CHAPTER V

SUMMARY AND CONCLUSIONS

SUMMARY

The evolution of Beas Valley drainage is related with the tectonic history of Himalaya. The Great Himalaya were uplifted first and then the mountain building process progressed southward that formed Pir Panjal, Lesser Himalaya, and the Siwalik-Hills respectively. The headwaters of Parbati, Sainj, and Tirthan rivers came into being at the same time as the first island was uplifted in the Great Himalayan region. The length of these streamlets increased with the progressive uplift of Himalaya and the consequent shrinkage of Tethys Sea. The final disappearance of Tethys Sea towards c. 55-50 Ma led to the formation of modern Beas Valley drainage. However the continued deformation has brought many changes in the drainage system of that time. The Parbati River evolved from the crest of Higher Himalaya and is the longest and oldest stream in the valley. The headwaters of Beas River evolved later during the Pir Panjal orogeny. Beas River extended its course through a fault zone. The Beas River flows in north to south direction upto Larji and then meets the combined course of pre-existing Sainj and Tirthan rivers at right angle. Here onwards, it starts to flow towards west. This leads to form a rectangular bend along Beas River course at the confluence site. The commonly recognised rectangular bends in the Beas River course are formed due to faults, thrusts, and erosion resistant rocks and thus have structural control. On the basis of the flow direction the Beas Valley can be divided into two sections: (i) the upper section from its source to Larji that forms a valley transverse to the general trend of the Himalaya, and (ii) the lower section downstream of Larji upto Beas-Chakki confluence forms a valley parallel to the general trend of the Himalaya. The Beas Valley supports an elongated rectangular drainage pattern. The upper Beas Valley is a consequent valley and follows a fault zone. But the lower Beas Valley being mostly of antecedent nature cuts across the geological structures. The Beas River divides the drainage system of upper Beas Valley into two unequal parts. The left bank tributaries are longer than the right bank tributaries. The longer tributaries section (left bank) is developed on the older Great Himalayan terrain. The smaller tributaries section (right bank) evolved on younger Dhauladhar terrain. The older tributaries are longer as they got more time to grade their profiles. The lower Beas Valley section is also asymmetrical but the longer tributaries section here lies along the right bank. This is also associated with the earlier uplift of Dhauladhar on the right bank than the left bank counterparts in the Siwalik-Hills.

The Beas River cuts across the Dhauladhar at Larji and forms an antecedent gorge. The absence of multiple levels of river terraces and thick lake deposits upstream of Larji confirms the antecedent nature of the gorge, as the evidences of damming are absent. The downcutting of gorge took place in three phases. The first phase marks slow uplift rate of Dhauladhar prior to the downcutting of Larji gorge. Considering the equality between uplift rates and rates of erosion at 0.55mm/year, the downcutting of gorge started at about 1.35 Ma. The second phase of downcutting suggests predomination of vertical downcutting and a pause in vertical incision at the termination stage of this phase at c. 0.95 Ma that carved a flat valley floor. Third phase was marked by fast vertical incision along the left bank at c. 0.91 Ma and is continuous even today.

The incised meanders in the Beas Valley are observed as the river enters the Siwalik-Hills from Lesser Himalaya. The Lesser Himalaya were uplifted earlier than the Siwalik-Hills. These Meanders were formed prior to the uplift of Siwalik-Hills in plains similar to the Indo-Gangetic plains of today. During the uplift of Siwalik-Hills MT and JT induced uplift axes were developed downstream of the MBT. The Beas River kept cutting through the emerging landmass along these uplift axes. Meanders of the Beas Valley are antecedent to the Siwalik-Hills. Vertical incision predominated along the uplift axes. Due to continued vertical incision the meandering course of Beas River was incised by more than 500 meters and this resulted in incised meanders. Upstream of thrust induced uplift axis the flow of Beas River was slackened. The river water was spread wide in the decelerated flow zone. This resulted in the predomination of deposition and bank carving through lateral erosion. The deposition on valley floor resulted in braided channels along the decelerated flow zone. The predomination of aggradation led to the burial of the meandering channels upstream of uplift axes. The divided flow of braided channels was obstructed along the uplift axes. Here single narrow channel emerged. The decrease in channel width led to increase in stream power. The obstructions offered along the uplift axes were not strong enough to dam the single thread stream channel. This enabled the river to retain its original meandering course along the uplift axes. The stable channel banks along the rising orogen prohibited the formation of braided channel patterns. The Beas River has another single thread channel across the erosion resistant Pinjor conglomerate beds of Upper Siwalik near Beas-Dehar confluence. Upstream of these hard rocks are easily erodible alluvium and other recent deposits. The easily erodible banks along alluvium and other recent deposits paved the way for the formation of braided channels. The narrow single thread and meandering channels in the Beas Valley are located along hard rocks and thrust induced uplift axes. The braided channel segments lie upstream of hard rocks and thrust induced uplift axes. This suggests that the channel patterns in the Beas Valley are controlled by the ongoing Himalayan tectonics and lithological variations.

The gradient analysis along the longitudinal profile of Beas River using Hack's gradient indices reveals highly uneven riverbed surface. The comparison of individual reach's gradient indices *(SL)* with the gradient index for the whole river *(K)* highlights some reaches of high *SL/K* values. These are marked by knickpoints in the longitudinal profile of the river. The knickpoints are developed where the erosion resistant rocks of Tethys Himalaya and Higher Himalaya are exposed in riverbed. These are mostly as Klippen of hard rock in low-grade rock formations of Lesser Himalaya. The knickpoints are also developed along transverse faults, MBT, PT, and VT induced uplift axes in the valley. The lowest *SL/K* value lies along JT-induced uplift axis and upstream of uplift axis is high *SL/K* value. The single thread meandering course is formed along uplift axes and braided channel patterns are upstream of uplift axes. The single thread incised meandering course has more stream power than the divided channels along braided course segments. The vertical incision predominates along the uplift axes (meandering course) and the deposition occurs upstream of uplift axes (along braided channels). The vertical incision along single thread meandering channel segment led to the formation of gentler gradient reaches. The knickpoints developed due to thrust induced uplift axes migrated upstream via headward erosion. The upstream migration of knickpoints, little or no vertical erosion along braided channel segments, and predomination of aggradation upstream of uplift axes caused steeper gradient along braided channels and gentle slope along meandering channels.

The Himalaya are one of the most active mountains of the world. These were uplifted due to convergence of Indian plate with the Asian plate. Uplift of Himalaya had been episodic in nature. Quaternary climate of Himalaya had also been fluctuating between glacial and interglacial cycles. Quaternary climatic perturbations induced uplift of mountains through isostatic rebound to erosional unloading, hydro-isotasy, and glacio-isostasy. The climatic changes had the potential to alter the stream power via isostatic uplift. The stream power of Himalayan rivers changes mainly due to perturbations in climate, climate induced uplift's, and tectonic uplift's. The stream power is high during rapid uplift and high river discharges. It decreases during slow uplift and low discharges. High stream power leads to vertical incision. Low stream power and high riverbed resisting power favours aggradation. The phases of aggradation followed by degradation leads to the formation of paired river terraces.

Three levels of river terraces at Banol downstream of Pandoh suggest three phases of Beas Valley evolution during Quaternary period. Along the right bank 160 meters high Banol terrace suggests the river downcutting of the same amount. Considering the equality between uplift rates of about 0.55 mm/year and rates of erosion, this surface was abandoned at c. 0.29 Ma. On the left bank 30 meters high Dhoda terrace was abandoned at c. 54.5 Ka. Two kilometres downstream of Dhoda the elevation of this surface declines sharply from 30 to 25 meters. Such divergent nature of terraces is the evidence of accelerated and tilted uplift. The lowest right bank Balh terrace at about 8 meters elevation was abandoned at c. 14.5 Ka, again considering the parity between uplift rates (0.55 mm/year) and rates of erosion. This is the time when the LGM (15 Ka) in the Himalaya was terminated and an interglacial period was initiated during which strengthening of Asian monsoons occurred. This resulted in the increase of stream power and abandonment of the lowest terrace. The high degree of angularity of huge sized boulders found on the present riverbed level suggests recency of their deposition and minimal effect of the processes of weathering and erosion. These boulders were probably derived from nearby mountains as a result of mass wasting. Conversely the small and medium sized rounded to subrounded boulders travelled longer distances and experienced the action of weathering and erosional processes for longer time. These are derived from the interior parts of the valley.

The depositional terraces of Tira-Sujanpur are located upstream of JT uplift axis, where deposition occurred due to slackening of flow. The increase in stream power after valley filling led to incision through its own deposits and formation of paired depositional river terraces. The increase in stream power is associated with the decline in uplift rate along JT, increase in Himalayan uplift rates, and high river discharges probably during interglacial period. The huge sized boulders on this former riverbed have been transported as traction load during flash floods that occurred during the termination of deposition. The different sized depositional material layers suggest fluctuating nature of stream power during aggradation phase. The inclination of bedding in the upstream direction is due to a local uplift along JT in the downstream of Tira-Sujanpur. The T_2 and T_3 level of terraces at Nadaun are paired and this suggests two incision episodes. The occurrence of red clay beds on these terraces suggests humid and warm climatic conditions and old ages of the terrace surface.

Dehra Gopipur terraces lie along the local uplift axis developed under the influence of a transverse fault and BBT. The Beas River deposited its load along the uplifting valley floor during a phase of slow uplift or during a period of low discharges associated with glaciation in the interior parts of valley. More than 5 meters thick mud beds suggest a long spell of climatic and tectonic stability. These beds overlie the sandstone beds of Siwalik. Vertical incision phase that abandoned the lowest terrace is still continuing. Here the T_1 and T_2 terrace surfaces are inclined towards north and have no vertical scarp. This is due to high uplift rate in the south along HFT that forced the river to shift its course gradually towards north.

The elevation of T_3 surface upstream of Dehra Gopipur is 50 meters and about 10 kilometres upstream of this site the elevation decreases to 3 meters. A transverse fault and BBT-induced uplift have uplifted these former riverbeds to greater height. Local uplift induced vertical incision along the anticline caused higher elevation of the scarp. The low elevation surface is lying along a syncline. The predomination of deposition and little vertical erosion along syncline resulted in very low elevation of the scarp. Hence Himalayan tectonics is manifested in the very high elevation of T_3 Dehra Gopipur terrace than its upstream counterparts.

The Beas River cuts across MBT, MT, JT, BBT, and HFT in the Siwalik basin. Uplift along the thrust lines acted like check dams for the load of River. Beas River deposited its load upstream of uplift axis and entered the downstream depositional zone with reduced load. The tributaries joining in the downstream depositional zones have major contributions in the deposition. Paired depositional river terraces are formed along depositional zones. The amount and nature of terrace deposits are controlled by the downstream thrust induced uplift. The present interglacial high discharges are also causing deposition upstream of uplift axes and vertical erosion along uplift axes. Deposition is evidenced by braided channel patterns. Narrow single thread channels and vertical scarps are formed in response of vertical incision. As the bedrock geology, structure, tectonics, and river discharges have sharp spatial variations from one Himalayan valley to another and this controls the action of erosion or deposition. Under such sharp spatial contrasts the correlation of Beas Valley river terraces with other Himalayan valleys may lead to misinterpretations.

The tectonic uplift, climatic perturbations, and the downcutting history of Beas River controlled the stream power of Banganga River. The Beas River during the lateral planation phases stabilized the base level of Banganga River. The vertical incision phases lowered the base level. This sets Banganga River into rejuvenation. A thin depositional layer of T_3 terrace is an indication of erosional terrace. These terrace deposits overlie on highly tilted beds of Siwalik. The high degree of tilting suggests excessive folding of Siwalik strata.

CONCLUSIONS

The evolution of Himalayan drainage is associated with the phases of Himalayan orogeny. The Parbati being longest and oldest river is the master stream in the valley. The upper Beas Valley is a transverse valley and the lower Beas Valley is longitudinal. The drainage pattern of Beas Valley is elongated rectangular. The upper Beas Valley is a consequent valley and follows the structural lines. However the lower Beas Valley being antecedent cuts across the geological structure. The rectangular bends along the river course are formed along faults, thrusts, and erosion resistant rocks. The Beas River divides the upper Beas Valley into two unequal parts. The left bank comprised of longer tributaries evolved on older Great Himalayan terrene. The right bank of smaller tributaries is developed on younger Dhauladhar. The older tributaries are longer as they got more time to grade their profiles. The lower Beas Valley is also asymmetrical but longer tributaries section is along right bank. The right bank consists of older Dhauladhar. Smaller left bank tributaries are developed on younger Siwalik-Hills. The Beas River cuts across Dhauladhar at Larji and forms an antecedent gorge. The downcutting of gorge started at c. 1.35 Ma, a pause in gorge downcutting phase occurred at c. 0.95 Ma, and then very fast episode of vertical incision started at c. 0.91 Ma, which is still continuing. The channel patterns along the Beas River have tectonic and lithological control. Narrow single thread channels are formed along local thrust induced uplift axes and hard rocks. The incised meandering channel patterns are antecedent to uplift along JT and MT induced uplift axes. Braided channels are formed upstream of erosion resistant rocks along easily erodible banks, upstream of thrust induced uplift axes in a slackened flow zone, and along synclines. The knickpoints along the highly uneven longitudinal profile are associated with transverse faults, MBT, PT, VT induced uplift axes, and erosion resistant rocks of Higher and Tethys Himalaya that occur as Klippen in low-grade Lesser Himalayan rocks. The external stimulus to stream power of Himalayan Rivers is due to tectonic driven uplift, climatic induced uplift, and fluctuations in river discharges. The episodic stream power caused phases of aggradation followed by degradation and formed depositional river terraces. The T_3 surface of Dehra Gopipur terraces is uplifted to greater heights than its upstream counterparts due to a transverse fault and BBT induced uplift axis. The longitudinal profile of Beas River has been uplifted along HFT, BBT, JT, and MT in the Siwalik basin. Local uplift produced differences in terrace elevations, nature, and amount of terrace deposits. This prohibits the correlation of Beas Valley terraces with the other Himalayan river terraces. The present riverbed features, terrace deposits, nature of terraces, terrace levels, and terrace heights record the signatures of palaeoclimate, tectonics, and geomorphological processes. A preliminary survey of these has been done. The conclusions reveal that the geological and tectono-climatic conditions control the evolution of Himalayan drainage and the geomorphic features including the river terraces in Beas Valley. This vindicates the hypothesis that these factors control the fluvial history of the study area. Our findings also verify that the tectonic changes control the formation of gross geomorphic features viz. evolution of drainage, gorge-formation, channel patterns, knickpoints, and river terraces. The changes in climate and tectonics are manifested in river morphology. The aims and objectives of this study thus have been largely achieved. The only exception is the objective with regard to the study of the relationship between geomorphology of the Beas Valley and that of the whole Himalaya. This could not be done because of the paucity of comparable studies in other parts of the Himalaya. This, however, can be taken up in future research.

SUGGESTIONS FOR FUTURE RESEARCH

The explorations in following fields of studies will enrich our knowledge about the geomorphology of the Beas Valley and accordingly it is suggested that research on these lines be done in future: -

1. The dating of Dehra-Gopipur, Dhaliara, and Haripur-Guler terraces will enable us to know the timing of artefacts found on these surfaces when these were buried. This will help to understand the Himalayan palaeocultures and geomorphological processes.
2. The dating of river terraces and their correlation with the last interglacial period will help to ascertain the external influence that abandoned terraces.
3. The hydrological measurements in valley have tremendous prospective. Work in this field will help in development, utilisation, management, and further research especially in geomorphology.

4. A detailed survey of the valley is needed to establish the extant and timing of Quaternary glaciation. This will help to resolve controversies regarding low elevation glaciation and transportation mode of huge sized boulders.
5. The study of Quaternary climate of Himalaya in general and that of Beas Valley in particular is necessary to ascertain the climate-landscape relationship.
6. A field-based study of braided channel patterns of Himalayan river valleys including the Beas Valley will highlight the mechanism of geomorphological processes acting under active tectonic and climatic conditions.
7. A detailed survey and the study of the genesis of landform features in other Himalayan river valleys will help to correlate these landforms with the features of Beas valley. This will help to generalise the action of geomorphological processes in highly active mountains likė Himalaya.