It is now being increasingly felt that the fossil material should not only be studied for taxonomic and phylogenetic consideration but should also help in the understanding of palaeoecological and palaeoenvironmental situations. Such an approach gains significance when we treat the problem of organic evolution against the background of palaeoecological niches. Consideration of various fossils through a palaeoecological framework enables us to study them as individuals of a once living community sensitive to its surroundings. Much as the present day ecology pertains to the relationships of the
living organisms with their environment, palaeoecology is concerned with the relationship between organisms of the geologic past and their life medium. Palaeoecology may be defined in simple terms as the study of "how and where animals and plants lived in the past" (Ager, 1963).

In literature palaeoecological studies appear to be organised at two different levels, viz., individual and population. The first type of study has been termed as palaeoautoecology and the second type as palaeosynecology. Palaeoautoecology is devoted to a single species, usually stressing the mode of life, functional morphology, population structure and adaptation to environment (Imbrie and Newell, 1964). Palaeosynecology is a study of whole communities and is essentially the synthesis of what we know of the autoecology of all the species making up the community (Ager, 1963). Palaeoecological conclusions should best be avoided on a single form. For authentic palaeoecological reconstructions inferences should be drawn from the characteristics of the fauna as a whole.

Hutton's dictum of uniformitarianism (present is key to the past), which forms the basis of geological reasoning, is equally applicable to palaeoecology. The past life can be interpreted to a certain degree by comparison with extant life, in the same way as we interpret the geologic past with reference to the present day natural geological processes. Inspired guesses as to
the life mode of a fossil form can be made with reference to its nearest living relative. This principle has its limitations. Though, the physical processes operational today might have prevailed in the same manner in the past, but the organisms might have changed. Therefore, uniformitarianism is to be used with caution and preferably in combination with evidences drawn from functional morphology, sediment studies and taphonomy. Even the employment of all these evidences allows only very rough estimate of the palaeoecosystems.

Knowledge of what is now known as palaeoecology can be traced back to ancient Greeks like Xenophanes, Xanthos and Herodotus who 500 years B.C. had recognised fossil sea shells as evidences of former marine incursion in parts of Italy, Asia minor and Egypt (Vide Hecker, 1963). During most of the following twenty centuries, palaeoecology made little headway till Leonardo da Vinci (1452-1519) recognised the importance and a means to distinguish between life associations and death assemblages when he wrote that paired fossil bivalves are evidence of live burial and separate shells imply post mortem movement. However, it was in the 18th and 19th centuries that palaeoecological studies actually began. Among the founding fathers of palaeoecology mention may be made of Marsigli (1658-1730), Milne Edwards (1800-1885), Forbes (1815-1854) and Kovalevskiy (1842-1883). A brief history
of palaeoecology occurs in the 'Treatise in marine Ecology and Palaeoecology', the second volume of which (Ed. H.S.Ladd, 1957) deals with marine palaeoecology.

There exist a number of papers on plant and invertebrate palaeoecology, whereas very limited reports focus on vertebrate palaeoecology. Mook (1916), Matthew (1939), Efremov (1940), Olson (1948, 1952, 1957), Myers (1949), Kurten (1953), Romer and Olson (1954), Romer (1955), Shotwell (1955, 1963) and Konizeski (1957) are some of the early workers who concentrated mainly on vertebrate palaeoecology. Among the students of mammalian palaeoecology mention may be made of Clark et al. (1967), Voorhies (1969), Dodson (1971, 1973), Behrensmeyer (1975, 1976, 1977), Boaz (1977), etc.

Sivalik Palaeoecology:

In spite of the rich assemblages of fossil vertebrates, especially mammalian, known from the Sivaliks since the last century, the record of palaeoecological work on these deposits is meagre. Barring a few, almost all the reports on these sediments deal with systematics of fossils, while the palaeoecological reconstruction has been virtually ignored. Krynine (1937) was perhaps the first worker who attempted to interpret the environment of deposition of Sivaliks on the basis of a petrological study of rock samples from the Indian subcontinent.
Efforts to elucidate the ecology of fossil hominoids from Sivaliks were made by Tattersall (1969a, 1969b) who, while discussing the palaeoecology of Ramapithecus, laid more stress on Nagri palaeoecology. Similarly, Prasad (1971), while describing the ecology of Ramapithecus, also emphasised the palaeoecology of Nagri Formation. In a later paper, Prasad (1975) remarked on the palaeoecology of Chinji, Nagri, Dhokpathan and Tatrot Formations of Sivalik Group, while dealing with the palaeoecology of South Asian Tertiary Primates. First serious effort to describe the environment of deposition of Pinjor Formation of Upper Sivaliks was made by Halstead and Nanda (1973). They studied a Pinjor section and differentiated eight cyclothemes from the lower part of Pinjor Formation.

Recently, Gaur et al. (1978) gave a new direction to Sivalik palaeoecology by studying the Upper Sivalik palaeocommunities from the Indian subcontinent. Studies on fossil communities from the Middle Sivaliks were conducted by Vasishat et al. (1978). Very recently Vasishat et al. (in press) have also attempted to elucidate the ecology and community structure of Lower Sivalik fossil assemblages from the Indian subcontinent. From the foregoing, it is clear that the Sivalik palaeoecological study is still in its infancy and much remains to be done in this regard.
The reconstruction of the environment and ecology of the Upper Sivalik deposits exposed in the northeast of Chandigarh has been approached here from geological, taphonomical and biological angles to extract the maximum information. The geological investigation aims at reconstructing the depositional environment while the taphonomical and biological studies are devoted to the palaeoecological interpretation of the data.

**Sedimentary Environments:**

The study of the sediments which enclose the fossils is a very useful tool for palaeoecologists. This is perhaps the direct way to have an idea of the environment in which the organisms thrived. A study of the past ecology of the fossil assemblages detached from the depositional environment leaves a wide and conspicuous hiatus in any palaeoecological investigation.

Much has been said about the fossil vertebrates from the Upper Sivalik deposits exposed in the northeast of Chandigarh, but little is known about the ecological conditions and depositional environments during that time. Besides the works of Sahni and Khan (1964), and Halstead and Nanda (1973), who to a certain extent took up this
To obtain environmental data for the present work a number of local sections around various fossil localities from all the three Formations of Upper Sivaliks were examined. Most of the information regarding the interpretation of sedimentary environments was collected in the field. Fresh hand specimens of the rocks were also collected to extract specific information on some sedimentological parameters after analysis in the laboratory. Besides other things, special attention was laid on the sedimentary structures, lithology and invertebrate fossil content of the local sections examined. Sections depicting the local stratigraphic order of sediments, sedimentary structures, invertebrate and vertebrate fauna and also the microfloral content are presented in Text Figures 4 to 19.

**Tatrot Formation:**

Sections of Tatrot Formation were examined at Naipli and Masol.

Section A₁ (about 1 km east of Masol):

The base of the section starts with a brownish clay bed which is about 6 meters in vertical thickness and is succeeded by a thin sandstone unit starting as medium grained greyish sandstone and grading into dirty
orange fine grained sandstone (Text Fig.4). The base of this sandstone unit is marked with load casts, which might have resulted due to the sand deposition on a hydroplastic clay layer (Reineck and Singh, 1973). Small amounts of grit is dispersed in this sandstone unit. The orangish sandstone vertically gives way to about 4 meter thick brownish clay unit. The next sequence commences as a thin band of medium sandstone, with pebbles at its base, giving way to fine sandstone and reddish brown clay upwards. The following sandstone unit displays gravel upto half its thickness and then passes into dirty orange silt which is marked with a network of desiccation fissures indicating definite sub-aerial exposure. The fissures are V-shaped in cross-section and are in general about one millimeter wide. This silt bed is topped by about 4 meter thick bed of chocolate clay followed up by medium grained greyish sandstone which shows small scale trough cross-bedding near its top. The next member is brownish clay which is followed vertically by about 1.5 meters of conglomerate. The conglomerate bed probably marks the base of Pinjors. The following bed is a dirty grey coarse grained sandstone topped by Subrecent to Recent deposit. The vertebrate fossil material from this section includes parts of turtle carapace, maxillary fragments, isolated teeth and horn-core of Leptobos, and dental fragments of Stegodon and Hexaprotodon. On the whole the Tatrot units
of this section show a dominant clay lithology and subordinate sandstones with grit or pebbles dispersed here and there. The grit, pebbles and coarse sands were probably deposited in channels and the silts and clays in the flood-plain. The dominant lithology, i.e., silts and clays, of the Tatrot units of this area point towards flood-plain environment for Tatrots in this section. The base of Pinjors, which is marked by a conglomeratic bed followed by coarse sand, appears to be the part of a channel sequence. The thick conglomeratic bed of basal Pinjors suggests a high energy regime with greater discharge and change in gradient probably caused by a small scale uplifting in the source area at the end of Tatrots.

Section A2 (about 0.75 km northeast of Masol):

This local section exhibits exclusively the Tatrot units represented by medium to fine grained sandstones, silts and clays (Text Fig.5). The base of the section is marked by about 4 meter thick unit of reddish brown clay followed by about 3.5 meters of dirty yellow fine grained sandstone which is overlain by about 2.5 meters of greyish silt. The silt layer is followed by medium grained light grey sandstone which is succeeded by a grey clay unit. The middle portion of the light grey sandstone bed displays small scale trough cross-bedding. About 6.5 meters thick fine grained yellowish grey sandstone, with
load structures at base, overlies the grey clay. The topmost bed is yellowish grey silt. A major portion of the section constitutes fine sand, silt and clay which probably represent the overbank deposits of a floodplain. The reddish brown clay at the bottom of the section and the greyish silt yielded mammalian fossils including isolated teeth and bone fragments of Archidiskodon and Leptobos.

Section A3 (about 0.5 km east of Masol):

The lowermost bed of this section is about 3.5 meter thick medium grained sandstone which becomes fine towards the top and gives way to a thin bed of dirty orange silt which displays a network of polygonal desiccation fissures (Text Fig.6). These fissures are roughly V-shaped in cross-section and upto one millimeter in width. The occurrence of these fissures strongly suggests sub-aerial exposure (Selley, 1970; Reineck and Singh, 1973). About three meter thick light brown clay unit with a few root casts overlies the silt layer and is inturn overlain by a greyish sandstone unit of about 1 meter thickness. The next two units are about 2 meters of brownish clay topped by about 1.5 meters of dirty grey silt. The top of the section displays Subrecent to Recent deposits. The basal medium grained sandstone is comparable to the point bar sands and the rest of the clay and silt units are perhaps the sediments deposited
in a flood-plain. The brownish clay near the top of the section has yielded isolated teeth of *Leptobos* and *Hexaprotodon* and the underlying sandstone produced dental fragments of *Sus*. The dominant lithology of this section is clay and silt. Thus, a major portion of this section was deposited as overbank sediments in a flood-plain.

All the three local sections exposed in the east of Masol were deposited in a flood-basin except for some sandstones with gravel in Section A₁ (Text Fig.4) and medium sandstone in Section A₃ (Text Fig.6) which could be the point bar sediments. In general, the sands are deposited in point bars and the finest sands, silts and clays are deposited during the seasonal floods when the river overflows their banks and inundates the surrounding flood-plain.

Section B₁ (about 0.15 km south of Naipli):

This section exhibits both the Tatrot and Pinjor sediments. The Tatrot sediments display sequences starting with sandstone which become finer upwards and eventually end in clay or silt (Text Fig.7). The base of the section is marked by about 3.5 meter thick chocolate clay bed. The next unit is about 2.5 meters of light grey sandstone which displays small scale cross-bedding near the top and then gives way to grey clay. The next cycle starts with a grey sandstone bed displaying load structure
at the base and ends in light brown clay bed which is overlain by about 1.5 meter thick grey sandstone. This sandstone bed is succeeded by chocolate clay unit. The last succession of Tatrot sediments in this section commences with a thick unit of grey sandstone which gradually changes into grey siliceous clay near the top. The next bed is about 1.5 meter thick conglomerate which probably marks the beginning of Pinjors. In this respect, this section resembles section A₁ (Text Fig.4) which also displays a similar conglomeratic bed at the base of Pinjors. The succeeding unit is about 5 meter thick bed of coarse grained yellowish grey sandstone. An overall view of this section reveals four fluvial cycles of Tatrot beds deposited in a flood-plain environment with clays and silts as overbank sediments and sandstones as point-bar sands. The vertebrate fossils from this section include, isolated teeth and associated bones of equids and bovids which do not show much signs of rolling but display cracks which are filled by sediments. The occurrence of conglomeratic bed at the base of Pinjors is suggestive of a high energy flow regime either due to increased discharge or increment in the gradient as a result of the earth movement of local magnitude. The latter view appears more acceptable in view of the suggestions of an orogeny at the end of Tatrots by Krishnan (1960). On the whole the Tatrot beds represent a low energy environment.
Pinjor Formation:

Sections of Pinjor Formation were examined for various palaeoenvironmentally significant geological aspects at Mirzapur, Siswan, Tipparian, Jainti Majri, Parach and Nadah.

Section C₁ (about 3 km east of Mirzapur):

This section starts with a 2 meter thick dirty brownish yellow silt which is succeeded by about 1.5 meters of dirty grey coarse grained sandstone lying on a scoured base (Text Fig.8). The basal part of the sandstone bed displays gravel and exhibits trough cross-bedding. Upwards, this sandstone grades into brownish yellow silt which is followed by a relatively thin bed of medium grained brownish yellow sandstone exhibiting load structures at its base. This brownish yellow sandstone grades into about 2 meter thick unit of brownish yellow silt which is followed, upwards, by chocolate clay. The gravel at the base of the dirty grey sandstone bed represents the bottom lag deposit of the shifting channel and the subsequent units of medium sand, silt and clay occur in a fining upward sequence. The fining upwards nature, from gravel to silt, suggests a point bar deposit (Allen, 1970). The remaining units of the section display two cycles of upward fining sediments. Each cycle starts with a thin unit of fine grained sandstone grading into
comparatively thicker units of silt followed by clay. The sediments of these two cycles, chiefly consisting of silts and clays, are comparable to the fine sediments deposited by the overbank flow in a flood-basin. The top of the section is covered by Subrecent to Recent deposits. The lower portion of the section is comparable to the point bar of a shifting channel and the upper one third resembles the flood-plain deposits. The flood-plain silts of the upper one third of the section have yielded cracked and partially leached teeth, mandibular fragments and postcranial bones of *Equus*, *Sus* and some bovids. Some of the postcranial bones are in the articulated position at the joint portion, probably due to drying of the tendons. These bones do not show signs of abrasion or rolling. All these characters also suggest a flood-plain environment for the upper one third of the section.

Section C2 (about 1.25 km east of Mirzapur):

The base of this section is occupied by about 3 meter thick unit of chocolate clay which is overlain by a coarse grained grey sandstone (Text Fig.9). The chocolate clay has yielded isolated teeth of *Equus*. The grey sandstone lies on a scoured surface and displays large scale trough cross-bedding that can be compared with 'P1' or 'Nu' type of cross-stratification of Allen (1963).
According to him these type of structures develop due to the migration of large-scale asymmetrical ripples. The evidences favour a channel origin of this sandstone unit. The succeeding unit is about 1.5 meter thick gravel bed, with a scoured base, which displays large-scale trough cross-bedding similar to the previous bed. The gravel also contains round to oval mud balls which were probably eroded from the underlying clay unit or from the undercut of the river. The maximum size of the mud ball was about 15 to 20 centimeter in diameter. The occurrence of mud balls suggests shorter transportation. This gravel unit, which occurs in the form of a large lens with limited lateral continuity, is definitely a bottom lag deposit of a channel. The vertebrate remains from this bed include isolated teeth of Equus and Bos, ends of metapodia plus other long bone ends of some large bovids, vertebrae, and dermal plates of turtles. The bones and teeth are slightly rolled but the turtle remains are untouched by abrasion. Probably these bones and teeth were deposited at the point bar. The animals that are represented in this bed probably inhabited the adjacent flood-plain as is evident from little transportation of the bone material. The next unit is about 3 meter thick coarse grained yellowish grey sandstone which is followed by about 1.5 meters of chocolate clay. These two beds are probably the point bar sands and clays. The last bed is coarse grained grey sandstone of about 2.5 meter
Section $C_2$ (about 0.5 km east of Mirzapur Rest House):

This section starts with about 2.5 meter thick chocolate clay bed which is followed by about half meter of gravel displaying small clay pebbles (Text Fig.10). The next unit is 4 meters of coarse grained dirty grey sandstone which shows fining upward tendency and is succeeded by about half meter of gravel with clay pebbles. The succeeding coarse grained yellowish grey sandstone is about 1 meter thick and exhibits small scale trough cross-bedding. This bed is followed by about half meter thick gravel bed with clay pebble inclusions. About 8 meter thick coarse grained sandstone unit, with small pebbles distributed here and there, follows the gravel bed and displays large scale cross-bedding comparable to the 'Pi' or 'Nu' cross-stratification of Allen (1963). This sandstone grades into about 6 meter thick silt unit which in turn gives way to about 7 meters of chocolate clay. The chocolate clay is followed by about 2 meters of cross-bedded coarse grained grey sandstone which is pebbly at its scoured base. The last two units of this
section are a thin gravel bed with clay pebbles and about 1 meter thick cross-bedded grey sandstone unit.

This section displays at least two complete and one incomplete fluvial cycles, each of them commencing with gravel and grading into coarse sandstone, fine sandstone or silt and finally clay. The top cycle is incomplete and only sandstone is deposited. The dominant lithology of the section is gravel and coarse sandstone which represent the bottom lag deposits and point bar deposits, respectively, of a channel. On the whole a major portion of this section appears to be deposited in a channel sequence of a meandering river. The vertebrate remains from this section include mandibular fragment of *Coelodonta* from the basal greyish sandstone. The thick cross-bedded grey sandstone of the second fluvial cycle yielded slightly rolled isolated teeth and ends of metapodial bones of *Equus* and *Bos*, and turtle carapace parts which were deposited along with the point bar sands. The succeeding silt bed yielded unrolled and better preserved teeth and metapodial of *Equus*.

Section D (west of Tipparian):

This section has at its base about 4 meter thick bed of coarse grained brownish yellow sandstone which is followed by about 2.5 meters of brownish yellow silt (Text Fig. 11). The next unit is about 2 meter thick bed
of yellowish grey medium grained sandstone which becomes siliceous at the top and is succeeded by about 1.5 meters of brownish yellow clay. These beds may be the last phases of a point bar deposit as is evident from the upward fining of the sediments. The sandstones have yielded slightly rolled teeth of Equus, Bos, fragments of molar plates of Elephas and Archidiskodon, and turtle remains. It appears that these remains were deposited, after some transportation, at the point bars by the laterally shifting stream channel. The remaining units of this section are three repeated sequences of fine sand, silt and clay occurring in the fining upward order with basal fine sandstones, intermediate silts and top clays. The fossils recovered from these units are leached bones, cracked teeth of small to large bovids and equids. These fossils do not show any sign of pre-depositional rolling indicating little or no transportation. The silt and clay of the second sequence possesses tubular structures resembling the root holes rimmed by silt. These features suggest a flood-plain environment for the upper half of the section while the lower half of the section resembles the point bar deposits of a channel during lean periods with medium to low energy regime. The top of the section is occupied by Subrecent to Recent deposits of siliceous clay with small blocks of sandstone embedded in it.

Section E* (about 2.5 km east-southeast of Siswan): About 7 meters of brownish yellow clay marks the
base of this section (Text Fig. 12). The following unit is about 2 meters of gravel lying on a scoured surface. This gravel bed, resembling the bottom lag deposit of the channel floor, is marked with lenses of dirty grey sandstone which can be assigned to the point bar deposit. The gravel bed is followed by a thick bed of dirty grey to yellowish grey coarse grained sandstone which is about 11 meters thick. This sandstone unit displays about 15-20 centimeter thick layers of silt and clay which have limited lateral continuity and are marked with load structures on their top, probably caused by the deposition of the overlying sandstone when the clay was still in a plastic state. This sandstone is succeeded by brownish yellow silt which grades into brownish yellow clay. This sequence of gravel, sandstone, silt and clay resembles the fining upward sequence encountered at the point bar deposits of meandering rivers. The succeeding units are alternating beds of fine sand and clay. The fine sand changes to clay, through silt, resembling the deposits of a flood-basin. The top bed is dirty yellow sandstone covered by Subrecent to Recent debris. The vertebrate fossils from the channel sand include bovid teeth and fragments of molar plates of Stegodon and Archidiskodon which display some signs of rolling and hence transport. The mammalian fossils from the overlying silt are unrolled and better preserved.
Section $E_2$ (about 1 km north of Siswan):

It is a small section and comprises alternating beds of fine sandstones and silts (Text Fig. 13). At the base, there is about 2.5 meter thick unit of brownish yellow silt which is followed by about 2 meters of fine grained dirty yellow sandstone. About 3.5 meter thick bed of brownish yellow silt follows the dirty yellow sandstone and displays a few small tubular structures resembling the root holes. The next unit is about 2 meters of fine grained dirty yellow sandstone which is overlain by about 1.5 meter thick brownish yellow silt layer. The fossil material from this section includes bovid mandibular fragments, isolated teeth, vertebrae and parts of ribs from the lower most sandstone and isolated bovid teeth and *Cervus* antler fragments from the overlying silt bed. The teeth and bones are cracked and leached. The main lithology of this section is brownish yellow silt. All these characters suggest a flood-plain environment for this section.

Section $F_1$ (about 1 km north of Jainti Devi Temple):

This section starts with about 9 meter thick unit of brownish yellow clay which is overlain by about 1.5 meters of fine grained dirty yellow sandstone (Text Fig. 14). The next unit is about 3.5 meters of chocolate clay which is followed by medium grained grey sandstone. The base of this sandstone bed displays load structures, pointing towards the gravitational instability of the two units before
lithification (Allen, 1970). The succeeding bed is dirty orange silt which grades into about 2.5 meter thick bed of chocolate clay. The chocolate clay is topped by about 1 meter thick bed of dirty grey sandstone followed by about 3 meters of yellowish grey clay. The next bed is about 1 meter thick greyish siliceous clay. This siliceous clay bed has yielded a number of microfloral and microfaunal remains besides gastropods and unionids. The microflora is represented by charophytes namely, *Sphaerochara* and *Chara*, and the microfauna by ostracodes, viz. *Ilyocypris*, *Zonocypris* and *Candonia*. The occurrence of these fossils indicates an environment with little movement of water. These conditions approach lacustrine type of environment, probably an oxbow lake, overbank pond, or an abandoned channel. The greyish nature of the sediments containing abundant organic matter suggests reducing conditions (Reineck and Singh, 1973), probably due to poor drainage. The mammalian fossils from this section include molar plate fragments of *Archidiskodon* from the lowermost sandstone bed and *Cervus* antler fragments, bovid podial bones and isolated teeth from the next grey sandstone bed. The dominant lithology of the section is fine sandstone, silt and clay which suggest that a major portion of the section was deposited in a flood-basin with occasional overbank ponds.
Section F (about 0.75 km northwest of Jainti Devi Temple):

Both the Pinjor and Boulder Conglomerate Formations are exposed in this section which starts with about 1.5 meters of fine grained siliceous dirty yellow sandstone, followed up by about half meter of brownish yellow clay (Text Fig.15). The next unit is dirty grey medium grained sandstone which grades upwards into brownish yellow silt. About 3 meter thick unit of coarse grained grey sandstone follows the brownish yellow silt and is in turn succeeded by about 4.5 meters of brownish yellow clay. Overlying this clay bed is about 3.5 meters of yellowish grey medium grained sandstone which gives way to brownish yellow silt. The succeeding unit is about 4 meter thick conglomeratic horizon which is poorly sorted with grain size varying from silt to boulder. This bed is marked with large lenses of coarse grained greyish sandstone. The next unit is brownish yellow silt displaying sandstone lenses. A conglomeratic bed overlies this brownish yellow silt. The dominant lithology of the Pinjor Formation in this section is medium to coarse grained sandstone which changes into silt or clay, upwards. Probably, the sands were deposited at the point bars, and the silts and clays as flood-plain subfacies. The Boulder Conglomerate Formation is dominated in this section by conglomeratic beds with sandstone lenses. The occurrence of conglomerates suggests earth movements in the source area. The frequently occurring sandstone
lenses in gravel represent the point bar deposits of highly braided rivers with repeated channel switching. The subordinate silts were perhaps deposited during periods of overbank flows. The illsorted conglomeratic beds are the bed load deposits. All these characters point towards the deposition of the Boulder Conglomerate Formation as alluvial fans, suggesting a change in slope and a tectonically active area (Reineck and Singh, 1973). Such structures are best developed in arid to semiarid and subarctic regions (Reineck and Singh, 1973).

Section C (about 1.5 km east of Parach):

The base of this section shows about 1.5 meter thick dark grey silt bed with abundant organic matter (Text Fig. 16). This bed yielded a rich collection of microfossils, invertebrates and fish material. Among the microfossils, the charophytes and ostracodes are profusely represented. *Sphaerochara, Chara, Hornichara* and *Nitellopsis* are the charophytes, and *Candona, Illyocypris, Zonocypris* and *Potamocypris* are the ostracodes recovered from this bed. Besides these, a number of gastropod shells and small seluroid fish material was collected. The occurrence of dark grey colour and lot of organic material is suggestive of reducing conditions (Reineck and Singh, 1973) which generally prevail in standing water or in regions of poor drainage. Many ostracode carapaces with both the valves
intact were recovered, which suggest little or no currents in the depositing medium. The occurrence of charophytes also suggests standing or slow moving water. The above evidences point towards a lacustrine type of environment for this bed which could be an over-bank pond or an abandoned channel. The grey siliceous clay is followed by a brownish yellow clay unit which displays thin laminations, each measuring about two or three millimeters in thickness. The occurrence of thin laminations suggests lacustrine conditions and also the seasonal deposition for each lamination. The laminated clay unit is followed by about 1.5 meters of dirty grey fine grained sandstone which grades into greyish yellow silt. The next unit is about 2 meters of brownish yellow clay which is succeeded by about 3 meter thick fine grained greyish sandstone bed exhibiting load structures at its base. This greyish sandstone grades into yellowish brown silt and clay. The following bed is yellowish grey sandstone which gives way to brownish yellow clay bed through an intermediate silt unit. The mammalian fossils from this section include a few dental fragments of *Hexaprotodon* from the lowermost sandstone bed. The dominant lithology of this section is clay and silt. The above evidences suggest that the lower part of this section was deposited in an overbank pond or an abandoned channel while the upper three fourth was deposited in a flood-plain, as is indicated by the general dominance of fine sediments.
Section H₁ (about 0.2 km west of Nadah Sahib Gurudwara):

This section starts with about 6 meter thick unit of coarse grained greyish sandstone which contains grit sized particles dispersed in it (Text Fig.17). The succeeding unit is 5.6 meters of coarse grained greyish sandstone. The following brownish yellow clay unit is comparatively thin and is succeeded by about 7 meters of coarse grained yellowish grey sandstone which is pebbly at its base and also displays load structures indicating the plastic nature of the underlying clay when this sandstone was deposited. Upwards, this sandstone unit gives way to brownish yellow clay via fine grained yellowish grey sandstone. The succeeding bed is coarse grained grey sandstone having pebbles at the base. Large scale trough cross-bedding was observed in this bed which compares well in morphology with 'Pi' cross-stratification of Allen(1963). According to him this type of cross-bedding results from the down stream migration of large-scale asymmetrical ripples. This bed is overlain by a thin unit of brownish yellow clay which is followed up by coarse grained greyish sandstone displaying pebbles at its base. The coarse grained sandstone is succeeded by about 1.5 meter thick brownish yellow clay bed. It seems that this section was deposited in at least five successions, each starting with coarse sandstone, generally with a pebbly base, gradually changing to clay through fine sandstone or silt. Such
fining upward sequences are typical of point bar formations of meandering rivers (Allen, 1970). It is likely that the pebbles were deposited as bottom lag deposits of the channel floor and much of the sand was deposited in the point bar formed by the lateral migration of the channel bend of a meandering river. The clays were probably deposited from the suspension. On the whole, a major portion of this section was deposited as channel lag or point bar deposits. The vertebrate fossils from this section include teeth and bones of _Bos_, from the lowermost sandstone, showing some signs of rolling. The fragments of _Rucervus_ antlers and _Equus_ teeth, podial bones, metapodial bone ends, recovered from the second sandstone unit, are neither rolled nor cracked indicating their immediate burial. _Sus_ and _Hexaprotodon_ teeth from the overlying clay unit are cracked and leached suggesting exposure before burial. The next sandstone unit yielded rolled _Equus_ and _Coelodonta_ dental and postcranial material, and unrolled _Stegodon_ molar plate fragments. Mammalian fossils from the topmost sandstone bed include teeth and metapodia of bovids and _Equus_. The teeth, podial bones, and metapodial bone ends in most of the sandstones of this section show signs of some transportation before their burial in the point bar sands of channels.

Section H2 (about 0.2 km west of Nadah):

The base of this section is marked with about 3 meters
of coarse grained dirty grey sandstone which shows upward fining, and is succeeded by about 7 meters of chocolate clay (Text Fig. 18). The sandstone yielded rolled isolated teeth and podial bones of Equus and bovids. From the chocolate clay were recovered jaw fragments, horn-cores, and ends of bones. Isolated teeth of Rhinoceros, and a jaw fragment of a small carnivore, viz. Vishnuictis, were also recovered from the chocolate clay. Some of the teeth and bones show cracks and signs of leaching due to constant exposure before burial. It seems that these bones were little transported before they were covered by sediments. The next member is about 6 meter thick bed of coarse grained dirty grey sandstone which is followed by about 1 meter of grey siliceous clay. The base of the dirty grey sandstone shows load structures indicating gravitational instability of the two layers before lithification (Allen, 1970). This sandstone unit yielded isolated teeth and a metapodial bone and of Sivatherium, isolated tooth of Sus and cervid antler fragments. The grey siliceous clay produced molar plates of Archidiskodon. The succeeding unit is coarse grained yellowish grey sandstone which in its upper one third displays a cross-bedded channel of coarse grit. This unit is followed by about 1 meter of yellowish grey clay which in turn is vertically succeeded by about 4 meter thick bed of coarse yellowish grey sandstone. The top of this section
is covered by a relatively thin layer of Subrecent to Recent deposits. The greater portion of this section is constituted by coarse sandstones which were probably deposited at the point bars of the river. The grits represent bottom lag deposits of the channel. The clays were deposited as over-bank deposits. On the whole, greater portion of the section resembles point bar deposits of a channel.

Boulder Conglomerate Formation:

Section $C_4$ (west of Mirzapur):

This section is characterized by alternating beds of conglomerate and siliceous clay (Text Fig. 19). The section starts with about 1.5 meters of conglomerate with grain size varying from silt to boulder. This bed is marked with lenses of siliceous clay. The next unit is about 2 meters of siliceous clay followed by about 2 meters of conglomerate which exhibits siliceous clay lenses. The next member is again a brownish yellow siliceous clay bed which is succeeded by about 3 meter thick conglomeratic unit displaying prominent siliceous clay lenses and load structures. The following member is about 1.5 meters of conglomerate displaying siliceous clay lenses. This bed is succeeded by about 1 meter thick siliceous clay unit which is overlain by about 4 meters of conglomerate displaying lenses of siliceous clay. The topmost bed is
about 4 meters of siliceous clay.

The siliceous clay beds of this section are laterally discontinuous, not extending laterally for more than 20 to 30 meters. The conglomeratic beds also display lateral pinching, though less often than the siliceous clay units. The largest boulder observed in this section was 25 cm across. On the whole, the sorting is very poor and the coarser unit dominates over the finer one. These characters of this section are strongly suggestive of alluvial fan deposits. The alluvial fan deposits are poorly sorted, immature, coarse grained sediments; usually gravel, cobbles and boulders predominate with subordinate amounts of sand and silt and in cross section are of limited lateral extent, generally lenticular or irregular shaped units (Reineck and Singh, 1973). The conglomerates were deposited as debris flow of the braided channels of the fans while the siliceous clays were deposited as bars of the braided channels of low sinuosity. The favourable conditions for the deposition of alluvial fans occur in tectonically active areas with actively sinking basin (Reineck and Singh, 1973). Thus, it may be postulated that these alluvial fans were deposited at the base of mountains which were gradually being elevated resulting in an increase in gradient and sinking of the alluvial fans. A summary of the characteristics of the Upper Sivalik sections described here, is presented in Table-27.
Upper Sivalik Palaeoenvironment of the area:

From the detailed study of the geology of the sections, it is evident that a major portion of the Upper Sivalik sediments of the present area were deposited under fluvial conditions by a meandering river system. The characteristic lithology is the sequences of sandstones and clay, the occurrence of which suggests that bulk of these deposits were laid down in a well-developed meander belt regime (Opdyke et al., 1979).

The Tatrot deposits were laid down by a more mature and meandering riverine system with the dominance of flood-plain deposits in relation to the channel facies. The occurrence of backswamps is also indicated. The riverine system responsible for Tatrot deposition was of comparatively higher sinuosity with a bigger flood-plain. At the beginning of Pinjors, evidences are suggestive of increased gradient possibly due to elevation of local magnitude in the mountains which supplied the detritus. The basal Pinjors do not show any difference in their depositional environment than the Tatrots, except that coarser member becomes more frequent. From base to the top of Pinjors, there is a gradual increase in the coarseness of the material, and the grits and pebbles become more frequent. The gradual increase in the coarseness of deposits also points towards a steady elevation in the
source area. Though, majority of the Pinjors were deposited as channel, point bar, levee, crevasse splay and flood-plain deposits, there are evidences for the occurrence of lacustrine conditions in the form of small ponds or oxbow lakes. The coarseness of sediments indicates a steady change from more humid conditions during Tatrots to relatively arid conditions during Pinjors which became more and more arid towards the top. The Boulder Conglomerate Formation suggests a sudden and sharp change in the gradient of the depositing riverine system. This probably can be related with the uplift in the adjacent mountain system. As a result, thick aprons of alluvial fans, assisted by a subsiding basin, resulted at the foot of the mountains and the sinuosity of riverine system became very low. During this time a braided river system showing constant channel switching developed. According to Reineck and Singh (1973), best alluvial fan deposits occur in arid to semi-arid and subarctic regions. Thus, it may be suggested that the climate during the deposition of Boulder Conglomerates was arid to semi-arid and relatively cold. Fossils are rare in these deposits which can be explained by the occurrence of highly oxidizing conditions during their deposition (Reineck and Singh, 1973). The occurrence of current bedding in all the three formations of Upper Šivaliks indicates their deposition under shallow water conditions (Pettijohn, 1957).
The average of the means ($M_z$) of the grain size of Tatrot and Pinjor sandstones increases from $\phi$ 2.6 to $\phi$ 2.3 (Table-5), respectively, indicating a general coarse nature of Pinjor sediments. The coarser nature of Pinjor deposits suggests high energy conditions. As can be observed in Table-5, the skewness value, which measures the normality of a distribution, for Pinjor and Tatrot sandstones ranges from -0.035 to 0.048 and -0.38 to 0.24, respectively. From the skewness value, it is clear that majority of the Pinjor sandstones have a dominant coarse population. The Tatrot sandstones show this character to a lesser extent. This also suggests a relatively high energy environment for Pinjor sediments as compared to Tatrot ones. Table-6 shows that a majority of the Tatrot samples fall in angular to subangular classes while bulk of the Pinjor samples are in subangular to subrounded category. This indicates a greater degree of roundness for Pinjor sands. Since the roundness value also depends on the amount of transportation of individual grains, therefore, either the Pinjor sands underwent longer transportation or they experienced a second cycle of abrasion. The second explanation seems more convincing, especially in view of the evidences of shorter transportation, e.g., the mud balls, in some sections of Pinjor Formation (Text Figs. 9, 10; Plate 6, Fig. F).
The sediments of Tatrot Formation display appreciable amount of red or brown colour which is much less in Pinjor deposits. The occurrence of red colouration denotes warm and humid climate with seasonal rainfall (Schwarzbach, 1963). According to Krynine, the red colouration is suggestive of a mean annual temperature of more than 16°C and rainfall of over 40 inches (vide Schwarzbach, 1963). From the distribution of red colouration it appears that during Tatrots the climate was warm and humid in general, but in Pinjors it became relatively less humid and less warm. It may be suggested that the climate became more arid during Pinjors and still more arid during the deposition of Boulder Conglomerate Formation. While dealing with the petrography of the Upper Sivalik sediments, Kharkwal (1969) pointed out that the kaolinisation of feldspars and the presence of ferruginous matter in the clays indicate the prevalence of warm and humid climate during the sedimentation of Upper Sivaliks. The occurrence of red and brown colouration, which abounds in Tatrots, also incates deposition under oxidizing conditions (Reineck and Singh, 1973).

There is decrease in the carbonate content of sediments from Tatrot to Pinjors (Table-7). The deposition of carbonate generally takes place under warmer conditions, for at low temperatures water contains more dissolved CO₂ and, hence, can carry more calcium carbonate in solution (Schwarzbach, 1963). Thus, it can be inferred that Tatrots experienced comparatively warmer conditions and the temperature became relatively low during Pinjors.
TAPHONOMY OF UPPER ŚIVALIK FOSSIL ASSEMBLAGES:

Very often, the fossil assemblages of terrestrial organisms comprise of a mixture of animals derived from different habitats. It would thus be important to determine whether a particular deposit constitutes the original habitat of an assemblage or alternatively, the assemblages have been derived from different habitats. The science of taphonomy usually provides answers to such intricate questions. As is well known, taphonomy deals with the study of the transition (in all its details) of the animal remains from the biosphere to the lithosphere (Efremov, 1940). Taphonomy thus involves all the biological and physical processes which operate during the transference of organic remains of the organisms from the biosphere to lithosphere. The post-mortem history of the animals, including their decay, transportation and burial, would, therefore, be relevant to taphonomic studies.

The structure of the fossil assemblage, which preserves the partial imprint of the original fauna, is determined by a number of factors. The mode of death, the post-mortem weathering and decomposition conditions, the nature of transporting and depositing medium, and diagenetic changes are some of the factors which profoundly affect the nature of a thanatocoenose.

Upper Śivalik fossil assemblages in the northeast of Chandigarh: Upper Śivalik thanatocoenose of this area is of mixed type and preserves organisms having varied habitat preferences.
A careful examination of this assemblage reveals that, in general, the populations living away from the depositional site are less represented than the ones inhabiting areas in the vicinity of the basin of deposition.

**Nature and mode of occurrence of fossils:** The fossil assemblage is of a fragmentary nature. Except a few, all the bones are disarticulated pointing towards pre-burial dispersal of the bones by various agencies. The articulated bones include a few joint portions from locality C₁ (Text Fig. 8). Generally, the joint ligaments become very hard due to dehydration and are easily fossilized without disarticulation. The fragmentary nature of the fossils could also be attributed to the recent weathering agencies which often break and damage the specimens after exhuming them from the sediments.

Many of the teeth and bones in the present assemblage display sediment filled cracks (Pl. 26, Fig. C) and a number of other specimens exhibit signs of pre-burial leaching (Pl. 26, Fig. B). Such specimens are more common in A₁, B₁, C₁, D₁, E₂ and G₁ localities (Text Figs. 5, 7, 8, 11, 13 and 16) which are characterized by flood-plain facies. It appears that before burial, these bones were exposed to drying and various other weathering agencies. The deformation of bones in this fossil assemblage is rare. Only a few specimens recovered from locality F₁ (Text Fig. 14) are
deshaped, apparently due to the removal of much of the inorganic material leaving behind organic material which is flexible and bends easily. At some localities, such as A\textsuperscript{3} \textsubscript{2} (Text Figs. 6 and 18), crushed teeth were recovered (Pl.26, Fig.A). Their occurrence can be attributed to the compaction of the sediments which might have crushed the friable/wet specimens. The crushed specimens are more common in the argillaceous units of the area.

On the whole, the fossils occur dispersed evenly in the rock units of the area. Occasional concentration of fossils in localized pockets has also been noticed. This tendency is especially noticeable in some localities with channel environment, which might be the result of deposition at the point bars of laterally shifting rivers.

**Relative abundance of various skeletal parts:** All the bones of a skeleton do not generally find equal representation in a fossil assemblage. The preservation potential of skeletal element is a function of a combination of factors such as, the type of skeletal element, its hydraulic behaviour, the nature of the depositing medium, etc. Generally, the elements which are more resistant to weathering and abrasion have a better chance of preservation. Consequently, such parts are encountered in greater numbers in a fossil assemblage than other elements.
Table-28 shows the percentage distribution of various skeletal elements of fossil mammals collected from the Upper Sivalik deposits of the area. A glance at this table is sufficient to find that this assemblage exhibits a definite bias in favour of dental elements. The mandibular fragments, skull and maxillary fragments, and isolated teeth constitute about 60 per cent of the assemblage. The post-cranial skeletal parts are under represented and comprise about 40 per cent of the total specimens in the fossil assemblage. It is evident that the teeth and jaw fragments have been preserved in greater proportions than expected from a random sample of bones originally present in a skeleton. Elements like radius, ulna, ribs, vertebrae, phalanges, etc. are very few. The greater preservation of dental parts may be explained by the far greater strength and durability of teeth to withstand weathering on the surface, and abrasion during transportation, than other skeletal parts. Moreover, since the dental parts are not the fancied food of the carnivores and scavengers, they are likely to be left undamaged.

The greater frequency of jaw fragments as compared to skulls and maxillary fragments can also be explained in the same manner. The jaws are more compact and less prone to surface weathering than the skulls, which are made of a number of individual bones containing many air spaces, and are, hence, more fragile. The profusion of isolated teeth (42.3%) indicates that some weathering agencies were
Percentage distribution of various skeletal parts in the Upper Sivalik mammalian assemblage of the area

<table>
<thead>
<tr>
<th>Skeletal element</th>
<th>Percentage distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skull</td>
<td>0.8</td>
</tr>
<tr>
<td>Mandibular ramii</td>
<td>7.5</td>
</tr>
<tr>
<td>Deciduous dental specimens</td>
<td>3.9</td>
</tr>
<tr>
<td>Isolated teeth</td>
<td>26.3</td>
</tr>
<tr>
<td>Mandibular</td>
<td>21.0</td>
</tr>
<tr>
<td>Maxillary</td>
<td>47.3</td>
</tr>
<tr>
<td>Humerus</td>
<td>2.8</td>
</tr>
<tr>
<td>Ulna</td>
<td>0.3</td>
</tr>
<tr>
<td>Femur</td>
<td>3.0</td>
</tr>
<tr>
<td>Tibia</td>
<td>4.3</td>
</tr>
<tr>
<td>Metapodia</td>
<td>9.3</td>
</tr>
<tr>
<td>Podial bones</td>
<td>8.8</td>
</tr>
<tr>
<td>Phalanges</td>
<td>1.2</td>
</tr>
<tr>
<td>Horn-cores</td>
<td>4.0</td>
</tr>
<tr>
<td>Antlers</td>
<td>4.0</td>
</tr>
<tr>
<td>Ribs</td>
<td>1.5</td>
</tr>
<tr>
<td>Vertebrae</td>
<td>1.3</td>
</tr>
</tbody>
</table>

Total: 59.5%
operational which resulted in the mechanical fragmentation of jaws and skulls. Besides taphonomic factors, the local earth movements and the recent weathering agencies may also be responsible for the fragmentation.

Among the post-cranial skeletal elements, the metapodia and podial bones have a greater representation than other parts. Their abundance may be attributed to the hardness and strength of these elements which gives them a positive advantage to withstand the weathering. Another reason may be the fact that these parts are generally left uneaten by predators and scavengers. Besides these factors, the sorting action of the depositing currents should also be considered. Small and fragile bones like ulna and radius show a very low frequency in the fossil assemblage. Such bones are not capable of withstanding severe weathering agencies and abrasion during transport and are, hence, often destroyed before burial.

The horn-cores, antlers, tibia, and femur find less than average representation. There is a greater frequency of tibia than femur which may be due to the preferential eating habits of the carnivores. The thighs having a greater portion of flesh are likely to be favoured by carnivores. Thus, the femur is often under greater stress than tibia and is, therefore, more susceptible to destruction. The antler frequency does not represent the actual abundance of cervids.
In general, due to its morphology an antler is likely to contribute more fragments than horn-cores. Moreover, since in many modern cervids the antlers are shed annually, their frequency in a fossil assemblage generally presents an inflated picture of the original population of these animals.

The frequency of ribs, vertebrae, scapulae, sacra and phalanges is negligible in this fossil assemblage. Their scarcity may be attributed to their weak and fragile nature. According to Behrensmeyer (1975) these parts are more easily removed from the original assemblage of bones due to transportation and preferential weathering on a flood-plain. There is a definite bias in favour of lower end of the bones in the present assemblage. This could be explained by the denseness and relative strength of the distal ends as compared to the proximal ones. On the whole, this fossil assemblage resembles the second and third dispersal groups put forth by Voorhies (1969), indicating a highly sorted nature of the bone assemblage.

At some localities, especially those with channel environment, concentration of certain specific skeletal elements has been noticed. The common bone association encountered at these places includes mandibular fragments, ends of femur, tibia, metapodia and isolated teeth. This indicates the operation of some sorting process which
removed the lighter, easily transportable, and less durable elements leaving behind relatively stronger, denser and less transportable elements. These bone associations are comparable to the bottom lag deposits of Voorhies second and third dispersal groups. The third dispersal group is better represented in these bone associations indicating their deposition in a channel. Many of the bones and teeth from the channel environment display signs of abrasion indicating pre-burial transportation.

The bones from flood-plain environments such as, localities $A_2$, $A_3$, $B_1$, $E_2$, $G_4$ etc. (Text Figs. 5, 6, 7, 13, 16) have a better representation of other skeletal elements, besides the aforesaid ones which are often found in channel environments. Teeth and mandibular fragments are the dominating elements. However, ends of femur, tibia, metapodia, humerus and other skeletal parts, viz. podial bones, horn-cores and antler fragments are also encountered. Radius, ulna, phalanges and vertebrae are very poorly sampled. These elements which form the first dispersal group of Voorhies (1969) are most easily destroyed and transported. It appears that during floods the currents were strong enough to winnow out these elements. Some of the bones from the above mentioned localities exhibit signs of pre-burial leaching and weathering. A number of other bones possess sediment filled cracks indicating pre-burial desiccation of these elements. It seems that a part of this assemblage was formed
by the cumulative accumulation on the flood-plain of the most durable parts of the skeleton. The flood-plain assemblage is autochthonous, though, it was highly altered by various taphonomic processes.

Abundance of various fossil groups: All the forms are not equally represented in a fossil assemblage. Some groups are more abundant than others. A few forms, which might have formed a part of the original community, may be altogether missing. The occurrence of a particular form in a fossil assemblage is dependent on the type of the form, its abundance in the original community, its habit and habitat, the proximity of its ecological niche to the depositing medium, the nature of taphonomic factors in operation, and the type of depositing medium. If majority of these factors are favourable, the chances of the inclusion of a fossil form in a thanatocoenose are greater.

In the present fossil assemblage from Upper Śivaliks, reptiles and mammals are the two major vertebrate types. Table-29 shows that in the Upper Śivalik fossil assemblage also there is an unequal representation of various fossil groups. Some forms are better recorded while some other are poorly represented.

Reptiles: The reptiles occur in both the Tatrot and Pinjor Formations of this area. As can be observed in
Percentage of various vertebrate types collected from the Upper Šivalik deposits of the area

<table>
<thead>
<tr>
<th>Vertebrate type</th>
<th>Upper Šivaliks</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tatrot</td>
<td>Pinjor</td>
<td>Boulder Conglomerate</td>
</tr>
<tr>
<td>REPTILIA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crocodilids</td>
<td>26</td>
<td>3.2</td>
<td>-</td>
</tr>
<tr>
<td>Chelonids</td>
<td>30</td>
<td>4.8</td>
<td>-</td>
</tr>
<tr>
<td>MAMMALIA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rodents</td>
<td>-</td>
<td>0.4</td>
<td>-</td>
</tr>
<tr>
<td>Carnivores</td>
<td>-</td>
<td>0.4</td>
<td>-</td>
</tr>
<tr>
<td>Proboscideans</td>
<td>14</td>
<td>15.0</td>
<td>-</td>
</tr>
<tr>
<td>Equids</td>
<td>-</td>
<td>20.1</td>
<td>-</td>
</tr>
<tr>
<td>Rhinocerotids</td>
<td>-</td>
<td>5.7</td>
<td>-</td>
</tr>
<tr>
<td>Suids</td>
<td>5</td>
<td>3.2</td>
<td>-</td>
</tr>
<tr>
<td>Hippopotamids</td>
<td>11</td>
<td>2.4</td>
<td>-</td>
</tr>
<tr>
<td>Cervids</td>
<td>-</td>
<td>3.2</td>
<td>-</td>
</tr>
<tr>
<td>Giraffids</td>
<td>3</td>
<td>2.4</td>
<td>-</td>
</tr>
<tr>
<td>Bovids</td>
<td>11</td>
<td>39.2</td>
<td>-</td>
</tr>
</tbody>
</table>
Table-29, the percentage of reptiles, including crocodilids and chelonids, is much more in Tatrots than in Pinjors. On the whole, the chelonids are more abundant than crocodilids. The remains of these two groups, especially those of crocodilids, are generally encountered in channel environments. The chelonids are also found in flood-plain environments. The occurrence of crocodilids, mainly in channel and rarely in the flood-plain environment, is in accordance with their aquatic habitat. Partial terrestrial nature of a few chelonid species is indicated by their occurrence in flood-plain environment.

Mammals: Though, both the Tatrot and Pinjor Formations of the area have yielded mammalian fossils, but the former seems to be richer in them than the latter. The Boulder Conglomerate Formation is almost barren of these remains. There can be many reasons for the less frequency of these fossils in Tatrots. The first reason can be that the Tatrot fauna was perhaps less diverse and less numerous than the Pinjors. The second explanation could be found in the different climatic conditions prevailing during Tatrot and Pinjors. As is indicated by sediment studies, the climate was warm and humid during Tatrots and relatively arid during Pinjors. Humid surface environment facilitates the decay and destruction of organic matter, such as bones, and will cause the quick dissolution of bone minerals (Behrensmeyer, 1975). Thus, many of the potential fossils might have
decayed due to the prevalence of humid surface conditions during Tatrots. Moreover, since the Tatrot sediments form a small part of the area available for fossil collection, they are likely to contribute less fossil material than the Pinjor deposits which form a major part of the area investigated.

As can be observed in Text Figs. 45 and 46, the primate fossils are unsampled in this fossil assemblage. A survey of the earlier reports shows that there are only two published primate specimens from this area. This rarity of primate fossils is quite baffling. A possible explanation for the paucity of primates may be the low numerical strength of these animals during Upper Śivalik times. This scarcity may also be attributed to the habitat of these forms, which generally keeps them away from the site of deposition. Consequently, only a few could have died near the areas where their bones could be quickly encased by sediments.

The carnivores are also under represented in the present collection, as is evident from Table 29 and Figs. 45 and 46. Besides a single specimen of Vishnuictis recorded in the present collection, about seven to eight carnivore specimens have been reported from this area by other workers. This deficiency of carnivores may be explained by their general solitary nature, which might had precluded the availability of their bones, in greater numbers, for
TEXT FIG. 45

DIAGRAM REPRESENTING RELATIVE ABUNDANCE OF VARIOUS MAMMALS COLLECTED FROM TATROT FORMATION
TEXT FIG. 46

DIAGRAM REPRESENTING RELATIVE ABUNDANCE OF VARIOUS MAMMALS COLLECTED FROM PINJOR FORMATION
fossilization. The less number of carnivores, as compared to the herbivores, is consistent with their low biomass in the 'Eltonian Pyramid', in which only a few carnivores are ecologically in balance with a large number of herbivores. Thus, the low frequency of carnivores in Upper Šivalik fossil assemblages may be a reflection of this principle.

Another mammalian group which is scarce in the Upper Šivaliks of the area is the order Rodentia. Since these forms are present in many of the existing environments and form a part of almost every ecosystem, their presence during Upper Šivalik times cannot be doubted. Their rarity may, therefore, reflect the biased character of this assemblage, which appears to be against smaller forms. Probably the taphonomic processes are to be blamed for the paucity of these forms. The rodent bones are small, fragile and are easily destroyed. According to Dodson (1973), due to their high surface area to volume ratios, the rodent bones are quickly weathered on the surface. The occurrence of high energy conditions during a major part of Upper Šivaliks may also be responsible for the rarity of rodents. The high energy environment might have either destroyed or winnowed away the small rodent bones. The collection bias may also be, to some extent, held responsible for the paucity of these forms. Due to their small size, the rodent bones and teeth are most likely to be missed during surface collection.
The most abundant forms in this assemblage are the bovids and equids, which are amply represented by various skeletal parts. Their abundance indicates the presence of these forms in greater numbers in the original community. Their profusion also points towards the gregarious nature of these animals. The next most abundant forms are the proboscideans. Their remains, though, occur in both flood-plain and channel environments, are more frequent in the former. These animals were perhaps autochthonous to the flood-plain environment. As their bones have low dispersal potential, their occurrence in channel environment indicates that these animals frequented the channels and a few of them died there. The hippopotamids are more numerous in Tatrots than in Pinjors. Their remains occur both in channel and flood-plain environments, indicating that these forms foraged on the flood-plains. The suids, cervids and giraffids are limited to flood-plain environments. Only a few specimens of these forms were collected from channel environments, where they are allochthonous.

UPPER ŚIVALIK PALAEOCOMMUNITIES OF THE AREA

The topical and upcoming theme of palaeoecology is the recognition and analysis of past communities in the fossil record. The fossil death assemblages studied in a community framework bring us closer to palaeoecosystems, the investigation of which is so vital to reconstruct the ecological conditions prevailing in the geological past.
A palaeocommunity may be defined as "an assemblage of organisms which often occur together" (Johnson, 1960). As has already been explained, a fossil assemblage is generally formed by the accumulation at the depositional site of the preservable portions of organisms. All the communities may not be equally represented in a fossil assemblage. According to Shotwell (1955), the communities living in close proximity to the site of deposition are more abundantly and completely represented than others.

A careful examination of the Upper Sivalik fossil assemblage from the northeast of Chandigarh reveals three distinct communities, viz., river and river bank community, pond community, and grassland and savannah community (Table-31). To find out the proximity of a community to the site of deposition, the requisite mammalian fossil data was analysed according to the method suggested by Shotwell (1955, 1958). The minimum number of individuals and the corrected number of specimens per individual were computed following Shotwell (1958). The results of this analysis are presented in Table-30.

**River and River bank Community**

It is not a well depicted community and is represented by the crocodilids and chelonids. The crocodilids are known mainly by their teeth and dermal scutes while
TABLE - 30

Basic data of Upper Sivalik fossil mammals collected by the author from the present area

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Murid indet.</td>
<td>1</td>
<td>1</td>
<td>0.9</td>
</tr>
<tr>
<td>Vishnuictis chopriis. nov.</td>
<td>1</td>
<td>1</td>
<td>0.9</td>
</tr>
<tr>
<td>Stegodon insignis</td>
<td>20</td>
<td>4</td>
<td>4.9</td>
</tr>
<tr>
<td>Archidiskodon planifrons</td>
<td>28</td>
<td>5</td>
<td>5.4</td>
</tr>
<tr>
<td>Elephas hysudricus</td>
<td>15</td>
<td>4</td>
<td>3.6</td>
</tr>
<tr>
<td>Equus sivalensis</td>
<td>66</td>
<td>7</td>
<td>9.1</td>
</tr>
<tr>
<td>Rhinoceros sivalensis</td>
<td>9</td>
<td>2</td>
<td>3.4</td>
</tr>
<tr>
<td>Rhinoceros palaeindicus</td>
<td>7</td>
<td>3</td>
<td>1.7</td>
</tr>
<tr>
<td>Coelodonta platyrhinus</td>
<td>6</td>
<td>3</td>
<td>1.5</td>
</tr>
<tr>
<td>Potamochoerus theobaldi</td>
<td>1</td>
<td>1</td>
<td>0.9</td>
</tr>
<tr>
<td>Sus falconeri</td>
<td>9</td>
<td>2</td>
<td>4.1</td>
</tr>
<tr>
<td>Sus pinjorensis. sp. nov.</td>
<td>2</td>
<td>1</td>
<td>1.9</td>
</tr>
<tr>
<td>Hexaprotodon sivalensis</td>
<td>18</td>
<td>2</td>
<td>8.3</td>
</tr>
<tr>
<td>Cervids</td>
<td>12</td>
<td>3</td>
<td>4.5</td>
</tr>
<tr>
<td>Sivatheruim giganteum</td>
<td>10</td>
<td>3</td>
<td>3.6</td>
</tr>
<tr>
<td>Bovines</td>
<td>111</td>
<td>11</td>
<td>11.9</td>
</tr>
<tr>
<td>Reduncines</td>
<td>4</td>
<td>2</td>
<td>2.2</td>
</tr>
<tr>
<td>Alcelephines</td>
<td>17</td>
<td>4</td>
<td>4.7</td>
</tr>
<tr>
<td>Antelopes</td>
<td>16</td>
<td>3</td>
<td>5.5</td>
</tr>
</tbody>
</table>
### Upper Śivalik fossil communities from the area in the northeast of Chandigarh

<table>
<thead>
<tr>
<th>River and river-bank community</th>
<th>Pond Community</th>
<th>Grassland and savannah community</th>
<th>Grassland population</th>
<th>Savannah population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crocodilids,</td>
<td>Sphaerochara, Chara, Nitellopsis, Hornichara;</td>
<td>Equus, Leptobos, Bos, Bovini, Alcephini, Antilopini, Reduncini</td>
<td>Vishnuictis, Stegodon, Archidiskodon, Elephas, Rhinoceros, Coelodonta, Potamochoerus, Sus, Rucervus, Sivatherium</td>
<td></td>
</tr>
<tr>
<td>Chelonids;</td>
<td>Canosa, Ilyocypris, Zonocypris, Potamocypris, Hemicypris; gastropods, unionids; seluroid fish</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hexaprotodon</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
the carapace and palestron fragments are the dominant parts
of the chelonids, sampled from this area. The lone mammalian
taxon assignable to this community is Hexaprotodon sivalensis
which might have inhabited relatively quiet and shallow areas
of the rivers. These amphibious animals are portrayed by
their skulls, mandible fragments, isolated teeth and some
post-cranial remains.

Pond Community:

The small over bank ponds, ox-bow lakes or other such
type of small water bodies of the flood-plain, were inhabited
by a diverse biota including algae, crustaceans, mollusks,
some insects and small fish. The floral population of this
community is depicted by a number of charophytes, viz.,
Sphaerochara, Hornichara, Chara, and Nitellopsis. The oogonia
form a major portion of the charophytic remains. A variety
of ostracodes, namely Candona, Ilyocypris, Zonocypris,
Potamocypris and Hemicypris form the curstacean population
of this community. Bulk of the ostracode valves are
disarticulated and only a few are articulated. The mollusks
are represented by shells and opercula of gastropods and the
valves of unionids. Some unidentified insects also form a
part of this community. The vertebrate population was
apparently restricted to small seluroid fish which are
depicted by scales and fragments of jaw, skull, and bones.
Grassland and savannah community:

Grassland and savannah constitute two different habitats. Nevertheless, the fauna of these two habitats frequently range into one another for food and shelter. For this reason the fauna of these two habitats have been grouped in a single community. A closer look at Table-30 reveals that more open habitat forms like equids, bovines, alcephines and antelopes are more completely represented than relatively closed habitat forms. Following Shotwell (1955), it can be hypothesised that the open habitat forms lived closer to the depositional basin, i.e., channels and flood-plains. It further suggests that the grasslands were proximal than the savannahs.

Grassland populations: As is indicated by their abundance in the Upper Šivalik thanatocoenose, the grassland populations were the ecological dominants. These forms formed a major portion of the Upper Šivalik faunal standing crop. Among the grassland forms, the equids and bovines are more abundant than others. The equids are represented by two taxa, viz., a large and robust Equus sivalensis and a small and slender Equus sivalensis minor. These are mainly depicted by their teeth, though, metapodia, podial bones, jaw fragments and long bone ends also occur. The equids might have inhabited the grasslands of the flood-plains.
Highly hypsodont nature of their teeth points towards grazing habits.

The bovines which are depicted by forms such as *Leptobos, Bos*, etc., were probably more numerous in the original community than other bovids. Evidences favour a gregarious nature for the bovines which probably foraged in large herds on the flood-plain grasslands. The hypsodont teeth of these animals were more suited to harsher and siliceous vegetation. Their teeth, mandible fragments, horn-cores, long bone ends, metapodia, podial bones, a few vertebrae and phalanges are the skeletal elements sampled in the present assemblage.

The alcelaphines and antelopes, which were also autochthones of the flood-plain grasslands, are less numerous than the bovines and equids. It appears that either these forms had a low numerical strength or they inhabited areas close to the distal limits of grasslands. Hence, fewer elements of these animals were available for fossilization. It is probable that due to their cursorial nature and high mobility, many of the alcelaphines and antelopes might have died in areas away from the site of deposition. Consequently, they could furnish fewer elements in the death assemblage. Teeth, mandibular fragments and metapodia of these forms are the dominant elements occurring in this fossil assemblage. The grazing habits of these animals are suggested by their hyposodont teeth. The tribe Reduncini is poorly represented. Their modern counterparts, which are found in Africa these
days, generally inhabit areas close to water. It seems that Upper Sivalik reduncini did not inhabit areas close to water as is evident from their occurrence only in flood-plain environments.

Savannah populations: The savannah populations of this community exhibit a variety of taxa such as Vishnuictis, Stegodon, Archidiskodon, Elephas, Rhinoceros, Coelodonta, Potamochoerus, Sus, Rucervus and Sivatherium. Among these forms, the proboscideans are best represented and occur in both the flood-plain and channel environments. It is probable that the proboscideans ranged into grasslands as well as savannah habitats of the landscape, besides frequenting the river. Mandibular fragments, isolated teeth, long bone parts and tusk fragments are the main skeletal elements of these forms sampled in this fossil assemblage. The tooth pattern of Archidiskodon and Elephas suggests that these animals were adapted to harsher vegetation. This tendency is more pronounced in Elephas which has highly hypsodont teeth with a greater number of dental plates. Its valleys are completely filled with cement and the enamel borders of the plates are plicated providing greater attritional surface area, useful for grinding tougher vegetation, such as grasses. Stegodon was perhaps a browser as is evident from its low crowned teeth, with relatively less cement in the valleys, and fewer plates.
The solitary carnivore member of this community is Vishnuictis. The nearest extant relative of this form is Viverra zebatha, i.e., the Indian civet, which is terrestrial and prefers cover. Vishnuictis might also have occupied relatively covered areas of the savannahs. Rhinoceros and Coelodonta are the rhinocerotid members of the savannah populations of this community. As can be observed in Table-29 and Figs. 45 and 46, these forms are not adequately represented in the Upper Sivalik fossil assemblage of this area. Their skeletal elements preserved in the assemblage include teeth, mandibular fragments, and a few long bone parts. The molars of these rhinocerotids are relatively hypsodont and display signs of consuming harsher and tougher vegetation. The occlusal surface of the tooth enamel of these forms display parallel striations which might have been caused by the silica grains present in the grasses they consumed. The low frequency of these forms in the fossil assemblage may point towards their low numerical strength and solitary nature. The rhinocerotids perhaps inhabited those areas of the savannahs which were closer to the grasslands, where they frequently foraged.

The representation of suids in this population is still poorer. Potamochoerus and Sus are the two suid genera collected from this area. These omnivorous animals probably occupied slightly closed habitats of the Upper Sivalik landscape. The tooth structure of Sus falconeri and Sus
pinjorensis exhibits modifications to accommodate slightly tougher vegetable materials also. These modifications are more pronounced in *Sus pinjorensis*, the third molar of which is exceptionally long and complicated. The lengthening of the last molar in this form has proceeded at the cost of other two molars which have shortened. This character of the third molar suggests partly grazing habits of this suid which might have preferred more open habitats like the African wart hog.

The deer are depicted by *Rucervus* and some other unidentified cervids which are known only by antlers in this assemblage. The antler structure of these forms would have given them a negative advantage in highly closed habitats. Therefore, it may be conjectured that like their modern counterparts, which are browsers and inhabit savannahs or grasslands near woods, these cervids also occupied the savannahs and grasslands of Upper Sivalik landscape.

PALAEOECOLOGY

Since the Upper Sivalik deposits are comparatively young, a number of living animals, allied to the extinct forms of these deposits, are available. To a certain extent, this facilitates the reconstruction of Upper Sivalik palaeoecology as constructive conjectures can be made as to the habits and habitats of extinct forms, keeping in view the ecology of their extant kith and kins.

Both the fossil fauna and flora provide useful information about the past ecological set up. Unfortunately,
the floral evidences in the present assemblage are very rare, being restricted to the Charophytes only. These fossils occur in Tatrot as well as Pinjor Formations of the area. The occurrence of Charophytic remains (Table-3) indicates the fresh-water origin of Upper Śivalik deposits of the area. These plants are capable of subsisting in oxygen deficient waters where the substratum contains lot of decomposing material. Such conditions generally prevail in places where the drainage is poor. Charophytes also suggest the presence of water bodies without much current action. According to Pal et al. (1962) charophytes generally grow in clean water with high pH. All these things indicate the existence of lacustrine conditions in the deposits in which the charophytes occur. In Tatrot and Pinjor deposits of the area, these forms are found in small and localised sediment patches, generally associated with fresh-water gastropods and ostracodes. The occurrence of these forms indicates that during Upper Śivalik times small localised lacustrine patches, such as small ponds, ox-bow lakes etc., existed which served the habitational requirements of these forms.

The invertebrate remains from this area are varied and include ostracodes, viz., Candona, Ilyocypris, Zonocypris, Potamocypris and Hemicypris, gastropods, unionids, etc. The occurrence of these forms further confirms the fresh-water origin of Upper Śivalik deposits.
of this area. Bhatia and Singh (1971) pointed out that Candona lactea inhabited fresh, clear and alkaline lakes. Ilyocypris gibba and I. bradyi are also known to occur in shallow-water bodies such as pools, ponds, ditches, springs, marshes, etc. Potamocypris is widely present in the Pleistocene lakes of Kashmir valley. Zonocypris costata inhabits small lakes (Klie, 1933, 1939). Thus, the presence of these ostracodes, many of which are inhabitants of lakes, ponds, etc., further confirms the occurrence of small scale lacustrine conditions, such as ponds, ox-brow lakes, etc., during Tatrot and Pinjor times. This view is further strengthened by the existence of fresh-water gastropods and unionids.

Among the vertebrates, reptiles and mammals are represented in this fossil assemblage. Being poikilothermic, the reptiles afford more useful and authentic palaeoecological information than the homoiothermic mammals. The temperature tolerance of reptiles is limited as compared to mammals which are more adaptive. The reptiles, which are represented by crocodilids and chelonids, are more abundant in Tatrots than in Pinjors (Table-29). Sahni and Khan (1964) reported Crocodilus piastris, Gavialis gangeticus, Gavialis lentodus, Clemys, sivalensis and a giant turtle Colossochelys atlas from the Tatrot sediments in the east of Chandigarh. The occurrence of these reptiles in great profusion during Tatrots warrants the existence of large fresh-water sheets to accommodate large populations.
of the animals. The profusion of these forms and the presence of giant chelonids is suggestive of warm and humid climatic conditions during Tatrots with ample backswamps. According to Rensch (vide Schwarzbach, 1963) the cold blooded animals attain maximum size and profusion in hot and wet climates. Pinjor fossil assemblage is deficient in reptiles (Table-29). Their deficiency certainly indicates their low numerical strength in the original community. This might be attributed to a change from the favourable warm and humid climate in Tatrots to relatively arid and cold conditions during Pinjors, which are not congenial for the propagation of these cold-blooded animals. These evidences also suggest a reduction of the backswamps during Pinjors.

Though a number of mammalian fossils have been recovered from the Tatrot and Pinjor Formations of this area, the Boulder Conglomerate Formation has proved to be unproductive. From the Tatrots, a number of proboscideans, suids, hippopotamids, giraffids and bovids have been collected. The occurrence of these forms indicates general wooded savannahs during Tatrots. Stegodon was mainly a browser while Archidiskodon might have been a grazer. Sivatherium was also a browser, probably of the wooded savannahs. The Tatrot suid, Potamochoerus, resembles its modern relative Potamochoerus porcus which prefers closed bush habitats. Thus the presence of this form in Tatrots
can be taken as an indication of the occurrence of areas covered with bush during Tatrots. The abundance of Hexaprotodon in Tatrots suggests the existence of large and quiet rivers. The extant African hippopotamid, Hippopotamus amphibius, inhabits comparatively shallow and slow rivers. The bovids are not as abundant in Tatrots as in Pinjors. These grazers suggest the occurrence of slightly more open conditions, resembling the treeless savannah, in some parts of Tatrot landscape. The absence of typically cursorial and grazing forms in Tatrots, such as Equids, alcelaphines and antelopes, is suggestive of general covered conditions and the absence of vast open country with grasslands. On the whole, in Tatrots there is an absence of typical forms which might point towards arid conditions. From the foregoing, it follows that Tatrots experienced warm and humid climate. The landscape depicted large quiet rivers, meandering through wooded savannahs with some open grass covered patches.

The Pinjor fossil assemblage shows a relatively low percentage of Hexaprotodon than Tatrots. This might suggest comparatively less wet conditions. Their scarcity may be attributed to the increased gradient of Pinjor rivers as is indicated by lithological studies. The Pinjor fossil assemblage is dominated by equids, bovines, alcelaphines and antelopes. Highly hypsodont nature of the dentitions
of these animals indicates arid conditions and the presence of grasses. According to Stirton (1947) the development of hypsodonty was contemporary with increasing aridity and the appearance of bunch grass. From the taphonomic studies, it seems that the areas close to the depositional site supported grasses and served as the habitational site for grassland populations. There are no typical forms to indicate the presence of gallery forests. The absence of primates and other members of arboreal community may suggest the reduction of wooded conditions. Apart from Stegodon and Archidiskodon, the proboscidean population of Pinjor times consists of Elephas hysudricus which is absent in Tatrots. The tooth structure of this animal suggests grazing habits, which further supports the presence of grassy vegetation. The presence of proboscideans, suids, giraffids and cervids, which were perhaps members of savannah population, is suggestive of the existence of savannahs, besides grasslands, during Pinjors. The distal nature of savannahs and other relatively closed habitats, to the depositional basis is denoted by taphonomic studies. On the whole, the evidences are in favour of a dominant grassy vegetation during Pinjors. The rarity of tragulids and other water loving bush-dwellers suggests the absence of a bush cover near water courses during Pinjors. The occurrence of Equus and alcelaphine remains in association with each other is interesting. It may be speculated that like the present day zebra and wild-beest or hart-beests of east African savannahs, these two forms were
also involved in some sort of commensalism. The occurrence of highly cursorial forms like alcelaphines and antelopes denotes open country conditions during Pinjors. The presence of rhinocerotids, such as *Rhinoceros* and *Coelodonta* with hypsodont dentition suited to siliceous vegetation, also suggests the occurrence of grassy vegetation and the prevalence of arid conditions. Among the suids, *Sus falconeri* and *Sus pinjorensis* display grazing habits. *Potamochoerus* like its modern counterpart, preferred relatively soft diet and inhabited relatively covered areas of the savannahs. *Sus falconeri* and *Sus pinjorensis* probably ranged between savannah and grasslands. Perhaps, the grasses also formed a part of their diet. Thus, from the faunal evidences it can be safely inferred that Pinjor times experienced relatively arid and probably cooler climatic conditions. The dominant vegetation was grasses. The Pinjor landscape depicted grass covered open country with meandering rivers. Savannahs of Pinjors which also supported some relatively closed areas, were less wooded than Tatrots. On the whole, no single type of habitat can be conjectured for Pinjors. The evidences suggest a mosaic of the aforesaid environmental types.

In the Boulder Conglomerates there is a virtual absence of floral as well as faunal fossil material. It is generally believed that during this time there was a large-scale extinction or migration of fauna due to the advent of colder climate. The reason for the rarity of fossils may also be looked in to the lithology of these sediments.
which are very coarse and are not considered to be congenial for the preservation of bone material which might have been destroyed before fossilization. Moreover, the coarse alluvial fan deposits do not generally preserve fossils due to the prevalence of highly oxidizing conditions during their deposition (Reineck and Singh, 1973).

CONCLUSIONS

It would thus be clear that the Upper Sivaliks of this area represent the fresh-water sediments deposited predominantly under fluvial conditions provided by a well-developed meandering riverine system. A small portion of these sediments was deposited under localised lacustrine conditions. The Tatrots were laid down by a relatively more mature and meandering river system. More or less low energy and shallow water conditions are indicated for Tatrots. During this time, the backswamps were more abundant than Pinjors. The climatic conditions were warm and humid with reasonably distributed rainfall. There is a relative abundance of reptiles in Tatrots. Except hippopotamids, all other mammalian taxa are under-represented. Unlike Pinjors, the Tatrots are deficient in cursorial and grazing forms. The faunal evidences favour the occurrence of wooded savannah conditions, in general, during Tatrots. The landscape was probably more wooded with relatively few open patches.
The Pinjors were also deposited by a meandering riverine system under relatively shallow-water and high energy conditions. There was a reduction in backswamps. However, occurrence of a few small ponds, ox-bow lakes or some other such poorly drained water bodies, is indicated by both lithology and invertebrate fossils. The faunal evidences suggest a relatively arid climate during Pinjors. Biological and geological evidences also indicate slightly lower temperatures during Pinjors than Tatrots. The Pinjor fauna is more diverse than Tatrots. However, the percentage of reptiles and hippopotamids is less in Pinjor as compared to Tatrots. The grazing and cursorial forms like equids, bovines, alcelaphines and antelopes were the ecological dominants at the time of Pinjors. There are very few forms in the Pinjor assemblage which preferred covered habitats. Pinjor fauna suggests the presence of savannahs and grasslands which were less wooded than Tatrots, though they supported some closed habitats also. The dominant vegetation during Pinjors was probably grasses. There were more open country conditions at the time of Pinjors as compared to Tatrots.

The Boulder Conglomerates were deposited by shallow braided streams of low sinuosity. The lithological evidences
indicate that during the deposition of Boulder Conglomerate Formation, thick aprons of alluvial fans were laid down on a subsiding basin. The climate during this time was arid and cold. The absence of floral and faunal evidences in Boulder Conglomerates precludes the reconstruction of ecological set-up of this time.