OBSERVATIONS ON THE UPPER SIWALIK FORMATION AND LATER PLEISTOCENE DEPOSITS IN INDIA

H. DE TERRA AND P. TEILHARD DE CHARDIN

CONTENTS

A. Introduction.
B. Observations on type sections through Upper Siwalik formations.
I. Indus and Potwar area.
1. Campbellpore.
2. Soan valley near Rawalpindi.
II. Himalayan foothills between Kahuta and Jammu.
3. Kahuta.
4. Mirpur.
5. Jammu.
6. Tawi valley near Udhampur.
III. Salt Range area.
7. Jhelum.
8. Tatrot.
9. Bhaun.
10. Naoshera.
C. Observations on post-Siwalik formations.
1. The Potwar silt and its possible origin.
2. Re-deposited Potwar lœss and younger river gravels.
D. Conclusions as to age and character of the various stages and preliminary remarks on their relationship to prehistorical cultures.
E. Supplementary note on the Narbadda Pleistocene in Central India.

ABSTRACT

New field studies, carried out last year, lead the authors to a more concise classification of Pleistocene sequences in India. The "Upper Siwaliks" are considered to be of Pleistocene age throughout with the uppermost stage being as young as the second glacial advance in the adjoining Himalaya. The "Boulder Conglomerate" stage witnessed the arrival of Ancient Man whose Paleolithic industries were discovered in NW-India as well as in the fossiliferous Narbadda formation in Central India. The Siwalik history closes during the middle Pleistocene and is followed by alternating erosion and deposition of lœssic beds beneath which a younger Paleolithic industry was found. The geological sections described permit of recognising three to four phases of mountain making since the close of the Pliocene period.

A. INTRODUCTION

TO ANYONE who studies closely the various publications and fossil collections of the Siwalik formations of northern India, it becomes evident that the boundaries, the paleontological and tectonic characters of the Upper Siwalik and later formations are rather imperfectly known. Therefore a closer field study of their stratigraphy was needed, not only in order to clarify questions still pending but also to build a stratigraphic foundation on which the dating of young crustal movements and of early human cultures in Northwest India could be based.

Pilgrim's[1] stratigraphic terms "Tatrot," "Pinjaur" and "Boulder Conglomerate" are universally used to designate the three stages of the Upper Siwalik formation, but the meaning of each term remained indefinite under the assumption that the three divisions make a faunistically and stratigraphically uniform group. This view had found its most pregnant expression in Van Vleck Anderson's[2] statement that in the "Nimadric system" (the post-Eocene freshwater formations of the Himalayan foothills) there appears to be "comformable gradation throughout."

As a result of observations made lately by the authors it seems on the contrary:

(1) that the older Upper Siwaliks (Tatrot-Pinjaur) represent a perfectly individual unit generally sharply separated from the Dhok Pathan stage below and from the Boulder Conglomerate stage above, and

(2) that this separation being made clear, the faunistic groups corresponding to the Middle and Upper Siwaliks become appreciably more distinct.

In the following we shall describe several type sections, studied by ourselves, in which the relationships between the three stratigraphic elements, namely the Middle Siwaliks, the older Upper Siwaliks and the Boulder Conglomerate are especially clear and decisive. In view of the fact that these sections comprise also post-Siwalik formations it seemed advisable to make brief references to them. From the facts exposed our conclusions will follow naturally.

We are under great obligation to the American Philosophical Society at Philadelphia for having supported our work which enabled us to carry out a joint research within a

[1] G. E. Pilgrim, Records Geol. Survey India; 1910 et seq.
[2] R. Van Vleck Anderson, *Bull. Geol. Soc. Am.*, **38**, p. 674.

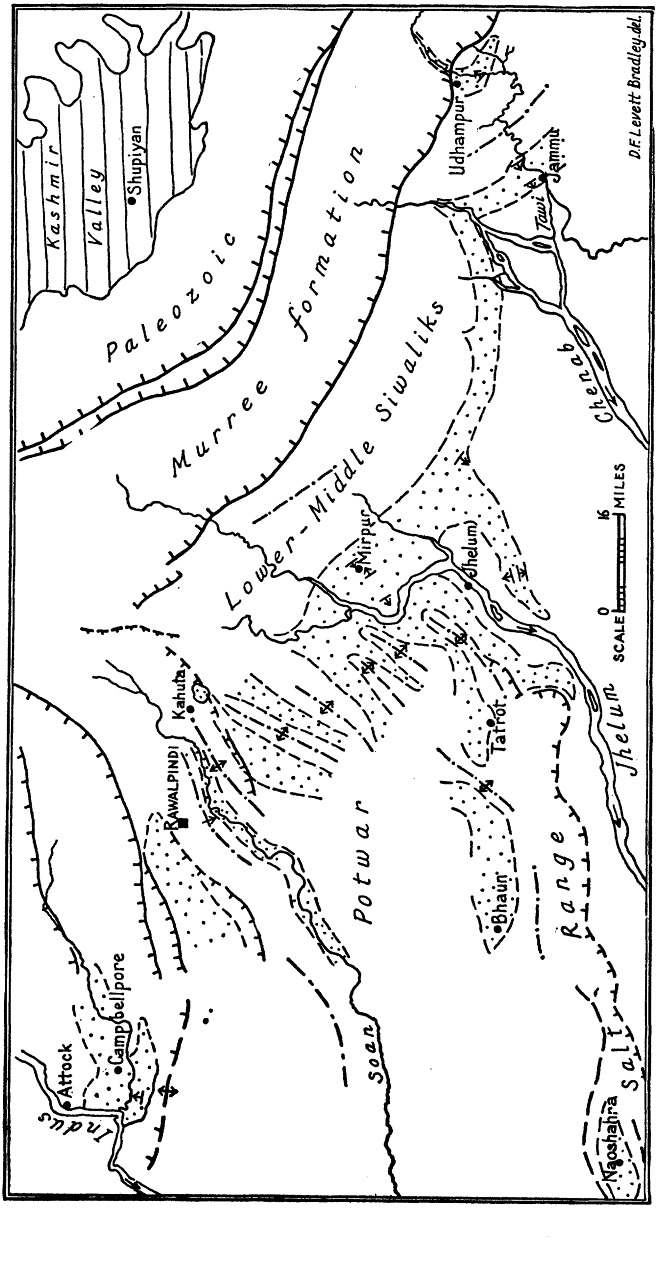

FIG. 1. Sketch map showing structural pattern and distribution of Upper Siwalik beds in the NW-Punjab

Upper Siwaliks = stippled; Kashmir Pleistocene = ruled; major Pliocene anticlines = broken line with dots; major overthrusts = solid or broken lines with right angle intervals.

more extensive program of geological and prehistorical studies in India. We also feel greatly obliged for the support of the Carnegie Institution in Washington and for the encouragement which Dr. John C. Merriam gave to the entire undertaking. The coöperation of the Geological Survey of India and of that of the American Museum of Natural History is most sincerely appreciated. In particular we thank Dr. Edwin H. Colbert who already determined a larger portion of Upper Siwalik fossils collected by us.

B. Observations on Type Sections through Upper Siwalik Formations

I. Indus and Potwar Areas

1. Campbellpore

The basin of Campbellpore lies southeast of Attock in a dissected portion of the Punjab plains which is here bordered in the east by the Indus river, towards the south by the Kala Chitta ridge, and in the west by the Haro river, a tributary of the Indus. The surface lies some 1200 feet above sea-level, forming a depression which is flanked in the north by thrusted Paleozoic rocks, and in the south by an anticline, built of Eocene limestone and Mesozoic formations. The basin is at least nine miles broad and over 15 miles long in a west-easterly direction.

The basin sediments are exceptionally well exposed as indicated in Fig. 2. This section begins near Choi, in the vicinity of the road to Basal and extends across the NNW-SSE strike of the formation to the Haro river and beyond over a distance of five miles. In the centre of the basin appears a horizontal gravel cap, some 8–20 feet thick, which contains large erratic blocks and glacially facetted boulders. This gravel is a fluvio-glacial outwash deposit which can be traced back to the mountain front where the Pleistocene glaciations have recently been investigated by de Terra and Paterson. Previously Wynne [1] had interpreted this boulder gravel as a

[1] *Rec. Geol. Survey of India*, **13**, 1880.

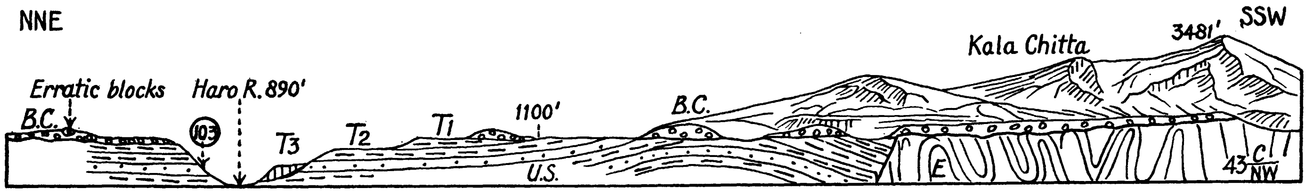

Fig. 2. General cross-section through Campbellpore basin

B. C. = Boulder Conglomerate; U. S. = older Upper Siwaliks; E = Eocene; $T_1 - T_5$ = Pleistocene terraces; total length 5 miles (all sections bear index mark of topographic sheets at right hand corner).

glacial deposit. Northeast of the Haro river this gravel continues up the slope of the Kala Chitta where it finally merges with a large fan composed of Eocene limestone blocks. This fan reveals a period of intense denudation in the ridge which is doubtless responsible for its accumulation. The fan merges along the Haro river with the fluvio-glacial outwash in which we recognise the "Boulder Conglomerate" of Upper Siwalik time.

Underneath the gravel lie the basin sediments proper. They are gently folded and apparently faulted against Eocene limestone. The upper portion of this sequence is shown in Fig. 3. The orange clays and whitish-grey sandstones in

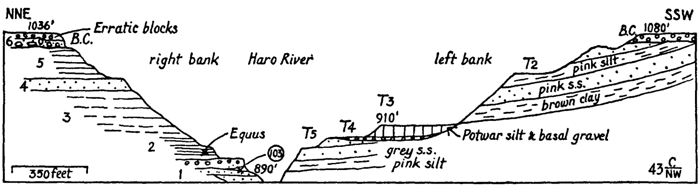

FIG. 3. Combined section through Campbellpore basin along Haro river
1 = grey pebbly s.s. and clay, 16 ft.; 2 = laminated greenish-brown silt and s.s., 12 ft.; 3 = orange silt and concretionary caly, 10 ft.; 4 = grey s.s., 8–10 ft.; 5 = light orange clay, 20 ft. (dip exaggerated).

this section resemble the Dhok Pathan rocks of Middle Siwalik age for which they might easily be mistaken at first glance. Luckily we found at the base of this upper group numerous fossils which prove its Upper Siwalik age. In the greenish silt was found a palate of horse (*Equus*), and in the underlying soft grey and sandy layers (at locality 103) we discovered a bone pocket, crowded with mammal bones belonging mainly to the following forms: *Stegodon*, *Bubalus* (sharply trihedral horn-cores), deer, *Hyæna*, *Felis*, *Machairodus*, *Mustela*, *Viverra*, *Boselaphus*, strepsiceros antelope, *Sus*, all of typical Pleistocene affinities.

In the southwestern continuation of the section appear conformably brown clay, pink silt and grey or pinkish sandstone in alternating fashion, and partly cross-bedded, which abruptly border the Eocene limestone in a thick series of bluish-grey silts. At places the brown clay contains indistinct plant remains, at others it is laminated. Both these features cause it to resemble the "lower Karewa" beds of Kashmir, which belong to the first interglacial period. In this region the beds form a flat anticline which is unconformably overlain by Boulder Conglomerate. The thickness of these beds must amount to some 500 feet.

It is in this connection interesting to note that Mr. T. Morris recently found a similar formation with similar fossils near Pezu in the Northwest Frontier Province. Here the Middle Siwaliks are present while at Cambpellpore no Dhok Pathan beds appear.

Noteworthy in this section are certain gravels and overlying yellow silts which rest against the Boulder Conglomerate, and at the same time fill the dissected relief within the basin where they form terraces along the Haro river. Such younger deposits are widespread in the Potwar region, some 40 miles east of Campbellpore, and they shall henceforth be called "Potwar silt."

2. Soan Valley near Rawalpindi

The Soan river is a tributary of the Indus which flows from north to south across the Potwar area near Rawalpindi. Its valley occupies a syncline in Siwalik formations which strikes northeastward in conformity with the syntaxis of Himalayan folds as outlined by Wadia.[1]

A few miles southeast of Rawalpindi, on the right bank of the Soan river, the Boulder Conglomerate is represented by a faintly tilted series of hard limestone conglomerates and alternating beds of pink sand, silt and clay which form high terrace remnants above the level of the Potwar plain (Fig. 4). This series overlies here unconformably the levelled edges of Murree sandstone and of Middle Siwalik rocks, a relationship which can clearly be studied on the left bank opposite Kund. As one proceeds further southeast the conglomerate changes, it becomes looser and is mainly composed of various quartzite

[1] D. N. Wadia, *Geol., Mining and Met. Soc. India, Quart. Jour.*, 4, 1932.

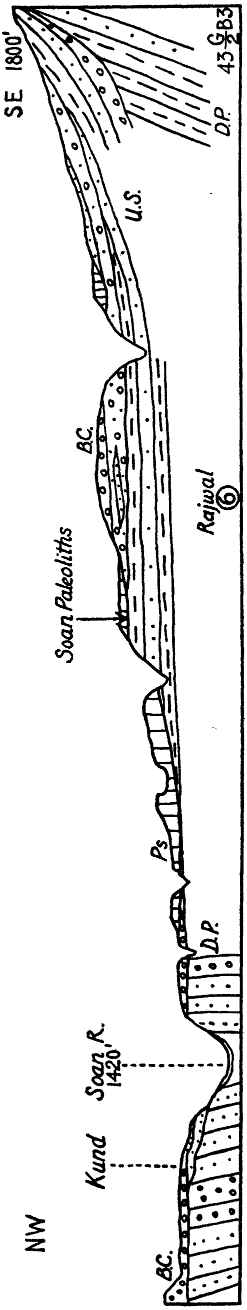

FIG. 4. Section through Soan basin near Rawalpindi

D. P. = Dhok Pathan (late Pliocene) s.s. and conglomerates; Ps = Potwar silt; Scale: 1" = ½ mile, height 10 ×.

pebbles with a transition to pink and grey sands and silt. This change in the pebble composition is no doubt due to a different supply of gravels, part of which seem to be derived from the conglomerates of the underlying Dhok Pathan rocks. A typical sequence is to be found at Rajwal where the cliffs expose a thickness of 110 feet. The intervening country between this place and the Soan river displays a deeply dissected series of light pink and yellow clay obviously representing, in parts at least, the Potwar silt. Early Paleolithic tools were found in the highest conglomerate layers, while a Middle Paleolithic industry in unworn state was frequently met with at the base of the Potwar silt.

Here again the Boulder Conglomerate consists of two facies, one with limestone gravels, the other with quartzite pebbles. The latter is bound to the Soan valley proper, whereas the other is traceable to an Eocene limestone ridge on the Himalayan side of the Potwar plain. Some 15 miles north of this section the limestone conglomerate contains large boulders and it seems to continue into the formerly glaciated valleys of the adjoining Pir Panjal range.

Beneath the Boulder Conglomerate lies a thick series of grey-brownish sands, red clay and layers of harder conglomerate which clearly belong to the older Upper Siwaliks. In the basal conglomeratic sandstone were found a few rolled fragments of mammal bones which, although they do not permit of identification, nevertheless show the state of fossilisation characteristic for the Upper Siwalik stage. The sombre colours and the loose consistency of these beds contrast sharply with the hard, brightly coloured rocks of Dhok Pathan age. At the base appears a thick brown and sandy conglomerate which adjusts its dip, like the overlying beds, to that of the Middle Siwalik group.

The section fig. 4 suggests subsidence of the Soan basin in three stages:

1. Subsequent to intense folding of older Siwalik rocks sinking and deposition of Upper Siwaliks.

2. Renewed folding with both Middle and older Upper Siwaliks tilted and deposition of Boulder Conglomerate.

3. Further tilting of all three formations.

II. Himalayan Foothills between Kahuta and Jammu

This region extends through the foothills of the Pir Panjal range east of Rawalpindi towards the outlet of the Tawi river at Jammu. Physiographically it presents low strike ridges and hills which rise 2000 to 3000 feet above the Punjab plain. Structurally it is characterised by the proximity to Himalayan overthrusts which give evidence of progressive crustal movements of Tertiary and Pleistocene age which appear to be directed against the Salt Range area in the Southwest.

3. Kahuta

T. T. Paterson, geological associate of the expedition, drew our attention to a small basin of Pleistocene beds near Kahuta which lies about 20 miles east of Rawalpindi. It makes a syncline in Middle Siwalik rocks which form boat-shaped strike ridges due to the pitching of fold axis in a southwesterly direction. The shape of the basin is sub-oval, its dimensions being 2¼ miles wide and some 3 miles long.

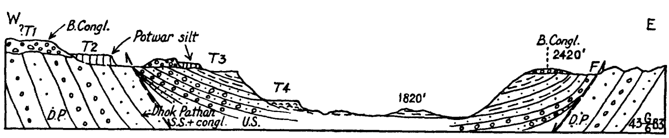

FIG. 5. General section through Kahuta basin
Total length ca. 3½ miles.

Section Fig. 5 begins in the vicinity of Gurhat hamlet and is drawn across the basin towards Gagari. At the former place an exposure shows the contact between steeply inclined hard Dhok Pathan sandstones and a soft grey conglomerate (15 feet thick) which is overlain by a series of grey soft sandstones, brown and pink clay and silt. The quick flattening of the dip and the rapid thinning out of the beds along the contact indicate drag-faulting due, no doubt, to "settling" of the softer rock material in the more rigid frame of Dhok Pathan rocks. A similar relationship was found along the road to Kahuta where the disturbed condition of the beds is very conspicuous. In this basin filling we did not find any fossils, yet its lithological composition is in all respects so similar to that of the Upper Siwaliks that it can only be referred to this group.

Basin filling and older beds are covered by patches of loose quartzite gravel. Its widespread occurrence on all neighbouring ridges suggests that it belongs to a large fan which may have been deposited by an ancestral Jhelum stream the present course of which is found only a few miles distant. In this coarse gravel we recognise the Boulder Conglomerate. The Potwar silt rests against the slope of the conglomerate terrace.

4. Mirpur

This basin also was pointed out to us by Mr. Paterson as representing an unusually complete sequence of Upper Siwaliks and disturbed Boulder Conglomerates.

Figure 6 gives a general section, showing north of the Jhelum river an anticline in pink and brown silt and sandstones. Towards Mirpur this asymmetrical fold is overlain

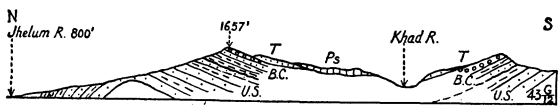

Fig. 6. Schematic section through Mirpur basin
T = high terrace; total length ca. 14 miles.

by pink sandy conglomerates with interbedded loose sandy layers which beds lie apparently conformable on the older group. This contact however must be in the nature of a disconformity, for the Boulder Conglomerate spreads widely across denuded Middle Siwalik rocks with which it forms an angular unconformity. It clearly indicates a period of intense deposition, both in the previously established Dhok Pathan synclines as well as on intervening levelled ridges, from which the Upper Siwalik beds may have been eroded. Accordingly their contact in the basin is disconformable with older Upper Siwaliks, and unconformable in the adjoining highlands where the first stage may never have been recorded by sediments. This situation may well account for the assumption of previous surveyors that the Boulder Conglomerate rests conformably on earlier Upper Siwalik rocks.

Most remarkable in this section is the folding of the Boulder Conglomerate with earlier Siwalik beds. This reveals continuity of folding on a structural pattern previously achieved by Himalayan orogeny.

The Potwar silt is here underlain by tilted cross-bedded brown silt and sand which are younger than the uppermost conglomerate layer. These beds may still belong to the Boulder Conglomerate stage. The latter forms a wide greatly tilted terrace level and towards the Khad river there occur at least three other but lower terraces which are clearly not dip-slopes but erosional terraces. In these the tilting is less pronounced but slight warping, which is directed away from the anticline, can still be noticed.

5. Jammu

On the border of the foothills and near the outlet of the Tawi river at Jammu occurs a very complete sequence of Siwalik formations. Here the first author took a section along the road which follows the right bank of the Tawi river, making excellent exposures between Jammu city and Nagrota. The conspicuous ridge on which Jammu is built rises some 700 feet above the level of the plains and consists entirely of loose bouldery gravel in a reddish matrix of sand and silt. This coarse conglomerate is underlain first by an alternating series of pink and yellow clay with conglomerate layers. One receives the impression as if the coarse conglomerate grades into the lower group which dips gently (5–10°) towards the plains. Professor G. Bose, of the Prince of Wales College Jammu, drew my attention to the frequency of facetted boulders occurring in the upper conglomerate. These boulders are either of quartzite, or less frequently of igneous rock. They display all the signs of having been smoothened and polished by ice. Here also a large waterworn flake of quartzite was found such as occur commonly in the Boulder Conglomerate near Mirpur and Rawalpindi. This upper group clearly belongs to the Boulder Conglomerate. Its thickness is about 1800 feet.

Below lies a series of alternating pink, yellow and grey silt, with sandstone layers and brown clay following upstream. These beds are more tilted than the upper group and resemble the Upper Siwaliks of the Soan and Campbellpore sections. Their Pleistocene age could be ascertained at Khanpur (arrow in Fig. 7) where coarse pebbly sandstones of grey colour yielded a molar of horse (*Equus*), isolated teeth of *Bos* and a molar of *Elephas planifrons*. This bone-bearing horizon is underlain by harder conglomerates, and brown to pink clay with freshwater shells. The total thickness of this group is approximately 2200 feet. At Nagrota[1] a slight disconformity separates the basal beds from underlying variegated clays and sandstones of typical Dhok Pathan facies. From this disconformity onward the dip of the underlying beds increases rapidly to 40 or 55° and more.

The section gives the impression as if the Upper Siwaliks form a huge fan in which two coarse horizons, namely the Boulder Conglomerate and the basal beds at Nagrota mark two stages of rapid accumulation which contrast with the more quiet sedimentation indicated by the intervening silt and clay layers. This twofold change from quiet to rapid deposition indicates two stratigraphic breaks or disconformities in an otherwise uniform sequence. The younger disconformity can be traced to an uplift of the adjoining Pir Panjal range, as Fig. 8 illustrates, while the older break is discernible in all Pleistocene sections indicative of strong uplift and folding along the mountain front at the close of the Tertiary.

[1] From this locality the Geological Museum at Jammu has *Stegodon ganesha* and *Hexaprotodon*.

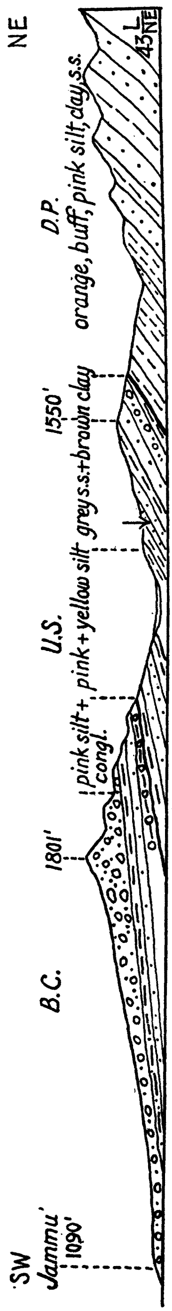

FIG. 7. Profile through front hills near Jammu

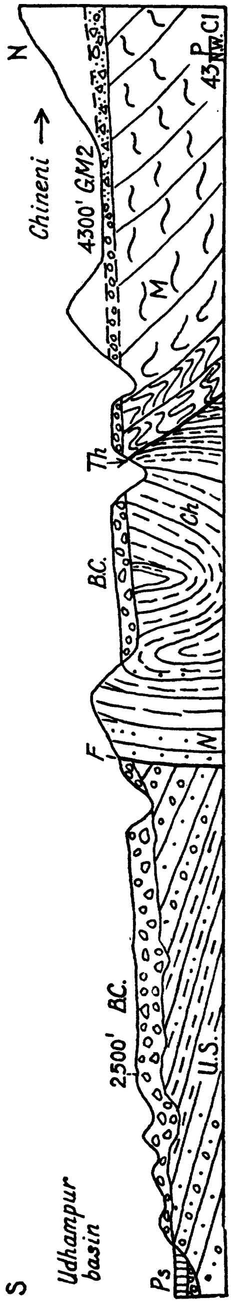

FIG. 8. Combined section along Tawi river near Udhampur

N = Nagri sandstone (middle Siwaliks); Ch = Chinji beds (lower Siwaliks); M = Murree sandstone (Miocene); F = fault; Th = thrust-fault; GM2 = ground-moraine of 2nd glaciation.

6. Tawi Valley near Udhampur

In the Himalayan foothills near Udhampur, some 15 miles north of section Fig. 7, Upper Siwalik beds occur in an isolated basin in greatly disturbed position. They constitute a thick series of grey conglomerates, sandstone and silt which are faulted against steeply folded Lower and Middle Siwaliks. Figure 8 shows this series to be unconformably overlain by a few hundred feet of conglomerates in a reddish sand matrix which build high level spurs along the northern slope of the basin. This deposit consists mainly of subangular Murree sandstone boulders and its thickness decreases notably north of a major thrust-plane (Th in Fig. 8). From here on also its composition becomes more varied until finally towards Chineni, the boulders lie in a clay matrix displaying signs of ice transport. Further upstream this deposit merges into a regular groundmoraine-filling of the Tawi valley. For reasons which will be discussed in another publication, this moraine should be considered as belonging to the second ice advance in the Pir Panjal range.

This section permits recognition of the following stages:

1. Fluvial accumulation of older Upper Siwaliks and tilting.

2. Denudation and deposition of Boulder Conglomerate, accumulation of which was determined by (*a*) erosion, released through thrust-faulting and (*b*) outwash from glacial deposits.

3. Erosion and deposition of Potwar silt (reddish) in the centre of the basin.

In this region the exact nature of the contact between the Upper and Middle Siwaliks remains to be ascertained but a steeper dip was generally noticed in the Dhok Pathan rocks which might indicate that the boundary is in the nature of an unconformity. The section demonstrates the dependence of the boundary between the two Upper Siwalik stages on the structural pattern, and it also shows that the unconformity is inevitably connected with a new drainage plan, initiated by a second orogenic phase.

III. Salt Range Area

This unit comprises the elevated, hilly as well as mountainous, tract between the Jhelum river in the southwest and the Potwar area in the northwest. The four sections described below lie on the slopes of the Salt Range anticlinorium, the central portion of which is sketched in Fig. 12.

7. Jhelum

Northwest and southeast of Jhelum city two anticlinal ridges mark the southern limit of the Siwalik folds. Their composition and structure, as interpreted in Fig. 9, is exceptionally suggestive.

In the northwestern ridge at Rohtas, the Boulder Conglomerate is represented by a conspicuous agradational terrace, making a 200 foot layer of quartzitic boulders loosely embedded in a red silty sand (Mirpur facies). On the crest of the ridge the conglomerate is dissected whereas on the slope it displays a wide level, clearly tilted towards the Jhelum valley. Younger gravels of different composition rest against the slope of the ridge.

The conglomerate overlies unconformably an anticline, the core of which is composed of Dhok Pathan rocks, such as grey-white sandstones, orange and red clays. This core is overlain, without any angular break, by a series of grey and mauve, soft and micaceous sands with alternating brown clays and conglomerate layers. At the southern entrance to the Rohtas gorge these beds stand vertically, and the ridge here breaks abruptly down to the valley floor. No fossils were found in this series but their lithological character sufficiently proves the Upper Siwalik age.

In the southeastern ridge, the so called Pabbi Hills, Dhok Pathan rocks do not emerge. Instead a thick, rhythmically deposited sequence of mauve, yellow and grey sands and silts appears which is surely referable to the older Upper Siwaliks. This is proved by the fossil fauna which we collected at Locality 104, at the crest of the ridge. Dr. Colbert determined from our collection the following forms: *Stegodon*

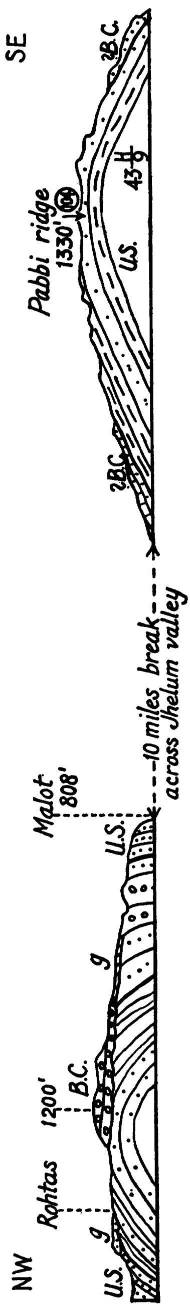

FIG. 9. Combined section through Siwalik folds near Jhelum

g = terrace gravel.

insignis, *Archidiskodon planifrons* (equals *Elephas planifrons*), *Cœlodonta platyrhinus*, *Rhinoceros sivalensis*, *Sus falconeri*, *Hexaprotodon sivalensis*, *Cervus sivalensis*, *Sivatherium giganteum*, *Taurotragus latidens*, *Bos acutifrons*, *Antilopine* horn-core.

Along the flanks of the ridge but especially on the northwestern slope, there appears a thick group of yellow and pink silts and yellow loam with small size conglomerate layers at the base. These beds resemble the Potwar silt to a certain degree but the greater variety of composition, the presence of thick basal gravels and the tilting rather argue for the presence of the Boulder Conglomerate stage.

If the observation is right that in the Rohtas section the Boulder Conglomerate is warped, and if it is true that in the Pabbi Hills the flanking beds are of late Upper Siwalik age, we may conclude that the folding of the former is anterior as a whole to the structure of the Pabbi Ridge in which the contact with the older Upper Siwaliks is conformable. This situation would suggest "propagation" of a crustal fold from the Salt Range anticlinorium towards the Punjab plains. If, on the other hand, the Boulder Conglomerate is absent in the Pabbi Hills, and not warped in the Rohtas section, then we would simply have another example of a clear unconformity between the Boulder Conglomerate and the older Upper Siwaliks.

8. Tatrot

Some 20 miles westsouthwest of the Rohtas section, the Salt Range forms two ridges one of which makes an anticline with NE strike whereas the other is in continuation of the northern anticline described in Fig. 9. Between them lies a basin which is occupied by folded Siwalik formations. The village of Tatrot lies almost on the boundary between Dhok Pathan and younger rocks which in the past have yielded many fossils. Evidently Pilgrim chose the name Tatrot for his lowest stage of the Upper Siwalik group on account of this fossil wealth which is now almost exhausted. Stratigraphically Tatrot is one of the least complete sections which we studied and would for this reason in our opinion not deserve to be mentioned in this discussion were it not for the reputation which the name Tatrot has gained in Indian geological literature.

Section Fig. 10 was taken in the middle portion of an escarpment which at Tatrot is built of resistant layers of grey conglomeratic sandstone. Below we found two similar, yet coarser and thinner beds, the lowest of which is composed of rounded and subangular pebbles of pink granite, porphyrite, various quartzites, chert and purple sandstone. A similar, yet even coarser composition is found in the upper conglomerate. Lithologically these beds contrast with the underlying

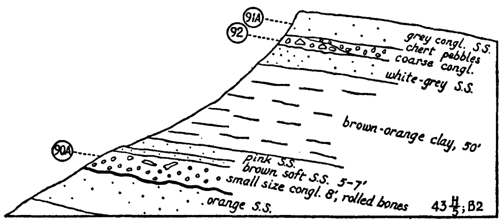

FIG. 10. Basal Pleistocene near Tatrot

Dhok Pathan rocks in which orange and pink colours prevail and in which the pebble components are different and less varied. The basal conglomerate therefore signifies a break in sedimentation due no doubt to a different supply of sediment which can be traced to the Paleozoic rocks emerging in the neighbouring Salt Range. At that time these older formations evidently were for the first time denuded, and it is reasonable to conclude that such process was brought about by uplift of the southern Salt Range tract. The younger beds then settled in a syncline, previously established, and recorded the new conditions in their lithology.

At the same time a new fauna appeared in this region. In the lower conglomerate (Fig. 10, 90*A*) we found only rolled bones, single teeth of *Bovids* and of *Hipparion* which fragments might, under the existing conditions, easily have been derived from underlying Dhok Pathan rocks. In the next layer a horn-core of *Gazella* was found and in the upper sandy conglomerate (Fig. 10, 92) an unworn jaw of *Sus hysudricus*. From information received by Dr. Colbert it seems that Mr. B. Brown collected in the upper layer (at the Am. Mus. locality 139, near 91*A* of Fig. 10) *Stegodon* sp., *Antelope* cf. *subtorta* (det. Pilgrim) and a molar of *Hipparion antilopinum*, and *Hippohyus lydekkeri*. In 1935 Mr. Aiyengar collected a few miles west of Tatrot from similar beds a skull of *Hemibos occipitalis* and *Hexaprotodon sivalensis*. The only discordant type in this otherwise Pleistocene fauna is *Hipparion* of which only single molars or fragments of such were collected. The evidence, cited above, for re-deposition of a few resistant fossil fragments of Dhok Pathan age, is highly suggestive of a possible mixture in these basal beds at Tatrot of a few Dhok Pathan forms, such as *Hipparion*, with Pleistocene types. It is this consideration which makes us think that the basal portion of the Upper Siwaliks at Tatrot is equally as old as the lower group at Jammu or Campbellpore.

At Hasnot and further westward the Siwaliks are overlain by coarse limestone conglomerates which cap the levelled edges of the earlier formations. It seems that they represent in parts the Boulder Conglomerate.

9. Bhaun

About 32 miles west of Tatrot lies another basin, adjoining the northern flank of the Salt Range. Here section Fig. 11 was studied along the Sauj Kas, a valley south of Bhaun, representing in parts the continuation of a profile previously described by de Cotter and Lahiri.[1] The authors gave a good interpretation of the angular conformity between Dhok Pathan and Upper Siwalik stages. As at Tatrot the latter begin with a basal conglomerate which the above named interpreted rightly as the beginning of a new cycle of sedimentation, initiated by uplift of the adjoining Salt Range.

[1] *Memoirs, Geol. Survey of India*, **62**, 1933.

In the upper portion of the grey and brown coloured gravels and sands (few red clays intercalated) appears another conspicuous conglomerate (*C*2 in Fig. 11) which seems to dissect the underlying cross-bedded micaceous sands. Here we collected a toothless mandible of *Hippopotamus*, bones of *Proboscideans*, turtle shells, teeth of crocodile and a phalanx

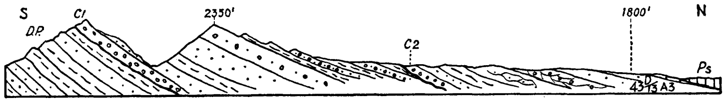

FIG. 11. Pleistocene sequence along Sauj Kas near Bhaun

*C*1 = basal conglomerate; *C*2 = basal layer of Boulder Conglomerate; total length ca. 2 miles.

of *?Camel*. The overlying series of pink silt and gravelly sand repeat the composition of the Boulder Conglomerate, as observed in the Soan valley, and should therefore be of similar age.

The Potwar silt covers a relief cut into the Upper Siwalik formation, and its thickness increases rapidly as one approaches the centre of the basin near Bhaun.

10. Naoshera

The foregoing sections already suggest that the Salt Range had undergone severe denudation in Upper Siwalik time, and they also indicate that the Upper Siwaliks had originally covered a wider area of its elevated tract. Conclusive proof for this was found in the Central Salt Range at Naoshera where a basin, about 5 miles wide, is underlain by Upper Siwalik and younger beds which are faulted along the slopes of the flanking Eocene limestone ridges.

Figure 12 gives a cross-section through the southern part of the basin, south of Naoshera. Here the basal group, consisting of thick grey or pink conglomerates, sandstones and clays, is overlain by more brightly coloured beds of finer texture. The conglomerate beds yielded a few rolled bones of artyodactyl mammals, also teeth and jaw fragments of *Bos*, displaying the poor fossilisation typical for many Upper

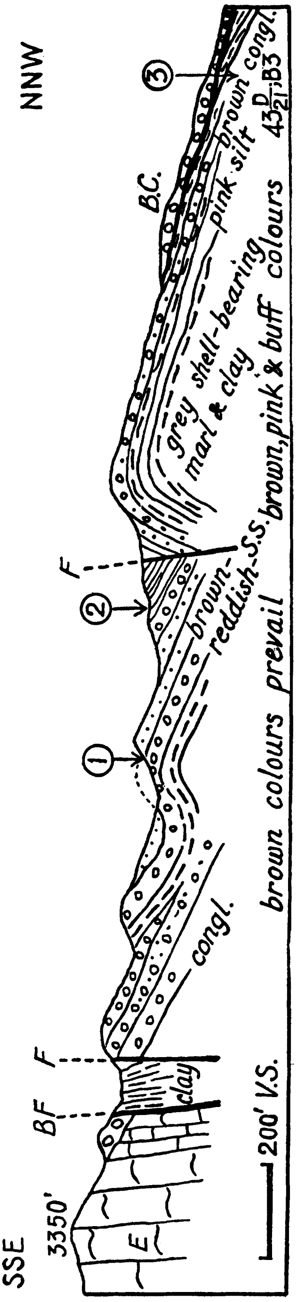

FIG. 12. Folded and faulted Pleistocene near Naoshera

Total length ca. 2 miles.

Siwalik fossils. This series is essentially a unit as compared with a higher group of bouldery limestone conglomerates and sands which overlie the dissected edge of the tilted group. The conglomerate is made exclusively of subangular Eocene limestone boulders, indicative of rapid erosion in the nearby Eocene limestone belt. The older conglomerates of the lower group reflect on the other hand by their great variety of pebbles (purple sandstone, shells of *Productus*, silicified wood, quartzites, etc.) a widespread denudation of the entire Salt Range with its complex association of Paleozoic to Cenozoic rocks. Here again as at Bhaun, Jammu and other places, two distinct cycles of sedimentation appear, one comprising the older Upper Siwaliks, the other the Boulder Conglomerate stage. The composition of the latter clearly reflects differentiation of the relief into single units from which selected rock waste was deposited in the lowlands. The section shows also severe crustal deformation, both normal faulting as well as folding, which are in themselves proof for the mountain uplift at the close of older Upper Siwalik time.

C. Observations on Post-Siwalik Formations

Although the scope of this report is essentially to demonstrate the character of the Upper Siwalik beds it seems, nevertheless, essential to refer briefly to some post-Siwalik stages. This will help to clarify the meaning of the term "Upper Siwalik" because it will show that their two stages, if taken together, belong clearly to that large, impressive pile of Himalayan foothill sediments which is called "Siwaliks."

1. The Lœss-like Potwar Silt and Its Possible Origin

Most of the sections discussed above contain a series of deposits which has been called "Potwar silt." This may be divided into two horizons, a thin basal gravel or sand, and an overlying mass of commonly yellow, sometimes also pink silt which at places reaches a thickness of 350 feet.

The lower horizon generally shows signs of fluvial deposition, dependent in its gravel composition on the underlying relief. The overlying silt is of remarkable uniformity, so much so that one is tempted to call it lœss, as Wadia [1] and others have done. In favour of this definition are the following characteristics: relative uniformity of composition, widespread occurrence independent of any physiographic obstacles, and local relationship with glacial deposits along the mountain front. The latter phenomena became clear only through recent glacial studies which Paterson and de Terra carried out in Kashmir and Poonch.

This cannot be fully discussed in this paper, and it should suffice to state here that the Potwar silt in the Soan area is cut into by a terrace, which is the third in a uniformly observed system of five terraces. In regions closely adjoining the Potwar plain, namely in Poonch, in Jammu and Kashmir, we found terrace 3 cut into the moraines of the third glaciation. This we took to indicate that it originated during the retreat phase of the ice and in the following third Interglacial, while terraces 4 and 5 (of depositional nature) would represent the fill stages of the fourth and fifth ice advances. Based on such observations, which will ultimately be fully discussed in a larger memoir, is our suggestion that the Potwar silt originated during the third glaciation when valley glaciers extended in Poonch down to a level of 4500 feet, or some 2500 feet above the higher regions at which the silt was encountered.

This relationship with the glacial cycle would speak in favour of the windblown origin of the Potwar silt, but other features seem to argue against this supposition. These are: uniform stratification in layers from a fraction of an inch to one foot thick, local occurrence of freshwater shells, and dependence of maximal thicknesses upon drainage lines, which here very often correspond with synclines. Such properties appear at first incompatible with the idea of windborn drift unless one could conceive an atmospheric agency which caused rhythmic precipitation of silt. In such a case stratification would naturally follow, provided that the surface soil was given a chance to accumulate.

[1] *Mem., Geol. Survey of India,* **51**, Pt. 2, 1926.

In this connection the first author calls attention to rhythmic precipitation of silt which occurs annually in Northwest India during the monsoon period. Here the semi-arid nature of the plains and the presence of silt stored up in thousands of feet of Siwalik rocks, provide for conditions favourable to dust-storms of great dimensions. These occur commonly in the spring and seem to reach their greatest force along certain "wind-tracts," as in the Soan and Indus valleys, where enormous quantities of loose silt are then whirled up. At this time the air is so charged with dust that it hangs like a thick veil over the landscape blotting out all details and even contours of mountain ranges. This phenomenon prevails for months (in April, May and half of June) during which time only few local thunderstorms temporarily clear the atmosphere. But once the monsoon rains "break" this dust veil is quickly torn down, and rain drops precipitate it as a film over the landscape. Here it accumulates more rapidly in depressions than on high ridges, and besides rainwash and increased stream action re-distribute it along drainage channels. Silt deposits resulting from this process are laminated, but if one pictures a larger silt supply and greater precipitation it is evident that the laminæ must grow into regular layers. Such conditions could easily have prevailed during the Pleistocene, at a time when the Himalayan glaciers began to expose thick groundmoraines in the mountainous tract and rivers intensified their erosion in the silt bearing Siwalik beds. Some sort of monsoon must have existed in this region, as it does nowadays, and its influence must have been felt in dust-storms of much greater proportions. In this case silt of uniform appearance would have precipitated in greater quantities along drainage channels, and land as well as freshwater molluscs might have existed anywhere. In fact this "pluvial lœss," as one might call it, would combine the properties of wind and river drift although the former would always dominate its lithological character. In many respects such a deposit can be mistaken for a lake bed. That the Potwar is not a lake deposit becomes evident from its distribution which is independent of any natural barrage. Also it can not be entirely of fluvial origin, for it is found on top of watersheds as well as in valleys, lying in the central Salt Range at 2600 feet and in the Jhelum valley 900 feet above sea-level.

Physiographically the Potwar silt makes for "badlands" and creates often a regular lœss landscape. It always fills an older relief which developed subsequent to the deposition of the Boulder Conglomerate. The intervening period then was one of long lasting erosion during which the present drainage pattern had principally developed; wherever the Potwar silt covers an anticline in the upward movement of which the Boulder Conglomerate has visibly taken part, one can observe slight tilting. It is of course difficult to decide whether in such cases the silt layers adjusted themselves to dip slopes during their deposition or whether they were subsequently disturbed by further upward bulging of the anticline. The tendency of the silt to accumulate thicker in synclines than on intervening ridges was often observed, even at such places where no larger drainage channels occur. This feature would point to slight deformation in post-Potwar time at which phase terraces 2 and 3 encountered tilting all along the Pir Panjal. The possibility of such a late movement in the adjoining plains can therefore not be ignored.

2. *Re-deposited Potwar and Younger Gravels*

Along the tributaries of the Soan river near Rawalpindi, as also in the central Salt Range and near Jhelum, valleys and smaller stream channels are filled up with a yellow or pinkish loam. This deposit reaches at places great thickness and its gravel layers and cross-bedding generally point to fluvial origin. Very often terrace 4 is made of this material which suggests a definite relationship with the fourth glacial advance in the mountains.

Along the Soan valley were found very small cores and flakes of agate in this deposit which indicate a prehistoric culture of possibly late Paleolithic age. The thickness of the loam varies greatly with the size of the stream channel in which it was deposited and it generally increases where the Potwar silt is thickest. This relationship suggests denudation of the Potwar silt and subsequent re-deposition by river action; at some places however, as for instance on high hillocks of Potwar silt, this loam is unstratified and independent from valleys. This position therefore recalls the distribution of Potwar silt which suggests that the loam represents, in parts at least, a later lœss, connected perhaps with the fourth glaciation in the mountains.

D. Conclusions as to Age and Character of the Various Stages and Their Relationship to Early Human Cultures

Our observations on Upper Siwalik and later formations in the Northwest Punjab permit in our opinion of the following conclusions:

(1) The nature of the boundary between Dhok Pathan and Upper Siwalik stages (Pliocene-Pleistocene boundary) is determined by the structural pattern in the Himalayan foothills. Consequently it is disconformable in synclines which received the new rock waste from an uplifted area in the neighbourhood, and unconformable at such places where previously established basins were disturbed in late Dhok Pathan time, or where new basins came into existence (Campbellpore, Naoshera). In all cases a sedimentary break exists (disconformity) which can be traced to uplift of adjoining regions. This break is indicated by

(*a*) basal conglomerates, proving a total change of sedimentary supplies;

(*b*) different colouring of Upper Siwalik beds in which sombre colours of brown, grey and pink prevail;

(*c*) poor consolidation in contrast to the underlying hard Dhok Pathan rocks;

(*d*) independence of distribution of Upper Siwaliks in individual basins, such as at Naoshera and Campbellpore.

(2) Similarly, the contact between the two Upper Siwalik stages is dependent on structure, for an angular unconformity

exists where the older beds had suffered folding or faulting as at Campbellpore, Udhampur and Rohtas. In other regions, deposition took place during subsidence previously begun in synclines (Soan, southeast of valley) in which case the contact is in the nature of a disconformity. The Boulder Conglomerate reflects in all cases a sedimentary break due to new orientation and rejuvenation of the drainage in which is reflected a second important phase of mountain making.

(3) At least three diastrophic phases become evident: one of latest Dhok Pathan time, a second of pre-Boulder Conglomerate and a third of pre-Potwar time. Most likely a fourth but less vigorous movement set in after the Potwar silt was laid down. The three important phases are common to both the Himalayan and the Salt Range tracts, thus revealing an interrelationship between Himalayan orogeny and Salt Range tectonics. In conformity with previous studies on Himalayan structures[1] it can be said that the successive sedimentary release of coarse detritus at the beginning of each stratigraphic stage as also the successive addition of new folds (Fig. 9) indicates progression of a lawful diastrophism connected with Himalayan mountain making, with an outspoken tendency of crustal movement towards the south. Such a process would explain the extraordinary coördination of young tectonic movements between the Salt Range (outlayer of the rigid Indian land mass) and the Himalaya (mobile belt), which mountain region evidently not only grew in height but widened its folded belt towards Peninsular India.

(4) If only the fossils are taken into consideration, it seems that most of the anomalies found in the faunal lists of previous investigators would disappear. All the specimens collected by ourselves make a distinct coherent fauna (*Stegodon*, *Elephas*, *Equus*, *Bos*, deer, *Sivatherium*, etc.) in which no discordant types such as *Mastodon* and *Merycopotamus* appear, and apparently no *Hipparion* either if one accepts the ex-

[1] H. de Terra, "Himalayan and Alpine orogenies," Rep. of the 16th Intern. Geol. Congress, Washington, 1934.

planation for the presence of a few stray molars at Tatrot which was given on p. 809.

(5) According to our observations a division of the Upper Siwaliks in Tatrot and Pinjaur stages is largely arbitrary and nominal. Subdivisions, based on certain differences in the fauna, may eventually be recognised, but on the whole the older Upper Siwalik stage represents one single cycle of sedimentation, such as is well documented at Campbellpore.

(6) The age of the Upper Siwaliks is old Pleistocene or early to Middle Pleistocene if a threefold division of the Pleistocene is employed. This conclusion is based on the simultaneous appearance of *Elephas*, *Stegodon*, *Equus* and *Bos* in the basal group and on the correlation of the Boulder Conglomerate with glacial deposits. The more recent faunistic studies of Matthew [1] and Colbert [2] led to similar conclusions.

Impressive as this crustal evolution is, it seems of lesser importance in comparison with the first appearance of Man at the very close of Siwalik time. From various places along the Soan valley, as also in the foothills of Jammu and Poonch the authors and Mr. Paterson collected a variety of stone tools and flakes which were found in upper gravels of the Boulder Conglomerate. These represent an early Paleolithic culture in which Chellean and Acheulean handaxes, choppers and flakes dominate. One site, in the Soan valley south of Chauntra proved to be especially rich in slightly worn Chellean tools which were found in a gravel apparently belonging to the basal Potwar series. These tools, some of which recall the Madras Chellean of Southern India, were evidently redeposited from an earlier gravel of pre-Potwar age which is here preserved in patches overlying Dhok Pathan rocks. Otherwise it would be difficult to explain the fresh preservation of another Stone Age culture which was found with the Chellean tools. This industry more commonly is met with in the basal gravel of the Potwar or on the surface of terrace ledges

[1] W. D. Matthew, "Critical Observations upon Siwalik Mammals." *Bull. Am. Mus. Nat. Hist.*, **56**, Art. VII, pp. 437–560.

[2] E. H. Colbert, "Siwalik Mammals in the Am. Mus. Nat. Hist.," *Trans. Am. Phil. Soc.*, New Ser., **26**, 1935.

from which the overlying silt had been removed by erosion. The implements, most of which are made of quartzite, are generally cruder than the early Paleolithic tools, choppers, scrapers, blades and worked flakes being prominent at many places. Heaps of flakes and cores indicate locally the relics of "workshops" of these ancient people whose technique of rock flaking developed on its own lines possibly from early Paleolithic to late Middle Paleolithic times. At this moment when a closer examination of the typological evolution of the "Soan culture" is still under way, it is difficult to say what stages of the Middle Paleolithic are represented. According to Paterson the Soan industry is essentially Clactonian with Levallois influence. The fact that we collected thin quartzite flakes with prepared striking platforms in the basal portion of the silt, indicates that Early Man lived in this region for long periods of time, and that he slowly progressed in his primitive stone industries.

E. Supplementary Note on the Pleistocene of the Narbadda Valley in Central India

In the Narbadda valley of the Central Provinces, between Hoshangabad and Narshingpur, Pleistocene beds form an old river terrace, some 120 feet above the stream. These deposits have long been known to contain Pleistocene fossils and also artifacts of which few had been collected by Seton Karr and others.

As indicated by Fig. 13 the formation consists here of two different horizons, each of which begins with a basal gravel overlain by brown and pinkish or orange coloured concretionary clays and silts. In the lower zone the conglomerate is coarser and more cemented, the clay is more intensely coloured and also richer in concretions than in the upper zone.

Fossils occur chiefly near the disconformity which separates both zones. We extracted from the base of layer 4, Fig. 13, skull fragments of *Bos namadicus*, *Bubalus*, *Elephas namadicus* (several jaws) and *Hexaprotodon*. Near Umaria was found in layer 4 a skull of *Bos namadicus*. In the lower zone we collected near Hoshangabad *Equus namadicus*, *Hexaprotodon*, *Elephas namadicus* and isolated teeth of *Bos*.[1] A closer study of our specimens might possibly detect a difference in fauna between the lower and upper zones.

In close association with these fossils we found abundantly prehistoric implements which seemed to be especially frequent in the gravel layers. In the lower zone appeared dominantly Chellean and Acheulean hand-axes, cleavers and flakes. Some of the Acheulean tools were absolutely fresh in appearance. In the upper zone we collected mainly chipped boulders, cores and flakes of quartzite and trap which recall the typological aspect of the Soan industry in Northwest India.

Outside of the valley the Pleistocene sequence is supplemented by an old laterite bed which emerges locally, as at

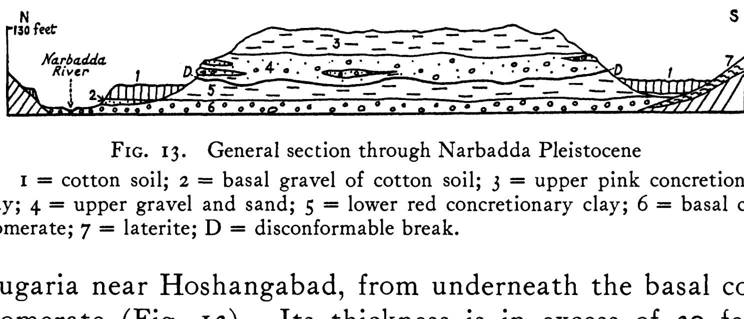

FIG. 13. General section through Narbadda Pleistocene

1 = cotton soil; 2 = basal gravel of cotton soil; 3 = upper pink concretionary clay; 4 = upper gravel and sand; 5 = lower red concretionary clay; 6 = basal conglomerate; 7 = laterite; D = disconformable break.

Tugaria near Hoshangabad, from underneath the basal conglomerate (Fig. 13). Its thickness is in excess of 30 feet. Obviously then the laterite originated prior to the basal zone of the Narbadda sequence which itself is devoid of any traces of lateritisation. The fact that laterite was preserved on the slopes of the Narbadda basin, and not in the valley might indicate a period of intense erosion which preceded the deposition of the lower gravels. The contact between both formations should be regarded as a major break, comparable with the disconformity between the older Upper Siwaliks and the Boulder Conglomerate stage in Northwest India. This relationship makes it highly probable that the laterite represents the early Pleistocene.

The "lower zone" of the Narbadda Pleistocene can be equated with the Upper Siwalik "Boulder Conglomerate" on

[1] All fossils are Pleistocene. No molar of *Stegodon* has ever been found, and as for *Leptobos* no certain trace of it has so far been discovered.

faunistic, archeological and lithological grounds. The association of advanced *Elephas* with *Hippopotamus* and large *Bos* suggests a stage slightly younger than the older Upper Siwaliks. In harmony with this is the appearance of an early Paleolithic culture in the basal gravel, clearly calling to one's mind the picture of heavy accumulation of river deposits during the glacio-pluvial stage of late Siwalik times in the Punjab. It follows that on these grounds a further correlation between the "Upper Zone" and the "Potwar silt" becomes rather plausible. Both are separated by a long erosion interval from the underlying beds and both contain implements of Soan type. The cotton soil might then well represent the latest Pleistocene which possibly is homotaxial with the re-deposited Potwar silt and the second lœss in the Punjab.

Age			NW-Punjab	Kashmir Valley	Narbadda Valley
Pleistocene	Upper		re-deposited Potwar and second lœss	4th Glacial	Cotton soil
Pleistocene	Upper		Erosion interval	3rd Interglacial	Erosion interval
Pleistocene	Upper		Potwar silt	3rd Glacial	Upper zone
Pleistocene	Middle		Long erosion interval	2nd Interglacial	Erosion interval
Pleistocene	Middle	Upper Siwaliks	Boulder Conglomerate	Upper Karewa beds 2nd Glacial Karewa gravels	Lower zone
Pleistocene	Lower	Upper Siwaliks	Pinjaur zone	1st Interglacial	?
Pleistocene	Lower	Upper Siwaliks	Tatrot-zone	1st Glacial	Narbadda laterite
Pliocene			Dhok Pathan-zone	Missing	Missing

FIG. 14. Correlation table of Pleistocene sequences
Undulating line = major breaks, generally marking crustal disturbances.

In Fig. 14 we have made an attempt to correlate the Pleistocene sequences in the three main fields of investigation.

We believe that this correlation opens up new perspectives for the Pleistocene geology of India and its human prehistory. Beyond India it will eventually have a definitive bearing on pending questions pertaining to the evolution of Man in southern Asia and to climatic changes in non-glaciated regions.