UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

MEASURED SECTIONS FROM THE BARA, LAKHRA, AND LAKI FORMATIONS IN SINDH PROVINCE, PAKISTAN: A PROGRESS REPORT

by

Christopher Wnuk, U.S. Geological Survey

John R. SanFilipo, U.S. Geological Survey

Mohammad Fariduddin, Geological Survey of Pakistan

S. Farah Fatmi, Geological Survey of Pakistan

Shafique A. Khan, Geological Survey of Pakistan

Altaf Chandio, Geological Survey of Pakistan

Open-File Report 92-281

Report prepared jointly by the Geological Survey of Pakistan
and the U.S. Geological Survey under the auspices of the
U.S. Agency for International Development

1992

CONTENTS

ILLUSTRATIONS

ABSTRACT

This report presents detailed stratigraphic and sedimentological descriptions of the coal-bearing part of the upper Paleocene Bara Formation, the upper Paleocene Lakhra Formation, and the basal part of the Paleocene/ Eocene Laki Formation in Sindh Province, Pakistan. The data presented here contributes to our overall understanding of the regional stratigraphy of the coal-bearing strata in Sindh. This report also contains the only existing detailed descriptions of the thick beds of clean sandstone that comprise the major part of the Bara Formation within the COALREAP study area. The descriptions of these sandstones are especially critical to the development of our understanding of the stratigraphy and sedimentology of the coal-bearing part of the Bara Formation.

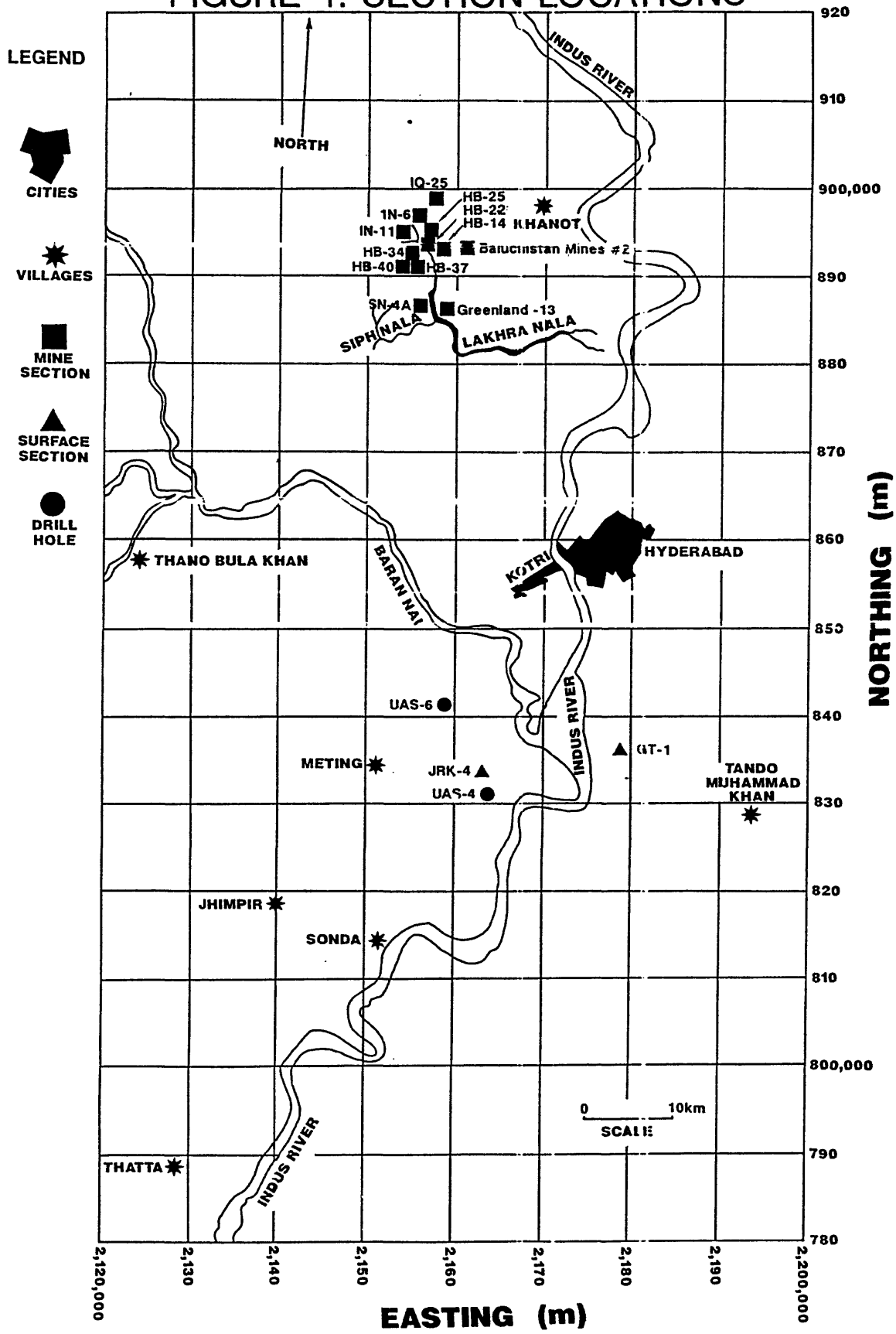
INTRODUCTION

Since 1985, the United States Geological Survey (USGS) and the Geological Survey of Pakistan (GSP) have been conducting a cooperative study of the coal resources of Pakistan. This initiative, the Coal Resource Exploration and Assessment Program (COALREAP), has been supported by funding from the Government of Pakistan (GOP) and the United States Agency for International Development (USAID). The overall objectives of this program are to "design, strengthen, and implement a comprehensive national program for qualitative and quantitative assessment of the coal resources of Pakistan; and to strengthen the capability of the GSP and other offices of the GOP to efficiently and effectively implement the program." To accomplish these objectives, the GSP and the USGS have initiated a systematic effort to compile existing coal data and to acquire new data through drilling and outcrop studies.

One of the areas targeted for comprehensive exploration and assessment is south Sindh Province. This region contains the majority of Pakistan's known coal resources and produces the greatest percentage of the country's annual coal production. Currently, coal is actively mined from the Paleocene Bara Formation in the Lakhra Coal Field on the crest of the Lakhra Anticline, 30 km northwest of Hyderabad, and from the Paleocene Sohnari Formation in the Meting-Jhimpir Coal Field, about 50 km southwest of Hyderabad (Figure 1). Over the past three decades both of these coal fields have experienced varying degrees of exploration activity, but almost all of this exploration has been concentrated within the confines of the known boundaries of the field or along the peripheries of these boundaries. A comprehensive bibliography of these early explorations can be found in SanFilipo and others (1988).

From 1981 to 1986, the GSP began exploration drilling that showed that coal was present in areas previously assumed to be barren. The COALREAP was undertaken to further test the coal potential of the strata beyond the

FIGURE 1: SECTION LOCATIONS



traditional coal field boundaries. This exploration showed that significant coal resources were present within the Bara Formation throughout the area between the town of Thatta and Khanot (Figure 1), and both east and west of the Indus River (see Schweinfurth and Husain, 1988; SanFilipo and others, 1990; Thomas and others, 1990). Speculative preliminary analyses based on data from oil and gas tests and from water well drilling suggest that much of south Sindh may be underlain by coal (Kazmi and others, 1990; SanFilipo and others, in prep.).

PURPOSE

As part of the COALREAP investigations in Sindh, a comprehensive program of surface and mine section measurements and detailed sedimentological re-analysis of COALREAP core was initiated in 1987. The objectives of this series of investigations was to acquire stratigraphic and sedimentological data from those parts of the stratigraphic section that were not regularly cored because they are not coal-bearing, but which, nevertheless, must be understood if accurate predictive coal basin models are to be formulated. The results of these investigations are presented in Thomas and others (1988, 1989), Wnuk, Fariduddin, Fatmi, and SanFilipo (1991), Wnuk, SanFilipo, Fatmi, and Fariduddin (1991), Wnuk, SanFilipo, Fatmi, Khan, and Fariduddin (in prep.), and Wnuk, SanFilipo, Chandio, and Fatmi, (in prep.). Each of these reports addresses a specific stratigraphic problem or a specific part of the stratigraphic section within a confined area.

In the process of gathering information for the reports discussed in the preceding text, numerous stratigraphic sections were measured which did not have direct bearing on the specific problems addressed in the more narrowly focused investigations, but which were deemed to be important to the overall understanding of the stratigraphy of south Sindh. It is the purpose of this

report to present this stratigraphic and sedimentologic information.

STRATIGRAPHIC SETTING

A generalized stratigraphic section for the study area is presented in Figure 2. The Paleocene Bara Formation contains the primary coal resources throughout the region and it is the main exploration target. The Bara Formation ranges in thickness from more than 1000 m (Quadri and Shuaib, 1986) to less than 60 m (Cheema and others, 1977). It consists primarily of sandstone with subordinate amounts of siltstone, claystone, and coal. The Bara Formation is primarily marginal marine in origin (Quadri and Shuaib, 1986) though some investigators are of the opinion that the coal bearing part of the formation is fluvial (Cheema and others, 1977; Gingerich and others, 1979).

The overlying Paleocene Lakhra Formation ranges in thickness from 0 to 400 m (Hunting Survey Corporation, 1961; Quadri and Shuaib, 1986). It consists mostly of calcareous or non-calcareous sandstone and claystone with lesser quantities of siltstones and shales. Limestone generally accounts for less than 20 percent of the section, though in places limestone or coquina is the dominant lithology. According to Quadri and Shuaib (1986), this unit was deposited on a restricted marine platform.

The Paleocene(?) Sohnari Member of the Laki Formation (Sohnari Formation of Outerbridge and others, 1991) is reported to range in thickness from 0 to 70 m (Outerbridge and others, 1991). The formation consists primarily of sandstone, siltstone, shale, and claystone. In places where the formation is very thin it tends to consist exclusively of very indurated claystone. Subordinate amounts of coal and shale-pebble conglomerate occur in places, and the coal is mined extensively in the Meting-Jhimpir area. The unit tends to weather to a very bright red color and has in the past been mistaken for a

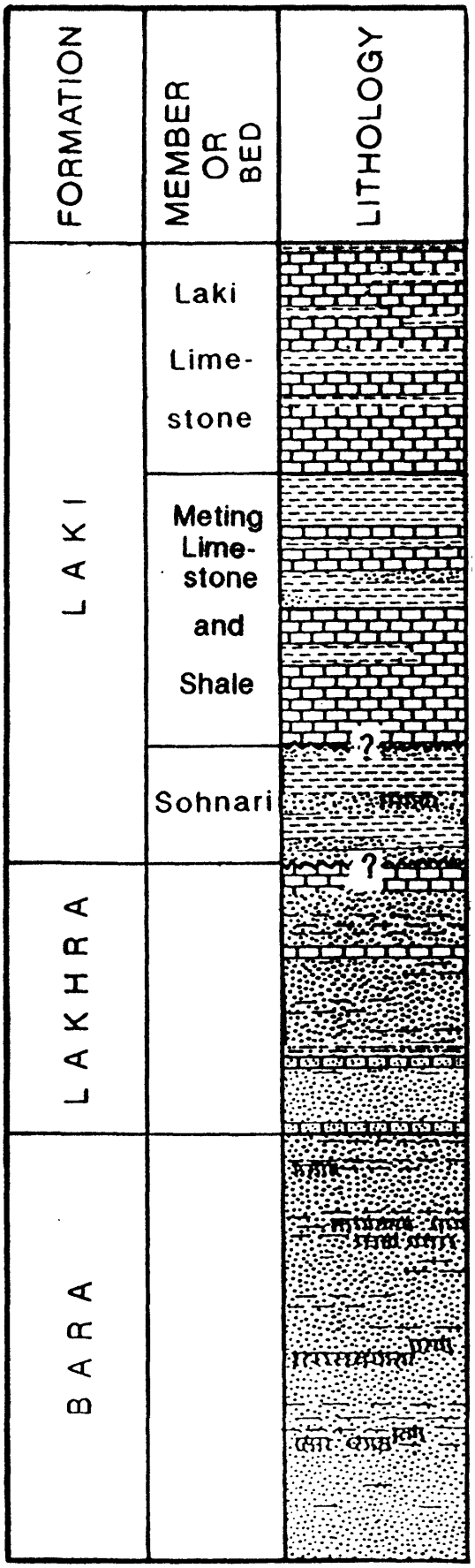


FIGURE 2:

Generalized stratigraphy of the Paleocene and Lower Eocene of south Sind Province, Pakistan

(modified from Thomas and others, 1988)

Limestone

Arenaceous Limestone

Claystone

Sandstone

Coal and Rooted Underclay

fossil laterite on the basis of this distinctive characteristic. According to Outerbridge and others (1991) the Sohnari was deposited in non-marine to brackish water environments.

The Laki Formation is entirely marine, consisting mostly of limestone with thin shale interbeds. In the Meting Limestone and Shale Member, which overlies the Sohnari Member, marine shales constitute approximately 50 percent of the section.

DISCUSSION

The locations of the drill holes, mine sections, and surface sections described in this report are shown in Figure 1; the descriptions of the measured sections are presented in the Appendix.

This report focuses on the lithic and sedimentary characteristics of the Bara Formation. Information about the shale, siltstone, and dirty sandstone lithologies in the Bara and lower Lakhra Formations is contained in the descriptions of the sediments in core holes UAS-4 and UAS-6. These lithologies, together with a small percentage of limestone in the Lakhra Formation, comprise about 50 percent of the section in these formations. The remainder of the section is composed of poorly consolidated clean sandstones found primarily in the Bara Formation. Because the Bara Formation is mostly confined to the subsurface and the poorly cemented sandstones are seldom recovered during coring, data about the clean sandstones can only be obtained from studies in underground mines. Consequently, the mine sections presented in this report contain the only detailed descriptions of the characteristics of the clean sandstones in the Bara Formation within the confines of the COALREAP study area. Complete surface exposures of the Bara Formation do occur in the Lakhi Range to the northwest of the Lakhra Anticline, but the sections are difficult to access from a logistic and security standpoint. Nonetheless,

one outcrop study of the Bara Formation was conducted in the Lakhi Range. The results are presented in Wnuk, SanFilipo, Chandio, and Fatmi, (in prep.).

Two outcrop sections have been included in this report. Section GT-1 is in the upper part of the Meting Shale and Limestone Member of the Laki Formation; section JRK-4 is in the basal part of the Meting Shale and Limestone Member. These sections were measured in order to stratigraphically position paleontological samples collected from these parts of the Laki Formation.

CONCLUSIONS

The data contained within this report contribute to our general understanding of the stratigraphy of the coal-bearing strata and associated sediments. The mine section descriptions of the clean sandstones that occur in the Bara Formation are especially important, because these are the only existing detailed descriptions of these sandstones within the study area. Though these sandstone units can comprise 50 percent or more of the thickness of the coal-bearing part of the Bara Formation, the sedimentological characteristics of these beds are unknown except for the mine sections, because the sandstones are mostly unconsolidated and, therefore, rarely recovered during drilling.

ACKNOWLEDGEMENTS

This study was funded through project 391-0478: Energy Planning and Development Project, Coal Resource Assessment Component 2A; Participating Agency Service Agreement (PASA) IPK-0478-P-IC-5068-00. We would like to express our gratitude to Director General A.H. Kazmi of the Geological Survey of Pakistan for his generous support and encouragement of this project. We would also like to thank our many colleagues at the Geological Survey of

Pakistan and the U.S. Geological Survey who contributed many valuable suggestions during the preparation of this manuscript. We must also acknowledge the assistance of the USAID support staff in Karachi and especially in Hyderabad. Without them this study would have been logistically impossible.

REFERENCES

Cheema, M.R., Raza, S.M., and Ahmad, H., 1977, Cainozoic, in Shah, S.M.I., ed., Stratigraphy of Pakistan: Memoirs of the Geological Survey of Pakistan, Vol. 12, 138 p.

Gingerich, P.D., Russell, D.E., Sigogne-Russell, D., Hartenburger, J.L., Shah, S.M. Ibraham, Hassan, M., Rose, K.D., and Ardrey, R.H., 1979, Reconnaissance survey and vertebrate paleontology of the Paleocene and Eocene Formations in Pakistan: Contributions from the Museum of Paleontology, The University of Michigan, v. 25, p. 105-116.

Hunting Survey Corporation, Limited, 1961, Reconnaissance geology of part of West Pakistan: Colombo Plan Cooperative Project, published for the Government of Pakistan by the Government of Canada, Oshawa, Maracle Press, 550 p.

Kazmi, A.H., Khan, M.S., Khan, I.A., Fatmi, S.F., and Fariduddin, M., 1990, Coal resources of Sindh, Pakistan, in Kazmi, A.H., ed. Proceedings of the Workshop on the Significance of Coal Resources of Pakistan, February 8-9, 1989, Karachi, Pakistan: Geological Survey of Pakistan, Quetta, p. 27-61.

Outerbridge, W.F., Frederiksen, N.O., Khan, M.R., Khan, R.A., Qureshi, H.J., Khan, M.Z., Niamatullah, Khan, S.A., 1991, The Sohnari Formation in southern Pakistan, U.S. Geological Survey Bulletin 1935, p. 27-34.

Quadri, V., and Shuaib, S.M., 1986, Hydrocarbon prospects of southern Indus Basin, Pakistan: The American Association of Petroleum Geologists Bulletin, v. 70, p. 730-747.

SanFilipo, J.R., Khan, R.A., and Khan, S.A., 1988, Part II, Chapter 2 - Geology and coal resources of the Lakhra and Sonda Coal Fields, with recommendations for future coal assessment work, in S.P. Schweinfurth and F. Husain, eds., Coal Resources of the Lakhra and Sonda Coal Fields, Southern Sindh Province, Pakistan - A Progress Report: Government of

Pakistan, Ministry of Petroleum and Natural Resources, Geological Survey of Pakistan Project Report (IR)PK-82, p. 2-1 - A3-2.

SanFilipo, J.R., Khan, R.A., Khan, S.A., 1990, Coal resources and the geologic controls of the Lakhra and Sonda Coal Fields, Sindh Province, Pakistan, in Kazmi, A.H., ed. Proceedings of the Workshop on the Significance of coal Resources of Pakistan, February 8-9, 1989, Karachi, Pakistan: Geological Survey of Pakistan, Quetta, p. 93-104.

SanFilipo, J.R., Wnuk, C., Fariduddin, M., Ahmad, M., Khan, S.A., Mehtab-ur-Rahman, Chandio, A.H., and Khan, R.A., in press, Potential for the occurrence of thick lignite deposits in the Thar Desert and the Lower Indus plain, Sindh Province, Pakistan: U.S. Geological Survey Open File Report, 131p.

Schweinfurth, S.P., and Husain, F., 1988, Coal resources of the Lakhra and Sonda Coal Fields, southern Sindh Province, Pakistan: A progress report: Geological Survey of Pakistan Project Report (IR) PK-82, Vol. I-VI.

Thomas, R.E., Khan, M.R., Khan, S.A., 1988, Measured sections of the Laki Formation, Ganjo Takkar, and Saidpur outlier, Hyderabad district, Pakistan: U.S. Geological Survey Open-File Report 88-550, 69p.

Thomas, R.E., Khan, M.R., Khan, S.A., 1989, Lateral relationships in the Laki Formation, Ganjo Takkar, and Saidpur outlier, Hyderabad District, Sindh Province, Pakistan: U.S. Geological Survey Miscellaneous Field Studies Map, MF-2084.

Thomas, R.E., and Khan, S.A., 1990, Indus East coal exploration, Sindh Province, Pakistan, in Kazmi, A.H., ed. Proceedings of the Workshop on the Significance of Coal Resources of Pakistan, February 8-9, 1989, Karachi, Pakistan: Geological Survey of Pakistan, Quetta, p. 105-107.

Wnuk, C., Fariduddin, M., Fatmi, S.F., and SanFilipo, J.R., 1991, The

stratigraphy and geometry of the Lakhra Formation in the Lakhra Coal Field area and implications for the coal resource potential of north Lakhra, Sindh Province, Pakistan: a progress report: U.S. Geological Survey Open File Report 91-9, 104 p.

Wnuk, C., SanFilipo, J.R., Fatmi, S.F., and Fariduddin, M., 1991, The stratigraphy and coal resource potential of the Sohnari Member of the Laki Formation in Sindh Province, Pakistan: A progress report: U.S. Geological Survey Open-File Report 91-326, 68p.

Wnuk, C., SanFilipo, J.R., Chandio, A., and Fatmi, S.F., in press, The stratigraphy and coal resource potential of the Bara Formation in the Fort Ranikot area, Sindh Province, Pakistan: A progress report: U.S. Geological Survey Open-File Report.

Wnuk, C., SanFilipo, J.R., Fatmi, S.F., Khan, S.A., and Fariduddin, M., in press, The coal resource potential of the middle and lower part of the Bara Formation in Sindh Province, Pakistan: A progress report: U.S. Geological Survey Open-File Report.

APPENDIX

CORE DESCRIPTIONS

DRILL HOLE UAS-4

Rotary Interval: 0 - 50 m

Core Interval: 50 - 250 m

Total Depth: 250 m

LAKHRA FORMATION

1. Limestone: N7, light gray; becomes sandy toward the base especially the bottom 7 cm; CONTAINS: Shell fragments, whole Turritella and foraminifera; grades into:
   0.67 m
   (50.67 m)

2. Sandstone: N7, light gray at top darkening to N6 medium light gray at the base; Medium-grained at the top fining downward to fine-grained at the base, poorly sorted; composed of quartz, some dark minerals, abundant interstitial clay, and calcareous cement at the top; non-calcareous at the base; CONTAINS: abundant forams and shell fragments at the top of the unit uncommon forams and shell fragments at the base; burrows; contact unknown:
   0.64 m
   (51.31 m)

3. Core loss: Presumed to occur in unit 2:
   0.97 m
   (52.28 m)

4. Claystone: 5Y3/2, olive gray; CONTAINS: planar bedding with laminations generally less than 4 mm thick; uncommon burrows; comminuted carbonaceous debris on some bedding plane surfaces; very fine- and fine-grained quartz sand laminations up to 1 mm thick, laminations contain no obvious bedding structure and laminations become more abundant downward; abundant dark minerals are associated with the sand laminations; contact unknown:
   2.37 m
   (54.65 m)

5. Core loss: Location unknown:
   0.29 m

(54.94 m)

6. Claystone: 5Y3/2, olive gray; CONTAINS: planar bedding with laminations generally less than 4 mm thick; uncommon burrows; comminuted carbonaceous debris on some bedding plane surfaces; very fine- and fine-grained quartz sand laminations up to 1 mm thick, laminations contain no obvious bedding structure and laminations become more abundant and thicker downward; abundant dark minerals are associated with the sand laminations; contact unknown:

   1.83 m
   (56.77 m)

7. Core loss: Location unknown:

   1.22 m
   (57.99 m)

8. Sandstone: 5Y4/1, olive gray; fine-grained, fines downward as argillaceous component becomes more abundant, poorly sorted; composed of quartz, mica flakes, and abundant interstitial clay; CONTAINS: burrows; carbonaceous debris on bedding plane surfaces; sharp contact with:

   1.61 m
   (59.60 m

9. Claystone: 5Y4/1, olive gray; non-calcareous; CONTAINS: uncommon carbonaceous debris on bedding plane surfaces; uncommon shell fragments and thin layers of shell debris; siderite bands; burrows, some burrows sideritized; contact unknown:

   1.00 m
   (60.60 m)

10. Core loss: Presumed to occur in sandstone unit 8:

    0.23 m
    (60.83 m)

11. Claystone: 5Y4/1, olive gray; non-calcareous; CONTAINS: uncommon carbonaceous debris on bedding plane surfaces; uncommon shell fragments and thin layers of shell debris; abundant sand and shell debris in the bottom 10 cm; siderite bands; burrows, some burrows sideritized; sharp contact with:

    1.27 m
    (62.10 m)

12. Sandstone: 5GY6/1, greenish-gray; medium-grained, some coarse grains, poorly sorted; composed of quartz, abundant glauconite, and abundant interstitial clay; homogeneous; non-calcareous; CONTAINS: abundant forams, forams are the only fossil remains present in this unit; glauconite and forams become less abundant downward; intense bioturbation; grades into:

    1.87 m
    (63.97 m)

13. Sandstone: N6, medium light gray; fine-grained, medium-grained in places, poorly sorted; composed of quartz, glauconite in places, abundant dark minerals, abundant interstitial clay and some calcareous cement; CONTAINS: some shell debris near the top of the unit and small local occurrences throughout the unit; some coalified wood fragments at the top of the unit; wavy bedding with clay bands up to 1 cm thick; flaser bedding in places; burrows in places; grades

    2.25 m
    (66.22 m)

into:

14. Claystone: 5Y4/1, olive gray; CONTAINS: abundant fine-grained sand laminations in the upper half, laminations less than 1 mm
5.01 m thick, laminations become less abundant downward; the sand
(71.23 m) in the laminations composed of quartz and abundant heavy minerals; abundant carbonaceous debris on some bedding surfaces; shell fragments become abundant in the basal meter; siderite bands; sideritized burrows; sharp contact with:

15. Limestone: N7, light gray; CONTAINS: glauconite; Turritella, forams, and shell fragments; becomes increasingly sandy downward;
1.65 m grades into:
(72.88 m)

16. Sandstone: 5GY5/1, medium dark greenish-gray; medium-grained, poorly sorted; composed of quartz, abundant interstitial clay, and
0.47 m calcareous cement; homogeneous; CONTAINS: shell fragments
(73.35 m) and forams; no evidence of bedding; contact unknown:

17. Core loss: Presumed to occur in sandstone units 16 or 18:

0.28 m
(73.63 m)

18. Sandstone: 5GY5/1, medium dark greenish-gray; medium-grained, poorly sorted; composed of quartz, abundant interstitial clay, and
0.96 m calcareous cement; homogeneous; CONTAINS: some pyrite;
(74.59 m) shell fragments and forams; no evidence of bedding; contact unknown:

19. Core loss: Presumed to occur in sandstone unit 18:

1.48 m
(76.07 m)

20. Claystone: N3, dark gray; CONTAINS: siderite bands and nodules; sand laminations; burrows in places; contact unknown:
2.66 m
(78.73 m)

21. Core loss: Location unknown, presumed to occur in unit 18:

2.20 m
(80.93 m)

22. Interbedded sandstone and claystone: 5Y4/1, olive gray; Sandstone is fine- to medium-grained; composed of quartz, heavy minerals,
5.91 m and abundant interstitial clay; sandstone becomes more
(86.84 m) abundant downward and unit coarsens downward; CONTAINS: wavy bedding in the top 70 cm; burrows; contact unknown:

23. Core loss: Presumed to occur in unit 22:

1.75 m
(88.59 m)

24. Interbedded sandstone and claystone: 5Y4/1, olive gray; non-calcareous; fine- to medium-grained; composed of quartz, heavy minerals, and abundant interstitial clay; sandstone becomes more abundant downward and unit coarsens downward; percentage of interstitial clay also decreases downward and basal meter is moderately clean; CONTAINS: wavy bedding in the top 70 cm; burrows; contact unknown:

1.94 m
(90.53 m)

25. Core loss: Presumed to occur in unit 24 or 26:

0.63 m
(91.16 m)

26. Sandstone: 5Y4/1, olive gray; poorly sorted; composed of quartz and abundant interstitial clay; CONTAINS: shell fragments; abundant coalified wood fragments, especially near the top of the unit; burrows; contact unknown:

0.77 m
(91.93 m)

27. Siltstone: 5Y4/1, olive gray; fines downward from sandy siltstone in the top 70 cm to claystone in the basal 50 cm; CONTAINS: siderite nodules; burrows; flat, quartz sand laminations in places; shell fragments; finely comminuted carbonaceous debris; grades into:

2.25 m
((94.18 m)

28. Siltstone: 5GY4/1, dark green-gray; sandy; CONTAINS: abundant glauconite; abundant <u>Assilina</u>; grades into:

0.21 m
(94.39 m)

29. Sandstone: N6, medium-light gray; medium-grained, well sorted, dirty becomes less argillaceous downward; composed of quartz, some heavy minerals, glauconite, abundant interstitial clay, and calcareous cement; CONTAINS: abundant wavy clay laminations up to 3 mm in thickness, laminations become less abundant downward; common shell fragments and carbonaceous debris especially in the top meter; burrows; contact unknown:

1.46 m
(95.85 m)

30. Core loss: Presumed to occur in sandstone units 29 or 31:

1.95 m
(97.80 m)

31. Sandstone: 5Y5/1, medium olive-gray; coarse-grained, poorly sorted; composed of quartz, rare glauconite pellets, and intraformational clay clasts; CONTAINS: siderite bands; contact unknown but presumed sharp:

0.14 m
(97.94 m)

32. Claystone: ranges from N4 to N2, medium dark gray to gray black;

becomes increasingly sandy downward; CONTAINS: sand laminations and siderite bands in the upper half of the unit, clay and carbonaceous laminations in the lower half of the unit, carbonaceous debris increases in abundance downward; wavy laminations and ripples occur in the bottom 50 cm, ripples and laminations defined by the accumulation of carbonaceous debris and clay on the laminations; burrows; contact unknown:

1.48 m
(99.42 m)

33. Core loss: Presumed to occur in unit 31:

0.86 m
(100.28 m)

34. Claystone: 10YR2/2, dusky yellow-brown; becomes increasingly silty downward; CONTAINS: laminar bedding; siderite bands and thin sand laminations in the upper 50 cm; abundant carbonaceous debris on most bedding surfaces, carbonaceous debris often pyritized; siderite bands and thin sand laminations in the upper 50 cm; burrows, some burrows are hollow and pyritized; grades into:

2.64 m
(102.92 m)

35. Siltstone: N4, medium-dark gray; fines downward; CONTAINS: abundant sand laminations in the top 90 cm, laminations become thinner downward; abundant burrows, especially in the top 90 cm; siderite nodules; abundant carbonaceous debris throughout; grades into:

1.95 m
(104.87 m)

36. Claystone: N4, medium-dark gray; non-calcareous; CONTAINS: burrows; finely comminuted carbonaceous debris on bedding plane surfaces; pyrite; siderite bands and nodules; grades down into:

0.71 m
(105.58 m)

37. Siltstone: N3, dark gray; coarsens downward; CONTAINS: abundant sand laminations in the top 90 cm, laminations become thicker and more abundant downward; rare carbonaceous laminations; common coalified wood fragments and abundant carbonaceous debris; abundant burrows, especially in the top 90 cm; siderite nodules; grades into:

4.70 m
(110.28 m)

38. Claystone: N5, medium gray; fines downward; CONTAINS: abundant fine-grained quartz sand laminations up to 5 mm thick, sand includes dark minerals; laminations become less abundant and thinner downward and disappear near the base; some carbonaceous laminations; burrows; contact unknown:

0.65 m
(110.93 m)

39. Core loss: Location unknown:

0.70 m
(111.63 m)

40. Sandstone: 5Y5/2, light olive-gray; medium-grained, poorly sorted, and dirty; composed of quartz, rare glauconite pellets, and

0.03 m (111.66 m) abundant interstitial clay; non-calcareous; CONTAINS: carbonaceous debris; Assilina; contact unknown:

41. Sandstone: N5, medium gray; fine-grained, well sorted, and dirty; composed of quartz, heavy minerals, and abundant
0.82 m (112.48 m) interstitial clay; CONTAINS: burrows; irregular flat and wavy laminations, some of the laminations may define ripples; rare resin; contact unknown:

42. Core loss: Location unknown, loss presumed to occur in unit 41 or unit 43:
0.20 m (112.68 m)

43. Sandstone: N5, medium gray; fine-grained, well sorted, and dirty; composed of quartz, heavy minerals, and abundant
0.85 m (113.53 m) interstitial clay; CONTAINS: burrows; shale laminations and ripples; contact unknown:

44. Core loss: Presumed to occur in unit 43:
2.08 m (115.61 m)

45. Interbedded sandstone and siltstone: N6-N5, medium gray to medium light gray; sandstone beds are fine-grained, dirty, and contain
1.31 m (116.92 m) abundant interstitial clay; UNIT CONTAINS: burrows; shale and carbonaceous laminations; flat and wavy laminations and poorly developed ripples; grades into:

46. Sandstone: N5-N7, medium gray to light gray; fine-grained, well sorted, clean; composed of quartz, uncommon heavy minerals, and some
5.82 m (122.74 m) interstitial clay; CONTAINS: burrows; flat and wavy carbonaceous and shale laminations; ripples; contact unknown:

47. Core loss: Presumed to occur in unit 46 or unit 48:
2.64 m (125.38 m)

48. Sandstone: 5Y7/1, very light olive-gray; coarse-grained, fining downward to medium-grained at the base, well sorted, clean;
0.70 m (126.08 m) composed of quartz, sparse dark minerals, and little interstitial clay; non-calcareous; poorly cemented, friable; CONTAINS: burrows; uncommon shale laminations; rare carbonaceous laminations; ripples; grades into:

49. Interlaminated sand and shale: N6, medium-light gray; sandstone laminations are composed of fine-grained quartz sand
0.24 m (126.32 m) containing abundant heavy minerals; carbonaceous debris often associated with sand laminations; claystone bands and laminations are medium gray and become thicker and more

abundant downward; UNIT CONTAINS: burrows; grades into:

50. Sandstone: N4, Medium-dark gray; coarse-grained, coarsens downward; poorly sorted, clean; composed of quartz and little
0.38 m interstitial clay; CONTAINS: abundant carbonaceous debris
(126.70 m) and carbonaceous laminations; burrows; intraformational clay pebbles up to 2 mm long; contact unknown:

51. Core loss: Presumed to occur in unit 50 or unit 52:

1.78 m
(128.48 m)

52. Sandstone: N4, Medium-dark gray; coarse-grained, coarsens downward; poorly sorted, clean; composed of quartz and little
0.41 m interstitial clay; CONTAINS: abundant carbonaceous debris
(128.89 m) and carbonaceous laminations; burrows; intraformational clay pebbles up to 2 mm long; contact unknown:

53. Sandstone: 5Y4/1, olive-gray; very fine-grained, well sorted; composed of quartz and interstitial clay; CONTAINS: burrows, top
1.23 m 35 cm contains large burrows filled with coarse sand from
(130.12 m) the overlying unit; abundant flat laminations less than 1 mm in thickness; abundant carbonaceous debris on laminations; ripples; siderite nodules; sharp contact with:

54. Sandstone: N5, medium gray; fine-grained, poorly sorted, dirty; composed of quartz, some dark minerals, and abundant
0.86 m interstitial clay; CONTAINS: flat laminations; abundant
(130.98 m) carbonaceous debris and coalified wood fragments; some carbonaceous laminations; abundant burrows, upper 50 cm homogenized by burrowing; laminations poorly preserved in the rest of the unit; contact unknown:

55. Core loss: Presumed to occur in sandstone unit 54 or unit 56:

0.41 m
(131.39 m)

56. Sandstone: N5, medium gray; fine-grained, poorly sorted, dirty; composed of quartz, some dark minerals, and abundant
0.32 m interstitial clay; CONTAINS: flat laminations; abundant
(131.71 m) carbonaceous debris and coalified wood fragments; some carbonaceous laminations; abundant burrows, upper 50 cm homogenized by burrowing; laminations poorly preserved in the rest of the unit; sharp contact with:

57. Shale: N3, Dark gray; CONTAINS: sparse, flat, fine-grained, quartz sand laminations less than 1 mm thick; finely comminuted
1.84 m carbonaceous debris on bedding plane surfaces; rare
(133.55 m) carbonaceous laminations; pyrite; grades into:

58. Sandstone: N5, Medium gray; medium-grained, poorly sorted, dirty;

composed of quartz and abundant interstitial clay;
1.24 m (134.79 m) CONTAINS: intensely burrowed, unit almost homogenized by burrowing; relict flat clay laminations preserved; abundant carbonaceous debris; grades into:

59. Shale: 5Y4/1, olive-gray; CONTAINS: burrows; abundant fine-grained quartz sand laminations usually less than 1 mm in thickness though occasionally some laminations attain 5 mm thickness; sand contains heavy minerals; rare ripple lenses; uncommon carbonaceous debris on some bedding plane surfaces, some of the carbonaceous debris in pyritized near the base of the unit; siderite nodules; grades into:
4.64 m (139.43 m)

60. Sandstone: 5Y5/1 lightening to 5Y6/1, medium light olive gray lightening to light olive gray; fine-grained, well sorted; moderately clean; composed of quartz, abundant heavy minerals, and some interstitial clay, percentage of clay decreases toward the middle of the unit then becomes more abundant downward; CONTAINS: abundant flat and wavy laminations, laminations disappear toward the middle of the unit then become more abundant downward; laminations defined by the accumulation of clay and carbonaceous debris; ripples in places; burrows; sharp contact with:
2.96 m (142.39 m)

61. Sandstone: 5Y5/1, medium light olive-gray; medium-grained with zones of coarse-grained sand toward the base of the unit, moderately well sorted, dirty; composed of quartz and abundant interstitial clay; poorly cemented, friable; CONTAINS: uncommon carbonaceous debris and coalified wood fragments; faint flat laminations; contact unknown:
0.82 m (143.21 m)

62. Core loss: Presumed to occur in unit 61 or unit 63:

0.37 m (143.58 m)

63. Sandstone: 5Y5/1, medium light olive-gray; medium-grained with zones of coarse-grained sand toward the base of the unit, moderately well sorted, dirty; composed of quartz and abundant interstitial clay; poorly cemented, friable; CONTAINS: uncommon carbonaceous debris and coalified wood fragments; faint flat laminations; sharp contact with:
0.30 m (143.88 m)

64. Siltstone: N7, light gray; dense; hard; non-calcareous; sandy in places; slickensided; CONTAINS: sparse carbonized and pyritized root traces and plant debris; carbonaceous debris becomes more abundant downward; ripples and irregular laminations in the lower half of the unit; grades into:
1.14 m (145.02 m)

65. Sandstone: N7, light gray; fine-grained coarsening downward to medium grained, well sorted, dirty; composed of quartz, heavy minerals, traces of glauconite pellets, and abundant interstitial clay, clay becomes less abundant downward; well
1.05 m (146.07 m)

indurated at the top of the unit, becomes less well cemented and the clay component disappears; CONTAINS: ripples; low angle cross-beds; contact unknown:

66. Core loss: Presumed to occur in unit 65 or unit 67:

0.56 m
(146.63 m)

67. Sandstone: N7, light gray; fine-grained coarsening downward to medium grained, well sorted, dirty; composed of quartz, heavy minerals, traces of glauconite pellets, and abundant interstitial clay, clay becomes less abundant downward; well indurated at the top of the unit, becomes less well cemented and the clay component disappears; CONTAINS: ripples; low angle cross-beds; contact unknown:

4.26 m
(150.89 m)

68. Core loss:

0.45 m
(151.34 m)

69. Sandstone: N7, light gray; medium-grained, well sorted, moderately clean; composed of quartz, heavy minerals, traces of glauconite pellets, and some interstitial clay, clay becomes less abundant downward though in places the clay can be abundant; poorly cemented, friable; CONTAINS: burrows; sparse carbonaceous laminations; ripples; low angle cross-beds; contact unknown:

0.56 m
(151.80 m)

70. Core loss: Presumed to occur in unit 69 or unit 71:

1.13 m
(152.93 m)

71. Sandstone: N7, light gray; medium-grained, well sorted, moderately clean; composed of quartz, heavy minerals, traces of glauconite pellets, and some interstitial clay, clay becomes less abundant downward though in places the clay can be abundant; poorly cemented, friable; CONTAINS: burrows; sparse carbonaceous laminations; ripples; low angle cross-beds; contact unknown:

2.00 m
(154.93 m)

72. Core loss: Presumed to occur in unit 71 or unit 73:

1.05 m
(155.98 m)

73. Sandstone: N7, light gray; medium-grained, well sorted, moderately clean; composed of quartz, heavy minerals, traces of glauconite pellets, and some interstitial clay, clay becomes less abundant downward though in places the clay can be abundant; poorly cemented, friable; CONTAINS: burrows;

0.40 m
(156.38 m)

sparse carbonaceous laminations; ripples; low angle cross-beds; contact unknown:

74. Core loss: Presumed to occur in unit 73:

5.70 m
(162.08 m)

75. Bone coal: Black; CONTAINS: rippled sandstone partings; contact unknown:

0.03 m
(162.11 m)

76. Sandstone: N7, light gray; medium-grained, well sorted, moderately clean; composed of quartz, heavy minerals, traces of glauconite pellets, and some interstitial clay, clay becomes less abundant downward though in places the clay can be abundant; poorly cemented, friable; CONTAINS: burrows; sparse carbonaceous laminations; ripples; low angle cross-beds; contact unknown:

1.03 m
(163.14 m)

77. Core loss: Presumed to occur in unit 76:

1.40 m
(164.54 m)

78. Claystone: N4, medium dark gray; CONTAINS: flat and wavy, fine-grained, quartz sand laminations usually less than 1 mm thick, in the top 50 cm these laminations are rippled and form ripple lenses; small zones of ripple lenses throughout; burrows; siderite bands and nodules; carbonaceous debris on some bedding plane surfaces; contact unknown:

1.86 m
(166.40 m)

79. Coal: Black; sharp contact with:

1.12 m
(167.52 m)

80. Sandstone: 5Y5/1, medium light olive-gray; fine-grained, well sorted, dirty; composed of quartz and abundant interstitial clay; indurated; CONTAINS: roots in the top 3 m; carbonaceous debris scattered throughout the unit, irregular, wavy carbonaceous laminations occur near the base of the unit; burrows, unit homogenized by burrowing; siderite nodules; grades into:

4.55 m
(172.07 m)

81. Siltstone: 5Y4/1 darkening to 5Y3/1, olive-gray darkening to dark olive-gray; CONTAINS: sparse carbonaceous debris; carbonaceous debris becomes more abundant downward; abundant burrows throughout, in places the unit is homogenized by burrowing; flat to irregular, fine-grained quartz sand laminations; uncommon siderite nodules; resin in the basal part of the unit: sharp contact with:

1.20 m
(173.27 m)

82. Bone coal: Black; CONTAINS: shale partings; resin; sharp contact with:

0.19 m
(173.46 m)

83. Siltstone: 5Y6/1 lightening to N7, light olive-gray lightening to light gray; sandy in the middle of the unit; CONTAINS: roots throughout; grades into:
2.16 m
(175.62 m)

84. Claystone: N7, light gray; rooted in the top 10 cm and intensely slickensided; sharp contact with:
0.54 m
(176.16 m)

85. Shale: N5 darkening downward to N2, medium gray to gray-black; CONTAINS: abundant carbonaceous debris and coalified wood fragments on bedding plane surfaces; carbonaceous debris is pyritized toward the base of the unit; some burrows; grades into:
0.81 m
(176.97 m)

86. Carbonaceous Shale: Black; CONTAINS: pyrite; sharp contact with:

0.18 m
(177.15 m)

87. Claystone: N4, medium dark gray; rooted throughout, most intense rooting occurs in the top 1.50 m; basal 75 cm fissile; CONTAINS: abundant carbonaceous debris and carbonized wood fragments; whole leaf impressions 20 cm above the base of the unit; pyritized carbonaceous debris in places;
2.33 m
(179.48 m)

88. Coal: Black; sharp contact with:

0.80 m
(180.28 m)

89. Claystone: 5Y2/1; olive-black; rooted; CONTAINS: carbonaceous debris and pyrite; sharp contact with:
0.36 m
(180.64 m)

90. Coal: Black; sharp contact with:

5.24 m
(185.88 m)

91. Claystone: N4, medium dark gray; rooted to a depth of 1.70 m; CONTAINS: carbonized root remains; finely comminuted carbonaceous debris on bedding plane surfaces throughout the unit; abundant siderite nodules in the basal three-fourths of the unit; fine-grained, flat, quartz sand laminations in
2.12 m
(188.00 m)

the basal 25 cm; ripples; burrows; sharp contact with:

92. Coal: Black; sharp contact with:

0.31 m
(188.31 m)

93. Claystone: N5, medium gray; CONTAINS: carbonized roots and plant debris; grades into:

0.15 m
(188.46 m)

94. Siltstone: N7, light gray; sandy, lithology grades to sandstone in some zones; rooted throughout, roots pyritized; grades into:

2.67 m
(191.13 m)

95. Claystone: 5YR4/1, brownish gray; CONTAINS: abundant carbonaceous debris; sharp contact with:

0.25 m
(191.38 m)

96. Carbonaceous shale: N2, gray-black; contact unknown:

0.03 m
(191.41 m)

97. Core loss: Location unknown:

0.10 m
(191.51 m)

98. Sandstone: 5Y6/1, light olive-gray; fine-grained, well sorted, dirty; composed of quartz, dark minerals and abundant interstitial clay; CONTAINS: scattered carbonaceous debris; burrows; ripples; flay clay and carbonaceous laminations; a zone of extremely indurated siderite cemented sandstone; abundant roots in the basal 1.28 m, rooting is presumed to originate from the overlying carbonaceous shale but roots are probably not detected in the top meter; contact unknown:

2.28 m
(193.79 m)

99. Core loss: Presumed to occur in sandstone unit 98:

0.31 m
(194.10 m)

100. Claystone: N3, dark gray; CONTAINS: abundant carbonaceous debris, some of the carbonaceous material is pyritized; sandstone filled burrows greater than 1 cm in diameter; siderite nodules; grades down into:

0.15 m
(194.25 m)

101. Claystone: 5Y4/1, olive-gray; coarsens downward and becomes a dirty, fine-grained sandstone at the base of the unit; CONTAINS:

0.54 m (194.79 m) burrows; sparse sandstone ripple lenses at the top of the unit, sand proportion becomes more abundant downward; finely comminuted carbonaceous debris on bedding plane surfaces; coaly laminations toward the base; grades into:

102. Bone coal: Black; CONTAINS: sandstone scour fills at the top of the unit; grades into:

0.09 m (194.88 m)

103. Siltstone: N5 grading downward to N7, medium gray grading downward to light gray; rooted throughout; CONTAINS: scattered zones of dirty, medium-grained sandstone; resin blebs near the contact with the underlying unit; contact unknown:

1.44 m (196.32 m)

104. Coal: Black; sharp contact with:

0.75 m (197.07 m)

105. Sandstone: 5Y2/1, olive-black in the top 8 cm then lightens to N7, light gray below; top 40 cm is a coarsening downward sequence grading from shale to siltstone to fine-grained sandstone; well sorted, dirty; composed of quartz and abundant interstitial clay; CONTAINS: roots throughout the unit, rooting intensity decreases downward; relict ripple and wavy bedding preserved toward the base of the unit; sparse carbonaceous debris; siderite nodules; sharp contact with:

1.53 m (198.60 m)

106. Carbonaceous shale: N2, gray-black; CONTAINS: abundant carbonaceous debris; slickensides; contact unknown:

0.05 m (198.65 m)

107. Siltstone: N6, medium light gray; coarsens downward from shale at the top to argillaceous fine-grained sandstone near the base then fines again to shale at the base of the unit; massive; homogeneous; no evidence of bedding preserved; CONTAINS: roots in the top 2.10 m; roots carbonized near the top, toward the base they are replaced by iron mineralization; contact unknown:

2.26 m (200.91 m)

108. Core loss: Location unknown:

0.23 m (201.14 m)

109. Shale: N5, medium gray; massive; homogeneous; hackly; rooted; slickensided; CONTAINS: abundant carbonized roots; grades into:

0.49 m (201.63 m)

110. Carbonaceous shale: Black; grades into:

0.07 m
(201.70 m)

111. Coal Black; contact unknown;

0.18 m
(201.88 m)

112. Claystone: N7, light gray; coarsens downward into siltstone then into extremely dirty, fine-grained sandstone, 16 cm from the base the unit fines again to siltstone; massive; homogeneous; rooted throughout; no evidence of bedding preserved; CONTAINS: abundant carbonized root remains; grades into:
2.21 m
(204.09 m)

113. Carbonaceous shale: N4, medium dark gray; sharp contact with:

0.11 m
(204.20 m)

114. Siltstone: N7, light gray; coarsens downward, argillaceous at the top of the unit, arenaceous at the base; rooted throughout; massive; homogeneous; no evidence of original bedding preserved; CONTAINS: carbonized roots at the top of the unit, iron mineralized roots at the base; contact unknown:
2.02 m
(206.22 m)

115. Core loss: Location unknown:

2.99 m
(209.21 m)

116. Claystone: N4, medium dark gray; CONTAINS: abundant siderite nodules; rare pyritized wood fragments; finely comminuted shell fragments, whole foraminifera, bands of shell coquina up to 2 cm thick; sparse mica flakes on bedding plane surfaces; slickensides; sharp contact with:
1.35 m
(210.56 m)

117. Coal: Black; sharp contact with:

0.15 m
(210.71 m)

118. Claystone: N4, medium dark gray; rooted; CONTAINS: abundant carbonaceous debris, much of the carbonaceous debris has been replaced by pyrite; contact unknown:
0.09 m
(210.80 m)

119. Carbonaceous shale: Black; intensely rooted; sharp contact with:

0.10 m
(210.90 m)

120. Claystone: N5, medium gray; rooted; CONTAINS: carbonized wood and roots; sharp contact with:

0.58 m
(211.48 m)

121. Coal: Black; very shaly in places; grades into:

0.58 m
(212.06 m)

122. Sandstone: 5Y5/1, medium light olive-gray; fine-grained, silty and carbonaceous at the top, well sorted; dirty; composed of quartz and abundant interstitial clay; CONTAINS: burrows; abundant rooting throughout the unit, bedding badly disturbed by rooting; ripples; carbonaceous and shaly laminations; siderite bands and wavy bedding toward the base;contact unknown:

1.49 m
(213.55 m)

123. Core loss: Presumed to occur in sandstone but location not certain:

4.23 m
(217.78 m)

124. Shale N3, dark gray; CONTAINS: abundant finely comminuted carbonaceous debris on bedding plane surfaces; contact unknown:

0.11 m
(217.89 m)

125. Sandstone: N7, light gray; fine-grained, poorly sorted, extremely dirty; composed of quartz and extremely abundant interstitial clay, the clay component decreases in abundance downward; rooted; massive; homogeneous; CONTAINS: no evidence of bedding; sharp contact with:

0.62 m
(218.51 m)

126. Carbonaceous shale: Black; sharp contact with:

0.01 m
(218.52 m)

127. Claystone: N7, light gray; rooted; CONTAINS: carbonaceous debris toward the base of the unit; grades into:

0.20 m
(218.72 m)

128. Bone coal: Black; CONTAINS: abundant shale laminations; contact unknown:

0.02 m
(218.74 m)

129. Core loss: Location unknown:

0.15 m
(218.89 m)

130. Sandstone: N7, light gray; fine-grained, poorly sorted; extremely dirty; composed of quartz and extremely abundant
2.19 m interstitial clay; CONTAINS: abundant roots, rooted top
(221.08 m) 1.4 m, bedding homogenized in the rooted zone; abundant red iron mineralization paralleling traces that are interpreted to be roots; ripples and wavy beds can be seen below 1.4 m; sharp contact with:

131. Claystone: N7, light gray; more intensely rooted than the overlying unit 130; CONTAINS: a carbonaceous film along root traces;
0.72 m red iron mineralization associated with root traces and some
(221.80 m) traces are pyritized; slickensides toward the base of the unit; sharp contact with:

132. Coal: Black; resinous; sharp contact with:

0.20 m
(222.00 m)

133. Carbonaceous shale: Black; intensely rooted; CONTAINS: abundant finely comminuted carbonaceous debris; sharp contact with:
0.26 m
(222.26 m)

134. Claystone: N6, medium light gray; intensely rooted; CONTAINS: abundant carbonaceous debris; grades into:
0.23 m
(222.49 m)

135. Carbonaceous shale: Black; grades into:

0.03 m
(222.52 m)

136. Coal: Black; sharp contact with:

0.39 m
(222.91 m)

137. Claystone: N4, medium dark gray; intensely rooted; carbonaceous at the base; CONTAINS: abundant carbonized root remains; grades
0.29 m into:
(223.20 m)

138. Coal: Black; grades into:

0.15 m
(223.35 m)

139. Carbonaceous shale: Black; intensely rooted; CONTAINS: abundant finely comminuted carbonaceous debris on bedding plane
0.23 m surfaces; sharp contact with:

(223.58 m)

140. Claystone: N6, medium light gray; intensely rooted; slickensided; CONTAINS: carbonized root remains; grades into:

0.43 m
(224.01 m)

141. Bone coal: Black; CONTAINS: abundant shale laminations and clay trails along root penetrations from overlying units; grades into:

0.28 m
(224.29 m)

142. Claystone: N1 grading to N3 downward, lightens from black at the top to dark gray at the base; rooted; CONTAINS: abundant carbonized root remains; some pyritized carbonaceous debris; relict, thin, flat sand laminations are preserved in the basal 20 cm; grades into:

1.11 m
(225.40 m)

143. Sandstone: N5, medium gray; fine-grained, well-sorted, dirty; composed of quartz and abundant interstitial clay; CONTAINS: wavy bedding in the top 30 cm; ripples; bedforms defined by clay and carbonaceous debris laminations, internal bedforms become more difficult to distinguish downward; burrows; contact unknown:

0.52 m
(225.92 m)

144. Core loss: Presumed to occur in unit 143 or unit 145:

2.12 m
(228.04 m)

145. Sandstone: 5Y5/1, medium light olive-gray; medium- to very coarse-grained, poorly sorted, dirty; composed of quartz and abundant interstitial clay; CONTAINS: burrows, unit appears homogenized by burrowing; sparse carbonaceous debris; faint clay bands; contact unknown:

0.49 m
(228.53 m)

146. Core loss: Presumed to occur in unit 145 or unit 147:

8.05 m
(237.03 m)

147. Sandstone: 5Y5/1, medium light olive-gray; fine-grained, well-sorted, clean; composed of quartz and little interstitial clay; CONTAINS: carbonaceous and shale laminations; abundant burrows; zones of indurated, iron cemented sandstone; some white kaolinite-like clay in matrix; contact unknown:

0.84 m
(237.87 m)

148. Core loss: Presumed to occur in sandstone unit 147:

0.46 m
(238.33 m)

149. Claystone: N3, dark gray; CONTAINS: sand-filled burrows; finely

comminuted carbonaceous debris on bedding plane surfaces;
0.45 m carbonaceous debris partially pyritized; sharp contact with:
(238.78 m)

150. Sandstone: N4, medium dark gray; medium-grained, well sorted; composed of quartz and some interstitial clay; CONTAINS: burrows;
0.57 m irregular and wavy shale and carbonaceous laminations;
(239.35 m) contact unknown:

151. Core loss: Presumed to occur in unit 150 or unit 152:

2.03 m
(241.38 m)

152. Sandstone: N7, light gray; fine-grained, well sorted, dirty; composed of quartz, heavy minerals, and abundant interstitial clay;
1.07 m CONTAINS: white, kaolinite-like grains of unknown affinity;
(242.45 m) ripples, accumulations of clay and carbonaceous debris define ripple surfaces; contact unknown:

153. Core loss: Presumed to occur in unit 152:

4.73 m
(247.18 m)

154. Claystone: N4, medium dark gray; CONTAINS: abundant carbonaceous laminations near the top of the unit, carbonaceous debris
2.00 m becomes less abundant downward with only finely comminuted
(249.18 m) carbonaceous debris on bedding plane surfaces near the base of the unit; carbonaceous laminations up to 1 mm in thickness; siderite bands and nodules; thin very fine-grained quartz sand laminations 1 mm or less in thickness; thin zones with rippled sand lenses; hollow, pyritized burrows scattered throughout the claystone; sharp contact with:

155. Sandstone: N5, medium gray; fine-grained, well sorted, clean; composed of quartz and little interstitial clay; CONTAINS: burrows;
0.43 m top 15 cm of the unit homogenized by burrowing; thick bands
(249.61 m) and laminations of carbonaceous debris; contact unknown:

156. Core loss: Presumed to occur in sandstone unit 155:

0.39 m
(250.00 m)

END OF CORE

DRILL HOLE UAS-6

Rotary Interval: 0 - 147.50 m

Core Interval: 147.50 - 321.19 m

Total Depth: 321.19 m

BARA FORMATION

1. Siltstone: 5Y5/2, medium light olive gray; sandy at the top of the unit; CONTAINS: calcareous nodules; indistinct shale bands; sparse, whole pelecypod shells and shell hash; grades into:
   1.12 m
   (148.62 m)

2. Sandstone: 5Y5/2, medium light olive-gray; fine- to medium-grained fining downward to fine-grained and then to very fine-grained sand, moderately well sorted, dirty; composed of quartz, glauconite pellets, and abundant interstitial clay; homogeneous; CONTAINS: burrows, some burrows in the upper part of the unit are filled with sand and shell hash; shell debris throughout, abundant Assilina in the upper 1.1 m, below 1.1 m only pelecypod shells remain; glauconite becomes rare toward the base of the unit; grades into:
   6.37 m
   (154.99 m)

3. Claystone: 5Y5/1, medium light olive-gray; silty at the top and bottom of the unit; CONTAINS: sparse, finely comminuted carbonaceous debris on bedding plane surfaces; calcareous nodules in the upper part of the unit, calcareous nodules are replaced with siderite nodules in the lower part of the unit; very fine-grained flat quartz sand laminations in the top 50 cm; grades into:
   3.42 m
   (158.41 m)

4. Limestone: 5GY6/1, green-gray; becomes increasingly arenaceous toward the base of the unit; CONTAINS: abundant Assilina and shell fragments; glauconite; intraformational clay pebbles; sand filled burrows; calcite cemented nodules; grades into:
   0.84 m
   (159.25 m)

5. Sandstone: 5Y4/1, olive-gray; coarsens downward from fine-grained to medium-grained, poorly sorted, very dirty; composed of quartz, glauconite, very abundant interstitial clay, and calcareous cement; CONTAINS: burrows filled wits sediments from the overlying unit; Assilina and shell fragments; contact unknown:
   0.41 m
   (159.66 m)

6. Core loss: Presumed to occur in sandstone unit 5:
   0.51 m
   (160.17 m)

7. Interbedded claystone and sandstone: 5Y5/1, medium light olive-gray; Sandstone: fine-grained, well sorted; composed of quartz, abundant heavy minerals, some mica flakes, and some interstitial clay; UNIT CONTAINS: finely comminuted carbonaceous debris on bedding plane surfaces and carbonaceous laminations; flat lying sand laminations; ripple lenses; burrows; abundant forams in the basal 1 cm; sharp contact with:

0.43 m
(160.60 m)

8. Coal: Black; resinous; burrowed; CONTAINS: pyrite; sharp contact with:

0.26 m
(160.86 m)

9. Siltstone: N6, medium light gray; rooted throughout; CONTAINS: carbonized and pyritized roots; siderite nodules; relict fine-grained quartz sand laminations toward the base of the unit; finely comminuted carbonaceous debris on laminations; slickensides in places; grades into:

0.92 m
(161.78 m)

10. Claystone: N5, medium gray; CONTAINS: fine-grains, well sorted, quartz, sand laminations and lenticular sand ripples in the top 70 cm, below 70 cm land laminations thin to less than 1mm and ripples disappear completely; carbonaceous debris on bedding plane surfaces; burrows; siderite bands and nodules; sparse, pyritized roots in the top 1.4 m; contact unknown:

3.75 m
(165.53 m)

11. Core loss: Location unknown:

1.54 m
(167.07 m)

12. Interbedded sandstone and claystone: 5Y5/1, medium light olive-gray; CONTAINS: fine-grained, well sorted, quartz sand laminations and ripples, sand contains heavy minerals and rare mica flakes; carbonaceous laminations, pyritized carbonaceous debris, siderite bands and nodules; sharp contact with:

1.01 m
(168.08 m)

13. Claystone: 5Y4/1, olive-gray; CONTAINS: burrows, burrows filled with siderite or poorly sorted medium- to coarse-grained quartz sand; finely comminuted carbonaceous debris on bedding plane surfaces; shell fragments and forams; contact unknown:

1.27 m
(169.35 m)

14. Core loss: Presumed to occur in sandstone; location unknown:

1.12 m
(170.47 m)

15. Claystone: 5Y4/1, olive-gray; CONTAINS: burrows, burrows filled with siderite or poorly sorted medium- to coarse-grained quartz sand; finely comminuted carbonaceous debris on bedding plane surfaces; shell fragments and forams; contact unknown:

3.13 m
(173.60 m)

16. Limestone: 5GY6/1, green-gray; CONTAINS: burrows; coal rip-up clasts at base; whole pelecypod shells and shell fragments; forams; glauconite; Turritella??; sharp contact with:
0.63 m (174.23 m)

17. Coal: Black; CONTAINS: burrows filled with limestone from the overlying sediments; grades into:
0.44 m (174.67 m)

18. Claystone: N4, medium dark gray; coarsens downward, becomes silty at 1.8 m and sandy at the base; rooted throughout; CONTAINS: flat very fine-grained quartz sand laminations and lenticular sand ripples in the lower third of the unit, carbonaceous debris occurs on the laminations; sparse coalified wood fragments; pyritized carbonaceous debris; rare, intact leaf compressions in the middle of the unit; grades into:
2.38 m (177.05 m)

19. Sandstone: N4, medium dark gray; fine-grained, well sorted, dirty; composed of quartz, some heavy minerals and abundant interstitial clay; CONTAINS: abundant burrows, unit homogenized by burrowing; scattered pyritized carbonaceous debris; contact unknown:
0.35 m (177.40 m)

20. Core loss: Location unknown; presumed to occur in unit 19 or unit 21:
1.17 m (178.57 m)

21. Sandstone: N7, light gray; fine-grained, well sorted, clean; composed of quartz, heavy minerals, and little interstitial clay; CONTAINS: flat shale bands and laminations up to 4 mm thick; ripples; burrows; thin zones have been homogenized by burrowing; contact unknown:
1.00 m (179.57 m)

22. Core loss: Presumed to occur in unit 21:
3.46 m (183.03 m)

23. Sandstone: Core badly fragmented during drilling, lithology appears to be the same as unit 21; contact unknown:
0.54 m (183.57 m)

24. Core loss: Presumed to occur in unit 23 or 25:
0.31 m (183.88 m)

25. Sandstone: N8, very light gray; medium-grained, well sorted, clean; composed of quartz, sparse heavies, no interstitial clay,

0.26 m (184.14 m) and calcareous cement; hard; dense; well cemented; CONTAINS: low angle cross-beds, carbonaceous debris defines some cross bed surfaces; intraformational shale clasts; rounded siderite pebbles up to 1 cm in diameter; coalified wood fragments; a whole leaf fossil preserved perpendicular to bedding; burrows (Ophiomorpha); contact unknown:

26. Claystone: 5YR4/1, brown-gray; CONTAINS: rare zones of white, calcite cemented sand up to 8 cm thick; burrows; rare carbonaceous laminations; sparse carbonaceous debris on bedding plane surfaces; sandy zones and sand laminations; siderite bands and nodules; pyrite; lenticular sand ripples in places; contact unknown:

1.10 m (185.24 m)

27. Core loss: Presumed to occur in sandstone unit 26 or 28:

1.10 m (186.34 m)

28. Sandstone: 5YR4/1, brown-gray; CONTAINS: rare zones of white, calcite cemented sand up to 8 cm thick; burrows; rare carbonaceous laminations; sparse carbonaceous debris on bedding plane surfaces; sandy zones and sand laminations; siderite bands and nodules; pyrite; lenticular sand ripples in places; contact unknown:

0.90 m (187.24 m)

29. Sandstone: 5YR6/1, light brown-gray; fine-grained, well sorted, dirty; composed of quartz, some heavy minerals, and abundant interstitial clay; CONTAINS: scattered carbonaceous debris and coalified wood fragments; pyrite; burrows; unit homogenized by burrowing; relict carbonaceous laminations up to 2 cm in thickness; contact unknown:

1.58 m (188.82 m)

30. Core loss: Presumed to occur in unit 29 or unit 31:

1.87 m (190.69 m)

31. Sandstone: N7, light gray; fine-grained, well sorted, dirty; composed of quartz, abundant heavies, and abundant interstitial clay; poorly cemented, friable; CONTAINS: abundant burrows, unit homogenized by burrowing in many parts; siderite nodules; rare carbonaceous debris; rare laminations preserved in places; contact unknown:

0.58 m (191.27 m)

32. Core loss: Presumed to occur in unit 31 or unit 33:

2.48 m (193.75 m)

33. Sandstone: N7, light gray; fine-grained, well sorted, dirty; composed of quartz, abundant heavies, and abundant interstitial clay; poorly cemented, friable; CONTAINS: abundant burrows, unit

1.22 m

(194.97 m) homogenized by burrowing in many parts; siderite nodules; rare carbonaceous debris; rare laminations preserved in places; contact unknown:

34. Core loss: Presumed to occur in unit 33 or unit 35:

1.24 m
(196.21 m)

35. Sandstone: N7, light gray; fine-grained, well sorted, dirty; composed of quartz, abundant heavies, and abundant interstitial clay; poorly cemented, friable; CONTAINS: abundant burrows, unit homogenized by burrowing in many parts; siderite nodules; rare carbonaceous debris; rare laminations preserved in places; contact unknown:

1.65 m
(197.86 m)

36. Claystone: N5, medium gray, CONTAINS: burrows, in the upper part of the unit burrows filled with sand from the overlying sediments; a zone of shell hash 20 cm thick in the middle of the unit; finely comminuted carbonaceous debris at the top of the unit, carbonaceous debris becomes more abundant downward; siderite nodules, pyritized wood fragments; very fine-grained, flat, quartz sand laminations and lenticular sand ripples in places; sand contains abundant heavy minerals and shell fragments; grades into:

1.22 m
(199.08 m)

37. Coal: Black; grades into:

0.20 m
(199.28 m)

38. Carbonaceous shale: N2, gray-black; rooted; CONTAINS: pyritized and coalified wood and plant fragments; sand laminations; resin blebs; grades into:

0.12 m
(199.40 m)

39. Claystone: N5, medium gray; rooted to a depth of 4.8 m; CONTAINS: burrows; fine-grained, well sorted, flat, quartz sand laminations and thicker sand zones up to 30 cm thick; siderite nodules; pyritized carbonaceous debris and roots; finely comminuted carbonaceous debris on bedding plane surfaces; carbonaceous laminations, laminations become more abundant downward; grades into:

7.15 m
(206.55 m)

40. Sandstone: N6, medium light gray; medium-grained, well sorted, dirty; composed of quartz, sparse heavy minerals, and abundant interstitial clay; CONTAINS: carbonaceous and clay laminations; scattered carbonaceous debris; burrows; contact unknown:

0.83 m
(207.38 m)

41. Core loss: Presumed to occur in unit 40:

0.62 m

(208.00 m)

42. Claystone: N5 grading to N4, medium gray darkening downward to medium dark gray; CONTAINS: carbonaceous debris on bedding plane surfaces; siderite bands; burrows; mica on bedding plane surfaces; sand laminations; pyrite; grades into:

1.63 m
(209.63 m)

43. Sandstone: N4, medium dark gray; very fine-grained, well sorted, dirty; composed of quartz, heavy minerals, mica, and abundant interstitial clay; CONTAINS: flat clay and carbonaceous laminations; carbonaceous laminations become more abundant toward the base of the unit; scattered carbonaceous debris and mica on shale laminations; burrows; coalified wood fragments; lenticular ripples; contact unknown:

3.14 m
(212.77 m)

44. Core loss: Presumed to occur in unit 43 or unit 45:

0.58 m
(213.35 m)

45. Sandstone: N6, medium light gray; medium-grained with rare coarse grains, unit fines downward becomming fine-grained 1 m below the top, well sorted, dirty; composed of quartz, rare heavy minerals, heavy minerals become more abundant downward, and abundant interstitial clay; CONTAINS: low angle cross-beds at the top of the unit; scattered carbonaceous debris and carbonaceous debris confined to bedding plane surfaces; burrows; below the top meter, most of the unit is homogenized by burrowing; sideritized zones up to 10 cm thick; pyrite; grades into:

5.62 m
(218.97 m)

46. Sandstone: N7, light gray; very fine-grained, well sorted, dirty; composed of quartz, abundant heavy minerals, and abundant interstitial clay; CONTAINS: burrows, unit homogenized by burrowing in the basal 50 cm; finely comminuted carbonaceous debris on bedding plane surfaces; flat shale and carbonaceous laminations; sideritized zones 2 to 5 cm in thickness; shell fragments; sharp contact with:

5.88 m
(224.85 m)

47. Coal: Black; CONTAINS: sand filled burrows; grades into:

0.39 m
(225.24 m)

48. Carbonaceous shale: N2, gray-black; rooted; CONTAINS: sand laminations; grades into:

0.05 m
(225.29 m)

49. Sandstone: N6, medium light gray; medium-grained at top, fines downward to fine-grained, well sorted, dirty; composed of quartz, sparse heavy minerals, and abundant interstitial clay; CONTAINS: sideritized zones, the siderite bands contain

2.87 m
(228.16 m)

preserved shell fragments; roots throughout the unit; abundant carbonaceous debris and laminations at the top, carbonaceous material becomes less abundant downward, burrows; pyrite; sharp contact with:

50. Sandstone: N7, light gray; medium-grained with rare coarse grains, well sorted, clean; composed of quartz, heavy minerals, and
0.26 m calcareous cement; well cemented; hard; dense; CONTAINS:
(228.42 m) burrows; roots throughout the unit; planar cross-beds; sharp contact with:

51. Sandstone: N6, medium light gray; medium-grained at top, fines downward to fine-grained, well sorted, dirty; composed of quartz,
0.46 m sparse heavy minerals, and abundant interstitial clay;
(228.88 m) CONTAINS: sideritized zones, the siderite bands contain preserved shell fragments; roots throughout the unit; abundant carbonaceous debris and laminations at the top, carbonaceous material becomes less abundant downward, burrows; pyrite; sharp contact with:

52. Claystone: N5, medium gray; rooted in the top 60 cm; CONTAINS: pyritized root traces and carbonaceous debris; finely
1.85 m comminuted carbonaceous debris on bedding plane surfaces;
(230.73 m) siderite nodules; flat siltstone laminations; sharp contact with:

53. Sandstone: 5Y4/1, olive-gray; fine-grained, well sorted, dirty; composed of quartz, glauconite, and abundant interstitial
1.41 m clay; CONTAINS: uncommon glauconite laminations in the top
(232.14 m) 50 cm; siderite nodules preserving shell fragments; below 50 cm the unit is intensely rooted, internal bedding completely destroyed by rooting, rooted part contains carbonized and pyritized roots and coalified wood fragments; grades into:

54. Claystone: N5, medium gray; rooted throughout; CONTAINS: fine-grained quartz sandstone laminations at the top of the unit;
0.60 m carbonaceous debris on bedding plane surfaces; coalified
(232.74 m) wood fragments; siderite nodules; pyritized carbonaceous debris; sharp contact with:

55. Carbonaceous shale: N3, dark gray; intensely rooted; CONTAINS: abundant coaly bands; pyritized carbonaceous debris; grades into:
0.36 m
(233.10 m)

56. Claystone: N5, medium gray; silty in places; rooted throughout, rooting intensity decreases downward; CONTAINS: rare slickensides;
2.96 m siderite nodules; pyritized and carbonized roots;
(236.06 m) carbonaceous debris on bedding plane surfaces; grades into:

57. Carbonaceous shale: Black; CONTAINS: abundant coalified and pyritized carbonaceous debris; grades into:

0.14 m
(236.20 m)

58. Coal: Black; sharp contact with:

0.35 m
(236.55 m)

59. Claystone: 5Y4/1, olive gray; rooted throughout; CONTAINS: abundant carbonaceous debris; abundant pyrite, core badly fragmented by pyrite decomposition; sharp contact with:
0.78 m
(237.33 m)

60. Bone coal: Black; grades into:

0.03 m
(237.36 m)

61. Claystone: N4, medium dark gray; rooted throughout; CONTAINS: abundant carbonaceous debris at the top of the unit becomes less carbonaceous downward; abundant pyrite, core badly fragmented due to the decomposition of the pyrite; grades into:
0.12 m
(237.48 m)

62. Sandstone: 5Y4/1, olive-gray; fine-grained, fines downward to sandy shale at the base of the unit, poorly sorted, dirty; composed of quartz and abundant interstitial clay; rooted throughout; CONTAINS: burrows; abundant pyrite, core badly fragmented due to the decomposition of the pyrite; sharp contact with:
0.79 m
(238.27 m)

63. Coal: Black; grades into:

0.01 m
(238.28 m)

64. Siltstone: 5Y5/1, medium light olive-gray; argillaceous at the top and bottom of the unit; intensely rooted, rooting intensity decreases downward; CONTAINS: relict very fine-grained quartz sand laminations; zones with abundant pyrite, in these places the core is badly fragmented due to the decomposition of the pyrite; very carbonaceous in the top 20 cm and again in the bottom 50 cm; sharp contact with:
2.06 m
(240.34 m)

65. Coal: Black; sharp contact with:

0.50 m
(240.84 m)

66. Carbonaceous shale: N3, dark gray; rooted throughout; CONTAINS: abundant coalified, carbonized, and pyritized plant remains including some recognizable compression fossils like an apparent seed and a trunk; grades into:
0.07 m
(240.91 m)

67. Sandstone: 5Y4/1 grading to 5Y5/1, olive-gray lightening downward to medium light olive gray; coarsens downward from shale at the top to very fine-grained sandstone at the base, poorly sorted, dirty; composed of quartz and abundant interstitial clay; rooted; CONTAINS: abundant carbonaceous debris; carbonaceous and shale laminations; ripples and wavy bedding; low angle cross-beds; contact unknown:

0.61 m
(241.52 m)

68. Core loss: Presumed to occur in unit 67:

0.83 m
(242.35 m)

69. Bone coal: Black; CONTAINS: pyrite; vitrinite bands; shale partings; contact unknown:

0.32 m
(242.67 m)

70. Claystone: 5Y2/1 grading to N3, olive-black lightening downward to dark gray; massive; homogeneous; CONTAINS: very sparse carbonaceous remains; contains no evidence of rooting associated with the overlying coal; core appears to be in place; contact unknown:

1.15 m
(243.82 m)

71. Coal: Black; grades into:

1.55 m
(245.37 m)

72. Bone coal: Black; rooted; CONTAINS: gray shale lenses defining root penetrations into the unit; resin blebs up to 5 mm in diameter; grades into:

0.10 m
(245.47 m)

73. Claystone: 5Y4/1, olive-gray in the top 20 cm then N7, light gray; basal 10 cm dark gray and carbonaceous; rooted; intensely slickensided; CONTAINS: carbonized roots; finely comminuted carbonaceous debris; sharp contact with:

0.84 m
(246.31 m)

74. Sandstone: 5Y6/1, light olive-gray; fine-grained, well sorted, moderately clean; composed of quartz, white kaolinite-like flakes, and some interstitial clay; poorly cemented, friable; CONTAINS: carbonaceous and clay lamina, but bedding characteristics unknown because core badly fragmented; contact unknown:

0.58 m
(246.89 m)

75. Core loss: Presumed to occur in unit 74 or unit 76:

1.03 m
(247.92 m)

76. Sandstone: N4, medium dark gray; fine-grained, well-sorted, dirty;

composed of quartz and abundant interstitial clay;
1.11 m (249.03 m) CONTAINS: abundant burrows, unit homogenized by burrowing; relict shale laminations are preserved locally; laminations are best preserved in siderite nodules; scattered coalified debris throughout; carbonaceous laminations occur near the base of the unit; sharp contact with unit 78:

77. Core loss: Presumed to occur within unit 76:

0.41 m (249.44 m)

78. Coal: Black; sharp contact with:

0.26 m (249.70 m)

79. Sandstone: 5Y5/1, medium light olive-gray; fine-grained with some medium grains fining to very fine-grained; well sorted, dirty; composed of quartz and abundant interstitial clay; rooted to a depth of 3.0 m below the top of the unit; CONTAINS: carbonized root remains; siderite nodules; burrows; flat and wavy laminations visible below the zone of most intense rooting; contact unknown:
1.30 m (251.00 m)

80. Core loss: Presumed to occur in unit 79 or unit 81:

0.70 m (251.70 m)

81. Sandstone: 5Y5/1, medium light olive-gray; fine-grained with some medium grains fining to very fine-grained; well sorted, dirty; composed of quartz and abundant interstitial clay; rooted to a depth of 3.0 m below the top of the unit; CONTAINS: carbonized root remains; siderite nodules; burrows; flat and wavy laminations visible below the zone of most intense rooting; contact unknown:
1.04 m (252.74 m)

82. Siltstone: 5Y5/1, medium light olive-gray; sandy at the top of the unit; CONTAINS: abundant siderite bands and nodules; flat clay bands between 1mm and 10 mm thick; finely comminuted carbonaceous debris on bedding plane surfaces; finely comminuted shell debris; grades into:
1.52 m (254.26 m)

83. Claystone: 5Y4/1, olive-gray; silty at the top; CONTAINS: sparse finely comminuted carbonaceous debris on bedding plane surfaces; flat sand laminations less than 0.1 mm thick composed of finely comminuted shell fragments; scattered pelecypod shell fragments throughout; siderite nodules; sharp contact with:
2.82 m (257.08 m)

84. Sandstone: N5, medium gray; fine-grained with some medium grains, well sorted, dirty; composed of quartz,abundant interstitial

0.25 m (257.33 m) clay, and a calcareous matrix; CONTAINS: abundant shell debris and whole shells, Turritella, Assilina; siderite nodules; carbonaceous debris; sharp contact with:

85. Claystone: N4, medium dark gray; CONTAINS: burrows filled with shell fragments from the overlying unit; flat fine- and very fine-grained quartz sand and carbonaceous laminations; 0.56 m (257.89 m) sideritized bands, in rare cases the siderite zones contain pyrite cores; sharp contact with:

86. Carbonaceous shale: 5Y2/1, olive-black; CONTAINS: fine-grained quartz sand laminations; sharp contact with:
0.13 m (258.02 m)

87. Claystone: N4, medium dark gray; intensely rooted; CONTAINS: abundant carbonized roots and comminuted carbonaceous debris; contact 0.16 m (258.18 m) unknown:

88. Core loss: Nature of loss unknown, possibly a coal may have been lost in this interval:
2.45 m (260.63 m)

89. Carbonaceous shale: N2, gray-black; rooted; CONTAINS: abundant carbonized debris; resin blebs; pyrite; grades into:
0.08 m (260.71 m)

90. Claystone: N5, medium gray; intensely rooted; slickensided; CONTAINS: abundant carbonized roots; a zone of orange colored (10R4/6) 1.31 m (262.02 m) rounded ferruginous concretions the size of medium to coarse sand grains; sharp contact with:

91. Bone coal: Black; shaly in the basal 10 cm; CONTAINS: abundant pyrite; grades into:
0.37 m (262.39 m)

92. Carbonaceous shale: N3, dark gray; rooted; CONTAINS: pyritized carbonaceous debris; grades into:
0.03 m (262.42 m)

93. Claystone: N2 grading downward to 5Y4/1, gray-black lightening to olive-gray; coarsens downward to siltstone; rooted 1.23 m (263.65 m) throughout; CONTAINS: carbonized and pyritized roots and other plant debris; flat quartz sand laminations toward the base of the unit; grades into:

94. Sandstone: 5Y6/1, light olive gray; fine-grained, well sorted, dirty; composed of quartz and abundant interstitial clay;

0.40 m (264.05 m) CONTAINS: roots in the top 40 cm; indistinct flat clay laminations; sparse carbonaceous debris; sideritized zones; ripples in places; contact unknown:

95. Core loss: Presumed to occur in sandstone unit 94 or unit 96:

2.62 m (266.67 m)

96. Sandstone: 5Y7/1, very light olive gray; medium-grained, coarse and very coarse grains in places, well sorted, moderately clean; composed of quartz and some interstitial clay; CONTAINS: contains abundant flat carbonaceous laminations; ripples; low angle cross-beds; shale bands and laminations; burrowed in places; contact unknown:

0.75 m (267.42 m)

97. Core loss: Presumed to occur in unit 96:

2.27 m (269.69 m)

98. Claystone: 5Y5/1, medium light olive-gray; badly fragmented during drilling; appears to CONTAIN: siderite nodules; carbonaceous debris; contact unknown:

0.28 m (269.97 m)

99. Core loss: Location unknown:

0.12 m (270.09 m)

100. Sandstone: 5Y6/1, light olive-gray; medium-grained with zones of coarse- and very coarse-grained sand, poorly sorted, dirty; composed of quartz, glauconite, and abundant interstitial clay; CONTAINS: siderite zones; clay bands; coalified axes and abundant coalified plant debris; flat carbonaceous laminations; contact unknown:

0.16 m (270.25 m)

101. Core loss: Presumed to occur in unit 100 or unit 102:

2.46 m (272.71 m)

102. Sandstone: 5Y6/1, light olive-gray; medium- to very coarse-grained, well sorted, clean; composed of quartz and little interstitial clay; CONTAINS: sideritized zones; carbonaceous laminations and possibly clay laminations; contact unknown:

0.17 m (272.88 m)

103. Core loss: Presumed to occur in unit 102:

2.18 m (275.06 m)

104. Claystone: N4, medium dark gray; CONTAINS: sparse, flat, very fine-grained quartz sand laminations throughout the unit, laminations 1 mm or less in thickness; abundant, finely comminuted carbonaceous debris on bedding plane surfaces; contact unknown:

0.25 m
(275.31 m)

105. Sandstone: N5, medium gray; coarse-grained, well sorted, dirty; composed of quartz and abundant interstitial clay; contact unknown:

0.16 m
(275.47 m)

106. Core loss: Location unknown; presumed to occur in unit 105:

1.49 m
(276.96 m)

107. Claystone: N4, medium dark gray; calcareous; CONTAINS: sand-filled burrows in the top 15 cm; sparse, comminuted carbonaceous debris on some bedding plane surfaces; abundant siderite bands and nodules; sparse shell fragments, especially in the lower half of the unit; sparse, very fine-grained, flat sand laminations; contact unknown:

1.68 m
(278.64 m)

108. Limestone: 5Y6/1, light olive-gray; argillaceous; CONTAINS: burrows; shell hash and forams; abundant coalified plant debris; traces of glauconite; grades into:

1.02 m
(279.66 m)

109. Bone coal: Black; CONTAINS: abundant burrows filled with limestone and shell fragments from the overlying unit; grades into:

0.38 m
(280.04 m)

110. Coal: Black; grades into:

0.34 m
(280.38 m)

111. Carbonaceous shale: Black; rooted; grades into:

0.13 m
(280.51 m)

112. Claystone: N2, gray-black; coarsens downward to siltstone containing fine-grained quartz sand lenses at the base, sand lenses are all less than 1 mm in thickness; rooted to a depth of 95 cm; CONTAINS: abundant carbonaceous debris in the top 30 cm, but carbonaceous debris becomes more sparse and more finely comminuted downward; some coalified axes; some pyritized carbonaceous debris; burrows and lenticular ripples in the basal 50 cm; grades into:

1.79 m
(282.30 m)

113. Sandstone: N5 grading to 5Y2/1, medium gray grading to olive-black in places; fine-grained at the top of the unit coarsening
0.78 m downward to medium-grained, poorly sorted, dirty; composed
(283.08 m) of quartz and abundant interstitial clay; CONTAINS: burrows, unit homogenized by burrowing; relict clay bands and laminations preserved; sideritized zones, these zones have flat laminations undisturbed by burrowing; contact unknown:

114. Core loss: Presumed to occur in unit 113 or unit 115:

1.15 m
(284.23 m)

115. Sandstone: N5 grading to 5Y2/1, medium gray grading to olive-black in places; fine-grained at the top of the unit coarsening
1.94 m downward to medium-grained, poorly sorted, dirty; composed
(286.17 m) of quartz and abundant interstitial clay; CONTAINS: burrows, unit homogenized by burrowing; relict clay bands and laminations preserved; sideritized zones, these zones have flat laminations undisturbed by burrowing; contact unknown:

116. Core loss: Presumed to occur in unit 115 or unit 117:

1.15 m
(287.32 m)

117. Sandstone: N5 grading to 5Y2/1, medium gray grading to olive-black in places; fine-grained at the top of the unit coarsening
0.29 m downward to medium-grained, poorly sorted, dirty; composed
(287.61 m) of quartz and abundant interstitial clay; CONTAINS: burrows, unit homogenized by burrowing; relict clay bands and laminations preserved; sideritized zones, these zones have flat laminations undisturbed by burrowing; contact unknown:

118. Core loss: Presumed to occur in unit 117 or unit 119, loss may include coal:

1.06 m
(288.67 m)

119. Sandstone: N5, medium-gray; medium-grained with some coarse grains, below 1.2 m the unit begins to fine downward; well sorted;
2.35 m composed of quartz, traces of glauconite, and abundant
(291.02 m) interstitial clay, unit becomes less argillaceous downward; rooted to a depth of 79 cm; CONTAINS: carbonized roots, scattered coalified plant debris; burrows, unit homogenized by burrowing in places; flat clay bands and laminations in the lower part of the unit; in the lower parts of the unit laminations are predominantly carbonaceous; contains ripples and low angle cross-beds in the less argillaceous parts the unit; sharp contact with:

120. Sandstone: N7, light gray; medium-grained, well sorted, clean; composed of quartz, some heavies, and calcareous cement; well cemented; sharp contact with:
0.18 m
(291.20 m)

121. Claystone: 5Y3/1, dark olive-gray; fines downward from sandy claystone to siltstone to claystone with flat sand laminations; CONTAINS: sparse carbonaceous debris on bedding plane surfaces; siderite bands; burrows, no burrows in the siderite bands; laminations thin downward; rare, thin lenticular ripples; grades into:
2.47 m
(293.67 m)

122. Sandstone: 5Y4/1, olive-gray lightening downward to 5Y5/1, medium light olive-gray; coarsens downward from silt with fine-grained sand laminations to fine-grained sand with flat carbonaceous laminations, well sorted, dirty; composed of quartz, abundant heavy minerals, abundant red ferruginous grains (oxidized glauconite grains?), and abundant interstitial clay; CONTAINS: abundant coalified plant debris; burrows; clay beds, one 25 cm thick shale zone in the middle of the unit containing thin, flat sand laminations and sand ripple lenses; contact unknown:
0.81 m
(294.48 m)

123. Core loss: Presumed to occur in unit 122 or unit 124:
1.36 m
(295.84 m)

124. Sandstone: 5Y5/1, medium light olive-gray; fine-grained sand with flat carbonaceous laminations, well sorted, dirty; composed of quartz, abundant heavy minerals, abundant red ferruginous grains (oxidized glauconite grains?), and abundant interstitial clay; CONTAINS: abundant coalified plant debris; burrows; clay beds, contact unknown:
1.11 m
(296.95 m)

125. Sandstone: N7, light gray; fine-grained, well sorted, clean; composed of quartz, abundant heavy minerals, mica flakes, red ferruginous grains (oxidized glauconite?), little interstitial clay, and calcareous cement; well cemented; CONTAINS: ripples, cross-bed surfaces defined by the accumulation of clay; contact unknown:
0.10 m
(297.05 m)

126. Claystone: 5Y4/1, olive-gray; CONTAINS: flat, fine-grained quartz sand laminations less than 1 mm thick; rare lenticular ripples; finely comminuted carbonaceous debris on bedding plane surfaces; rare large coalified axes; siderite bands and nodules; uncommon burrows; pyritized carbonaceous debris; grades into:
2.42 m
(299.47 m)

127. Sandstone: N4, medium dark gray; fine-grained, well sorted, dirty; composed of quartz, heavy minerals, and abundant interstitial clay; CONTAINS: burrows, unit homogenized by
0.83 m

(300.30 m) burrowing; contact unknown:

128. Core loss: Presumed to occur in unit 127 or unit 129:

0.70 m
(301.00 m)

129. Sandstone: N4, medium dark gray; fine-grained, well sorted, dirty; composed of quartz, heavy minerals, and abundant
0.43 m interstitial clay; CONTAINS: burrows, unit homogenized by
(301.43 m) burrowing; contact unknown:

130. Claystone: N3, dark gray; CONTAINS: abundant pyritized and coalified wood fragments and plant debris; flat very fine-grained
1.40 m quartz sand laminations; rare lenticular sand ripples; sharp
(302.83 m) contact with:

131. Sandstone: 5Y4/1, olive-gray; fine-grained, well sorted, dirty; composed of quartz, heavy minerals, and abundant
0.82 m interstitial clay; CONTAINS: burrows, unit homogenized by
(303.65 m) burrowing; carbonaceous debris and coalified wood fragments; contact unknown:

132. Sandstone: N7, light gray; fine-grained, well sorted, clean; composed of quartz, abundant fine-grained red ferruginous grains,
1.99 m sparse glauconite pellets, and little interstitial clay;
(305.64 m) CONTAINS: very abundant carbonaceous laminations; contact unknown:

133. Core loss: Presumed to occur in unit 132 or unit 136:

0.33 m
(305.97 m)

134. Sandstone: N7, light gray; fine-grained, well sorted, clean; composed of quartz, abundant fine-grained red ferruginous grains,
2.44 m sparse glauconite pellets, and little interstitial clay;
(308.41 m) CONTAINS: carbonaceous laminations; no evidence of internal bedforms between 307 and 308 m, unit massive and homogeneous; contact unknown:

135. Conglomerate: N7, light gray; composed of intraformational clay pebbles supported in a matrix of fine-grained quartz sand;
0.90 m the sand contains traces of glauconite and is calcite
(309.31 m) cemented; sharp contact with:

136. Sandstone: N7, light gray; fine-grained, well sorted, moderately clean; composed of quartz, some heavy minerals and abundant
2.42 m interstitial clay; CONTAINS: flat laminations; ripples; low
(311.73 m) angle cross-beds; iron mineralized zones; contact unknown:

137. Core loss: presumed to occur in unit 136 or unit 138:

0.28 m
(312.01 m)

138. Sandstone: 5Y4/1, olive-gray; fine-grained, well sorted, dirty; composed of quartz and abundant interstitial clay; 0.30 m (312.31 m) CONTAINS: burrows; siderite nodules; flat carbonaceous and shale laminations; contact unknown:

139. Core loss: Presumed to occur in unit 138 or unit 140:

0.72 m
(313.03 m)

140. Sandstone: 5Y4/1, olive-gray; fine-grained, well sorted, dirty; composed of quartz and abundant interstitial clay; 0.30 m (313.33 m) CONTAINS: burrows; siderite nodules; flat carbonaceous and shale laminations; contact unknown:

141. Sandstone: 5Y4/1, olive-gray; fine-grained, grades into claystone in the basal 20 cm; well sorted, dirty; composed of quartz and 2.60 m abundant interstitial clay; rooted in the top 1.40 m, (315.93 m) rooting intensity decreases downward; CONTAINS: burrows; siderite nodules; flat carbonaceous and shale laminations; contact unknown:

142. Sandstone: N3, dark gray; fine-grained, poorly sorted, dirty; composed of quartz, abundant heavy minerals; and abundant 1.90 m interstitial clay; CONTAINS: burrows, unit homogenized by (317.83 m) burrowing, burrowing less intense in the basal 50 cm; scattered carbonaceous debris and thick bands of carbonaceous debris; coalified wood fragments; core severely disrupted by the decomposition of pyrite in the top 20 cm; low angle cross-beds; contact unknown:

143. Core loss: Presumed to occur in unit 142 or unit 144:

0.96 m
(318.79 m)

144. Sandstone: N7, light gray; fine-grained, well sorted, clean; composed of quartz, heavy minerals, and little interstitial clay; 2.40 m CONTAINS: abundant flat shale and carbonaceous laminations; (321.19 m) ripples; siderite nodules.

END OF CORE

MINE SECTION DESCRIPTIONS

Iqbal Mines, Lakhra Coal Field, IQ-25

Total depth of mine: 99.58 m
Thickness of measured section: 99.58 m

LAKHRA FORMATION

1. Sandstone: Very fine-grained, poorly sorted; yellow-brown with purple-maroon mottling; composed of quartz and very abundant interstitial clay; CONTAINS: clay beds and laminations up to 3 mm in thickness; sparse ironstone bands; grades into:
   2.56 m (2.56 m)

2. Interlaminated claystone and sandstone: Coarsens upward, sparse siltstone laminations become evident in the upper part of the unit; light gray weathers yellow-brown, maroon, and purple; the top 10 cm of the unit consists of glauconitic yellow-brown sandstone; sharp contact with:
   0.90 m (3.46 m)

3. Sandstone: Yellow-brown; CONTAINS: glauconite; abundant shell fragments of oysters, gastropods and Turritella; sharp contact with:
   0.90 m (4.36 m)

4. Interlaminated sandstone and claystone: Coarsens upward, sandstone beds become more prominent upward; Sandstone: very fine-grained, poorly sorted; yellow-brown; composed of quartz and abundant interstitial clay; Claystone: olive-brown; laminations range in thickness between 2 and 5 mm; unit CONTAINS: bands of secondary gypsum along bedding planes; sharp contact with:
   0.64 m (5.00 m)

5. Sandstone: Fine- to coarse-grained, poorly sorted; yellow-brown; composed of quartz, glauconite, very abundant interstitial clay, and calcareous cement; weakly indurated at the base, becomming increasingly well cemented as the calcite content increases upward; CONTAINS: burrows, unit homogenized by burrowing; gastropods, shell fragments; grades into:
   2.38 m (7.38 m)

6. Sandstone: Fine-grained, well sorted; yellow-brown; composed of quartz, little interstitial clay, and calcareous cement in the upper 20 cm; poorly cemented, friable; sharp contact with:
   0.58 m (7.96 m)

7. Interlaminated sandstone and claystone: Sandstone beds: very fine-grained, yellow-brown; poorly cemented, friable; Claystone beds: range in thickness between 1 and 3 mm; olive-brown; grades into:
   0.25 m (8.21 m)

8. Sandstone: Fine-grained, fines upward to very fine-grained, concurrently interstitial clay becomes less abundant upward,

3.33 m (11.54 m) poorly sorted; yellow-brown; composed of quartz, very abundant interstitial clay, and a small amount of calcareous cement; poorly cemented, friable especially in the upper part of the unit; CONTAINS: burrows; sparse shell fragments; grades into:

9. Limestone: Yellow-brown; arenaceous; CONTAINS: glauconite; forams, shell fragments; sharp contact with:

0.77 m (12.31 m)

10. Sandstone: Fine-grained, poorly sorted; yellow-brown; composed of quartz, abundant interstitial clay, and calcareous cement in places; CONTAINS: light yellow-brown claystone laminations between 1 and 10 mm in thickness; cross-bedding; sparse shell fragments throughout, shell fragments are more abundant in the calcite cemented zones; grades into:

3.84 m (16.15 m)

11. Interbedded sandstone and claystone: Sandstone beds: fine-grained, poorly sorted; yellow-brown; composed of quartz and very abundant interstitial clay; laminar bedded; Claystone beds: light yellow-brown; grades into:

0.58 m (16.73 m)

12. Siltstone: Yellow-brown; coarsens upward, becomes increasingly sandy toward the top; CONTAINS: burrows; sharp contact with:

1.28 m (18.01 m)

13. Claystone: Light gray with yellow-brown mottling; CONTAINS: burrows in the upper part of the unit, burrows are filled with sediment from the overlying unit; grades into:

0.77 m (18.78 m)

14. Siltstone: Light gray, mottled red-brown, yellow-brown, and maroon; grades into:

1.10 m (19.88 m)

15. Sandstone: Very fine-grained, fines upward, poorly sorted; light gray with pink-brown and maroon weathered zones; composed of quartz and abundant interstitial clay; CONTAINS: abundant burrows, unit homogenized by burrowing; grades into:

2.24 m (22.12 m

16. Sandstone: Maroon and red-brown weathering colors; CONTAINS: iron replaced plant fragments; burrows, unit homogenized by burrowing; grades into:

0.64 m (22.76 m)

17. Sandstone: Fine- to medium-grained, well-sorted; light gray; composed of quartz and little interstitial clay; poorly cemented, friable; CONTAINS: abundant burrows; scattered ironstone bands; siderite nodules in places; sharp contact with:

1.28 m (24.04 m)

18. Claystone: Coarsens upward becomming silty in the upper 30 to 50 cm; yellow-brown, maroon, and red-brown; CONTAINS: burrows; siderite bands in places; ironstone bands in places; secondary gypsum veins along bedding planes and fractures; grades into:
    3.20 m
    (27.24 m)

19. Marl: Yellow-brown, weathers to dark brown; CONTAINS: bivalves, forams, and shell fragments; grades into:
    0.50 m
    (27.74 m)

20. Claystone: Light gray, light yellow-brown in the upper part of the unit; CONTAINS: siderite nodules and bands; rare bands of secondary gypsum in the upper part of the unit; grades into:
    3.70 m
    (31.44 m)

21. Siltstone: Olive-brown; calcareous; CONTAINS: abundant Turritella, shell fragments; secondary gypsum along bedding planes; grades into:
    1.00 m
    (32.44 m)

22. Siltstone: Gray-brown; calcareous; CONTAINS: glauconite, shell fragments; grades into:
    0.95 m
    (33.39 m)

23. Claystone: Light gray; CONTAINS: burrows in the upper part, burrows are filled with sediment from the overlying unit; bivalves and abundant shell fragments; sharp contact with:
    1.25 m
    (34.64 m)

24. Sandstone: Brown-gray; calcareous; CONTAINS: glauconite; burrows, gastropods, cephalopods, oysters, bivalves, and shell fragments; grades into:
    0.65 m
    (35.29 m)

25. Siltstone: Brown-gray; slightly calcareous; CONTAINS: siderite nodules; burrows filled with shell fragments and sand; gastropods, Turritella, shell fragments; grades into:
    0.65 m
    (35.94 m)

26. Claystone: Olive-gray; coarsens upward; calcareous; CONTAINS: basal 10 cm contains glauconite and abundant shell fragments, scattered shell fragments occur in the rest of the unit; grades into:
    2.88 m
    (38.82 m)

27. Mudstone: Olive-gray; calcareous; homogeneous; CONTAINS: very fine-grained quartz sand; burrows; scattered shell fragments, abundant shell fragments in the top 50 cm; grades into:
    5.45 m
    (44.27 m)

28. Siltstone: Light brown; calcareous; CONTAINS: zones of claystone in places; glauconite; abundant small bivalves, oysters, and

0.50 m (44.77 m) shell fragments; grades into:

29. Claystone: Light gray; CONTAINS: scattered siderite nodules and sparse shell fragments in the lower part of the unit, siderite bands in the upper part; burrows filled with shell fragments in the upper part; glauconite in the upper part; secondary gypsum along bedding planes; sharp contact with:

3.40 m (48.17 m)

30. Sandstone: Medium- to fine-grained, some coarse grains, poorly sorted; medium gray; composed of quartz, abundant interstitial clay, glauconite, and calcareous cement; CONTAINS: gastropods, oysters, abundant Turritella, and shell fragments; sharp contact with:

1.55 m (49.72 m)

31. Claystone: Green-gray; silty; CONTAINS: abundant siderite bands and nodules; scattered shell fragments; burrows filled with sand and shell fragments; grades into:

3.85 m (53.57 m)

32. Sandstone: Fine- to medium-grained, poorly sorted; green-gray; composed of quartz, glauconite, and very abundant interstitial clay; CONTAINS: burrows filled with shell fragments and sand; scattered siderite nodules; gastropods, Turritella, crab shell fragments, bivalves and abundant shell fragments; grades into:

1.90 m (55.47 m)

BARA FORMATION

33. Sandstone: Medium gray; composed of quartz and very abundant interstitial clay; CONTAINS: burrows, unit homogenized by burrowing; traces of laminar bedding locally preserved; sparse coalified plant fragments; scattered shell fragments in the upper part of the unit; possibly rooted; grades into:

3.30 m (58.77 m)

34. Interlaminated sandstone and claystone: coarsens upward, claystone bands become less abundant upward; Sandstone beds: very fine-grained, well-sorted, light gray; composed of quartz and little interstitial clay; poorly cemented, friable; Claystone beds: light gray; unit CONTAINS: scattered siderite nodules; abundant burrows; sharp contact with:

1.10 m (59.87 m)

35. Claystone: Dark gray; CONTAINS: burrows filled with fine sand; top 15 cm contains abundant coaly bands and laminations; grades into:

0.50 m (60.37 m)

36. Claystone: Dark gray; silty; CONTAINS: burrows; sparse carbonized plant fragments; sand laminations less than 1 mm thick; sharp contact with:

1.80 m (62.17 m)

37. Sandstone: Very fine-grained, coarsens upward as the percentage of

interstitial clay decreases upward, poorly sorted; light
2.40 m gray at base, lightens upward; composed of quartz and
(64.57 m) abundant interstitial clay; poorly cemented, friable;
CONTAINS: scattered siderite nodules; dark mineral grains;
burrows; grades into:

38. Sandstone: Very fine-grained, poorly sorted; olive-gray; composed of quartz and very abundant interstitial clay; CONTAINS:
2.00 m burrows, unit homogenized by burrowing; shell fragments
(66.57 m) consisting mostly of bivalves; sparse coalified plant fragments; siderite nodules; grades into:

39. Siltstone: Medium gray; CONTAINS: roots; fine-grained quartz sand filled burrows, unit homogenized by rooting and burrowing;
1.00 m sharp contact with:
(67.57 m)

40. Bone coal: Black; CONTAINS: sparse resin blebs; sand filled burrows near the top part of the unit; sharp contact with:
0.30 m
(67.87 m)

41. Claystone: Medium gray; silty; CONTAINS: roots; sand filled burrows; grades into:
1.60 m
(69.47 m)

42. Siltstone: Medium gray; CONTAINS: sand filled burrows, unit homogenized by burrowing; abundant siderite nodules; grades
3.40 m into:
(72.87 m)

43. Claystone: Light gray at top darkening downward to medium gray; CONTAINS: thin carbonaceous shales in the lower part of the
2.20 m unit, the carbonaceous shales contain abundant resin blebs;
(75.07 m) red-brown ferruginous nodules; scattered coalified plant fragments in the upper part of the unit; grades into:

44. Carbonaceous shale: Black; grades into:

0.30 m
(75.37 m)

45. Claystone: Medium gray; silty; CONTAINS: slickensides, roots, unit homogenized by rooting; abundant siderite bands and nodules
3.95 m in the upper two-thirds; coalified plant fragments; sharp
(79.32 m) contact with:

DETAILED SECTION BEGINS WITH UNIT 46

46. Carbonaceous shale: Black; carbon content increases toward the middle of the unit and then decreases toward the top; CONTAINS:
0.36 m clay slicks that follow root penetrations parallel to

(79.68 m) bedding surfaces; ripple-form siltstone lenses with convex upper and lower contacts up to 3 cm thick in top 10 cm, lenses have no obvious internal structure; sharp contact with:

47. Claystone: Light gray; massive; homogeneous; intensely rooted underclay; CONTAINS: coalified root traces; sharp contact
0.60 m with:
(80.28 m)

48. Carbonaceous shale: Black; almost bone coal; CONTAINS: abundant coalified wood and plant fragments on bedding plane
0.17 m surfaces; intensely rooted; shale slicks along root
(80.45 m) penetrations; sharp contact with:

49. Claystone: Medium gray; massive; homogeneous; soapy; intensely rooted underclay; CONTAINS: coalified root traces; sharp contact
0.50 m with:
(80.95 m)

50. Carbonaceous shale: Black; almost bone coal; CONTAINS: abundant coalified wood and plant fragments on bedding plane
0.18 m surfaces; intensely rooted; shale slicks along root
(81.13 m) penetrations; sharp contact with:

51. Siltstone: Medium gray; CONTAINS: common, finely comminuted carbonaceous debris on flat, laminar bedded surfaces; rare
0.24 m sand filled burrows in the basal 2 cm of the unit; rooting
(81.37 m) not observed; sharp contact with:

52. Sandstone: Very fine-grained, well sorted; white; clean, composed of quartz with little interstitial clay; CONTAINS: flat
0.06 m laminar bedding, laminations composed of carbonaceous
(81.43 m) debris; sharp contact with:

53. Claystone: Medium gray; CONTAINS: sparse roots and burrows; sand laminations up to 5 mm thick; isolated sand ripple lenses;
0.26 m bands of laminar carbonaceous debris up to 2 cm thick,
(81.69 m) individual carbonaceous laminations are up to 1 mm thick; grades into:

54. Sandstone: Fine-grained, poorly sorted; pale brown; composed of quartz and interstitial clay; CONTAINS: burrows and roots;
0.28 m carbonaceous debris on laminar surfaces, lamina are orange
(81.97 m) to medium brown and up to 8 mm thick, lamina are indistinct on fresh surfaces; sharp contact with:

55. Sandstone: Very fine-grained, well sorted; white; clean, composed of quartz with little interstitial clay; CONTAINS: flat
0.03 m laminar bedding, laminations composed of carbonaceous
(82.00 m) debris; sharp contact with:

56. Siltstone: Dark gray; fines upward; CONTAINS: burrows; fine-grained

quartz sand laminations ranging between 0.5 and 1 mm in
0.22 m thickness; sandstone laminations disappear in the upper half
(82.22 m) of the unit; siltstone interbeds up to 5 mm in thickness; carbonaceous debris associated with sandstone laminations in the lower half of the unit and homogeneously distributed in the upper half of the unit; possibly rooted in the upper half; sharp contact with:

57. Bone coal: Black; rooted; burrowed from overlying unit; grades into:

0.16 m
(82.38 m)

58. Shale: Dark gray; CONTAINS: abundant carbonaceous debris on bedding plane surfaces; roots; sharp contact with:

0.16 m
(82.54 m)

59. Claystone: Medium gray; intensely rooted; soapy; underclay; CONTAINS: coalified root traces; grades into:

0.55 m
(83.09 m)

60. Bone coal: Black; CONTAINS: irregular bands of dull coal; some resin blebs; sparse bands of secondary gypsum; grades into:

0.21 m
(83.30 m)

61. Shale: Dark gray; CONTAINS: roots; abundant carbonaceous debris on bedding surfaces; grades into:

0.11 m
(83.41 m)

62. Bone coal: Black; CONTAINS: irregular bands of dull coal; roots, clay slicks along root penetrations; grades into:

0.10 m
(83.51 m)

63. Shale: Dark gray; CONTAINS: roots; abundant carb debris and plant fragments on bedding plane surfaces; grades into:

0.14 m
(83.65 m)

64. Bone coal: Black; CONTAINS: irregular bands of dull coal; grades into:

0.18 m
(83.83 m)

65. Shale: Dark gray; fissile; CONTAINS: roots; abundant carbonaceous debris and plant fragments on bedding plane surfaces; grades
0.21 m into:
(84.04 m)

66. Claystone: Dark gray with red ferruginous bands that may be oxidized siderite; CONTAINS: abundant carbonaceous debris on bedding surfaces; abundant carbonized roots; sharp contact with:
0.29 m
(84.33 m)

67. Claystone: Dark gray; CONTAINS: laminar bedding; sparse burrows; red and yellow-brown siderite bands; sparse, finely comminuted carbonaceous debris on some bedding surfaces; rare root penetrations; sharp contact with:
1.14 m
(85.47 m)

68. Sandstone: Very fine-grained, poorly sorted; medium gray; composed of quartz and abundant interstitial clay; CONTAINS: ripples, clay laminations define ripple surfaces; no evidence of burrows; sharp contact with:
0.04 m
(85.51 m)

69. Sandstone: Very fine- to fine-grained, poorly sorted; medium gray; composed of quartz and very abundant interstitial clay; CONTAINS: burrows, unit homogenized by burrowing; evenly distributed finely comminuted carbonaceous debris; sharp contact with:
1.05 m
(86.56 m)

70. Sandstone: Fine-grained, well-sorted; white; very clean, composed of quartz and no interstitial clay; weakly cemented, friable; CONTAINS: common claystone beds ranging in thickness from 5 to 20 mm, claystone beds are medium gray or weathered orange and brown, sharp contact between claystone and sandstone beds; the interbedded sandstones range from 1 to 14 cm thick; sandstone beds become thinner upward, claystone beds become more abundant upward; sandstone is laminar bedded with small scale ripples up to 15 mm thick, carbonaceous debris on some ripple beds, rare dewatering plumes and dish structures observed in some claystone beds; sand filled burrows parallel bedding planes in claystone units, burrows become more abundant upward; carbonaceous debris preferentially associated with sandstone beds; sharp contact with:
0.85 m
(87.41 m)

71. Sandstone: Fine-grained, well-sorted; white; very clean, composed of quartz and no interstitial clay; appears to contain small scale cross-beds but the unit is too clean for ripples to be well defined; sharp contact with:
0.22 m
(87.63 m)

72. Sandstone: Fine-grained, well-sorted; white; composed of quartz and little interstitial clay; CONTAINS: multiple small-scale ripple cross-beds, ripples up to 2 cm amplitude, cross-sets are mostly defined by clay laminations and in some cases carbonaceous and coaly laminations; sparse burrows parallel to bedding surfaces in the basal 2 cm; sharp contact with:
0.09 m
(87.72 m)

73. Sandstone: Fine-grained, well-sorted; white; composed of quartz and no interstitial clay; CONTAINS: sparse woody debris on large-scale planar cross-beds 7 cm high; sharp contact with:
0.07 m
(87.79 m)

74. Sandstone: Fine-grained, well-sorted; white; composed of quartz and little interstitial clay; CONTAINS: wavy bedding, coaly
0.02 m debris defines bedding surfaces; sharp contact with:
(87.81 m)

75. Sandstone: Fine-grained, well-sorted; white; very clean, composed of quartz and no interstitial clay; unit consists of a single
0.03 m ripple cross-set; sharp contact with:
(87.84 m)

76. Sandstone: Fine-grained, well-sorted; white; very clean, composed of quartz and no interstitial clay; CONTAINS: 50 percent of
0.04 m the unit composed of coaly laminations; symmetrical wave
(87.88 m) ripples, ripple laminations defined by carbonaceous debris; sharp contact with:

77. Sandstone: Fine-grained, well-sorted; white; very clean, composed of quartz and no interstitial clay; CONTAINS: ripple cross-
0.13 m beds and low angle cross-bed laminations defined by
(88.01 m) carbonaceous debris; sharp contact with:

78. Sandstone: Fine-grained, well-sorted; white; clean, composed of quartz and no interstitial clay; CONTAINS: coaly laminations that
0.05 m define low-angle cross-beds, low-angle carbonaceous
(88.06 m) laminations are truncated by the overlying unit; beds are wedge shaped; sharp contact with:

79. Sandstone: Fine-grained, well-sorted; white; very clean, composed of quartz and no interstitial clay; CONTAINS: low-angle cross-
0.05 m beds and sparse small-scale ripples; laminations are defined
(88.11 m) by accumulations of coaly debris; sharp contact with:

80. Covered: Sandstone; white; poorly cemented; friable; sharp contact with:
0.13 m
(88.24 m)

81. Sandstone: Fine-grained, well-sorted; white; very clean, composed of quartz and no interstitial clay; CONTAINS: a single set of
0.32 m high-angle planar cross-beds; cross-bed surfaces defined by
(88.56 m) accumulations of sparse carbonaceous debris; sharp contact with:

82. Claystone: Medium gray; pinches laterally in both directions; has the appearance of a clay drape; sharp contact with:
0.08 m
(88.64 m)

83. Sandstone: Fine-grained, well-sorted; white; clean, composed of quartz and no interstitial clay; CONTAINS: coaly laminations that
0.07 m define low-angle cross-beds, beds are wedge shaped and the

(88.71 m) unit is observed to thicken to 28 cm on the other side of the incline; sharp contact with:

84. Sandstone: Fine-grained, well-sorted; white; very clean, composed of quartz and no interstitial clay; CONTAINS: low-angle cross-
0.14 m beds and sparse small-scale ripples; laminations are defined
(88.85 m) by accumulations of coaly debris; a zone of convoluted bedding 5 cm thick; sharp contact with:

85. Sandstone: Fine-grained, well-sorted; white; very clean, composed of quartz and no interstitial clay; poorly cemented, friable;
0.10 m entire unit is a single planar cross-bed set; sparse coaly
(88.95 m) debris defines cross-bed surfaces; sharp contact with:

86. Sandstone: Fine-grained, well-sorted; white; very clean, composed of quartz and no interstitial clay; poorly cemented, friable;
0.13 m entire unit is a single planar cross-bed set; sparse coaly
(89.08 m) debris defines cross-bed surfaces; sharp contact with:

87. Sandstone: Fine-grained, well-sorted; white; very clean, composed of quartz and no interstitial clay; CONTAINS: low-angle cross-
0.21 m beds and sparse small-scale ripples; laminations are defined
(89.29 m) by accumulations of coaly debris; sharp contact with:

88. Sandstone: Fine-grained, well-sorted; white; clean, composed of quartz and no interstitial clay; CONTAINS: coaly laminations that
0.17 m define low-angle cross-beds, sandstone interlaminations up
(89.46 m) to 18 mm thick; units are wedge shaped; ripple cross-beds in the thicker sand laminations; sharp contact with:

89. Sandstone: Fine-grained, well-sorted; white; very clean, composed of quartz and no interstitial clay; CONTAINS: low-angle cross-
0.15 m beds and sparse small-scale ripples; laminations are defined
(89.61 m) by accumulations of coaly debris; sharp contact with:

90. Sandstone: Fine-grained, well-sorted; white; clean, composed of quartz and no interstitial clay; CONTAINS: coaly laminations up to
0.18 m 4 mm thick that define low-angle cross-beds; up to 30
(89.79 m) percent of the rock unit is comprised of coaly material; units are wedge shaped; sharp contact with:

91. Sandstone: Fine- to medium-grained, the medium grains become less abundant upward, well sorted; white; composed of quartz and
2.50 m little interstitial clay; poorly cemented, friable, a
(92.29 m) significant proportion of the unit is timbered; CONTAINS: low-angle cross-beds; cross-bed surfaces are defined by accumulations of coaly debris; individual carbonaceous laminations range from 0.5 to 4 mm in thickness; carbonaceous laminations occur in sets up to 3 cm thick; cross-bedded units are wedge shaped; zones up to 43 cm thick that contain no carbonaceous laminations; sharp contact with:

92. Coal: Black; grades downward into bone coal at the base; CONTAINS: shale slicks along root penetrations in the basal
0.63 m part of the unit; secondary sulfur and gypsum; grades into:
(92.92 m)

93. Siltstone: Dark gray; intensely rooted; CONTAINS: abundant coalified plant fragments on bedding plane surfaces; grades into:
0.23 m
(93.15 m)

94. Coal: Black; CONTAINS: abundant clay slicks along root penetrations; grades into:
0.22 m
(93.37 m)

95. Claystone: Light gray; intensely rooted; slickensided; CONTAINS: sparse carbonaceous film preserved along some root traces;
0.20 m grades into:
(93.57 m)

96. Carbonaceous shale: Black; intensely rooted; CONTAINS: abundant light gray clay slicks that follow root penetrations from the
0.13 m overlying unit; grades into:
(93.70 m)

97. Coal: Black; grades downward into bone coal; CONTAINS: sparse clay slicks; grades into:
0.33 m
(94.03 m)

98. Carbonaceous shale: Dark gray; CONTAINS: abundant coalified debris on bedding plane surfaces: grades into:
0.11 m
(94.14 m)

99. Coal: Black; grades into:

0.18 m
(94.32 m)

100. Carbonaceous shale: Black; fissile; sharp contact with:

0.03 m
(94.35 m)

101. Claystone: Medium gray; rooted; slickensided; CONTAINS: fragmental carbonaceous debris on bedding plane surfaces; grades into:
0.08 m
(94.43 m)

102. Claystone: Light gray; intensely rooted; blocky; massive; CONTAINS: sparse carbonized root traces; grades into:
0.66 m

(95.09 m)

103. Claystone: Dark gray; intensely rooted; slickensided; CONTAINS: abundant carbonaceous debris on bedding plane surfaces;
0.15 m sharp contact with:
(95.24 m)

104. Coal: Black; sharp contact with:

0.08 m
(95.32 m)

105. Siltstone: Medium gray; intensely rooted; slickensided; blocky; fines upward to claystone; CONTAINS: abundant carbonaceous debris
0.20 m on bedding plane surfaces; grades into:
(95.52 m)

106. Claystone: Light gray; intensely rooted; blocky; homogeneous, no evidence of bedding; coarsens upward to mudstone; CONTAINS:
2.64 m abundant carbonaceous debris on bedding plane surfaces;
(98.16 m) brown sideritized zones; grades into:

107. Shale: Dark gray; intensely rooted; slickensided; CONTAINS: abundant carbonaceous debris; grades into:
0.39 m
(98.55 m)

108. Coal: Black; resinous; sharp contact with:

0.76 m
(99.31 m)

109. Shale: Dark gray; fissile; CONTAINS: abundant coalified debris on bedding plane surfaces; base not exposed.
0.27 m
(99.58 m)

BASE OF INCLINE

Indus Mines, Lakhra Coal Field, Mine IN-6

Total depth of mine: 68.80 m
Thickness of measured section: 30.92 m

BARA FORMATION

1. Sandstone: White; clean, composed of quartz with little argillaceous matrix; CONTAINS: burrows; ripples; planar cross-beds up to 10 cm thick; no shale bands or laminations; sharp contact with:
   2.65 m
   (2.65 m)

2. Sandstone: Interbedded with medium gray shale beds and laminations, shale beds are usually less than 10 cm thick, laminated, and contain carbonized plant fragments on some bedding surfaces; sharp contacts between shale beds and sandstone beds; sandstone zones light gray, sand composed of quartz and little argillaceous matrix; CONTAINS: uncommon burrows; small and larger scale ripples; planar cross-beds up to 15 cm thick; ripples and cross-beds appear unidirectional, apparent orientation is up-incline; sharp contact with:
   3.70 m
   (6.35 m)

3. Claystone: Dark gray; massive; CONTAINS: red iron nodules scattered in the upper 1.5 m; unit covered with a surface efflorescence of gypsum and salt so internal bedding structures are difficult to observe; sharp contact with:
   2.75 m
   (9.10 m)

4. Bone coal: Black; sharp contact with:

   0.17 m
   (9.27 m)

5. Claystone: Medium gray; rooted; sharp contact with:

   0.30 m
   (9.57 m)

6. Coal: Black; grades into:

   0.25 m
   (9.82 m)

7. Carbonaceous shale: Black; presumed to be rooted; grades into:

   0.20 m
   (10.02 m)

8. Claystone: Medium gray, darkens upward; massive; presumed to be rooted; CONTAINS: laminations of carbonaceous debris that become more abundant upward; sharp contact with:
   0.95 m
   (10.97 m)

9. Coal: Black; contains numerous sandstone partings up to 10 cm

thick, sand partings are rippled, climbing ripples in
0.25 m places, ripples have an apparent unidirectional, down-
(11.22 m) incline orientation; bed forms are defined with carbonaceous debris on bedding surfaces; sharp contact with:

10. Claystone: Light to medium gray, color darkens upward; massive; coarsens upward, slightly silty at the top; CONTAINS:
2.75 m sideritized zones; uncommon, small sideritized burrows;
(13.97 m) roots at the top of the unit; sharp contact with:

11. Coal: Black; sharp contact with:

0.60 m
(14.57 m)

12. Claystone: Medium gray; contains thin sand laminations throughout and the unit coarsens upward into a sandstone in the top 0.25 m;
1.40 m sandstone is laminated or wavy bedded with abundant
(15.97 m carbonaceous debris on bedding surfaces; upper part of the unit is presumed to be rooted; sharp contact with:

13. Sandstone: Interbedded with shale beds and laminations; sandstone beds range in thickness from 1 to 2 cm up to 10 cm, contain
2.60 m asymmetrical current ripples and climbing ripples
(18.57 m) throughout, ripples are unidirectional down-incline; shale beds consist of interbedded sandstone and shale laminations approximately 1 mm thick; shale beds overly many of the larger sandstone ripples and the sandstone laminations within these shale beds typically contain micro-ripples; unit contains no burrows or carbonaceous debris; there are sharp contacts between the individual shale and sandstone zones; grades into:

14. Sandstone: Medium gray; intensely burrowed, unit homogenized by burrowing; remnants of original bedding locally preserved;
4.25 m bedding consisted of interlaminated sand and shale beds that
(22.82 m) rarely exceeded 5 mm in thickness though rare sandstone beds can attain 20 mm; laminar and wavy bedforms predominate, occasional climbing ripples, current ripples especially common toward the top of the unit, these ripples are unidirectional and orientated down-incline; carbonaceous debris occurs on some bedding surfaces; sharp contact with:

15. Sandstone: White; very clean, composed of quartz and very little argillaceous matrix; bedding surfaces are defined by the
4.85 m accumulation of carbonaceous debris and rare shale
(27.67 m) laminations, the carbonaceous debris tends to be confined to discrete zones 5 to 100 mm thick and the thickness of these zones decreases upward, the zones containing the carbonaceous debris are separated from one another by thicker zones which contain little or no carbonaceous debris, the thickness of the debris free zones increases upward; laminar and wavy bed forms predominate; planar

cross-beds up to 10 cm thick, current and climbing ripples up to 3 cm amplitude, and rare symmetrical ripples occur in the organic debris-free zones; unit is sparsely burrowed throughout, burrows are up to 1 cm in diameter and lined with fecal pellets; sharp contact with:

16. Sandstone: Medium gray; composed of quartz and a very abundant argillaceous matrix; CONTAINS: carbonaceous debris; sharp contact with:
    0.20 m
    (27.87 m)

17. Mudstone: Medium gray; coarsening upward to siltstone at the top; CONTAINS: thin, flat sand and silt laminations; very rare carbonaceous debris; sparse burrows, burrows are sideritized and become smaller and less common upward, burrows do not penetrate into the underlying coal; the unit appears to be rooted in places; sharp contact with:
    2.15 m
    (30.02 m)

18. Coal: Black; minimum thickness recorded, bottom contact not observed.
    0.90 m
    (30.92 m)

BASE OF INCLINE

Mine Section IN-11

Indus Mines, Lakhra Coal Field, MINE IN-11

Total depth of mine: 48.00 m
Thickness of measured section: 34.13 m

BARA FORMATION

1. Sandstone: White; clean, composed of quartz with little argillaceous matrix; CONTAINS: sparse burrows; rare coalified wood fragments; planar cross-beds up to 90 cm thick, zones of laminar and ripple bedded sandstone occur between the planar cross-beds; shale and, in places, carbonaceous debris defines ripple and lamina surfaces; rare occurrences of convoluted bedding (dewatering features?); sharp contact with:

   3.65 m
   (3.65 m)

2. Claystone: Medium gray; sharp contact with:

   0.45 m
   (4.10 m)

3. Shale: Dark gray; CONTAINS: abundant coalified plant fragments; sharp contact with:

   0.15 m
   (4.25 m)

4. Claystone: Medium gray; no evidence of rooting; sharp contact with:

   0.90 m
   (5.15 m)

5. Sandstone: Contains interbedded, red, iron-rich shale beds up to 2 cm thick and between 5 and 60 cm apart; sandstone interbeds are cream colored and weathered so that sedimentary structures are difficult to see; sandstone is fine-grained, contains small scale ripples and uncommon burrows throughout; sharp contact with:

   4.85 m
   (10.00 m)

6. Claystone: Coarsens upward to siltstone; massive; weathered; sharp contact with:

   0.60 m
   (10.60 m)

7. Bone coal: Black; CONTAINS: 50 percent shale partings and shale pebbles; grades into:

   0.25 m
   (10.85 m)

8. Shale: Black; carbonaceous; grades into:

   0.20 m
   (11.05 m)

9. Coal: Black; CONTAINS: abundant shale partings; sharp contact with:
   0.48 m
   (11.53 m)

10. Claystone: Medium gray; massive; homogeneous; rooted to at least 1.8 m below the coal; claystone surface covered by a thick blanket
    3.05 m of efflorescing salt and gypsum; sharp contact with:
    (14.58 m)

11. Sandstone: White; clean, composed of quartz and very little argillaceous matrix; CONTAINS: internal scour contacts;
    17.50 m scattered clay pebbles and a thin clay pebble conglomerate
    (32.08 m) 45 cm above the top of the coal; carbonaceous debris that defines bedding surfaces; rare zones of laminar bedded sandstone; planar cross-beds up to 75 cm thick; low angle cross-beds; small scale ripples; rare calcite cemented sandstone zones up to 60 cm thick; scattered burrows, burrows lined with fecal pellets; very rare zones of siderite accumulation up to 30 cm thick; rare coalified wood fragments sharp contact with:

12. Coal: Black; CONTAINS: sandstone filled burrows penetrating the top 15 cm of the coal.
    2.05 m
    (34.13 m)

BASE OF INCLINE

Mine Section Baluchistan Mines 652

Baluchistan Mines, Lakhra Coal Field, Mine 2

Total depth of mine: 50.10 m
Thickness of measured section: 37.49 m

BARA FORMATION

1. Claystone: Weathered, surface covered with a gypsum efflorescence; CONTAINS: silty and sandy zones; zones of sideritized burrows; grades into:
   11.60 m
   (11.60 m)

2. Sandstone: Medium gray; silty at the base, fines again near the top to silty sandstone, then to silty claystone; CONTAINS: burrows, unit homogenized by burrowing; grades into:
   3.40 m
   (15.00 m)

3. Carbonaceous shale: Black; cleated like coal; CONTAINS: two coal bands up to 12 cm thick near the bottom of the unit; grades into:
   1.70 m
   (16.70 m)

4. Claystone: Dark gray; coarsening upward to sandy claystone at the top; CONTAINS: roots, unit intensely rooted throughout; sharp contact with:
   1.80 m
   (18.50 m)

5. Interbedded sandstone and claystone: Sandstone is light gray; fine-grained; 5 to 10 cm thick; rippled, ripple surfaces covered with carbonaceous debris; Claystone is medium gray; 5 to 10 cm thick; sharp upper and lower contacts with the sandstone beds; entire unit contains common burrows throughout; sharp contact with:
   1.70 m
   (20.20 m)

6. Claystone: Medium gray; silty in places; CONTAINS: burrows; thin sand laminations; sharp contact with:
   1.05 m
   (21.25 m)

7. Sandstone: White; very fine- to fine-grained at the base, coarsens upward then fines abruptly at the top; clean, composed of quartz and no argillaceous matrix; unit extremely weakly cemented, much of the unit is covered; CONTAINS: scattered clay pebbles; large scale planar cross-beds and ripples, the size of the cross-beds and ripples decrease upward; near the base clay laminations define cross-bed forms, higher in the unit cross-bed forms are defined by grain size differences; very thin clay beds are found in the top meter of the unit; sharp contact with:
   4.65 m
   (25.90 m)

8. Sandstone: Medium gray; CONTAINS: abundant burrows, unit homogenized by burrowing; traces of original laminar bedding; grades into:
   0.55 m

(26.45 m)

9. Sandstone: White; fine-grained; clean, composed of quartz and no argillaceous matrix; extremely weakly cemented, primarily a
1.70 m covered interval; CONTAINS: laminar bedding and small scale
(28.15 m) ripples; laminations and ripple cross-sets are covered primarily with carbonaceous debris and occasionally with clay; sparse burrowing associated with laminated zones; sharp contact with:

10. Sandstone: White; clean, composed of quartz and no argillaceous matrix; extremely weakly cemented, primarily a covered interval;
2.70 m CONTAINS: low-angle cross-beds up to 20 cm thick; medium
(30.85 m) gray clay beds from 3 to 20 cm in thickness in the basal meter, clay beds are in sharp contact with the sandstone; sharp contact with:

11. Sandstone: White; clean, composed of quartz and no argillaceous matrix; extremely weakly cemented, primarily a covered interval;
4.00 m CONTAINS: low-angle cross-beds between 10 and 20 cm in
(34.85 m) thickness; rare shale laminations on some cross-bed surfaces; rare heavy mineral laminations; very rare laminar bedded zones up to 3 cm thick, laminations covered with carbonaceous debris; sharp contact with:

12. Claystone: Light gray; massive; coarsens upward to siltstone; CONTAINS: slickensides in the base of the unit; no burrows;
1.50 m no carbonaceous debris; grades into:
(36.35 m)

13. Carbonaceous shale: Black; CONTAINS: abundant carbonaceous debris; grades into:
0.08 m
(36.43 m)

14. Coal: Black; CONTAINS: a 10 cm thick shale parting; the parting grades into a 17 cm thick carbonaceous shale which grades
0.76 m back into coal; grades into:
(37.19 m)

15. Carbonaceous siltstone: Black.

0.30 m
(37.49 m)

BASE OF INCLINE

Mine Section HB-14

Habibullah Mines, Lakhra Coal Field, HB-14

Total depth of mine: 32.40 m
Thickness of measured section: 21.80 m

BARA FORMATION

1. Sandstone: Very fine-grained, fines upward, grading imperceptibly into a claystone; medium gray, mottled red; weathered; interbedded with clay beds up to 3 cm thick in the lower third of the unit, clay beds disappear above this height; intensely burrowed, unit homogenized by burrowing; sharp contact with:
   9.40 m
   (9.40 m)

2. Sandstone: Light gray; CONTAINS: common burrows throughout, 1 to 2 cm in diameter; low-angle cross-bedding; large ripples up to 8 cm in amplitude, small scale ripples are not observed; cross-bedding has a unidirectional orientation; laminar bedded areas occur toward the top of the unit; sharp contact with:
   3.05 m
   (12.45 m)

3. Siltstone: Medium gray; coarsens upward; CONTAINS: burrows; grades into:
   0.75 m
   (13.20 m)

4. Siltstone: Medium gray; CONTAINS: fine sand laminations less than 1 mm thick; carbonaceous debris on bedding surfaces; sharp contact with:
   1.00 m
   (14.20 m)

5. Claystone: Medium gray; rooted throughout; sharp contact with:

   2.65 m
   (16.85 m)

6. Carbonaceous shale: Black; fissile; rooted; sharp contact with:

   0.30 m
   (17.15 m)

7. Shale: Medium gray; silty; rooted throughout; sharp contact with:

   1.10 m
   (18.25 m)

8. Coal: Black; sharp contact with:

   0.15 m
   (18.40 m)

9. Claystone: Medium gray; rooted throughout; sharp contact with:

1.60 m
(20.00 m)

10. Carbonaceous shale: Black; fissile; rooted; grades into:

0.15 m
(20.15 m)

11. Coal: Black; laterally variable in thickness, begins to pinch toward the east; the coal also contains significant shale partings toward the east.
1.65 m
(21.80 m)

BASE OF INCLINE

Habibullah Mines, Lakhra Coal Field, HB-22

Total depth of mine: 37.40 m
Thickness of measured section: 30.45 m

BARA FORMATION

1. Sandstone: Light gray; CONTAINS: laminar, wavy and ripple bedding; internal scours which become prominent toward the top of the unit; scattered claystone cobbles up to 10 cm in diameter, cobbles occur in the basal 90 cm; occasional burrows, the unit is intensely burrowed in the top 30 cm; sharp contact with:
   2.55 m (2.55 m)

2. Sandstone: White; the lower part of the unit is rippled and laminated, and contains burrows and possible heavy mineral concentrations; planar cross-beds and internal scours occur in the upper 60 cm; sharp contact with:
   1.40 m (3.95 m)

3. Claystone: Medium gray; massive; sharp contact with:
   0.20 m (4.15 m)

4. Sandstone: Light gray; clean, composed of quartz and little argillaceous matrix; CONTAINS: low angle cross-beds, individual cross-sets range in thickness from 10 to 35 cm and the cross-set units decrease in thickness upward, cross-beds have unidirectional orientations; ripples in the upper part of the unit have wavelengths of 30 cm and amplitudes of 4 cm; cross-beds and ripples defined by shale laminations; grades into:
   3.45 m (7.60 m)

5. Sandstone: Light gray sandstone interbedded with medium gray claystone; unit consists of clean sandstone beds up to 15 cm thick interbedded with zones of up to 30 cm of interlaminated sandstone and shale, the sandstone and shale laminations are approximately equal in thickness and range between 5 mm and 10 mm; the interlaminated sand/shale zones are wavy and ripple bedded and contain abundant carbonaceous debris; the thicker sandstone beds are free of carbonaceous material; at the contact with the underlying claystone, the basal 20 cm of the sandstone is calcite cemented; sharp contact with:
   1.85 m (9.45 m)

6. Claystone: Medium brown; silty at base, fines upward, then coarsens again near the top; CONTAINS: secondary gypsum and bands of red iron mineralization; grades into:
   3.60 m (13.05 m)

7. Sandstone: Light gray sandstone interbedded with medium gray claystone; claystone beds average 3 cm in thickness at the base of the unit and thicken upward; there are sharp contacts between the claystone and the sandstone beds; the sandstone beds
   6.10 m (19.15 m)

average 20 cm in thickness at the base and thin to 5 cm at the top; sand beds are rippled, ripples decrease in amplitude and wavelength upward; claystone beds often appear rippled because they settled over rippled sand surfaces; the top 50 cm consists of interlaminated sandstone and shale; laminations are 1 to 2 mm thick; burrows occur throughout the unit but intense burrowing occurs only in the top 50 cm; sharp contact with:

8. Sandstone: White; very clean, composed of quartz with almost no argillaceous matrix; CONTAINS: large, unidirectional planar cross-beds 30 to 60 cm thick; scattered peat and shale pebbles; zones of laminar and ripple bedding up to 2 cm thick; lamina surfaces are defined by carbonaceous debris and sometimes by clay; the zones containing the carbonaceous debris have scattered burrows but burrows do not occur elsewhere within the unit; sharp contact with:

   7.75 m (26.90 m)

9. Sandstone: Light gray; CONTAINS: flat bands of peat and shale pebbles; ripples; thin, unidirectional tangential cross beds less than 10 cm thick; zones of laminar bedding and climbing ripples; scattered medium gray claystone beds up to 5 cm thick; bedding surfaces defined by abundant carbonaceous debris and some shale laminations; no evidence of burrowing; sharp contact with:

   2.50 m (29.40 m)

10. Coal: Black; varies in thickness from 60 cm to 1.5 m within the mine; CONTAINS: sand filled burrows that penetrate up to 10 cm into the coal; grades into:

    1.05 m (30.45 m)

11. Claystone: Medium gray; rooted.

BASE OF INCLINE

Mine Section HB-25

Habibullah Mines, Lakhra Coal Field, HB-25

Total depth of mine: 65.00 m
Thickness of measured section: 17.97 m

BARA FORMATION

1. Sandstone: Light gray, CONTAINS: scattered, laterally discontinuous pods of indurated, calcite cemented sandstone; planar cross-beds up to 30 cm thick, planar crossbeds dominate the lower half of the unit, the upper part is dominated primarily by laminar and wavy bedding; small-scale ripples occur but they are not prominent; burrows restricted to the planar cross-bedded units; sharp contact with:

   2.75 m
   (2.75 m)

2. Mudstone: Medium gray; unit variable in grain size, more silty in some places, more clayey in others; basal 1.5 m contains interbedded, rippled sandstone lenses; CONTAINS: zones of carbonaceous debris, carbonaceous debris confined to bedding surfaces; unit covered by a thick blanket of efflorescing gypsum and salt deposits; the unit appears to contain a rooted zone; sharp contact with:

   6.50 m
   (9.25 m)

3. Sandstone: White; extremely clean, composed of quartz and almost no argillaceous matrix; CONTAINS: thick planar cross-beds almost always larger than 15 cm and usually more than 30 cm; common internal scours; common tangential cross-beds; scattered flat laminated and small-scale ripple bedded horizons; cross-bed surfaces commonly defined with carbonaceous debris mixed with small amounts of clay; in places laminations are expressed by differences in the sand grain size; rare zones of heavy mineral concentrations; the zones of planar cross-beds are interbedded with ripples and laminations; burrows occur in the laminated units; sharp contact with:

   6.90 m
   (16.15 m)

4. Carbonaceous shale: Black; grades downward into bone coal; intensely rooted; grades into:

   0.12 m
   (16.27 m)

5. Coal: Black; minimum thickness; bottom not exposed.

   1.70 m
   (17.97 m)

BASE OF INCLINE

Mine Section HB-34

Habibullah Mines, Lakhra Coal Field, HB-34

Total depth of mine: 49.10 m
Thickness of measured section: 22.40 m

BARA FORMATION

1. Coal: Black; grades into:

0.40 m
(0.40 m)

2. Carbonaceous shale: Black; fissile; sharp contact with:

0.20 m
(0.60 m)

3. Sandstone: Interbedded with medium gray claystone beds up to 10 cm thick; sandstone is light gray; CONTAINS: small scale ripples and laminar beds; burrows, burrowing becomes more intense upward and the unit grades into a medium gray sandstone that is homogenized by burrowing; small scale ripples are locally preserved in this homogenized unit; the top 1.8 m is rooted, rooting destroys evidence of burrowing in the uppermost parts of the sandstone; grades into:
4.20 m
(4.80 m)

4. Siltstone: Dark gray; massive; grades into a claystone in the middle part of the unit and then to a sandy siltstone toward the top; CONTAINS: sand laminations less than 1 mm thick in the lower part of the unit; sharp contact with:
2.75 m
(7.55 m)

5. Sandstone: Medium gray; CONTAINS: scattered coalified wood or peat fragments; burrows; unit homogenized by burrowing, burrows filled with clean, white sand while surrounding sandstone contains abundant interstitial clay; grades into:
2.00 m
(9.55 m)

6. Sandstone: White to light gray; fining upward; CONTAINS: large scale planar cross-beds up to 1.2 m thick in the basal part of the unit; planar cross-beds decrease in size upward, cross-bed surfaces are defined by grain size differences, by shale laminations, and occasionally by accumulations of carbonaceous debris; scattered clay pebbles in the cross-bedded units; ripples decreasing in amplitude with height; rare, thin, medium gray clay beds near the top of the unit; laminar bedding, becomming more prominent upward; rare burrows typically associated with the laminar bedded units; sharp contact with:
5.50 m
(15.05 m)

7. Siltstone: Light gray; massive; fining to claystone at the base; CONTAINS: roots in the upper two-thirds of the unit; sharp contact with:
2.35 m
(17.40 m)

8. Carbonaceous shale: Black; CONTAINS: abundant plant fragments and coaly bands but no recognizable plant fossils or roots;
   0.30 m grades into:
   (17.70 m)
9. Siltstone: Dark gray; CONTAINS: abundant, finely comminuted carbonaceous debris on bedding surfaces and occasional coal
   0.90 m pebbles; no evidence of rooting or burrowing; sharp contact
   (18.60 m) with:

10. Coal: Black; grades into:

    0.20 m
    (18.80 m)

11. Carbonaceous shale: Black; CONTAINS: roots; grades into:

    0.10 m
    (18.90 m)

12. Claystone: Banded light and medium gray, unit darkens downward to dark gray; massive; slickensided; CONTAINS: roots, unit
    1.20 m homogenized by rooting; sharp contact with:
    (20.10 m)

13. Bone coal: Black; grades into:

    0.10 m
    (20.20 m)

14. Coal: Black; CONTAINS: numerous splits that are observed to thicken laterally, near the incline the coal contains a
    2.20 m quartzose, rippled sandstone parting ranging between 1 and
    (22.40 m) 20 cm in thickness; near the base the coal contains a shale parting that is cleated like coal but contains thin sand laminations.

BASE OF INCLINE

Mine Section HB-37

Habibullah Mines, Lakhra Coal Field, HB-37

Total depth of mine: 38.20 m
Thickness of measured section: 17.75 m

BARA FORMATION

1. Sandstone: Interbedded with claystone; claystone beds are medium gray, range between 10 and 20 cm in thickness, and some have scoured upper surfaces where they are in contact with the overlying sandstone; sandstone beds are light gray and contain scattered burrows and planar cross-beds, each sandstone bed is a single cross-bed set, the cross-beds appear to have a uni-directional orientation; in at least one place a sandstone bed is observed to intertongue with a claystone bed; there are sharp contacts between the sandstone and claystone units; sharp contact with:

   2.90 m
   (2.90 m)

2. Sandstone: Light gray; weathered, bedding structures are difficult to observe; CONTAINS: large, planar cross-beds up to 30 cm thick; uncommon laminated bedding in places, small clay pebbles associated with one of the laminar bedded zones; common claystone bands up to 10 cm thick; scattered burrows; sharp contact with:

   3.10 m
   (6.00 m)

3. Claystone: Light gray; massive; sharp contact with:

   1.40 m
   (7.40 m)

4. Sandstone: Light gray with red hematite mottling; weathered, bedding structures difficult to observe; CONTAINS: planar cross-beds 10 to 30 cm thick as the dominant bedform, the thickness of the cross-sets increases with height, the thick planar cross-sets are usually interbedded with thin cross-bedded units no more than 5 cm thick, cross-beds are unidirectional; tangential cross-beds; occasional zones of laminar bedding; rare small-scale ripples; rare clay beds up to 10 cm thick; occasional burrows; sharp contact with:

   6.10 m
   (13.50 m)

5. Shale: Medium gray, massive, and rooted in the basal 60 cm; light gray, massive, and unrooted in the rest of the unit; grades into:

   3.00 m
   (16.50 m)

6. Carbonaceous shale: Black; fissile; contains partings of gray shale; grades into:

   0.20 m
   (16.70 m)

7. Coal: Black; bony at top and bottom: grades into:

   1.05 m

(17.75 m)

8. Sandstone: Dark gray; organic rich; contains abundant carbonaceous debris. Thickness not determined.

BASE OF INCLINE

Habibullah Mines, Lakhra Coal Field, HB-40

Total depth of mine: 34.30 m
Thickness of measured section: 20.05 m

BARA FORMATION

1. Sandstone: Very fine-grained; white; clean, composed of quartz and little argillaceous matrix; CONTAINS: common burrows, burrows cemented with fecal pellets; no obvious bedding structure, massive; grades into:
   1.35 m (1.35 m)

2. Siltstone: Medium gray; weathered, contains beds of red iron mineralization; CONTAINS: rare burrows; laminar bedding; grades into:
   4.85 m (6.20 m)

3. Sandstone: White; fine- to medium-grained, very coarse-grained in places, the unit fines to a very fine-grained sandstone interbedded with siltstone and claystone in the top meter; clean, composed of quartz and little argillaceous matrix; CONTAINS: large planar cross-beds; shale pebbles at the base of some internal scours; cross-bed surfaces devoid of carbonaceous debris or shaly laminations; common burrows, one 60 cm thick zone appears to have been homogenized by burrowing; grades into:
   3.35 m (9.55 m)

4. Sandstone: Interbedded with medium gray clay beds up to 10 cm thick; clay beds frequently scoured by overlying sandstone beds and in places the clay beds are completely scoured away; Sandstone beds are light gray and range between 15 and 60 cm in thickness; CONTAIN: tangential planar cross-sets up to 20 cm thick; the sandstone beds between the clay beds may consist of an single planar cross-bedded unit or several cross-bed sets; some of the sandstone beds show an upward decrease in cross-bed thickness within the bed; in-phase climbing ripples occur in places; abundant burrows; abundant shale pebbles; sharp contact with:
   4.00 m (13.55 m)

5. Siltstone: Medium gray; interbedded with claystone and sandstone; sandstone interbeds are up to 10 cm thick and sometimes have a scour contact with the underlying fine-grained unit; sandstone beds become less common upward; the top 15 cm contains numerous sand filled burrows that penetrate from the overlying unit; some carbonaceous debris is preserved on laminar bedding surfaces in the silt; sharp contact with:
   2.55 m (16.10 m)

6. Claystone: Light gray; massive; coarsens upward to siltstone at the top; weathered; CONTAINS: intense rooting in the basal 60 cm, roots are preserved as impressions and slickensides; common burrows in the upper part of the unit, burrows preserved as red iron replacements; sharp contact with:
   2.70 m (18.80 m)

7. Carbonaceous shale: Black; grades into bone coal; intensely rooted; the unit has the appearance of coal that had clay pushed into it by rooting from the overlying unit; grades into:

0.05 m
(18.85 m)

8. Coal: Black.

1.20 m
(20.05 m)

BASE OF INCLINE

Mine Section Saquib Mines Greenland-13

Saquib Mines, Lakhra Coal Field, Greenland-13

Total depth of mine: 26.84 m
Thickness of measured section: 26.84 m

BARA FORMATION

1. Sandstone: Yellow-brown; CONTAINS: secondary gypsum along bedding planes; abundant siderite bands; sharp contact with:
   2.70 m
   (2.70 m)

2. Claystone: Yellow-gray; fissile; CONTAINS: laminar bedding; scattered thin sand laminations up to 1 mm in thickness; secondary gypsum bands parallel to bedding in the upper part of the unit; scattered siderite nodules; sharp contact with:
   0.60 m
   (3.30 m)

3. Sandstone: Yellow-brown; CONTAINS: shell fragments; siderite nodules; abundant glauconite; sharp contact with:
   0.20 m
   (3.50 m)

4. Sandstone: Poorly sorted; dark brown; composed of quartz, abundant glauconite, and abundant interstitial clay; CONTAINS: abundant kaolinite bands; grades into:
   0.30 m
   (3.80 m)

5. Claystone: Yellow-brown; silty, coarsens upward; fissile; flat laminated; CONTAINS: burrows; secondary gypsum bands paralleling bedding planes; grades into:
   6.50 m
   (10.30 m)

6. Claystone: Yellow-brown, olive-brown in places; massive; homogeneous; coarsens upward into siltstone; CONTAINS: siderite nodules and bands up to 5 cm thick; bands of secondary gypsum; sharp contact with:
   3.50 m
   (13.80 m)

7. Sandstone: Poorly sorted; yellow-brown; composed of quartz, very abundant interstitial clay, glauconite, and calcareous cement; CONTAINS: shell fragments; burrows, unit homogenized by burrowing; bands of secondary gypsum; sharp contact with:
   0.50 m
   (14.30 m)

DETAILED SECTION DESCRIPTION BEGINS WITH UNIT 8

8. Sandstone: Fine-grained, well-sorted; red, light gray to white in the upper part of the unit; clean, composed of quartz and no interstitial clay; non-calcareous, weakly cemented; CONTAINS: current ripples; festoon cross-bedding, cross-bed sets are from 4 to 10 cm thick; unit uniformly cross-bedded throughout; cross-beds are defined by clay accumulations on the slip-face; sharp contact with:
   2.56 m
   (16.86 m)

9. Sandstone: Very fine-grained, poorly sorted; light gray with red and yellow-brown banding; composed of quartz and very abundant
0.56 m interstitial clay; CONTAINS: no evidence of bedding other
(17.42 m) than the weathering induced color banding; grades into:

10. Sandstone: Silty at base coarsening upward to very fine-grained sandstone at top, clay content decreases upward, poorly
0.77 m sorted; light gray; composed of quartz and extremely
(18.19 m) abundant interstitial clay; fissile; CONTAINS: no evidence of bedding, unit homogeneous; no obvious burrows however unit presumed to be homogenized by burrowing; sharp contact with:

11. Claystone: Medium gray, yellow-brown and red banding and mottling; CONTAINS: very fine-grained sand and occasionally silt
0.39 m laminations up to 1 mm thick; abundant carbonaceous debris
(18.58 m) associated with some sand laminations; sand laminations become thinner and less abundant upward; rare lenticular ripples up to 5 cm thick; uncommon bedding plane burrows; secondary gypsum; sharp contact with:

12. Sandstone: Very fine- to fine-grained, poorly sorted; light gray, red and yellow-brown mottling; composed of quartz and
0.22 m interstitial clay; massive; CONTAINS: burrows, unit
(18.80 m) homogenized by burrowing; sparse carbonaceous debris; carbonaceous material pyritized in places; bands of secondary gypsum; grades over a short distance into:

13. Interlaminated sandstone and claystone: Sandstone: light gray; contains sand laminations up to 1 mm thick; ripple lenses up
0.14 m to 4 mm thick; Claystone: medium gray clay beds up to 3 mm
(18.94 m) thick; contains burrows; entire unit extensively disrupted by burrowing; in places burrowing has homogenized the unit with the overlying and underlying units; sharp contact with:

14. Sandstone: Very fine- to fine-grained, poorly sorted; light gray, red and yellow-brown mottling; the zone of weathering begins
0.74 m 22 cm above the base; composed of quartz and interstitial
(19.68 m) clay; massive; CONTAINS: burrows, unit homogenized by burrowing; sparse carbonaceous debris, pyritized in places carbonaceous debris becomes slightly more abundant upward; bands of secondary gypsum; sharp contact with:

15. Interlaminated sandstone and claystone: Sandstone: light gray; contains sand laminations up to 1 mm thick; ripple lenses up
0.04 m to 4 mm thick; Claystone: medium gray clay beds up to 3 mm
(19.72 m) thick; contains burrows; entire unit extensively disrupted by burrowing; grades over a short distance into:

16. Sandstone: Very fine- to fine-grained, poorly sorted; light gray, composed of quartz and interstitial clay; massive;
0.14 m CONTAINS: burrows, unit homogenized by burrowing; sparse
(19.86 m) carbonaceous debris, carbonaceous debris pyritized in

places; sharp contact with:

17. Siltstone: Medium gray; CONTAINS: flat bedded sand laminations up to 1 mm thick; sideritized bands; rare burrows; very rare shell
0.44 m fragments; very rare burrows parallel to bedding, no
(20.30 m) carbonaceous debris on bedding surfaces; sharp contact with:

18. Mudstone: Dark brown; CONTAINS: matrix supported fine- to medium-grained quartz sand grains; indurated, non-calcareous
0.21 m nodular zones; abundant glauconite pellets; abundant shell
(20.51 m) fragments but no whole shells; homogeneous, no evidence of bedding; sharp contact with:

19. Sandstone: Fine-grained, poorly sorted; light gray; composed of quartz and interstitial clay; CONTAINS: siderite nodules; sparse
0.24 m shell fragments; abundant burrows, unit homogenized by
(20.75 m) burrowing; sharp contact with:

20. Interlaminated sandstone and claystone: Sandstone: fine-grained, light gray; flat laminated, ripple cross-bedded in places;
0.12 m Claystone: medium gray; CONTAINS: finely comminuted
(20.87 m) carbonaceous debris on claystone surfaces; carbonaceous debris also covers some ripple surfaces; very rare shell fragments in the sandstone; abundant burrows; grades over a short distance into:

21. Sandstone: Very fine- to fine-grained, poorly sorted; light gray; composed of quartz and interstitial clay; non-calcareous;
0.20 m CONTAINS: discontinuous clay flasers up to 1 mm thick;
(21.07 m) scattered, common, homogeneously distributed shell fragments; siderite bands up to 5 mm thick; no obvious ripples; common burrows; grades over a short distance into:

22. Interlaminated sandstone and claystone: Sandstone: fine-grained, light gray; flat laminated, ripple cross-bedded in places;
0.05 m Claystone: medium gray; CONTAINS: finely comminuted
(21.12 m) carbonaceous debris on claystone surfaces; carbonaceous debris also covers some ripple surfaces; very rare shell fragments in the sandstone; rare burrows; sideritized clay beds; grades over a short distance into:

23. Sandstone: Very fine- to fine-grained, poorly sorted; light gray; composed of quartz and interstitial clay; non-calcareous
0.27 m though the unit does have a single carbonate cemented zone
(21.39 m) 4 cm thick; CONTAINS: discontinuous clay flasers up to 1 mm thick; scattered, common, homogeneously distributed shell fragments; siderite bands up to 5 mm thick; no obvious ripples; no burrows; grades over a short distance into:

24. Interlaminated sandstone and claystone: Sandstone: fine-grained, light gray; flat laminated, ripple cross-bedded in places;
0.08 m Claystone: medium gray; CONTAINS: finely comminuted
(21.47 m) carbonaceous debris on claystone surfaces; carbonaceous

debris also covers some ripple surfaces; very rare shell fragments in the sandstone; no burrows; sideritized clay beds; grades over a short distance into:

25. Sandstone: Very fine- to fine-grained, poorly sorted; light gray; composed of quartz and interstitial clay; non-calcareous;
0.18 m (21.65 m) CONTAINS: discontinuous clay flasers up to 1 mm thick; scattered, common, homogeneously distributed shell fragments; siderite bands up to 5 mm thick; no obvious ripples; no burrows; grades over a short distance into:

26. Interlaminated sandstone and claystone: Sandstone: fine-grained, light gray; flat laminated, ripple cross-bedded in places;
0.05 m (21.70 m) Claystone: medium gray; CONTAINS: finely comminuted carbonaceous debris on claystone surfaces; carbonaceous debris also covers some ripple surfaces; very rare shell fragments in the sandstone; no burrows; grades over a short distance into:

27. Sandstone: Very fine- to fine-grained, poorly sorted; light gray; composed of quartz and interstitial clay; non-calcareous;
0.10 m (21.80 m) CONTAINS: discontinuous clay flasers up to 1 mm thick; scattered, common, homogeneously distributed shell fragments; siderite bands up to 5 mm thick; no obvious ripples; no burrows; grades over a short distance into:

28. Interlaminated sandstone and claystone: Sandstone: very fine-grained, poorly sorted; light gray; composed of quartz and abundant
1.28 m (23.08 m) interstitial clay; sand beds range in thickness between 0.5 and 6 mm, sand beds thicken to 40 mm toward the top of the unit; CONTAINS: abundant clay bands and laminations that range in thickness between 0.1 and 10 mm, the thicker clay beds often contain very thin sand laminations; clay beds and laminations become less prominent upward and the percentage of sand increases upward; some sideritized yellow-brown clay bands; sparse bedding plane burrows; rare, scattered shell fragments throughout; small amounts of comminuted carbonaceous debris on some bedding surfaces; calcite cemented bands containing shell fragments occur toward the top; grades into:

29. Interbedded sandstone and claystone: Sandstone: very fine-grained, well-sorted; medium green-gray; composed of quartz and some
1.77 m (24.85 m) interstitial clay; non-calcareous but the unit contains calcite cemented nodules up to 14 cm thick and 1.5 m long, tops and bottoms of the nodules parallel bedding; laminar bedded, clay laminations range in thickness between 0.2 and 5 mm; rare coaly laminations, scattered coalified wood fragments; wavy bedding in places, sand ripple lenses in places; Claystone: medium gray; laminar bedded, laminations range in thickness between 0.1 and 10 mm; the thicker shale beds often contain very thin sandstone laminations; claystone beds contain finely comminuted carbonaceous debris

Mine Section Saquib Mines Greenland-13 cont.

on bedding surfaces; CONTAINS: scattered vertical burrows throughout; scattered lenses of shell fragments and quartz sand in the top 25 cm of the unit, many of these lenses appear to be burrow fillings; scattered yellow-brown siderite bands between 2 and 10 mm thick; sharp contact with:

30. Sandstone: Fine-grained, poorly sorted; medium green-gray; composed of quartz, abundant glauconite pellets, and very abundant interstitial clay; this unit is split and intertongues with the overlying unit; CONTAINS: abundant shell fragments; hard bands that may be sideritized clay; sparse coalified plant fragments; burrows, traces of ripples and laminar bedding indicate that the unit has been homogenized by burrowing; sharp contact with:

0.10 m
(24.95 m)

31. Interbedded sandstone and claystone: Sandstone: very fine-grained, well-sorted; light gray; composed of quartz and some interstitial clay; non-calcareous; laminar bedded, laminations range in thickness between 0.2 and 5 mm; also contains sand ripple lenses; Claystone: medium gray; laminar bedded, laminations range in thickness between 0.1 and 10 mm; the thicker shale beds often contain very thin sandstone laminations; claystone beds contain finely comminuted carbonaceous debris on bedding surfaces; CONTAINS: scattered vertical burrows throughout; scattered lenses of shell fragments and quartz sand in the top 25 cm of the unit, many of these lenses appear to be burrow fillings; scattered yellow-brown siderite bands between 2 and 10 mm thick; sharp contact with:

0.79 m
(25.74 m)

32. Coal: Black; CONTAINS: occasional sand-filled burrow penetrations in the top 4 to 5 cm; common, apparently randomly orientated sand dikes that traverse the coal bed and penetrate through the overlying unit.

1.10 m
(26.84 m)

BASE OF INCLINE

NOTE: It is not clear if there is a Lakhra-Bara contact within the mine. If the lowest shell bed is defined as the contact, then the base of unit 7 becomes the base of the Lakhra Formation.

Sind Mines, Lakhra Coal Field, Mine SN-4A

Total depth of mine: Not Measured
Thickness of measured section: 18.03 m

BARA FORMATION

1. Sandstone: Rhythmically bedded, alternating between clean white sandstones that are ripple bedded and medium gray sands that have been homogenized by burrowing; ripple cross-sets are defined by accumulations of carbonaceous debris; the thickness of the homogenized units increases upward from 10 cm in the basal portions of the unit to over a meter in the top part of the unit; rippled zones contain sparse burrows; the thickness of the rippled zones decreases from up to 45 cm in the basal part of the unit to less than 10 cm in the top part of the unit; unit contains rare planar cross-beds up to 15 cm thick; the basal 1.7 m contains 6 burrow/rippled zones, followed by 60 cm of planar cross-bedded sandstone, and then an additional 10 burrow/rippled zones in the rest of the unit; sharp contact with:

6.50 m
(6.50 m)

2. Shale: Medium gray; CONTAINS: abundant comminuted carbonaceous debris; grades into:

0.08 m
(6.58 m)

3. Coal: Black; shaly at the top and bottom; grades into:

0.25 m
(6.83 m)

4. Siltstone: Medium gray; CONTAINS: thin sand laminations in the basal part of the unit, laminations become less prominent upward; abundant carbonaceous debris on all bedding plane surfaces; no evidence of rooting; sharp contact with:

2.55 m
(9.38 m)

5. Sandstone: Medium gray; CONTAINS: fragments of coalified debris scattered throughout; abundant burrows, unit homogenized by burrowing; sharp contact with:

2.55 m
(11.93 m)

6. Sandstone: White; clean, composed of quartz with no argillaceous matrix; CONTAINS: sparse burrows; low-angle cross-beds; cross-sets defined by grain size differences; rare, discontinuous clay bands; laminar bedded zones up to 3 cm thick, laminations defined by accumulations of carbonaceous debris; rare coalified wood fragments; sharp contact with:

4.35 m
(16.28 m)

7. Carbonaceous shale: Black; grades into:

0.10 m
(16.38 m)

8. Coal: Black; sharp contact with:

0.20 m
(16.58 m)

9. Claystone: Medium gray; CONTAINS: abundant roots, unit homogenized by rooting; sharp contact with:

0.45 m
(17.03 m)

10. Coal: Black; contains numerous shale partings.

1.00 m
(18.03 m)

BASE OF INCLINE

OUTCROP DESCRIPTIONS

SECTION GT-1

LAKI LIMESTONE

1. Limestone: Slope; covered interval; sharp contact with:

2.50 m (2.50 m) **Sample 90-EB-23 collected at 0 m**

2. Limestone: Ledge; white; nodular; burrowed; calcarenaceous; sharp contact with:

3.00 m (5.50 m)

3. Claystone: Chocolate brown; fissile; section mostly covered; lithological composition assessed by digging 4 test pits 50 to 70 cm deep; CONTAINS: celestite veins at the top of the unit; calcareous marly mudstone in the middle and at the top of the unit (samples 90-EB-19,22 were collected in this lithology, samples 90-EB-20,21 were collected in the claystone); sharp contact with:

10.00 m (15.50 m)

Sample 90-EB-22 collected at 5.90 m
Sample 90-EB-21 collected at 8.1 m
Sample 90-EB-20 collected at 9.2 m
Sample 90-EB-19 collected at 11.3 m

METING SHALE

4. Ironstone: Ledge; maroon and yellow-brown; indurated; dense; CONTAINS: abundant, interbedded secondary gypsum bands; sharp contact with:

0.07 m (15.57 m)

5. Limestone: Ledge; light yellow-brown; massive; homogeneous; hard; CONTAINS: common foraminifera tests; sparse whole pelecypod shells; grades into:

0.68 m (16.25 m)

6. Sandstone: Slope; gray-brown with yellow-brown mottling; medium- to coarse-grained fining upward to fine-grained at the top of the unit, poorly sorted, dirty; composed of quartz, rare glauconite pellets, very abundant interstitial clay, and calcareous cement; massive; homogeneous; no internal bedforms; CONTAINS: graded bedding; burrows; foram tests near the top of the unit; sharp contact with:

0.45 m (16.70 m)

Sample 90-EB-29 collected at 16.55 m

7. Claystone: Slope; chocolate brown; fissile; badly weathered; sharp contact with:

2.90 m
(19.60 m)

8. Limestone: Ledge; yellow-brown; massive; homogeneous; fine-grained calcarenite; CONTAINS: no evidence of bedding; intensely burrowed; sparse forams but no larger shells or shell fragments; sharp contact with:

0.95 m
(20.55 m)

9. Claystone: Slope; chocolate-brown with yellow-brown mottling; fissile; badly weathered; CONTAINS: abundant glauconite in places; sharp contact with:

2.90 m
(23.45 m)

Sample 90-EB-18 collected at 22.95 m

10. Limestone: Ledge; yellow-brown; massive; homogeneous; CONTAINS: abundant forams in a fine-grained calcarenaceous matrix; no evidence of bedding; grades into:

0.70 m
(24.15 m)

11. Green sand: Slope; composed of 50 percent glauconite pellets and extremely abundant foraminiferal remains; massive; homogeneous; CONTAINS: no evidence of bedding; sharp contact with:

0.35 m
(24.50 m)

12. Claystone: Slope; chocolate-brown with yellow-brown mottling; CONTAINS: thin zones composed exclusively of fine-grained glauconite pellets; flat laminations; small ripples; laminations and rippled defined by the accumulation of foram tests, shell fragments and glauconite pellets on the laminae; foraminiferal remains extremely abundant; sharp contact with:

1.00 m
(25.50 m)

13. Limestone: Ledge; yellow-brown; argillaceous; indurated; CONTAINS: uncommon shells and shell fragments, mostly pelecypods; abundant burrows, unit homogenized by burrowing, burrows calcium mineralized; grades into:

0.53 m
(26.03 m)

14. Claystone: Slope; chocolate-brown with yellow-brown mottling; coarsens upward into calcareous mudstone; massive; homogeneous; blocky; CONTAINS: abundant, homogeneously distributed shell hash and whole, small pelecypod shells; no evidence of bedding; sharp contact with:

0.70 m
(26.73 m)

Sample EB-90-16 collected at 26.53 m

15. Claystone: Slope; chocolate-brown, yellow-brown mottling associated with laminations, red mottling begins about 2.50 m above the base; unit fines upward; fissile; slightly calcareous; CONTAINS: abundant, flat, very fine-grained sandstone and

6.40 m
(33.13 m)

siltstone laminations, laminations appear to consist of more than 50 percent heavy minerals, laminations become less abundant upward and disappear 2.50 m above the base of the unit; grades into:

Sample 90-EB-9 collected at 32.83 m
Sample 90-EB-11 collected at 31.53 m
Sample 90-EB-10 collected at 30.73 m
Sample 90-EB-12 collected at 30.43 m
Sample 90-EB-13 collected at 29.63 m
Sample 90-EB-14 collected at 28.73 m
Sample 90-EB-15 collected at 27.43 m

16. Mudstone: Slope; yellow-brown; massive; homogeneous; blocky; calcareous; CONTAINS: sand grains composed of calcite; interbeds of slightly more arenaceous mudstone; no evidence of bedding; sharp contact with:
    1.30 m
    (34.43 m)

Sample 90-EB-7 collected at 34.23 m
Sample 90-EB-8 collected at 33.43 m

17. Limestone: Ledge; yellow-brown; massive; homogeneous; calcarenaceous; CONTAINS: abundant whole shells, particularly gastropods and pelecypods; intensely burrowed, burrows are calcite replaced in places; sharp contact with:
    0.25 m
    (34.68 m)

18. Limestone: Ledge; cream; moderately indurated; massive; homogeneous; calcarenaceous; CONTAINS: forams but no larger shell remains or shell fragments; no evidence of bedding; grades into:
    0.95 m
    (35.63 m)

Sample 90-EB-5 collected at 35.53 m

19. Marl: Slope; light brown; massive; homogeneous; becomes more indurated and calcareous upward; CONTAINS: abundant, matrix supported calcareous sand grains; forams; pelecypod shell fragments appear toward the top of the unit; grades into:
    1.00 m
    (36.63 m)

Sample 90-EB-4 collected at 36.43 m

20. Calcarenite: Ledge; cream; very fine-grained; massive; homogeneous; argillaceous; grades into:
    0.30 m
    (36.93 m)

21. Claystone: Slope; brown; fissile; coarsens upward to mudstone at the top of the unit; calcareous; CONTAINS: abundant, flat, very fine-grained calcite sand laminations; abundant dark minerals; burrows, burrows become more abundant upward; sharp contact with:
    0.70 m
    (37.63 m)

Sample 90-EB-3 collected at 37.33 m

22. Sandstone: Ledge; light brown; fine-grained, poorly sorted, dirty; composed of quartz, abundant interstitial clay, and
0.40 m calcareous cement; CONTAINS: planar laminations in the top
(38.03 m) 15 cm, more massive and bioturbated in the bottom 25 cm; planar laminations are better preserver in other places in this sandstone bed outcrop; sharp contact with:

23. Claystone: Slope; brown; CONTAINS: flat sand laminations, in places the laminations appear irregular possibly due to
0.90 m bioturbation; sharp contact with:
(38.93 m)

Sample 90-EB-2 collected at 38.13 m

24. Calcarenite: Ledge; light yellow-brown; medium-grained; CONTAINS: forams and foram and other shell fragments; sharp contact
0.08 m with:
(39.01 m)

25. Sandstone: Ledge; yellow-brown; very fine-grained, well sorted, dirty; composed of quartz, abundant interstitial clay, and
0.07 m calcareous cement; grades into:
(39.08 m)

26. Claystone: Brown; fissile; calcareous; CONTAINS: abundant very fine-grained quartz sand laminations usually less than 1 mm in
0.50 m thickness, sand laminations are dirty and contain an
(39.58 m) abundance of heavy minerals.

Sample 90-EB-1 collected at 39.38 m

*Samples with EB in the sample number were collected by Elizabeth Brouwers from the U.S. Geological Survey, Denver, Colorado.

END OF SECTION

SECTION JRK-4

METING LIMESTONE

1. Limestone: White; granular, believed to be a well cemented calcarenite; thinly bedded, beds on the order of 1 to 10 cm thick;
   1.35 m (1.35 m) indurated, ledge former; CONTAINS: burrows; chert nodules; no observed fossils; contact not exposed:

2. Limestone: Pale yellow; foraminiferal limestone containing forams in a fine-grained calcarenite matrix; indurated, ledge former;
   2.90 m (4.25 m) CONTAINS: burrows; echinoderms; chert nodules; sharp contact with:

3. Limestone: Pale yellow; massive; calcarenite; indurated, ledge former; CONTAINS: abundant Alveolina and other foram types, forams
   7.30 m (11.55 m) become less abundant upward, forams are randomly orientated in the more massive part of the unit; thin bedding in the top half meter, thin bedded part contains chert nodules, echinoderms, and several thin foram accumulations on bedding plane surfaces; sharp contact with:

4. Coquina: White; composed almost exclusively of Assilina-like discoidal forams; indurated, ledge former; CONTAINS: foram
   3.00 m (14.55 m) filled Ophiomorpha burrows; low-angle cross-beds; a fine-grained, calcarenitic matrix filling the space between forams near the top of the unit; sharp contact with:

5. Limestone: Pale yellow; nodular; massive; fine-grained calcarenite; indurated, ledge former; CONTAINS: burrows, unit
   3.00 m (17.55 m) homogenized by burrowing; Alveolina and other foram types; gastropods; grades into:

6. Limestone: Pale yellow; argillaceous; thin bedded; fine-grained calcarenite; indurated, ledge former; CONTAINS: laminar
   5.50 m (23.05 m) bedding, beds are on the order of 2 to 3 mm thick; small scale ripples; coarse shell hash accumulations on some bedding plane surfaces; weathered glauconite on some bedding plane surfaces; sparse fossil remains though there rare, thin foram beds, these beds become up to 10 cm thick toward the top of the unit; burrows, burrowing becomes more intense toward the top of the unit; contact unknown:

7. Covered:

   1.00 m (24.05 m)

SOHNARI FORMATION

Not Measured