* 7/2), fine-grained, burrowed, abundant carbonaceous material, coal streaks	9.14
13. Mudstone (112), black (*N* 1), carbonaceous, coarse quartz grains	.20

12.	Sandstone (541), very light-gray, quartzose, coarse-grained, friable, carbonaceous material, iron-stained, some black minerals, medium- to thick-bedded, burrowed, coal specks	8.84
11.	Sandstone (543), black, carbonaceous	.15
10.	Sandstone (548), light-gray, carbonaceous material, fine- to medium-grained, iron-stained, burrowed	.30
9.	Sandstone (543), black, carbonaceous	.15
8.	Sandstone (551), same as unit 5	3.96
7.	Sandstone (551), same as unit 5	5.18
6.	Sandstone (551), same as unit 5, small tabular crossbed sets	10.97
5.	Sandstone (551), very light-gray (*N* 8), fine- to coarse-grained, quartzose, iron-stained, burrowed, large tabular crossbed sets, some black minerals, very coarse quartz grain bands in places	14.93
4.	Sandstone (551), very light-gray (*N* 8), fine- to coarse-grained, generally flat-bedded with some tabular crossbeds, iron-stained, some iron nodules, burrowed, bands of very coarse grains in places, some black minerals, quartzose	19.81
3.	Sandstone (551), very light-gray (*N* 8) to very pale-orange (10*YR* 8/2), quartzose, fine-grained, hard, friable, burrowed, iron-stained, carbonaceous material, crossbedded, medium- to thick-bedded	9.14
2.	Sandstone (553), very pale-orange (10*YR* 8/2), quartzose, burrowed, thick-bedded, fine-grained, some black minerals, iron-stained	9.45
1.	Sandstone (548), very light-gray (*N* 8) to dark-yellowish-orange (10*YR* 6/6), fine-grained, burrowed, burrows filled with ferruginous material, iron-stained, massive, carbonaceous material, ferruginous sandstone nodules 0.03 × 0.18 m	12.19

Section starts in the lower part of the Lumshiwal Formation.

SECTION 10. SECTION OF CRETACEOUS AND PALEOCENE ROCKS IN THE NORTHERN SURGHAR RANGE, KURD-SHO AREA

[The section is located north of the village of Nasriwala at the head of the large canyon of Wahan Bhoji. The location of the base of the section is approximately lat 32°01'10" N. and long 71°18'10" E. on Survey of Pakistan 1:50,000-scale topographic sheet 38 O/8 and was measured by Shahid Javed and S. Tahir A. Mashhadi on April 7, 1989]

		Thickness (meters)
Lockhart Limestone (lower part):		
20.	Limestone (896), fossiliferous, nodular, clayey	+15.24
Hangu Formation:		
19.	Sandstone (643), very light-gray (*N* 8) to grayish-yellow (5*Y* 8/4), fine-grained, carbonaceous bands in places	3.96
18.	Sandstone (548), yellowish-gray (5*Y* 7/2), fine-grained, argillaceous, iron-stained, ferruginous in places	8.53
17.	Sandstone/mudstone (548), yellowish-gray (5*Y* 7/2), fine-grained, argillaceous, carbonaceous, ferruginous material, thin-bedded	1.52
16.	Sandstone (748), same as unit 15, ferruginous	3.96
15.	Sandstone (748), very light-gray (*N* 8), fine- to coarse-grained, quartzose, coal streaks, burrowed, friable, iron-stained	3.35
14.	Mudstone (338), light-brownish-gray (5*YR* 6/1), burrowed, carbonaceous material, sandy nodules, resins	.91
13.	Coal (020), black (*N* 1), bright resins, associated with clay bands	.27
12.	Mudstone (333), light-brownish-gray interbedded with dark gray (*N* 3) claystone	8.84
11.	Carbonaceous shale (030), black (*N* 1), resins	.20
10.	Coal (020), black	.08
9.	Sandstone (543), very light-gray (*N* 8), fine-grained, burrowed, abundant carbonaceous material, iron-stained	.91
	Total Hangu Formation	32.53
Lumshiwal Formation (in part):		
8.	Sandstone (543), black (*N* 1), carbonaceous	0.08
7.	Sandstone (551), same as unit 6, fine- to medium-grained in the upper part	7.62
6.	Sandstone (551), very light-gray (*N* 8), to pale-yellowish-orange (10*YR* 8/6), coarse-grained, quartzose, large tabular crossbed sets, burrowed, iron-stained, bands of very coarse quartz in places, friable	9.14
5.	Sandstone (551), white (*N* 9) to very light-gray (*N* 8), thick-bedded, fine-grained, coarse-grained in the upper part, coarse quartz grains in bands at places, burrowed, iron-stained, crossbedded, quartzose, friable	7.01
4.	Sandstone (551), same as unit 3	10.97
3.	Sandstone (551), white (*N* 9) to very light-gray (*N* 8), unit 3, crossbedded in the upper part, bands of coarse quartz grains in the upper part	17.07
2.	Sandstone (558), very light-gray to pale-greenish-yellow (10*Y* 8/2), fine-grained, medium- to thick-bedded, quartzose, friable, burrowed, iron-stained, carbonaceous material	11.28
1.	Sandstone (548), very light-gray (*N* 8), fine-grained, massive, burrowed, iron-stained, carbonaceous material, argillaceous in the lower part	8.53

Section starts in the lower part of the Lumshiwal Formation.

SECTION 11. SECTION OF CRETACEOUS AND PALEOCENE ROCKS IN THE NORTHERN SURGHAR RANGE, CHICHALI PASS

[The section is located in Chichali Nala. Dip is about 40° W., strike is N. 65° E. Approximate location of the base of the section is lat 33°00'30" N., long 71°24'25" E. on Survey of Pakistan 1:50,000-scale topographic sheet 38 O/8. The section was measured by Shahid Javed, Peter D. Warwick, and S. Tahir A. Mashhadi on April 4, 1989. Samples were collected for pollen analyses]

		Thickness (meters)
Lockhart Limestone (lower part):		
10.	Limestone (906), light-gray, nodular	+22.00
Hangu Formation(?):		
9.	Covered (000), probably claystone or limestone	1.22
8.	Claystone (133), light-brownish-gray, carbonaceous, iron-stained, contains alum	3.66
	Total Hangu Formation	4.88
Lumshiwal Formation:		
7.	Claystone (123), black, carbonaceous	0.30
6.	Coal (020), dull, weathered, **SAMPLES K–SH–6, NF89P–8, NF89P–9**	.05
5.	Mudstone (337), olive-gray, rooted, iron-stained	.01
4.	Sandstone (558), very light-gray, fine-grained, quartzose, heavily burrowed	1.52

3. Sandstone (540), black, carbonaceous	.91
2. Sandstone (551), very light-gray, fine-grained, quartzose, friable, large tabular crossbed sets, carbonaceous matter, iron-stained, coarser and more ferruginous in the upper horizons, rounded fine sandstone nodules with calcite cement in the upper part, nodules with about 10-cm diameter	18.90
1. Sandstone (548), medium-dark-gray to light-olive-gray (5*Y* 6/1), fine-grained, thick-bedded to massive, heavily burrowed, carbonaceous material throughout, iron-stained	42.67
Total Lumshiwal Formation	64.36

Section starts in the lower part of the Lumshiwal or upper part of the Chichali Formation.

SECTION 12. SECTION OF CRETACEOUS AND PALEOCENE ROCKS IN THE NORTHERN SURGHAR RANGE, MUHABBAT KHEL

[The section is located near Pakistan Mineral Development Corporation mine E–3, north of the village of Muhabbat Khel. The approximate location of the base of the section is lat 32°59'52" N., long 71°25'31" E. on Survey of Pakistan 1:50,000-scale topographic sheet 38 P/5. The section was measured by Shahid Javed and S. Tahir A. Mashhadi on April 8, 1989]

	Thickness (meters)
Lockhart Limestone (lower part):	
20. limestone (996), light-gray, fossiliferous, nodular	+9.00
Hangu Formation:	
19. Mudstone (330), light-olive-gray (5*Y* 6/1)	.46
18. Sandstone (543), very light-gray (*N* 8), fine-grained, iron-stained	.76
17. Mudstone (434), light-olive-gray (5*Y* 6/1), with thin light-gray limestone interbeds	4.88
16. Sandstone (550), pale-reddish-brown, fine-grained, iron-stained, soft, friable, coarse quartz grains	.99
15. Mudstone (333), interbedded mudstone and claystone, light-brownish-gray to dark-gray, abundant carbonaceous material, highly carbonaceous in places	5.79
14. Carbonaceous shale (030), dark-gray	.30
13. Sandstone (548), very light-gray, very fine-grained, argillaceous, abundant carbonaceous material, burrowed	2.74
12. Sandstone (743), yellowish-gray, quartzose, fine- to medium-grained, coal streaks, heavily burrowed, flat-bedded	1.98
11. Claystone (123), dark-gray (*N* 3), carbonaceous material abundant	1.52
10. Coal (020), bright, sandy layers in lower parts	.46
9. Sandstone (748), very light-gray, fine-grained, quartzose, abundant coal streaks, with 0.61-m-thick coal band in middle	.91
8. Coal (020), black, bright, sandy inclusions	.33
7. Sandstone (743), very light-gray, fine-grained, quartzose, carbonaceous material, abundant coal streaks, thin coal layers at intervals, rooted	1.83
Total Hangu Formation	22.95
Lumshiwal Formation (in part):	
6. Claystone (123), dark-gray (*N* 3), carbonaceous, resins	0.08
5. Sandstone (748), very light-gray, fine-grained, friable, abundant coal streaks	.27
4. Sandstone (543), black, carbonaceous	.08
3. Sandstone (550), dark-gray (5*Y* 7/2), coarse-grained, bands of very coarse quartz grains in places, carbonaceous material, coal streaks	1.83
2. Sandstone (548), dark-gray, fine-grained, carbonaceous, burrowed	.09
1. Sandstone (548), grayish-yellow, fine-grained, burrowed, carbonaceous material, massive	5.49

Section starts in the lower part of the Lumshiwal Formation.

SECTION 13. MINE SECTION OF PALEOCENE ROCKS IN THE NORTHERN SURGHAR RANGE, MUHABBAT KHEL

[Mine section from Pakistan Mineral Development Corporation lease area, mine E–3, gate 1, tunnel 1, near the village of Muhabbat Khel. The mine is located at Muhabbat Khel at lat 32°59'52" N., long 71°25'31" E. on Survey of Pakistan 1:50,000-scale topographic sheet 38 P/5. The section was measured by Shahid Javed and S. Tahir A. Mashhadi on April 8, 1989. Composite coal channel sample was collected by Shahid Javed on Oct. 30, 1989, for chemical and physical characterization]

	Thickness (meters)
Hangu Formation (in part):	
5. Sandstone (550), very light-gray, fine-grained, quartzose, friable, abundant coal streaks	+0.30
4. Coal (020), bright, sandy inclusions, **SAMPLE MKE 3–5** (combined with unit 2)	.23
3. Sandstone (748), very light-gray, fine-grained, quartzose, abundant coal streaks	.52
2. Coal (020), bright, sandy layers, **SAMPLE MKE 3–5** (combined with unit 4)	.30
1. Sandstone (748), very light-gray, fine-grained, abundant coal streaks, burrowed, quartzose	+.30

SECTION 14. SECTION OF JURASSIC, CRETACEOUS, AND PALEOCENE ROCKS IN THE WESTERN SALT RANGE, NAMMAL PASS

[The section is located about 0.4 km south of the Mianwali-Talagang road, in a small canyon cutting the Jurassic to Tertiary section in the western Salt Range. Beds dip approximately 45° NE. Section starts in the upper part of the Jurassic Datta Formation and continues to the Paleocene Lockhart Limestone. Samples were collected for pollen analysis. The approximate location of the section is lat 32°40'30" N., long 71°47'10" E. on Survey of Pakistan 1:50,000-scale topographic sheet 38 P/14. The section was measured by Peter D. Warwick and Tariq Shakoor on November 15, 1990]

	Thickness (meters)
Lockhart Limestone (lower part):	
19. Limestone/marly claystone (800), partly covered	+6.00
Hangu Formation:	

18. Mudstone (300), mostly covered, marly in places, thickness estimated 7.62
17. Mudstone (337), light-gray, rooted, partly covered, locally displaced, includes thin carbonaceous shale layers that laterally develop into beds (several centimeters thick) of carbonaceous shale with coaly streaks, mudstone **SAMPLE PW–90–13**, carbonaceous shale **SAMPLE NF89P–10**, with roof above carbonaceous shale **SAMPLE NF89P–11** 3.66
16. Sandstone (540), light-gray, flat-bedded, weathered, stained red 10.97
15. Claystone (133), light-gray, massive, bauxitic, locally mined, complete leaf fossil found, claystone for pollen **SAMPLE PW–90–12** 7.62

    Total Hangu Formation 29.87

Lumshiwal and Datta Formations, undivided (in part):

14. Sandstone (540/543) with claystone interbeds, light-gray, iron-stained in places, flat-bedded 2.13
13. Carbonaceous shale/mudstone (123/322), interbedded with fine sandstone, locally bauxitic, **SAMPLE PW–90–11** .... .82
12. Sandstone (543), light-gray, claystone interbeds, flat-bedded, rippled 3.35
11. Sandstone (541), light-gray, medium-grained, very quartzose, crossbedded, scoured base 5.49
10. Claystone (122), dark-gray, silty layers, **SAMPLE PW–90–10** .... .15
9. Sandstone (543), light-gray, interbedded with claystone, flat-bedded 1.22
8. Claystone (122), dark-greenish-gray, siltstone layers .... .15
7. Sandstone (540), light-gray, fine- to medium-grained, bedded with 0.30-m-thick beds, clayey breaks 6.40
6. Sandstone (543), light-gray with iron stains, interbedded with claystone, burrowed, flat-bedded .... .30
5. Sandstone (543), light-gray, interbedded with claystone, flat-bedded .... .79
4. Mudstone (332), light-gray, layers of claystone .... .30
3. Sandstone (543), light-gray, interbedded with claystone, flat-bedded .... .61
2. Claystone (122), dark-gray, stained yellow, silty, **SAMPLE PW–90–9** .... .30
1. Sandstone (540), light-gray, iron-stained quartzose, medium-grained, rooted(?) 15.24

Section starts in upper part of the Datta Formation(?) at the top of a red quartzose sandstone; the contact between the Datta and Lumshiwal Formations is not clear.

APPENDIX II. BACKGROUND DATA AND ANALYTICAL RESULTS FROM COAL SAMPLES FROM THE SURGHAR RANGE, NORTHERN PAKISTAN (TABLES II–1 TO II–3)

Table II–1. Background data for Surghar Range coal samples.

[Key, National Coal Resource Data System (NCRDS) reference number (sample information for Key numbers 602 to 611 are from Landis and others, 1971, and are not part of the NCRDS data system); LABNO, laboratory number; POINTID, sample number; QUAD, Survey of Pakistan 1:50,000 topographic sheet; DATE, date collected; SAMPTHK, sampled coal-bed thickness, in meters; SAMPTYP, sample type; ANAL, analysis type; VALREP, number of analytical values (single or multiple samples); ESTRANK, estimated rank; LOCNAME, location name; S, section; U, unit (appendix I, this report); NDE, no data entered; USBM, U.S. Bureau of Mines]

KEY	LABNO	POINTID	COLLECTOR	LATITUDE	LONGITUDE	QUAD	DATE
372	W235587	85-MK-004	GSP-GHAZNAVI	325200000N	710900000E	38 P/1 (15')	860403
373	W235588	85-MK-005	GSP-GHAZNAVI	325300000N	710900000E	38 P/1 (15')	860403
374	W235589	85-MKGL-006	GSP-GHAZNAVI	330000000N	711400000E	38 P/1 (15')	860403
572	W239745	85MIG123	GSP-GHAZNAVI	325810000N	711110000E	38 P/1 (15')	870325
929	T434033	MK-HT-3	USGS-WARWICK	325100000N	710845000E	38 P/1 (15')	891030
930	T434034	MK-HT-2	USGS-WARWICK	325100000N	710845000E	38 P/1 (15')	891030
931	T434035	MK-HT-1	USGS-WARWICK	325100000N	710845000E	38 P/1 (15')	891030
937	T434041	MKCT-6	GSP-JAVED	325239000N	710930000E	38 P/1 (15')	890409
938	T434042	MK-NCN-4	GSP-JAVED	325854000N	711323000E	38 P/1 (15')	891030
941	T434045	MKE 3-5	GSP-JAVED	325952000N	712531000E	38 P/1 (15')	891030
942	T434046	MKD3-7	GSP-JAVED	325535000N	710850000E	38 P/1 (15')	891030
602	D-91602	NDE	USBM–Eyrich	NDE	NDE	38 P/1 (15')	NDE
603	D-91603	NDE	USBM–Eyrich	NDE	NDE	38 P/1 (15')	NDE
604	D-91604	NDE	USBM–Eyrich	NDE	NDE	38 P/1 (15')	NDE
605	D-91605	NDE	USBM–Eyrich	NDE	NDE	38 P/1 (15')	NDE
606	D-91606	NDE	USBM–Eyrich	NDE	NDE	38 P/1 (15')	NDE
607	D-91607	NDE	USBM–Eyrich	NDE	NDE	38 P/1 (15')	NDE
608	D-91608	NDE	USBM–Eyrich	NDE	NDE	38 P/1 (15')	NDE
609	D-91609	NDE	USBM–Eyrich	NDE	NDE	38 P/1 (15')	NDE
611	D-91611	NDE	USBM–Eyrich	NDE	NDE	38 P/1 (15')	NDE

KEY	COUNTRY	PROVINCE	DISTRICT	SAMPTHK	FORMATION	SYSTEM	SERIES	FIELD	BED NAME
372	PAKISTAN	PUNJAB	MIANWALI	0.91	HANGU	TERTIARY	PALEOCENE	MAKARWAL	MAKARWAL
373	PAKISTAN	PUNJAB	MIANWALI	2.29	HANGU	TERTIARY	PALEOCENE	MAKARWAL	MAKARWAL
374	PAKISTAN	PUNJAB	MIANWALI	0.74	HANGU	TERTIARY	PALEOCENE	MAKARWAL	MAKARWAL
572	PAKISTAN	PUNJAB	MIANWALI	NDE	HANGU	TERTIARY	PALEOCENE	MAKARWAL	MAKARWAL
929	PAKISTAN	PUNJAB	MIANWALI	1.46	HANGU	TERTIARY	PALEOCENE	MAKARWAL	UPPER BENCH, MAKARWAL
930	PAKISTAN	PUNJAB	MIANWALI	0.76	HANGU	TERTIARY	PALEOCENE	MAKARWAL	LOWER BENCH, MAKARWAL
931	PAKISTAN	PUNJAB	MIANWALI	0.67	HANGU	TERTIARY	PALEOCENE	MAKARWAL	UPPER
937	PAKISTAN	PUNJAB	MIANWALI	0.48	HANGU	TERTIARY	PALEOCENE	MAKARWAL	MAKARWAL
938	PAKISTAN	PUNJAB	MIANWALI	0.54	HANGU	TERTIARY	PALEOCENE	MAKARWAL	MAKARWAL
941	PAKISTAN	PUNJAB	MIANWALI	0.53	HANGU	TERTIARY	PALEOCENE	MAKARWAL	MAKARWAL
942	PAKISTAN	PUNJAB	MIANWALI	0.94	HANGU	TERTIARY	PALEOCENE	MAKARWAL	MAKARWAL
602	PAKISTAN	PUNJAB	MIANWALI	NDE	HANGU	TERTIARY	PALEOCENE	MAKARWAL	MAKARWAL
603	PAKISTAN	PUNJAB	MIANWALI	NDE	HANGU	TERTIARY	PALEOCENE	MAKARWAL	MAKARWAL
604	PAKISTAN	PUNJAB	MIANWALI	NDE	HANGU	TERTIARY	PALEOCENE	MAKARWAL	MAKARWAL
605	PAKISTAN	PUNJAB	MIANWALI	NDE	HANGU	TERTIARY	PALEOCENE	MAKARWAL	MAKARWAL
606	PAKISTAN	PUNJAB	MIANWALI	NDE	HANGU	TERTIARY	PALEOCENE	MAKARWAL	MAKARWAL
607	PAKISTAN	PUNJAB	MIANWALI	NDE	HANGU	TERTIARY	PALEOCENE	MAKARWAL	MAKARWAL
608	PAKISTAN	PUNJAB	MIANWALI	NDE	HANGU	TERTIARY	PALEOCENE	MAKARWAL	MAKARWAL
609	PAKISTAN	PUNJAB	MIANWALI	NDE	HANGU	TERTIARY	PALEOCENE	MAKARWAL	MAKARWAL
611	PAKISTAN	PUNJAB	MIANWALI	NDE	HANGU	TERTIARY	PALEOCENE	MAKARWAL	MAKARWAL

Table II–1. Background data for Surghar Range coal samples—Continued.

KEY	ANALYTICAL LABORATORY	SAMPTYP	ANAL	VALREP	ESTRAN	LOCNAME
372	USBM AND USGS	CHANNEL	AS RECEIVED	SINGLE	BITUMINOUS	NDE
373	USBM AND USGS	CHANNEL	AS RECEIVED	SINGLE	BITUMINOUS	NDE
374	USBM AND USGS	CHANNEL	AS RECEIVED	SINGLE	BITUMINOUS	NDE
572	USGS AND GEOCHEMICAL TESTING CO., SOMERSET, PA.	GRAB	AS RECEIVED	SINGLE	BITUMINOUS	NDE
929	DICKINSON LABORATORIES, INC., EL PASO, TEX.	CHANNEL	AS RECEIVED	SINGLE	BITUMINOUS	PMDC HAQ TUNNEL NO. 1 (S2, U4A)
930	DICKINSON LABORATORIES, INC., EL PASO, TEX.	CHANNEL	AS RECEIVED	SINGLE	BITUMINOUS	PMDC HAQ TUNNEL NO. 1 (S2, U2A)
931	DICKINSON LABORATORIES, INC., EL PASO, TEX.	CHANNEL	AS RECEIVED	SINGLE	BITUMINOUS	PMDC HAQ TUNNEL NO. 1 (S2, U2B)
937	DICKINSON LABORATORIES, INC., EL PASO, TEX.	CHANNEL	AS RECEIVED	SINGLE	BITUMINOUS	PMDC CENTRAL TUNNEL (S5, U2)
938	DICKINSON LABORATORIES, INC., EL PASO, TEX.	CHANNEL	AS RECEIVED	SINGLE	BITUMINOUS	MAKARWAL NEW C NARMIA (S9, U16)
941	DICKINSON LABORATORIES, INC., EL PASO, TEX.	CHANNEL	AS RECEIVED	SINGLE	BITUMINOUS	PMDC MINE E–3, (S13, U2,4)
942	DICKINSON LABORATORIES, INC., EL PASO, TEX.	CHANNEL	AS RECEIVED	SINGLE	BITUMINOUS	WILAYAT SHAH MINES (S7, U2)
602	USBM AND USGS	CHANNEL	AS RECEIVED	SINGLE	BITUMINOUS	GODARMAL MINE
603	USBM AND USGS	CHANNEL	AS RECEIVED	SINGLE	BITUMINOUS	CHARLES MINE
604	USBM AND USGS	CHANNEL	AS RECEIVED	SINGLE	BITUMINOUS	CHARLES MINE
605	USBM AND USGS	CHANNEL	AS RECEIVED	SINGLE	BITUMINOUS	OMPARKASH MINE
606	USBM AND USGS	CHANNEL	AS RECEIVED	SINGLE	BITUMINOUS	OMPARKASH MINE
607	USBM AND USGS	CHANNEL	AS RECEIVED	SINGLE	BITUMINOUS	OMPARKASH MINE
608	USBM AND USGS	CHANNEL	AS RECEIVED	SINGLE	BITUMINOUS	LANDOO MINE
609	USBM AND USGS	CHANNEL	AS RECEIVED	SINGLE	BITUMINOUS	LANDOO MINE
611	USBM AND USGS	CHANNEL	AS RECEIVED	SINGLE	BITUMINOUS	MINE-RUN COMPOSITE

Table II–2. Analytical results (proximate, ultimate, and physical test data) from Surghar Range coal samples.

[Key = National Coal Resource Data System (NCRDS) reference number (sample information for Key numbers 602 to 611 are from Landis and others, 1971, and are not part of the NCRDS data system); MOIS, moisture; VM, volatile matter; FC, fixed carbon; Ash, percent ash yield; H, hydrogen; C, carbon; N, nitrogen; O, oxygen; TS, total sulfur; SulS, sulfate sulfur; PyrS, pyritic sulfur; OrgS, organic sulfur; Btu, calorific value in British thermal units; N, number of samples; MIN, minimum value; MAX, maximum value; MEAN, arithmetic mean; sd, standard deviation; DEF, °C deformation temperature; SOF, °C softening temperature; FLD, °C fluid temperature; FSI, free swelling index; ADL, air dry loss; NDE, not determined. Values with qualifiers were excluded from statistical calculations. G, greater than the value shown. All values as percentage except Btu, DEF, SOF, FLD, FSI, and ADL. Refer to appendix table II–1 for sample background data]

Proximate-ultimate data, as-received basis

KEY	MOIS	ADL	VM	FC	Ash	H	C	N	O	TS	SulS	PyrS	OrgS	Btu
372	5.94	3.6	40.86	40.82	12.38	5.38	61.88	0.98	15.32	4.06	0.08	1.32	2.66	11310
373	6.24	NDE	41.53	44.00	8.23	5.43	65.23	0.98	14.71	5.42	NDE	NDE	NDE	11917
374	6.67	NDE	43.36	41.37	8.60	5.55	63.12	1.17	15.82	5.74	NDE	NDE	NDE	11604
572	7.73	5.75	43.94	39.81	8.52	5.46	59.92	0.98	18.47	6.65	0.60	2.70	3.35	10956
929	4.40	2.69	35.68	35.61	24.31	4.95	50.80	0.46	13.01	6.45	0.46	3.24	2.75	9516
930	4.82	2.52	38.89	45.98	10.31	5.40	63.83	0.79	14.79	4.84	0.08	1.02	3.74	11580
931	4.42	1.78	40.66	47.00	7.92	5.02	55.52	0.88	26.61	4.03	0.66	0.48	2.89	11621
937	6.17	4.05	38.56	44.09	11.18	5.36	59.91	0.74	18.68	4.09	0.63	0.82	2.64	10785
938	6.76	4.93	38.20	40.99	14.05	5.25	57.70	0.77	17.65	4.56	0.47	1.34	2.75	10466
941	4.09	2.07	33.46	36.76	25.69	4.60	52.49	0.59	13.6	3.01	0.06	0.46	2.49	9536
942	5.79	2.97	39.62	43.20	11.39	5.33	61.09	1.12	15.19	5.86	0.13	3.50	2.23	11096
602	5.00	NDE	44.90	41.10	9.00	5.50	64.90	0.20	16.00	4.40	NDE	NDE	NDE	11850
603	6.00	NDE	43.70	43.20	6.90	5.40	64.80	1.00	16.30	5.60	NDE	NDE	NDE	11800
604	4.50	NDE	42.90	36.30	16.30	5.20	58.10	0.90	14.10	5.40	NDE	NDE	NDE	10700
605	4.20	NDE	43.60	40.60	11.60	5.10	60.20	0.70	17.50	4.90	NDE	NDE	NDE	10900
606	4.30	NDE	37.10	38.20	20.40	4.60	52.60	0.60	16.90	4.90	NDE	NDE	NDE	9550
607	5.50	NDE	44.70	38.70	11.10	5.50	62.30	0.80	16.20	4.10	NDE	NDE	NDE	11400
608	5.80	NDE	45.30	40.10	8.80	5.50	63.30	0.90	16.40	5.10	NDE	NDE	NDE	11570
609	5.90	NDE	45.10	39.80	9.20	5.50	63.10	1.00	15.80	5.40	NDE	NDE	NDE	11510
611	4.20	NDE	42.10	39.20	14.50	5.00	60.20	0.50	14.60	5.20	NDE	NDE	NDE	11010
N:	20	9	20	20	20	20	20	20	20	20	9	9	9	20
MIN:	4.09	1.78	33.46	35.61	6.90	4.60	50.80	0.2	13.01	3.01	0.06	0.46	2.23	9516
MAX:	7.73	5.75	45.30	47.00	25.69	5.55	65.23	1.17	26.61	6.65	0.66	3.50	3.74	11917
MEAN:	5.42	3.37	41.21	40.84	12.52	5.25	60.05	0.80	16.38	4.98	0.35	1.65	2.83	11034
sd:	1.04	1.33	3.38	3.06	5.36	0.29	4.32	0.24	2.84	0.89	0.26	1.17	0.45	761

Proximate-ultimate data, dry basis

KEY	VM	FC	Ash	H	C	N	O	TS	SulS	PyrS	OrgS	Btu
372	43.44	43.40	13.60	5.01	65.79	1.04	10.69	4.31	0.08	1.40	2.83	12024
373	44.30	46.92	8.78	5.04	69.57	1.04	9.79	5.78	0.06	2.19	3.53	12710
374	46.46	44.33	9.21	5.15	67.63	1.26	10.60	6.15	0.16	2.99	3.00	12433
572	47.62	43.15	9.23	4.98	64.95	1.06	12.57	7.21	0.65	2.92	3.64	11874
929	37.33	37.24	25.43	4.67	53.14	0.48	9.51	6.75	0.48	3.39	2.88	9954
930	40.86	48.30	10.84	5.11	67.06	0.83	11.03	5.09	0.08	1.08	3.93	12166
931	42.54	49.18	8.28	4.74	58.09	0.92	23.74	4.21	0.69	0.50	3.02	12158
937	41.10	46.99	11.91	4.97	63.85	0.79	14.08	4.36	0.67	0.87	2.82	11494
938	40.97	43.96	15.07	4.82	61.88	0.83	12.49	4.89	0.50	1.44	2.95	11225
941	34.89	38.33	26.78	4.32	54.73	0.61	10.41	3.13	0.06	0.48	2.59	9943
942	42.05	45.86	12.09	4.97	64.85	1.18	10.67	6.22	0.13	3.72	2.37	11778
602	47.20	43.40	9.40	5.20	68.30	0.20	12.20	4.70	NDE	NDE	NDE	12470
603	46.50	46.20	7.30	5.10	68.90	1.00	11.80	5.90	NDE	NDE	NDE	12560
604	44.90	38.00	17.10	4.90	60.80	0.90	10.70	5.60	NDE	NDE	NDE	11200
605	45.50	42.40	12.10	4.80	62.90	0.80	14.30	5.10	NDE	NDE	NDE	11380
606	38.80	39.90	21.30	4.30	55.00	0.70	13.60	5.10	NDE	NDE	NDE	9980
607	47.30	41.00	11.70	5.20	65.90	0.80	12.00	4.40	NDE	NDE	NDE	12060
608	48.10	42.50	9.40	5.10	67.30	0.90	11.90	5.40	NDE	NDE	NDE	12290
609	48.00	42.20	9.80	5.10	67.10	1.00	11.30	5.70	NDE	NDE	NDE	12230
611	44.00	40.90	15.10	4.80	62.80	0.60	11.30	5.40	NDE	NDE	NDE	11490
N:	20	20	20	20	20	20	20	20	11	11	11	20
MIN:	34.89	37.24	7.30	4.30	53.14	0.20	9.51	3.13	0.06	0.48	2.37	9943
MAX:	48.10	49.18	26.78	5.20	69.57	1.26	23.74	7.21	0.69	3.72	3.93	12710
MEAN:	43.59	43.21	13.22	4.91	63.53	0.85	12.23	5.27	0.32	1.91	3.05	11671
sd:	3.75	3.38	5.55	0.26	4.91	0.25	3.01	0.96	0.27	1.18	0.47	857

Table II–2. Analytical results (proximate, ultimate, and physical test data) from Surghar Range coal samples—Continued.

Results of physical tests on Makarwal coal samples

KEY	DEF	SOF	FLD	FSI
372	2270	2490	2630	1.0
373	NDE	NDE	NDE	NDE
374	NDE	NDE	NDE	NDE
572	1930	1960	2100	0.5
929	2410	2450	2520	NDE
930	2540	2570	2630	NDE
931	2100	2130	2230	NDE
937	2060	2100	2290	NDE
938	2130	2150	2260	NDE
941	2700G	2700G	2700G	NDE
942	1950	1960	1980	NDE
602	2440	2540	2680	1.5
603	2090	2210	2380	2.5
604	2100	2190	2440	1.5
605	2390	2510	2600	1.0
606	2550	2650	2800	1.5
607	2510	2570	2700	1.5
608	2070	2140	2450	1.5
609	2000	2090	2210	1.5
611	2050	2260	2500	1.5
N:	17	17	17	11
MIN:	1930	1960	1980	0.5
MAX:	2550	2650	2800	2.5
MEAN:	2211	2292	2435	1.4
sd:	216	229	230	0.5

Table II–3. Major-, minor-, and trace-element data for Surghar Range coal samples.

[Key, National Coal Resource Data System reference number; N, number of samples; MIN, minimum value; MAX, maximum value; MEAN, arithmetic mean; sd, standard deviation; USGSASH, percent ash for trace-element data. Values with qualifiers were excluded from statistical calculations. L, less than the value shown; H, interference for an element that cannot be resolved by any routine method; B, sample was not analyzed]

Optical emission spectrographic analyses on coal ash (ppm)

KEY	Ag	Au	B	Ba	Be	Bi	Dy	Er
372	0.34	6.8L	750.0	180.0	16.0	10.0L	22.0L	4.6L
373	0.70	6.8L	800.0	140.0	17.0	10.0L	22.0L	4.6L
374	0.57	6.8L	860.0	150.0	32.0	10.0L	22.0L	4.6L
572	0.56	6.8L	650.0	170.0	76.0	22.0L	10.0L	4.6L
N:	4	0	4	4	4	0	0	0
MIN:	0.34		650	140	16.0			
MAX:	0.70		860	180	76.0			
MEAN:	0.54		765	160	35.2			
sd:	0.15		89	182	8.1			

KEY	Ga	Gd	Ge	Ho	In	Ir	Mo	Nb
372	43.0	32.0L	67.0	6.8L	10.0L	15.0L	150.0	50.0
572	55.0	22.0L	470.0	1.5L	6.8L	10.0L	57.0	20.0
N:	2	0	2	0	0	0	2	2
MIN:	43.0		67.0				57.0	20.0
MAX:	55.0		470.0				150.0	50.0
MEAN:	49.0		268.5				103.5	35.0
sd:	8.5		285.0				65.8	21.0

KEY	Nd	Ni	Os	Pd	Pr	Pt	Re	Rh	USGSASH
372	83.0	110.0	15.0L	1.00L	100.0L	2.2L	10.0L	2.2L	13.70
373	190.0	150.0	15.0L	1.00L	100.0L	2.2L	10.0L	2.2L	8.80
374	70.0	76.0	15.0L	1.00L	100.0L	2.2L	10.0L	2.2L	9.00
572	73.0	51.0	10.0L	0.68L	12.0	1.5L	10.0L	1.5L	9.00
N:	4	4	0	0	1	0	0	0	
MIN:	70	51.0							
MAX:	190	150.0							
MEAN:	104	112.0							
sd:	57.6	37.0							

KEY	Ru	Sn	Sr	Te	Tl	Tm	V	Y	Zr
372	2.2L	23.0	810.0	0B	10.0L	4.6L	380	0.0	270
373	2.2L	0.0H	780.0	0B	10.0L	4.6L	270	0.0	360
374	2.2L	0.0H	2400.0	0B	10.0L	4.6L	190	0.0	280
572	1.0L	48.0	2600.0	0B	10.0L	3.2L	110	77.0	190
N:	0	2	4	0	0	0	4	1	4
MIN:		23.0	780.0				110		190
MAX:		48.0	2600.0				380		360
MEAN:		35.5	1647.5				237		275
sd:		17.7	987.8				115		69

Table II–3. Major-, minor-, and trace-element data for Surghar Range coal samples—Continued.

Neutron activation analyses on whole coal (ppm)

KEY	As	Br	Ce	Co	Cr	Cs	Eu	Hf	La	Lu
372	7.10	3.78	23.1	2.63	34.4	0.71	0.442	2.07	12.10	0.1L
373	8.00	1.76	21.8	4.72	25.3	0.3L	0.335	1.49	11.30	0.093
374	2.44	4.81	11.0	1.76	11.0	0.2L	0.239	0.77	4.48	0.110
572	5.98	15.10	9.4	1.88	12.0	0.141	0.283	0.55	4.22	0.073
N:	4	4	4	4	4	2	4	4	4	3
MIN:	2.44	1.76	9.4	1.76	11.0	0.141	0.239	0.55	4.22	0.073
MAX:	8.00	15.10	23.1	4.72	34.4	0.710	0.442	2.07	12.10	0.110
MEAN:	5.88	6.36	16.3	2.75	20.7	0.425	0.324	1.22	35.25	0.092
sd:	2.44	5.96	7.1	1.37	11.2	0.400	0.087	0.69	57.26	0.018

KEY	Rb	Sb	Sc	Se	Sm	Ta	Tb	Th	U	W	Yb
372	50.0L	0.63	4.53	13.8	2.07	0.570	0.305	4.50	13.700	0.91	1.17
373	40.0L	0.27	2.68	19.1	1.57	0.570	0.191	4.00	1.390	0.46	0.63
374	30.0L	0.22	2.51	13.3	1.13	0.286	0.138	2.40	2.420	0.59	0.53
572	28.0L	0.20	2.88	7.4	1.38	0.134	0.195	1.82	0.906	0.45	0.51
N:	0	4	4	4	4	4	4	4	4	4	4
MIN:		0.20	2.41	7.4	1.13	0.134	0.207	1.82	0.906	0.45	0.51
MAX:		0.63	4.53	19.1	2.07	0.570	0.070	4.50	13.700	0.91	1.17
MEAN:		0.33	3.15	13.4	1.54	0.390	0.207	3.18	4.604	0.60	0.71
sd:		0.20	0.93	4.8	0.40	0.220	0.070	1.27	6.097	0.21	0.31

X-ray fluorescence analyses on coal ash

KEY	Al (ppm)	Al_2O_3 (percent)	Ca (ppm)	CaO (percent)	Fe (ppm)	Fe_2O_3 (percent)	K (ppm)	K_2O (percent)
372	1061.0	20.057	195	2.731	07800	15.42	118	1.400
373	1135.0	21.456	197	2.759	245900	35.16	39	0.469
374	889.7	16.819	341	4.776	292700	41.86	40	0.481
572	780.5	14.754	271	3.795	304100	43.48	62	0.745
N:	4	4	4	4	4	4	4	4
MIN:	780.5	14.754	195	2.731	107800	15.42	39	0.469
MAX:	1135.0	21.456	341	4.776	304100	43.49	118	1.418
MEAN:	966.5	18.271	251	3.515	237600	33.98	65	0.778
sd:	161.0	3.044	69	0.975	90100	12.89	37	0.445

KEY	Si (ppm)	SiO_2 (percent)	S (ppm)	SO_3 (percent)	Ti (ppm)	TiO_2 (percent)
372	231700	49.580	0.860	2.150	1.25	2.090
373	138900	29.720	0.997	2.493	1.98	3.311
374	115400	24.700	1.420	3.550	1.07	1.789
572	55708	11.935	3.300	8.250	0.45	0.752
N:	4	4	4	4	4	4
MIN:	113400	24.268	0.860	2.150	0.45	0.752
MAX:	231700	49.580	3.300	8.250	1.98	3.311
MEAN:	149800	32.067	1.644	4.110	1.19	1.980
sd:	113400	24.268	1.129	2.820	0.63	1.050

Table II–3. Major-, minor-, and trace-element data for Surghar Range coal samples—Continued.

Atomic absorption analyses on coal ash

KEY	USGSASH (percent)	Cu (ppm)	Li (ppm)	Mg (percent)	MgO (percent)	Na (percent)	Na_2O (percent)	Zn (ppm)
372	13.7	63	140	0.58	0.963	0.17	0.229	180
373	8.8	130	170	0.38	0.631	0.22	0.297	140
374	9.0	110	200	0.44	0.730	0.18	0.243	39
572	9.0	140	130	0.29	0.481	0.62	0.837	160
N:	4	4	4	4	4	4	4	4
MIN:	8.8	63	130	0.29	0.481	0.17	0.229	39
MAX:	13.7	140	200	0.58	0.963	0.62	0.837	180
MEAN:	10.1	111	160	0.42	0.700	0.29	0.401	130
sd:	2.4	34	32	0.12	0.200	0.21	0.292	63

KEY	Cd (percent)	Mn (percent)	Pb (percent)
372	0.32	110	65
373	0.32	93	20
374	0.28	200	69
572	0.60	12	22
N:	4	4	4
MIN:	0.28	212	22
MAX:	0.60	200	120
MEAN:	0.38	104	69
sd:	0.15	77	40

X-ray fluorescence analyses on whole coal

KEY	Cl (ppm)	P_2O_5 (ppm)
372	100L	0.011
373	100L	0.010
374	100L	0.010
572	150	2.840
N:	1	4
MIN:		0.010
MAX:		2,840
MEAN:		0.718
sd:		1.415

Wet chemical analyses (flameless atomic absorption) on whole coal

KEY	Hg (ppm)
372	0.005L
373	0.005L
374	0.005L
572	0.050
N:	1

Wet chemical analyses (specific ion electrode) on whole coal

KEY	F (ppm)
372	70
373	30
374	70
572	20L
N:	3
MIN:	30
MAX:	70
MEAN:	57
sd:	23

APPENDIX III. RESULTS OF PALYNOLOGICAL STUDIES ON ROCK SAMPLES FROM THE SURGHAR RANGE

[Note: The following are excerpts from two unpublished reports by Asrar M. Khan of the Hydrocarbon Development Institute of Pakistan. These reports have been edited by Peter D. Warwick to reflect only palynological results from the Surghar Range area. The original reports contained palynological results from other northern Pakistan coal fields. The locations of samples are given in text-table 1 and appendix I. The stratigraphic position of samples with age dates are shown on text-figure 4]

PALYNOSTRATIGRAPHY OF U.S. GEOLOGICAL SURVEY-GEOLOGICAL SURVEY OF PAKISTAN SAMPLES FROM THE MAKARWAL AREA

By ASRAR M. KHAN

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INTRODUCTION

Eight field samples (PW–90–1 to PW–90–8) from the Makarwal area were received from Peter Warwick, USGS, for palynostratigraphy. Only two samples, PW–90–1 and PW–90–3, yielded palynomorphs and age has been assigned, whereas six samples (PW–90–2, PW–90–4 to PW–90–8) were barren of palynomorphs.

PALYNOSTRATIGRAPHY

Sample PW–90–1.—The sample yielded abundant organic matter and a quantitatively and qualitatively rich microfloral assemblage. The assemblage includes *Inaperturopollenites* spp., *Zonalapollenites turbatus*, *Z. trilobatus*, *Zonalapollenites* spp. *Ginkgocycadophytus nitidus*, *Gleicheniidites senonicus*, *Deltoidospora juncta*, *Stereisporites antiquasporites*, *Trilobosporites apiverrucatus*, *Contignisporites glebulentus*, bisaccate pollen, *Vitereisporites* sp., *Podocarpidites* sp., *Cingutriletes clavus*, *Cycadopites* sp.?, *Hymenozonotriletes* sp., *Cyathidites minor*, *C. crassingulatus*, *Leiotriletes* sp., *Lycopodiumsporites* sp., *Taurocusporites* sp., *Appendicisporites* sp., *Equisetosporites* sp., *Ephedripites* sp., *Concavissimisporites punctuates*, *Cicatricosisporites hallei*, and *Appendicisporites* sp.

Age.—The above assemblage indicates an Early Cretaceous age for the sample.

Sample PW–90–2.—The sample yielded moderately rich black, carbonized organic particles. The sample is barren of palynomorphs.

Age.—Cannot be assigned.

Sample PW–90–3.—The sample is abundantly rich in dark organic matter and has yielded a rich palynoflora. The assemblage includes *Proxapertites operculatus*, *P. cursus*, *Spinizonocolpites bacculatus*, *S. echinatus*, *Araucariacites* sp., *Echitriporites* sp., *Longapertites vaneendenburgi*, *Verrutriletes* sp., *Echiperiporites* sp., *Tricolpites* sp., *Spinizonocolpites* sp., *Echitriporites trianguliformis*, *Ephedripites* sp., *Crassoretitriletes* sp., *Gemmatricolpites* sp., *Ischyosporites* sp., *Liliacidites* sp., *Psiladiporites* sp., *Polypodiisporites* sp., *Cyathidites australis*, *Retistephanocolpites williamsi*, *Triorites minutipori*, *Dandotiasporites* sp., *Foveotricolpites perforatus*, *Trisaccites* sp., and *Dyadosporites* sp. (fungal).

Age.—The above assemblage indicates a Paleocene age for the sample.

Sample PW–90–4.—The sample yielded a very low quantity of organic matter. The sample is barren of palynomorphs.

Age.—Cannot be assigned.

Sample PW–90–5.—The sample yielded sporadic particles of black organic matter. The sample is barren of palynomorphs.

Age.—Cannot be assigned.

Sample PW–90–6.—The sample yielded rich organic matter. Single occurrence of Spinizonocolpites sp. and *Triorites sp.*

Age.—Cannot be assigned.

Sample PW–90–7.—The sample yielded a very low quantity of organic matter. The sample is barren of palynomorphs.

Age.—Cannot be assigned.

Sample PW–90–8.—The sample yielded abundant dark-brown, unstructured organic matter. The sample is barren of palynomorphs.

Age.—Cannot be assigned.

OBSERVATIONS

Sample PW–90–1 appears to be of the same horizon as sample K–SH–5 or K–SH–1 of Early Cretaceous age, and sample PW–90–3 appears to be of the same horizon as K–SH–2 of Paleocene age.

PALYNOSTRATIGRAPHY OF U.S. GEOLOGICAL SURVEY SAMPLES FROM THE MAKARWAL AREA

By ASRAR M. KHAN

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INTRODUCTION

Of the 10 samples studied, 3 were barren of palynomorphs (SH–MK–HT–2, K–SH–3, and K–SH–4). The remaining seven samples yielded reasonably good mico-floral assemblage.

Sample SH–MK–HT–1.—The sample yielded abundant dark-colored organic matter. Only a few miospores, such as *Spinizonocolpites baculatus*, *Spinizonocolpites echinatus*, a monocolpote pollen, and a trilette spore were recovered.

The *Spinizonocolpites* spp. may indicate a Paleocene age.

Sample SH–MK–HT–2.—The sample yielded rich dark-colored, mostly unstructured organic matter. The sample is barren of palynomorphs.

Age cannot be assigned to this sample.

Sample K–SH–1.—The sample yielded moderately rich organic matter and also a rich microflora. The assemblage includes *Gleicheniidites cercinidites*, *Cyathidities australis Liliacidites* sp., *Lygodiumsporites* sp., *Grinkgocycadophytus nitidus*, *Zonalapollenites dampieri*, *Deltoidospora* sp., *Microcachryidites antarcticus*, *Matonisporites crassingulatus Cycadopites* sp., *Inaperturopollenites* sp., *Classopollis classoides*, *Sphagnites clavus*, *Phyllocladites* sp., *Cicatricosisporites australiensis*, *Cedripites* sp., *Vitreisporites pallidus*, *Pityosporites grandis*, *Zonalapollenites trilobatus*, and *Cingulatisporites* sp.

The above assemblage indicates a Late Jurassic to Early Cretaceous age.

Sample K–SH–2.—The sample yielded abundant organic matter, mostly unstructured. A rich microflora was recovered from the sediments. The assemblage includes *Lycpodiumsporites* sp., *Spinizonocolpites echinatus* (short), *Triorites* sp., (*Myrica type*) *Retistephanocoliptes* sp. Monoporate, Triporate (annulate) pollen *Spinizonocolpites echinatus* (medium), *Ephedrepites* sp., *Spinizonocolpites echinatus* (long), *Proxapertites* sp., *Longapertites* sp. (psilate), *Concavisporites* sp., *Tricolpopollenites* sp., *Spinizonocolpites baculatus*, *Lygodiumsporites* sp., *Echitricoliptes* sp., and *Triporites* sp.

The above angiospermic palynomorph assemblage indicates a Paleocene age for this sample.

Sample K–SH–3.—The sample yielded abundant unstructured, carbonized organic matter. The sample is barren of palynomorphs.

Age cannot be determined.

Sample K–SH–4.—The sample yielded abundant unstructured, carbonized organic matter. The sample is barren of palynomorphs.

Age cannot be determined.

Sample K–SH–5.—The sample yielded abundant organic matter and was rich in microflora. The palynofloral assemblage includes *Appendicisporites problematicus*, *Matonisporites crassingulatus*, *Tricolpites crassimurus*, *Cyathidites australis*, *Gleicheniidites cerciniditis*, *Podocarpidites* sp., *Camarazonosporites* sp., *Araucariacites australis*, *Zonalapollenites segmentatus*, *Baculatisporites truncatus*, *Z. trilobatus*, bisaccate pollen, *Concavisporites infirmus*, *Microcachryidites antarcticus*, *Contignisporites cooksoni*, *Cycadopites* sp.?, *Coupereisporites complexus*, *Vitreisporites* sp., *Rugubivesiculites* sp., *Lycopodiumsporites austroclavidites*, *Cicatricosisporitespotomaensis*, *Z. acusus*, *Classopolis* sp., *Cedripites* sp., *Acanthotriletes levendensis*, *Cingulatisporites* sp., *Pityosporites grandis*, *Ischyosporites* sp., and *Trilobosporites* sp.

The above palynofloral assemblage is indicative of a Late Jurassic to Early Cretaceous age.

Sample K–SH–6.—The sample yielded abundant dark-colored, unstructured organic matter. Only a few palynomorphs, such as *Retitricolpites Foveosporites* sp., *Lygodiumporites* sp., and *Cupuliferoidaeopollenites* sp., were found.

An Early Cretaceous age is assigned to this sample on the basis of *Cupuliferoidaepollenites* sp.

Sample T–SH–2.—The sample yielded abundant organic matter. The palynofloral assemblage includes *Classopollis classoides*, *Gleicheniidites cercinidites*, *Cyathidites* sp., bisaccate pollen, *Biretisporites* sp., *Zonalapollenites segmentatus*, *Cyathidites australis*, *Eucomiidites* sp., *Distalangulisporites perplexus*, *Concavisporites juriensis*, *Deltoidospora psilostoma*, and *Cancavisporite* sp.

The above palynomorph assemblage is indicative of an Early Cretaceous age. The absence of any angiospermic pollen also suggests an Early Cretaceous age for this sample.

Sample T–SH–3.—The sample yielded abundant organic matter. The microfloral assemblage includes *Classopollis classoides*, *Cyathidites* sp., *Zonalapollenites dampieri*, *Inaperturopollenites* spp., *Appendicisporites bilateralis*, *Entylissa* sp., *Ischyosporites* sp., *Densoisporites* sp., *Podocarpidites* sp., *Cyathidites australis*, *Sphagnites* sp., *Cingulatisporites* sp., and *Ginkgocycadophytus* sp. A few dinoflagellates, such as *Gonyaulacysta* sp. and *Balisphearidium* sp., were also encountered.

The above palynofloral assemblage indicates an Early Cretaceous age for this sample.

CONCLUSIONS

Ten grab samples were palynologically studied. Three samples (SH–MK–HT–2, K–SH–3, and K–SH–4) were barren of palynomorphs. Therefore, age cannot be assigned to these samples.

Two samples, SH–MK–HT–1 and K–SH–2, are of Paleocene age.

The remaining five samples (K–SH–1, K–SH–5, K–SH–6, T–SH–2, and T–SH–3) are of Late Jurassic to Early Cretaceous age. Late Jurassic and Early Cretaceous ages can be differentiated if sampling is performed in a continuous sequence.