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# Variability of orographic architecture of Indo-Burmese Ranges (NE India): constraints from morphotectonic and lineament analysis

Raghupratim RAKSHIT[1,] *, Devojit BEZBARUAH[1], Farha ZAMAN[1] and Bubul BHARALI[2]

[1] Dibrugarh University, Department of Applied Geology, Dibrugarh – 786004, Assam, India

[2] Pachhunga University College, Department of Geology, Aizawl – 796007, Mizoram, India

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Activeness of the tectonic and related sub-surface processes control the surface features that lead to variations in topography and lithostratigraphy. To understand the role of active tectonics in shaping the topography, morphotectonic and lineament studies are important. In this study, geological categorization has helped understand the orogenic evolution of the Indo-Burmese Range (IBR), NE India. This is an arcuate hill range that shows many unique topographic characteristics that incited to categorise the entire IBR into different tectonically active domains: Northern (Changlang district of Arunachal Pradesh); Naga Hills; Cachar and Manipur; and Southern (Mizoram). The Northern and Southern domains are more active than the others. Lineament analysis also indicates the presence of active features in the region with NW–SE, NE–SW, ESE–WNW trends are being common. The Northern and Naga Hills domains have mostly E–W younger lineaments whereas the Cachar and Manipur domains rather show N–S younger trends. The Southern Mizoram domain shows a dominance of older N–S lineaments with younger NW–SE lineaments. These variations result from differential stress conditions, i.e. Indian Plate movement and westward stress from the Burma Plate. This study shows how overall variations in tectonic settings can be related to the orogenic evolution.

Key words: active tectonics, lineaments, Indo-Burmese Ranges, Naga Hills.

## INTRODUCTION

Topography is not only a representation of surface variations; it is also the outcome of subsurface processes. In mountain or hill ranges, topographic variations indicate past and present deformational activity that can provide glimpse into the future. In this study, an attempt is made to establish a relationship between topographic variations and the role of active tectonics in the Indo-Burmese Ranges (IBR), in NE India (Fig. 1). Oblique subduction of Indian Plate beneath Burma Plate in northeastern part of India has resulted in the IBR (Wang et al., 2014). This obliquity in compressional tectonic stress has led to the formation of an arcuate thrust-folded belt of hill ranges that has undergone diverse tectonic deformational events including strike-slip movements (cf. Krzywiec et al., 2009; Rakshit et al., 2018; Zaman et al., 2019). IBR evolves from a wide and higher hill range near 24°N to close, tight, and less elevated hills at ~16°N; above which the range swirls towards the east where it became very close and narrowed down considerably (Wang et al., 2014).

Identification and analysis of the tectonic control on the surface features necessitates morphotectonic and lineament mapping and observations (Šliaupa et al., 2017; Kowalski, 2017, Urbano et al., 2017). O'Leary et al. (1976) defined a lineament as "...a mappable, simple or composite linear feature of a surface, whose parts are aligned in a rectilinear or slightly curvilinear relationship and which differs distinctly from the patterns of adjacent features and presumably reflects a subsurface phenomenon...". Surface features are expressions of sub-surface activities and among the important surface structures are linear features (Yajuan et al., 2008; Pirasteh et al., 2013). These features may be associated with deformation of the rocks, including structures like folds and faults due to variations in the strain distribution; this could indicate changes in the palaeostress conditions around the region (Kania, 2015; Šimonová and Plašienka, 2017). Changes in the lineament trend with respect to the different tectonic domains motivate investigation of this research problem, and may be associated with differences in subduction process and related tectonic features in the region. Identification of these active features would also helpful to study ancient landslides in relation to their active neighbouring slide zones (e.g., Urbano et al., 2017; Rakshit et al., 2017; Zaman and Bezbaruah, 2019). Apart from morpho-

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* Corresponding author, e-mail: raghupratim@gmail.com

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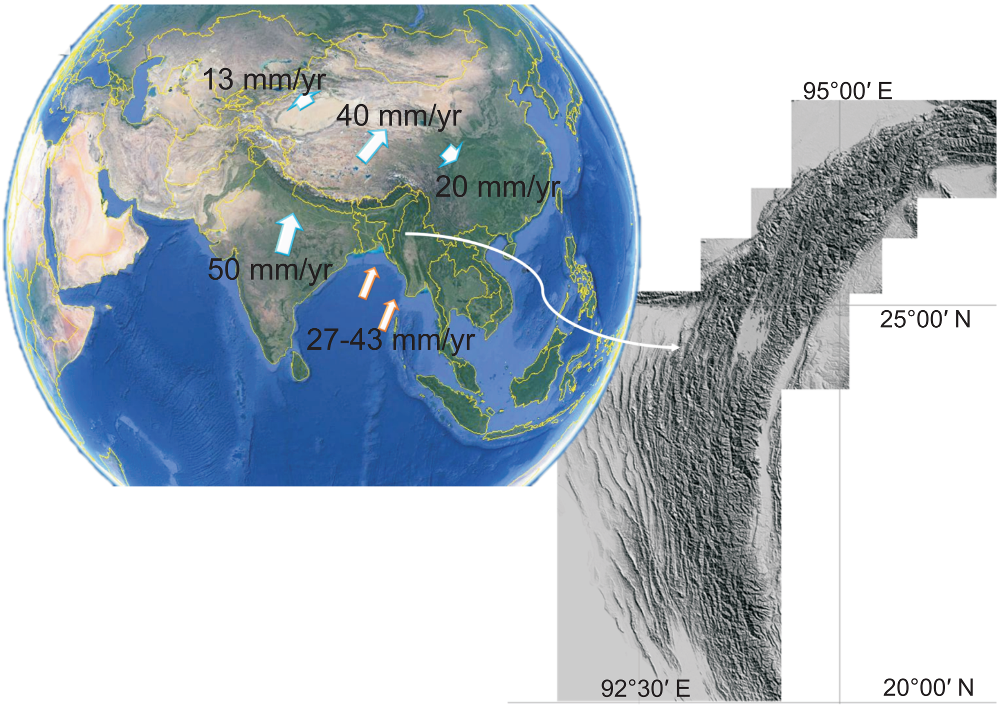


**Fig. 1. Location map of the Indo-Burmese Ranges in south-east Asia**

The black line on the Indian map is the India-Eurasian arc system (modified after Avouac and Tapponnier, 1993); blue-lined arrows show the movement of India and Tibet relative to Siberia (Avouac and Tapponnier, 1993) and orange-lined arrows show the direction of Indian Plate motion relative to the Sunda Plate (Wang et al., 2014)

tectonic analysis, understanding the influence of tectonics on base level changes as well as on climatic and other local factors that control and, bring change to, the fluviatile system, is important to assessing landscape dynamics (Schumm, 1977; Bull, 2007). Morphotectonic parameters were calculated from the drainage basins demarcated using Survey of India toposheets (1:50,000) and a digital elevation model (DEM 3 arc resolution, SRTM). The DEM has many advantages over conventional toposheets, providing a profile for any transect including river long profiles (Howard, 1967; Hack, 1973; Twidale, 2004). Moreover, a customised shaded image has been used from mosaic images of SRTM-DEM, that enhances regional structural and lineament studies (Masoud and Koike, 2006, 2011; Solomon and Ghebreab, 2006). The images used in this study for identification of tectonic features and structural lineaments were investigated and mapped by using a semi-automated technique of lineament extraction in a supervised computing environment. In this technique the lineaments extracted from DEM were supervised under human control to minimize the error. Moreover, these lineaments were rectified by using toposheet-drawn lineaments for better understanding.

In this study, topographic characteristics along the IBR have been studied that enable division of the entire range into four geotectonic domains (Fig 2: i-iv). These divisions are the basis for other morphotectonic and lineament studies. Four geomorphologically important areas and related river basins have been selected for active tectonic studies, one from each domain (Fig. 2: red box areas). These river basins are: Noa-Dihing (Northern domain); Dikhow (Naga Hills domain); Chiri-Jatinga-Ghagra (Cachar and Manipur domain); and Tut-Dhaleshwari-Tuirial (Southern domain). In this study an attempt has been made to establish the relationship between active tectonics in the orogenic evolution of the IBR through morphotectonic and lineament analysis. This study may also help in understanding some complexities like natural hazards, river migration and even in hydrocarbon prospecting.

## MATERIAL AND METHODS

### DESCRIPTION OF THE STUDY AREA

The Indo-Burmese ranges represent an accretionary wedge system that has been uplifted and deformed since Cretaceous time (Wang et al., 2014). Most of the central-southern part of the IBR is going through Early Pleistocene deformational events, and deformation continues at present (Rakshit et al., 2018). There are number of active faults (Fig. 2), such as: the Dauki Fault (DF) near the Shillong plateau; Chittagong coastal Fault (CCF); Gaumti Fault (GF) in the western part of the Bangladesh plains; Kabaw (KBF) and Sagaing (SGF) faults in the east around Myanmar; Himalayan Frontal Thrust (HFT); Main central thrust (MCT) and other parallel faults along the northern edge of the Himalayan Belt (Steckler et al., 2016). Disang Thrust (DT), Naga Thrust (NT), Churachandpur-Mao Fault (CMF), Halflong Fault, Kaladan Fault (KF), Mat Fault and Tyao faults are other important faults in the IBR (Rakshit et al., 2018). The Inner Belt of the IBR comprises Cretaceous-Eocene sedimentary to meta-sedimentary rocks (Fig. 2) and ophiolite belts whereas the outer parts include Miocene to Plio-Pleistocene sedimentary units (Singh et al., 2017).

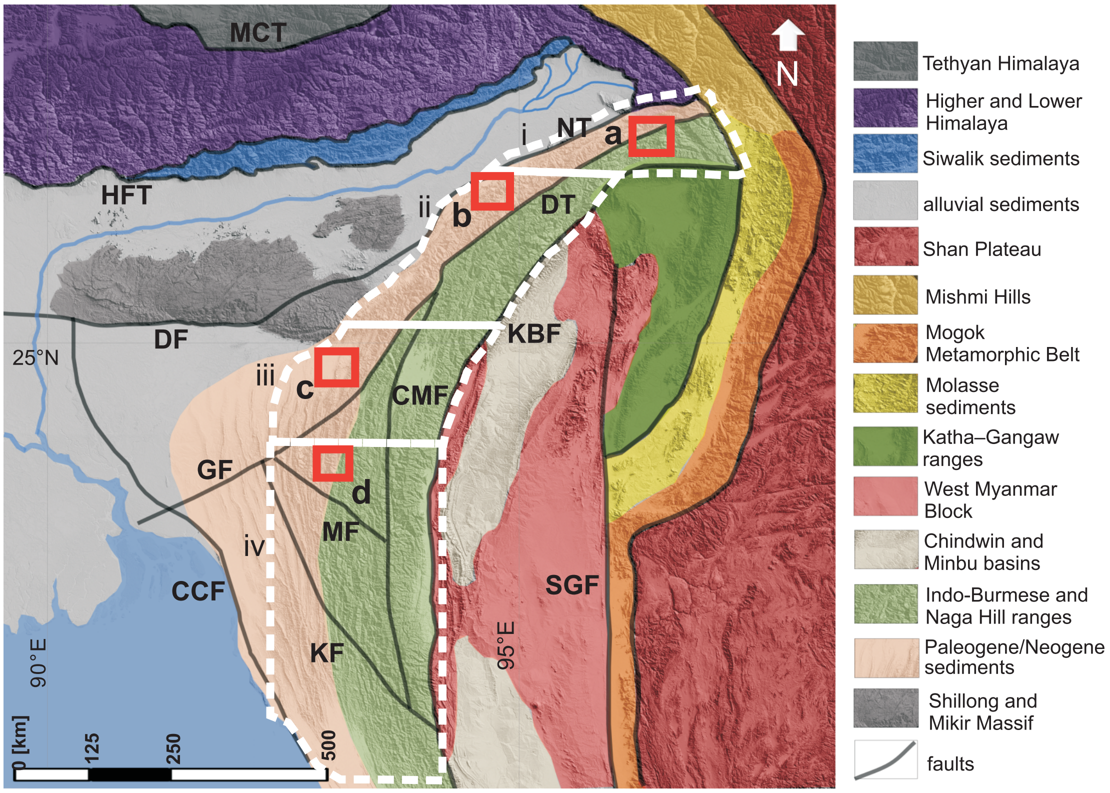


**Fig. 2. Regional geological map modified after Singh et al. (2017) and Rakshit et al. (2018)**

White dotted lines indicate the border of all the domains i – northern or Changlang, ii – Naga Hills, iii – Cachar and Manipur, iv – southern or Mizoram; red boxes are the morphotectonic and local lineament study areas that include: a – Noa-Dihing River Basin, b – Dikhow River Basin, c – Chiri-Jatinga-Ghagra basins, d – Tut-Dhaleshwari-Tuirial basinal regions from different tectonic domains; CCF – Chittagong coastal Fault, CMF – Churachandpur-Mao Fault, DF – Dauki Fault, DT – Disang Thrust, GF – Gaumti Fault, HFT – Himalayan Frontal Thrust, KBF – Kabaw Fault, KF – Kaladan Fault, MCT – Main Central Thrust, MF – Mat Fault, NT – Naga Thrust, SGF – Sagaing Fault are also marked; see text for details

### DATA SOURCES

Survey of India toposheets (1:50,000) were used in this study as base maps for active tectonics and lineament studies. Toposheet numbers are 92 A/1, A/2, A/6, A/7, A/10, A/11, A/14, A/15, 83 M/13, M/14 for the Noa-Dihing River, Changlang area; 83 I/12, I/16; 83 J/5, J/6, J/7, J/8, J/9, J/10, J/11, J/12 for the Dikhow River, Naga Hills; 83 C/10, C/11, C/12, C/14, C/15, C/16; 83 G/1, G/2, G/3, G/4 for the Cachar region and 83A/9, A/10, A/13 and A/14 for Aizawl, Mizoram region. Moreover, a *SRTM-DEM* at 3-arc resolution was also used to evaluate lineament and morphotectonic parameters.

### METHODOLOGY

*Global Mapper v.15* software was used to georeference the toposheets and DEM, and for the construction of topographic profiles and basin analysis. Basins and drainage networks were demarcated using toposheets and then satellite images were used for calculation of the morphotectonic parameters. Measurement procedures and formulae for calculation of the parameters are shown in Figure 3. Semi-automated extraction and a supervised computing environment were utilised for lineament mapping (Seleem, 2013). Two lineament analytical methods were used: lineament distribution, and the intersection and generation (I&G) of lineaments. *Rozeta* software was used to work out the distribution pattern of the lineaments as rose diagrams. The I&G method is an experimental technique that has been utilized for the first time to analyse intersections based on the relative stage of the lineaments. This helps show, at a particular intersection point, which lineament is older and which is younger, by virtue of which changes in the stress conditions can be inferred. Lineaments of younger generations “transfected” some or most of the genetic characterization of relatively older lineaments. An intersection point of two (or more) lineaments can be addressed via the relationship of stage of their formation. Here, old or young lineaments are classified based on the relative stage between the two, where the younger lineament deformed older ones. Care should be taken using this terminology as it represents only the relative “stage” not “age” of the lineaments. In different domains the age of the lineaments would be different.

## RESULTS

### TOPOGRAPHIC CHARACTERISTICS OF THE IBR

The IBR have a very dynamic geotectonic history which caused the entire region to be deformed in many tectonically unique regimes. These different regimes can be identified by observing different criteria, such as topographic variations from profiles, relationship of folded hills, deformation structures within the valleys and so on. In this study, four topographical profiles – AA’, BB’, CC’ and DD’ (Fig. 4) – were constructed across the IBR (see Table 1 for details).

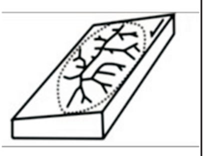
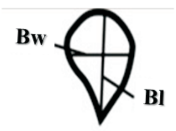
| Morphotectonic parameter | Mathematical formula | Measurement procedure | Range for activeness values |
|---|---|---|---|
| Asymmetric factor | AF = 100 x (Ar / At)<br>Ar - area of the basin to the right (facing downstream) of the Trunk stream;<br>At - total area of the drainage basin (Keller ad Printer, 2002) |  | ~50 symmetrical basins<br>Class I: AF < 5,<br>Class II: 5-10,<br>Class III: 10-15,<br>Class IV: >15 |
| Transverse Topographic Symmetry Factor | T = Da/Dd<br>Da - distance from the midline of the drainage basin to the midline of the active meander belt;<br>Dd - distance from the basin midline to the basin divide (Cox, 1994) |  | Symmetrical basins T = 0<br>Asymmetrical basins T >0<br>up to T values equals to 1 |
| Basin Shape Index | Bs = Bl/Bw<br>Bl - length of a basin measured from the highest point;<br>Bw - the width of a basin measured at its widest point (Cannon, 1976; Ramirez-Herrera, 1998) |  | Class 1 (Bs = 4);<br>Class 2 (3 = Bs = 4)<br>Class 3 (Bs = 3) |

**Fig. 3. Different morphotectonic parameters and their derivation techniques**

Classification and their range of class values are also shown here

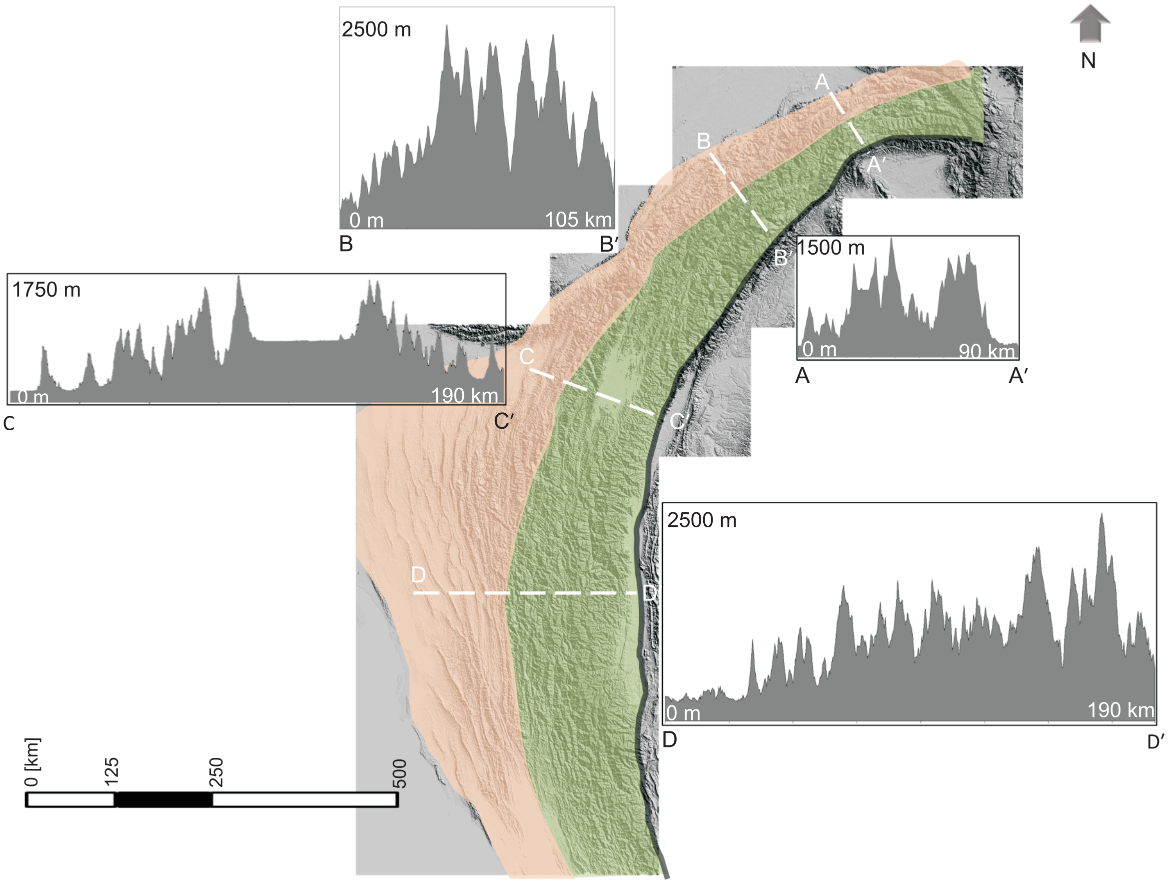


**Fig. 4. Profile sections along different transects across the Indo Burmese Ranges, indicating different elevations for different domains due to differential stress distribution**

Table 1

**Details of different aspects of topographic variations along the four transects**

| Profile location | Location | Topographic variations | Morphotectonic features | Remarks |
|---|---|---|---|---|
| AA' | Changlang region, northern most section of IBR | western part: lower elevated Paleogene/Neogene sedimentary rocks;<br>central and eastern part uplifted by some thrusting events to ~2250 m a.s.l. | deep gorges, broad U-shaped and V-shaped valleys; tight anticlinal hills are trending NE–SW to EW direction | north of transect, hill ranges are more disturbed and eroded compared to the wider southern hill range |
| BB' | Naga Hills | western part: Paleogene/Neogene hill ranges is showing growth in the frontal part;<br>central to east-central part: raised to ~1800 to 2400 m a.s.l. by thrusting events;<br>eastern part: elevated up to 2500 m | closely spaced and tightly folded hill ranges; moderate to deep gorges or V-shaped valleys are associated with mid-depth gorges differently orientated and cross faults are present in the region. The hills are deformed along NW–SE, NE–SW and EW directions | hills and valleys are abruptly deformed in some places and punctuated in one particular point of intersection. Gorges are found in synclinal portion of the hill range or been created by latest disturbances in the region |
| CC' | Cachar and Manipur region, through Imphal Valley | valley has average elevation >800 m is higher than many hill ranges in the eastern and western front. It is bounded by hill ranges on eastern and western side. Here the hills are mostly oriented in NE–SW, dissected by NW–SE lineaments. This section possesses lowest elevated hill range (~1750 m) compared to other sections | here the hills are mostly NE–SW oriented, dissected by some NW–SE lineaments. Hills around this region is associated with broader valleys compared to other sections along the IBR | here, Imphal Valley is an outstanding feature. Lowest elevated hill range have eroded topography compared to others. This kind of variability is observed south of the transect to some extent |
| DD' | Mizoram Fold Belt region, southern section | here hills are continuously uplifted from western to eastern side up to 2500 m a.s.l. The hills are trending in the NW–SE, NE–SW and NS directions | gently open folded hills with broad valleys in west frontal part; central to eastern part shows continuous increase in closeness and tightness of the folds with deep gorges | this profile represents a typical accretionary wedge pattern, forming in subduction setting |

The characteristics revealed provide enough evidence to categorise the entire IBR into four domains: the Northern or Changlang, Naga Hills, Cachar and Manipur, and Southern or Mizoram domains respectively.

## MORPHOTECTONIC ANALYSIS

Morphotectonic studies are helpful to understand how active the tectonic domains are. After detailed studies of the regional geomorphological and tectonic setting, four study areas were selected (Fig. 2). These are the Noa-Dihing River section for the Northern or Changlang domain, the Dikhow River section for the Naga Hills domain, the Chiri-Jatinga-Ghagra Rivers for the Cachar and Manipur domain and the Tut-Dhaleshwari-Tuirial River sections around Aizawl for the Southern or Mizoram domain.

Tilting in a basin can cause asymmetry, which indicates a prevalence of tectonic activity around that basin (Hare and Gardner, 1985; Cox, 1994). Asymmetric Factor (AF), Transverse Topographic Symmetric Factor (T) and Basin Index (Bs) parameters can be used for understanding the asymmetry of a basin (Cannon, 1976; Ramirez-Herrera, 1998; Bull, 2007). However, before considering any facts related to the Bs values, one has to understand the lithological variations in the area. In an argillaceous or soft sediment region, the basin “tries” to attain maturity, i.e. roundness in basin shape, much more quickly than in other places (Rakshit and Bezbaruah, 2016). The morphotectonic parameters were evaluated for the basins studied and are listed in Table 2.

**Noa-Dihing River section.** In the northern domain, the Noa-Dihing River (Fig. 5A) is one of the longest rivers, its basin covering a total area of 2940 km$^2$. The main basin was considered to evaluate the overall activity and deformational pattern. The basin has an AF value of 56.59 (Table 2) and this SW-ward tilted basin is moderately asymmetrical with a T value of 0.42. A Bs value of 3.75 indicates the elongated basin class. This indicates the presence of active tectonic features associated with the northern IBR and rigid Mishmi Block.

**Dikhow River section.** Morphotectonic parameters were calculated for 38 basins of the Dikhow River (Fig. 5B). In this section, the AF range is 13.83–79.22; with |AF| range from III–IV which indicate basins that are moderately to highly asymmetrical. This indicates that this part of the Naga Hill is tectonically active. Most of the basins show NW to westerly tilting with a few tilted towards the NE and SE. Moreover, the T value has the range of 0.06–0.83 while values of Bs range from 0.80–3.80 which indicates the presence of both rounded and elongated-semi-elongated basins in the area. This also suggests that the basins are under the high tectonic stress conditions associated with the Naga Orogeny.

**Chiri-Jatinga-Ghagra Rivers.** These rivers form the major sub-basin of the Barak River in the Cachar region (Fig. 5C). These basins show an AF range of 48.13–70.18 with T values between 0.34 and 0.63 which indicate that the basins are symmetrical to highly asymmetrical in nature. All the basins are tilted towards their western side and the basins are circular to semi-circular in shape (Bs range 1.67–3.14). These basins reflect the influence of the moving India plate and the resistive Shillong and Mikir Plateau in causing such active deformational features.

**Tut-Dhaleshwari-Tuirial Rivers (Aizawl section).** This region comprises N–S trending ranges of hills with 108 basins, reflecting flow on either eastern or western flanks towards these rivers (Fig. 5D). In the Aizawl section the AF range is 21.56–83.41. Here, most of the basins show WNW, WSW,

Table 2

**Morphotectonic parameters for different sections of the landscape domains**

| Study section | AF | T | Bs |
|---|---|---|---|
| Noa-Dihing River<br>Northern or Changlang domain | 56.59 | 0.42 | 3.75 |
| Dikhow River (and sub-basins);<br>Naga Hills domain | 13.83–79.22 | 0.06–0.83 | 0.80–3.80 |
| Chiri-Jatinga-Ghagra rivers;<br>Cachar and Manipur domain | 48.13–70.18 | 0.34–0.63 | 1.67–3.14 |

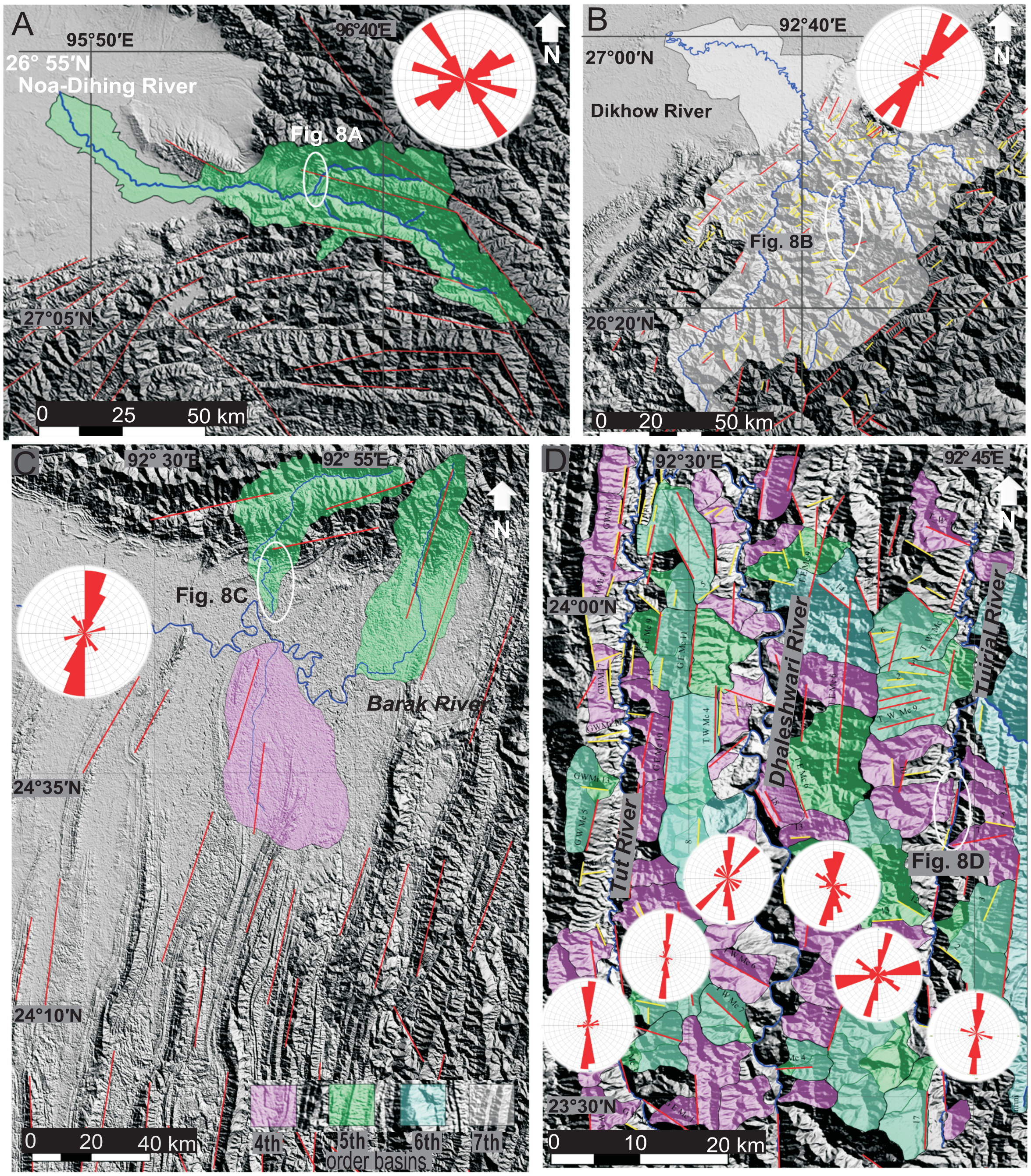


Fig. 5. Lineament and basin map for different domains are shown here with different order basins being marked in different colours (see index); red straight lines are the major lineaments in different domains: A – Changlang, B – Naga Hills, C – Cachar and Manipur, D – Mizoram; the rose diagram indicates local lineament distribution

ENE, ESE tilts, with a few tilts toward the north. Moreover, these basins are dominantly in the III (values within 0.5–10.0) and IV (values within 10.0–15.0) AF groups. This indicates that the area around the Aizawl, Mizoram fold belt region also is tectonically active. The T value range in this section is from 0.08–0.67 which also indicates the tectonic activity of the area. Bs ranges from 0.39–0.93 but this parameter is not useful in indicating the tectonic activity of an area with soft and argillaceous rocks. Overall the parameters indicate that the rising IBR clearly influence the active features along with the Indian Plate movement stress conditions.

## LINEAMENT ANALYSIS

In present study, lineaments of >35 km length are considered. This length is chosen because these lineaments are clearly visible as linear features on the maps analysed. Moreover, the purpose of this study is to identify large structural lineaments. Lineament analysis has been carried out for all the four domains individually, and also for the entire IBR. In the lineament map (Fig. 6), the patterns were observed to show a distinct change in orientation from the north to south of the IBR. The Northern domain shows primarily ENE–WSW oriented regional lineaments with some NNE–SSW and WNW–ESE trending lineaments. In the Noa-Dihing area (within this domain), the local lineaments show diverse trends: NW–SE, WNW–ESE and NE–SW directions (Fig. 5A). In the Naga Hills domain, dominantly NW–SE and NNE–SSW oriented lineaments are present with some NE–SW trending lineaments. The Dikhow River basin contains mostly NE–SW and NW–SE local lineaments (Fig. 5B). In the Cachar domain, lineament patterns are dominantly NNE–SSW but towards Manipur the trend becomes N–S. This is because of the change in the orientation of the lineaments in this domain compared to the Naga Hills. There are two major orientation patterns, one dominantly towards the NW–SE and other trends N–S. River basins around the Barak River have dominantly NNE–SSW lineaments (Fig. 5C). In the Southern domain, the area is dominated by N–S lineaments that are clearly visible in the DEM, although there are plenty of NW–SE local lineaments that intersect the other lineaments. In this domain in detail, lineament orientations change from N–S, NE–SW to E–W trends respectively before again showing a local N–S trend from west to east (Fig. 5D). 118 regional lineaments have been taken into account, distributed from north to south as

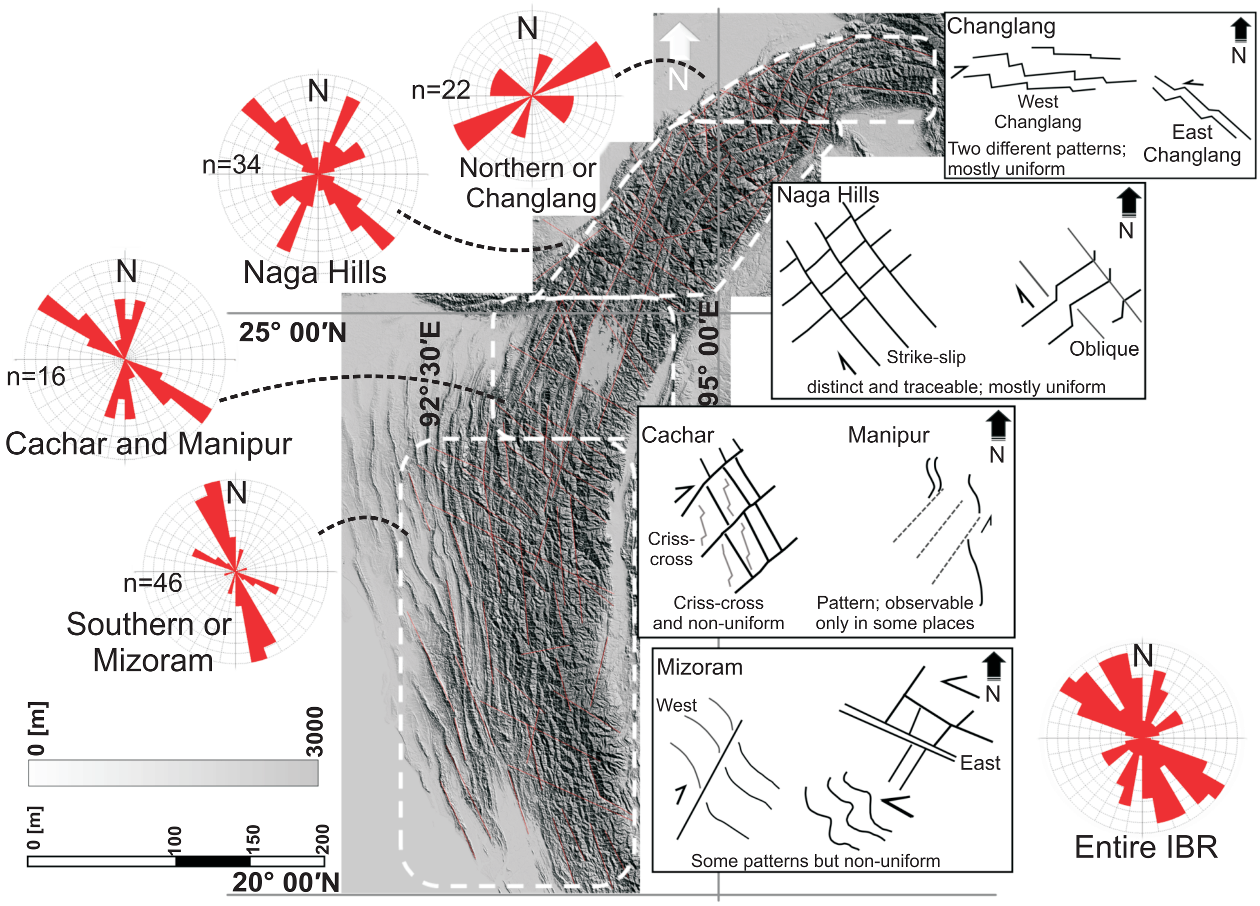
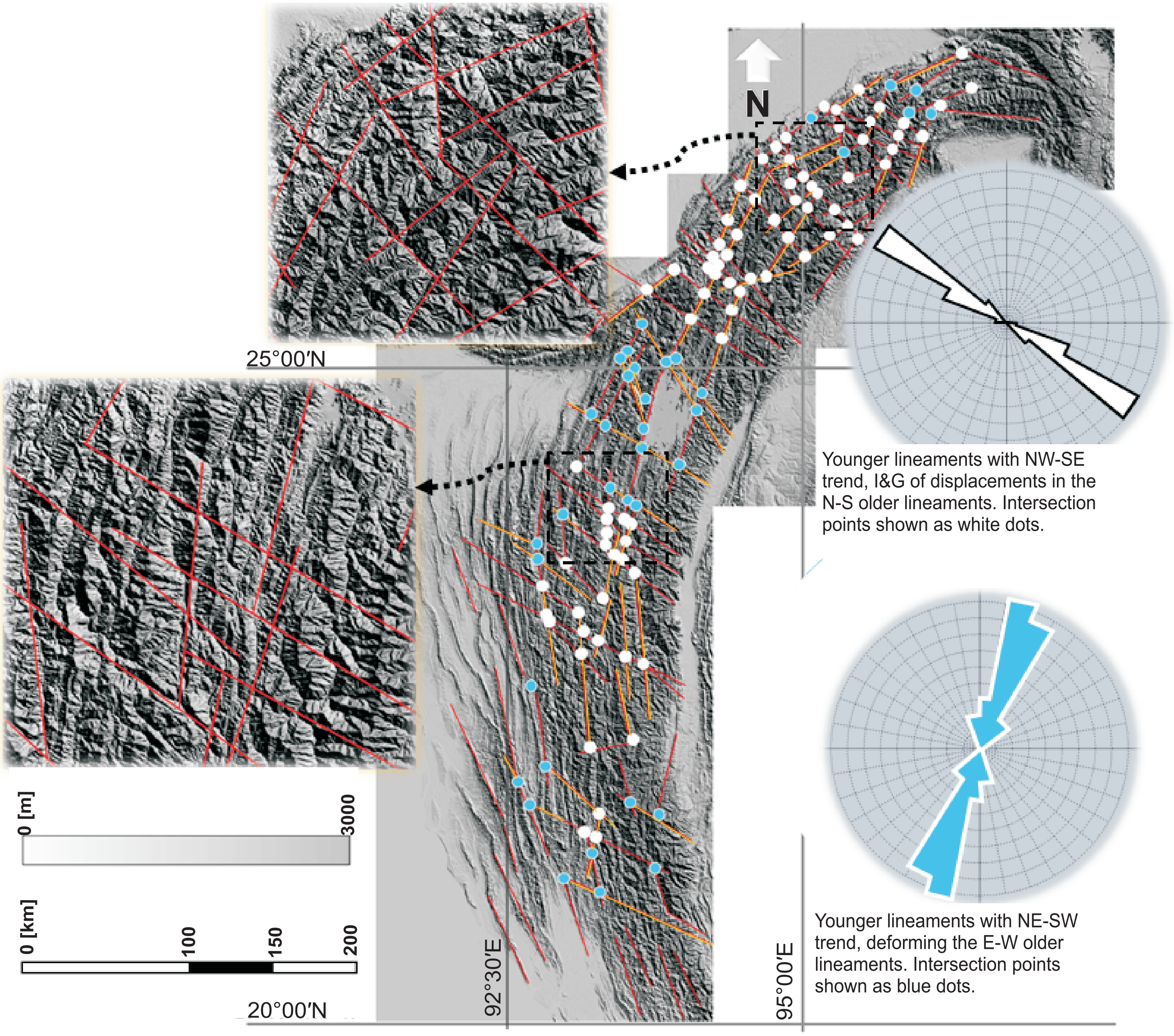


**Fig. 6. Regional lineament distribution, lineament trends in rose diagrams and different lineament patterns shown in simple illustrations for each domain; here the number of lineaments (n) is also shown within the rose diagrams**

with 22 in Changlang, 34 in the Naga Hills, 16 in Cachar and Manipur and 46 in the Mizoram domain. Average lengths of the lineaments in these domains are 67, 96, 107 and 86 km from north to south respectively (Fig. 6). Here, one set of lineaments were found to be cut or deformed by another set of lineaments, generally of different trend. Young linear features that displace comparatively older lineaments were used to identify changes in stress criterion (by the I and G method). In all four domains an older generation of lineaments are displaced by younger lineaments although in different patterns. In the Northern and Naga domains younger lineaments mostly show WNW–ESE trends, whereas in the Cachar and Manipur domain a N–S trend dominates among young lineaments. In the Southern domain, some young lineaments near Cachar and Manipur domain and in the central part show WNW–ESE trends and in rest of the area dominantly have N–S trends. In Figure 7, white dots represent displacements of older lineaments dominantly by NW–SE trending younger lineaments, while blue dots show NE–SW younger lineament trends.

## CONCLUSIONS

Unique topographic patterns in the profile sections, and variations in the closeness and tightness of anticlinal hills and synclinal valleys (Fig. 8) were helpful in categorising the entire IBR into four domains: Northern or Changlang; Naga Hills; Cachar and Manipur; and Southern or Mizoram domains. In the morphotectonic studies, different parameters – AF and T – indicated different domains that are tectonically active. Symmetrical to asymmetrical river basins are active and tilting or defor-



Younger lineaments with NW-SE trend, I&G of displacements in the N-S older lineaments. Intersection points shown as white dots.

Younger lineaments with NE-SW trend, deforming the E-W older lineaments. Intersection points shown as blue dots.

**Fig. 7. Intersection and generation of lineament deformation for the younger (red lines) and older (orange lines) stages of lineaments; density distribution diagram for younger lineaments showing NW–SE (white intersection dots and white rose diagram) and NE–SW (blue intersection dots and rose diagram); the inset diagrams are closer views of the lineament intersections**

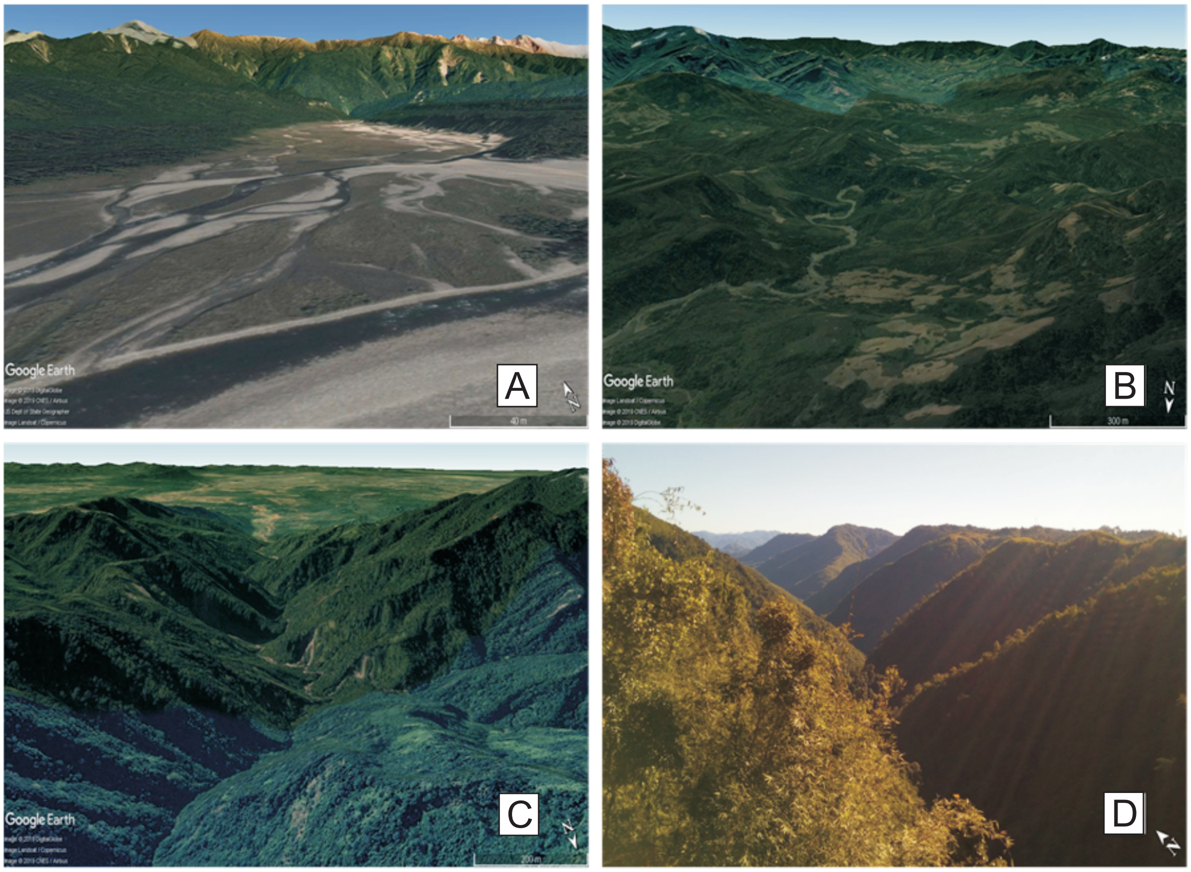


**Fig. 8. Tectonic features of the study sections**

**A** – river flowing along an E–W lineament in Changlang; **B** – N–S valleys are deformed by E–W features in the Naga Hills; **C** – N–S lineament from hill to valley in the Cachar region; **D** – N–S older lineament in Mizoram

mation produces corresponding AF and T values. As regards the Bs values, active tectonic behaviour is not certain, as some of the basins show semi-circular to circular basins. The entire Naga-Cachar-Mizoram Hill range is comprised of Paleogene-Neogene sedimentary rock sequences. Therefore, in most cases the shape of a basin is mostly controlled by the lithological variations in the area, which causes mostly circular basins in this tropical climatic region. Tectonic activity leads to variations in the topographic profiles as the ridges and valleys changes their E–W trend to N–S and NW–SE trends from north to south of the IBR. The subduction of the Indian Plate beneath the Burma Plate has resulted in shortening in the IBR region. Initial shortening occurred in the suture zone and subsequently the dominant shortening is accommodated in the frontal part of the IBR. From the suture zone towards the frontal part of the IBR, the décollement surface becomes shallower and shortening occurs because of thin-skin tectonics. In the Changlang domain, as the frontal thrust meets the resistant Mishimi Block that resists thrust propagation, there is a change in the local stress regime. In this domain, the dominant trend of lineament is ENE–WSW. These older lineaments are displaced by younger ESE–WNW lineaments. There is a slight change in the trend of lineaments from east to west of this domain. Towards the western part, major lineaments have a NE–SW trend. In the Western Changlang and Naga Hills regions, shortening in the frontal part occurs within the Assam-Arakan sedimentary basin. The thick sedimentary cover (>5 km) in the frontal part offers less resistance for thrust propagation. Therefore, the stress field which is responsible for development of structural lineaments is different than that of East Changlang. The dominant trend of lineaments in this domain is NE–SW and these lineaments are displaced by younger NW–SE trending lineaments. The change in orientation between the older and younger generation of lineaments is due to differential resistance to thrust propagation in the frontal part of the IBR in these two domains. The younger lineaments are developed to accommodate deferential strain that occurs due to differential resistance to thrust propagation in the frontal part. In the southwestern part of the Naga Hills domain, the Mikir and Shillong Plateau lies in the frontal part of the IBR and this acts as a resistant wedge for thrust propagation. This results in the change in orientation of structural lineaments in this part of Naga Hills domain. Farther south-west in the Cachar-Manipur and Mizoram domain, a thick sedimentary prism of the Bengal Basin (22 km thick; Steckler et al., 2016) is present in frontal part of the IBR. Therefore, it offers less resistant to thrust propagation. This results in the develop-

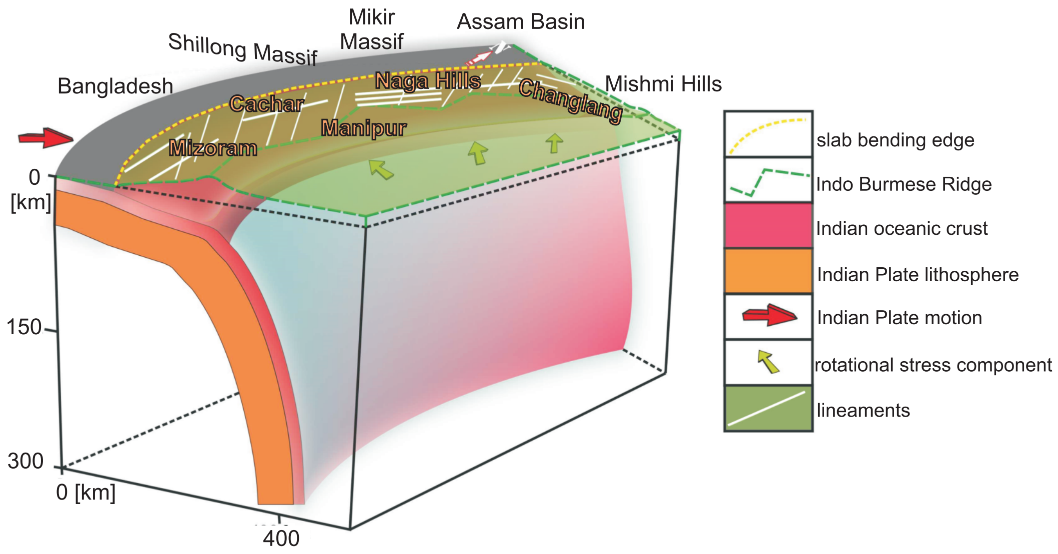


**Fig. 9. Evolutionary model for deformation of the IBR landscape; only the Indian plate side and related components have been shown here (modified after Webb et al., 2017; Rakshit et al., 2018)**

ment of major lineaments of almost N–S orientation because of E–W major compressive stress (Wang et al., 2014) in this zone, and most of these lineaments are thrust splays due to frontal propagation (Fig. 9). These older lineaments are later displaced by younger NW–SE trending lineaments. This orogeny, as the IBR, evolved in an arcuate shape due to differential resistance to thrust propagation in the frontal part in different domains. Moreover, changes in the differential stress conditions for the younger lineaments have created many strike-slip and oblique slip faults around the region.

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