CHAPTER - VI

6.1 CONCLUSIONS

Active tectonics is considered as those tectonic processes that produce deformation of earth’s crust in modern time. The Northeast India is a tectonically active and complex region. Analysis of drainage pattern in this region gives us an idea of the surface and the subsurface structures and their activities. So, the trends of the rivers, the drainage patterns and recent changes in the characteristics of these drainages are studied very minutely to know about any changes or deformation in some parts of the Assam-Arakan Basin. Some of the important structures like Rudrasagar High, Nazira Low, Jorhat Fault, Belt of Schuppen, Dauki Fault, Kopili Fault/Lineament and Dhansiri-Bomdila Fault/Lineament, along with major rivers like the Dikhu, Jhanzi, Dhansiri (North), Dhansiri (South), Kopili, Bargang and parts of the Brahmaputra as well as some smaller rivers within the Belt of Schuppen and the Dauki Fault showing characteristic drainage patterns and drainage anomalies have been studied here.

The Northeast region can be geologically and tectonically divided into four major zones, viz. the Himalayan folded belt and Tertiary hills and mountains, the Naga-Patkai Ranges, the Shillong Plateau including Mikir Hills and the Brahmaputra Valley in Assam. The study area comprises mostly Tertiary sediments situated in the Assam-Arakan Geological province, which covers two geological provinces, viz. the Upper Assam - Naga Hills and the Surma Valley- South Shillong Plateau. These four
geotectonic provinces are characterised by several tectonic lineaments and faults.

The study is undertaken on the following aspects:

1. Influence of the subsurface structures on drainage over thick alluvium covered area;
2. Influence of exposed structures on drainage pattern along the Belt of Schuppen and the Dauki Fault;
3. Influence of major lineaments or inferred faults, viz. Kopili and Bomdila Faults on the courses of some major river systems.

The drainage networks of the Dikhu and Jhanzi Rivers in Sivasagar district, Assam, have been considered in order to investigate the role of neotectonics and to examine the role of subsurface structures on the development of surface drainage network and drainage anomalies/geomorphic features in the alluvium covered Brahmaputra Valley. Interpretation of drainage patterns and drainage anomalies of the area and its surroundings reveals a large and prominent annular pattern formed by the Dikhu and Jhanzi and some other smaller rivers. The evidences of neotectonism are presence of large and small annular patterns, paleochannels and abandoned channels, fine reticulate drainage pattern, change in regional slope of the area from earlier westerly to present northerly direction, compressed meanders, low-lying swampy areas, right angle bends and parallel stream alignments. The influence of active subsurface structures on development of drainage anomalies are substantiated by comparing these drainage anomalies with prominent established subsurface structures described as follows:
1. The most prominent drainage anomaly shown by a large annular pattern of the Dikhu-Jhanzi infers presence of a subsurface high at the central part near Changmaigaon, which can be correlated to the Rudrasagar High as confirmed by seismic section. Development of compressed meanders in the upstream segments of the Dikhu, Namdang and Jhanzi indicates the presence of the upwarp on their downstream part. The paleochannels at Changmaigaon and Bihubar further confirm the presence of this upwarping. The topographic profile across this annular drainage pattern shows a high of about +6 m in between the rivers Namti and Namdang, which confirms the reason of abandonment of the Mori Namdang channel which was once flowing through the centre of this upwarp.

2. The fine textured reticulate drainage with higher drainage density observed around Mezenga can be correlated to the Mezenga/Nazira Low. The topographic profile across this low confirms a depression of about -5.0 m at the centre than the surroundings. The low resulted in the deposition of fine silts thereby giving rise to the development of the fine textured reticulate drainage.

3. The semi-circular Mori Dikhu paleochannel and the circular drainage anomaly are due to influence of the Bihubar/Naginimara/Geleki High which caused the diversion of the course of the river Dikhu from the Mori Dikhu paleochannel towards its present course. The topographic profile drawn across the centre of the anomaly confirms a high of about +5.0 m.

4. The knicks of the rivers Jagduar, Jhanji, Digali, Namdang, Dikhu, Dorika
and Disang are aligned in ENE-WSW direction, which shows significant parallelism to the nearly E-W trending Jorhat Fault. Sagging of the ground and thereby development of large belt of swampy area just north of the above parallel lineament is another evidence of the recent activities of this fault.

These drainage anomalies are substantiated with two way time (TWT) structure map and seismic sections which support the active nature of these structures up to the basement. Thus, it is seen that active subsurface structures have direct influence on development and modification on the courses and network of the Dikhu and the Jhanzi River systems and subsequently resulted in the development of drainage anomalies and lineaments over thick alluvium.

Among the large number of complex regional geological structures in Northeast India, the two large regional structures, viz. the Belt of Schuppen and the Dauki Fault have played major roles in deformation of the region and in influencing several streams flowing over them. The influence of active tectonics of these structures on the courses of the rivers has been investigated using morphometric and morphotectonic parameters.

The study of eight streams flowing within the Belt of Schuppen area, having drainage basins of 4th to 6th order, reveals that the drainage patterns are dendritic, parallel to subparallel and trellis. Trends of most of the streams show a strong influence of structures in their main courses along with right angled bends. All the streams conform to the different laws of drainage composition. The influence of
geologic structures on the streams can be confirmed by the fact that the values of the mean bifurcation ratios are more than 3.0. The mean lengths of different orders of some of the streams do not maintain a uniform value inferring that the development of stream is not uniform.

The higher drainage density (3.20 - 4.38 km\(^{-1}\)) indicates weakly impermeable rocks, active incision, larger surface run-off and steeper ground surfaces which also favour high stream frequency of the basins (3.20 to 6.35 km\(^2\)). The constant of channel maintenance (3.3 and 4.4 km\(^2\)/ km), indicate that 3-4.5 km\(^2\) area is required to maintain 1 km of these stream channels which indicate low magnitude of surface erodibility. The lengths of the overland flow for the drainage basins are low (0.11 - 0.15 km) which indicates short flow paths with steeper ground slopes with more run off, less infiltration and early stage of basin development.

The drainage basin asymmetry factor indicates tilting and asymmetrical nature of the basins influenced by neotectonism. The shape parameters show that six basins are highly elongated while two are semi-circular. The basin elongation ratio indicates that the area has high to moderate relief and the drainage system is structurally controlled with active to slightly active tectonic activity.

The maximum basin relief, relief ratio, relative relief and the ruggedness number show that two of the streams (Junka and Tiru/ Shihu) are relatively less rugged streams with gradual slope while all the other river basins are highly rugged in nature. Strong relief and steep slope are indicative of the basin lying in the mountainous
region. The stream channel slope indicates that most of the streams maintain steep slopes except for the Junka and the Tchungnala. The HI values (0.23 – 0.47) show that the river Junka, Tsusangyung and Zameha lie in young topographic terrain indicating high topography where the river basins lie in consolidated rocks which can resist erosion while the other five rivers have low HI values which indicate stable landform with evenly dissected basins. The steepness index indicate that five (Tiru/Shisu, Tsuetnala, Tchungnala, Tsurang and Tsusangyung) drainage basins have high rate of uplift, high incision rate and is in unstable condition while three (Junka, Zameha and Kukhipani) indicate low upliftment, low incision and is under more stable condition. Low concavity index of the basins Tiru/Shihu, Tsusangyung and Tsuetnala suggest steep drainage with increase in incision rate or rock strength, commonly associated with knick points in the river profiles. The concavity index of the Junka, Zameha, Kukhipani, Tchungnala and Tsurang suggest actively uplifting channels in homogeneous substrates experiencing close to uniform tectonic uplift rates. The average valley floor to valley width ratio indicates low uplift rates and suggests a broader valley for the Junka and the Tchungnala (1.95 and 0.97 respectively) whereas rest of the basins represent high uplift rates, deep valleys, active incision and narrow valley. This also suggests gradual upwarping of the region.

Relation between the stream profile and SL index shows that the knick points have distinct anomalous SL values which also give us an idea about the graded nature of the stream. Except for the Zameha the other streams show considerable amount of incision and deposition in their entire river lengths inferring that they are tectonically
instable. No significant influence of lithology in the distribution pattern of the anomalous points is seen along all the stream profiles. It is noteworthy that the anomalous points of SLGI along the rivers show that most of these points lie where the thrusts pass through the basin inferring influence of active tectonics in the study region. The mountain front sinuosity index shows that the Belt of Schuppen area is presently slightly active.

The five drainage basins selected from the Dauki Fault area belong to 4th – 7th order streams showing anomalous right angled bends in their linear courses. The drainage patterns of the area are mostly dendritic, parallel and trellis. Some parts of the drainage basin also show annular or radial type drainage pattern. The bifurcation ratio values indicate that the development of the stream segments are uniform characterising a natural stream system. The length ratio of the stream orders indicates that none of the streams flowed independently for much longer distances. Most of the mean stream lengths maintain more or less uniform value inferring that the development of streams of lower order is over uniform soil having uniform gradient.

The Dolong and Diyung are both high altitude rivers, having high drainage density of about 3.8-4.0 km\(^{-1}\) indicating that the region has non-resistant or highly impermeable subsoil and is under thick forest cover, which also favour high stream frequency (5.2-5.6 km\(^{2}\)). On the other hand, the rivers Jatinga, Larang and Gumra have comparatively less drainage density of about 2.3-2.8 km\(^{-1}\) with a low stream frequency of 2.4-3.1 km\(^{2}\), which infers that these streams flow over areas having more percolation than run-off. High drainage density may also be due to active incision of
the valleys which indicate larger surface run-off and steeper ground surfaces. The lengths of the overland flow for the basins are low (0.12-0.19 km) indicating short flow paths, steep ground slopes, more run-off and less infiltration. It also indicates early stage of basin development. Comparatively high values of length of overland flow (0.22 km) of Larang indicate less run-off and more infiltration. The constant of channel maintenance of these drainage basins vary within 2.3 and 4.0 km$^2$/ km, which indicate that the area is underlain by hard resistant rocks with thick forest cover. All the streams conform to the different laws of stream composition. The drainage basin asymmetry factor indicates tilting and asymmetrical nature of the basins influenced by neotectonism. The shape parameters of the basins indicate that all the basins are elliptical/ oval to near circular in shape. The basin elongation ratio shows that most of these basins are structurally controlled.

The maximum basin relief, relief ratio, relative relief and the ruggedness number of all the rivers show that they are situated in high elevation and highly rugged area with steep to gradual slope and strong relief. Hypsometric integral values indicate that the rivers Dolong and Diyung are situated in high topography representing a youthful and mature stage while rest three have relatively low topography indicating stable landform with evenly dissected basins. All the basins have high steepness index (0.27-0.53) suggesting high rate of uplift as well as incision and is in unstable condition. The low concavity index (0.12 – 0.29) of the basins Diyung, Dolong and Larang suggests steep drainage with increase in incision rate or rock strength, commonly associated with knick points in the river profiles while the high concavity
index of the Jatinga (0.42) and Gumra (0.41) suggest actively uplifting channels in homogeneous substrates experiencing close to uniform tectonic uplift rates. Low values of average valley floor to valley width ratio indicate that the all the river basins lie in an active mountain front, deep valleys, active incision that represent high uplift rates and suggest a narrow valley but in some parts of the Diyung, Dolong, Jatinga and Larang basins a comparative higher value (0.59-0.80) is observed indicating a broader “U” shaped valleys. The longitudinal profiles of nearly all the streams show a number of gradual and abrupt changes in slopes with distinct knick points. All the basins except Diyung and Dolong show alternating nature of deposition and incision at the lower reaches of the rivers which indicate their tectonically instable nature. Most of the SL gradient index anomalous points are distributed where there is change in slope/gradient in the river or where the river takes a gradual right angled turn. These points are located there where the Dauki Fault passes through the basin.

From the study of the morphometric and morphotectonic parameters of these river basins lying within both the Belt of Schuppen and the Dauki Fault areas, it can be inferred that all the rivers show strong influence of the regional tectonic features. The rivers follow the structural trends of these geological structures. Inferences drawn from the study of different morphotectonic parameters for both Belt of Schuppen and Dauki Fault areas indicate that the overall status of tectonic activity of Belt of Schuppen area is 67.25% active and 32.75% slightly active while the tectonic activity of the Dauki Fault area is 20% active and 80% slightly active. Thus, the tectonic activity of the Belt of Schuppen area is relatively higher than in the Dauki Fault area.
The strain map of these areas also indicate that Belt of Schuppen area has higher strain rate ($256 - 500 \times 10^{-9}$ nanostrain/yr) in six basins as compared to the Dauki Fault area ($16-32 \times 10^{-9}$ nanostrain/yr). The strain value decreases from the Belt of Schuppen area towards the Dauki Fault area inferring that the degree of tectonic activity is not uniform in these regional structures. Hence it can be concluded that the status of the present tectonic activity is more in Belt of Schuppen as compared to the Dauki Fault area. This study gives us an idea of the nature of tectonic activities and provides a future scope to a more detail study of the influence of neotectonics in these regions.

Northeast region of India being a highly seismically active region lies in the highest (zone V) seismic hazard zonation map of India. The Kopili and Bomdila Faults/Lineaments are two major structural-cum-geomorphic features of Northeast India influencing the neotectonic activities of the region. Interrelationship between these faults/lineaments with existing geomorphic features as evident from study of channel patterns of the Kopili-Dhansiri (N) as well as Dhansiri (S)-Bargang Rivers supplemented by seismotectonics, gravity and topographic profiles is well observed in this region. It is observed that seismic activities are fairly intense in both the Kopili-Dhansiri (N) and Dhansiri (S)-Bargang Valleys.

The Kopili Fault/Lineaments has influenced the drainage pattern in Kopili-Dhansiri (N) Valley. The study for the same on the three blocks, i.e. Kopili, Sonai and the Dhansiri (N) River reveals the neotectonic activities which are characterized by:

i) Straight NW-SE courses of the Kopili and Dhansiri (N) Rivers lie along the
trend of the Kopili Fault/Lineament.

ii) Subsequent change of the straight course of the Dhansiri (N) River infers change in the nature of activity of the Kopili Fault/Lineament.

iii) Different trend of regional drainage in the Sonai Block as compared to the Kopili and Dhansiri (N) Blocks infers that these drainages are not influenced by the Kopili Fault/Lineament.

iv) Presence of large number of abandoned channels and bils/swampy lands in the Kopili Valley.

v) Presence of tilting and disturbed sediment strata exposed in the scarps of the Kopili River.

vi) Development of knicks on the major structures like MCT and Belt of Schuppen at both ends of the Kopili Fault/Lineament.

vii) Highly seismic activity along the northern and the eastern part of the Kopili Fault.

So far seismotectonics is concerned, the focal mechanism solutions of the region show that the Kopili Fault is characterized by strike-slip fault which dips towards NE direction with an average dip angle of about 75°. But further north, transgressing MCT, the region is characterized by thrust mechanisms. The depth section plot indicates that the bottom of the seismogenic zone to be 45±2 km up to which large concentrations of earthquakes is observed. The projected depth view of the focal mechanism solutions and primary fault planes show NNE trending P-axes while the T-axes are mostly oriented along NW-SE direction confirming the extension
of the fault transversely below the Himalayas. The curvatures and closures of the gravity contours along the fault line indicate influence of the Kopili Fault/Lineament up to the basement. The sparse distribution of the contours in the central part of the Kopili Fault/Lineament may be due to the thick deposit of the alluvium and deeper basement. The gravity value increases as we move from the north to the south of the fault/lineament indicating thicker basement as we approach the Belt of Schuppen area. The Kopili Fault/Lineament occupies the place in the topographical profiles where there are breaks in slope. Presently the paleochannels occupy the topographic highs which in turn forced the earlier river channels to move away from the highs. The drainage pattern study and the profiles represent that the Kopili Fault/Lineament can be traced from Diyungmukh along the Kopili River through Jamunamukh, the Kalang River, and the Lali Jan through the Dhansiri (N) River up to MCT in the Bhutan Himalayas. All these evidences show that the Kopili-Dhansiri (N) Fault/Lineament is neotectonically active and this neotectonic activity is responsible for the existing regional landform and drainage trends in this area.

The indicator of ongoing neotectonic activities in the Dhansiri (S)-Bargang region along the Bomdila Fault/Lineament are as follows –

a) A prominent NW-SE linear course of the lower part of the Dhansiri (S) River from Golaghat up to Dhansirimukh. Moreover, the Brahmaputra from Dhansirimukh along the direction of the river Dhansiri (S) and the river Bargang from Tengabari upstream are aligned along the same trend.
b) Occurrence of a large number of abandoned channels during 1971-1975 as compared to 1955 indicates change in regional slope of the area.

c) Presence of a linear 18 m high topographic scarp on the left bank of the Dhansiri (S) near Numaligarh tea estate.

d) Abandonment of the westerly course of the earlier Dhansiri (S) River (flowing through Kaziranga presently known as the Mora Dhansiri River) towards the present WNW direction by avulsion.

e) Development of prominent knicks on existing regional structures like MCT and Belt of Schuppen along the Bomdila Fault.

f) Intense seismic activity along the northern and the western part of the Bomdila Fault.

The fault plane solutions show that the Bomdila Fault/Lineament is characterized by strike-slip fault, dipping towards NNE direction with an average dip angle of about 50-55°. It is believed that the fault transgresses below the Himalaya in the north and Belt of Schuppen in the south. The bottom of the seismogenic zone is within 50±2 km in the Dhansiri (S) Valley where large concentration of earthquakes is observed up to the north. The projected depth view of the focal mechanisms and primary fault plane solutions show dominant NW-SE trending P-axes while the T-axes are mostly oriented along NNW direction which confirms the transverse tectonics. The gravity contours indicate influence of the Bomdila Fault/Lineament up to the basement. Towards the northern and the southern end of the fault the gravity contours are closely spaced contours with U–shaped pattern indicating the association of the
fault with the trend of the gravity contours. Low gravity value over this area is due to the presence of thick alluvial deposits, which progressively become thinner towards NW and SE of the Bomdila Fault/Lineament. In the Brahmaputra Valley, it is seen that the sediment thickness increases towards Bomdila Fault/Lineament than in Kopili Fault/Lineament. The topographic profiles across this Fault/Lineament show abrupt relief differences. The location of the fault may be traced along these points along the Dhansiri (S) River, the Brahmaputra River and the Bargang River.

Thus the study proves that both the Kopili and the Bomdila Fault/Lineaments have major influence in modifying the courses of the rivers mentioned earlier. Moreover, these two Faults/Lineaments can be traced from the Belt of Schuppen across the Brahmaputra up to the MCT along these two major river groups. Hence, both Kopili and Bomdila Faults may be renamed as the Kopili - Dhansiri (N) Fault and the South Dhansiri (S) - Bargang/ Bomdila Fault, respectively.

The most important aspects revealed in the study are-

1. The courses of the hilly streams/rivers have been controlled by the major structures over which they are flowing.
2. Active subsurface structures have direct influence on the development and modification on the courses of some major rivers in the Brahmaputra Valley.
3. Evidences of neotectonics can be seen in many rivers of Northeast India.
4. The Belt of Schuppen is tectonically more active than the Dauki Fault area.
5. The Kopili Fault and the Bomdila Fault are both active in recent time.
The indepth study of these faults/lineaments through multidisciplinary approach helps us in understanding the tectonic behaviour of these structures. These studies might lead to an understanding of the probable occurrence of any seismic event in the vicinity of these structures in near future. A further study on this matter, therefore, will help to prevent loss of life and property by adopting adequate methods of earthquake preparedness and mitigation. In future, if these structures result in a sudden and significant change in the topography, there will be a drastic change in the courses of the rivers which might lead to a disaster in this riverine region.