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Mapping of Kaladan Fault and Hydrocarbon Prospectivity within Kaladan-Kabaw Fault Systems along Indo-Burmese Wedge

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Abstract:

Discovery of hydrocarbons along the Disang-Naga-Schupen belt was established during late 18th century. Owing to limited study, debate is still on regarding appropriate plate boundary model for Indo-Burmese Arch region. Chittagong Coastal Fault, Kaladan fault, Churachandpur-Mao fault and Kabaw fault are the major fault systems in the southern part of Disang-Naga-Schupen belt within thrust-belt areas of Indo-Burmese arch. A number of major hydrocarbon discoveries have already been established adjacent to the north-south trending fault systems. Gas discovery towards west of Kaladan fault (Bangladesh and Tripura) in Miocene paly, presence of producing basins towards east of Churachandpur-Mao fault, Kabaw Fault (Cindwin Basin and Central Burmese Basin) in Oligocene-Miocene play and newly discovered Plio-Pleistocene play in the southern part of Kaladan-Churachandpur-Mao fault systems (Rakhine Offshore Basin) prove the hydrocarbon prospectivity throughout the Indo-Burmese fold-belt region. Mapping of North-South trending Kaladan-Kabaw fault system in general and Kaladan fault in particular is yet to be well documented. A few published literature poorly satiesfy the geomorphology as well as positioning of Kaladan fault system towerds north. Seismicity data, geomorphological charecterstics coupled with satellite data support the existence of Kaladan fault towards extreme north and merging with Disang-Dauki fault system which is also consistent for a deepseated long trending fault system. Eventhough a number of oil and gas seepages are reported within Kaladan-Kabaw fault systems, the commerciality of hydrocarbon is yet to be established especially central and southern part of huge virgin area within the wedge of the fault systems except a recent discovery in Lower Miocene play. With this paper, an attempt is made to describe the tectonics including mapping of Kaladan fault, stratigraphy, hydrocarbon prospectivity, occurrence of source, reservoir rock and seal within North-South trending Kaladan-Kabaw fault systems of Indo-Burmese wedge.

Introduction:

The geo-tectonic positioning of Assam-Arakan Basin makes this area attractive for hydrocarbon exploration. Assam-Arakan basin exists in the intervening area of two collision zones, *viz*., the E-W India Eurasia collision zone to the north and N-S India-West Burma collision zone to the East. Therefore, tectonic activities/ elements are supposed to play in sedimentation and deformation as well as hydrocarbon generation, migration and entrapment. Studies of coal and hydrocarbon prospects have been limited by both geographic and political access as well as economic realities. These limitations have produced a patchwork of relatively small regions of well documented geology within a larger region where the geological knowledge consists mainly of conjecture. Published documents are limited on detail study of major Indo-Burmese plate system in general and Chittagong-Tripura-Mizoram-Burmese fold belt in particular of the large Assam-Arakan region. Moreover, Tectonic significance of some of the major Fault systems (*viz*., Kaladan Fault system Churachandpur-Mao fault, Kabaw fault and Sagaing fault system) is yet to be evaluated and their kinematics of development is yet to be understood properly. Though the area is very significant in respect of regional tectonic evolution and its set-up in relation to the development of the eastern margin of the Indian plate, no comprehensive work has so far been carried out to unravel the evolutionary process and history of this fold belt (Nandy *et al*.,1983). A detail geoscientific study will update the regional framework of geological knowledge and guide for future successful hydrocarbon exploration programme in the thrust-belt with a sheath of about 300 km wide from eastern Bangladesh extending to Indo-Myanmar fold belt area.

Background:

The drifting of large Indian plate from Gondwanaland and movement towards northward and further collation with Eurasian plate during mid-Eocene (~45Ma) is well documented (Patriat and Achache, 1984; Dewey *et al*., 1989; Patriat and Achache, 1984; Stampfli *et al*., 2008) (**Figure-1**). Plate reconstruction models (Hall, 2002) suggest that the subduction of the Indian plate probably occurred in the Indo Burmese Wedge until ca. 50 Ma, when the entire arc was predominantly southeast-northwest trending (Guzman and Speziale, 1996; Kundu and Gahalaut., 2012, 2013).

However, due limited availability of detailed studies, debate is still on regarding most appropriate plate boundary model for Indo-Burmese Arc region (Gahalaut *et al*., April, 2013). Subduction along this plate boundary is well known, but whether it is still active is a debatable issue (Gahalaut *et al*., April, 2013). Regional views and local understanding need to be correlatable with respect to plate tectonic concept to this particular Indo-Burmese area.

On the other hand, geological understanding and petroleum exploration activities are limited in the geosynclinal part (Naga Schuppen belt and the Cachar, Tripura, Mizoram, Manipur and western part of Burmese fold belts) of large Assam-Arakan basin.

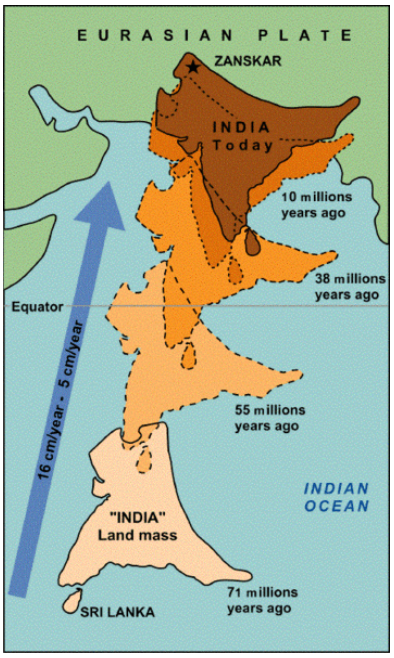


Fig 1: The northward drift of India from 71 Ma ago to present time. Note the simultaneous counter-clockwise rotation of India. Collision of the Indian continent with Eurasia occurred at about 55 Ma. Source: www.usgs.org (modified)

Significance of tectonic setting of NE India with special emphasis on Tripura-Cachar-Mizoram Fold Belt are:

- Tectonic transportation from East to West is reflected in Late Mesozoic-Tertiary Tripura-Cachar-Mizoram fold belt of NE India.

- Tripura-Cachar-Mizoram fold belt is characterized by a series of tens or even sometimes more than hundreds of kms. anticlines and synclines along N-S directions.

Fault systems along Indo-Burmese wedge:

Chittagong Coastal Fault, Kaladan fault, Churachandpur-Mao fault, Kabaw fault systems are bow shaped satisfying Elliot's bow-and-arrow rule and indicating tectonic transportation from east to west. Whereas, in and around Sagaing fault system, the tectonic transportation intensity towards east is diminishing. (**Fig.2a**). The significance of the above fault systems is as under:

- Almost north-south trending fault systems are the responsible for all major tectonic evolution and activities in the of eastern Bengal basin, Tripura-Cachar-Mizoram-Manipur fold belt, Central Burmese Basin, Cindwin Basin and Rakhine Basin of Burma.

- North-south trending faults (Chittagong Coastal Fault, Kaladan fault, Churachandpur-Mao fault, Kabaw fault and Sagaing fault) are merging or running parallel to Dauki-Disang-Naga fault system in the north and Andaman-Nicobar Ridge, Sumatra Fault system in the south (**Fig. 3**). Hil-Hakalulu lineament coinciding with Chandpur-Barisal Gravity high seems to be further disappearing/ merging with Dauki-Disang-Naga fault system towards east.

- A number of major hydrocarbon discovery has already been established adjacent to the above mentioned north-south trending fault systems. Gas discovery towards west of Kaladan fault system (Bangladesh and Tripura), presence of producing basins towards east of Churachandpur-Mao fault, Kabaw Fault (Cindwin Basin and Central Burmese Basin) and newly discovered basin in the southern part of Kaladan- Churachandpur-Mao fault systems (Rakhine Offshore Basin) prove the hydrocarbon potentiality throughout the Indo-Burmese fold-belt region.

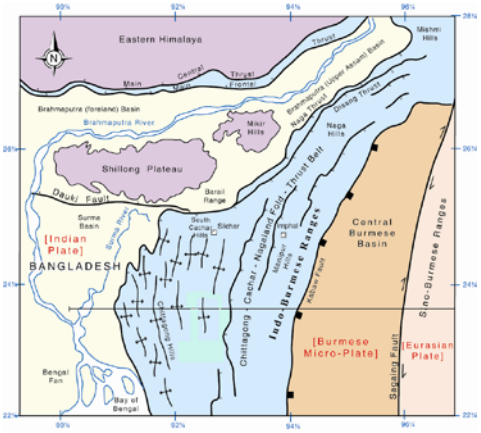


Fig 2a: Tectonic elements along large Indian and Burmese Plate system

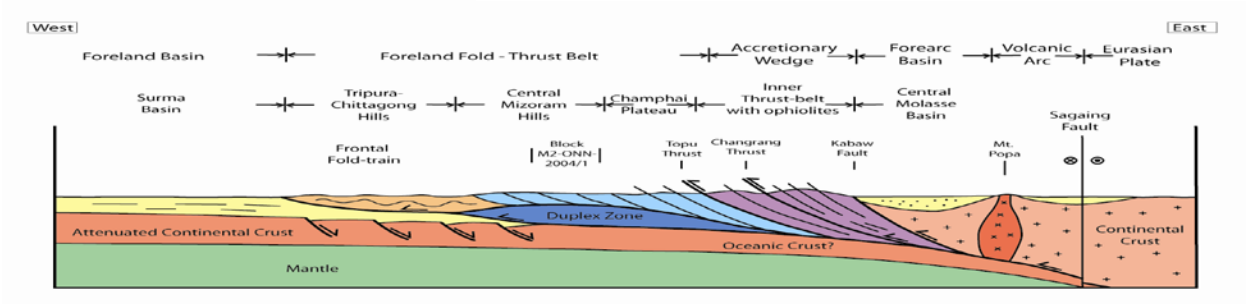


Fig 2b: Schematic crustal-scale cross section across the Tripura salient of the Indo-Burmese orogenic belt and the central Mizoram Hills between the Surma Basin and the Sagaing Fault. (Schelling, 2009)

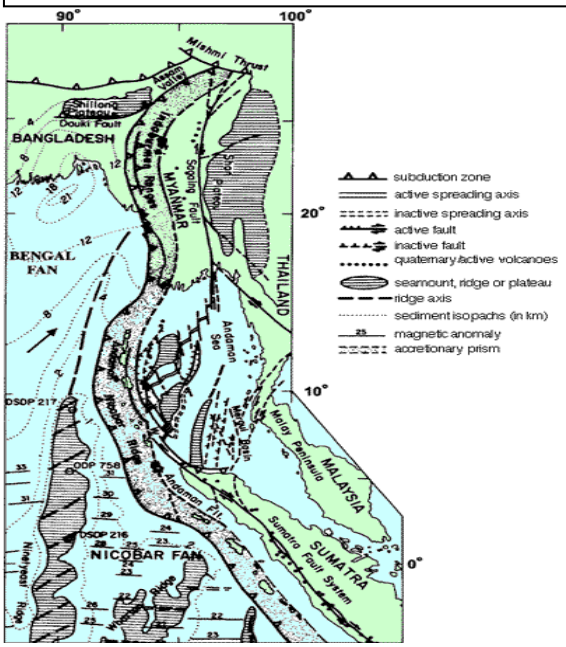


Fig 3: A tectonic map of the north-eastern Indian Ocean (adapted from Curray J.R. 1991, "Possible greenschist metamorphism at the base of a 22 km sediment section, Bay of Bengal," *Geology* 19:1097-1100)

Structural Framework of Kaladan Fault System:

North-South trending Kaladan Fault System is one of the major fault systems along large Indian and Burmese plate systems. The Kaladan Fault System is described as a dextral strike slip fault system similar to the Churachandpur-Mao fault, Kabaw fault and Sagaing fault system in a number of published literature (Murphy, 1988., Curiale et. al., 2002; Gahalaut et.al.; 2013). The positioning and mapping of the Kaladan Fault System, particularly in the northern fringe is fairly traced in most of the publications (Curiale et. al., 2002). Regional seismicity map is sufficient enough to explain the northern positioning of Kaladan Fault System and also to well describe the seismic significance of deepseated nature (**Fig. 4 & 5**). The integration of seismicity data and geomorphological charecterstics including satellite data (**Fig 6 & 7**) support the existence of Kaladan Fault System towards extreme north and merging with Disang-Dauki Fault system which is also consistent for a deepseated (~75-100 km) long trending fault system. The folding along the this fold-belt system are also long linear to sub - parallel, sub - arcuate, narrow, tight, sharp, linear, usually doubly plunging and trending north - south.

The Indo-Burmese wedge along with continental-oceanic part and well documented sedimentary model (**Fig. 8**) is quite significant to describe the Tripura-Cachar-Mizoram-Manipur fold belt part.

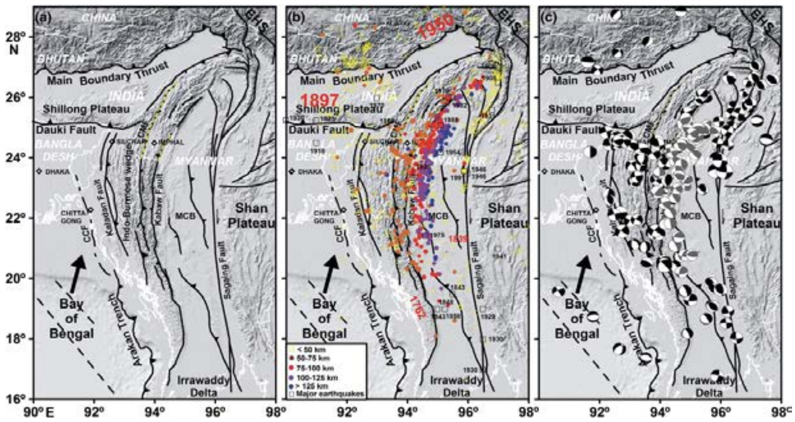


Fig 4: General tectonics (a) shows the India–Sunda relative plate system. (b) Seismicity and (c) earthquake focal mechanisms (Curtsey: Geological Society of America)

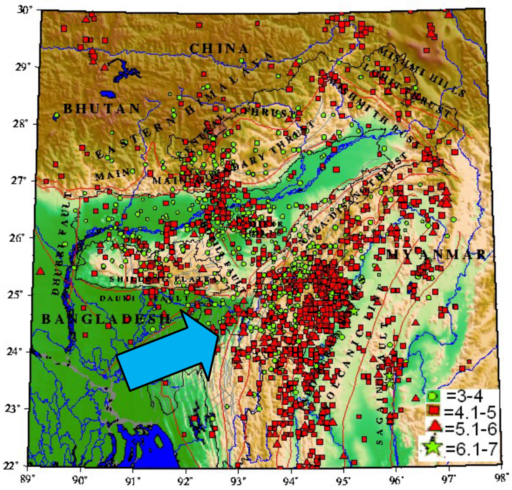


Fig 5: Micro-seismicity map of North East India, East of Burma: local network data (1982-1992) and seismicity along northern part of Kaladan fault. (map: modified after Kayal et al., 2008)

General observations from west to east depict that the Indo-Burmese Fold Belt is within the two major fault systems – Kaladan fault in the west and Kabaw fault (Western Fold Belt of Myanmar - along which ultra-basic rocks and exotic limestone in the form of ophiolite suite are present, Pramumijoyo Dr. I. S. et. Al., Report on Regional Geology of Myanmar, April, 2010) in the east. Sharp crested anticlines are prominent towards west and flat crested anticlines are dominant towards east in between these fault systems (**Fig. 9**). The signature can also be observed from recently carried out different models of the structural balanced sections from east to west along the fold-belt (**Fig. 10**). Beyond these two fault systems, the folding nature along this fold-belt zone becomes significantly gentler. The flattening of structures towards east of Kaladan Fault is contrary to the traditional knowledge of tightening of structures towards the east. Above phenomenon can be explained with the hypothesis that the fold-belt area within these fault systems (Kaladan fault and Kabaw fault) could be a remnant of the larger Indian Plate System (Tethyan Plate System). The validation can only be possible while detail geoscientific study could be carried out.

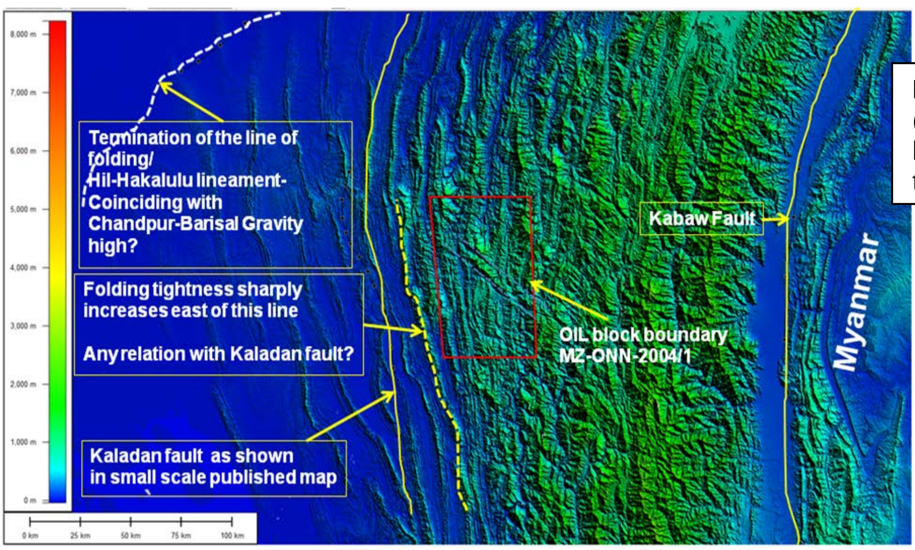
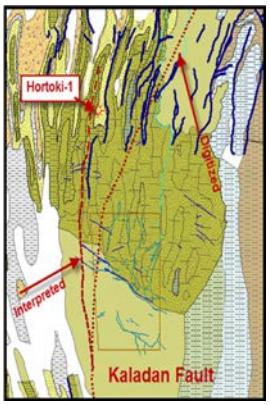
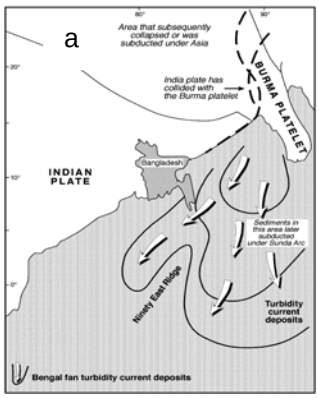


Fig 6: Satellite image (DEM) of the fold-belt area between Kaladan fault in the west and Kabaw fault





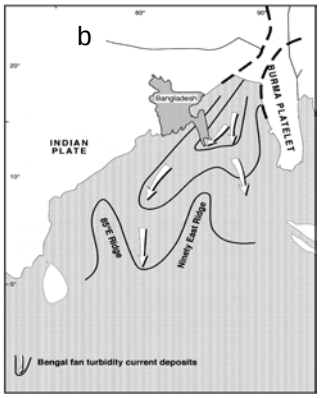


Fig 8: Middle Oligocene (32 Ma) Bengal Fan, shown with form lines of sediments formed by the Bengal Fan turbidity currents. (b) Early Miocene (20 Ma) form line of Bengal Fan.

Fig 7: Interpretation of Kaladan Fault on the basis of Satellite Data (After Kent, 2010 and Feb., 2013) with digitized Kaladan Fault as per published data.

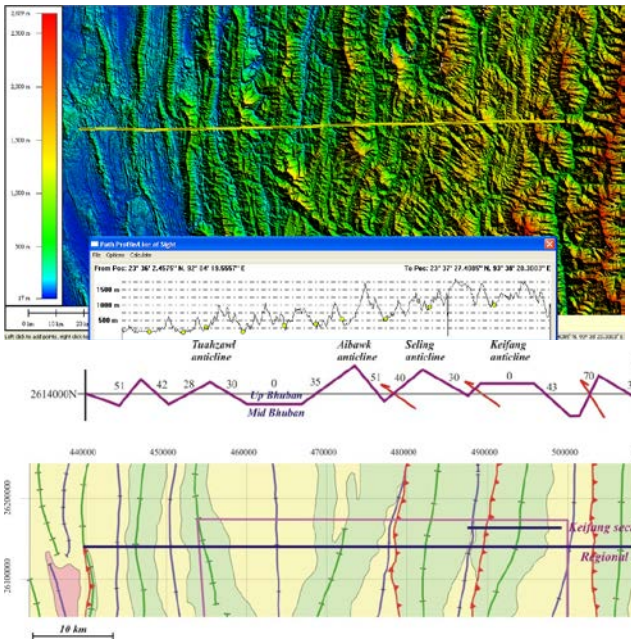


Fig 9: Section from west to east along Kaladan-Kabaw Fault System showing the elevation difference from west to east.

Fig 10: Cross-sectional balancing from east to west along selected few anticlines of Indo-Burmese wedge.

Hydrocarbon Exploration:

Hydrocarbon discovery has already been established as seep liquids or through the drill bit around the Indo-Burmese fold-belt region during the recent past centuries (**Fig 11**). Thick sandstone gas pay within Lower Bhuban formation (Lower Miocene) during 2009 in "Khubal Structure" in East Tripura has generated a new impetus to hydrocarbon exploration from Lower Bhuban reservoirs in Eastern Tripura and has helped in establishing Tripura-Cachar region as a part of giant petroleum gas province comprising of Bangladesh-Tripura-Cachar-Mizoram (Shyam et al., 2011). The commerciality of hydrocarbon is yet to be identified within Kaladan-Kabaw Fault Systems except the new discoveries in the Lower Miocene play in Hortoki-1(during 2012) in the north and of Plio-Pleistocene play in Rakhine Basin (during 2003-06) to the extreme south east of Bay of Bengal. A huge pile of sedimentation was accumulated since early Miocene age in Tripura-Cachar-Mizoram fold-belt and sediment supply was probably from the north eastern and western fringe of Indian and Burmese plate systems respectively. Due to tectonic loading, sediment thickness probably becomes high from west to east of Kaladan fault system.

Source rock potential in the land-plant–dominated organic-rich arenaceous/ argillaceous shales and siltstones of the middle and lower Miocene (Bhuban formation) is leading to the gas window. However, monotonous sequence of splintery shales from Cretaceous to Middle Eocene (thick lower to upper Disang Shale) could be suitable as source rock along with Mid-Oligocene (Intercalated shales of Jenam Formation) predominantly argillaceous sequence of shales consisting siltstones, mudstones and carbonaceous shale (Rangarao, 1983) (**Table-1**). Primarily, vertical migration is more relevant through fault and fracture systems associated with the fold-belt. These fault systems have been periodically reactivated through the present. Short up-dip migration along the flanks of the basin is also likely (Wandrey et al., 2006). Trap and Seal is already proven along the fold-belt area. But, the geological age of fault systems and impact on depositional history of proven petroleferious horizon along this thrust belt area could be a vital part from hydrocarbon entrapment mechanism. The pace of exploration is slower along this fold-belt patch compared to surroundings, probably because of difficult logistics and geological challenges. The recent exploration results/findings in this fold-belt by exploration companies are highly

encouraging equally from the possibility of giant discovery and for the prioritization of future exploration acreages along this least explored area.

Formation	Thickness (m)	TOC (%)	VR_O(%)	Kerogene Type
Up. Disang Gp.	>3000-2000	0.69-4.0	0.9-1.94	II & III
Jenam	1500-1200	2.5-4.5	0.64-1.2	II & III
Bhuban	>2400-1000	0.2-1.5 (U) 1.76 (L)	0.9-1.0	No Data
Bokabil	1200-1000	0.2-1.5	No Data	No Data

Table 1. Source Rock Data Compilation (Source: Potential Shale Gas Basins of India: Possibilities & Evaluation by Dr. V K Rao, IUGF, 2011;Curiale et al., AAPG Bulletin, v. 86, no. 4 (April 2002), pp. 625–652;Thickness: Schelling, 2009 report, OIL, Mizoram

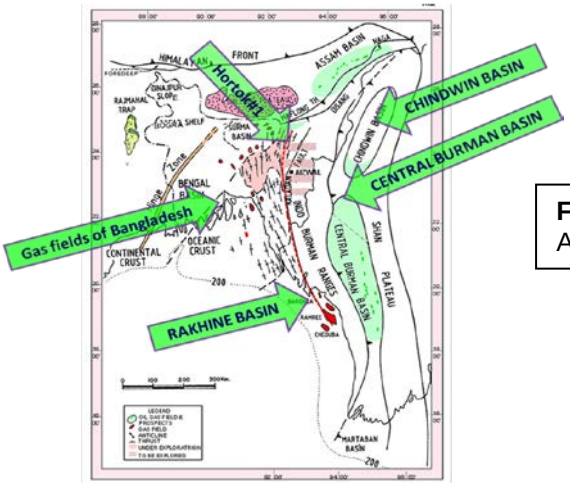


Fig 11: Regional Hydrocarbon Producing Areas (Modified after Curiale et. al., 2002)

Conclusion:

The detail study of the entire Kaladan Fault System and the nature of adjacent faults is very relevant to well describe plate boundary model for Indo-Burmese Arch region. Additionally, the study can be further intensified to have a better uderstanding of the geology of Indo-Burmese wedge so that future hydrocarbon exploration stretegy can be traced out for gient discovery in comming days, particularly, in this least explored promising thrust-belt area.

References:

Alam, M. Mustafa.,2003: The curtain goes up on a sedimentary basin in south-central Asia: unveiling the sedimentary geology of the Bengal Basin of Bangladesh: Sedimentary Geology 155, p. 175–178.

Bllakeey, I., 2010 Bay of Bengal: Many Possibilities and Challenges Ahead., Geo Expro., vol.7, no. 6., p., 17-21.

Chakravorty, D., Gupta, S., Shyam, R., Bandari, A., 2011: A Re look into exploration strategy of Lower Bhuban play in Eastern Tripura, India. A Case study., GeoIndia2011

Gahalaut,V.K., Kundu, Bhaskar., Laishram, Sunil Singh., C.,Joshi., Kumar, A., Singh, M. Devchandra., Tiwari, R.P., Chadha, R.K., Samanta, S.K., Ambikapathy, A., Mahesh, P., Bansal, A., and Narsaiah, M., 2013: Geology,Geological Society of America 2013;41., p 235-238,.

Kayal, J.R., Seismic Environments in Northeast India Region: An Appraisal, 2008.

Kent, N., 2013: Integrated Structural and Stratigraphic Study of the Assam-Arakan Foldbelt., A Research Proposal to Oil India Limited by Kent GeoScience Associates.

Kundu, B., and Gahalaut, V. K., 2013: Tectonic geodesy revealing geodynamic complexity of the Indo-Burmese arc region, North East India, Current Science, vol. 104, no. 7.

Mathur, L. P., nad P. Evans, 1964, Oil in India: 22nd Session International Geological Congress Proceedings, p. 7–52.

Mukhopadhyay, D., 2011: Structural Restoration and Cross Section Balancing of Aibwak, Seling and Tauhzal Anticlines and Its Adjoining Areas., Report OIL.

Nandy, D. R., Dasgutpa, S., Sarkar, K., and Ganguly, A., 1983: Tectonic Evolution of Tripura-Mizoram fold belt, Surma Basin, North East India., Quart. Jour. Geol. Min. Met. Soc. India, Vol. 55, No. 4, p. 186-194.

Schelling, D., 2009: Structural Geology of Exploration Block MZ-ONN-2004/1., Report, OIL.
