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GEOLOGICAL SURVEY

THE STRATIGRAPHY AND GEOMETRY OF THE LAKHRA FORMATION IN THE LAKHRA COAL FIELD AREA AND IMPLICATIONS FOR THE COAL RESOURCE POTENTIAL NORTH OF LAKHRA, SIND PROVINCE, PAKISTAN: A PROGRESS REPORT

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ABSTRACT

The discovery of anomalously shallow coal beds in the northern part of the Lakhra Coal Field by the combined efforts of the Geological Survey of Pakistan and the United States Geological Survey during exploration work conducted in the 1960's indicates the occurrence of stratigraphic anomalies and suggests the possibility that additional shallow coal resources may be present here. Previously, far northern Lakhra was not seriously considered a potential exploration target because of presumed thick overburden. In order to assess the exploration potential in areas north of Lakhra, this study investigates the character and degree of stratigraphic thinning of the Lakhra Formation in the Lakhra Coal Field just south of north Lakhra. An abrupt thinning of the Lakhra Formation to less than a third of its original thickness can be seen over a distance of 5 km. Preliminary data suggest that this thinning trend continues to the north beyond the study area and probably results in the absence of the Lakhra Formation within 30 km of the northernmost measured section in this study. This presumed depositional thinning trend may also affect the underlying, coal-bearing Bara Formation. Consequently, because of the absence of the Lakhra Formation, and possibly part of the upper part of the Bara Formation, the coal-bearing part of the Bara Formation may be considerably shallower than the structural plunge of the Lakhra Anticline would indicate. Assuming that the coal-bearing facies of the Bara Formation persists to the north, the more structurally deformed areas in the Lakhi Range between north Lakhra and Sehwan at the northernmost end of the range may also be potential coal exploration targets.

INTRODUCTION

Prior to the USAID-sponsored Coal Resource Exploration and Assessment Program (COALREAP), there have been no detailed, systematic studies of the stratigraphy of the coal-bearing strata in Sind Province, Pakistan. In the past, public and private sector exploration in the Sind region has been based on empirical understanding of the known distribution of existing coal beds. New exploration efforts have been confined to the peripheries of the existing coal fields. In order to improve the efficiency and efficacy of the COALREAP, one of the primary program objectives has been to develop a thorough understanding of the stratigraphy, sedimentology, and facies relationships of the coal-bearing and related strata. To accomplish this objective the United States Geological Survey (USGS) and its counterpart agency, the Geological Survey of Pakistan (GSP), have been compiling all of the existing published and unpublished geologic data for south Sind. Geologists from both agencies have compiled geologic data on the surface and subsurface rocks in the entire coal-bearing region (Landis and others, 1988; Schweinfurth and Husain, 1988; Thomas and others, 1988a,b,1989; SanFilipo and others, 1988a,b). The results of these studies will be presented in a series of reports that address various aspects of the coal geology of the study area.

This report discusses the geology of the Lakhra Formation, and the stratigraphic relationships among the Lakhra, Bara, Sohnari, and Laki Formations. This study was prompted by the discovery of anomalously shallow Bara Formation coal beds by GSP and USGS (Ghani and others, 1973) in north Lakhra. This discovery was followed by detailed mine investigations in the area by the Pakistan Mineral Development Corporation, PMDC, (PMDC, 1976), and by expanded exploratory and developmental drilling programs by the Japanese International Cooperation Agency, JICA, (JICA, 1981) and the John T. Boyd Company (1985) on PMDC leases in north Lakhra. Additional anomalously shallow

coal was discovered in the northwest Lakhra area by the Ghazala Mining Company (SanFilipo and others, 1988a). An explanation for this shallowing trend will have a significant impact on future coal exploration planning in the entire north Lakhra area and could potentially lead to the discovery of additional coal deposits.

GEOLOGIC SETTING

The geologic map of part of Sind Province (between 25°00' and 25°50' north latitude and 68°00' and 68°35' east longitude) and the surrounding areas is presented in figure 1. The Lakhra Formation is part of the Ranikot Group as defined in Cheema (1977). Some investigators, particularly those in the petroleum industry, consider the Ranikot Group to have formation status, and they regard the Lakhra as the upper part of the Ranikot Formation (Williams, 1959).

The Ranikot Group is widely distributed in the subsurface throughout southern Sind Province. It has been reported in oil and gas wells drilled as far north as Khairpur, as far west as the eastern fringe of the Axial Belt, and as far east as Rajasthan Desert in India (Quadri and Shuaib, 1986; SanFilipo and others, in press). The distribution of the Lakhra Formation is not as well understood, because it is not consistently identified as a separate formation in oil and gas well logs. The Lakhra Formation crops out only on the Lakhra anticline and in areas to the south, though there are contradictory reports that the formation can be found in some places within the Lakhi Range as well (Cheema, 1977; Abdullah, 1980).

In the Lakhra area (fig. 2), the Lakhra Formation is composed predominantly of shallow-marine clastic sediments. The formation is dominantly clastic, consisting of approximately 40 percent claystone and siltstone and 40 percent argillaceous, fine-grained sandstone. Limestone is subordinate,

usually accounting for less than 20 percent of the formation thickness. The sandstone and claystone beds are weakly cemented and form slopes. They typically contain abundant glauconite and are green to olive gray when fresh but weather to yellow brown or yellow orange. The sandstones may contain sparse, poorly preserved shell fragments; the claystones commonly contain shell fragments in addition to well-preserved microfaunas (Amin, 1967; Usmani, 1983; Usmani and Ahmed, 1986a,b, 1987; Brouwers, 1989, written communication; Wardlaw, 1989, written communication). The sandstone beds are uniformly massive and appear to have been homogenized by burrowing, though relict planar beds and ripples are preserved in places.

Limestones and coarse-grained or conglomeratic sandstones compose approximately 25 percent of the formation thickness. Both lithologies are well cemented ledge formers. The coarse-grained sandstones are thin (usually less than 0.5 m thick). They are intensely burrowed and abundantly fossiliferous. Often the sandstones contain intraformational clay and sandstone clasts and glauconite that weathers to a yellow-brown color. The coarse-grained sandstone beds tend to be most abundant in the lower half of the unit. The limestone beds are usually more than 1 m thick; beds more than 15 m have been measured in outcrop. They are abundantly fossiliferous and some beds are foraminiferal coquinas. The limestones are argillaceous, sometimes arenaceous, nodular in places, glauconitic in places, and yellowish-brown where weathered. The limestone beds are most common in the top half of the unit.

Cheema (1977) designates the "Lakhra-Bohlari section" on the southern flank of the Lakhra anticline as the type section for the Lakhra Formation, but nowhere does he give specific map coordinates that precisely locate this section. From Cheema's description, we presume that his designated type-section begins at Siph Nala (fig. 1) and extends to the vicinity of the

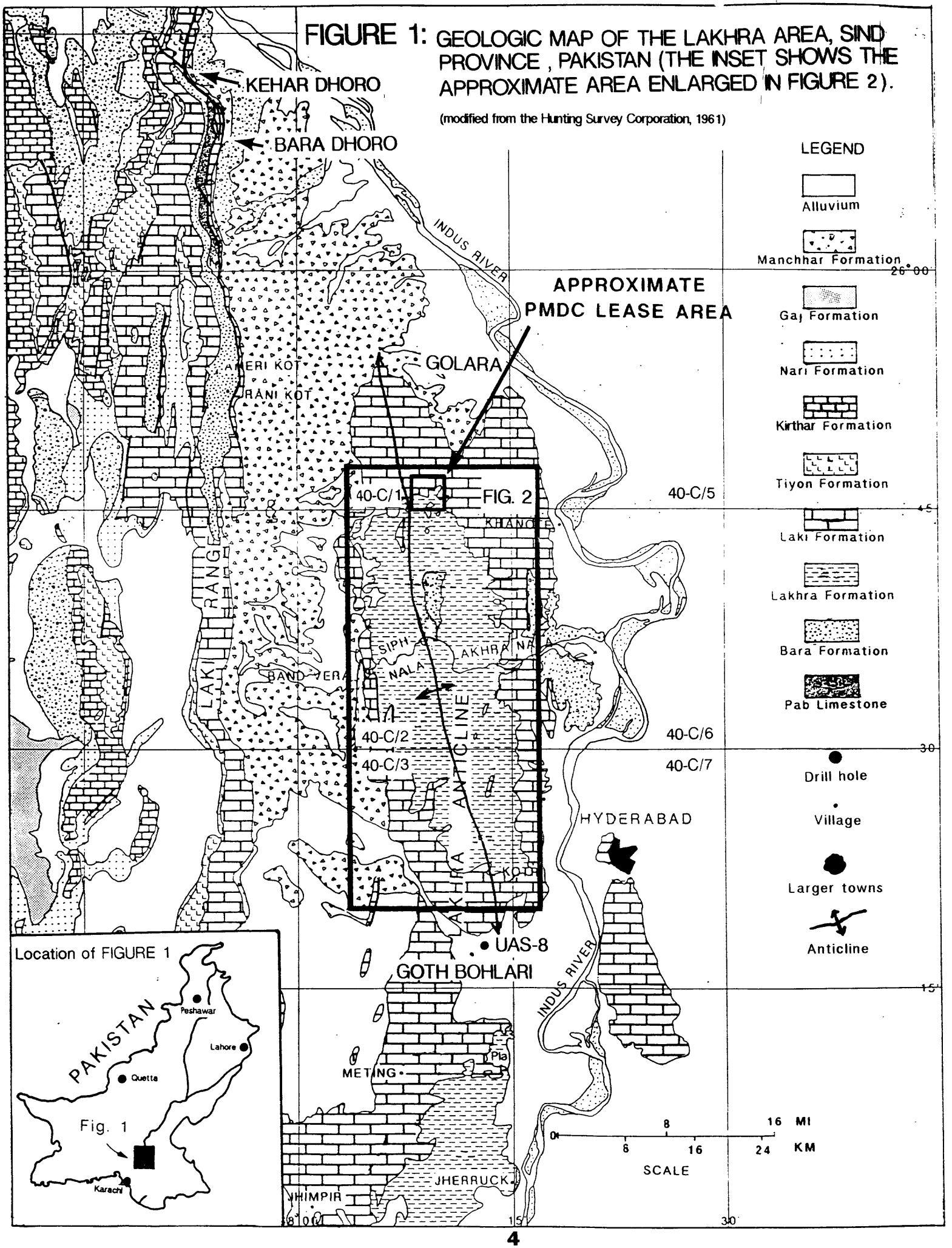

FIGURE 1: GEOLOGIC MAP OF THE LAKHRA AREA, SIND PROVINCE , PAKISTAN (THE INSET SHOWS THE APPROXIMATE AREA ENLARGED IN FIGURE 2).

(modified from the Hunting Survey Corporation, 1961)

village of Goth Bohlari 37 km to the south. Cheema reports that the Lakhra Formation attains a maximum thickness of 242 m along this section. This thickness estimate was corroborated by Ghani and others (1973) who reported that the Lakhra Formation attains a thickness of 271 m in the Bohlari area; however, Ghani and others (1973) do not indicate their source for this thickness estimate. Quadri and Shuaib (1986) report thicknesses as great as 400 m for the "upper Ranikot carbonate unit" along the central part of the Karachi Trough and along the sub-Kirthar foredeep. Quadri and Shuaib (1986) imply that the Lakhra Formation is confined to the western part of the Southern Indus Basin, along the deepest trend of the Karachi Trough.

The Lakhra Formation conformably overlies the coal-bearing Bara Formation and is reported to be unconformably overlain by the coal-bearing Sohnari Member of the Laki Formation (Vredenburg, 1906; Cheema, 1977). SanFilipo and others (1988a) indicate that the Sohnari-Lakhra contact is intertonguing and gradational, with no direct evidence of unconformity. Outerbridge and others, in press, have recently assigned formational status to the Sohnari Member and they concur that there is no evidence of unconformity between the Sohnari and Lakhra Formations.

METHODS

The thickest and most complete exposures of the Lakhra Formation occur along a line of westerly trending cliffs crossing the Lakhra anticline on quadrangle 40-C/2. A total of 6 surface sections were measured along the cliffs above Siph Nala and Lakhra Nala. The eastern and westernmost sections are separated by 15 km. Seven surface sections, one drill hole and one mine section were measured in a north-south direction following the cliffs above Lailian Nala and Tel Nala on quadrangle 40-C/2 and then following the line of

mesas along the southeastern corner of quadrangle 40-C/2 and the eastern edge of quadrangle 40-C/3. The northern and southernmost sections are separated by 31 km. The locations of all of these sections are shown in figure 2.

THE LAKHRA PROBLEM

Much of the published data about the thickness and distribution of the Lakhra Formation in north Lakhra and the Lakhi Range is contradictory. Most investigators agree that the Lakhra thins toward the north or northwest, but the amount and cause of this thinning trend has not been determined. A resolution to these problems will significantly impact the assessment of the coal potential of northern Lakhra and the Lakhi Range.

The detailed descriptions of the surface, mine, and core sections measured in Lakhra are presented in Appendix 1. East-west and north-south cross sections are illustrated in figures 3 and 4.

Measurements of the thickness of the Lakhra Formation made during the GSP/USGS drilling and section measurement program are not in agreement with the published literature. The thickest measured section of the Lakhra Formation (section SN-7/8) is 194 m thick, not 240 to 271 m as reported by Ghani and others (1973) and Cheema (1977). The GSP/USGS drilling records for drill hole UAS-8 (SanFilipo and others 1988b), approximately 3 km east of Goth Bohlari (fig. 1) indicate that the Lakhra Formation is only about 70 - 95 m thick there, not 271 m as reported by Ghani and others (1973). The cause of this discrepancy is unknown.

It is unclear why the designated Lakhra type-section was extended as far south as Bohlari. The region south of the Siph Nala cliffs is topographically subdued and contains numerous faults. The thickest exposures of the Lakhra Formation occur along Siph and Lakhra Nalas. Contacts with the overlying Sohnari Member and the underlying Bara Formation can be seen in these cliffs,

hence a section in the cliffs south of Siph Nala would be appropriate for a type-section. Though the results of oil and gas drilling indicate that the Lakhra Formation is thicker to the west (Quadri and Shuaib, 1986), the sections there are not exposed at the surface.

No single cliff section in the Lakhra formation contains both the upper and lower formation boundaries. Consequently, composite sections extending over 4 to 6 km must be used in order to define the Lakhra Formation. The best sections to combine are sections SN-1/1A with SN-2 and sections SN-7 with SN-8 (designated SN7/8 in figure 4). Both of these composite sections have minor structural or stratigraphic complications. In composite section SN-1/1A/2, a small faulted anticline separates section SN-1/1A from SN-2. At SN-2, however, Unit 1 is continuous across the probable fault trace and there is no evidence of displacement, so there does not appear to be a loss of the upper part of the Lakhra section at SN-2. In the basal part of the Lakhra section, because of the gradational nature between the Lakhra and the Bara Formations, there is a small chance that the Lakhra-Bara contact has been misidentified in section SN-1/1A and that the actual contact is not exposed (contrary to the report of Ghani and others, 1973). If we have misidentified this contact, in the worst case scenario, the Lakhra-Bara contact is still expected to subcrop in the very shallow subsurface because unmistakable Bara Formation sediments are exposed at the surface and on strike just a short distance away. Given these circumstances, it is unlikely that more than 10 to 20 m of section might be buried. This same caveat also applies to the other measured sections in this study, particularly to section SN-7/8. However, because of its greater thickness, section SN-7/8 is the preferred composite section.

Part of the problem in assigning a thickness to the Lakhra Formation stems from the fact that the boundary between the Lakhra and the Bara

FIGURE 2: Location of measured sections, drill holes, and mine section in the Lakhra Anticline

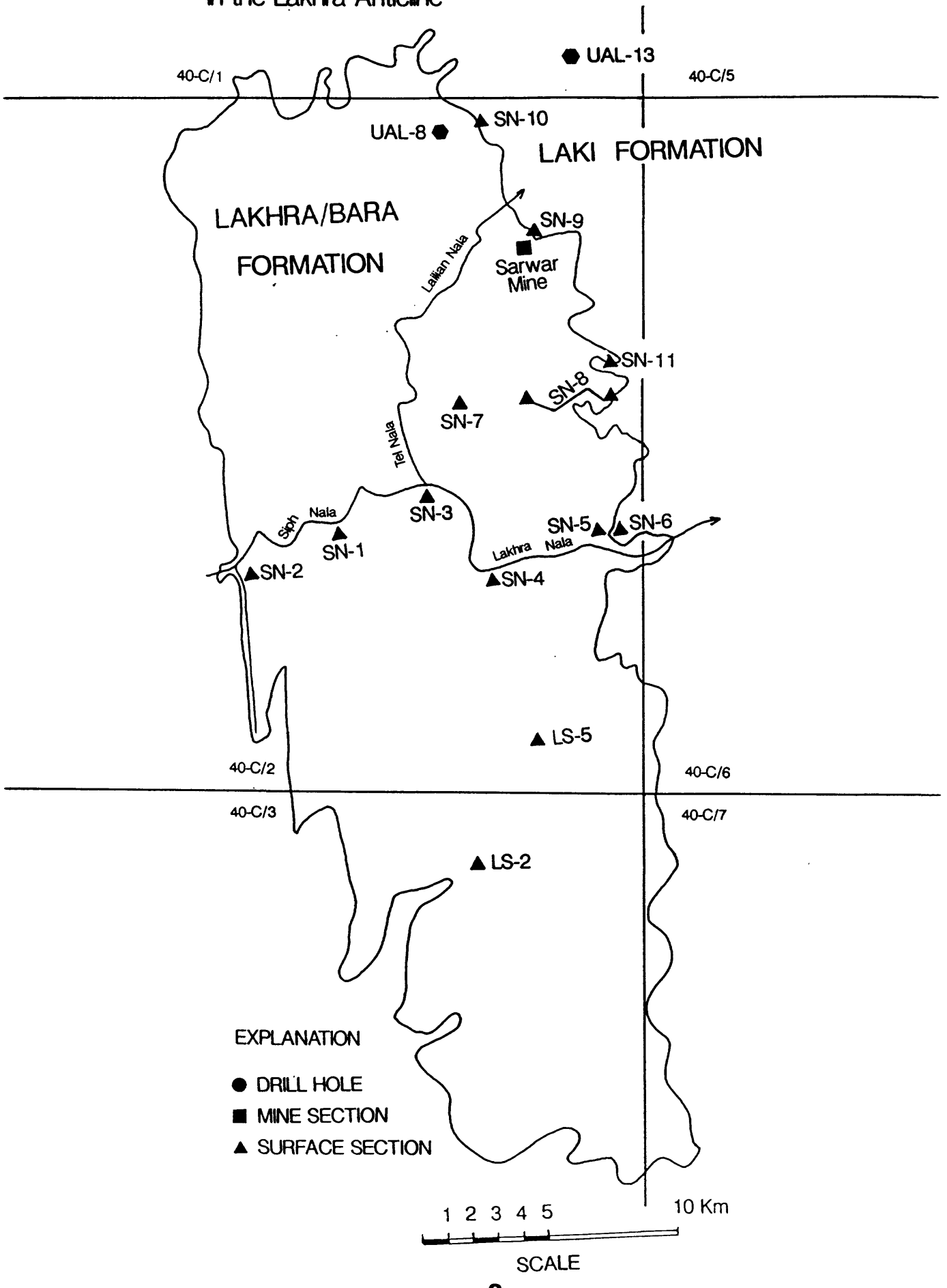

FIGURE 3: EAST-WEST CROSS SECTION OF THE LAKHRA FORMATION IN THE NORTH PART OF THE LAKHRA ANTICLINE

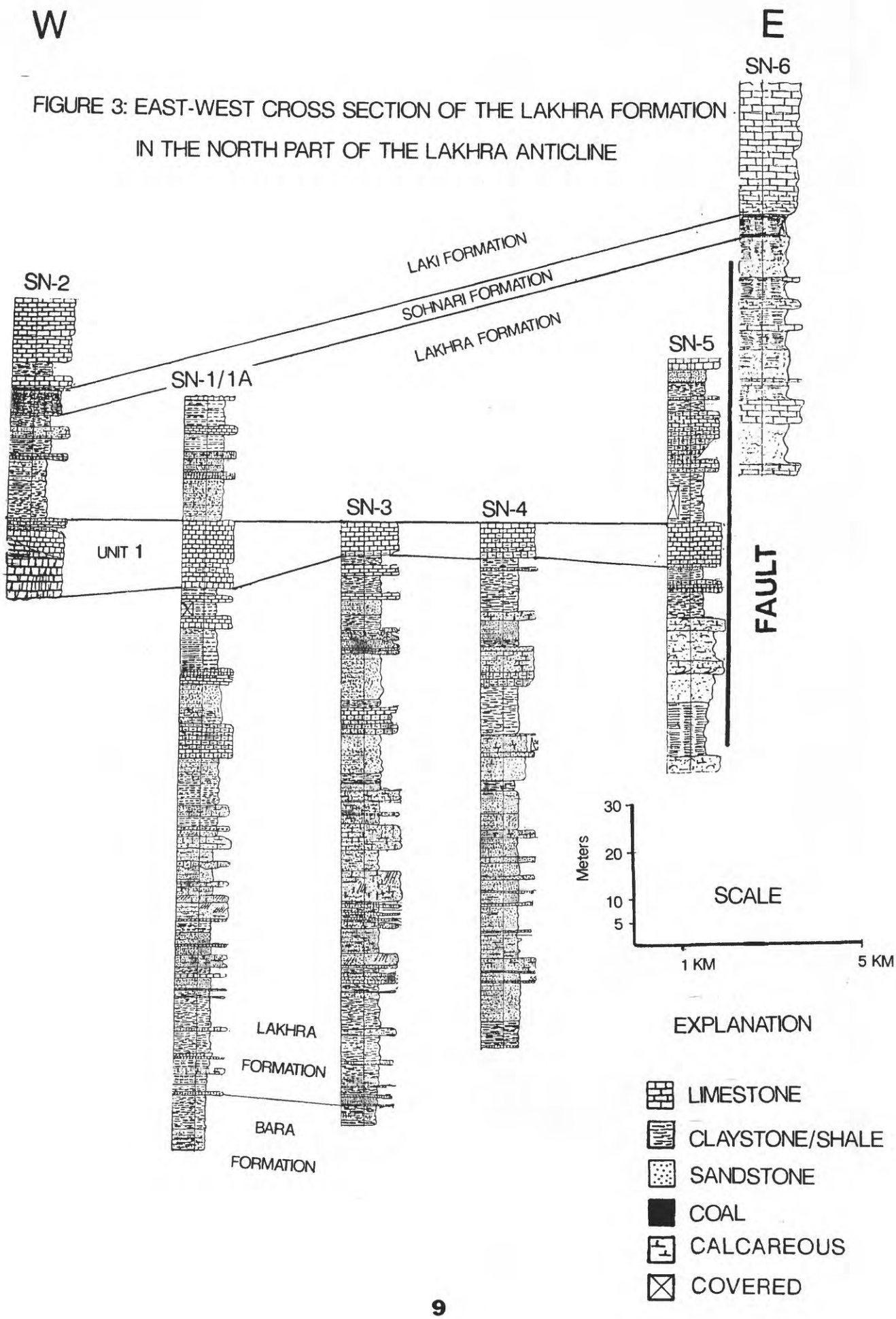

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FIGURE 4: NORTH-SOUTH CROSS SECTION OF THE LAKHRA FORMATION IN THE NORTH PART OF THE LAKHRA ANTICLINE

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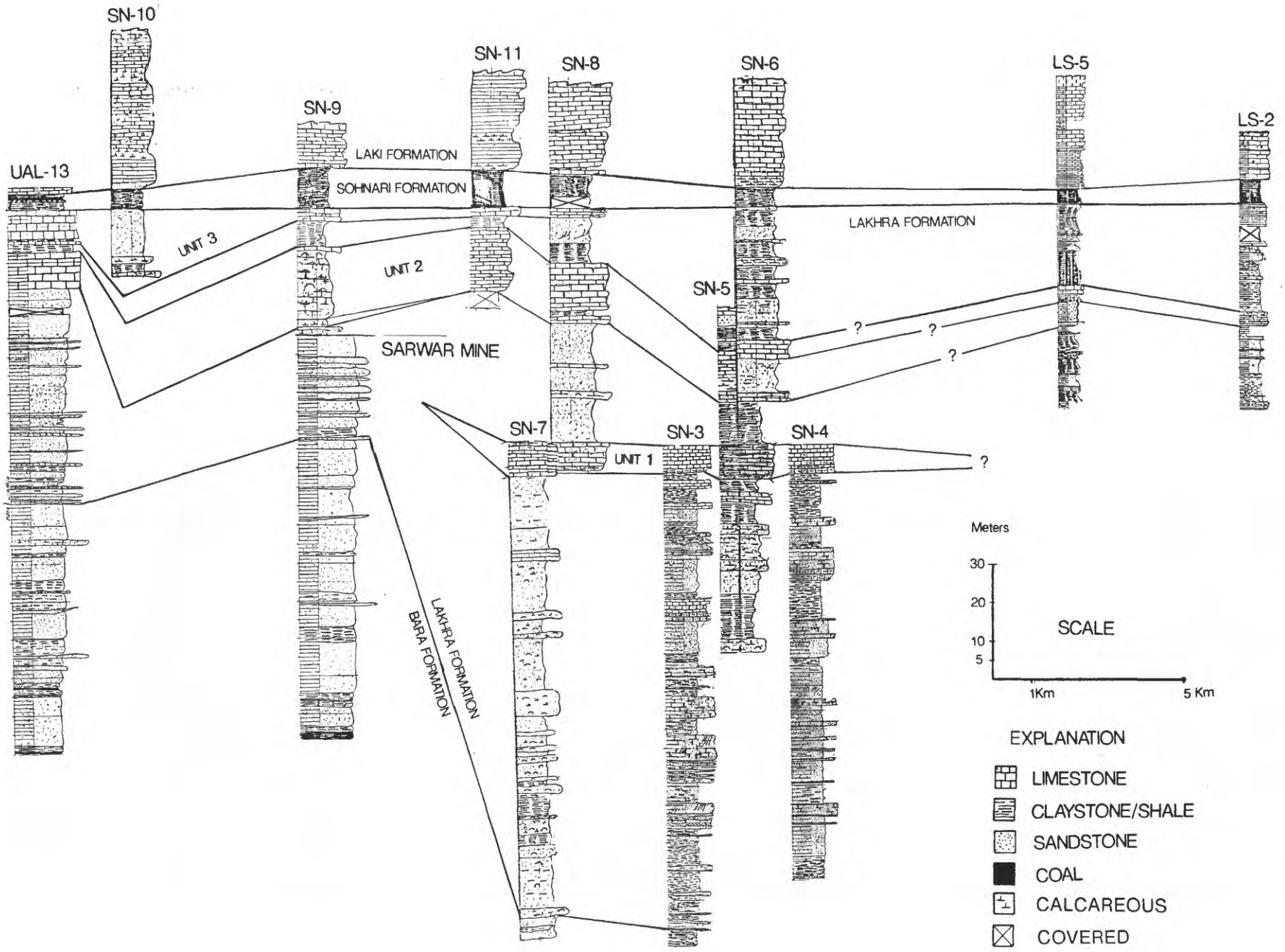

Formation is gradational. There is no single identifiable horizon that can be used as a boundary between the formations. Empirically, the Lakhra formation is defined as the sediments between the highest and lowest limestone beds.However, in many places the Lakhra facies does not contain limestone; this results in reports of anomalously thin Lakhra occurrences (Outerbridge and Khan, in preparation). In the Siph Nala area, the calcareous units are fossiliferous, calcite-cemented sandstones. Limestones do not occur below the middle of the unit.

The Lakhra-Bara contact is identified on the basis of one or more indefinite characteristics such as: (1) the glauconite content of Bara sediments is significantly less than that of Lakhra sediments (though abundant glauconite may be present in the upper 50 m of Bara sediments, and may sporadically occur in other places within the Bara section); (2) as the glauconite content decreases, there is a concurrent color change in core from greenish to grayish cast, reflecting the lower glauconite content of the Bara.In outcrop, Bara sediments tend to weather variegated red, maroon, purple, violet, yellow brown, gray, and white whereas the Lakhra tends to be much more uniformly yellow brown or sometimes red/maroon; (3) the sandstone beds in the Bara Formation are much cleaner and less bioturbated than sandstones in the Lakhra Formation. The sandstones in the Bara Formation typically contain a variety of internal bedforms while the sandstones in the Lakhra Formation are homogeneous; (4) the thin, calcareous sandstone beds that are so common in the Lakhra Formation are less abundant in the upper part of the Bara Formation, and tend to be separated by much thicker interburden; (5) the faunas in the calcareous sandstones in the Bara Formation are much less diverse and tend to consist primarily of pelecypod shell fragments. The faunal assemblages in the Lakhra Formation contain a much greater diversity of

organisms including gastropods, pelecypods, echinoderms, corals, crabs, and forams, though in the lowest parts of the Lakhra Formation the faunal diversity may be very low at times; and (6) the presence of Turritella has been considered a definitive indicator for the Lakhra Formation; unfortunately, Turritella does not consistently occur in the lowest Lakhra calcareous sandstones. Because these differences between the Lakhra and Bara Formations are inconclusive, if not ambiguous, it is difficult to choose a consistent boundary between the two units. The Lakhra/Bara contacts that have been indicated in figures 3 and 4 and in the descriptions of the appendix are almost certainly diachronous.

The detailed section measurements reported in this study indicate that the thickest Lakhra Formation deposits occur in the Siph Nala area. From Siph Nala, the Formation thins markedly toward the north, less so toward the south, and slightly toward the nearby west. As has been observed by numerous investigators (Hunting Survey Corporation, 1961; Ghani and others, 1973; Cheema, 1977), the greatest thickness decrease occurs toward the north. The loss of section is precipitous; the Lakhra Formation thins from 194 m at SN-7/8 to 60 m at SN-9, 5.5 km to the north.

The Lakhra Formation also thins toward the south and southeast, but because there are no thickness data for the Lakhra Formation between Siph Nala and drill hole UAS-8 near Goth Bohlari, we cannot determine whether the thinning occurs gradually or occurs abruptly as it does toward the north. Part of the thinning appears to be related to facies changes within the formation, as limestones appear to account for a greater proportion of the lithology southward (SanFilipo and others, 1988b). More information will be available about the Lakhra Formation in this area if the recommended drilling in south Lakhra is completed (SanFilipo and others, 1988a).

Figures 3 and 4 indicate that there are rapid lateral changes in the

clastic facies. Individual carbonate beds appear to persist laterally over greater distances than individual clastic beds, but the carbonates can also thicken or thin rapidly and units or parts of units grade laterally into calcareous clastics over very short distances.

The correlations for the Sohnari Formation and the Unit 1 limestone beds (figs. 3 and 4) are unequivocally established. The Sohnari is correlated on the basis of its distinctive color and lithology, Unit 1 by physically tracing along the outcrop. The correlation of Unit 2 between sections is based on the thicknesses and stratigraphic positions of individual limestone beds. Additional information about the thickness and lithologic characteristics of the lower part of the Lakhra Formation south of Siph Nala could potentially change the correlation lines between SN-6 and LS-5.

The relationships between SN-9, SN-10, and drill hole UAL-13 are also unclear. Unit 2 in SN-9 logically appears to correlate to the lower half of the thick limestone that underlies the Sohnari in UAL-13, but in section SN - 10, which lies between UAL-13 and SN-9 and is 4 km west of UAL-13, there is no occurrence of thick limestone. Nor do thick limestones occur in UAL-8 (SanFilipo and others, 1988b), 2 km west of SN-10, or in the holes drilled by the John T. Boyd Co. (J.T. Boyd Co., 1985) even farther to the west. Three interpretations are possible. Most likely, Unit 2 may correlate between UAL-13 and SN-9 (as indicated in figure 4), but may pinch out or grade into a more clastic facies in a west-northwest direction (toward the PMDC lease). Alternatively, the limestone at the top of UAL-13 may be an entirely new unit unrelated to Unit 2. It is also possible that there is a thick limestone in the subsurface below SN-10. This limestone may not have been detected in drill hole UAL-8, 2 km to the west of SN-10, because there may be multiple normal faults (as suggested in the isopach map of the Lailian coal seam by

Waheeduddin and others, 1984) between UAL-8 and SN-10, and the limestone may have been eroded from the upthrown block at UAL-8.

There is a gradual northward decrease in the stratigraphic separation between the Sohnari Formation and the top of Unit 2 (fig. 4). This trend appears to reverse locally in the vicinity of SN-10, but because of the unclear correlation of this section with section SN-9, the apparent increasing stratigraphic separation may be more the result of a facies change than a real thickening. The increasing stratigraphic separation between unit 2 and the Sohnari toward the south, particularly south of section SN-7/8, parallels the general thickening trend of the whole Lakhra Formation.

The Lakhra Formation is characterized in the Lakhra Coal Field area by the occurrence of numerous thin calcareous units, usually less than 50 cm thick, that consist of poorly sorted, moderately clean to dirty, fine- to very coarse-grained, calcite cemented sandstone. In some places, these indurated beds are less calcareous and finer grained, usually mudstones or siltstones. All of these indurated beds are ledge formers and there is a sharp contact between these beds and the underlying units. They contain intraformational sandstone and claystone clasts, glauconite pellets, and abundant whole shells and shell fragments. Many beds are graded, and the size of the shell fragments in particular appears to fine upward. Most beds appear burrowed. These beds also tend to be most prevalent in the lower half of the unit. The sedimentary characteristics of these deposits suggests that they may be tempestites (see Einsle and Seilacher, 1982 and papers contained therein). These beds are probably more persistent laterally than some of the other lithologic units, and therefore, may be useful as regional stratigraphic markers. Additional studies of these beds must be made in order to confirm these observations.

The thickness of the indurated ledge-formers does not vary between the area where the Lakhra Formation is thin and where it thickens; however, as the

Lakhra thickens, the interburden between the individual ledges increases significantly. This trend toward thickened interburden also occurs in the upper part of the section where limestone is the dominant ledge former. There is progressively more clastic interburden between the limestone ledges toward the south.

DISCUSSION

Because of the structural plunge of the Lakhra anticline, the Bara Formation is (a) buried progressively deeper in the subsurface toward the north and is (b) covered by progressively thicker Laki Formation, and much farther to the north, by Manchar Formation overburden. Because of these adverse structural and stratigraphic conditions, the Bara Formation coal beds were always considered too deep to mine economically anywhere that the Laki Formation was exposed at the surface. However, with the discovery that the Lakhra Formation thins to the north, came the realization that coal beds may be much closer to the surface than previously expected. Ascertaining the extent of this thinning trend, determining whether the thinning is confined to the Lakhra Formation or if it also affects the Bara Formation and possibly even the Laki Formation, and determining if the thinning is depositional or erosional, are all results that will be useful in determining whether there is any potential for the occurrence of mineable coal north and west of the PMDC leases explored by the Boyd Company. These results will also allow some speculation concerning the coal potential as far north as Fort Ranikot and beyond.

It is well established that the Lakhra Formation thins toward the north (Ghani and others, 1973; Cheema, 1977), but there are differing opinions regarding the amount that the formation thins. Cheema (1977) and Abdullah (1980) contend that the Lakhra thins drastically but persists as far north as

Kehar Dhoro (see figure 1), while Hunting Survey Corporation (1961), Ghani and others (1973), and Gingerich and others (1979) indicate that the formation disappears well to the south of Bara Dhoro, possibly as far south as Golara.

From figure 4 it is evident that the major change in the thickness of the formation occurs in the lower three quarters of the formation. Comparisons between sections SN-7/8 and SN-9 indicate that there is a similar number of calcareous sandstone ledge-formers in both sections (7 in SN-9, 8 in SN-7/8) but the amount of interburden between individual ledges in SN-7/8 is significantly greater than in SN-9. In contrast, in the upper part of the formation, the thick limestone Unit 2 can be traced between sections SN-7/8 and SN-9 with only a minor change in the thickness of the interburden between the top of the Unit 2 limestone and the base of the Sohnari Formation. Thus the thickening of the Lakhra Formation south of SN-9 is attributable to increasing sediment input or to more rapid sediment accumulation due to faster basin subsidence.

The extent of the southward thickening of the Lakhra Formation is unknown. The Lakhra Formation in drill hole UAS-8, approximately 35 km south of section SN-4, is only 94 m thick and consists almost exclusively of limestone, so not only is there a thinning trend toward the south, there is also a major facies change. Additional drill hole data between SN-4 and UAS-8 will be necessary to determine the characteristics of this facies change and the geometry of the thinning.

None of the previous investigators who have studied the Lakhra Formation offer explanations for the cause of the observed thinning trend. Blanford (1878), Nuttall (1931), Williams (1959), Cheema (1977), and Farshori (unpublished) maintain that there is an unconformity between the Lakhra and the Sohnari Formations. The implication from their conclusions is that the

thinning of the Lakhra Formation could be attributed to erosion at the unconformity. Vredenburg (1906), however, believes that the unconformity represents a period of nondeposition and that there has been little or no erosion at the unconformity.

Examination of the contacts between the Lakhra Formation and the Sohnari Formation in drill holes from the Sonda, Thatta, and the Indus East areas strongly suggest that the contact is conformable (SanFilipo and others, 1988a; Outerbridge and others, in press). Figure 4 does indicate a thinning trend northward for the interburden between unit 2 and the Sohnari Formation. Part of this thinning trend (the change most evident between sections SN-6 and SN-7/8) may be related to the same northward decrease in sediment accumulation that is observed in the lower part of the section. At this time we do not have enough data to address this question, both because of the dearth of information between Siph Nala and UAS-8 south and because the correlation of Unit 2 with rocks north of section SN-9 is uncertain. Additional drilling to the north will be needed to answer this question. As a preliminary to any further drilling to the north however, it would be critical to study, in detail, the surface geology at the type area of the Bara Formation at Bara Dhoro and the principal reference section of the Bara Formation at Fort Ranikot, and to examine several carefully selected Boyd Co. cores from the drilling on the PMDC lease.

Preliminary reconnaissance investigations conducted at the principal reference section of the Bara Formation at Fort Ranikot (fig.1, approximately 30 km northwest of section SN-10) and the type section of the Bara Formation at Bara Dhoro (fig. 1, approximately 60 km northwest of section SN-10) indicate major facies changes northward. The Sohnari Formation was not observed at either locality. In addition, the Lakhra Formation as well as the highest marine facies of the Bara Formation appear to be absent at Fort

Ranikot, but the area is structurally complex and the Lakhra and Sohnari may have been faulted out of the section. Much additional work needs to be done in this area.

At Bara Dhoro, Lakhra-like sediments were observed, i.e. sediments that weathered to the yellow brown color so characteristic of the Lakhra Formation. We are not convinced at this time, however, that these were Lakhra Formation sediments and we suspect that these may, in fact, be the more marine parts of the Bara Formation. The yellow brown color is derived from the weathering of the glauconite that is abundant in parts of the Bara Formation.

CONCLUSIONS AND RECOMMENDATIONS

Thick limestone beds such as Units 1 and 2 in figures 2 and 3 are laterally persistent over large areas. The lateral persistence of thinner beds of limestone cannot be demonstrated in the Lakhra area though several have been mapped in the Sonda area.

Resistant calcareous sandstone beds are interpreted as storm deposits on the basis of graded bedding, basal scour contacts, and the occurrence of intraformational clasts. Persistence of approximately similar numbers of these resistant, calcareous sandstone beds, regardless of the thickness of the section, suggests that at least some individual beds may have basin-wide distributions. Paleontological dates for the base and top of the Lakhra Formation will be needed to test this conclusion.

The northward thinning of the Lakhra formation occurs abruptly over a very short distance. The thinning is attributed herein to decreasing sedimentation or sediment accumulation toward the north as evidenced by the decreasing thickness of the interburden between resistant calcareous sandstone beds between sections SN-7/8 and Sn-9.

There is great uncertainty about the relationship between sections UAL-13 and SN-10 and the sections further south. Resolution of the relationship between these units will be helpful in determining whether or not there is an erosional contact between the Sohnari and the Lakhra Formations. Though we cannot determine the precise correlation between SN-9 and SN-10, we are of the opinion that there has been no erosive removal of the Lakhra Formation northward. The decreasing thickness of the Lakhra Formation to the north is believed to be caused by non-deposition or by reduced sedimentation rates. We believe that the absence of the Lakhra and Sohnari farther to the north is due entirely to non-deposition. Detailed sections must be measured north of the Lakhra Coal Field at the principal reference section at Fort Ranikot and the type area at Bara Dhoro, and selected core from the drilling by the Boyd Company should also be examined to aid in testing this conclusion.

With the northward thinning of the Lakhra Formation, and possibly of the upper part of the Bara Formation, areas to the north of the PMDC tract drilled by the Boyd Co. may also have coal potential. Detailed investigations of Bara Formation outcrops north of Fort Ranikot are needed in order to make a preliminary assessment of the coal potential of this region before committing resources to drilling.

Additional drilling must be done to the south in order to determine the rate of Lakhra Formation thinning in that direction and to determine the character of the facies changes.

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APPENDIX 1

LITHOLOGIC DESCRIPTIONS

SECTION: SN-1

LAKHRA FORMATION

1. Limestone: Crystalline; argillaceous; yellow brown; indurated, ledge former; CONTAINS: burrows; forams; sharp contact with:
   0.80 m
   (0.80 m)

2. Shale: olive brown, red in places; fissile; slope former; sharp contact with:
   5.60 m
   (6.40 m)

3. Limestone: Argillaceous; yellow brown; indurated, ledge former; CONTAINS: abundant forams, also echinoderms, oysters, and corals; sharp contact with:
   1.80 m
   (8.20 m)

4. Shale: olive brown, localized red staining; fissile; slope former; sharp contact with:
   3.90 m
   (12.10 m)

5. Sandstone: Fine-grained, well sorted; yellow brown; composed of quartz, some interstitial clay, and calcareous cement; indurated, ledge former; CONTAINS: burrows and abundant forams; sharp contact with:
   1.50 m
   (13.60 m)

6. Sandstone: Fine-grained, poorly sorted; yellow brown; composed of quartz, abundant interstitial clay, and some calcareous cement; poorly cemented, slope former; CONTAINS: forams in the top half of the unit; sharp contact with:
   3.10 m
   (16.70 m)

7. Limestone: Argillaceous and very arenaceous, containing fine-grained sand; yellow brown; indurated, ledge former; CONTAINS: forams, corals, nautiloids, oysters, and burrows; sharp contact with:
   1.30 m
   (18.00 m)

8. Sandstone: Fine-grained, poorly sorted; yellow brown; composed of quartz and extremely abundant interstitial clay; poorly cemented, slope former; CONTAINS: abundant clay laminations in the base, unit coarsens upward and laminations become less common and then disappear in the top few meters; basal 2 m contains iron cemented burrows up to 8 cm in diameter, burrows decrease in size upward averaging less than 4 cm in diameter; sharp contact with:
   9.00 m
   (27.00 m)

9. Limestone: Crystalline, vuggy, slightly argillaceous, pale yellow-

brown; indurated, ledge former; CONTAINS: echinoderms,
9.00 m whole shells and shell fragments; sharp contact with:
(36.00 m)

10. Limestone: Slightly argillaceous, pale yellow brown, soft, very prone to weathering, ledge former; CONTAINS: abundant coral
1.90 m colonies; grades into:
(37.90 m)

11. Limestone: Crystalline; slightly argillaceous; pale yellow brown; indurated, ledge former; CONTAINS: echinoderms, forams, and
3.40 m abundant oysters; sharp contact with:
(41.30 m)

12. Claystone: Variegated, olive brown, yellow brown and red; massive; slope former; CONTAINS: burrows(?); sharp contact with:
1.70 m
(43.00 m)

13. Limestone: Crystalline; argillaceous; yellow brown; indurated, ledge former; CONTAINS: forams and rare Turritella and shell
1.50 m fragments; sharp contact with:
(44.50 m)

14. Covered: Presumed to be clay

3.00 m
(47.50 m)

15. Limestone: Argillaceous and glauconitic; yellow brown; indurated, ledge former; CONTAINS: oysters, echinoderms, very abundant
2.80 m Assilina and Opercolina forams; sharp contact with:
(50.30 m)

16. Shale: Silty at the contact, fining upward; red becoming olive brown with red and purple zones in the upper third; fissile;
9.10 m slope forming; sharp contact with:
(59.40 m)

17. Limestone: Arenaceous, contains fine-grained quartz sand; yellow brown; indurated; ledge former; CONTAINS: burrows; some oysters;
1.20 m abundant forams; sharp contact with:
(60.60 m)

18. Sandstone: Fine-grained, poorly sorted; yellow brown; composed of quartz and abundant interstitial clay; poorly cemented,
0.20 m slope former; CONTAINS: sparse shell fragments; sharp
(60.80 m) contact with:

19. Marl: Argillaceous; yellow brown; indurated, ledge former; CONTAINS: abundant forams; sharp contact with:
0.25 m
(61.05 m)

20. Limestone: Coquina; yellow brown; indurated, ledge former; CONTAINS:

abundant oysters and forams; sharp contact with:

1.40 m
(62.45 m)

21. Sandstone: Very fine- to fine-grained, poorly sorted; basal half-meter shaly, coarsens upward to fine-grained sandstone then fines again to very fine sandstone; yellow brown, basal third contains sparse, red, ferruginous silt zones; composed of quartz and extremely abundant interstitial clay; poorly cemented, slope former; grades into:

8.60 m
(71.05 m)

22. Limestone: Very argillaceous throughout, arenaceous in the bottom meter; yellow brown; indurated, ledge former; CONTAINS: foram coquina composed of Assilina and Opercolina in places, oyster concentrations in places, gastropods, echinoderm spines, and burrows; grades into:

7.80 m
(78.85 m)

23. Sandstone: Fine-grained, poorly sorted; yellow brown; composed of quartz and abundant interstitial clay; poorly cemented, slope former; CONTAINS: clay bands toward the base; grades into:

5.20 m
(84.05 m)

24. Shale: olive brown; fissile; slope-forming; CONTAINS: fine-grained sandstone laminations; red, ferruginous siltstone bands; sharp contact with:

5.20 m
(89.25 m)

25. Sandstone: Fine- to coarse-grained, poorly sorted; yellow brown; composed of quartz, interstitial clay, and calcareous cement; indurated, ledge former; CONTAINS: abundant burrows throughout; zones of abundant Turritella, gastropod, and shell fragments between 40-60 cm and 130-150 cm; above 150 cm there are abundant echinoderm, oyster, and shell fragments; calcareous mud pebbles occur in the top 10 cm; sharp contact with:

2.30 m
(91.55 m)

26. Shale: olive brown; fissile; slope former; CONTAINS: abundant iron cemented burrows; sharp contact with:

2.30 m
(93.85 m)

27. Sandstone: Fine- to coarse-grained, poorly sorted; yellow brown; composed of quartz, abundant interstitial clay, glauconite, and calcareous cement; indurated, ledge former; CONTAINS: burrows, forams, gastropods, and shell fragments; grades into:

0.80 m
(94.65 m)

28. Sandstone: Fine- to coarse-grained, poorly sorted; yellow brown; composed of quartz and abundant interstitial clay; poorly cemented, slope former; CONTAINS: burrows; sharp contact with:

1.50 m
(96.15 m)

29. Sandstone: Medium- to very coarse-grained, poorly sorted; yellow brown; composed of quartz, interstitial clay, glauconite, and calcareous cement; indurated, ledge former; CONTAINS: gastropods, forams, Turritella, and shell fragments; sharp

2.50 m
(98.65 m)

contact with:

30. Sandstone: Fine- to medium-grained, poorly sorted, coarsens upward from fine-grained at the base to medium-grained at the top; 3.00 m variegated yellow brown with abundant red and purple zones; (101.65 m) composed of quartz and abundant interstitial clay; poorly cemented, slope former; sharp contact with:

31. Sandstone: Fine- to medium-grained, poorly sorted; yellow brown; composed of quartz, abundant interstitial clay, and 0.90 m calcareous cement; indurated, ledge former; CONTAINS: (102.55 m) abundant burrowing throughout, the unit appears homogenized by burrowing; uncommon shell fragments in the top 10 cm; scour contact with:

32. Sandstone: Fine-grained, coarse-grained at the top, poorly sorted; yellow brown; composed of quartz and abundant interstitial 3.80 m clay; poorly cemented, slope former; sharp contact with: (106.35 m)

33. Sandstone: Medium- to very coarse-grained, poorly sorted; yellow brown; composed of quartz, interstitial clay, and calcareous 1.10 m cement; indurated, ledge former; CONTAINS: rare bone (107.45 m) fragments; abundant oyster and Turritella fragments in the basal half; bedding appears to have been homogenized by burrowing; grades into:

34. Sandstone: Medium-grained, poorly sorted; variegated purple, yellow and white; composed of quartz and some interstitial clay; poorly 0.90 m cemented, slope former; grades into: (108.35 m)

35. Sandstone: Fine- to medium-grained, poorly sorted; yellow brown; composed of quartz and abundant interstitial clay; poorly 0.70 m cemented, slope former; sharp contact with: (109.05 m)

36. Sandstone: Fine-grained, poorly sorted; yellow brown; composed of quartz, interstitial clay, and calcareous cement; indurated, 0.70 m ledge former; CONTAINS: festoon cross-bedding; a zone of (109.75 m) climbing ripples 8 cm thick; burrowing in the upper half of the unit; scour contact with:

37. Sandstone: Fine-grained, poorly sorted; yellow brown; composed of quartz and abundant interstitial clay; poorly cemented, slope 0.20 m former; CONTAINS: rare shell ghosts; sharp contact with: (109.95 m)

38. Sandstone: Medium-grained, poorly sorted; yellow brown; composed of quartz, abundant interstitial clay, and calcareous cement; 0.40 m indurated, ledge former; CONTAINS: large Turritella, (110.35 m) gastropods, oysters, and flat lying shell fragments; sharp contact with:

39. Sandstone: Fine-grained, well-sorted; light gray; composed of quartz,

very little interstitial clay, and gypsum(?) cement;
3.55 m (113.90 m) interbedded with fine-grained, variegated red, yellow, and purple sandstone containing abundant interstitial clay; unit coarsens upward into a medium-grained sandstone in the top meter; poorly cemented, slope former; CONTAINS: low angle cross-beds up to 10 cm thick, ripples, and flat laminations and, in places, planar cross-sets up to 15 cm thick; sharp contact with:

40. Sandstone: Medium- to coarse-grained, poorly sorted; yellow brown; composed of quartz, abundant interstitial clay, and
0.35 m (114.25 m) calcareous cement; indurated, ledge former; CONTAINS: iron cemented sandstone pebbles; forams; bivalves; abundant shell fragments; some oysters and gastropods; some echinoderm fragments; sharp contact with:

41. Shale: Variegated, olive brown with bands of red and purple iron cemented shale; fissile; slope former; sharp contact with:
2.40 m (116.65 m)

42. Sandstone: Fine-grained, poorly sorted; yellow brown; composed of quartz and very abundant interstitial clay; poorly cemented,
2.50 m (119.15 m) slope former; sharp contact with:

43. Sandstone: Medium- to coarse-grained, poorly sorted; greenish-yellow; composed of quartz, some interstitial clay, and calcareous
0.55 m (119.70 m) cement; indurated, ledge former; CONTAINS: abundant Turritella, forams, oysters, bivalves, shell fragments, and burrows up to 4 cm in diameter; sharp contact with:

44. Sandstone: Fine-grained, poorly sorted, silty at base and coarsening upward; yellow brown; composed of quartz and very abundant
1.90 m (121.60 m) interstitial clay; poorly cemented, slope former; CONTAINS: clay bands; gypsum cemented sand bands; iron-cemented, branching, Ophiomorpha burrows up to 4 cm in diameter; sharp contact with:

45. Sandstone: Fine- to medium-grained, poorly sorted; yellow brown; composed of quartz, abundant interstitial clay, and
0.80 m (122.40 m) calcareous cement; indurated, ledge former; CONTAINS: burrows; forams; Turritella, oysters, and shell fragments; sharp contact with:

46. Sandstone: Fine- to coarse-grained, poorly sorted; yellow brown; composed of quartz, abundant interstitial clay, and a small
1.00 m (123.40 m) amount of calcareous cement; indurated, ledge former; CONTAINS: a monotypic assemblage of abundant whole and broken oyster shells; calcareous, tabular sandstone pebbles and cobbles up to 10 cm long and 1 cm thick, pebbles and cobbles are more indurated than the surrounding sediment; grades into:

47. Sandstone: Fine-grained, poorly sorted; yellow brown; composed of

quartz and abundant interstitial clay; poorly cemented,
0.70 m slope former; CONTAINS: zones of fine-grained, clean,
(124.10 m) gypsum cemented sandstone; sharp contact with:

48. Shale: Olive brown; fissile; slope former; sharp contact with:

1.40 m
(125.50 m)

49. Sandstone: Medium-grained, poorly sorted; yellow brown; composed of quartz, interstitial clay, and calcareous cement; indurated,
0.95 m ledge former; CONTAINS: very abundant Turritella shell
(126.45 m) fragments and some oyster shell fragments in the top 10 cm; grades into:

50. Sandstone: Very fine-grained, poorly sorted; yellow brown; composed of quartz and very abundant interstitial clay; poorly cemented,
2.30 m slope former; CONTAINS: Turritella fragments and shell
(128.75 m) fragments; sharp contact with:

51. Sandstone: Medium-grained, poorly sorted; yellow brown; composed of quartz, glauconite, interstitial clay, and calcareous cement;
0.25 m indurated, ledge former; CONTAINS: calcareous mud pebbles
(129.00 m) throughout; forams, oysters, Turritella, whole shells and fragments; sharp contact with:

52. Shale: Brown; fissile; slope former; sharp contact with:

1.10 m
(130.10 m)

53. Sandstone: Coarse-grained, poorly sorted; yellow brown; composed of quartz, glauconite, interstitial clay, and calcareous cement;
0.25 m indurated, ledge former; CONTAINS: rounded, calcareous mud
(130.35 m) pebbles throughout; shell fragments and abundant forams; sharp contact with:

54. Shale: olive brown; fissile; slope former; sharp contact with:

6.50 m
(136.85 m)

55. Sandstone: Medium-grained, poorly sorted; yellow brown; composed of quartz, interstitial clay, glauconite, and calcareous
0.80 m cement; indurated, ledge former; CONTAINS: calcareous mud
(137.65 m) pebbles throughout; burrows; forams, gastropods, pelecypods, Turritella, and shell fragments; grades into:

56. Shale: olive brown; fissile; slope former; CONTAINS: flat sandstone laminations; siderite nodules; burrows?; becomes
4.90 m sandy in the top 30 cm; sharp contact with:
(142.55 m)

57. Sandstone: Fine- to medium-grained, poorly sorted; dark yellow brown; composed of quartz and abundant interstitial clay; poorly

0.50 m (143.05 m) cemented, slope former; grades into:

58. Sandstone: Medium-grained, poorly sorted; dark yellow brown; composed of quartz, abundant interstitial clay, and calcareous cement; 0.45 m (143.50 m) indurated, ledge former; CONTAINS: mud pebble conglomerate at base, pebbles are calcareous, tabular, and randomly orientated; forams and shell fragments in the base; sharp contact with:

59. Shale: Gray; fissile; slope former; CONTAINS: scattered laminations composed of fine-grained quartz sand; sharp 2.10 m (145.60 m) contact with:

60. Sandstone: Medium-grained, poorly sorted; olive brown; composed of quartz, abundant interstitial clay, and calcareous cement; 1.40 m (147.00 m) indurated, ledge former; CONTAINS: bivalves, gastropods, Turritella, and shell fragments; sharp contact with:

61. Siltstone: Coarsening upward into fine-grained, very argillaceous, quartz sandstone; yellow brown; poorly cemented, slope 2.10 m (149.10 m) former; grades into:

62. Shale: olive brown; fissile; slope former; sharp contact with:

1.50 m (150.60 m)

63. Sandstone: Fine- to medium-grained, poorly sorted; dark yellow brown; composed of quartz, some interstitial clay, and calcareous 0.60 m (151.20 m) cement; indurated, ledge former; CONTAINS: burrows; shell fragments and forams in the bottom half; mud pebble conglomerate in the basal 10 cm, the pebbles are calcareous, tabular, and parallel to bedding; wavy bedding in the top half, homogeneous bedding in the bottom half; sharp, irregular contact with:

BARA FORMATION

64. Shale: olive brown; fissile; slope former; CONTAINS: sandy zones up to 20 cm thick and sand laminations less than 1 mm thick, 7.45 m (158.65 m) laminations become more abundant upward, sand is fine-grained; unit coarsens upward into a sandy mudstone at the top; sharp contact with:

65. Sandstone: Fine-grained, medium-grained in places, poorly sorted; variegated red, yellow, gray, and white; composed of quartz 4.80 m (163.45 m) and a small percentage of interstitial clay; poorly cemented, slope former; CONTAINS: burrows; zones of small scale ripples; flat clay bands and laminations; bands of white clay (kaolinite?)

END OF SECTION

SECTION: SN-2

METING LIMESTONE

1. Limestone: Crystalline; vuggy; thin-bedded, beds average 10 cm in thickness; pale brown, weathering white; indurated, ledge former; CONTAINS: abundant Alveolina forams in the basal 80 cm; sharp contact with:
   8.20 m
   (8.20 m)

2. Limestone: Argillaceous; massive; pale brown, weathers white; indurated, ledge former; CONTAINS: abundant Alveolina forams; sharp contact with:
   5.60 m
   (13.80 m)

3. Shale: Variegated, olive brown with red and gray bands; fissile; slope former; sharp contact with:
   2.90 m
   (16.70 m)

4. Limestone: Arenaceous, composed of medium grained to granule sized lime sand; pale brown, weathers white; indurated, ledge former; unit channel-form and lenticular pinching laterally to 5 cm over a distance of 50 m; CONTAINS: echinoderm spines, epsilon cross-bed sets, planar cross-sets in the epsilon units, cross-beds are graded and fine upward; abundant Alveolina forams function as sand grains and granules; sharp contact with:
   2.00 m
   (18.70 m)

5. Limestone: Argillaceous, buff, weathers white; indurated, ledge former; CONTAINS: oysters, abundant burrows; sharp contact with:
   0.30 m
   (19.00 m)

SOHNARI FORMATION

6. Shale: White, kaolinitic(?); slope former; sharp contact with:
   0.40 m
   (19.40 m)

7. Shale: Red, top 2 m variegated white and purple; massive; indurated, forms ledges locally; CONTAINS: abundant roots throughout, ferruginous root casts locally preserved; sharp contact with:
   5.60 m
   (25.00 m)

LAKHRA FORMATION

8. Shale: olive brown; fissile; slope former; sharp contact with:
   2.50 m
   (27.50 m)

9. Sandstone: Very fine-grained, poorly sorted; yellow brown; composed of quartz, interstitial clay, and calcareous cement; indurated, ledge former; CONTAINS: forams, rare shell fragments, and
   2.50 m

(30.00 m) abundant burrows, unit homogenized by burrowing; grades into:

10. Limestone: Argillaceous, arenaceous, containing very fine-grained quartz; yellow brown; indurated, ledge former; CONTAINS: shell fragments and forams; sharp contact with:
0.15 m
(30.15 m)

11. Shale: olive brown, containing occasional red, ferruginous bands; slope former; sharp contact with:
3.20 m
(33.35 m)

12. Limestone: Argillaceous, yellow brown; indurated, ledge former; CONTAINS: forams, corals, gastropods, and shell fragments; sharp contact with:
1.20 m
(34.55 m)

13. Shale: Coarsens upward from shale to shale with fine-grained sand bands to argillaceous fine-grained sandstone at the top; olive brown lightens upward to yellow brown; slope former; sharp contact with:
12.60 m
(47.15 m)

14. Limestone: Arenaceous, containing quartz sand; yellow brown; indurated, ledge former; CONTAINS: forams and rare shell fragments; sharp contact with:
1.60 m
(48.75 m)

15. Limestone: Argillaceous; yellow brown; indurated, ledge former; CONTAINS: abundant forams and rare gastropods; sharp contact with:
0.40 m
(49.15 m)

16. Limestone: Very argillaceous; yellow brown; weakly cemented, weathers quickly, slope former; CONTAINS: abundant forams; sharp contact with:
0.80 m
(49.95 m)

17. Limestone: Main ledge forming limestone in the region, equivalent to unit 9 of section SN1
not measured

END OF SECTION

SECTION: SN-3

LAKHRA FORMATION

1. Limestone: Argillaceous; crystalline top 3 m; vuggy; pale yellow brown; indurated though basal half-meter weathering rapidly, ledge former; CONTAINS: clay (kaolinite?) nodules in places; pelecypods, oysters, echinoderms, shell fragments, and abundant forams; sharp contact with:
   7.20 m
   (7.20 m)

2. Shale: Variegated olive brown with rare red mottling in places; fissile; slope forming; sharp contact with:
   1.95 m
   (9.15 m)

3. Limestone: Argillaceous; yellow brown; indurated but weathering rapidly in places, ledge former; CONTAINS: corals, Turritella, oysters, gastropods, nautiloids, pelecypods, echinoderms, shell fragments, and abundant forams and burrows; basal 5 cm contains no fossils; sharp contact with:
   2.30 m
   (11.45 m)

4. Shale: olive brown; fissile; slope former; sharp contact with:
   3.60 m
   (15.05 m)

5. Limestone: Arenaceous, argillaceous; yellow; indurated, ledge forming; CONTAINS: gastropods, corals, pelecypods, oysters, echinoderm spines, Turritella, crinoids; abundant forams, burrows, shell fragments and corals; grades into:
   1.60 m
   (16.65 m)

6. Sandstone: Fine-grained, poorly sorted; yellow brown; composed of quartz and very abundant interstitial clay; poorly cemented, slope former; CONTAINS: burrows; grades into:
   3.20 m
   (19.85 m)

7. Shale: olive brown; fissile; slope former; sharp contact with:
   3.50 m
   (23.35 m)

8. Sandstone: Medium-grained, poorly sorted; yellow brown; composed of quartz, interstitial clay, and calcareous cement; indurated, ledge former; CONTAINS: forams, gastropods, shell fragments, and abundant burrows; scour contact with:
   0.70 m
   (24.05 m)

9. Sandstone: Medium-grained, poorly sorted; yellow brown; composed of quartz, interstitial clay, and calcareous cement; indurated but becoming increasingly poorly cemented upward, ledge former; CONTAINS: well-cemented, calcareous, sand nodules containing abundant shell fragments and red, iron stained forams; burrows; sharp contact with:
   1.50 m
   (25.55 m)

10. Sandstone: Fine-grained, poorly sorted; yellow brown; composed of

quartz and interstitial clay; poorly cemented, slope former;
1.90 m contains sparse shell fragments; homogenized by burrowing;
(27.45 m) sharp contact with:

11. Sandstone: Fine-grained, poorly sorted; yellow brown; composed of quartz, interstitial clay, and some calcareous material;
0.60 m poorly cemented, slope former; CONTAINS: shell fragments
(28.05 m) and abundant oysters and forams; sharp contact with:

12. Sandstone: Fine-grained, poorly sorted; yellow brown; composed of quartz, interstitial clay, and calcareous cement; indurated,
0.60 m ledge former; CONTAINS: burrows, gastropods, oysters,
(28.65 m) forams, Turritella, and shell fragments; sharp contact with:

13. Sandstone: Fine-grained, poorly sorted; yellow brown; composed of quartz and abundant interstitial clay; poorly cemented,
10.00 m slope former; grades into:
(38.65 m)

14. Shale: Arenaceous; olive brown; fissile; slope former; sharp contact with:
1.50 m
(40.15 m)

15. Limestone: Argillaceous; yellow; indurated, ledge former; CONTAINS: burrows; sparse forams and oysters; grades into:
1.20 m
(41.35 m)

16. Limestone: Argillaceous, slightly arenaceous; yellow; indurated, ledge former; CONTAINS: abundant oysters and forams; burrowed;
2.70 m grades into:
(44.05 m)

17. Limestone: Arenaceous, becoming less arenaceous upward, argillaceous; yellow; indurated, ledge former; CONTAINS: echinoderms,
1.90 m oysters, and abundant forams; grades into:
(45.95 m)

18. Sandstone: Fine-grained, poorly sorted; yellow brown; composed of quartz and interstitial clay; poorly cemented, slope former;
9.00 m CONTAINS: zones of abundant, iron cemented burrows up to
(54.95 m) 5 cm in diameter, unit homogenized by burrowing; abundant oyster fragments and a small percentage of other shell remains in the top 3 m; contact covered:

19. Shale: olive brown; fissile; slope former; CONTAINS: burrows and fine-grained sand laminations; sharp contact with:
1.55 m
(56.50 m)

20. Shale: Variegated red and gray; fissile; slope former; sharp contact with:
0.60 m
(57.10 m)

21. Sandstone: Fine-grained, poorly sorted; yellow brown; composed of quartz and interstitial clay; poorly cemented, slope former; 1.60 m (58.70 m) sharp contact with:

22. Sandstone: Fine- to medium-grained, poorly sorted; yellow brown; composed of quartz, interstitial clay, and calcareous cement in places; indurated, ledge former; CONTAINS: burrows throughout, abundant shell fragments, rare bone fragments; 1.95 m (60.65 m) sharp contact with:

23. Limestone: Arenaceous, containing coarse quartz grains, argillaceous; yellow brown; indurated, ledge former; CONTAINS: oysters, gastropods, pelecypods, and abundant shell fragments; sharp 0.25 m (60.90 m) contact with:

24. Sandstone: Fine- to medium-grained, unit fines upward, poorly sorted; variegated red, white, and yellow brown; composed of quartz and abundant interstitial clay; poorly cemented, slope 2.70 m (63.60 m) former; CONTAINS: clay bands toward the top; burrows; sharp contact with:

25. Limestone: Very argillaceous, contains abundant medium-grained quartz sand; yellow brown; indurated, ledge former; CONTAINS: oysters, bivalves, gastropods, and shell fragments; sharp 0.55 m (64.15 m) contact with:

26. Sandstone: Fine- to medium-grained, poorly sorted; variegated red with some white; composed of quartz and abundant interstitial clay; poorly cemented, slope former; sharp contact with: 1.90 m (66.05 m)

27. Sandstone: Medium- to coarse-grained, poorly sorted; yellow brown; composed of quartz, abundant interstitial clay, glauconite, and calcareous cement, becomming less calcareous upward; 6.00 m (72.05 m) indurated, ledge former; CONTAINS: burrows, bedding homogenized by burrowing; Turritella, gastropods, local concentrations of shell fragments; sharp contact with:

28. Sandstone: Fine-grained, basal 50 cm are medium-grained, poorly sorted; variegated yellow brown, red, and purple; composed of quartz and abundant interstitial clay; poorly cemented although 4.30 m (76.35 m) there are several ledges up to 10 cm thick that are well indurated; slope former; CONTAINS: burrows; clay bands; sharp contact with:

29. Sandstone: Medium- to coarse-grained, poorly sorted; light tan interbedded with thin zones of variegated red and white; composed of quartz, some interstitial clay, and calcareous 6.40 m (82.75 m) cement; indurated, ledge former; CONTAINS: planar cross-beds up to 1 m thick; thin zones of climbing ripples; internal scour and fill contacts; burrows; zones of shell fragment accumulations; sharp contact with:

30. Sandstone: Fines upward from medium- to very fine-grained, poorly sorted; variegated red and yellow brown; composed of quartz and interstitial clay; poorly cemented, slope former; sharp contact with:
0.55 m (83.30 m)

31. Sandstone: Medium-grained, poorly sorted; yellow brown; composed of quartz, interstitial clay, and calcareous cement; indurated, ledge former; CONTAINS: burrows and shell fragments; sharp contact with:
0.70 m (84.00 m)

32. Sandstone: Fine-grained, poorly sorted; variegated red and yellow-brown; composed of quartz and interstitial clay; poorly cemented, slope former; sharp contact with:
0.80 m (84.80m)

33. Sandstone: Medium- to coarse-grained, poorly sorted; yellow brown; composed of quartz, interstitial clay, and calcareous cement; indurated, ledge former; CONTAINS: burrows and shell fragments; grades into:
0.35 m (85.15 m)

34. Sandstone: Fine-grained, poorly sorted; variegated red and yellow-brown; composed of quartz and interstitial clay; poorly cemented, slope former; sharp contact with:
0.50 m (85.65 m)

35. Sandstone: Medium-grained, poorly sorted; yellow brown; composed of quartz, interstitial clay, and calcareous cement; indurated, ledge former; CONTAINS: gastropods, sparse shell fragments, and abundant burrows, unit homogenized by burrowing; grades into:
0.30 m (85.95 m)

36. Sandstone: Fine-grained, poorly sorted; variegated red and yellow-brown; composed of quartz and interstitial clay; poorly cemented, slope former; sharp contact with:
0.45 m (86.40 m)

37. Sandstone: Medium- to coarse-grained, poorly sorted; yellow brown; composed of quartz, interstitial clay, and calcareous cement; indurated, slope former; CONTAINS: Ophiomorpha burrows; local concentrations of shell fragments; clay pebbles; lenticular bed form; grades into:
1.30 m (87.70 m)

38. Sandstone: Fine-grained fining upward to very fine-grained, poorly sorted; variegated red with some gray and yellow brown; composed of quartz and abundant interstitial clay; poorly cemented, slope former; sharp contact with:
5.50 m (93.20 m)

39. Sandstone: Medium-grained, well-sorted; variegated yellow brown and white with local areas of pink staining; composed of 99 percent quartz and a very small percentage of interstitial clay; indurated, ledge former; CONTAINS: planar cross-beds; tabular, laminar bedded units at 1.5 m; small scale low-angle cross-beds at the top; lenticular bed forms; shell fragments concentrated on bedding surfaces and cross-bed surfaces; grades into:
2.50 m (95.70 m)

40. Sandstone: Medium- to coarse-grained, poorly sorted; yellow brown; composed of quartz and interstitial clay; indurated, ledge former; CONTAINS: calcareous sand pebbles; oysters, gastropods, pelecypods, Turritella, and very abundant shell fragments; homogeneous bedding; grades into:
0.60 m (96.30 m)

41. Shale: Sandy at top and bottom; variegated gray and yellow brown; fissile; slope former; grades into:
1.10 m (97.40 m)

42. Sandstone: Fine-grained, poorly sorted; yellow brown; composed of quartz, interstitial clay, and calcareous cement; indurated, ledge former; CONTAINS: shell fragments and molds, abundant burrows up to 4 cm in diameter; grades into:
0.80 m (98.20 m)

43. Sandstone: Fine-grained, poorly sorted; yellow brown; composed of quartz, interstitial clay, calcareous cement; weakly cemented, ledge former; grades into:
0.50 m (98.70 m)

44. Limestone: Very argillaceous upper half, arenaceous bottom half containing fine- to very coarse-grained quartz sand, yellow-brown; indurated, slope former; CONTAINS: Turritella, oysters, gastropods, shell fragments; rippled sand bands; abundant glauconite; grades into:
0.70 m (99.40 m)

45. Shale: Variegated gray with red bands; fissile; slope former; CONTAINS: fine-grained quartz sand ripples toward the top of the unit; sharp contact with:
1.80 m (101.20 m)

46. Siltstone: Calcareous, yellow brown; indurated, ledge former; CONTAINS: oysters, gastropods, Turritella, and abundant shell fragments; glauconite; sharp contact with:
0.15 m (101.35 m)

47. Sandstone: Fine-grained, poorly sorted; yellow brown; composed of quartz and extremely abundant interstitial clay; poorly cemented, slope former; grades into:
1.50 m (102.85 m)

48. Shale: olive brown; fissile; slope former; CONTAINS: fine-grained, quartz sand laminations; grades into:
6.40 m (109.25 m)

49. Mudstone: Slightly calcareous, arenaceous, containing poorly sorted fine- to very coarse-grained quartz sand; yellow brown; indurated, ledge former; CONTAINS: clay pebbles; Turritella, gastropods, oysters, and shell fragments; glauconite; no evidence of bedding, homogeneous; grades into:
1.20 m (110.45 m)

50. Sandstone: Fine-grained, poorly sorted; yellow brown; composed of

quartz and abundant interstitial clay; poorly cemented,
1.50 m slope former; grades into:
(111.95 m)

51. Shale: olive brown; fissile; slope former; CONTAINS: abundant carbonaceous debris on bedding surfaces; thin, very fine-
4.50 m grained quartz sand laminations that become more abundant
(116.45 m) upward; sharp contact with:

52. Sandstone: Fine-grained, poorly sorted; yellow brown; composed of quartz, extremely abundant interstitial clay, glauconite,
0.80 m and calcareous cement; indurated, ledge former; CONTAINS:
(117.25 m) Turritella, gastropods, corals, shell fragments, sparse forams; shell molds; calcareous mud pebbles; no evidence of bedding, internally homogeneous; sharp contact with:

53. Shale: olive brown with variegated red and yellow brown zones; fissile; slope former; CONTAINS: burrows; abundant thin
2.80 m sand laminations throughout; a 10 cm thick band of black
(120.05 m) manganese(?) staining at the contact with the overlying unit; grades into:

54. Sandstone: Fine-grained, poorly sorted; yellow brown with variegated red and olive brown clay bands; composed of quartz and very
2.00 m abundant interstitial clay; poorly cemented, slope former;
(122.05 m) CONTAINS: abundant shale bands throughout; burrows(?); sharp contact with:

55. Sandstone: Fine- to very coarse-grained, poorly sorted; yellow brown; composed of quartz and very little interstitial clay;
0.10 m indurated, ledge former; CONTAINS: burrows; sharp contact
(122.15 m) with:

56. Shale: Variegated red, gray, olive brown, and yellow brown; fissile; slope former; CONTAINS: sandstone laminations;
1.60 m sharp contact with:
(123.75 m)

57. Sandstone: Medium- to coarse-grained, poorly sorted; yellow brown; composed of quartz, interstitial clay, and calcareous
0.45 m cement; indurated, ledge former; CONTAINS: calcareous mud
(124.20 m) pebbles; calcareous mud-filled burrows; gastropod molds and shell fragments; no evidence of bedding, unit internally homogeneous; sharp contact with:

58. Sandstone: Very fine-grained, poorly sorted; yellow brown; composed of quartz and very abundant interstitial clay; poorly cemented,
1.50 m slope former; CONTAINS: abundant shale bands and
(125.70 m) laminations; abundant carbonaceous debris on bedding surfaces; sharp contact with:

59. Sandstone: Medium- to coarse-grained, poorly sorted; yellow brown; composed of quartz, interstitial clay, and calcareous
0.25 m cement; indurated, ledge former; CONTAINS: abundant oyster
(125.95 m) shells and molds; sharp contact with:

BARA FORMATION

60. Shale: Variegated red and yellow brown; fissile; slope former; CONTAINS: fine-grained quartz sand laminations; grades into:
1.75 m
(127.70 m)

61. Sandstone: Fine-grained, well-sorted; variegated white and pink; composed of quartz and little interstitial clay; poorly cemented, slope former; CONTAINS: burrows; sharp contact with:
1.50 m
(129.20 m)

62. Shale: Variegated white, purple, and yellow brown; fissile; slope former; CONTAINS: sandstone laminations; carbonaceous debris on bedding surfaces; kaolinite(?)
1.00 m
(130.20 m)

END OF SECTION

SECTION SN-4

LAKHRA FORMATION

1. Limestone: Datum ledge; crystalline, increasingly argillaceous downward; vuggy; yellow; indurated, ledge former; CONTAINS: Nautilus, shell fragments, and abundant forams; sharp contact with:
   7.50 m
   (7.50 m)

2. Shale: olive brown with variegated red and gray zones; fissile; slope former; sharp contact with:
   2.10 m
   (9.60 m)

3. Limestone: Very argillaceous, arenaceous containing coarse-grained quartz sand; yellow; indurated, ledge former; CONTAINS: gastropods, pelecypods, forams, shell fragments, and burrows; sharp contact with:
   0.60 m
   (10.20 m)

4. Shale: Variegated red, gray, yellow brown; fissile; slope former; CONTAINS: abundant fine- and very fine-grained sandstone bands and laminations; rare gastropod shell molds; sharp contact with:
   9.00 m
   (19.20 m)

5. Sandstone: Medium- to coarse-grained, poorly sorted; yellow brown; composed of quartz, interstitial clay, and calcareous cement; indurated, ledge former; CONTAINS: Turritella, corals, pelecypods, gastropods, oysters, Nautilus, echinoderms, crabs, shell fragments; burrows, unit homogenized by burrowing; grades into:
   2.00 m
   (21.20 m)

6. Sandstone: Fine- to medium-grained, poorly sorted; yellow brown; composed of quartz and abundant interstitial clay; poorly cemented, slope former; CONTAINS: abundant shale laminations; grades into:
   4.50 m
   (25.70 m)

7. Shale: Variegated red and gray; fissile; slope former; sharp contact with:
   1.50 m
   (27.20 m)

8. Sandstone: Coarse-grained, poorly sorted; yellow brown; composed of quartz, abundant interstitial clay, and calcareous cement; indurated, ledge former; CONTAINS: oysters, gastropods, pelecypods, echinoderms, shell molds and fragments, abundant forams and burrows; sharp contact with:
   1.00 m
   (28.20 m)

9. Sandstone: Medium- to coarse-grained, poorly sorted; yellow brown; composed of quartz, abundant interstitial clay, and calcareous cement; indurated, ledge former; CONTAINS: shell fragments that become more abundant upward; abundant burrows, unit homogenized by burrowing; grades into:
   4.50 m
   (32.70 m)

10. Limestone: Argillaceous and arenaceous; yellow brown; basal 20 cm well indurated the remainder of the unit weathers badly, ledge

1.50 m (34.20 m) former; CONTAINS: corals, gastropods, forams, pelecypods, echinoderms, shell fragments, and burrows; grades into:

11. Limestone: Very argillaceous, arenaceous; yellow brown; indurated but intensely weathered, ledge former; CONTAINS: burrows, gastropods, forams, and shell fragments; sharp contact with:
1.60 m (35.80 m)

12. Shale: Variegated red, purple, yellow brown, and gray; fissile; slope former; CONTAINS: very fine- to medium-grained quartz sandstone bands and laminations, the unit is especially sandy in the middle; sharp contact with:
10.50 m (46.30 m)

13. Sandstone: Medium-grained, poorly sorted; yellow brown; composed of quartz, interstitial clay, and calcareous cement; indurated, ledge former; CONTAINS: clay pebbles; Turritella, gastropods, burrows, and shell fragments; grades into:
0.20 m (46.50 m)

14. Sandstone: Medium-grained at base fining upward to fine-grained at the top, poorly sorted; composed of quartz and abundant interstitial clay; poorly cemented, slope former; CONTAINS: calcareous sand nodules in the top 40 cm, nodules contain shell fragments and shell molds; Turritella and burrows; grades into:
3.80 m (50.30 m)

15. Sandstone: Fine-grained with rare medium and coarse grains, poorly sorted; yellow brown; composed of quartz, abundant interstitial clay, and calcareous cement; indurated, ledge former; CONTAINS: sparse oyster shell fragments and abundant burrows throughout, unit homogenized by burrowing; sharp contact with:
1.00 m (51.30 m)

16. Sandstone: Fine-grained, poorly sorted; yellow brown with red mottled zones in places; composed of quartz and abundant interstitial clay; poorly cemented, slope former; CONTAINS: bone fragments in float; sharp contact with:
5.20 m (56.50 m)

17. Shale: Variegated red, gray, and yellow brown; fissile; slope former; CONTAINS: very fine-grained quartz sand laminations; sharp contact with:
2.15 m (58.65 m)

18. Sandstone: Fine-grained, poorly sorted; yellow brown, variegated red, white, and yellow brown at the top; composed of quartz and interstitial clay that is abundant in places; poorly cemented, slope former; CONTAINS: numerous thin, very clean, well-indurated sand zones; shale bands and laminations; zones of intense burrowing; grades into:
5.10 m (63.75 m)

19. Sandstone: Fine- to medium-grained at base fining upward to fine-grained at top, poorly sorted; yellow brown; composed of quartz and abundant interstitial clay; poorly cemented, slope former; CONTAINS: rare pelecypod shell molds; sharp contact with:
3.30 m (67.05 m)

20. Sandstone: Medium- to coarse-grained, poorly sorted; yellow brown with purple mottling in places; composed of quartz, interstitial
1.70 m clay, glauconite at the top, and calcareous cement;
(68.75 m) indurated, ledge former; CONTAINS: Turritella, gastropods, echinoderms, oysters, pelecypods, and abundant fragmental shell material; shell material becomes less abundant upward; abundant burrows, unit homogenized by burrowing; unit varies between 1.7 and 0.85 m in thickness; grades into:

21: Sandstone: Fine-grained, poorly sorted; yellow brown; composed of quartz and extremely abundant interstitial clay; poorly
4.30 m cemented, slope former; CONTAINS: burrows; abundant olive
(73.05 m) brown shale bands and laminations; grades into:

22. Sandstone: Fine-grained, poorly sorted; yellow brown; composed of quartz, interstitial clay, and calcareous cement; indurated,
1.20 m ledge former; CONTAINS: abundant clay pebbles in the top
(74.25 m) 20 cm; burrows, abundant Turritella, gastropods, and oysters; grades into:

23. Sandstone: Fine-grained, poorly sorted; yellow brown; composed of quartz and very abundant interstitial clay; poorly cemented,
3.00 m slope former; CONTAINS: burrows, oyster shells throughout;
(77.25 m) abundant olive brown shale bands and laminations, especially in the bottom half; grades into:

24. Sandstone: Fine- to medium-grained, poorly sorted; yellow brown; composed of quartz, abundant interstitial clay, and
0.50 m calcareous cement; weakly indurated, ledge former;
(77.75 m) CONTAINS: oysters, Turritella, abundant pelecypods (Venericardia?); abundant burrows, unit homogenized by burrowing; grades into:

25. Sandstone: Fine- to medium-grained, poorly sorted; yellow brown with prominent gray shale bands in the middle of the unit;
2.20 m composed of quartz and abundant interstitial clay; poorly
(79.95 m) cemented, slope former; grades into:

26. Sandstone: Fine- to coarse-grained, poorly sorted; yellow brown; composed of quartz, interstitial clay, and calcareous
0.35 m cement; indurated, ledge former; CONTAINS: crab shell
(80.30 m) fragments, sparse gastropods, abundant pelecypods (Venericardia?), and shell molds; burrowed, unit homogenized by burrowing; grades into:

27. Sandstone: Fine-grained coarsening upward to fine- to medium-grained, poorly sorted; yellow brown with rare, thin red zones;
2.10 m composed of quartz and abundant interstitial clay; poorly
(82.40 m) cemented, slope former; CONTAINS: burrows, unit homogenized by burrowing; sharp contact with:

28. Sandstone: Fine- to coarse-grained, poorly sorted; yellow brown; composed of quartz, abundant interstitial clay, and
0.40 m calcareous cement; indurated, ledge former; CONTAINS:
(82.80 m) calcareous mud pebbles; oysters, pelecypods, Turritella,

gastropods, and shell fragments; no evidence of bedding, unit homogeneous; sharp contact with:

29. Sandstone: Fine-grained, medium-grained in places, poorly sorted; pale tan, red mottling in places, yellow brown at the top; composed of quartz, abundant interstitial clay, and gypsum? cement associated preferentially with medium-grained sandstone; poorly cemented, slope former; CONTAINS: burrows up to 3 cm in diameter; sharp contact with:
5.30 m (88.10 m)

30. Sandstone: Medium-grained, well-sorted; pale tan; composed of quartz, little interstitial clay, and calcareous cement; indurated, ledge former; CONTAINS: shell fragments; some burrows; shell debris on cross-bed surfaces; sharp contact with:
0.30 m (88.40 m)

31. Sandstone: Medium- to coarse-grained, poorly sorted; variegated red and purple; composed of quartz and interstitial clay; poorly cemented, slope former; CONTAINS: burrows, unit homogenized by burrowing;sharp contact with:
5.70 m (94.10 m)

32. Sandstone: Medium-grained, well-sorted; pale tan, variegated in places; composed of quartz, little interstitial clay, and calcareous cement; indurated, ledge former; CONTAINS: planar cross-beds; internal scours;
2.80 m (96.90 m)

33. Sandstone: Fine-grained, poorly sorted; yellow brown; composed of quartz, abundant interstitial clay, and some calcareous cement; indurated, ledge former; CONTAINS: no evidence of bedding, unit is homogeneous; sharp contact with:
0.15 m (97.05 m)

34. Sandstone: Fine-grained, poorly sorted; light yellow brown, cream in places; composed of quartz and abundant interstitial clay; poorly cemented, slope former; sharp contact with:
2.10 m (99.15 m)

35. Sandstone: Fine- to coarse-grained, poorly sorted; yellow brown; composed of quartz, interstitial clay, and calcareous cement; indurated, ledge former; CONTAINS: clay pebbles; sand pebbles; gastropods, oysters, and shell fragments; sharp contact with:
0.20 m (99.35 m)

36. Sandstone: Very fine-grained coarsening upward to fine-grained, poorly sorted; yellow brown to dark brown with gray shale bands in the basal 0.5 m; composed of quartz and abundant interstitial clay; poorly cemented, slope former; unit homogeneous, no evidence of bedding above the shale bands; grades into:
8.30 m (107.65 m)

37. Shale: Variegated red and white; blocky; slope former; CONTAINS: zones with abundant burrows; very fine-grained, quartz sand laminations; grades into:
4.40 m (112.05 m)

38. Shale: olive gray; fissile; slope former; CONTAINS: very fine-grained quartz sand laminations less than 1 mm thick;

0.75 m burrows; sharp contact with:
(122.80 m)

39. Sandstone: Fine-grained, poorly sorted; gray; composed of quartz and abundant interstitial clay; poorly cemented, slope former;
0.50 m CONTAINS: shale laminations; abundant carbonaceous debris,
(133.30 m) coalified wood fragments; burrows, unit homogenized by burrowing

END OF SECTION

SECTION SN-5

LAKHRA FORMATION

1. Limestone: Crystalline; argillaceous; yellow brown; indurated, ledge former; CONTAINS: burrows, forams, and shell fragments; sharp contact with:
   2.40 m
   (2.40 m)

2. Sandstone: Fine-grained, poorly sorted; yellow brown; composed of quartz and abundant interstitial clay; poorly cemented, slope former; CONTAINS: burrows; grades into:
   2.80 m
   (5.20 m)

3. Shale: olive brown; fissile; slope former; sharp contact with:
   3.20 m
   (8.40 m)

4. Limestone: Argillaceous, yellow brown; indurated, ledge former; CONTAINS: burrows, Nautilus, forams, rare gastropods, and sparse shell material; sharp contact with:
   0.60 m
   (9.00 m)

5. Shale: olive brown; fissile; slope former; sharp contact with:
   2.70 m
   (11.70 m)

6. Limestone: Crystalline; argillaceous; yellow brown; indurated, ledge former; CONTAINS: forams, burrows, and shell fragments; sharp contact with:
   1.80 m
   (13.50 m)

7. Limestone: Crystalline; argillaceous, vuggy; orange; indurated, ledge former; CONTAINS: burrows, rare pelecypods, shell fragments, and abundant forams; sharp contact with:
   1.40 m
   (14.90 m)

8. Limestone: Argillaceous, yellow brown; indurated, ledge former; CONTAINS: burrows, forams, and shell fragments; grades into:
   2.80 m
   (17.70 m)

9. Marl: Extremely argillaceous; yellow; weakly indurated, slope former; CONTAINS: sand and shale bands; forams and burrows; grades into:
   4.50 m
   (22.20 m)

10. Limestone: Arenaceous, containing medium- to coarse-grained quartz sand and grading downward into a sandstone at the base; argillaceous; yellow brown; indurated, ledge former; CONTAINS: Turritella, gastropods, shell fragments, burrows, and abundant forams; sharp contact with:
    2.90 m
    (25.10 m)

11. Shale: olive brown, variegated red and gray at the top; fissile; slope former; contact unknown:

3.00 m
(28.10 m)

12. Covered: presumed to be shale, possibly sandstone; contact unknown:

7.10 m
(35.20 m)

13. Shale: olive brown; fissile; slope former; sharp contact with:

1.00 m
(36.20 m)

14. Limestone: Primary Lakhra Formation datum bed; crystalline; argillaceous, slightly arenaceous; vuggy; pale yellow; 9.40 m indurated, ledge former; CONTAINS: burrows, echinoderms, (45.60 m) gastropods, pelecypods, shell fragments, and abundant forams; grades into:

15. Shale: Coarsens upward to very argillaceous, very fine-grained sandstone in the top meter; yellow brown; slope former; 3.00 m CONTAINS: fine-grained sand laminations; 10 cm very (48.60 m) argillaceous limestone at the base; grades into:

16. Limestone: Very argillaceous; arenaceous, becomming increasingly quartz sand rich upward; yellow brown; weakly indurated, slope 2.40 m former; CONTAINS: burrows, bivalves, shell fragments, and (51.00 m) sparse gastropod molds and forams, sharp contact with:

17. Shale: olive brown, upper half variegated red and gray; fissile; slope former; sharp contact with:

5.80 m
(56.80 m)

18. Sandstone: Fine- to medium-grained, poorly sorted; yellow brown; composed of quartz, abundant interstitial clay, and 2.80 m calcareous cement; indurated, ledge former; CONTAINS: (59.60 m) corals, pelecypods, oysters, echinoderms, crinoids, shell fragments, and abundant forams and burrows; sharp contact with:

19. Sandstone: Medium- to coarse-grained at the base fining upward to fine-grained, poorly sorted; yellow brown; composed of quartz and 6.70 m interstitial clay, clay becomes more abundant upward; poorly (66.30 m) cemented, slope former; CONTAINS: shale laminations in the basal half; Turritella and bivalve molds; sharp contact with:

20. Sandstone: Medium-grained, poorly sorted; yellow brown; composed of quartz, abundant interstitial clay, and calcareous cement; 1.30 m well indurated, ledge former; CONTAINS: planar cross-sets (67.60 m) up to 40 cm thick; burrows; sharp contact with:

21. Sandstone: Medium- to coarse-grained, poorly sorted; yellow brown;

composed of quartz, abundant interstitial clay, and
1.30 m calcareous cement; well indurated, ledge former; CONTAINS:
(68.90 m) oysters, forams, and shell fragments; sharp contact with:

22. Sandstone: Fine- to medium-grained, poorly sorted; yellow brown; composed of quartz and interstitial clay; poorly cemented,
6.40 m slope former; sharp contact with:
(75.30 m)

23. Shale: Variegated red, gray, olive brown, and yellow brown; fissile; fine-grained quartz sand content increases upward;
11.70 m slope former; sharp contact with:
(87.00 m)

24. Sandstone: Fine- to coarse-grained, poorly sorted; yellow brown; composed of quartz, interstitial clay, and calcareous
3.80 m cement; indurated, ledge former; CONTAINS: burrows,
(90.80 m) bivalves, gastropods, echinoderms, oysters, forams, and shell fragments

END OF SECTION

SECTION SN-6

METING LIMESTONE

1. Limestone: Crystalline; argillaceous; pale yellow, weathers white; indurated, ledge former; CONTAINS: abundant Alveolina, and rare nautiloids, gastropods, and pelecypods; grades into:
   12.20 m
   (12.20 m)

2. Shale: Very calcareous, light yellow brown; fissile; slope former; grades into:
   2.20 m
   (14.40 m)

3. Limestone: Crystalline; argillaceous; pale yellow, weathers white; indurated, ledge former; CONTAINS: abundant Alveolina, and rare nautiloids, gastropods, and pelecypods; grades into:
   10.00 m
   (24.40 m)

4. Shale: Very calcareous; light yellow brown; fissile; slope former; sharp contact with:
   1.10 m
   (25.50 m)

5. Limestone: Yellow; thin, interbedded limestone bands and very argillaceous limestone bands; indurated, ledge former; sharp contact with:
   3.30 m
   (28.80 m)

SOHNARI FORMATION

6. Shale: Variegated gray, red, purple, yellow brown; sandy in places; massive; indurated; locally ledge forming; sharp contact with:
   5.00 m
   (33.80 m)

LAKHRA FORMATION

7. Sandstone: Fine-grained, poorly sorted; yellow brown; composed of quartz, interstitial clay, and calcareous cement; indurated, ledge former; CONTAINS: forams; grades into:
   0.70 m
   (34.50 m)

8. Shale: Variegated brown, red, gray, yellow brown; fissile; slope former; CONTAINS: very fine-grained quartz sand laminations less than 1 mm in thickness; grades into:
   4.30 m
   (38.80 m)

9. Sandstone: Fine-grained, poorly sorted; variegated red, white, gray, black; composed of quartz and interstitial clay; poorly cemented, slope former; CONTAINS: gray clay bands; (subsequent correlations may show this to be the first Sohnari Formation unit); sharp contact with:
   3.30 m
   (42.10 m)

10. Limestone: Argillaceous; pale yellow; indurated, ledge forming;

CONTAINS: abundant glauconite; abundant forams and shell fragments composed of corals, pelecypods and echinoderms; lenticular, thins laterally from 90 cm to less than 10 cm, unit is present only locally; unit grades laterally into 20 cm of medium-grained, well sorted quartz sand that is burrowed and contains little interstitial clay; sharp contact with:

0.90 m
(43.00 m)

11. Shale: Increasing quartz sand content toward the top; olive brown with abundant red bands; fissile; slope former; sharp contact with:

4.00 m
(47.00 m)

12. Marl: Argillaceous, pale yellow brown to cream; homogéneous; weakly cemented, intensely weathered, ledge former; CONTAINS: shell fragments and forams; sharp contact with:

2.15 m
(49.15 m)

13. Sandstone: Fine- to medium-grained, poorly sorted; olive brown; composed of quartz and abundant interstitial clay; poorly cemented, slope former; grades into:

0.40 m
(49.55 m)

14. Shale: Fine- to medium-grained quartz sand content increases with height; olive brown with red and gray mottling; fissile; slope former; CONTAINS: quartz sand bands; sharp contact with:

2.95 m
(52.50 m)

15. Limestone: Arenaceous, extremely argillaceous; yellow brown; indurated but extensively weathered ledge former; CONTAINS: common Assilina some Alveolina forams; shell fragments; burrows; sharp contact with:

1.30 m
(53.80 m)

16. Shale: Variegated red, gray, olive brown, yellow brown; fissile; slope former; sharp contact with:

4.30 m
(58.10 m)

17. Sandstone: Silty at base, coarsens upward to fine-grained, poorly sorted; yellow brown, red and white mottling in the middle of the unit; composed of quartz and abundant interstitial clay; poorly cemented, slope former; CONTAINS: shale bands and laminations; burrows; carbonaceous debris on bedding surfaces; ripples in the basal part of the unit; no evidence of bedding in the top part of the unit; sharp contact with:

6.00 m
(64.10 m)

18. Limestone: Very argillaceous, yellow brown; indurated, ledge former; CONTAINS: Turritella, gastropods, corals, shell fragments, and burrows; sharp contact with:

0.30 m
(64.40 m)

19. Sandstone: Very fine-grained, poorly sorted; yellow brown; composed of quartz and very abundant interstitial clay; poorly cemented, slope former; sharp contact with:

1.05 m
(65.45 m)

20. Shale: Variegated red and gray; fissile; slope former; sharp contact with:

3.45 m
(68.90 m)

21. Limestone: Crystalline; argillaceous; brown; indurated, ledge former; CONTAINS: burrows and forams; sharp contact with:

4.75 m
(73.65 m)

22. Sandstone: Fine- to coarse-grained, poorly sorted; yellow brown; composed of quartz, pink quartz, glauconite, and abundant interstitial clay; poorly cemented, slope former; CONTAINS: thin bands of crystalline, argillaceous limestone that contain forams; sharp contact with:

8.80 m
(82.45 m)

23. Limestone: Crystalline; very argillaceous; brown; indurated, ledge former; CONTAINS: burrows, forams, and shell fragments

2.75 m
(85.20 m)

END OF SECTION

SECTION SN-7

LAKHRA FORMATION

1. Limestone: Primary regional datum bed in the Lakhra Formation; crystalline; argillaceous; yellow; indurated, ledge former; CONTAINS: burrows, corals, oysters, shell fragments, and abundant forams and echinoderms; sharp contact with:

10.20 m
(10.20 m)

2. Shale: olive brown; fissile; slope former; sharp contact with:

1.50 m
(11.70 m)

3. Sandstone: Very fine- to fine-grained, poorly sorted; red; composed of quartz and abundant interstitial clay; poorly cemented, slope former; CONTAINS: occasional shale bands; contact unknown:

11.75 m
(23.45 m)

4. Covered: Slope former; presumed to be sandstone; sharp contact with:

4.50 m
(27.95 m)

5. Limestone: Very argillaceous; yellow brown; weakly indurated, slope former; CONTAINS: burrows, forams, gastropods, pelecypods, and corals; grades into:

3.85 m
(31.80 m)

6. Sandstone: Fine- to medium-grained; yellow brown; poorly sorted; composed of quartz, interstitial clay, and calcareous cement; indurated, ledge former; CONTAINS: gastropods and shell fragments; abundant Turritella, forams, and burrows; grades into:

5.30 m
(37.10 m)

7. Sandstone: Fine-grained, poorly sorted; yellow brown with local occurrences of red banding; composed of quartz, abundant interstitial clay, and some calcareous cement; weakly indurated, slope former; CONTAINS: thin shale bands and laminations in the bottom half; burrows, unit homogenized by burrowing; zones of oyster shell fragments and zones of forams; sharp contact with:

8.30 m
(45.40 m)

8. Sandstone: Fine-grained, poorly sorted; yellow brown; composed of quartz, abundant interstitial clay, and calcareous cement; indurated, ledge former; CONTAINS: Turritella, gastropods, pelecypods, forams, and abundant oysters and burrows; sharp contact with:

2.10 m
(47.50 m)

9. Sandstone: Fine-grained, poorly sorted; yellow brown; composed of quartz, abundant interstitial clay, and some calcareous cement in places; poorly cemented though in places it is indurated, slope former; CONTAINS: sparse shell debris; burrows throughout; sharp contact with:

4.10 m
(51.60 m)

10. Sandstone: Fine- to coarse-grained, poorly sorted; yellow brown; composed of quartz, abundant interstitial clay, and
0.90 m calcareous cement; indurated, ledge former; CONTAINS:
(52.50 m) Turritella, echinoderms, shell fragments, and abundant forams; intensely burrowed throughout; sharp contact with:

11. Sandstone: Medium- to coarse-grained, poorly sorted; yellow brown; composed of quartz, abundant interstitial clay, and some
8.50 m calcareous cement; poorly cemented though unit is moderately
(61.00 m) cemented in places, slope former; CONTAINS: burrows throughout; sharp contact with:

12. Sandstone: Medium-grained at base coarsening upward to very coarse-grained at the top, poorly sorted; yellow brown; composed of
5.10 m quartz, abundant interstitial clay; and some calcareous
(66.10 m) cement; poorly cemented, slope former; CONTAINS: burrows; sparse shell fragments; grades into:

13. Sandstone: Fine- to coarse-grained, poorly sorted; yellow brown; composed of quartz, abundant interstitial clay, and
4.00 m calcareous cement; indurated, ledge former; CONTAINS:
(70.10 m) Turritella, gastropods, pelecypods, shell fragments, and burrows; sharp contact with:

14. Sandstone: Medium- to coarse-grained, zones of very coarse grains, poorly sorted; yellow brown; composed of quartz,
2.50 m interstitial clay, and calcareous cement; indurated, ledge
(72.60 m) former; CONTAINS: gastropods, pelecypods, and abundant shell fragments in the bottom half; abundant burrows in the bottom half, beds homogenized by burrowing; abundant sandstone cobbles in the shell beds; large scale planar cross-beds in the upper half, cross-bed direction measurements (2) indicate dip to the west and northwest; sharp contact with:

15. Sandstone: Fine- to medium-grained, poorly sorted; yellow brown; composed of quartz and abundant interstitial clay; poorly
4.30 m cemented, slope former; sharp contact with:
(76.90 m)

16. Sandstone: Medium-grained, very coarse-grained in places, well sorted; yellow brown; composed primarily of quartz, little
0.80 m interstitial clay, and calcareous cement; indurated, ledge
(77.70 m) former; CONTAINS: large scale planar cross-beds; rare shell fragments; in places the unit has Turedo burrowed tree trunks; the unit is discontinuous and cannot be traced across the nala; sharp contact with:

17. Sandstone: Fine- to very coarse-grained, poorly sorted; yellow brown; composed of quartz and abundant interstitial clay; poorly
3.00 m cemented, slope former; CONTAINS: kaolinite bands; sharp
(80.70 m) contact with:

18. Sandstone: Fine- to coarse-grained, poorly sorted in the bottom half, medium-grained, well-sorted in the top half; yellow brown;

1.10 m composed of quartz, abundant interstitial clay, and
(81.80 m) calcareous cement; indurated, ledge former; CONTAINS: Turritella, gastropods, pelecypods, shell fragments, burrows, and sparse oysters; shell material disappears in the upper half of the unit; sharp contact with:

19. Sandstone: Fine-grained, poorly sorted; yellow brown; composed of quartz and abundant interstitial clay; poorly cemented,
2.60 m slope former; grades into:
(84.40 m)

20. Sandstone: Fine- to coarse-grained, poorly sorted; yellow brown; composed of quartz, interstitial clay, and calcareous
1.70 m cement; poorly cemented at base, increasingly better
(86.10 m) cemented upward, ledge former; CONTAINS: Turritella, gastropod, pelecypod fragments, and abundant oyster shells; bands of gypsum cemented sandstone at the top of the unit: sharp contact with:

21. Sandstone: Fine- to medium-grained, poorly sorted; yellow brown; composed of quartz, interstitial clay, and calcareous
1.40 m cement; indurated, ledge former; CONTAINS: Turritella,
(87.50 m) gastropods, forams, pelecypods, and shell fragments; grades into:

22. Sandstone: Fine-grained, poorly sorted; yellow brown; composed of quartz and interstitial clay; poorly cemented, slope former;
1.20 m sharp contact with:
(88.70 m)

23. Sandstone: Fine-grained, poorly sorted; yellow brown; composed of quartz, glauconite, interstitial clay, and calcareous
0.90 m cement; indurated, slope former; CONTAINS: burrows;
(89.60 m) Turritella, gastropods, pelecypods, forams and shell fragments; sharp contact with:

24. Shale: Variegated red, gray, yellow brown, olive brown; fissile; slope former; CONTAINS: numerous fine-grained sandstone
1.00 m laminations, unit becomes increasingly sandy upward; sharp
(90.60 m) contact with:

25. Sandstone: Fine-grained, poorly sorted; yellow brown; composed of quartz, glauconite, abundant interstitial clay, and
0.85 m calcareous cement; indurated, ledge former; CONTAINS:
(91.45 m) forams, gastropods, and shell fragments and molds; no evidence of bedding, unit homogeneous; sharp contact with:

26. Sandstone: Fine- to coarse-grained, poorly sorted; yellow brown; composed of quartz, abundant interstitial clay, calcareous
1.35 m cement; indurated, ledge former; CONTAINS: burrows,
(92.80 m) Turritella, oysters, pelecypods, forams, echinoderms, gastropods, shell molds and fragments; sharp contact with:

27. Shale: olive brown, fissile, slope former; sharp contact with:

6.30 m
(99.10 m)

28. Mudstone: olive brown; slightly calcareous; indurated, ledge former; CONTAINS: gastropod, pelecypod, and other shell fragments; burrows; abundant glauconite; clay pebbles; grades into:
0.70 m
(99.80 m)

29. Sandstone: Fine-grained, poorly sorted; yellow brown; composed of quartz and very abundant interstitial clay; poorly cemented, slope former; CONTAINS: common shale bands which become more abundant downward; sharp contact with:
1.60 m
(101.40 m)

30. Sandstone: Fine-grained, poorly sorted; yellow brown; composed of quartz, abundant interstitial clay, and some calcareous cement in the basal part of the unit, unit becomes non-calcareous upward; poorly indurated except at the base, slope former; CONTAINS: Turritella, gastropods, pelecypods, forams, corals, and shell fragments, shell material disappears in the non-calcareous zone; sharp contact with:
2.30 m
(103.70 m)

31. Shale: Variegated red and gray; fissile; slope former; CONTAINS: fine-grained, quartz sand laminations; sharp contact with:
2.30 m
(106.00 m)

32. Sandstone: Fine-grained, poorly sorted; yellow brown; composed of quartz and abundant interstitial clay; poorly cemented but case-hardened at the surface, locally a ledge former; CONTAINS: burrows; sharp contact with:
2.20 m
(108.20 m)

33. Sandstone: Fine-grained, poorly sorted; yellow brown; composed of quartz and abundant interstitial clay; non-calcareous; indurated ledge former; CONTAINS: zones of Turritella, gastropod, and shell fragments, and abundant forams; burrows, unit homogenized by burrowing; sharp contact with:
1.50 m
(109.70 m)

34. Sandstone: Fine-grained, poorly sorted; variegated purple, red, gray, and thick zones of yellow brown; composed of quartz and very abundant interstitial clay; poorly cemented, slope former; CONTAINS: shale beds and bands throughout, shale beds up to 0.5 m thick; bands of very clean, gypsum cemented sandstone up to 2 cm thick, the clean sands contain very rare heavy mineral laminae; burrows; gastropods, bivalves, and shell molds in some beds; sharp contact with:
14.20 m
(123.90 m)

35. Sandstone: Fine- to medium-grained, poorly sorted; yellow brown; composed of quartz, very abundant interstitial clay, and some calcareous cement; indurated, ledge former; CONTAINS: shell fragments and molds; abundant burrows, unit homogenized by burrowing; grades into:
1.60 m
(125.50 m)

36. Sandstone: Interbedded with 40 percent shale bands and laminations at base; medium- to coarse grained fining upward to fine-grained at the top, poorly sorted; variegated red, gray, and
5.30 m

(130.80 m) yellow brown; composed of quartz and extremely abundant interstitial clay; poorly cemented, slope former; (this bed may represent the first of the bara formation sediments)

END OF SECTION

SECTION SN-8

METING LIMESTONE

1. Limestone: Crystalline, pale yellow, weathers white; indurated, ledge former; CONTAINS: burrows, pelecypods, shell fragments, forams, and abundant Alveolina; grades into:
   12.50 m
   (12.50 m)

2. Shale: Yellow; fissile; calcareous; slope former; grades into:
   0.70 m
   (13.20 m)

3. Limestone: Crystalline; pale yellow, weathers white; indurated, ledge former; lower 5 m covered but test pits indicate limestone; grades into:
   9.30 m
   (22.50 m)

4. Shale: Yellow; fissile; calcareous; slope former; sharp contact with:
   0.40 m
   (22.90 m)

5. Limestone: Argillaceous, pale yellow, weathers white; indurated, ledge former; CONTAINS: burrows; pelecypod and other shell fragments; abundant forams especially Alveolina; sharp contact with:
   1.30 m
   (24.20 m)

SOHNARI FORMATION

6. Claystone: Red; massive, homogeneous, blocky texture; appears brecciated in places; indurated, ledge former; unit believed to be rooted; contact unknown:
   6.00 m
   (30.20 m)

7. Covered: presumed to be the same as the overlying unit; contact unknown:
   3.00 m
   (33.20 m)

LAKHRA FORMATION

8. Limestone: Argillaceous, arenaceous in the basal meter; yellow brown; indurated, ledge former; CONTAINS: oysters, echinoderm spines, shell fragments, and abundant forams and burrows; grades into:
   2.45 m
   (35.65 m)

9. Sandstone: Fine-grained, poorly sorted; yellow brown; composed of quartz and abundant interstitial clay; poorly cemented, slope former; CONTAINS: shale beds and laminations, thicker shale beds have sand laminations and bands, some of these sand bands are up to 5 cm thick and consist of clean, well cemented low angle cross-bedded sandstone; burrows; grades into:
   6.30 m
   (41.95 m)

10. Shale: olive brown; fissile; slope former; CONTAINS: thin sand laminations; sharp contact with:
5.60 m
(47.55 m)

11. Limestone: Argillaceous; yellow brown to yellow; indurated, ledge former; CONTAINS: gastropods, pelecypods, echinoderms, shell fragments, burrows, and abundant forams; sharp contact with:
12.20 m
(59.75 m)

12. Shale: Calcareous; olive brown; slope former; CONTAINS: abundant shell debris; sharp contact with:
1.80 m
(61.55 m)

13. Limestone: Crystalline; argillaceous; yellow; indurated, ledge former; CONTAINS: burrows, gastropods, echinoderms, Nautilus (observed in float), forams, pelecypods, and shell fragments; sharp contact with:
1.20 m
(62.75 m)

14. Sandstone: Very fine-grained coarsening upward to fine-grained at top, poorly sorted; yellow brown; composed of quartz, extremely abundant interstitial clay, and some calcareous cement; poorly cemented, slope former; CONTAINS: burrows and decomposed shell material; sharp contact with:
10.55 m
(73.30 m)

15. Limestone: Crystalline; yellow brown; indurated, ledge former; CONTAINS: echinoderms, shell fragments, and abundant forams and burrows; sharp contact with:
1.30 m
(74.60 m)

16. Sandstone: Fine-grained, poorly sorted; yellow brown; composed of quartz and abundant interstitial clay; poorly cemented, slope former; CONTAINS: abundant burrows, unit homogenized by burrowing; grades into:
6.00 m
(80.60 m)

17. Sandstone: Fine-grained, poorly sorted; yellow brown; composed of quartz, abundant interstitial clay, and calcareous cement; indurated, ledge former; CONTAINS: burrows, Turritella, pelecypods, shell fragments, and abundant forams; sharp contact with:
2.00 m
(82.60 m)

18. Sandstone: Fine-grained, poorly sorted; red; composed of quartz, interstitial clay, and hematitic cement (presumed to be secondary); weakly cemented, slope former; CONTAINS: large burrows, unit homogenized by burrowing; sharp contact with:
11.50 m
(94.10 m)

19. Limestone: This unit believed to be the regional datum ledge; argillaceous and arenaceous at base, crystalline at top; indurated, ledge former; CONTAINS: burrows, Turritella, gastropods, echinoderms, oysters, shell fragments, and abundant forams; sharp contact with:
7.35 m
(101.45 m)

20. Shale: yellow brown; fissile; slope former; CONTAINS: laminar

bedding, burrows; bands of botryoidal hematite; grades into:

0.65 m
(102.10 m)

21. Sandstone: Fine-grained, poorly sorted; yellow brown; composed of quartz and abundant interstitial clay; well-cemented; CONTAINS: burrows; no evidence of bedding, unit homogeneous

0.60 m
(102.70 m)

END OF SECTION

SECTION SN-9

METING LIMESTONE

1. Limestone: Crystalline; cream, weathers white; indurated, ledge former; CONTAINS: gastropods, echinoderms, shell fragments, and abundant Alveolina; contact unknown:
   12.70 m
   (12.70 m)

2. Covered: Slope; presumed to be shaly or marly; contact presumed sharp:
   3.40 m
   (16.10 m)

SOHNARI FORMATION

3. Claystone: Massive; blocky; red; indurated, ledge former; appears intensely rooted throughout, roots are replaced by iron and preserved locally; grades into:
   6.60 m
   (22.70 m)

4. Shale: Red; fissile; slope former; CONTAINS: roots and slickensides; sharp contact with:
   0.90 m
   (23.60 m)

LAKHRA FORMATION

5. Limestone: Arenaceous, yellow brown; indurated, ledge former; CONTAINS: burrows, forams, gastropod and shell fragments; sharp contact with:
   2.60 m
   (26.20 m)

6. Shale: Red, calcareous, sandy toward the base; slope former; sharp contact with:
   6.50 m
   (32.70 m)

7. Limestone: Crystalline; yellow brown; indurated, ledge former; CONTAINS: corals, shell and echinoderm fragments, and common forams; sharp contact with:
   0.35 m
   (33.05 m)

8. Sandstone: Fine-grained, poorly sorted; yellow brown; composed of quartz, very abundant interstitial clay; and some calcareous cement; poorly cemented at the base, becomming better cemented upward, ledge former; CONTAINS: oysters, shell fragments, and abundant forams; shell material becomes less common toward the base; rare shale bands toward the base; grades into:
   4.20 m
   (37.25 m)

9. Sandstone: Fine- to medium-grained, some coarse grains, fining upward to a fine-grained sandstone; poorly sorted; yellow brown; composed of quartz, abundant interstitial clay, glauconite, and calcareous cement; indurated, ledge former; CONTAINS:
   10.90 m
   (48.15 m)

burrows, echinoderms, gastropods, pelecypods, oysters, shell fragments, and abundant forams; grades into:

10. Sandstone: Medium- to coarse-grained at the base, fine- to medium-grained with some coarse grains at the top, poorly sorted; brown at the base, yellow brown at the top; composed of quartz, abundant interstitial clay, and calcareous cement; clay content increases as calcareous cement decreases upward; indurated at base, becomes less well cemented upward, ledge former; CONTAINS: sparse shell fragments; burrows, unit homogenized by burrowing; sharp contact with:

2.50 m (50.65 m)

11. Sandstone: Medium- to coarse-grained, moderately sorted; yellow brown; composed of quartz, little interstitial clay, and calcareous cement; indurated, ledge former; CONTAINS: burrows; large scale planar cross-beds; sharp contact with:

2.10 m (52.75 m)

12. Sandstone: Fine- to coarse-grained, poorly sorted; yellow brown; composed of quartz, interstitial clay, and calcareous cement; poorly cemented, slope former; sharp contact with:

1.40 m (54.15 m)

13. Sandstone: Medium- to very coarse-grained, poorly sorted; yellow brown; composed of quartz, interstitial clay, and calcareous cement; indurated, ledge former; CONTAINS: forams and shell fragments; burrows, unit homogenized by burrowing; sharp contact with:

0.15 m (54.30 m)

14. Sandstone: Fine- to coarse-grained, poorly sorted; yellow brown; composed of quartz, interstitial clay, and some calcareous cement; poorly indurated, slope former; CONTAINS: possible decomposed shell material; no evidence of bedding, unit homogeneous

1.50 m (55.80 m)

END OF SECTION

SECTION SN-9A

This section is a partial off-set from section SN-9. It was measured 50 m north of section SN-9.

LAKHRA FORMATION

1.	Limestone: 1.15 m (1.15 m)	Yellow brown; indurated, ledge former; CONTAINS: burrows, forams, gastropods, shell fragments, and echinoderms; grades into:
2.	Sandstone: 1.25 m (2.40 m)	Fine-grained, poorly sorted; yellow brown; composed of quartz, interstitial clay, and calcareous cement; indurated, ledge former; CONTAINS: forams and shell fragments; no evidence of bedding; grades into:
3.	Shale: 7.90 m (10.30 m)	Variegated gray, red, yellow brown; fissile; becomes very sandy in the top 1.5 m; slope former; sharp contact with:
4.	Sandstone: 0.40 m (10.70 m)	Fine-grained, poorly sorted; yellow brown; composed of quartz, interstitial clay, and calcareous cement; indurated, slope former; CONTAINS: shell fragments and abundant forams; sharp contact with:
5.	Limestone: 0.35 m (11.05 m)	Argillaceous; yellow brown; indurated, ledge former; CONTAINS: burrows, forams, corals, shell and pelecypod fragments; sharp contact with:
6.	Sandstone: 9.40 m (20.45 m)	Fine- to medium-grained, some coarse grains, fining upward to a fine-grained sandstone; poorly sorted; yellow brown; composed of quartz, abundant interstitial clay, glauconite, and calcareous cement; indurated, ledge former; CONTAINS: burrows, echinoderms, gastropods, pelecypods, oysters, shell fragments, and abundant forams; the base of this unit correlates to the base of unit 9 in section SN-9

END OF SECTION

SECTION SN-10

METING LIMESTONE

1. Limestone: Cream, weathers white; CONTAINS: pelecypods, gastropods, forams including abundant Alveolina; sharp contact with:

19.05 m
(19.05 m)

SOHNARI FORMATION

2. Claystone: Red; massive; blocky; intensely rooted; sharp contact with:

5.00 m
(24.05 m)

LAKHRA FORMATION

3. Sandstone: Fine-grained, in places medium and coarse grains are found, poorly sorted; primarily pale brown though in places the unit is red, cream, or yellow brown; composed of quartz, interstitial clay, and, in places, abundant heavy minerals; CONTAINS: burrows, unit homogenized by burrowing; sharp contact with:

12.45 m
(36.50 m)

4. Sandstone: Fine-grained, poorly sorted; variegated red and gray; composed of quartz and abundant interstitial clay; poorly cemented, slope former; CONTAINS: burrows, unit homogenized by burrowing; grades into:

2.20 m
(38.70 m)

5. Shale: Variegated red, gray, yellow brown; fissile; slope former; CONTAINS: sand laminations toward the top and becomes increasingly sandy upward; sharp contact with:

2.50 m
(41.20 m)

6. Limestone: Very argillaceous, slightly arenaceous; yellow brown; indurated ledge former; CONTAINS: abundant glauconite; burrows; gastropods, oysters, pelecypods, echinoderm and shell fragments, and abundant forams; sharp contact with:

0.45 m
(41.65 m)

7. Shale: Brown; fissile; slope former.

0.35 m
(42.00 m)

END OF SECTION

SECTION SN-11

METING LIMESTONE

1. Limestone: Cream, weathers white; indurated; CONTAINS: gastropods, pelecypods, shell fragments, forams, especially abundant Alveolina; grades into:
   11.80 m
   (11.80 m)

2. Limestone: Cream, weathers white; indurated but weathers easily; CONTAINS: burrows; abundant Alveolina; sharp contact with:
   14.15 m
   (25.95 m)

SOHNARI FORMATION

3. Claystone: Red; massive; blocky; appears rooted throughout, the basal meter and the top 4 m tend toward fissility; contact uncertain:
   9.75 m
   (35.70 m)

LAKHRA FORMATION

4. Covered: Believed to be limestone: contact unknown:

   6.00 m
   (41.70 m)

5. Limestone: Regional datum bed; argillaceous; yellow brown; indurated, ledge former; CONTAINS: Nautilus; one very well indurated crystalline bed in the middle of the unit about 1 meter thick; contact unknown:
   15.90 m
   (57.60 m

6. Covered: Lithology unknown; contact unknown:

   4.50 m
   (62.10 m)

7. Limestone: Crystalline, light brown; CONTAINS: forams, pelecypods, echinoderm and shell fragments.
   0.75 m
   (62.85 m)

END OF SECTION

SECTION LS-2

METING LIMESTONE

1. Limestone: Yellow, weathers white; calcarenite, indurated, ledge former; CONTAINS: wavy bedding; parallel laminations; vertically penetrating burrows and burrows on bedding plane surfaces; ripples becomming more common upward; few fossils; thin foram beds up to 5 cm thick, foram beds become more common upward; echinoderm spines; sharp contact with:
   12.50 m
   (12.50 m)

SOHNARI FORMATION

2. Siltstone: Fines upward to shale; fissile; red, maroon, purple, gray, and green gray; deeply weathered; slope former; CONTAINS: laminated bedding in the basal part of the unit; sharp contact with:
   3.50 m
   (16.00 m)

3. Claystone: Massive; white at base with red and purple bands, red, gray, and purple at the top, mottled breccia-like color texture; intensely rooted at the top, rooting intensity appears to decrease downward; sharp contact with:
   2.80 m
   (18.80 m)

4. Altered limestone: Yellow brown and red; same as underlying unit except that it is extremely altered and broken up by the crystallization of gypsum; sharp contact with:
   0.40 m
   (19.20 m)

LAKHRA FORMATION

5. Limestone: Yellow brown; massive; argillaceous, becomes more argillaceous upward; calcarenitic matrix; indurated, ledge former; CONTAINS: abundant forams, Assilina, Opercolina and other foram types, foraminiferal limestone; rare pelecypods; no evidence of bedding, unit presumed to have been homogenized by burrowing; contact unknown;
   5.80 m
   (25.00 m)

6. Covered:
   4.00 m
   (29.00 m)

7. Limestone: Yellow brown; argillaceous; arenaceous, containing some medium-grained quartz sand; indurated, ledge former; CONTAINS: an especially well-indurated unit that appears to be an internal scour; gastropods, shell fragments, burrows, unit homogeneous, presumed to be homogenized by burrowing; abundant forams including Opercolina, Discocyclina, Assilina as well as other foram types, foraminiferal limestone; sharp contact with:
   1.30 m
   (30.30 m)

8. Sandstone: Medium-grained, well sorted; red and white; composed of quartz, little interstitial clay, and ferruginous cement; indurated, ledge former; CONTAINS: no observable bedding structures; sharp contact with:
   0.50 m
   (30.80 m)

9. Sandstone: Fine-grained, moderately sorted; red; composed of quartz, some interstitial clay, and ferruginous cement; weakly
0.20 m indurated, slope former; CONTAINS: low-angle cross-beds;
(31.00 m) sharp contact with:

10. Siltstone: White, pink at the base, top of the unit weathers to a sulfur colored yellow; white units extremely low in density;
0.70 m slope former; CONTAINS: sand laminations; sharp contact
(31.70 m) with:

11. Sandstone: Fine-grained, poorly sorted; red and white; composed of quartz and abundant interstitial clay; indurated, ledge
2.10 m former; CONTAINS: ripples in the lower part of the unit;
(33.80 m) burrows, upper part of the unit homogenized by burrowing; grades into:

12. Shale: Red and gray with yellow brown bands; coarsens upward to silt at the top; slope former; CONTAINS: sand laminations,
3.95 m possible heavy mineral concentrations in the sand; rare
(37.75 m) kaolinite nodules; burrows in the upper part of the unit; possibly oxidized carbonaceous debris on some bedding surfaces; sharp contact with:

13. Sandstone: Fine- to medium-grained, poorly sorted; yellow brown; composed of quartz, interstitial clay, and a calcareous
0.15 m cement; indurated, ledge former; CONTAINS: various genera
(37.90 m) of gastropods including Turritella, abundant forams, rare pelecypods; sharp contact with:

14. Sandstone: Very fine-grained, poorly sorted; yellow brown; non-calcareous; composed of quartz and very abundant
0.70 m interstitial clay; poorly cemented, ledge forming in places;
(38.60 m) CONTAINS: small scale ripples, iron cemented burrows; grades into:

15. Shale: olive brown with yellow brown bands; coarsens upward becomming extremely sandy at the top; fissile; slope former;
8.50 m CONTAINS: very fine-grained quartz sand beds and
(47.10 m) laminations; laminar bedding; small scale ripples in some sand beds; very rare red hematitic nodules; sharp contact with:

16. Limestone: Pale yellow brown; clean; fine-grained calcarenite; massive; indurated, top 30 cm recrystallized and hard, ledge former;
3.45 m CONTAINS: shell fragments; abundant randomly orientated
(50.55 m) forams, some forams are filled with glauconite, foraminiferal limestone; presumed burrowed; sharp contact with:

17. Covered:

3.00 m
(53.55 m)

18. Sandstone: Very fine- to fine-grained, poorly sorted; dark yellow-brown; composed of quartz, glauconite pellets, interstitial matrix, and a small percentage of calcareous matrix; weakly cemented, slight ledge former; CONTAINS: scattered rounded clay pebbles; burrows; homogeneous, no evidence of bedding; grades into:
0.70 m (54.25 m)

19. Sandstone: Very fine-grained, fines downward and becomes very shaly at the base, poorly sorted; yellow brown, variegated red and gray at the base; composed of quartz and very abundant interstitial clay; poorly cemented, slope former; CONTAINS: sand laminations in the shale; sharp contact with:
2.60 m (56.85 m)

20. Sandstone: Fine-grained, poorly sorted; maroon; composed of quartz, abundant interstitial clay, and ferruginous cement; indurated, ledge former; CONTAINS: burrows; pelecypod shells; iron replaced gastropod shells; sharp contact with:
0.10 m (56.95 m)

21. Sandstone: Very fine-grained, becomes increasingly shaly upward, poorly sorted; red and gray; composed of quartz and very abundant interstitial clay; poorly cemented, slope former; CONTAINS: shale beds and laminations; no evidence of bedding, unit appears homogeneous; grades into:
2.90 m (59.85 m)

22. Sandstone: Medium-grained, poorly sorted; red, yellow brown; composed of quartz, interstitial clay, and ferruginous cement; indurated, ledge former; CONTAINS: abundant burrows; grades into:
0.25 m (60.10 m)

23. Sandstone: Very fine- to fine-grained, poorly sorted; red, yellow-brown, gray; composed of quartz, interstitial clay, and some ferruginous cement; poorly cemented, slope former; CONTAINS: no evidence of bedding, unit homogeneous; grades into:
4.50 m (64.60 m)

24. Shale: Coarsens upward; olive brown in the lower half, variegated red, gray, and yellow brown in the upper half; fissile; calcareous at the base; slope former; CONTAINS: fine-grained quartz sand laminations, laminations become more prominent upward; rare yellow brown iron rich bands; iron rich nodules; grades into:
7.40 m (72.00 m)

25. Limestone: Yellow brown; massive; argillaceous, top is very argillaceous; indurated, slope former; CONTAINS: shell fragments, oysters, gastropods, pelecypods, abundant forams including Opercolina as well as other forms; burrows, unit homogenized by burrowing; grades into:
1.10 m (73.10 m)

26. Limestone: Yellow brown; massive; very argillaceous, contains clay bands that become more prominent downward; fine-grained calcarenite matrix; indurated, ledge former; CONTAINS: siderite nodules in the basal 50 cm; iron rich bands in the lower third of the unit; glauconite; gastropods, oysters, forams and shell fragments; abundant burrows, unit homogenized by burrowing. **END OF SECTION**
1.20 m (74.30 m)

SECTION LS-5

METING LIMESTONE

1. Limestone: White; massive; nodular; indurated, ledge former; CONTAINS: abundant Alveolina; abundant burrows, unit homogeneous, no evidence of bedding; contact unknown:
   12.10 m
   (12.10 m)

2. Covered: Shaly material weathering at base; contact unknown:
   2.50 m
   (14.60 m)

3. Limestone: White; massive; nodular; indurated, ledge former; CONTAINS: abundant burrows, unit homogenized by burrowing; abundant Alveolina, some Orbitolites; grades into:
   5.20 m
   (19.80 m)

4. Limestone: White; massive; calcarenite; weathers more rapidly than overlying limestone, indurated, slope former; CONTAINS: laminar bedding; burrows; sparse shell fragments and forams including Alveolina; sharp contact with:
   10.50 m
   (30.30 m)

SOHNARI FORMATION

5. Claystone: Red; massive; blocky fracture; indurated, ledge former in places; CONTAINS: white kaolinitic breccia pebbles in a red matrix in some places, in other places the claystone is a red breccia in a red matrix; white kaolinite nodules at the top; no unequivocal rooting though there are some vertical lineations that suggest that the unit was rooted; sharp contact with:
   3.60 m
   (33.90 m)

LAKHRA FORMATION

6. Limestone: Pale yellow brown; argillaceous; calcarenite; massive; homogeneous; CONTAINS: shell fragments, abundant forams including Discocyclina and Assilina; sharp contact with:
   0.60 m
   (34.50 m)

7. Limestone: Orange; crystalline; massive; very indurated, ledge former; CONTAINS: pelecypods, shell fragments, common forams including Opercolina and Assilina; appears burrowed; sharp contact with:
   0.65 m
   (35.15 m)

8. Shale: olive brown at base with red and medium gray mottling in places, yellow brown laminations in places, upper two-thirds of the unit is light gray with some white and abundant red mottling; fissile; slope former; CONTAINS: beds of yellow brown siltstone at the base, abundant glauconite in the siltstone; beds of red ironstone near the top; sharp contact with:
   7.30 m
   (42.45 m)

9. Mudstone: yellow brown; slightly calcareous; indurated, ledge former;

CONTAINS: sparse medium-grained quartz; oysters, pelecypods, gastropods, abundant forams including Assilina and Opercolina; glauconite; sharp contact with:

0.40 m
(42.85 m)

10. Sandstone: Very fine-grained, poorly sorted; yellow brown with some red staining; composed of quartz and very abundant interstitial clay; poorly cemented, slope former; CONTAINS: thin olive brown shale beds and laminations up to 1 cm thick; zones of bright yellow brown nodules; burrows; sharp contact with:

1.60 m
(44.45 m)

11. Sandstone: Very fine-grained, well-sorted; yellow brown; composed of quartz and some interstitial clay; poorly cemented, slope former, ledge forming in places; CONTAINS: laminar bedding; ripple bedding; low-angle cross-beds; burrowed throughout, burrows abundant in places; sharp contact with:

2.30 m
(46.75 m)

12. Claystone: Olive brown, gray brown in places; slope former; CONTAINS: yellow brown laminations; black manganese stain on fractures in some places; sharp contact with:

9.00 m
(55.75 m)

13. Limestone: Yellow brown; massive; calcarenite; foraminiferal limestone; weathered at base becomes increasingly indurated upward, ledge former; steeply dipping beds; CONTAINS: abundant burrows, unit homogenized by burrowing; gastropods, pelecypods, shell fragments, abundant forams including Assilina, Discocyclina, and Opercolina; contact unknown:

4.50 m
(60.25 m)

14. Covered: Believed to be very fine- to medium-grained sandstone; unit badly disturbed by fracturing associated with drag folding; sharp contact with:

5.50 m
(65.75 m)

15. Limestone: Red; massive; fine-grained calcarenite; indurated, ledge former; bed flat-lying and difficult to trace around the hillside, the fault appears to cross through this bed but displacement appears to be minor; CONTAINS: shell fragments replaced with gypsum; sharp contact with:

0.70 m
(66.45 m)

16. Limestone: Yellow; massive; arenaceous; calcarenite; indurated, ledge former; CONTAINS: sparse medium grains of quartz sand; glauconite; shell fragments and abundant forams including Assilina; appears burrowed; contact unknown:

0.45 m
(66.90 m)

17. Covered: Poorly cemented, slope former; sharp contact with:

1.50 m
(68.40 m)

18. Limestone: Yellow brown; slightly argillaceous; calcarenite; indurated, ledge former; CONTAINS: burrows, Nautilus, oysters, bivalves, gastropods, pectins, and abundant forams including Assilina, Opercolina, Discocyclina, and Orbitolites; sharp contact with:

0.40 m
(68.80 m)

19. Shale: olive green; fissile; coarsens upward to very fine-grained very argillaceous sandstone in the top 80 cm; deeply
3.55 m weathered; slope former; CONTAINS: very fine-grained quartz
(72.35 m) sand laminations which increase in abundance and thickness upward; yellow brown bands; sharp contact with:

20. Sandstone: Very fine- to medium-grained poorly sorted; light yellow-brown; deeply weathered and disturbed by secondary gypsum
1.35 m formation; composed of quartz and abundant interstitial
(73.70 m) clay; sharp contact with:

21. Limestone: Yellow brown; slightly argillaceous; massive; calcarenite; indurated, ledge former; CONTAINS: sparse medium quartz
0.75 m grains; burrows, gastropods, pelecypods, shell fragments,
(74.45 m) and abundant forams including Assilina and Opercolina; sharp contact with:

22. Sandstone: Fine-grained, poorly sorted; brown with gray and yellow-brown mottling; composed of quartz and extremely abundant
1.90 m interstitial clay; deeply weathered; poorly cemented, slope
(76.35 m) former; CONTAINS: no evidence of bedding, unit homogeneous; grades into:

23. Shale: olive brown with yellow brown bands; fissile; coarsens upward; slope former; CONTAINS: sparse, limonite replaced
3.55 m carbonaceous debris; beds and laminations of very fine-
(79.90 m) grained quartz sand up to 2 cm thick, beds and laminations become more abundant upward; small, horizontal, iron cemented burrows; sharp contact with:

24. Sandstone: Fine- to medium-grained, poorly sorted; yellow brown; composed of quartz and very abundant interstitial clay;
0.30 m poorly cemented, slope former; CONTAINS: shale filled
(80.20 m) burrows, unit homogenized by burrowing; sharp contact with:

25. Sandstone: Fine- to very coarse-grained with some quartz granules, poorly sorted; yellow brown; composed of quartz, little
0.45 m interstitial clay, and some calcareous cement; indurated,
(80.65 m) ledge former; CONTAINS: abundant burrows, unit homogenized by burrowing; gastropods and abundant forams including Assilina and some Discocyclina; sharp contact with:

26. Sandstone: Very fine- to medium-grained, coarsens upward, medium grains become more prominent upward and the argillaceous component
3.00 m decreases upward; poorly sorted; gray brown with bands of
(83.65 m) red and yellow brown mottling; composed of quartz and abundant interstitial clay; poorly cemented, slope former; CONTAINS: shale laminations in the lower part of the unit, shale laminations disappear upward; iron cemented burrows throughout, unit homogenized by burrowing; grades into:

27. Shale: olive brown with bands of red and yellow brown iron staining; coarsens upward into siltstone, quartz sand
4.50 m content increases upward; poorly cemented, slope former;
(88.15 m) CONTAINS: burrows; thin fine quartz sand laminations; sharp

contact with:

28. Limestone: Yellow brown; argillaceous; fine-grained calcarenite; indurated, ledge former; CONTAINS: burrows, oysters, Turritella, pelecypods, shell fragments, and forams including Assilina and Alveolina. This limestone is exposed in the floor of the nala, hence the measured thickness is only a partial thickness.
    0.20 m
    (88.35 m)

END OF SECTION

DRILL HOLE UAL-13

Rotary Interval: 0 - 54.06 m

Core Interval: 54.06 - 248.34 m

Total Depth: 248.34 m

METING LIMESTONE

1. Marl: Light green gray; soft; argillaceous, becomes more argillaceous downward; sandy, sand grains composed of calcareous material; massive; homogeneous; CONTAINS: abundant matrix supported forams (Alveolina), shell fragments; grades into:
   0.12 m
   (54.18 m)

2. Shale: Medium green gray; fissile; homogeneous; CONTAINS: finely comminuted shell debris in the top 10 cm and at the base, unit is barren of shell debris between the top and bottom; pyrite nodules; sharp contact with:
   1.15 m
   (55.33 m)

3. Limestone: Light gray; hard; dense; homogeneous; CONTAINS: whole shells and shell fragments; very rare, rounded black flint pebbles; vague rooting textures but rooting cannot be identified definitively; pyrite; sharp contact with:
   0.12 m
   (55.45 m)

SOHNARI FORMATION

4. Sandstone: Medium green gray; fine-grained, moderately well sorted; dirty; composed of quartz and abundant interstitial clay; massive; homogeneous; rooted; CONTAINS: no evidence of bedding; contains rare carbonized root remains, roots are most abundant in the lower half of the unit; burrows; a 15 cm thick zone of very fine-grained, argillaceous, well sorted, medium green gray sandstone with sparse shell fragments and whole oyster shells; contact unknown:
   1.12 m
   (56.57 m)

5. Carbonaceous shale: Black; fissile; appears rooted; CONTAINS: abundant carbonaceous debris; resin blebs; grades into:
   0.24 m
   (56.81 m)

6. Bone coal: Black; CONTAINS: abundant resin blebs; sharp contact with:

   0.21 m

(57.02 m)

7. Conglomerate: Composed of orange and white, rounded, clay pebbles supported in a matrix of black, carbonaceous, resinous clay; the carbon content of the matrix rapidly decreases downward and the matrix becomes a light gray clay at the base of the unit; clay pebbles decrease in diameter downward from maximum diameters of 4 cm at the top of the unit to maximum diameters of 1 cm at the base of the unit; rooted; grades into:
   0.56 m
   (57.58 m)

8. Claystone: White; massive; homogeneous; rooted; CONTAINS: roots; pyrite crystals; foram ghosts at the base of the unit; 5 cm thick medium gray carbon rich shale 1.1 m from the top of the unit; sharp contact with:
   1.90 m
   (59.48 m)

9. Claystone: Medium gray; rooted; slickensided; CONTAINS: abundant carbonaceous debris; sharp contact with:
   0.10 m
   (59.58 m)

LAKHRA FORMATION

10. Limestone: White; extremely argillaceous in the top 30 cm and basal 10 cm; calcsiltite; massive; homogeneous; CONTAINS: no evidence of bedding; no evidence of rooting; scattered forams and shell fragments; no intact shells; shell fragments become more abundant downward and uncommon whole shells occur toward the base of the unit; Assilina type forams become more abundant downward; grades into:
    7.70 m
    (67.28 m)

11. Claystone: Medium green gray; massive; homogeneous; slightly calcareous; CONTAINS: scattered forams, shell molds, and finely comminuted shell fragments; rare glauconite pellets; grades into:
    0.60 m
    (67.88 m)

12. Limestone: Medium gray; very argillaceous; massive; homogeneous; CONTAINS: no evidence of bedding; abundant Assilina type forams; grades into:
    0.85 m
    (68.73 m)

13. Claystone: Medium gray; massive; homogeneous; CONTAINS: no evidence of bedding; common, scattered forams; shell molds and uncommon whole shells; scattered glauconite pellets in places; grades into:
    2.16 m
    (70.89 m)

14. Limestone: Medium gray; massive; homogeneous; CONTAINS: no evidence of bedding; extremely abundant glauconite pellets (5%-10%); abundant Assilina type forams and foram fragments; sharp contact with:
    0.26 m
    (71.15 m)

15. Claystone: Medium gray; massive; homogeneous; CONTAINS: no evidence of

bedding; scattered forams, shell fragments, and shell molds; glauconite pellets; burrows at the top of the unit filled with limestone from unit 15; grades into:

0.40 m
(71.55 m)

16. Limestone: Medium green gray; foraminiferal limestone; extremely argillaceous; massive; homogeneous; CONTAINS: no evidence of bedding; common glauconite pellets, and in places glauconite is very abundant; grades into:

2.61 m
(74.16 m)

17. Limestone: White; argillaceous at the top of the unit, below 2 m the clay content is significantly reduced; massive; homogeneous; foraminiferal limestone; CONTAINS: no evidence of bedding; common glauconite pellets and glauconite filled forams; uncommon zones with large bivalve fragments and whole bivalves; shells and shell fragments become more abundant downward; grades into:

5.47 m
(79.63 m)

18. Limestone: Medium gray; arenaceous; massive; homogeneous; foraminiferal limestone; CONTAINS: no evidence of bedding; abundant, very fine- to fine-grained quartz sand containing 10 percent dark minerals; uncommon glauconite and glauconite replaced forams; grades into:

1.15 m
(80.78 m)

19. Sandstone: Medium green gray; fine-grained, well sorted, dirty; composed of quartz, extremely abundant dark minerals, some interstitial clay, and calcareous cement; weakly cemented; massive; homogeneous; CONTAINS: no evidence of bedding; Assilina type foram fragments; grades into:

3.88 m
(84.66 m)

20. Sandstone: Medium gray; fine- to medium-grained, well sorted, clean; composed of quartz, abundant dark minerals, and little interstitial clay; poorly cemented; friable; massive; homogeneous; non-calcareous; CONTAINS: very rare irregular clay laminations but the unit is so clean that internal bedding structures cannot be distinguished; contact unknown:

0.95 m
(85.61 m)

21. Core loss: Presumed to occur in unit 20 or unit 22:

2.00 m
(87.61 m)

22. Sandstone: Medium gray; fine- to medium-grained, well sorted, clean; composed of quartz, abundant dark minerals, and little interstitial clay; poorly cemented; friable; massive; homogeneous; non-calcareous; CONTAINS: very rare irregular clay laminations but the unit is so clean that internal bedding structures cannot be distinguished; contact unknown:

0.59 m
(88.20 m)

23. Core loss: Presumed to occur in unit 22 or unit 24:

0.05 m
(88.25 m)

24. Sandstone: Medium gray; fine- to medium-grained coarsening downward to medium-grained with some coarse grains, well sorted, clean;

4.70 m composed of quartz, abundant dark minerals, and little
(92.95 m) interstitial clay; poorly cemented; friable; massive; homogeneous; calcareous at the base; CONTAINS: very rare irregular clay laminations but the unit is so clean that internal bedding structures cannot be distinguished; contact unknown:

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

1.00 m
(93.95 m)

26. Sandstone: Medium gray; fine- to medium-grained, well sorted, clean; composed of quartz, common dark minerals, and little
0.96 m interstitial clay; poorly cemented, friable; massive;
(94.91 m) homogeneous; CONTAINS: no evidence of bedding; contact unknown:

27. Calcareous sandstone: Light gray; fine- to medium-grained, well sorted, clean; composed of quartz, abundant dark minerals,
0.16 m common glauconite pellets up to 1 mm in diameter, and
(95.07 m) calcareous cement; well cemented; homogeneous; CONTAINS: no evidence of bedding; whole shells and shell fragments, bivalves, and gastropods; contact unknown:

28. Sandstone: Medium gray; fine- to medium-grained coarsening to fine- to coarse-grained at the base, well sorted, clean; composed of
1.40 m quartz and little interstitial clay; poorly cemented,
(96.47 m) friable; massive; homogeneous; non-calcareous; CONTAINS: no evidence of bedding; sharp, angular and irregular contact with:

29. Calcareous sandstone: Medium gray; fine- to coarse-grained, moderately sorted, clean; composed of quartz, abundant glauconite
0.12 m pellets up to 1 mm in diameter; common dark minerals, little
(96.59 m) interstitial clay, and calcareous cement; indurated; sharp irregular contact with:

30. Sandstone: Medium green gray; fine- to medium-grained with coarse grains in places, coarsens in the basal meter with grains up
2.32 m to very coarse-grained and glauconite pellets up to 3 mm in
(98.91 m) diameter; well sorted, dirty; composed of quartz, sparse glauconite pellets; abundant dark minerals, and abundant interstitial clay; massive; homogenized by burrowing; moderately indurated; non-calcareous; CONTAINS: sparse, finely comminuted shell fragments that are decomposed to the point that they no longer react with HCl and shell molds in the basal meter; contact unknown:

31. Core loss: Presumed to occur in unit 30 or unit 32:

0.90 m
(99.81 m)

32. Sandstone: Medium green gray; fine-grained with rare medium to coarse grains, well sorted, dirty; composed of quartz, abundant dark minerals, and abundant interstitial clay; massive; homogenized by burrowing; sharp contact with:

0.75 m
(100.56 m)

33. Calcareous sandstone: Light gray; fine-grained with some medium grains, well sorted, clean; composed of quartz, abundant dark minerals, very rare glauconite pellets, and calcareous cement; well indurated; dense; homogeneous; CONTAINS: no evidence of bedding, no graded bedding, and no intraformational clasts; abundant bivalve shells and shell fragments, shell fragments most abundant in the middle three-fourths of the unit; sharp contact with:

0.30 m
(100.86 m)

34. Sandstone: Medium gray; fine-grained, well sorted, moderately clean; composed of quartz, abundant dark minerals, and some interstitial clay; poorly cemented, friable; non-calcareous; homogenized by burrowing; CONTAINS: no evidence of bedding; contact unknown:

1.42 m
(102.28 m)

35. Core loss: Presumed to occur in unit 34 or unit 36:

0.48 m
(102.76 m)

36. Sandstone: Medium gray; fine-grained, well sorted, moderately clean; composed of quartz, abundant dark minerals, and some interstitial clay; poorly cemented, friable; non-calcareous; homogenized by burrowing; CONTAINS: no evidence of bedding; contact unknown:

2.46 m
(105.22 m)

37. Core loss: Presumed to occur in unit 36 or unit 38:

0.62 m
(105.84 m)

38. Sandstone: Medium gray; fine-grained, well sorted, moderately clean; composed of quartz, abundant dark minerals, and some interstitial clay; poorly cemented, friable; non-calcareous; homogenized by burrowing; CONTAINS: no evidence of bedding; contact unknown:

1.48 m
(107.32 m)

39. Sandstone: Medium green gray; fine- to medium-grained with some coarse grains, coarsens to medium-grained at the base, poorly sorted, dirty; composed of quartz, abundant dark minerals, rare glauconite pellets, pellets become less abundant downward, abundant interstitial clay containing a large percentage of glauconite, and some calcareous cement which disappears toward the base; massive; homogenized by burrowing; CONTAINS: no evidence of bedding; sparse shell fragments and shell ghosts, shell remains become less abundant downward; very rare carbonized wood fragments; contact unknown:

3.15 m
(110.47 m)

40. Sandstone: Medium gray; very fine- to medium-grained with some coarse

grains, poorly sorted, dirty; composed of quartz, abundant
1.00 m dark minerals, rare glauconite pellets, abundant
(111.47 m) interstitial clay, and a small amount of calcareous cement; massive; homogenized by burrowing; CONTAINS: no evidence of bedding; contact unknown:

41. Core loss: Presumed to occur in unit 40 or unit 42:

0.36 m
(111.83 m)

42. Sandstone: Medium gray; very fine- to medium-grained with some coarse grains, poorly sorted, dirty; composed of quartz, abundant
0.85 m dark minerals, rare glauconite pellets, abundant
(112.68 m) interstitial clay, and a small amount of calcareous cement; massive; homogenized by burrowing; CONTAINS: no evidence of bedding; contact unknown:

43. Core loss: Presumed to occur in unit 42:

1.38 m
(114.06 m)

44. Calcareous sandstone: Light gray; fine- to medium-grained, coarsening downward slightly, well sorted, clean; composed of quartz,
0.18 m some dark minerals, very abundant glauconite, and abundant
(114.24 m) calcareous cement; hard; dense; homogeneous; CONTAINS: burrows; graded bedding?; abundant shells, shells are largest and most abundant in a 3 cm thick zone 3 cm above the base of the unit; sharp contact with:

45. Sandstone: Medium gray; fine-grained, well sorted, moderately clean; composed of quartz, very abundant dark minerals which may be
0.13 m rounded glauconite pellets, and some interstitial clay;
(114.37 m) poorly cemented; friable; massive; homogenized by burrowing; contact unknown:

46. Core loss: Presumed to occur in unit 45 or unit 47:

0.69 m
(115.06 m)

47. Sandstone: Medium gray; fine-grained, well sorted, moderately clean; composed of quartz, very abundant dark minerals which may be
1.40 m rounded glauconite pellets, and some interstitial clay;
(116.46 m) poorly cemented; friable; massive; homogenized by burrowing; contact unknown:

48. Core loss: Presumed to occur in unit 47:

0.45 m
(116.91 m)

49. Calcareous sandstone: Light gray; fine-grained with some medium grains, clean, well sorted; composed of quartz, abundant glauconite

0.50 m (117.41 m) pellets up to 3 mm in diameter, some dark minerals which may also be glauconite pellets, little interstitial clay, and abundant calcareous cement; hard; dense; well cemented; CONTAINS: abundant, rounded, intraformational clay and sandstone pebble rip-up clasts, the sandstone clasts are clean, calcareous, and contain abundant small glauconite pellets, clasts become more abundant and larger downward; abundant shell fragments, shell fragments become more abundant and larger downward; the shell fragments and lithic clasts appear to be graded but there is no concurrent downward coarsening downward observed in the sand matrix; sharp contact with:

50. Calcareous sandstone: Light gray; fine- to medium-grained, clean, well sorted; composed of quartz, abundant glauconite pellets up to 3 mm in diameter, some dark minerals which may also be glauconite pellets, little interstitial clay, and abundant calcareous cement; hard; dense; well cemented; CONTAINS: sparse shell fragments; no intraformational rip-up clasts; sharp contact with:

0.17 m (117.58 m)

51. Sandstone: Medium gray; fine-grained with some medium grains, well sorted, dirty; composed of quartz, abundant dark minerals some or all of which may be small glauconite pellets, some interstitial clay, and a small amount of calcareous cement; massive; homogenized by burrowing; CONTAINS: no evidence of bedding; sparse shell fragments; sharp contact with:

0.58 m (118.16 m)

52. Sandstone: Dark gray; very fine- to very coarse-grained, poorly sorted, dirty; composed of quartz, abundant interstitial clay, and a small amount of calcareous cement; poorly cemented, friable, core badly fragmented during drilling; CONTAINS: sparse shell fragments; sparse, intraformational sandstone clasts that have been oxidized to an orange color; sharp contact with:

0.28 m (118.44 m)

53. Limestone: Light gray; arenaceous, contains a significant percentage of fine- to medium-grained quartz sand; hard; dense; well indurated; massive; homogeneous; CONTAINS: no evidence of bedding; abundant bivalve shells that mostly parallel bedding in a concave up or concave down orientation, some shells are perpendicular; shell size is uniform throughout the unit; rare Turritella; abundant heavy minerals; rare glauconite pellets; grades into:

0.26 m (118.70 m)

54. Calcareous sandstone: Medium gray; fines downward from fine- to medium-grained with some coarse grains at the top of the unit to fine-grained with some medium grained at the base, moderately well sorted, dirty; composed of quartz, abundant dark minerals, sparse glauconite pellets, very rare intraformational clay clasts, abundant interstitial clay, and calcareous cement; well cemented; CONTAINS: rare coaly fragments; common shell fragments that become smaller and less abundant downward; grades into:

0.29 m (118.99 m)

55. Sandstone: Medium gray; very fine- to fine-grained, medium-grained in places, fines downward to very fine-grained sandstone and then to sandy siltstone at the base of the unit, poorly sorted, dirty; composed of quartz, very rare glauconite pellets, very abundant interstitial clay, and some calcareous cement; poorly cemented, somewhat friable; massive; homogeneous; CONTAINS: no evidence of bedding though there are rare claystone bands up to 3 mm thick preserved in the upper part of the unit; abundant, finely comminuted, homogeneously distributed shell fragments in places; grades into:

1.54 m
(120.53 m)

56. Sandstone: Medium gray; very fine-grained with rare medium grains, poorly sorted, very dirty; composed of quartz, very rare glauconite pellets, very abundant interstitial clay, and a small amount of calcareous cement; indurated but somewhat friable; massive; homogeneous; CONTAINS: a calcareous, well cemented, 14 cm thick concentration of shell fragments 57 cm from the top of the unit, this shell concentration does not appear to be associated with an erosional surface; finely comminuted shell fragments; whole, flat-lying, concave up and down bivalve shells; shell fragments become uncommon in the basal half of the unit; no evidence of bedding; sharp contact with:

2.43 m
(122.96 m)

57. Sandstone: Medium gray; very fine-grained, well sorted; composed of quartz and calcareous cement; extremely well indurated; dense; massive; homogeneous; CONTAINS: no evidence of bedding; no shell remains; traces of mineralized plant fragments; sharp contact with:

0.06 m
(123.02 m)

58. Sandstone: Medium gray; very fine-grained, poorly sorted, dirty; composed of quartz, abundant dark minerals, very abundant interstitial clay, and a small amount of calcareous cement; CONTAINS: abundant siderite nodules; very sparse carbonaceous debris; burrows; faint planar laminations and very rare carbonaceous laminations in the upper half of the unit; clay bands in the middle 40 cm; massive and homogeneous in the bottom half of the unit; rare finely comminuted shell fragments in the bottom half of the unit; grades into:

3.26 m

59. Limestone: Gray-green; argillaceous, reacts weakly with HCl; low density; well indurated; CONTAINS:sparse very coarse quartz grains; very abundant glauconite; sparse shell fragments some pyrite; grades into:

0.14 m
(126.42 m)

60. Limestone: medium green gray; slightly argillaceous, becomes less argillaceous downward; dense; massive; homogeneous; CONTAINS: no evidence of bedding; some dark minerals; shell fragments in the upper third of the unit, whole shells in the lower two thirds of the unit, gastropods, forams, and bivalves are especially abundant; uncommon green glauconitic clay pebbles; uncommon scattered glauconite pellets; sharp contact with:

0.60 m
(127.02 m)

61. Claystone: Medium gray; CONTAINS: sparse, thin, planar, very fine-grained quartz sand laminations less than 1 mm thick; abundant very fine-grained heavy minerals are associated with the laminations; siderite bands and nodules; uncommon pyrite; very rare small burrows; top 57 cm contains limestone filled large burrow penetrations from the overlying unit; grades into:

1.24 m
(128.26 m)

62. Sandstone: Medium gray; very fine-grained, well sorted, dirty; composed of quartz, abundant dark minerals, rare glauconite pellets, abundant interstitial clay, and calcareous cement; poorly cemented, friable; core badly fragmented by drilling; CONTAINS: uncommon shale bands and laminations; rare, finely comminuted shell fragments; contact unknown:

0.83 m
(129.09 m)

63. Core loss: Presumed to occur in unit 62 or unit 64:

0.38 m
(129.47 m)

64. Sandstone: Medium gray; very fine-grained, well sorted, dirty; composed of quartz, abundant dark minerals, rare glauconite pellets, abundant interstitial clay, and calcareous cement; poorly cemented, friable; core badly fragmented by drilling; CONTAINS: uncommon shale bands and laminations; rare, finely comminuted shell fragments; grades into:

0.60 m
(130.07 m)

65. Claystone: Medium gray; CONTAINS: planar, fine-grained quartz sand laminations usually less thin 1 mm thick, abundant very fine-grained heavy mineral accumulations are associated with the sand laminations; burrows; siderite bands and nodules; sparse finely comminuted carbonaceous debris on some bedding plane surfaces; contact unknown:

1.11 m
(131.18 m)

66. Core loss: Loss probably occurred in unit 64:

1.21 m
(132.39 m)

67. Calcareous conglomerate: Medium gray; dirty; poorly sorted; CONTAINS: matrix supported rounded and tabular claystone and sandstone intraformational pebbles, the matrix consists of fine- and some medium-grained quartz and carbonate sand grains, extremely abundant glauconite pellets, rare dark minerals, and very abundant interstitial clay, unit becomes more argillaceous downward; matrix contains some calcareous cement, some finely comminuted shell debris but no larger fragments or whole shells, some pyrite, and uncommon large pieces of carbonaceous debris; sandstone pebbles are well indurated, clean, much more calcareous than the surrounding matrix, and well cemented, they are composed of fine-grained quartz sand with abundant heavy minerals and scattered glauconite pellets; clay pebbles are non-calcareous; sharp contact with:

0.56 m
(132.95 m)

68. Claystone: Medium gray; CONTAINS: planar silt laminations up to 3 mm thick; very fine-grained, planar quartz sand laminations less than 0.5 mm thick; sideritized bands; sharp contact with:

0.08 m
(133.03 m)

69. Sandstone: Medium gray; fine-grained, poorly sorted, very dirty; composed of quartz, glauconite pebbles, abundant dark minerals, very abundant interstitial clay, and a small amount of calcareous cement; massive; homogeneous; CONTAINS: finely comminuted shell fragments, shell fragments most abundant in the top 1 cm; small, rounded, quartz sandstone intraformational pebbles in the top 1 cm; contact unknown:

0.07 m
(133.10 m)

70. Core loss: Location unknown:

0.26 m
(133.36 m)

71. Claystone: Medium gray; CONTAINS: planar silt laminations up to 3 mm thick; very fine-grained, planar quartz sand laminations less than 0.5 mm thick; sideritized bands; sharp contact with:

0.03 m
(133.39 m)

72. Sandstone: Medium gray; very fine- to fine-grained, poorly sorted, very dirty; composed of quartz, very abundant interstitial clay and a small amount of calcareous cement; well cemented; massive; homogeneous; CONTAINS: no evidence of bedding; shell fragments in the upper half of the unit, shell fragments become more abundant and coarsen downward and whole shells, especially gastropods, become common toward the base; rounded and tabular intraformational sandstone pebbles up to 3 cm across the longest axis, pebbles become more abundant downward; shell fragments and the intraformational clasts coarsen downward but there is no concurrent downward coarsening in the sand matrix; in the top centimeter of the unit there is a concentration of shell fragments and small, rounded, intraformational sandstone pebbles in a sandstone matrix composed of sand grains that are slightly coarser grained than the rest of the unit; sharp contact with:

0.42 m
(133.81 m)

73. Sandstone: Medium gray; very fine- to fine-grained, poorly sorted, very dirty; composed of quartz, very abundant interstitial clay and a small amount of calcareous cement; well cemented; massive; homogeneous; CONTAINS: no evidence of bedding; shell fragments that become larger and more abundant downward, rare whole shells; rounded and tabular intraformational sandstone clasts that become larger and more abundant downward; contact is unknown but believed to be sharp:

0.29 m
(134.10 m)

74. Sandstone: Medium gray; very fine- to fine-grained, poorly sorted, dirty; composed of quartz, abundant dark minerals, and very

0.86 m (134.96 m) abundant interstitial clay; indurated; CONTAINS: regular and irregular flat and wavy clay laminations up to 5 mm thick; burrows; sparse, homogeneously distributed shell hash, shell fragments are flat lying; sharp contact with:

75. Sandstone: Medium gray; very fine- to fine-grained, poorly sorted, very dirty; composed of quartz, very abundant interstitial clay and a small amount of calcareous cement; well cemented; massive; homogeneous; CONTAINS: no evidence of bedding; shell fragments that become larger and more abundant downward, rare whole shells; rounded and tabular intra-formational sandstone clasts that become larger and more abundant downward; sharp contact with:

0.19 m (135.15 m)

76. Sandstone: Medium gray; fine-grained, poorly sorted, dirty; composed of quartz, some dark minerals, some glauconite pellets, and abundant interstitial clay; massive; homogeneous; CONTAINS: scattered shell fragments; uncommon carbonaceous debris; burrows; inferred sharp contact with:

0.23 m (135.38 m)

77. Core loss: Location unknown:

0.32 m (135.70 m)

78. Sandstone: Light to medium gray; fine-grained, well sorted, moderately clean; composed of quartz, abundant dark minerals, some interstitial clay, and calcareous cement; hard; dense; well cemented; CONTAINS: irregular flat and wavy laminations; abundant coalified debris; common, finely comminuted shell fragments; burrows; sharp contact with:

0.22 m (135.92 m)

79. Sandstone: Light to medium gray; fine-grained, well sorted, moderately clean; composed of quartz, abundant dark minerals, and some interstitial clay; poorly cemented, friable;cemented; CONTAINS: irregular flat and wavy laminations; abundant coalified debris; rare shell fragments; burrows; sharp contact with:

0.54 m (136.46 m)

80. Calcareous sandstone: Brown; fine-grained at the top of the unit coarsening downward to fine- to medium-grained at the base, well sorted, moderately clean; composed of quartz, abundant glauconite, uncommon dark minerals, some interstitial clay, and abundant calcareous cement in the upper half of the unit, calcareous cement becomes significantly less abundant downward; very hard and well cemented in the upper half of the unit, weakly cemented and friable in the lower half; massive; homogeneous; CONTAINS: abundant, flat-lying shell fragments throughout the unit, in places shells form faint laminations; sharp contact with:

0.33 m (136.79 m)

81. Sandstone: Brown; fine-grained at the top of the unit coarsening downward to fine- to medium-grained at the base, well sorted, moderately clean; composed of quartz, abundant glauconite, uncommon dark minerals, some interstitial clay,

0.82 m (137.61 m)

and abundant calcareous cement in the upper half of the unit, calcareous cement becomes significantly less abundant downward; very hard and well cemented in the upper half of the unit, weakly cemented and friable in the lower half; CONTAINS: abundant, flat-lying shell fragments throughout, in places shells form faint laminations; abundant, small, whole gastropods at the top of the unit; common, thick carbonaceous laminations; sharp contact with:

82. Sandstone: Medium light gray; fine-grained, well sorted, moderately clean; composed of quartz, common dark minerals, and some
4.75 m interstitial clay; weakly cemented, friable; CONTAINS:
(142.36 m) finely comminuted shell fragments in the top 50 cm but shell material disappears quickly below the top; very irregular planar clay and carbonaceous laminations; in places in the upper 1.5 m the laminations exhibit low-angle truncations; laminations are not apparent in the middle part of the unit and become pronounced again in the bottom 2 m; rarely, some laminations define ripple surfaces; minor burrowing throughout; sharp contact with:

83. Sandstone: Dark gray; very fine-grained, poorly sorted, very dirty; composed of quartz and very abundant interstitial clay; well
1.10 m cemented with clay; CONTAINS: burrows and sideritized
(143.46 m) burrow traces, in places bedding appears to have been homogenized by burrowing; planar clay and sand laminations abundant in places; sparse carbonaceous debris; rare, finely comminuted shell fragments; rare, faint, traces of ripple bedding; sharp contact with:

84. Sandstone: Medium brown; coarsens downward from fine- to medium-grained at the top of the unit to medium-grained at the base, poorly
0.70 m sorted, dirty; composed of quartz, abundant glauconite,
(144.16 m) abundant dark minerals where grain size is finest, dark minerals disappear as grain size coarsens, and abundant interstitial clay; poorly cemented and friable at the base, better cemented at the top; CONTAINS: coalified wood fragments; very rare intraformational sandstone clasts; shell fragments, abundant fragments become smaller downward; poorly developed, planar, carbonaceous and shell laminations, otherwise, no traces of internal bedforms; sharp contact with:

85. Sandstone: Medium gray; fine-grained, well sorted, dirty; composed of quartz, abundant very fine-grained dark minerals, rare
2.40 m glauconite pellets, and abundant interstitial clay; weakly
(146.56 m) cemented, somewhat friable; CONTAINS: sparse, finely comminuted shell fragments, the basal third of the unit contains zones that are barren of shell remains, these zones tend to be slightly finer grained than the shell bearing zones; clay bands up to 5 mm thick, clay bands often contain planar sand laminations less than 1 mm thick; rare carbonaceous laminations; the sandstone between the laminations is massive, homogeneous, burrowed, and shows no evidence of bedding; clay bands have not been observed to be

penetrated by burrows; no evidence of clearly repeated depositional cycles within the unit; sharp contact with:

86. Calcareous sandstone: Medium gray; fine-grained, poorly sorted, dirty; composed of quartz, sparse dark minerals, abundant glauconite, abundant interstitial clay, and calcareous cement; hard; dense; well cemented; massive; homogeneous; CONTAINS: no evidence of bedding; abundant, finely comminuted shell fragments; sideritized zones; sharp contact with:

1.35 m
(147.91 m)

87. Sandstone: Medium gray; fine-grained, well sorted, clean; composed of quartz, 5% - 10% very fine-grained dark minerals, sparse glauconite pellets, and little interstitial clay; poorly cemented, friable; CONTAINS: sparse burrows; sideritized zones; planar clay laminations 1-5 mm thick, the interbedded sandstone shows no evidence of internal bedforms; contact unknown:

0.48 m
(148.39 m)

88. Core loss: Presumed to occur in sandstone unit 87 or unit 89:

0.22 m
(148.61 m)

89. Sandstone: Medium gray; fine-grained, well sorted, clean; composed of quartz, 5% - 10% very fine-grained dark minerals, sparse glauconite pellets, and little interstitial clay; poorly cemented, friable; CONTAINS: sparse burrows; sideritized zones; planar clay laminations 1-5 mm thick, the interbedded sandstone shows no evidence of internal bedforms; contact unknown:

1.50 m
(150.11 m)

90. Claystone: Medium gray; CONTAINS: very fine-grained, planar, quartz sand laminations less than 0.5 mm thick; rare sand filled burrows; sparse carbonaceous debris on bedding plane surfaces; grades into:

0.84 m
(150.95 m)

91. Sandstone: Medium gray; fine-grained, well sorted, dirty; composed of quartz, abundant, very fine-grained dark minerals, and abundant interstitial clay; poorly cemented, friable; CONTAINS: extremely rare carbonaceous debris; planar clay bands and laminations, the thicker clay bands contain thin, planar quartz sand laminations; locally, clay bands may be thicker and more closely spaced; besides the laminations there is no evidence of other internal bedforms and no evidence of tidal couplets; contact unknown:

0.30 m
(151.25 m)

92. Core loss: Presumed to occur in unit 91 or unit 93:

0.08 m
(151.33 m)

93. Sandstone: Medium gray; fine-grained, well sorted, dirty; composed of quartz, abundant, very fine-grained dark minerals, and abundant interstitial clay; poorly cemented, friable;

2.75 m

(154.08 m) CONTAINS: extremely rare carbonaceous debris; planar clay bands and laminations, the thicker clay bands contain thin, planar quartz sand laminations; locally, clay bands may be thicker and more closely spaced; besides the laminations there is no evidence of other internal bedforms and no evidence of tidal couplets; contact unknown:

94. Core loss: Presumed to occur in unit 93:

0.13 m
(154.21 m)

95. Claystone: Medium gray; sideritized; CONTAINS: thin, planar quartz sand laminations; sharp contact with:

0.10 m
(154.31 m)

96. Sandstone: Medium gray; fine-grained with some medium grains, poorly sorted, dirty; composed of quartz, rare glauconite pellets, some very fine-grained dark minerals, very abundant interstitial clay and some calcareous cement, becomes more calcareous and indurated downward; weakly cemented; massive; homogeneous; CONTAINS: no evidence of bedding; common, finely comminuted shell fragments homogeneously distributed throughout the unit; burrows; rare coalified wood fragments; sharp contact with:

0.90 m
(155.21 m)

97. Sandstone: Brown; fine- to medium-grained, poorly sorted, dirty; composed of quartz, very abundant glauconite pellets, abundant interstitial clay, and calcareous cement; weakly cemented, somewhat friable; CONTAINS: shell fragments that are larger and more abundant than the shell fragments in the overlying unit; fragments are flat-lying; rare, intra-formational clay rip-up clasts up to 2.5 cm in diameter; sharp contact with:

0.09 m
(155.30 m)

98. Sandstone: Medium gray; fine- to medium-grained in the top 10 cm fining to fine-grained below, well sorted, dirty; composed of quartz, dark minerals, abundant interstitial clay, and a small amount of calcareous cement in the upper part of the unit; becomes non-calcareous downward; weakly cemented, somewhat friable; CONTAINS: no evidence of bedding in the top part of the unit, massive and homogeneous; clay bands become more abundant downward, there is an abrupt change from sandstone with some clay laminations to claystone with some sand laminations at the base of the unit; some sideritized clay bands; siderite nodules; very rare coalified debris; carbonaceous laminations; burrows; finely comminuted shell debris that becomes less abundant and then disappeared downward; contact unknown:

1.41 m
(156.71 m)

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

0.31 m
(157.02 m)

100. Claystone: Medium gray; CONTAINS: burrows, iron staining around burrow traces; sparse, finely comminuted carbonaceous debris
2.59 m on bedding plane surfaces, carbonaceous debris becomes less
(159.61 m) abundant downward; siderite bands; sparse, planar sand laminations rarely exceeding 1 mm in thickness and usually much thinner; finely comminuted shell fragments appear near the base of the unit; shell debris usually associated with medium-grained quartz sand; sharp contact with:

101. Claystone: Medium gray; slightly calcareous; CONTAINS: extremely thin planar silt laminations; very finely comminuted shell hash
0.56 m covers many lamina surfaces; sharp contact with:
(160.17 m)

102. Marl: Buff; calcareous; massive; homogeneous; CONTAINS: no evidence of bedding; abundant glauconite pellets; abundant
0.36 m finely comminuted shell hash in the upper part of the unit,
(160.53 m) shell debris becomes more abundant and coarser grained downward; sharp contact with:

103. Siltstone: Medium gray; slightly calcareous; argillaceous at the top, coarsens downward; massive; homogeneous; CONTAINS: no
4.76 m evidence of bedding; homogeneously distributed shell hash
(165.29 m) throughout, shell hash becomes less abundant and less calcareous in the basal 1.5 m, locally there are areas of greater shell hash concentrations; areas with shell hash concentrations also tend to have concentrations of glauconite pellets, in other parts of the unit glauconite is uncommon; siderite nodules; material from the overlying unit penetrates the top 25 cm as burrow fillings; fine-grained, planar quartz sand laminations become more abundant in the basal 1.5 m; there are no identifiable cyclic sedimentation patterns preserved; grades into:

104. Sandstone: Brown-gray; fine-grained, poorly sorted, dirty; composed of quartz, abundant glauconite pellets, uncommon dark minerals,
1.03 m abundant interstitial clay, and calcareous cement in the
(166.32 m) upper half of the unit becomming non-calcareous in the lower half; hard and well cemented in the upper half, weakly cemented in the lower half; massive; homogeneous; CONTAINS: no evidence of bedding; abundant, homogeneously distributed shell hash; rare carbonaceous debris; no evidence of graded bedding; grades into:

105. Sandstone: Medium gray; fine-grained, poorly sorted, dirty; composed of quartz, uncommon dark minerals, and abundant interstitial
0.74 m clay; poorly cemented, friable; massive; homogeneous;
(167.06 m) CONTAINS: no evidence of bedding; sparse shell fragments homogeneously distributed throughout the unit; siderite nodules; sparse carbonaceous debris; contact unknown:

106. Core loss: Presumed to occur in sandstone unit 105 or unit 107:

1.16 m

(168.22 m)

107. Sandstone: Medium gray; fine-grained, poorly sorted, dirty; composed of quartz, uncommon dark minerals, and abundant interstitial
1.36 m clay; poorly cemented, friable; massive; homogeneous;
(169.58 m) CONTAINS: no evidence of bedding; sparse shell fragments homogeneously distributed throughout the unit; siderite nodules; sparse carbonaceous debris; contact unknown:

108. Core loss: Presumed to occur in unit 107:

0.14 m
(169.72 m)

109. Claystone: Medium gray; CONTAINS: very fine-grained, planar, quartz sand laminations; siderite bands and nodules; abundant dark
0.19 m minerals; burrows; sharp contact with:
(169.91 m)

110. Sandstone: Medium gray; fine-grained, poorly sorted, dirty; composed of quartz, uncommon dark minerals, and abundant interstitial
1.24 m clay; poorly cemented, friable; core badly fragmented during
(171.15 m) drilling; massive; homogeneous; CONTAINS: no evidence of bedding; sparse shell fragments homogeneously distributed throughout the unit; siderite nodules; sparse carbonaceous debris; contact unknown:

111. Sandstone: Pale brown in the top 20 cm then light gray; fine-grained, well sorted, moderately clean; composed of quartz, and a
1.08 m small amount of interstitial clay; poorly cemented, friable;
(172.23 m) core badly fragmented during drilling; CONTAINS: finely comminuted and homogeneously distributed shell fragments in the pale brown part of the unit, no shell remains preserved in the light gray part; no observed internal bedforms but several planar clay bands and laminations are preserved in the basal part of the unit; grades into:

112. Sandstone: Medium gray; fine-grained,fines downward, poorly sorted, dirty; composed of quartz, uncommon dark minerals, and
0.29 m abundant interstitial clay; poorly cemented, friable;
(172.52 m) massive; homogeneous; CONTAINS: faint clay bands that are poorly preserved and appear to be almost homogenized into the unit by burrowing; sparse shell fragments homogeneously distributed throughout the unit; siderite nodules; sparse carbonaceous debris; contact unknown:

113. Core loss: Suspected to occur in sandstone unit 111:

0.49 m
(173.01 m)

114. Sandstone: Medium gray; fine-grained,fines downward, poorly sorted, dirty; composed of quartz, uncommon dark minerals, and
0.21 m abundant interstitial clay; poorly cemented, friable;
(173.22 m) massive; homogeneous; CONTAINS: faint clay bands that are

poorly preserved and appear to be almost homogenized into the unit by burrowing; sparse shell fragments homogeneously distributed throughout the unit; siderite nodules; sparse carbonaceous debris; grades into:

115. Claystone: Medium gray; CONTAINS: planar laminations defined by slight differences in grain size; planar, very fine-grained
0.65 m quartz sand laminations; very rare shell fragments; very
(173.87 m) sparse carbonaceous debris; sparse burrows some of which are sideritized; siderite bands and nodules; sharp contact with:

116. Mudstone: Medium gray; slightly calcareous; homogenized by burrowing; CONTAINS: abundant shell fragments, whole shells; siderite
0.20 m nodules; sideritized burrows; grades into:
(174.07 m)

117. Claystone: Medium gray; CONTAINS: planar laminations defined by slight differences in grain size; planar, very fine-grained
0.04 m quartz sand laminations; very rare shell fragments; very
(174.11 m) sparse carbonaceous debris; sparse burrows some of which are sideritized; siderite bands and nodules; contact unknown:

118. Core loss: Location unknown, loss possibly occurs in unit 114:

0.15 m
(174.26 m)

119. Siltstone: Medium gray; CONTAINS: common planar laminations 1-3 mm thick, laminations are defined by slight differences in
2.90 m grain size; very rare very finely comminuted carbonaceous
(177.16 m) debris and shell hash; sparse burrows although in places there are zones that are homogenized by burrowing, these zones are not sharply defined and the unit does not appear to be composed of a series of cyclic non-deposition events; grades into:

120. Calcareous sandstone: Medium gray; fine-grained, poorly sorted, dirty; composed of quartz, uncommon dark minerals, abundant
0.31 m interstitial clay, and calcareous cement; hard, well
(177.47 m) cemented; massive; homogeneous; CONTAINS: no evidence of bedding; no graded bedding; abundant, finely comminuted shell fragments; sharp contact with:

121. Calcareous sandstone: Medium gray; fine-grained, poorly sorted, moderately clean; composed of quartz, uncommon dark
0.36 m minerals, some interstitial clay, and abundant calcareous
(177.83 m) cement; hard, very well cemented; massive; homogeneous; CONTAINS: no evidence of bedding; no graded bedding; abundant, finely comminuted shell fragments; sharp contact with:

122. Siltstone: Medium gray; CONTAINS: planar laminations defined by minor differences in grain size; siderite nodules, nodule growth
1.47 m has caused the deformation of some laminations; sparse
(179.30 m) burrows; rare layers of finely comminuted shell debris; very

rare carbonaceous debris on some bedding plane surfaces; grades into:

123. Siltstone: Medium gray; massive; homogenized by burrowing; CONTAINS: relict planar laminations defined by minor differences in
0.36 m grain size; siderite nodules; rare,finely comminuted shell
(179.66 m) debris; very rare carbonaceous debris; grades into:

124. Sandstone: Medium gray; fine-grained, poorly sorted, dirty; composed of quartz, common glauconite pellets, common dark minerals,
1.32 m abundant interstitial clay especially in the top 20 cm, and
(180.98 m) calcareous cement; well cemented; massive; homogeneous; CONTAINS: no evidence of bedding; sparse, finely comminuted shell fragments; contact suspected to be gradational (interval removed for paleo analysis):

125. Sandstone: Medium gray; fine-grained, poorly sorted, dirty; composed of quartz, common dark minerals, abundant interstitial clay,
1.12 m and some calcareous cement; weakly cemented, friable;
(182.10 m) massive; homogeneous; CONTAINS: no evidence of bedding; sparse, finely comminuted shell fragments; grades into:

126. Sandstone: Medium gray; fine-grained, well sorted, dirty, composed of quartz and abundant interstitial clay, unit becomes more
3.54 m argillaceous downward; moderately well cemented but friable;
(185.64 m) unit mostly homogenized by burrowing; CONTAINS: relict, planar clay laminations preserved in places; rare coalified plant fragments; very rare, finely comminuted shell fragments; siderite nodules; sideritized and pyritized burrows; grades into:

127. Siltstone: Dark gray; fissile; CONTAINS: thin, planar, very fine-grained quartz sand laminations in the top 30 cm, sandstone
1.26 m laminations become less abundant downward; abundant finely
(186.90 m) comminuted carbonaceous debris on bedding plane surfaces; sharp contact with:

128. Coal: Black; sharp contact with:

0.35 m
(187.25 m)

129. Siltstone: Medium gray; fissile; CONTAINS: carbonized and coalified debris on some bedding plane surfaces; no evidence of
0.32 m rooting, overlying coal appears allochthonous; very thin
(187.57 m) planar sand laminations at the base of the unit; grades into:

130. Claystone: medium gray; CONTAINS: very thin, very fine-grained planar quartz sand laminations; very rare, very finely comminuted
1.10 m carbonaceous debris on some bedding plane surfaces,
(188.67 m) carbonaceous debris becomes more abundant near the base of the unit; sharp contact with:

131. Carbonaceous shale: Black; CONTAINS: very fine-grained quartz sand

and abundant coalified wood fragments; sharp contact with:

0.02 m
(188.69 m)

132. Claystone: medium gray; fissile; unrooted; CONTAINS: very thin, very fine-grained planar quartz sand laminations; very rare, very finely comminuted carbonaceous debris on some bedding plane surfaces; sharp contact with:

0.33 m
(189.02 m)

133. Carbonaceous shale: Black; sharp contact with:

0.08 m
(189.10 m)

134. Claystone: medium gray; unrooted; CONTAINS: very thin, very fine-grained planar quartz sand laminations; abundant carbonaceous debris on some bedding plane surfaces, rare burrows; sharp contact with:

0.51 m
(189.61 m)

135. Sandstone: Medium light gray; very fine-grained and argillaceous at the top of the unit coarsening downward to fine-grained and less argillaceous at the base; well sorted, dirty; composed of quartz, abundant dark minerals, and abundant interstitial clay, clay becomes less abundant downward; indurated at the top of the unit becomming poorly cemented and friable at the base; CONTAINS: closely spaced planar clay laminations; sparse burrows; sparse carbonaceous debris; grades into:

1.22 m
(190.83 m)

136. Sandstone: Medium light gray; very fine-grained, well sorted, clean; composed of quartz, abundant dark minerals, and some interstitial clay; poorly cemented, friable; CONTAINS: closely spaced planar clay laminations; sparse burrows; sparse carbonaceous debris; grades into:

0.80 m
(191.63 m)

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

1.43 m
(193.06 m)

138. Sandstone: Gray-brown; fine-grained; composed of quartz, abundant dark minerals, and calcareous cement; the unit reacts weakly with HCl and appears to be sideritized; dense; extremely hard and well cemented; massive; homogeneous; CONTAINS: no evidence of bedding; sharp contact with:

0.06 m
(193.12 m)

139. Sandstone: Medium light gray; very fine-grained, well sorted, clean; composed of quartz, abundant dark minerals, and some interstitial clay; poorly cemented, friable; CONTAINS: closely spaced planar clay laminations; sparse burrows; sparse carbonaceous debris; grades into:

0.12 m
(193.24 m)

140. Sandstone: White; fine-grained, well sorted, clean; composed of quartz and little interstitial clay; poorly cemented, friable; homogeneous; burrowed; contact unknown:

0.13 m
(193.37 m)

141. Core loss: Presumed to occur in unit 140 or unit 142:

0.42 m
(193.79 m)

142. Sandstone: White; fine-grained, well sorted, clean; composed of quartz and little interstitial clay; poorly cemented, friable; homogeneous; burrowed; contact unknown:
0.15 m
(193.94 m)

143. Sandstone: Gray-brown; fine-grained; composed of quartz, abundant dark minerals, and calcareous cement; the unit reacts weakly with HCl and appears to be sideritized; dense; extremely hard and well cemented; massive; homogeneous; CONTAINS: no evidence of bedding; sharp contact with:
0.04 m
(193.98 m)

144. Sandstone: White; fine-grained, well sorted, clean; composed of quartz, uncommon dark minerals, and no interstitial clay; poorly cemented, friable; core badly fragmented during drilling; CONTAINS: low-angle cross-beds as the dominant bed-form, the low-angle cross-beds defined by accumulations of coarse sand sized particles of coal, the coal grains are flattened to tabular; planar clay laminations in places; burrows in places; sharp contact with:
1.12 m
(195.10 m)

145. Sandstone: White; fine-grained, well sorted, clean; composed of quartz, uncommon dark minerals, and no interstitial clay; poorly cemented, friable; core badly fragmented during drilling; CONTAINS: relict planar laminations; most of the laminations have been destroyed by burrowing; sharp contact with:
0.07 m
(195.17 m)

146. Sandstone: White; fine-grained, well sorted, clean; composed of quartz, uncommon dark minerals, and no interstitial clay; poorly cemented, friable; core badly fragmented during drilling; CONTAINS: planar laminations defined by accumulations of carbonaceous debris; no evidence of burrowing; sharp contact with:
0.10 m
(195.27 m)

147. Sandstone: Gray-brown; fine-grained; composed of quartz, abundant dark minerals, and calcareous cement; the unit reacts weakly with HCl and appears to be sideritized; dense; extremely hard and well cemented; massive; homogeneous; CONTAINS: no evidence of bedding; sharp contact with:
0.04 m
(195.31 m)

148. Sandstone: White; fine-grained, well sorted, clean; composed of quartz, uncommon dark minerals, and no interstitial clay; poorly cemented, friable; core badly fragmented during drilling, internal bedforms cannot be determined; sharp contact with:
0.06 m
(195.37 m)

149. Sandstone: White; fine-grained, well sorted, clean; composed of quartz, uncommon dark minerals, and no interstitial clay; poorly cemented, friable; core badly fragmented during
0.10 m

(195.47 m) drilling and internal bedforms are difficult to identify; APPEARS TO CONTAIN: ripples or low-angle cross-beds; contact unknown:

150. Sandstone: Medium gray; fine-grained, well sorted, dirty; composed of quartz and abundant interstitial clay; moderately cemented,
0.26 m somewhat friable; CONTAINS: clay bands up to 6 mm in
(195.73 m) thickness; ripples; burrows; sharp contact with:

151. Sandstone: White; fine-grained, well sorted, clean; composed of quartz, uncommon dark minerals, and no interstitial clay;
0.03 m poorly cemented, friable; core badly fragmented during
(195.76 m) drilling; CONTAINS: low-angle cross-beds; contact unknown:

152. Core loss: Loss presumed to occur someplace within the white sandstone but specific location unknown:
0.62 m
(196.38 m)

153. Sandstone: White; fine-grained, well sorted, clean; composed of quartz, uncommon dark minerals, and no interstitial clay;
0.24 m poorly cemented, friable; core badly fragmented during
(196.62 m) drilling; CONTAINS: sparse burrows; ripples; planar laminations; uncommon clay beds up to 3 mm thick; sharp contact with:

154. Sandstone: White; fine-grained, well sorted, clean; composed of quartz, uncommon dark minerals, and no interstitial clay;
0.46 m poorly cemented, friable; core badly fragmented during
(197.08 m) drilling; CONTAINS: alternating zones of ripples and planar laminations defined by the accumulation of carbonaceous debris; basal 5 cm is planar laminated and moderately burrowed; contact unknown:

155. Core loss: Loss is presumed to have occurred within the white sandstone but the specific location of the loss is unknown:
0.56 m
(197.64 m)

156. Sandstone: Medium gray; fine-grained, well sorted, moderately clean; composed of quartz, uncommon dark minerals, and some
0.03 m interstitial clay; poorly cemented, friable; core badly
(197.67 m) fragmented during drilling; CONTAINS: planar carbonaceous laminations; sharp contact with:

157. Siltstone: Medium gray; CONTAINS: planar sand and carbonaceous laminations; burrows; sharp contact with:
0.06 m
(197.73 m)

158. Sandstone: White; fine-grained, well sorted, clean; composed of quartz, uncommon dark minerals, and no interstitial clay;
0.09 m poorly cemented, friable; core badly fragmented during
(197.82 m) drilling; CONTAINS: very abundant flat or low-angle carbonaceous laminations; contact unknown:

159. Core loss: Loss is presumed to occur in the white sandstone but the exact location of the loss is unknown:

0.14 m
(197.96 m)

160. Siltstone: Medium gray; CONTAINS: abundant planar fine-grained quartz sand and carbonaceous laminations; sparse burrows along
0.16 m bedding planes; sharp contact with:
(198.12 m)

161. Sandstone: White; medium-grained, well sorted, clean; composed of quartz and no interstitial clay; poorly cemented, friable;
0.26 m core badly fragmented by drilling; contact unknown:
(198.38 m)

162. Core loss: Presumed to occur in unit 161 or unit 163:

0.86 m
(199.24 m)

163. Sandstone: Medium gray; medium- to coarse-grained, well sorted, clean; composed of quartz and little interstitial clay; poorly
0.25 m cemented, friable; core badly fragmented by drilling and
(199.49 m) consequently the unit contains no recognizable internal bedforms; CONTAINS: a zone of gray brown, fine-grained sandstone, composed of quartz, abundant dark minerals, and calcareous cement; the unit reacts weakly with HCl and appears to be sideritized; it is dense; extremely hard and well cemented; massive; homogeneous, containing no evidence of bedding; contact unknown:

164. Core loss: Presumed to occur in unit 163 or unit 165:

0.14 m
(199.63 m)

165. Sandstone: White; medium-grained, well sorted, clean; composed of quartz and no interstitial clay; poorly cemented, friable;
0.58 m core badly fragmented by drilling; sharp contact with:
(200.21 m)

166. Claystone: Medium gray; CONTAINS: planar laminations defined by minor grain size variations; very fine-grained quartz sand
0.02 m laminations at the base of the unit; sharp contact with:
(200.23 m)

167. Carbonaceous shale: Black; allochthonous; CONTAINS: abundant intermixed clay, sand, and carbonaceous debris; sharp
0.03 m contact with:
(200.26 m)

168. Sandstone: White; medium-grained, well sorted, clean; composed of quartz and no interstitial clay; poorly cemented, friable;
0.32 m core badly fragmented by drilling; APPEARS TO CONTAIN:

(200.58 m) mega-ripple scale planar cross-beds; contact unknown:

169. Core loss: Presumed to occur in unit 168 or unit 170:

1.05 m
(201.63 m)

170. Sandstone: White; medium- to very coarse-grained, coarsens downward, well sorted, clean; composed of quartz, calcareous cement,
0.49 m and no interstitial clay; dense; well cemented; CONTAINS:
(202.12 m) abundant coalified wood fragments and large trunks; sparse intraformational clay clasts; no evidence of internal bedding; sharp contact with:

171. Sandstone: White; medium- to very coarse-grained, coarsens downward, well sorted, clean; composed of quartz, calcareous cement,
0.51 m and no interstitial clay; dense; well cemented; CONTAINS:
(202.63 m) abundant coalified wood fragments and large trunks; sparse intraformational clay clasts; no evidence of internal bedding; sharp contact with:

172. Claystone: Light gray; massive; homogeneous; rooted; CONTAINS: pyritized roots; rounded, sand-sized, black to dark red
0.74 m ferruginous concretions; contact unknown:
(203.37 m)

173. Core loss: Location unknown:

0.09 m
(203.46 m)

174. Claystone: Light gray, darkens to medium gray in the bottom 15 cm; massive; homogeneous; rooted; CONTAINS: pyritized roots;
0.68 m rounded, sand-sized, black to dark red ferruginous
(204.14 m) concretions; abundant carbonized and pyritized plant debris in the basal 15 cm; sharp contact with:

175. Coal: Black; sharp contact with:

0.35 m
(204.49 m)

176. Claystone: Medium gray; intensely rooted but the unit does not appear to be a severely altered as the light gray "underclay"
0.57 m claystones; CONTAINS: abundant pyritized and carbonized
(205.06 m) plant debris; contact unknown:

177. Siltstone: Light gray; massive; homogeneous; rooted; coarsens downward becomming sandy in the basal third of the unit; CONTAINS:
1.55 m pyritized roots; rounded, sand-sized, black to dark red
(206.61 m) ferruginous concretions; grades into:

178. Siltstone: Medium gray; very sparsely rooted to the base of the unit; coarsens downward, the percentage of sand increases toward
1.09 m the base; CONTAINS: rare burrows; abundant planar siltstone

(207.70 m) laminations, planar, very fine-grained quartz sand laminations toward the base of the unit; some wavy laminations; in the lowest part of the unit, some laminations show low-angle truncations of underlying laminations; finely comminuted carbonaceous debris on bedding plane surfaces; grades into:

179. Siltstone: Medium light gray; very argillaceous; CONTAINS: burrows, in places unit almost homogenized by burrowing; in places
7.11 m there are zones that are considerably finer grained than the
(214.81 m) surrounding sediments; rare zones of convoluted bedding 1 to 5 cm thick; rare ripples; very sparse carbonaceous debris; flat and wavy laminations that frequently truncate underlying laminations at very low angles; zones of flaser bedding filling troughs between wavy laminations; no indication of bidirectional cross-bedding; no tidal couplets; no evidence of repeating depositional cycles; sharp contact with:

180. Mudstone: Light gray; massive; homogeneous; rooted; CONTAINS: pyritized roots; rounded, sand-sized, black to dark red
1.33 m ferruginous concretions; grades into:
(216.14 m)

181. Siltstone: Medium light gray; very argillaceous; coarsens downward and grades into laminated sandstone in the basal 20 cm; sparsely
0.95 m rooted; CONTAINS: pyritized traces around roots; burrows,
(217.09 m) in places unit almost homogenized by burrowing; in places there are zones that are considerably finer grained than the surrounding sediments; rare ripples; very sparse carbonaceous debris; flat and wavy laminations that frequently truncate underlying laminations at very low angles; zones of flaser bedding filling troughs between wavy laminations; no indication of bidirectional cross-bedding; no tidal couplets; no evidence of repeating depositional cycles; grades into:

182. Sandstone: Light gray; very fine- to medium-grained, moderately sorted, moderately clean; composed of quartz and abundant
0.20 m interstitial clay; poorly cemented, friable; massive;
(217.29 m) homogeneous; CONTAINS: no evidence of internal bedforms; grades into:

183. Sandstone: Light gray; fine- to medium-grained, coarsens downward to medium-grained with some coarse grains, well sorted, clean;
1.20 m composed of quartz and little interstitial clay; poorly
(218.49 m) cemented, friable; core badly fragmented during drilling; massive; homogeneous; CONTAINS: no evidence of bedding; contact unknown:

184. Core loss: Presumed to occur in unit 183 or unit 185:

0.50 m
(218.99 m)

185. Sandstone: Light gray; fine- to medium-grained, coarsens downward to medium-grained with some coarse grains, well sorted, clean;
0.60 m composed of quartz and little interstitial clay; poorly
(219.59 m) cemented, friable; core badly fragmented during drilling; massive; homogeneous; CONTAINS: no evidence of bedding; contact unknown but sharp contact with unit 187 suspected:

186. Core loss: Presumed to occur in unit 185:

1.62 m
(221.21 m)

187. Claystone: Pink-brown; CONTAINS: abundant, planar, fine-grained quartz sand laminations, abundant laminations composed of
0.22 m coalified wood fragments; rare burrows; sharp contact with:
(221.43 m)

188. Sandstone: Light gray; fine-grained, well sorted, clean; composed of quartz and little interstitial clay; poorly cemented,
0.60 m friable; core badly fragmented during drilling; massive;
(222.03 m) homogeneous; CONTAINS: no evidence of bedding; contact unknown:

189. Core loss: Presumed to occur in unit 188 or unit 190:

0.18 m
(222.21 m)

190. Sandstone: White; fine-grained, clean, well sorted; composed of quartz and no interstitial clay; poorly cemented, friable; core
1.50 m badly fragmented during drilling; CONTAINS: multiple zones
(223.71 m) of carbonaceous laminations and it appears that the entire unit is dominated by low-angle cross-bedding; contact unknown:

191. Core loss: Presumed to occur in unit 190 or unit 192:

0.30 m
(224.01 m)

192. Sandstone: White; fine-grained, clean, well sorted; composed of quartz, abundant dark minerals, and no interstitial clay;
2.22 m poorly cemented, friable; core partially preserved;
(226.23 m) CONTAINS: very rare heavy mineral laminations; unit appears to be dominated by high-angle planar cross-beds; contact unknown:

193. Core loss: Presumed to occur in unit 192:

0.50 m
(226.73 m)

194. Carbonaceous shale: Black; fissile; CONTAINS: common whole leaf impressions; abundant pyrite, core badly deteriorated due to
0.28 m the decomposition of the pyrite; sharp contact with:

(227.01 m)

195. Siltstone: Black; argillaceous at the top of the unit, coarsening downward to black, dirty, poorly sorted, argillaceous
0.94 m sandstone at the base; CONTAINS: no evidence of rooting;
(227.95 m) abundant pyritized carbonaceous debris on bedding plane surfaces; planar, very fine-grained quartz sand laminations in the finer grained portions of the unit; sharp contact with:

196. Carbonaceous shale: Black; grades downward into bone coal then to coal and back again to carbonaceous shale at the base; sharp
0.29 m contact with:
(228.24 m)

197. Mudstone: Medium gray; silty at the top of the unit and coarsens downward; homogenized by rooting; unit does not have the
1.01 m appearance of a deeply weathered, light gray "underclay";
(229.25 m) CONTAINS: abundant pyritized root traces; common carbonaceous debris; grades into:

198. Sandstone: Medium gray; fine-grained, well sorted, dirty; composed of quartz, and abundant interstitial clay and silt; moderately
0.67 m indurated; CONTAINS: low-angle parallel laminations less
(229.92 m) than 1 mm thick, the laminations show low-angle truncations of underlying laminations; sparse rooting in the upper part of the unit; no evidence of tidal bundles; contact unknown:

199. Core loss: Presumed to occur in unit 198 or unit 200:

0.14 m
(230.06 m)

200. Sandstone: Medium gray; fine-grained, well sorted, dirty; composed of quartz, and abundant interstitial clay and silt; moderately
0.29 m indurated; CONTAINS: low-angle parallel laminations less
(230.35 m) than 1 mm thick, the laminations show low-angle truncations of underlying laminations; no evidence of tidal bundles; contact unknown:

201. Sandstone: Light gray; fine-grained, clean, well sorted; composed of quartz, sparse dark minerals, and little interstitial clay;
2.11 m poorly cemented, friable; CONTAINS: rare root traces near
(232.46 m) the top of the unit; low-angle laminations that truncate underlying laminations; possibly small ripples that have amplitudes less than 1 cm; silty zones with flat laminations; rare burrows; the basal 15 cm consists of a high-angle planar cross-bed set; laminations are defined by clay or heavy mineral accumulations; sparse carbonaceous debris; grades into:

202. Sandstone: Light gray; fine-grained, clean, well sorted; composed of quartz, sparse dark minerals, and little interstitial clay;
0.50 m poorly cemented, friable; CONTAINS: disturbed bedding,
(232.96 m) bedding appears concentric and possibly may be convoluted

and associated with slumping; near vertical laminations in places; some laminations defined by the accumulation of rare carbonaceous debris; sharp contact with:

203. Sandstone: Light gray; fine-grained, clean, well sorted; composed of quartz, sparse dark minerals, and little interstitial clay;
0.23 m poorly cemented, friable; homogeneous; CONTAINS: no
(233.19 m) evidence of internal bedding; sharp contact with:

204. Sandstone: Light gray; fine-grained, clean, well sorted; composed of quartz, sparse dark minerals, and little interstitial clay;
0.14 m poorly cemented, friable; CONTAINS: sparse, tabular
(233.33 m) intraformational clay pebbles, no observable increase in the grain size of the matrix sandstone; sharp contact with:

205. Sandstone: Light gray; fine-grained, clean, well sorted; composed of quartz, sparse dark minerals, and little interstitial clay;
0.08 m poorly cemented, friable; CONTAINS: confused bedding; rare
(233.41 m) carbonaceous debris; sharp contact with:

206. Sandstone: Light gray; fine-grained, clean, well sorted; composed of quartz, sparse dark minerals, and little interstitial clay;
1.47 m poorly cemented, friable; CONTAINS: low-angle cross-beds,
(234.88 m) cross-bed surfaces defined by accumulations of carbonaceous debris or by very rare heavy mineral laminations; contact unknown:

207. Core loss: Presumed to occur in unit 206 or unit 208:

0.26 m
(235.14 m)

208. Sandstone: Light gray; fine-grained, clean, well sorted; composed of quartz, sparse dark minerals, and little interstitial clay;
0.72 m poorly cemented, friable; CONTAINS: low-angle cross-beds,
(235.86 m) cross-bed surfaces defined by accumulations of carbonaceous debris or by very rare heavy mineral laminations; contact unknown:

209. Core loss: Presumed to occur in unit 208 or unit 210:

0.65 m
(236.51 m)

210. Sandstone: Light gray; fine-grained, clean, well sorted; composed of quartz, sparse dark minerals, and little interstitial clay;
0.78 m poorly cemented, friable; CONTAINS: low-angle cross-beds,
(237.29 m) cross-bed surfaces defined by accumulations of carbonaceous debris or by very rare heavy mineral laminations; contact unknown:

211. Core loss: Presumed to occur in unit 210 or unit 212:

0.52 m
(237.81 m)

212. Sandstone: Light gray; fine-grained, clean, well sorted; composed of quartz, sparse dark minerals, and little interstitial clay; poorly cemented, friable; CONTAINS: low-angle cross-beds; contact unknown:

1.16 m
(238.97 m)

213. Core loss: Presumed to occur in unit 212 or unit 214:

0.59 m
(239.56 m)

214. Sandstone: Light gray; fine-grained, clean, well sorted; composed of quartz, sparse dark minerals, and little interstitial clay; poorly cemented, friable; CONTAINS: low-angle cross-beds in the upper 50 cm, below 50 cm the unit darkens slightly and coarsens downward to coarse-grained sandstone that has completely disintegrated in core; contact unknown:

0.82 m
(240.38 m)

215. Core loss: Presumed to occur in unit 214 or unit 216:

0.46 m
(240.84 m)

216. Sandstone: Light gray; fine-grained, coarsens downward to medium-grained toward the base and very coarse-gained at the base, clean, well sorted; composed of quartz, sparse dark minerals, and little interstitial clay; poorly cemented, friable; CONTAINS: abundant, irregular, discontinuous carbonaceous laminations in the upper third of the unit, in the basal two-thirds, carbonaceous laminations truncate underlying laminations at low angles; carbonaceous debris becomes more abundant downward and, toward the base, carbonaceous laminations account for 30 percent of the rock, at the base the unit becomes extremely carbonaceous; abundant burrows; possible ripples; sharp contact with:

5.56 m
(246.40 m)

217. Siltstone: Light gray; massive; homogeneous; rooted; CONTAINS: pyritized roots; rounded, sand-sized, black to dark red ferruginous concretions; sharp contact with:

0.69 m
(247.09 m)

218. Carbonaceous shale: Black; sharp contact with:

0.15 m
(247.24 m)

219. Claystone: Light gray; massive; homogeneous; rooted; CONTAINS: pyritized roots; rounded, sand-sized, black to dark red ferruginous concretions; contact unknown:

0.47 m
(247.71 m)

220. Core loss: Location unknown:

0.63 m
(248.34 m)

END OF CORE

Sarwar (#1) Mine Section, Lakhra Coal Field, Saquib Mines

Total depth of mine: 107.36 m
Thickness of measured section: 107.36 m

The top of this mine section is believed to underlie directly, or with very little covered interval, section SN-9.

LAKHRA FORMATION

1. Sandstone: Fine-grained, poorly sorted; composed of quartz and abundant interstitial clay in the upper 2 m, much less clay in the lower part of the unit; poorly cemented though there are areas within the unit that are better cemented; CONTAINS: cross-beds and ripples; no evidence of bedding in the upper part, top 2 m of the unit homogeneous; sharp contact with:
   5.50 m
   (5.50 m)

2. Sandstone: Indurated; CONTAINS: shell fragments; top of the unit contains planar cross-beds up to 1 m thick; sharp contact
   (7.20 m)

3. Sandstone: Fine-grained, poorly sorted; yellow brown; composed of quartz and interstitial clay; poorly cemented; CONTAINS: no evidence of bedding, unit homogeneous; sharp contact with:
   1.40 m
   (8.60 m)

4. Sandstone: Calcareous; indurated; CONTAINS: pelecypods and shell fragments; sharp contact with:
   1.80 m
   (10.40 m)

5. Sandstone: Fine-grained, poorly sorted; yellow brown; composed of quartz and interstitial clay; poorly cemented; CONTAINS: scattered shell fragments throughout; no evidence of bedding, unit homogeneous; sharp contact with:
   0.60 m
   (11.00 m)

6. Sandstone: Calcareous; indurated; CONTAINS: abundant shell fragments; sharp contact with:
   0.25 m
   (11.25 m)

7. Sandstone: Fine-grained, well-sorted; composed of quartz and little interstitial clay; poorly cemented; CONTAINS: large scale planar cross-bed sets; sharp contact with:
   2.10 m
   (13.35 m)

8. Sandstone: Calcareous; indurated; CONTAINS: abundant shell and pelecypod fragments; sharp contact with:
   1.40 m
   (14.75 m)

9. Sandstone: Fine-grained; yellow brown; poorly cemented; CONTAINS: uncommon bands of shell fragments; sharp contact with:
   1.70 m
   (16.45 m)

10. Sandstone: Calcareous; indurated; CONTAINS: forams and shell fragments; sharp contact with:

0.20 m
(16.65 m)

11. Sandstone: Fine-grained, poorly sorted; yellow brown; composed of quartz and interstitial clay; poorly cemented; CONTAINS: no evidence of bedding, unit homogeneous; sharp contact with:

3.40 m
(20.05 m)

12. Sandstone: Calcareous; indurated; sharp contact with:

1.00 m
(21.05 m)

13. Sandstone: Fine-grained, poorly sorted; composed of quartz and interstitial clay; poorly cemented; CONTAINS: no evidence of bedding, unit homogeneous; grades into:

3.00 m
(24.05 m)

14. Shale: Gray; hard; laminated; sharp contact with:

2.40 m
(26.45 m)

15. Sandstone: Calcareous; indurated; CONTAINS: abundant shell fragments; no evidence of bedding, unit homogeneous; sharp contact with:

0.45 m
(26.90 m)

BARA FORMATION

16. Sandstone: Fine-grained, poorly sorted; medium gray; composed of quartz and, extremely abundant interstitial clay; slightly indurated; CONTAINS: shale bands containing thin sand laminations; foram, gastropod, and pelecypod shell fragments scattered throughout, the shell fragments are confined to the sand zones; grades into:

2.45 m
(29.35 m)

17. Sandstone: Fine-grained, poorly sorted; fines downward, very shaly in the bottom meter; medium-gray; composed of quartz and interstitial clay; CONTAINS: flat shale bands and laminations, small amplitude ripples throughout; burrows; sharp contact with:

7.20 m
(36.55 m)

18. Sandstone: Fine-grained; light gray; CONTAINS: laminar beds; flasers; shale bands; carbonaceous debris on some bedding surfaces; some burrows; very rare shell fragments; some ripple beds; sharp contact with:

3.20 m
(39.75 m)

19. Sandstone: Fine-grained, poorly sorted; medium gray; composed of quartz and abundant interstitial clay; CONTAINS: scattered shell debris and several discrete zones of shell fragments, no evidence of bedding, unit homogeneous; sharp contact with:

4.00 m
(43.75 m)

20. Sandstone: Fine-grained; light gray; CONTAINS: flaser and ripple beds throughout; shell fragments throughout though there are zones where shell fragment accumulations are especially dense; burrows; common shale bands 3 to 4 cm in thickness; sharp contact with:

3.40 m
(47.15 m)

21. Sandstone: Indurated, contains abundant shell fragments; sharp contact with:

0.35 m
(47.50 m)

22. Sandstone: Fine-grained; light gray; CONTAINS: interbedded shale bands that become less prominent upward; flaser bedding; small ripples; a 10 cm thick iron cemented shale pebble lag in the middle of the unit; burrows; sharp contact with:

2.90 m
(50.40 m)

23. Sandstone: Fine-grained, poorly sorted; medium gray; composed of quartz and abundant interstitial clay; CONTAINS: common shell fragments that are confined to distinct zones and beds; sharp contact with:

1.70 m
(52.10 m)

24. Sandstone: Fine-grained; light gray; CONTAINS: shale bands and laminations; flat laminations and small ripples; sparse burrows; rare shell fragments; sharp contact with:

3.60 m
(55.70 m)

25. Sandstone: Fine-grained, poorly sorted; medium gray; CONTAINS: siderite bands; a bed of shell fragments at the top of the unit; no evidence of bedding, homogeneous unit; sharp contact with:

1.70 m
(57.40 m)

26. Interbedded sandstone and shale: Sandstone light gray, shale medium gray; CONTAINS: shale and sand bands and laminations; carbonaceous debris on laminations; sharp contact with:

1.00 m
(58.40 m)

27. Sandstone: Fine-grained, poorly sorted; medium gray; composed of quartz and abundant interstitial clay; CONTAINS: siderite nodules; Turritella and Turritella fragments, gastropods, pelecypods, and shell fragments; shell fragments mostly confined to specific beds with little shell debris between beds; no evidence of bedding, unit homogeneous; sharp contact with:

3.50 m
(61.90 m)

28. Sandstone: Fine-grained, well-sorted; light gray; CONTAINS: laminar beds; small scale ripples and ripples up to 10 cm in amplitude; carbonaceous laminations; abundant shale bands up to 2 cm thick, shale bands become more abundant upward; grades into:

3.05 m
(64.95 m)

29. Sandstone: Fine-grained, poorly sorted; gray; composed of quartz and abundant interstitial clay; CONTAINS: siderite bands; bands and lenses of shell debris; grades into:

2.95 m
(67.90 m)

30. Siltstone: Sand content increases upward; medium gray; CONTAINS: burrows, gastropods, pelecypods, shell debris; shell beds up
2.90 m to 5 cm thick; sand laminations; siderite bands; sharp
(70.80 m) contact with:

31. Sandstone: Fine-grained; calcareous; indurated; CONTAINS: burrows; siderite; and abundant shell fragments; sharp contact with:
0.45 m
(71.25 m)

32. Sandstone: Fine-grained, poorly sorted; medium gray; composed of quartz, abundant interstitial clay, and some calcareous
6.20 m cement; weakly cemented; CONTAINS: scattered shell
(77.45 m) fragments; burrows, unit homogenized by burrowing; grades into:

33. Shale: Dark gray; slightly calcareous; CONTAINS: carbonaceous debris on bedding surfaces; thin sand laminations; burrows;
4.10 m siderite nodules; some shell debris, shell debris becomes
(81.55 m) more abundant upward; grades into:

34. Sandstone: Fine-grained, poorly sorted; fining upward to siltstone at top; medium gray; composed of quartz and abundant
10.10 m interstitial clay; CONTAINS: laminar bedding preserved in
(91.65 m) places; burrows, unit homogenized by burrowing; sharp contact with:

35. Sandstone: Fine-grained, well-sorted; white; composed of quartz; CONTAINS: large scale planar cross-beds; ripples; laminar
3.50 m bedding; rare clay bands; sharp contact with:
(95.15 m)

36. Shale: Gray; CONTAINS: sand laminations; siderite nodules; burrows; carbonaceous debris on bedding surfaces; sharp
1.60 m contact with:
(96.75 m)

37. Carbonaceous shale: Black; burrowed near the top; sharp contact with:

0.30 m
(97.05 m)

38. Shale: Light gray; rooted; sharp contact with:

1.50 m
(98.55 m)

39. Sandstone: Fine-grained, well-sorted; white; composed of quartz; CONTAINS: ripples; climbing ripples; planar cross-beds;
5.60 m zones of laminar bedding; rare shale bands and laminations;
(104.15 m) burrows associated with some of the laminar bedded zones; grades into:

40. Shale: Gray with red iron stained bands; CONTAINS: laminar bedding; abundant carbonaceous debris on bedding surfaces;

1.35 m sharp contact with:
(105.50 m)

41. Coal:

1.86 m
(107.36 m)

END OF SECTION