

THE PLIOCENE-PLEISTOCENE BOUNDARY IN NORTH-WESTERN INDIA.

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ABSTRACT.

Recent work in the area between Kashmir Himalayas and the Salt Range, a terrain of most copious sedimentation, reveals no unconformity or palaeontological gap of any significance between late Tertiary and Pleistocene. On the contrary, the voluminous series of fresh-water and subaerial deposits of the Siwalik system, 17,000 feet thick there, bridge the gap, on the whole uninterruptedly, from the Middle Miocene to the lower part of the Pleistocene. The main unconformity of the area is post-Upper Siwalik, Lower Pleistocene at the earliest, but this too is not a *hiatus* of any regional importance as it tends to diminish in the Soan valley. From the palaeontological work of Pilgrim (1911-39), detailed field work of the present writer (1921-25) and of G. de P. Cotter (1926-28) little doubt remains that the Upper Siwalik, except perhaps in the very topmost zone, is preglacial and lies astride the Pliocene-Pleistocene boundary. Two type areas of Pliocene-Pleistocene deposits are described: (i) the North-West limb of the Soan Synclinal, and (ii) the North-East slopes of the Pir Panjal range of Kashmir, in relation to the geotectonic history of North-West India during the Pliocene-Pleistocene interval—the period of maximum uplift of the Himalayas.

INTRODUCTION.

Recent work in the north-western corner of India, between Salt Range mountains and the foot of the Hazara—Kashmir Himalayas—a terrain of most copious sedimentation, reveals, except for a few minor and local breaks, no unconformity or palaeontological gap of any significance between the late Tertiary and Pleistocene. On the contrary, the voluminous series of fresh-water and subaerial deposits (the Siwalik system, 17,000 feet thick) bridges the gap, on the whole uninterruptedly, from Middle Miocene to Lower Pleistocene. A number of small breaks and discordances, due to contemporaneous erosion, do occur in the sequence, as indeed one would expect in a zone of active aggradation by the vigorous repeatedly rejuvenating streams descending from a tract of recent elevation. The Middle and Upper Siwalik series (Pontian to Lower Pleistocene) are strongly developed and are capable of more or less precise division into stages by means of the locally abundant mammalian fauna. The Middle Siwalik (Upper Miocene-Mid Pliocene), broadly speaking, grades off into the Upper Siwalik without any but a few minor breaks which, however, are sporadic and disappear laterally. The main unconformity of the area is post-Upper Siwalik denoted by an unconformable overlap between the Upper Siwaliks and their overlying sub-recent river alluvia. But this too is not a hiatus of any regional importance, tending to diminish in the

Soan valley. At least 10,000 feet of sediments intervene between the Dhok Pathan stage (Pontian) of the upper Mid Siwalik and the Boulder-Conglomerate stage, the topmost stage of the Upper Siwalik in the Soan valley (a tributary of the Indus). From the palaeontological work of Pilgrim in this area based on more than two decades of research on the fossil bovids, pigs, giraffes and carnivores (1911-39) generally corroborated by detailed field-geological mapping of G. de P. Cotter in the years 1926-28 and of the present writer during 1921-25, little doubt now remains that the Upper Siwalik, except perhaps in the very topmost zone, is pre-glacial and lies astride the Pliocene-Pleistocene interval of Europe. Indeed the upper Mid Siwaliks and Upper Siwaliks, from Lower Pliocene upwards, have been grouped together into one unit by more than one observer from the difficulty of separating them by a definite geological dividing line.

AREAS OF PLIOCENE-PLEISTOCENE DEPOSITS.

(i) *Sections on the North-Western Limb of the Soan Syncline (Rawalpindi district).*

Clear sections of Upper Tertiary systems of Northern India showing transitional passage into the Quaternary are exposed in the north-western limb of the wide synclinal fold in the Soan valley, Rawalpindi district. Incidentally these sections are of importance as representing in a straightforward manner the tectonic history of North-Western India from the beginning of the Tertiary to recent times. The field geology of the area was mapped by the present writer on the 1-inch scale in 1921-24. Previous to that A. B. Wynne had mapped the country on 8 miles = 1 inch scale in 1870's. The table on the opposite page is a generalised section of the rock sequence, well seen near Gorakhpur on the northern bank of the Soan, 9 miles S.S.W. of Rawalpindi.

Lying in a piedmont belt of slow subsidence, *pari passu* with the rising mountains to the north, the Middle and Upper Siwalik strata of the Soan basin show a great deal of folding and deformation, being for considerable stretches vertical in their attitude, or even slightly overfolded at places. From vertical dip there is a gradual decrease in the angle of inclination towards the central part of the syncline, the dip flattening to 8°-10°, where the Boulder-Conglomerate stage passes into the older alluvium and from this to horizontality in the newer alluvium, loess and surface gravels. In the area to the east and west of the central Soan basin, the junction between the Boulder-Conglomerate and the older alluvium is unconformable, due to a rapid overlap, the discordance increasing with distance.

W. D. Mathew (1929), De Terra (1939), Colbert (1935) and G. E. Lewis (1937) are inclined to regard the Boulder-Conglomerate as of the Middle Pleistocene age and De Terra takes a conglomerate beneath the Tatrot as denoting a line of unconformity and places the base of the Upper Siwaliks so high up as the boundary between the Pliocene and Pleistocene. Apart from the fact that

TABLE OF FORMATIONS IN THE SOAN SECTION.

AGE.	FORMATION.	THICKNESS.
RECENT AND SUB-RECENT.	Residual gravel-cap; modern alluvia; loess, deeply worn subaerially into labyrinthine ravines. <i>Fossils</i> : living species. Many human artefacts.	500-800 ft.
MID AND UPPER PLEISTOCENE.	Silty clays of warm red colours; gravel and pebbly grit, locally conglomeratic. Synclinally inclined 8°-10°. <i>Fossils</i> : Scarce <i>Elephas</i> , <i>Canis</i> , <i>Bos</i> , many palaeoliths.	variable.
LOWER PLEISTOCENE TO UPPER PLIOCENE.	<i>Boulder-Conglomerate and Tatrot stages</i> : Conglomerates, coarse pebbly grit, sand-rock and thick earthy clays of red and drab colours. Stages represented Tatrot to Boulder-Conglomerate. Pinjor stage not clearly divisible. <i>Fossils</i> : <i>Sivatherium</i> , <i>Cervus</i> , <i>Rhinoceros</i> , <i>Sus</i> , <i>Bos</i> , <i>Equus</i> , <i>Elephas</i> , <i>Hippopotamus</i> , <i>Hyaena</i> .	5,700-6,000 ft.
PONTIAN AND SARMATIAN.	<i>Dhok Pathan stage</i> : Soft pebbly sandstones; harder scarp-forming sandstones, pale grey and micaceous, interbedded with few shales of red, orange and drab colours. Bands of concretionary clay pseudo-conglomerates. <i>Fossils</i> : <i>Hipparion</i> , <i>Mastodon</i> , <i>Bramatherium</i> , <i>Helladotherium</i> , <i>Tragocerus</i> and many antelopes, Anthropoid apes.	4,000 ft.

the basal Tatrot conglomerate of Attock area is an intraformational conglomerate of local occurrence, disappearing laterally, e.g. in the Soan basin, this view has no support from the fossil fauna of the Tatrot stage which, as Pilgrim has shown, is considerably older than Pleistocene. Quite a large number of species as well as genera, including *Hipparion*, have passed upwards from the underlying Dhok Pathans of Pontian age into the Tatrot, while genera such as *Equus* and *Elephas* are rare. While minor unconformities due to contemporary erosion are observed at various levels no important stratigraphic hiatus can be made out between the Middle and Upper Siwalik of the Potwar area as a whole. Such minor breaks and interruptions must be a common feature in a thick fluvial-cum-subaerial series laid down during a period of great earth disturbances. Lateral variation is a universal feature of the Siwaliks, it being a matter of common observation that a fairly wide lens of conglomerate strata traced laterally thins out into a sandstone or grit stratum or even may be replaced by thick beds of clay on either side. A number of small

local breaks and discordances, due to contemporaneous erosion, do occur in the sequence and make, at a few localities, a striking show, as indeed one would expect in a zone of active aggradation by the vigorous, repeatedly rejuvenated streams descending from a mountain-range of recent uplift. But these local unconformities soon tail off in all directions. A geologist working at isolated centres in the Siwalik terrain will naturally place a great deal of emphasis on such minor erosional unconformities and conglomerates met with in the Dhok Pathan, Tatrot and Pinjor stages.

(ii) *The North-East Slopes of the Pir Panjal Range (Kashmir).*

This area also furnishes pertinent evidence on the nature of the boundary under discussion. The Pir Panjal is a sharply defined and individualised tectonic range of the middle Himalayas, separating the foot-hills and plains of the Punjab from the higher ranges of Kashmir. On the gently-sloping north-east face of the range (west flank of Kashmir valley) there occurs, overlying the eroded Mesozoic Himalayan formations, thick sheets of unconsolidated fluvial, lacustrine and glacial deposits (Karewa series) extending from a height of 11,500 feet down to a level of 5,200 feet, which have all but concealed the solid geology of this face of the mountains. In these, the passage of the pre-glacial river and lake-formed beds to those containing the debris of the earlier glaciations is so gradual that it is impossible to draw a dividing line. Moreover it is not definitely known that the onset of the Ice Age in South Kashmir was coeval with the beginning of the Pleistocene, or, as seems more probable, was deferred to a somewhat later date. At a level of about 5,500 feet above the base of the Karewa series a conspicuous erosional unconformity is observed, marked by a bouldery or conglomeratic horizon resting on the denuded edges of folded Lower Karewa beds. The stratigraphical horizon of these boulder-beds, from their contained fossil plants of living species, *Elephas* bones and teeth and some human implements could not be lower than Middle Pleistocene. De Terra regards these boulder-beds as making the second interglacial stage. The lower, more folded and disturbed Karewa beds are also fossiliferous at various localities and horizons throughout their thickness of 5,500 feet though no distinctive remains of chronological value have been found, the fossils being well-preserved leaves, fruits and seeds mostly of dicotyledon plants.

The unconformity mentioned above divides the Karewa series into two unequal divisions. The Lower Karewas, commencing with non-glacial basal pebble-beds, blue, buff and grey clays and sands, succeeded by silts, varved clays, lignite beds and silts interbedded with moraines of the first and second glacial stages (De Terra). The unconformity at the top of the Lower Karewas represents an erosive interval during which over 2,000 feet of the Lower Karewas were denuded from the crests of two prominent anticlines into which they are folded. The stratigraphic level of this unconformity appears to be between the

Lower and Middle Pleistocene and is therefore contemporaneous with the slight stratigraphic break above the Boulder-Conglomerate horizon in the Potwar on the southern side of the Pir Panjal range. The Upper Karewas are about 1,000 feet thick, almost wholly composed of the glacial wash and coarser morainic debris of the third and fourth glaciations, Middle Pleistocene, intercalated with the clay and marl deposits of the lake which intermittently filled the upper Jhelum valley of Kashmir during a large part of the Pleistocene.* Valuable pioneering work in the glacial succession as recorded in the Karewas and in the river-terraces of Kashmir has been done by De Terra during late years, but considerable detailed and systematic investigation remains to be done in the earlier Pleistocene and late Pliocene of Kashmir.

GEOTECTONIC HISTORY OF NORTH-WESTERN INDIA DURING THE PLIOCENE-PLEISTOCENE.

The period immediately succeeding the Tertiary was a period of intense orogenic activity in North-West India, it being the final phase of the uplift of the Himalayas, during which, to judge from various evidences observed in the Pir Panjal, the Kashmir Himalayas were uplifted from 5,000–8,000 feet. The tilting and folding of the river and lake-formed Karewas with the fossil plants, fish, batrachians, *elephas*, *rhinoceros*, and a few human implements, and their extension to altitudes up to 11,500 feet, afford a rough estimate of the extent of the movements and of their time duration.

The same conclusion is suggested by the Soan sections of the Potwar on the Punjab side of the Pir Panjal. From the vertically inclined Dhok Pathan and Upper Siwaliks there is seen a gradual decrease in the amount of inclination into the overlying, almost horizontally reposing Soan alluvium. Here every stage is well dated from *Hipparion* to *Equus*, *Mastodon* to *Elephas* and man's traces occur in the topmost disturbed beds. An important chapter in the orogenic history of late Tertiary and early Quaternary time is thus recorded in the Pliocene-Pleistocene formations lying on either side of this interesting Kashmir range, and yet these piedmont formations record no unconformities. The successive orogenic upheavals, instead of interrupting, seem to have accentuated sedimentation in the sub-montane troughs which were being depressed complementary to the rising mountains.

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* The pulsations of this extinct glacial lake of Kashmir are recorded in the succession of the Karewa Series: Pleistocene Ice-Age Deposits of Kashmir, *Proc. Nat. Inst. Sci. Ind.*, 7, 49–59 (1941).

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