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Morphology and Stratigraphy of the Ghaggar River Terraces at Water-Gap Locale

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Abstract

River Ghaggar has formed two fundamental categories of fluvial terraces on its western bank at Siwalik water gap locale, which are mostly depositional and erosional. The occurrence of terraces on its west bank clearly indicates the east ward movement of Ghaggar River. The shifting channel provided accretional point bars and back water pools with clean washed bottom gravel. Efforts to straighten and narrow the channel intensified the velocities and propensity of the river to shift its channel increased. Terraces cut on bedrock by lateral planation and veneered with the fluvial deposits associated with that process. Although actual glacial conditions never prevailed in this area, but the occurrence of these terraces and the proximity of the area to the glaciated areas in the Himalayas probably suggest the occurrence of peri-glacial conditions. While the climate was of peri-glacial type the river brought enormous quantities of rock-waste and deposited its surplus load in the form of terraces. These terraces are unpaired and discontinuous. The terraces are largest near the water-gap and become gradually smaller with increasing distance from it. All the major terrace level are separated by steep scraps at places almost vertical, while at others steeply sloping in accordance to the upper Siwalik beds. Lithologically these terraces are mainly composed of sandstones, pebbles, cobbles and gravels derived from the boulder conglomerates which are hard but can be easily eroded. The sub-angular, sub-rounded and little rounded clastic and sandstone gravels indicate their local provenance and short distances they have travelled. They were re-deposited in the stratigraphic layers of lower terrace levels during inter-glacial periods, when the flow of the river was violent and torrential. The beginning of the Holocene period is suggested by textural changes in lithology.

Key words: *Ghaggar river, Lithological variations, Morphology, River terraces, Stratigraphy, Water-gap locale*

Introduction

The Ghaggar River also called Sarasvati has been closely linked with the physiographic and cultural evolution of the part of the Malwa region of the Punjab plain, which is often referred to as the Yamuna-Sutlej divide. At present the Ghaggar is an inland and largely a seasonal stream as neither the master stream nor any of its feeders take their rise in the snow covered region of the Himalayas. The Ghaggar had been a prominent perennial river with a vast drainage basin in the past but due to the processes of river capture and unilateral shifting of its course it lost numerous tributaries in its upper course. It is generally thought that tectonic movements in the north western Himalayan region also led to river diversions, captures and drastic reduction in the water-flow in the rivers. The present paper lay emphasis on the morphology and stratigraphy of the two fundamental categories of fluvial terraces existing on the western bank of the Ghaggar river at the water-gap locale: mostly depositional and erosional. Except for the highest terrace level (T1) the others are depositional. Lithologically, terrace material consists of thickly bedded massive conglomerates with boulders, cobbles, pebbles, sandstone and quartzite.The introduction to study area includes its location, geology, climate, drainage pattern, geomorphological significance and objectives of the study.

Location of the study area

The location of any geomorphic study area can be discussed in terms of its absolute location, relative location and topographical location.

a. Absolute location: The study area lies between 300 40´ North to 30o45´ North and from 76o 49´ East to 76 o 56´ East.

b. Relative location: The study area lies at about fifteen kilometers North-East of Chandigarh.

c. Geomorphic location: The depositional terrace system is located in the Siwalik Hill Ghaggar water-gap region. These terraces are located on the western bank of the Ghaggar River. Towards the south they merge with adjacent plains. (Fig.1)

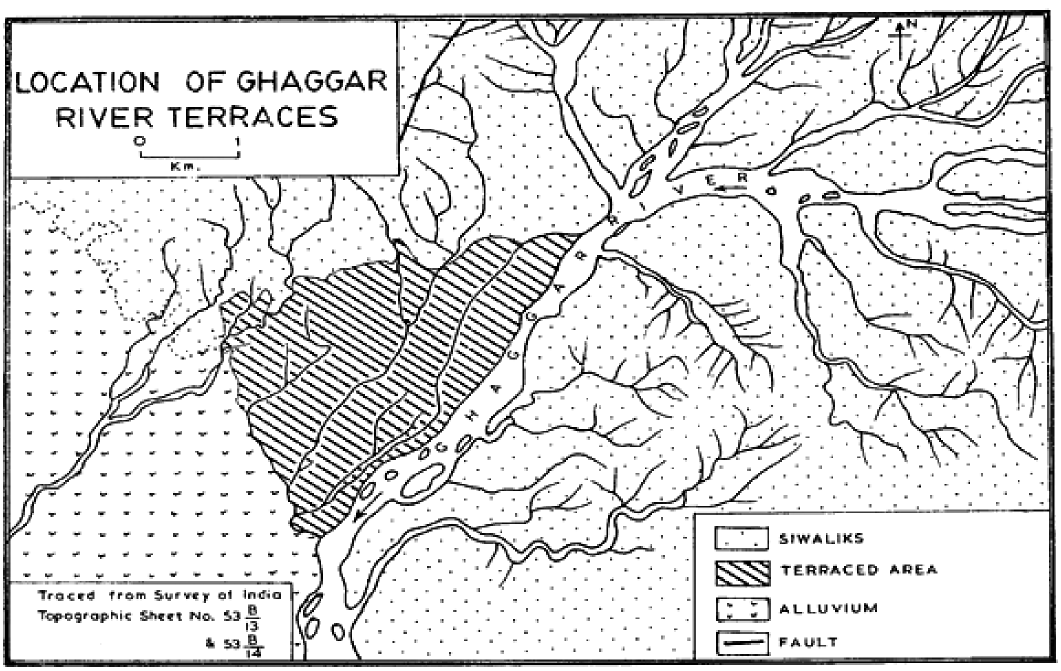

Fig.1: Location of Ghaggar River Terraces

Geology of the study area

In any geomorphic study, the description of geology of the study area is of central significance. Essentially it deals with geomorphic purpose, with lithology and structure (Fig. 2).

Lithology: Lithologically these terraces are mainly composed of sandstones, pebbles, cobbles and gravels derived from the boulder conglomerates, which are hard but can be easily eroded (Fig. 3). The Ghaggar water-gap system is mainly composed of brownish yellow and yellowish grey sandstones and ash colour conglomerates. Tandon and Kumar (1984) reported a volcanic ash bed in the Ghaggar river section NE of Chandigarh. The Boulder Conglomerates which constitute the upper most formation consists of coarse Conglomerates which represent boulders, cobbles and pebbles. At times, they are in sorted laterally with silt as well as sandstones forming lenses.

Structure: The structure of the Upper Siwalik reveals broad anticlines and regional and local faults. Two parallel fault trace were identified between Panchkula and Mansa Devi which have uplifted the Ghaggar terraces. The evidence of the displacement of different terrace levels along the branching faults, as well as the maximum height of the T1 scarp (38m), suggests continued tectonic movement through late Pleistocene to Holocene times. The gentle wrapping of the terraces near the fault line on the hanging wall side suggest that the sediment succession has been warped or folded in response to riding over a band in a fault with a steeper fault plane near the surface (Javed and Nakata, 2003). The terraces are located uncomformably on the Upper Boulder Conglomerate. This type of geometry of deformation is commonly associated with the thrusts that normally step up in the direction of slip to a higher décollement or a ramp in a décollement resulting in fault-bend folding as defined by Suppe (1983). The occurrence of the straight faceted range suggests the ongoing tectonic activity in the region.

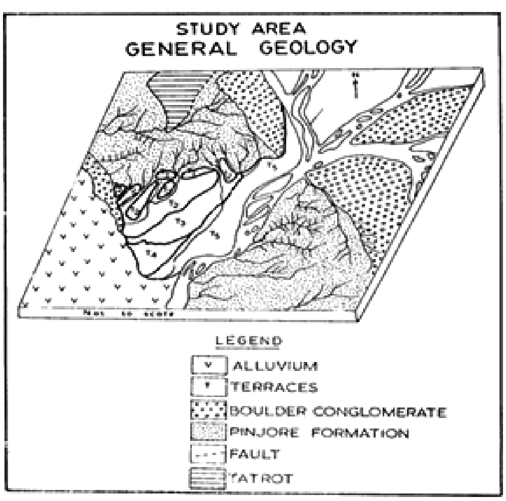

Fig.2: Study Area General Geology

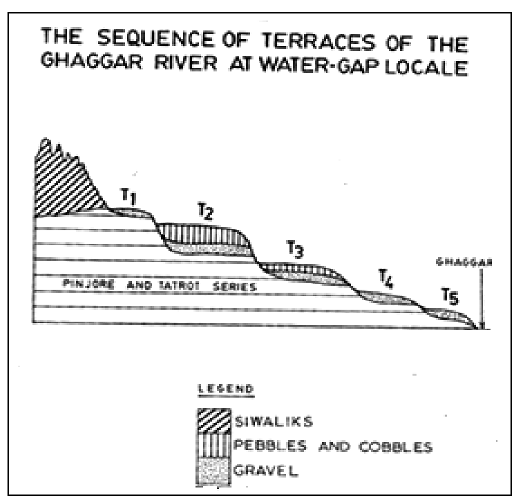

Fig.3: The Sequence of Terraces of the Ghaggar River at Water-Gap Locale

Climatic conditions

The study area experiences Koppen's CWg climate. The maximum temperature during summer reaches up to 450C. The study area receives an annual rainfall of 35 inches, of which about 30 inches are received in the monsoon months (June to October). The winter rain is limited to December and January only. The rains are of high intensity and of short duration.

Drainage pattern

The Ghaggar river rises in the Siwalik Hills of Sirmaur at a height of about 5,576 feet (near 300 4´ North and 770 12´ East). Neither the master stream nor any of its feeders take their rise in the snow covered region of Himalayas. It, therefore, depends for its water supply wholly upon the monsoon rains or springs in catchment area. The dendritic pattern is found to be the dominating one over most of the drainage system of the Ghaggar. The valley is all covered with sand and the narrow channel runs through these sands, throwing threadlike branches and enclosing islands and sandbars (Fig.1) in Pinjore several tributaries from the eastern slope of the Siwalik join it, but they are all seasonal. The most important of these torrents are the Jhajra and Koshallia Nadis which join together before meeting the Ghaggar. The Ghaggar enters the plains through a gap in the Siwalik range North-East of Chandigarh as a rapid and variable mountain torrent and flow through the plains in numerous drainage channels.

The geomorphological significance of the Ghaggar water-gap terrace system

- Water-gap location of terraces.
- Climatic response to glacially controlled climatic fluctuations. The area is indirectly influenced by glacial-climatic fluctuations.
- None paired terraces.
- The geological time range spreads from the middle Pleistocene to the late recent.
- Combination of climatic and tectonic factors influenced the terrace system.
- Except for the highest terrace level (T1) the others are depositional.
- From North-East to North-West at the foot of Siwalik Hills or their equivalents, the terraces having water-gap location show broad generic and genetic similarities.
- The topographic expression in the terrace levels show distinct convergence due to tilting and gentle warping.

Objectives of the study

The main objective of the present research paper isto analyse the morphology and stratigraphy of the Ghaggar terrace system at water-gap locale.

Morphology and Stratigraphy of Ghaggar Terraces

The Ghaggar terraces are well developed between Panchkula and Dara Kharauni, and the Chandigarh-Kalka motor road lie partly on the fifth terrace (T5). This level is comprised of alluvium and sub- recent conglomerates. Two fundamental categories of fluvial terraces exist on the western bank of Ghaggar River at the water-gap locale: mostly depositional and erosional. Erosion of the bed rock valley-floor and erosion of the valley-fill deposited by the river itself resulted in the formation of erosional and depositional terraces. Except for the highest terraces level (T1) the others are depositional. Lithologically, terrace material consists of boulders, cobbles, pebble, sandstones and quartzite.

Size of the terraces

The most important determinants of the size of the terraces have been the original size of the channel, particularly, its width, the amount of discharge it carried formerly, the aggressiveness of flow, the extent by which the river channel has swung laterally, thus, determining the size of abrasion platform on which subsequently terrace material were deposited, the extent of tectonic uplift experienced by the segment through which the river has been flowing and which affects the extent of shifting, and size of the meander loop and direct and indirect influence of local climatic conditions also determine the size of terraces to some extent. The terraces are largest near the water-gap and become gradually smaller with increasing distance from it. While discussing the size of the choe terraces Mukerji (1975), mentioned that the terraces are the largest near the water-gap and become gradually smaller with increasing distances from them. The width of fifth terrace (T5) vary from half to one mile, while width of highest terraces level (T1) is just 400 to 500 meters and length of T1 vary from 600 and 900 meters. Near the water-gap the terraces have maximum extent but they are found in patches in deep interiors (Fig. No.14 and 15 : See page No 10).

Shape of the terraces

The shapes of the terraces vary from T5 to T1. The shape of T5 is analogous to a rectangle while T4 occupies almost a triangular shape (Fig.2). T3 has a trapezoid shape, T2 occupies sub-rounded to rectangular shape and T1 has rounded to sub-rounded shape.

Elevation of the terraces

The relative difference of elevation is clear from Fig.16. The river bed is at an elevation of about 350 meters above the mean sea level. The highest and the oldest terrace level (T1) stands at an elevation of about 105 meters from the river bed and at about 455 meters from the mean sea level. The height difference between this highest terrace level and the next lower one (T2) is about 38 meters, fairly steep scarp separating the two at most places. T2 is very well defined all along the river course. The height difference between T3 and T4 is about 11 meters, while T4 is separated from T5 by a scrap about 18 meters. The fifth and the youngest terrace level (T5) occurs just above the river bed, rising to about a height of 8 meters.All the major terrace levels are separated by steep scarps at places almost vertical (Figures 4, 6, 8, 10 and 12 : See page No 9/10), while at others steeply sloping in accordance to the Upper Siwalik beds. The terrace levels T1 and T4 are found in patches at some places while at other places it is parallel to the river course. The T3 and T5 levels are well developed and are almost exactly parallel to river course.

Stratigraphic Exposure

Five segments are revealed in the vertical profile of the stratigraphy of the third terrace level (Fig. 8 : See page 9).

1. A vertical layer of about 0.5 meter thick of modern pedogenically immature soil of clay loam texture and its parent material, standing at a recessional position at the top;

2. A thick layer of clay with boulders about 2.0 meters thick;
3. A regular layer of little indurated heterogeneous mass of clastic gravels of pebbles, cobbles and boulders, lodged in a matrix of sandy silt, about 3.5 meters thick;
4. A layer of pebbly, silty clay, about 3.0 meters thick, and
5. An irregular layer or with pebbles, about 2.0 meters thick, located below the distinct bounding plane of pebbly, silty clay bed.

To understand the depositional processes, genesis and specific geomorphic history of the Ghaggar terraces, the boulders bed is most crucial. It comprises of mostly oblate, sub-angular and sub-rounded gravels (Figures 5, 7, 9, 11 and 13 See page No 9). It is clear from the matrix that the load carried was mostly traction load and some suspended load. From the thickness of the bed as also of the others, the preponderantly horizontal aspect of the gravels, cobbles, pebbles, boulders, appearance of stratification and heterogeneous mixture of particles, it can be inferred that:

1. There was sudden and manifold increase in discharge, competence, capacity and critical tractive force of the river.
2. Fluctuations in the flow were there as of today shooting, high summer monsoon discharge to low pre-and post–monsoonal discharge. It is also suggested that a major change in climate from a cold, dry climate with strong seasonal variations prevailing since 50 ka (fifty thousand years) to warm and humid climate at about 10 ka (ten thousand years) resulted in a change in depositional processes from sediment gravity-flows to braided streams (Singh et al., 2001).
3. Both laminar flow traction and turbulent motions were responsible for the transportation and dumping of the eroded material in the present matrix form.
4. The flow was outrageous and torrential.
5. Rate of erosion velocity was high.

The sub-angular, sub- rounded and little rounded clastic and sandstone gravels indicate their local Provenance and short distances they have travelled. Since they have been derived from boulder conglomerates which have a firm geological age of second Interglacial (Sahni and Khan, 1959 and Mohapatra, 1973), they were re-deposited in the stratigraphic layers of third terrace level during third Inter-glacial, when the flow of the river was violent and torrential. The thickness of T3 as compare to T2 and T4 is much shorter and less moist than Mindel Riss Inter-glacial but fairy long than post glacial time. Wurm glacial was much drier and shorter than Riss glacial and Riss Glacial drier than Mindel (Mukerji, 1975).

The beginning of Holocene period is suggested by the textural changes in lithology. The low frequency of gravel deposits in the Tatrot deposits, west of Ghaggar probably point towards deposition under low energy conditions in general (Gaur, 1987). While explaining the stratigraphy of middle level choe terrace (Mukerji, 1975) also emphesised that the fine texture indicates lower fluvial energy, gentler thalweg gradients, lower discharge, erosion and re-deposition of clay and silt beds of the underlying Upper Siwalik formation. The low energy conditions might have resulted either due to low water discharge or due to the low gradient of the river.

Fig.16: Lithological variations, elevation and age constraints of the Ghaggar River Terraces.

Identification	Maximum Elevation of the Terraces above river bed	Elevation (Above msl)	*Age	Constituents	Remarks
T_1	105 Metres	455 Metres	2nd Interglacial	**Composition:** Boulders, cobbles, pebbles and shale. **Shape:** Rounded to sub-rounded. **Possible Provenance:** Upper Siwaliks.	Not well developed, occur in small patches and occupy highest position from the river bed.
T_2	67 Metres	417 Metres	Riss	**Composition:** Shale, sandstone, quartzite, pebbles and cobbles. **Shape:** Sub-rounded to rounded. **Possible Provenance:** Upper Siwaliks.	Fairly well developed terrace but at some places found in patches.
T_3	37 Metres	387 Metres	3rd interglacial	**Composition:** Boulders, cobbles, pebbles and quartzite. **Shape:** Trapezoid. **Possible Provenance:** Upper Siwaliks.	Well developed almost all along the Ghaggar and occupy fairly large areal extent.
T_4	26 Metres	376 Metres	Wurm	**Composition:** Sandstone, quartzite, boulders and pebbles. **Shape:** Triangular. **Possible Provenance:** Upper Siwaliks.	Not well developed.
T_5	8 Metres	358 Metres	Holocene *(Sahni & Khan, 1959)	**Composition:** Sandstone, boulders, Cobbles and pebbles. **Shape:** Analogous to rectangle. **Possible Provenance:** Upper Siwaliks.	Youngest, well developed, closest to the river bed and occupy maximum areal extent as compare to other terrace levels.

Conclusion

The Ghaggar river has made five terrace levels on its western bank at water-gap locale. Except for the highest terrace level (T1) the others are depositional. During third interglacial period, when the flow of the river was violent and torrential it brought enormous amount of eroded material from the Siwaliks and deposited at the water-gap locale. Lithologically terrace material consists of thickly bedded massive conglomerates with boulders, cobbles, pebbles, sandstone and quartzite. All the major terrace levels are separated by steep scarps at places almost vertical, while at others steeply sloping in accordance to the upper Siwalik beds. Due to unilateral channel shift and down cutting, entrenchment and aggradation, five terrace levels were evolved. During the third interglacial period the rate of sedimentation was very high and then later on there was drop in the rate of sedimentation after the termination of the Pinjore formation. The low energy conditions might have resulted either due to low discharge of due to low gradient of the river. The Ghaggar section forms an ideal location for further interdisciplinary studies along the Plio-Pliestocene times.

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Fig.4: Slight undercutting at the base of the river bank and earlier entrenchment of the river reveals the stratigraphy of T_5. Notice the thick sandstone body in the middle. Terrace is deposited on the bed rocks of Upper Siwalik. Increase in the fineness of texture toward the upper, younger layers.

Fig.5: Surficial material on terrace level no. 5.

Fig.6: Fairly dissected scarp separating T_4 from T_5. Slumping and sliding produce ruggedness of slope.

Fig.7: Surficial material on terrace level no.4. Notice the size of large boulder of more than one metre in length and more than half metre in width.

Fig.8: Stratigraphy of terrace level No. 3

Fig.9: Surficial material on terrace level No.3. Thick boulder layer in the middle represents enormous discharge of Riss-Wurm interglacial.

(see page 5 for the text)

Fig.10: Scarp separating T_2 from T_3. Scrap is covered by thick vegetation.

Fig.11: Surficial material on terrace level no.2.

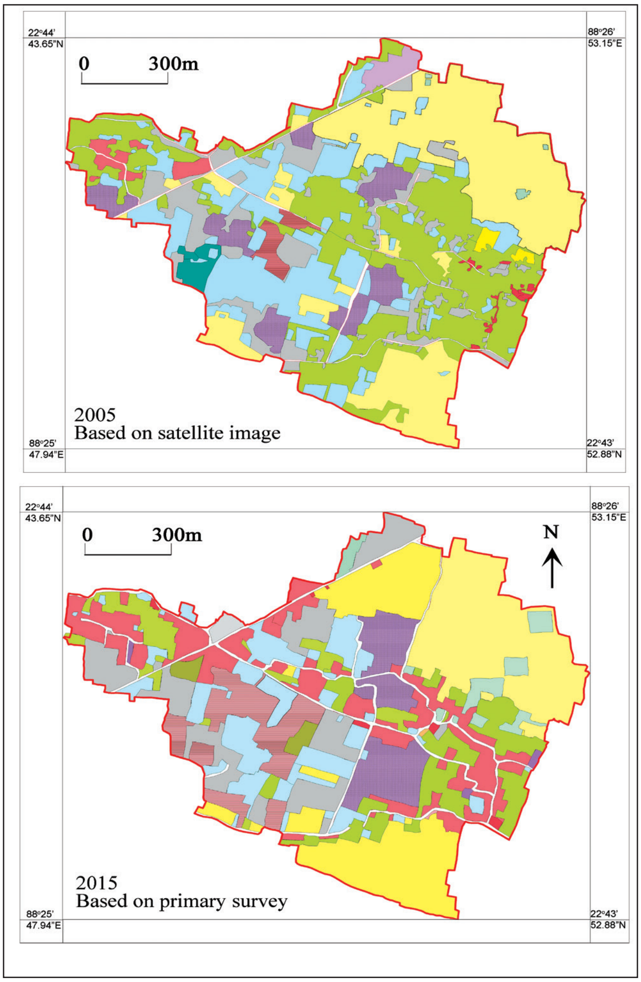
Fig.12: Dissected scarp separating highest terrace level T_1 and T_2. Slumping and sliding produce ruggedness of slope.

Fig.13: Surficial material on T_1.

Fig.14: T_1 found in patches.

Fig.15: T_2 found in patches.

(see page 5 for the text)



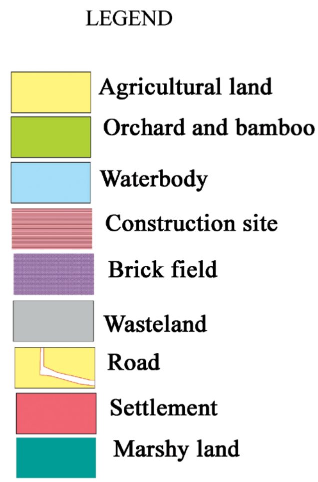


Figure 4: Landuse change in Berunanpukuria from 2005 to 2015 (see page 16 for the text)

Plate 1 : The MGNREGA Scheme for wetland excavation
(see page 16 for the text)

Plate 2 : Decrease in wetland area due to adjoining construction work
(see page 16 for the text)

Plate 3: Extraction of water from wetland

Plate 4: Pesticides being applied to surrounding agricultural fields

Plate 5: Wetlands surrounded by agricultural field

Plate 6: Wetland covered by water hyacinth

Plate 7a: Brick kiln adjoining wetland

Plate 7b: Fly ash disposal adjoining wetlands

(see page 17/22 for the text)