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A Neotectonic based Geomorphic Analysis to delineate Structures for Exploration in Synclinal areas in Cachar area and an Alternative Model to explain their Structural Evolution.

S.Mazumder, K.K.S.Pangtey and D.S.Mitra

Remote Sensing & Geomatics, KDMIPE, ONGC, 9, Kaulagarh Road, Dehradun (Uttarakhand)

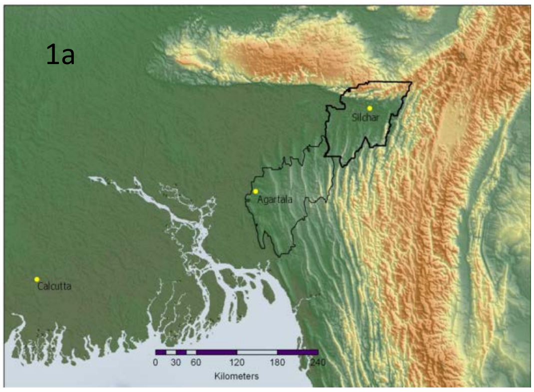
Presenting author, E-mail: subhom007@gmail.com

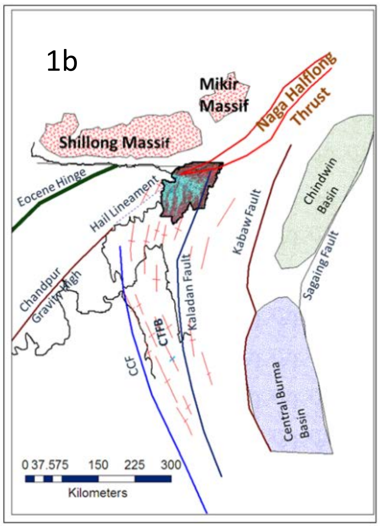
Abstract:

The Tripura Cachar fold belt comprises of heavily deformed series of eastward dipping thrust slices and intensely folded units characterized by occurrence of wide synclines as opposed to narrow anticlinal units. In the Cachar basin, most of the hydrocarbon producing fields is located in the culminations of anticlinal structures. However other wells drilled on similar analogous structural settings had been found to turn up dry. In this paper a neotectonic based geomorphic analysis had been carried out to delineate a fault network as well as geomorphic highs in entire Cachar area which are believed to be expressions of subsurface structures. These structures had been subsequently validated with extensive fieldwork and available geophysical data for verifying their subsurface continuity. Of these structures, geomorphic highs nested in synclinal areas are believed to be manifestations of subtle structural highs. These had been categorized as per their degree of confidence to represent structural highs and can be considered as areas of exploratory interest. Also in this paper, an alternative tectonic model of generation of the interpreted fault pattern and the structural highs in the synclinal areas has been proposed involving three phases of successive structural deformation that are active even now. Initially a westerly directed compressive stress resulting from the collision of Indian and Burmese plate might result in NS trending westward verging thrusts and narrow series of parallel anticlines and synclines. Subsequently due to the opening of Andaman Sea, a dextral strike slip component was added to the tectonic regime resulting in the formation of NE-SW and NW-SE trending dextral cross faults to the already developed structures changing their orientation from N-S to a NNE-SSW. Finally the activity of the E-W Dauki Fault resulted in a southward compression causing the development of the E-W trending reverse faults. Due to this southward compression the earlier developed parallel anticlines were forced to bend and diverge outward forming broad synclinal valleys. In some instances, the N-S compressions might also cause the development secondary synclinal structural highs nested within the broad and diverging synclinal valleys. Since the NNE-SSW faults in Cachar area are found to be the most reactivated, based on the proposed genesis, synclinal structures associated with NNE-SSW faults might be considered interesting from exploration point of view.

Introduction

Tripura –Cachar Basin is a part of the Assam Arakan Fold Belt formed as a result of subduction of the Indian Plate below the Eurasian and Burmese Plates. The area consists of a heavily deformed accretionary prism with a series of eastward dipping thrust slices and heavily folded units sitting above oceanic crustal units with a north-south running long axis with characteristic occurrence of wide synclines as opposed to narrow anticlines. In the Cachar basin, gas and oil fields are limited to only a few areas of Banaskandi, Bhubandar, Badarpur-Hilara, Adamtila and Patharia. mostly located in anticlinal culminations. However, other wells drilled on analogous structural settings were found to turn up dry. Additionally logistic constraints steep dips and high pressures, inherent stratigraphic and structural complexities have limited exploratory success in these areas. To counter these problems in exploration as well as to complement the limited seismic data, a morphotectonic approach based on neotectonic studies had been attempted in this paper to identify and delineate newer structures in the synclinal areas which might contribute to the present exploration scenario.





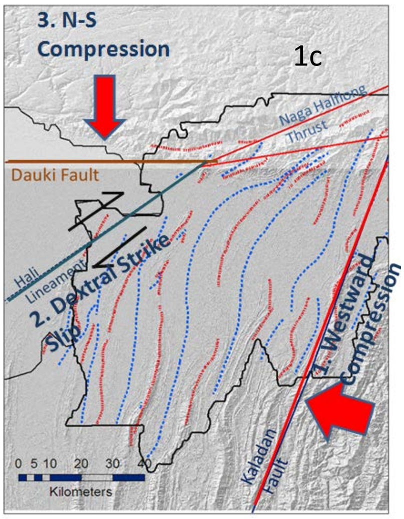


Fig 1a: A DEM based tectonic layout of the Tripura-Cachar belt along with(1b) the different tectonic elements surrounding the Cahar area (1c) Tectonic stresses acting upon the Cachar sedients at present causing their neotectonic

Tectonic Setup and Neotectonics

Tectonically the northern margin of the Assam Arakan fold belt is marked by the extension of the east-west trending Dauki Fault which is a thrust with right lateral displacement (Angelier and Baruah, 2009). Further to the east is the Naga-Haflong-Disang Thrust separating the Cachar fold belt from the Schuppen belt. The eastern part of Cachar area is bounded by the north south Kaladan Thrust that delimits it from the structurally more complex Indo-Burma Range (Gahalaut et al, 2013). Also a prominent NE-SW trending structural lineament namely the Hali-Hakalula Lineament which Kunte (1989) considers to be a major wrench fault delimits the fold belt towards the northwest. Northeastward this lineament joins with the Dauki Fault whereas south-eastward it passes over the Barisal-Chandpur Subsurface Gravity High proposed to be the manifestation of continent–oceanic crust boundary. Based on the above tectonic setup of the Cachar basin, the entire region is subject to the interplay of three principal tectonic forces probably active even at the present thus making the area neotectonically active. (Fig 1c).

1. E-W directed compression resulting from the collision of the Indian and Burma Plate that initiated the westward vergent thrusts and the N-S trending folds.

2. A NE-SW trending dextral strike slip motion associated with the opening up of the Andaman sea that caused the block couple rotation of the folded belt

3. Lastly an episode of N-S compression resulting from the Mio-Pliocene activity of the E-W trending Dauki Fault.

According to Islam et al, 2011 at present the Indian plate is moving at 46.7 mm/year towards N51° (NE) w.r.t the Eurasian plate and this NE-ward movement the driving force of present day crustal deformation and neotectonic deformations in the area. The NE ward movement is also associated with present day rotation of the Sunda/ Burmese plate in the N10° direction at 35mm/year. All of these leads to a convergence between the India, Sunda and Eurasian plates that is accommodated by present day slip or movement along the major tectonic features and boundaries of the Indian plate making them neotectonically active. Of this Dauki fault alone accommodates 25% of the regional surface displacement rate making it the most neotectonically active element in the basin.

Morphotectonic Analysis

In any region neotectonic, deformations are believed to be reactivations of existing deep seated structures formed due to an earlier regime of tectonics. Though the displacement amount associated with neotectonically reactivated structures is very low, it causes a marked and abrupt change in the overlying geomorphic elements of the area especially the drainage network. In case of drainage, the regions of neotectonic deformation are recorded as localized drainage anomalies and are basically parts of it where the drainage is structurally controlled as opposed to slope controlled. Study of these anomalies may provide an idea about the different sub surface structural elements in the study area.

The Cachar region consists of a centrally located E-W oriented transverse low drained by the Barak River which forms the trunk river of the regional drainage network of area (Fig 2a). The overall drainage in the area is controlled by the regional structure of the area. In the north the major rivers are found to flow along the synclinal axes towards the Barak River with the lower order rivers defining a dendritic drainage network on the pediment of the North Cachar Hills. Further south of the Barak river the drainage is also found to be controlled by the NS trending parallel synclinal axes with the major drainages flowing southward oriented along the synclinal valleys. These major rivers along with other lower order drainages are found to define a trellis pattern of drainage controlled by the alternating ridges and valleys. Within this regionally structurally controlled drainage networks, localized drainage anomalies had been identified based on the principles discussed in detail in Mazumder et al, 2013 Such anomalous drainage behaviour are manifested features like sinuosity variations, rectangular drainages, drainage offsets and compressed meanders that are more prominent in drainages of lower order (Fig 2b). Based on these parameters microlinears were delineated and joined as per their trend and continuity to define probable regional faults (Fig 2c) that were subsequently validated by a field checks (Fig 2d).

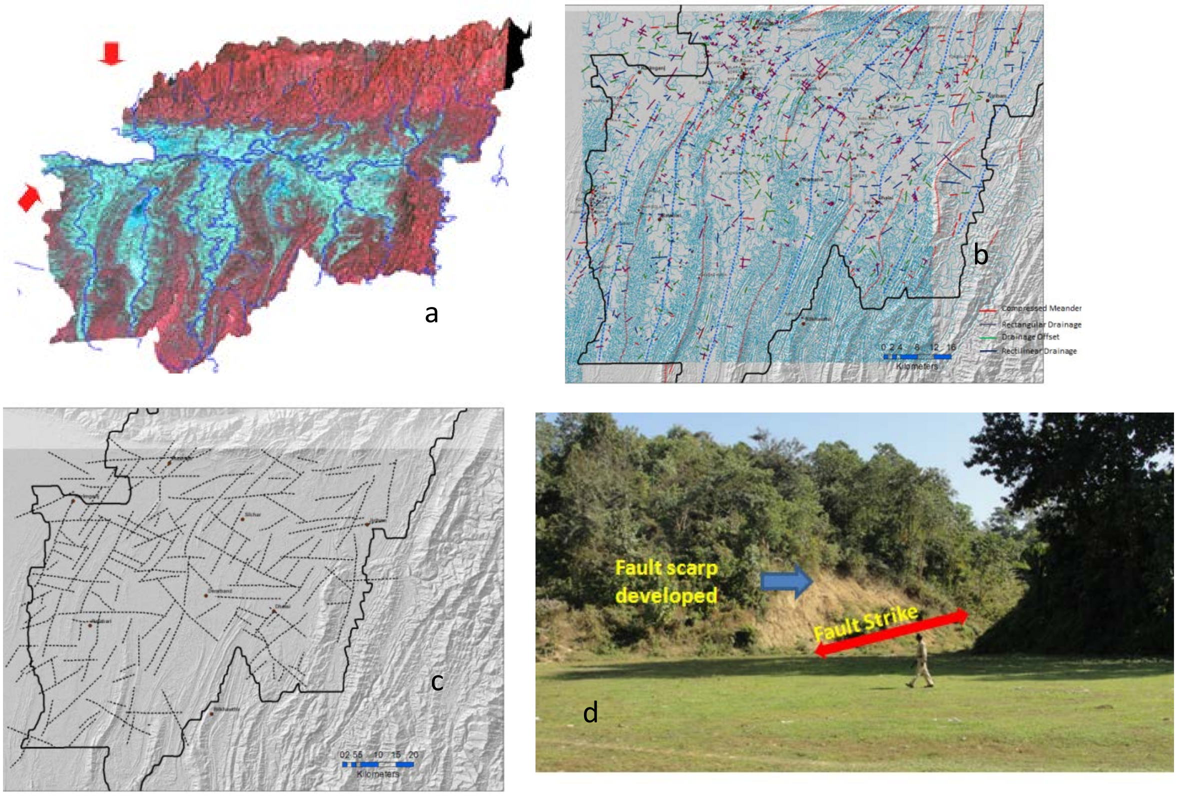
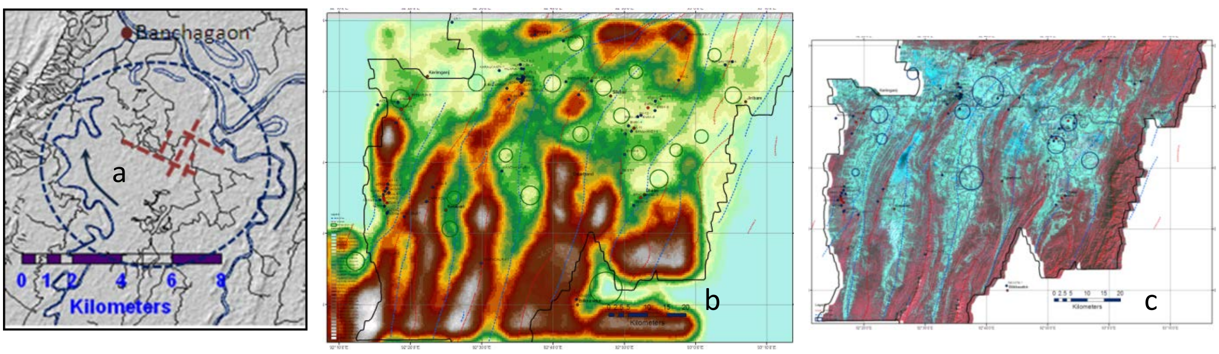


Fig 2: a Regional drainage of the Cachar area, showing centrally located E-W oriented transverse low drained by the Barak River depicted by LANDSAT 432 FCC image draped on the DEM. b, Microlinears delineated from anomalous drainage in a manifested in drainage features like sinuosity variations, rectangular drainages, drainage offsets and compressed meanders c) Microfaults joined as per their trend and continuity to define regional fault network d) field evidences of neotectonism to validate the interpretations

In a similar way, geomorphic highs had been delineated based on radial and peripheral drainage that are considered to be surface expressions of subsurface structural highs. These geomorphic highs had been checked for pondings, rectangular drainages(Fig 3a) , (Trenchard, 2007) tonal anomalies (Fig 3c) and drainage density lows (Fig 3b) (Mazumder et al, 2009) which would imply a greater probability of these geomorphic highs to represent structural highs (Fig 3d).



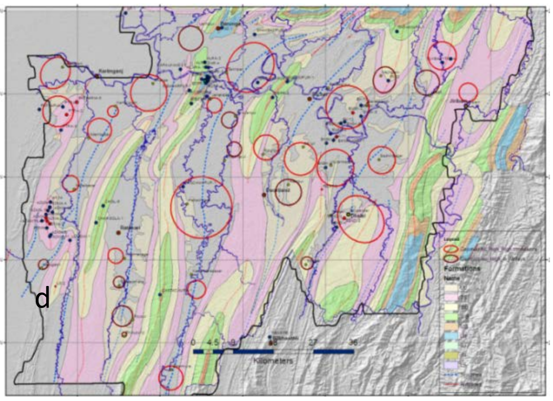


Fig 3: a) Rectangular drainages associated with a peripheral drainage suggesting an underlying structural high.(b) Drainage density lows in Cachar basin indicative of a geomorphic high induced by an structural high (c) Tonal anomalies deduced from a LANDSAT image with isolated lighter tones indicative of a terrain overlying a structural high (d) Geomorphic highs marked in brown in synclinal valleys of Cachar area overlain on geological map of the basin with the red circles implying a greater probability of these geomorphic highs to represent structural highs.

These geomorphic interpretations had been correlated with collateral data like seismic, earthquake epicentres and well data (Fig 4) to validate them and to delineate their subsurface continuities.

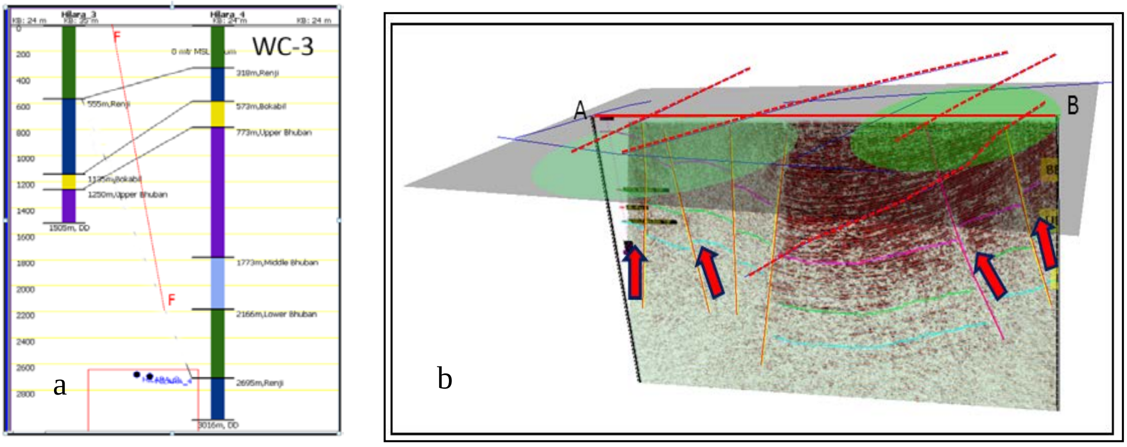


Fig 4 a)Structural correlation of adjacent wells occurring on either side of interpreted faults showing a vertical separation c) Correlation of faults and geomorphic highs on surface those interpreted in seismic section validating the surface interpretations as well as implying their subsurface continuity

Discussion

Based on the above studies, morphotectonic faults and geomorphic highs had been interpreted in the entire Cachar area especially in synclines and are considered as manifestations of subsurface faults and structural highs (fig 5a). Trend analysis carried out on the interpreted faults in the area shows a dominant NNE-SSW component suggesting that the NNE-SSW faults are the main structure building and bounding faults and the most reactivated structures (Fig 5b). The NE-SW trend and E-W trends are possibly the results of the dextral strike slip along the Hali-Hakalula Lineament and also N-S compression due to Dauki Fault (Fig 5c). Both these later trends are cross faults that cut across the longitudinal structure building faults.

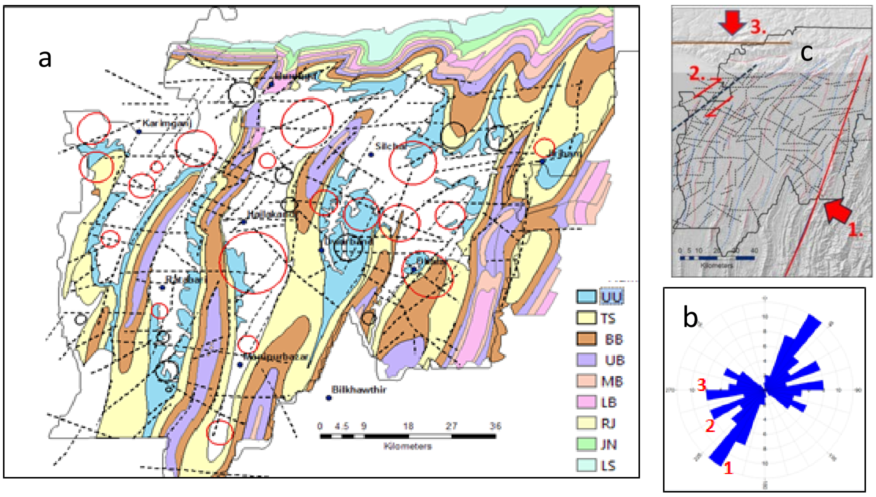


Fig 5: *a)* Interpreted fault network and structural highs in synclines interpreted in Cachar overlain on geological map (red implies higher confidence) c) Rose diagram of fault network with a predominant NNE-SSW trend due to westward oriented stress (1 in Fig 5b) and subsidiary NE-SW and E-W trends due to tectonic stresses 2 and 3 (Fig 5c)

Based on the three trends of tectonic stresses, a probable hypothesis of the generation of the structures in the Cachar area might be presumed:

Initially a westerly directed compressive stress resulting from collision of Indian and Burmese plate might result in NS trending westward verging thrusts and narrow series of parallel anticlines and synclines (Fig 6)formed up to the western front marked by CCF

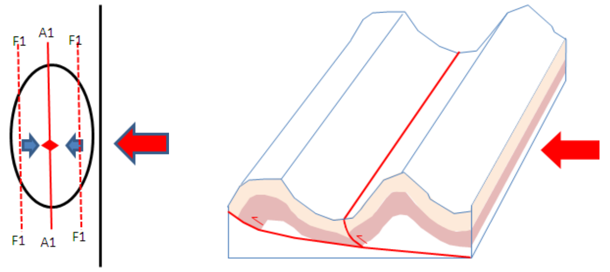


Fig 6) *Westerly directed compressive stress resulting in westward verging thrusts (F1) and evenly spaced parallel anticlines and synclines with N-S axial planes (A1)*

Subsequent to the opening of Andaman Sea, a dextral strike slip component was added to the tectonic regime resulting in the formation of NE-SW and NW-SE trending dextral cross faults to the already developed structures changing their orientation from N-S to a NNE-SSW trend (Fig 7)

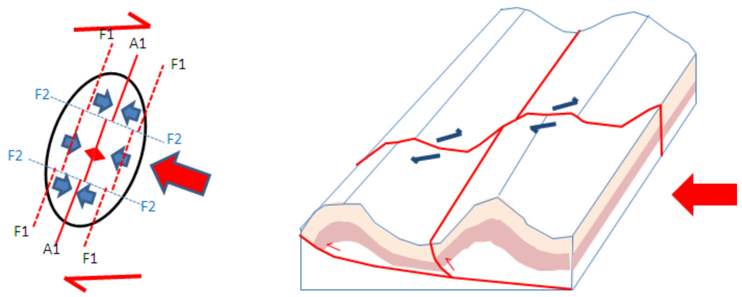


Fig 7) *Right lateral slip acting on N-S oriented folded terrain resulting in NE-SW and antithetic NW-SE strike slip faults (F2) and rotation of N-S oriented fold axes to NNE-SSW(A1)*

Finally the activity of the E-W Dauki Fault and uplift of Shillong Massif resulted in N-S compression causing the development of E-W trending reverse faults and folds. To accommodate this compression the earlier developed parallel anticlines were forced to bend and diverge outward forming broad synclinal valleys. In some instances, the N-S compressions might also cause the development of E-W oriented secondary synclinal structural highs nested within the broad and diverging synclinal valleys (Fig 8). These synclinal structures are probably the ones that are manifested in the surface as geomorphic highs in the valleys since the NS compression was probably not strong enough to expose the deeper bed to the surface. In areas where the structural highs formed by N-S compression coincided with the already developed NNE-SSW trending antiforms, areas of antiformal culminations were formed like that of the already explored structures of Adamtila, Patharia and Badarpur.

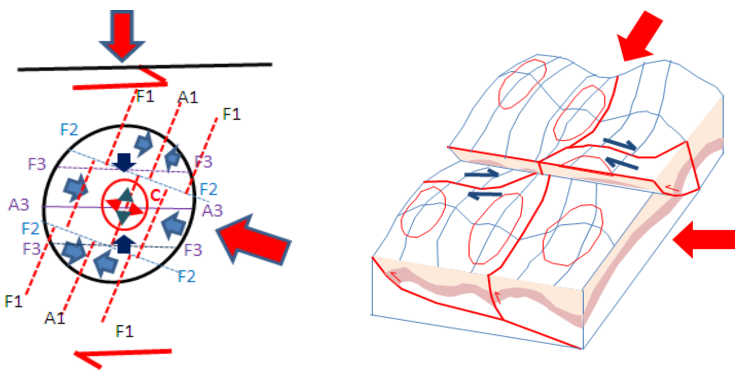


Fig 8) *NNE-SSW rotated folds subjected to N-S compression causing the development of the E-W trending reverse faults (F3) and fold (A3). Earlier developed parallel anticlines are forced to bend and diverge outward forming broad synclinal to accommodate these secondary structural highs. In case of anticlines, these form a culmination*

Many instances of such buried synclinal structures (Fig 9) manifested as geomorphic highs and nested within bent anticlinal ridges are found to occur in the Cachar area suggesting that the above premise might be a probable mechanism of formation of the synclinal structures.

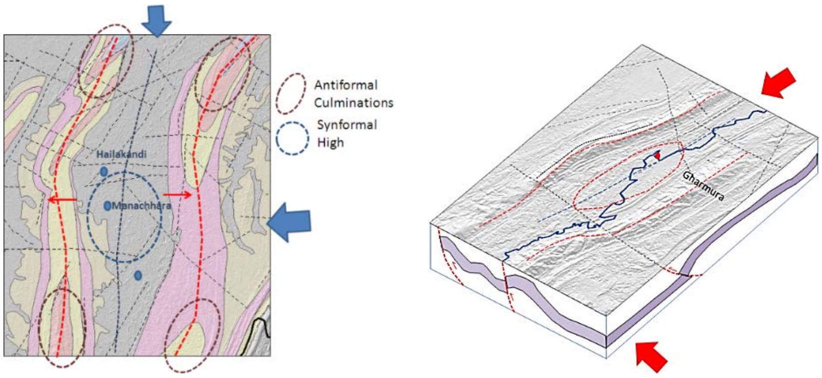


Fig 9) *Instances of such synclinal highs and antiformal culminations in Cachar basin that might be formed in the proposed mechanism as discussed above*

In Cachar, hydrocarbon migration to the traps is recent with short distance transportation occurring vertically along basement rooted faults and any structures evolving in the latest tectonic phase might have accumulation of hydrocarbons of commercial importance (Chakravorty et al, 2011). Since in Cachar area, the NNE-SSW faults are the most reactivated structures they might act as a conduit of vertical migration as evident from the multiple hydrocarbon seepages along them. Similarly geomorphic highs deduced to be of higher confidence of representing structural highs and nested in such synclinal valleys as well as associated with NNE-SSW faults might act as exploratory targets. The N-S and NE-SW faults cutting across them might compartmentalize these structures preventing further migration.

Conclusions

From the above neotectonic based geomorphic analysis, a fault network as well a number of probable structural highs had been delineated in the Cachar part of the Assam-Arakan fold belt. Of these the structural highs nested in in the synclinal areas bounded by diverging anticlines had been premised to be formed from a three phased structural evolution. These synclinal structures associated with NNE-SSW faults might be considered interesting from exploration point of view. The N-S and NE-SW faults cutting across them might prevent further migration

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