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# THE STRATIGRAPHY OF THE SIWALIK SERIES IN THE NORTHERN POTWAR, PUNJAB, PAKISTAN

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[PLATES XX–XXII]

CONTENTS



SUMMARY

Detailed mapping of the Jhamat area in the west and of the Soan syncline in the east forms the basis of revision of the stratigraphy of the Siwalik Series in the northern Potwar region. The succession is here affected by facies changes of regional significance :—

1. Near the Indus River the uppermost 3000 feet of the Middle Siwalik sequence (Upper Nagri and Dhok Pathan stages) contain thick beds of conglomerate which die out eastwards and south-eastwards into sandstones and clays. Farther eastwards, across the Soan syncline, a clay facies develops at progressively lower horizons in the Nagri Stage, replacing a considerable portion of the massive sandstones of the type area. The facies change is accompanied by a reduction in thickness. The facies variation in the Middle Siwalik rocks is indicative of a channel environment in the west at Jhamat, clearly coinciding with the line of the present Indus River and grading eastwards into deposits of " flood-plain " type.
2. The Lower Siwalik rocks show a development of coarser facies in the opposite direction to that noted in the Middle Siwalik. At the eastern end of the Soan syncline the lowest 1500 feet of the Chinji Stage, which in the west is almost entirely of clay-shale facies, contain thick beds of hard sandstone and the sequence is very similar to that of the underlying Kamlial Stage.

In the Soan area, the complete Siwalik succession from the Kamlial Stage to the Pinjor Stage (Villafranchian) is free from any marked unconformities but is overlain with strong unconformity by post-Siwalik Pleistocene beds—the Lei Conglomerates. This interpretation differs greatly from that of de Terra (1936, 1939), who placed the first great unconformity of the area at the base of the Tatrot Stage. The revision explains Pilgrim's reluctance to include the Villafranchian in the Pleistocene, since in the Indian Siwalik belt this stage forms the highest member of a conformable succession which was intensely folded and subjected to peneplanation before the next deposition took place. The decision at the International Congress in 1948 to adopt the Villafranchian as the base of the Pleistocene places the Siwalik phase of Himalayan orogenesis within the Pleistocene System.

## I. Introduction

Physiographically, the Potwar region may be defined as the elevated, dissected peneplain which lies between the Indus and Jhelum rivers, forming a platform between the Salt Range in the south and the outer ranges of the sub-Himalaya, the Kala Chitta and Margala Hills in the north (see Fig. 1).

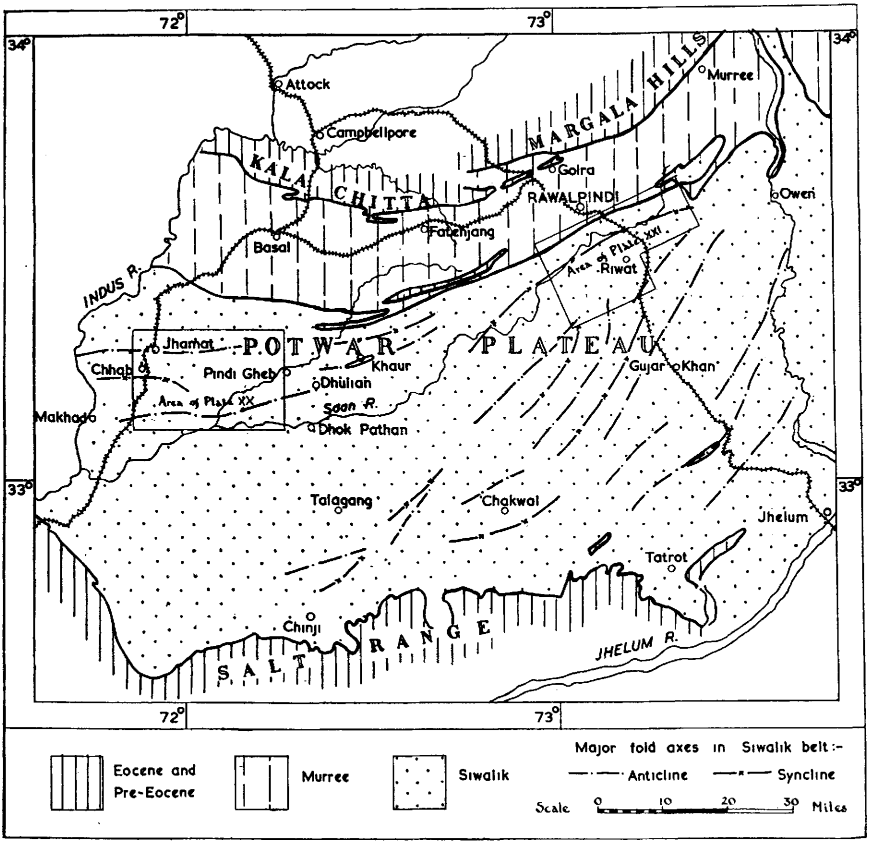



Fig. 1.—Geological sketch-map of the Potwar region, Punjab, Pakistan.

The Potwar forms a part of the folded geosynclinal accumulation of Middle and Upper Tertiary freshwater deposits which border the Himalayan mountains throughout their length from Assam to the North-West Frontier. Anderson (1927) has conveniently grouped these deposits in the " Nimadric System ", a name which, being a compound of " Himadri ", meaning snowy range and an alternative for Himalaya, with the Sanskrit prefix " ni ", meaning under, nether or downward, indicates their geological position. The general succession, classification and average thicknesses of the Nimadric rocks in the north-west portion of the Himalayan foredeep can be summarized as follows, the Siwalik Series being given in detail :—

TABLE I.—GENERAL SUCCESSION

| | Series | | Stage and Lithological Characters | Thickness in feet (approx.) |
|---|---|---|---|---|
| PLEISTOCENE | SIWALIK SERIES | UPPER | BOULDER CONGLOMERATE STAGE. Coarse sand, gravel and conglomerate. | 4500–6000 |
| | | | PINJOR STAGE. Pink silt, sandstone, gravel, conglomerate (Soan syncline). | |
| | | | Pebbly sandstones of Rhotas, Hatar (Salt Range) and Kangra. | |
| | | | TATROT STAGE. Clay, sandstone, conglomerate. | |
| PLIOCENE | | MIDDLE | Bhander Beds (Salt Range). | 500 |
| | | | DHOK PATHAN STAGE. Variegated shales, sandstones. Conglomerate (Jhamat). | 1000 |
| | | | NAGRI STAGE. Pepper-coloured sandstones, drab and red shales. | 1500 (Salt Range)–6000 |
| | | LOWER | UPPER CHINJI STAGE. Brick-red shales, grey sandstone. | 1500 (Salt Range)–6000 |
| | | | LOWER CHINJI STAGE. Bright-red shales (Potwar). Nahan Sandstone of Kangra. | |
| | | | KAMLIAL STAGE. Hard red and brown ridge-forming sandstones, deep red shales (Potwar). Lower Nahan Sandstones of Kangra. | 500–2500 |
| MIOCENE | MURREE | | | Up to 8000–9000 |
| | | | | Maximum total 31,000 |

In general, the lower part of the Nimadric System, up to the base of the Middle Siwalik, is composed of fine- or medium-grained sandstone in beds ranging from a few inches to hundreds of feet in thickness, alternating with beds of brightly coloured clay, clay-shale and siltstone. The main lithological types and the sedimentary characteristics of these lower beds of the system strongly suggest dominantly lacustrine rather than fluviatile conditions of accumulation. The Middle Siwalik sees the introduction of coarse sand-rock into the system, with evidence of fluviatile deposition. During Upper Siwalik times great thicknesses of coarse conglomerate, alternating with finer grades of sediment, were deposited. Similar coarse sediments occur locally at lower (Middle Siwalik) stratigraphical horizons towards the northern limit of the outcrops.

A predominance of clay or of sandstone over extensive vertical ranges formed the original basis of subdivision of the Siwalik Series into stages; these stages were subsequently adopted as zones on the evidence of the prolific vertebrate faunas, which have attracted world-wide attention. It must be emphasized, however, that the palaeontological zones lack sharp definition and that the beds are not throughout fossiliferous, either in the stratigraphical or the geographical sense. In these circumstances, lithology must often be relied upon in identifying the various subdivisions, and in nearly all cases forms the basis on which the zonal boundaries can be mapped. In view of the lateral variation of facies which is to be expected in deposits of this type, it is not surprising that previous workers, particularly those engaged in mapping on a regional scale, have expressed difficulty in finding clear lines of demarcation between certain zones. Both

Anderson (1927) and Cotter (1933) were critical of the Siwalik/Murree boundary as defined by Pilgrim and Pinfold (i.e. at the base of the Kamlial Stage), and Cotter suggested raising the boundary between the series to the base of the Chinji Stage. The present paper demonstrates that the same difficulty applies to the boundaries of all the Siwalik stages of the northern Potwar. Here the entire succession is subject to facies changes on a regional scale, which yield important information on the problem of Siwalik palaeogeography. These facies changes are described in detail in two areas—the Jhamat area in the west and the Soan syncline in the east. Both areas have yielded other important information on the history of the Nimadric geosyncline in its later stages and, particularly the Soan area, on the date of its deformation.

The field investigations on which the present paper is based were carried out whilst the author was engaged in the search for oilfields in the service of the Attock Oil Company, and it is by kind permission of the Directors of the Company that these results are published.

## II. The Jhamat Area

The map (Pl. XX) shows the massive Nagri sandstones at the western end of the Dhulian anticline in the south-east to be overlain by thin alternations of clay and sandstone of the Dhok Pathan Stage; on the other hand, in the north-west, flanking the Nagri sandstones in the core of the Jhamat anticline, is a succession dominated by thick beds of conglomerate. The area is discussed in some detail by Cotter (1933, pp. 117–20), who regards the entire thickness of conglomeratic facies, amounting to about 2500 feet on the north flank of the Jhamat fold and over 3000 feet on the south flank towards the Chhab syncline, as a conglomeratic facies of the Dhok Pathan Stage of the Middle Siwalik. This conclusion is based on the mapping of Lahiri, who noted that beds of conglomerate at Jhamat pass eastwards into pebbly sandstones and finally into true sandstones with only a few scattered pebbles. A similar facies change is stated to occur south of the Soan River between Trap Rest House and Tamman, though it is not clear whether this is at the same horizon as that at Jhamat. The present mapping of the area indicates that the author cannot agree with Cotter in placing the entire thickness of the conglomerates in the Dhok Pathan Stage. The evidence of strike-mapping from the area south of the Dhulian oilfield is that the two lowest conglomerate horizons, which occur in massive sandstone on the Jhamat fold, are of Nagri age. With regard to the uppermost conglomerate and succeeding brown, banded clays, there is no evidence from strike-mapping, so that the placing of the Middle/Upper Siwalik boundary must rest on palaeontological evidence. From localities 6 and 7 (see Pl. XX), on the north flank of the Jhamat fold, a well-preserved fauna was collected from beds below the highest conglomerate. The association of *Aceratherium* cf. *lydekkeri* Pilgrim, *Tragocerus* sp. and *Hippopotamus* sp. (one incisor) suggests a Dhok Pathan age for these beds.

From the uppermost conglomerate at Makhad, Pilgrim (1910) identified the genus *Sivatherium* from a metatarsal bone, and referred the conglomerate to the Upper Siwalik. The author sees no reason to doubt Pilgrim's conclusion, and places the uppermost conglomerate and succeeding beds in the Upper Siwalik.

The error of observers prior to Lahiri and Cotter lay in including the entire thickness of conglomerates in the area in the Upper Siwalik, not appreciating that the junction of the conglomerate facies with the underlying sandstones and clays was some 3000 feet higher at Makhad than at Jhamat.

There are five beds of conglomerate on either flank of the anticline near the longitude of Jhamat village. They vary in thickness from about 40 feet to 150 feet, the two uppermost beds being over 100 feet and somewhat coarser in grade. Eastwards and south-eastwards the conglomerates thin progressively and show interleaving with sandstone. They die out as a series of lenses. Two conglomerate beds, however, show an unusual development in their most easterly exposures.

North of Jhamat village, the fourth conglomerate from the base of the sequence is composed, like the others, of pebbles and cobbles of gneiss, quartzite and a variety of sedimentary rocks of Palaeozoic, Mesozoic, and Eocene age. When traced eastwards the bed thins to about 30 feet in the area north of Dabula village. Suddenly, over a short distance, it passes into a boulder-bed, about 20 feet thick, composed predominantly of Upper Tertiary sandstones with only a scattering of older pebbles. Some of the boulders are over two feet across, and although the majority are well water-worn, a considerable number are subangular. The lithological aspect of some of the boulders is that of Murree beds; that of others is suggestive of Kamlial Stage sandstones.

On the south flank of the Jhamat anticline, the second conglomerate from the base of the full sequence near the Makhad road in the west shows a similar change in grade and composition before it dies out in the area north and north-east of Nakka Gulam Shah. Here the Tertiary boulders are more weathered, but their cores are of deep colour, suggesting Murree sandstone.

Whatever the precise horizon from which these boulders were derived, it is clear that the parent rock was well cemented and consolidated before erosion. This fact precludes their being the product of redistribution of contemporaneous Siwalik beds.

*Summary and Conclusions.*—The evidence of the present mapping confirms the conclusions of Lahiri and Cotter that the greater part of the conglomerate succession at Jhamat is a lateral facies development in a northerly and westerly direction in the upper part of the Middle Siwalik, which in the type area to the east and south-east is a succession of alternating sandstones and clays. It is considered, however, that the lowest conglomeratic development is in the Nagri Stage and that the highest conglomerate and succeeding beds may belong to the lower part of the Upper Siwalik.

The conglomerates are a conformable sequence with no evidence of overlap at any level. In their most easterly development two conglomerate beds display a marked change in grade and composition over a short distance to become largely composed of subangular and rounded boulders of Nimadric sandstone, thought to be mainly of Murree derivation. These boulder-beds provide evidence that deformation from the Himalayan region had already advanced southwards to incorporate sediments of the Nimadric geosyncline towards the end of Middle Siwalik times.

A possible explanation of the restriction of these large Nimadric boulders to the eastern limits of conglomerate development is that the large river responsible for the spread of conglomerate had a gorge section upstream from the Jhamat area. The coarse material at the edge of this river may have been derived from undercutting and collapse of the banks in the gorge. It seems reasonable to suggest that this large river was the ancestral Indus.

## III. The Eastern Part of the Soan Syncline, near Rawalpindi

### (a) Introduction and Previous Work

In its deepest part the Soan syncline exposes some 16,000 feet of Siwalik strata. Overlying this succession with strong unconformity are post-Siwalik Pleistocene deposits from which the type specimens of the Soan palaeolithic artefacts were collected. The area is thus a key to Siwalik stratigraphy and to the history of North-West India in the Pleistocene period, and has been recognized as such by all previous workers.

Wadia published the most recent map of the area in 1928, together with a general account of the stratigraphy. de Terra, in association with Teilhard de Chardin (1936) and Paterson (1939) has more recently made special studies of the upper part of the Siwalik Series and the post-Siwalik deposits in an attempt to elucidate the Pleistocene history of the entire region.

It has long been realized that the Siwalik succession of the Soan area, particularly that on the south flank of the fold, shows important differences from that in the western Potwar, and that its classification in terms of the type lithological and palaeontological zones (Kamlial, Chinji, Nagri, etc.) presents a considerable problem. As de Terra remarks (1939, p. 284): " These beds present a somewhat puzzling sequence which seems to defy all efforts at stratigraphic classification." The main object of the work here described was to tackle this problem of classification by mapping the area in detail, starting from the north-west in the Kalas Kas section, north-west of Adiala village, where several datum horizons of the Siwaliks of the western Potwar had been recognized and their position checked by strike-traverse from the areas of type lithology.

Air photographs greatly facilitated the mapping, being particularly valuable in the wealth of strike detail they provide in this semi-arid terrain. Without air cover the work would have lost greatly in speed and accuracy. The map of the area (Pl. XXI) is described as one of the "solid" geology. This description implies the omission of post-Siwalik Pleistocene deposits in addition to recent alluvium. Both distribution and relationships of these later deposits will be discussed in some detail. The Siwalik sequence from Kamlial to Pinjor shown on the map is regarded as a fundamentally conformable succession and, in this, the present interpretation differs from that of previous workers.

Figures for the thickness of the Siwalik stages in various localities have been determined by field measurement and from geometrically constructed cross-sections. Prospecting operations have demanded a detailed study of thickness variations in the Potwar. One of the important factors arising in this work concerns the amount of attenuation which the beds have undergone at various angles of dip, which affects the comparison of the thickness of the same group of beds when it is measured in contrasted angles of dip. In general the steep limb attenuation in the Potwar Siwaliks is of the order of 30 per cent when the beds are vertical, and the amount of attenuation for other angles of dip can best be estimated from the formula 30 (1—*cos* dip) per cent. The thickness figures quoted in this paper are, therefore, expanded for the amount of attenuation so calculated. It is considered that this method affords a much more reliable basis for comparison of stratigraphical thicknesses than the direct comparison of field measurements.

### (b) Structure

The structure is a simple trough, bounded on the north-west by a complex, faulted, severely compressed anticline in Murree beds and on the south-east by a strike-fault of great throw—the Riwat fault. The deepest part of the trough lies between the Grand Trunk Road and Gorakhpur village. In this sector, some 16,000 feet of Siwaliks are folded into the syncline. The north flank is here practically vertical to within a short distance of the synclinal axis. South of the axis is a belt of low dips, increasing from 5° to 10° over a distance of approximately two miles, thereafter steepening in a short distance to between 75° and 80°. Mention must here be made of a fundamental disagreement with de Terra's cross-section of the Soan syncline at this point (1939, p. 281, fig. 163). This section shows a wide zone of steep dips immediately to the south of the synclinal axis for which the present author has found no evidence in the field. According to his observations, dips never attain more than 10° for two miles south of the axis. At the south-eastern end of this, as also in a previous section (1936, p. 798) de Terra shows Tatrot conglomerates to rest with angular unconformity on Dhok Pathan beds. Reference to the present map (Pl. XXI) and section (Pl. XXII) will show that there is no evidence of such an unconformity. The attitude of the beds conforms with that of a synclinal bend in a conformable sequence, and Tatrot and Pinjor beds are folded into the syncline with a steeply dipping and compressed section north of the axis. The matter is of considerable importance as it affects the position and magnitude of the main unconformity in the Soan area. de Terra places this major break at the base of the Tatrot Stage (i.e. at the base of the Upper Siwalik), whereas the present interpretation places it much higher, at the base of the Lei Conglomerate (the Boulder Conglomerate of de Terra).

### (c) Stratigraphy

Table II summarizes the Siwalik Series of the Soan area and the thicknesses of the local lithological groups at various points. In view of the considerable differences in lithology at many horizons compared with the type areas farther west, and the element of doubt as to the precise correlation of certain parts of the succession, it is necessary to describe the rocks in terms of the local lithological groups. The brief description which follows will be adequate for general purposes. For those interested in the full details, and for those who may visit or work in the area, a full record of structural and stratigraphical detail has been compiled and deposited in the Geological Society's library.

The main basis of the classification of the local groups in terms of the type stages in the west is the mapping of certain horizons (principally the top of the Kamlial Stage and the base of the Nagri Stage) from the type areas into the area of different facies covered by the present map. The position of the Middle/Upper Siwalik boundary and the precise age of the uppermost Siwalik beds in the Soan area have not been determined with certainty. It is clear that this range of beds is subject to marked lateral variation of facies in the Potwar region, so that correlations on the basis of comparative lithology are unreliable. The correlations here suggested are based partly on strike-mapping, but largely on the palaeontological evidence cited by Wadia (1928).

*Local Group* 1 : *Kamlial Stage*.—Anderson (1927) and Cotter (1933) have expressed difficulty in discerning any clear line of demarcation

TABLE II.—SUMMARY OF THE STRATIGRAPHY OF THE SOAN SYNCLINE

| Stages | Local Groups | Thicknesses in feet: North Flank: Kalas Kas | North Flank: Jarai Kas | North Flank: N.W. Railway–Soan Gorge * | South Flank: Kas Dovac | South Flank: Ling River * |
|---|---|---|---|---|---|---|
| | Recent river gravels and other alluvium | | | | | |
| | | *Unconformable junction* | | | | |
| | Potwar Loessic Silt | | 0 | – | 200 | |
| | | *Unconformable junction* | | | | |
| | Lei Conglomerate | | 0 | – | 350 | |
| | | *Major unconformity* | | | | |
| TATROT-PINJOR | Group 6: Siwalik Conglomerate | | 2600 in centre of basin | | | |
| TATROT-PINJOR | Group 5: Brown sandstones and deep-red clays | | 3000 | – | 3500 | |
| DHOK PATHAN | Group 4: Variegated and orange clays; thin white and brown sandstones | 4907 (Groups 3–4) | 1661 (4373, Groups 3–4) | 3565 (Groups 3–4) | 1311 (3493, Groups 3–4) | 3005 (Groups 3–4) |
| NAGRI | Group 3: Nagri sandstones; red and drab clays | | 2712 | | 2182 | |
| CHINJI | Group 2b: Chinji red shales, grey and buff sandstones | 5,368 | 4722 | 3536 | 3393 | 2613 |
| CHINJI | Group 2a: Riwat Beds; ridge-forming sandstones, deep-red shales | | | 1400–1500 | 844 | 1300 (approx.) |
| | Total of groups 2–4 | 10,273 | 9095 | 8501–8601 | 7130 | 6918 |
| | Group 1: Kamlial ridge-forming sandstones | 1944 | 2125 | 2152 | | 200 |

* Figures for these sections derived from cross-sections; otherwise from surface measurements.

between Kamlial and Murree beds. For this reason the latter author (1933, pp. 100–4) raised the base of the Siwalik Series to the Kamlial/Chinji boundary, which he considered to be a constant mappable horizon. This suggestion loses all force in the Soan area, where, as will be described, " Kamlial " facies develops over a considerable range of the lower Chinji, and the problem of mapping a constant boundary is no less difficult than that of mapping the base of the Kamlials elsewhere. The author has found it necessary to establish a more elaborate definition of the Kamlial Stage than that of a " ridge-forming body, mainly of sandstone " which appears to have been the basis of previous mapping. The spheroidal weathering, the colour of weathered surfaces and finer grain of the sandstones serve to distinguish the Kamlial Stage from the Murree Series, which in the Soan area contains ridge-forming sandstones. The colour and fine grain of the sandstones and the prevailing deep red of the siltstones in the Kamlial Stage allow a contact with the overlying Chinji Stage to be mapped without great difficulty even in the eastern Soan area where the latter stage contains ridge-forming sandstones similar to those in the Kamlial. The mapping unit thus defined as Kamlial yields, throughout the northern Potwar, heavy mineral residues characterized by a flood of tourmaline and a paucity of epidote. In the Chinji and Murree beds epidote is high and tourmaline rare.

*Local Group 2a : Riwat Beds.*—The Riwat Beds are a development of " Kamlial " facies in the lowest 1500 feet of the Chinji Stage in the eastern part of the Soan syncline. The Kamlial aspect of the formation is due to the prominence of ridge-forming sandstones up to 200 feet thick which, apart from their coarser grain, are indistinguishable from those of the underlying Kamlial Stage. In well-exposed sections, however, these sandstones are seen to alternate with Chinji-type clays and sandstones. The key to the stratigraphical position of these beds is in the strike-mapping, for they pass eastwards into Chinji beds of type lithology. On the south of the syncline this passage can be seen in the area of Riwat village on the Grank Trunk Road.

In confirmation of the strike-mapping, it is to be noted that:—

(1) The thickness variations detailed in Table II above show that where the Riwat Beds are developed there is a corresponding reduction in thickness of the Chinji Stage.

(2) That the so-called " Kamlial " fauna collected by Wadia from the Riwat Beds near Jaba (1928, pp. 340–1) consists, with one exception, of species which are recorded in the list of Chinji fossils. The exception —*Dicerathium bugtiense* Pilgrim—is probably an extension of the stratigraphical range of this form.

(3) The heavy mineral residues of the sandstones near Riwat village are of Chinji type, being high in epidote and lacking the characteristic Kamlial tourmaline flood.

*Local Group 2b : Chinji Stage.*—Along the outcrop from the Kalas Kas to the Jarai Kas, in the north-western portion of Pl. XXI, the predominant bright-red shales, alternating with thin, ash-grey, poorly cemented sandstones, are typical of the Chinji Stage throughout the western Potwar. The junction with the Kamlial Stage below and the massive Nagri sandstones above is clear-cut. This clarity is lost in the rest of the Soan area, due to:—

(1) The development of the Riwat Beds described above.

(2) The development of shale facies, locally of Chinji aspect, in the

Nagri Stage, whereby the Nagri/Chinji junction loses much of its distinctiveness.

(3) The development in the Chinji of buff-coloured sandstones, usually associated with the Nagri Stage. These are prominent along the south flank of the syncline and it is only by strike-mapping round the fold from the north flank that the Nagri/Chinji junction can be placed in these sections.

*Local Group* 3 : *Nagri Stage.*—Across the northern Potwar the Middle Siwalik stages are affected by a progressive change of facies. Near the Indus River in the west the Dhok Pathan Stage and the upper part of the Nagri Stage include thick beds of conglomerate which, as already described, pass eastwards into massive sandstones in the Nagri and sandstones and clays in the Dhok Pathan. South of the Dhulian oilfield the Nagri Stage is 4700 feet thick and more than 65 per cent of the formation is massive sandstone. The overlying Dhok Pathan beds of the type locality are softer, variegated clays alternating with light-coloured sandstones. Eastwards to the area of Pl. XXI, a "Dhok Pathan" facies develops at progressively lower levels, giving a heterochronous boundary with the underlying massive Nagri sandstones. In the Soan area about 1500 feet of massive sandstone remain at the base of the Nagri Stage in the north-west of Pl. XXI, giving a datum level at the base of the Nagri for the Middle Siwalik in this area. The upper limit of the local group mapped as Nagri is at a convenient mappable bed of massive sandstone and is clearly at a considerably lower horizon than the top of the Nagri in the west.

*Local Group* 4 : *Variegated Group.*—This is the most conspicuous horizon in the Siwalik sequence of the Soan area. It is 1750 feet thick in the Kalas Kas section on the north flank and about 1300 feet in various sections along the south flank. Of this formation, 80 per cent is made up of orange and variegated clays and siltstones with thin intercalated beds of brown and whitish sandstones. Beds of white sandstone at the top of the group provide a valuable mapping horizon. Westwards on both flanks of the fold, similar beds of sandstone appear higher in the succession, making the horizon less useful in strike-mapping. A strike-traverse along the north flank indicated that the white sandstones at the top of group 4 in the eastern Soan occur about 500–800 feet above the Nagri/Dhok Pathan junction in the type area, making the greater part of the group to be equivalent to the Nagri Stage.

*Local Group* 5 : *Brown Sandstones.*—In the eastern part of the Soan syncline this group comprises 3000 to 3500 feet of monotonous alternations of deep brownish-red silty clays and brown sandstones in which individual beds rarely exceed 100 feet in thickness. The grade of the sand rock varies from fine sand, grit and gravelly sand to lenses of conglomerate. The coarser beds are more common on the north flank of the fold. A characteristic feature of these outcrops is the weathering into angular or subangular blocks.

Wadia (1928) mapped the base of these brown sandstones as the unconformable base of the Upper Siwalik, considering the Middle Siwalik to be overlapped along the south flank (1928, p. 342). The present map shows no such overlap. Westwards, beyond the limits of Pl. XXI, the lower part of the brown sandstones shows a change of facies. Both sandstones and clays become lighter in colour and white sandstone beds appear. Here the succession is similar in lithology to the type Dhok Pathan Stage and the beds were mapped as such by Cotter (1933). Thus the base of the Upper Siwalik on Wadia's map, which extended to longitude 72° 45′, strikes into the middle of Cotter's Dhok Pathan Stage as mapped from the type section to the west. Cotter, therefore, considered the lower part of Wadia's Upper Siwalik to be of Dhok Pathan age (1933, pp. 119–20), and pointed out that Wadia's Upper Siwalik faunal list included Dhok Pathan forms. He suggested that the base of the Upper Siwalik in the Soan area should be placed at the base of the Siwalik Conglomerate and this interpretation was adopted by de Terra (1936, 1939). Both these authors appear to have ignored Wadia's clear statement (1928, p. 344) that his fossil localities were " restricted to the pre-Boulder-conglomerate stages, the latter stage having yielded only indeterminable proboscidean bones." It must be noted that Wadia, following the nomenclature of the Geological Survey of India, applied the term "Boulder-conglomerate" to the 2000-3000 feet of folded Siwalik Conglomerate—not to the overlying, relatively thin group of highly unconformable conglomerates to which de Terra restricted the term.

Since Wadia collected undoubted Upper Siwalik genera from below the Siwalik Conglomerate, the base of the Upper Siwalik in the Soan area must lie within the brown sandstones, which locally are a homogeneous lithological group. There is no evidence that the base of the Upper Siwalik is marked by unconformity or by a basal conglomerate.

*Local Group* 6 *: Siwalik Conglomerate.*—The conglomerate succession is well exposed in steeply dipping beds on the north flank in the Jarai Kas and in the Soan River south of the bridge over the Grand Trunk Road. On the south flank it is best exposed in the Kas Dovac, where the dip of the beds begins to decrease rapidly within the outcrop of the conglomerates. This decrease in dip is purely a structural feature and is not related to conditions during deposition. This is confirmed by the quasi-vertical attitude of the same range of beds on the north flank. It is to be noted that in de Terra's section of the same area (1939, p. 281) the identical conglomerates are labelled Tatrot on the south flank and Dhok Pathan on the steeply dipping north flank. The present investigations have produced no evidence for unconformity either at the base of, or within, the Siwalik Conglomerate of the Soan valley.

The low dip of the upper part of the Siwalik Conglomerate on the south flank makes the relationship with later unconformable deposits—the Lei Conglomerate—difficult to elucidate, especially as the unconformable bed is in many cases a conglomerate which contains much material derived from the Siwalik Conglomerate itself. The key to these relationships is on the north flank where the steep folding of the Siwaliks gives rise to pronounced angular unconformity.

The Siwalik Conglomerate group is not made up entirely of conglomerate. In the Kas Dovac there are two main conglomerate horizons separated by a zone of deep red and pinkish clay and silt with thin brown sandstone beds. de Terra (1936, 1939) includes the upper conglomerate in his Boulder Conglomerate Zone, which on the north flank is composed predominantly of limestone pebbles. He explains the difference in composition as a difference in source of the derived material. In fact, the two conglomerates are of different age, de Terra having failed to distinguish between the folded Siwalik Conglomerate and the succeeding unconformable beds in this area in which there is no great discordance in dip. The cross-sections of the Soan valley at this point (Pl. XXII) provide an excellent example of the distortion which is introduced by constructing such sections on a much exaggerated vertical scale. The upper section on Pl. XXII is to true vertical scale, and represents the correct relationship of the conformable and unconformable beds. Adopting an exaggerated vertical scale, the construction on the synclinal fold involves great distortion of both dip and thicknesses; thus the Siwalik Conglomerate has a much steeper dip on the south flank than the observed value, and the thickness of the group has to be drawn much greater on the south flank than on the north. This may partly have been the source of de Terra's error in interpreting the stratigraphy.

At all levels of the Siwalik Conglomerate group there is pronounced lateral variation. The beds of conglomerate are lenticular on a large scale and contain lenses of sand, silt and clay, as shown on the cross-sections (Pl. XXII).

There is as yet no faunal evidence on which a correlation of the group with the type zones of the Upper Siwalik can be suggested, but in view of the fact that the upper part of the underlying brown sandstone group is not older than Tatrot (on Wadia's faunal evidence), it seems reasonable to follow Wadia in suggesting that part, if not the whole, of the Conglomerate Stage belongs to the Pinjor Stage. This correlation is important in giving the earliest date for the final phase of Himalayan earth-movement in the Potwar, for whilst an unknown thickness of post-Conglomerate group beds may have been eroded from the folded series, the folding is at the earliest post-Pinjor. The strong folding movement was followed by a period of denudation, and it was not until the area had been subjected to extensive peneplanation that further deposition took place in the Soan area. It is this old peneplain, now rejuvenated, which dominates the topography of the Potwar region. The topography, however, had not achieved maturity, for there were still residual monadnocks of considerable size and the stream courses were still incised, particularly on the northern fringe of the Potwar. That an ancient river course occupied a position almost coincident with the present Soan, at least in the section along the Grank Trunk Road, is demonstrated by the profile of the unconformity at the base of the Lei Conglomerate in Pl. XXII (lower section). de Terra has suggested that this ancestral Soan carried the waters of the Jhelum River which then flowed through the Panjar gap, above Owen, westwards across the Potwar.

*Local Group* 7 : *Lei Conglomerate*.—Though this formation is essentially valley-fill, it spilled over on to the lower parts of the peneplain itself and covered extensive areas of the northern Potwar. Over a large part of the north side of the Soan valley, northwards to the foothills, the formation is still preserved. Its facies is very variable. In the Soan valley the conglomerate is mostly a very poorly graded gravelly conglomerate of Eocene limestone with a small proportion of older sedimentary rocks, quartzite and igneous material. Large boulders occur locally, particularly in the more westerly exposures. The beds of conglomerate are markedly lenticular and intercalated with beds of sand and silt of pale brown to ochre colour. The silt shows evidence of aeolian origin and is difficult, except in colour, to distinguish from the overlying yellow Potwar Loessic Silt. The alternation of aeolian silt and conglomerate is well displayed in sections around and to the north-west of Rawalpindi. de Terra's restriction of the term " Boulder Conglomerate " to this formation, which has a maximum thickness of about 350 feet, is somewhat confusing in the field, since the term could perhaps be more appropriately applied, as Wadia applied it, to the 2000–3000 feet of Siwalik Conglomerate below. In the author's opinion the term " Boulder Conglomerate Zone " has long outlived its usefulness. Pilgrim (1910, 1923) originally applied the term to conglomerates in the Siwalik Hills at Moginand, but no vertebrate fossils were recorded from the conglomerate beds themselves; the Upper Siwalik fauna of this locality came from beds 5000 feet lower in the succession and it is apparent that Pilgrim's Boulder Conglomerate Zone was a facies zone. As a description of facies, "boulder-conglomerate" could be applied to beds of identical lithology which occur in the Potwar over a vertical range of 6000–7000 feet of the Siwalik Series, from the upper part of the Nagri Stage at Jhamat to the highest Siwalik beds. In view of the present confusion in the terminology, until a more reliable basis than comparative lithology can establish more precise correlation between the widely separated areas, it seems wiser to retain local names for the various formations. The highly unconformable post-Siwalik conglomerate of the Soan area is, therefore, here referred to a locality at which there is no doubt as to the horizon of the conglomerate—the section of the Lei River south-east of Rawalpindi.

Identifiable mammalian fossils have not yet been found in the Lei Conglomerate and this must introduce an element of speculation in any suggestion as to its age. de Terra considered it to coincide with the second ice advance of his complete glacial cycle in Kashmir, and thus of Middle Pleistocene age. He also considered the occurrence of pre-Soan artefacts in its upper layers to confirm a Middle Pleistocene age. There is a suggestion in de Terra's writings that this correlation is influenced by other considerations when he states (1939, p. 266), "As in our opinion the Pinjor fauna is early Pleistocene, we cannot help but assign a somewhat later age to these beds." There seems to be a possibility that the Lei Conglomerate may belong to the upper part of the Lower Pleistocene.

*Local Group* 8 *: Potwar Loessic Silt.*—Deposition of the Lei Conglomerate was followed by a renewal of the forces of degradation during which the conglomerate was removed from extensive areas. There is evidence that the drainage pattern during this period was not, especially in detail, coincident with that of pre-Lei Conglomerate times, and it is probable that the Jhelum River established its present course below Owen at this time. It was on the boulder- and gravel-strewn land-surface of this period that Palaeolithic man roamed and manufactured the large numbers of stone implements of the Soan culture. The period of man's habitation of the Potwar seems to have suffered an abrupt interruption in Upper Pleistocene times as no Upper Palaeolithic cultures have been recorded; the next clear records left in the region are of Neolithic man.

The hiatus in Upper Palaeolithic times coincides with the arresting of denudation forces and the laying down of a thick mantle of loessic silt. The mode of deposition of the Potwar Loessic Silt has been much debated, as the deposit combines characters usually ascribed to aeolian, fluvial and lacustrine sediments. Subaerial deposition seems to be the most acceptable explanation of the evidence. It is probable that the Loessic Silt coincided with a period of glacial advance in the north with a consequent freezing of the source of southerly drainage. Such melt-water as may have flowed in this direction was clearly quickly choked by accumulating loess. The one exception may have been the Indus River. The author knows of no exposure of Loessic Silt near the river itself and the extensive coarse sand and silt deposits near Jand in the western Potwar may indicate the removal of the finer grades of the loessic material by Indus flood-waters.

The silt-bearing air currents must have been at the higher altitudes, those at lower levels being sufficient to cause concentration in the valleys but not strong enough to produce dune bedding in material of this grade. Periodic rainfall, with local, temporary bodies of water would provide an explanation of the bedding, banding, occasional lamination and marginal slope wash of gravel and conglomerate.

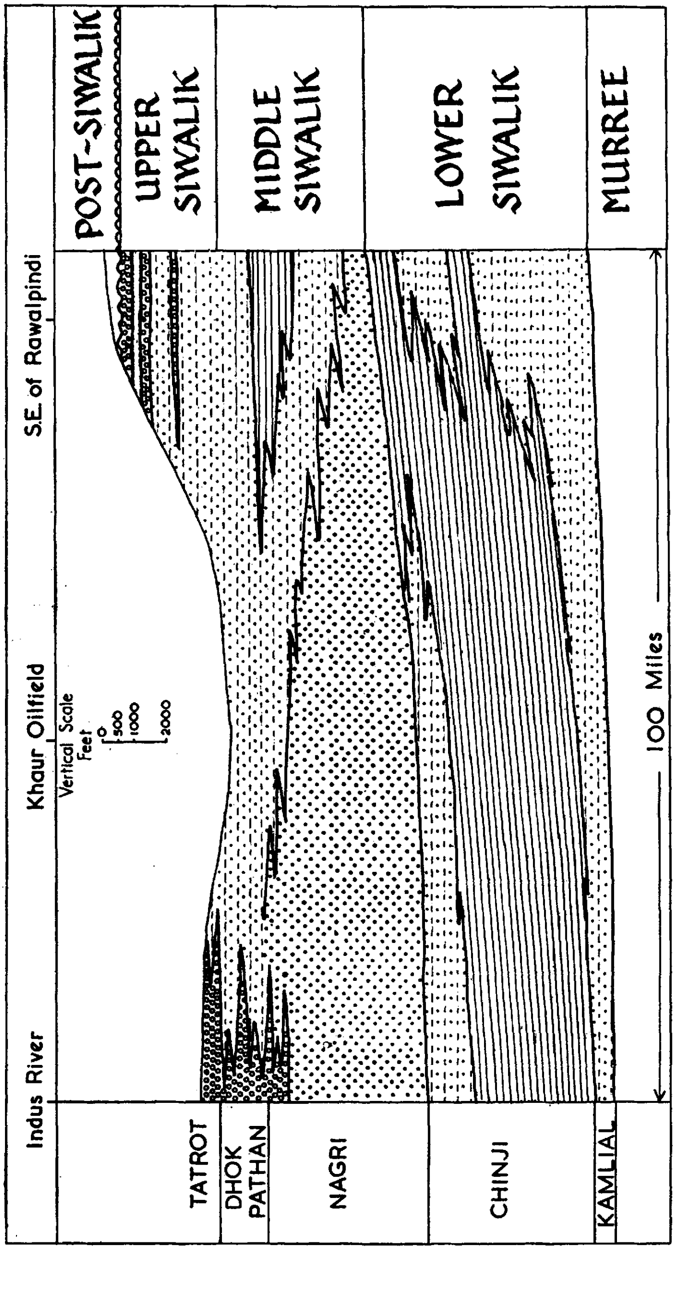
Following the period of silt deposition, a widespread mantle of gravel was deposited on the almost level surface. This may relate to a period of rapid glacial melt in the Himalayan region which caused extensive flooding before the run-off could establish the restricted channels of the drainage system as it now exists. In the author's opinion, the large "erratic" boulders recorded from various localities from the northern and western Potwar were dumped at this period. One such boulder of granitoid gneiss, about two feet across at its maximum, collected near Tut village in the Sil valley below Pindigheb, shows unmistakable glacial facets. This leads to the suggestion that the large erratics of this period were carried down by flood-waters in blocks of ice.

## IV. General Summary and Conclusions

### (a) Siwalik Facies and Thickness Variation in the Northern Potwar

From the detailed investigations described above, and from previous work in the area of the Khaur and Dhulian oilfields, the stratigraphy of the Siwalik Series, approximately along the northern boundary of its outcrop, can be summarized in the diagram Fig. 2.

The Siwalik sequence in the extreme west and in the east of this northern outcrop displays conspicuous departures from the standard succession for the region, which was based on the exposures in the central and southern parts of the Potwar. The most conspicuous departures occur in the Middle Siwalik, which is affected by a progressive change of facies. On the Jhamat fold, the entire Dhok Pathan Stage and the upper part of the Nagri Stage include thick beds of conglomerate. At this point the thickness of the Middle Siwalik is not less than 6500 feet. The conglomerate facies fades eastwards to give way to a Nagri Stage of thick, massive sandstones overlain by the predominantly clay-shale facies of the type section of the Dhok Pathan Stage. Here the combined thickness is about 5700 feet, though the upper limit of the Dhok Pathan Stage is not determinable. Still farther to the east, along the north limb of the Soan syncline, clay-shale facies develops at progressively lower horizons of the Nagri Stage until, in the East Soan area, this facies dominates the entire Middle Siwalik succession. Lack of a clearly defined Middle/Upper Siwalik junction in these eastern areas makes it difficult to arrive at a figure for the overall thickness of the Middle Siwalik. At the eastern end of the Soan syncline and along the south flank, the total thickness of the Middle Siwalik probably does not exceed 4700 feet. Thickness trends within the area mapped in detail are more clearly demonstrated by the measurements of the local lithological groups (Table II, p. 382). Local groups 3 and 4, which are undoubtedly Middle Siwalik, show a progressive thinning from 4900 feet in the Kalas Kas, at the western end of the north flank, to 3600 feet at the Soan Gorge. The thinning of these groups across the fold to the south flank is very pronounced, as is illustrated by the difference of 1100 feet between the Jarai Kas and the Kas Dovac measurements. The isopachytes of groups 3 and 4 in the East Soan area run in a direction N.20°–30°E. which represents a much more pronounced northerly swing than those of the Lower Siwalik in the same area. The evidence from the Soan area indicates that Middle Siwalik beds thin




SIWALIK FACIES IN THE NORTHERN POTWAR, PAKISTAN

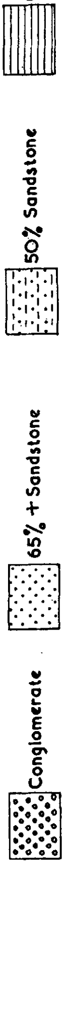



FIG. 2.

rapidly towards the line of the Jhelum, which is also an important syntaxial line in relation to the entire Himalayan orogenic cycle. It is important to note that geosynclinal movement along it was significantly less, at least in Middle Siwalik times, than in the western Potwar. The easterly change across the Potwar to finer grades of sediment which has here been described is similar to that which accompanies the thinning of the Middle Siwalik southwards towards the Salt Range in the western Potwar, as described by van V. Anderson (1927). This facies distribution points clearly to the region of the present Indus River as the source of the greater part of Middle Siwalik sediments of the Potwar region, and demonstrates that the drainage of the Siwalik trough was dominantly transverse in Middle Siwalik times. The evidence constitutes a firm denial of the Indobrahm hypotheses of Pilgrim (1919) and Pascoe (1920) as applied to this region. The latter hypothesis states that the Siwalik Series are the deposits of the flood-plain of a single river which flowed westwards from Assam to the Potwar region (approximately coinciding with the present Soan River) and then southwards to the sea. Evidence, accumulating from detailed surveys of the Siwaliks such as those here described, indicates that at no time in the history of the Nimadric geosyncline did such a river exist.

In the Lower Siwalik, apart from a progressive thickening of the Kamlial Stage eastwards from the area of the Khaur/Dhulian oilfields, the lithology of the type sections is maintained until the north-eastern end of the Soan syncline is reached. Here the lowest 1500 feet of the Chinji Stage develops a " Kamlial " facies, which has been described in section III as a separate local lithological group. This separation is important to demonstrate their stratigraphical position, but the lithological grouping for the purposes of mapping is distinctly with the Kamlial Stage. Wadia (1928) has adopted this grouping in Pūnch State, giving a thickness of about 4000 feet for his Palandri Stage. The present work shows that at least the upper 1500 feet of this stage is homotaxial with the Chinji Stage of the western Potwar.

In a consideration of thickness changes in the Soan area, the Riwat Beds must be included with the Chinji Stage, and from the figures in Table II (p. 382), it will be seen that the latter shows a small though persistent reduction along the north flank by about 400 feet at the Soan Gorge section. The importance lies not in the small amount of thinning, but in the fact that the isopachytes of the Chinji Stage are running SW.–NE., in contrast to the W.–E. trend in the western Potwar. It will be noted that the change in direction of the isopachytes observes a close parallel with the change in direction of the fold axes and of the major strike-faults of the region, indicating the identity of the forces which produced first the geosynclinal movement and later the structural deformation. The limited data available suggests that between the Ling River and Riwat the Chinji Stage is not appreciably thicker than 4100 feet—a pronounced thinning of 800–900 feet across the fold from the north flank.

### (b) The Relationship of the Siwalik Phase of Himalayan Orogenesis to the Pliocene/Pleistocene Boundary in North-West India

Both de Terra (1936, 1939) and Wadia (1951) have stressed that the sections in the Soan valley are a key to the Pliocene/Pleistocene history of the sub-Himalayan region, and the interpretations of the former author have figured in subsequent writings on this subject by other authors

(Krishnaswamy 1947). It is necessary, therefore, to consider the wider implications of the revised relationships and classification of Siwalik and post-Siwalik beds, which have been deduced from the present work.

The Soan evidence is critical to de Terra's general statement that throughout the region the Upper Siwalik (Tatrot Stage) overlies the Middle Siwalik with strong unconformity or disconformity, the hiatus between the two formations representing the main period of the Siwalik orogeny. He held these field relationships to confirm the views of American palaeontologists, first published by Matthews in 1929, that the Tatrot fauna was of Pleistocene age and was separated from underlying Dhok Pathan fauna by a time-break equivalent to the Upper Pliocene. This apparent harmony of geological and palaeontological evidence made a strong position from which it was argued that the base of the Upper Siwalik should be regarded as the base of the Pleistocene System in the Indian region.

However valid the ultimate conclusion may prove to be, the results of the present investigation clearly support the arguments of Pilgrim (1910, 1939, 1944) that many of de Terra's premises are manifestly false. Firstly, it has been demonstrated that de Terra's choice of the base of the Siwalik Conglomerate as the base of the Upper Siwalik in the Soan area is against the evidence of the undoubted Upper Siwalik fauna collected by Wadia from below the conglomerate. The palaeontological and strike-mapping evidence shows that the Middle/Upper Siwalik boundary lies within a thick homogeneous group of sandstone and clay alternations and is marked neither by unconformity nor a basal conglomerate. Even if we were to accept the base of the Siwalik Conglomerate as the boundary, there is still no evidence of unconformity, as this formation is folded conformably with the underlying beds in the steep north flank of the syncline. This is but confirmation of Pilgrim's observation "that, as the Geological Survey of India have established, throughout the whole Sub-Himalayan region from Jammu to Nepal the Boulder Conglomerate shares completely in the folding which has affected the underlying Pinjor beds and no unconformity is observable" (1939, p. 439). Other key sections of this range of beds are those described by Paterson in Pūnch State (de Terra & Paterson 1939, pp. 206–7). Here also the Siwalik Conglomerate is conformable to the underlying Pinjor Stage. It is evident, however, that the lower limit of Pilgrim's Boulder Conglomerate Zone, which in the type locality lies 5000 feet above beds with a Pinjor fauna, is very variable in the sub-Himalaya. In the northern Potwar it appears to coincide with the Pinjor Stage in the Soan syncline, and in the Jhamat area descends through the Dhok Pathan Stage to the upper part of the Nagri Stage of the Middle Siwalik.

In Pūnch State, Paterson considers that the deposition of conglomerate was accompanied by diastrophism, and the upper layers of what he regards as a continuous deposit in the basins are strongly transgressive elsewhere, merging higher up the valleys into boulder-moraine of the second glaciation. This picture of continuous diastrophism and sedimentation is also applied to the "Boulder Conglomerate" of the Soan area by Wadia (1951, p. 48). It has been shown, however, that in the Soan area the evidence is against continuous earth-movement. Here the period of the Siwalik orogeny is clearly defined as post-Siwalik Conglomerate (Pinjor) and pre-Lei Conglomerate. It is possible that the major unconformity separating the two conglomerates is bridged to some extent by great thicknesses of late Siwalik conglomerates in the basins of Pūnch, but the present work has shown that even a major unconformity may be difficult to detect in areas of low dips, and where the upper formations are to an important degree derived from the lower. This difficulty is well illustrated by the fact that de Terra's "Boulder Conglomerate" of the Soan valley, which is mainly post-Siwalik Lei Conglomerate, includes part of the Siwalik Conglomerate below the unconformity in the area of low dips on the south flank of the syncline. The author feels justified in suggesting that an unconformity similar to that in the Soan area may exist in Pūnch. Pilgrim (1944) saw the need for subdivision of the formations which have been collectively called "Boulder Conglomerate". His upper and lower subdivisions could, in the author's opinion, be applied to an extensive stratigraphical range of formations, and in the present paper the term Siwalik Conglomerate (Pinjor) has been used for the conformable, and the local name Lei Conglomerate for the unconformable, formations. If the unconformity in the Soan area is regional and synchronous, the correlation of the Lei Conglomerate with the Tawi Conglomerate near Jammu and the upper part of Paterson's "Boulder Conglomerate" in Pūnch would be more certain than at present. It is this range of beds which Paterson and de Terra established as merging into boulder-moraine of the second glaciation towards the mountain tract. Similar Middle Pleistocene conglomerates are involved in late fold movements in the Salt Range area, but in the northern Potwar deformation is restricted to the lines of the major faults. This faulting stresses the need for caution in attempting to trace the conglomerates and associated terraces through the foothills to the glaciated mountain tract.

The clear separation of Siwalik and post-Siwalik Pleistocene beds in the Soan area provides a possible basis of direct correlation by structural relationships. Of particular importance in this respect is the correlation of the sub-Himalayan succession with that in the intra-montane lake basin of Kashmir. The Pliocene/Pleistocene succession in Kashmir is grouped into Upper and Lower Karewa formations which are separated by a period of earth-movement and denudation. The Lower Karewa lake-beds, correlated on palaeontological evidence with the Pinjor by de Terra and with the "lower Boulder Conglomerate" by Pilgrim, were folded, uplifted along the southern margin by 6000–8000 feet, and extensively denuded before the deposition of the Upper Karewa beds. The Karewa gravel at the base of the Upper Karewa is correlated by de Terra with the second glaciation. The unconformity in Kashmir appears, therefore, to be synchronous with the Siwalik orogeny in the sub-Himalaya, though it must be noted that the deformation is less in Kashmir, where the folding dies out towards the Himalayan side of the basin.

It seems probable, therefore, that there is a regional unconformity in North-West India, representing the Siwalik phase of Himalayan orogenesis. This diastrophism commenced in post-Pinjor times and was followed by extensive denudation before the deposition of beds which de Terra has correlated with the second glaciation.

The greatest source of controversy concerns the recognition of earlier glacial deposits. In Kashmir, de Terra ascribed the Lower Karewa lake-beds, estimated to be about 2000 feet thick, to the first interglacial. South of the Himalayan slope, evidence for the first glaciation was limited to outwash fans at the base of the Karewas and to high truncated spurs on the Pir Panjal Range. Subsequent to de Terra's work Wadia (1941) has stated: (1) that the Lower Karewa is about 5500 feet thick and that its lower levels range down to equivalents of the Dhok Pathan

Stage; (2) that moraines of the first glaciation are interbedded about half-way in the succession.

With regard to the sub-Himalayan tract, Pilgrim (1939, 1944) repeatedly opposed the suggestion of de Terra that the Tatrot/Pinjor represented the first glacial cycle. He considered the facies and fauna of these stages to indicate that they were pre-glacial, holding the same view with regard to the Villafranchian of Europe. Prior to 1940 he was of the opinion that the Siwalik Boulder Conglomerate was also pre-glacial, emphasizing its conformable relationship with the underlying Pinjor. The discovery of direct evidence of glaciation in the Bain Boulder-bed in the North-West Frontier Province (Morris 1938), which was fixed by clear faunal evidence to be " slightly later than Pinjor " (Pilgrim 1944, p. 31), induced Pilgrim to accept the Siwalik Boulder Conglomerate as representing the first glacial cycle, though without any direct evidence of glaciation in these beds. The present work has shown that the Siwalik Boulder Conglomerate is a heterochronous formation ranging from the Dhok Pathan Stage of the Middle Siwalik to the highest Siwalik beds, and since vertebrate fossils are rare and poorly preserved in this facies, Pilgrim's suggestion that it should form the base of the Pleistocene would be extremely difficult to apply. Adopting the decision at the International Geological Congress in London (1948) to include the Villafranchian in the Pleistocene System, the fact that the Pinjor Stage has a widely distributed and prolific fauna (except in the conglomeratic facies in the most northerly outcrops) gives the Pleistocene a convenient palaeontological boundary. It is quite another matter, however, to follow de Terra in assigning the Tatrot/Pinjor to the first glacial cycle. The author knows of no unequivocal evidence of glacial formations in the Upper Siwalik beds of the sub-Himalaya other than that of the Bain Boulder-bed. Since this is probably later than Pinjor, the equivalent horizon may well be missing at the post-Siwalik unconformity in the Soan area and elsewhere. One implication of de Terra's scheme must be emphasized. If the Upper Siwalik represents the first glacial cycle, we are faced with the fact that the Siwalik orogeny caused no significant interruption in the deposition of beds representing the complete succession of glacial and interglacial stages. Under de Terra's scheme, the first interglacial must constitute a very long period of geological time, representing firstly the deposition of many thousands of feet of Upper Siwalik formations, and secondly the period of the Siwalik orogeny and subsequent peneplanation. Alternatively, we must accept that the pace of diastrophism and denudation is much greater than we have hitherto thought possible.

The decision to make the Villafranchian the base of a revised Pleistocene System does not, therefore, resolve the considerable differences of opinion with regard to early Pleistocene history in the North-West Indian region. As Wadia has emphasized (1951), the revised base of the system has no significance in the lithological grouping of the formations, and its only advantage lies in the provision of a palaeontological datum level. The only " natural " boundary in the region is at the post-Villafranchian unconformity. This is clearly Pilgrim's original boundary, which had much to commend it. On the evidence of interbedded moraines in the Lower Karewa lake-beds in Kashmir, and on that of the Bain Boulder-bed, it seems unquestionable, however, that there were glaciations before the Siwalik orogeny, though the precise dating and correlation of the beds in which this evidence occurs remains an important problem.

The fact that glaciation commenced before the Siwalik orogeny and the uplift of the Pir Panjal Range shows that if glaciation is dependent on diastrophism, we have to look to the building of the Great Himalaya and other ranges to the north for the cause of the early glaciations in this region.

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## EXPLANATION OF PLATES XX–XXII

### Plate XX

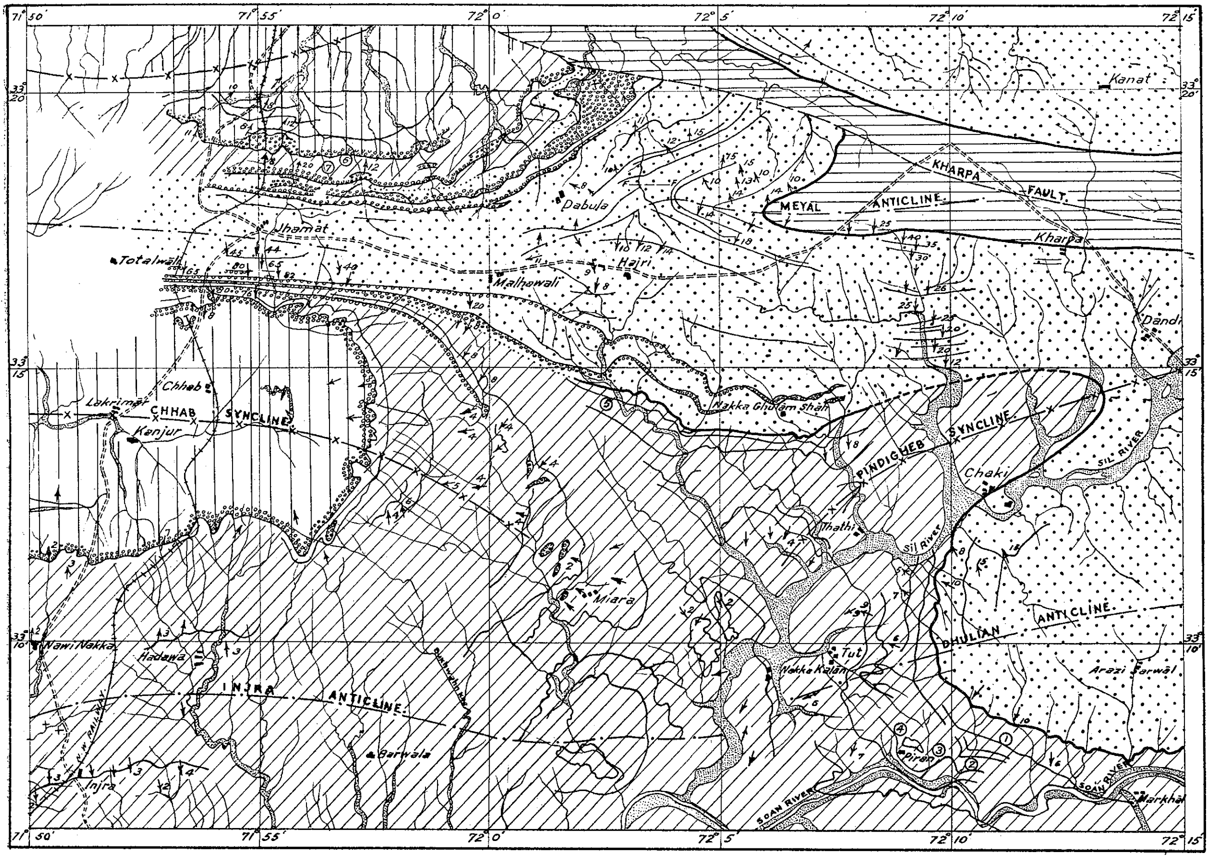
Map showing the westerly development of Middle Siwalik Conglomerates on the Jhamat fold in the western Potwar, Punjab, Pakistan. Scale: 1 inch to 4 miles.

### Plate XXI

Map showing the solid geology of the eastern end of the Soan syncline in the eastern Potwar, Punjab, Pakistan. Scale: 1 inch to 2 miles.

### Plate XXII

Cross-sections of the Soan syncline, south-east of Rawalpindi, Punjab, Pakistan. Scale: horizontal, 1½ inches to 1 mile; vertical, various.



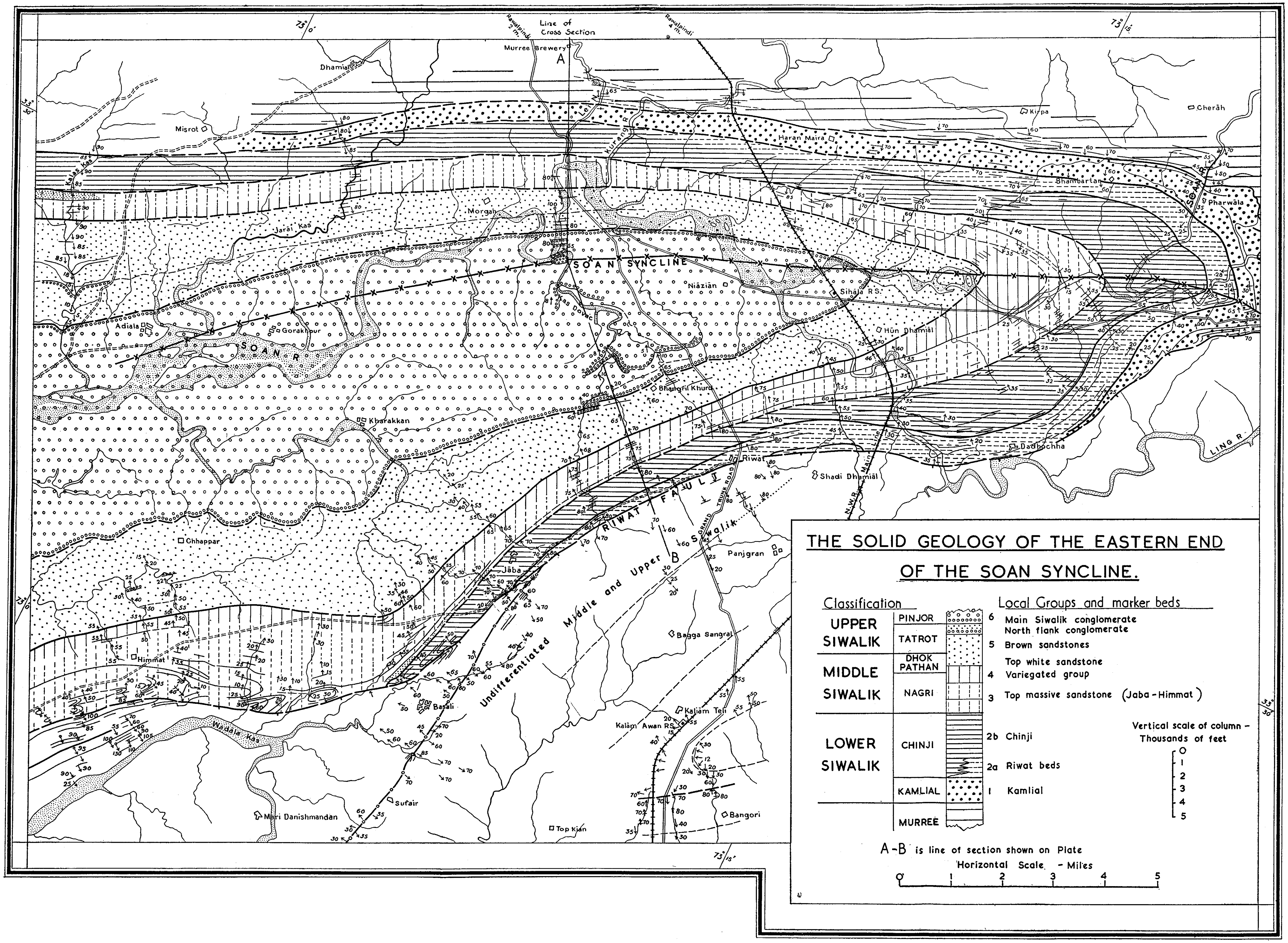

Conglomerate UPPER SIWALIK DHOK PATHAN NAGRI CHINJI

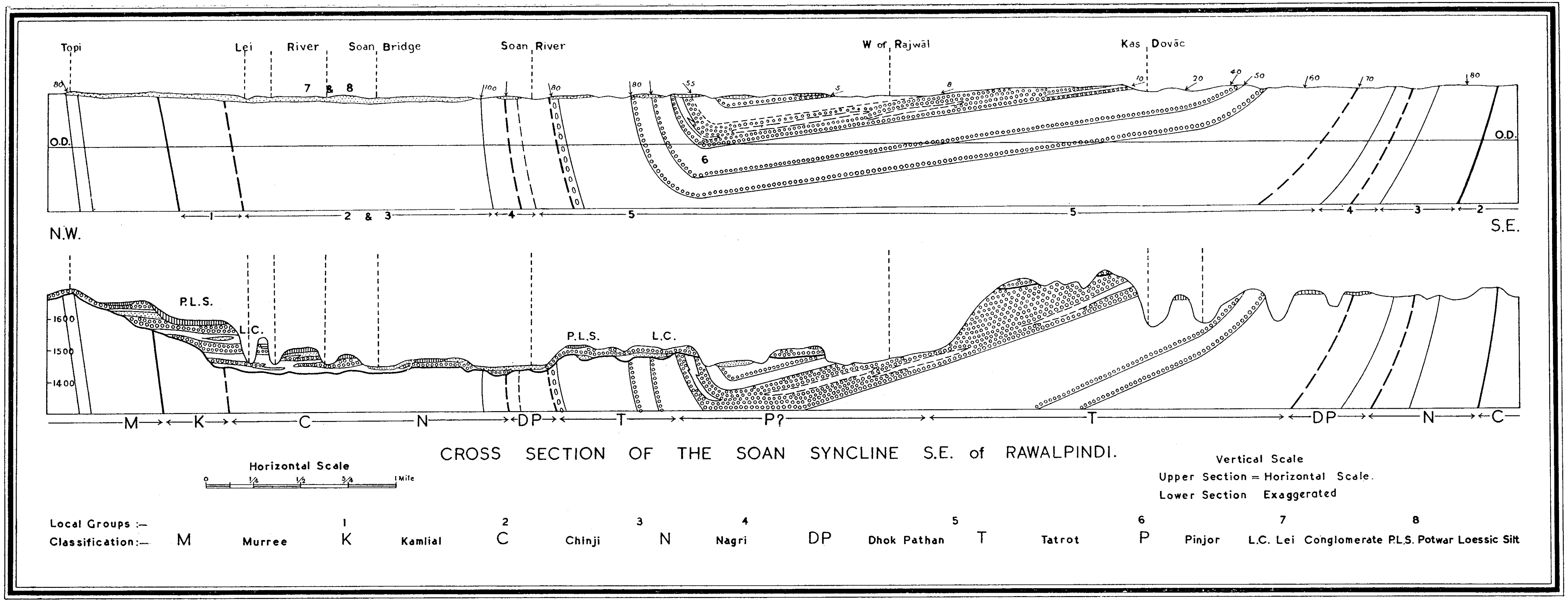
Strike lines are clay / sandstone junctions

Scale of miles
0 1 2 3 4 5

Fossiliferous localities ⑦

DEVELOPMENT OF MIDDLE SIWALIK CONGLOMERATES ON THE JHAMAT FOLD, WESTERN POTWAR, PUNJAB.


THE SOLID GEOLOGY OF THE EASTERN END OF THE SOAN SYNCLINE.
Classification
Local Groups and marker beds
UPPER SIWALIK
PINJOR
6 Main Siwalik conglomerate
North flank conglomerate
TATROT
5 Brown sandstones
MIDDLE SIWALIK
DHOK PATHAN
Top white sandstone
4 Variegated group
NAGRI
3 Top massive sandstone (Jaba-Himmat)
LOWER SIWALIK
CHINJI
2b Chinji
2a Riwat beds
KAMLIAL
1 Kamlial
MURREE
Vertical scale of column - Thousands of feet
0 1 2 3 4 5
A-B is line of section shown on Plate
Horizontal Scale - Miles
0 1 2 3 4 5
Line of Cross Section
Murree Brewery
A
B
SOAN SYNCLINE
SOAN R.
RIWAT FAULT
Undifferentiated Middle and Upper Siwalik
LING R.
Wadala Kas
Jarai Kas
Kurang R.
Dhamial
Misrot
Morgah
Adiala
Gorakhpur
Kharakkan
Chhappar
Himmat
Jaba
Basali
Sufair
Mari Danishmandan
Top Kian
Kalam Awan R.S.
Bangori
Bagga Sangral
Panjgran
Riwat
Shadi Dhamial
Dadhochha
Hun Dhamial
Sihala R.S.
Niazian
Bhangril Khurd
Haran Maira
Kirpa
Cherah
Pharwala
Bhambartan
Grand Trunk Road
N.W.R. Main Line
73° 0'
73° 15'
33° 30'




CROSS SECTION OF THE SOAN SYNCLINE S.E. of RAWALPINDI.