CHAPTER IV

GEOLOGICAL SETTING OF THE AREA

The chapter embodies a comprehensive account of the major structural features of the area and field disposition of the various lithostratigraphic units of the Siwalik Group, viz., the Nahan Formation (Lower Siwalik), the Kala Amb Formation (Middle Siwalik) and the Saketi Formation (Upper Siwalik). Since the Sandstone and Conglomerate Members of the Saketi Formation can be distinguished in the field, disposition of these units is discussed herein separately.

MAJOR STRUCTURAL FEATURES

The Siwalik rocks exposed between the Chaggar and the Markanda rivers exhibit simple structures. The folds are both of symmetrical and asymmetrical types. Faults are numerous but only the persistent ones have been mapped (Map 1). There are two important thrusts which mark the junction between the Siwalik and the Pre-Siwalik; and the Nahan and the Saketi Formation of the Siwalik Group. The major structural features of the area are elucidated with the help of geological sections (Maps 5, 6 and 7).
MOGINAND-DABSU SECTION

Along the M-D Section, the rocks of the various lithostratigraphic units show a monoclinal structure (Map 5). The Tilokpur Sandstone Member of the Saketi Formation (Upper Siwalik) grades into the Mandhna Conglomerate Member. The latter, in turn, has a tectonic junction with the Nahan Formation. The thrust is referred to as Jansu Thrust (Pl.II, B). The thrust plane dips at an angle of 35° in northeasterly direction. The Nahan Formation does not show much variation in dip direction and has a tectonic junction with the rocks of the Sirmur Group. The thrust is referred to as Nahan Thrust. The thrust plane dips in the northeasterly direction at an angle of 55°.

MANDLAI-BALSAR SECTION

Along the M-B Section (Map 6), the Tilokpur Sandstone Member is exposed in the form of a homocline and grades into Mandhna Conglomerate Member. The Conglomerate sequence is folded into a symmetrical syncline, the complementary anticline of which has been truncated by the Jansu Thrust. The rocks of the Nahan Formation are once again folded into a symmetrical syncline, the northeastern limb of which has been cut off by the Nahan Thrust. The thrust separates the Nahan rocks from the Sirmur rocks and dips at an angle of 40° in the northeasterly direction.
JHANDA-KANSWALA SECTION

Along the J-K Section (Map 7), all the three formations of the Siwalik Group are exposed. In the southwestern sector of the map, the Kala Amb Formation (Middle Siwalik) is folded into a series of anticlines and synclines. A fault of limited areal extent traverses the rocks North of Jhanda. Near Saketi, the Tilokpur Sandstone Member is thrown into an asymmetric syncline, the northeastern limb of which is a faulted one. The beds constituting the complementary anticline of the Saketi Syncline grade into the Mandhna Conglomerate. The Mandhna Conglomerate Member has a thrust junction with the Nahan Formation. The Jansu Thrust dips at an angle of $40^\circ$ towards Northeast. The Nahan rocks are exposed in the form of a homocline having rolling dips in northeasterly direction. At Kanswala, the Nahan Thrust has brought the Nahan Formation in juxtaposition with the Pre-Siwalik sequence (Map 7).

FIELD DISPOSITION OF THE SIWALIK GROUP

The various lithostratigraphic units of the Siwalik Group exposed between the rivers Ghaggar and Markanda have been mapped by the author on 1:31,680 scale. The field disposition of the three units is discussed herein along the following sections:

i) The Ghaggar River

ii) Meginand-Morni Road

iii) Talokpur-Morni Road
iv) The Run Stream
v) Kala Amb-Nahan Road
vi) Kala Amb-Khajurna Road
vii) The Markanda River

THE GHAGGAR RIVER

Along the Ghaggar River, the Tilokpur Sandstone Member crops out West of village Moginad and remains exposed up to the village Gumthala. At places, the rocks are exposed in the river bed as rifles. On the left bank of the river, South of Nadha Gurdwara, the rocks are locally warped into a syncline. The Sandstone Member comprises poorly indurated and friable, well bedded (PI.II, C), purplish-grey, greenish-grey, pale-grey, pale-brown, and purplish-brown, medium to fine grained sandstones with intercalations of purplish-brown, pale-brown to reddish-brown sandy-clays. The sandstones, at places, are pebbly (Pl.II, D). The various sedimentary structures observed include current-bedding, convolute laminations, ripple marks, load casts and slump structures. The rocks bear vertebrate remains in the neighbourhood of Chauki and Nadha.

Further up stream, about 200 m Northeast of Gumthala, the Tilokpur Sandstone Member is conformably overlain by the Mandhna Conglomerate Member. The change from sandstone facies to conglomerate facies is rather gradual.
The conglomerates, along the Ghaggar River, have a Northwest-Southeast strike, dipping in the northeasterly direction at angles varying from 25° to 32° (Map 1). In the Kalsu Stream and other small streams joining the westward flowing Ghaggar River, the well indurated Mandhna Conglomerate made up of subangular to subrounded boulder to granule-sized fragments of grey, buff and purple sandstone; pink and white quartzites; pale-brown and buff limestones; grey and purple siltstones and shales and dark grey chert are seen overlain by the terrace deposits. The cobble and pebble sized fragments of the conglomerates show an anisotropic apposition fabric and well developed imbrication. Granule-sized fragments show parallel-linear arrangement (Pl.II, E). The well indurated conglomerates bear lenses and beds of sandstones and sandy-clays which frequently bear granule and pebble-sized fragments.

Near Bharal, the bluish-green, dark-purple, purplish-grey, dark-grey and reddish-brown clays and siltstones of the Nahan Formation are seen thrust over Mandhna Conglomerate Member. The thrust junction extends in N 17° W - S 17° E direction and has a northeasterly dip. The throw appears to be of a high magnitude as the Kala Amb Formation (Middle Siwalik) has been altogether obliterated in this section.

The rocks of the Nahan Formation remain exposed along the Ghaggar River up to Dabsu where they are thrust over by the Subathu Formation of the Sirmur Group. The...
thrust is referred to in this work as the 'Nahan Thrust'. It extends in N 56° W - S 56° E direction. The thrust plane dips at an angle of 44° in the northeasterly direction. The rocks are seen badly crushed and brecciated in the vicinity of the tectonic junction.

The various lithological units of the Nahan Formation exposed along the Ghaggar River include pebbly sandstones, fine to medium-grained, well indurated sandstones and purple, reddish-purple, bluish-grey clays/shales/siltstones. Ripple marks, current bedding, slump structures and sole markings are the common sedimentary structures. The clays/shales weather out into nodules.

MOGINAND-MORINI ROAD

In the southern part of this section, the Tilokpur Sandstone Member is covered with Recent alluvium. The pale-brown and greenish-grey sandstones and pale-brown sandy-clays of the Tilokpur Sandstone Member remain exposed along the Moginand-Nadha Road. The rocks have the regional Northwest-Southeast strike, dipping 15° to 20° in northeasterly direction. Nagal and Moginand are well known for yielding rich vertebrate remains.

The road between Nadha and Berwali runs in almost a flat country. Fragmentary remains of vertebrate fossils occur in the weathered sandstones exposed in the neighbourhood of Berwali. About 500 m East of Berwali, the
Tilokpur Sandstone Member grades into Mandhna Conglomerate Member. The beds in the immediate vicinity of the stratigraphic junction do not show any discordance in the direction and amount of dip.

Along Berwali-Morni Road, the Mandhna Conglomerate crops out at a number of places. For most of the distance, the road runs on the top of the hill. The conglomerate sequence has a Northwest-Southeast strike, dipping north-easterly at an inclination varying from 12° to 36°. The composition of the conglomerate does not show much variation from the one described along the Ghaggar River. The type locality of the Mandhna Conglomerate Member is located in this section (Map 1).

At Jansu, the Mandhna Conglomerate Member has a thrust junction with the Nahan Formation. The tectonic junction is referred to as 'Jansu Thrust' after the village Jansu. The thrust runs in N35°W-S35°E direction and the thrust plane dips in north-easterly direction at an angle of 36°. The Nahan sequence remains exposed up to Morni (cf Qidwai and Swarnkar, 1980). The rocks have the regional Northwest-Southeast trend and rolling dips varying from 35° to 60°. The lithology of the Nahan Formation is more or less the same as described along the Ghaggar River. The Nahan rocks are thrust over by the Subathu Formation. The tectonic junction is noticed about
200 m North of Morni. Near the thrust, the rocks are badly disturbed. In the neighbourhood of Morni, the Nahan Thrust follows N32°W-S32°E trend. The thrust plane is inclined at an angle of 48° in northeasterly direction.

TALOKPUR-MORNI ROAD

Near Talokpur*, the Tilokpur Sandstone Member is seen overlain by Recent alluvium. Between Talokpur and Paonta, an alternating sequence of greyish-green sandstones and pale-brown sandy clays is exposed. Near village Paonta, well developed current bedding is noticed in the pale-grey sandstones. The sandstones at places acquire a pebbly nature. The sequence bears remains of vertebrate fossils in the neighbourhood of Talokpur, Paonta and Katli. The ossiferous horizon in the neighbourhood of Talokpur appears to be the eastward continuation of the one exposed at Belwali, Bunga and Kharpurali. The trend of the rocks is Northwest-Southeast, dipping 22° to 30° in northeasterly direction. The rocks of the Tilokpur Sandstone Member remain exposed up to 500 metres Northeast of village Katli where they are overlain by the Nahan Formation. The thrust is the continuation of the Jansu Thrust which follows the

*Talokpur and Tilokpur are different localities (Table 22)
Northwest-Southeast trend and dips 55° in northeasterly direction. The Mandhna Conglomerate does not crop out along the Talokpur-Morni Road (Map 1).

The Nahan rocks remain exposed from South of Banan to North of Morni. The sequence does not show much variation from the one described along the Ghaggar River.

**THE RUN STREAM**

The Run Stream originates in the Sirmur Group and drains the area from Balsar, in the North, to Mirpur, in the South, where it enters the plains. The rocks of the Saketi Formation (Tilokpur Sandstone Member and Mandhna Conglomerate Member) and Nahan Formation are well exposed along the stream.

Following the upstream course, the Tilokpur Sandstone Member is seen covered by a veneer of Recent alluvium near village Mirpur. The sequence has a N20°W-S20°E strike and dips 60° in southwesterly direction. About 200 m upstream, near village Kotla, the beds dip 20° due North and thereafter the northeasterly dips continue for a considerable distance up to near Gularwala.

The Tilokpur Sandstone Member is represented by the lithological units described along the Talokpur-Morni Road. About 200 m upstream of Andheri, the Kandaiwala Stream joins the Run Stream. Further upstream, about 100 m West
of Papri, the Tilokpur Sandstone sequence is conformably overlain by the Mandhna Conglomerate Member, both dipping at an angle of 40° due Northeast. The contact follows the northerly course of the Run Stream for about 400 m before deviating to the Northwest near village Bhogpur.

The Mandhna Conglomerate Member exposed in the Run Stream, Kandaiwala Stream and Tarapur Stream is composed of pebble, cobble and boulder-sized, subrounded to rounded fragments of sedimentary rocks. The megaclast frequently shows imbrication pattern. Near Bariwala and Singhwala, the beds show reversal of dips probably on account of the effect of Jansu Thrust which has brought the conglomerates in juxtaposition with the Nahan Formation (Map 1).

Further North, the Nahan sequence is exposed in the two tributaries of the Run Stream which join near Gularwala. The thickness of the Nahan Formation along this section is considerably less as compared to that in other parts of the area. The Nahan Thrust which separates the Nahan Formation of the Siwalik Group from the Subathu Formation of the Sirmur Group runs more or less East-West between the two tributaries and the thrust plane dips 40° due North.
KALA AMB-NAHAN ROAD

The Kala Amb-Nahan Road runs in a flat country for about 500 m from Kala Amb. In the neighbourhood of village Mainthal, the rocks of the Tilokpur Sandstone Member of the Saketi Formation comprising an alternating sequence of pale-brown and light-purple clays and medium to coarse-grained, poorly indurated, pale-grey, greenish-grey and pale-brown, micaeous sandstone are exposed. The Tilokpur Sandstone Member derives its name from the village Tilokpur located about 6 km Northwest of Kala Amb. Sandstone Member is very well exposed around Tilokpur and justifies the condition of suitability of a type locality.

The Tilokpur Sandstone Member is traversed by an East-West running local intraformational fault. The presence of the tectonic feature is evidenced by the change in the trend of the rocks. The rocks of the Tilokpur Sandstone Member remain exposed with southwesterly dip all along the road up to the knee bend turn where the beds have a northeasterly dip. The anticlinal feature is of local nature. Most of the exposures of the Tilokpur Sandstone Member along this road are highly weathered. Slump structures and graded bedding are common sedimentary structures.

The contact between the Tilokpur Sandstone Member and the Mandhna Conglomerate Member is gradational. Lithologically, the Conglomerate Member is composed of well
rounded and elongated fragments of pale-green, purple, greyish-purple, greyish-white, grey and buff sandstones, pink and white quartzites, pale-brown and buff limestones and dark-grey chert. Lenses of sandstones and sandy clays, imbrication pattern, slump structures and apposition fabric are some of the more common sedimentary features of the Mandhna Conglomerate. The rocks have a Northwest-Southeast strike, dipping 18° to 45° in northeasterly direction. The conglomerates have a thrust junction with the Nahan Formation. The tectonic junction is noticed about one kilometre South of Sainwala. The junction happens to be the easterly continuation of the Jansu Thrust. The thrust plane dips at an angle of 40° in northeasterly direction (Map 1).

In the vicinity of Sainwala, the Nahan Formation comprises fine grained, pale-green, brown, pale-grey, light-grey, buff and mottled sandstones and reddish-brown, purplish-grey and dark-purple clays/siltstones. The sandstones, at places, acquire pebbly nature (Pl.II, F). Local folding is seen at some places (Pl.III, A).

The Nahan rocks of the type locality bear a variety of sedimentary structures including current-bedding, colour banding, laminites, horizontal laminations, graded bedding, load casts, organic markings, parting lineations, ripple marks and mud cracks. The trend of the Nahan rocks near
Ambwala is N70°W-S70°E, dipping in N20°E direction at an angle of 40°. Further, along the road, the Nahan rocks remain exposed up to the bifurcation of the road to Dehra Dun and further beyond.

From the bifurcation of the road up to the Nahan town, the outcrops are mostly covered by settlements, vegetation and rock debris. North of the town, however, the rocks are well exposed along the Nahan-Simla Road. In this section, the Nahan sequence has a N70°E-S70°W strike, dipping in N20°W at angles varying from 25° to 70°. The trend continues almost all along the road up to the Nahan Thrust. The purple clays bear streaks and patches of bluish-green clays. The sandstone-clay sequence shows laminite structure. Near the Nahan Foundary, well preserved mud cracks are seen in the pale-brown sandstones. Presence of gullies is a common feature to note. Near Banog, current bedding and colour banding are seen in the purplish-grey sandstone.

Three hundred metres uphill of Banog, the purple clays and greyish-brown sandstones of the Nahan Formation (Middle Miocene) are overlain by pale-green and pale-brown shales of the Subathu Formation (Paleocene-Eocene). The tectonic contact is referred to in this work as 'Nahan Thrust' which is synonym of the Main Boundary Fault of Medlicott (1864).
KALA AMB-KEAJURNA ROAD

Kala Amb is located on the terrace deposits of the Markanda River. In the river bed and deep cuttings, however, the rocks of the Kala Amb Formation (Middle Siwalik) are exposed. In the type locality, the sequence comprises pale-green, dirty-white, greyish-white, buff and salt-and-pepper sandstones and pale-brown, greenish-grey and chocolate clays/siltstones. The sandstones bear concretionary bodies and pebble-sized fragments of undecomposed parent rocks. The more common sedimentary structures noticed in the rocks of the Kala Amb Formation include massive bedding, horizontal laminations, cross-bedding, graded bedding, load casts, ripple marks, mud cracks and calcareous concretions.

The Kala Amb sequence is seen very well exposed in the tributaries of the Markanda River, especially in those located to the East and Southeast of Kala Amb. At places, local folding and faulting is noticed (Pl.III, B).

Along the Kala Amb-Khajurna Road, about 200 m from the bifurcation of the road to Yamuna Nagar, the salt-and-pepper sandstones of the Kala Amb Formation pass conformably into pale-brown sandy-clays of the Saketi Formation (Upper Siwalik). The trend of the rocks of the two formations is N80°W-S80°E, dipping 35° in N10°E direction. The Tilokpur sandstone sequence comprising greyish-white,
medium to fine-grained, moderately indurated sandstones having thin intercalations of pale-brown and pale-grey clays is exposed along the Kala Amb-Khajurna Road up to the North of Pipalwala.

At the Saketi Fossil Park, the rocks of the Tilokpur Sandstone Member comprising poorly indurated, medium to fine-grained, pale-grey, greyish-purple and pale-brown sandstones and pale-brown and light-purple sandy-clays are exposed. The trend of the rocks is N70°E-S70°W, dipping at an angle of 10° in the southeasterly direction.

The Saketi Fossil Park is one of the National Fossil Parks developed by the Geological Survey of India in order to preserve the fossil sites and reconstruct the environments in which the Siwalik mammals lived. Some of the important vertebrate fossils found in the neighbourhood of Saketi include Dicoryphochoerus, Hexaprotodon, Sivatherium, Stegodon ganesa, Stegodon bombifrons, Equus, Paramachaenodus, Colossoschelys atlas, and remains of some Rhinocerotids and Suids. Life size models of Hexaprotodon, Sivatherium, Stegodon ganesa, Paramachaenodus and Colossoschelys atlas have been placed in the Saketi Fossil Park.

For most of the distance between Saketi and Pipalwala, the road follows the strike of the beds. About 300 m North
of Pipalwala, on the Kala Amb-Khajurna Road, the rocks of Tilokpur Sandstone Member pass conformably into those of the Mandhna Conglomerate. The beds of the two formations in the immediate vicinity do not show any discordance in direction and amount of dip. The conglomerates remain exposed along the road up to near Dhaduwala with more or less the same lithology as noticed along the Kala Amb-Nahan Road.

The Mandhna Conglomerate has a thrust junction with the Nahan Formation. The tectonic junction is the easterly extension of the Dansu Thrust. The Nahan sequence along this section comprises dark-grey and greyish-purple, fine-grained, well indurated, sandstones and purple and mottled clays. Badlands are noticed at a number of places along the road and in the valleys. The sandstone is current-bedded. The Nahan sequence remains exposed up to Khajurna and further beyond.

**The Markanda River**

In the neighbourhood of Kala Amb, salt-and-pepper sandstones and chocolate clays of the Kala Amb Formation crop out in the river cutting. After about 100 m in the upstream direction, they are seen conformably overlain by the Tilokpur Sandstone Member of the Saketi Formation.

In the river section, the quality of exposures is far better than the one noticed along the Kala Amb-Saketi
Road. The well bedded, sandstone-clay sequence of the Tilokpur Sandstone Member shows laminite structure. At places, natural rifles are noticed in the river bed. North of Bambuwala, an East-West running fault traverses the Tilokpur Sandstone sequence. The crushed and brecciated nature of the rocks and conspicuous variation in the trend of the beds is very clearly visible in the Markanda River section. The anticlinal axis passes through the confluence of the Sallani Stream and the Markanda River (Map 1).

Between Khera and Pipalwala, the exposures are not good. For most of the distance, the rocks are covered by dense forest. From Pipalwala onward up to Khajurna, the Markanda River follows closely the Kala Amb-Khajurna Road, the geological setting of which has already been discussed in the preceding section.

From Khajurna onwards, the River takes an easterly turn up to Shambuwala where the Patwas stream joins it. The Nshan Formation comprising typical greyish-purple and greenish-grey sandstones and purple clays, remains exposed for about one kilometre in this section. The sequence is covered by terraces of the Markanda River which nearly obliterate the exposures of the Nshan Formation up to one kilometre East of Shambuwala. The river terraces are made up of granule to boulder-sized, subangular to
subrounded fragments of pale-green, purplish-grey and purple sandstones; pale-grey, dark-grey and purple shales and buff and pale-brown limestones. The beds are almost horizontal.

In the Patwas Stream, the Nahan rocks are very well exposed. The beds have the regional northeasterly dip, the amount varies from $20^\circ$ to $40^\circ$. North of Katli, the Nahan rocks are seen thrust over by the carbonaceous and olive-green shales of the Subathu Formation. The tectonic contact is the easterly extension of the Nahan Thrust (Map 1).