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Geological framework of Western Arunachal Himalaya and Eastern Arunachal Himalaya - Are they identical? Some observations

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Abstract: *Himalayan – Tibetan orogenic belt is the most dynamic and tectonically vibrant belt of the globe creating an icon of continent – continent collision tectonism. It is known to the geoscientific communities that Himalaya is the youngest, loftiest and arguably most spectacular 2500 km long, arcuate belt stretching between two notable syntaxial bends – Nanga Parbat in the west and Namche Barwa to the east, both being located across the International boundaries in Indian Himalayan context. Many similarities and dissimilarities along and across the Himalayan belt are witnessed specifically in the Eastern Himalayan region. In this communication such an approach is attempted from Western Arunachal Himalaya (Tawang sector) and Eastern Arunachal Himalaya (Lohit – Dibang sector of Mishmi block).*

Keywords: *Tawang sector, Lohit – Dibang sector, Arunachal Himalaya, Geodynamic evolution.*

I. Introduction

To understand the collisional tectonism of the Himalaya, many research updates are available but yet a crystal clear solution is at sight [1]. Compared to other parts of the Himalayan belt, the tectonic configuration of Eastern Himalaya is least studied and understood. Many similarities and dissimilarities along and across the Himalayan belt are witnessed in the entire orogenic belt. Imprints of intensive deformational impacts over the different lithounits, remobilisation of Indian Proterozoic basement followed by upliftment or thrusted dismembered tectonic units or slices over the younger sequences are some of the classical documents portrayed by the Great Himalayan Orogenic Belt [2]. In our present discussion, we have correlated the similarities and dissimilarities between the Western parts of Arunachal Himalaya (Tawang sector) with the Eastern Arunachal Himalayan belt (Lohit – Dibang sector of Mishmi block) based on their tectonostratigraphy and structure.

The Arunachal Himalaya can be divisible into three sectors – Western (Tawang), Central (Subansiri) and Eastern (Lohit-Dibang) of which the western and central sectors are comparatively better studied from geological and geodynamical perspectives but Eastern Arunachal Himalaya (Lohit Himalaya) is relatively least studied because of many local problems, inaccessibilities, deep forestation, lack of good transport communication and International boundary problem etc. As such Arunachal Himalaya occupies a unique position from political perspective because of International boundaries - China to the north, Bhutan to the west and Myanmar to the east.

II. EASTERN ARUNACHAL HIMALAYAN BELT

Eastern Arunachal Himalayan belt (EAHB) is also known as Mishmi Himalaya or traditionally Lohit Himalaya. Three main river valleys namely Siang river valley to the west, Dibang river valley to the central and Lohit river valley towards eastern part constitute the Mishmi block. These three river valleys portray the non – uniform thrust bound lithotectonostratigraphic setting with regional NW-SE extension as against generalised E-W lithotrends of western and central sectors of Arunachal Himalaya, whereas Indo – Myanmar mobile belt has a regional NE – SW trend and transects the Mishmi Himalaya in the extreme northern end by Mishmi thrust. Two different traverses are taken; one along Dibang valley and another along Lohit valley. Along these two traverses at the lowest structural level, Brahmaputra alluvium followed by Lesser Himalaya, Higher Himalaya (Mishmi Group/Dibang Group), Ophiolite complex representing suture zone and Lohit granitoid complex are observed. Lohit thrust at the upper structural high and Mishmi thrust at lower stage are observed (Figs. 1a,b, 2). The thrust bound configuration is discussed by [2], [3].

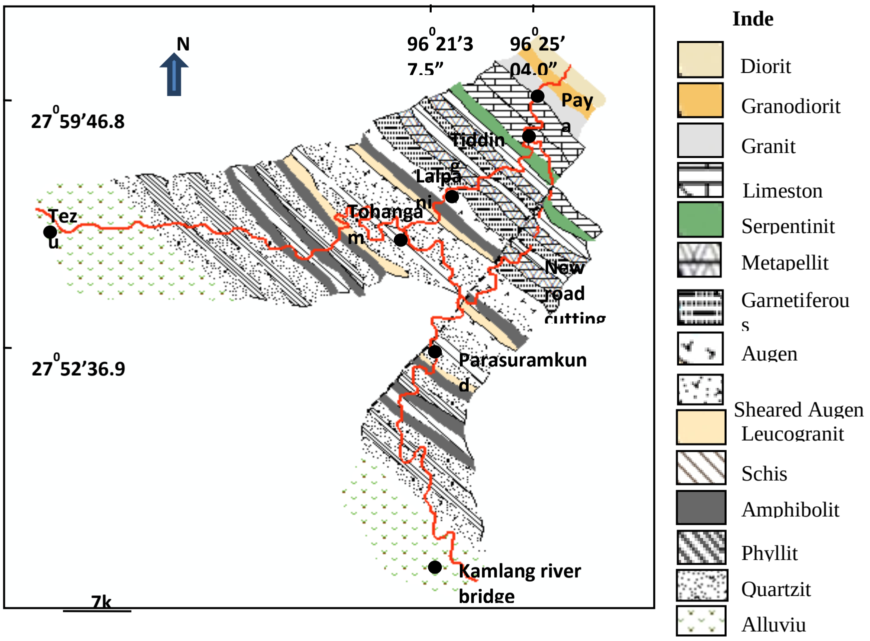


Figure 1a. Lithological Map from Kamalang river bridge (bottom) to Paya (top) along Lohit valley

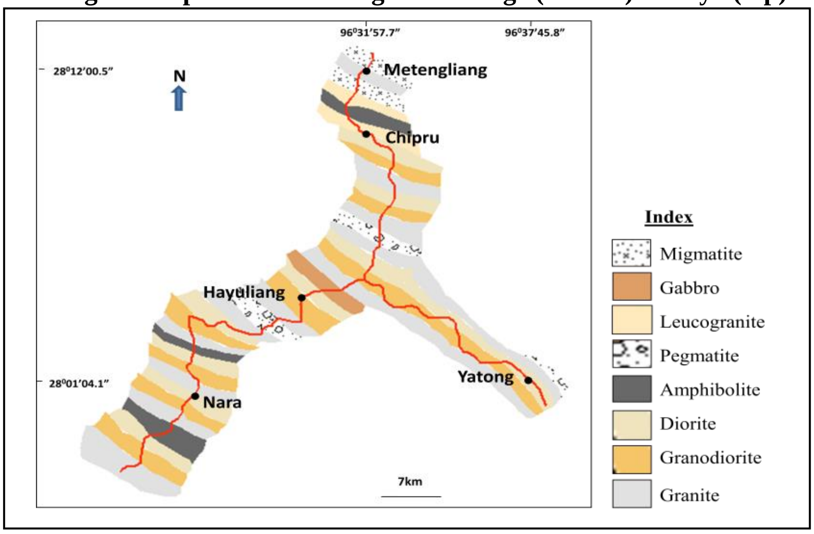


Figure 1b. Lithological Map from Paya (bottom) to Nara (top) along Lohit valley

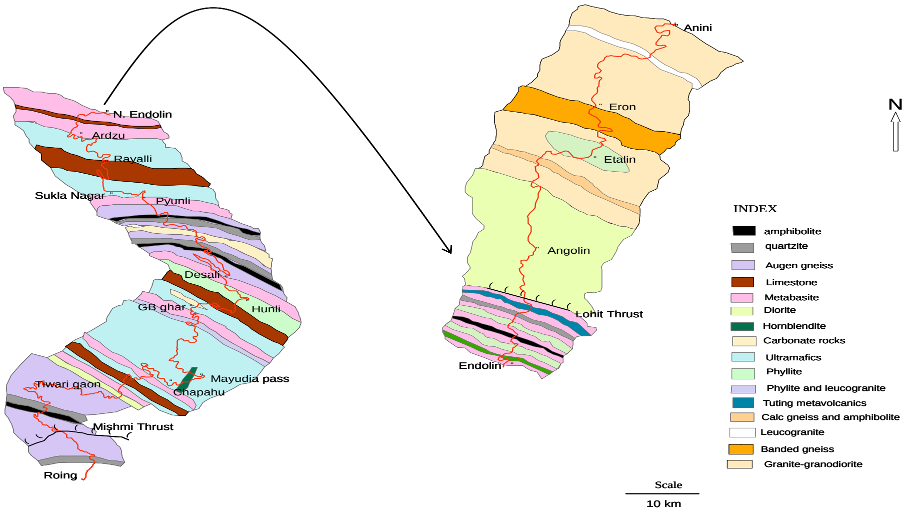


Figure 2. Lithological map along Dibang valley (after [7])

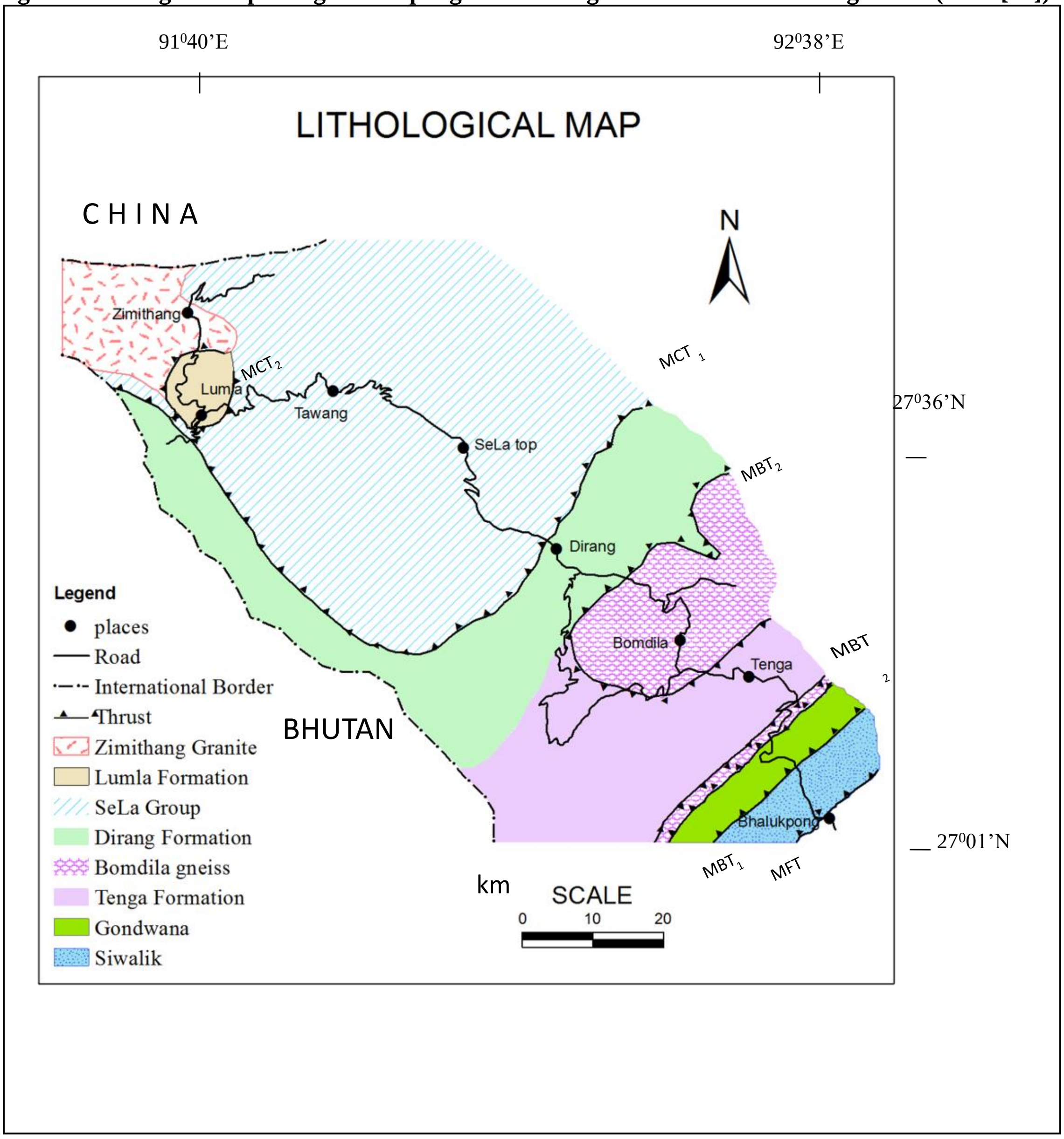
In Dibang valley Pleistocene river terraces are observed in the Deopani river near Roing (the Head quarter of the Lower Dibang valley district). Proterozoic augen gneisses thrust over Pleistocene river terraces. This thrust is designated as Mishmi Thrust. In Lohit valley Pleistocene river terrace is overlain by Lesser Himalaya and the latter is thrust over by Proterozoic gneiss. Reference [4] has advocated two fold divisions of Lesser Himalaya into Lesser Himalayan sedimentary sequences (LHSS) and Lesser Himalayan crystalline (LHC) and as such these two nomenclatures are used in this communication. Lesser Himalayan Sedimentary Sequence dominantly comprises of phyllite, quartzite, quartz – actinolite – schist and Lesser Himalayan Crystalline comprises of biotite gneiss and augen gneiss with protoliths of amphibolites in both Lohit and Dibang sectors. The thickness of the sheared gneissic belt is more in the Lohit valley than the Dibang valley (Figs.1a,b;2). Lesser Himalaya is overlain by metasedimentary and metavolcanic rock association and they represent the Dibang Group in Dibang valley and Mishmi Group in Lohit valley ([5], [6], [7]). The thickness of the rocks of the Dibang Group is almost double than that of Mishmi Group. The Dibang Group has two distinct stratigraphic units- metavolcanic Ithun Formation followed by metasedimentary Hunli Formation [6]. Amphibolites, hornblende schist, actinolite – chlorite schist, metapellite, carbonaceous phyllite, crystalline limestone, quartzites are the main constituents of metasedimentary and metavolcanic rock association in the both valleys (Figs. 1a,b & 2). These rock units are further overlained by Mayudia Mafic Ultramafic Complex and Tidding ophiolite complex in Dibang valley and Lohit valley respectively. The mafic – ultramafic complex represents a layered assemblage of ultramafics (Peridotite/Serpentinite), coarse grained pyroxenite, hornblendite, dunite and basic schist with intercalation of chert, mafic dykes / sills and leucogranite veins [8]. Thickness of these rock units are more in Dibang valley than the Lohit valley. Huge occurrences of diorite – granodiorite – tonalite - granite gneiss enclosing some of the schistose assemblages are seen. Popularly this gneiss complex is named as Lohit Granitoid Complex or Mishmi massif which separates the metavolcanics and metasedimentary units. This tectonic contact is marked as Lohit thrust and is located between Paya and Nara in Lohit valley and south of Endolin in the Dibang valley [2]. One point of argument, why Siwalik and Gondwana lithosequences are absent in Lohit and Dibang valleys (?). Another aspect needs further explanation whether Siang block along Siang river valley behave independently with a major antiformal fold structure with sinistral vergence occupying the core by rocks of Permian age?. The lithosetting, metamorphism and structural behaviour of the Siang domal structure do not match with the geological framework of the Lohit and Dibang sectors, neither seems to be a continuation of the Lohit and Dibang valley further west (?). Reference [9] have advocated that probably Siang sector could be addressed as a separate entity of geounit showing an antiformal syncline linked with western Arunachal Himalaya rather than an integral part of Mishmi Himalaya. Geomorphological approach relating to E – W trending Tsangpo river and its deflection towards south along or parallel to the Namcha Barwa and Siang antiformal planar orientation has got some bearings regarding linkage and genetic relationship of tectonism between the two major structures.

III. WESTERN ARUNACHAL HIMALAYAN BELT

The western sector of Arunachal Himalaya is referred to here as Bhalukpong – Tawang – Zimithang sector which portrays varied group of lithocomponents from Proterozoic to Pleistocene period. A series of tectonic contacts and thrusts are delineated from lower structural level to the south to higher structural levels to the north [2]. Pleistocene/Brahmaputra alluvium zone represents southern end of the lithounits and they are thrust over by Siwalik followed by Gondwana, Lesser Himalaya, and Higher Himalaya and at extreme end emplacement of Zimithang granite of Permian age marks the northern end of the geotransect (Fig.3). The lithounits are highly deformed, intensively sheared and metamorphosed during Himalayan orogeny and registered the imprints of multideformational phases and associated metamorphic signatures.

Referrence [10] have established an anticlinal fold of isoclinal geometry near Bhalukpong at or near Assam – Arunachal Pradesh Interstate boundary at the lower structural level which marks the Main Frontal Thrust (MFT) separating Siwalik at the hanging wall of MFT from Brahmaputra alluvium. The footwall side of the conventional Main Boundary Thrust (MBT) is traceable at $27^0$05'20"N: $92^0$35'18"E and is occupied by Eocene marine and volcanic strata bound sequences. The MBT is not represented as a single line but constitutes a zone, forming lower (MBT_1) and upper (MBT_2) respectively(Fig.3). MBT_1 separates Permian sequences from overlying Proterozoic Bomdila Group. Bomdila Group comprises of Dedza Formation, Tenga Formation and Dirang Formation and they are intruded by large scale Bomdila augen gneiss. Carbonaceous phyllite, phyllite and dolomitic limestone are the main lithounits of the Dedza Formation; Tenga Formation is constituted by quartzite, mafic meta volcanics and phyllites. The Dirang Formation is mainly metasedimentary unit forming garnet-kyanite-staurolite bearing metapelite, quartzite, phyllite with minor intercalation of metavolcanics including amphibolites, quartz – actinolite schist and they form footwall of the MCT. Low grade metamorphism of the Lesser Himalayan Sedimentary Sequence is structurally overlain by megacrystic granitic gneiss (Bomdila augen gneiss). An undoubted tectonic contact is noted by earlier researchers. It has a linkage with Cenozoic thrusting upliftment mechanism and represents a tectonic counterpart of Palaeo to Mesoproterozoic basement rocks of Indian subcontinent [11]. The Dirang Formation is structurally overlain by garnet-kyanite-sillimanite bearing metapelitic rocks, leucogranite, garnetiferous amphibolite, calc-silicate rocks, sillimanite bearing quartzofeldspathic gneiss and migmatites together forming “SeLa Group” on the hanging wall side of the MCT zone. Around 4 km from Dirang, on way to Tawang, the MCT is observed ($27^{0}22’42”$N: $92^{0}13’54”$E). Lithological variation and presence of a hot spring along the interface between SeLa Group and Dirang Formation may be considered as another signature indicating the presence of a thrust namely MCT (= Dirang Thrust). Referrences [12], [13] have the opinion that the MCT marks as a 5-7 km ductile zone rather than a single line similar to that of MCT zone of Bhagirathi valley [14]. Beyond Tawang, on way to Zimithang, a huge closed outcrop named as Lumla Formation is observed and has been referred to as tectonic window ([15], [10], [16]). Lumla is equated with the rocks of Dirang Formation. The Dirang thrust may be designated as MCT_1 and Lumla thrust be as MCT_2. The southern tectonic contact of Lumla Formation with SeLa Group is marked at $27^{0}33’14”$N: $91^{0}45’29”$E while the northern contact with Zimithang granite is marked at $27^{0}37’48”$N: $91^{0}43’16”$E, 35.5 km from Lumla towards Zimithang. Zimithang granite is a huge batholithic body of deformed to partly undeformed coarse grained leucocratic to mesocratic rock of Permian age [12].

Figure 3 lithological map along Bhalukpong – Zimithang Traverse of the Tawang sector (after [11]).



The International boundary between India and Tibet is passing through this granite massif at a few kilometers north of Zimithang and hence tracing of its northern limit is beyond our scope. Formation of Shonga-tser Lake (popularly known as Madhuri lake) at $27^{0}43’40”$N: $91^{0}49’42”$E is an imprint of Neotectonic activity near International Boundary between India and Tibat. Its contact with the Sela Group is traceable towards east and SE of Zimithang – Tak –Tsang Gompa road. The Zimithang granite is thrusted over the Lumla Formation and this thrust is considered as upper limit of the Lumla Thrust or may be referred to as "Zimithang Thurst" (ZT) ([2], [11]) equivalent to Kaktang thrust of Bhutan [17]. South Tibetan Detachment System (STDS) separating Tethyan sedimentary sequence is not exposed in this geotransect.

IV. TECTONOSTRATIGRAPHY

Reference have suggested The continental crust south of Indo Suture Zone is a part of the Indian craton [18]. Referrence [19] on the other hand, stated that Precambrian of Himalaya is not simply correlatable with the Precambrian of Aravali craton. Lots of researches are still going on to give emphasis to understand the genesis of this orogenic system since the development of plate tectonics in sixties, owing to the fact that continent – continent collision is the dominant and most efficient process in forming the supercontinent, which profoundly affect the geologic and biologic evolution of the earth. However, there is a general concern and probably agreement that the Great Himalayan Orogeny might have erased all the earlier structural evidences and associated metamorphism irrespective of Indian and/or Tibetan plates. The entire metamorphism of Himalayan Orogen can be partitioned into Protohimalayan, Eohimalayan and Neohimalayan corresponding to Cretaceous - Early Eocene period, middle Eocene to late Oligocene and early Miocene to recent respectively [20]. Since Himalaya is a thrust bound orogenic belt and a resultant of continent-continent collision tectonism, it is apparent that the normal stratigraphic sequences are obliterated or disordered. Therefore, tectonostratigraphy plays a vital role in the Himalayan belt.

In a collisional zone like Arunachal Himalaya, it is difficult to establish a normal stratigraphic sequence due to large scale thrusting or nappes. Therefore, tectonostratigraphy is the only tool to handle the complicated history of Arunachal Himalayan evolution. The WAHB bears a true Himalayan signature, which is a lateral extension from Western Himalaya through Nepal Himalaya, Sikkim Himalaya and Bhutan Himalaya up to Bame fault (probably inclusive of Siang Domal structure ?). All the lithopackages of Sub- Himalaya, Lesser Himalaya, Higher Himalaya and Trans Himalaya are present here. Whereas, EAHB or Mishmi Block is a separate thrusted geo-unit transported from Mogok Belt of Burma [21], juxtaposed like tectonic roof or umbrella over the two pillars like WAHB and Indo Myanmar Mobile Belt (IMMB) [9]. Referrence [3] also suggested tectonostratigraphic succession of the Mishmi block as follows (from south to north):

LGC (Lohit Granitoid Complex)
--------------Lohit Thrust---------------
Tidding Formation
--------------Tidding Thrust-------------
Mayudia group
-------------------MCT--------------------
Lalpani Group
-------------Lalpani Thrust---------------
Sewak Group
--------------Mishmi thrust--------------
Brahmaputra alluvium

With respect to the above stratigraphic successions, an attempt has been made to revise the tectonostratigraphic succession of the Dibang and Lohit valleys of the EAHB as follows (Table 1):

Modified tectonostratigraphic succession of the Dibang valley of Eastern Arunachal Himalaya (modified after [6]) is shown in table 1 below:

Table-1: Tectonostratigraphic succession of Dibang valley

	Lohit Granitoid Complex		Diorite, granodiorite, tonalite, gabbro, granite, Leucogranite, mafic dykes and sills	Tertiary
	Italin Formation		Garnet-staurolite-kyanite schist, garnetiferous amphibolites, quartzite	
	------------------------- Intrusive /DSZ-ductile shear zone-/Lohit Thrust ----------------------			
	Tuting Metavolcanics (TMV), Tidding metavolcanics		Amygdular sheared Basalt, ultramafics, serpentinite, crystalline limestone, metavolcanics	Cretaceous (?)
			----Tidding Suture zone----	
	Mayudia Mafic-Ultramafic complex		Ultramafics,peridotite/serpentinite/pyroxenite); dunite, amphibolites with interlayering of cherty quartzite, leucogranite veins, garnetiferous graphite schist, Hornblendite dykes/sills.	
	------------------------- Mayudia Thrust -------------------------			
	DIBANG GROUP	**Hunli Formation**	Quartz-chlorite ± actinolite schist with thick carb. Phyllite, phyllite and thin intercalations of limestone, carbonate rock.	
		Ithun Formation	Amphibolite intercalations of quartzite	
	----------- DSZ - ductile shear zone -------------------			

	Roing Gneiss (equivalent to **Bomdila Gneiss)**	Augen gneiss in association with amphibolites and quartzite, hornblende schist. Actinolite schist.	Meso-proterozoic
	---------------------------------	----------Mishmi Thrust----------- Pleistocene River Terrace	

Similarly, tectonostratigraphic succession of the Tawang sector of the WAHB is presented in table 2.

Table-2: Tectonostratigraphic succession of Tawang sector

LITHOUNITS			LITHOLOGY	AGE (approx.)
Zimithang granite			Grey to pink massive to augened granite, a medium grained leoco phase intrudes to grey phase	286±41 Ma 878±12 Ma (Yin, 2006)
Lumla Formation MCT_2– Thrust window				
			Leucogranite	27±5 Ma 28-20 Ma (Kumar, 1997)
Intrusive contact				
Higher Himalayan Sequence	SeLa Group		Migmatitic gneiss, sillimanite bearing gneiss, quartzites, amphibolites	
Main Central Thrust—MCT--				
Lesser Himalayan Sequence	Lesser Himalayan Crystalline (LHC)		Augen gneiss	1676±122 Ma 1914±14 Ma (Dikshitulu,1953)
	Lesser Himalayan Sedimentary Sequence(LHSS)	Dirang / Lumla Formation	Metapelite, quartzite, amphibolite, calc –silicate rocks	~950 to ~2960 Ma
		Tenga / Dedza / Chiellipam Formation	Phyllite, Conglomerate, low grade quartzite Limestone, schistose rocks etc	
MBT_2 (Depositional Contact)				
GondwanaSupergroup			Sandstone, shale, carbonaceous shale, thin coal seams	Upper Palaeozoic/Mesozoic age
Main Boundary Thrust (MBT_1)				
Siwalik			Shale, Sandstone, mudstone.	13–2.5 Ma
Main Frontal Thrust (MFT)				
Alluvium				

V. DISCUSSION

In Tawang sector from lower to upper reaches i.e. from south to north Brahmaputra Alluvium, Siwalik, Gondwana, Lesser Himalaya including Bomdila gneiss, Higher Himalaya and Zimithang granite of Permian age are recorded and all the lithounits are marked by thrust system. Along Lohit and Dibang valleys of Mishmi block from south to north the lithosequences are found as Brahmaputra alluvium followed by Lesser Himalaya, Higher Himalaya (Mishmi group=Dibang group), Tidding suture zone and Lohit granitoid complex. Lohit thrust at the upper structural high between Tidding ophiolite zone and LGC and Mishmi thrust at lower stage between LHSS and Brahmaputra alluvium are observed. Such indifferent geological framework between these two extreme ends of Arunachal Himalaya leads to some amount of confusion and complexities. Why Siwalik and Gondwana are missing from Lohit and Dibang valley? Why ophiolites (Tidding serpentinite) are missing in Tawang sector? Why conglomerate and sillimanite (as prograde product) are absent in Lohit and Dibang sector?. Even clockwise rotational movement of Indo Myanmar mobile belt to the SE and anticlockwise rotation of the Mishmi block against clockwise rotation of the Himalayan belt around Namche Barwa syntaxial zone are some of the notable features which may through some insights regarding the geodynamic evolutionary history of the Mishmi block, more specifically Arunachal Himalaya.

The most spectacular geotransect joining Bhalukpong at the lowest structural level and Zimithang at the highest structural level bears the identity of an important tectonostratigraphic sequence and sets as a unique multideformed terrain representing from Sub Himalayan zone, Lesser Himalayan Zone and Higher Himalyan Zone. Unfortunately, nowhere Tethyan sequence is observed along this geotransect and therefore, Indo – Tibetan detachment fault system is not exposed anywhere in the northern boundary of the Indian plate within the Territory of the Indian subcontinent..

Paucity of geochronological data from rocks of different stratigraphic zones point to some amount of difficulties to set the order of stratigraphy, therefore, tectonostratigraphy of western part of Arunachal Himalaya with some amount of correlation between eastern, central and western parts of Arunachal Himalayan belt elsewhere in the Indian plate is desiphered. The lithostratigraphic units from lower to higher reaches of the western part of Arunachal Himalayan belt within Indian Territory are more or less can be equated and correlated with Subansiri sector of Arunachal Himalaya. The same is also co relatable with the Siang sector of Mishmi block. But it is not identical and hence not co relatable with the Dibang and Lohit sectors of Mishmi block. The notable differences between Western Arunachal Himalaya (Tawang sector) and Lohit and Dibang sectors of Eastern Arunachal Himalaya are as follows:

Proper representative of suture zone is marked as ophiolites and it is present in the Lohit and Dibang sector of the Mishmi Himalaya while they are missing in the Tawang sector. In Tawang sector, both Siwalik and Gondwana rocks are well exposed while in Lohit and Dibang, Siwalik and Gondwana are missing. In Tawang sector sillimanite is present in metapelitic rocks of the SeLa group (amphibolites facies), while metapelites of Dibang and Lohit sector are devoid of sillimanite and rocks are affected by garnet to staurilite-kynite zones belonging to greenschist to middle amphibolites facies [9]. Permian acid magmatic rocks (Zimithang granite- 286±41Ma- [12]) are found in Tawang sector and such acid magmatic influx is absent in Lohit and Dibang sectors. Nagmandir and Shergaon conglomerate horizons are found in Lesser Himalyan sequences of Tawang sector [11], while in Lohit and Dibang sector, no conglomerate is found. High grade migmatitic rocks of SeLa Group are found in Tawang sector while they are missing in Dibang and Lohit sector. Tertiary granite – granodiorite complex (=Lohit granitoid complex) is significantly observed in Lohit and Dibang sectors but such granite-granidiorite complex is not found in Tawang sector. Gondwana and Siwaliks are present in Tawang, Subansiri and Siang sectors. Therefore, it would be more logical to draw attention of the geoscientific communities that western Arunachal Himalaya has a litholinkage with the Subansiri and Siang sectors of Arunachal Himalaya. Dibang and Lohit sectors have probably maintained their own status in Indian context delinking with rest parts of the Himalayan belt and might have tectonically transported from Burmese plate (Mogok belt of Myanmar, [21]) and rest over the two pillars like western Arunachal Himalayan to the SW and Indo Myanmar mobile belt to the SE as tectonic linkage or tectonic roof [7],[12].

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