UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

PROJECT REPORT
Pakistan Investigations
(IR)PK-55

# GEOLOGY AND COAL RESOURCES OF THE LAKHRA COAL FIELD HYDERABAD AREA, PAKISTAN

OPEN FILE REPORT
75-553
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Prepared under the auspices of the
Government of Pakistan and the
Agency for International Development
U. S. Department of State

1975

# GEOLOGY AND COAL RESOURCES OF THE LAKHRA COAL FIELD, HYDERABAD AREA PAKISTAN

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# GEOLOGY AND COAL RESOURCES OF THE LAKHRA COAL FIELD,

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## ABSTRACT

The Lakhra coal field is about 20 miles northwest of the ancient city of Hyderabad on the west side of the Indus River Valley in the southern part of Pakistan.

The Lailian coal bed in the lower part of the Ranikot Formation underlies an area of at least 64 sq mi on the Lakhra anticline, averages 3.6 feet thick, but is locally as much as 8.2 feet thick. The estimated reserves in the bed total 239.7 million long tons, of which 21.9 million long tons is classified as measured reserves, 43.8 million long tons as indicated reserves, and 174 million long tons as inferred reserves.

The coal is apparently subbituminous C and lignite A in rank. It lies at depths of 83 to 439 feet below the surface of the gently dipping rocks along the crest of the 43-mile-long Lakhra anticline. Though the coal is liable to burn spontaneously, the simplicity of the structure, the shallow depth of the coal bed, and the easy accessibility of the area should warrant large-scale utilization of the coal in the Lakhra field.

# INTRODUCTION

## Purpose and scope of the investigation

The Lakhra coal field was studied to ascertain the geology and structure of the area and to collect coal resources data, including the thickness and extent of beds; characteristics of the coal, roof, and floor; structural configuration of the coal-bearing unit; position of the coal beds with respect to the surface and zone of weathering; and position of the coal beds with respect to the ground-water table. The thickness, distribution, and chemical characteristics of a laterite deposit in the area were also studied.

The present report summarizes data obtained during the period 1961 through 1966. The Lakhra coal field was mapped at a scale of 1 inch to one mile. During the course of this work 34 holes totaling 13,804 feet were drilled over a distance 20 miles north-south and 4 miles east-west. Mr. Ishaque Durrazai, of the Geological Survey of Pakistan, supplied subsurface information about two holes (L29 and L30) that were drilled in the early part of 1965. Subsurface information about four holes (L31, 32, 33, and 34) drilled during the 1965-66 field season was supplied by A. T. Moosvi of the Geological Survey of Pakistan.

## Location, extent, and accessibility of the coal field

The coal-bearing area takes its name from the principal intermittent drainage system called Lakhra Nala. Pak-Hunt International Oil Co. (Hunt and others, 1953) used the term "Lakhra anticline" in their report on the exploration for oil in the area. The anticline extends 43 miles north to south and 15 miles east to west. The coal field area does not have a well-defined boundary; however, in the present report, discussion of the geology, structure, and coal resources is restricted to the area covered by Survey of Pakistan topographic sheet 40 C/2 and part of sheet 40 C/1.

The lower part of the Ranikot Formation is exposed around Lailian Colliery(lat 25°40'40" N and long 68°09'02" E; Survey of Pakistan grid coordinates 2,358,900 yds. E and 975,400 yds. N), which has been used as the main reference location in this report. The colliery is 85 miles northeast of Karachi, 22 miles northwest of Hyderabad, and 12 miles west-southwest of Khanot Railway Station(fig. 1).

It is about 40 miles by road from Hyderabad or Kotri to the center of the coal field. The road is metalled to Khanot Railway Station, which is 28 miles from Kotri, by rail or by road. From Khanot to Lailian Colliery, the road, although unmetalled, is maintained by Messrs. H. K. M. Habibullah Mining Co. Burmah Oil Co. or Pak-Hunt International Oil Co. made a road from Lailian to Band Virah, a police outpost that is connected with Kotri by unmetalled road. The companies also graded a number of other jeep roads in the area.

All the drill hole sites except L27 and L25 are easily accessible from the Lailian Colliery. Sites L27 and L25 are approachable from Manjhand(fig. 1).

## Report history, responsibilities, and acknowledgments

This report includes the results of a cooperative program of coal resource investigations in Pakistan conducted by the Geological Survey of Pakistan with the assistance of the U. S. Geological Survey and the U. S. Bureau of Mines. The program was sponsored by the Government of Pakistan and the Agency for International Development, U. S. Department of State. R. L. Harbour and M. A. Ghani shared responsibilities for the Lakhra coal field investigations (Harbour and Ghani, unpub. data, 1963). After Harbour's departure from Pakistan, Ghani assumed responsibility for the collection and synthesis of information, and prepared an earlier version of this report for submittal to the Geological Survey of Pakistan prior to taking educational leave. In 1969, by agreement between the Geological Survey of Pakistan and the Agency for International Development, E. R. Landis assumed responsibility for review, revision, and additions, as required, of the report submitted by Ghani, and for the subsequent fulfillment of publication plans.

Many of the personnel of the Geological Survey of Pakistan aided in the investigation--the help of A. S. A. Matin, Ishaque Durazzai, A. T. Moosvi, and H. Rahman is especially acknowledged. William Kebblish and D. P. Schlick of the U.S. Bureau of Mines kindly supplied analytical data and helped acquire mining information. S. Anthony Stanin contributed the section on the "basal Laki laterite" and analytical data on the laterite. The mining companies in the field were very cooperative, and the hospitality and cooperation rendered during the field work by M/s. K. B. H. M. Habibullah Mining Co. and the Baluchistan Coal Co. are greatly appreciated.

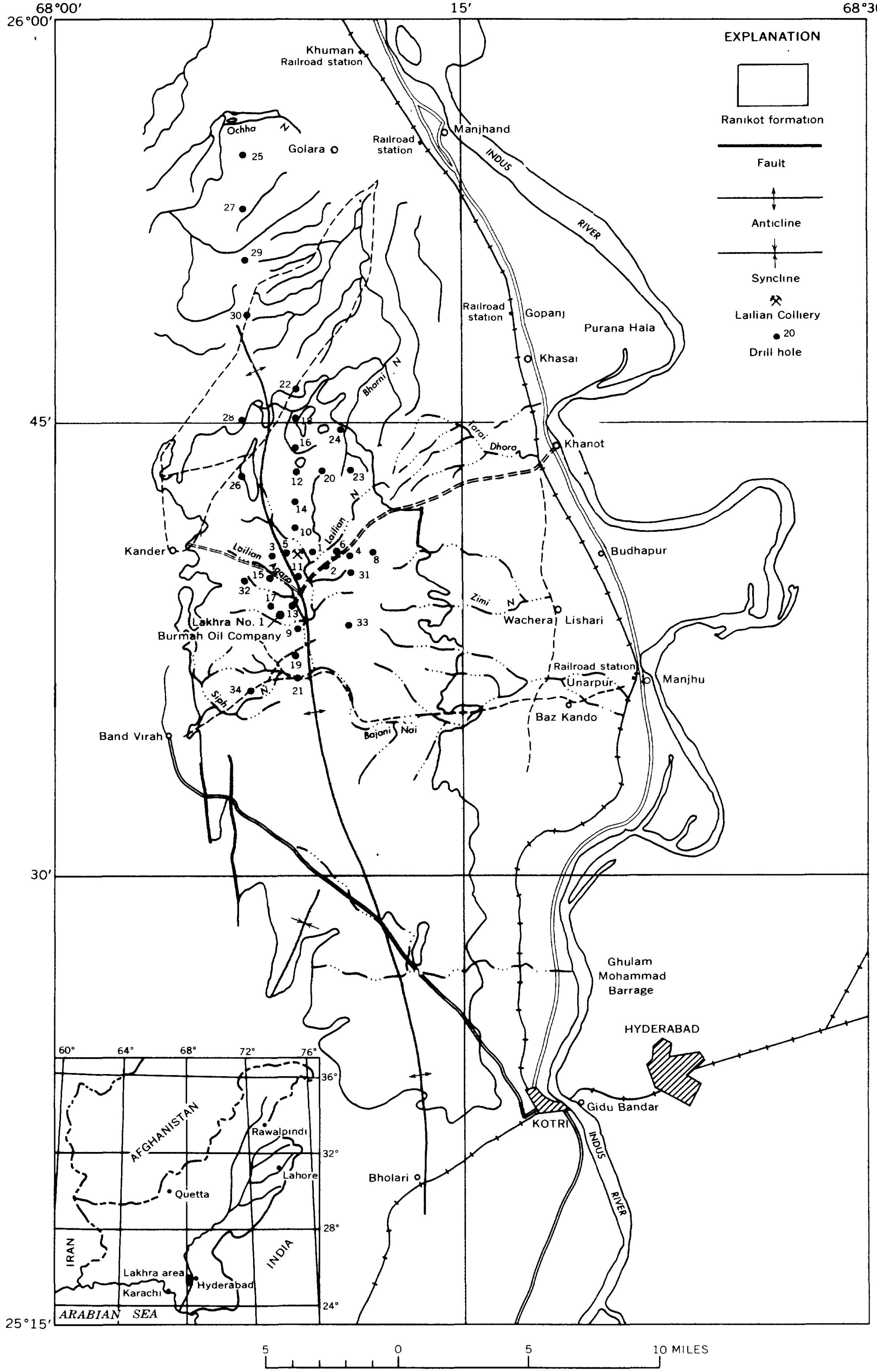


Figure 1.—Index map showing the Lakhra anticline and the outcrop of the Ranikot Formation, Pakistan

# GEOGRAPHY

## Topography and relief

Flat-topped hills, which slope down gently toward the Indus Plain, stand out in the eastern, northern, and southern parts of the area. The broad Lakhra valley crosses the central part of the area and is joined by a number of tributary nalas.

The highest point in the area--686 feet above sea level--is 5.5 miles south-southeast of Lailian Colliery. The lowest point is located at the confluence of Siph Nala and Lakhra Nala and is 238 feet above sea level.

## Drainage and water supply

Lakhra Nala with its tributaries forms the main drainage system in the area. Lakhra Nala flows from northeast to south and then swings southeast and finally to the east. Before turning to the east it is joined by Siph Nala, an important tributary that flows across the crest of the Lakhra anticline.

In the vicinity of drill holes L25 and L27, Occha Nala flows from south to northeast. During the summer this river maintains a reservoir of water 7 feet deep and a quarter of a mile in length at the maximum. This was the source of drilling water for holes L25 and L27.

The Hyderabad area receives a mean annual rainfall of 7.09 inches, of which 6.03 inches fall between the months June through September. The following table gives the distribution of rainfall throughout the year (Ahmed, 1964):

| | Mean rainfall in inches | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Station | Jan. | Feb. | March | April | May | June | July | Aug. |
| Hyderabad | 0.17 | 0.24 | 0.20 | 0.07 | 0.19 | 0.39 | 2.98 | 2.03 |
| | Sept. | Oct. | Nov. | Dec. | Annual | | | |
| Hyderabad | 0.63 | 0.03 | 0.06 | 0.10 | 7.09 | | | |

Nomadic people who visit the area sink wells 5 to 10 feet deep in the alluvium of Lakhra Nala and other nalas, but these wells generally become dry in the winter season. A number of permanent wells are present near Ban Virah, Lailian, and a few other places. These wells are lined with limestone slabs and can supply limited quantities of water throughout the year.

Wells drilled to the water table might provide greater quantities of water. The water table as recorded in the exploratory drill holes is more than 100 feet below the surface in most places. In some holes, collapse of the drill holes, the smaller diameter of the holes toward the bottom, or casing in the holes prevented a satisfactory reading of the water table. However, the regional water table appears to lie nearly 200 feet above mean sea level. The record of the water table reading for each well is given in the Appendix.

While exploring for oil in the area, Burmah Oil Co. and Pak-Hunt International Oil Co. brought water from the Indus River by pipeline. The Indus River is almost 14 miles northeast of Lailian Colliery.

## Vegetation, cultivation, and population

Because of scanty rainfall, the area is barren; the bald hills have a few grassy patches on the slopes. However, trees and shrubs 10 to 15 feet tall are fairly common along the nalas.

Cultivation is limited to patches in comparatively low lying areas where rainwater can accumulate. Small dykes or earthworks are built in each cultivated plot to collect the rainwater; the concrete dam at Band Virah is the most notable of such structures. These cultivated plots are widely scattered, but many are in the western part of the area around Kander, Band Virah, and nearby villages. In the northernmost part of the area, the land around the village of Golara (topographic sheet 40 C/1) is fairly well cultivated. Only one crop, generally maize, is grown, and whether there is a crop or not depends on the mercy of rain.

Nomads with their cattle and goats visit the area during the winter season when blades of grass grow on the hill slopes and in the valleys. During that season they tend their cattle and plough land, but with the coming of summer they move northward to higher altitudes or down to the Indus valley. The winter villages of the nomads consist of a few shelter huts. By the month of June the villages are deserted. A few families live at Band Virah throughout the year. The nomadic people are poor, but prefer their traditional way of life to mining coal.

## HISTORICAL REVIEW

As early as 1855, Baluch nomads during the course of sinking a well in the valley reportedly struck 8 feet of coal at a depth of 41 feet. The place was investigated by geologists from the Geological Survey of India. Three experimental shafts were sunk a short distance from the original well, to depths of 56, 44 and 28 feet, but no coal was found in any of them. In 1857, a Mr. Inman put down a shaft at Lailian and encountered a coal bed 5 feet 9 inches thick that becomes very thin within a short distance. In 1867, W. T. Blanford made a hurried traverse from Kotri to Lainyan(Lailian) and Ranikot to ascertain the prospect of additional discoveries of coal. He gave a negative report. Later, in evaluating the deposit Blanford said, "In short, as was shown by a discussion of all the data, there is nothing which could properly be called a coal seam, but merely a mass of lignite not extending much more than 50 yards in any direction." (Blanford, 1879, p. 192-193.) Carter published a note in 1861 on the discovery of lignite at Lailian. He briefly discussed the quality of the coal from Lailian (Lainyan) and showed the coal to be similar to that of some other Tertiary rock units.

The first systematic surveying of the area was carried out by Fedden (1880) and Blanford(1876, 1878a, 1878b, 1879). A geological map of the western part of the former province of Sind was prepared at a scale of 16 miles to an inch(Blanford, 1878a).

Hunting Survey Corp. (1961) produced a reconnaissance geological map of the area at a scale of 4 miles to an inch--geological map No. 7, Hyderabad, covers the area. The map, along with the accompanying report, was of great value and was used as a guide in the preparation of the geological map (1:63,360 scale) of the present report.

Geologists of the Burmah Oil Co. prepared a geological map of the central part of the Lakhra anticline at a scale of 4 inches to 1 mile. The Burmah Oil Co. drilled one test well in the area (fig. 1) and recorded coal cuttings from the following depth intervals: (1) 170-210 feet; (2) 225-255 feet; (3) 420-421 feet; and (4) at 635 feet (Burmah Oil Co. report "a").

Pak-Hunt International Oil Co. drilled four test wells in the area (fig. 9). Coal cuttings recorded in the different wells are as follows:

| Test well no. | Depth interval through which coal cuttings appeared in the flush sample |
|---|---|
| Pak-Hunt Lakhra No. 1 | 482-503 feet, at 830 feet,<br>1,520-1,570 feet. |
| " " " No. 2 | 240-270 feet.<br>300-390 feet.<br>480-510 feet. |
| " " " No. 3 | 480-510 feet, in nearly all samples.<br>To a depth of 1,480 feet. |
| " " " No. 4 | 240-270 foot depth; at 660 feet,<br>870-930 feet. |

## GEOLOGY

The exposed rocks in the Lakhra field are assigned to the Ranikot Formation, the Laki Limestone, and the Manchhar Formation. The Ranikot Formation is divided into an upper part and a lower part. Sandstone, shale, or claystone, and coal are the main constituents of the lower part of the Ranikot Formation, whereas the upper part consists of limestone, sandstone, claystone or shale, and siltstone. Only the uppermost 60 feet of the lower part is exposed in the area, but it is more than 3,000 feet thick in drill holes. The lower part is devoid of megafauna but some beds in the upper part are profusely fossiliferous. The presence of fossiliferous beds and limestone distinguishes the upper part of the Ranikot from the lower part.

The Laki Limestone overlies the Ranikot Formation unconformably. A highly ferruginous lateritic claystone, ranging from 0 to 25 feet in thickness separates the Ranikot Formation from the overlying Laki Limestone in most places. This laterite unit, considered by many previous workers to be the lowermost unit of the Laki sequence, has been referred to as the "Basal Laki laterite." The Laki Limestone is light gray, white to light yellowish gray, finely crystalline, fossiliferous, hard, resistant, and cliff-forming.

The Manchhar Formation overlies the Laki Limestone unconformably. Laterite, conglomerate, pebble beds, and friable sandstone are the lithologic components of this unit. A thin cover of alluvium rests on the Manchhar Formation.

The lithologic succession of the rocks can be summarized as follows:

| Unit | Thickness | Lithology |
|---|---|---|
| Alluvium | 0-10 feet | Unconsolidated stream, colluvial, and eolian deposits of sandstone, siltstone, and claystone with limestone and sandstone pebble beds. |
| Manchhar Formation (Miocene and Pliocene?) | 0-60 feet | Laterite, pebble beds, conglomerate; soft and poorly sorted sandstone, siltstone, and clay. |
| ---Unconformity--- | | |
| Laki Limestone (Early Eocene?) | 68 feet exposed, 330 feet thick nearby | Limestone, light yellowish-gray, finely crystalline, fossiliferous, hard, resistant, cliff-former. Laterite at the base. |
| ---Unconformity--- | | |
| Upper part of the Ranikot Formation(Paleocene, Montian to Landenian?) | 450 to 800 feet | Fossiliferous limestone, sandstone, claystone, or shale |
| Lower part of the Ranikot Formation (Danian to Montian?) | 60 feet exposed, thickness at Pak-Hunt Lakhra No. 3 is 3083 feet | Sandstone, shale, or claystone, coal; devoid of megafauna. |

## Ranikot Formation

The Ranikot Formation was originally called the Ranikot "Series" by W. T. Blanford(1876). The name comes from the old fort of Ranikot (lat 25°52'45" N; long 67°55'00" E) in the Laki Range, northwest of Kotri. The lower limit of the Ranikot "Series" was first extended downward to include the *Cardita beaumonti* beds but subsequent descriptions by Blanford(1878a, 1878b, 1879), Vredenburg(1906), Nuttal(1931), and others have restricted the terms Ranikot "Series" or Ranikot Formation to a part of the original unit, the lower strata being mapped separately as the *Cardita beaumonti* beds. The Hunting Survey Corp.(1961) assigned Group status to the Ranikot Series and included the *Cardita beaumonti* formation, Lower Ranikot formation, and Upper Ranikot Formation in the Ranikot Group. In this report the Ranikot is considered to be a formation divided informally into an upper part and a lower part. The so-called *Cardita beaumonti* formation is not exposed in the area and is not further discussed here.

None of the terminology used in this report has been formally approved by the Stratigraphic Committee of Pakistan.

## Lower part

The lower, nonfossiliferous, part of Blanford's (1879) "Ranikot Series" is described here as the lower part of the Ranikot Formation.

Lithology and internal stratigraphy.--The unit is composed predominantly of sandstone and subordinate amounts of claystone or shale, siltstone, and coal. The unweathered sandstone is light gray, gray, white, and greenish gray, but weathers into various shades of yellow, red, and brown. It is coarse to fine grained, mostly subangular and poorly sorted, crossbedded to massive, friable, loosely cemented. The claystone or shale and siltstone are light gray to gray, pyritic, sandy, and gypsiferous; associated with irregularly distributed coaly films; and range from nonlaminated to poorly laminated. The highest minable coal bed, designated the Lailian coal bed, is within this unit and is overlain and underlain by claystone in most of the area. The coal is resinous and pyritic, and weathers into small chips on exposure to air. The Lailian coal is about 125 feet stratigraphically below the top of the lower part of the Ranikot Formation. It lies from a minimum depth of 83 feet below the surface (at Lailian Colliery) to a maximum depth of as much as 439 feet (in drill hole L 26). In addition to the Lailian coal bed, other coal beds are at depths of 169, 268, 372, 345, 396, 420, and 435 feet in drill hole L 1, and at 290, 302, 337, 363, and 455 feet in drill hole L 2, but these other beds all seem to be very lenticular.

*Contacts*.--The lower part of the Ranikot Formation conformably overlies the so-called *Cardita beaumonti* formation. The contact is not exposed in the area but information is available from exploratory wells--Burmah Oil Co. No. 1, and Pak-Hunt International Oil Co. Nos. 1, 2, 3, and 4. The lower part of the Ranikot is conformable with the overlying upper part of the Ranikot formation.

*Distribution and thickness*.--The lower part of the Ranikot Formation is exposed in an area of about 20 square miles(pl. 1) on the crest of the Lakhra anticline. Only 60 feet of the unit is exposed, but it has been cored to a depth of 837 feet at drill hole L27. The thickness as recorded in Pak-Hunt International Oil Co. No. 3 is 3,085 feet (Hunt and others, 1953). The pre-Laki disconformity has stripped away part of this unit at drill hole L25.

*Age and correlation*.--No marine megafossils were found in the cores or exposed sections. However, at Pak-Hunt International Oil Co. Nos. 1 and 2, *Operculina* sp. was identified in this unit (Hunt and others, 1953). Because of its conformable contact with the underlying *Cardita beaumonti* formation of Danian age, and its conformable contact with the overlying upper part of the Ranikot Formation of middle to late Paleocene age (Montian to Landenian), a Danian to Montian age may be assigned to this unit.

### Upper part

The fossiliferous part of Blanford's (1876) "Ranikot Series" is identified herein as the upper part of the Ranikot Formation.

Lithology and internal stratigraphy.--The upper part of the Ranikot Formation consists of sandstone, limestone, claystone or shale, and siltstone. Sandstone is dominant in the basal beds, whereas limestone is dominant in the upper part and alternates with sandstone and claystone.

The sandstone is thin to thick bedded, light gray, chocolate, yellow, brown, and red in color; fine to coarse in texture with subangular to subrounded grains; fossiliferous in certain layers; calcareous, and at places grades into sandy limestone. It is hard and resistant where calcareous and fossiliferous.

The limestone is light gray, weathered to yellow and brown; sandy; fossiliferous; and in places grades into coquina. It is typically thick bedded to massive, hard and resistant. The shale or claystone and siltstone are light gray, stained yellow and brown, soft, slope-forming, and mostly covered.

Contacts.--The upper part of the Ranikot conformably overlies the lower part of the Ranikot Formation but unconformably underlies the Laki Limestone. At places the Laki is missing and the Manchhar Formation overlies the upper part of the Ranikot. The unit is of variable thickness because of post-Ranikot erosion.

Distribution and thickness.--The upper part of the Ranikot Formation is exposed around the periphery of the area included on topographic sheet 40 C/2. The unit is 890 feet thick in the Bholari area, 450 feet in the Khanot area, and completely missing around drill holes L25 and L27.

Age and correlation.--The unit is very rich in fossil Foraminifera, mollusks, echinoids, and corals. Different workers of the Geological Survey of India (Duncan, 1880; Duncan and Sladen, 1882-1885; Vredenburg, 1906; Nuttal, 1931; and others) give a voluminous account of the paleontology of the unit.

Vredenburg(1928) regarded the unit as Thanetian in age and Nuttal(1925, 1931) correlated the unit to parts of the Thanetian and Montian stages of Europe. The unit may range in age from Montian to Landenian.

## Laki limestone

The Laki Limestone is equivalent to the "Laki Series" of Vredenburg (1906) who derived the term from the Laki hill range and village in the western part of the Hyderabad Division.

Lithology and internal stratigraphy.--The formation consists of finely crystalline limestone and very subordinate amounts of claystone or marl and lateritic clay. The limestone is light yellowish-gray, white, and light gray, stained yellow to brown, and weathers to light gray. It is a nodular, hard, resistant, massive, cliff former. Foraminifera abound throughout the formation, but most of the megafauna is present in the middle part.

The claystone or marl in the Laki Limestone is light gray to gray, and stained yellow. It is gypsiferous, fossiliferous, calcareous, soft, and laminated, and forms lenses or thin beds in the lower half.

Contacts.--The Laki Limestone is unconformable on the Ranikot Formation. The old erosion surface transects the Ranikot at the rate of 23 feet per mile from Bholari to Lailian and at 30 feet per mile from Lailian toward drill hole L25. Little or no angular discordance can be seen at the contact of the two units. The upper part of the Ranikot Formation is missing at drill hole L25, but is as much as 800 feet thick in the surface sections measured nearby. The economic importance of the unconformity between the Ranikot and the Laki is shown by the fact that the Lailian coal is present at the relatively shallow depth of 403 feet in drill hole L25, because the upper part of the Ranikot and part of the lower part of the Ranikot were stripped off by erosion prior to the deposition of the Laki.

The Laki limestone is overlain unconformably by the Manchhar Formation in the northern and western parts of the area. In the eastern part, around Khanot, alluvium rests on the Laki Limestone.

Distribution and thickness.--The Laki is 365 feet thick at drill hole L25. In the area under discussion the Lakhra anticline is flanked by the Laki on the east, north, and west sides.

Age and correlation.--The Laki is generally considered to be of early Eocene age. Vredenburg (1928) considered the "Laki Series" to be early Lutetian in age. Later work by Nuttall (1925, 1931) shows that the "Laki Series" corresponds to the Ypresian.

"Basal Laki laterite"

W. L. F. Nuttal(1925) subdivided the "Laki Series" of Vredenburg(1906) into 4 units, of which the lower unit, a lateritic claystone, he named the "Basal Laki laterite."

Lithology and internal stratigraphy.--In outcrops the "Basal Laki laterite" is a highly ferruginous, dark red, maroon, dark brown, and yellowish-brown massive claystone containing concretions of iron oxide, interbedded sandy layers, and light tan pisolites in places. Locally, where the overlying limestone has been stripped off by erosion, the laterite has a duricrust or hardpan on exposed surfaces.

On the surface the "Basal Laki laterite" is a widespread, very conspicuous lithologic unit in the Lakhra area; even partially exposed outcrops are readily recognizable when viewed in the field from great distances. The "lateritic" rocks are composed principally of highly ferruginous claystones and siltstones, some of which are very gypsiferous. To acquire the prominent color characteristics observed in the field, the rocks may have undergone a period of subaerial weathering prior to deposition of the Laki Limestone, or they may owe their present "red bed " surface appearance to the oxidation processes that followed post-structure erosion and the denudation of these strata.

The possibility that the present surface lithologic character of the "laterite" may be only surficial in nature is suggested by several factors. Similar "lateritic" rocks crop out in surface sections in the Meting area, which is south of the Lakhra anticline; however, no similar "lateritic" beds have been recovered from exploratory core holes in the same area. From the core data it appears that the "lateritic" or red bed" surface sections are represented by unoxidized, dark-gray and gray pyritic claystone, and siltstone in the subsurface. Moreover, many surface exposures of the Ranikot Formation, particularly outcrops of the lower Ranikot sequences, display "red bed" characteristics in the Lakhra and Meting areas, while subsurface evidence of the same strata indicate that their unaltered equivalents are actually dark gray and gray lithic units.

If these conditions apply to the "Laki laterite" and the present discoloration and alteration surface features of the rocks are the result of fairly "recent" oxidation processes, then in all probability the so-called "Laki laterite" is not a true laterite.

Preliminary microscopic examinations were made on several thin sections of "lateritic" rocks from the Lakhra area. In thin section, the rocks appear to be composed principally of halloysite, deeply colored and irregularly blotched with iron oxide, with very minor amounts of quartz grains and calcite as accessory minerals.

Contacts.--Wherever observed, the contact between the "Basal Laki laterite and the underlying Ranikot Formation does not show any angular discordance; however, because the laterite is regarded as an integral unit of the overlying Laki Limestone, the contact between the laterite and the Ranikot Formation is considered to be unconformable.

The contact between the "Basal Laki laterite" and the overlying Laki Limestone is considered to be conformable.

Distribution and thickness.--The "Basal Laki laterite" is lenticular, and ranges in thickness from 0 to 25 feet. The laterite was found to be missing in drill holes L23, L25, and L 27.

Age and correlation.--No diagnostic fossils have been found in rocks of the "Basal Laki laterite" by which to ascertain its age. Because the laterite is regarded to be the lowermost unit of the Laki Limestone, it is considered early Eocene(Ypresian) in age.

## Manchhar Formation

Blanford(1876, p. 9; 1879) described the Manchhar Formation and named it after Manchhar Lake, which is a few miles west of Sehwan.

Lithology and internal stratigraphy.--East of Kander and in some other places, the Manchhar Formation is composed of laterite and pebbles of laterite and sandstone mixed with sand, silt, and clay. The laterite is ferruginous and dark brown, red, and yellow in color. The pebbles are composed of ferruginous laterite, ferruginous sandstone, and gray sandstone. They are brown, dark brownish red, and gray, smooth-surfaced, and show a resinous lustre.

The Manchhar Formation west of Band Virah and Kander is of conglomeratic sandstone, siltstone, and claystone. The conglomerate consists of pebbles of sandstone, yellowish claystone, and limestone embedded in a sand and clay matrix. The sandstone is gray to light gray in color with some streaks of yellow and red; it is fine to coarse grained, loosely cemented, and poorly sorted.

Contacts.--East and northeast of Kander the Manchhar Formation rests on the upper part of the Ranikot Formation, but in other places it rests on the Laki Limestone. Little or no angular discordance is observable, but the unconformity marks a long period of erosion or nondeposition, from middle Eocene to early Miocene time. In most localities, the Manchhar is overlain by Holocene or Pleistocene alluvium. In some places the Manchhar closely resembles the alluvium.

Distribution and thickness.--The Manchhar Formation is in discontinuous patches east of Kander but is present over a large area west of Band Virah and Kander. It ranges from 0 to 60 feet in thickness in the area.

Age and correlation.--No fossils of value for age determination were found in the Manchhar Formation. However, the Manchhar of the Lakhra area (Blanford, 1876, 1879) can be correlated lithologically with that of the type area, which has an assigned age of Miocene and Pliocene age. The formation in the Lakhra area is therefore assumed to be Miocene and Pliocene age also.

### Alluvium

The youngest rocks in the area are unconsolidated stream, colluvial, and eolian deposits composed of sandstone, siltstone, claystone, and limestone and sandstone pebble and cobble beds. The alluvium is as much as 10 feet thick or more in places and is widespread in the western part of the mapped area where it is composed largely of colluvial and eolian deposits. Stream-laid deposits are present in the larger water courses in the central and eastern parts of the mapped area but are of mappable extent only along parts of Lakhra Nala.

## STRUCTURE

The rocks in the Lakhra field form a doubly plunging anticline, known as the Lakhra anticline. The crest of the anticline can be traced from Bholari Railway Station(topographic sheet 40 C/3) northward to near Golara village (topographic sheet 40 C/1). Faults striking parallel to the crest line are common and a few folds paralleling the major structure are present in the southern part of the mapped area.

### Folds

The Lakhra anticline is gently and symmetrically folded with almost horizontal beds near the axis. Away from the crest line the dip increases to as much as $6^{\circ}$.

The lower part of the Ranikot Formation crops out in the center of the anticline, whereas the upper part of the Ranikot Formation, the Laki Limestone and the Manchhar Formation, are exposed on the flanks. The Ranikot Formation dips from less than $1^{\circ}$ to $3^{\circ}$. The Laki Limestone dips $3^{\circ}$ to $6^{\circ}$. In the central part of the area under discussion the crest line trends north, but to the north it swings to the north-northeast, and further south it turns south-southeast toward Bholari(pl. 1).

The Hunting Survey Corp. shows the extension of the crestline from Bholari to Ochha Nala, a distance of nearly 40 miles(Hunting Survey Corp., 1961, map no. 7). The anticline extends from east to west for nearly 15 miles and plunges to north and south at a rate of $0.5^{\circ}$ to $1^{\circ}$.

Small anticlines and synclines trend north, parallel to the main Lakhra anticline in the southern part of the area, near Babar Bund and Manri Band. South of Band Virah, a faulted anticline is oriented north-south. Its eastern limb is faulted down and the Laki Limestone has been brought in contact with the Manchhar Formation.

## Faults

The rocks are broken by closely spaced faults parallel to the regional structure. The faults strike north to south and dip $70^{\circ}$ to $90^{\circ}$ toward the east in the eastern flank, and on the western flank the dip is either vertical or toward the west. The throw ranges from a few feet to as much as 100 feet.

## ECONOMIC GEOLOGY

### Coal

Coal is "a readily combustible rock containing more than 50 percent by weight, and more than 70 percent by volume of carbonaceous material, formed from compaction or induration of variously altered plant remains similar to those of peaty deposits. Differences in the kinds of plant materials(type), in degree of metamorphism(rank), and range of impurity(grade), are characteristics of the varieties of coal"(Schopf, 1956).

### Characteristics of Lakhra coal

As pointed out in the preceding definition of coal, coals can be, and commonly are, classified by rank, type and grade, of these classifications, the classification by rank--that is, by degree of metamorphism in the progressive series that begins with peat and ends with graphocite(Schopf, 1966)--is most important. Classification by type of original plant material is often done if enough mega- and microscopic description is available, and classification by grade--that is, by type and quantity of impurities--is commonly used because of its importance in utilization of coal. Other categorizations are possible and are commonly used in resource evaluations--such factors as the thickness of overburden and thickness and areal extent of individual beds are commonly considered.

Rank.--The position of a coal within the progressive series that begins with peat and ends with graphocite--that is, its rank--is dependent on the temperature and pressure that the coal has experienced throughout time. Coal is derived largely from plant material and is therefore composed largely of carbon, hydrogen, and oxygen, along with smaller quantities of nitrogen, sulfur, and other elements. The proportions of the various constituents change as a coal undergoes metamorphism--higher rank coals have more fixed carbon and less hydrogen and oxygen than the lower ranks. Coals are analyzed by relatively standardized methods evolved through the years by the cooperation of various groups engaged in analytical work. In general use throughout most of the world are two standardized forms of coal analysis: the proxmiate analysis and the ultimate analysis. In the proximate analysis, four constituents are reported--moisture, volatile matter, fixed carbon, and ash. In the ultimate analysis, hydrogen, carbon, nitrogen, oxygen, and sulfur are determined. The calorific, or heating, value is an important property and is commonly expressed in British thermal units(Btu) per pound--one Btu is the amount of heat needed to raise the temperature of one pound of water one degree Fahrenheit(in the metric system, heating value is expressed in kilogram--calories per kilogram). Additional tests are commonly made, particularly to determine the caking, coking, and other properties, such as tar yield, which affect classification or utilization.

**TABLE I.—CLASSIFICATION OF COALS BY RANK.[a]**

| Class | Group | Fixed Carbon Limits, per cent (Dry, Mineral-Matter-Free Basis) | | Volatile Matter Limits, per cent (Dry, Mineral-Matter-Free Basis) | | Calorific Value Limits, Btu per pound (Moist,[b] Mineral-Matter-Free Basis) | | Agglomerating Character |
|---|---|---|---|---|---|---|---|---|
| | | Equal or Greater Than | Less Than | Greater Than | Equal or Less Than | Equal or Greater Than | Less Than | |
| I. Anthracitic | 1. Meta-anthracite | 98 | ... | ... | 2 | ... | ... | Nonagglomerating |
| | 2. Anthracite | 92 | 98 | 2 | 8 | ... | ... | |
| | 3. Semianthracite[c] | 86 | 92 | 8 | 14 | ... | ... | |
| II. Bituminous | 1. Low volatile bituminous coal | 78 | 86 | 14 | 22 | ... | ... | Commonly agglomerating[e] |
| | 2. Medium volatile bituminous coal | 69 | 78 | 22 | 31 | ... | ... | |
| | 3. High volatile *A* bituminous coal | ... | 69 | 31 | ... | 14 000[d] | ... | |
| | 4. High volatile *B* bituminous coal | ... | ... | ... | ... | 13 000[d] | 14 000 | |
| | 5. High volatile *C* bituminous coal | ... | ... | ... | ... | 11 500 | 13 000 | |
| | | | | | | 10 500 | 11 500 | Agglomerating |
| III. Subbituminous | 1. Subbituminous *A* coal | ... | ... | ... | ... | 10 500 | 11 500 | Nonagglomerating |
| | 2. Subbituminous *B* coal | ... | ... | ... | ... | 9 500 | 10 500 | |
| | 3. Subbituminous *C* coal | ... | ... | ... | ... | 8 300 | 9 500 | |
| IV. Lignitic | 1. Lignite *A* | ... | ... | ... | ... | 6 300 | 8 300 | |
| | 2. Lignite *B* | ... | ... | ... | ... | ... | 6 300 | |

[a] This classification does not include a few coals, principally nonbanded varieties, which have unusual physical and chemical properties and which come within the limits of fixed carbon or calorific value of the high-volatile bituminous and subbituminous ranks. All of these coals either contain less than 48 per cent dry, mineral-matter-free fixed carbon or have more than 15,500 moist, mineral-matter-free British thermal units per pound.

[b] Moist refers to coal containing its natural inherent moisture but not including visible water on the surface of the coal.

[c] If agglomerating, classify in low-volatile group of the bituminous class.

[d] Coals having 69 per cent or more fixed carbon on the dry, mineral-matter-free basis shall be classified according to fixed carbon, regardless of calorific value.

[e] It is recognized that there may be nonagglomerating varieties in these groups of the bituminous class, and there are notable exceptions in high volatile *C* bituminous group.

One of the most widely used rank classifications is the "Standard Specifications for Classification of Coals by Rank"(see table 1), adopted by the American Society for Testing and Materials(1967). The ASTM system differentiates coals into classes and groups on the basis of mineral-matter-free fixed carbon or volatile matter and the calorific value, supplemented by determination of agglomerating(caking) characteristics. Table 2 presents analyses of samples of Lakhra coal determined by the Pittsburgh laboratories of the U. S. Bureau of Mines and in the Quetta laboratories of the Geological Survey of Pakistan. The eight analyses in which the heating value is reported indicate an apparent rank of subbituminous C for three samples, lignite A for four, and lignite B for one. In the absence of more reliable analyses, some of the Lakhra coal is assumed to have an apparent rank of subbituminous C and some has an apparent rank of lignite A.

Grade.--Classification of coals by grade, or quality, is based largely on the extent of ash, sulfur, and other constituents that adversely affect utilization. The Lakhra coal samples have an average ash content of about 15 percent and an average sulfur content of about 4 percent on an "as received" or "air dried" basis. In contrast, selected analyses of 642 United States coals (Fieldner, Rice, and Moran, 1942) have an average ash content of 8.9 percent and an average sulfur content of 1.9 percent. The Lakhra coals would be classed as medium to high ash and high sulfur grades.

Thickness and extent of beds.--The Lailian coal bed is extensive but the deeper coal beds appear to be of limited extent. The Lailian coal bed was cored in 28 bore holes out of 34 holes, which are spaced over a distance of 20 miles from north to south and 4 miles from east to west(pl. 2). The thickness of the bed is as much as 9.6 feet, including a shale interbed that does not exceed 1.5 feet in thickness. The thickness of the coal bed as struck in each drill hole is given in the drill logs (p. 55) and represented in the columnar sections(figs. 2, 3, 4, 5, and 6).

Other coal beds below the Lailian appear to be lenticular, although present information is fragmentary. One bed reaches a thickness of 7.7 feet at a depth of 398 feet at hole L3, and it is 4.1 feet thick at a depth of 396 feet at hole L1, and possibly 2.5 feet thick at a depth of 455 feet at drill hole L2. Its position at holes L6, L4, and farther east is not known. The coal beds above the Lailian bed are thin and appear to be very lenticular.

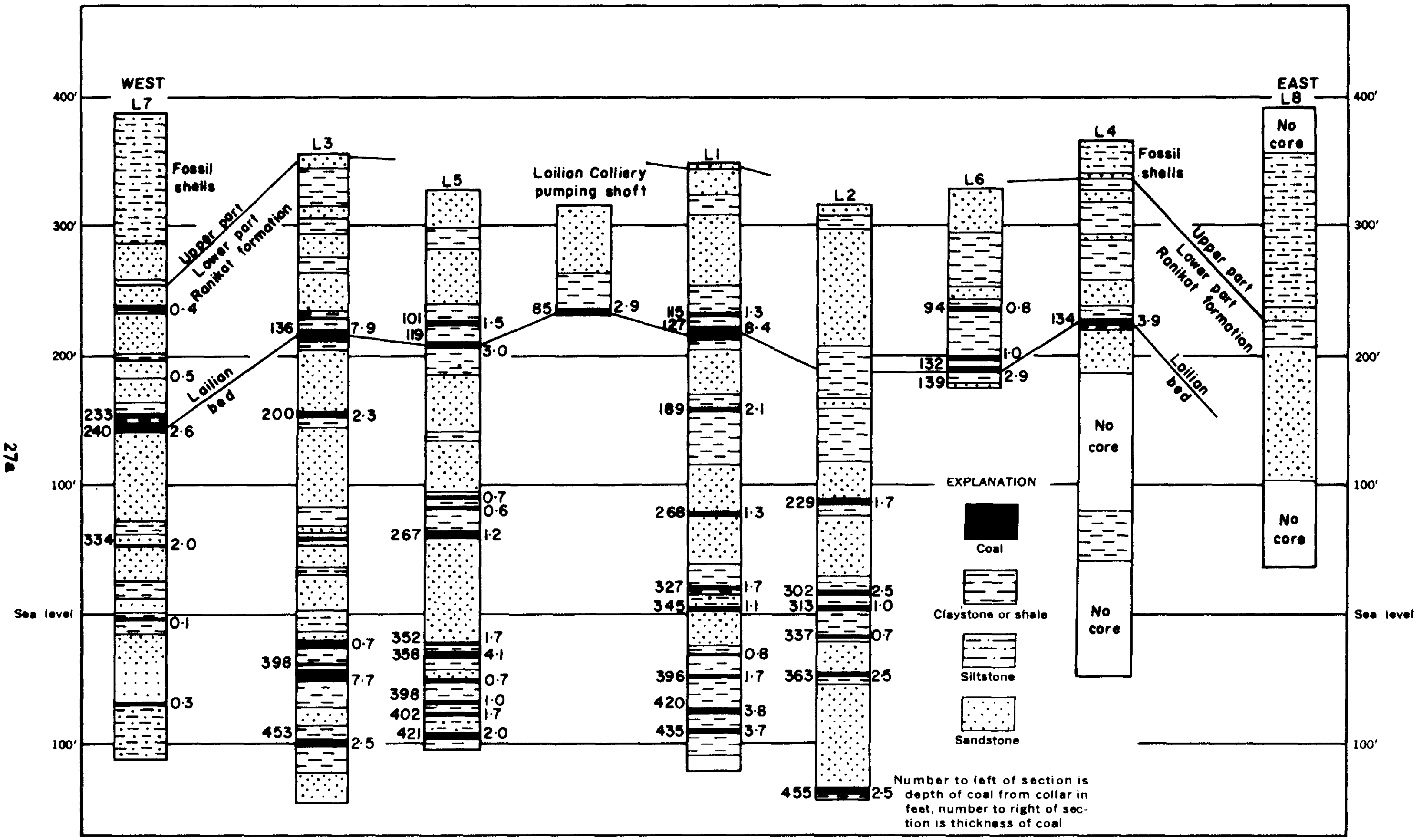


Figure 3.—Correlation of horizons in the east-west line of drill holes at Lailian Colliery in the Lakhra coal field, Pakistan.

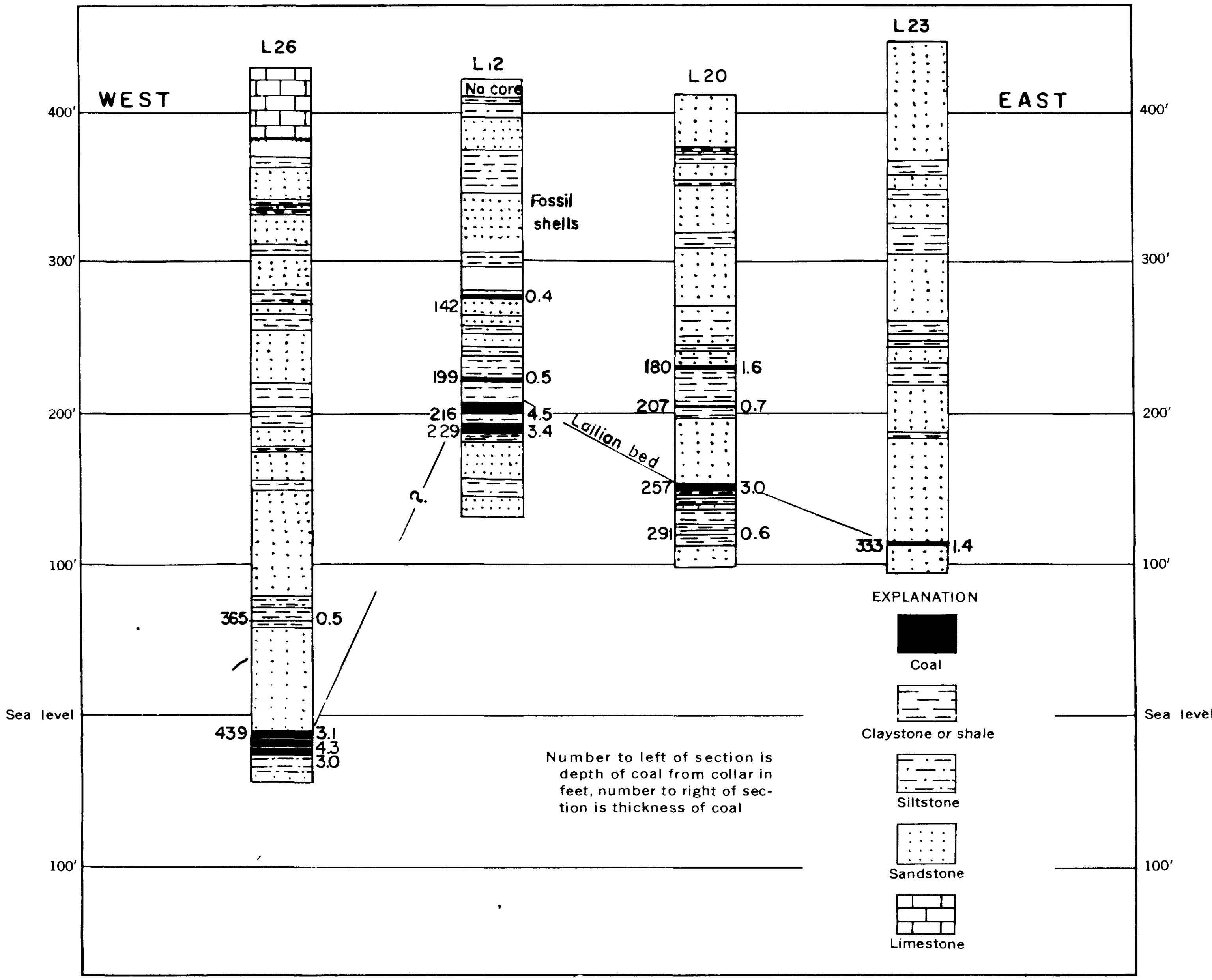


Figure 4.—Correlation of coal horizons in the east-west line of drill holes, 3 miles north of Lailian Colliery, Pakistan.

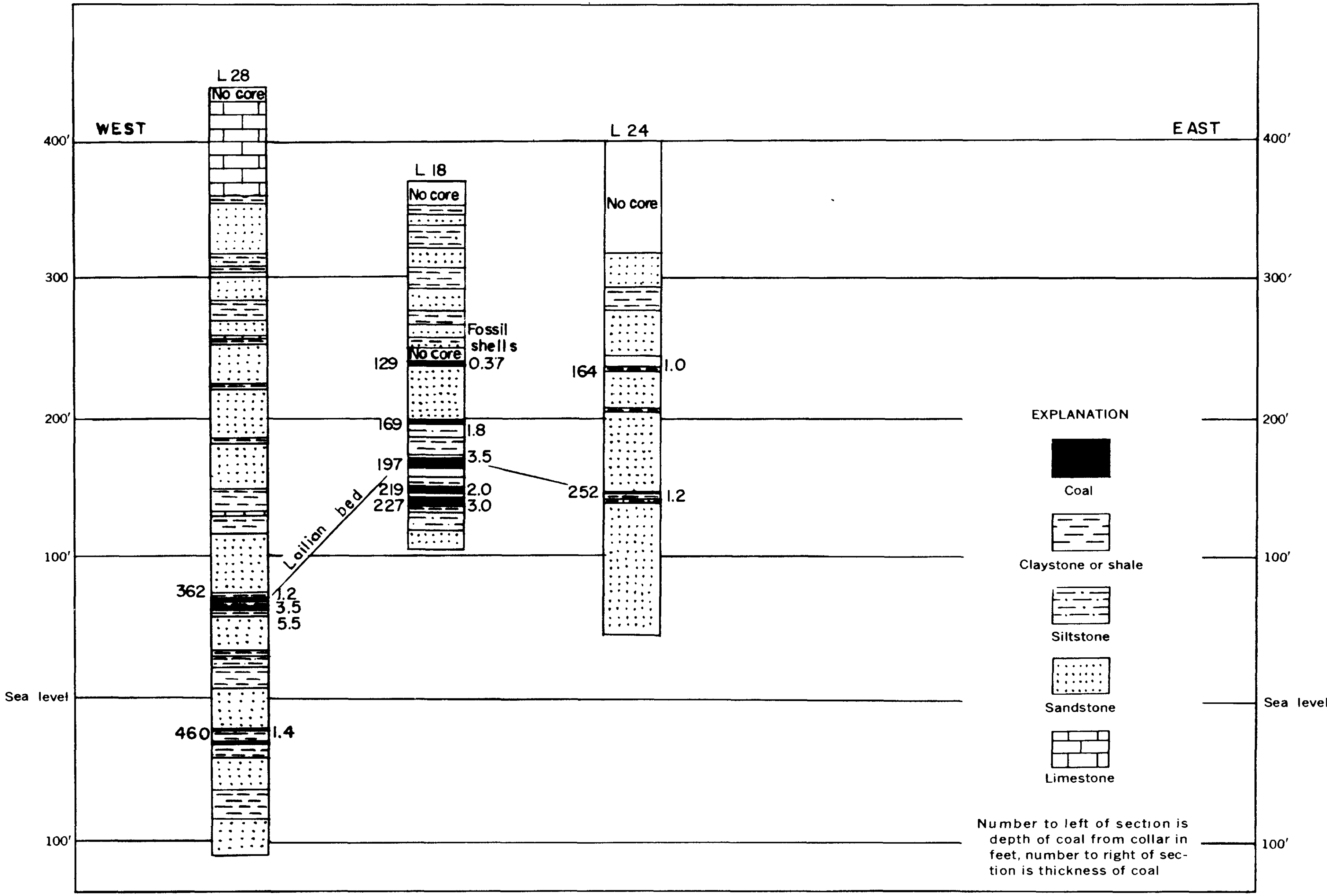


Figure 5.—Correlation of coal horizons in the east-west line of drill holes, 5 miles north of Lailian Colliery, Pakistan.

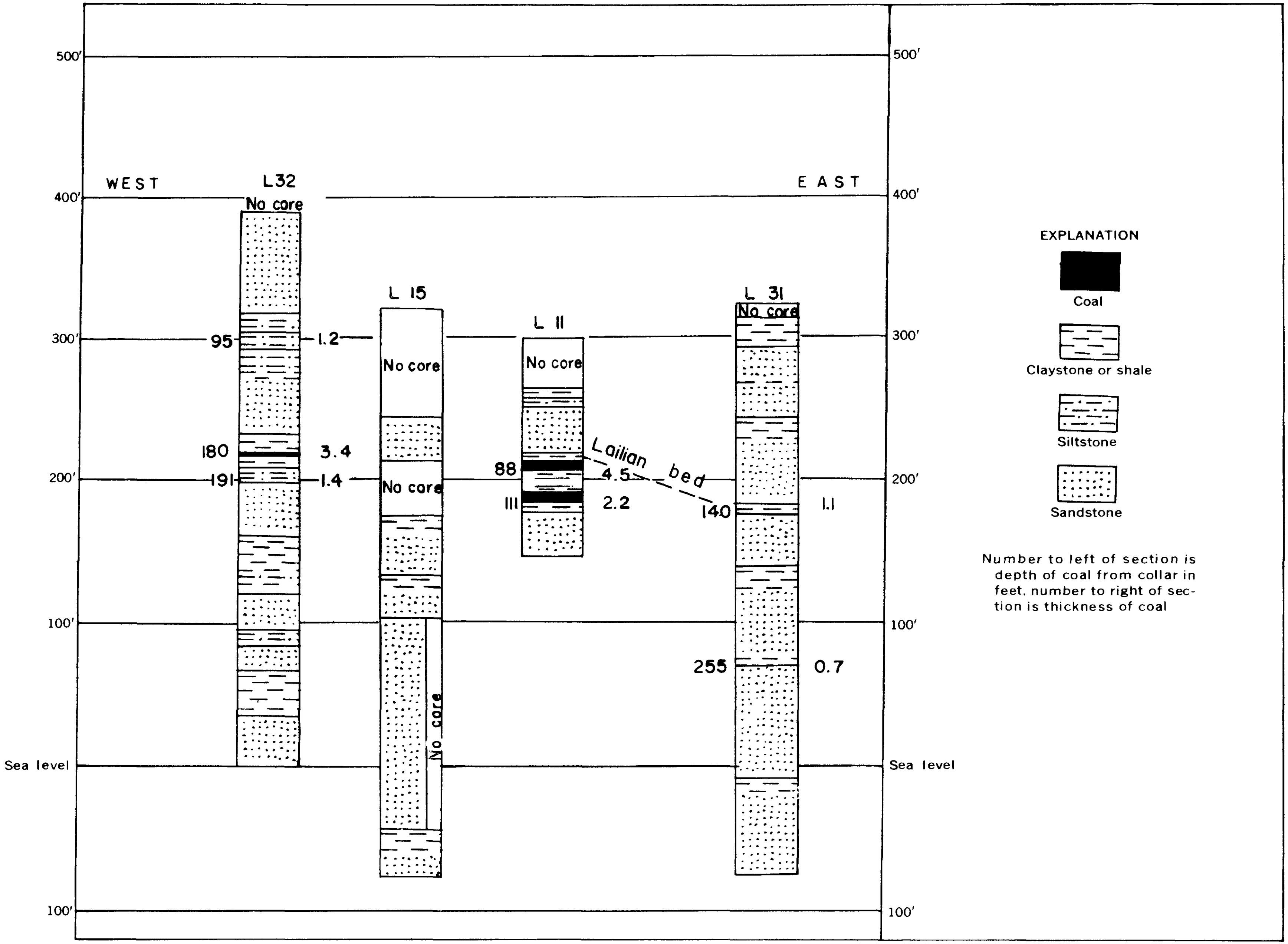


Figure 6.—Correlation of coal horizons in the east-west line of drill holes, 1 mile south of Lailian Colliery, Pakistan.

Thickness of overburden.--In many areas the amount of rock between the coal beds and the surface is of considerable importance because of the relationship of the overburden thickness to exploration and mining methods, problems that may be encountered during mining, and probable mining costs and other economic factors. Because most of the mines in Pakistan begin on a coal outcrop, and mining proceeds to only relatively shallow depths, the amount of overburden has not in the past been of great importance. In parts of the world where underground mining either has been, or probably will be, done at considerable depths, coal resources have been categorized by thousands of feet of overburden (Averitt, 1969, p. 24, 25). In areas where strip mining is possible, the amount of overburden is extremely critical. In 1965 in the United States the maximum economical ratio of overburden thickness to coal thickness--sometimes called the strip ratio--was about 30:1; the average thickness of overburden removed was about 50 feet; and the maximum thickness of overburden removed was in the 125-foot range(Averitt, 1968, p. 4). In 1968, about 34 percent of the total United States coal production came from stip mines. Although the 30:1 ratio seems technically feasible for present and near-future strip mining, a more limiting and probably much more realistic ratio is derived from the fact that the average thickness of coal recovered in the stip mines of the United States in 1965 was 5.2 feet, and the resulting ratio of average overburden thickness to average coal thickness is about 10:1(Averitt, 1968, table 1).

Table 3.--Strip ratios in the Lakhra coal field.

| Information point on figure 2 | Depth of weathering (feet) | Depth to Lailian (L) bed or other (feet) | Thickness of Lailian (L) bed or other (feet) | Strip ratio (overburden thickness (feet) divided by coal thickness (feet) |
|---|---|---|---|---|
| Lailian Colliery: | 72 | 83(L) | 0.9(L) | 92:1 |
| GSP drill hole: | | | | |
| L1 | 97 | 127(L) | 8.4(L) | 15:1 |
| L2 | 171 | ?(L) | 0 (L) | -- |
| L2 | 171 | 229 | 1.7 | 135:1 |
| L3 | 78 | 136(L) | 7.9(L) | 17:1 |
| L4 | 91 | 134(L) | 3.9(L) | 34:1 |
| L5 | 100 | 101 | 1.0 | 101:1 |
| L5 | 100 | 119(L) | 3.9(L) | 40:1 |
| L6 | 130 | 132 | 1.0 | 132:1 |
| L6 | 130 | 139(L) | 2.6(L) | 53:1 |
| L7 | 65 | 240(L) | 2.6(L) | 92:1 |
| L8 | 59 | -- | 0 (L)? | -- |
| L9 | 95 | 111(L) | 3.7(L) | 30:1 |
| L10 | 165 | 122(L) | 1.2(L)1/ | 100:1 |
| L11 | 142 | 88(L) | 4.5(L)2/ | 20:1 |
| L12 | 53 | 216(L) | 4.5(L) | 48:1 |
| L13 | 111 | 114(L) | 3.0(L) | 38:1 |
| L13 | 111 | 122 | 2.7 | 45:1 |
| L14 | 87 | 55 | 1.31/ | 42:1 |
| L14 | 87 | 170(L) | 4.5(L) | 38:1 |
| L15 | 170 | -- | 0 (L) | -- |
| L16 | <60- <180 | 195(L) | 5.5(L) | 35:1 |
| L17 | 168 | ?(L) | 0 (L) | -- |
| L17 | 168 | 175 | 0.7 | 250:1 |
| L18 | 48 | 129 | 0.3 | 430:1 |
| L18 | 48 | 197(L) | 3.5(L) | 56:1 |
| L19 | 63 | 133(L) | 2.8(L) | 47:1 |
| L19 | 63 | 144 | 1.6 | 90:1 |
| L20 | 74 | 180 | 1.6 | 112:1 |
| L20 | 74 | 258(L) | 3.0+(L) | 86:1 |
| L21 | 55 | 155(L) | 3.2(L) | 48:1 |
| L22 | 53 | 230(L) | 3.3(L) | 70:1 |
| L23 | 98 | 333(L) | 1.4+(L) | 238:1 |
| L24 | 96 | 252(L) | 1.5(L) | 168:1 |
| L25 | 351 | 403(L) | 5.0(L) | 81:1 |
| L26 | 116 | 439(L?) | 7.4(L?) | 59:1 |
| L27 | 220 | 288 | 2.0 | 144:1 |
| L27 | 220 | 355(L) | 2.7(L) | 132:1 |
| L28 | 93 | 362(L) | 10.5(L) | 35:1 |
| L29 | -- | 374(L) | 1.7(L) | 220:1 |
| L30 | -- | 293(L) | 1.0(L) | 293:1 |
| L31 | 187 | 141(L) | 1.1(1) | 128:1 |
| L32 | 80 | 180(L) | 3.4(L) | 53:1 |
| L33 | 132 | -- | 0 (L) | -- |
| L34 | 99 | -- | 0 (L) | -- |

1/ Weathered

2/ Unweathered(?)

Table 3 presents the data pertinent to strippability of coals in the Lakhra field. If the accepted parameters are (1) a maximum strip ratio of about 30:1, and (2) a maximum overburden of about 125 feet, coal that is potentially strippable may be present at four locations. The least overburden is 88 feet and the lowest strip ratio is 17:1. In comparison with strip-mining practice in the United States, these deposits would certainly be considered marginally strippable.

Another factor that limits strippability of coals in the Lakhra field is the great depth of weathering. The depths of weathering listed in table 3 range from 48 to 351 feet and average about 115 feet. Weathering tends to destroy the coals; in several drill holes where the Lailian bed was expected at relatively shallow depths, within the weathered zone, it was absent--presumably destroyed by oxidation. This factor indicates that unless unusual conditions exist in local areas, the coal will probably not be found in minable or usable condition at depths of much less than 80 to 100 feet.

## Reserves

Reserve estimates are shown for the Lailian coal bed in table 4. The bore-hole information is inadequate for estimating reserves of coal below the Lailian bed.

Table 4.--Estimated coal reserves of the Lailian coal bed.

(In millions of long tons)

| Measured reserves | Indicated reserves | Inferred reserves | Total reserves |
|---|---|---|---|
| 21.9 | 43.8 | 174.0 | 239.7 |

Reserves were estimated for the 80-square-mile area that contains all the borings in the Lakhra anticline. Within this area the average thickness of the Lailian coal bed is about 3.6 feet. The coal is missing around holes L2, L15, L17, L33, L34, and is weathered around hole L10, and it is assumed that the coal is absent in an area of about 16 square miles.

"Measured" reserves were estimated by assuming that the same thickness of coal as is present in each boring extends a quarter of a mile in all directions. "Indicated" reserves were estimated by assuming that the coal extends a quarter of amile in all directions beyond the perimeter of "measured" reserves with the same thickness as was encountered in the boring. For areas where the coal lies less than 120 feet below the surface, "indicated" and "inferred" reserves were reduced 50 percent to allow for coal destroyed by weathering. "Inferred" reserves were estimated by subtracting "measured" and "indicated" tonnage from "total" reserves. "Inferred" reserves include all coal lying more than one-half mile from any boring, but within the general area of exploration. The specific gravity of the coal was assumed to be 1.5..

## Mining factors

Zone of weathering.--The primary colors of the rocks are altered to the secondary colors yellow, brown, and red, to a certain depth in each hole. These secondary colors are caused by the ferric oxide of iron, which is formed by the weathering of ferrous iron, glauconite, and pyrite. The change of color is abrupt from the weathered to the unweathered zone. In most places the iron oxide cements the rock, making it coherent enough to support the roof and walls of mining entries without extra timbering.

Coal within the zone of weathering is generally destroyed or turned powdery by oxidation. The process of weathering might be one of the reasons for the absence of the Lailian coal at holes L15 and L17, because the zone of weathering extends far deeper than the expected depth of the Lailian coal. The range in depth of the zone of weathering is from 48 to 351 feet, and averages about 115 feet in the borings. The depth of the zone of weathering has been noted in the drill logs of the bore holes and also in table 3.

Ground water table.--Because the position of the coal bed with reference to the ground-water table is important, efforts were made to ascertain the depth of the standing water level in each of the drill holes. In some drill holes it was not possible to measure the water level because the hole collapsed, or because the diameter of the hole was too small toward the bottom to allow measurement. Also, in some holes, circulating drilling water interfered with the accurate determination of the level of the water table. The standing water level measured from the collar of the table ranges from depths of 10 feet along stream courses to 262 feet measured at drill hole L 10, but drill hole L24 was found to be dry to 300 feet. The water table lies below the zone of weathering throughout the area. The measurement to the distance to this water table is given in the log for each drill hole(p. 55). The drillers were not equipped to take water samples, the quality of the water was not determined; however, the water of the wells in the area is sweet.

Rocks above and below the coal.--The rocks overlying the coal are sandstone, siltstone, and claystone. The gross lithology is represented in the columnar sections (figs. 2 to 6). Information on the materials above and below the Lailian coal is contained in the drill logs. Claystone forms the roof over the Lailian coal bed except in the northern part of the area, where sandstone caps the coal bed. The sandstone is soft to moderately hard and is generally harder within the zone of weathering. The claystone is moderately hard and plastic, and contains films of pyrite and coaly matter.

The claystone roof appears to be strong and would require minimum support in underground mining. Moreover, water seepage should not create any problems because of the imperviousness of the claystone.

## Prospecting

Prospecting by drilling or sinking test pits is necessary because of the thick weathered zone and the variation in thickness of the coal. In sinking test pits for coal, several factors should be considered:

1) Minable coal beds probably will not be found close to the surface because these may have been destroyed by weathering.
2) Below the lowest fossiliferous beds, most of the rock is soft, easily dug sandstone. Unlined vertical shafts have been sunk to depths of 90 feet, but deeper shafts may cave unless they are lined.
3) Light-gray claystone commonly will be found above and below the Lailian coal bed. Prospect pits should be carried through the claystone-coal sequence and well into the underlying soft sandstone in order to avoid mistaking thin coal beds above the Lailian bed for the main coal bed.
4) Chances of finding minable coal are best in the zone below the water table, but mining in this zone will require pumping.

## Other valuable materials

Limestone and laterite are present in large quantities in the area. Clay, gypsum, and glass sand also exist, but are not promising in quality and quantity. Showings of gas were reported by Pak-Hunt International Oil Co. and have been further explored by the Pakistan Oil and Gas Development Corp.

### Limestone

Limestone in the Ranikot Formation flanks the anticline on the east and south. The yellow or brown color caused by the associated iron oxide might be prejudicial for the manufacture of cement.

The Laki Limestone is yellowish gray and has only slightly yellow stains. It is present in inexhaustible quantity at Lakhra and adjoining areas. The Laki Limestone is being utilized for the manufacture of cement at the Zeal Pak Cement Factory, Hyderabad. This limestone could also be used to manufacture lime.

### Clay

White clay was cored in drill hole L2 at depths of 17 feet and 100 feet. Two samples were analyzed and the chemical data are given below(in percent):

| | $SiO_2$. | $Al_2O_3$ | $Fe_2O_3$ | CaO | MgO | $Na_2O$ | Loss on ignition |
|---|---|---|---|---|---|---|---|
| 10-foot bed at 110 feet | 59.75 | 25.89 | 2.62 | 1.47 | 0.32 | -- | 9.91 |
| 3-foot bed at 17 feet | 53.38 | 32.85 | 1.75 | 1.02 | 0.58 | -- | 10.02 |

White clay was not encountered in any other boring. Small pockets and lenses were found in one of the Habibullah Co's. mines. The white clay is probably lenticluar but present information is insufficient to show the extent.

## Gypsum

Lenses of gypsum and selenite are present in the claystones and soft sandstones in the upper part of the Ranikot Formation, and small chunks of selenite are scattered in the hill slopes. No large deposits have been observed, and no gypsum bed was encountered in the drill holes.

## Glass sand

Loose quartz sand was penetrated at shallow depth in all the bore holes. At shallow depth the sand has secondary iron oxide colors, and is probably undesirable for the manufacture of glass. Samples of white sand were collected from 280 to 292 feet in drill hole L24. The samples contained traces of dark minerals, and the sand is almost certainly too deep for quarrying. Because of the depth of weathering, the possibility of finding good quality glass sand in the area within shallow depth is remote.

## Laterite

At the contact between the Ranikot and the Laki a layer of ferruginous claystone and siltstone is present which has commonly been called "laterite." The thickness measured in the area ranges from 7 to 19½ feet. It is brick-red to brown in color with sporadic white spots and is moderately hard. At drill holes L23, L25, and L27, the so-called "laterite" is missing.

The The "laterite" in the Lakhra area was discussed by M. I. Ahmad of the Geological Survey of Pakistan in an unpublished summary report on "laterite" in Pakistan. Samples of this material were collected by S. H. A. Shah, of the Geological Survey of Pakistan, and the following is the result of the chemical and mineralogical analysis of one of his samples.

Table 5 .--Chemical and mineralogic analyses of sample 1780 (in percent).

[Chemical analysis by Shapiro and others, U.S. Geological Survey, by X-ray fluorescence and rapid melting; mineralogic analysis by S. H. A. Shah, Pakistan Geological Survey, and T. Botinelly, U.S. Geological Survey, estimated by fluorescent X-ray].

| Chemical | | Mineralogic | |
|---|---|---|---|
| $SiO_2$ | 12.5 | Kaolinite | 20 |
| $Al_2O_3$ | 30.7 | Hematite | 40 |
| $Fe_2O_3$ | 27.3 | Boehmite | 10 |
| FeO | 2.6 | Calcite | 10 |
| MgO | 3.3 | Fluid | 20 |
| CaO | 2.7 | | |
| $Na_2O$ | .50 | | |
| $K_2O$ | .10 | | |
| $H_2O-$ | 2.0 | | |
| $H_2O+$ | 12.5 | | |
| $TiO_2$ | 4.0 | | |
| $P_2O_5$ | .19 | | |
| MnO | .50 | | |
| $CO_2$ | 1.6 | | |

The sample contains almost equal percentages of iron oxide and aluminum oxide. Hematite constitutes 40 percent of the sample. This quantity of hematite will give nearly 26 percent of iron.

S. A. Stanin of the U. S. Geological Survey collected 34 samples of the so-called "laterite" from localities in the Lakhra area. The analyses are given in table 6.

Table 6.--Analyses of "laterite" samples from the Lakhra area (in percent).
[Analyses by the Chemical Laboratory of the Geological Survey of Pakistan, Quetta]

| Location: Latitude | Location: Longitude | Lab no. | Field no. | $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | FeO | $TiO_2$ | $P_2O_5$ | CaO | MgO | Loss on ignition |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 25°43'30" N. | 68°08'00" E. | 1245(1) | 64-SAS-1 | 17.54 | 13.64 | 20.00 | 2.51 | 4.49 | 0.04 | 11.21 | 0.97 | 24.86 |
| 25°43'30" N. | 68°08'00" E. | 1245(2) | 64-SAS-2 | 12.60 | 13.29 | 40.24 | 1.79 | 2.55 | .08 | 5.04 | .97 | 20.88 |
| 25°45'24" N. | 68°07'54" E. | 1245(3) | 64-SAS-3 | 7.34 | 4.41 | 61.03 | 2.51 | 7.14 | .03 | 4.34 | 1.37 | 10.71 |
| 25°45'24" N. | 68°07'54" E. | 1245(4) | 64-SAS-4 | 23.04 | 20.53 | 24.43 | 9.69 | 3.57 | .10 | .28 | 2.06 | 16.05 |
| 25°45'24" N. | 68°07'54" E. | 1245(5) | 64-SAS-5 | 12.84 | 11.88 | 51.88 | 1.79 | 2.04 | .13 | .14 | 1.26 | 15.13 |
| 25°45'33" N. | 68°07'53" E. | 1245(6) | 64-SAS-6 | 22.62 | 15.63 | 40.69 | 1.07 | 3.57 | .12 | .28 | 1.08 | 12.85 |
| 25°45'33" N. | 68°07'53" E. | 1245(7) | 64-SAS-7 | 23.00 | 22.15 | 31.13 | .35 | 3.78 | .16 | 1.40 | .83 | 16.58 |
| 25°45'33" N. | 68°07'53" E. | 1245(8) | 64-SAS-8 | 21.68 | 26.29 | 26.41 | .64 | 3.57 | .12 | .56 | .76 | 19.96 |
| 25°45'33" N. | 68°07'53" E. | 1245(9) | 64-SAS-9 | 22.22 | 22.52 | 32.32 | .35 | 4.53 | .05 | 1.40 | .79 | 15.24 |
| 25°45'28" N. | 68°07'32" E. | 1245(10) | 64-SAS-10 | 22.48 | 21.54 | 34.24 | .86 | 3.57 | .09 | .84 | .86 | 15.36 |
| 25°45'28" N. | 68°07'32" E. | 1245(11) | 64-SAS-11 | 23.44 | 20.42 | 34.24 | .78 | 3.57 | .11 | .42 | .94 | 16.04 |
| 25°42'21" N. | 68°07'25" E. | 1245(12) | 64-SAS-12 | 20.64 | 32.61 | 22.98 | .86 | 3.54 | .09 | .70 | .43 | 17.72 |
| 25°42'21" N. | 68°07'25" E. | 1245(13) | 64-SAS-13 | 18.48 | 18.78 | 41.89 | .93 | 2.70 | .04 | .84 | .51 | 15.34 |
| 25°42'21" N. | 68°07'25" E. | 1245(14) | 64-SAS-14 | 13.74 | 22.53 | 39.89 | 1.58 | 3.00 | .60 | 1.40 | 1.33 | 16.51 |
| 25°42'21" N. | 68°07'25" E. | 1245(15) | 64-SAS-15 | 20.90 | 17.18 | 39.89 | .65 | 2.20 | .08 | 1.40 | 1.63 | 15.21 |
| 25°42'34" N. | 68°07'31" E. | 1245(16) | 64-SAS-16 | 8.02 | 1.62 | 17.85 | .50 | .70 | .07 | 36.40 | 1.19 | 32.78 |
| 25°42'34" N. | 68°07'31" E. | 1245(17) | 64-SAS-17 | 33.40 | 23.90 | 19.94 | .72 | 3.00 | .04 | 1.82 | 1.73 | 15.32 |
| 25°41'57" N. | 68°12'18" E. | 1245(18) | 64-SAS-18 | 14.00 | 19.22 | 41.89 | .65 | 2.50 | .14 | 1.12 | .72 | 19.79 |
| 25°41'57" N. | 68°12'18" E. | 1245(19) | 64-SAS-19 | 9.02 | 45.71 | 18.27 | .43 | 3.00 | .05 | 1.26 | .90 | 21.16 |
| 25°41'57" N. | 68°12'18" E. | 1245(20) | 64-SAS-20 | 13.30 | 26.34 | 38.71 | .35 | 2.50 | .07 | 1.12 | 1.37 | 15.62 |
| 25°42'25" N. | 68°12'09" E. | 1245(21) | 64-SAS-21 | 26.60 | 26.58 | 25.86 | 1.14 | 2.80 | .10 | .58 | 1.77 | 14.48 |
| 25°42'25" N. | 68°12'09" E. | 1245(22) | 64-SAS-22 | 11.68 | 36.36 | 25.77 | .86 | 3.20 | .12 | .42 | .61 | 20.84 |
| 25°42'25" N. | 68°12'09" E. | 1245(23) | 64-SAS-23 | 10.62 | 39.58 | 23.66 | 1.14 | 3.40 | .14 | .56 | .90 | 20.06 |
| 25°42'25" N. | 68°12'09" E. | 1245(24) | 64-SAS-24 | 9.60 | 32.23 | 34.63 | .43 | 2.70 | .07 | .98 | .76 | 18.26 |
| 25°42'25" N. | 68°12'09" E. | 1245(25) | 64-SAS-25 | 11.80 | 44.99 | 17.71 | .57 | 4.50 | .07 | 1.40 | 1.10 | 17.18 |
| 25°42'25" N. | 68°12'09" E. | 1245(26) | 64-SAS-26 | 14.12 | 45.39 | 11.41 | .50 | 4.60 | .10 | .70 | .76 | 21.90 |
| 25°42'25" N. | 68°12'09" E. | 1245(27) | 64-SAS-27 | 24.74 | 29.57 | 29.84 | .43 | 1.50 | .10 | .14 | .32 | 12.56 |
| 25°32'07" N. | 68°06'35" E. | 1245(28) | 64-SAS-28 | 11.60 | 39.24 | 21.95 | .71 | 4.50 | .13 | .70 | .57 | 20.28 |
| 25°32'07" N. | 68°06'35" E. | 1245(29) | 64-SAS-29 | 8.72 | 30.72 | 34.79 | .28 | 3.00 | .18 | .56 | .86 | 20.26 |
| 25°32'07" N. | 68°06'35" E. | 1245(30) | 64-SAS-30 | 5.44 | 22.27 | 39.89 | .50 | 3.80 | .04 | 2.80 | 1.23 | 23.42 |
| 25°32'07" N. | 68°06'35" E. | 1245(31) | 64-SAS-31 | 5.22 | 23.56 | 43.88 | .36 | 3.90 | .10 | 1.82 | 1.81 | 18.94 |
| 25°32'07" N. | 68°06'35" E. | 1245(32) | 64-SAS-32 | 7.66 | 27.97 | 31.91 | .36 | 4.20 | .06 | 2.80 | 1.52 | 23.62 |
| 25°32'07" N. | 68°06'35" E. | 1245(33) | 64-SAS-33 | 11.32 | 17.79 | 45.87 | .57 | 3.10 | .07 | 1.96 | 1.26 | 17.68 |
| 25°32'07" N. | 68°06'35" E. | 1245(34) | 64-SAS-34 | 11.04 | 14.03 | 39.89 | .86 | 3.70 | .12 | 8.40 | 2.36 | 18.80 |

## MINING OPERATIONS--1969

by

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Since 1959 more than 20 coal prospecting and mining lenses have been granted in the Lakhra coal field, but in June 1969, only four mining companies were active in the field--the K. B. H. M. Habibullah Coal Co., Baluchistan Coal Co., Indus Coal Co., and Khan Coal Co.

The following section on mining methods, operatins, and marketing deals with the operations of the two largest producers in the field. The information was extracted from a series of reports prepared as a part of the Mining Technology and Development Project--a joint effort of the Directorate of Mineral Development, Government of Pakistan, and the United States Agency for International Development. The project was established to help increase production and efficient extraction of indigenous minerals by mining companies throughout the country.

### Habibullah Mining Co.

The Habibullah Mining Co. was granted licenses in 1959 for two leases, each for 3,200 acres, in the Lakhra coal field. Development and exploitation followed rapidly. Most of the coal is used by the brick industry, but a small amount is used for process heating in the Hyderabad area.

Production averaged 126 tons per day in 1968; approximately a 50-percent increase was planned for 1969. Total number of employees ranged from 200 to 500 and was directly related to market conditions.

The nearly level coal bed in the lease areas is commonly 2 to 5 feet thick; overburden ranges from 65 to 125 feet. The roof and bottom consist of dry shale and slate. The upper strata consist of dry claystone, siltstone, and thin bands of sandstone. The general roof and bottom conditions are good, and wide areas can be mined while retreating without roof subsidence.

Management estimates that of the 6,400 acres in the leases, 5,000 acres contain coal that averages 2½ feet in thickness and has a specific gravity of 1.2. Reserves are estimated to be 18 million tons. With a production of 100 tons per day and a work year consisting of approximately 300 days, the life expectancy, according to management, would be 600 years, considering full extraction of the coal. Calculating a 60-percent recovery, with production approaching 200 tons per day, coal reserves at the present rate of production will last for approximately 180 years.

## Mine development program

Mode of entry.--The system of gaining access to the coal bed is basically the same throughout the coal field. Either shafts or inclined slopes are driven. The shafts are commonly 8 to 10 feet in diameter, are unlined except at the shaft collar, and have a 50-foot chimney constructed at the top to be used as a return airway. Inclines can be substituted for return air shafts at the discretion of the management.

The inclined slope driven at a gradient of one in two or one in three usually averages from 100 to 250 feet in length. Dimensions are approximately 6 feet high and 7 feet wide; the roof is supported by round bars and posts approximately 4 inches in diameter, installed on 3- to 4-foot centers depending upon the immediate roof. At times extra timber is set as conditions change.

Mining method.--To prevent the loss of a large mine through fires due to spontaneous combustion of the coal, the area is divided into 700-foot-square blocks, each block being considered as one mine, and having a shaft and haulage incline near the center. The area is subdivided underground into four equal blocks, each being 350 feet square.

An air connection is made at the bottom of the incline and shaft and two entries driven into the virgin coal to the boundary line of one block. Cross cuts are driven between the two entries for air connections and the roof is taken down or the bottom trenched to allow enough area for transportation of bagged coal by the workers.

The room-and-pillar system is used to develop separately one of the four 350-foot square blocks. This is done by driving entries 5 feet wide on 37½ foot centers, with cross cuts on equal centers. Blocks approximately 35 feet square remain for roof support and are mined while retreating.

After the mining has been completed in one of the four blocks, the second is mined, followed in turn by the remaining two blocks. The shaft and incline are sealed and mining is started in another four-panel block. The same system is again used in new areas. This system allows management to operate many different mines within a small area. Approximately 15 of these mines are in operation, employing from 5 to 25 men.

This system has been proved to be successful and production can easily be increased by employing more workers.

No machinery is used underground (the coal is relatively soft and easily mined,) and all coal is produced by means of hand tools.

Method of coal transportation.--The conventional system is used for all coal transportation. Coal is loaded at the working face into burlap bags and carried by workers to the outside surface, a maximum distance of 800 feet. This distance is reduced when a new panel is started or when the panel is being completed.

The coal is unloaded on the surface, rebagged, and trucked approximately 12 miles by unimproved road to the Khanot Railway station, if railroad cars are available, or trucked the remaining 30 miles by hard-surfaced road to Kotri where a more dependable car supply exists.

Pumping.--Very little water is present in the mines and no pumps were seen in visits to any of the underground workings.

At present, arrangements are being made to pump water from the Indus River to the operating mines, a distance of 12 miles by pipeline; this will be used as the main source of water supply. Filter beds are used for purification purposes.

Ventilation.--Natural ventilating pressure is used by means of chimneys that increase the vertical distance between intake and return, and improve the ventilation system. The chimneys are approximately 50 feet high, and tapered at the top to a 4-foot diameter opening.

Single wooden doors or brattice cloth are used underground to control the air current. Stoppings are built of refuse plastered with mud and straw to prevent air leakage.

Because of many working entries underground it is difficult to get the maximum amount of air to each working face area. The temperature of the return air current is very high, and the early morning shift is commonly the only one worked in order to take advantage of lower outside air temperatures.

Power requirements.--No power is used underground. One 10-kw generator is available on the surface to supply needed electricity, if required.

Required equipment.--No additional equipment is needed at the present time. Additional production would require more mine workers and some hand tools.

The equipment available at the mine is as follows:

2 air compressors, 200 psi.
1 generator, 10-kw.
7 Beco engines.
250 electric cap lights.
1 fan, 4½-foot diameter.
1 locally made ventilation fan.

## Conclusions and recommendations

Although market conditions determine the mine production, the management feels that extra production, when needed, can be achieved by opening more mines and increasing the labor force. Eventually, however, the only alternative will be through increased efficiency of the workers. This can be obtained by providing better tools, services, and mining plans for coal extractions.

At the present time, haulage of coal from the working face to the outside by burlap bag is time consuming and inefficient. With faster movement of coal through the mine, production could easily be increased. Haulage could be improved through the use of roller conveyors in low working areas, track haulage in main entries, and mechanized haulage inclines to the outside surface.

A higher percentage of coal recovery from the developed 350-foot square coal blocks may be possible through a systematic system of splitting the block until the coal is completely mined, and then allowing the roof to cave after the maximum amount of timber has been recovered. This will accomplish three main purposes. First, a systematic supervised system will be established; second, less coal will be lost, resulting in a higher percentage of recovery for each shaft and incline installation; and third, a maximum amount of timber will be recovered, which will lower the cost of roof supports.

Additional ventilation, through the use of exhaust fans and mining systems designed to have a minimum amount of control and regulation, should lower the temperature in the mine and improve production.

**Coal ignition due to spontaneous combustion has presented another problem. Although distant markets are available, the coal cannot be** transported long distances because of the fire danger. This factor reduces potential markets. The railroad has been assisting the mining industry in trying to provide faster transportation to consumers, but conditions do not permit improvements at this time.

To prove the coal bed throughout the two leases a regular pattern of core samples should be taken. If more productive systems of mining are adopted, this information will be necessary for future planning of the mine workings.

## Baluchistan Coal Co.

Baluchistan Coal Co. was granted a 3-year coal prospecting license in 1965 in the Lakhra field by the Department of Mineral Development. The lease contains 3,099 acres, with provision for the inclusion of an additional 916 acres.

This lease area is south of the mines being operated by the Habibullah Co. An unimproved road approximately 12 miles long connects the mine with the Khanot Railway Station where coal can be loaded into railroad cars when available, or trucked an additional 30 miles to the Kotri siding where car supply is more dependable.

During the first two years of prospecting, 4,820 tons of coal were produced. At present(1969) approximately 70 workers are employed, who produce 30 tons per day. Because of the lack of demand for the coal, the mines are only operated during the three to four coldest months of the year. The company plans to develop the mines in anticipation of improved market conditions. At present the bed being worked is from 3 to 4 feet thick and has an overburden of approximately 125 feet. The coal is used primarily in the Hyderabad area for the brick kiln industry and home-heating purposes.

The prospecting lease area has not been core drilled extensively enough to determine the reserves, but management estimates reserves in excess of one million tons. The life expectancy has not been calculated because reliable information is not available, and production cannot be predicted.

### Mine development program

Mode of entry.--Four parallel inclines, each 400 feet apart driven on a gradient of 1 in 3, have been driven to the coal bed. Each incline is slightly more than 400 feet long. Number 2 incline has a 20-foot chimney constructed on the surface to improve the natural ventilating pressure and this incline is considered as a return airway. Number 3 and 4 inclines serve both as intake airways and haulage inclines. Number 5 incline has been driven 408 feet as an exploratory incline to prove the coal bed. Number 1 prospecting incline had been driven in another location to prove the bed, without results.

The inclines are driven approximately 6 feet high and 8 feet wide, the roof being supported by round 4- to 5-inch-thick wooden posts and cross bars on 4-foot centers. Weaker strata requires extra timber sets with wooden lagging strung on the top of the bars for extra roof support.

Mining methods.--This area is considered a prospecting lease and 4,820 tons of coal were produced in the first 2 years of operation. Two bore holes have been drilled by the Geological Survey of Pakistan in this immediate area with encouraging results.

Three inclines, nos. 2, 3, and 4, have been connected underground and a natural ventilation system established. The entries have been driven from the incline bottoms on an unsystematic pattern. The general method of development by the workers, who are on a production basis, is to drive parallel entries, and cross cuts or breakthrough for air connections.

The mining of the coal bed diverts the entry toward the thicker parts, resulting in convergence of parallel entries.

Roof or bottom is removed along the main haulageways to provide the necessary height for the workers who transport the coal underground. The refuse derived is packed in the entries between the intake and return, providing a support for the roof, and when sealed with mud and straw provides a stopping that prevents shorting of the air current.

All mining is done with hand tools. Coal is mined by picks at the working face and shoveled into burlap bags. Hand saws are used to cut posts and wooden bars and all timbers and sets are tightened with hammers. Air-compressor equipment and tools are required when driving haulage inclines through sandstone, limestone, or slate.

The roof was found to be adequately supported in all haulage inclines and underground workings.

Method of coal transportation.--All coal at the working face is loaded into burlap bags containing approximately 150 pounds when full, and carried to the outside surface. If a winch has been installed in the haulage incline, the coal is pulled to the surface, eliminating the extra 400-foot haul for the men. Coal is trucked to the Kotri railhead and loaded into railroad cars. This method of coal transportation is typical of that used in the majority of mines throughout the country.

Pumping.--Pumps are not commonly required because the area is very dry.

Ventilation.--Natural ventilating pressure is provided by the use of chimneys which are approximately 20 feet high and are tapered at the top to a 3-foot diameter opening. The chimneys increase the vertical distance between intake and return, thus improving the ventilation system.

Either single wooden doors or brattice cloth is used underground to control the air current. Stoppings are built of mine refuse plastered with mud and straw to prevent air leakage. With many working entries underground it is difficult to get the maximum amount of air to each working face area. The temperature of the return air current is generally very high and the early morning shift is usually worked to take advantage of lower outside air temperatures.

Power requirements.--No electric power is used underground. Some electricity is produced by small diesel-operated generating sets for electric motors and surface illumination purposes.

Required equipment.--Management plans to procure a 50-kw power-generating set and a second air compressor. A small amount of equipment is required with the present system of mining.

## Comments and recommendations

Systematic core drilling of the entire lease would enable management to gain valuable information with which reserves could be determined and suitable mining plans could easily be adopted. Without known reserves, mechanization of the present property may prove costly, if development is based primarily on probable reserves.

Management should consider the following if the present mining system is used:

1). A mining system adopted in strict compliance with the original mine plans. This will allow the mine to be developed on a predetermined plan and will result in uniform operations.

2). Surveyors should install stations, sites, or spads underground to allow workers to drive entries in a straight and parallel line, with air connections made at regular intervals.

3). Improved ventilation underground consisting of exhaust fans capable of delivering 15,000 to 20,000 cubic feet of air per minute, with effective control and regulation. Increased quantities of air underground will lower the temperature, improving conditions for production.

4). The transportation of coal underground could be improved by using roller conveyors to transport the bagged coal to the main haulage road and installing track in main entries. Use of either flat cars for bagged coal or mine cars for the bulk coal, would be helpful. Electric hoists could easily haul the coal cars to the surface.

5). For faster coal transportation, underground, chain, or belt conveyors should be considered.

6). Air-compressor tools used at the working face would allow easier mining of the coal. Compressors could be installed on the outside surface and the air piped underground.

From the above-mentioned six items, those concerning mine planning, improved haulage and increased ventilation are of most importance and should be considered in future planning. Market requirements will determine the amount of mechanization at each mine and plans should be formulated at the present time to meet this eventual occurrence.

## CONCLUSIONS AND RECOMMENDATIONS

The Lailian coal bed lies at a shallow depth of 83 to 439 feet for an area of at least 64 square miles. Easy accessibility, low dip of the beds, simplicity of the structure, large reserves, favorable roof and floor material, and the possibility of obtaining a supply of timber from the neighboring areas, all favor large-scale mining of this bed.

The coal is subject to spontaneous combustion. The effect of this factor, can, however, be minimized to a great extent by making fuel briquettes out of the coal. Petroleum asphalt is generally used as binding material. Excluding water, binders usually constitute 6 to 8 percent of the total raw material. The binders or adhesives form a thin coating over the coal and thereby protect it from direct contact with the oxygen of the air and prevent spontaneous combustion. In this matter the coal could be transported in the form of briquettes for industrial and domestic use.

To make optimum use of the coal resources, the possibility of utilizing the Lailian coal for the manufacture of coal chemicals, and possibly a high-carbon char, should be investigated. Several interesting processes have already been developed in the United States and Europe for producing metallurgical fuel from non-coking or poorly coking coals. These processes are now in the pilot stage or in limited commercial production.

The availability of ample coal, limestone, and clay suggests the possibility of establishing a cement plant at Khanot or Kotri to supplement the output of the Pakistan Industrial Corporation which is already producing cement at Hyderabad. Although natural gas is used in the Hyderabad cement plant and also in the manufacture of electricity for the region, future development of the coal at Lakhra for cement, electricity, and coal chemicals seems worth considering to help the local mining industry, to facilitate the diversification in coal utilization, and to conserve the natural gas for use elsewhere.

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# APPENDIX

Measured sections and drill hole logs L1 - L34

Lailian Colliery

Location of pumping shaft: At site labelled "well" on Survey of Pakistan sheet 40 C/2.

Survey of Pakistan Grid coordinates: 2,358,900 yds. E., 975,400 yds. N. (Lat 25°40'40" N., Long 68°09'02" E.)

Ground elevation: 316 feet above sea level.

Depth of zone of weathering: 72 feet?

Depth of standing water level: Near top of coal at 83 feet.

Section measured from bottom of pumping shaft to the surface at the entry of the main incline 230 ft to the southwest.

| Thickness (ft) | Stratum, ground level |
|---|---|
| 1.0 | Sandstone, dark red, ferruginous |
| 6.0 | Sandstone, gray |
| 2.0 | Shale, light gray, containing hard brown ferruginous layers |
| 44.0 | Sandstone, orange and light gray, thinly bedded, friable |
| 3.2 | Claystone, light yellow, chalky |
| 0.1 | Coal |
| 0.5 | Claystone, light brown |
| 0.2 | Claystone, coaly |
| 8.0 | Claystone, light gray, massive, lenses of friable sandstone |
| 1.0 | Shale, reddish-orange |
| 1.4 | Shale and coal, interlaminated |
| 2.0 | Shale, red and yellow |
| 0.3 | Shale, black, coaly |
| 12.0 | Claystone and siltstone, light gray, laminated |
| 0.8 | Claystone black |
| 0.4[1] | Coal, Lailian bed, average of two measurements |
| 0.3 | Shale, average of two measurements |
| 0.5[1] | Coal, Lailian bed, mine wall, average of two measurements |
| 0.2 | Claystone, dark brown, coaly. Bottom of mine. |

[1] Proximate and ultimate analyses, Table 2.

## Drill-hole logs

Drill hole L1
Location: 0.5 mile east of Lailian Colliery pumping shaft.
Survey of Pakistan Grid coordinates: 2,359,800 yds. E., 975,400 yds. N.
Ground elevation: 347 feet above sea level.
Depth of zone weathering: 97 feet     Depth of standing water level: 120 feet
Total depth: 468 feet.

Description of thicker coal cores:

| Depth (ft) | Thickness (ft) | Stratum |
|---|---|---|
| | | Claystone roof |
| | 0.3 | Coal |
| | 4.0 | Claystone |
| | 0.5 | Coal |
| 115 ------------ | 0.3 | Claystone |
| | 1.3 | Coal |
| | 10.1 | Claystone, light gray |
| 127 2/ ---------- | 4.9 1/ | Coal, Lailian bed |
| | 1.3 | Claystone |
| | 3.5 1/ | Coal, Lailian bed |
| | | Claystone floor |
| | | |
| | | Coaly shale roof |
| 189 ------------ | 2.1 | Coal |
| | | Coaly shale floor |
| | | |
| | | Sandstone roof |
| 268 ------------ | 1.3 | Coal, sandy at top |
| | 1.2 | Claystone |
| | 0.3 | Coal, dirty |
| | | Siltstone floor |
| | | |
| | | Claystone roof |
| 327 ------------ | 1.7 | Coal |
| | | Coaly shale floor |
| | | |
| | | Claystone roof |
| 345 ------------ | 1.1 | Coal, shattered, possibly as thick as 3.5 ft |
| | | Claystone floor |
| | | |
| | | Claystone roof |
| 396 ------------ | 1.7 | Coal |
| | | Claystone floor |
| | | |
| | | Claystone roof |
| 420 ------------ | 1.8 | Coal, dirty |
| | 0.6 | Claystone |
| | 2.0 | Coal, shattered, but at least 1.7 ft thick |
| | 1.0 | Claystone |
| | 0.5 | Coal, very dirty |
| | 9.4 | Claystone and siltstone |
| 435 ------------ | 0.8 | Coal |
| | 0.6 | Coaly shale |
| | 2.9 | Coal, between 2.4 and 3.8 ft thick |
| | | Claystone floor |

1/ Proximate analysis, Table 2
2/ Most depths given only for potentially economic coal beds. Depths to smaller beds can be extrapolated by adding or subtracting the figures in thickness column.

Drill hole L2

Location: 1.1 mile east-southeast of Lailian Colliery shaft.

Survey of Pakistan Grid coordinates: 2,360,600 yds. E., 974,500 yds. N.

Ground elevation: 317 feet above sea level.

Depth of zone of weathering: 171 feet.

Depth of standing water level: 235 feet.

Total depth: 462 feet.

Lailian coal seam is missing in this hole.

| Depth (ft) | Thickness (ft) | Stratum |
|---|---|---|
| | | Sandstone roof |
| | 0.3 | Coaly shale |
| 229---------- | 1.3 | Coal |
| | 0.1 | Coaly shale |
| | 0.1 | Coal |
| | 0.3 | Clay and siltstone |
| | 0.1 | Coal |
| | 0.1 | Siltstone |
| | 0.2 | Coal |
| | | Coaly shale floor |
| | | |
| | | Claystone roof |
| | 0.2 | Coaly shale |
| | 0.6 | Coal |
| | 0.9 | Shale |
| 302---------- | 2.5 | Coal |
| | 4.8 | Siltstone and claystone |
| 313---------- | 0.5 | Coal, between 0.2 and 1.6 ft thick |
| | 0.5 | Coal, dirty |
| | | Claystone floor |
| | | |
| | | Claystone roof? |
| 337---------- | 0.7 | Coal, shaly; because of core loss coal may be as thick as 3 ft |
| | | Claystone floor |
| | | |
| | | Sandstone roof? |
| 363---------- | 2.5 | Coal, between 1.0 and 4.2 ft thick |
| | | Siltstone floor |
| | | |
| | | Sandstone roof? |
| 455---------- | 2.5 | Coal, badly shattered; because of core loss, coal may be as thick as 6 ft |
| | | Claystone floor |

Drill hole L3

Location: 1 mile west of Lailian Colliery pumping shaft.

Survey of Pakistan Grid coordinates: 2,357,100 yds. E., 975,450 yds. N.

Ground elevation: 355 feet above sea level.

Depth of zone of weathering: 78 feet.

Depth of standing water level: Not known

Total depth: 501 feet

Description of thicker coal cores:

| Depth (ft) | Thickness (ft) | Stratum |
|---|---|---|
| | | Claystone roof |
| 136 ------------ | 0.2 | Sandstone |
| | 0.8 | Coal |
| | 8.5 | Claystone |
| | 3.5 1/ | Coal, Lailian bed |
| | 1.2 | Claystone |
| | 3.7 1/ | Coal, Lailian bed |
| | 0.5 | Claystone |
| | 0.7 | Coal |
| | | Claystone floor |
| | | |
| | | Sandstone roof |
| 200 ------------- | 2.3 | Coal, shattered core, at least 1.3 ft thick |
| | | Claystone floor |
| | | |
| | | Claystone roof |
| | 1.3 | Coal |
| | 0.2 | Dirty coal |
| | 0.2 | Coal |
| | 2.2 | Coaly shale |
| | 0.3 | Coal, clayey |
| 398 ------------- | 7.7 1/ | Coal, shattered core, 3.8 ft recovered in core |
| | | Claystone floor |
| | | |
| | | Claystone roof |
| 453 ------------- | 2.5 1/ | Coal, dense, hard, dull luster |
| | 0.4 | Shale, coaly |
| | 0.3 | Siltstone |
| | | Claystone floor |

1/ Proximate analysis, Table 2.

Drill hole L4

Location: 2 miles east of Lailian Colliery pumping shaft.

Survey of Pakistan Grid coordinates: 2,362,400 yds. E., 975,250 yds. N.

Ground elevation: 362 feet above sea level.

Depth of zone of weathering: 91 feet.

Depth of standing water level: More than 95 feet.

Total depth: 412 feet.

Description of thicker coal cores:

| Depth (ft) | Thickness (ft) | Stratum |
|---|---|---|
| | | Claystone roof |
| 134 ----------- | 3.9 1/ | Coal, Lailian, 3.5-ft core recovered but bed could be as much as 5.6 ft thick |
| | | Claystone floor |

Below 142 feet little core was recovered

1/ Proximate analysis, Table 2.

Drill hole L5

Location: 0.5 mile west of the Lailian Colliery pumping shaft.

Survey of Pakistan Grid coordinates: 2,258,000 yds. E., 975,400 yds. N.

Ground elevation: 329 feet above sea level.

Depth of zone of weathering: 100 feet.

Depth of standing water level: At least 130 feet.

Total depth: 433 feet.

Description of thicker coal cores:

| Depth (ft) | Thickness (ft) | Stratum |
|---|---|---|
| | | Claystone roof |
| 101 ---------- | 1.0 | Coal |
| | 0.7 | Coaly shale |
| | 0.5 | Coal |
| | | Shale floor |
| | | |
| | | Claystone roof |
| | 0.2 | Coal |
| | 0.3 | Shale |
| 119 ---------- | 3.0 | Coal, Lailian bed |
| | 1.8 | Claystone |
| | 0.3 | Coal |
| | | Claystone floor |
| | | |
| | | Claystone roof |
| 267 ---------- | 1.2 | Coal, shattered |
| | 0.1 | Siltstone, coaly |
| | | Sandstone floor |
| | | |
| | | Sandstone roof |
| 352 ---------- | 1.7 | Coal, shattered core, but not thicker than 2.1 ft |
| | 3.8 | Claystone and shale, not thicker than 5.2 ft |
| | 1.0 | Coal |
| | 0.1 | Claystone |
| | 3.1 | Coal, between 2.4 and 5.6 ft thick |
| | | Claystone floor |

Drill hole L5 (cont'd)

| Depth (ft) | Thickness (ft) | Stratum |
|---|---|---|
| 398 ------------ | 1.0 | Coal, between 0.9 and 1.4 ft thick |
| | 2.4 | Shale and claystone |
| | 0.2 | Coal |
| | 1.0 | Claystone |
| | 0.4 | Coal, between 0.2 and 2.0 ft thick |
| | 0.2 | Shale |
| 402 ------------ | 0.8 | Coal |
| | 0.1 | Shale |
| | 0.3 | Coal |
| | 0.2 | Shale |
| | 0.6 | Coal |
| | 0.4 | Shale |
| | 0.2 | Coal |
| | 0.3 | Shale |
| | 0.1 | Coal |
| | | Shale floor |
| | | |
| | | Siltstone roof |
| 421 ------------ | 0.3 | Coal |
| | 0.2 | Shale |
| | 2.0 | Coal |
| | 0.1 | Siltstone |
| | 0.8 | Coal, clayey |
| | | Claystone floor |

Drill hole L6

Location: 1.5 miles east of Lailian Colliery pumping shaft.

Survey of Pakistan Grid coordinates: 2,361,500 yds. E., 975,300 yds. N.

Ground elevation: 328 feet above sea level.

Depth of zone of weathering: 130 feet

Depth of standing water level: At least 150 feet.

Total depth: 155 feet.

Description of thicker coal cores:

| Depth (ft) | Thickness (ft) | Stratum |
|---|---|---|
| | | Claystone roof |
| 132 ----------- | 1.0 | Coal |
| | 0.3 | Claystone |
| | 0.1 | Coal |
| | 0.5 | Claystone |
| | 0.5 | Coal |
| | 4.8 | Claystone and siltstone |
| | 0.3 | Coal |
| | 0.3 | Claystone |
| 139 ----------- | 2.6 | Coal, Lailian bed |
| | 0.1 | Shale, coaly |
| | | Claystone floor |

Drill hole L7

Location: 2 miles west of Lailian Colliery pumping shaft.

Survey of Pakistan Grid coordinates: 2,355,400 yds. E., 975,500 yds. N.

Ground elevation: 388 feet above sea level.

Depth of zone of weathering: 65 feet.

Depth of standing water level: 184 feet.

Total depth: 499 feet

Description of thicker coal cores:

| Depth (ft) | Thickness (ft) | Stratum |
|---|---|---|
| | | Claystone roof |
| 240 ---------- | 2.6 | Coal, Lailian bed |
| | | Claystone floor |
| | | |
| | | Sandstone roof |
| | 1.0 | Claystone |
| 334 --------- | 2.0 | Coal, between 1.8 and 2.5 ft thick |
| | 0.4 | Coal, dirty |
| | 0.9 | Claystone |
| | | Sandstone floor |

Drill hole L8

Location: 2.6 miles east of Lailian Colliery pumping shaft.

Survey of Pakistan Grid coordinates: 2,363,900 yds. E., 975,200 yds. N.

Ground elevation: 389 feet above sea level.

Depth of zone of weathering: 59 feet.

Depth of standing water level: At least 184 feet.

Total depth: 393 feet.

No coal was cored. The Lailian bed is probably missing, and the driller reports no show of coal from the cuttings at any depth.

Drill hole L9

Location: 3 miles south of Lailian Colliery pumping shaft.

Survey of Pakistan Grid coordinates: 2,358,700 yds. E., 970,200 yds. N.

Ground elevation: 274 feet above sea level.

Depth of zone of weathering: 95 feet.

Depth of standing water level: 194 feet.

Total depth: 303 feet.

Description of thicker coal cores:

| Depth (ft) | Thickness (ft) | Stratum |
|---|---|---|
| | | Claystone roof |
| | 1.0 | Coal |
| | 0.5(?) | |
| 111 --------------- | 3.7 | Coal, Lailian bed |
| | 11.3 | Claystone |
| 126 --------------- | 2.6 | Coal, clayey |
| | 0.1 | Claystone |
| | 0.6 | Coal, Clayey |
| | 6.1 | Claystone |
| | 0.6 | Coal, clayey |
| | 0.8 | Claystone |
| 137 -------------- | 1.1 | Coal |
| | | Claystone floor |
| | | |
| | | Claystone roof |
| 258 --------------- | 1.6 | Coal, dirty |
| | | Claystone floor |

Drill hole L10

Location: 1 mile north of Lailian Colliery pumping shaft.

Survey of Pakistan Grid coordinates: 2,358,900 yds. E., 977,300 yds. N.

Ground elevation: 350 feet above sea level.

Depth of zone of weathering: 165 feet.

Depth of standing water level:
1) 133 feet at 340-foot depth of hole.
2) 202 feet at completion of hole.

Total depth: 426 feet.

Description of thicker coal cores:

| Depth (ft) | Thickness (ft) | Stratum |
|---|---|---|
| | | Sandstone roof |
| 122 | 1.2 | Coal, Lailian bed, claystone, and gypsum. powdery, deeply weathered |
| | | Claystone floor |
| | | |
| | | Claystone roof |
| | 0.1 | Coal |
| | 0.7 | Claystone |
| 258 | 1.8 | Coal, between 1.8 and 2.2 ft thick |
| | | Claystone floor |
| | | |
| | | Claystone roof |
| 360 | 1.5 | Coal, between 1.5 and 2.0 ft thick |
| | | Claystone floor |

Drill hole L11

Location: 1 mile south of Lailian Colliery pumping shaft.

Survey of Pakistan Grid coordinates: 2,358,800 yds. E., 973,600 yds. N.

Ground elevation: 306 feet above sea level.

Depth of zone of weathering: (1) 0 to 82 feet and (2) 121 to 142 feet.

Depth of standing water level: More than 118 feet.

Description of thicker coal cores:

| Depth (ft) | Thickness (ft) | Stratum |
|---|---|---|
| | | Claystone roof |
| | 0.1 | Coal, very clayey |
| 88 | 4.5 | Coal, Lailian bed, between 3.8 and 6.0 ft thick |
| | | Claystone floor |
| | | |
| | | Claystone roof |
| | 0.1 | Coal |
| | 0.5 | Claystone |
| | 0.4 | Coal |
| | 0.3 | Claystone |
| 111 | 2.2 | Coal, good quality, between 1.9 and 3.3 ft thick |
| | | Claystone floor |

Drill hole L12

Location: 3 miles north of Lailian Colliery pumping shaft.

Survey of Pakistan Grid coordinates: 2,359,100 yds. E., 980,000 yds. N.

Ground elevation: 421 feet above sea level.

Depth of zone of weathering: 53 feet

Depth of standing water level: 152 feet

Total depth: 289 feet

Description of thicker coal cores:

| Depth (ft) | Thickness (ft) | Stratum |
|---|---|---|
| | | Claystone roof |
| 216 | 4.5 | Coal, slightly clayey: Lailian bed between 4.5 and 6.4 ft thick |
| | 8.4 | Claystone and clayey siltstone |
| 229 | 1.3 | Coal, clayey at top and bottom |
| | 0.7 | Claystone |
| | 2.1 | Coal, slightly clayey |
| | | Claystone floor |

Drill hole L13

Location: 2 miles south of Lailian Colliery pumping shaft.

Survey of Pakistan Grid coordinates: 2,358,600 yds. E., 971,950 yds. N.

Ground elevation: 276 feet above sea level.

Depth of zone of weathering: 111 feet.

Depth of standing water level: More than 102 feet.

Total depth: 175 feet.

Description of thicker coal cores:

| Depth (ft) | Thickness (ft) | Stratum |
|---|---|---|
| | | Claystone roof |
| 114 ---------- | 0.5 | Coal, Lailian bed |
| | 0.3 | Claystone and dirty coal |
| | 2.5 | Coal, appears slightly weathered, between 1.8 and 6.0 ft thick |
| | 4.7 | Claystone |
| 122 ---------- | 2.7 | Coal, appears slightly weathered, between 2.5 and 5.0 ft thick |
| | | Claystone floor |

Drill hole L14

Location: 2 miles north of Lailian Colliery pumping shaft.

Survey of Pakistan Grid coordinates: 2,359,000 yds. E., 978,900 yds. N.

Ground elevation: 387 feet above sea level.

Depth of zone of weathering: (1) 0 to 40 ft and (2) 67 to 87 feet.

Depth of standing water level: 159 feet.

Total depth: 278 feet.

Description of thicker coal cores:

| Depth (ft) | Thickness (ft) | Stratum |
|---|---|---|
| | | Sandstone roof |
| | 1.0 | Claystone, coaly, fossil shells |
| 55 | 1.3 | Coal, clayey |
| | | Sandstone floor |
| | | |
| | | Claystone roof |
| 170 | 4.5 | Coal, Lailian bed |
| | 0.3 | Claystone |
| | 1.5 | Coal, clean, Lailian bed |
| | 0.2 | Coal, clayey |
| | | Siltstone floor |
| | | |
| | | Claystone roof |
| | 0.6 | Coal |
| | 1.4 | Claystone, coaly |
| 194 | 1.7 | Coal, good quality |
| | 3.6 | Claystone |
| | 0.3 | Coal |
| | | Claystone floor |
| | | |
| | | Clayey siltstone roof |
| | 0.3 | Claystone |
| 210 | 0.2 | Coal |
| | 0.1 | Claystone |
| | 3.0 | Coal, good quality between 2.1 and 4.2 ft thick |
| | | Claystone floor |

Drill hole L15

Location: 1.4 miles southwest of Lailian Colliery pumping shaft.

Survey of Pakistan Grid coordinates: 2,357,000 yds. E., 973,700 yds. N.

Ground elevation: 324 feet above sea level.

Depth of zone of weathering: (1) 0 to 145 feet and (2) 150 to 170 feet.

Depth of standing water level: more than 133 feet.

Total depth: 400 feet.

No coal found in the drill hole. Both Lailian bed and thick coal bed found at depth of 398 feet in drill hole L3 are missing.

Drill hole L16

Location: 4 miles north of Lailian Colliery pumping shaft.

Survey of Pakistan Grid coordinates: 2,359,100 yds. E., 982,350 yds. N.

Ground elevation: 415 feet above sea level.

Depth of zone of weathering: Between 60 and 180 feet.

Depth of standing water level: 223 feet.

Total depth: 261 feet

Depths cored: (1) 0 to 60 ft; and (2) 180 to 261 ft.

Description of thicker coal cores:

| Depth (ft) | Thickness (ft) | Stratum |
|---|---|---|
| | | Claystone roof |
| 195 ----------- | 3.6 1/ | Coal, Lailian bed |
| | 0.2 | Claystone |
| | 1.9 1/ | Coal |
| | 0.8 | Claystone |
| | 0.6 | Coal |
| | 0.1 | Claystone |
| | 0.4 | Coal |
| | 2.9 | Claystone |
| 205 ----------- | 1.2 | Coal, clayey in upper 1 in. |
| | 9.1 | Claystone |
| | 0.6 | Sandstone |
| 216 ----------- | 1.2 | Coal |
| | 0.9 | Claystone |
| | 0.4 | Coal |
| | 5.0 | Claystone |
| 224 ------------ | 2.2 | Coal,may be slightly clayey |
| | | Claystone floor |

1/ Proximate and ultimate analyses, Table 2.

Drill hole L17

Location: 2.2 miles south-southwest of Lailian Colliery pumping shaft.

Survey of Pakistan Grid coordinates: 2,356,950 yds. E., 972,000 yds. N.

Ground elevation: 313 feet above sea level.

Depth of zone of weathering: 168 feet.

Depth of standing water level: More than 194 feet.

The only coal found was 0.7 feet at a depth of 175 feet. Lailian coal bed is missing at an expected depth of 50 feet within the weathered zone. The thick bed found at a depth of 398 feet in drill hole L3 is also missing.

Drill hole L18

Location: 5 miles north of Lailian Colliery pumping shaft.

Survey of Pakistan Grid coordinates: 2,359,300 yds. E., 984,300 yds. N.

Ground elevation: 369 feet above sea level.

Depth of zone of weathering: 48 feet.

Depth of standing water level: 255 feet.

Total depth: 261 feet.

Description of thicker coal cores:

| Depth (ft) | Thickness (ft) | Stratum |
|---|---|---|
| | | Soft sandstone roof |
| 129 ----------- | 0.3 | Coal, thickness uncertain because of 7 ft of lost core |
| | | Claystone floor |
| | | |
| | | Soft sandstone roof |
| 169 ----------- | 1.8 | Coal, thickness uncertain; 7 ft of core lost |
| | 1.4 | Claystone |
| | 0.2 | Coal |
| | | Claystone and siltstone floor |
| | | |
| | | Claystone roof |
| 197 ----------- | 3.5 | Coal, Lailian bed, between 2.5 and 4.1 ft thick |
| | | Claystone floor |
| | | |
| | | Claystone roof |
| | 0.3 | Coal |
| | 3.8 | Claystone |
| | 0.4 | Coal, clayey |
| 219 ------------ | 1.6 | Coal, clean, between 1.1 and 4.1 ft thick |
| | 1.6 | Claystone |
| | 0.6 | Coal |
| | 4.1 | Claystone |
| 227 ------------ | 3.0 | Coal, between 2.7 and 3.7 ft thick |
| | 1.8 | Claystone |
| | 0.2 | Coal |
| | | Claystone floor |

Drill holes L19 and L19A:

Location: 4 miles south of Lailian Colliery pumping shaft.

Survey of Pakistan Grid coordinates: 2,358,500 yds. E., 968,500 yds. N.

Ground elevation: 291 feet above sea level.

Depth of zone of weathering: (1) 0 to 48 ft, and (2) 53 to 63 ft

Depth of standing water level: 197 feet

Total depth: 208 feet

Description of Lailian coal bed:

| Depth (ft) | Thickness (ft) | Stratum |
|---|---|---|
| | | Claystone roof |
| 133 | 2.8 | Coal, Lailian bed, between 2.5 and 3.3 ft thick |
| | 8.7 | Claystone, silty |
| 144 | 1.6 | Coal |
| | | Claystone floor |

Drill hole L20

Location: 3.2 miles north-northeast of Lailian Colliery pumping shaft.

Survey of Pakistan Grid coordinates: 2,360,800 yds. E., 980,700 yds. N.

Ground elevation: 410 feet above sea level.

Depth of zone of weathering: 74 feet.

Depth of standing water level: 226 feet.

Total depth: 311 feet.

Description of thicker coal cores:

| Depth (ft) | Thickness (ft) | Stratum |
|---|---|---|
| | | Claystone roof |
| 180 | 1.6 | Coal, slightly clayey at top and bottom |
| | | Claystone floor |
| | | |
| | | Soft sandstone roof |
| | 0.1 | Claystone |
| 258 | 0.4 | Coal, Lailian bed |
| | 0.2 | Claystone |
| | 2.6 | Coal, Lailian bed, 2.4 ft was recovered; coal is between 2.8 and 8.0 ft thick |
| | | Claystone floor |

## Drill hole L21

Location: 5 miles south of Lailian Colliery pumping shaft.

Survey of Pakistan Grid coordinates: 2,358,600 yds. E., 966,900 yds.N.

Ground elevation: 236 feet above sea level.

Depth of zone of weathering: 55 feet plus.

Depth of standing water level: (1) 61 ft at 142 ft depth of hole; (2) More than 158 ft at completion of hole.

Total depth: 217 feet.

Depths cored: 49 to 217 feet.

Description of thicker coal cores:

| Depth (ft) | Thickness (ft) | Stratum |
|---|---|---|
| | | Claystone roof |
| | 0.6 | Coal |
| | 11.8 | Claystone |
| 155 ----------- | 3.2 | Coal, Lailian bed |
| | | Claystone floor |

## Drill hole L22

Location: 6 miles north of Lailian Colliery pumping shaft.

Survey of Pakistan Grid coordinates: 2,359,350 yds. E., 986,100 yds. N.

Ground elevation: 379 feet above sea level

Depth of zone of weathering: 53 feet.

Depth of standing water level: More than 230 feet.

Total depth: 285 feet.

Description of thicker coal cores:

| Depth (ft) | Thickness (ft) | Stratum |
|---|---|---|
| | | Soft sandstone roof |
| | 0.6 | Sandstone, hard |
| 230 ----------- | 3.3 | Coal, Lailian bed |
| | 0.4 | Claystone |
| | 1.8 | Coal, Lailian bed |
| | | Claystone floor |

## Drill hole L23

Location: 3.6 miles northeast of Lailian Colliery pumping shaft.

Survey of Pakistan Grid coordinates: 2,362,600 yds. E., 980,600 yds. N.

Ground elevation: 446 feet above sea level.

Depth of zone of weathering: 98 feet.

Depth of standing water level: Not measured.

Total depth: 351 feet.

Description of thicker coal cores:

| Depth (ft) | Thickness (ft) | Stratum |
|---|---|---|
| | | Sandstone roof |
| | 0.4 | Claystone |
| 330 ---------- | 1.4+ | Coal, Lailian bed, between 1.4 and 6.0 ft thick |
| | | Claystone floor |

## Drill hole L24

Location: 4.9 miles north-northeast of Lailian Colliery pumping shaft.

Survey of Pakistan Grid coordinates: 2,362,250 yds. E., 983,350 yds. N.

Ground elevation: 387 feet above sea level.

Depth of zone of weathering: 96 feet.

Depth of standing water level: More than 300 feet.

Total depth of hole: 354 feet.

Description of thicker coal cores:

| Depth (ft) | Thickness (ft) | Stratum |
|---|---|---|
| | | Claystone roof |
| 252 ---------- | 1.2 | Coal, Lailian bed |
| | 0.1 | Claystone |
| | 0.3 | Coal |
| | | Claystone floor |

Drill hole L25

Location: 15 miles north and 2 miles west of Lailian Colliery pumping shaft.

Survey of Pakistan Grid coordinates: 2,356,580 yds. E., 1,001,830 yds. N.

Ground elevation: 153 feet above sea level.

Depth of zone of weathering: 351 feet.

Depth of standing water level: 30 feet.

Total depth of hole: 426 feet.

Description of thicker coal cores:

| Depth (ft) | Thickness (ft) | Stratum |
|---|---|---|
| | | Sandstone roof |
| 403 ------------ | 5.0 1/ | Coal, Lailian bed, recovered 4.5 ft |
| | | Sandstone floor |

1/ Proximate and ultimate analyses, Table 2.

Drill hole L26

Location: 3.5 miles north-northwest of Lailian Colliery pumping shaft.

Survey of Pakistan Grid coordinates: 2,355,580 yds. E., 980,650 yds. N.

Ground elevation: 427 feet above sea level.

Depth of zone of weathering: 116 feet.

Total depth of hole: 471 feet.

Description of thicker coal cores:

| Depth (ft) | Thickness (ft) | Stratum |
|---|---|---|
| | | Sandstone roof |
| 439 ---------- | 3.1 | Coal, Lailian bed? |
| | 1.4 | Claystone |
| | 4.3 | Coal, upper 0.3 ft dirty |
| | | Siltstone floor |

Drill hole L27

Location: 13 miles north and 2 miles west of Lailian Colliery pumping shaft.

Survey of Pakistan Grid coordinates: 2,356,450 yds. E., 998,300 yds. N.

Ground elevation: 478 feet above sea level.

Depth of zone of weathering: 220 feet.

Depth of standing water level: Could not be measured because of the collapse of hole.

Total depth of hole: 890 feet.

Description of thicker coal cores:

| Depth (ft) | Thickness (ft) | Stratum |
|---|---|---|
| | | Sandstone roof |
| 288 | 2.0 | Coal, recovered 1.4 ft |
| | | Claystone floor |
| | | Claystone roof |
| 355 | 2.7 | Coal, Lailian bed, core was broken; actual thickness was difficult to measure; upper 0.2 ft dirty coal |

Drill hole L28

Location: 5.3 miles north-northwest of Lailian Colliery pumping shaft.

Survey of Pakistan Grid coordinates: 2,355,750 yds. E., 984,280 yds. N.

Ground elevation: 440 feet above sea level.

Depth of zone of weathering: 93 feet.

Depth of standing water level: Dry up to 250 feet. Hole collapsed beyond this depth.

Total depth of hole: 551 feet.

Description of thicker coal cores:

| Depth (ft) | Thickness (ft) | Stratum |
|---|---|---|
| | | Claystone roof |
| 362 | 1.2 | Coal |
| | 0.2 | Claystone |
| | 0.35 | Coal |
| | 1.0 | Claystone |
| 364.8 | 3.5 | Coal, Lailian bed |
| | | Claystone floor |
| | | Claystone roof |
| 369 | 5.5 | Coal |
| | | Claystone floor |

Drill hole L29

Location: 11 miles north and 2 miles west of Lailian Colliery pumping shaft.

Survey of Pakistan Grid coordinates: not available.

Depth of zone of weathering: not measured.

Depth of standing water level: not measured.

Total depth: 465 feet.

Description of thicker coal cores:

| Depth (ft.) | Thickness (ft.) | Stratum |
|---|---|---|
| | | Sandstone roof, light gray, fossil shells, fine grained |
| | 0.1 | Claystone, black, carbonaceous |
| 371(?) ------------------- | 1.7 | Coal, Lailian bed, lignitic, pyritic, clayey?, loss of 5.7-ft-core in the run suggests greater thickness |
| | | Sandstone floor, soft, loose |

Drill hole L30

Location: 9 miles north and 2 miles west of Lailian Colliery pumping shaft.

Survey of Pakistan Grid coordinates: not available.

Depth of zone of weathering: not measured.

Depth of standing water level: not measured.

Total depth: 383 feet.

Depth cored: 8 to 383 feet.

Description of thicker coal cores:

| Depth (ft) | | Thickness (ft) | Stratum |
|---|---|---|---|
| | | 5.0 | Sandstone roof, soft |
| 199 | ------------------ | 1.0 | Coal, brownish black, friable, pyritic, gypsiferous, loss of core suggests greater thickness |
| | | 6.0 | Claystone floor, light gray, coal partings, pyritic |
| | | 1.0 | Shale or claystone roof, sandy, coal partings |
| 292 | ------------------ | 1.0 | Coal, friable, pyritic |
| | | 5.5 | Claystone floor, carbonaceous |
| | | 7.5 | Claystone roof |
| 332 | ------------------ | 1.0 | Coal, thickness might be greater because of loss of 5 ft core; Lailian coal bed? |
| | | 8.0 | Claystone floor, sandy |

Drill hole L31

Location: 2 miles east and 1 mile south of Lailian Colliery pumping shaft.

Survey of Pakistan Grid coordinates: Not available.

Ground elevation: 331 feet.

Depth of zone of weathering: 187 feet?

Depth of standing water level: Not measured.

Total depth: 403 feet.

Depth cored: 390 feet.

Description of thicker coal cores:

| Depth (ft) | Thickness (ft) | Stratum |
|---|---|---|
| | 0.6 | Claystone roof |
| 141 | 1.1 | Coal, friable, gypsum-bearing, Lailian bed |
| | 0.9 | Claystone floor |

Drill hole L32

Location: 2 miles west and 1 mile south of Lailian Colliery pumping shaft.

Survey of Pakistan Grid coordinates: not available.

Ground elevation: 400 feet above sea level.

Depth of zone of weathering: 80 feet.

Depth of standing water level: not measured.

Total depth: 402 feet.

Depth cored: 390 feet.

Description of thicker coal cores:

| Depth (ft) | Thickness (ft) | Stratum |
|---|---|---|
| | 1.1 | Shale and siltstone roof |
| 95 | 1.2 | Coal, lignitic, friable |
| | 1.0 | Shale, floor |
| | 6.1 | Claystone roof |
| 180 | 3.4 | Coal, pyritic, friable, Lailian bed |
| | 2.0 | Siltstone floor, moderately hard |
| 191 | 1.4 | Coal, pyritic, friable |
| | 1.5 | Claystone floor |

Drill hole L33

Location: 3 miles south and 1.93 miles east of Lailian Colliery pumping shaft.

Survey of Pakistan Grid Coordinates: not available.

Ground elevation: 373 feet above sea level.

Depth of zone of weathering: 132 feet.

Depth of standing water level: not measured.

Total depth: 267 feet.

Lailian coal bed and other coal beds of minable thickness are missing in this drill hole.

Drill hole L34

Location: 5.3 miles south and 2 miles west of Lailian Colliery pumping shaft.

Survey of Pakistan Grid coordinates: not available.

Ground elevation: 292 feet above sea level.

Depth of zone of weathering: 99 feet?

Depth of standing water level: not measured.

Total depth: 322 feet.

Depth cored: all through.

Lailian coal bed and other coal beds are missing in this hole.

Table 2.--Analyses of Lakhra coals.

| Lab and no. | Location and bed | Basis | Proximate analysis (percent) | | | | Ultimate analysis (percent) | | | | | Btu per lb. | Other |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Moisture | Vola-tile matter | Fixed car-bon | Ash | H | C | N | O | S | | |
| USBM 1/ H-51788 | North face Lailian Colliery | AR | 31.8 | 30.0 | 29.2 | 9.0 | 6.8 | 42.1 | 0.8 | 38.0 | 3.3 | 7,530 | Non-caking. |
| | | MF | -- | 43.9 | 42.9 | 13.2 | 4.8 | 61.7 | 1.1 | 14.3 | 4.9 | 11,050 | Ash fuses at 2520° -2680°F. |
| | | MAF | -- | 50.6 | 49.4 | -- | 5.5 | 71.7 | 1.3 | 16.4 | 5.7 | 12,730 | |
| USBM H-45314 | Northwest entry Lailian Colliery Lailian bed | AR | 31.8 | 30.8 | 30.0 | 7.4 | 6.8 | 43.0 | 0.8 | 38.4 | 3.6 | 7,660 | Non-Caking; ash fuses at 2620° -2730° F. |
| | | MF | -- | 45.1 | 44.1 | 10.8 | 4.9 | 63.1 | 1.2 | 14.7 | 5.3 | 11,230 | |
| | | MAF | -- | 50.6 | 49.4 | -- | 5.4 | 70.7 | 1.3 | 16.6 | 6.0 | 12,590 | |
| USBM H-33049 | Lailian Colliery 100 ft W. of pump shaft | AR | 39.4 | 25.3 | 20.7 | 14.6 | 6.4 | 28.8 | 0.6 | 47.8 | 1.8 | 4,630 | Ash initial deformation temperature 2910°+F. |
| | | MF | -- | 41.8 | 34.0 | 24.2 | 3.4 | 47.4 | 1.0 | 21.1 | 2.9 | 7,640 | |
| | | MAF | -- | 55.1 | 44.9 | -- | 4.4 | 62.5 | 1.3 | 28.0 | 3.8 | 10,080 | |
| USBM H-51789 | Drill hole L16 Lailian bed | AR | 35.7 | 28.0 | 25.8 | 10.5 | 7.0 | 38.7 | 0.7 | 39.3 | 3.8 | 7,010 | Non-caking. |
| | | MF | -- | 43.5 | 40.1 | 16.4 | 4.7 | 60.3 | 1.1 | 11.5 | 6.0 | 10,910 | Ash fuses at 2000° -2260°F. |
| | | MAF | -- | 52.0 | 48.0 | -- | 5.7 | 72.1 | 1.3 | 13.8 | 7.1 | 13,040 | |
| USBM J-37993 | Khan Coal Mine (northern part of coal field) | AR | 27.7 | 26.2 | 22.7 | 23.4 | 5.6 | 33.3 | 0.6 | 30.6 | 6.5 | 6,040 | Ash initial deformation temperature 2100°F. |
| | | MF | -- | 36.3 | 31.4 | 32.3 | 3.6 | 46.1 | 0.8 | 8.2 | 9.0 | 8,360 | |
| | | MAF | -- | 53.6 | 46.4 | -- | 5.3 | 68.1 | 1.2 | 12.1 | 13.3 | 12,350 | |
| USBM J-37989 | Indus Coal Co. (about 2 mi. south of Khan Mine) | AR | 24.3 | 29.5 | 26.3 | 19.9 | 5.7 | 38.7 | 0.7 | 29.4 | 5.6 | 7,020 | Ash initial deformation temperature 2060°F. |
| | | MF | -- | 38.9 | 34.8 | 26.3 | 3.9 | 51.1 | 1.0 | 10.3 | 7.4 | 9,280 | |
| | | MAF | -- | 52.9 | 47.1 | -- | 5.3 | 69.4 | 1.3 | 13.9 | 10.1 | 12,600 | |
| USBM J-37987 | Habibullah Coal Co. (central part of coal field) | AR | 31.0 | 29.2 | 26.4 | 13.4 | 6.3 | 38.8 | 0.8 | 36.3 | 4.4 | 6,900 | Ash initial deformation temperature 1940°F. |
| | | MF | -- | 42.4 | 38.1 | 19.5 | 4.2 | 56.2 | 1.1 | 12.6 | 6.4 | 10,000 | |
| | | MAF | -- | 52.6 | 47.4 | -- | 5.2 | 69.8 | 1.4 | 15.6 | 8.0 | 12,410 | |
| USBM J-37990 | Baluchistan Coal Co. (south-central part of field) | AR | 30.0 | 27.7 | 26.8 | 15.5 | 6.2 | 38.4 | 0.8 | 35.9 | 3.2 | 6,770 | Ash initial deformation temperature 2080°F. |
| | | MF | -- | 39.6 | 38.3 | 22.1 | 4.1 | 54.8 | 1.1 | 13.4 | 4.5 | 9,670 | |
| | | MAF | -- | 50.3 | 49.2 | -- | 5.3 | 70.3 | 1.4 | 17.2 | 5.8 | 12,410 | |
| GSP 2/ 1162(4) | Drill hole L1 Lailian bed | AD | 6.5 | 37.3 | 38.8 | 17.4 | -- | -- | -- | -- | 4.6 | -- | -- |
| | | MF | -- | 39.9 | 41.5 | 18.6 | -- | -- | -- | -- | 4.9 | -- | -- |
| | | MAF | -- | 49.0 | 51.0 | -- | -- | -- | -- | -- | 6.0 | -- | -- |
| GSP 1162(1) | Drill hole L3 Lailian bed | AD | 7.4 | 42.8 | 39.8 | 10.0 | -- | -- | -- | -- | 3.2 | -- | -- |
| | | MF | -- | 46.2 | 43.0 | 10.8 | -- | -- | -- | -- | 3.5 | -- | -- |
| | | MAF | -- | 51.8 | 48.2 | -- | -- | -- | -- | -- | 3.9 | -- | -- |
| GSP 1162(2) | Drill hole L3 7-ft bed at | AD | 7.2 | 39.1 | 35.1 | 18.6 | -- | -- | -- | -- | 5.8 | -- | -- |
| | | MF | -- | 42.0 | 37.9 | 20.1 | -- | -- | -- | -- | 6.3 | -- | -- |
| | 398-ft depth | MAF | -- | 52.7 | 47.3 | -- | -- | -- | -- | -- | 7.8 | -- | -- |
| GSP 1162(3) | Drill hole L3 3-ft bed at 453-ft depth | AD | 5.5 | 42.8 | 38.2 | 13.5 | -- | -- | -- | -- | 4.9 | -- | -- |
| | | MF | -- | 45.3 | 40.4 | 14.3 | -- | -- | -- | -- | 5.2 | -- | -- |
| | | MAF | -- | 52.8 | 47.2 | -- | -- | -- | -- | -- | 6.0 | -- | -- |
| GSP 1162(5) | Drill hole L4 Lailian bed | AD | 8.8 | 36.7 | 29.5 | 25.0 | -- | -- | -- | -- | 2.1 | -- | -- |
| | | MF | -- | 40.3 | 32.3 | 27.4 | -- | -- | -- | -- | 2.3 | -- | -- |
| | | MAF | -- | 55.5 | 44.5 | -- | -- | -- | -- | -- | 3.2 | -- | -- |



1/ USBM, analysis by the U. S. Bureau of Mines, Pittsburgh, Pennsylvania.

2/ GSP, analysis by the Geological Survey of Pakistan, Quetta, Pakistan.

Basis: AD, air dried; AR, as received(moist) sample; MF, moisture free; MAF, moisture and ash free.