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Paleomorphology, Lithofacies and Tectonics at Play in Northwest Himalayan Basin

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ABSTRACT

Kirthar, Sulaiman and Northwest Himalayan sedimentary basins, which are oil and gas producing areas of Pakistan, are proposed to replace the existing Indus Basin.

The N. W. Himalayan Basin is extended to include all areas situated north of Indo-Gangetic water divide. It is subdivided into 8 troughs and 8 depressions based on paleobarriers deduced from lithofacies variations, isopachites and impact of unconformities, in Early Eocene. Based on the nature of rocks marked by major thrust faults, 7 provinces of the N.W. Himalayan Basin are suggested.

The nomenclature and courses of 5 major thrust faults and 2 major strike slip faults are revised. One of the later introduced for the first time, apart from the assumed extension of HFT east of Mangla.

The occurrence of a specific set of rocks enclosed by major thrust faults has led to the identification of 13 tectonostratigraphic blocks, 5 of these homologous on either side of the Muzaffarabad High.

Northwest Himalayas are subdivided into 5 morphotectonic divisions based on variations in altitudes, geology and major thrust alignments.

Based on well data, distribution of highs and water divides, a model of oil distribution is suggested, which could be useful in understanding hydrocarbon occurrence in these basins.

INTRODUCTION

The vastness of the Indus Basin, variations in the complexities of geology from one region to the other, variations in alignments and terminology of major faults from author to author and a lack of close examination and synthesis of published data, prompted the author to take this exercise.

The first serious attempt to provide a base for the basinal set up for a part of Pakistan was made by the Hunting Survey Corporation (1961). Zuberi and Dubois (1962) and Rehman (1963) followed with brief accounts based on HSC report. The first comprehensive attempt for the whole of Pakistan appeared in the form of The Geological Map of Pakistan (Abu Bakr and Jackson, 1964). In this map Pakistan is broadly divided into Baluchistan Basin, Indus Basin and Northern Montane Area. The Baluchistan Basin was subdivided into 6 belts: i. South Makran, ii. North Makran, iii. Raskoh, iv. Chagai, v. Zhob and vi. Axial. The Indus Basin was subdivided into i. Kirthar Province, ii. Sulaiman Province, iii. Kohat-Potwar Province, iv. Waziristan, v. Trans Indus and Salt Ranges and vi. Axial Belt.

With basic framework laid down as above, the later workers made attempts to improve it. Shah (1977), introduced a single axial belt separating the Baluchistan and Indus basins. He also introduced Jacobabad-Khairpur, Sargodha and Muzaffarabad highs. Kazmi & Riaz (1982) revised the southern limit of the Northern Montane Area, designating the rest of the area, to the north, as Karakoram-Himalayan, Crystalline & Thrust Zone. He also recognized Sargodha-Shahpur and Nagarparkar ridges. Farhat (1993) identified axial belt as a collision zone and added Nanga Parbat in the Indian basement complex in addition to the existing Sargodha and Nagarparkar. The Northern Montane Area was classified as composed of, from north to south, i. Hindukush-Karakoram Belt, ii. Kohistan and Ladakh arcs, iii. Peshawar-North Hazara and Kashmir-Zanskar Zone.

An intimate relationship between the abrupt facies variations and major thrust faults was spotted in the Kohat-Potwar Province (Latif et al., 1993). An exercise on similar lines in Hazara, Islamabad, & Azad Kashmir, at the base of Paleocene resulted in identifying 5 different facies of the Hangu Formation, apart from a barren zone indicating the presence of barrier ridges in the northwestern and eastern parts of southern Hazara (Latif et al., 1992). A similar exercise in the older sequences near Nathiagali, Hazara resulted in the spotting of algal limestones and gypsum, representing intertidal environments at Eocambrian level (Latif, 1970 & 1973) and confirmed by a water divide at Mesozoic level separating Haro Trough and Dor Depression (Latif et al., 1995). Comparative history of development of basin architecture is given in Table-1.

PROPOSED BASINAL ARCHITECTURE

There appears to be a consensus on the broad divisions, i.e., Baluchistan Basin, Indus Basin, Collision Zone and the Indian Basement Complex. The Indus Basin is subdivided further into three provinces, Kirthar, Sulaiman and Kohat-Potwar. The boundary of these basins are marked at localities Jacobabad (C5) and Marwat (C9) in figure 1. The sediments are thining out at these places as compared to maximum, development of sediments at Phulji (C3), Zindapir (C8) and Surghar (C10) in figure 1. The later three are considered as separate provinces (Abu Bakr and Jackson, 1964).

The three provinces of Indus Basin synchronize with three depressions of sufficiently large size to be identified as

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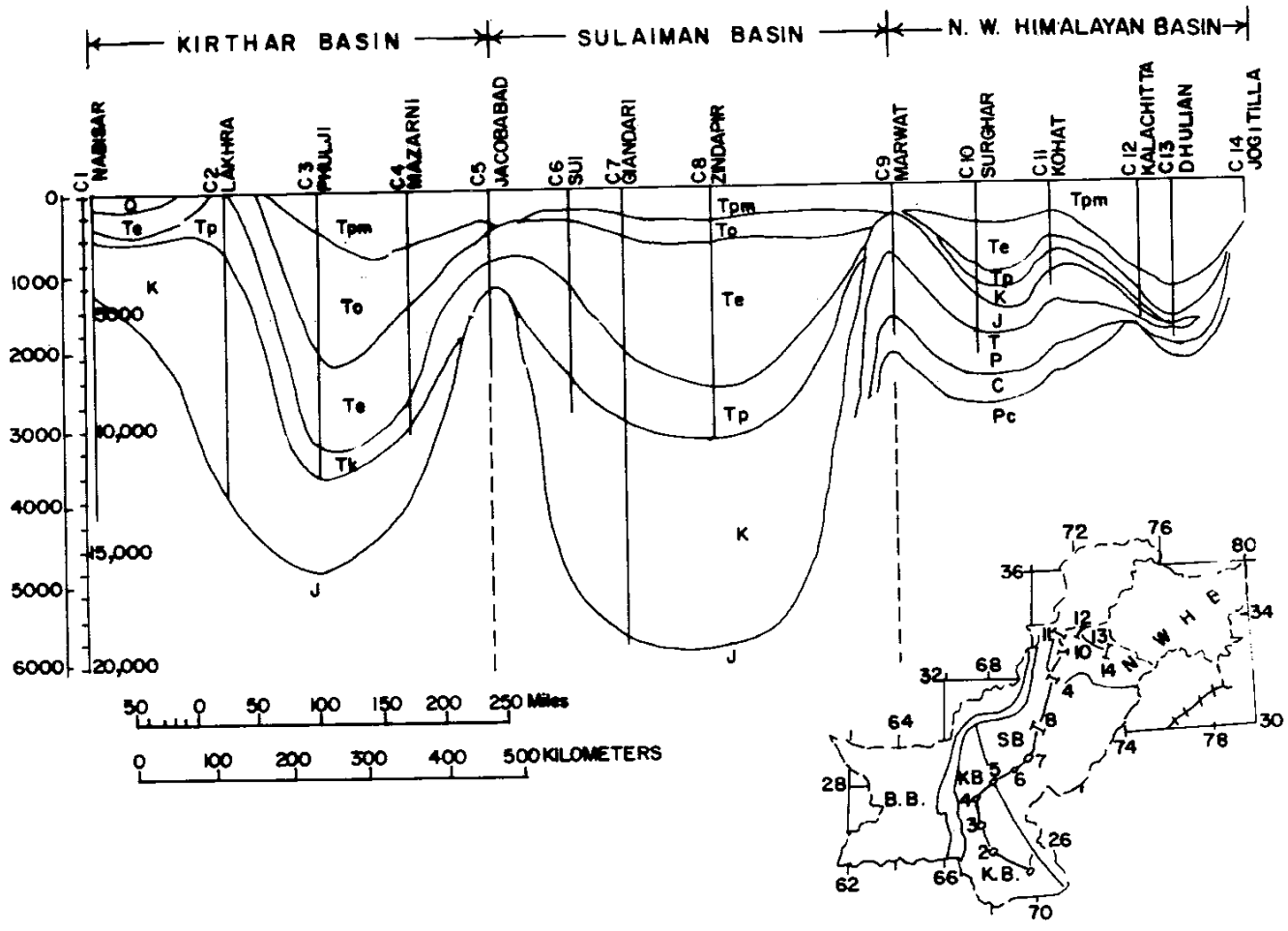


SYMBOL INDEX

Q	QUARTERNARY
Tpm	MIOCENE - PLIOCENE
To	OLIGOCENE
Te	EOCENE
Tp	PALEOCENE
K	CRETACEOUS
J	JURASSIC
T	TRIASSIC
P	PERMIAN
C	CAMBRIAN
Pc	PRE CAMBRIAN
⊢⊣	SURFACE
∘	WELL

Figure 1- Inter basin section correlation. (Modified after Abu Bakr and Jackson, 1964)

Section location map.

independent basins. It is, therefore, proposed that Kirthar and Sulaiman Ranges are separated by the Jacobabad-Khairpur High. The Kohat-Potwar Province falls in the northwest Himalayan Basin, with Salt Range representing the southern extension. It is proposed that the extended Kohat-Potwar Province may be redesignated as the Northwest Himalayan Basin separated from Sulaiman Basin by the Sargodha-Shahkot High and its western offshoot (Figure 2). A paleobarrier in western Kohat separates Sulaiman and the N.W. Himalayan Basins in western Kohat (Latif & Humayon, 1986; Latif et al., 1993). The said paleobarrier is extended further north to pass through between Peshawar and Nowshera in the north, later on heading northeastwards through Tarbela, Kakul and Daulatmar and truncated by the Jhelum Fault situated to the west of the Muzaffarabad High, during Early Eocene.

Beyond the northern limits of the N.W. Himalayan Basin/Indian Plate, Island Arc Belt intervenes with Asian Plate in the north represented by Hindukush and Karakoram belts.

LIMITS OF THE NORTHWEST HIMALAYAN BASIN

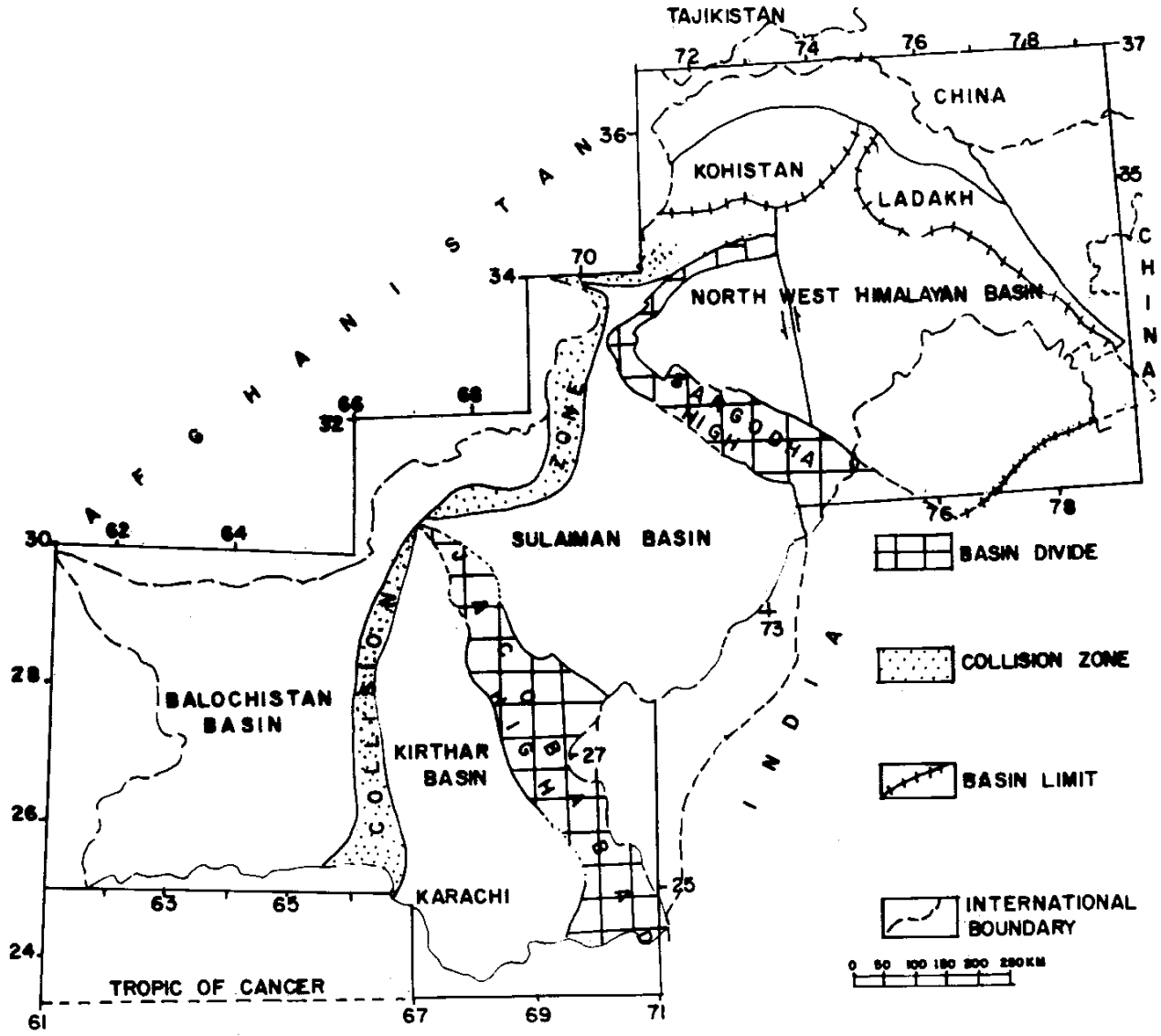
The Indus and Ganges water systems divide is considered to demarcate the boundary between northwestern and southeastern Himalayas. As such the water divide between Sutlej River, the last southeastern tributary of Indus and Yamuna Rivers; and the last northwestern tributary of the Ganges River mark the southeastern limit of the Northwest Himalayan Basin (Figure 3). The southern limit is marked by the Himalayan Frontal Thrust, HFT, formerly known as the Salt Range Thrust and the southwestern limit east of Mangla, through southwest of Jammu Province into northern India, by the assumed extension of HFT, see structural setting (Figure 4). The western limit is marked by the barrier that separates Sulaiman Basin in the west and the N.W. Himalayan Basin in the east upto a line joining north of Parachinar and just south of Peshawar, extending from Pezu in the south through Bannu, and western Kohat upto its south of Peshawar. Peshawar and tribal belt west and northwest of Peshawar with Harichand Ophiolite Complex near Dargai though considered to be the extension of the Bela-Muslimabagh Waziristan Belt are provisionally included in the N.W. Himalayan Basin. The northern limit in Swat and Hazara, northeastern limit in Kashmir and Himachal Pardesh is marked by the Main Mantle Thrust, MMT (Figure 4).

SUBDIVISIONS OF THE NORTHWEST HIMALAYAN BASIN

The northwest Himalayan Basin has been divided into two major belts (Figure 3).

A: Western Belt

Situated west of the Muzaffarabad High, the belt consists of the following provinces:



(MODFIED AFTER LATIF ETAL. 1993 & FARHAT. 1993)

Figure 2- Basin architecture - Pakistan.

1. Southern Hazara-Salt Range Province

The province is marked by the Himalayan Frontal Thrust (HFT) in the south and the Pir Panjal Thrust (PPT) in the northwest (Figure 3), of the Jhelum Fault and covers areas of Salt Range, Surghar Range, Kohat, Potwar, Attock-Cherat Range, Kalachitta and southern Hazara upto the northern tip of Hazara Kashmir Syntaxis (HKS), in the Kaghan valley. The exposed rocks are of sedimentary nature.

2. Central Hazara-Nowshera Province

The province is marked by PPT in the south the Main Central Thrust (MCT) in the northwest of the Jhelum Fault and covers areas in Hazara between HKS and MCT line passing between Kaghan and Naran in the Kaghan valley and includes areas of lower Kaghan valley, Sherwan and Nowshera north of the Attock-Cherat Range (Figure 3). Dargai Ophiolite Complex considered to be a continuation of Bela-Waziristan Ophiolite Complex, identified as Bela-Dargai Province, and as such considered the western limit of the province. As the extension of the ophiolite of Dargai is open for further studies, the Khyber Agency including Peshawar that fall west of the Bela-Dargai Complex are placed in this province provisionally. The exposed rocks are of sedimentary and metasedimentary nature intruded by granite and bedded volcanic rocks.

3. Higher Himalayan Province

The province is marked by MCT in the south and MMT in the north, west of the Jhelum Fault and covers areas north of MCT line in Kaghan valley near Naran, Nanga Parbat region and southern Swat (Figure 3). The area is dominated by crystalline rocks.

B: Eastern Belt

Situated east of the Muzaffarabad High, the belt consists of the following provinces.

1. Jammu Province

The province is marked by the Himalayan Frontal Thrust (assumed) in the southwest and PPT in the northeast, situated east of the Jhelum Fault and covers Poonch and Jammu areas of Jammu and Kashmir state in addition to siwalik region of Himachal Pardesh, India. The exposed rocks are of

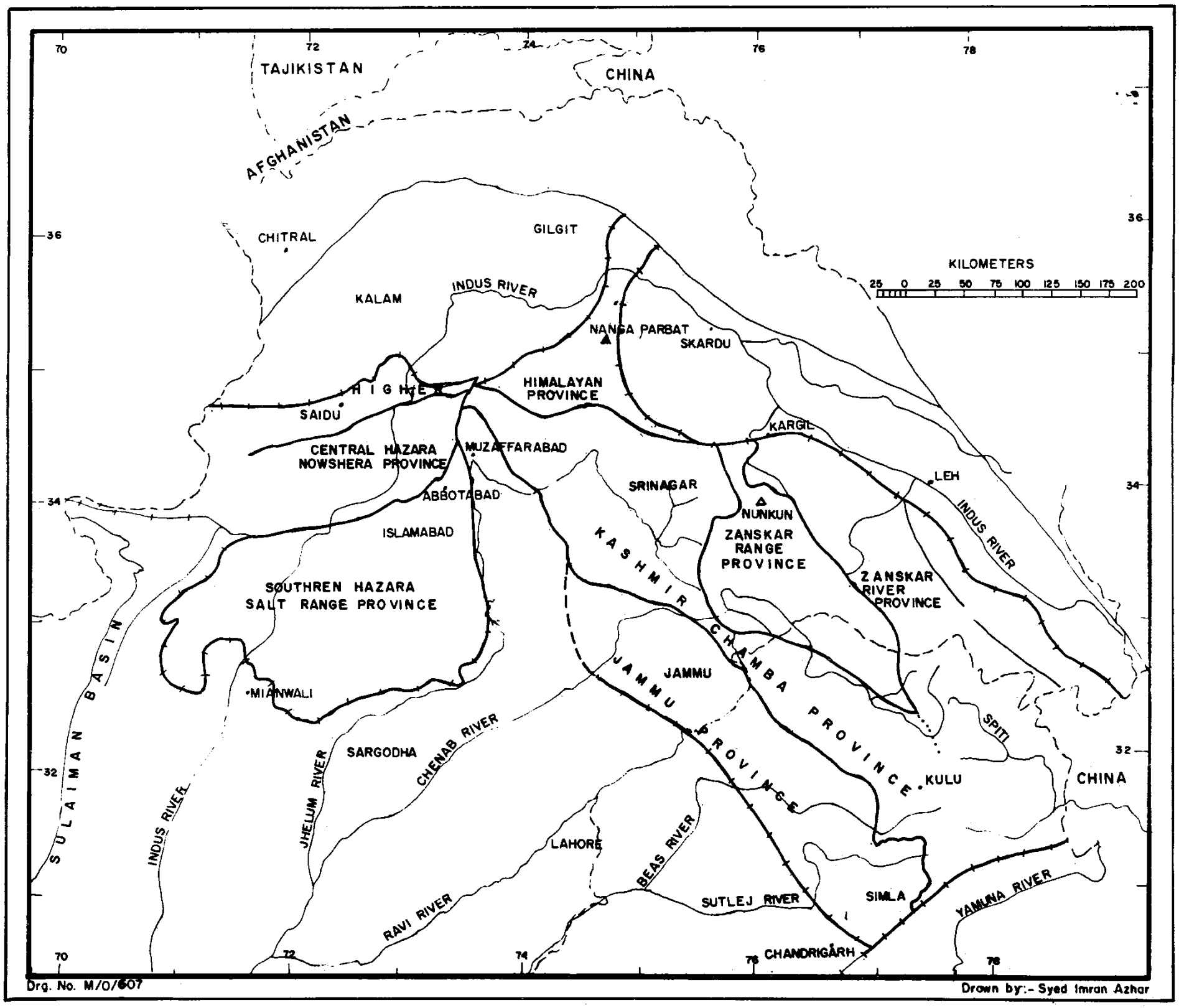


Figure 3- Subdivision of the Northwest Himalayan Basin into provinces.

sedimentary nature. It is a homolog of Southern Hazara-Salt Range Province of Western Belt.

2. Kashmir-Chamba Province

The province is marked by PPT in southwest and MCT (assumed) to the east of Kashmir valley and northeast of Chamba Region, situated east of the Jhelum Fault. Sedimentary and metasedimentary rocks with granite intrusions dominate the province. The province is homologous to the Central Hazara-Nowshera Province of the western belt.

3. Zanskar Range Province

The province is marked by MCT (assumed) in the west and southwest that separates Kashmir and Chamba respectively, and Zanskar River Province in northeast. Rocks are of crystalline nature and the province is homologous to the Higher Himalayan Province of the Western Belt.

4. Zanskar River Province

The province is situated to the northeast of the Zanskar Range Province and southwest of MMT that marks the boundary with Ladakh Province, Island Arc, in the northeast (Figure 3). A relatively complete, fossiliferous, well developed sequence of sedimentary rocks is encountered in the province.

Table 1. Comparative chart showing the history of development of basin architecture.

Abu Bakr & Jackson 1964	Shah, S.M.I., 1977	Kazmi & Riaz 1982	Farhat H., 1993	Latif M.A., This article
BALUCHISTAN BASIN	BALUCHISTAN BASIN	BALUCHISTAN BASIN	BALUCHISTAN BASIN	BALUCHISTAN BASIN
S. Makran Belt N. Makran Belt Raskoh Belt Zhob Belt	Makran-Zob Region	Makran Flysh Basin	Makran Zhob Basin	Makran-Zhob Province
Chagi Belt	Eruptive Zone	Chagi volcanics calcareous alkaline magmatic belt	Chagai-Raskoh magmatic Arc	Chagai-Raskoh Province
AXIAL BELT	AXIAL BELT	BELA-CHAMAN KURRAM FAULT ZONE & OPHIOLITE	BELA-MUSLIMBAGH WAZIRISTAN COLLISION ZONE	BELA-DARGAI PROVINCE
INDUS BASIN	INDUS BASIN	INDUS BASIN	INDUS BASIN	SUPER INDUS BASIN
Kirthar Province Sulaiman Province Trans-Indus & Kohat Province	Kirthar Province Sulaiman Province Kohat-Potwar Province	Kirthar Province Sulaiman Province Himalayan Fold Belt	Kirthar Province Sulaiman Province Kohat-Potwar Province	Kirthar Basin Sulaiman Basin Northwest Himalayan Basin 1. Southern Hazara & Salt Range Province 2. Central Hazara-Nowshera Province 3. Higher Himalayan Province 4. Jammu Province 5. Kashmir-Chambear Province 6. Zanskar Range Province 7. Zanskar River Province
NORTHERN MONTANE AREA	NORTHERN MONTANE AREA	HIMALAYAN CRYSTALLINE ZONE	KASHMIR ZONE	
NORTHERN MONTANE AREA	NORTHERN MONTANE AREA	KOHISTAN VOLCANIC & CALC. ALKALINE MAGMATIC BELT	KOHISTAN & LADAKH AREA	ISLAND ARCS KOHISTAN PROVINCE LADAKH PROVINCE
Northern Montane Area	Northern Montane Area	Karakoram (Tethyan) Fold Belt	Hindukush-Karakoram Belt	Asian Plate Hindukush Belt Karakoram Belt
	INDIAN SHIELD	BURRIED RIDGES	INDIAN BASEMENT COMPLEX	INDIAN BASEMENT HIGHS
	Jacobabad High Sargodha High Muzaffarabad High	Nagarparker Sargodha-Shahpur	Nagarparker Sargodha-Shahkot	1. Jacobabad-Khairpur 2. Sargodha-Shahkot 3. Jhelum-Muzaffarabad 4. Pezu-Nowshera-Daulaltmar

STRUCTURAL SETTING OF THE NORTHWEST HIMALAYAN BASIN

Faults and the morphotectonic divisions of the Northwest Himalayan Basin are very closely associated. The major thrust faults that run almost along the strike of rock formations are cut across by major strike slip faults to chop. The N.W. Himalayan Basin, not only into troughs and depressions but also into tectonostratigraphic blocks, each with a different set of exposed stratigraphic units (Table 2).

Table 2. Synonymy of faults.

The Pir Panjal Thrust (PPT)			
Panjal Fault	Wadia, D.N.	1928	Ind.Geol.Sur.Mem.51/52, p. 185-370
Sobrah Fault	Latif, M.A.	1969	Ph.D, thesis, London Univ. (Unpub)
Attock Fault	Kazmi, et al.	1982	Tectonic Map of Pakistan, Geol.Surv.Pakistan. 286 & 289, ig 1/34a.
Abbottabad Thrust	Baig, et al.	1987	Kashmir Jour Geol 5, 4.
Khairabad Fault	Hussain, A.	1990	Geologic Map of Attock-Cherat Range Geol. Surv. Pakistan
The Nathiagali Thrust (NGT)			
Kalabagh Fault	Latif, M.A.	1969	Ph.D., thesis, London Univ. (Unpub)
Campbelpur Fault	Kazmi & Riaz	1982	Tectonic Map of Pakistan, Geol. Surv. Pakistan
Hazara Thrust	Baig, M.S. et al.	1987	Kashmir Jour Geol 5, 1-22, Figure 1
Cherat Fault	Hussain, A. et al.	1990	Geologic Map of Attock Cherat Range. Geol. Surv. Pakistan
The Main Boundary Thrust (MBT)			
Murree Fault	Wadia, D.N.	1928	Ind. Geol. Mem. 51/2, 185-370
Mangial Fault	Latif, M.A.	1969	Ph.D., thesis, London Univ. (Unpub)
Parachinar Fault	Kazmi & Riaz	1982	Tectonic Map of Pakistan, Geol. Surv. Pakistan
Margala Thrust	Baig, et al.	1989	Kashmir Jour. Geol. 6&7, 33, Figure 1
The Sub Himalayan Thrust (SHT)			
Udhampur Fault	Kazmi & Riaz	1982	Tectonic Map of Pakistan, Geol. Surv. Pakistan
Fatehjang Fault	Kazmi & Riaz	1982	Tectonic Map of Pakistan, Geol. Surv. Pakistan
Khairi Murat	Khan, et al.	1986	Amer. Assn. Petroleum Geol. Bull. 70/4
Himalayan Frontal Thrust	Baig & Lawrence	1987	Kashmir Jour. Geol. 5 Figure 1
Kashmir Boundary Thrust	Chaudry, et al.	1993	Pak. Jour. Geol. Figure 3
The Himalayan Frontal Thrust (HFT)			
Salt Range Thrust	Gee, E.R.	1980-81	Pakistan Geological Salt Range Series, 1-6 U.K. Overseas Geological Survey
The Strike Slip Faults			
Jhelum Fault	Kazmi & Riaz	1982	
The Indus Fault			
Darband Fault	Calkins, et al.	1975	U.S.G.S. Prof. Paper 716-C
Tarbela Fault Zone	Kazmi, A. H.	1979	Geodyr.amics of Pakistan 288-289, Figure 1, No. 39
Kalabagh Fault	Kazmi, A. H.	1979	Figure 1, No. 31
Thakot-Sakargar Fault	Ashraf, et al.	1980	Special Geol Bull Pesh univ. 13, 212, Figure 1
Lakrai-Tarbela-Darband Fault	Tahirkheli, R.A.K.	1980	Special Geol Bull Pesh Univ. 13, p 42-43, Figure 1
Thakot Fault	Baig & Lawrence	1987	Kashmir Jour Geol. 5, Figure 1

LATERAL SPREAD

The Pir Panjal Thrust (PPT)

The Pir Panjal Thrust (PPT) is recorded all along The Pir Panjal Range from the south of Kishtwar, at the southeastern edge of the Kashmir valley to Hazara-Kashmir Syntaxis (HKS), north of Balakot in the Kaghan valley, Hazara. The western limb of HKS is truncated by the Jhelum Strike Slip Fault. The displaced block of rocks along with the PPT is recorded at Garhi Habibullah Khan south of Balakot. From GHK, the PPT is oriented in a southwesterly direction and is recorded at Tarnawai, Kakul, Sobrah, Serai Niamat Khan and Soka Nala

Hazara, later to be covered by the recent alluvial sediments of the Indus River and or its tributaries. It cuts the recent alluvium to form river terraces south of Haro River and is recorded upto the Indus River, identified locally as the Attock Fault (Kazmi & Riaz, 1982). Across the Indus River, the PPT is mapped and identified locally as the Khairabad Fault, in the Attock-Cherat Range (Hussain et al., 1990). The fault is covered by the recent sediments of the Peshawar valley south of the Peshawar and is expected to form terraces. PPT is recorded in Khyber Agency and after passing through south of Landikotal enters Afghanistan.

The PPT is associated with volcanic rocks all along the Pir Panjal Range upto HKS in Kaghan valley. Across HKS in southern Hazara, the volcanic rocks appear to have been subjected to erosional agencies after the uplift of eastern regions of Hazara, Muzaffarabad High, after the deposition of Early Paleozoic sediments. The reworked volcanic rocks are recorded at Daulatmar, Gaklanian and Kakul in Hazara and identified as Galdanian Formation, the age of which formation was left open by Latif (1974, p 18) and is considered to be post Panjal volcanics's deposition. Homolog of rocks northeast and north of PPT of Kashmir and Kaghan occur northwest of PPT in the Sherwan area where volcanic rocks appear to be present, as per verbal communication.

The Nathiagali Thrust (NGT)

On one hand the NGT extends northeast of the type area near Nathiagali through Bakot Nala to be truncated by the Jhelum Fault and on the other hand towards west southwest, it is recorded at Samundar Katha, Nara, Langrial and Gandhian and is covered by the recent alluvial cover south of Haripur. It forms terraces and is identified as Campbelpur Fault (Kazmi & Riaz, 1982) and extends upto Indus River. Across the Indus River in Attock-Cherat Range, the fault is mapped and identified as Cherat Fault, by Hussain et al., (1990). Beyond Dag, Western Attock-Cherat Range, the fault is covered by the alluvial sediments of Peshawar valley where it is expected to form terraces. The fault is recorded in Khyber Agency and passing by Ali Masjid enters Afghanistan north of Jabbar (Figure 4).

The NGT brings rocks of Jurassic to Eocene age in a thrusted contact with Hazara Group Eocambrian in Hazara. Various formations of Paleogene and Miocene age are thrusted against the Dakhner Formation, Precambrian, in the Attock-Cherat Range. Undifferentiated Precambrian rocks are thrusted against Mesozoic and Miocene rocks, in the Khyber Agency.

The Main Boundary Thrust (MBT)

The MBT approaches towards Kashmir valley from India and is recorded along the Pir Panjal Range parallel to PPT upto HKS north of Balakot in Kaghan valley, Hazara. The western limb of HKS is truncated by the Jhelum strike slip Fault. The displaced block along with MBT is recorded south of Kohala from where it follows the course of Kanher Kas, and later passes through Kuldana Tret, and Islamabad in a southwesterly direction. It is oriented in an east west direction west of Islamabad, passes north of Fatehjang in Kalachitta Range, and across Indus River north of Kohat, it enters Afghanistan from just south of Parachinar. It is probable that the Kurram Thrust is the extension of MBT. Rocks of Mesozoic and or Paleogene are thrusted along the Rawalpindi Group, Miocene (Figure 4).

The Sub Himalayan Thrust (SHT)

The fault is mapped at Simla and Dharamsala, India. It is recorded at Basoli, Udhampur, Riasi and Kotli in Jammu and Kashmir to be truncated by the Jhelum strike slip fault near Basian, Punjab, Pakistan, about 7 kms south of Kohala on the Jhelum River. The fault reappears near Kotli, Rawalpindi District, in the truncated and displaced block on Jhelum River and proceeds in a southwesterly direction and passing by Khairi Murat Range, locally mapped as Khairi Murat Fault (Khan et al., 1986), it takes an almost eastwest turn. It is recorded as Fatehjang Fault at Fatehjang (Kazmi & Riaz, 1982) later passing by Dakhni it appears to divide the Kohat and Daudkhel depressions across Indus River to be truncated by the Kurram Fault in the west. The Rawalpindi Group, Miocene, is thrusted along the Siwalik Group, Late Miocene to Early Pleistocene (Figure 4).

The Himalayan Frontal Thrust (HFT)

The Himalayan Frontal Thrust extends east of the Pezu-Bannu High and is located at the base of the Salt Range (the southern most tip of Himalayas) upto Mangla. Southeast of Mangla lineaments indicate extension of thrust in Azad Kashmir through Bhimber upto Tawi River near Chamb-Jaurian (Kazmi & Riaz, 1982). Since the area south eastwards i.e. Akhnur, southern Jammu upto Kathua are not accessible, therefore, the extension on the ground can not be confirmed. The thrust is expected to pass by Marala, Sialkot, southern Jammu & Kathua in Kashmir, there from the enter Indian Punjab upto Simla region and Himachal Pardesh (India) and beyond. The trend is confirmed by Fuchs (1968) and Gupta and Singh (1980).

Seen in a broader perspective, the Salt Range appears to synchronize with the wedge end of the Indian Plate. A close examination of figure 5 will indicate that various thrusts combined in the west and thrust along the Arakan Yoma in the east of Indo-Pakistan subcontinent may be the continuation of the HFT southwards in the west and east respectively. Northward movement of the Indian Plate is indicated on both sides (Figure 5). It is of interest to note that contrary to the northward movement of the Indian Plate, the central Salt Range and the block northwards upto at least MMT has slided southwards along the Indus & Jhelum strike slip faults. Similarly the Khisor and Sulaiman blocks appears to have slided south and southeastwards, respectively, along strike-slip faults (Figure 5).

The Strike Slip Faults

It is a left lateral strike slip fault that is named after Jhelum River along which it runs for about 175 km from Muzaffarabad to Jhelum, out of about 300 km of recorded length from beyond MMT, Choar Plain in Allai Kohistan, towards Kot Radha Kishan southwest of Lahore. After cutting the MMT the fault truncates the western limb of HKS including PPT & MBT. Blocks of Panjal Volcanics and Mesozoic limestone are dragged several km south of the source area. A fault between Balakot and

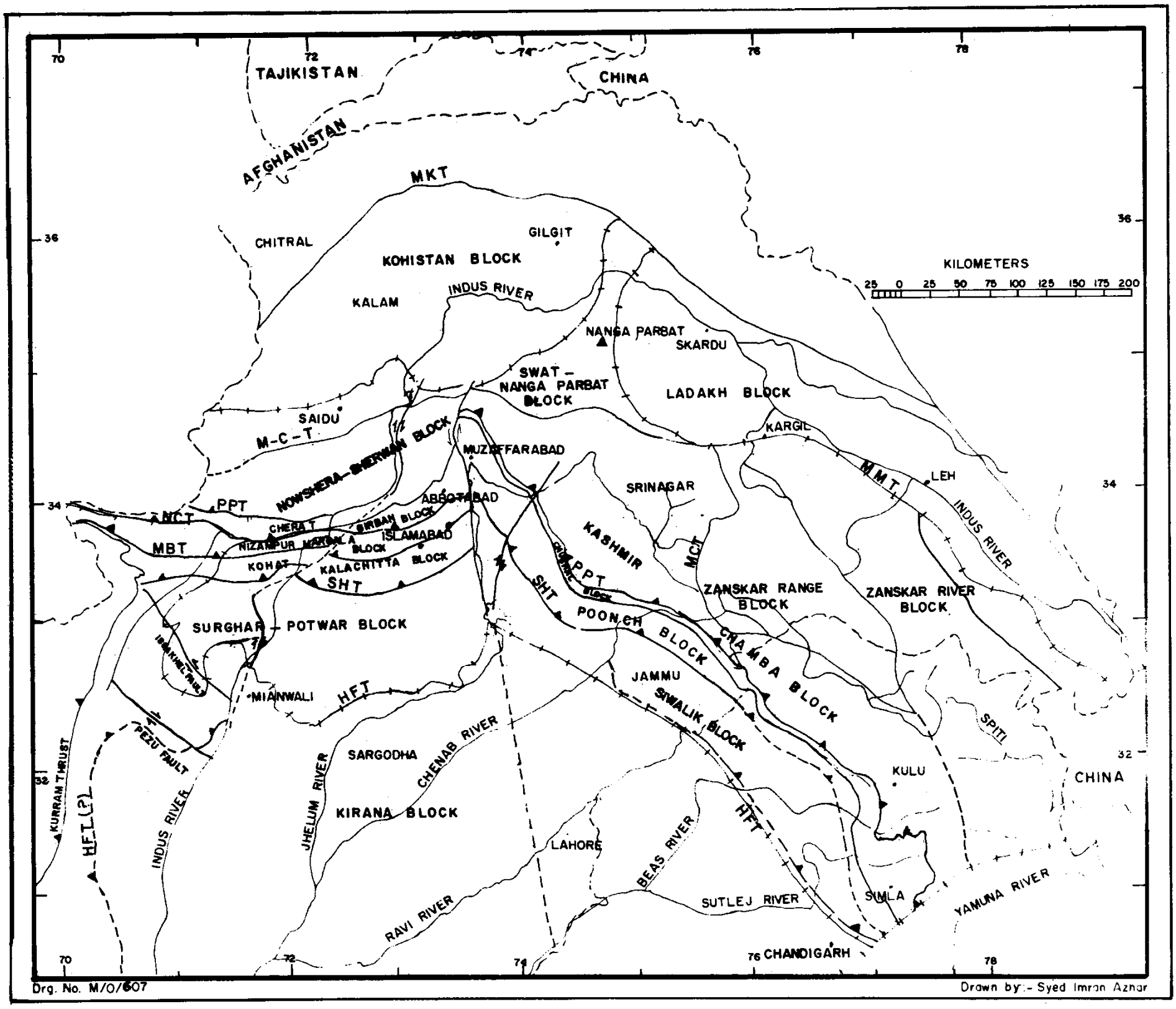


Figure 4- Tectonostratigraphic divisions of Northwestern Himalayan.

Muzaffarabad identified as Muzaffarabad Fault (Calkins et al., 1975) is truncated south of Muzaffarabad by the Jhelum Fault. A large number of faults in the west in Hazara that head in a northwesterly direction are truncated in the east by the Jhelum Fault. These are, from north to south, PPT, Lagarban, SGT, Thandiani, Chitragali, Phalkot, NGT, Dungagali, Ayubia and Changlagali. Further south in Punjab, the faults truncated by the Jhelum Fault, are MBT, SHT & HFT. The only fault situated east of Jhelum River and truncated near Basian south of Kohala is SHT. An offset of 31 km along the western limb of HKS has been calculated by Baig and Lawrence (1987). Quaternary terraces along the course of the fault are uplifted and tilted between Balakot in the north to Mangla in the south and probably southeast of Mangla in Chaj and Rachna doabs (Yasin et al., 1993). One of the large number of faults observed on aerial photographs/landsat imageries (Kazmi & Riaz, 1982) apparently indicates the extension of Jhelum Fault towards Kot Radha Kishen southwest of Lahore after passing through Chaj Rachna and Bari doabs. The fault may be an older basement fault reactivated during Himalayan Orogeny (Baig et al., 1987).

The Indus Fault

It is a right lateral strike slip fault that is named after Indus River along which it runs a crow flight distance of about 260 km from beyond Besham in the NNE to Kalabagh in SSW. It is a north-south trending, high angle fault that cuts the Indus Suture Zone in Allai Kohistan. The serpentinite, talc, peridotite and amphibolite from Allai Kohistan have been dragged as sliver and lenses along this fault for several km further south. It shows the right lateral sense of motion a ductile to brittle deformation is pronounced along this fault. The Thakot Fault may be the extension of the Darband Fault in Allai Kohistan and is the surface rupture of the Tarbela Seismic Zone of

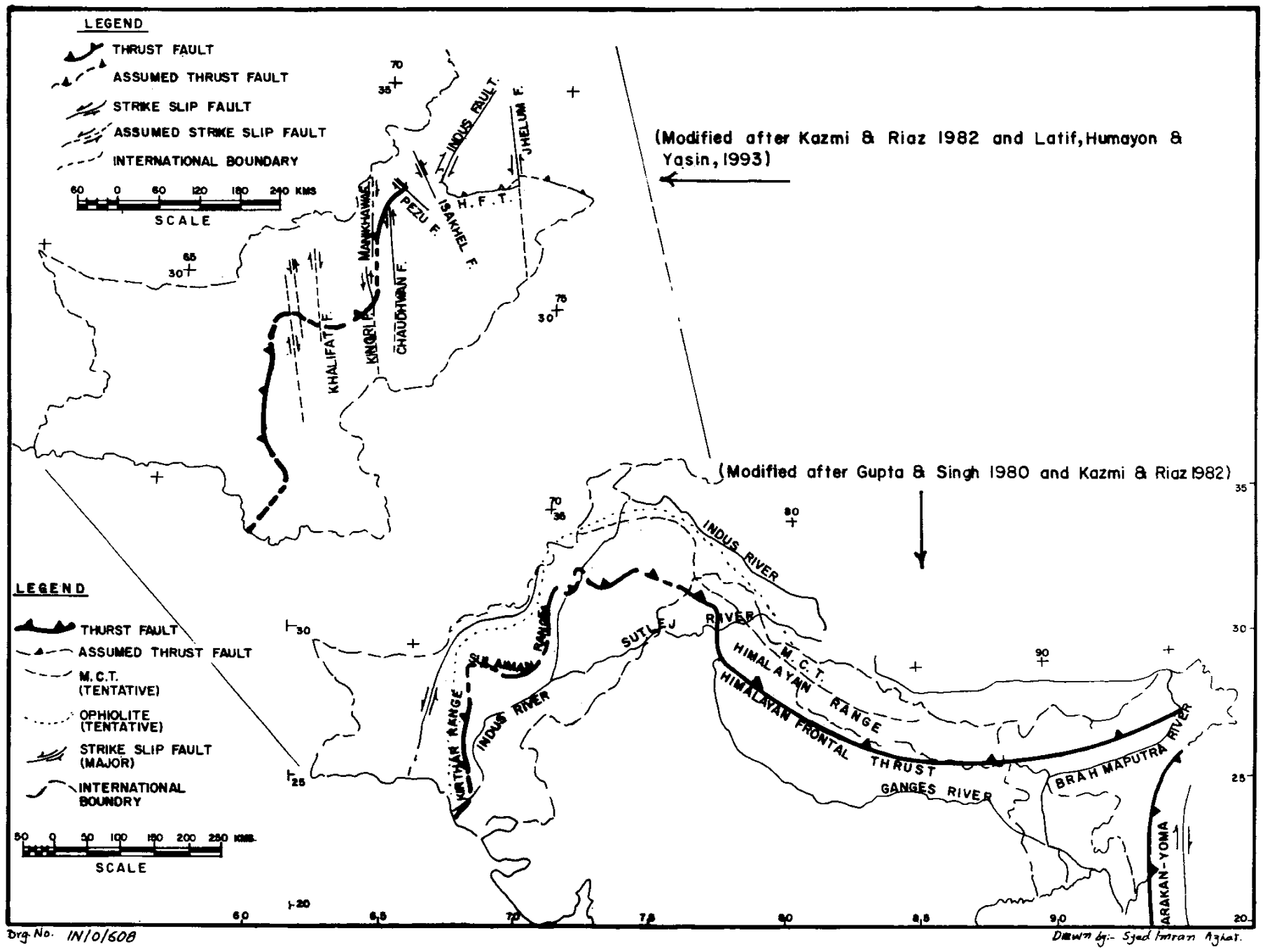


Figure 5- Frontal thrust's direction (above) and Indogangitic Plain's contact with the fold belts north of south Asia (below).

Seeber and Ambruster (1981). The fault may be an older basement fault of the Tethyan margin which has been reactivated during Himalayan Orogeny (Baig and Lawrence, 1987). The Darband Fault (Calkins et al., 1975) (Figure 1) the Tarbela component in particular, shows a left lateral sense of movement as against right lateral shown by Baig & Lawrence (1987) above. As against just one Darband Fault (Calkins et al., 1975; Kazmi, 1979, p.288-289) has recorded a number of prominent NS trending fractures of large dimension seen parallel to River Indus near Tarbela. Further north along Indus River (Baig et al., 1989, p.33) has recorded the presence of 2 faults, side by side. The Thakot and Puran faults showing opposite sense of motion with respect to each other and are responsible for the northward movement of the Besham block with respect to the surrounding area. It is probable that the fault recorded by Calkins et al., (1975) may be the one out of Tarbela Fault Zone of Kazmi (1979), that shows an opposite sense of movement in relation to that described by Baig and Lawrence (1987), above. The occurrence of faults with opposite sense of movement has also been recorded further south near Kalabagh. The Daudkhel Fault assumed to be the extension of the Indus Fault shows a right lateral sense of movement against the Issa Khel Fault which shows a left lateral movement resulting thereby a northward push of the intervening Karak block. Marwat block situated southwest of the Karak block is pushed southwards along Issa Khel and Pezu Faults, opposite to the behavior along the Issa Khel Fault. An identical opposite sense of movement has also been noticed in the case of Jhelum Fault further east at Mangla where opposite sense of movements along Jhelum Fault in the west and Mangla Fault in the east have pushed northwards the intervening Palandri block.

After passing through Tarbela, the Indus Fault is covered by recent alluvial cover between Hazro and Attock further south it crosses the Indus River near Khushalgarh. It brings various formations of Rawalpindi and Siwalik groups in a faulted contact, turns south eastwards and later joins the Daudkhel Fault in a NS direction. Incidentally Daudkhel Fault referred above is one of the three faults in the Kalabagh region. Whereas the one in the west is known as Kalabagh Fault, that in the east is identified here as the Daudkhel Fault. The evaporate rocks of the Bahadurkhel Depression are dragged for several kms southwards to Daudkhel. The Indus Fault appears to truncate various EW oriented faults like, MMT, MCT, PPT, NGT, MBT, SHT and HFT.

TECTONOSTRATIGRAPHIC BLOCKS OF THE N.W. HIMALAYAN BASIN

The Muzaffarabad High subdivides the Northwest Himalayan Basin into two major belts, an eastern, Jammu & Kashmir and Himachal Pardesh and a western, northern Punjab and the NWFP the two belts are further subdivided into various blocks by the major thrust faults oriented in a NW-SE direction in the eastern belt and NNE-SSW to EW in the western. Each block is singled out from the adjacent one in northwest and north respectively by a dominant set of exposed stratigraphic units. Such blocks are identified as tectonostratigraphic blocks. These are briefly described below for reference starting from the western belt, being better known, and homologs from eastern belt identified (Figure 4).

1. The Kirana Block

The block is named after Kirana Hills south of Sargodha. It is situated south of the Himalayan Frontal Thrust all along from the eastern border of Waziristan about 25 km southeast of Miram Shah, NWFP, Pakistan, that marks the northwestern end of the Pezu Fault to Chandigarh, India. With the exception of isolated exposures of the Indian Basement Complex at Kirana Hills, Chiniot, Sangla Hill and Shahkot in Punjab, Pakistan, the block is covered by Quaternary sediments.

2. Surghar-Potwar Block

The block is named after Surghar Range and Potwar Plateau situated between Pezu-Bannu Peshawar High in the west to Muzaffarabad High in the east. The southern limit of the block is marked by the Himalayan Frontal Thrust and northern by Sub Himalayan Thrust. The block is occupied dominantly by the Siwalik group of rocks of Late Miocene to Early Pleistocene age.

3. Kohat-Kalachitta Block

The block is named after Kohat and Kalachitta Range situated between Pezu-Peshawar High in the west and Muzaffarabad High in the east. The southern limit is marked by SHT and the northern by MBT. The Rawalpindi group of Miocene age, dominates the exposures.

Poonch block, with identical exposures, marked by SHT and MBT in southwest and northeast respectively, extending to area situated between Chandigarh and Simla, India, is considered homologous to the Kohat-Kalachitta block in the west.

4. Nizampur-Margala Block

The block is named after Nizampur and Margala Hills situated between Pezu-Peshawar High and Muzaffarabad High in west and east respectively. The southern limit is marked by MBT and the northern by the Nathiagali Thrust (NGT). Dominant rock exposures are related to the Paleocene Galis group, Paleocene to Early Eocene with Hothla group of late Jurassic to late Cretaceous in second place.

The well represented rock units between MBT and PPT in Hazara and Attock-Cherat Range are squeezed in the eastern belt with the central Hazara Nathiagali Thrust also unrepresented. As elements of both the Nizampur-Margala and Cherat-Sirban blocks are represented to some extent in a narrow belt between MBT and PPT in the eastern belt, the later is considered to be homologous to the two blocks together. The narrow belt in the east is identified as Chushal Block after Chushal in the Kaghan valley near Paras.

5. Cherat-Sirban Block

The block is named after Attock-Cherat Range and Sirban Mountain south of Abbottabad Hazara, situated between Pezu-Peshawar High in the west and Muzaffarabad High in the east. The southern limit is marked by NGT and the northern by PPT. Dominant rock exposures are related to Hazara, Abbottabad and Thandiani groups of Precambrian, Cambrian and Jurassic ages respectively.

The homologue to the block in the eastern belt is identified as Chushal block as at no.4 above.

6. Nowshera-Sherwan Block

The block is named after Nowshera situated on either side of Indus River. Pezu-Peshawar High during Early Eocene extends ENE towards Thandiani, Hazara. The Early Eocene hiatus appears to extend both in the older sequences as well as the younger. There are no representative sediments younger than Jurassic. Dominant rock exposures are related to Precambrian and Paleozoic and Permian. Similar rocks are recorded in Khyber Agency west of Peshawar. The western limit of the block is, therefore, provisionally extended upto the border with Afghanistan. The eastern limit is marked by the Muzaffarabad High. The southern limit is marked by PPT and the northern by MCT provisionally.

East of Muzaffarabad High in the eastern belt, identical stratigraphic units are represented in the Kashmir valley identified as the Kashmir Block. The block is marked in the southwest by PPT and north and east by assumed MCT. Similar situation most probably exists in the Chamba Block situated to the southwest of Kashmir Block.

7. Swat-Nanga Parbat Block

The block is named after Swat and Nanga Parbat where rocks of crystalline nature are exposed. The block is marked by MCT in the south and MMT in the north.

Similar rocks are recorded southeast of Kashmir Block, identified as Zanskar Range Block.

8. Zanskar River Block

The block is named after Zanskar River having its source in the Zanskar Range in southwest. Here the most complete fossiliferous sequence in Himalayas is recorded from Proterozoic to Eocene and represents the Tethys Himalayas. The block is bounded in the southeast by Zanskar Range of Higher Himalayan crystalline, same as Swat-Nanga Parbat and in the northeast by MMT, beyond which the Ladakh Arc is located.

MORPHOTECTONIC DIVISIONS OF THE NORTHWEST HIMALAYAN BASIN

Various subdivisions of Himalayas have been suggested from the Imperial Gazetteer of India, 1908 (Chaudry and Ghazanfar, 1993). The main purpose has been to demarcate various physiographic blocks to be used as reference and base for various scientific pursuits. Initially there were two suggestions, i. that whole Himalayas may be subdivided into northwestern and southeastern Himalayas marked by water divide between Indus and Ganges water systems, ii. that Indus River in the west may be treated to mark the limit of Himalayan in northwest. Three broad divisions were suggested in the Gazetteer of India, 1908 (Chaudry and Ghazanfar, 1993) i. The Tibetan Highland Zone consisting of highly fossiliferous rocks, ii. Zone consisting of granites and crystalline schists etc. of unknown age and iii. Sub-Himalayas consisting entirely of Tertiary rocks derived from wastes of the highlands to the north. The later subdivisions were summed up and modified by Chaudry & Ghazanfar (1993) as follows: i. Tethyes Himalayas consisting of rocks identical to those in Kaghan and Bannu in Kohistan and Karora sequence of Swat, ii. Higher Himalayas to include set of rocks between MMT and MCT, iii. Lesser Himalayas to include areas between MCT and MBT and iv. Outer Himalayas to include molassic sediments south of MBT.

A modified version of Chaudry & Ghazanfar (1993) is proposed (Figure 6 & 7), as follows, based on the following considerations in order of priority, i. altitudes, ii. geology, iii. tectonic lines and iv. cis Indus Himalayan Preference.

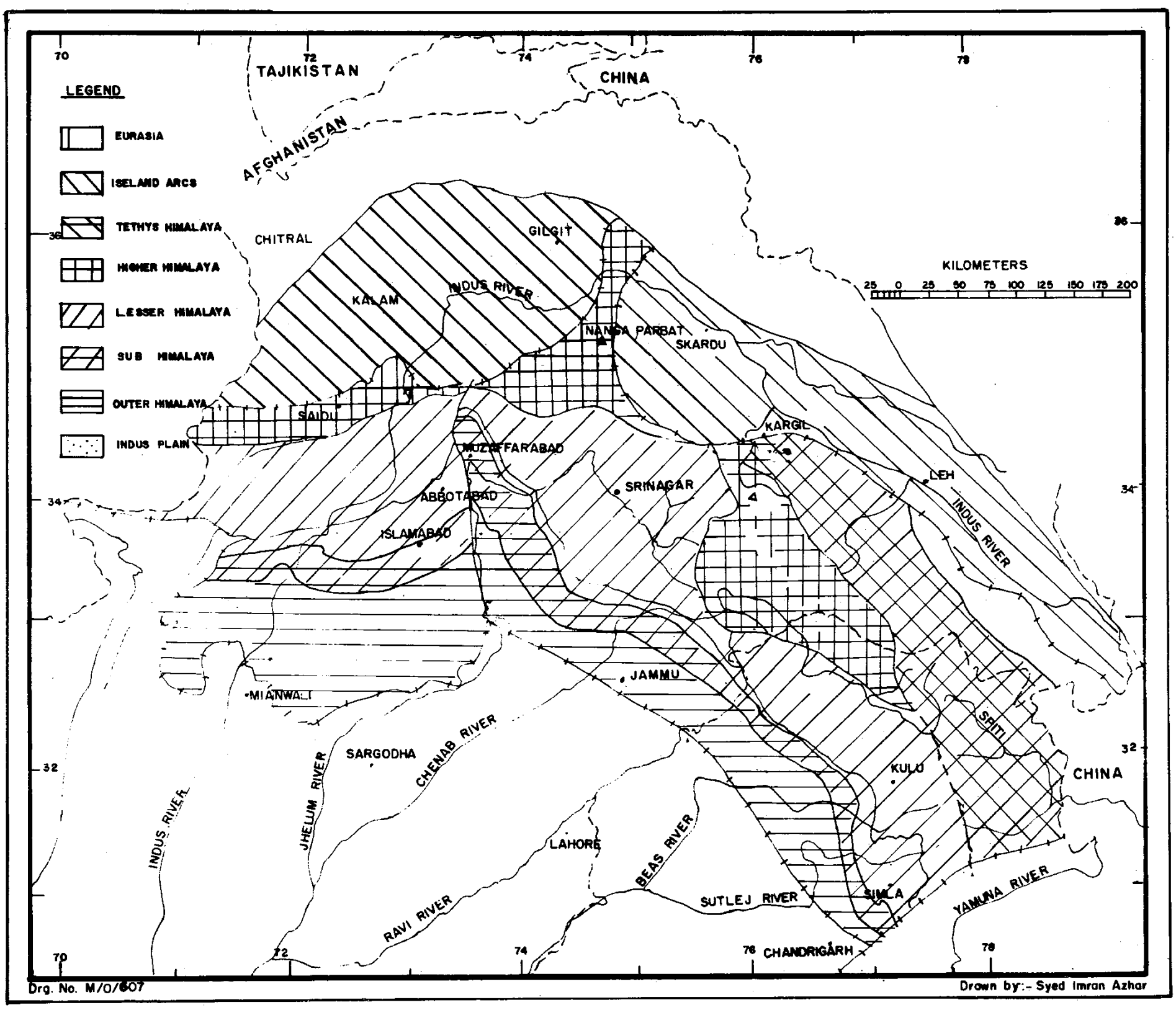


Figure 6- Morphotectonic divisions of Northwest Himalayan.

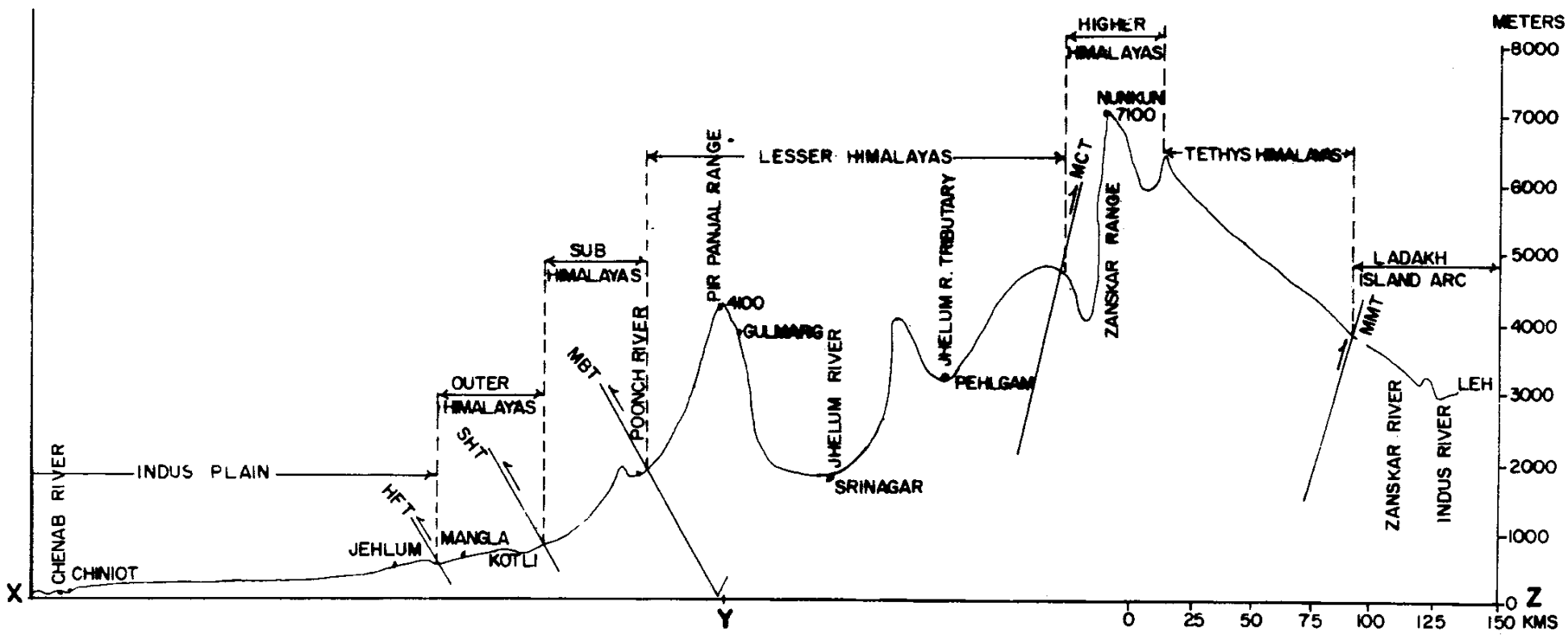


Figure 7- Morphotectonic cross-section of Northwest Himalayan.

1. Tethys Himalayas

Terrain situated northeast of snowy Zanskar Range and southwest of MMT showing almost a complete sequence of richly fossiliferous rocks.

2. Higher Himalayas

Terrain occupied by snowy ranges, consisting of pelites, calc-pelites, marbles, sheet granites and sheets of amphibolite, metamorphosed to upper amphibolite and at places to eclogite facies, marked by MCT that is situated in south southeast in Swat, south of Nanga Parbat region west southwest of Zanskar Range and beyond in the same strike direction towards Himachal Pardesh, India.

3. Lesser Himalayan

Terrain situated under 5000 meters OD approximately and over 1200 meters OD approximately, situated between MCT and MBT, consisting of a northern metamorphic belt and a southern sedimentary belt.

4. Sub Himalayan

Terrain situated under 2000 meters OD approximately and over 800 meters OD approximately, situated between MBT and SHT, consisting dominantly of rocks belonging to Rawalpindi group, Miocene.

5. Outer Himalayas

Terrain situated under 1000 meters OD approximately, situated between SHT and HFT, consisting dominantly of rocks belonging to the Siwalik group, Late Miocene to Early Pleistocene. The Indus Plain is situated south of the Outer Himalayan Division.

PALEOMORPHOLOGY OF THE NORTHWEST HIMALAYAN BASIN IN EARLY EOCENE

The paleophysiography of a basin may not be uniform throughout the geological past. Accordingly it is not possible to give a comprehensive picture of a basin's paleotopography applicable to the whole of geological past. It is quite a project, as it demands multidiscipline studies involving startigraphers, regional geologists, sedimentologists, paleontologists, paleoecologists in particular, structural geologists and geophysicists. Early Eocene level has been carried out by Latif & Humayon (1986) and Latif et al., (1993) (Figure 8). This, however, does not imply that this model as such is applicable to the rest of geological past, though evidences in support of a positive comparison for parts are not lacking.

The Indian Shield, Precambrian, extends to Pakistan and serves as a base for the following sedimentation. It is generally covered by post Precambrian sediments though few of its exposures are met at Nagarparkar in Sind; Shahkot, Sangla Hill, Chiniot and Sargodha, in Punjab and Lately in Nanga Parbat region. Based on subsurface contours of the Indian Shield near Sargodha, a burried ridge is earmarked aligned in a WNW-ESE direction (Kazmi & Riaz, 1982). The buried ridge serves as a water divide termed as Sargodha-Shahkot High, that separates the Northwest Himalayan Basin from the Sulaiman Basin. A narrow wedge extends towards Pezu in WNW and then northwards towards Bannu and later passing by western Kohat heads towards Peshawar. The wedge like extension of the high serves as a barrier between Northwest Himalayan Basin to the east and Sulaiman Basin in the west upto at least PPT in north, during Early Eocene (Latif and Humayon, 1986 : Latif et al., 1993). Further north a number of faults, with WSW-ENE strike in general are reported between PPT and MCT. From north to south these are: i. Peshawar Basin Fault (114), Nowshera Fault (113), Kund Fault (112) (Kazmi et al., 1982). A fault lineament is also reported by the same authors north of Peshawar Basin Fault and south of

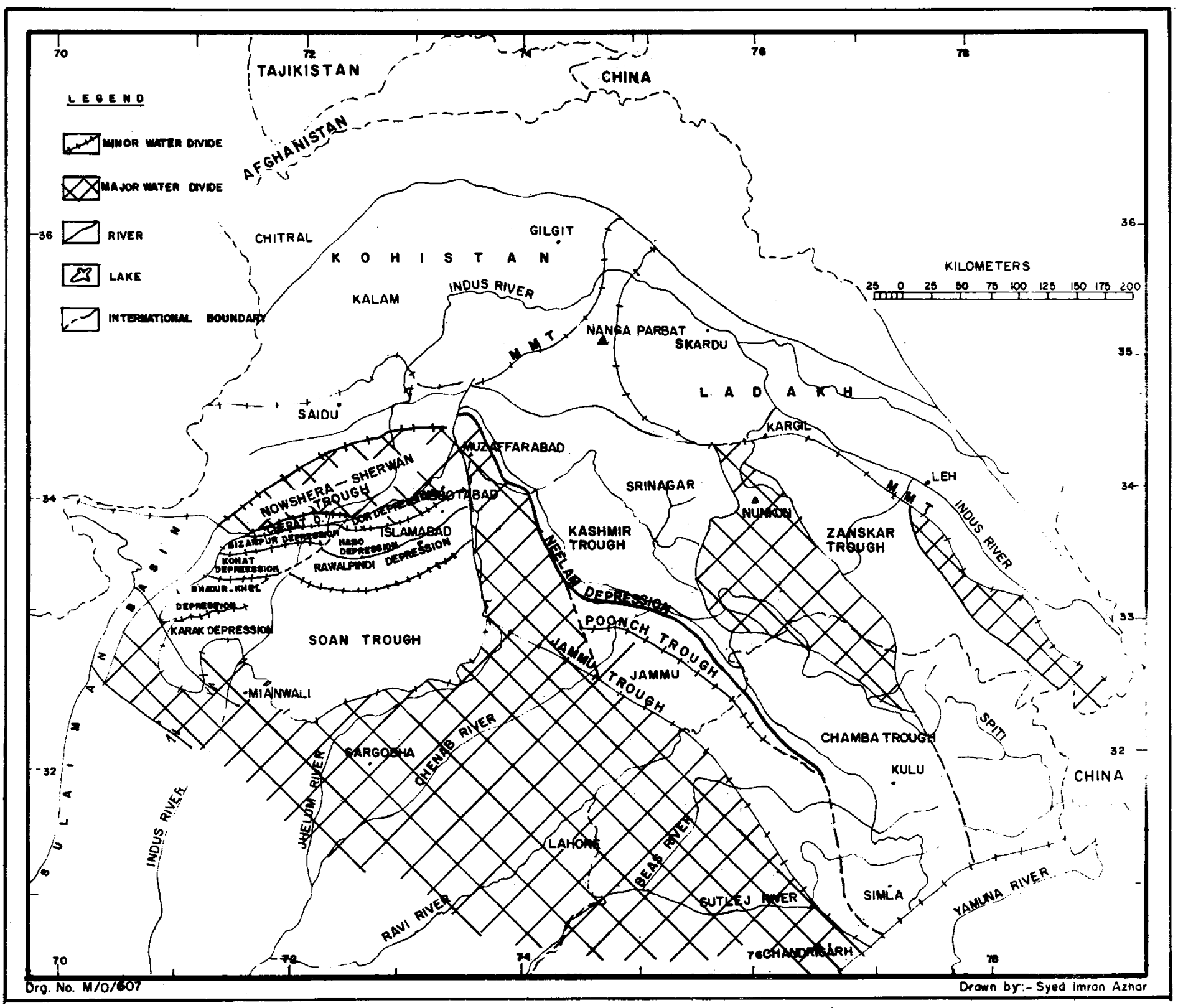


Figure 8- Paleogeography of precollision Northwest Himalayan Basin and Sothern Hazara-Salt Range province during Early Eocene.

Dargai Ophiolite Complex. A series of active faults are mapped near Misri Banda, Manki, Cherat cement plant and Spin Khak, by Hussain et al., (1990) the first three in the same strike direction ENE-WSW and the later one in a NE-SW strike direction. The later three could be merged into a single Spin Khak Fault. If extended further southwest it is expected to join the southwestern edge of the barrier referred above (Latif & Humayon, 1986 : Latif et al., 1993). Early Eocene sediments are absent NNW of Spin Khak Fault and north of PPT. North of Sangargali Thrust in Hazara (Latif, 1970). Early Eocene sediments are absent. Spin Khak and Sangargali Thrusts line passing through Tarbela Lake and Kakul, NW of Abbottabad earmark the southern edge of the belt devoid of Early Eocene sediments; in other words the extension of the Pezu-Bannu Barrier. The northern edge of the barren zone could be marked either by the Peshawar Basin Fault or a combination of MCT (Chaudry & Ghazanfar, 1990 & 1993), and Peshawar Basin Fault from south of Dargai Ophiolite Complex.

Northeast of the Sargodha Buried Ridge, Shah (1977), (Figure 1a), has indicated the presence of a NNW-SSE striking Muzaffarabad High. Presence of such a high is confirmed by the thinning of various formations towards east in Salt Range and Potwar keeping in view the strike direction or rocks (Gee, 1980-81). Further north in Hazara, isopachites of various formations indicate line synchronizing with the western edge of the Muzaffarabad High (Latif et al., 1993). The Muzaffarabad High appears to join the Pezu-Nowshera High to enclose part of the NW Himalayan Basin from Salt Range to southern Hazara. The enclosed area is further subdivided by EW striking water divides, assumed on lithofacies basis (Latif & Humayon, 1986).

SUBDIVISIONS OF THE NORTHWEST HIMALAYAN BASIN

Across the western water divide the subdivisions from south to north are: i. Karak Depression, ii. Bahadurkhel Depression, iii. Kohat Depression, iv. Nizampur Depression, v. Cherat Depression & vi. Nowshera-Sherwan Trough. East of the divide, that coincides approximately with the Indus Fault, the subdivisions from south to north area: i. Soan Trough, ii. Rawalpindi Depression, iii. Haro Trough & iv. Dor Depression. Karak Depression (marine) together with Bahadurkhel Depression (evaporitic, mainly salt and gypsum) is separated from Soan Trough (marine) in the east by the Daudkhel evaporites. Similarly Kohat Depression (mainly gypsum and gypsiferous limestones) is separated by a divide from Rawalpindi Depression (marine); Nizampur Depression in the west is separated from Haro Trough and Cherat Depression from Dor Depression. All marine with intervening alluvial cover. Soan Trough and Rawalpindi Depression are separated by the Khairi Murat divide. Chorgali Formation at Chorgali Pass in Khairi Murat Range was deposited in intertidal to supratidal environments (Jorgan & Abbas, 1991) confirming the presence of a water divide along Khairi Murat Range. The variations in thicknesses of various formations of Salt Range (Gee, 1980-1981), coupled with the strike direction of rock formations and on the basis of published works, various formations of the Soan Trough whether due to sedimentation or later erosion or both, are expected to thin towards the trough margins which happens to be all round the Soan Trough. Haro Trough and Dor Depression further north in Hazara are divided by a high way down at Eocambrian level as indicated by interidal algal Miranjani and Langrial limestone formations and gypsum beds (Latif, 1970 & 1973). The high is further confirmed at Mesozoic and Basal Paleocene level (Latif et al., 1993 & 1995) respectively. Isopachites of unconformaties also follows a similar pattern. The Haro Trough is enclosed between Nathiagali divide in NNW, Muzaffarabad High in the east and Islamabad divide in the south. Not much information is directly collected from the Rawalpindi Depression. However, the presence of Khairi Murat and Islamabad water divides in the south and north respectively, indirectly delineate the Rawalpindi Depression. The Dor Depression is enclosed by Nathiagali divide in SSE and by Muzaffarabad High in the East. The boundary in NNW is marked by Sobrah divide assumed on the basis of indirect evidence of the presence of a high at Basal Paleocene level (Latif et al., 1992). Early Eocene being absent. NNW of the Sobrah divide, the terrain is identified as the Nowshera-Sherwan Trough.

With the exception of a narrow strip of Azad Kashmir to the east of the Muzaffarabad High, rest of the area in Jammu & Kashmir is under the control of India, Indian Armed Forces in particular and as such not accessible to Pakistani Geologists. Spiti area, India, is prohibited to all non Indians. As such recent first hand information is lacking. the geological information published in India is also not easily available at least to the Pakistani Geologists. The author may, therefore, be excused for the developrnent of Northwest Himalayan Basin scenario of that region based on scanty information and or assumptions.

Whereas Salt Range extends westwards at least as far as the Pezu-Bannu High, its extension in the east of Mangla is not reported. Salt Range is closely associated with the Salt Range Thrust redesignated here as Himalayan Frontal Thrust, HFT. A lineament is reported heading ESE of Mangla close to the Jammu & Kashmir-Pakistan border (Kazmi & Riaz, 1982). A fault traced by Fuchs (1968) takes almost the same course prior to crossing over to India. This is identified as HFT by Gupta and Singh (1980). Rocks of eastern Salt Range type are reported to extend towards Punjab plains east of Mangla (Khan et al., 1986). It is, therefore, assumed that the terrane between the assumed HFT east of Mangla and SHT is occupied by a trough, designated here as the Jammu Trough and is considered to be homologous with the Soan Trough and the Karak Depression. Northwest of the Jammu Trough is the Poonch Trough situated between SHT and MBT. Further north a narrow belt between MBT & PPT is identified as Neelam Depression. The wide valley of Kashmir situated between PPT and MCT is designated as Kashmir Trough. The course of MCT east of Kashmir Trough has been problematic. Zanskar Range situated east of Kashmir Trough is considered to be a part of Higher Himalayas due to crystalline nature of rocks and higher altitudes. As Zanskar Trough (Tethys Himalayas) is situated NE of Zanskar Range followed further NE by Ladakh Arc, there is every possibility of MCT's running between the eastern margin of Kashmir Trough and the western margin of crystalline Zanskar Range, heading south southwestwards towards Kishtwar. It is interesting to note that MCT heading NW from India towards Kashmir is reported either missing or merging with the PPT south of Kishtwar. The narrow Kishtwar belt is expected to mark the boundary between the Kashmir and Chamba Troughs in the north and south respectively (Figure 7).

CONCLUSIONS

Two major highs, the Jacobabad-Khairpur and Sargodha-Shahkot separate Kirthar, Sulaiman and Northwest Himalayan Basins, respectively. The three combined basins are separated from the Baluchistan Basin by a collision zone, identified as Bela-Dargai Province.

Based on the nature of rocks and location of major faults, the Northwest Himalayan Basin is subdivided into seven provinces: 1. Southern Hazara-Salt-Range Province, 2. Central Hazara-Nowshera Province, 3. Higher Himalayan Province, 4. Jammu Province, 5. Kashmir-Chamba Province, 6. Zanskar Range Province & 7. Zanskar River Province. The limit of the N.W. Himalayan Basin is extended to include all areas situated in Indus River Basin north of the water divide of Indus and Ganges River systems, placed between the water divide of Sutlej and Yamuna Rivers.

The nomenclature and courses of 5 major thrust faults and two strike slip faults is revised. Of these Indus Fault is introduced for the first time and Himalayan Frontal Thrust, formerly Salt Range Thrust is assumed to extend southeast of Mangla north of the Punjab Plain. The faults are 1. Pir Panjal Thrust (PPT), 2. Nathiagali Thrust (NGT), 3. Main Boundary Thrust (MBT), 4. Sub Himalayan Thrust (SHT), 5. Himalayan Frontal Thrust (HFT), 6. Jhelum Strike Slip Fault & 7. Indus Strike Slip Fault.

The proposed sub-division will help in re-defining some of the known petroleum zones of Pakistan.

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