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THE STRATIGRAPHY AND COAL RESOURCE POTENTIAL OF THE BARA FORMATION IN THE FORT RANIKOT AREA, SINDH PROVINCE, PAKISTAN: A PROGRESS REPORT

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CONTENTS

ABSTRACT..... 1

INTRODUCTION..... 3

BACKGROUND..... 7

REGIONAL STRATIGRAPHY..... 9

METHODS..... 13

RESULTS AND DISCUSSION..... 15

CONCLUSIONS AND RECOMMENDATIONS..... 26

ACKNOWLEDGEMENTS..... 26

REFERENCES..... 29

APPENDIX 1..... 32
SECTION RN-1A..... 32
SECTION RN-1B..... 41
SECTION RN-1C..... 52

ILLUSTRATIONS

FIGURE 1: Coal fields and coal occurrences of Pakistan..... 4

FIGURE 2: General geology of the area around the Lakhra Anticline, the Lakhi Range, and the Sonda coal field showing the locations of the areas discussed in this report..... 5

Figure 3: Detailed map showing the location of the 1990 measured section and the location of the 1989 reconnaissance survey.. 8

FIGURE 4: Generalized stratigraphy of the Lakhra Anticline area..... 10

Figure 5: Lithologic log of the Bara Formation in the Fort Ranikot area, Sindh..... 14

Figure 6: Geology of the Fort Ranikot area in the northern part of the Lakhi Range as mapped by the Hunting Survey Corporation..... 16

Figure 7: Detail of the fold..... 18

TABLES

TABLE 1: Carbonaceous shale, rooted zone, and covered interval thicknesses and intercepts..... 23

ABSTRACT

Reports from villagers living in the area of the northern part of the Lakhi Range suggest that coal had been mined in the mountains northwest of the Lakhra Anticline sometime within the past 100 years. The region in question lies 30 km northwest of Pakistan's largest coal field. Since the same strata that are mined for coal on the Lakhra Anticline are exposed in the northern Lakhi Range, these mountains, as well as some ridges to the west, may be regarded as potential coal prospects. This reconnaissance study was initiated to evaluate the coal resource potential of the coal-bearing Bara Formation in the area of Fort Ranikot in the Lakhi Range.

Coal was not found in the Bara rocks at Fort Ranikot. However, five rooted carbonaceous shales that may have been the residuum from weathered high ash coals were found. The two thickest of these carbonaceous shale beds were 1.20 m and 0.95 m. Five other rooted intervals were also identified. In the area of the Lakhra Anticline, rooted intervals are almost always associated with coal beds or carbonaceous shale, though this correlation may not hold at Fort Ranikot. Six covered intervals were observed. Because covered intervals typically occur in shaly zones, there is the possibility that additional rooted intervals, carbonaceous shales, or coal beds may have been obscured.

Structural complications may also have been a major factor in obscuring potential coal beds. The section was measured across the flanks of the most compressed part of the anticline. In similar structural settings elsewhere in the world, the compressional forces may mobilize the coal and squeeze it from the flanks. A more comprehensive assessment of the coal potential of the Bara Formation at Fort Ranikot will require investigations of the much less deformed strata in the western part of Lakhi Range and

perhaps one or two well placed drill holes.

The Lakhi Range is the only place in Pakistan where the complete thickness of the coal-bearing Bara Formation can be studied. Elsewhere in Pakistan this formation lies in the subsurface and is unstudied below its uppermost 250 m. The lithologic, sedimentologic and stratigraphic data derived from this study significantly improves our understanding of the regional stratigraphy of this formation and the depositional environments in which it accumulated. A better understanding of the sedimentology and stratigraphy of the Bara Formation will contribute to increased efficiency in coal exploration in south Sindh.

We are of the opinion that a complete section of the Bara Formation was measured in Fort Ranikot in the Lakhi Range. This section was 486 m thick. However, because of the structural complexities in this area, it is possible that the section was faulted, and that a substantial, undetermined thickness of Bara is missing.

INTRODUCTION

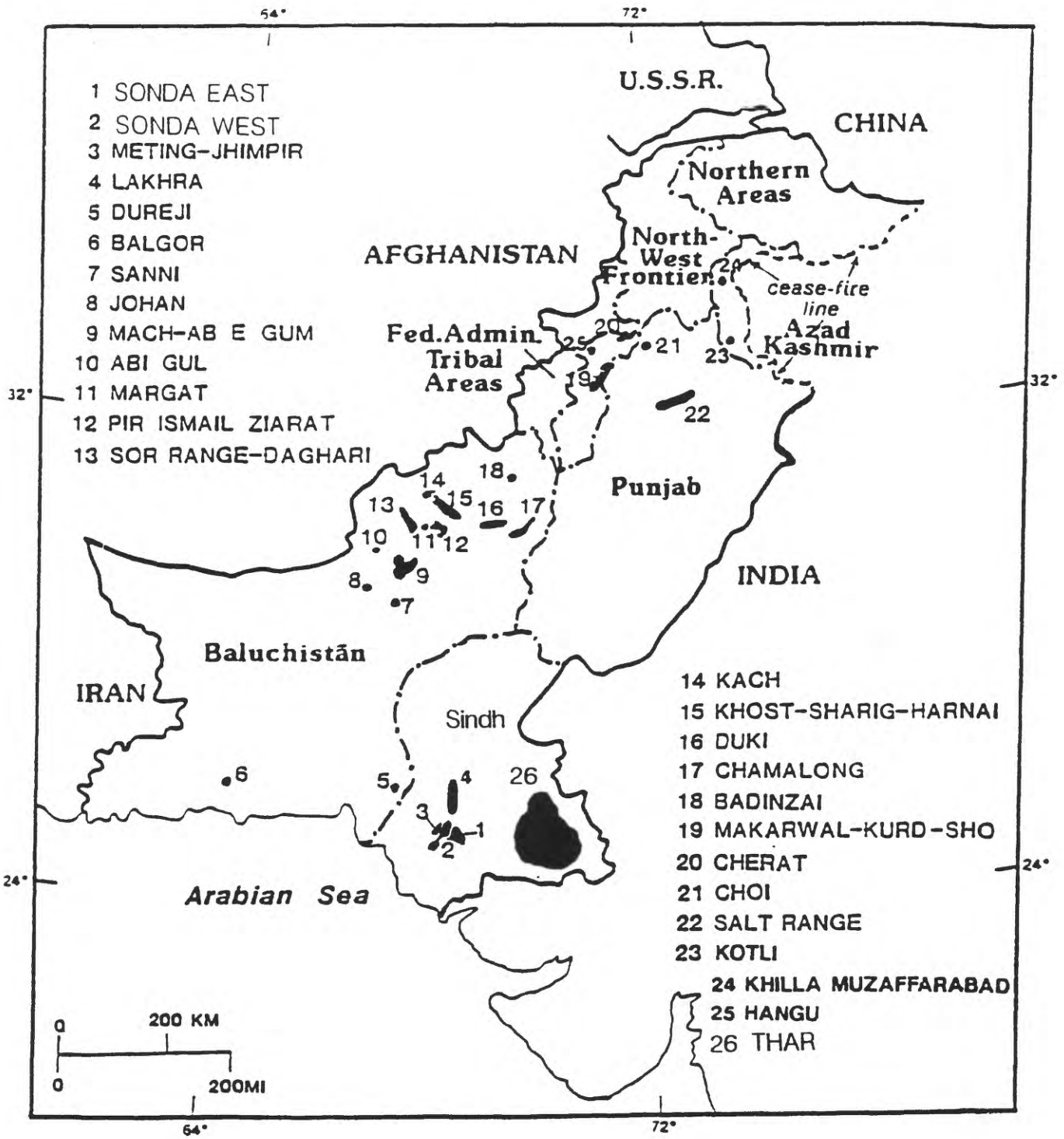
The Bara Formation contains most of Sindh's known coal resources and supplies most of province's coal production from mines located on the crest of the Lakhra Anticline (figs.1, 2). From a geologic perspective, there is no a priori reason to suppose that the occurrence of coal in the Bara Formation is confined to the area of the Lakhra Anticline, a conclusion confirmed by the recent discovery of coal in the Thar Desert (SanFilipo and others, 1992). But, with the exception of the Thar drilling, exploration for coal has been restricted to the Lakhra Anticline and to areas no more than 80 km southwest, south, and southeast of Hyderabad (Landis and others, 1988; Schweinfurth and Husain, 1988), even though oil and gas drilling records suggest that coal is geographically widespread in the Bara Formation.

The Bara Formation occurs in the subsurface throughout most of Sindh (Quadri and Shuaib, 1986), but outcrops of this formation are rare. Surface exposures are confined to small occurrences of the uppermost non-coal-bearing 10 to 20 m of the Bara on the crest of the Lakhra Anticline and in the banks of the Indus River near Jherruck and Daduri (fig. 2). Using aerial photographs, the Hunting Survey Corporation (1961) mapped Ranikot Group strata (which may include some Bara Formation) between the Bera and Daphro East Ridges and in the Daphro West Ridge west of Fort Ranikot. However, the only major exposure of Bara Formation occurs in the Lakhi Range where the whole thickness of the unit is exposed in places. Since COALREAP drilling has never penetrated more than the uppermost 250 m of the Bara Formation, the Lakhi Range is the only area in Sindh in which the coal resource potential of the middle and lower parts of the 500 - 1000 m thick Bara Formation can be assessed.

This report is a preliminary assessment of the stratigraphy,

FIGURE 1: COAL FIELDS AND COAL OCCURRENCES OF PAKISTAN

(Modified from SanFilipo and others, 1988)



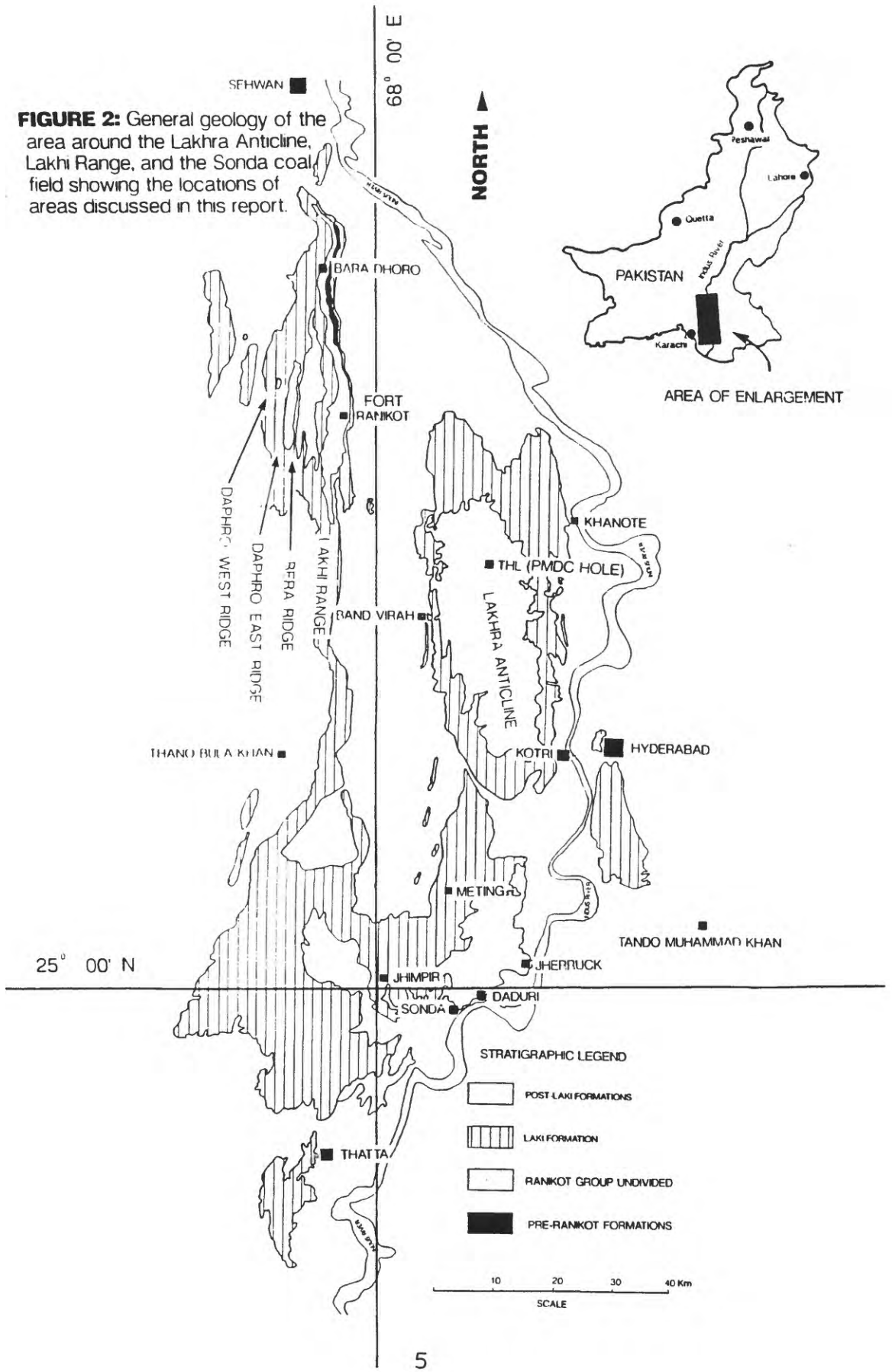


FIGURE 2: General geology of the area around the Lakhra Anticline, Lakhi Range, and the Sonda coal field showing the locations of areas discussed in this report.

sedimentology, and coal resource potential of the Lakhi Range in the vicintity of Fort Ranikot. This study site was chosen because of its relative accessibility compared to other parts of the Lakhi Range and because of the presence of an apparently complete section of the Bara Formation at the site. Analysis of the Fort Ranikot section provides stratigraphic, lithologic, and sedimentologic data that cannot be obtained elsewhere in Sindh. This study contains the first description and characterization of the thick sandstones separating coal zones, and consequently, is a critical contribution to the stratigraphy of the Bara Formation. Previously, the nature of these sandstones was unknown because they were never recovered during drilling. The stratigraphic and sedmentologic data contained within this report will significantly improve regional facies models thereby improving the efficiency of coal exploration in this part of Sindh.

No coal was found in Fort Ranikot though several carbonaceous shales were seen. However, surficial weathering and structural complications along the line of section may have obscured potential coal occurrences. Carbonaceous shales were common as well as evidence in the form of rooted horizons of repeated episodes of terrestrial exposure. Further south in the area of the Lakhra Anticline rooted zones are almost exclusively associated with coal beds (Wnuk and others, 1993). Additional fieldwork will be needed to determine accurately if coal occurs in the northern part of the Lakhi Range.

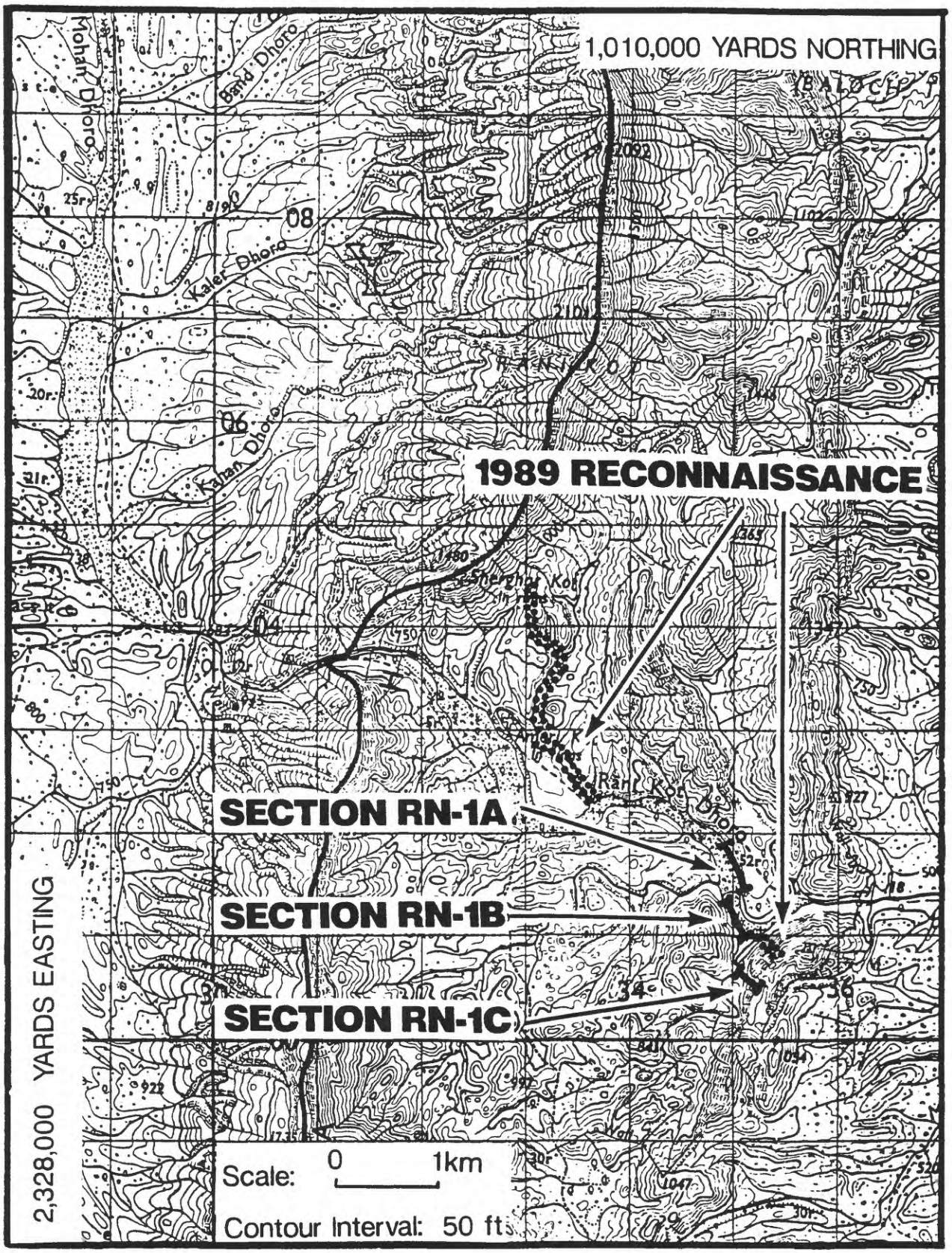
This study was undertaken in March 1990 under the auspices of the Coal Resource Exploration and Assessment Program (COALREAP), a project agreement between the United States Agency for International Development (USAID) and the United States Geological Survey (USGS), the Geological Survey of

Pakistan (GSP), and the Government of Pakistan (GOP). Establishing a National Coal Exploration Plan (NCEP) and implementing a coal resource assessment program which includes exploration guided by the recommendations of the NCEP are two of the primary missions of the PASA agreement between the USGS and USAID.

BACKGROUND

In 1985, F.O. Simon participated in a reconnaissance survey that attempted to locate old coal mine workings that were reported to occur by villagers living in the northern part of the Lakhi Range. The attempt was unsuccessful (F.O. Simon, oral communication, 1989). In April 1989, SanFilipo and Wnuk, along with members of the faculty from the University of Sindh made reconnaissance surveys of the Bara Formation type section (fig. 2) at Bara Dhoro and the principal reference section (fig. 3) at Fort Ranikot. Although no evidence of abandoned coal workings were found, they determined that the Bara Formation had some coal potential which merited more detailed investigation. Hence, this study. In 1990, the authors and Elizabeth Brouwers of the USGS, and S. Farah Fatmi of GSP attempted to make reconnaissance surveys for Bara Formation sediments in the ridges west of the Lakhi Range. The travel time to these areas was lengthy but the region was accessible by 4-wheel drive vehicles; however, because of the lack of time during that trip, it could not determined if the Bara Formation is actually exposed in any of those western ridges as reported by Blanford (1879).

FIGURE 3: Detail of the central part of quadrangle 35-O/13 showing the location of the measured sections in the Fort Ranikot area.



REGIONAL STRATIGRAPHY

The generalized stratigraphy of Paleocene and lower Eocene strata in the Lakhra Anticline, approximately 30 km southeast of Fort Ranikot is shown in figure 4. According to Cheema and others (1977), the Khadro Formation contains the oldest Paleocene rocks. Cheema and others (1977) indicate that the formation consists of beds of greenish- and yellow-brown, poorly cemented, dirty, calcareous and ferruginous, medium-grained sandstone, olive shale and siltstone, and thin, brown, fossiliferous, argillaceous limestone. At any place within the Lakhi Range, between 1 and 3 basalt beds may be exposed in the Khadro. Blanford (1878), Cheema and others (1977), and Ahmed and Siddiqui (unpublished data) place the contact between the Bara and Khadro Formations on the top of the highest basalt unit. Other workers place all of the basalt units in the basal 50 m of the Bara Formation (Farshori, unpublished data; Abdullah, unpublished data). In this report, we will follow the conventions of Cheema and others (1977) with regard to the Khadro-Bara contact. The Khadro Formation is 67 m thick in its type area, Khadro Dhoro in the Lakhi Range, and is reported in Cheema and others (1977) to be 140 m thick in the Lakhra Anticline.

The overlying Paleocene Bara Formation (fig. 4) consists of beds of white or gray sandstone, that weather white, gray, red, purple, or maroon. The sandstone is poorly cemented, clean or dirty, non-calcareous, and fine- to coarse-grained. Approximately 40 percent of the formation consists of beds of gray siltstone and claystone that weather brown or maroon. In the Lakhra area, 1 to 2 percent of the formation consists of coal beds. The Bara Formation contains the majority of the known coal resources in Sindh.

The Bara Formation ranges in thickness from more than 1,000 m in the

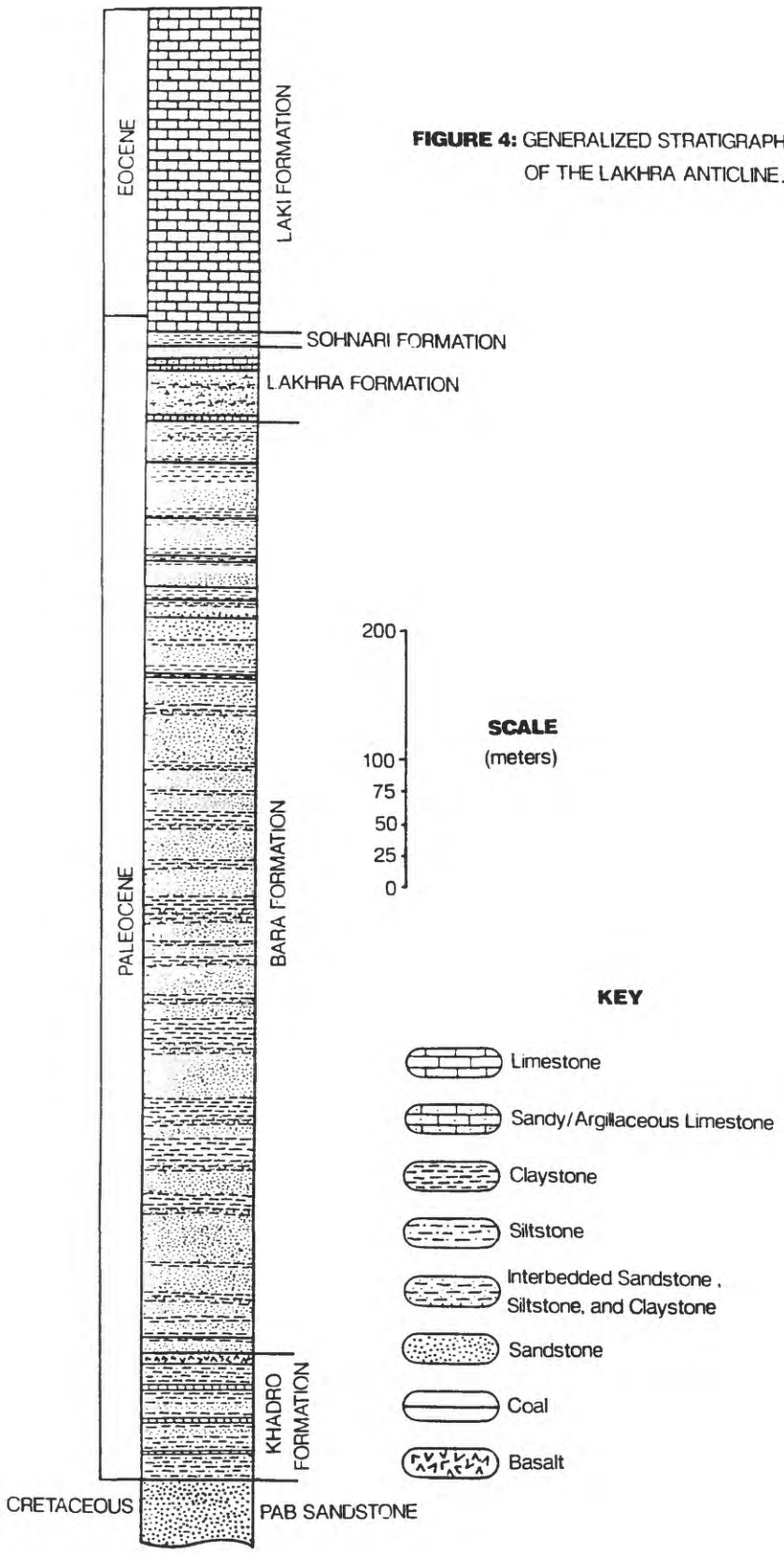


FIGURE 4: GENERALIZED STRATIGRAPHY OF THE LAKHRA ANTICLINE.

Karachi Trough 50 km southwest of the Lakhra Anticline (Quadri and Shuaib, 1986) to less than 60 m in the northern part of the Sulaiman Range, Balochistan (Williams, 1959). Cheema and others (1977), Ahmed and Siddiqui (unpublished data), and Farshori (unpublished data) report widely divergent thicknesses for the Bara Formation at the principal reference section at Fort Ranikot. Cheema and others (1977) state that the Bara Formation is 600 m thick, Ahmed and Siddiqui (unpublished) indicate that the Formation is 355 m thick, and Farshori (unpublished) indicates a formation thickness of 305 m. This paper reports a Bara thickness of 486 m. The reasons for these discrepancies are unknown.

The Paleocene Lakhra Formation (fig. 4) consists of beds of green or green-gray sandstone and gray siltstone and claystone that weather yellow-brown, olive, brown, maroon, or red. The sandstone is poorly cemented, clean or dirty, fine- to medium-grained, and calcareous or non-calcareous. Limestone beds generally account for less than 20 percent of the section, although in places limestone or coquina is the dominant lithology. The Lakhra Formation is 400 m thick in the Karachi Trough (Quadri and Shuaib, 1986) and 194 m thick on the Lakhra Anticline (Wnuk, Fariduddin, and others, 1991). There are conflicting reports concerning the thickness and distribution of the Lakhra Formation north of the Lakhra Anticline. The Hunting Survey Corporation (1961) has indicated that the Upper Ranikot (Lakhra) Formation is not present in the Lakhi Range. Cheema and others (1977) disagree with the Hunting Survey assessment, stating that the Lakhra is present in the Lakhi Range, but they indicated that the Lakhra Formation is absent in the Fort Ranikot area. Ahmed and Siddiqui (unpublished data), and Farshori (unpublished data) report the presence of at least 50 m of Lakhra Formation in the Fort Ranikot area. Wnuk, Fariduddin, and others (1991) show the

Lakhra thinning northward from the core of the Lakhra Anticline. Consequently, the absence of Lakhra strata at the principal reference section, which is approximately 30 km north of the crest of the Lakhra Anticline would be a reasonable consequence of the observed thinning trends within the Formation.

The terms Bara Formation and Ranikot Group are often used interchangeably within this report. The stratigraphic nomenclature of the Paleocene strata in Sindh is confused. The Hunting Survey maps do not actually identify a Bara Formation, rather they map the undivided Ranikot Group consisting of, from bottom to top, the Cardita beaumonti beds, the Lower Ranikot Formation, and the Upper Ranikot Formation. Current stratigraphic usage by the Geological Survey of Pakistan is summarized by Cheema and others (1977). They rename the three Hunting subdivisions, from bottom to top, as the Khadro Formation (after Williams, 1959), the Bara Formation, and the Lakhra Formation. Among geologists from the oil industry, the term Ranikot Formation is used by some authors for the Bara Formation only while the Lakhra Formation is correlated to the Dungan Formation of Balochistan (Williams, 1959). Other authors use the term Ranikot Formation to include the Khadro, Bara, and Lakhra Formations (Quadri and Shuaib, 1986).

The Paleocene Sohnari Formation (fig. 4) of Outerbridge and others (1991) consists of beds of gray and white sandstone, and gray siltstone and claystone that weather maroon, red, purple, and sometimes gray and white. Where the formation is thin, it usually consists of beds of very indurated gray claystone that weathers to a distinctive red color. Beds of coal and shale-pebble conglomerate occur in places. Up to 5 percent of the Sonhari section thickness may be coal but economic coal deposits are only known to

occur in the area between Meting and Jhimpir (fig. 2). The formation is up to 58 m thick south of the Lakhra Anticline but may be absent in the Lakhi Range (Wnuk, SanFilipo, and others, 1991).

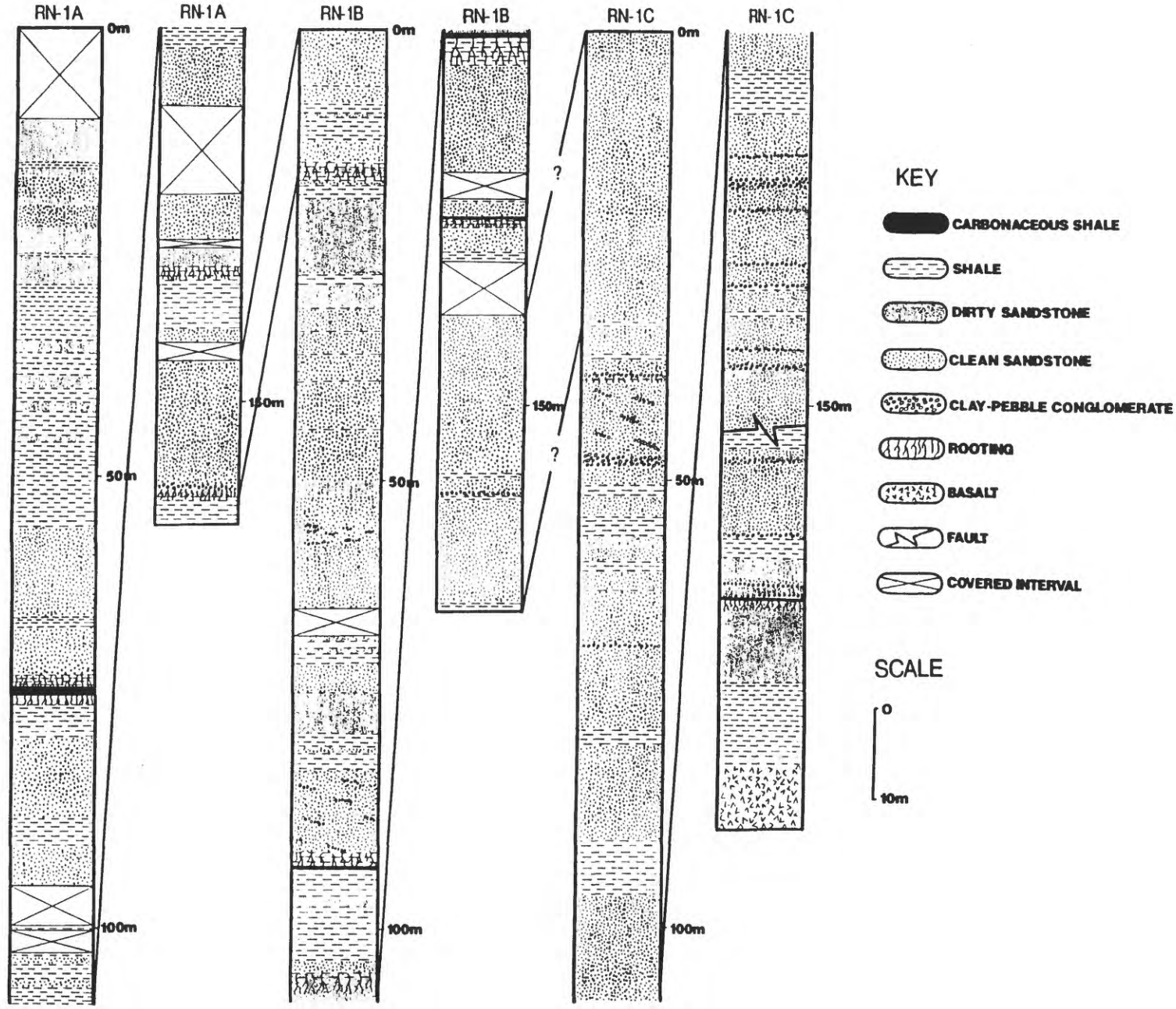
The Paleocene-Eocene Laki Formation (Usmani, 1983) consists of beds of light gray limestone interbedded with olive colored shale. The nomenclature for this formation is confused, but an overview of the naming conventions can be obtained from Cheema and others (1977), Ahmed and others (1984) and Outerbridge and others (1991). The Laki Formation ranges in thickness from 600 m at the southern end of the Lakhra Anticline to 240 m in the northern part of the Lakhi Range (Cheema and others, 1977).

METHODS

The Fort Ranikot section (Appendix 1 and fig. 5) was measured in March 1990, with a brunton and Jacob's staff. Approximately 537.55 m of section were measured in three offset sections (fig. 3), RN-1A, 1B, and 1C. Subtracting 51.7 m of overlap between the offset sections, the total measured thickness of the Bara Formation was 485.85 m, from the top of the basalt to the contact with the overlying Laki Formation. Of the total measured section thickness, 42.30 m, or approximately 8 percent of the section was covered. Section RN-1A had the greatest amount of covered interval, 30.10 m of the total 163.26 m (18 percent), section RN-1B contained 12.20 m of covered interval of the total section length of 175.81 m (7 percent), and there were no covered intervals in section RN-1C which was 197.48 m thick0.

The section was sampled and examined by the paleontologists S. Farah Fatmi from the Geological Survey of Pakistan and Elizabeth Brouwers from the U.S. Geological Survey. They collected 14 samples for palynological and

FIGURE 5: LITHOLOGIC LOG OF THE BARA FORMATION AT FORT RANIKOT, SINDH.



paleontological analysis. Seven of these samples were scanned for pollen. Results of the pollen scan are discussed in Frederiksen (1992).

RESULTS AND DISCUSSION

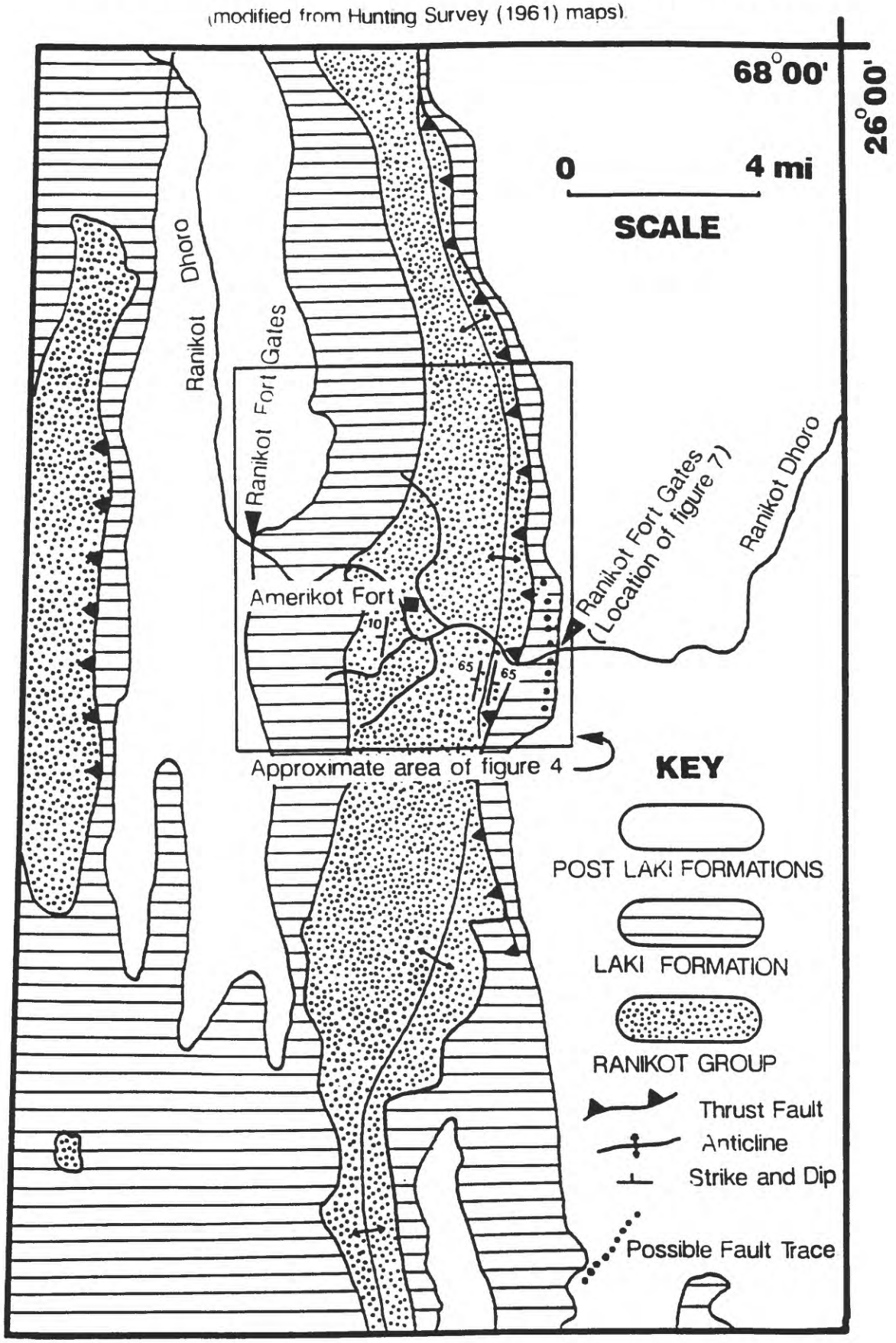
The Bara Formation is exposed in the core of the north to north-northeast trending, anticlinal Lakhi Range (fig. 6). The anticline is asymmetrical with the western flank being much broader than the eastern flank. Maximum dips around the core of the anticline are 65 degrees. The western flank flattens to less than 10 degrees 300 m from the axial trace. The Bara Formation was measured in the east flank of the anticline because it is better exposed there. The formation is mostly covered in the western flank due to the gentler dips.

There are several structural complications in the measured section. Bedding-plane faults were detected in some shale beds. Also, some of the thinner shaly intervals (5 m or less) between thick sandstone units varied in thickness by 100 percent over distances as short as 100 m. For comparison, similar shaly zones in the less deformed western flank of the anticline maintain approximately uniform thickness over distances approaching 1 km. Both the bedding-plane faults and the apparent flow of the shales are interpreted as structural readjustment of the strata caused by the folding. Until a section of the Bara Formation is measured in the less deformed western flank of the anticline, there is no way to estimate how much the shaly intervals on the measured section may have been thinned by faulting and flowage.

One reverse fault cuts section RN-1A. The fault is subparallel to bedding and occurs in one of the clean sandstone units. We were unable to

FIGURE 6: Geology of the Fort Ranikot area in the northern part of the Lakhi Range as mapped by the Hunting Survey Corporation.

(modified from Hunting Survey (1961) maps).



determine the amount of movement on this fault, but because there is no structural deformation (drag folding) of the strata along the fault trace and because the fault is subparallel to bedding we believe that this fault does not significantly alter the thickness of the section.

The Hunting Survey (1961) maps (Geological Map No. 6, Thano Bula Khan and Geological Map No. 11, Bela) show multiple faults between the Laki Limestone and the underlying formations in the northern part of the Lakhi Range and at least one fault between the Laki and Ranikot Groups in the southern part of the Lakhi Range. Abdullah (1980) has shown that the faults mapped by the Hunting Survey in the northern half of the Lakhi Range (between 26°00′ and 26°15′ N, on Geological Map No. 11, Bela) are thrust faults. A reconnaissance survey by us to Bara Dhoro (fig. 2) in 1989 to visit the Bara Formation type section confirmed Abdullah's observations. From the Hunting Survey map of the Fort Ranikot area (26~00′ to 25~45′ N, Geological Map No. 6, Thano Bula Khan) a thrust fault would be presumed to separate the Laki Formation from the Ranikot Group as well. However, on traversing Ranikot Dhoro across the fault trace indicated on the Hunting maps, no evidence of a fault crossing the stream was found by us. On a northward traverse up the first tributary west of the Ranikot Fort wall, bedding irregularities and dip changes indicative of a fault were seen, but the scale and intensity of the observed deformation appeared too little to have been caused by a major thrust. No bedding disturbances were observed south of Ranikot Dhoro where the section RN-1C was measured. A box fold (fig. 7) within the Laki Limestone was seen on an eastward traverse to the Fort Ranikot gateway. If this structure is interpreted as a drag fold, the plane of the thrust fault mapped by the Hunting Survey would appear to pass through the Laki Limestone in this area and the Laki-Bara contact may,

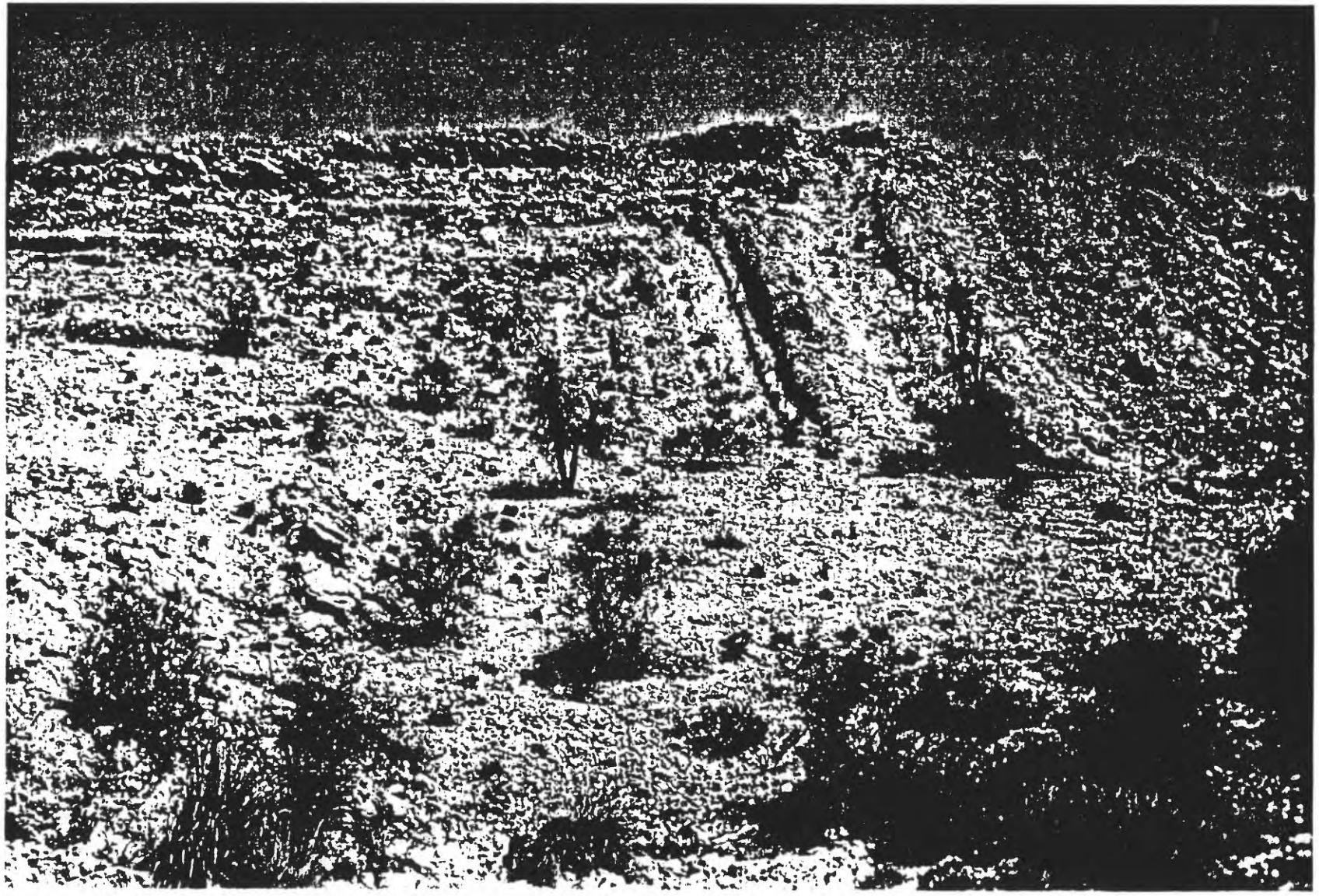


FIGURE 7: DETAIL OF POSSIBLE DRAG FOLDS

therefore, be undisturbed.

Because of the apparent absence of major structural deformation along the lines of measured section, we are of the opinion that the measured section encompasses the complete Bara Formation. There are, however, some stratigraphic anomalies in the Bara-Laki succession in this area that may yet prove to be structurally controlled. These will be discussed below.

The Laki-Bara contact is covered at the top of Section RN-1C, but it is exposed 300 m to the north. There, light-gray, rooted underclays are in direct contact with the Laki Limestone. The stratigraphic succession is similar to the Laki-Sohnari transition some 30 km to the south-southeast in the Lakhra Anticline described by Wnuk, SanFilipo, and others, (1991) except that the rooted zone is not as intensely leached as are root zones in the Sohnari further to the south (though this has yet to be confirmed by chemical analysis). Also the very distinctive breccia-like claystone texture and bright red coloration of the Sohnari in Lakhra are absent at Fort Ranikot.

Characteristic Lakhra lithologies are also absent. This observation is in contradiction to the results of Ahmed and Siddiqui (unpublished data) who reported approximately 50 m of Lakhra strata topping approximately the same section as ours. Their criteria for distinguishing between the Lakhra and Bara Formations is unclear. Their section description indicates that the Lakhra and Bara Formations are lithologically identical. Analysis of their stratigraphic column and descriptions suggests that they make the distinction on the basis of the first appearance of shell remains. However, south of the Lakhi Range, Lakhra shell assemblages typically contain well preserved Turritella and other gastropods, forams, crinoids, bivalves, crustaceons, echinoderms, and corals in well exposed beds. We did not

observe any shell remains in this section although the Bara is known to contain low diversity assemblages of thin-shelled bivalves, gastropods and forams in Lakhra and areas to the south (Wnuk and others, 1992). Ahmed and Siddiqui (unpublished data) also report that plant fossils occur within the section that they identified as Lakhra at Fort Ranikot. The detailed studies of the Lakhra Formation in Lakhra by Wnuk, Fariduddin, and others (1991) show that the Lakhra Formation does not contain plant fossils, and that it tends to be low in organic debris in general. Furthermore, the Lakhra formation weathers to a very characteristic yellow-brown color in the areas where it is exposed south and east of the Lakhi Range. We attribute this coloration to the chemical decomposition of glauconite that is abundant in the Lakhra Formation drill core. Similarly colored, yellow-brown sediments were not observed on the east flank of the anticline in the Fort Ranikot section. Yellow-brown rocks were seen below the Laki Limestone in the western flank of the anticline, but these rocks could not be studied during either 1989 or 1990 so it is not known if they represent Lakhra strata. On the basis of these several observations, it is our opinion that the Lakhra Formation is absent at the Fort Ranikot area.

Various explanations can account for the apparent absence of the Lakhra and Sohnari Formations including: 1) a fault causing the juxtaposition of the Laki Formation against the Bara Formation; 2) an unconformity that removed the Sohnari and Lakhra Formations, and possibly even the top of the Bara Formation; or 3) non-deposition of the Sohnari and/or Lakhra Formations over a local topographic high. Because there is no clear evidence of a fault between the Laki and the Bara Formations in the area of the measured section, the first explanation appears to be incorrect. However, if Lakhra rocks are found in the western flank, the first

explanation will need to be reconsidered. Without additional stratigraphic studies in the Lakhi Range, it is difficult to choose between the second and third stratigraphic alternatives and their various permutations. At first inspection, the presence of a Bara-like (rather than an intensely weathered and leached Sohnari-like) rooted seat earth in contact with the Laki Limestone may be taken as evidence of an erosional unconformity between the Laki and the underlying strata. According to this interpretation the Sohnari, Lakhra, and a part of the Bara Formations were eroded prior to the deposition of the Laki Limestone. However, the concurrent northward thinning of both the Sohnari and Lakhra Formations documented by Wnuk, SanFilipo, and others (1991) and Wnuk, Fariduddin, and others (1991) in the area of the Lakhra Anticline is more consistent with the third alternative - that the Sohnari and Lakhra thin and pinch-out over a pre-existing high. Alternatively, Outerbridge and others (1991) have suggested that the Sohnari is a tongue of the Bara. The implication in the Fort Ranikot area is that the Lakhra Formation may pinch-out while the Sohnari and Bara Formations coalesce.

No lignites were exposed in the Ranikot section, but three factors may explain the apparent lack of coal. First, in the Lakhra and Sonda coal fields, lignites are found in the fine-grained facies that occur between the thick, clean, sandstone units (SanFilipo and others, 1988). At Fort Ranikot, six intervals were mostly covered and their detailed lithology could not be determined. Based on small exposures and weathering characteristics, these intervals are interpreted to consist primarily of fine-grained sediments. Second, the section was measured across the area of tightest folding and there is some evidence that fine-grained rocks (which would include the beds of lignite) may have been squeezed out as a result of the deformation.

Third, weathering may have obscured thinner lignite beds. On the Lakhra Anticline weathering effects are known to penetrate as deeply as 30 m below the surface so we made no attempt to excavate covered parts of the section.

Ten rooted intervals were found in the Fort Ranikot section (Table 1). Wnuk and others (1993) note that 41 of 47 rooted intervals (87 percent) in the Bara Formation strata penetrated by the Pakistan Mineral Development Corporation test hole (designated THL, fig. 2) are immediately overlain by a coal or carbonaceous shale bed. The 6 rooted zones not overlain by coal in the test hole are instead in erosive contact with an overlying sandstone bed. The coals were probably eroded prior to or as a consequence of the deposition of these sandstones. The presence of rooted zones at Fort Ranikot suggests that the coal potential of this area should not be discounted until additional studies are made, especially given the strong association between rooted zones and coal and carbonaceous shale beds in the Bara Formation occurring in the other areas drilled in south Sindh.

Rooted zones occur throughout the Bara section at Fort Ranikot, although they are most abundant in the upper two-thirds of the formation. This distribution of rooting differs significantly from root distribution in the PMDC THL hole where rooted strata occur only in the upper 260 m of the 565 m of Bara that were penetrated in that hole (Wnuk, and others, 1993). A bed of carbonaceous shale overlying a rooted underclay was exposed 18.45 m above the base of the Bara Formation in a cut bank of Ranikot Dhoro in section RN-1C. The shale was relatively unweathered. Palynological analysis of sample EB-90-88 indicates that it may be from the oldest preserved Paleocene terrestrial facies in the Bara Formation. Although the results of the analysis are not definitive, they are not inconsistent with a Danian age (Frederiksen, written communication, 1992). This lower zone did not appear

TABLE 1

Thickness and intercepts of carbonaceous shale, rooted intervals, and covered intervals in measured sections RN-1A, RN-1B, and RN-1C.

SECTION RN-1A

INTERVAL	LITHOLOGY	UNIT	ROOTING	BED THICKNESS	BED INTERCEPTS
1	covered	1	?	10.00 m	0.00-10.00 m
2	siltstone	44	rooted	1.55 m	71.44-72.99 m
2	carbonaceous shale	45	rooted	0.95 m	72.99-73.94 m
2	sandstone	46	rooted	1.30 m	73.94-75.24 m
2	sandstone	47	rooted	0.80 m	75.24-76.04 m
2	mudstone	48	rooted	2.50 m	76.04-78.54 m
2	shale	49	rooted	0.15 m	78.54-78.69 m
3	covered	53	?	4.50 m	95.19-99.69 m
3	shale	54	not observed	0.62 m	99.69-100.31 m
3	covered	55	?	2.30 m	100.31-102.61 m
4	covered	63	?	10.20 m	117.06-127.26 m
5	covered	65	?	1.10 m	131.96-133.06 m
5	sandstone and shale	66	not observed	1.80 m	133.06-134.86 m
5	mudstone	67	rooted	7.00 m	134.86-141.86 m
5	sandstone	68	not observed	1.70 m	141.86-143.56 m
5	covered	69	?	2.00 m	143.56-145.56 m
6	sandstone	73	rooted	1.10 m	159.16-160.26 m

(this interval correlates to units 9-11 in section RN-1B)

TABLE 1 (continued)

SECTION RN-1B

INTERVAL	LITHOLOGY	UNIT	ROOTING	BED THICKNESS	BED INTERCEPTS
6	shale	9	rooted	0.35 m	14.43-14.78 m
6	sandstone	10	rooted	0.30 m	14.78-15.08 m
6	shale	11	rooted	1.40 m	15.08-16.48 m
7	covered	34	?	3.20 m	67.25-70.45 m
8	shale	46	rooted	1.40 m	94.40-95.80 m
8	carbonaceous shale	47	not observed	0.50 m	95.80-96.30 m
9	shale	52	rooted	0.40 m	107.75-108.15 m
9	sandstone	53	rooted	1.95 m	108.15-110.10 m
10	carbonaceous shale	55	not observed	0.05 m	111.60-111.65 m
10	carbonaceous shale	56	not observed	0.10 m	111.65-111.75 m
10	shale	57	not observed	0.20 m	111.75-111.95 m
10	carbonaceous shale	58	not observed	0.40 m	111.95-112.35 m
10	shale	59	rooted	3.00 m	112.35-115.35 m
11	covered	61	?	3.00 m	127.35-130.35 m
12	carbonaceous shale	64	rooted	1.20 m	132.25-133.45 m
13	covered	67	?	6.00 m	137.11-143.11 m

TABLE 1 (continued)

SECTION RN-1C

INTERVAL	LITHOLOGY	UNIT	ROOTING	BED THICKNESS	BED INTERCEPTS
14	shale	10	rooted	0.50 m	38.25-38.75 m
15	shale	15	rooted ?	0.80 m	50.25-51.05 m
16	carbonaceous shale	79	not observed	0.20 m	172.83-173.03 m
16	sandstone	80	rooted	1.05 m	173.03-174.08 m

to have coal potential in this area; however, the occurrence of terrestrial have potential for coal elsewhere in Sindh.

CONCLUSIONS AND RECOMMENDATIONS

Because field time was very limited, this investigation had to be a reconnaissance survey. The primary objective of this study was to measure and describe as complete a section of the Bara Formation as possible, because existing descriptions of both the type section and the principal reference section lack detail and the measurements are contradictory. We hoped to return to this area at a later date to consider the structural complexities. However, a return proved to be impossible due to security requirements stemming from an armed attack on one of our field parties. Consequently, a number of unresolved structural questions persist. Accurately determining whether the Sohnari, Lakhra, and Bara Formations thin, thicken, are faulted, or eroded in the Lakhi Range has significant implications for future coal exploration in the Fort Ranikot area. According to the data published in the Hunting Survey maps (Hunting Survey, 1961), the Bara Formation underlies at least 600 sq km of the Lakhi Range. This is an area comparable in size to the area currently producing coal on the Lakhra Anticline. If coal is present in the Bara Formation in the Lakhi Range, it may be accessible by mining directly into the Bara Formation exposed in the western flank of the Lakhi Anticline and possibly in the ridges west of the Lakhi Range. If the Sohnari and Lakhra Formations are thinned or absent, Bara Formation coal beds may also be accessible by shaft in areas where the overlying Laki Formation (which Cheema and others (1977) report to be up to 240 m thick in this area) has been thinned by erosion.

The measurements of the section in the Fort Ranikot area must be considered preliminary. There are enough questions about the geology of the Bara Formation strata around the Fort to justify additional work there. More work must be done to resolve the disparities in the reported thicknesses of the Bara Formation and to confirm the apparent absence of the Lakhra Formation and Sohnari Formation in this region.

Excellent exposures of the Bara Formation can be found in many places throughout the Lakhi Range. In order to obtain a more complete understanding of the coal potential of the Fort Ranikot area and the facies characteristics and variability of the Bara Formation, a series of sections should be measured over the length of the Lakhi Range.

The numerous carbonaceous shales and rooted intervals suggest that this area has a coal potential, and a surficial geologic survey can go far to evaluate this potential. However, surficial and structural processes tend to obscure the coal beds, so one or two well placed drill holes will be needed to more definitively evaluate the coal prospects of this area.

According to the Hunting Survey maps, Ranikot (probably Bara Formation) rocks are also exposed between the Bera and the Daphro East Ridges directly west of Fort Ranikot, and in a small outlier in the Daphro West Ridge. These areas are accessible by 4-wheel drive vehicles and should be included in a follow-up study.

The Hunting Survey maps indicate that there are Laki Formation outliers west of the Daphro West Ridge. Though these outliers appear to be severely faulted and folded and probably would be difficult to mine, if a coal resources are eventually proven to occur in the Lakhi Range, then the rocks under these far western Laki outcrops may also become prospective for coal.

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APPENDIX 1

PRINCIPAL REFERENCE SECTION AT RANIKOT FORT

SECTION RN-1A

The section begins at the base of the first exposed Laki Limestone ledge.

BARA FORMATION

1. Covered: Lithology is unknown but may include some Laki Limestone; the thickness of the covered interval has been estimated; 10.00 m (10.00 m) contact unknown:

2. Sandstone: Tan; very fine-grained, dirty; composed of quartz, abundant interstitial clay, and in places, the matrix is silicified giving the rock an orthoquartzitic appearance; CONTAINS: 10 cm festoon cross-bedding at the base of the unit, followed by 30 cm massive sandstone, then a 10 cm thick festoon cross-set interpreted to be asymmetrical ripples, then 20 cm massive sandstone, then 30 cm of planar laminated sandstone, then 20 cm massive sandstone, and the unit is topped by 30 cm of planar laminated sandstone; sharp contact with: 1.50 m (11.50 m)

3. Sandstone: Light gray; very fine-grained, dirty; composed of quartz and abundant interstitial clay; weathered, friable, slope former; CONTAINS: no evidence of bedding except for some very faint traces of planar laminations at the top of the unit; sharp contact with: 0.90 m (12.40 m)

4. Ironstone: Deep maroon; argillaceous, sandy in places; parent rock appears to be a claystone though the unit weathers like a sandstone; the top 10 cm of the unit is bleached in places and shows an irregular contact with the underlying red material the unit looks like the typical Sohnari Member further to the south: 0.75 m (13.15 m)

5. Sandstone: Gray to pale yellow; very fine-grained, dirty; composed of quartz and abundant interstitial clay; very weathered, friable, slope former; CONTAINS: lenses of siltstone; abundant gypsum; no evidence of bedding: 0.80 m (13.95 m)

6. Sandstone: Maroon, iron-stained; fine-grained, dirty; composed of quartz and abundant interstitial clay; ledge former; CONTAINS: no evidence of bedding; grades into: 0.70 m (14.65 m)

7. Shale: Medium gray; silty, coarsens upward into a very fine-grained sandstone at the top of the unit; CONTAINS: planar, very fine-grained quartz sandstone laminations and flint clay layers up to 5 cm thick in places in the lower part of the 0.50 m (15.15 m)

unit, grading into a sandstone with silt laminations in the upper part of the unit:

8. Ironstone: Maroon:

0.10 m
(15.25 m)

9. Shale: Light gray, weathers brown; silty, sandy in places; poorly exposed; slope former; grades into:

0.50 m
(15.75 m)

10. Sandstone: Maroon and gray; very fine-grained becomming increasingly silty upward; composed of quarts and abundant interstitial clay and silt; slope former; CONTAINS: planar silty shale laminations; abundant secondary gypsum; appears to be dominated by flat bedding but unit is poorly exposed; sharp contact with:

0.75 m
(16.50 m)

11. Sandstone: Dark maroon; very fine- to fine-grained; composed of quartz and a few dark minerals; CONTAINS: secondary gypsum; pseudobotryoidal ironstone at the top of some beds which are cemented by gypsum; beds 10 to 20 cm thick in which the bedding appears massive and homogeneous possibly due to weathering, these beds are separated by 2 to 5 cm thick sets of symmetrical oscillation ripples; sharp contact with:

0.70 m
(17.20 m)

12. Sandstone: White, weathers maroon; very fine-grained, subangular; composed of quartz, and sparse mica and dark minerals; friable; poorly exposed; CONTAINS: no evidence of bedding:

1.30 m
(18.50 m)

13. Sandstone: Red; very fine- to fine-grained; composed of quartz, and sparse mica and dark minerals; CONTAINS: faint bedding, possibly of current ripples or small scale planar cross-beds; grades into:

0.35 m
(18.85 m)

14. Sandstone: Very light gray; very fine-grained, subrounded; composed of quartz, a few dark mineral grains, sparse mica flakes, and some interstitial kaolinite-like clay; CONTAINS: slightly irregular bedding; dark gray siltstone laminations; sharp contact with:

0.70 m
(19.55 m)

15. Sandstone: Maroon; very fine-grained, subrounded; composed of quartz and sparse mica; ledge former; CONTAINS: faint planar bedding though most traces of bedding appears to have been erased by weathering; sharp contact with:

0.40 m
(19.95 m)

16. Sandstone: White, very fine-grained, moderately clean; composed of quartz, some mica, and some interstitial clay; CONTAINS: faint siltstone laminations; grades into:

0.10 m
(20.05 m)

17.	Sandstone:	0.25 m (20.30 m)	Red; very fine- to fine-grained, subrounded; composed of quartz, and some mica flakes; CONTAINS: red siltstone laminations, unit dominated by planar bedding though it appears to have small current ripples in places; grades into:
18.	Sandstone:	0.15 m (20.45 m)	White; very fine-grained, subrounded; composed of quartz; friable; CONTAINS: dark brown flat to wavy silt laminations; abundant carbonaceous debris and mica on silt lamina surfaces; no current features observed; sharp contact with:
19.	Sandstone:	0.40 m (20.85 m)	Pink; very fine- to fine-grained, subrounded; composed of quartz; ledge former; CONTAINS: faint, low-angle wedge sets and small oscillation ripple sets between the wedge sets; sharp contact with:
20.	Shale:	0.10 m (20.95 m)	Light gray; silty; sharp contact with:
21.	Sandstone:	1.00 m (21.95 m)	Light gray to white; very fine- to fine-grained, subangular, silty; composed of quartz and some interstitial silt; friable; slope former; CONTAINS: indistinct bedforms due to the intensity of the weathering; in places the unit is cemented with gypsum at the surface:
22.	Sandstone:	3.10 m (25.05 m)	White with purple banding; very fine- to fine-grained, argillaceous; composed of quartz and abundant interstitial clay; ledge former; CONTAINS: wavy to flat bedding with some shale laminations, bedding occurs in sets up to 10 cm thick, bedding sets thicken to 30 cm toward the top of the unit; tabular sets of low-angle cross-beds between small current and oscillation ripple sets 2 to 10 cm thick, ripple amplitudes are approximately 2 cm; moderately burrowed, burrows vertical and mostly confined to the current ripple sets; small growth faults up to 10 cm in length offset bedding sets; sharp contact with:
23.	Claystone:	0.65 m (25.70 m)	Gray; interbedded with hard, white flint clay, flint clay beds are up to 5 cm thick; shale interbeds are up to 5 to 10 cm thick; flint clay becomes more abundant toward the middle of the unit; CONTAINS: sparse carbonaceous debris toward the base of the unit; grades into:
24.	Sandstone:	0.60 m (26.30 m)	White with purple banding; very fine- to fine-grained, argillaceous; composed of quartz and abundant interstitial clay; ledge former; CONTAINS: wavy to flat bedding with some shale laminations, bedding occurs in sets up to 10 cm thick, at the base, the sets are flat to wavy bedded, at the top the sets are capped with oscillation ripples; contact covered:
25.	Sandstone:	0.15 m	White, weathers gray; fine- to medium-grained, slightly argillaceous; composed of quartz and some kaolinite-like clay matrix:

(26.45 m)

26. Sandstone: White with purple mottling, very fine-grained, argillaceous; composed of quartz and abundant kaolinite-like clay matrix; 1.05 m ledge former; CONTAINS: no evidence of bedding, unit (27.50 m) believed to have been bioturbated; sharp contact with:

27. Interbedded sandstone and shale: Sandstone is white, weathers maroon; very fine- to fine-grained, muddy; composed of quartz and 0.80 m abundant interstitial clay and silt; occurs in beds 5 to (28.30 m) 15 cm thick; CONTAINS: small scale ripples,; some flint clay partings; Shale is gray; occurs in beds up to 10 cm thick CONTAINS: very fine-grained quartz sand laminations, scattered carbonaceous debris on bedding plane surfaces; sharp contact with:

28. Shale: Gray-brown, with ocher staining; silty; CONTAINS: scattered carbonaceous debris on bedding plane surfaces; sulfur 7.00 m staining; selenite beds up to 10 cm thick at the top of the (35.30 m) unit; grades into:

SAMPLE 90-FF-1 COLLECTED 4 m ABOVE THE BASE OF UNIT 28

29. Sandstone: White; fine- to medium-grained, subangular, dirty; composed of quartz and some kaolinite-like clay in the matrix; 0.67 m CONTAINS: abundant siderite nodules; faint laminar bedding; (35.97 m) sharp contact with:

30. Shale: Pale chocolate brown; slightly silty; fissile; poorly exposed; CONTAINS: abundant carbonaceous debris on bedding 1.50 m plane surfaces; no evidence of rooting; sharp contact with: (37.47 m)

31. Shale: Pink-gray to light gray; very silty; CONTAINS: scattered carbonaceous debris on bedding plane surfaces; grades into: 1.10 m (38.57 m)

32. Sandstone: Medium gray; very fine- to medium-grained, extremely muddy; composed of quartz and extremely abundant interstitial clay 0.30 m and silt; almost a mudstone; homogeneous; CONTAINS: no (38.87 m) evidence of bedding; grades into:

33. Sandstone: light brown, weathers red; very fine- to medium-grained, poorly sorted, argillaceous; composed of quartz and abundant 1.00 m interstitial clay; CONTAINS: brown-gray shale laminations up (39.87 m) to 3 cm thick; abundant gypsum and siderite nodules; grades into:

34. Shale: Medium gray, weathers brown; slightly silty; poorly exposed; slope former; CONTAINS: common carbonaceous debris on 1.80 m bedding plane surfaces; carbonaceous films are wad stained or (41.67 m) pyritic in places; no evidence of rooting but the unit is extremely weathered and fissile; abundant siderite nodules;

selenite crystals:

35. Sandstone: Red-brown; very fine-grained, muddy; composed of quartz and abundant interstitial clay; friable; CONTAINS: faint planar laminations; grades into:
1.00 m
(42.67 m)

36. Shale: Medium gray, weathers brown; slightly silty; poorly exposed; slope former; CONTAINS: common carbonaceous debris on bedding plane surfaces; carbonaceous films are wad stained or pyritic in places; no evidence of rooting but the unit is extremely weathered and fissile; abundant siderite nodules; selenite crystals; grades into:
3.00 m
(45.67 m)

37. Sandstone: Red-brown; very fine-grained, muddy; composed of quartz and abundant interstitial clay; friable; CONTAINS: faint planar laminations; grades into:
0.40 m
(46.07 m)

38. Shale: Medium gray, weathers brown; slightly silty; poorly exposed; slope former; CONTAINS: abundant carbonaceous debris on bedding plane surfaces; carbonaceous films are wad stained or pyritic in places; no evidence of rooting but the unit is extremely weathered and fissile; abundant siderite nodules; selenite crystals; sharp contact with:
9.50 m
(55.57 m)

39. Sandstone: White, brown-gray; fine- to medium-grained, fines upward to very fine- to fine-grained at the top of the unit; subrounded, clean; composed of quartz and no interstitial clay; friable; slope former; CONTAINS: platy bedded at the top of the unit; faint planar bedding in places, otherwise the unit appears homogeneous; burrows?; sharp contact with:
9.50 m
(65.07 m)

40. Flint clay: White with brown banding; hard but has a soft coating that appears to be gypsum (entire unit gypsum?); sharp contact with:
0.07 m
(65.14 m)

SAMPLE 90-JRS-1 COLLECTED IN UNIT 40

41. Sandstone: White, mottled red and brown; fine-grained, argillaceous; composed of quartz and abundant interstitial clay; CONTAINS: planar laminations and a few white flint clay partings; sharp contact with:
1.30 m
(66.44 m)

42. Sandstone: Maroon with white and red banding; fine- to medium-grained, angular to subangular, clean; composed of quartz and no interstitial clay; CONTAINS: tabular sets of low-angle planar cross-beds; sharp contact with:
3.00 m
(69.44 m)

43. Sandstone: Yellow-brown with purple staining and mottling; fine-grained, well sorted, dirty; composed of quartz and abundant interstitial clay; CONTAINS: low-angle cross-bed sets and parallel laminated wedge-sets up to 70 cm thick, individual bed sets truncate one-another at low angles; sharp contact
2.00 m
(71.44 m)

with:

44. Siltstone: Light gray; fissile; CONTAINS: roots; abundant very fine-grained quartz sand laminations; sharp contact with:
1.55 m
(72.99 m)

45. Carbonaceous shale: Chocolate-brown; fissile; possibly the remains of an oxidized bone-coal or coal; sharp contact with:
0.95 m
(73.94 m)

46. Sandstone: White with red mottling; fine-grained, sub-angular to sub-rounded, well sorted, dirty; composed of quartz and abundant interstitial clay; CONTAINS: roots; relict low-angle cross-beds, cross-bed sets truncate one another at low angles; grades into:
1.30 m
(75.24 m)

47. Sandstone: Light gray; fine-grained, poorly sorted, extremely dirty; composed of quartz and very abundant interstitial clay; intensely rooted; massive; homogeneous; CONTAINS: no evidence of bedding; grades into:
0.80 m
(76.04 m)

48. Mudstone : Medium gray; massive; homogeneous; rooted throughout; CONTAINS: fine-grained, matrix-supported quartz sand scattered throughout; sharp contact with:
2.50 m
(78.54 m)

49. Shale: Light gray; rooted; sharp contact with:
0.15 m
(78.69 m)

50. Sandstone: Cream and purple-black; fine-grained coarsening upward to fine- to medium-grained, sub-rounded to sub-angular, well sorted, clean; composed of quartz and little interstitial clay; poorly cemented, friable; CONTAINS: low-angle cross-bed sets that truncate one another at low angles; sharp contact with:
9.10 m
(87.79 m)

51. Shale: Light brown; fissile; CONTAINS: sparse carbonaceous debris on bedding plane surfaces; rare, very fine-grained quartz sand laminations; grades into:
2.70 m
(90.49 m)

52. Sandstone: White, violet, pink, maroon, yellow-brown; fine-grained, fines upward to very fine- to fine-grained at the top, sub-rounded to sub-angular, well sorted, clean; composed of quartz and some interstitial clay, unit becomes more argillaceous upward; CONTAINS: clay bands and laminations at the base of the unit, and appears to be planar laminated throughout; burrows, in places the unit appears intensely burrowed; contact unknown:
4.70 m
(95.19 m)

53. Covered: Lithology unknown:

4.50 m
(99.69 m)

54. Shale: Medium gray; CONTAINS: abundant, very fine-grained quartz sand laminations; abundant carbonaceous debris on bedding plane surfaces; contact unknown:

0.62 m
(100.31 m)

55. Covered: Lithology unknown:

2.30 m
(102.61 m)

56. Shale: Medium gray; CONTAINS: abundant very fine-grained quartz sand laminations, laminations become more abundant toward the top and the unit coarsens upward into a laminated sandstone at the top; abundant carbonaceous debris on bedding plane surfaces; sharp contact with:

0.70 m
(103.31 m)

SAMPLE EB-90-103 COLLECTED 35 cm FROM THE TOP OF UNIT 56

57. Sandstone: Cream, red and yellow-brown; very fine- to fine-grained, sub-angular, well sorted, clean; composed of quartz, ferruginous cement, and little interstitial clay; internal bedforms, if present, are obscured by the ferruginous cement; sharp contact with:

0.90 m
(104.21 m)

58. Shale: Chocolate-brown; fissile; CONTAINS: sparse carbonaceous debris though carbonaceous debris is abundant on some bedding-plane surfaces; rare sulfurous efflorescence; sharp contact with:

1.35 m
(105.56 m)

59. Sandstone: Variegated red, white, and yellow-brown; fine-grained, sub-angular to primarily sub-rounded, well sorted, very clean; composed of quartz and no interstitial clay; poorly cemented, friable; CONTAINS: low-angle cross-beds, individual cross-bed sets truncate one another at low angles; sharp contact with:

1.10 m
(106.66 m)

60. Mudstone: Yellow-brown and gray; massive; homogeneous; CONTAINS: matrix-supported very fine- to medium-grained quartz grains; rounded, ferruginous concretions at the top of the unit; no evidence of bedding; grades abruptly into:

3.90 m
(110.56 m)

61. Sandstone: Cream; fine- to medium-grained, sub-angular to sub-rounded, well sorted, clean; composed of quartz, zones of ferruginous cement that parallel ground surface but cross internal bedding surfaces within the sandstone, and little interstitial clay; internal bedforms cannot be determined due to the intensity of the weathering; sharp contact with:

4.20 m
(114.76 m)

62. Sandstone: Dark brown; fine- to medium-grained coarsening upward to

medium-grained at the top of the unit, sub-angular to sub-
2.30 m rounded, well sorted, moderately clean; composed of quartz,
(117.06 m) some interstitial clay, and abundant ferruginous cement;
CONTAINS: low-angle cross-beds, individual cross-bed sets truncate one another at low angles; contact unknown:

63. Covered: Lithology unknown:

10.20 m
(127.26 m)

64. Sandstone: Yellow-brown; fine-grained, sub-angular to sub-rounded, well sorted, moderately clean; composed of quartz and some
4.70 m interstitial clay; unit deeply weathered so internal bedforms
(131.96 m) cannot be determined; top and base of the unit not seen; contact unknown:

65. Covered: Possibly shale; contact unknown:

1.10 m
(133.06 m)

66. Interlaminated sandstone and shale: Sandstones are light gray; very fine-grained, sub-rounded to sub-angular, well sorted, clean;
1.80 m composed of quartz, some dark minerals, and little
(134.86 m) interstitial clay; laminations are usually less than 1 mm thick though some beds are up to 1 cm thick. Shales are chocolate-brown and yellow-brown, and appear to be coaly in places; they contain abundant carbonaceous debris on bedding plane surfaces. Unit contains abundant horizontal bedding plane burrows; sharp contact with:

67. Mudstone: Olive-gray with yellow-brown and red mottling; fines downward to siltstone; blocky; hard; possibly rooted; CONTAINS:
7.00 m interbeds of slickensided claystone; rare, claystone nodules;
(141.86 m) scattered, matrix-supported quartz sand grains that are up to medium-grained; grades into:

68. Sandstone: Yellow-brown; fine-grained, fines upward and becomes more argillaceous toward the top of the unit, sub-angular to sub-
1.70 m rounded, well sorted, dirty; composed of quartz and abundant
(143.56 m) interstitial clay; intensely weathered, massive and homogeneous; poorly cemented, friable; CONTAINS: no evidence of bedding; contact unknown:

69. Covered: Probably shale; extremely sandy at the base and mottled gray, red, and yellow-brown; grades into:

2.00 m
(145.56 m)

70. Sandstone: Gray and yellow-brown; fine-grained, sub-angular to sub-rounded, well sorted, moderately clean; composed of quartz
2.30 m and some interstitial clay; poorly cemented, friable; poorly
(147.86 m) exposed; appears massive and homogeneous; CONTAINS: no

evidence of bedding; abundant, finely comminuted carbonaceous debris; sharp contact with:

71. Sandstone: Brown; medium-grained, sub-angular to sub-rounded, well sorted, moderately clean; composed of quartz and some interstitial clay; poorly cemented, friable; CONTAINS: low-angle cross-beds, individual cross-bed sets truncate one another at low angles; rare high-angle cross-beds; grades into:

11.00 m
(158.86 m)

72. Conglomeratic sandstone: Dark brown; fine- to very coarse-grained, primarily angular to sub-angular, poorly sorted, dirty; composed of quartz and abundant interstitial clay; CONTAINS: abundant red and yellow-brown intraformational clay clasts; cross-beds; sharp contact with:

0.30 m
(159.16 m)

73. Sandstone: Mottled brown and gray or yellow-brown and red; fine-grained, fines upward to shale at the top of the unit, subangular to subrounded, well sorted, extremely dirty; composed of quartz and abundant interstitial clay; blocky; massive; homogeneous; rooted; CONTAINS: no evidence of bedding; abundant, finely comminuted carbonaceous debris; sharp contact with:

1.10 m
(160.26 m)

74. Shale: Correlates to the base of unit 14 in section RN-1b

3.00 m
(163.26 m)

SECTION RN-1B

BARA FORMATION

1.	Sandstone: 2.00 m (2.00 m)	White, pink, and yellow-brown; fine-grained, well sorted, very clean; composed of quartz and no interstitial clay; poorly cemented, friable; CONTAINS: abundant planar carbonaceous and shale laminations; high and low angle cross-beds (probably oscillation ripples); burrows, burrowing intensity increases toward the top and the unit has been homogenized by burrowing at the top; sharp contact with:
2.	Sandstone: 3.80 m (5.80 m)	Dark yellow-brown; very fine- to medium-grained, primarily subrounded, moderately well sorted, moderately clean; composed of quartz and some interstitial clay; poorly cemented, friable; CONTAINS: low-angle cross-beds, individual cross-beds are typically less than 10 cm thick, cross-bed sets truncate one another at low angles; clay pebble lag conglomerates at the base of some of the truncations, clay pebbles are rounded and up to 3 cm in diameter, individual lags are lenticular and persist laterally for several meters, they can be up to 60 cm thick; sharp contact with:
3.	Shale: 0.18 m (5.98 m)	Light gray; sandy; clay drape; laterally discontinuous; CONTAINS: abundant carbonaceous debris on bedding plane surfaces; sharp contact with:
4.	Sandstone: 2.03 m (8.01 m)	Dark yellow-brown; fine- to medium-grained, primarily subrounded, well sorted, moderately clean; composed of quartz and some interstitial clay; CONTAINS: low-angle cross-beds, cross-bed sets are truncated at low angles; some high-angle cross-beds in places; a zone of intraformational mudstone and claystone clasts in the middle of the unit, the clasts are up to 10 cm in diameter; sharp contact with:
5.	Mudstone: 1.07 m (9.08 m)	Medium gray; massive; homogeneous; CONTAINS abundant, anastomosing, iron-replaced burrows; no evidence of bedding; sharp contact with:
6.	Sandstone: 0.60 m (9.68 m)	Brown; fine-grained, primarily subrounded, well sorted, dirty; composed of quartz and abundant interstitial clay; CONTAINS: abundant intraformational clay clasts in the basal half of the unit; planar laminations; sharp contact with:
7.	Mudstone: 2.35 m (12.03 m)	Medium gray; massive; homogeneous; CONTAINS abundant, anastomosing, iron-replaced burrows; no evidence of bedding; sharp contact with:
8.	Sandstone:	Brown; fine- to medium-grained, primarily subrounded, well

			sorted, clean; composed of quartz and little interstitial
		2.40 m	clay; CONTAINS: low-angle cross-beds, individual cross-bed
		(14.43 m)	units are a maximum of 30 cm thick, cross-bed sets truncate one another at low angles; sharp contact with:
9.	Shale:		Light gray; hackly; intensely rooted; grades abruptly into:
		0.35 m	
		(14.78 m)	
10.	Sandstone:		Yellow-brown and light gray; fine-grained, well sorted, extremely dirty; composed of quartz and abundant interstitial
		0.30 m	clay; massive; homogeneous; rooted; CONTAINS: no evidence of
		(15.08 m)	bedding; abundant carbonaceous debris; grades into:
11.	Shale:		Light gray; blocky; intensely rooted; grades into:
		1.40 m	
		(16.48 m)	
12.	Shale:		Medium gray; CONTAINS: sparse carbonaceous debris though carbonaceous debris abundant on some bedding plane surfaces;
		3.40 m	sharp contact with:
		(19.88 m)	
			SAMPLE EB-90-102 COLLECTED 10 cm ABOVE BASE OF UNIT 12
13.	Sandstone:		Yellow-brown; fine- to medium-grained, subrounded to subangular, well sorted, clean; composed of quartz and little
		0.27 m	interstitial clay; poorly cemented, friable; lenticular, unit
		(20.15 m)	is only 2 m wide; CONTAINS: low-angle cross-beds, cross-bed sets truncate one another at low angles; sharp contact with:
14.	Shale:		Medium gray; fissile; becomes increasingly sandy toward the top of the unit; CONTAINS: abundant, fine-grained quartz
		1.85 m	sand laminations and lenses; siltstone interbeds; burrows,
		(22.00 m)	unit intensely burrowed at the top; the base of this unit correlates to unit 74 in section RN-1A; grades into:
15.	Sandstone:		Medium gray; fine-grained, well sorted, extremely dirty; composed of quartz, common mica flakes, and abundant
		7.70 m	interstitial clay; CONTAINS: abundant carbonaceous debris on
		(29.70 m)	bedding plane surfaces; abundant planar shale laminations; numerous internal channel scours up to 1 m deep, the channel sands are fine-grained, subrounded to subangular, well sorted moderately clean and contain low-angle cross-beds, the cross-bed sets truncate one another at low angles, the channel sands are lenticular and contain little carbonaceous debris although some channel sands contain abundant carbonaceous debris and mica flakes; the laminated sands outside the channel bodies have planar laminations, individual parallel lamina sets truncate one another at very low angles; unit contains numerous slump blocks with bedding rotated perpendicular to the prevailing bedding trend; sharp contact

with:

16. Sandstone: White, yellow, and yellow-brown; fine-grained, subrounded to subangular, well sorted, clean; composed of quartz and little interstitial clay; CONTAINS: abundant wavy carbonaceous beds; bedding plane burrows; grades into:
0.45 m (30.15 m)

17. Shale: Medium gray; fissile; sandy at the base, fines upward; CONTAINS: abundant carbonaceous debris on bedding plane surfaces; rare coalified trunks; abundant very fine-grained quartz sand laminations less than 1 mm thick; grades into:
1.00 m (31.15 m)

18. Sandstone: Light gray with yellow-brown mottling; fine- to medium-grained, subrounded to subangular, well sorted, clean; composed of quartz and little interstitial clay; CONTAINS: abundant carbonaceous debris; burrows, unit homogenized by burrowing; relict wavy lamination preserved at the top of the unit; grades into:
2.75 m (33.90 m)

19. Shale: Light gray; CONTAINS: abundant planar very fine-grained quartz sand laminations less than 1 mm thick and sand lenses; abundant carbonaceous debris on bedding plane surfaces; sharp contact with:
0.65 m (34.55 m)

20. Sandstone: Light gray and yellow-brown; very fine- to fine-grained, subrounded to subangular, well sorted, clean; composed of quartz and little interstitial clay; CONTAINS: zones with planar bedding, abundant shale and carbonaceous debris on bedding plane surfaces; common burrows, top of the unit homogenized by burrowing; low-angle cross-beds, cross-bed sets truncate one another at low angles; sharp contact with:
2.00 m (36.55 m)

21. Shale: Medium gray; silty; blocky; clay drape; unit pinches out laterally (possibly as a result of structural deformation); CONTAINS: sparse carbonaceous debris; sparse sand-filled burrows; sharp contact with:
0.50 m (37.05 m)

22. Sandstone: Yellow-brown and light gray; very fine- to coarse-grained, subrounded to subangular, poorly sorted, clean; composed of quartz and little interstitial clay; CONTAINS: burrows, unit appears homogenized by burrowing; abundant carbonaceous debris; sharp contact with:
2.00 m (39.05 m)

23. Shale: Shale:Medium gray; extremely sandy; blocky; clay drape; unit pinches out laterally (possibly as a result of structural deformation); CONTAINS: abundant carbonaceous debris; sparse sand-filled burrows; sharp contact with:
0.50 m (39.55 m)

24. Sandstone: Yellow-brown; fine- to medium-grained, subrounded to subangular, well sorted, clean; composed of quartz, sparse dark minerals, and little interstitial clay; CONTAINS: abundant burrows, unit homogenized by burrowing; sharp contact with:
2.50 m (42.05 m)

25.	Shale: 0.30 m (42.35 m)	Medium gray; silty; blocky; clay drape; unit pinches out laterally (possibly as a result of structural deformation); CONTAINS: sparse carbonaceous debris; sparse sand-filled burrows; sharp contact with:
26.	Sandstone: 5.00 m (47.35 m)	Yellow-brown; fine- to medium-grained, subrounded to subangular, well sorted, clean; composed of quartz, sparse dark minerals, and little interstitial clay; CONTAINS: low-angle cross-beds, cross-bed sets truncate one another at low angles; sparse burrows; sharp contact with:
27.	Shale: 0.40 m (47.75 m)	Medium gray; silty; blocky; clay drape; unit pinches out laterally (possibly as a result of structural deformation); CONTAINS: sparse carbonaceous debris; sparse sand-filled burrows; sharp contact with:
		SAMPLE EB-90-101 COLLECTED FROM TOP OF UNIT 27
28.	Sandstone: 1.20 m (48.95 m)	Mottled white, pale brown and red; fine- to coarse-grained at the base and containing angular intraformational clay clasts up to 3 cm in diameter, grades upward into fine- to coarse-grained sandstone, poorly sorted, clean; composed of quartz and little interstitial clay; the basal part of the sandstone has the appearance of a channel lag; CONTAINS: burrows, unit homogenized by burrowing; sharp contact with:
29.	Sandstone: 4.60 m (53.55 m)	White; medium- to coarse-grained, subrounded, well sorted, clean; composed of quartz and little interstitial clay; poorly cemented, friable; CONTAINS: low-angle cross-bed sets that are typically less than 10 cm thick, cross-bed sets truncate one another at low angles; sharp contact with:
30.	Sandstone: 1.10 m (54.65 m)	White; fine-grained, subrounded to subangular, well sorted, dirty; composed of quartz and abundant interstitial clay; CONTAINS: sparse burrows, top of the unit homogenized by burrowing; wavy bedding, shale laminations define wavy surfaces; sharp contact with:
31.	Sandstone: 2.90 m (57.55 m)	Very fine- to coarse-grained, subangular to subrounded, poorly sorted, clean; composed of quartz and little interstitial clay; CONTAINS: burrows, unit completely homogenized by burrowing; sharp contact with:
32.	Sandstone: 3.20 m (60.75 m)	Yellow-brown; medium-grained, well sorted, clean; composed of quartz and little interstitial clay; well cemented; CONTAINS: high-angle cross-beds, unit consists of a single cross-bed set; individual cross-bed laminations grade from very coarse-grained at the base of the lamination to fine- to medium-grained at the top; sharp contact with:
33.	Sandstone: 6.50 m (67.25 m)	White; fine-grained, subrounded to subangular, well sorted, clean; composed of quartz and little interstitial clay; CONTAINS: abundant, planar, carbonaceous laminations that occur in wedge-shaped sets up to 70 cm thick, wedge-sets

truncate one another at very low angles; thin zones of short wavelength and low amplitude oscillation ripples; abundant burrows in the top 50 cm; contact unknown:

34. Covered: Probably interbedded sandstone and shale; contact unknown:

3.20 m
(70.45 m)

35. Sandstone: Yellow-brown; fine- to very coarse-grained, subrounded to subangular, poorly sorted, dirty; composed of quartz and
0.25 m abundant interstitial clay; CONTAINS: burrows, unit
(70.70 m) homogenized by burrowing; sharp contact with:

36. Shale: Medium gray; CONTAINS: burrows; sparse carbonaceous debris; fine-grained quartz sand laminations that are especially
0.95 m abundant in the lower part of the unit; laminations become
(71.65 m) less abundant and thinner toward the top; grades into:

37. Sandstone: Yellow-brown; fine- to very coarse-grained, subrounded to subangular, poorly sorted, dirty; composed of quartz and
0.55 m abundant interstitial clay; CONTAINS: burrows, unit
(72.20 m) homogenized by burrowing; grades into:

38. Shale: Medium gray; CONTAINS: burrows; sparse carbonaceous debris; fine-grained quartz sand laminations that are especially
1.00 m abundant in the lower part of the unit; laminations become
(73.20 m) less abundant and thinner toward the top; sharp contact with:

39. Sandstone: Gray-brown; fine-grained, subangular to subrounded, well sorted, clean; composed of quartz, little interstitial clay,
3.00 m and some calcareous cement; well cemented; CONTAINS: low-
(76.20 m) angle cross-beds less than 10 cm thick, cross-bed sets truncate one another at low angles; abundant vertical and horizontal burrows, top of the unit homogenized by burrowing; sharp contact with:

40. Shale: Medium gray; fissile; CONTAINS: rare quartz sand laminations; sand-filled burrows; sparse carbonaceous debris
0.55 m on bedding plane surfaces; possible weathered siderite
(76.75 m) nodules; rare sulfurous efflorescence; grades into:

41. Interlaminated shale and sandstone: Medium gray; unit coarsens upward and sandstone laminations dominate the upper part of the
4.10 m unit; CONTAINS: abundant, very fine-grained quartz sand
(80.85 m) laminations, mica flakes are abundant on some lamina surfaces; individual lamina sets truncate one another at very low angles; burrows, burrows parallel bedding plane surfaces; current ripples; lenticular bedding; abundant finely comminuted carbonaceous debris on some bedding plane surfaces; grades into:

42. Shale: Medium gray; CONTAINS: sparse sulfurous efflorescence; common, finely comminuted carbonaceous debris on bedding

1.55 m (82.40 m) plane surfaces; sharp contact with:

43. Sandstone: White; fine-grained, subrounded to subangular, very well sorted, very clean; composed of quartz and no interstitial 0.70 m clay; poorly cemented, friable; CONTAINS: abundant burrows, (83.10 m) unit homogenized by burrowing; sharp contact with:

44. Shale: Medium gray; fissile; CONTAINS: scattered, finely comminuted carbonaceous debris on bedding plane surfaces; fine-grained 2.30 m quartz sand laminations less than 1 mm thick; siltstone (85.40 m) interbeds up to 2 cm thick; limonite bands which may originally have been siderite bands before weathering; sharp contact with:

SAMPLE EB-90-100 COLLECTED 5 cm FROM TOP OF UNIT 44

45. Sandstone: Fine- to medium-grained, subangular to subrounded, clean, well sorted; composed of quartz, sparse dark minerals, and 9.00 m little interstitial clay; CONTAINS: intraformational clay (94.40 m) clasts; graded cross-bed laminations that grade from very coarse-grained to granular at the base of the lamina to fine-grained at the top of the lamina; dominantly high-angle tangential cross-beds with some low-angle cross-beds in places, individual cross-bed sets are up to 1 m thick at the base, bed thickness decreases upward to as little as 15 cm at the top of the unit; the top of the unit is dominated by oscillation ripples; abundant horizontal burrows and trackways on bedding plane surfaces; sharp contact with:

46. Shale: Variegated red, pale pink, gray, cream, yellow-brown; fissile; blocky; rooted; massive; homogeneous; unit coarsens 1.40 m to mudstone toward the middle and then fines again to shale (95.80 m) at the top; CONTAINS: relict, interbedded, very dirty, planar bedded very fine-grained quartz sandstone beds; sharp contact with:

47. Carbonaceous shale: Chocolate-brown; papery; low density; CONTAINS: no evidence of rooting, but the unit is nevertheless suspected 0.50 m of being rooted; grades into: (96.30 m)

SAMPLE EB-90-99 COLLECTED FROM THE MIDDLE OF UNIT 47

48. Siltstone: Light pink-gray; fissile; fines upward; CONTAINS: abundant carbonaceous debris at the top of the unit, carbonaceous 2.95 m debris becomes less abundant downward and disappears at the (99.25 m) base; (with some excavation into less weathered parts, this unit has an excellent potential as a whole plant mega-fossil locality); sharp contact with:

49. Sandstone: White; fine-grained, subrounded to subangular, well sorted, dirty; composed of quartz and abundant interstitial clay; 1.20 m poorly cemented, friable; CONTAINS: current ripples; low-

(100.45 m) angle cross-beds, cross-bed sets truncate one another at low angles; wavy bedding; planar laminations, individual sets of planar laminations truncate one another at low angles; sharp contact with:

50. Shale: Medium pink-gray, yellow-brown or red in places; fissile; CONTAINS: sparse carbonaceous debris on bedding plane surfaces, carbonaceous debris is abundant on some surfaces; very fine-grained quartz sand laminations and sand bands up to 1 cm thick; sulfurous efflorescence in places; sharp contact with:

5.70 m
(106.15 m)

SAMPLE EB-90-98 COLLECTED 1.70 m FROM THE TOP OF UNIT 50

51. Sandstone: Cream; very fine- to fine-grained, subrounded to subangular, well sorted, dirty; composed of quartz and abundant interstitial clay; poorly cemented, friable; CONTAINS: low-angle cross-beds, cross-bed sets are less than 10 cm thick and truncate one another at low angles; sharp contact with:

1.60 m
(107.75 m)

52. Shale: Variegated, white, pink, maroon, violet, and yellow-brown; blocky; intensely rooted; CONTAINS: no evidence of crbonaceous debris; sharp contact with:

0.40 m
(108.15 m)

53. Sandstone: Cream; fine-grained, fines upward to fine- to very fine-grained, well sorted, dirty; composed of quartz and abundant interstitial clay; poorly cemented, friable; CONTAINS: abundant burrows, bedding intensely disturbed by the burrowing; appears to contain oscillation ripples at the base of the unit; abundant planar laminations covered with abundant finely comminuted carbonaceous debris in the upper part of the unit; abundant roots in the upper part of the unit; sharp contact with:

1.95 m
(110.10 m)

54. Sandstone: Mottled white, pink, yellow-brown; fine-grained, fines upward to very fine-grained sandstone and then to shale in the top 30 cm, subrounded to subangular, well sorted, clean at the base but becomes more argillaceous upward; composed of quartz, sparse dark minerals, some mica flakes, and abundant interstitial clay; CONTAINS: abundant finely comminuted carbonaceous debris on bedding plane surfaces, mica flakes on bedding plane surfaces; some burrows especially in the shaly part of the unit; planar shale and carbonaceous laminations; sharp contact with:

1.50 m
(111.60 m)

55. Carbonaceous shale: Pale pink; CONTAINS: abundant carbonaceous debris; good potential for whole plant mega-fossil remains at the base of the unit; sharp contact with:

0.05 m
(111.65 m)

56. Carbonaceous shale: (Weathered Coal?); sharp contact with:

0.10 m

(111.75 m)

57. Shale: Pale pink, fissile; extremely carbonaceous; presence of rooting cannot be determined; sharp contact with:
0.20 m
(111.95 m)

58. Carbonaceous shale: (Weathered coal?); dark brown; sulfurous; papery; grades into:
0.40 m
(112.35 m)

59. Shale: Blocky; rooted; silty at the base, fines upward; CONTAINS: sparse carbonaceous debris at the base, grades upward into a carbonaceous shale at the top of the unit; abundant whole plant mega-fossil remains; sharp contact with:
3.00 m
(115.35 m)

60. Sandstone: Brown; fine- to coarse-grained, poorly sorted, dirty; composed of quartz and abundant interstitial clay; CONTAINS: abundant intraformational clay clasts; abundant graded cross-bed laminations, laminations grade from coarse-grained at the base to fine- to medium-grained at the top; low-angle cross-beds, cross-bed sets truncate one another at low angles; sigmoidal cross-beds; sparse burrows; rare shale drapes up to 10 cm thick; contact unknown:
12.00 m
(127.35 m)

61. Covered interval: Believed to be mostly or completely shale; may possibly contain coaly intervals; contact unknown:
3.00 m
(130.35 m)

62. Shale: Highly mineralized; extremely hard; top not exposed; contact unknown:
0.10 m
(130.45 m)

63. Sandstone: Cream; coarse-grained to granular at the base fining upward to fine- to medium-grained at the top, poorly sorted at the base, very well sorted at the top, very clean; composed of quartz, rare dark minerals, and no interstitial clay; poorly cemented, friable; CONTAINS: abundant carbonized wood fragments on cross-bed surfaces; low-angle cross-beds which define low amplitude oscillation ripples; sharp contact with:
1.80 m
(132.25 m)

64. Shale: Light gray; low density; grades upward into carbonaceous shale at the top of the unit; the carbonaceous shale is fissile, papery and rooted; CONTAINS: extremely abundant, finely comminuted carbonaceous debris; some whole plant mega-fossils; very fine-grained quartz sand laminations in places; white, kaolinite-like nodules; sharp contact with:
1.20 m
(133.45 m)

SAMPLE EB-90-97 COLLECTED 50 cm FROM THE TOP OF UNIT 64

65. Sandstone: Yellow-brown; in the basal part of the unit the sandstone

contains low-angle cross-beds, the cross-beds truncate one another at low angles, the sets are up to 20 cm thick and are festooned; the cross-bed laminations are graded, grading from coarse-grained at the base of the lamination to fine-grained at the top; the graded laminations are approximately 1 cm thick; the sandstone in this part of the unit is well sorted, subangular to primarily subrounded, and moderately clean; it is composed of quartz and little interstitial clay; poorly cemented, friable; the middle of the unit is dominated by high-angle cross-beds up to 25 cm thick, the high-angle cross-bed sets truncate one another at low angles; sparse burrows occur in the middle part of the unit; the sandstone fines upward; the upper part of the unit is dominated by low amplitude (1 cm or less) and short wavelength (less than 10 cm) oscillation ripples; the top of the unit contains abundant shale and mudstone breaks; abundant burrows; some sandstone beds contain abundant, flat lying intraformational clay clasts; the very top of the unit is dominated by fine-grained, dirty, planar laminated sandstone; laminations covered with abundant, finely comminuted carbonaceous debris; sharp contact with:

3.00 m (136.45 m)

66. Shale: Variegated, light gray, yellow-brown, pale pink; coarsens upward; CONTAINS: abundant fine-grained, muddy, quartz sand laminations up to 5 mm thick; sparse carbonaceous debris; contact unknown:

0.66 m (137.11 m)

67. Covered interval: A major erosional break which probably consists of shale and which may contain some coaly intervals; contact unknown:

6.00 m (143.11 m)

68. Sandstone: White with pink variegations; fine- to medium-grained, subangular to primarily subrounded, well sorted, clean; composed of quartz and little interstitial clay; poorly cemented, friable; CONTAINS: rhythmic bedding with a repeating sequence of truncating, high-angle tangential wedge-shaped cross-beds up to 1.5 m thick and up to 20 m across, the repeating sequences higher within the unit tend to have greater maximum thicknesses than the sequences lower within the unit; these are interpreted to be very long wavelength oscillation ripples, with wavelengths on the order of 5 to 10 m (swaley cross-stratification?); the long wavelength structures grade downward through all size ranges into thin-bedded, low amplitude, short wavelength oscillation ripples no more than 1 cm thick and commonly these sequences are topped with a planar laminated shale drape; the cross-bed laminations are typically graded ranging from coarse grained at the base of the lamination to fine grained at the top; many of the bedding plane surfaces are covered with a wide variety of horizontal trace fossils; sharp contact with:

15.00 m (158.11 m)

69. Sandstone: Variegated yellow-brown and white; fine- to coarse-grained, subangular to subrounded, moderately well sorted, moderately

2.40 m (160.51 m) clean; composed of quartz and some interstitial clay; poorly cemented, friable; CONTAINS: intraformational clay clasts defining cross-bed surfaces, clay clasts are heavily concentrated in some beds; low-angle cross-beds, cross-beds truncate one another at low angles; cross-bed amplitudes are up to 30 cm; sharp contact with:

70. Shale: Gray with yellow-brown and red mottling; blocky; CONTAINS: sparse carbonaceous debris on bedding plane surfaces; zones with concentrations of siderite; sharp contact with:

0.70 m (161.21 m)

71. Sandstone: Cream; fine-grained, subangular to primarily subrounded, well sorted, moderately clean; composed of quartz and some interstitial clay; CONTAINS: low-angle cross-beds, cross-beds truncate one another at low angles, the low-angle cross-beds interpreted as oscillation ripples with wavelengths greater than 1 m; the ripples become smaller in scale upward and toward the top of the unit have wavelengths of 10 cm and amplitudes of 5 mm; sharp contact with:

1.30 m (162.51 m)

72. Conglomeratic sandstone: Pale yellow-brown; fine-grained to granular, subangular to subrounded, poorly sorted, moderately clean; composed of quartz and some interstitial clay; poorly cemented, friable; CONTAINS: high-angle tangential cross-beds; abundant intraformational clay pebbles concentrated on cross-bed surfaces; scour contact with:

0.60 m (163.11 m)

73. Shale: Light gray; hackly; CONTAINS: sparse, finely comminuted carbonaceous debris; whole plant mega-fossils; sharp contact with:

0.50 m (163.61 m)

SAMPLE EB-90-96 COLLECTED FROM THE TOP OF UNIT 73

74. Sandstone: Pink to white; medium-grained at the base of the unit, fines upward to fine-grained and becomes increasingly argillaceous upward, subangular to primarily subrounded, very well sorted, very clean at the base becomes dirty toward the top; composed of quartz and no interstitial clay in the lower part of the unit and abundant interstitial clay at the top; poorly cemented, friable; CONTAINS: high-angle cross-beds at the base, some cross-bedded units are up to 1 m thick; oscillation ripples with wavelengths of more than 2 m; graded cross-bed laminations grading from coarse-grained at the base to fine- to medium-grained at the top of the lamination; toward the top, the unit is dominated by low-angle cross-beds,cross-bed sets truncate one another at low angles; cross-bed laminations in the upper part of the unit are also graded; grades into:

10.00 m (173.61 m)

75. Sandstone: Brown; fine- to medium-grained with very coarse grains,granules, and quartz pebbles up to 7 mm in diameter in places; subangular to subrounded, poorly sorted, dirty;

1.70 m

(175.31 m) composed of quartz and abundant interstitial clay; poorly cemented, friable; CONTAINS: intraformational clay clasts; low-angle cross-beds, individual cross-bed sets truncate one another at low angles; high-angle cross-beds up to 10 cm thick in places; sharp contact with:

76. Shale: Medium gray; fissile; CONTAINS: finely comminuted carbonaceous debris on bedding plane surfaces; rare sulfurous efflorescence.

0.50 m
(175.81 m)

SAMPLE EB-90-95 COLLECTED 15 cm FROM THE TOP OF UNIT 76

END OF SECTION

The exact correlation between section RN-1B and RN-1C was not determined in the field. Unit 76 in section RN-1B is believed to correlate approximately to Unit 2 in section RN-1C. However, a best fit correlation will be needed between RN-1B and RN-1C because the exact correlation could not be determined in the field.

SECTION RN-1C

BARA FORMATION

1. Sandstone: White; fine- to medium-grained, subrounded to subangular, extremely clean; composed of quartz and no interstitial clay; poorly cemented, friable; CONTAINS: multiple sequences of ripples grading to wavy beds grading to planar laminations, planar laminated zones consist dominantly of shale bands and laminations; high-angle cross-beds up to 20 cm thick in places; sharp contact with:

   22.70 m
   (22.70 m)

NOTE: This unit was measured at the end of the day and was deeply eroded and mostly covered. Most of the section covered by this interval is remeasured in detain in section RN-1B.

2. Sandstone: Medium to very coarse-grained; moderately well sorted; clean; composed of quartz and little interstitial clay; CONTAINS: rare, high-angle tangential cross-beds up to 70 cm thick; conglomeratic lenses near the base of the unit; intraformational clay pebbles on cross-bed surfaces; sand grain size varies in the different cross-bed laminations; multiple internal scour surfaces; low-angle cross-beds, cross-bed sets truncate one another at low angles; sharp contact with:

   7.40 m
   (30.10 m)

3. Sandstone: Yellow-brown; fine-grained, subrounded, well sorted, clean; composed of quartz, little interstitial clay, and calcareous cement; well cemented; CONTAINS: festoon cross-beds; oscillation ripples?; sharp contact with:

   0.75 m
   (30.85 m)

4. Sandstone: Dark brown; fine-grained, well sorted, clean; composed of quartz, ferruginous cement, and little interstitial clay; CONTAINS: planar laminations; sharp contact with:

   1.70 m
   (32.55 m)

5. Shale: Medium gray; fissile; soapy; slickensided; CONTAINS: some carbonaceous debris; sharp contact with:

   0.40 m
   (32.95 m)

SAMPLE EB-90-94 COLLECTED 10 cm FROM THE TOP OF UNIT 5

6. Sandstone: White: medium-grained, subrounded, well sorted, clean; composed of quartz and little interstitial clay; CONTAINS: planar laminations; possible oscillation ripples; burrows; low-angle cross-beds at the top of the unit; sharp contact with:

   2.80 m
   (35.75 m)

7. Shale: Light gray; fissile; CONTAINS: fine-grained quartz sand laminations less than 1 mm thick; sharp contact with:

   0.60 m
   (36.35 m)

8. Sandstone: Fine- to very coarse-grained at the base, fines upward, poorly sorted, clean; composed of quartz and little interstitial clay; CONTAINS: low-angle cross-beds, cross-bed sets truncate one another at low angles; sharp contact with:
1.40 m (37.75 m)

9. Conglomeratic sandstone: Dark maroon-black; medium- to very coarse-grained, poorly sorted, moderately clean; composed of quartz, some interstitial clay, and ferruginous cement; massive; homogeneous; CONTAINS: abundant intraformational clay clasts; no evidence of bedding; sharp contact with:
0.50 m (38.25 m)

10. Shale: Light gray; sandy at the base fines upward; blocky; rooted; sharp contact with:
0.50 m (38.75 m)

11. Sandstone: Brown; coarse-grained, well-sorted, clean; composed of quartz, common very fine-grained dark minerals, and little interstitial clay; CONTAINS: sparse intraformational clay pebbles that define cross-bed laminations; low-angle cross-beds, cross-bed sets truncate one another at low angles; lenses of black (iron cemented) conglomeratic sandstone in places; internal scour surfaces; sharp contact with:
4.50 m (43.25 m)

12. Sandstone: Fine- to very coarse-grained, unit coarsens upward to very coarse-grained, subrounded to subangular, poorly sorted, clean; composed of quartz and little interstitial clay; CONTAINS: stacked clay pebble lag conglomerates; high-angle cross-beds less than 10 cm thick, cross-bed thickness increases toward the middle of the unit, cross-bed surfaces defined by clay pebbles, clay pebbles become more abundant toward the top of the unit; sharp contact with:
3.80 m (47.05 m)

13. Conglomerate: Black; medium-grained to granular, angular, poorly sorted; composed of quartz, abundant rounded intraformational clay pebbles, no interstitial clay and ferruginous cement; sharp contact with:
1.50 m (48.55 m)

14. Sandstone: Brown; fine-grained; subrounded, well sorted, clean; composed of quartz and little interstitial clay; poorly cemented, friable; CONTAINS: low-angle cross-beds up to 70 cm thick, cross-beds truncate one another at low angles; sharp contact with:
1.70 m (50.25 m)

15. Shale: Medium gray; blocky; possibly rooted; CONTAINS: sparse carbonaceous debris; sharp contact with:
0.80 m (51.05 m)

16. Sandstone: Brown; medium-grained, fines upward to fine- to medium-grained at the top of the unit, subrounded, well sorted, clean; composed of quartz and little interstitial clay; CONTAINS: low-angle cross-beds, the cross-beds truncate one another at low angles; intraformational clay clasts that
2.50 m (53.55 m)

typically occur on cross-bed laminations; sparse burrows, burrows become slightly more abundant at the top of the unit; sharp contact with:

17. Shale: 2.10 m (55.65 m) — Medium gray; CONTAINS: very fine-grained planar bedded quartz sand laminations, lamina sets truncate one another at low angles; sparse burrows; abundant carbonaceous debris at the top of the unit; grades into:

18. Sandstone: 1.50 m (57.15 m) — Mottled yellow-brown and white; fine-grained, well sorted, very dirty; composed of quartz and abundant interstitial clay; CONTAINS: planar laminations; abundant carbonaceous debris on bedding plane surfaces; shale interbeds; sharp contact with:

19. Sandstone: 1.40 m (58.55 m) — Yellow-brown; medium-grained, subrounded, well sorted, very clean; composed of quartz and no interstitial clay; CONTAINS: low-angle cross-beds, cross-beds truncate one another at low angles; grades cross-bed laminations, beds grade from very coarse-grained at the base of the lamination to very fine grained at the top; some high-angle cross-beds that are up to 70 cm thick; sharp contact with:

20. Shale: 1.10 m (59.65 m) — Medium gray; CONTAINS: abundant very fine-grained quartz sand laminations; sparse carbonaceous debris on bedding plane surfaces, some surfaces are covered with abundant carbonaceous debris; sharp contact with:

SAMPLE EB-90-93 COLLECTED 10 cm FROM THE TOP OF UNIT 20

21. Sandstone: 2.40 m (62.05 m) — Variegated white, red, purple, and black; fine- to medium-grained, coarse-grained in places, well sorted, clean; composed of quartz and little interstitial clay; poorly cemented, friable; CONTAINS: abundant coalified wood fragments; common burrows; abundant shale beds up to 3 cm thick; planar laminations; oscillation ripples at the top of the unit; sharp contact with:

22. Shale: 0.17 m (62.22 m) — Gray; fissile; clay drape; CONTAINS: rare carbonaceous debris in places; sharp contact with:

23. Sandstone: 3.00 m (65.22 m) — Medium-grained, subangular to subrounded, well sorted, clean; composed of quartz and little interstitial clay; CONTAINS: high-angle cross-beds up to 50 cm thick at the base of the unit, cross-bed thickness decreases upward, there are low-angle truncations between the cross-beds; graded cross-bed laminations, individual lamina sometimes grade from very coarse-grained at the base to fine-grained at the top; sparse burrows at the top of the unit; sharp contact with:

24. Sandstone: Brown; fine- to medium-grained, subrounded, poorly sorted, dirty; composed of quartz and abundant interstitial clay;

1.10 m (66.32 m) CONTAINS: burrows, burrows increase in abundance toward the top of the unit; cross-bedded, cross-beds truncate one another at low angles; intraformational clay clasts at the base of some cross-bed laminations; sharp contact with:

25. Sandstone: Medium- to coarse-grained, subrounded, poorly sorted, moderately clean; composed of quartz and some interstitial clay; CONTAINS: high-angle cross-beds; intraformational clay pebbles along cross-bed laminations; burrows, the top of the unit has been homogenized by burrowing; sharp contact with:

0.85 m (67.17 m)

26. Sandstone: Brown; fine-grained, subrounded to subangular, well sorted, clean; composed of quartz and little interstitial clay; CONTAINS: burrows, unit appears to have been homogenized by burrowing; grades into:

0.80 m (67.97 m)

27. Clay pebble conglomerate: Composed of fine- to coarse-grained sand and angular, intraformational clay pebbles up to 1 cm in diameter; sharp contact with:

0.50 m (68.47 m)

28. Sandstone: White; fine-grained, angular to subrounded, well sorted, clean; composed of quartz and little interstitial clay; poorly cemented, friable; CONTAINS: high-angle cross-beds up to 130 cm thick at the base of the unit, cross-bed thickness decreases upward, cross-beds truncate one another at low angles; burrows at the base; sharp contact with:

3.40 m (71.87 m)

29. Sandstone: Brown; fine-grained, primarily subrounded, well sorted, clean; composed of quartz, little interstitial clay, and zones with ferruginous cement; CONTAINS: high-angle cross-beds up to 30 cm thick at the base of the unit; festoon cross-bedding; low-angle cross-beds, the low-angle cross-beds truncate one another at low angles; sharp contact with:

3.10 m (74.97 m)

30. Sandstone: Brown; fine- to medium-grained, subangular to subrounded, well sorted, clean; composed of quartz, little interstitial clay, and ferruginous cement in places; CONTAINS: burrows, most of the unit homogenized by burrowing, relict traces of low-angle cross-beds preserved in places; sharp contact with:

2.70 m (77.67 m)

31. Shale: Mottled gray, maroon, and yellow-brown; fissile; CONTAINS: fine-grained quartz sand laminations; abundant carbonaceous debris on bedding plane surfaces; sharp contact with:

1.45 m (79.12 m)

32. Sandstone: White with pale yellow, red, and yellow-brown variegation; medium-grained, well sorted, clean; composed of quartz and little interstitial clay; CONTAINS: low-angle cross-beds; burrows, top of the unit homogenized by burrowing; sharp contact with:

4.00 m (83.12 m)

33. Sandstone: Variegated white, yellow-brown, maroon; fine- to medium-grained, subangular to rounded, moderately well sorted,

	6.80 m (89.92 m)	clean; composed of quartz, sparse dark minerals, and no interstitial clay; CONTAINS: abundant burrows, unit homogenized by burrowing; relict low-angle cross-beds preserved in places, some of the cross-bed laminations are composed of dark minerals or carbonaceous debris; sharp contact with:
34.	Shale: 0.60 m (90.52 m)	Medium gray; fissile; CONTAINS: sparse carbonaceous debris; sparse sulfurous efflorescence; sharp contact with:
		SAMPLE EB-90-92 COLLECTED 20 cm FROM THE TOP OF UNIT 34
35.	Sandstone: 0.45 m (90.97 m)	Yellow-brown; fine- to coarse-grained, angular to subrounded, moderately well sorted, clean; composed of quartz and no interstitial clay; poorly cemented, friable; CONTAINS: abundant burrows, unit homogenized by burrowing; sharp contact with:
36.	Shale 5.30 m (96.27 m)	Mottled yellow-brown and medium gray; fines upward; CONTAINS: abundant fine-grained quartz sand laminations less than 1 mm thick, some laminations are up to 5 mm thick in the lower part of the unit, laminations become less abundant upward; rare carbonaceous debris; sharp contact with:
37.	Sandstone: 3.10 m (99.37 m)	Brown; fine- to medium grained fining upward to fine-grained, well sorted, clean; composed of quartz, ferruginous cement in places, common dark minerals and no interstitial clay; laterally truncates unit 38; CONTAINS: sparse burrows; festoon cross-bedding; ripple cross-bedding; sharp contact with:
38.	Sandstone: 4.20 m (103.57 m)	Light brown; medium-grained, subangular to subrounded, very well sorted, clean; composed of quartz and no interstitial clay; poorly cemented, friable; CONTAINS: low-angle cross-beds, individual cross-bed sets truncate underlying bed sets at low angles; the upper 2 m of the unit are dominated by planar bed sets that are more than 10 m wide, individual planar bed sets truncate underlying bed sets at extremely low angles; sharp contact with:
39.	Sandstone: 4.80 m (108.37 m)	Fine- to medium-grained at the base fining upward to fine-grained at the top of the unit, subangular to subrounded, well sorted, clean; composed of quartz, no interstitial clay, rare dark minerals at the base, abundant dark minerals at the top; CONTAINS: high-angle cross-beds at the base, some cross-bed sets are up to 40 cm thick; festoon cross-beds in the middle of the unit; oscillation ripples at the top of the unit; abundant burrows in the top 1 meter where the unit has been homogenized by burrowing; sharp contact with:
40.	Sandstone	Brown; medium-to very coarse-grained, subangular to subrounded, poorly sorted, clean; composed of quartz,

1.50 m (109.87 m) abundant very fine- to fine-grained dark minerals, no interstitial clay; poorly cemented, friable; CONTAINS: festoon cross-bedding, cross-beds are up to 10 cm thick; minor internal scours containing lags of coarse to very-coarse grained sand; intense burrowing in the top 15 cm of the unit; sharp contact with:

41. Sandstone: Light brown; medium-grained, well sorted, clean; composed of quartz, ferruginous cement preferentially concentrated in the coarsest grained parts of the unit, no interstitial clay; 3.20 m (113.07 m) CONTAINS: high-angle cross-beds up to 1 m thick, the cross-bed laminations are graded, grading from coarse grained at the base to medium grained at the top of the lamination; internal channel-form scours; wedge shaped bedding in the channel scours; sparse burrows though laterally, some units are completely homogenized by burrowing; sharp contact with:

42. Shale: Variegated light gray, red, and yellow-brown; fissile; CONTAINS: abundant carbonaceous debris on bedding plane surfaces; strong potential for whole plant megafossils; 5.00 m (118.07 m) planar laminations; abundant fine- to medium-grained quartz sandstone interbeds in the basal meter, sandstone contains rare dark minerals; sharp contact with:

SAMPLE EB-90-91 COLLECTED 10 cm FROM THE TOP OF UNIT 42

43. Sandstone: Mottled red, white, and yellow-brown; medium- to coarse-grained, subangular to subrounded, well sorted, dirty; 1.60 m (119.67 m) composed of quartz and abundant interstitial clay; CONTAINS: abundant burrows, unit homogenized by burrowing; sharp contact with:

44. Sandstone: Dark brown, red, and yellow-brown; medium-grained, subangular to subrounded, well sorted, moderately clean; composed of quartz and some interstitial clay; CONTAINS: high-angle 3.00 m (122.67 m) cross-beds, individual cross-beds are up to 1.5 m thick; intraformational clay pebbles that are concentrated on cross-bed surfaces; graded cross-bed laminations, the laminations grade from very coarse at the base to medium-grained at the top; zones with abundant burrows; sharp contact with:

45. Conglomerate: Gray with red and yellow-brown mottling in places; very fine-grained to pebble sized, poorly sorted, dirty; 0.20 m (122.87 m) lenticular; cross-bedded; CONTAINS: abundant intraformational flattened clay clasts up to 1 cm in diameter, clay clasts parallel surfaces of the cross-bed laminations and are restricted to the lower half of the unit; sharp contact with:

46. Sandstone: Dark brown, red, and yellow-brown; medium-grained, subangular to subrounded, well sorted, moderately clean; composed of quartz and some interstitial clay; CONTAINS: high-angle 2.10 m (124.97 m) cross-beds, individual cross-beds are up to 1.5 m thick; intraformational clay pebbles that are concentrated on cross-

bed surfaces; sharp contact with:

47. Conglomerate: Black; very fine-grained to pebble sized, poorly sorted, dirty; lenticular; cross-bedded; CONTAINS: burrows; abundant ferruginous cement; abundant intraformational flattened clay clasts up to 1 cm in diameter, clay clasts parallel surfaces of the cross-bed laminations and are restricted to the lower half of the unit; sharp contact with:

1.70 m
(126.67 m)

48. Sandstone: Light brown; medium-grained, subrounded to subangular, well sorted, clean; composed of quartz and no interstitial clay; CONTAINS: planar cross-beds; festoon cross-beds; burrows; grades into:

1.90 m
(128.57 m)

49. Conglomerate: Black; very fine-grained to pebble sized, poorly sorted, dirty; lenticular; cross-bedded; CONTAINS: abundant ferruginous cement; abundant intraformational flattened clay clasts up to 1 cm in diameter, clay clasts parallel surfaces of the cross-bed laminations and are restricted to the lower half of the unit; sharp contact with:

0.50 m
(129.07 m)

50. Sandstone: Light brown; medium- to coarse-grained, coarse- to very coarse-grained in some beds, well sorted, clean, grades upward into a dirty, fine-grained, laminated sandstone in the top 25 cm; composed of quartz, sparse dark minerals, and no interstitial clay; poorly cemented, friable; CONTAINS: high-angle, tangential cross-beds, cross-bed sets truncate one another at low-angles; numerous internal reactivation surfaces within individual cross-bed sets; graded, fining upward cross-bed laminations; sparse burrows in places though some beds are completely homogenized by burrowing; some carbonaceous and shaly laminations in places, abundant carbonaceous debris in the top 25 cm; sharp contact with:

5.70 m
(134.77 m)

51. Conglomerate: Black; very fine-grained to pebble sized, poorly sorted, dirty; lenticular; cross-bedded; CONTAINS: abundant ferruginous cement; abundant intraformational flattened clay clasts up to 1 cm in diameter, clay clasts parallel surfaces of the cross-bed laminations and are restricted to the lower half of the unit; sharp contact with:

0.30 m
(135.07 m)

52. Sandstone: Coarse-grained, angular to subrounded, well sorted, moderately clean; composed of quartz and some interstitial clay; CONTAINS: the unit consists of a single set of high-angle cross-beds, cross-bed laminations have intraformational clay pebbles on lamina surfaces; sparse burrows though the top 15 cm of the unit is homogenized by burrowing; sharp contact with:

1.80 m
(136.87 m)

53. Conglomerate: Black; very fine-grained to pebble sized, poorly sorted, dirty; lenticular; cross-bedded; CONTAINS: abundant ferruginous cement; abundant intraformational flattened clay clasts up to 1 cm in diameter, clay clasts parallel surfaces of the cross-bed laminations and are restricted to the lower

0.30 m
(137.17 m)

half of the unit; scour contact with:

54. Shale — Light gray; appears to be a clay drape; unit mostly scoured away by unit 53; sharp contact with
0.15 m
(137.32 m)

55. Sandstone: — Light brown; medium-grained, angular to subrounded, mostly angular, well sorted, clean; composed of quartz, abundant
1.31 m — dark minerals, and no interstitial clay; CONTAINS: abundant
(138.63 m) — burrows, bedding has been homogenized by burrowing; sharp contact with:

56. Sandstone: — Mottled gray, red, and yellow-brown; fine- to coarse-grained, subrounded, poorly sorted, extremely dirty; composed of
1.50 m — quartz and abundant interstitial clay; massive; homogeneous;
(140.13 m) — CONTAINS: no evidence of bedding; sharp contact with:

57. Shale: — Variegated violet, red, yellow-brown, and gray; fissile; coarsens upward becomming silty at the top of the unit;
0.80 m — CONTAINS: common carbonaceous debris on bedding plane
(140.93 m) — surfaces, unit has good potential to contain whole plant mega-fossil remains; sharp contact with:

58. Sandstone: Light brown; fine- to medium-grained with rare coarse grains, subrounded, well sorted, dirty; composed of quartz, common
3.00 m — dark minerals, and abundant interstitial clay; CONTAINS:
(143.93 m) — festoon cross-beds up to 10 cm thick; sharp contact with:

59. Conglomerate: Black; very fine-grained to pebble sized, poorly sorted, dirty; lenticular, up to 80 cm thick in places and the unit
0.50 m — splits laterally into two units; cross-bedded; CONTAINS:
(144.43 m) — abundant ferruginous cement; abundant intraformational flattened clay clasts up to 1 cm in diameter, clay clasts parallel surfaces of the cross-bed laminations and are restricted to the lower half of the unit; sharp contact with:

60 Sandstone: Light brown; fine- to medium-grained with rare coarse grains, subrounded, well sorted, dirty; composed of quartz, common
1.25 m — dark minerals, and abundant interstitial clay; CONTAINS:
(145.68 m) — festoon cross-bedding; sharp contact with:

61. Conglomerate: Black; very fine-grained to pebble sized, poorly sorted, dirty; lenticular; cross-bedded; CONTAINS: abundant
0.90 m — ferruginous cement; abundant intraformational flattened clay
(146.58 m) — clasts up to 1 cm in diameter, clay clasts parallel surfaces of the cross-bed laminations and are restricted to the lower half of the unit; sharp contact with:

62. Sandstone: — Variegated light gray, yellow-brown, red, and purple-black; fine-grained, subrounded, well sorted, dirty; composed of
0.80 m — quartz, some dark minerals, and abundant interstitial clay;
(147.38 m) — CONTAINS: planar bedding; burrows, burrows parallel bedding surfaces; abundant carbonaceous debris on bedding plane

surfaces; wavy bedding, wavy bed sets truncate underlying wavy bed sets at low angles; oscillation ripples in places, ripples have amplitudes up to 5 mm; sharp contact with:

63. Sandstone: Brown; fine-grained, subrounded, well sorted, dirty; composed of quartz, abundant dark minerals, and abundant interstitial clay; CONTAINS: trough cross-beds, rounded ironstone pebbles occur at the base of many of the trough cross-bed units; sharp contact with:

3.60 m
(150.98 m)

64. Sandstone: Brown; fine-grained, subrounded, well sorted, dirty; composed of quartz, abundant dark minerals, and abundant interstitial clay; massive; homogeneous; CONTAINS: no evidence of bedding, unit is probably burrowed intensely; contact unknown:

2.30 m
(153.28 m)

FAULT: DISPLACEMENT UNKNOWN BUT PROBABLY MINOR TO MODERATE, AT MOST TENS OF METERS

65. Shale: Variegated light gray, yellow-brown, and red; CONTAINS: abundant carbonaceous debris; sandstone lenses at the base of the unit; sharp contact with:

1.80 m
(155.08 m)

SAMPLE EB-90-90 COLLECTED 60 cm ABOVE THE BASE OF THE UNIT

66. Sandstone: Yellow-brown, white in places; fine- to very coarse-grained, subrounded, poorly sorted, moderately clean; appears massive and homogeneous, unit may have been homogenized by burrowing; sharp contact with:

1.20 m
(156.28 m)

67. Conglomerate: Black; lenticular; fine-grained to granular; with subangular to subrounded quartz clasts; CONTAINS: red intraformational clay clasts; cross-beds; sharp contact with:

1.00 m
(157.28 m)

68. Sandstone: Brown; medium- to coarse-grained, fines upward to medium-grained at the top, subangular, well sorted, moderately clean becomming clean at the top of the unit; composed of quartz, dark minerals, and some interstitial clay; CONTAINS: high-angle cross-beds up to 1.5 m thick at the base of the unit, cross-bed thickness decreases upward to a maximum o f 20 cm at the top of the unit, cross-bed sets truncate underlying cross-bed sets at low angles, cross-beds appear unidirectional toward the north; sparse burrows; oscillation ripples in the top 2.5 m of the unit; scour contact with:

8.20 m
(165.48 m)

69. Conglomerate: Lenticular; very fine-grained to pebble sized (with pebbles up to 8 mm in diameter), angular, poorly sorted, moderately clean; massive; homogeneous; CONTAINS: intraformational clay clasts, no evidence of bedding; sharp contact with:

0.42 m
(165.90 m)

70. Shale: Dark gray, red, yellow-brown, white, pale brown; fissile;

CONTAINS: yellow sulfurous efflorescence in the dark gray parts of the unit; sparse carbonaceous debris becomming more carbonaceous upward, top of the unit has some potential to contain whole plant mega-fossils; sandstone interbeds up to 10 cm thick, sandstone is medium-grained to granular, rounded, poorly sorted, moderately clean, with some dark minerals; no evidence of burrowing; kaolinite-like nodules; sharp contact with:

2.90 m
(168.80 m)

SAMPLE EB-90-89 COLLECTED 50 cm ABOVE THE BASE OF THE UNIT

71. Sandstone: Light gray to brown, red at the top of the unit; fine- to very coarse-grained, subangular to primarily subrounded, poorly sorted, moderately clean; composed of quartz and some interstitial clay; CONTAINS: shale lenses up to 5 cm thick; sparse carbonaceous debris though the shale beds are extremely carbonaceous; burrows, burrows are yellow-brown, unit appears to have been homogenized by burrowing; sharp contact with:

2.00 m
(170.80 m)

72. Sandstone: Brown; fine-grained, subangular to subrounded, well sorted, dirty; composed of quartz and abundant interstitial clay; CONTAINS: trough cross-bedding; sharp contact with:

0.37 m
(171.17 m)

73. Conglomeratic sandstone: Dark red-brown; fine-grained to granular quartz grains, subangular to primarily rounded; lenticular; CONTAINS: high-angle cross-beds; intraformational clay clasts in places; sharp contact with:

0.15 m
(171.32 m)

74. Carbonaceous shale: Dark gray at the base, red-brown in the top three-fourths of the unit; extremely fissile; low density, papery; CONTAINS: abundant whole plant mega-fossil remains; sand laminations less than 1 mm thick in the basal one-fourth of the unit; abundant yellow sulfurous efflorescence; sharp contact with:

0.60 m
(171.92 m)

75. Sandstone: White to pale pink; fine- to medium-grained, subangular to primarily subrounded; moderately clean; composed of quartz, rare dark minerals, and some interstitial clay; poorly cemented, friable; non-calcareous; lenticular; CONTAINS: abundant carbonaceous debris; burrows; sharp contact with:

0.30 m
(172.22 m)

76. Sandstone: Pale brown; fine-grained, subangular to subrounded, well sorted, dirty; composed of quartz and abundant interstitial clay; CONTAINS: abundant carbonaceous debris; planar laminations; abundant shale interbeds; sharp contact with:

0.20 m
(172.42 m)

77. Carbonaceous sandstone: Black; very fine- to medium-grained, subangular to subrounded, poorly sorted, dirty; composed of quartz and extremely abundant interstitial clay; CONTAINS: abundant carbonaceous debris; sharp contact with:

0.25 m
(172.67 m)

78. Sandstone: Light gray to pale brown; fine- to medium-grained, subangular

to subrounded, well sorted, dirty; composed of quartz and
0.16 m abundant interstitial clay; CONTAINS: clay bands and
(172.83 m) laminations; abundant coalified wood fragments; intraformational clay pebbles; burrows; no evidence of rooting; sharp contact with:

79. Carbonaceous shale: Black with yellow sulfurous efflorescence; CONTAINS: coal streaks; sharp contact with:

0.20 m
(173.03 m)

SAMPLE EB-90-88 COLLECTED AT THE TOP OF UNIT 79

80. Sandstone: Light brown with a yellow sulfurous efflorescence; fine- to medium-grained fining upward to fine-grained, subangular to
1.05 m subrounded, well sorted, dirty; composed of quartz and
(174.08 m) abundant interstitial clay; CONTAINS: roots; planar shale and carbonaceous laminations, lamina sets truncate underlying lamina sets at low angles; abundant carbonaceous debris on bedding plane surfaces; sharp contact with:

81. Sandstone: Brown; fine-grained, subangular to subrounded, well sorted, dirty; composed of quartz and abundant interstitial clay;
8.20 m calcareous in places; CONTAINS: sparse carbonaceous debris;
(182.28 m) scattered, discontinuous shale beds up to 1 cm thick; oscillation ripples with wavelengths up to 2 m and amplitudes up to 25 cm in places; carbonaceous debris and shale preferentially accumulated in ripple troughs; sharp contact with:

82. Carbonaceous shale: Dark gray, mottled yellow-brown and red in places; fissile; low density; CONTAINS: abundant, finely comminuted
1.70 m carbonaceous debris in places; abundant yellow sulfurous
(183.98 m) efflorescence in places; abundant fine-grained quartz sand laminations less than 1 mm thick, laminations become more abundant upward; abundant carbonaceous laminations; no evidence of rooting; grades into:

83 Carbonaceous shale: Medium gray; fissile; CONTAINS: abundant yellow sulfurous efflorescence; sharp contact with:

0.55 m
(184.53 m)

84. Gypsum: Secondary weathering product; sharp contact with:

0.15 m
(184.68 m)

85. Shale: Dark gray, mottled yellow-brown and red in places; fissile; low density; CONTAINS: abundant, finely comminuted
6.80 m carbonaceous debris in places; abundant yellow sulfurous
(191.48 m) efflorescence in places; abundant fine-grained quartz sand laminations less than 1 mm thick, laminations become more abundant upward; abundant carbonaceous laminations; no

evidence of rooting; grades into:

SAMPLE EB-90-87 COLLECTED 50 CM FROM THE BASE OF UNIT 85

86. Basalt: Pale to dark green, weathers red; amygdaloidal; layered in pillow-like structures; the top of the unit has the same texture and is not scoriaceous; no evidence of contact metamorphism with the overlying unit; base not exposed.

6.00. m
(197.48 m)

END OF SECTION