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SIWALIKS OF THE INDIAN SUBCONTINENT

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The term 'Sewalik hills' was introduced by Cautley in 1832 to designate the sub-Himalayan hill ranges occurring between the rivers Ganga and Yamuna which yielded the memorable vertebrate fossils around Hardwar. The term was adopted by Falconer in 1835 to designate the "nearly continuous series of Tertiary formations "stretching "from the Punjab down to Irrawaddi." These hills are relatively low, ranging in height from 1000-1200 m above mean sea level with variable trends running parallel to the Himalayas. Behind and between the ridges, there are narrow strike valleys known as "*duns*" filled up with sub-Recent clastic detritus. They have an outcrop pattern, more or less, bounded by a major thrust, the Main Boundary Fault in the north and the Indo-Gangetic alluvium on the south. They are generally 10-12 km wide and present themselves as a series of parallel ridges with a steep scarp towards south and a gentler dip slope on the north. Siwalik outcrops around Kalka are 16-30 km wide but widen considerably to attain a width of 90 km in the Nalagarh-Pathankot sector due to the Main Boundary thrust receding to the northeast. To the northwest of Pathankot, they again narrow down to around 12 km width which is more or less maintained in the rest of Himalaya upto the Dibang gorge, close to the orographic bend of the Himalaya.

Genetically, the Siwaliks represent clastic sediments of the nature of freshwater molasse which accumulated in a long narrow foredeep formed to the south of the rising Himalaya which had its inception in the third and most intense uplift during the Middle Miocene. They have accumulated under four different environments, namely, lacustrine, channel and flood plains, outwash plains and piedmont with frequent diachronous shifts. The formations range from Middle Miocene to Middle Pleistocene in age.

As already stated, they are underlain by the Lower Tertiary Upper Murree/Dharamsala sediments generally with a faulted but occasionally with gradational contact and below the Gangetic alluvium, which thickens southwards, the Siwaliks have been found to rest over the Pre-Tertiary basement.

Structurally, the Siwaliks have been folded and overthrust to the south by the Lower Tertiary formations which in turn are thrust over by the pre-Tertiaries. Within the Siwalik basin itself, frequent reversals of the stratigraphic sequence has been brought about by thrusting. The intensity of thrusting decreases from northeast to the southwest, where the Siwaliks are characterised by broad open folds dissected by high angle reverse faults heading north. In some areas, closely-spaced thrusts have resulted in the development of Schuppen structures. The fold-fault pattern that has resulted from the overall structural evolution is one of the synclinal valleys and anticlinal ridges separated by thrust planes. Broadly, they may be divided into three tectonic zones, namely, the Outermost zone showing open folds, the Middle Zone of open folds and monoclines intercepted by north-hading reverse faults, and the Inner zone of closely spaced compressed folds and faults lying close to the Main Boundary Fault.

Lithologically, the Siwaliks represent a great thickness of the detrital rocks, such as coarsely bedded sandstones, sandrock, clays and conglomerates measuring between 5000-5500 m in thickness. Primary sedimentary structures observed in the Siwalik sediments include large scale tabular and trough cross beds and cut and fill structures. Besides, small scale cross beds, wavy and parallel lamination, lunate and linguoid ripple marks, flute and load casts, horizontal bedding and mud cracks are also common.

Ever since their discovery in 1832, the Siwalik vertebrates have presented a fascinating picture of mammalian evolution during the Late Tertiary and Early Quaternary of the Indian subcontinent. Studies that began with the pioneering work of Falconer (1868), Cautley (1835), Baker and Durand (1836) a century and half ago, continue upto the present day and the numerous workers who have contributed to the various problems connected with it include, to mention a few Medlicott (1879), Wynne (1877), Middlemiss (1890), Lydekker (1876, 1880, 1883, 1886 a, b), Theobald (1881), Blanford (1879), Pilgrim (1913), Pinfold (1918), Cotter (1933), Matthew (1929, 1950), Colbert (1935 & 1942), Colbert and Hooijer (1951), Wadia (1928, 1948 & 1968), Lahiri (1934), Lewis (1937), Gill (1951 a, b), De Tera and Paterson (1939), De Terra and Teilhard (1936), Teilhard and Stirton (1934), Sahni and Mathur (1964), Sahni and Khan (1964), Tripathi (1968) and lately the officers of the Oil and Natural Gas Commission. The earlier workers like Baker and Durand (1836), Falconer and Cautley (1849), were so

Fourth Prof. M.R. Sahni Memorial Lecture delivered on March 1, 1986 thrilled with this discovery that they devoted their most of the attention to the description of the fossils only paying little or no attention to the stratigraphical importance of these fossils. Falconer thought that the Siwalik vertebrates constitute a single faunal unit of Miocene age. He, however, did not preclude the possibility of the fauna extending to more than one subdivision of the Tertiaries. Lydekker subsequently, found that faunal elements dealt with by him from these deposits have an older aspect and he proposed the term Lower Siwaliks (Pliocene) for this older fauna. Through the efforts of Pilgrim, later, it was found that the fauna described by Falconer really belonged to the Upper Siwaliks and those described by Lydekker to the Middle Siwaliks and the immediate ancestors of these lie in the rock formations of the Salt Range and Potwar Plateau which was designated later, as the Lower Siwaliks on the basis of the relative stages of the evolution of the mammals in them. Thus, Pilgrim (1913) provided a palaeontological base for the three fold division of the Siwaliks arrived at by Medlicott between the year 1858-1860.

Lower Siwaliks constitute grey and green greywackes with fine to medium grained clastics containing calacreous cement disseminated throughout the rock mass interbedded with well developed sandy clays of chocolate and maroon colours. The clay horizons often pass laterally into clay conglomerates (Pseudo-conglomerates of Pilgrim). In its lower part, the Lower Siwaliks are characterised by rapid alternation of sand stones and clays, almost in equal proportions traceable over long distances. They can be subdivided into several formations based mainly on the relative proportion of clays and sandstones. These beds were known for the absence of real pebbles in them but recent work of Oil and Natural Gas Commission has shown that well rounded pebbles of quartzites occur locally towards the top of the Lower Siwaliks which is characterised by predominance of sandstone over clays.

The Lower Siwalik fauna is distinctly Miocene in its constitution as it includes various species of *Dryopithecus*, and hyracodont, primitive felids, mastodonts, *Listriodon* and relatively primitive pigs; a rather primitive anthracothere; *Macrotherium* and primitive bovids.

Middle Siwaliks consist predominantly of sandstone of light grey colour, which vary in thickness from 10 to 20 m. They are coarse grained and grade from greywacke in the lower portions to arkose in the higher portions. They are soft and friable because of the lack of calcareous matter which occur in segregations rather than disseminated throughout the mass as in the Lower Siwaliks. They are less well sorted as compared to those of the Lower Siwaliks and contain unweathered feldspars and abundant woody matter in the process of carbonisation. Pebbles are common in the coarser clastics especially towards the top. The clays are dull coloured and more arenaceous. The thickness of the Middle Siwaliks which conformably and gradationally overly the Lower Siwaliks is 1390 m.

The Middle Siwalik fauna particularly the Dhok Pathan exhibits very close Pontian affinities. It has Pontian carnivore, *Orycteropus*, advanced mastodonts, *Hipparion*, *Chilotherium*, *Aceratherium*, rather advanced suids and *anthracotheres*, cervids, large giraffids and Pontian bovids.

The Upper Siwaliks comprise variegated, soft and massive pebbly sandstone with grey and brown clay bands and are predominantly conglomeratic in the upper portions. The sandstone and conglomerates are incoherent, loose and friable. They contain streaks of lignite at places. They are quite thick, about 2350 m or so in thickness.

The Upper Siwalik fauna contains the *Equus*, *Elephas* and the *Bos*, Pleistocene carnivores, mammoths and ungulates.

Pilgrim (1913) proposed further subdivision of the three groups of the Siwaliks into seven formations based mainly on their faunal associations and the different formations cannot be definitely recognised in the field merely on lithological grounds. His final classification of the Siwalik Supergroup rests as follows:—

Boulder Conglomerate:
(Second glaciation or Upper Pleistocene): Massive boulder conglomerates, thick earthy clay, sand and pebble grit. Fauna includes *Bubalus platyceros*.

Upper Siwalik

Pinjor Formation (Upper Villafranchian or Lower Pleistocene): Pink or brown silt and sand with intercalations of dull red and grey sandy clays. It has yielded the typical Upper Siwalik fauna with such Villafranchian forms as *Semnopithecus, Archidiskodon, Stegodon, Equus, Camelus, Leptobos, Sivatherium, Indratherium, Giraffa*, etc.

Tatrot Formation (First glaciation, Astian to Lower Villafranchian): Coarse, usually soft sandstones with interspersed conglomerate bands and silt layers with large scale delta structure and frequent facies changes. Fauna includes, *Elephas* and *Bos*, two characteristics Villafranchian forms but *Equus* has not been reported.

———————*disconformity*———————

Middle Siwalik

Dhok Pathan Formation (Pontian): Soft massive sandstones interbedded with thin dull coloured sandy clays. It has got the typical Pontian forms like, *Cercopithecus, Agriotherium, Indarctos, Simocyon, Parataxidea, Plesioqulo, Eomellivora, Machairodus, Paramachoerodus, Stegolophodon, Rhinoceros, Hipparion, Merycopotamus, Iragocerus, Proamphibos, Vishnutherium*, etc.

The Bandar beds which Pilgrim placed above this formation has been found to be only a local facies.

Nagri Formation (Sarmatian): Paper coloured sandstone and red shale. It has an impoverished fauna which includes *Crocuta, Ramapithecus, Sugrivapithecus, Meganteron, Hipparion, Orycteropus*, etc. Proboscideans are conspicuous by their absence in this formation.

Chinji Formation (Tortonian): Orange brown and brick red sandstone and shale. It is the earliest *Hipparion*-bearing formation of the Siwaliks. Other important forms include *Dyropithecus, Sivapithecus, Hipparion, Sivanasua, vishnuonix, Sansanosmilus, Deinotherium, Serredentinus, Giraffokeryx, Gazella*, etc.

Lower Siwalik

Kamlial Formation (Helvetian):
It is the lowermost formation of the Siwaliks comprising hard, red and grey sandstones and shales. Its fauna includes: *Amphicyon, Hyaenaelurus lahirii, Deinotherium, Trilophodon, Palaeochoerus, Conohyus* and ***Listriodon***. All these forms are holdovers to the Chinji Formation except *Hyaenaelurus* which also figures prominently in the underlying Murrees.

Upper Murree

Conformable passage downwards into Upper Burdigalian. Murree sandstones and shales. The Murree fauna includes *Anthracotherium bugtiense, Hemimeryx* sp. *Brachyodus* cf. *africanus, Palaeochoerus pascoei, Teleoceras fatehjangense, Hyaenaelurus bugtiense*, etc.

Siwalik sediments pass upwards from lower to higher beds with few apparent breaks. There are small local unconformities, and thinning out and overlap are frequent, but these irregularities are no more than are to be expected in subaerial accumulation as the Siwaliks are. There has been no widespread break in deposition and inspite of considerable lateral variation in individual beds, the above general sequence is remarkably constant. Each stage, corresponding to a slight change in the conditions of deposition, grades in most places conformably into the next across a transition zone. There is absolutely no trace of any unconformity between the lowermost stage of the Siwaliks, the Kamlials and the underlying Murrees and Dharamshalas. In sections where the Murrees and Siwaliks are in unfaulted contact, there is no break but clear indications of continuous deposition from one epoch to the other, and there is no real evidence against the existence of a continuous sedimentation from the base of the Murree to the overlying Siwaliks. Anderson (1927) went to the extent of proposing to designate all the freshwater sediments of Potwar as the 'Nimadric System', thus doing away with the division into Murree and Siwaliks. Similarly, Cotter (1933) suggested that the base of the Siwaliks should be shifted to the Kamlial-Chinji boundary which he considered to be a better defined and more readily mappable horizon than the Upper Murree-Kamlial junction while according to Gill (1951) it is no less difficult than that of mapping the base of Kamlials.

Delineation of boundaries of the other formations also have been rendered equally difficult by frequent facies changes. In Potwar area, the Chinji-Nagri contact is also obscured because of the local development of a shaly facies in the Nagri with a marked "Chinji aspect" and the introduction of buff coloured sandstones of a distinct Nagri aspect into Chinji. The Nagri-Dhok Pathan boundary has been similarly rendered obscure due to the development of a Dhok Pathan facies at much lower levels in the Nagri making it only a diachronous boundary between the two formations.

Identical impasse engulfs the Middle and Upper Siwalik contact also in the southern link of the Son syncline where Wadia (1928) and Gill (1951) do not agree with each other over the question of Upper Siwalik sediments overlapping the Middle Siwaliks entirely.

Further, west of long.73°, Wadia (1928) and Cotter (1933) do not agree with each other in placing the boundary between the Upper and Middle Siwaliks. Wadia (1928) considered that the base of the group of brown sandstones and brownish red silty clays corresponds with the lower boundary of Upper Siwalik but this group acquired a Dhok Pathan aspect because of lateral variation and according to Cotter, the lower part of Wadia's Upper Siwaliks actually belong to the Dhok Pathan Formation and he also thought that the Upper Siwalik fauna as given by Wadia (1928) included Dhok Pathan forms. In the Jwalamukhi area, however, the soft massive sandstones of the Middle Siwaliks give passage to the massive Upper Siwalik conglomerates containing pebbles of basic volcanic rock which are absent in the Middle Siwalik with a 10 m thick transitional zone occurring between the two. This abrupt transition not marked elsewhere, has led several workers to infer a local time break between Middle and the Upper Siwaliks. From the foregoing, it becomes amply clear that the extension of the various Siwalik subdivisions on a regional scale beyond their type areas present insurmountable difficulties.

From the above discussion, it may be reasonably concluded that the different units would not have an appreciable geographic extent during any particular interval of time to form good time stratigraphic units. Vertebrate fossils also do not occur throughout and thus, stratigraphic units can not be mapped on a regional scale on the basis of palaeontological data alone. Polospores have also not proved to be of much help in this regard because of their paucity of the fine clastics which occur generally in the oxidised red facies. Strike mapping provides a great help when outcrops continue for long distances but again, the matter becomes equally difficult in case of sequences repeated by folding or faulting or separated by big patches of post-Siwalik deposits.

Study of the petrography particularly the heavy mineral fractions of the Siwaliks has proved very useful in delineating the boundaries between the different stratigraphical horizons because of the fact that Siwalik clastics have been derived from an active orogenic belt and sediments furnished during a particular orogenic cycle differ from those of the other. This method also has its limitations, however, for it is not yet known decisively whether the entry of a particular heavy mineral is completely isochronous in the stratigraphic column. Moreover, the distribution of the marker minerals is not absolutely homogenous even in a small area and it is quite natural because of the varying composition of the provenance of the Siwalik sediments which could not be expected to be uniform over a strike length of 2900 km. Compositional variations are, sometimes gradational, but more often than not, abrupt. Further, the first appearance of a particular mineral species at a particular point in the stratigraphical column is very difficult to establish unless a huge bulk of rock samples is processed.

The Dharamshala-Lower Siwalik boundary is marked by the increase in the percentage of heavy minerals giving a darker appearance of the rock and the incoming of less rounded heavy minerals, like staurolite, zoisite and epidote. A similar change in heavy mineral content of the rocks is found to occur at the top of the Barails in Assam which are considered to be approximately homotaxial with the Dharamshala (Late Eocene-Oligocene).

The lower boundary of the Middle Siwalik coincides with the first appearance of kyanite in the heavy mineral assemblage and in general, the heavy mineral suite in Middle Siwaliks is more complex than that of the Lower Siwaliks.

The Upper Siwalik is characterised by a very complex suite of heavy minerals, including hornblende, sillimanite and andalusite, indicating a derivation in part from the cores of the nappes in the Himalaya to the north of the foothills, the nappes having by that time been stripped of their less metamorphosed cover. The basal Conglomerate of the Upper Siwaliks also contains pebbles of basic igneous rocks which are absent in the Middle Siwaliks.

It is interesting to note here that the results based on the heavy mineral distribution are, more or less in agreement with those obtained in lithological or palaeontological grounds. One fact, however, emerges very boldly and that being the validity of the age old three fold classification of the Siwaliks. It is also rather indisputable that the evidence at hand does not permit us to further subdivide the Siwaliks into formations.

Pilgrim's researches attracted wide attention on these deposits. A large number of American and European workers made fresh collections from the Siwaliks. The studies which were made on these collections, both freshly acquired and those already existing in various museums of India and abroad, during the thirties and forties of the present century have left a vast literature dealing with the evolution, migration and other related topics of the vertebrates and their bearing on the stratigraphic aspect of the problem. It is concievable that wide areas of disagreement exist in the different assessments of the problem as a whole.

With regard to the different areas of agreement and disagreement, it may be stated that all are in agreement with the threefold division of the Siwalik Supergroup. Opinion, however, differs on the stratigraphical status of the Group only and not Supergroup as envisaged in this paper. There is wide agreement with Pilgrim in dividing the Siwaliks into formations except in case of Tatrot and Pinjor Formations of Pilgrim which have been united into one 'Tatrot stage' by Lewis (1937) and Pinjor by Acharya *et al.* (1976). Many Subsequent workers have not agreed to this modification, although lately, there is shift of opinion in favour of such a step (Acharya *et al.* 1976). Local stratigraphical names have also been proposed to modify different formations of Pilgrim further but they do not substantially alter the character of the classification proposed by him.

A fresh look on the faunal list of the different formations of Siwaliks as proposed by Pilgrim reveals some interesting facts. There is hardly any difference between the Kamlial and Chinji Formations so far as their fauna is

Table 1.

	Chinji	Nagri	Dhok Pathan
Dryopithecus punjabiense	×	×	
Sivapithecus indicus	×	×	
Amphicyon palaeindicus	×	×	
Crocuta gigantea latro		×	×
Crocuta gigantea schlosser		×	×
Vinayakia	×	×	
Hipparion theobaldi		×	×
Macrotherium salinum	×	×	
Gaindatherium browni	×	×	
Aceratherium perimense	×	×	×
Aceratherium blanfordi	×	×	×
Chilotherium intermedium	×	×	×
Palaeochoerus perimensis	×	×	
Conohyus sindiense	×	×	
Tetraconodon	×	×	×
Listriodon pentapotamiae	×	×	×
Potamochoerus hysudricus	×	×	×
Potamochoerus ingens	×	×	
Hemimeryx pusillus	×	×	
Dorcabune minus	×	×	×
Selenoportax vexillaris	×	×	×
Sus		×	×
Hippohyus		×	×
Orycteropus		×	×

concerned.

The Kamlial Formation which preceedes the Chinji contains *Amphicyon, Deinotherium, Trilophodon, Palaeochoerus, Conohyus, Listriodon* and *Hyaenaelurus*. All these forms are holdovers to the succeeding Chinji except the last one which is a holdover from the earlier fauna. In India, *Hyaenaelurus* appears in the Gaj Formation as *H. bugtiense* and persists upto the Kamlial Formation as *H. lahirii*.

It has also been noted that a large number of genera pass from the Chinji Formation to the succeeding Nagri so much so that it has become almost a Lower Siwalik fauna.

Apart from many physical differences between Chinji and Nagri Formations, the faunal evidence is also suggestive of its distinction from the preceding Chinji and the succeeding Dhok Pathan Formation. It differs from preceding Chinji and succeeding Dhok Pathan in the complete absence of any proboscidean remains. It contains such elements as are common to the Chinji fauna and also to the Dhok Pathan fauna. But the genera *Hippohyus, Sus*, and *Orycteropus* which have not been found in the Chinji and are related to Dhok Pathan forms clearly indicate that the Nagri fauna is nearer to that of Dhok Pathan than the Chinji one. Truely speaking, this fauna provides a sort of bridge between the Siwalik Vindobonian and the Pontian faunas and it contains the Sarmatian elements. It has now been confirmed that *Hipparion* does not occur in Chinjis.

Between the Dhok Pathan and the overlying Tatrot, there is definite faunal break. At the end of the Dhok Pathan deposition and prior to the deposition of the Tatrot sediments, there has been an uplift which folded the Dhok Pathan beds and initiated a new cycle of erosion. This period of erosion, after the Dhok Pathan beds, indicates a long hiatus corresponding to theLatePliocene which in Siwaliks is neither represented by sediments nor fauna. This is corroborated by the fact that the Tatrot sediments are found only along basins, stream channels and not on the Potwar peneplain. At several places they overlap the underlying Middle Siwalik beds. The antecedent nature of a stream called Nandna and the accentuation of the Kala Chitta range and its eastwards extension lend support to this uplift. Whenever Tatrot beds overlie the Dhok Pathan strata, a basal conglomerate or conglomeratic sandstone is always discernible. At certain places the thickness of the conglomerate is about 30 m. This conformity, however, is not always present but in view of the Potwar peneplanation which must have involved considerable time, it represents a long break in deposition when about 300 m of the Dhok Pathan sediments were eroded away and is not of local importance only.

As regard to age of the Tatrot fauna, with the latest addition of *Camelus sivalensis* to the existing list of *Elephas, Bos* and *Equus* there can be no doubt that they are Villafranchian in age. The succeeding interglacial fauna of Pinjor, is also Villafranchian. Of late, it has been felt that Villafranchian in Europe represents two faunas, the lower and the upper and the correspondence of the Tatrot and Pinjor faunas to the Villafranchian lends support to it. De Terra and Teilhard (1936) are of the opinion that from a palaeontological view point, the Tatrot and the Pinjor stages represent more or less an uniform fauna and one cycle of sedimentation. The gradual sedimentary passage between these stages made the division of the two units rather arbitrary.

As already stated, the Boulder Conglomerate Formation consists of coarse boulder conglomerates, thick earthy clays, sands and pebble gritts and not merely conglomerate as the name signifies. Pilgrim (1913) thought that this formation had yielded the Upper Siwalik fauna but the subsequent work of Brown (1925) has revealed the presence of only a bovid, the *Bubalus platyceros* from this formation which makes its status as a formation shaky.

From the foregoing, it is evident that lithological, sedimentological and palaeontological evidences separately do not give a clear picture of the different aspects of Siwalik stratigraphy but they do help in clearing a lot of doubts when applied in conjunction. It is suggested that systematic collections should be made afresh from the important sections and these sections studied afresh in all aspects of the Siwalik geology, as has been done in Siwaliks falling in Pakistan.

Recently, radioactive minerals have been recorded from the Siwalik (Yokoyama *et al.* in press, Tandon and Kumar, 1984) and absolute ages might be determined to arrive at a better picture of the age relationship of the different groups/formations. Once this is done, the relative evolutionary advances in the different fossil groups could be established for purposes of precise correlations. In view of the hydrocarbon and radioactive contents of Siwaliks, this might prove rewarding. At least, two bentonitic horizons have been located in Pinjor beds in Jammu (Yokoyama *et al.*, in press) and also in Karewas in Kashmir (Burbank and Johnson 1983) which have helped in precise dating of the Pinjors. Similar bentonitic beds have been found westwards in Pakistan Siwaliks also which have helped in establishing correlation of the Siwaliks of these two areas.

Source of the tuffaceous layers in Pakistan Siwaliks has been traced to the Dacht-e-Nawar volcanic complex of east-central Afghanistan (Johnson *et al.* 1982). These interstratified bentonitic horizons have enabled precise radiometric age determinations of a number of sections.

The age data have been further supported by palaeomagnetic studies of various successions. Calibration of the faunal assemblages in these radiometrically dated sequences have provided a framework for establishing precise temporal ranges of the various vertebrate taxa and creating standard stratotypes for each biostratigraphic division.

On the bases of magnetic polarity stratigraphy, radiometric ages and hipparionine fauna (Barry *et al.* 1982) have designated four biostratigraphic interval zones for the Middle and Upper Siwalik in the classic Hasnot area of Potwar region. These zones are:

1. "*Hipparion* s.l." *Selenoportax lydekkari* Biostratigraphic Interval Zone: The zone spans a time range approximately between 9.5 and 7.4 m.y. B.P.

2. *Selenoportax lydekkeri/Hexaprotodon sivalensis* Biostratigraphic Interval zone: Approximate age 7.4-5.3 m.y. B.P.

3. *Hexaprotodon sivalensis/Elephas planifrons* Biostratigraphic Interval Zone: Approximately 5.3-2.9 m.y. B.P. The lower boundary of this zone is recognised from the lowest occurrence of *Hexaprotodon sivalensis* and the Upper boundary from the lowest occurrence of *Elephas planifrons.*

4. *Elephas planifor* /"*Hipparion* s.l." Biostratigraphic Interval Zone: Age estimates of this zone are approximately 2.9 and 1.5 m.y. B.P.

Numerous other verteberate taxa, their appearances and disappearances have been calibrated in these zones. In time span and the faunal content, these interval zones roughly correspond to the Pilgrim's faunal zones of Nagri, Dhok Pathan, Tatrot and Pinjor.

The chronostratigraphic framework developed for the Siwalik Supergroup in Potwar region will enable more accurate correlations in the Indian subcontinent and elsewhere.

In the Indian counterpart there is a general paucity of radiometric datable materials. Only known occurrence of bentonitic tuffs are in the Upper Siwalik (Nagrota Formation) of Uttarbaini south-east of Jammu. Recently Yokoyama *et al.* (in press) have attempted fission- track age determination of one of the bentonitic band and have reported its age to be 1.6 ± 0.2 m.y. B.P. They have also commented on the ages of the associated vertebrate fauna. Unfortunately this age data has only a limited application in distant correlations unless supported by magnetostratigraphic studies of the entire succession. Occurrence of four tuffaceous mudstones interstratified in the Upper Siwalik (Pinjor Formation) of Ghaghar River section east of Chandigarh, has recently been reported by Tandon and Kumar (1984) but these have not been radiometrically dated. Vertebrate fauna of this part of the Siwalik is fairly well known and any attempt on precise ages coupled with magnetostratigraphic studies of the sections will go a long way in correlations of the Siwaliks.

Magnetostratigraphy of the Siwalik sequences in India is also in a very primitive stage of study. Only attempts are those by Yokoyama (1981), Azzaroli and Napoleone (1982) and Tandon *et al.* (1984) in the Upper Siwaliks around Chandigarh. These preliminary studies have thrown light on the Plio-Pleistocene boundary in this area. However, the results of these independent studies are conflicting. According to Yokoyama the upper part of Tatrot are correlatable with the Olduvai Event in the Matuyama Reversed Epoch, whereas Tandon *et al.* (1984) hold that the Tatrot-Pinjor boundary corresponds to the Gauss-Matuyama boundary and the Olduvai Event in the Matuyama Reversed Epoch span 160 m of the Middle part of the Pinjor Formation. Their interpretations have put the Plio-Pleistocene boundary 170 m higher above the Tatrot-Pinjor faunal boundary.

It is thus seen that clear picture of precise ages has not yet emerged from these studies in the Siwaliks of India to be of use in distant correlations.

Fortunately enough, however, more systematic collections of vertebrate fossils have been made in recent years from many parts of the Siwaliks especially from the Lower Siwaliks of Kalagarh (U.P.), Middle and Upper Siwaliks of Saketi, Nalagarh and Haritalyanger (Himachal Pradesh), Upper Siwalik north and east of Chandigarh and Lower, Middle and Upper Siwaliks of Jammu, Ramnagar and Uttarbaini in J & K State. These collections have helped in building up local biostratigraphic biozones and correlations.

The vertebrate fauna recovered from the Chinji beds of Ramnagar, Udhampur district, J & K, by a number of workers is large and characteristic of the Chinji type area. Considering the outcome of the fossil content from various other Lower Siwalik localities in the Tawi-Ganges region of the Siwalik hill tract, the Ramnagar area seems to be the most promising for designating the stratotype for the Lower Siwalik fauna in this part.

The Ramnagar section though exhibits a full development of the Siwalik Supergroup, all other units are poorly fossiliferous. Instead another section, i.e. the southern limb of the Suruin-Mastgarh Anticline in Jammu district holds prospects for future studies. Recently a very large collection of vertebrate fossils has been made from different lithounits in this part by the G.S.I. which is under study.

Again the entire Siwalik Supergroup is best exposed in the haritalyanagar sector of H.P. but here, the Chinji zone is poorly fossilferious. The Middle Siwalik, however, are fairly rich in fossil content. Thus for developing the Middle Siwalik (Nagri/Dhok Pathan) type section the Haritalyanagar beds are perhaps most suitable as they have been the source of best collections so far made.

The Lower Siwalik of Ramnagar and Middle Siwalik of Haritalyanagar are the classic areas for fossil hominoids. More collections have been made recently but the material is still insufficient and too fragmentary to work out human lineages.

Some concluding results have been obtained from the systematic collections, made during the last three decades, from the Upper Siwalik exposures in Yamuna-Sutlej sector. The traditional Tatrot and Pinjor biozones have been recognised with fair degree of accuracy though, their names are not in accordance with the stratigraphic code. The Tatrot beds are recognised from the characteristic presence of *Stegodon bombifrons, Hipparion theobaldi., H. antilopinum, Proamphibos lachrymans* and *Hippohyus tatroti*. The occurrence of *Hipparion* is very rare in the Pinjor, if, at all it is there. Instead *Equus* makes it first appearancee and is profusely distributed. The association of *Hipparion* along with other three species (mentioned above) distinguishes the Tatrot from Pinjor. Profuse distribution of *Hexaprotodon sivalensis* and other aquatic forms in the Tatrot is also a distinguishing criteria.

For delineating the much debated Neogene/Quaternary boundary in this region the stratigraphers are still not in agreement and hold individual opinions. Obviously, more work is needed to reach a common conclusion.

The Upper Siwalik of the Indian subcontinent have been found to be completely devoid of early hominoids, but during the recent investigations some interesting facts have come to light. Numerous Early Palaeolithic tool-bearing sites have been noticed in the Upper Siwalik exposures in the region between Yamuna (H.P.) and Tawi (J & K). Some workers now believe the source of these artifacts to be in the Siwalik sediments underneath. In a number of instances *in situ* tools have been recovered from the main component of the Upper Siwalik strata (Verma, 1975). At many localities the artifacts and Siwalik fossils occur in close association as well. If, it is really the case, the antiquity of the Early Palaeolithic culture will no doubt extend much down i.e. in the Plio-Pleistocene instead of its being Middle Pleistocene, as is believed at present. In fact the time-stratigraphic position of the Early Palaeolithic Culture had not been clearly understood in the Indian subcontinent. The problem invites further attention on a larger scale, through a coordinated approach by biostratigraphers and anthropologists.

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