STRATIGRAPHIC ASPECT OF RECENT EARTHQUAKE OCCURRED ALONG THE BALAKOT-BAGH FAULT, NORTH-WEST HIMALAYAS, PAKISTAN

BY

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Abstract: *The Balakot-Bagh thrust running from Balakot through Muzaffarabad to Bagh Azad Kashmir along the eastern limb of Hazara Kashmir Syntaxis. Stratigraphically this fault occurred between the late Cambrian Abbottabad Formation and the Miocene Murree Formation from Balakot to Muzaffarabad city which is a major unconformity, while from Muzaffarabad city to Bagh through Chikar it runs within the Murree Formation.The BBT is a shallow thrust which enters upto the depth of Middle Eocene Kuldana Formation . Along the BBT, the Murree Formation thrusting over Siwalik Group due to under lying shales of the Kuldana Formation which act as a decollement. The two unconformities have been observed during this study. First major unconformity is marked between the late Cambrian Abbottabad Formation and the Paleocene Hangu Formation and the second minor oneoccur between the middle Eocene Kuldana Formation and the Miocene Murree Formation.*

INTRODUCTION

Stratigraphy in particular and tectonics of the study area are found to be very interesting during and after the occurrence of 8th October 2005, Earthquake in Hazara & Kashmir. Himalayas are extended from Burma to India and then in Kashmir and Northern Pakistan. Where it bended and formed the Nanga Perbat syntaxis and Hazara Kashmir syntaxis. The area remained uplifted at least two times. The oldest unconformity is of late Cambrian Abbottabad formation forming bauxite/laterite as part of Galdanian Formation in Hazara which merge with Cretaceous unconformity of Muzaffarabad and Kotli areas. The second unconformity is between middle Eocene Kuldana Formation and Miocene Murree Formation. The third unconformity is found between the Miocene Murree Formation and Pliocene/Pliestocene Siwalik group in Chikar towards Bagh area of Azad Kashmir (Figs. 1 & 2, Tables 1 & 2).

There might be some stratigraphic barriers due to non-continuity of certain formations in Hazara, Azad Kashmir and occupied Kashmir but they were not as they were introduced by Ghazanfar and Chaudhry (1987) that these are three stratigraphic provinces.

In my view the three provinces are as Kashmir, Muzaffarabad and Hazara. These regions had same geological environments during Precambrain times depositing Salkhala sediments overlain by Hazara/Dogra slates and Tanol qunartizite and pelites. The Cambrian conditions remained similar as well in all the three areas by depositing limestone and dolomites. In all the three stratigraphic areas during late Cambrian unconformity is seen in Hazara in form of Galdanian Formation with subsequent non-deposition till the formation of Data Formation of Jurassic.(Table 1) But there are such formations ever up to late Cretaceous in the Muzaffarabad-Kotli Basin. Where as in Kashmir Basin in Kahuta-Pir Panjal Range, Gondwana Formation of Carboniferous occurs and is not seen in other two basins. It is once again mentioned here that Hazara is the only area where we find Mesozoic rocks but after this era, rock types right from Paleocene to lower Miocene are found every where. These rocks are Paleocene Hangu Formation, Paleocene Lockhart Limestone, late Paleocene Patala Formation, Early Eocene Margala Hill Limestone, Early Eocene Chor Gali Formation Middle Eocene Kuldana Formation, Miocene Murree Formation and Pliocene to Pleistocene Siwalik Group. The occurrence of Hazara-Kashmir Systaxis of the North-Western Himalayas as around Muzaffarbad form a great

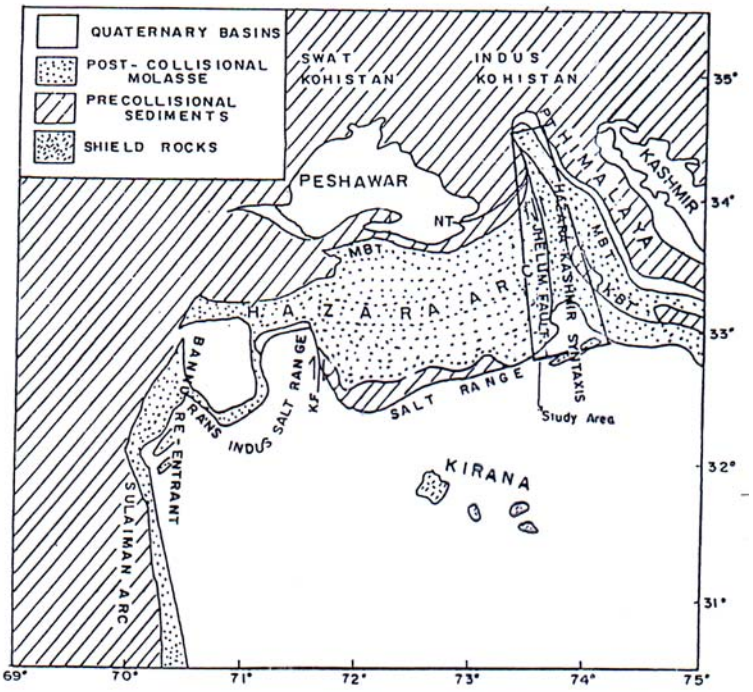

Fig. 1: Tectonic map of the Hazara Arc modified after Chaudhry & Ghazanfar (1992), Khan & Ali (1994) and Seeber et al. (1981)

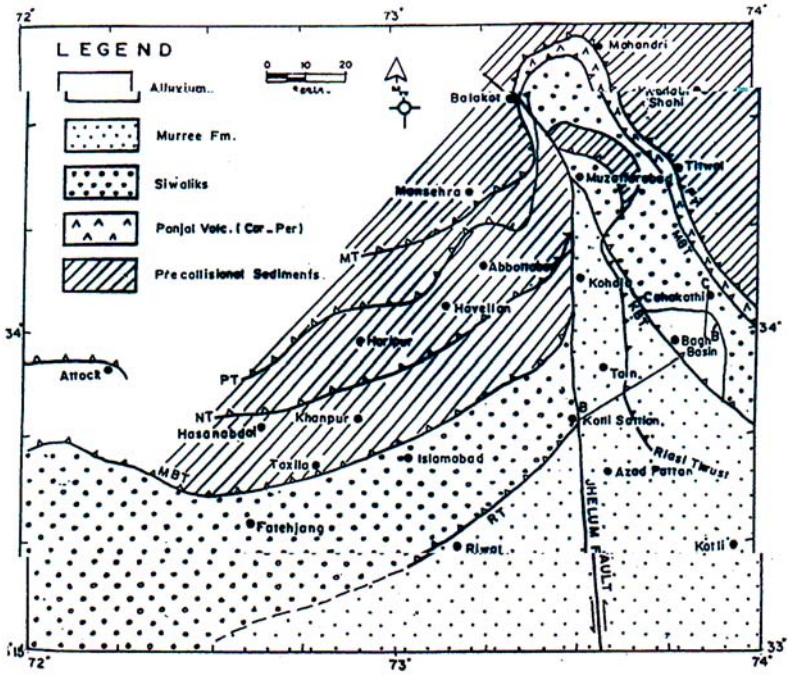

Fig.2: Generalize Tectonic map of Hazara-Kashmir Syntaxis in Northern Pakistan & Kashmir. BBT=Balakot-Bagh Thrust, PT=Panjal Thrust, MBT=Main Boundry Thrust, KBT=Kashmir Boundary Thrust, RT=Riwat Thrust, modified after Wadia (1928), Latif (1970), Calkins, et al. (1975), Baig and Lawrance (1987), Chaudhry and Ghazanfar (1992).

anticlinal structure with a lot of imbricate and nappe blocks (Fig.1).The rock units exposed in the area are given in table 1 & 2.

In recent publications Bossart et. al. (1984) and Greco (1986 & 1989) have misidentified the Kuldana Formation as Murree Formation. The Murree Formation is everywhere of the Miocene age as this identification by them is erroneous.

Table-1
Stratigraphic Sequence of Hazara Kashmir Syntaxis.

Rock type	**Age**
Alluvium	Recent to sub-Recent
Siwalik Group	Pliocene to Pleistocene
----------Unconformity----------	
Murree Formation	Oligocene to lower Miocene
----------Unconformity----------	
Kuldana Formation	Middle Eocene
Chor Gali Formation	Lower Eocene
Margala Hill Limestone	Lower Eocene
Patala Formation	Upper Paleocene
Lockhart Limestone	Lower Paleocene
Hangu Formation	Lower Paleocene
----------Unconformity----------	
Abbottabad Formation	Cambrian
Hazara Formation	Precambrian

PREVIOUS WORK

The project area has remained a site of deep interest for the geologists working on stratigraphy and tectonics since a long time. A brief summary of the previous work is given below:

Lydekker (1876, 1883) and Middlemiss (1896) carried out their work in Kashmir and Hazara. They established the broad outline of the geology in this region and named some of the rock units.

Wadia (1931) explained the syntaxis of the northwest Himalaya on the basis of geosynclina| group of deposits laid down on the bed of Tethys against the northern shores of Gondwana land.

Qureshi and Imam (1960) did the geological mapping of the area for iron and manganese ore deposits.

Calkins, Offield, Abdullah and Ali (1975) mapped Balakot area at 1:125,000 and discussed its geology. They delt the stratigraphy and structure of a sequence of rocks that range in age from Precambrian to Miocene. Structurally the area lies on the western flank of the Hazara Kashmir Syntaxis and contains iron, manganese, high alumina, clays, gypsum, dolomite and graphite. This work was done jointly by the Geological survey of Pakistan and U.S. Geological Survey.

The main interest of field of Thakur and Gupta (1983) was the regional stratigraphy, paleontology and structure of Kashmir and Ladakh Himalayas.

The Swiss geologists Bossart, Dorthe, Dietrich, Greco, Ottiger and Ramsay (1984) in collaboration with Institute of Geology Azad Jammu& Kashmir University described the lithological, stratigraphic and structural features of Hazara Kashmir Syntaxis.

Ottiger (1986) did his work on the geology of Hazara-Kashmir Syntaxis. He reviewed the lithological Formations and rhythmic sedimentation in Lower Murree Formation in detail.

Ghazanfar, Chuadry and Latif (1987) established three different sets of stratigraphic sequences which occur close together in the region of Hazara-Kashmir Syntaxis. These have been termed as the Kashmir sequence, the Muzaffarabad sequence and the Hazara sequence. The Balakot area contains elements of all three but mainly the Muzaffarabad sequence.

Ghazanfar, Chaudry, Zaka and Baig (1987) mapped nearly 65 square Kilometers of the area in vicinity of Balakot and described major structures and stratigraphy of the area. A new stratigraphic interpretation of the metamorphics was presented. The small but interesting Bamphora structure was explained. Bossart, Dietrich, Greco, Ottigar and Ramsay (1988) gave the interpretation of the tectonic and structure of the Hazara Kashmir Syntaxis, southern Himalayas of Pakistan.

Bossart and Ottiger (1989) studied the rocks of Murree and described it as a descending foreland basin of Late Paleocene to Middle Eocene age.

Greco Antonio (1990) described the stratigraphical and metamorphic features of the rocks of the Hazara Kashmir Syntaxis. He subdivided the area into Sub, Lesser and Higher Himalayan tectonic elements. A mode for the tectonic evolution of the area based on the coherent and continuous development of the observed small and large scale structural and metamorphic features were suggested by him.

Table-2:
Stratigraphic Correlation from Cambrian to Miocene Rocks of Hazara-Kashmir Syntaxis, Northwest Himalayas, Pakistan.

Western limb of Hazara Kashmir Syntaxis Hazara	**Eastern limb of Hazara Kashmir Syntaxis**			**AGE**
	Balakot	**Kotli**	**Yadgar**	
Murree Formation	Murree Formation	Murree Formation	Murree Formation	Miocene
Fetehjang member -- disconformsity— Kuldana Formation	Kuldana Formation	Kuldana Formation	Kuldana Formation	Early to Middle Eocene
Chor Gali Formation	Chor Gali Formation	Chor Gali Formation	Chor Gali Formation	Early Eocene
Margala Hill Limestone	Margala Hill Limestone	Margala Hill Limestone	Margala Hill Limestone	Early Eocene
Patala Formation		Patala Formation	Patala Formation	Late Paleocene
Lockhart Limestone			Lockhart Limestone	Late Paleocene
Hangu Formation	Hangu Formation	Hangu Formation	Hangu Formation	Early Paleocene
	unconformity	unconformity	unconformity	Late Cretaceous
---------unconformity--------- Kawagarh Formation				Early Cretaceous
Lumshiwal Formation				Early Cretaceous
Chichali Formation				Jurassic
Samana Suk Formation				Jurassic
Datta Formation ---------unconformity--------- Guldanian Formation				Cambrian
--------disconformity--------- Hazira Formation				Cambrian
Abbottabad Formation	Abbottabad Formation	Abbottabad Formation	Abbottabad Formation	

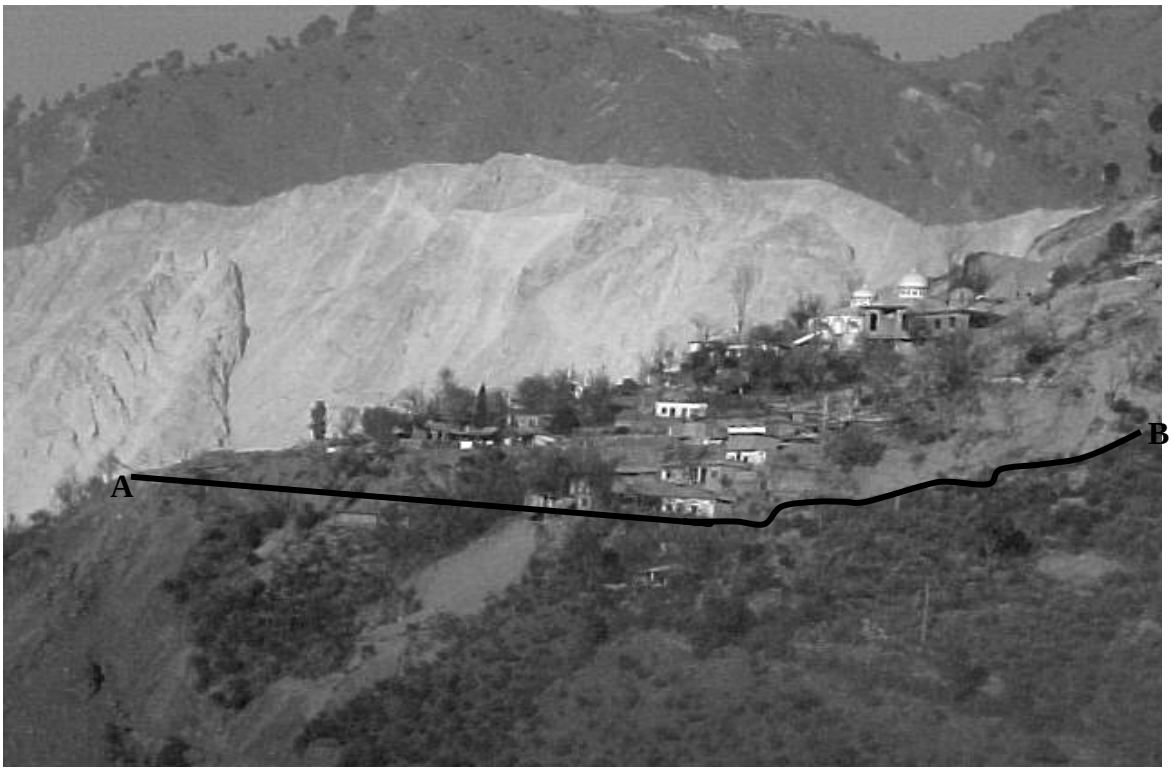

Photo – 1: Line A – B marks the thrusted contact between the Abbottabad Formation above and The Murree Formation below at Neela Dandi, Muzaffarabad.

Photo – 2: Neelum River crosses the Abbottabad and the Murree Formations and the BBT at Chehla Bandi near University Campus Muzaffarabad.

Photo – 3: Line A – B marks the BBT at Upper Ranjata, Muzaffarabad.

Photo – 4: Line A – B marks the BBT at Chattakian, Muzaffarabad.

Photo – 5: Stromatolites upto 1meter within the Abbottabad Formation.

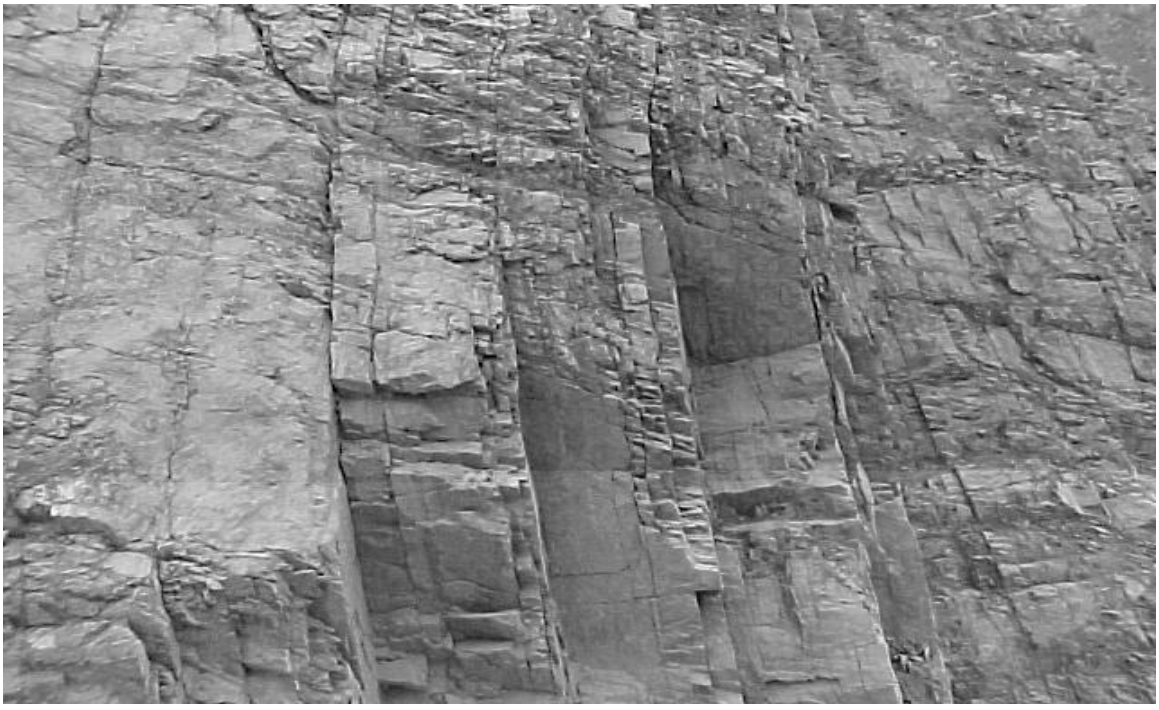

Photo – 6: Bedded Muzaffarabad Formation at Yadgar, Muzaffarabad.

Medlicott (1876) did the preliminary work on Jammu Hills as the Sub-Himalayan Series.

Lydekker (1883) described the geology of Kashmir and Chamba territories and the British district of Kaghan for Geoloigcal Survey of India.

Wadia (1928) first time described the Geology of the Poonch state (Kashmir) and adjacent portions of the Punjab on 1:4 inches scale. His studies were mainly focused on stratigraphic and mineralogical aspects. He established broad outline of the geology of this region. He reported a nearly identical Ossiferous Pseduconglomerates with chelonian and mammalian bones from the basal purple shales at Nikial. The paleontologists of the University of Michigan and the Museum National de Historre Naturelle of France visited Wadia's sections in 1981, but they were unable to rediscover his fossil bed.

Ashraf and Chaudhry (1980) have carried out a comprehensive work on the geology of Azad Kashmir especially in Poonch and Kotli area. They also described the clayey bauxite and clay deposits of Kotli in detail. They separated the Siwalik Group by comparing the overall compositions of these rocks in Poonch area.

Ashraf, Chaudhary and Qureshi (1983) discovered the Precambrian formation "Dogra Slate" in Kotli (Nail Nala) for the first time. The lithostratigraphic units range in age from Precambrian to Recent consisting mainly of sedimentary rocks with minor intrusions of basic sills and dykes. They described two prominent unconformities. Their work in the area has led many geologists.

Baig and Lawrence (1987) did an extensive geological work on the different phases of orogeney and dated the Precambrian to Early Paleozoic rocks in the Himalaya. They gave the evidence of tectonism from Late Precambrian to Early Cambrian rocks in Hazara, Kotli and the Nepal Himalaya by the presence of an angular unconformity. They also correlated the Hazaran orogeney in the Himalaya which occurred before the Permo-Triassic breakup of Gondwana with the Pan-African, Baikalian, Cadomian, Katangan and Assyntic orogenies of Africa, Asia and Europe.

Wells and Gingerich (1987) interpreted the paleo-environments of Paleogene strata in the area. In their studies they correlated these strata with Muzaffarabad, Hazara, Kohat, Kala Chitta, Kalakot and the Jammu regions giving the names of the units from A to J as Subathu Formation deposited by a single cycle of transgression and regression during the Early Eocene.

Recent work has been contributed by Rustam (2003) on the study of shallow geological structure in the core of Hazara Kashmir Syntaxis based on residual gravity data in the area. All this geological work in the area is mainly on the structure, tectonics and stratigraphy. In the light of the previous work mentioned above, it is evident that the present research is the first comprehensive contribution in the new direction related to the stratigraphic analysis of the stratified rocks of Neotethys Ocean in Azad Kashmir and Hazara area of the Himalayas of Pakistan related to the BBT.

STRATIGRAPHIC SETTING

The rock units exposed along the Balakot-Bagh Thrust (BBT) formerly known as Kashmir Boundary Thrust (KBT)/ Murree fault (MF)/ Muzaffarabad fault (MF)/Himalayan Frontal Thrust (HFT) are Abbottabad formation, Murree Formation and Siwalik group.

ABBOTTABAD FORMATION

Waagen and Wynne in 1872 studied the sequence of dolomite and quartzite rocks overlying the Hazara Formation in the Sirban Hill near Abbottabad town and named it "Below the Trias". Middlemiss (1896) renamed it "Infra-Trias". Marks and Ali (1962) suggested the name Abbottabad Formation. Calkins, Offield and Ali (1969) who mapped southern Hazara and studied all its exposures adopted the name Abbottabad Formation. Latif (1970a) named this unit of rocks as "Abbottabad Group" and divided it into constituent formations.

The type section of the formation is designated near Abbottabad town. The exposures are found between Muzaffarabad and Balakot and in the upper area of Hazara Kashmir Syntaxis. The formation consists mainly of cherty dolomite, chert bands and pure dolomite bands with many lithologic facies from place to place.

At some places, basal conglomerate is overlain by quartozose sandstone followed upward by alternating dolomite and limestone which is mainly fractured with white, grey, creamish, off white and blue in colour. The large sized stromatolites upto one meter radius are present at based bedding plains especially in Yadgar area of Muzaffarabad (Photo-5). The Main Boundary thrust (MBT) after swinging around the syntaxial bend becomes Balakot-Bagh Thrust (Murree Thrust) near Muzaffarabad separating Hazara Formation and Abbottabad Formation (Sirban Formation of Latif, 1974). The formation is 100-900m thick in the Hazara Kashmir Syntaxis. From Balakot to Muzaffarabad city, it has unconformable contact with over lying Hangu Formation towards the northeastern Neelum valley and Thrusted contact towards the south-western side with Murree Formation. The formation has revealed the presence of small conical tubes

Photo – 7: Neelum River crossing the BBT and the Paleogene sequence at Yadgar Muzaffarabad.

Photo – 8: Paleogene sequence in the core of BBT at Yadgar Muzaffarabad.

known as *Hyolithes* sp. on the basis of these fossils the Cambrian age is given to the formation.

The sheared material (Aggregate) of Abbottabad Formation were used in building and other construction purposes which caused heavy damage in the area. This invaluable material is still being used by the people for constructions (Photo - 6).

MURREE FORMATION

The "Mari Group" of Wynne (1874), "Murree Beds" of Lydekker (1876) and "Murree Series" of Pilgrim (1910) have been formally named Murree Formation by the Stratigraphic Committee of Pakistan from the Murree Hills in Murree District.

The formation is composed of red thinly laminated siltstone, shale, clay, with subordinate intraformational conglomerate. The sandstone is fine to medium grained, pale green to grey, maroon coloured, calcareous and greywacke in nature. The beds of sandstone, clay or shale alternate with each other. This pattern shows a cyclic deposition. In sandstone veins of calcite and quartz are common. At few places beds of calcareous sandy conglomerates are calcareous, flattened and squeezed in various shapes. Some of which are tapered to point on one end. Evidently these pebbles originally were soft calcareous and balls formed at the site of depositions rather than the detritus material brought from elsewhere.

The large areas of Jhelum Valley and Neelum Valley are covered with Murree Formation (Figs 1&2). In the Jhelum Valley it is thickly exposed and its upper faulted contact with Punjal Volcanics throughout the area extending in SE direction to the occupied Kashmir, in NW direction to the Neelum valley with in the Hazara Kashmir Syntaxis (Fig. 2). It is unconformably underlain by the Kuldana Formation of Middle Eocene time (Photo - 7).

This contact is marked by Ashraf et al. (1993) as brecciated base near Panjgran, Neelum valley. Bossart et. al. (1983) and Greco (1989) misidentified Kuldana Formation and called it as lower part of Murree Formation giving Paleocene and Eocene age, which is misinterpretation possibly due to reworked complete forminiferal fauna found by them in this formation. The lithology and fauna of Kuldana Formation is distinctly different from it everywhere so as in this area. Therefore, their inclusion of Kuldana formation erroneously in this formation is due to two reasons. First may be due to similar colour of both the formations and secondly due to reworking of unbroken foraminiferal fauna from soft natured Kuldanas to stratigraphically higher level into shales of Murree Formation. Ashraf et. al, (1973) marked the Main Boundary Thrust between Carboniferous to Triassic Panjal Formation and Miocene Murree Formation along the eastern limb of Hazara Kashmir Syntaxis. (Figs.1 & 2)

DISCUSSION

The Himalayan mountain belts have developed as a result of collisions between various continental and micro continental plates of Gondwana and Euresia (Stocklin, 1977, Tahirkheli et. al, 1979, Farah et. al, 1984). Early separated plates of Gondwana (Cimmeria) separated during the Permo-Triassic times and collided with Euresia in the Mid-Mesozoic in association with the closing of the Paleotethys sea (Sengor, 1984).

Between the Late Cretaceous and Mid-Eocene, the Indo-Pakistani Plate collided with Cimmeride Blocks and the Neotethys ocean was closed initiating the formation of current system of Himalayan folded Belts. The complete closer of the Neotethys ocean occurred in the Middle Eocene, followed by initiation of the main phase of thrusting and folding in the northwest Himalayas. The Kashmir Himalayas including the Panjal Block, Karakuram Range, Harmosh Range as well as the Nangaparbat Dome are all essentially closely related units. Powell & Conaghan (1973) put them all in the Himalayas. During the lower Cretaceous period the Tethys was well in place with India on one shore and Asia on the other. At least part of the Pir Panjal Range was not submerged. It formed part of the Indian mass.

Transgression of the sea took place in Paleocene and during Paleocene to Middle Eocene sea conditions persisted. However, sedimentation took place under unstable shelf basin conditions. The collision resulted in cyclic up and down movements resulting in the deposition of a sequence of limestones and shales. During part of Paleocene fairly shallow water restricted sea conditions developed where by coal and ironstones were formed followed again by the local deepening and deposition of limestones, shales and sandstones of Lockhart Limestone, Patala Formation, Margala Hill Limestone, Chor Gali Formation, Kuldana Formation and Murrree Formation. The Indian plate started under thrusting the Asian plate in Early Miocene.

Structurally the area is characterized by severe tectonic effects. It is highly folded, faulted and jointed. This is because the area lies close to one of the major syntaxial bend of the Himalayas know as Hazara Kashmir Syntaxis. The Hazara Kashmir Syntaxis is one of the most important structural feature of the region and displays prominent scar on the geological map (Fig. 2). The southern range of the Himalaya extend northward in a gentle unbroken curve of northern India, continue into Kashmir and Hazara District of Pakistan, where they from the eastern limb of the Syntaxis. Essentially continuous,

the major faults and most of the geological units turn abruptly westward at Paras to form the apex of the Syntaxis and then southward to form the western limb. The two main boundary faults wrap around the Syntaxis are considered equivalent to Waadia's Punjal and Murree Faults. Stratigraphically the syntaxis contain the youngest rocks in the core and successively older rocks wrap around the periphery.

CONCLUSION

1) The Earthquake of 8th Oct. 2005 was struck along the Balakot-Bagh Thrust formerly known as Murree Fault/ Muzaffarabad Fault/ Main Boundary Thrust, Himalayan Frontal Thrust becomes steeper near Balakot NWFP in the north and at Muzaffarabad it turns in the north south trend & dips very steeply westward to the Bagh District of Azad Kashmir.

2) Stratigraphically the Balakot-Bagh Thrust is running between the late Cambrian Abbottabad Formation & Miocene Murree Formation from Balakot to Muzaffarabad city. Afterward it occurred within the Miocene Murree Formation upto Bagh towards South east direction.

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