Stratigraphy of the Bannu and Dera Ismail Khan Areas, Pakistan

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GEOLOGICAL INVESTIGATIONS IN PAKISTAN

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

The 14,000- and 38,000-foot sequences include rocks of Cambrian(?) to Quaternary age; type sections are designated and named for seven units

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FOREWORD

In 1956, the Geological Survey of Pakistan and the U.S. Geological Survey began a cooperative program to intensify the mapping and appraisal of the geological resources of Pakistan. The program was initiated under an agreement dated October 1955 between the Government of Pakistan and the International Cooperation Administration, predecessor of the Agency for International Development, U.S. Department of State. It included joint geological reconnaissance of unmapped areas, detailed mapping and appraisal of mineral districts, and development of facilities and staff to increase the capacity of the Geological Survey of Pakistan.

This volume entitled "Geological Investigations in Pakistan" is intended to present some of the more significant results of the cooperative program in Pakistan, which extended from 1956 to 1970. It consists of papers that have been prepared by U.S. Geological Survey geologists and by their counterparts in the Geological Survey of Pakistan, summarizing the investigations believed to be most important for those interested in the geology and resources of Pakistan. More detailed information from these investigations, as well as reports from other studies made during the program, are available from the Geological Survey of Pakistan in Quetta. Much of the regional geological information obtained during this program, and from surveys made earlier, was summarized in a new Geological Map of Pakistan prepared cooperatively and published by the Geological Survey of Pakistan in 1964.

The cooperative program in Pakistan, which directly involved the services of about 110 professional personnel from Pakistan and 43 from the United States, operated successively under the direction of four Directors-General of the Geological Survey of Pakistan and three Chiefs of Party appointed by the U.S. Geological Survey. Program directors for Pakistan were E. R. Gee (1956–59), N. M. Khan (1959–64), A. F. M. M. Haque (1964–69), and A. M. Khan (1969–70). United States participation was supervised by J. A. Reinemund (1956–63), M. G. White (1963–66), and D. L. Rossman (1967–70), each of whom also served as senior geologic consultant to the Director-General.

Geologic specialists provided by the U.S. Geological Survey were supplemented by four mining engineers from the U.S. Bureau of Mines, who provided collateral assistance to the Pakistan Department of Mineral Development, and by a drilling specialist and an administrative specialist from the Agency for International Development. The Geological Survey of Pakistan, through the Ministry of Industries and Natural Resources, provided counterpart personnel facilities, and services for the program, and arranged cooperative support from the Pakistan Department of Mineral Development, as well as from the Pakistan Industrial Development Corporation, Pakistan Council of Scientific and Industrial Research, and other agencies concerned with resource development.

This program would not have been possible without the excellent support of all agencies involved, both in Pakistan and the United States. The geological information and institutional growth obtained through this program should contribute significantly toward orderly economic and scientific development in one of Asia's largest and newest nations.

A. M. Khan

Abdul Mannan Khan, Director-General
Geological Survey of Pakistan

John A. Reinemund

John A. Reinemund, Chief
Office of International Geology
U. S. Geological Survey

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By WILLIAM R: HEMPHILL, U.S. GEOLOGICAL SURVEY, and ABDUL H. KIDWAI, GEOLOGICAL SURVEY of PAKISTAN

ABSTRACT

The Bannu and Dera Ismail Khan quadrangles cover an area of more than 8,600 square miles in north-central Pakistan, between lat 31° and 33°N. and long 70° and 71°E. This area contains two main physiographic units: the alluvial lowlands, which include the structurally undisturbed Indus and Bannu plains, and the folded belt, which includes the Khisor, Marwat, Bhittanni, and Sulaiman Ranges, as well as the highlands of Waziristan. These ranges and highlands form a nearly continuous mountain system between the Salt Range–Potwar Plateau region to the northeast and Baluchistan to the southwest.

Total stratigraphic thickness exceeds 14,000 feet in the Khisor and Marwat Ranges. Sedimentary rocks of the following age are present: Cambrian(?), Permian, Triassic, Jurassic, Cretaceous, middle and late Tertiary, and Quaternary. Lower Tertiary rocks are not present. Stratigraphic terminology for rocks in the Khisor and Marwat Ranges is the same as that used in the Salt Range and Potwar Plateau region to the northeast.

Total stratigraphic thickness exceeds 38,000 feet in the Sulaiman Range–Waziristan area. Sedimentary rocks of Jurassic, Cretaceous, Tertiary, and Quaternary age are present. Rocks of Paleocene and Eocene age are particularly well developed in this region, in places exceeding 13,000 feet. Stratigraphic terminology for units of Mesozoic age is the same as that used in Baluchistan to the southwest. New names are proposed and type sections are designated for seven units in the eastern foothills of the Sulaiman Range. These units are the Baska Shale of early Eocene age; the Domanda Shale and Drazinda Shale Members of the Kirthar Formation, middle and late(?) Eocene age; the Chitarwata Formation of late Oligocene to late Miocene age; and the Vihowa, Litra, and Chaudhwan Formations of Pliocene and Pleistocene(?) age.

INTRODUCTION

LOCATION AND ACCESSIBILITY

The area described in this report covers more than 8,600 square miles in north-central Pakistan, between lat 31° and 33°N. and long 70° and 71°E. (fig. 1). This area is covered by two Survey of Pakistan topographic sheets (1:250,000 scale series): 38 L, the Bannu quadrangle, and 39 I, the Dera Ismail Khan quadrangle. Principal towns are Bannu in the north and Dera Ismail Khan in the south; both towns are major commercial centers as well as seats of the provincial government for local administration of the surrounding area. The village of Tank (pl. 1), northwest of Dera Ismail Khan, is the railhead of the southern branch of the Lakki-Marwat-Pezu-Tank narrow-gage branch line of the Pakistan Western Railway. Jandola, to the west, is the headquarters of the South Waziristan Scouts, a military unit maintained in this part of the frontier region contiguous with Afghanistan. A similar unit, the Tochi Scouts, is headquartered at Miram Shah, west of Bannu.

The main access to the area is the Northwest Frontier Road, a surfaced highway that connects Dera Ismail Khan and Bannu with Kohat and Peshawar to the northeast. Another improved route into the area is from Lahore and the Salt Range region, by way of Lakki, west to the junction with the Northwest Frontier Road. Other improved roads connect Tank and Bannu with the hill country to the west; however, travel to Jandola and Miram Shah or to Razmak and Wana, west of the area described, is controlled; armed escort is commonly necessary, and travel arrangements must be cleared with local authorities. Unsurfaced roads provide access from Dera Ghazi Khan to the south and from Fort Sandeman and Quetta to the west and southwest, but these routes are subject to flash floods and are passable only during dry weather.

PREVIOUS WORK

The first geologic observations in the Bannu quadrangle and in Waziristan were by Stewart (1860), a medical doctor with the 14th Punjab Infantry, who traveled from the village of Tank northwest along Tank Zam to Kaniguram. He returned to Bannu along the Khaisora River valley. Oldham (1860) was able to interpret some of Stewart's lithologic descriptions in stratigraphic terms recognized east of the Indus River.

Another early account of the geology of the Bannu quadrangle was by Costello (1864), an army surgeon headquartered in Bannu, who observed the dominant rock types in the mountain ranges south and southeast of the Bannu Plain (pl. 1), recognized brachiopods and

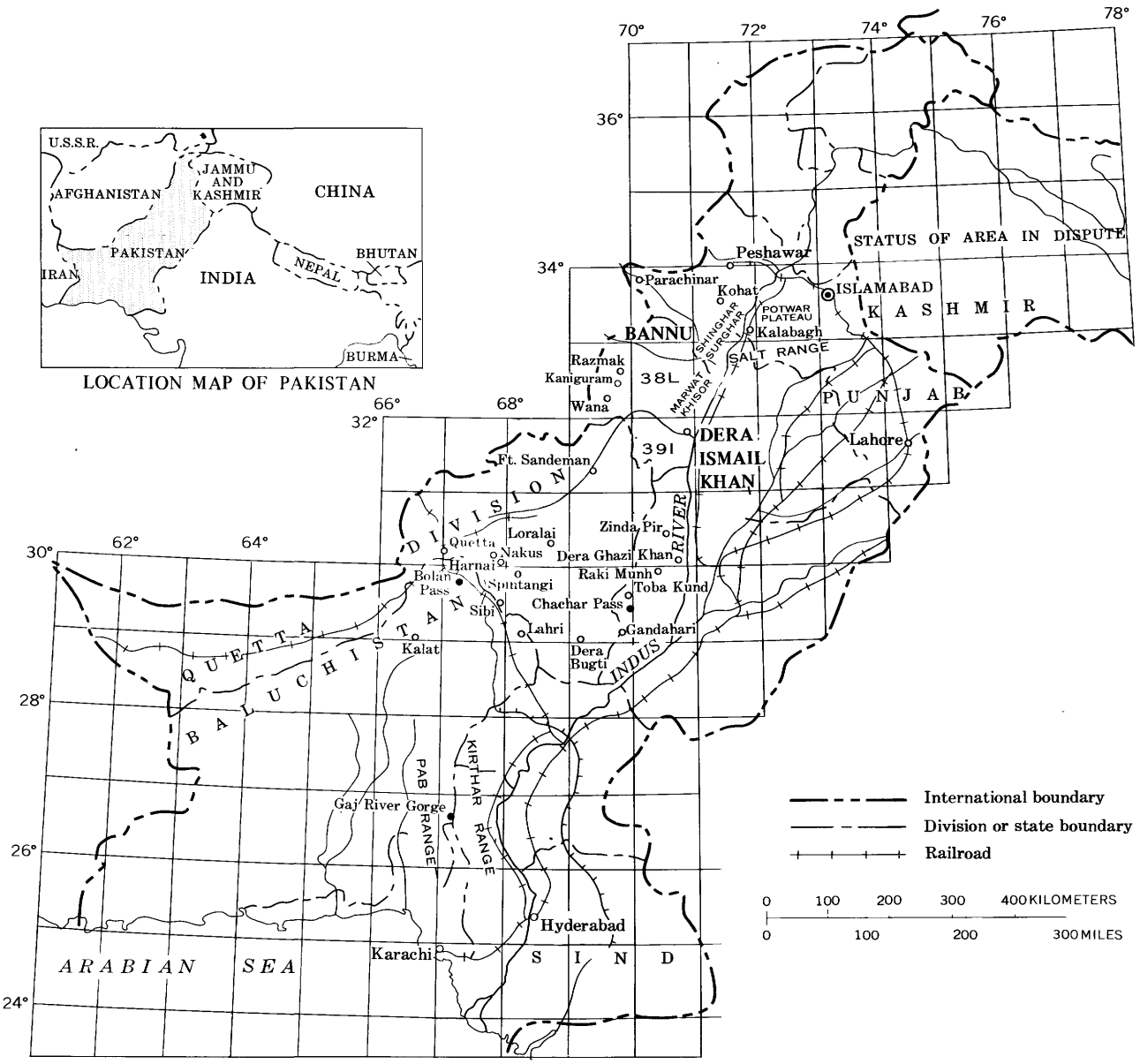

FIGURE 1.—Pakistan, showing the Bannu (38 L) and Dera Ismail Khan (39 I) quadrangles.

mollusks at Shaikh Budin and in the Khisor Range, and collected mammalian bones and teeth in the Marwat Range.

A more extensive description of the same area was provided by Verchere (1867, p. 9–21), a physician also assigned to Bannu. His report includes cross sections of the Shaikh Budin–Paniala area (pl. 1). He correctly identified the ages of some of the rock units, extended his survey into Waziristan as far as Razmak (fig. 1), noted evidence of igneous rocks west of Razmak, and produced the first geologic map of the region at a scale of 1:1,000,000. Many of Verchere's observations, however, are grossly inaccurate.

The most comprehensive and reliable of the early reports is that of Wynne (1880), the first professional geologist to visit Bannu quadrangle. He described in detail many rocks that today are recognized as mappable units at Shaikh Budin and in the Khisor, Marwat, and Bhittanni Ranges. His report also includes cross sections and measured sections, a summary of the mineral resources, and geologic maps at scales of 1:253,440 and 1:63,360. Wynne was not permitted beyond Shaikh Budin because of tribal unrest to the west.

Griesbach (1884) was the first geologist to visit the northern Sulaiman Range. His report includes some excellent panoramic sketches made from the highest peaks of the range, but the speed at which the accompanying military column advanced did not permit him adequate time to observe structural and stratigraphic relationships of rocks in the region.

In 1889, reports of oil seeps near Mughal Kot prompted the initial economic interest in the hill country west of Dera Ismail Khan; collection of the early oil samples and results of assays were described by King (1891, p. 5–6; 1892, p. 6–7). Oldham (1891) visited the seeps, collected additional samples of the oil for laboratory analysis, and noted major structural features observable along the line of march. La Touche (1892) examined the seeps in some detail and outlined an exploratory drilling program which, though modest by modern standards, was commensurate with technical limitations of the time. La Touche (1893) also mapped the foothills east of the Sulaiman Range between Toi Nala and the Zao River, and he systematically described the physiography, stratigraphy, general structural setting, and economic geology of the mapped area.

Smith (1895; also in Griesbach, 1896, p. 8–9) was the first geologist to visit northern Waziristan. He accompanied a military column from the Bannu Plain westward along the Tochi River to the Afghanistan frontier and described the rocks and the attitude of beds along the line of march. Smith (1895, p. 109–110) sampled the intrusive rocks in the upper part of the valley, just west of the Bannu quadrangle, and identified their age as "up to middle Eocene times at least" (their age is more likely early Eocene). These samples were later analyzed petrographically by Hayden (1896) who reported them to be mostly serpentines and gabbros.

In 1921, Stuart (1922, p. 87) visited the lower part of the Tochi Valley, reexamined Smith's work, and was " able *** to confirm his observations." Stuart was then assigned to a military column operating in southern Waziristan, but his observations were hindered "owing to the severity of the fighting ***" with local Waziri tribesmen. In places "the survey *** had to be done hurriedly and under fairly heavy fire; [therefore] there was no opportunity of searching for fossils" (Stuart, 1922, p. 87, 97). These difficulties were more severe than most geologists normally expect in the field. Stuart managed, however, to observe the more significant structural and stratigraphic features along the line of march from the Khirgi Post (pl. 1) along Tank Zam and tributary streams to a point about midway between Razmak and Wana (fig. 1), and he produced a reconnaissance map (1:500,000 scale) based on his own and Smith's (1895) traverses. Stuart (1922, p. 90) was the first to record that some rocks in the northern Sulaiman Range and in southern Waziristan are as old as Jurassic and the first to identify Cretaceous units in this region correctly.

With the exception of Wadia (in Pascoe, 1930, p. 61–68) who evaluated several potential damsites south of Wana (fig. 1) and in the Jandola-Manzai region, no further work was conducted until Coulson (in Heron, 1937, p. 71–74; 1938, p. 83–84) began a systematic survey of southern Waziristan. This work was stopped in 1937, midway during the second field season, because of a tribal uprising.

Outside the tribal area, Morris (1938) mapped and described in some detail rocks of the Siwalik Group in the Khisor, Marwat, and Bhittanni Ranges and demonstrated the marked similarity of the heavy-mineral assemblages of these rocks with lithostratigraphic equivalents in the Potwar Plateau. Morris also discovered in Bain Pass in the Bhittanni Range (pl. 1) the controversial boulder bed within the folded Siwalik section. Some workers believe that the bed may be of glacial origin. Possible artifacts have been collected from it.

Pinfold (1939) discussed the correlation of lower Tertiary rocks throughout the region between Sind and the western Punjab, and his map at a scale of 1:1,000,000 shows the gross distribution of Tertiary and older units in the northern Sulaiman Range and southeastern Waziristan. Both Pinfold's and Morris' work drew in large part from unpublished reports of oil companies who sponsored work in the region during the 1920's and 1930's.

Following World War II, geological studies in the Bannu and Dera Ismail Khan quadrangles were limited primarily to investigations conducted by oil companies. With the exception of references to the Mughal Kot area by Williams (1959) and the report of the Hunting Survey Corporation, Ltd. (1960), all this work is unpublished. Many of these reports and measured sections, however, are on file at the National Stratigraphic Library, Geological Survey of Pakistan, Quetta.

PRESENT INVESTIGATIONS

Geological studies of the Bannu and the Dera Ismail Khan quadrangles were conducted by the Geological Survey of Pakistan in cooperation with the U.S. Geological Survey, as a part of the Mineral Exploration and Development Program sponsored jointly by the Government of Pakistan and the Agency for International Development, U.S. Department of State. As a result of this work, the two 1° quadrangles were mapped at a scale of 1:250,000 (pls. 2, 3). A generalized geologic map of both quadrangles at a scale of 1:500,000 (pl. 1) and columnar sections (pl. 4) show the lateral and vertical relationships of the stratigraphic units in the area. The structural framework of the region around the quadrangles is shown on plate 5. This report discusses the stratigraphic nomenclature and lithology of rock units in the Bannu and Dera Ismail Khan quadrangles and compares units that crop out in the Khisor, Marwat, and Bhittanni Ranges in the eastern part of the area with chronostratigraphic units in the Sulaiman

Range–Waziristan area in the western part. Where appropriate, these units are related to stratigraphic units defined by other workers in adjacent areas outside the quadrangle boundaries.

This investigation is particularly significant from a regional point of view because the Bannu and Dera Ismail Khan quadrangles are strategically located between the Salt Range–Potwar Plateau region (fig. 1), where some of the earliest stratigraphic studies in Pakistan were made (Wynne, 1878; Waagen, 1889, 1891), and the Baluchistan-Sind region, where comprehensive reconnaissance geologic and stratigraphic studies have been completed by Williams (1959) and by the Hunting Survey Corporation, Ltd. (1960). The Khisor, Marwat, Bhittanni, and Sulaiman Ranges, as well as the highlands of Waziristan (pl. 1) form a nearly continuous mountain system between these two regions. Rocks of late Tertiary age are nearly unbroken in their outcrop for more than 300 miles from the Potwar Plateau to the foothills of the southern Sulaiman Range and beyond. Older rocks are also well exposed, though less extensively. The section near Mughal Kot in the Sulaiman Range and the foothills to the east (pl. 1) is outstanding in its completeness, continuity, and excellence of exposure; because this section is readily accessible on the Fort Sandeman–Dera Ismail Khan road, it is destined to become one of the classic reference sections of Pakistan.

FIELDWORK AND ACKNOWLEDGMENTS

The fieldwork on which this report is based began in January 1960 and continued intermittently until February 1964. Annual field activities were generally limited to the period between late October and early April to avoid the extremely hot humid weather normal for the Indus Plain and adjacent areas during late spring and summer. Vertical aerial photographs, obtained under the auspices of the Canadian Colombo Plan, were used extensively to extend the identification of rock units from areas where they are readily observed in the field into regions where travel is difficult or not feasible. Measurements of stratigraphic sections are based on steel tape and hand-level traverses, supplemented by photogrammetric measurement of traverse distance and strike and dip.

Sibghatullah, Jamiluddin, A. B. Roy, A. A. Qureshi, and N. A. Bhatti, Geological Survey of Pakistan, assisted the authors in the survey at various times. Habib-ur-Rahman, Geological Survey of Pakistan, and Curt Teichert, U.S. Geological Survey, visited the field party during November 1963 and made many suggestions that served to clarify stratigraphic nomenclature policies as applied to the Bannu and Dera Ismail Khan quadrangles.

The Office of the Commissioner, Dera Ismail Khan Division, was most cooperative throughout the investigation in arranging travel and accommodation where schedules and operations required visits to areas within and adjacent to tribal territory. In several instances, the Commissioner personally interceded to provide armed escort and to insure that field schedules and objectives could be met. The Drazinda, Tank, and Bannu contingents of the Frontier Constabulary repeatedly provided lodging and assistance, and the field party continually relied upon their cooperation. The Officer's Mess, South Waziristan Scouts at Jandola, and the Tochi Scouts at Miram Shah provided accommodations and most cordial hospitality on numerous occasions. The assistance provided by these individuals and organizations, both civil and military, is gratefully acknowledged.

STRATIGRAPHIC UNITS AND CORRELATION

Sedimentary rocks in the Sulaiman Range and eastern Waziristan are Jurassic to Quaternary in age (table 1; pls. 2, 3) and total some 38,000 feet in thickness. Lithology and stratigraphic nomenclature in this part of the area are similar to those of stratigraphic systems established in the lower Indus basin and in Quetta Division, particularly for rocks of Jurassic and Cretaceous age. Sedimentary rocks in the Khisor, Marwat, and Bhittanni Ranges exceed 14,000 feet and include rocks believed to be as old as Cambrian (pl. 2). In this part of the area, stratigraphic nomenclature established in the Potwar Plateau and the Salt Range is generally more appropriate.

The stratigraphic nomenclature in Pakistan is being reviewed by the Stratigraphic Committee of Pakistan for conformity with the Stratigraphic Code (Day and others, 1962). The status of stratigraphic names used in this report is indicated as follows: no asterisk, name formally accepted under the Stratigraphic Code or believed to be acceptable under the code; (*), name does not meet the requirements of the code, but has been used in previous published or unpublished reports.

Rocks of the Jhelum Group, which crop out along the south flank of the Khisor Range in the eastern part of the Bannu quadrangle, are believed to be of Cambrian age because in lithology and stratigraphic position they closely resemble rocks believed to be of Cambrian age in the Salt Range. Abundant evaporites associated with the Jhelum Group in both the Salt and Khisor Ranges suggest that at least part of the group was deposited under arid conditions.

The Jhelum Group is overlain disconformably by rocks of the Nilawahan and Zaluch Groups of Permian age. Within the mapped area the Nilawahan Group is restricted to the south flank of the Khisor Range, but

TABLE 1.—*Sequence of rocks in the Dera Ismail Khan and Bannu areas*

Age	Khisor-Bhittanni-Marwat Ranges and Shaikh Budin (eastern Bannu quadrangle)	Waziristan-Sulaiman Range (western Bannu and Dera Ismail Khan quadrangles)	Obsolete names (asterisk, as used in text, indicates name not conformable with the Stratigraphic Code (Day and others, 1962)
Middle and Late Tertiary, Quaternary, and Quaternary(?)	Siwalik Group: Malagan Formation	Siwalik Group: Chaudhwan Formation[1]	Sheri Ghasha formation*
	Dhok Pathan Formation		Marwat formation*
	Nagri Formation	Litra Formation[1]	Kargocha formation*
	Chinji Formation	Vihowa Formation[1]	
		Chitarwata Formation[1]	
Early Tertiary		Kirthar Formation: Drazinda Shale Member[1] Pir Koh Limestone Member Domanda Shale Member[1] Habib Rahi Limestone Member Baska Shale[1] Ghazij Shale Dunghan Formation	Upper chocolate clays* White marl band* Lower chocolate clays* Platy limestone*, *Assilina* bed* Shales with alabaster*
Cretaceous	Lumshiwal Sandstone(?) Chichali Formation	Pab Sandstone Mughal Kot Formation Parh Limestone Sembar Formation	Black zone* Nishpa formation* Blackish zone;* Belemnite beds.*
Jurassic	Samana Suk Limestone Datta Formation	Sulaiman Limestone Group: Undivided	Baroch limestone* Variegated series*
Triassic and Triassic(?)	Kingriali Dolomite Tredian Formation: Khatkiara Sandstone Member Landa Member Mianwali Formation: Narmia Member Mittiwali Member Kathwai Member		Kingriali dolomites* Kingriali sandstone* Bivalve beds;* Ceratite beds.*
Permian	Zaluch Group: Chhidru Formation Wargal Limestone Amb Formation		Upper Productus beds;* also Bellerophon beds.* Middle Productus limestone;* also Middle Productus beds.* Lower Productus beds.*
	Nilawahan Group: Undivided		Nilawan series.* Lavender clay;* Speckled sandstone;* Olive series* or Conularia beds;* Talchir boulder bed.*
Cambrian(?)	Jhelum Group: Undivided		Salt pseudomorph beds* or Gypsiferous series* or Khisor gypsiferous beds;* Magnesian sandstone;* Neobolus beds;* Purple sandstone.*

[1]New name proposed in this report.

the overlying Zaluch Group is exposed both in the southern Khisor Range and along the south flank of Shaikh Budin (pls. 1, 2). The Zaluch Group is divided as follows from bottom to top: Amb Formation, Wargal Limestone, and Chhidru Formation. The basal unit of the Nilawahan Group, the so-called Talchir boulder bed* is considered by Gee (1945, p. 275), B. Sahni (1939, p. 138), and other workers to be of glacial origin, but the sediments overlying this unit in the Salt Range contain *Conularia* and other marine fauna as well as nonmarine lamellibranchs (Reed, 1939) and pollen (B. Sahni, 1939, p. 139–141). The upper part of the Nilawahan Group and the Zaluch Group are marine.

The Mianwali Formation of Triassic age disconformably overlies the Zaluch Group at Shaikh Budin and in the southern part of the Khisor Range. The Mianwali Formation is divided from bottom to top as follows: Kathwai, Mittiwali, and Narmia Members. The Mianwali Formation is succeeded by the Tredian Formation and the Kingriali Dolomite; both formations are of probable Triassic age. The Tredian Formation is divided into the underlying Landa and the overlying Khatkiara Sandstone Members. The Triassic was a period when predominantly shallow-water marine conditions prevailed, although poorly preserved plant fragments (Sitholey, 1943) indicate that the Landa Member of the Tredian Formation may have been deposited in a nonmarine environment. Triassic rocks

are not present in the Sulaiman Range (pls. 1, 3) and were not recognized in the western part of the Bannu quadrangle.

The Sulaiman Limestone Group of Jurassic age is the oldest rock unit recognized in the Sulaiman Range and eastern Waziristan and is believed to be the chronostratigraphic equivalent, at least in part, of the Datta Formation and the Samana Suk Limestone at Shaikh Budin and in the southern Khisor Range. The Sulaiman Limestone Group and the Samana Suk Limestone are marine, but the Datta Formation, particularly the lower and middle parts, may represent alternating shallow-marine and fresh-water conditions.

The Sulaiman Limestone Group is disconformably overlain by rocks of Cretaceous age, which from oldest to youngest are as follows: Sembar Formation, Parh Limestone, Mughal Kot Formation, and the Pab Sandstone. These rocks were deposited in a generally shallow sea. The Pab Sandstone may represent a littoral or fluvial depositional phase during which the Cretaceous sea receded.

Cretaceous rocks in the eastern part of the Bannu quadrangle are limited to the Chichali Formation and the Lumshiwal Sandstone (?). The Chichali Formation lithologically resembles its stratigraphic equivalent, the Sembar Formation in the Sulaiman Range. The Lumshiwal Sandstone(?) may be the equivalent of the Pab Sandstone, but this correlation is uncertain.

In the Sulaiman Range, the Dunghan Formation of Paleocene age overlies the Pab Sandstone. The formation wedges out near the north end of the Sulaiman Range, however, and it is not recognized to the north. The Dunghan Formation was deposited in a shallow sea which transgressed the region after its recession at the end of the Cretaceous. The Dunghan Formation as well as other rocks of early and middle Tertiary age is not present at Shaikh Budin and in the Khisor Range.

The Dunghan Formation is followed by the Ghazij Shale, Baska Shale, and Kirthar Formation. All are of Eocene age and were deposited in a shallow sea where lagoonal conditions prevailed intermittently. The Kirthar Formation is divided into four members, from oldest to youngest as follows: Habib Rahi Limestone, Domanda Shale, Pir Koh Limestone, and Drazinda Shale Members. The Habib Rahi Limestone Member may be traced northward into the Kohat region, but the upper three members thin and wedge out in Waziristan.

The Chitarwata Formation of late Oligocene to late Miocene age disconformably overlies the Kirthar Formation in the eastern foothills of the Sulaiman Range, but the unit is not recognized in Waziristan. The Chitarwata Formation was deposited in a fluvial or lacustrine environment.

In Waziristan and the Sulaiman Range, rocks of the Siwalik Group are of probable Pliocene age and overlie the Chitarwata and Kirthar Formations. In this area the group is divided into three formations: the Vihowa, Litra, and Chaudhwan Formations. The Chaudhwan Formation may be as young as Pleistocene. At Shaikh Budin and in the Khisor Range, rocks of the Siwalik Group overlie Cretaceous and older rocks; in this area the Siwalik Group is believed to be as young as Pleistocene and is divided into four formations: the Chinji, Nagri, Dhok Pathan, and Malagan Formations. The Siwalik Group is composed of continental detritus derived from highlands to the west and northwest.

Extensive alluvial and sand dune deposits of the Indus and Bannu Plains are of Holocene age. Older terrace deposits in the foothills in the eastern parts of the Bannu and Dera Ismail Khan quadrangles may be of late Pleistocene age.

CAMBRIAN(?) SYSTEM

JHELUM GROUP

The term "Jhelum Group" was used by the Geological Survey of Pakistan (Pakistan Geol. Survey, 1964) for that part of the stratigraphic sequence hitherto referred to by the following informal descriptive terms: Salt pseudomorph beds* or Gypsiferous series* (Gee, 1945) or Khisor gypsiferous beds* (B. R. Hussain, unpub. data, Pakistan Geol. Survey, Natl. Strat. Libr., 1960); Magnesian sandstone*; Neobolus beds*; and purple sandstone*. Type locality of the Jhelum Group is in the Salt Range.

In the Bannu quadrangle, outcrop of the Jhelum Group is limited to the southern Khisor Range. Although these rocks are devoid of index fossils (B. R. Hussain, unpub. data, Pakistan Geol. Survey, Natl. Strat. Libr., 1960), they are believed to be of Cambrian age because of their close lithologic and stratigraphic similarity to rocks in the Salt Range believed to be of probable Cambrian age by Gee (1934, p. 115, 116) and earlier workers. Rocks of the Jhelum Group are not discussed in detail in this report because they are poorly exposed and because the section is incomplete within the Bannu quadrangle.

PERMIAN SYSTEM

NILAWAHAN GROUP

The term "Nilawan group"* was introduced by Teichert (1966) to replace the name "Nilawan series"* proposed by Gee (in Pascoe, 1959, p. 746).[1] According to Gee, the type locality is in Nila Wahan gorge in the Salt Range. The term is spelled "Nilawahan Group" by

[1] An even earlier use of the term "Nilawan series*" was by Gee (in Reed, 1939, p. 474).

the Geological Survey of Pakistan (Pakistan Geol. Survey, 1964), and this spelling is retained in this report.[2] The Nilawahan Group includes that part of the stratigraphic sequence previously referred to by the following informal descriptive terms: "Lavender clay,*" "Speckled sandstone,*" "Olive series*" or "Conularia beds,*" and "Talchir boulder-bed.*" Because the units have not yet been given formal names and are thicker and better exposed in their type localities in the Salt Range, outside the area of this report, they are discussed here collectively as the Nilawahan Group.

In the Bannu quadrangle, outcrop of the Nilawahan Group is limited to the Khisor Range. The upper part of the Nilawahan Group southeast of Paniala consists of dark-brown to black claystone and a few thin beds of green and gray siltstone. The claystone is fissile, carbonaceous, micaceous, and calcareous. According to Hussain (unpub. data, Pakistan Geol. Survey, Natl. Strat. Libr., 1960), one calcareous zone about 100 feet below the top contains abundant bryozoans and brachiopods (athyrids, productids, and spiriferids). Varicolored sandstone in the middle part is medium to coarse grained, massive, crossbedded, soft, friable, micaceous, and partly calcareous. The sandstone contains thin beds of purple micaceous siltstone.

The lower part is a conglomerate which commonly grades laterally into green and gray siltstone and fine- to coarse-grained sandstone. The conglomerate contains boulders, cobbles, and pebbles of quartzite, granite, granite gneiss, and mafic rocks. The boulders are ellipsoidal, striated, and as much as 3 feet in diameter. The lower contact with rocks believed to be of Cambrian age is disconformable.

According to Hussain (unpub. data, Pakistan Geol. Survey, Natl. Strat. Libr., 1960), the thickness of the Nilawahan Group southeast of Paniala is 822 feet.

Gee (in Pascoe, 1959, p. 745–746), who referred to this unit as the Nilawan series*, considered it to be of late Carboniferous age. Hussain (unpub. data, Pakistan Geol. Survey, Natl. Strat. Libr., 1960) speculated that most of the rock units that make up this group in the Khisor Range are of Carboniferous age but that fossils in the upper part may be as young as Permian. Teichert (1966, p. 11), however, noted that in the Salt Range, rocks of the Artinskian Stage (Amb Formation, Zaluch Group) conformably overlie rocks of the Nilawahan Group and that the Nilawahan Group must also be of Permian age. Nonmarine lamellibranchs and the flora *Gangamopteris* collected from the lower part of Nilawahan Group in the Salt Range indicate an Early Permian age according to Reed (1939). In this report the Nilawahan Group is assumed to be Early Permian in age.

[2] This one-word spelling approximates the spelling of the two-word geographic name which appears as "Nila Wāhan" on Survey of Pakistan topographic sheet 43 D, the Sargodha quadrangle (1:250,000-scale series, first edition, 1959), and as "Nila Wāhān" on topographic sheet 43 $\frac{D}{10}$ (1:50,000-scale series, first edition, 1963).

ZALUCH GROUP

The term "Zaluch Group" was proposed by Teichert (1966) to replace the descriptive name "Productus limestone*" of Waagen (1889). Teichert (1966) divided the Zaluch Group into three formations: from bottom to top, the Amb Formation, the Wargal Limestone, and the Chhidru Formation. These formations are synonymous with the Lower Productus beds,* Middle Productus limestone,* and the Bellerophon beds* of B. R. Hussain (unpub. data, Pakistan Geol. Survey, Natl. Strat. Libr., 1960). They are also synonymous with the Lower, Middle, and Upper Productus beds* of Gee (1945) and earlier workers. Type localities proposed by Teichert (1966) are in the western Salt Range.

In the Bannu quadrangle, rocks of the Zaluch Group are restricted to the south flank of Shaikh Budin and to the area south and southeast of Paniala where they form steep, commonly impassable ridges and cliffs. These rocks were not examined in detail by the authors, and lithologic descriptions and stratigraphic boundaries are interpreted in part from Hussain (unpub. data, Pakistan Geol. Survey, Natl. Strat. Libr., 1960).

The Zaluch Group is richly fossiliferous and contains a particularly abundant brachiopod fauna. Hussain (unpub. data, Pakistan Geol. Survey, Natl. Strat. Libr., 1960) considered the lower part of the Zaluch Group to be of Permian age and the upper part not younger than middle Permian. Teichert (1966), however, who studied the Zaluch Group in some detail in the Salt Range, considered it to range in age from Early Permian (Artinskian)[3] to Late Permian (Pamirian), and this range is adopted in this report.

AMB FORMATION

The Amb Formation consists of gray and brown sandstone and thin intercalations of calcareous shale and subordinate limestone. The sandstone is medium to coarse grained, thick bedded, calcareous, and micaceous. The limestone is brownish gray, crystalline, and argillaceous and contains fusulinids, bryozoans, brachiopods (athyrids, productids, and spiriferids), and crinoids. The lower contact with rocks of the Nilawahan Group is conformable and sharp. The Amb For-

[3] The Artinskian is considered to be Early Permian by virtue of Teichert's use of a two-part time-rock division of the Permian; that is, Lower and Upper Permian Series. Some workers, however, who use a three-part division of the Permian, consider the Artinskian to be the lowermost stage of the Middle Permian Series.

mation is about 170 feet thick in the area southeast of Paniala.

WARGAL LIMESTONE

The Wargal Limestone consists of brown and gray limestone and thin beds of gray calcareous shale. Near the top, the limestone is sandy, argillaceous, cherty, and thin bedded. In the middle part, the limestone is massive, nodular, and finely crystalline. Near the base, the limestone is both thin and thick bedded and sandy. The upper part of the Wargal Limestone is richly fossiliferous and contains algae, corals, bryozoans, brachiopods (athyrids, productids, and spiriferids), gastropods, cephalopods, and crinoids. The lower contact with the Amb Formation is transitional. The Wargal Limestone is about 640 feet thick in the area southeast of Paniala.

CHHIDRU FORMATION

The Chhidru Formation consists mostly of gray and brown sandstone. The sandstone is fine to medium grained, thick bedded, friable, calcareous, and micaceous. Thin argillaceous limestone beds are grayish brown, fine to medium grained, and sandy. Specimens of *Bellerophon*, as well as productids and other brachiopods, are abundant. The upper contact with the Mianwali Formation is disconformable; the lower contact with the Wargal Limestone is transitional. The Chhidru Formation is about 130 feet thick south of Paniala.

TRIASSIC SYSTEM

MIANWALI FORMATION

The term "Mianwali group*" was used by Danilchik and Shah (1973) for rocks in the Salt and Surghar Ranges previously identified in part by the descriptive name "Ceratite beds.*"[4] The first formal recognition of the term "Mianwali" as a formation and its division into the Narmia, Mittiwali[5], and Kathwai Members was made almost simultaneously by Kummel and Teichert (1966, p. 310) and by Kummel (1966, p. 374–380).

In the Bannu quadrangle, outcrop of the Mianwali Formation is restricted to the south flank of Shaikh Budin and to the area south and southeast of Paniala; the formation forms a slope. The Mianwali Formation was not examined in detail by the authors, and lithologic descriptions and stratigraphic boundaries are interpreted in part from Hussain (unpub. data, Pakistan Geol. Survey, Natl. Strat. Libr., 1960). Although Triassic rocks have not been recognized in the western part of the Bannu area, Triassic rocks have been mapped in the vicinity of Fort Sandeman (Hunting Survey Corporation, Ltd., 1960, p. 72 and geol. map No. 29) west of the Sulaiman Range (fig. 1, pl. 5), and quite likely this belt extends northward into south-central Waziristan, west of the area discussed in this report. These Triassic rocks are probably equivalent in age, at least in part, to rocks of the Mianwali Formation at Shaikh Budin and in the southern Khisor Range.

KATHWAI MEMBER

The Kathwai Member of the Mianwali Formation consists of a brown thin-bedded limestone, about 3 feet thick in the upper part, and a reddish-brown massive dolomite, about 7 feet thick in the lower part. The dolomite is calcareous, medium to coarse grained, thick and thin bedded, commonly crossbedded, and in places strongly resembles a sandstone in the outcrop; however, study of thin sections (Curt Teichert, oral commun., 1964) confirms its identity as a dolomite. According to Hussain (unpub. data, Pakistan Geol. Survey, Natl. Strat. Libr., 1960), who observed this unit throughout the Khisor Range, "the red bed at the base of the formation is lateritic and *** suggests a break in sedimentation." The lower contact with the Zaluch Group is sharp and is believed to be disconformable. The Kathwai Member is about 10 feet thick southeast of Paniala.

MITTIWALI MEMBER

In Spinnagara Nala, the Mittiwali Member of the Mianwali Formation consists of brownish-gray limestone in the upper part. The limestone is fine grained, sandy, brecciated, and contains abundant ammonites. In the middle part, greenish-brown sandstone is interbedded with green calcareous shales. The sandstone is calcareous and micaceous. Brownish-gray limestone at the base is finely crystalline, argillaceous, and contains thin beds of gray, sandy, calcareous shales. Ammonites are common. The contact with the underlying Kathwai Member is sharp. The Mittiwali Member is 239 feet thick in Spinnagara Nala (Hussain, unpub. data, Pakistan Geol. Survey, Natl. Strat. Libr., 1960).

NARMIA MEMBER

In Spinnargara Nala, the Narmia Member of the Mianwali Formation consists of gray-brown limestone, which is thin and thick bedded, crystalline, and argillaceous near the top, and thin and thick beds of calcareous sandstone which is fine and medium grained. Toward the base, limestone beds are less abundant; sandstone beds are more abundant but less calcareous.

[4] In keeping with this usage, Kummel (oral commun., 1964) initially considered dividing the Mianwali group* as follows: Landa formation,* Narmia formation,* and Mittiwali formation.* This division was preferred by Danilchik (written commun., 1964) and retained in modified form by the Geological Survey of Pakistan (Pakistan Geol. Survey, 1964). However, subsequent modification of the nomenclature, partly by the Stratigraphic Committee of Pakistan, gave formation status to the Mianwali and downgraded its divisions from formations to members. The Landa Member became the basal unit of the newly created Tredian Formation (see text), and the Kathwai Member was created as the lowermost unit of the Mianwali Formation.

[5] Although the terms "Narmia and Mittiwali Members" were first used by the Geological Survey of Pakistan (Pakistan Geol. Survey, 1964), the formation to which these units belonged was not specified.

The limestone contains abundant ammonites, but these fossils are rare in the sandstone. The contact with the Mittiwali Member is transitional. The Narmia Member is 249 feet thick in Spinnagara Nala (Hussain, unpub. data, Pakistan Geol. Survey, Natl. Strat. Libr., 1960).

TREDIAN FORMATION

The first formal recognition of the term "Tredian Formation" was made nearly simultaneously by Kummel and Teichert (1966, p. 310) and by Kummel (1966, p. 373–374, 376, 378, 380). Both references credit the proposal of this term to unpublished material by E. R. Gee.

The Tredian Formation is divided into two members: the upper Khatkiara Sandstone Member and the lower Landa Member. In the Bannu quadrangle, the outcrop of the Tredian Formation is restricted to the south flank of Shaikh Budin and to the area south and southeast of Paniala. The Tredian Formation was not examined in detail by the authors, and lithologic descriptions and stratigraphic boundaries have been interpreted in part from Hussain (unpub. data, Pakistan Geol. Survey, Natl. Strat. Libr., 1960). The Tredian Formation is probably of Triassic age.

LANDA MEMBER

The term "Landa Member" of the Tredian Formation was proposed by Kummel (1966, p. 380).[6] The Landa Member is composed of fine-grained greenish-gray sandstone, siltstone, and green and gray shale. Plant fossils are common in the siltstone, and brachiopods are found near the top. The contact with the underlying Mianwali Formation is placed arbitrarily at the top of the uppermost limestone bed of the Narmia Member.

The Landa Member is 115 feet thick in Spinnagara Nala, south of Paniala (Hussain, unpub. data, Pakistan Geol. Survey, Natl. Strat. Libr., 1960). This unit, together with the underlying Mianwali Formation, forms a slope in the Shaikh Budin and Paniala areas.

KHATKIARA SANDSTONE MEMBER

The term "Khatkiara Sandstone" was proposed by Danilchik and Shah (1973) to replace the informal term "Kingriali sandstone,"* of Gee (1945). References to this unit by Kummel (1966, p. 373–374, 376, 380), however, show the word "sandstone" deleted from the name and the unit downgraded to a member of the Tredian Formation. Kummel (1966, p. 380) erroneously attributed this nomenclature modification to Danilchik and Shah (1973). In this report, however, the term "Khatkiara Sandstone Member" is retained in view of its prior usage by the Geological Survey of Pakistan (Pakistan Geol. Survey, 1964).[7]

The Khatkiara Sandstone Member of the Tredian Formation consists of brown and white sandstone that is soft, friable, and micaceous in places. The sandstone is fine and medium grained, and thick and thin bedded. Near the top, the sandstone is dolomitic and contains thin beds of gray and black shale. The Khatkiara Sandstone Member does not contain many fossils, although Hussain (unpub. data, Pakistan Geol. Survey, Natl. Strat. Libr., 1960) reported scolecodonts and worm tubes at Spinnagara Nala. This unit, together with the overlying Kingriali Dolomite, forms steep, commonly impassable cliffs and ridges in the Paniala and Shaikh Budin areas.

The lower contact is disconformable, as indicated by a conglomerate bed at the base in Spinnagara Nala; the conglomerate contains rounded pebbles and limonitized plant fragments derived from the underlying Landa Member and, possibly, older rocks (B. R. Hussain, unpub. data, Pakistan Geol. Survey, Natl. Strat. Libr., 1960). Southeast of Paniala, the Khatkiara Sandstone Member is 150 feet thick (S. M. Ahmed, unpub. data, Pakistan Geol. Survey, Natl. Strat. Libr., ref. No. 114(b), 1960).

KINGRIALI DOLOMITE

The name "Kingriali dolomites*" was first used by Gee (1945) and revised as "Kingriali Dolomite" by Danilchik and Shah (1973). The type locality is in the Kingriali hills of the Khisor Range east of the Bannu quadrangle.

The Kingriali Dolomite consists of hard brown and gray dolomite that weathers tan and is fine grained, crystalline, and thin bedded, thick bedded, or massive. Thin beds of soft-green calcareous dolomitic shale alternate with argillaceous dolomite in the upper part of the formation. The dolomite in the lower part of the formation contains pelecypods, gastropods, and crinoid stems.

The Kingriali Dolomite forms ridges and cliffs. The upper contact with the Datta Formation is disconformable, as suggested by the red oxidation or laterization of the uppermost dolomite bed southeast of Shaikh Budin. The lower contact with the underlying formation is transitional. The Kingriali Dolomite is 465 feet thick in the Paniala area (S. M. Ahmed, unpub. data, Pakistan Geol. Survey, Natl. Strat. Libr., ref. No. 114(b), 1960) and is of probable Triassic age.

[6] Although the term "Landa Member" was first used by the Geological Survey of Pakistan (Pakistan Geol. Survey, 1964), the formation to which this unit belonged was not specified. Also, see footnote 4.

[7] Although the term "Khatkiara Sandstone Member" was used by the Geological Survey of Pakistan (Pakistan Geol. Survey, 1964), the formation to which this unit belongs was not specified.

JURASSIC SYSTEM (WAZIRISTAN-SULAIMAN RANGE)

SULAIMAN LIMESTONE GROUP

The term "Sulaiman limestone*" was first used by Pinfold (1939); the type section, in the gorge between Mughal Kot and Dhana Sar (lat 31°26'N.; long 70°01' E.), was formally described by Williams (1959), and his term "Sulaiman Limestone Group" is used by the Geological Survey of Pakistan (Pakistan Geol. Survey, 1964).

At the type section, the Sulaiman Limestone Group is mostly dark-gray to blue limestone that is thin to thick bedded or massive, hard, and, in part, oolitic; it contains some secondary calcite and chert nodules. Weathered surfaces are commonly light gray to brownish gray. Blue-black calcareous claystone intercalations are common in the lower part of the section. About 100 feet of ferruginous micaceous ripple-marked sandstone and calcareous sandstone crops out about 1,200 feet above the base of the exposed section. A strong odor of petroleum is noticeable in limestone beds near the base. Belemnites are found near the top; the formation also contains algae, orbitoids, corals, bryozoans, brachiopods, lamellibranchs, gastropods, crinoids, and burrows.

The Sulaiman Limestone Group forms the highest peaks in the Sulaiman Range. Its exposed thickness in the gorge west of Mughal Kot is 4,656 feet, but the total thickness is not known.

The Sulaiman Limestone Group forms a continuous outcrop for more than 70 miles northward along the crest of the Sulaiman anticline (pls. 1, 5). At the Gumal River, the limestone plunges under the overlying younger rocks to the nose of the anticline, but isolated outcrops have been tentatively identified throughout both northern and southern Waziristan, notably northwest of Splitoi Post (pl. 2), east of Wana (fig. 1; pl. 5), and east of Miram Shah (pls. 1, 2).

The Sulaiman Limestone Group is of Jurassic age and is believed to be the chronostratigraphic equivalent, at least in part, of the Datta Formation and Samana Suk Limestone at Shaikh Budin and in the southern Khisor Range. (See sections "Datta Formation" and "Samana Suk Limestone.") Williams (1959, p. 7) believes that the upper part of the Sulaiman Limestone Group in the Sulaiman Range may be the Takatu Limestone. He considers the Takatu Limestone to be of Late Jurassic age because near Kalat (fig. 1) in Quetta Division the Takatu overlies rocks from which ammonites of Middle Jurassic age have been collected. The lower 1,200 feet of the Sulaiman Limestone Group in the gorge east of Mughal Kot is believed by the authors to be the Loralai Limestone, recognized to the west near Fort Sandeman and Loralai in Quetta Division. Williams (1959, p. 7) considers the Loralai Limestone to be of Early Jurassic (Liassic) age.

JURASSIC SYSTEM (KHISOR-BHITTANNI-MARWAT RANGES)

DATTA FORMATION

The name "Datta Formation" was introduced by Danilchik and Shah (1973) to replace the descriptive term "Variegated series*" of earlier workers. The type section is along Datta Nala in the Surghar Range (lat 33°00'N.; long 71°19'E.).

In the Bannu quadrangle, outcrops of the Datta Formation are limited to the south flank of Shaikh Budin and to the Khisor Range. The Datta Formation consists mostly of varicolored sandstone, with very subordinate amounts of varicolored siltstone and claystone. The sandstone is fine to coarse grained, thick or thin bedded, soft, friable, and micaceous in places. Calcareous shale is present near the top of the formation, carbonaceous shale in the middle part, and gypsiferous shale near the base. Pure white sand is a distinctive feature of the basal part of the sandstone near Paniala and Chunda (pl. 2). The lower contact with the Kingriali Dolomite is disconformable.

The Datta Formation is 1,470 feet thick southeast of Shaikh Budin (S. M. Ahmed, unpub. data, Pakistan Geol. Survey, Natl. Strat. Libr., ref. No. 79(b), 1960), 624 feet south of Paniala, and 263 feet south-southwest of Budh Banda, where the formation is disconformably overlain by the Nagri Formation (Hussain, unpub. data, Pakistan Geol. Survey, Natl. Strat. Libr., 1960).

The Datta Formation is considered to be as old as Early Jurassic (late Lias) on the basis of an ammonite fauna identified by L. F. Spath (in Heron, 1937, p. 74) from what is presumably a bed in the Datta Formation 1 mile south-southeast of Paniala.

SAMANA SUK LIMESTONE

The term "Samana Suk Limestone" was used by Davies (1930, p. 3) for rocks in the east-central part of the Parachinar area (Meissner and others, 1973). The Samana Suk Limestone, as used in this report, replaces the term "Baroch limestone*" of Gee (1945) and Danilchik and Shah (1973).

In the Shaikh Budin area, the Samana Suk Limestone is brown and gray crystalline and fine-grained thin- and thick-bedded limestone that is argillaceous in places. Oolites near the top are commonly coated with pyrite. Subordinate amounts of calcareous claystone alternate with the limestone beds. Purple and gray sandstone in the upper part is fine and medium grained and thick and thin bedded. Limestone near the base is gray and brown and thin bedded. The lower contact with the Datta Formation is transitional.

The Samana Suk Limestone is fossiliferous and contains abundant ammonites, particularly in the upper part, as well as Foraminifera, corals, lamellibranchs, and gastropods.

The Samana Suk Limestone forms ridges and steep impassable cliffs. It is 1,030 feet thick east of Shaikh Budin, but is absent in the Khisor Range south of Budh Banda (S. M. Ahmed, unpub. data, Pakistan Geol. Survey, Natl. Strat. Libr., ref. No. 79(b), 1960; B. R. Hussain, unpub. data, Pakistan Geol. Survey, Natl. Strat. Libr., 1960). The lower part may be present southwest of Paniala.

The Samana Suk Limestone appears to be as young as Late Jurassic (late Callovian) on the basis of a cephalopod fauna described by Spath (1939, p. 121) in the Surghar Range. Sahni (1939, p. 2, 15–17) also considers the Samana Suk Limestone to be of "about Callovian age" on the basis of rhynchonellids and terebratulids collected from a locality 2½ miles southeast of Pezu. (Also see Heron (1937, p. 74) for reference to what is presumably the same locality.)

CRETACEOUS SYSTEM (WAZIRISTAN-SULAIMAN RANGE)

SEMBAR FORMATION

The term "Sembar Formation" was proposed by Williams (1959) to replace the term "Belemnite beds*" of Oldham (1890). The type section is designated by Williams to be near Sembar Pass (lat 29°55′05″N.; long 68°34′48″E.) in eastern Quetta Division.

The Sembar Formation is present throughout the Sulaiman Range region. In the area west of Mughal Kot, the formation consists of soft black claystone, locally somewhat silty and sandy, with minor thin beds and concretions of dark-gray to black limestone. Ferruginous and calcareous sandstone crops out near the base. A basal conglomerate 4 feet thick is composed of belemnitic limestone pebbles and cobbles derived from the underlying Sulaiman Limestone Group. The Sembar Formation forms slopes and valleys; the lower contact with the Sulaiman Limestone Group is disconformable and sharp. The formation is 931 feet thick in the gorge west of Mughal Kot. Although the formation has been recognized in the Bannu quadrangle, no reliable measurement of its thickness could be made because of extensive folding and faulting.

In the gorge west of Mughal Kot, the Sembar Formation is believed to be of Early Cretaceous age although Foraminifera, belemnites, and other fossils are badly preserved and sparse. Stuart (1922, p. 95) collected belemnites in dark-red and green shales between Ahnai Tangi and Sora Rogha Post (pl. 2) and correlated these beds with the Sembar Formation ("Belemnite shales* of Baluchistan *** Lower Neocomian in age"). Williams (1959, p. 8), however, observed the Sembar Formation in several localities in eastern Quetta Division and noted that the fauna ranges in age from Late Jurassic to Aptian (Early Cretaceous). He pointed out, however, that the "great majority of occurrences *** appear to be Neocomian age" (basal Early Cretaceous). The Sembar Formation resembles the Chichali Formation (table 1) which overlies rocks of Jurassic age in the Shaikh Budin area. (See section "Lumshiwal Sandstone(?) and Chichali Formation.")

PARH LIMESTONE

The term "Parh" was first used by Blanford (1879) and more precisely defined by Williams (1959), who designated the type section to be in the upper Gaj River area (lat 26°54′45″N.; long 67°05′45″E.) (fig. 1). The Parh Limestone may be recognized throughout the Sulaiman Range area and is present to the north in Waziristan. In the Dera Ismail Khan quadrangle, the Parh Limestone is light gray, hard, porcelaneous, thick and thin bedded. Limestone in the upper part contains abundant Foraminifera. In the gorge west of Mughal Kot, clastic material is absent in the uppermost 155 feet, but subsidiary dark-gray calcareous claystone beds, containing abundant Foraminifera and belemnites, become increasingly abundant toward the middle part. Argillaceous limestone and calcareous claystone crop out in the lower part. A basal limestone bed contains nodules of marcasite (FeS_2).

The contact with the underlying Sembar Formation is transitional, and the boundary is placed arbitrarily at the base of the lowermost cliff-forming limestone. The Parh Limestone forms a ridge; the topographic expression and light tone on aerial photographs contrast markedly with overlying and underlying formations.

The Parh Limestone is 1,147 feet thick in the gorge west of Mughal Kot. As mapped on plate 3, the Parh Limestone also includes the Goru Formation, recognized by Williams (1959) and others. Near Sora Rogha in South Waziristan Agency, the combined thickness of the Goru Formation and the Parh Limestone is 1,845 feet (S. M. Ahmed, unpub. data, Pakistan Geol. Survey, Natl. Strat. Libr., ref. No. 279, 1960).

The Parh Limestone is mainly Late Cretaceous in age. Williams (1959, p. 9–10) studied the Parh Limestone in several localities in the lower Indus Basin and reported that the formation is invariably of Late Cretaceous age ("Senonian though perhaps ranging downward into the Turonian"). J. Keizer (unpub. data, Pakistan Geol. Survey, Natl. Strat. Libr., 1959) assigned a somewhat wider age range (Albian-Campanian), including part of the Early Cretaceous, mainly on the basis of a Foraminifera fauna collected in the gorge west of Mughal Kot. There is no stratigraphic

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equivalent of the Parh Limestone in the Shaikh Budin–Khisor Range area (table 1).

MUGHAL KOT FORMATION

Williams (1959, p. 10) designated the type section of the Mughal Kot Formation to be in the gorge 1–3 miles west of Mughal Kot Post (lat 31°26′52″N.; long 70°02′58″E.). The Mughal Kot Formation is synonymous with the Nishpa formation[8]* of J. Keizer (unpub. data, Pakistan Geol. Survey, Natl. Strat. Libr., 1959).

The Mughal Kot Formation has been traced on aerial photographs throughout the Sulaiman Range and northward into Waziristan. In the type section, the top of the Mughal Kot Formation consists of a light-gray calcareous sandstone, about 160 feet thick. The sandstone is very calcareous, argillaceous, hard, and thick bedded to massive; it alternates with thin-bedded sandy calcareous gray claystone, commonly sulfurous, in beds as much as 5 feet thick. Oil seeps are found along joints and bedding planes. This upper unit may be equivalent to the Fort Munro Limestone Member of Williams (1959).

The calcareous sandstone at the top is underlain by calcareous claystone, sandy limestone, and calcareous sandstone. The claystone is dark gray and silty in places. The limestone is gray and argillaceous. The sandstone is thin bedded, hard, commonly ferruginous, ripple marked, and contains burrows.

Shaly limestone in the lower part of the formation is bluish gray to black, thin bedded, soft, sandy, and weathers dark gray. Subordinate interbedded sandstone weathers reddish brown and is thin bedded, hard, calcareous and ferruginous. A conglomerate at the base contains subangular pebbles derived from the underlying Parh Limestone. J. Keizer (unpub. data, Pakistan Geol. Survey, Natl. Strat. Libr., 1959) reported corals in the upper part of the formation and orbitoids, mollusks, and echinoids throughout.

The Mughal Kot Formation generally forms slopes. The lower contact with the Parh Limestone is disconformable. West of Mughal Kot the formation is 3,722 feet thick; study of aerial photographs suggests that the formation thins southward. Although the Mughal Kot Formation has been recognized in Waziristan, no reliable measurement of its thickness was made because of extensive folding and faulting.

The Mughal Kot Formation is believed to be Late Cretaceous in age, mainly because of its stratigraphic position above the Parh Limestone and because the overlying Pab Sandstone is generally believed to be of Late Cretaceous age at its type locality and other areas. J. Keizer (unpub. data, Pakistan Geol. Survey, Natl. Strat. Libr., 1959) also considers the Mughal Kot Formation (which he identifies as Nishpa shales*) to be of Late Cretaceous age, mainly Maestrichtian, and less than one-tenth of the section of Campanian age. Keizer's age determinations apparently are based on studies of Foraminifera. There is no stratigraphic equivalent of the Mughal Kot Formation in the Shaikh Budin–Khisor Range area (table 1).

PAB SANDSTONE

The term "Pab Sandstone" was introduced by Vredenburg (1907, p. 117); the type section in the Pab Range (lat 25°31′12″N.; long 67°00′19″E.) was designated by Williams (1959).

The Pab Sandstone may be recognized throughout both the eastern and western flanks of the Sulaiman Range. In the Mughal Kot area, the Pab Sandstone is a quartzitic gray and blue sandstone that is fine to coarse grained, subangular to rounded, thin and thick bedded to massive, commonly crossbedded, and conglomeratic near the base; it weathers light to dark brownish gray. Some beds contain burrows and plant roots. Crossbedding suggests a westerly direction of sediment transport. Subordinate silty claystone beds are blue and dark gray and commonly less than 1 foot thick but as much as 15 feet locally. These claystones are carbonaceous and sulfurous in places and, according to J. Keizer (unpub. data, Pakistan Geol. Survey, Natl. Strat. Libr., 1959), contain abundant plant fragments. In Mughal Kot gorge, oil seeps are found along bedding planes and fractures about 125 feet below the top of the unit.

The Pab Sandstone forms a cliff beneath the ridge-forming Dunghan Formation. The lower contact with the Mughal Kot Formation appears to be conformable.

West of Mughal Kot, the Pab Sandstone is 776 feet thick; study of aerial photographs suggests that the formation thickens southward. Northward, the Pab Sandstone becomes less distinct and increasingly difficult to trace on aerial photographs; it appears to be less than 500 feet thick in Gat Tangi. Although the Pab Sandstone can be recognized in southern Waziristan, no reliable measurement of its thickness was made because of extensive folding and faulting.

The Pab Sandstone is of Late Cretaceous (Maestrichian) age in its type locality in the Pab Range, and the formation is believed to be of Late Cretaceous age in the Sulaiman Range. J. Keizer (unpub. data, Pakistan Geol. Survey, Natl. Strat. Libr., 1959) suggested that the upper part of the Pab Sandstone in the Sulaiman Range may be as young as late Paleocene. Correlation of the Pab Sandstone with the Lumshiwal Sandstone(?) (table 1) near Shaikh Budin is uncertain.

[8] J. Keizer (1959, p. 5) stated that the term "Nishpa shales*" was proposed in a report by Vachell and Morrison in 1928. However, the complete reference was not given by Keizer, and attempts to obtain it or a copy of the report have not been successful. It appears that the report by Vachell and Morrison was not published.

CRETACEOUS SYSTEM (KHISOR-BHITTANNI-MARWAT RANGES)

LUMSHIWAL SANDSTONE(?) AND CHICHALI FORMATION

The Lumshiwal Sandstone was named by Gee (1945); the type locality is in the Surghar Range, but identity of the formation in the Shaikh Budin area is not firmly established. At Shaikh Budin the Lumshiwal Sandstone(?) is believed to be equivalent to Wynne's bed number 8 (1880, fig. 10), to his "sandstones above jurassic beds" (1880, p. 79), and to his bed number 3 (1880, p. 81). The Chichali Formation was named by Danilchik (1961) to replace the descriptive term "Belemnite beds*" of earlier workers; the type locality is also in the Surghar Range. At Shaikh Budin, the Chichali Formation is equivalent to the Blackish zone* of Wynne (1880, p. 78, 81, and fig. 10) and to the Black zone,* which according to Hussain (unpub. data, Pakistan Geol. Survey, Natl. Strat. Libr., 1960), was a term used by Pakistan Petroleum, Ltd., in their work in this area. The Lumshiwal Sandstone(?) and the Chichali Formation are discussed together in this report.

East of Shaikh Budin, sandstone in the upper part is brown and gray, soft, and friable. Subordinate blue-gray shales are thin bedded and silty. Dark-gray siltstones in the lower part are glauconitic and calcareous; the lowest bed contains belemnites. The contact with the underlying Samana Suk Limestone is sharp and may be disconformable. On the west flank southeast of Pezu, Coulson (in M. R. Sahni, 1939, p. 3) reported yellowish-green glauconitic sandstone containing ammonites, belemnites, and brachiopods in the upper part and poorly preserved belemnites in the lower part.

The combined thickness of the Lumshiwal Sandstone(?) and the Chichali Formation is 288 feet east of Shaikh Budin. Coulson (in M. R. Sahni, 1939, p. 3) reported the unit to be more than 500 feet thick on the west flank. The outcrop is restricted to the Shaikh Budin area, although Hussain (unpub. data, Pakistan Geol. Survey, Natl. Strat. Libr., 1960) reported that the Black zone* appears in the Gori Tang area near Paniala. These rocks were not recognized there by the authors.

The Chichali Formation is of Early Cretaceous age (Neocomian) as determined from an extensive collection of ammonites and belemnites from the Surghar Range described by Spath (1939). Further work by Spath (in M. R. Sahni, 1939, p. 2–3) on ammonites collected by Coulson tends to confirm this age determination in the Shaikh Budin area. Coulson's collection was made from a yellowish-green glauconitic bed 2¼ miles southeast of Pezu. M. R. Sahni (1939), however, preferred a Late Jurassic age (Oxfordian-Kimmeridgian) on the basis of brachiopods (terebratellids and terebratulids) collected in the same locality from the same bed as the ammonites but somewhat lower. These Jurassic fossils may have been derived from older rocks, particularly in view of the arenaceous character of this section as described by Coulson; therefore, considering this possibility as well as the work by Spath both at Shaikh Budin and in the Surghar Range, an Early Cretaceous age (Neocomian) is retained in this report for the Chichali Formation.

The age of the Lumshiwal Sandstone(?) is uncertain. Danilchik and Shah (1973) are undecided as to an Early or Late Cretaceous age, for the Lumshiwal Sandstone. If further study establishes a Late Cretaceous age, this formation could be considered a chronostratigraphic equivalent, at least in part, to the Pab Sandstone in the Sulaiman Range.

TERTIARY SYSTEM (WAZIRISTAN-SULAIMAN RANGE)

DUNGHAN FORMATION

The term "Dunghan limestone*" was introduced by Oldham (1890); Williams (1959) designated the type section to be near Harnai (lat 30°08′38″N.; long 67°59′33″E.) and renamed the unit Dunghan Formation.

The Dunghan Formation may be recognized along the west flank of the Sulaiman Range south of Waziristan. Near Mughal Kot, the Dunghan Formation is a gray to dark-gray hard finely crystalline and very thick bedded limestone. According to J. Keizer (unpub. data, Pakistan Geol. Survey, Natl. Strat. Libr., 1959), it contains algae, Foraminifera, corals, and gastropods. The upper part becomes sandy downward. A very sandy bluish-gray limestone in the middle part becomes argillaceous downward. Two beds in the middle part are each about 15 feet thick and are composed of brown fine- to medium-grained calcareous sandstone. The lower part of the formation is composed of dark-blue micaceous silty claystone that according to Keizer (unpub. data, Pakistan Geol. Survey, Natl. Strat. Libr., 1959) contains gastropods.

The Dunghan Formation forms a sharp ridge along the east flank of the Sulaiman Range. The contact with the overlying Ghazij Shale is distinct and conformable at Mughal Kot; the lower contact with the Pab Sandstone may be disconformable.

The Dunghan Formation is 625 feet thick west of Mughal Kot. Study of aerial photographs suggests that the Dunghan Formation wedges out 2 miles south of the Zao River and less than half a mile west of the west boundary of the Dera Ismail Khan quadrangle. The formation was not observed in Waziristan to the north,

and there are no stratigraphic equivalents at Shaikh Budin and in the Khisor Range. Pinfold (1939, p. 194), however, states that to the south the outcrop of the Dunghan Formation is almost continuous to the Bolan Pass (fig. 1).

Foraminifera collected from the upper part of the formation in the gorge west of Mughal Kot "indicate a Paleocene age" (J. Keizer, unpub. data, Pakistan Geol. Survey, Natl. Strat. Libr., 1959); however, the lower part may be as old as Late Cretaceous.

GHAZIJ SHALE

The term "Ghazij" was introduced by Oldham (1890). Williams (1959) proposed that the type section be at Spintangi (fig. 1) in Quetta Division (lat 29°57′06″N.; long 68°05′00″E.) and used the term "Ghazij formation*" to describe this unit. The Geological Survey of Pakistan (Pakistan Geol. Survey, 1964), however, retained the term "Ghazij Shale" used by earlier workers, and this term is retained in this report. The Ghazij Shale crops out extensively throughout the eastern foothills region of the Sulaiman Range, and in Waziristan to the north.

In the Mughal Kot area, the upper half of the Ghazij Shale consists mostly of soft fissile claystone that is brown and brownish red and commonly weathers to red or maroon. Coarse-grained sandstone and conglomerate crop out near the top.

To the east, the upper part of the Ghazij Shale is markedly more calcareous. Along the Domanda fault, between Zam and Domanda Posts, the upper part of the formation includes green and brown limy claystone and subordinate amounts of marly limestone that are absent in the Mughal Kot area. The marly limestone beds contain abundant larger Foraminifera, as well as bryozoans, mollusks, and echinoids.

Near Mughal Kot the lower half of the Ghazij Shale consists of green, dark-gray, and brown claystone, weathering gray or drab. The claystone is carbonaceous in places. Locally, subordinate amounts of gray siltstones contain abundant larger Forminifera. Also present are ripple-marked crossbedded sandstone and quartzitic sandstone that are calcareous in places. Plant fragments are found about 1,500 feet above the base. The lower 1,400 feet is entirely dark-gray to black fissile claystone.

The Ghazij Shale forms valleys and low ridges; it is estimated to be 9,000 feet thick in the Mughal Kot area. The formation is probably considerably thinner to the south in the Dera Ghazi Khan quadrangle (fig. 1).

To the north, in the Bannu quadrangle, a complete section of the Ghazij Shale has not been observed owing to extensive folding and faulting; however, the red and brownish-red claystones of the upper part have been observed as far north as Shinki Post, but the total thickness of the formation is believed to be thinner than in the Sulaiman Range.

E. B. Fritz (written commun., 1963) suspected an early Eocene age for the Ghazij Shale on the basis of the following Foraminifera collected from the lower part of the Ghazij Shale in Toi Nala:

Anomalina sp.
Globorotalia aff. *G. wilcoxensis* Cushman and Ponton
Rotalia sp.
Discocyclina sp.
Nonion aff. *N. micra* Cole

Fritz also suspected the early Eocene age on the basis of the following Foraminifera from the upper part of the Ghazij north of Domanda:

Lockhartia hunti Ovey var. *pustulosa* Smout
Oribtolites complanata Lamarck
Peneropolis
Alveolina oblonga d'Orbigny
Miliolidae
Discocyclina sp.

Eames (1952, p. 163) believed the Ghazij Shale to be of early Eocene age on the basis of his studies at Zinda Pir (fig. 1). Keizer (unpub. data, Pakistan Geol. Survey, Natl. Strat. Libr., 1959) studied Foraminifera collected from the upper part of the Ghazij Shale near Domanda and believed them indicative of a Paleocene and early Eocene age; the authors note, however, that the lower part of the formation cannot be older than Paleocene because the underlying Dunghan Formation is Paleocene. An early Eocene age for both the lower and upper part of the Ghazij Shale appears to be more likely.

The Ghazij Shale is contiguous with the Panoba Shale mapped by Meissner and others (1973) in the Parachinar quadrangle. The Ghazij Shale has no stratigraphic equivalent in the Shaikh Budin–Khisor Range area (table 1).

BASKA SHALE

The name "Baska Shale" is proposed by the authors to replace the descriptive term "Shales with alabaster*" of Eames (1952). The type section is designated to be 1½ miles east-northeast of Baska village (lat 31°29′N.; long 70°08′E.). The Baska Shale can be recognized throughout the eastern foothills region of the Sulaiman Range, especially in the south where its outcrop can be readily traced on aerial photographs. The Baska Shale is also present in Waziristan, but is less distinctive as a separate mappable unit.

In the Sulaiman foothills, the Baska Shale consists mostly of green and greenish-gray claystone, containing alabaster in nodules and veins. The claystone alternates with bedded alabaster, gypsiferous limestone, and marl containing larger Foraminifera and lamelli-

branchs. Alabaster beds range in thickness from a few inches to more than 30 feet. Claystone is bright red and purple toward the base. The Baska Shale forms slopes. The lower contact is fairly sharp in the northern part of the Dera Ismail Khan quadrangle where sandstones of the underlying Ghazij Shale form low cliffs. In the Jandola area, the lower contact with the Ghazij Shale is believed to be transitional.

The Baska Shale is 607 feet thick 4½ miles north of Domanda Post (J. Keizer, unpub. data, Pakistan Geol. Survey, Natl. Strat. Libr., 1959); 620 feet was measured by the authors near Baska village. The section measured by La Touche (1893, p. 87) near Zor Shahr village on Khora River is interpreted to include 555 feet of Baska Shale. Farther north, the formation is 160 feet thick northwest of Jandola, where only one gypsum bed, 2 feet thick, crops out at or near the base of the formation.

E. B. Fritz (written commun., 1963) believed that the Baska Shale is of late early Eocene age (Cuisian?) on the basis of the following Foraminifera collected in Toi Nala:

Cuneolina sp.
Lockhartia hunti Ovey
Dictyoconoides vredenburgi (Davies)

Both Eames (1952, p. 163) and J. Keizer (unpub. data, Pakistan Geol. Survey, Natl. Strat. Libr., 1959) also believed that the Baska Shale is of early Eocene age. The Baska Shale thins northward and is not mappable north of Shuza Nala (pl. 2) in Waziristan; no stratigraphic equivalent is present in the Shaikh Budin–Khisor Range area (table 1). The Baska is tentatively identified as far south as the Dera Bugti area (fig. 1) on the basis of descriptions by Blanford (1883, p. 51, 107, and 110), who reported thick beds of gypsum in sections markedly similar to those observed by the authors in the northern Sulaiman Range where the identity of this rock unit is established. Hunting Survey Corporation, Ltd. (1960, p. 444), noted that rock gypsum in beds of early to middle Eocene age (lower Spintangi formation*) extends almost continuously from the Sulaiman Range and the Dera Bugti Hills to Spintangi and Nakus (fig. 1).

KIRTHAR FORMATION

The term "Kirthar" was introduced by Blanford (1879); Williams (1959) designated the type section to be the gorge of the Gaj River (lat 26°56′10″N.; long 67°09′06″E.) and used the term "Kirthar Formation" to describe the unit. In the eastern foothills of the Sulaiman Range, the Kirthar Formation may be divided into four members: from bottom to top, Habib Rahi Limestone Member, Domanda Shale Member, Pir Koh Limestone Member, and Drazinda Shale Member.

HABIB RAHI LIMESTONE MEMBER

The Habib Rahi Limestone Member includes the *Assilina* bed* of Eames (1952) and the Platy limestone* of La Touche (1893, p. 88) and of Eames (1952). The Habib Rahi Limestone Member has been designated by the Stratigraphic Committee of Pakistan to be the lower unit of the Kirthar Formation along the east flank of the Sulaiman Range and in northern and southern Waziristan. The Habib Rahi Limestone Member also has been designated by the Committee to be the upper member of the Kohat Formation in the Parachinar and Kohat 1° quadrangles to the north. The north boundary of the Bannu 1° quadrangle, latitude 33°, is arbitrarily selected as the boundary between these two terminology systems.

The upper part of the Habib Rahi Limestone Member is a grayish-brown hard limestone that weathers white; it is fine grained, thin bedded, and contains large Foraminifera and, in the Mughal Kot area, nodules and thin discontinuous beds of chert. These hard beds alternate with subordinate beds of soft brown shaly limestone and calcareous siltstone. A weak odor of petroleum is noticeable in the limestone in places near the top. The lower part consists of a hard argillaceous limestone that is light brown, massive, and contains abundant *Assilina*. The contact between the Habib Rahi Limestone Member and the Baska Shale in South Waziristan and with the Ghazij Shale in North Waziristan is transitional.

The member is very well exposed and accessible on the Fort Sandeman–Dera Ismail Khan road north of Zam Post; the authors propose that this exposure be designated a reference section for the Habib Rahi Limestone Member.

The Habib Rahi Limestone Member forms a persistent ridge that is an excellent marker both in the field and on aerial photographs. Study of photographs of Spina Ghora ridge indicates that the Habib Rahi forms an unbroken outcrop between the Jandola area and Shinki Post in northern Waziristan.

Near Shinki Post, the upper unit is 90 feet thick and consists of gray limestone that weathers brown; it is mostly massive and rubbly, but is bedded near the base. The lower unit is 49 feet thick and consists of massive brown limestone. Both the upper and lower units near Shinki Post contain *Alveolina* but rarely *Assilina*.

The total thickness of the Habib Rahi Limestone Member near Shinki Post is 139 feet, but the unit is absent on the southeast limb of the syncline east of Mir Ali. The thickness is 110 feet at Zam Post, 100 feet northeast of Mughal Kot, 131 feet 4½ miles north of Domanda Post (J. Keizer, unpub. data, Pakistan Geol. Survey, Natl. Strat. Libr., 1959), 156 feet north of Nili Kach, and 181 feet northwest of Jandola.

DOMANDA SHALE MEMBER

The term "Domanda Shale Member" is proposed by the authors to replace the descriptive term "Lower chocolate clays*" of Eames (1952). The type section is desinated to be just west of Domanda Post and adjacent to the Fort Sandeman–Dera Ismail Khan road (lat 31°35′30″N.; long 70°12′E.). The Domanda Shale Member crops out extensively in the Sulaiman foothills region; it has been recognized near Raki Munh village (fig. 1) and has been traced northward into central Waziristan.

The Domanda Shale Member consists mostly of dark-brown and greenish-gray claystone and contains Foraminifera. Northeast of Nili Kach, subordinate amounts of gray and brown sandstone crop out in the upper 150 feet of the member; this sandstone contains rounded fine to medium grains and is commonly massive or thick bedded and calcareous. Near the top, these sandstone beds are as much as 18 feet thick and contain gastropods as much as 10 inches long, as well as abundant lamellibranchs. South of Drazinda, gypsiferous marls found near the top contain lamellibranchs, gastropods, and echinoids. Eames (1952, p. 164) reported vertebrate remains about 600 feet above the base of the member near Raki Munh (fig. 1). Abundant fragments of celestite in the scree northwest of Chalweski Post are derived from the upper part of the member. Near Nili Kach, the lower 30 feet contains hard grayish-brown limestone and gray siltstone; the limestone weathers light brown. Siltstone is thin bedded in both hard and soft shaly layers. The contact with the Habib Rahi Limestone Member is transitional. The Domanda Shale Member forms slopes and valleys.

The member is 1,020 feet thick 4½ miles north of Domanda Post (J. Keizer, unpub. data, Pakistan Geol. Survey, Natl. Strat. Libr., 1959), 739 feet thick northeast of Nili Kach, and 507 feet thick northwest of Jandola. The thickness is estimated to be 1,000 feet west of Domanda Post. The formation is not present near Shinki Post in northern Waziristan, and study of aerial photographs strongly suggests that the Domanda Shale Member wedges out along Spina Ghora ridge in southern Waziristan.

PIR KOH LIMESTONE MEMBER

The Pir Koh Limestone Member of the Kirthar Formation is equivalent to the White marl band* of Eames (1952). The term was designated by the Stratigraphic Committee of Pakistan.

The Pir Koh Limestone Member is light gray and brown, fine grained, mostly thinly and regularly bedded, argillaceous, and contains abundant large Foraminifera; it weathers white. The member commonly contains subordinate beds of soft shaly limestone and dark-gray calcareous claystone. Near Nili Kach, a greenish-gray calcareous clay, 6 feet thick, crops out near the base. Limestone at the base is irregularly bedded and 6 feet thick. The lower contact is transitional.

The Pir Koh Limestone Member forms a persistent conspicuous ridge in the Gumal Pass area and throughout the eastern foothills of the Sulaiman Range. Its outcrop has been traced on aerial photographs for more than 150 miles, from Raki Munh village in the south to Waziristan to the north.

The Pir Koh Limestone Member is 41 feet thick in Manda Nala, 40 feet thick northeast of Nili Kach, and about 33 feet thick northwest of Jandola. The member is not present in the section near Shinki Post in northern Waziristan, and a study of aerial photographs strongly suggests that the unit wedges out along Spina Ghora ridge in southern Waziristan.

DRAZINDA SHALE MEMBER

The term "Drazinda Shale Member" of the Kirthar Formation is proposed by the authors to replace the descriptive term "Upper chocolate clays*" of Eames (1952). The type locality is designated by the authors to be east and northeast of Drazinda (lat 31°46′N.; long 70°09′E.). The Drazinda Shale, Pir Koh Limestone, and the Domanda Shale Members are coextensive in Waziristan, where they are believed to wedge out within a short distance of each other along Spina Ghora ridge, and in the Sulaiman foothills region.

The Drazinda Shale Member consists of dark-brown to gray claystone and subordinate fossiliferous marl beds which decrease in abundance toward the base. The upper part is gypsiferous and particularly fossiliferous, containing abundant large Foraminifera and lamellibranchs, as well as bryozoans and echinoids. Locally, the uppermost claystone beds are red and appear to be oxidized. A coaly sulfurous zone, 2 or 3 feet thick, crops out near the top in the Sheranna Nala–Gumal Pass area. A sandstone marker bed in the middle part is persistent in the Gumal Pass area south as far as the pass southeast of Chareh village. The sandstone is greenish gray, fine grained, calcareous, thick bedded to massive, and weakly crossbedded; it is about 30 feet thick in the Gumal Pass area, where it forms a sharp ridge. Brown and greenish-gray claystone in the lower part contains abundant large Foraminifera locally. Celestite forms nodules near Sperakar Tangi and reticulating veins east of Chareh village. The Drazinda Shale Member forms slopes and valleys. The lower contact with the Pir Koh Limestone Member is conformable and sharp.

The Drazinda Shale Member is 1,250 feet thick north of Domanda Post, 1,837 feet thick northeast of Nili Kach, but only 175 feet thick along the road to Razmak

and less than 40 feet thick north of Jandola. The thickness is estimated to be as much as 1,500 feet northeast of Drazinda. The member is not present near Shinki Post in northern Waziristan.

AGE AND CORRELATION OF THE KIRTHAR FORMATION

On the basis of studies of Foraminifera, both Eames (1952, p. 163) and Keizer (unpub. data, Pakistan Geol. Survey, Natl. Strat. Libr., 1959) believed that the lower three members of the Kirthar Formation are of middle Eocene age and that the uppermost part of the Drazinda Shale Member may be as young as late Eocene. E. B. Fritz (written commun., 1963) suggested that the following Foraminifera collected from the Habib Rahi Limestone and Domanda Shale Members in Toi Nala and north of Domanda may be as old as early Eocene (late Ypresian?):

Operculina sp.
Assilina sp.
Nummulites sp.
Rotalia (*Lockhartia*?) sp.
Eponides sp.
Linderina brugesi? Schlumberger
Nummulites mamilla de Roissy
Amphistegina sp.
Discocyclina sp.
Assilina aff. *A. daviesi* de Cizancourt
Assilina subspinosa Davies
Gaudryina sp.
Cibicides sp.
Discorbis sp.
Globorotalia palmerae Cushman and Bermudez
Rotalia sp. (aff. *R. becarri* Linne)

A middle Eocene age seems more likely, however, in view of age determinations based both on marine fish fauna (D. H. Dunkle, oral commun., 1965; Rahman and Dunkle, 1966) collected from the Habib Rahi Limestone Member in the foothills of the Sulaiman Range near Zinda Pir (fig. 1) and on mammal and crocodile remains (Pilgrim, 1940) collected from what is interpreted to be the Domanda Shale Member (Nuttall, 1926, p. 118) about 35 miles south-southeast of Raki Munh and 3–5 miles south of Toba Kund (fig. 1). Because the remains in the latter locality are poorly preserved and fragmentary, the middle Eocene age is somewhat uncertain; nevertheless, they tend to corroborate the middle Eocene age based on Foraminifera and marine fish.

The Habib Rahi Limestone Member of the Kirthar Formation can be traced northward from the eastern foothills of the Sulaiman Range through Waziristan into the Kohat region, where it forms the upper unit of the Kohat Formation. Isolated outcrops of the Habib Rahi Limestone Member also appear in the western part of the Tochi River valley, in the Wana 1° quadrangle, adjacent to the border with Afghanistan. The three upper members of the Kirthar Formation become thinner northward from the foothills of the Sulaiman Range and wedge out in Waziristan. There is no equivalent of the Kirthar Formation in the Shaikh Budin–Khisor Range area (table 1).

South of the mapped area, all four members of the Kirthar Formation have been recognized in the Dera Ghazi Khan 1° quadrangle (fig. 1), but south of Raki Munh village the extent of the individual members is less well known. J. Keizer (unpub. data, Pakistan Geol. Survey, Natl. Strat. Libr., 1959) implied that the four members have been recognized as far south as lat 28°50′, south of Dera Bugti (fig. 1). Blanford (1883, p. 107, 109) stated that a limestone "forming the surface of Gandahari hill"[9] and the hills south of Dera Bugti (p. 100) overlies thick-bedded gypsum (Baska Shale?) northeast of Dera Bugti (p. 107) and in Chachar Pass (p. 110). The authors suggest that this limestone unit may be the Habib Rahi Limestone Member. Both Blanford (1883, p. 100–101) and Nuttall (1926, p. 119) also described an upper shaly nummulitic limestone, slightly nodular and 50–75 feet thick, at the top of the Eocene section near Dera Bugti. The upper limestone is separated from the lower by several hundred feet of nummulitic shale, which is "reddish brown or coffee-colored" (Blanford, 1883, p. 100). Blanford (1883, p. 103–105) observed that this upper limestone thickens near Dera Bugti and to the north but that it is missing near Gandahari hill (p. 107) and in Chachar Pass (p. 109). It is not known whether this upper limestone of Blanford's is the Pir Koh Limestone Member of the northern Sulaiman Range or whether it is a separate unit unrecognized in the north. Tracing members of the Kirthar Formation south from the central Sulaiman Range and northwest from Dera Bugti may permit establishment of specific lithostratigraphic equivalents in the Spintangi area (Oldham, 1890, p. 96–98).

CHITARWATA FORMATION

The term "Chitarwata Formation" is proposed by the authors for rocks heretofore questionably identified as the Nari Formation in the Sulaiman foothills (Eames, 1952; J. Keizer, unpub. data, Pakistan Geol. Survey, Natl. Strat. Libr., 1959). The type section is designated to be at Chitarwata Post (lat 31°03′N.; long 70°14′E.).

The Chitarwata Formation crops out throughout the Sulaiman foothills of the Dera Ismail Khan quadrangle, but it is most readily identified in the southern part of the area. The formation appears to thin in the north-

[9]The hill that is apparently Blanford's "Gandahari hill" is shown as the "Giandari Range" on Survey of Pakistan topographic sheet 39G.

ernmost part of the quadrangle and may wedge out along the west flank of Sorai Ghar in Waziristan. The formation was not recognized in the Jandola area.

The Chitarwata Formation consists of red, gray, and green claystone and subordinate amounts of siltstone and sandstone. The siltstone is variegated, friable, and ferruginous; the sandstone is white, brownish yellow, subangular to subrounded, fine grained, friable, calcareous in places, and commonly ferruginous. (See "Measured Sections".)

In Litra and Kaura Nalas and Vihowa Rud, hard ferruginous sandstone and conglomerate beds crop out at or near the top of the formation. In the section southwest of Domanda Post, variegated claystone in the upper part is somewhat silty and contains thin carbonaceous beds, sulfur stains, and root fragments. Gypsiferous claystone, ferruginous beds of ripple-marked crossbedded sandstone, and variegated siltstone crop out in the lower 300 feet. In the Domanda Post area, the upper part forms slopes; the lower part commonly forms ridges and cliffs.

Generally, the upper contact is difficult to follow, particularly on aerial photographs of the northern part of the area. The lower contact with the Drazinda Shale Member of the Kirthar Formation is disconformable.

The Chitarwata Formation is 1,260 feet thick southwest of Domanda Post; the thickness is estimated to be 500 feet at Chitarwata Post and in Litra and Kaura Nalas.

The formation is of Late Oligocene to late Miocene age on the basis of the occurrence of the flora *Croftiella escheri* Rantzien (identified by H. Hiltermann, Budesanstalt fur Bodenforschung, Hanover, West Germany, written commun., 1961) collected from variegated claystone in Toi Nala southwest of Domanda. Eames (1952, p. 162) did not examine this unit in detail at Zinda Pir and near Raki Munh but believed the sequence, which includes the Chitarwata Formation in these areas, to be of early Miocene age, "probably Aquitanian." This age determination is apparently based on a vertebrate fauna collected by Pilgrim (1908, p. 143, 159, 166) from these rocks in the range of hills south of Dera Bugti. Eames (1950, p. 53–54) concluded that because there is "no paleontological evidence against these beds being Upper Nari age ***," that is "basal Miocene age," they "would be more appropriately grouped with the Gaj Series," which is mainly of Miocene age (Burdigalian) in its type locality (Vredenburg, 1906, p. 174; Hunting Survey Corporation, Ltd., 1960, p. 120–121).

The Chitarwata Formation appears to wedge out near the north end of the Sulaiman Range and is not recognized in Waziristan. There is no stratigraphic equivalent in the Shaikh Budin–Khisor Range area (table 1), although the Chitarwata Formation may be the equivalent of the Mitha Khatak Formation of the western Surghar Range (Danilchik and Shah, 1973).

Blanford (1883, p. 55–56, 107–111) noted rocks lithologically similar to the Chitarwata Formation (which he calls "upper Nari beds") in the foothills of the Sulaiman Range as far south as Gandahari hill, east of Dera Bugti; Blanford did not identify these rocks elsewhere in the Dera Bugti region and implied that they wedge out east of Gandahari (Blanford, 1883, map accompanying report). Pilgrim (1908, p. 145; 1912, pl. 31, map accompanying report) reexamined the Dera Bugti area and indicated that these rocks extend west of Gandahari hill and wedge out about 45 miles west of Dera Bugti village. That rocks of the Chitarwata Formation are present throughout a large part of the area south of Dera Bugti was suggested indirectly by Blanford (1883, p. 57). He observed "highly ferruginous bands" and varicolored "clays and sands" near the base of the "Lower Siwalik," but did not distinguish these rocks as a separate unit. Blanford's lithologic description closely resembles the Chitarwata Formation observed by the authors in the northern Sulaiman Range.

Although the Chitarwata Formation may be the lateral equivalent of the Nari and (or) Gaj Formations of the Kirthar Range, continuity with these units has not been established. Available evidence suggests that continuous outcrop of the Chitarwata Formation is restricted to the eastern foothills of the Sulaiman Range and the Dera Bugti area.

SIWALIK GROUP

In the Sulaiman Range–Waziristan area, the Siwalik Group is divided into the Vihowa, Litra, and Chaudhwan Formations.

VIHOWA FORMATION

The term "Vihowa Formation" is proposed by the authors for the lower unit of the Siwalik Group, heretofore unnamed in the Sulaiman Range–Waziristan area. The type section is designated to be Vihowa Rud (lat 31°04′N.; long 70°16′E.). The formation crops out throughout the Sulaiman foothills region of the Dera Ismail Khan 1° quadrangle.

In Chaudhwan Zam, the Vihowa Formation consists of gray and brown sandstone and subordinate amounts of red and brownish-red sandy siltstone. The sandstone consists of subangular, medium, and coarse grains and is massive, thick bedded, and crossbedded.

In Chaudhwan Zam, the sandstone contains abundant scattered pebbles in the upper part, clay material and ferromagnesian mineral grains in the middle part, and abundant secondary calcite in the middle and lower parts. Very coarse grained sandstone and pebble conglomerate near the base contain abundant derived

fossil fragments, mostly of Foraminifera. Mammalian bone fragments were found near Baddha village. La Touche (1893, p. 90) also reported bones and teeth between Parwara and Landai villages in a "somewhat pebbly band near the base of the Siwaliks."

The predominant rock type in Litra Nala and Vihowa Rud is red siltstone; the formation, however, is sandier in the Chaudhwan Zam area and in the north. The Vihowa Formation forms ridges and slopes.

The contact with the Chitarwata Formation may be disconformable, although definitive evidence of a disconformity was generally not observed. Eames (1950, p. 162), however, recognized an unconformity between rocks of the Siwalik Group and the Chitarwata Formation ("Upper Nari") in the Raki Munh section (fig. 1). Where the Chitarwata Formation is missing or was not recognized in the Bannu quadrangle, the contact with the underlying Drazinda Shale Member of the Kirthar Formation is disconformable and sharp.

The Vihowa Formation is 1,410 feet thick at Chaudhwan Zam and is estimated to be about 2,300 feet thick in Vihowa Rud and Litra Nala. Aerial photographs suggest that the thickness of the combined Chitarwata and Vihowa Formations decreases northward and northeastward from Gandari Kach in South Waziristan Agency. Study of the photographs also suggests that the Vihowa Formation wedges out about 1.7 miles southeast of Nili Kach (pl. 2).

LITRA FORMATION

The term "Litra Formation" is proposed by the authors for the middle unit of the Siwalik Group, heretofore unnamed in the Sulaiman Range–Waziristan area. The type section is designated to be Litra Nala (lat 31°01′N.; long 70°25′E.). The Litra Formation crops out throughout the Sulaiman foothills region and in Waziristan.

The Litra Formation consists of friable light-gray and brown sandstone that is fine and medium grained, thick bedded, massive, and silty and clayey in places; the grains are angular to subrounded. Some beds are coarsely micaceous and garnetiferous. Other beds contain abundant well-preserved burrows, some as long as 25 inches. Abundant mammalian bone fragments were noted in the vicinity of Nilohar Nala.

In Chaudhwan Zam, conglomerates consisting of rounded pebbles and cobbles in a coarse-grained sandstone matrix are present in the upper 1,600 feet and become increasingly common toward the top. (See "Measured Sections.") Conglomerate beds are also common, particularly in the upper and middle parts of the formation in the Jandola and Khirgi Post areas. Scattered pebbles and cobbles in the lower part on Chaudhwan Zam consist of chert, sandstone, quartzite, and limestone, commonly containing Foraminifera.

In Litra Nala, the formation is composed almost entirely of massive strongly crossbedded sandstone. Northward, however, subordinate brown claystone and siltstone beds become increasingly common; in the Gumal Pass and Jandola areas, brown and brownish-red claystone and siltstone are the predominant rock types. (See "Measured Sections.") Throughout the Sulaiman Range and Waziristan, the Litra Formation forms steep ridges and cliffs.

The contact between the Litra and the Vihowa Formations is transitional; where the Vihowa Formation is missing north of Nili Kach, the lower contact with the Drazinda Shale Member of the Kirthar Formation is disconformable and sharp. Along the southeast limb of the syncline east of Mir Ali, the Litra Formation rests directly on the Ghazij Shale.

The Litra Formation is 5,560 feet thick in Chaudhwan Zam and 5,408 feet thick in Gumal Pass. The thickness is estimated to be 5,600 feet in Litra Nala. The Litra Formation is believed to be equivalent to the Nagri and Chinji Formations in the Bhittanni, Marwat, and Khisor Ranges as shown in figure 2.

CHAUDHWAN FORMATION

The term "Chaudhwan Formation" is proposed by the authors for the upper unit of the Siwalik Group, heretofore unnamed in the Sulaiman Range–Waziristan area. The type section is designated to be in Chaudhwan Zam (lat 31°37′N.; long 70°15′E.). (See "Measured Sections.") The Chaudhwan Formation crops out throughout the eastern foothills of the Sulaiman Range in Waziristan.

The Chaudhwan Formation consists mostly of hard massive conglomerate composed of boulders, cobbles, and pebbles of limestone, quartzite, and sandstone in a medium- and coarse-grained sandstone matrix. Subordinate amounts of brown and gray sandstone, siltstone, and claystone crop out in the middle part of the unit in Chaudhwan Zam, in the middle and lower parts in Litra and Kaura Nalas, and in the lower 1,600 feet near Gumal Pass. (See "Measured Sections.") The sandstone is subangular, fine to medium and coarse grained, and commonly crossbedded. Locally, sandstone and siltstone beds contain abundant burrows. The formation contains a greater proportion of sandstone, siltstone, and claystone in the southern part of the Dera Ismail Khan quadrangle than in the Chaudhwan Zam and Gumal River areas, where massive conglomerate is the predominant rock type. Throughout most of its outcrop area, the Chaudhwan Formation forms steep, commonly impassable, cliffs. One of the higher peaks, Girni Sar, is underlain by several thousand feet of the Chaudhwan Formation.

Boulder and cobble conglomerates are generally thickest and coarsest in those regions adjacent to the

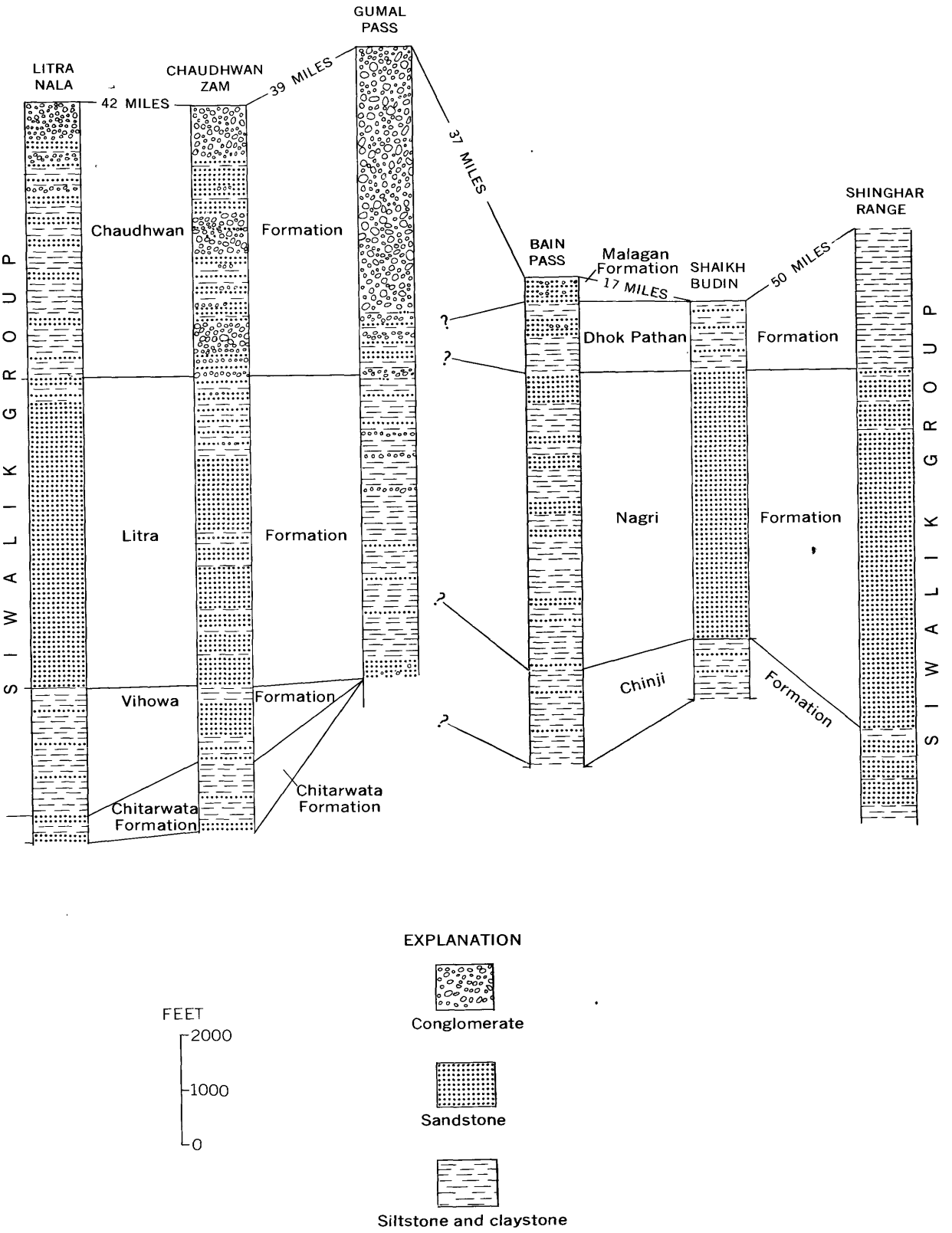

FIGURE 2.—Probable correlation of rocks of the Siwalik Group and the Chitarwata Formation in the Bannu and Dera Ismail Khan areas. Column for Shaikh Budin interpreted from Morris (1938); column for Shinghar Range modified from Danilchik and Shah (1973).

highlands of Waziristan and the northern Sulaiman Range where major faulting occurred during the Pleistocene. These deposits become finer grained away from the highlands.

The contact with the overlying surficial deposits of the Indus and Bannu Plains is commonly indistinct. The contact with the Litra Formation is transitional where observed in the Bannu quadrangle and in the southern part of the Dera Ismail Khan quadrangle; in the local area north of Chaudhwan Zam, however, the lower contact is an unconformity with pronounced angularity. Intraformational angular unconformities were noted in this area as well and are apparently closely related to movements along the Domanda fault during late Pliocene or Pleistocene time. North of the Khora River, the uppermost conglomerates of the Chaudhwan Formation are overturned just east of the Domanda fault.

The Chaudhwan Formation is 4,900 feet thick in Chaudhwan Zam and 5,940 feet thick in Gumal Pass. The thickness is estimated to be 5,000 feet in Litra Nala and 7,000 feet south of Torzoi Nala. Less than 200 feet is exposed north of the Khora River. Morris (1938, p. 392) estimated about 7,000 feet[10] for the "coarse conglomerate and boulder-beds in the hills along the Tochi River, and adjacent to the Bannu Plain.[11]

The Chaudhwan Formation is believed to be equivalent to the Malagan Formation, the Dhok Pathan Formation, and the upper part of the Nagri Formation in the Bhittanni, Marwat, and Khisor Ranges (fig. 2).

AGE AND CORRELATION OF ROCKS OF THE SIWALIK GROUP

The age of the Litra Formation in the Sulaiman Range area is tentatively designated as late Pliocene on the basis of a horse tooth (*Hipparion* cf. *H. antelopinum*)[12] collected from the middle part of the Litra Formation near Raki Munh village. This form is most typical of the late Pliocene. The age of the underlying Vihowa Formation and overlying Chaudhwan Formation are assumed to be Pliocene also, although the upper part of the Chaudhwan Formation may be as young as Pleistocene. Farther south, the lower part of the Siwalik Group may be somewhat older. According to Pilgrim (1908, p. 164), his collection of vertebrate fauna from "Lower Siwalik" near Dera Bugti is indicative of early to late Miocene age (Burdigalian to Sarmatian).

The Vihowa Formation appears to wedge out near the north end of the Sulaiman Range. The Litra and Chaudhwan Formations, however, may be recognized throughout Waziristan as well as in the foothills east of the Sulaiman Range. To the south in the Dera Bugti and southern Sulaiman Range areas, Blanford's (1883, p. 57) description of the "Lower Siwalik" resembles that of the Litra Formation, and he reported that the "Lower Siwalik" is present throughout the periphery of the southern foothills; also he suggested that the unit is less well defined northwest of Dera Bugti and that it "disappears" north of Lahri (1883, p. 59–60). Blanford (1883, p. 60–62) further reported that the "Upper Siwalik," the lithologic description of which is identical to that of the Chaudhwan Formation, forms "an unbroken fringe to the Indus alluvium from *** near Sibi *** to Dera Ghazi Khan." Northwest of Dera Ghazi Khan, Blanford (1883, p. 61–62) stated that "the beds bordering the alluvial plain are apparently 'Lower Siwalik' " and implied that the "Upper Siwalik," or Chaudhwan Formation, is missing in this area. Recent studies, however, both in the field and from aerial photographs, indicate that the Chaudhwan Formation is present in this area, although in a facies that to Blanford may have resembled the "Lower Siwalik."

In northern Waziristan, the Litra Formation is contiguous with the Kamlial, Chinji, and Nagri Formations in the southwestern part of the Parachinar quadrangle, as mapped by Meissner, Hussain, Rashid, and Sethi (1973). The Chaudhwan Formation in northern Waziristan is contiguous with the Dhok Pathan Formation as mapped by Meissner, Hussain, Rashid, and Sethi (1973) and is equivalent to the thick gently folded boulder conglomerates overlying the sandstone unit of the Dhok Pathan Formation along the axis of the broad east-trending syncline north of Bannu. These boulder conglomerates, which constitute much of the Chaudhwan Formation in the foothills region adjacent to the northern Sulaiman Range and Waziristan, are probably equivalent to the upper Siwalik conglomerate* of Gansser (1964, p. 48), to the Siwalik conlomerate* of Gill (1952, p. 382, 385–386, 392), and to the Boulder conglomerate* of Wadia (1928, 1951) in the Potwar Plateau region east of the Indus River.

In the Potwar Plateau a boulder conglomerate yielding paleolithic artifacts is described by De Terra and Paterson (1939, p. 264–266; also Krishnaswami, 1947, p. 17–18, 20, and pl. 14) as the uppermost stage of the Siwalik Group; in places the conglomerate unconformably overlies older Siwalik rocks with pronounced angularity (De Terra and Paterson, 1939, p. 279–304; Krishnaswami, 1947, p. 18, 20). Gill (1952, p. 375, 380, 382, 385–387, 391, 392), however, cited evidence that this unconformity is of post-Siwalik age and that the Potwar Plateau deposition was essentially conformable throughout Siwalik time. This concept agrees with the authors' observations of Siwalik rocks in the foothills

[10] This estimate is apparently interpreted from Smith (1895, pl. 3).
[11] Although Morris included the upper part of the Tochi River section with his description of the Nagri Formation (Marwat formation*), lithologically, these rocks more closely resemble the Chaudhwan Formation (pl. 1).
[12] Identification and probable age determination by F. C. Whitmore and D. C. Dunkle, U.S. Geological Survey (written commun., Feb. 11, 1963).

adjacent to Waziristan and the Sulaiman Range, where the only angular unconformities noted appear to be of only local significance. It appears that the paleolithic artifacts described by De Terra and Paterson may, in fact, be from the post-Siwalik Lei Conglomerate (Gill, 1952, p. 375, 381–382, 386–387, 392) which overlies the folded Upper Siwalik conglomerate* and older rocks with pronounced angularity in parts of the Potwar Plateau region.

TERTIARY SYSTEM (KHISOR-BHITTANNI-MARWAT RANGES)

SIWALIK GROUP

In the Khisor, Bhittanni, and Marwat Ranges, the Siwalik Group is divided into the Chinji, Nagri, Dhok Pathan, and Malagan Formations.

CHINJI FORMATION

The Chinji Formation was named by Pilgrim (1913), and the type locality in the Potwar Plateau was designated by Lewis (1937). The term "Chinji Formation" has been extended from the Potwar Plateau into the Khisor and Bhittanni Ranges in the eastern and central parts of the Bannu quadrangle. The term, as used in this report, is equivalent lithostratigraphically to the Kargocha formation* of Morris (1938, p. 388). The extension of the term "Chinji Formation" from the Potwar Plateau westward into the Bannu quadrangle and its substitution for Morris' term in the Bhittanni Range is based upon the following reasons:

1. Morris (1938, p. 389–390) recognized the so-called Kargocha formation* in outcrops throughout the central and northern Khisor Range, in the subsurface in the northern Marwat Range, and in outcrops in the Shinghar and Surghar Ranges which Danilchik and Shah (1973) and other workers regard to be the Chinji Formation.
2. The heavy-mineral assemblages between the so-called Kargocha Formation* at the north end of the Khisor Range and the Chinji Formation in the Potwar Plateau and in the Shinghar and Surghar Ranges exhibit marked similarity (Morris, 1938, p. 393–394).

In Liar Sir Kurram Nala in the Bhittanni Range, the Chinji Formation (see "Measured Sections") consists of brownish-red clay that is hard and silty in places and contains abundant burrows. Subordinate amounts of hard gray and brown sandstone crop out in thin, thick, and massive beds that are commonly cross-bedded. Sand grains are subangular and range from fine to coarse. Zones predominantly of claystone are 100–400 feet thick; zones of sandstone range from a few inches to 35 feet. Scattered pebbles in coarse- and medium-grained sandstones were noted in the middle and lower parts in Liar Sir Kurram Nala. There, a red silty sandstone containing abundant scattered pebbles is a prominent feature about 400 feet above the base of the exposed section.

The lower contact is not exposed along the crest of the Marwat Kundi anticline; however, the formation rests disconformably on rocks of Cretaceous age along the northwest flank of Shaikh Budin where a conglomerate 10–15 feet thick crops out at the base. The Chinji Formation commonly forms slopes.

The section in Liar Sir Kurram Nala is 1,662 feet thick, but the base is not exposed. Morris (1938, p. 389) reported a complete section of about 1,100 feet at the northwest corner of Shaikh Budin; this section thins to a maximum of 50 feet at the northeast corner of Shaikh Budin and to about 50 feet along the south limb of the syncline near Chunda. The Chinji Formation does not crop out in the Marwat Range and is absent south-southeast of Paniala in the Khisor Range. Morris (1938, p. 388) estimated about 10,000 feet[13] for the Chinji Formation (his Kargocha formation*) along the Tochi River, but this thickness seems excessive. The Chinji Formation, if it exists in the Jandola area, is not distinguished readily from the reddish-brown claystone and sandstone of the Litra Formation. Coulson (in Heron, 1937, p. 72) also failed to recognize the Chinji Formation in Waziristan, but pointed out that Siwalik rocks in this area may represent "lithological variations of the Chinjis and other Siwalik strata."

NAGRI FORMATION

The name "Nagri" was adopted by Pilgrim (1913) for a faunal zone in the Potwar Plateau. Predating Pilgrim's Nagri was the term "Dangot sandstone*" proposed by Wynne (1877, p. 120) and reproposed by Danilchik and Shah (1973). The term Nagri, however, has achieved wide acceptance and apparently is preferred by the Stratigraphic Committee of Pakistan. The type locality in the Potwar Plateau was designated by Lewis (1937). The term "Nagri Formation" has been extended from the Potwar Plateau into the Marwat and Bhittanni Ranges in the eastern and central parts of the Bannu quadrangle. The term, as used in this report, is equivalent lithostratigraphically to the Marwat formation* of Morris (1938, p. 390). The extension of the term "Nagri Formation" from the Potwar Plateau westward into the Bannu quadrangle, and its substitution for Morris' term in the Bhittanni Range is based upon the following reasons:

1. Morris (1938, p. 392–393) recognized the so-called Marwat formation* throughout the Khisor and Marwat Ranges, as well as in the Shinghar Range where it is contiguous with the "Dangot sandstone*" of Wynne (1877) and Danilchik and Shah (1973).

[13] This estimate is apparently interpreted from Smith (1895, p. 107).

Farther east in the Salt Range, Morris (1938, p. 393) considered the formation to be synonymous with the "Nagri."

2. Heavy-mineral assemblage collected from the formation in the Khisor, Marwat, Shinghar, and Surghar Ranges and the Potwar Plateau are markedly similar and indicative of a common identity (Morris, 1938, p. 393–394).

In the Bain Pass area, the Nagri Formation (see "Measured Sections") consists of gray sandstone that commonly weathers brown and that crops out in zones 20–60 feet thick. Beds are massive and thick and commonly contain scattered pebbles. Most of the sand grains are medium, subangular, and subrounded. Subordinate amounts of brown silty claystone alternate with fine grained thin-bedded sandstone and brown siltstone. Claystone and siltstone zones generally range from 30 to 80 feet in thickness and are as much as 425 feet thick near the top of the formation.

In Bain Pass, crossbedding in the upper part of the formation suggests an easterly direction of sediment transport; study of aerial photographs suggests that the upper beds are more conglomeratic northwestward and westward toward Waziristan. Claystones in the middle part contain secondary selenite in places; some sandstone beds contain hard boulder-sized sandstone concretions with clay fragments inside and angular grains of hornblende, tourmaline, and muscovite oriented parallel to the bedding. Sandstone is commonly micaceous in the lower part in Bain Pass and in Liar Sir Kurram Nala; some claystone contains burrows. The formation forms sharp ridges and valleys.

The Nagri Formation is generally fossiliferous and contains mammalian bones and teeth. A nearly complete mammalian jawbone with teeth was collected east of Budh Banda in the Khisor Range, but unfortunately the specimen was too fragile to permit transportation to the laboratory. Near Bain Pass, Morris (1938, p. 391, 414–415) collected mammalian bones and teeth. Abundant fresh-water lamellibranchs have also been reported 300 feet below the horizon marking the extension of the Bain boulder bed* (Morris, 1938, p. 391) through Bain Pass, south of Pahar Khel.

The contact with the Chinji Formation is conformable and fairly sharp along the axis of the Marwat Kundi anticline; the Nagri Formation, however, disconformably overlies rocks of Jurassic age southeast of Paniala.

The Nagri Formation is 5,353 feet thick where it was measured on the northeast limb of the Marwat Kundi anticline near Bain Pass. Morris (1938, p. 391) reported about 6,200 feet in the south limb of the anticline and about 4,800 feet along the north flank of Shaikh Budin. A thickness of 5,000 feet is estimated east of Paniala, where the formation is composed almost entirely of massive crossbedded sandstone.

The Nagri Formation is probably equivalent to the lower part of the Chaudhwan Formation and to the Litra Formation in Waziristan (fig. 2). Morris (1938, p. 393–394) showed that the heavy-mineral assemblage of the formation in the northern Marwat, Khisor, Surghar, and Shinghar Ranges and the Potwar Plateau is distinctive from the underlying Chinji Formation in the same region.

The Bain boulder bed* of Morris (1938) crops out about 3,000 feet above the base of the Nagri Formation in the area between Bain Pass and Pezu, where the bed is readily distinguished both in the field and on aerial photographs. The Bain boulder bed* consists of both angular and rounded unsorted boulders, cobbles, and smaller fragments of foraminiferal limestone, claystone, gypsum, granite, basalt, and diabase, as well as greenstone schist and other metamorphic rocks. The matrix is a greenish-gray white commonly powdery material ranging in grain size from silt to clay. Thin-section study by Morris (1938, p. 396–398) showed the matrix to be composed of angular grains of quartz, hornblende, and feldspar. Coulson (1938, p. 433–434, 436) collected a possible artifact from the Bain boulder bed* 5½ miles northwest of Pezu. The Bain boulder bed* commonly forms a ridge and a dip slope.

The Bain boulder bed* is about 30 feet thick along the road southeast of Bain Post. Morris (1938, p. 401) reported 20 feet along the north flank of Shaikh Budin and a known maximum of 70 feet northeast of Pai.

Morris (1938, p. 403) interpreted the sediments of the Bain boulder bed* as having been deposited on the bottom of an early Pleistocene lake from a floating glacial ice tongue that had its source in the highlands of Waziristan; he correlated this glaciation with the Günz glacial stage in Europe (1938, p. 415). Stuart (1922, p. 93, 97) suggested that the large angular boulders in the extensive gravel terraces southwest of Razmak may be of glacial origin. The authors, however, have seen no direct evidence of glaciation in the Waziristan highlands, either in the single field reconnaissance along the roads north and southwest of Razmak or on aerial photographs of the region west of Razmak.

Gansser (1964, p. 49–50) agreed that the Bain boulder bed* resembles a tillite, but in view of the proximity of the Himalayas to the region of Siwalik deposition, he wondered why evidence of glaciation is so limited. He speculated that the Bain boulder bed* could be a mudflow or fanglomerate deposit, which in some circumstances may resemble a glacial till.

Walter Danilchik (U.S. Geol. Survey, written commun., 1967) observed that the Bain boulder bed* contains boulders of pumice and interpreted the light-gray

matrix to be a pumiceous tuff. He believed the unit to be the product of a volcanic mudflow, and although he offered no suggestion as to the source of the volcanic material, he speculated that the uraniferous sand in the Litra Formation near Raki Munh may owe its origin to the decomposition of much dispersed tuffaceous constituents of the overlying sandstones in the Siwalik Group.

The authors have no information that would conclusively support or reject a volcanic theory for the Bain boulder bed*, although the bentonite deposits in rocks of the Siwalik Group in the southern Potwar Plateau (Bogue and Schmidt, 1961) and in Kashmir (Ali and others, 1965) do indicate some volcanic activity to the northeast in the late Tertiary. The presence of a widespread tuffaceous zone in the Siwalik Group could provide an invaluable index horizon, but to date these rocks have not been studied in sufficient detail; moreover, a tuffaceous bed or beds could easily be overlooked.

DHOK PATHAN FORMATION

The name "Dhok Pathan" was adopted by Pilgrim (1913) for a faunal zone in the middle part of the Siwalik; the type locality in the Potwar Plateau was designated by Lewis (1937). The term "Dhok Pathan Formation" has been extended from the Potwar Plateau into the Marwat and Bhittanni Ranges in the eastern and central parts of the Bannu quadrangle. The term, as used in this report, is equivalent lithostratigraphically with the Sheri Ghasha formation* of Morris (1938, p. 405). The extension of the term "Dhok Pathan Formation" from the Potwar Plateau southwestward into the Bannu quadrangle and its substitution for the Sheri Ghasha formation* of Morris is based upon Morris' observation (1938, 405–406) that the outcrop of the Sheri Ghasha formation* can be traced from the Marwat Kundi anticline along the Marwat and Shinghar Ranges and is contiguous with the Dhok Pathan Formation in the Salt Range arc.

Near Bain Pass, the Dhok Pathan Formation consists of brown claystone and subordinate amounts of brown sandstone. (See "Measured Sections.") The sand grains are mostly medium and subrounded; the sandstone crops out in both thin and thick beds, and crossbedding is common. Conglomerate stringers were noted near the top of the formation along the northeast limb of the Marwat Kundi anticline. Abundant pebbles and cobbles were also noted in scree that probably was derived from the middle part. Crossbedding in the lower part suggests an easterly or northeasterly direction of sediment transport. The formation forms low ridges and slopes along the flanks of the Bhittanni, Marwat, and Khisor Ranges. The contact with the underlying Nagri Formation is conformable and sharp.

The Dhok Pathan Formation is 1,326 feet thick in the northeast limb of the Marwat Kundi anticline near Bain Pass; Morris (1938, p. 405) measured 2,550 feet in the southeast limb. The formation may be traced on aerial photographs eastward and northward along the flanks of the Marwat and Khisor Ranges. The Dhok Pathan is believed to be a facies of the middle or lower part of the Chaudhwan Formation in Waziristan (fig. 2).

MALAGAN FORMATION

The Malagan Formation was named by Morris (1938, p. 406) after the village of Malagan (lat 32°22′N.; long 70°38′E.), on the southeast flank of the Bhittanni Range. Near Bain Pass, the formation (see "Measured Sections") consists of brown medium- to coarse-grained sandstone in thick, irregular, and massive beds. Scattered pebbles, pebble and conglomerate stringers, and burrows are common. Study of aerial photographs of the area northwest of Khairu Khel strongly suggests that the formation becomes more conglomeratic northeastward. Southeast from Bain Pass on the north flank of the Marwat Kundi anticline the formation becomes thinner, less conglomeratic, and more difficult to distinguish from the underlying Dhok Pathan Formation. The formation is absent or not recognizable on aerial photographs east of Pezu Pass, although both Morris (1938, p. 406) and Danilchik and Shah (1973) reported the Malagan Formation in the Marwat Range.

The contact with the overlying surficial deposits of the Indus and Bannu Plains is commonly indistinct and probably unconformable. Throughout most of the Bhittanni Range, the Malagan Formation is conformable and folded with the underlying rocks of the Siwalik Group; however, study of aerial photographs of the area north of Rod Nala strongly suggests that the Malagan Formation unconformably overlies both the Dhok Pathan and the Nagri Formations with pronounced angularity.

The formation is 402 feet thick where measured on the northeast limb of the Marwat Kundi anticline near Bain Pass; Morris (1938, p. 406) measured about 2,200 feet on the south limb. The Malagan Formation is equivalent to and contiguous with the upper part of the Chaudhwan Formation in Waziristan (fig. 2).

AGE AND CORRELATION OF ROCKS OF THE SIWALIK GROUP

The age of the Chinji Formation at Shaikh Budin and in the Bhittanni Range is tentatively designated as Pliocene; the age of the Nagri, Dhok Pathan, and Malagan Formations in the Khisor, Marwat, and Bhittanni Ranges is designated as Pleistocene. These ages are based upon the following early Pleistocene mammalian bones and teeth collected by Morris (1938, p. 386, 391, 402, and 414–415) from the Nagri Formation

(which he identified as the Marwat formation*) in the Bhittanni Range:

Bos or *Bubalus* sp.
Hypselephas hysudricus (Falconer and Cautley)
Equus cautleyi Hopwood
Archidiskodon planifrons (Falconer and Cautley)
Rhinoceros paleoindicus (Falconer and Cautley)
Equus sivalensis (Falconer and Cautley)
Stegodon insignis (Falconer and Cautley)
Hippopotamus sp.
Elephas sp.
Gazella sp.
Stegodon sp.
Giraffa sp.

The Nagri Formation and the Siwalik Group would therefore be somewhat younger in this region than in the eastern foothills of the Sulaiman Range, where a Pliocene age for the Litra Formation is tentatively indicated (see "Age and Correlation of Rocks of the Siwalik Group"), and in the Dera Bugti area, where Pilgrim (1908, p. 164) reported that the rocks of the "Lower Siwalik"* are of Miocene age. The Siwalik Group would also be somewhat younger than in the Potwar Plateau, where the Nagri fauna reported by Morris (1938, p. 414–415) and other workers indicate a late Miocene or an early Pliocene age. Morris (1938, p. 415) concluded that deposition of lithostratigraphic units of the Siwalik Group transgressed time from Miocene and Pliocene in the eastern Potwar Plateau region to as late as early Pleistocene in the Khisor, Marwat, and Bhittanni Ranges, a distance of about 100 miles.

Pilgrim (1908, p. 164) also recognized a "faunistic gap between the Lower Siwaliks of Sind and the fossiliferous Siwaliks of the Punjab" and noted that the Sind fauna is older than that of the "fossiliferous Siwaliks" of the Punjab. Pilgrim apparently did not consider the concept of rock units crossing time boundaries, but his observation of the faunistic gap tends to confirm the northward age transgression of the lower part of the Siwalik Group from Miocene at Dera Bugti, to Pliocene (tentatively) at Raki Munh, and to early Pleistocene in the Bhittanni, Marwat, and Khisor Ranges. Perhaps units of the Siwalik Group are youngest in the region adjacent to Waziristan and Shaikh Budin, but their lithostratigraphic equivalents are older both to the northeast in the Potwar Plateau and to the south in the foothills of the Sulaiman Range and in the Dera Bugti area. Further study of vertebrate faunas of the Siwalik Group in the intervening area in the western Potwar Plateau, Surghar Range, in the northern Khisor and Marwat Ranges, and in the foothills of the Sulaiman Range may confirm this time transgression.

Morris' Pleistocene age determination for the Nagri Formation (1938, p. 386, 402, 415) and his report that the combined thickness of this and younger units of the Siwalik Group reaches a maximum of nearly 11,000 feet in the Bhittanni Range (1938, p. 391, 405, 406; pls. 36, 37) testify to the recency of major structural events that followed Siwalik deposition in this region. These events included upwarping of the Marwat Kundi anticline and strike-slip faulting along its axis, as well as reverse faulting and overturning of the youngest rocks of the Siwalik Group in Waziristan and in the foothills of the Sulaiman Range.

QUATERNARY SYSTEM

Surficial deposits of Quaternary age include alluvium and sand dunes of the Indus and Bannu Plains, alluvial fans along the hill fronts, and unconsolidated detritus along the slopes and in the valleys of the mountain ranges and foothills. These deposits are of Holocene age.

Older terrace deposits cover extensive areas underlain by rocks of early Tertiary age in the foothills of the Sulaiman Range and early and late Tertiary age in the hills east of Waziristan (pls. 2, 3). These terrace deposits are strongly cemented and in places attain a thickness of more than 250 feet. They may be as young as late Pleistocene.

MEASURED SECTIONS

Kirthar Formation near Nili Kach, Waziristan (pl. 4)

	Thickness (ft)
Pliocene:	
Litra Formation:	
0. Sandstone, brownish-gray, massive, strongly crossbedded, medium- and coarse-grained; subrounded and subangular grains, scattered pebbles in some beds; conglomeratic near base; cobble conglomerate at base ranges in thickness from a few inches to 2 ft	287
Eocene:	
Kirthar Formation:	
Drazinda Shale Member:	
1. Claystone, brownish-green; coaly, sulfurous zone about 70 ft below top; abundant minute lamellibranchs as well as nodules and pellets about 100 ft above the base	389
2. Claystone, greenish-brown	190
3. Claystone; greenish brown in upper part, greenish red in lower part; beds in middle of unit contain abundant Foraminifera and lamellibranchs	269
4. Limestone, gray, thin-bedded, marly; contains fragments of lamellibranch and Foraminifera	2
5. Claystone, brown	30
6. Limestone; similar to unit 4	10
7. Claystone, brown	30
8. Sandstone, gray, thick-bedded, weakly crossbedded, fine-grained	2
9. Claystone, brown	49
10. Limestone; similar to unit 4	2
11. Claystone, brown	5
12. Sandstone, greenish-gray, thick-bedded to massive, weakly crossbedded, fine-grained; conspicuous both in field and on aerial photographs	29

Kirthar Formation near Nili Kach, Waziristan (pl. 4)—Con.

	Thickness (ft)
Eocene—Continued	
Kirthar Formation—Continued	
Drazinda Shale Member—Continued	
13. Claystone, brownish-red	15
14. Limestone, greenish-gray, weathing brown, irregularly bedded, thick-bedded; interbedded claystone; abundant lamellibranch fragments and Foraminifera	15
15. Claystone, brownish-red	98
16. Limestone, gray, weathering brown, mostly thick-bedded; abundant Foraminifera and fragments of lamellibranchs	8
17. Claystone, brown	129
18. Limestone, light-brown to gray, weathering cream or white, marly; contains abundant lamellibranchs and some Foraminifera; conspicuous on aerial photographs	4
19. Limestone, marly; interbedded claystone, greenish-gray	8
20. Claystone, greenish-brown	87
21. Claystone, brown; interbedded limestone, marly; contains abundant Foraminifera, bryozoans, and lamellibranchs. Interbedded limestones are 1–2 feet thick at 10–15 ft intervals	53
22. Claystone, brown	321
23. Claystone, green	30
24. Claystone, green and dark-gray	62
Total Drazinda Shale Member	1,837
Pir Koh Limestone Member:	
25. Limestone, brownish-gray, hard; in beds 6–12 in. thick; contains Foraminifera; interbedded limestone, shaly, soft, in beds 6–12 in. thick near base of unit but thinner toward top	28
26. Claystone, green	6
27. Limestone, brown, weathering white, irregularly bedded, marly; abundant Foraminifera	6
Total Pir Koh Limestone Member	40
Domanda Shale Member:	
28. Claystone, greenish-gray	16
29. Sandstone, gray, weathering brown, irregularly bedded, fine- to medium-grained, very calcareous; contains large gastropods (some exceeding 10 in., apex to aperture) and abundant lamellibranchs, including oysters	17
30. Sandstone, brown, massive, very fine grained, calcareous	6
31. Claystone, poorly exposed	20
32. Sandstone, light-gray, weathering brown, fine-grained	2
33. Claystone, poorly exposed	9
34. Sandstone, white or gray, irregularly bedded, fine- to medium-grained; rounded grains	4
35. Claystone, greenish-gray; marl and siltstone in thin beds 3–6 in. thick throughout unit	57
36. Sandstone, brown, fine-grained	2
37. Claystone; similar to unit 35. Sandstone, gray-brown, medium-grained,	

Kirthar Formation near Nili Kach, Waziristan (pl. 4)—Con.

	Thickness (ft)
Eocene—Continued	
Kirthar Formation—Continued	
Domanda Shale Member—Continued	
37. Claystone; similar to unit 35—Continued rounded grains, calcareous, 3 inches thick, 267 ft above base of unit	376
38. Claystone, dark-grayish-green; marl 3–8 in. thick at 3–4 ft intervals; abundant Foraminifera	42
39. Claystone; similar to unit 38; interbedded marl, 1–2 in. thick	110
40. Claystone, gray; very subordinate marl, 1–2 in. thick	30
41. Siltstone, gray, shaly-bedded, soft; in beds as much as 3 ft thick; limestone, thin-bedded; siltstone, gray, thin-bedded, hard calcareous	48
Total Domanda Shale Member	739
Habib Rahi Limestone Member:	
42. Limestone, grayish-brown, weathering light-brown or white, thin-bedded, hard, dense; limestone, brown, shaly-bedded, soft; siltstone, calcareous, in beds 6–18 in. thick	126
43. Limestone, brown, massive; contains abundant *Assilina*	30
Total Habib Rahi Limestone Member	156
Total Kirthar Formation	2,772
44. Poorly exposed	>100

Chitarwata Formation near Domanda (pl. 4)

Pliocene:	
Vihowa Formation:	
000. Sandstone, brown to gray, thick-bedded to massive; subrounded to subangular grains; contains secondary calcite; very coarse grained sandstone and conglomerate, containing abundant fragments of Foraminifera	30
00. Siltstone, red-purple; sandstone, gray, medium-grained, subrounded grains	165
0. Sandstone, brownish-red to gray, massive, crossbedded, fine- to medium-grained; subangular grains	65
Upper Oligocene to upper Miocene:	
Chitarwata Formation:	
1. Claystone, red and gray, silty	65
2. Sandstone, fine-grained	2
3. Claystone, silty; contains plant roots	125
4. Sandstone, very fine grained	8
5. Claystone, purple	80
6. Claystone; varicolored containing sulfur stains and 6-in. carbonaceous bed near top	125
7. Sandstone, very fine grained	20
8. Siltstone, brown	110
9. Sandstone, very fine grained	10
10. Claystone, irregularly spotted red and gray; weathering red, brownish-red, and light-brown; silty in places; subordinate siltstone and sandstone, thick-bedded, very fine grained and fine-grained	50

Chitarwata Formation near Domanda (pl. 4)—Continued

	Thickness (ft)
Upper Oligocene to upper Miocene—Continued	
Chitarwata Formation—Continued	
11. Sandstone, very coarse grained	3
12. Sandstone, grayish-white, weathering brown; contains scattered ferruginous material	50
13. Claystone, varicolored; subordinate sandstone, very fine grained; siltstone; sandstone, very coarse grained, 4 ft thick near base of unit	320
14. Claystone, varicolored, massive; contains secondary gypsum	17
15. Sandstone, buff, crossbedded, friable, medium-grained	5
16. Siltstone, lavender and brownish-yellow	28
17. Sandstone, grayish-white to cream, friable, fine-grained	1
18. Sandstone, gray to pink, friable, very fine grained	8
19. Sandstone, cream and reddish-brown, thin-bedded, fine-grained; contains limonite concretions	11
20. Siltstone, varicolored, poorly exposed	47
21. Sandstone, cream to brown, thin-bedded, fine-grained, limonite-stained	6
22. Siltstone, varicolored	47
23. Sandstone, buff to yellow, thin-bedded, very fine grained; siltstone bed 18 in. thick near top	10
24. Same as unit 22	61
25. Siltstone, cream, hard, spheroidally weathered	1
26. Siltstone, soft	4
27. Siltstone; same as unit 25	1
28. Siltstone, varicolored	23
29. Siltstone, buff to cream, spheroidal-weathering, very friable, limonite-stained	22
Total Chitarwata Formation	1,260
Eocene:	
Kirthar Formation:	
Drazinda Shale Member:	
30. Shale, chocolate, weathering gray to greenish-brown; abundant selenite fragments	>30

Vihowa Formation in Chaudhwan Zam and in Toi Nala near Domanda (pl. 4)

Pliocene:	
Litra Formation:	
0. Sandstone, brown to gray, massive, cross-bedded, medium-grained; subangular grains; scattered pebbles, particularly near base	40
Vihowa Formation:	
1. Siltstone, red, poorly exposed	300
2. Sandstone, gray, medium- to coarse-grained; rounded grains; abundant scattered pebbles	50
3. Sandstone, gray, massive; fine grained and rounded grains near top, medium grained and subangular toward base; sandstone, thin-bedded, hard near base; pebble conglomerate in medium-grained sandstone matrix near base	357

Vihowa Formation in Chaudhwan Zam and in Toi Nala near Domanda (pl. 4)—Continued

	Thickness (ft)
Pliocene—Continued	
Vihowa Formation—Continued	
4. Sandstone, gray, massive, poorly sorted, medium-grained; subangular grains; conglomerate beds as much as 6 ft thick; clayey sandstone, very coarse grained, poorly exposed	140
5. Sandstone, brownish-red, thin-bedded, fine-grained, well-cemented	30
6. Sandstone, gray, thick-bedded, medium- to coarse-grained; subangular grains; abundant secondary calcite and fossil fragments	13
7. Sandstone, gray, thick-bedded, cross-bedded, medium- to coarse-grained; abundant pebbles in some beds; alternates with sandstone, thin-bedded, very fine grained	125
8. Siltstone, red to brown, poorly exposed; sandstone, very coarse grained, thin-bedded	135
9. Sandstone, brown to gray, thick-bedded to massive; subrounded to subangular grains; contains secondary calcite; very coarse grained sandstone and conglomerate containing abundant fragments of Foraminifera	30
10. Siltstone, red-purple; sandstone, gray, medium-grained, subrounded	165
11. Sandstone, brownish-red to gray, massive, crossbedded, fine- to medium-grained; subangular grains	65
Total Vihowa Formation	1,410
Upper Oligocene to upper Miocene:	
Chitarwata Formation:	
12. Claystone, red and gray, silty	65
13. Sandstone, fine-grained	2
14. Claystone, silty; contains plant roots	125

Litra Formation in Chaudhwan Zam, near Domanda (pl. 4)

Pleistocene(?) and Pliocene:	
Chaudhwan Formation:	
0. Sandstone, brown, thick-bedded to massive, fine- to medium-grained; abundant lenses of pebble and cobble conglomerate	60
Pliocene:	
Litra Formation:	
1. Sandstone, brownish-gray, thick-bedded to massive, medium-grained; subangular grains; interbedded pebble and cobble conglomerate; siltstone, 6 ft thick at top of unit	33
2. Siltstone, clayey	53
3. Sandstone, brown, thin- to thick-bedded, fine- to medium-grained, in zones as much as 6 ft thick; interbedded pebble and cobble conglomerate in zones as much as 4 ft thick	27
4. Sandstone, brown, thin- to thick-bedded, medium- to fine-grained, subangular grains, in zones 2 in. to 6 ft thick; subordinate siltstone and very fine grained sandstone	58

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Litra Formation in Chaudhwan Zam, near Domanda (pl. 4)—Continued

Pliocene—Continued Litra Formation—Continued	Thickness (ft)
5. Conglomerate, cobble, in coarse-grained sandstone matrix	5
6. Sandstone, brownish-gray, fine-grained; subangular grains	4
7. Claystone, brown	18
8. Conglomerate, pebble and cobble; matrix of sandstone, medium-grained, subangular grains	8
9. Siltstone, brown, and claystone	82
10. Sandstone, light-gray, thin-bedded to massive crossbedded, medium-grained; subangular grains	65
11. Sandstone, light-gray, massive, subangular grains; pebble conglomerate	10
12. Siltstone, brown, clayey	17
13. Sandstone, brown, thick-bedded to massive, medium-grained; subrounded grains; contains burrows; siltstone, brown, in beds as much as 15 ft thick; lenses of pebble conglomerate; cobble conglomerate near top of unit	155
14. Siltstone, brown	70
15. Sandstone, thick-bedded, medium-grained; subrounded grains; contains conglomerate stringers	8
16. Siltstone, brown	6
17. Sandstone, thick-bedded, fine- to medium-grained; angular grains	8
18. Sandstone, fine-grained; siltstone	180
19. Sandstone, thick-bedded, crossbedded, fine- to coarse-grained; contains stringers of conglomerate and burrows	19
20. Sandstone, fine-grained; siltstone, brown	61
21. Sandstone, brown, medium-grained; subrounded grains; contains stringers of pebble conglomerate	3
22. Siltstone, brown	48
23. Claystone, red; alternates with siltstone and pebble and cobble conglomerate	640
24. Sandstone, light-gray, massive, friable, medium-grained; subangular grains; conglomerate, 3 ft thick near middle of unit; conglomerate is crossbedded and composed of pebbles and cobbles in a coarse-grained sandstone matrix	125
25. Sandstone, brown, weathers gray, thick- to thin-bedded, fine-grained; subangular grains	41
26. Conglomerate, pebble; in matrix of very coarse and coarse-grained sandstone	3
27. Siltstone, brown	8
28. Sandstone, brown, medium-grained; subangular grains	4
29. Claystone, brownish-red	19
30. Sandstone, light-gray, massive, crossbedded, medium-grained; subangular grains; contains burrows; conglomerate stringers	168
31. Sandstone, brown, medium-grained; subangular grains; contains brown siltstone fragments; conglomerate near base	34
32. Sandstone, brown, thick-bedded, crossbedded, fine-grained; subrounded grains; contains siltstone and claystone fragments; subordinate brown siltstone	32
33. Sandstone, light-gray, massive, crossbedded, medium-grained; subangular grains	45
34. Sandstone, brown, massive, medium-grained; subrounded grains; contains burrows	50
35. Claystone, brownish-red	22
36. Sandstone, light-gray, massive, crossbedded, medium-grained; subangular grains; conglomerate, 10 ft thick near middle of unit	202
37. Siltstone, brown, weathering brownish-red	54
38. Sandstone, light-gray, thick-bedded to massive, weakly crossbedded, medium-grained; subangular grains	68
39. Sandstone, gray to brownish-gray, thick-bedded, fine- to medium-grained; subordinate brown siltstone and fine-grained sandstone	260
40. Siltstone, brown; sandstone, brown, fine-grained, soft; sandstone, light-brown, thick-bedded, fine- to medium-grained	96
41. Conglomerate, light-brown, gritty; medium- to coarse-grained sandstone matrix	4
42. Siltstone, light-brown, hard; sandstone, light-brown, thin- and thick-bedded, very fine grained	221
43. Sandstone, light-brown, massive, fine-grained; subangular grains; contains scattered pebbles	25
44. Siltstone, light-brown, hard; sandstone, light-brown, very fine grained, in beds ranging from 2 in. to 6 ft	137
45. Sandstone, light-gray, massive, medium-grained	48
46. Siltstone, light-brown, hard; sandstone, light-brown, very fine grained and fine- to medium-grained, in beds ranging from 2 in. to 8 ft thick	174
47. Sandstone, light-gray, thick-bedded to massive, friable, medium-grained; angular grains	26
48. Conglomerate, pebble; grit and coarse-grained sandstone matrix; interbedded sandstone	13
49. Sandstone, gray, massive, crossbedded, medium-grained; claystone and siltstone, red, in zones 15–30 ft thick	595
50. Siltstone and claystone, dull-red	18
51. Sandstone, light-gray, massive, crossbedded, fine-grained	117
52. Siltstone and claystone, dull-red	18
53. Sandstone, gray, massive, crossbedded, very fine grained; contains secondary calcite and burrows	45

Litra Formation in Chaudhwan Zam, near Domanda (pl. 4)—Continued

	Thickness (ft)
Pliocene—Continued	
Litra Formation—Continued	
54. Claystone, red	90
55. Sandstone, gray, massive, crossbedded, fine-grained	30
56. Claystone, red; contains thin beds of siltstone near base of unit; sandstone, brown, medium-grained, 4 ft thick near middle of unit	130
57. Sandstone, gray, massive, crossbedded, medium-grained; subrounded grains	150
58. Siltstone and claystone, red, poorly exposed	110
59. Sandstone, gray, medium-grained; subrounded grains	6
60. Conglomerate, chert pebble, brown, hard, well-cemented	5
61. Sandstone, light-gray, massive, strongly cross bedded, soft, friable, medium-grained; subrounded grains	161
62. Sandstone, gray, massive, crossbedded, medium-grained; subrounded grains; conglomerate in 12–18 in.beds	14
63. Conglomerate	4
64. Claystone, red; contains very fine grained sandstone beds, 4–6 in. thick, near middle of unit	170
65. Sandstone, gray massive, crossbedded, medium-grained; subangular grains; contains abundant burrows	95
66. Siltstone, red, poorly exposed	40
67. Sandstone; same as unit 65	115
68. Siltstone, red, alternating with light-gray friable medium- to fine-grained garnetiferous sandstone	150
69. Sandstone, brown to gray, massive, crossbedded, medium-grained; subangular grains; contains scattered pebbles, particularly near base	40
Total Litra Formation	5,560
Vihowa Formation:	
70. Siltstone, red, poorly exposed	300
71. Sandstone, gray, medium- to coarse-grained; rounded grains; abundant scattered pebbles	50

Litra Formation near Gumal Pass, Waziristan (pl. 4)

Pleistocene(?) and Pliocene:	
Chaudhwan Formation:	
00. Conglomerate, boulder-cobble; silty claystone 20 ft thick near top of unit	78
0. Conglomerate, cobble and boulder	19
Pliocene:	
Litra Formation:	
1. Covered, but probably brown silty claystone	34
2. Sandstone, brown, weathering brown, thin- and thick-bedded, crossbedded; contains abundant scattered pebbles	13
3. Claystone, brown, silty, poorly exposed	58
4. Sandstone; similar to unit 2, but mainly thin bedded	16

Litra Formation near Gumal Pass, Waziristan (pl. 4)—Con.

	Thickness (ft)
Pliocene—Continued	
Litra Formation—Continued	
5. Claystone, brown, somewhat silty; in beds 20–30 ft thick, poorly exposed; alternates with sandstone similar to unit 2, in beds 5 ft thick	240
6. Conglomerate, cobble	8
7. Claystone, brown; similar to unit 5, but contains conglomeratic sandstone bed, 12 ft thick, near middle of unit	242
8. Claystone, brown, silty; poorly exposed in beds 40–50 ft thick; alternates with sandstone, brown, thin- and thick-bedded, crossbedded, medium-grained, locally conglomeratic in zones 10–15 ft thick; sandstone zones become thinner and more numerous toward base of unit	389
9. Conglomerate	10
10. Siltstone, brown, clayey; subordinate sandstone, brown, medium-grained, in zones as much as 10 ft thick; some brown claystone	253
11. Sandstone, brown, mostly thick-bedded, crossbedded, medium-grained; subrounded grains	15
12. Claystone, brown; in zones 15–25 ft thick; alternates with sandstone, brown, thick- and thin-bedded. Sandstone, gray, crossbedded, 12 ft thick in middle part of unit; conglomerate, 8 ft thick in lower part	147
13. Sandstone, brown, mostly thick-bedded, medium-grained; about 25 ft thick; grades downward into conglomerate	54
14. Claystone, brown	76
15. Conglomerate	8
16. Claystone, brown, poorly exposed	112
17. Sandstone, brown, thick-bedded, crossbedded, medium-grained	16
18. Conglomerate	4
19. Claystone, brown; silty in places; subordinate sandstone, brown, crossbedded, medium-grained; conglomerate. Sandstone and conglomerate beds are 4–8 ft thick and occur at 10- to 25-ft intervals	305
20. Conglomerate, cobble	25
21. Claystone; similar to unit 19, but without conglomerate; contains burrows and ripple-marked sandstone	318
22. Sandstone, conglomeratic	6
23. Claystone; similar to unit 19	209
24. Claystone, brownish-red; somewhat silty; in zones 15–35 ft thick; subordinate sandstone, gray, fine-grained, in zones 8–15 ft thick. Sandstone is massive near top but becomes thick- and thin-bedded and crossbedded toward base	386
25. Sandstone, gray, massive, fine-grained	8
26. Siltstone	12
27. Sandstone; similar to unit 25	12
28. Claystone, brownish-red; silty in zones 15–35 ft thick; subordinate sandstone, gray, massive and thick- and thin-bedded, crossbedded, fine-grained in zones a few inches to 10 ft thick	449

Litra Formation near Gumal Pass, Waziristan (pl. 4)—Con.

	Thickness (ft)
Pliocene—Continued	
Litra Formation—Continued	
29. Sandstone, brownish-gray, thick-bedded and massive, medium- to coarse-grained; subrounded grains; contains abundant scattered pebbles	15
30. Claystone, brownish-red; subordinate siltstone and sandstone, more abundant near the top of the unit	150
31. Sandstone, brown, thin- and thick-bedded, crossbedded, medium- and coarse-grained, becoming fine-grained near base	26
32. Claystone, brownish-red; minor amounts of interbedded sandstone	41
33. Sandstone, thin- and thick-bedded, crossbedded, fine-grained; interbedded brown claystone	57
34. Claystone and sandstone; similar to unit 32	128
35. Sandstone and claystone; similar to unit 33	27
36. Claystone and sandstone; similar to unit 32	84
37. Sandstone and claystone; similar to unit 33	14
38. Claystone and sandstone; similar to unit 32	96
39. Sandstone, brown, crossbedded, fine-grained; angular grains	15
40. Claystone, brownish-red	120
41. Sandstone, brown, massive, crossbedded, fine-grained; contains burrows	10
42. Claystone	20
43. Sandstone, brown, thick-bedded and massive, fine- and medium-grained; becomes coarse-grained and conglomeratic near base	22
44. Claystone, brownish-red; 15–20 ft thick beds; alternates with sandstone, brown, thin- and thick-bedded, crossbedded, fine-grained, conglomeratic in places	122
45. Sandstone, fine-grained, conglomeratic	7
46. Claystone, brownish-red	6
47. Sandstone, massive, fine-grained	6
48. Claystone, brownish-red	49
49. Sandstone, brown, massive, fine-grained	19
50. Claystone, brown, red; sandstone, thick-bedded, 4 ft thick near middle of unit	131
51. Sandstone, brown, crossbedded, medium- to coarse-grained, conglomeratic	3
52. Claystone, brownish-red, somewhat silty, poorly exposed; sandstone, gray, massive, about 20 ft thick near top of unit; sandstone thin- and thick-bedded, crossbedded, about 20 ft thick near base of unit	226
53. Conglomerate, pebble	14
54. Sandstone, thick-bedded, crossbedded	39
55. Claystone, reddish-brown	55
56. Conglomerate, pebble, crossbedded; alternates with sandstone, crossbedded, coarse-grained	28
57. Sandstone, gray, massive, fine-grained	15
58. Claystone, brownish-red, poorly exposed; sandstone beds, brownish-gray, thin- and thick-bedded, crossbedded. Claystone beds range from 10 to 20 ft in thickness in upper part of unit. Sandstone appears to be absent in lower part of unit	151
59. Sandstone, brownish-gray, massive, strongly crossbedded, medium- and coarse-grained; subrounded and subangular grains; scattered pebbles in some beds; conglomeratic near base; conglomerate, cobble, at base varies in thickness from a few inches to 2 ft	287
Total Litra Formation	5,408
Eocene:	
Kirthar Formation:	
Drazinda Shale Member:	
60. Claystone, brownish-green; coaly, sulfurous zone about 70 ft below top of unit; abundant minute lamellibranchs about 100 ft above base of unit	389

Chaudhwan Formation in Chaudhwan Zam, near Domanda (pl. 4)

Holocene and Pleistocene:	
0. Boulders and unconsolidated fan deposits adjacent to the Indus Plain	>150
Pleistocene(?) and Pliocene:	
Chaudhwan Formation:	
1. Conglomerate; composed mainly of boulders and cobbles of limestone, quartzite, and sandstone in a medium- and coarse-grained sandstone matrix; very subordinate sandstone and siltstone beds 2–3 ft thick in lower part	935
2. Siltstone; in beds ranging from 2 to 3 ft to 25 to 30 ft in thickness; subordinate amounts of claystone. Siltstone alternates with approximately proportionate amounts of sandstone in zones as much as 6 ft thick. Sandstone is thin and thick bedded, occasionally crossbedded, fine to medium grained; contains rare burrows, lenses of very coarse grained sandstone, and scattered pebbles. Pebble-cobble conglomerate beds as much as 20 ft thick in upper and lower parts of unit	660
3. Cover; probably underlain by siltstone and claystone	185
4. Sandstone, thick-bedded; subangular grains	35
5. Claystone and clayey siltstone	60
6. Conglomerate, boulder	15
7. Sandstone, brown, thick-bedded, poorly sorted, medium- and fine-grained; contains scattered pebbles. Medium-grained sandstone is crossbedded	15
8. Siltstone, brown, clayey	30
9. Conglomerate, boulder	10
10. Sandstone, light-brown, thin- and thick-bedded, very fine grained, poorly sorted; subordinate sandstone, brown, fine- to medium-grained, subangular grains; contains beds and lenses of pebbles, cobbles, and very coarse grained sandstone	70

Chaudhwan Formation in Chaudhwan Zam, near Domanda (pl. 4)—Continued

	Thickness (ft)
Pleistocene(?) and Pliocene—Continued	
Chaudhwan Formation—Continued	
11. Conglomerate, boulder	80
12. Claystone, brown, and siltstone, brown; zones range in thickness from 15 to 60 ft. Claystone and siltstone beds alternate with subordinate boulder conglomerate in zones 15–20 ft thick and with sandstone in zones 2–10 ft thick. Sandstone is brownish gray, thin and thick bedded, fine to medium grained, has subangular grains, and contains scattered pebbles and cobbles	205
13. Conglomerate, boulder	285
14. Siltstone, brown, clayey; subordinate sandstone, brown, thin- and thick-bedded, fine- and medium-grained, subangular grains	70
15. Conglomerate, boulder	80
16. Siltstone, brown, clayey; in beds as much as 20 ft thick. Siltstone alternates with sandstone, brown, thin- and thick-bedded, fine- and medium-grained, subangular grains; contains scattered pebbles and cobbles. Sandstone zones range in thickness from 2 in. to 4 ft. Boulder and cobble conglomerate, 15 ft thick, about 50 ft above base	625
17. Conglomerate, boulder	50
18. Siltstone, brown	25
19. Conglomerate, boulder	25
20. Conglomerate, boulder; in beds 6–20 ft thick alternating with beds of brown siltstone, 6–15 ft thick	316
21. Sandstone, brown, silty	35
22. Sandstone, brown, thick-bedded, fine- to medium-grained; poorly sorted angular grains; contains scattered pebbles	15
23. Conglomerate, boulder	10
24. Sandstone, brownish-gray, thick- and thin-bedded, fine- to medium-grained; poorly sorted angular grains; contains scattered pebbles and conglomerate lenses	35
25. Siltstone, brown	10
26. Conglomerate, boulder	4
27. Siltstone, brown	15
28. Conglomerate, boulder	5
29. Sandstone, brown, thick-bedded to massive, crossbedded, poorly sorted	40
30. Conglomerate, boulder	255
31. Conglomerate, boulder and cobble, with subordinate sandstone, thick-bedded, fine- to medium-grained; contains burrows	120
32. Sandstone, thick-bedded to massive, fine- to medium-grained; contains pebble conglomerate lenses as much as 1 ft thick	51
32. Conglomerate, boulder and cobble; subordinate sandstone in beds and lenses as much as 12 ft thick. Sandstone is brown, thick bedded, medium grained, has subangular grains, and contains burrows	122
34. Sandstone, brown, thick-bedded to massive, medium-grained; subangular grains; pebble and cobble conglomerate in beds as much as 6 ft thick, some crossbedding; subordinate siltstone in beds less than 2 ft thick	104
35. Conglomerate, cobble and boulder; subordinate lenses of thick-bedded to massive medium-grained sandstone	105
36. Sandstone, light-brown, thick-bedded to massive, fine- to medium-grained; subordinate cobble and boulder conglomerate lenses	48
37. Conglomerate, cobble and boulder; subordinate sandstone, thick-bedded, fine- to medium grained, in beds as much as 6 ft thick	90
38. Sandstone, brown, thick-bedded to massive, fine- to medium-grained; contains abundant lenses of pebble and cobble conglomerate	60
Total Chaudhwan Formation	4,900
Pliocene:	
Litra Formation:	
39. Sandstone, brownish-gray, thick-bedded to massive, medium-grained; subangular grains; pebble and cobble conglomerate beds. Siltstone, 6 ft thick, at top of unit	35

Chaudhwan Formation near Gumal Pass, Waziristan (pl. 4)

Holocene and Pleistocene:	
0. Boulders and unconsolidated fan deposits adjacent to the Indus Plain	>50
Pleistocene(?) and Pliocene:	
Chaudhwan Formation:	
1. Conglomerate; composed of boulders, cobbles, and pebbles of limestone, quartzite, and sandstone in a medium- and coarse-grained sandstone matrix	4,435
2. Claystone, brown, silty	18
3. Conglomerate, cobble	7
4. Claystone, brown, silty	29
5. Conglomerate, and sandstone, crossbedded	29
6. Claystone, silty, brown	42
7. Conglomerate, boulder and cobble	35
8. Covered, but probably similar to unit 6	57
9. Conglomerate	69
10. Same as unit 8	43
11. Conglomerate, cobble; subordinate crossbedded sandstone	29
12. Covered, but probably underlain by silty clay	22
13. Conglomerate; subordinate sandstone, crossbedded	46
14. Same as unit 12	46
15. Same as unit 11	22
16. Poorly exposed. Appears to be silty claystone in beds 10–30 ft thick, alternating with conglomeratic sandstone and conglomerate in beds 10–30 ft thick	225
17. Conglomerate, cobble; contains subordinate crossbedded sandstone	27

Chaudhwan Formation near Gumal Pass, Waziristan (pl. 4)—Continued

	Thickness (ft)
Pleistocene(?) and Pliocene—Continued	
Chaudhwan Formation—Continued	
18. Same as unit 12	34
19. Conglomerate, boulder	22
20. Claystone, silty	57
21. Conglomerate, cobble and boulder	16
22. Same as unit 12	27
23. Conglomerate, boulder and cobble	31
24. Claystone, brown, silty; sandstone, brown, conglomeratic, about 15 ft thick near middle of unit	61
25. Conglomerate, cobble	18
26. Claystone, silty	60
27. Sandstone, brownish-gray, weathering brown, strongly crossbedded; thickbedded near top, but becomes thinbedded at base. Sandstone contains abundant scattered pebbles and conglomerate lenses. Subordinate beds of silty claystone in zones 15–25 ft thick	214
28. Claystone, brown, silty	122
29. Conglomerate, boulder and cobble; silty claystone 20 ft thick near top of unit	78
30. Conglomerate, cobble and boulder	19
Total Chaudhwan Formation	5,940
Pliocene:	
Litra Formation:	
31. Covered, but probably brown silty claystone	34
32. Sandstone, brown, weathering brown, thin- and thick-bedded, crossbedded; contains abundant scattered pebbles	13

Chinji Formation in Liar Sir Kurram Nala, Bhittanni Range (pl. 4)

Pleistocene:	
Nagri Formation:	
0. Sandstone, gray, massive, crossbedded, medium-grained; subangular grains; micaceous conglomerate layers near base; siltstone and claystone 20 ft thick about 30 ft above base	80
Pliocene(?):	
Chinji Formation:	
1. Claystone, reddish-brown; hard siltstone and fine-grained sandstone, thin- and thick-bedded, commonly weathers in relief along cliff. Abundant burrows. Most thick-bedded siltstone and sandstone beds are restricted to upper part of unit	418
2. Sandstone, gray, weathering gray, medium-grained, subangular, thick-bedded and massive, weakly crossbedded; abundant scattered pebbles in 2-ft zone at base	116
3. Claystone; similar to unit 1	20
4. Sandstone, brown, fine- and medium-grained, subangular, weakly crossbedded; abundant pebbles in some beds	20
5. Claystone, brown; similar to unit 1. Sandstone, massive, fine-grained, 10 ft thick in middle of unit	120
6. Sandstone, brownish-yellow, weathering dark-brown, medium-grained, angular grains, coarse grained in places; abundant scattered pebbles	20

Chinji Formation in Liar Sir Kurram Nala, Bhittanni Range (pl. 4)—Continued

	Thickness (ft)
Pliocene(?)—Continued	
Chinji Formation—Continued	
7. Claystone, brown; similar to unit 1	203
8. Sandstone, brownish-gray, weathering brown, medium-grained, crossbedded, thick-bedded to massive; contains burrows	20
9. Claystone, brownish-red; similar to unit 1	275
10. Sandstone, brown, weathering brown, strongly crossbedded, medium-grained; subangular to subrounded grains; contains scattered pebbles and burrows	10
11. Claystone; similar to unit 1	45
12. Sandstone, brown, weathering brown, medium-grained; similar to unit 10; silty sandstone, medium-grained, rounded grains, and abundant scattered pebbles; sandstone, gray, weathering very light gray, massive, lenticular, wedges out along strike	40
13. Claystone; similar to unit 1	355
Total exposed Chinji Formation	1,662
Axis of Marwat Kundi anticline. Base of Chinji Formation is not exposed.	

Nagri Formation: upper part (units 1–50) in Bain Pass; lower part (units 51–73) in Liar Sir Kurram Nala (pl. 4)

Pleistocene:	
Dhok Pathan Formation:	
0. Claystone, brown; contains siltstone; sandstone, brown, thin- and thick-bedded, and very fine and fine-grained. Sandstone is more common near top of unit	255
Nagri Formation:	
1. Sandstone, gray and brown, weathering brown, thick-bedded and massive, medium- to coarse-grained; contains scattered pebbles	35
2. Covered, but believed to be underlain by siltstone and claystone	108
3. Sandstone, gray, massive, medium-grained; subangular grains	63
4. Siltstone, brown, and claystone, brown	23
5. Sandstone; similar to unit 3	40
6. Sandstone, brown, thin-bedded, medium- and fine-grained; siltstone, brown, predominant in upper part of unit	63
7. Sandstone, gray, massive, medium-grained. Weak crossbedding suggests northeast direction of sediment transport	96
8. Claystone and siltstone, brown; sandstone, thin-bedded, very fine grained	425
9. Claystone, brown; sandstone, brown, massive, medium-grained, 8 ft thick in middle of section. Weak crossbedding suggests northeasterly direction of sediment transport	81
10. Sandstone, brown, weathering brown, massive, medium-grained; subrounded grains	10
11. Siltstone, brown, clayey, particularly in the upper part	173
12. Sandstone, brown, weathering brown, massive, to poorly bedded, weakly crossbedded, medium-grained; subangular to subrounded grains. Scattered pebbles and lenticular conglomerates as much as 1 ft thick	33

Nagri Formation: upper part (units 1–50) in Bain Pass; lower part (units 51–73) in Liar Sir Kurram Nala (pl. 4)—Con.

Pleistocene—Continued

Nagri Formation—Continued	Thickness (ft)
13. Claystone, brown	35
14. Sandstone, brown, weathering brown, medium- to coarse-grained; abundant scattered pebbles and conglomerate stringers. Crossbeds suggest southeasterly direction of sediment transport	14
15. Sandstone, gray, massive, medium-grained; subrounded grains. Crossbeds suggest southeasterly direction of sediment transport. Dark minerals tend to be concentrated parallel to bedding and crossbedding	28
16. Siltstone, brown	21
17. Sandstone, brownish-gray, weathering brown, massive, fine-grained	21
18. Claystone, brown	117
19. Sandstone, brown, thick-bedded, medium-grained; scattered pebbles	15
20. Claystone, brown	30
21. Sandstone, gray, massive, crossbedded, medium-grained; subangular and subrounded grains; scattered pebbles and thin conglomerate stringers near top. Crossbeds near top suggest northeasterly direction of sediment transport	56
22. Claystone, brown, poorly exposed	87
23. Sandstone, gray, massive, medium-grained; subangular and subrounded grains; scattered pebbles	103
24. Claystone, light-brown	73
25. Sandstone, gray, massive, medium-grained; subangular and subrounded grains	36
26. Clay, silty	41
27. Sandstone, brown, thick-bedded, very fine grained	6
28. Clay, brown	30
29. Sandstone, brown, thick-bedded, fine-grained	6
30. Siltstone, light-brown; minor beds of brown fine-grained sandstone	94
31. Sandstone, brown, massive	6
32. Siltstone; similar to unit 30	97
33. Sandstone, gray, weathering light-brown, massive, medium-grained; subangular grains	50
34. Claystone, brown	60
35. Sandstone; similar to unit 33	37
36. Siltstone	104
37. Sandstone, gray; subangular grains; poorly sorted pebbles and boulders in places. Upper part is irregularly bedded	65
38. Siltstone, light-brown; sandstone, gray, very fine grained; claystone, brown	30
39. Sandstone, gray, massive and thick-bedded, friable, medium-grained; subrounded and subangular grains. Dark minerals tend to be oriented parallel to bedding planes. Hard boulder-size concretions contain fragments of clay	115
40. Claystone, light-brown; minor amounts of sandstone, gray, thin-bedded, very fine grained; siltstone, gray. Selenite fragments in scree	240

Nagri Formation: upper part (units 1–50) in Bain Pass; lower part (units 51–73) in Liar Sir Kurram Nala (pl. 4)—Con.

Pleistocene—Continued

Nagri Formation—Continued	Thickness (ft)
41. Sandstone, brown, hard, thin-bedded and thick-bedded to massive, weakly crossbedded, medium- and coarse-grained; subrounded grains. Some beds contain poorly sorted pebble conglomerate	12
42. Siltstone, brownish-gray	25
43. Sandstone, gray, weathering brownish-gray, massive, medium-grained; subangular and subrounded grains	25
44. Claystone, brownish-gray; sandstone, thin- and thick-bedded, very fine grained; siltstone, brownish-gray	253
45. Sandstone, gray, weathering brownish-gray, massive, weakly crossbedded, fine- and medium-grained; micaceous in places	149
46. Siltstone, brownish-red and gray, thin-bedded; contains silty clay and very fine grained sandstone	121
47. Sandstone, gray, weathering brownish-gray, massive, medium-grained; subangular to subrounded grains; micaceous in places	25
48. Claystone, brownish-red, massive; siltstone, brown, thin-bedded	122
49. Sandstone, gray, massive and irregularly bedded, fine- to medium-grained	20
50. Claystone; similar to unit 48	58
51. Sandstone, greenish-gray, weathering brownish-gray, massive and crossbedded, medium-grained; subangular grains	8
52. Claystone, light-brown, in beds 2–5 ft thick; sandstone, thin-bedded, irregularly bedded, fine-grained, in zones 1–3 ft thick	111
53. Sandstone, gray, weathering brownish-gray, massive, medium-grained; subangular grains	45
54. Claystone; similar to unit 52, but contains burrows and fine-grained sandstone zones as thick as 8 ft	45
55. Sandstone; similar to unit 53	40
56. Claystone, brown	20
57. Sandstone, light-brown, thick-bedded and massive, medium-grained; subangular to subrounded grains	25
58. Claystone; poorly exposed, but believed to be similar to unit 52	110
59. Sandstone, massive	20
60. Claystone; poorly exposed, but believed to be similar to unit 52	120
61. Sandstone, crossbedded; similar to unit 53	30
62. Claystone; similar to unit 52	70
63. Sandstone, gray and brown; weakly crossbedded at top and near base. Generally similar to units 53 and 57	80
64. Claystone; similar to unit 52	100
65. Sandstone, brown and gray, weathering dark-brown, thick-bedded and massive, weakly crossbedded, medium-grained; subrounded grains	45
66. Claystone; poorly exposed, but believed to be similar to unit 64	30

Nagri Formation: upper part (units 1–50) in Bain Pass; lower part (units 51–73) in Liar Sir Kurram Nala (pl. 4)—Con.

	Thickness (ft)
Pleistocene—Continued	
Nagri Formation—Continued	
67. Sandstone, gray, weathering brown, massive, weakly crossbedded, medium-grained. Thin-bedded zone near middle of unit. Scattered pebbles and conglomerate stringers	40
68. Claystone; similar to unit 52	85
69. Sandstone; similar to unit 67	30
70. Claystone; similar to unit 52	105
71. Sandstone, gray, weathering brown, thick-bedded and massive; strongly crossbedded in upper part; abundant scattered pebbles	35
72. Claystone; similar to unit 52; subordinate beds consist mainly of very fine grained sandstone and siltstone	502
73. Sandstone, gray, massive, crossbedded, medium-grained; subangular grains; micaceous; conglomerate layers near base; siltstone and claystone 20 ft thick about 30 ft above base	80
Total Nagri Formation	5,353
74. Claystone, reddish-brown; hard siltstone and fine-grained sandstone, thin- and thick-bedded, commonly weathers in relief along cliff. Abundant burrows. Most thick-bedded siltstones are restricted to upper part of unit	418

Dhok Pathan Formation near Bain Pass, Bhittanni Range (pl. 4)

Pleistocene:	
Malagan Formation:	
0. Sandstone, brown, generally thin-bedded, but becomes more thick bedded and massive toward top, medium- to coarse-grained; scattered pebble conglomerate in places	57
Dhok Pathan Formation:	
1. Claystone, brown; siltstone and some thin-bedded sandstone near base	40
2. Sandstone, brown, thin- and thick-bedded, crossbedded, medium-grained; subrounded grains	15
3. Claystone, brown	22
4. Sandstone, brown, thin- and irregularly bedded, medium-grained	12
5. Claystone	9
6. Sandstone, brownish-gray, thick-bedded and massive, weakly crossbedded, medium-grained; contains discontinuous pebble conglomerate stringers	31
7. Claystone, brown	34
8. Sandstone; similar to unit 6, but less massive	30
9. Claystone, brown; siltstone and fine-grained sandstone in beds 1–2 ft thick at intervals of 8–10 ft. Sandstone, 8 ft thick near middle of unit, is crossbedded, fine to medium grained, poorly sorted, and contains subangular grains	96
10. Sandstone, brown, mainly thin bedded, crossbedded	34
11. Claystone, brown	30
12. Sandstone, brown, mainly thick bedded, crossbedded, medium-grained; subrounded grains	14

Dhok Pathan Formation near Bain Pass, Bhittanni Range (pl. 4)—Continued

	Thickness (ft)
Pleistocene—Continued	
Dhok Pathan Formation—Continued	
13. Covered, but believed to be underlain by siltstone, very fine grained sandstone, and claystone	47
14. Sandstone, brown, thick- and irregularly bedded near top but more massive near base; crossbedded; medium to coarse grained near top, but becomes generally fine grained downward; scattered pebbles in middle part	44
15. Mainly covered, but believed to be underlain by brown thick- and thin-bedded fine-grained sandstone; contains some siltstone. Abundant pebbles and cobbles in scree	95
16. Sandstone, brown, thin- and thick-bedded, medium-grained; contains pebbles and cobbles in upper part	88
17. Mainly covered, but believed to be underlain predominantly by claystone and subordinate siltstone, and sandstone, very fine grained and fine-grained, subrounded grains	310
18. Sandstone, brown, thin- and thick-bedded, medium-grained. Weak crossbedding suggests easterly or northeasterly direction of sediment transport	15
19. Mainly covered, but believed to be underlain predominantly by claystone and subordinate siltstone. Brown thin-bedded fine- to medium-grained sandstone, is more common near top	95
20. Sandstone, brown, massive, medium-grained; subrounded grains	10
21. Claystone, brown, and some siltstone; subordinate sandstone, brown, thin- and thick-bedded, very fine and fine-grained. Sandstone is more common near top of unit	255
Total Dhok Pathan Formation	1,326
Nagri Formation:	
22. Sandstone, gray and brown, weathering brown, thick-bedded and massive, medium- to coarse-grained; contains scattered pebbles	35

Malagan Formation near Bain Pass, Bhittanni Range (pl. 4)

Holocene and Pleistocene:	
0. Unconsolidated surficial deposits of the Bannu Plain. Contact with Malagan Formation is not exposed	>50
Pleistocene:	
Malagan Formation:	
1. Sandstone, brown, thick-bedded to massive, irregularly bedded, weakly crossbedded, medium- and coarse-grained; mostly subangular grains; contains burrows and abundant scattered pebbles and conglomerate stringers	248
2. Sandstone, brown and gray, thin- and irregularly bedded; thick-bedded and massive in places; contains scattered pebbles; pebble and cobble conglomerate stringers in middle part	97

Malagan Formation near Bain Pass, Bhittanni Range (pl. 4)—Continued

	Thickness (ft)
Pleistocene—Continued	
Malagan Formation—Continued	
3. Sandstone, brown, medium- to coarse-grained; generally thin bedded, but becomes more thick bedded and massive near top; contains pebble conglomerate in places	57
Total exposed Malagan Formation	402
Dhok Pathan Formation:	
4. Claystone, brown; siltstone and some thin-bedded sandstone near base	40

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