Structure and Stratigraphy of Azad Pattan, Panjar, Karat, Chanas, Dangali, Dadyal and Malikpur areas of Districts Mirpur, Sudhnoti Azad Kashmir and district Rawalpindi, Pakistan.

Omer Iqbal, Mirza Shahid Baig, Shahab Pervez, and M. Iqbal Siddiqi,

Abstract : As Hazara Kashmir Syntaxes is the part of Himalayan Fold and thrust belt situated in sub- Himalayan and the studied areas i.e Districts Mirpur, Sudhnoti and Rawalpindi lies between its limbs. The Himalayan molasse deposits in Kashmir basin ranging from Early Miocene to Recent. These Himalayn molasse deposits present in the studied area included Chinji, Nagri, Dhok Pathan, Soan Formations (Siwalik Group) of Middle to Late Miocene to Pliocene while Mirpur Formation of Pleistocene and Kamlial and Murree Formations (Rawalpindi Group) of Early Miocene to Middle Miocene age are exposed in the studied area. These deposits originated from higher Himalayas and transported by paleo-river from north and are cover sequence of Indian plate. The studied area is highly deformed into 41 folds and 14 faults. The folds are northwest-southeast trending or southwest-northeast trending, asymmetric, tight to gentle in nature and southwest, northeast or southeast, northwest verging. Jhelum Fault is regional Fault which is Left lateral strike slip with subordinate reverse motion that truncates the structures on its eastern and western sides. The 13 other major splays fault of Jhelum Fault are also encountered during the course of study. These deformations are the consequences of northeast-southwest or northwest-southeast Himalayan compression in studied area. The facing had been marked on the basis of certain primary sedimentary structures like cross-bedding, Load coast and ripups and these sedimentary structures noticed during the course of study.

Keywords: Kashmir Basin, Hazara Kashmir Syntaxes, Stratigraphy and Structure, β and π diagrams, Pakistan , Azad Jammu & Kashmir.

INTRODUCTION

The project areas included Mirpur, Sudhnoti and Rawalpindi districts, Azad Kashmir and Pakistan. The project areas situated at 73°28'00" to 73°41'50" east , 33°15'00" to 33°45'00" north that founded on topographic sheet no. 43 G/7, 43 G/10 and 43 G/11 of Survey of Pakistan (Figure 1, Plate 1). The project is located in the southern part of the Hazara Kashmir Syntaxes and is imbricated along Punjal Thrust, Main Boundary Thrust and Riasi Fault (Baig and Lawrence, 1987). The western limb of the Hazara Kashmir Syntaxes terminated by regional Jhelum Fault (Figure 1). The workers like Ashraf *et al.* (1983), Wells and Gingerich (1987), and also Geological Survey of Pakistan carried only regional geological mapping and stratigraphic while the present study is manipulation of both detailed geological and structural mapping of the area. The purpose of present study is:

- To make the Geological map of 768 km² area on scale 1:50,000.
- To make the structural map
- To make structural cross-sections
- To make ⊙⊙and ⊙⊙diagrams for structural analysis of the area.

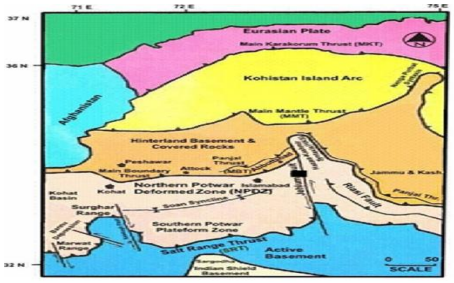


Figure 1: Tectonic map of northwest Himalayas of Pakistan. The rectangle shows the location of the project area. (Modified after Baig and Lawrence 1987; Monaliza and Azam 2004).

- Author=Omer Iqbal, B.S(Hon) in Applied Geology & currently pursuing master degree in Petroleum Geology, The university of AJ&K,
- Co Authors= Prof .Dr. Mirza Shahid Baig, The university of AJ&K, Assis. Prof. Shahab Pervez, The university of AJ&K and Assis. Prof. M. Iqbal Siddiqi, The university of AJ&K.

Methodology

The data acquired in 30 days field work. The attitude of the bedding planes of rock units was mapped by Brunton compass. The facing has been marked on the basis of certain Primary Sedimentary structures. The important features were also snapped . The processing of acquired data has been done in laboratory by plotting on the stereograms and structural maps. With the help of this data mapping has been accomplished i.e Geological Map (Plate 1), Structural Map (Plate 2) and Structural Cross-sections (3a,3b,3c,3d,3e,3f and 3g).

Stratigraphy

In Kashmir basin the stratigraphic units constitute the cover sequence of Indian Plate. The oldest rock unit present in the studied areas is Murree Formation. The Kamlial Formation of Early to Middle Miocene while Chinji, Nagri, Dhok pathan and Soan Formation (Siwalik Group) of Late Miocene to Pliocene and Mirpur Formation of Pleistocene age are exposed above Murree Frmation (Table 1). The stratigraphic units are classified and described as under.

1 Rawalpindi Group

The Rawalpindi group consists of enormous beds of sandstone and shale. The Rawalpindi group is divided into two lithostratigraphic units i.e Kamlial Formation and Murree Formation.

a) Murree Formation

This rock unit was named by Wadia (1931) and Ashraf *et al*., (1983). Murree Formation of Early Miocene is exposed only near Bisota area (Plate 1). Lithologically this unit is mainly consisting of alternative cycles of massive micacious sandstone, shale and also clays. Sandstone is red to purple, fine to medium grained, well compacted. Mineralogically the sandstone consists of more mica and also quarts, feldspar, epidote and chemically matures. The sandstone also shows load cost and ripups. The colour of shales is reddish, purple and maroonish (Photo1).

Photo 1: Load cast in the sandstone of Murree Formation (Plate 1; station Chakla-1). Photograph facing southeast.

b) Kamlial Formation

The Kamlial Formation of Early to Middle Miocene was proposed by Lewis (1937). Kamlial Formation is exposed near kamra, Chhalar, Panjar, Pajand and Kanial areas (Plate 1). Lithologically this unit consist of sandstone, clays and intraformational conglomerates. The sandstone is gray, medium grained, hard and compact and minerlogically composed of quartz, feldspar, tourmaline, biotite and epidote. It contain more tourmaline and usually presence of spheroidal weathering and shows cross bedding and load cost. Wood fossils and leaf impressions have been recorded The upper and lower contact with the Chinji and Formation respectively is gradational(Photo 2and 3).

Photo 2: Wood fossil in the sandstone of Kamlial Formation (Plate 1; station Panjar-1). Photograph facing southwest.

Photo 3: Local spheroidal weathering in the sandstone of Nagri Formation (Figure 3; station Peera -3). Photograph facing south.

2 Siwalik group

This group consists of colossal beds of sandstones, clays and conglomerates. Middle Miocene to late Pleistocene age is assigned to this group on the basis of vertebrate fossils. There are four lithostratigraphic units i.e, Chinji, Nagri, Dhok Pathan and Soan Formation.

a) Chinji Formation

The Chinji Formation of Middle to Late Miocene is found near Kamra, Bisota, Azad Pattan, Jhika Gali, Rumbli, Panjar, Chanas, Pajand, Chapper, Malikpur and Makhlot areas (Plate 1). Lithologically this unit is mainly consisting of sandstone , siltstone , clays and thin lenses of conglomerates at some places. The color of sandstone and siltstone is greenish grey, ash grey and red to purple respectively. The clays have variegated color i.e maroon, brick red, ash grey and red to brown with brick red color being prominent (Photo 4). The purple and reddish brown mudstone is also present. It has 30% sandstone and 70% clays and shows load cost and ripups. The upper contact with Nagri Foramtion and lower with Kamlial Formation is gradational.

Photo 4: Variegated clays of Chinji Formation (Plate 1; station Nawan-4). Photograph facing southeast.

b) Nagri Formation

Nagri Formation of Late Miocene is exposed near Chiras, Azad pattan, Jhika Gali, Rumbli, Atkora, Karot, Tanuchhi, Chanas, Jabran, Salgiati, Dheri qasim, Sandal, Makhlot and Chapper areas (Plate 1). Lithologically this unit is mainly consisting of greenish grey sandstone, siltstone and mudstone. The sandstone is massive, medium to coarse grained and mineralogically composed of quartz, feldspar, brown garnets, more epidote and biotite while less muscovite and black tourmaline and shows cross bedding and load coast. Sandstone and clay ratio is 60%: 40%. Sandstone constitute more biotite than any other units of this group that impart grayish grey colour to the sandstone. The diagnostic feature of this unit is volcanic clast of Punjal volcanoes and these clasts are rare in the basal part (Photo 5 and 6). The layers of conglomerates are rare. Along different horizons this unit also has sub-rounded to rounded clasts of volcanic, igneous and metamorphic units of Paleozoic era.

Photo 5: Volcanic clast in Nagri Formation (Plate 1; station Diwangargh-2). Photograph facing southwest.

Photo 6: Cross bedding in the sandstone of Nagri Formation (Plate 1; station Palina-1). Photograph facing southwest.

c) Dhok Pathan Formation

Dhok Pathan Formation of Late Miocene is exposed near Namb, Atkora, Karot, Nara, Salgiati, Gharala, Dheri Qasim, Chapper, Malikipur, Bandiala, kangar, Barma, Sandal and Baletra areas (Plate 1). Lithologically this unit is mainly consisting of alternative cycles of sandstone, clays, thick level of conglomerates and also siltstone. The sandstone is 60% and clays are 40%.The clays are reddish to brown while sandstone is fine to medium grained, medium to thick bedded, less compacted grey, and mineralogically consists and also shows cross bedding and load coast. Mineralogically it consists of quartz, feldspar, muscovite, brown garnet, green epidote, less biotite and tourmaline. The grains of quartz and feldspar are sub rounded to round. The hornblende and pink garnet are more prominent at middle and upper part of Formation respectively. It is also consist of Flasser bedding or lenticular bedding and ribbed topography (Photo 7, 8 and 9). The layers of conglomerates are 1 meter in thickness is observed.

Photo 7: Ribbed topography in Dhok Pathan Formation (Plate 1; station Shigran-1). Photograph facing southeast.

Photo 8: Lenticular bedding in the sandstone of Dhok Pathan Formation (Plate 1; station Dheri Qasim-1). Photograph looking north-northwest.

Photo 9: Polymict conglomeratic bed in Dhok Pathan Formation (Plate 1; station Sorakhi-4). Photograph facing southeast.

d) Soan Formation

Soan Formation of Pliocene is exposed near Ghoi, Gharala, Kahtala, Dhoke sodran, Nakka, Kangar, Baletra and Siakh (Plate 1). Lithologically this unit is mainly consisting of conglomerates, grey sandstone, clays, bentonite clays and claystone. The conglomerates are poorly sorted, compact, sub rounded to rounded having diabase, sandstone, chert, gneisses, schist, porphyritic igneous rocks, which is of boulder to pebble size. Clays are brown and yellowish grey. Sandstone is of grayish colour. The bantonite clay is present at the base of Soan Formation. The sand and clay are used as matrix and cement. This upper contact with Dhok Pathan Formation is gradational while lower contact with Mirpur Formation is disconformable marked by angular unconformity (Photo 10, 11and 12).

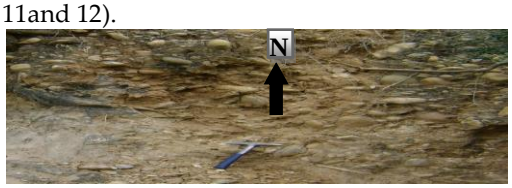


Photo 10: Conglomerates of Soan Formation (Plate 1; station Band-1). Photograph is facing south.

Photo 11: Conglomerates and sandy matrix of upper Soan Formation (Plate 1; station Sehar-2). Photograph facing northwest.

Photo 12: Bantonite clays in lower Soan Formation (Plate 1; station Dhok Sudran-3). Photograph looking northeast.

e) Mirpur Formation

Mirpur Formation of Pleistocene is exposed near Nara, Mohra chachian, Ghoi and Nakka (Plate 1). It is mainly consisting of conglomerates having cobbles and pebbles of limestone, cherty dolomite, sandstone, quartzite, granite, granite gneiss, metamorphic rocks and Punjal volcanic (Photo 13) and there is also an unconformity between Mirpur Formation and Quaternary alluvium.

Photo 13: Conglomerates of Mirpur Formation (Plate 1; station Nara 1). Photograph is facing southwest.

f) Quaternary Alluvium

Recent is represented by Quaternary alluvium. It is exposed in Chiras, Rumbli, Nara, Gharala, Mohra Chachian, Bandiala, Plina, Nakka (Plate 1). It is mainly consisting of silt, gravel and unconsolidated deposits of clay. The sand and silt are used as cement and less compact. It marked unconformity at the top of Mirpur Formation (Photo 14).

Photo 14: Cultivated area of Recent alluvium (Plate 1, Station Ankar-3). Photograph facing southeast.

Table 1: showing the stratigraphic sequence of the project area (Islam 2006).

Formation	Age	Description
Quaternary alluvium	Recent	Consists of gravel, unconsolidated deposits of clay and silt,
…….Unconformity…….		
Mirpur Formation	Pleistocene	Consists of conglomerates and having cobble and pebble size clasts of sedimentary igneous and metamorphic rocks.
…….Unconformity…….		
Soan Formation	Pliocene	Consists of conglomerates, grey sandstone, clays, bentonite clays and claystone.
Dhok Pathan Formation	Late Miocene	Sandstone, siltstone and clays are prominent.Sandstone is grey, fine to medium grained and medium to thick bedded.
Nagri Formation	Late Miocene	Greenish grey sandstone, siltstone, and mudstone. Sandstone is massive and medium to coarse grained. Sandstone and clay ratio is 60%:-40%.
Chinji Formation	Middle to Late Miocene	Red to purple, greenish grey, ash grey sandstone and siltstone. The mudstone is purple and reddish brown. The Formation has 70% clays and 30% sandstone.
Kamlial Formation	Early to Middle Miocene	Sandstone, clays and intraformational conglomerates
Murree Formation	Early Miocene	Mainly clays, shales and sandstone. Sandstone is red to purple red and fine to medium grained.
Kuldana Formation	Middle to Late Eocene	Variegated shales with subordinate sandstone. Shales are arenaceous.
Chorgali Formation	Early Eocene	Mostly calcareous shale, limestone and dolomitic limestone.
Margalla Hill Limestone	Early Eocene	Main nodular fossiliferous limestone with shales.
Patala Formation	Late Paleocene	Mainly shales interbedded with marl and limestone.
Lockhart Formation	Early Paleocene	Grey to dark grey limestone with subordinate shales.
Hangu Formation	Early Paleocene	Mainly laterite, bauxite and fireclay.
…….Unconformity…….		
Muzaffarabad Formation	Cambrian	Mainly dolomitic limestone with cherty dolomite and chert bands.
…….Unconformity…….		
Dogra Formation	Precambrian	Slates.

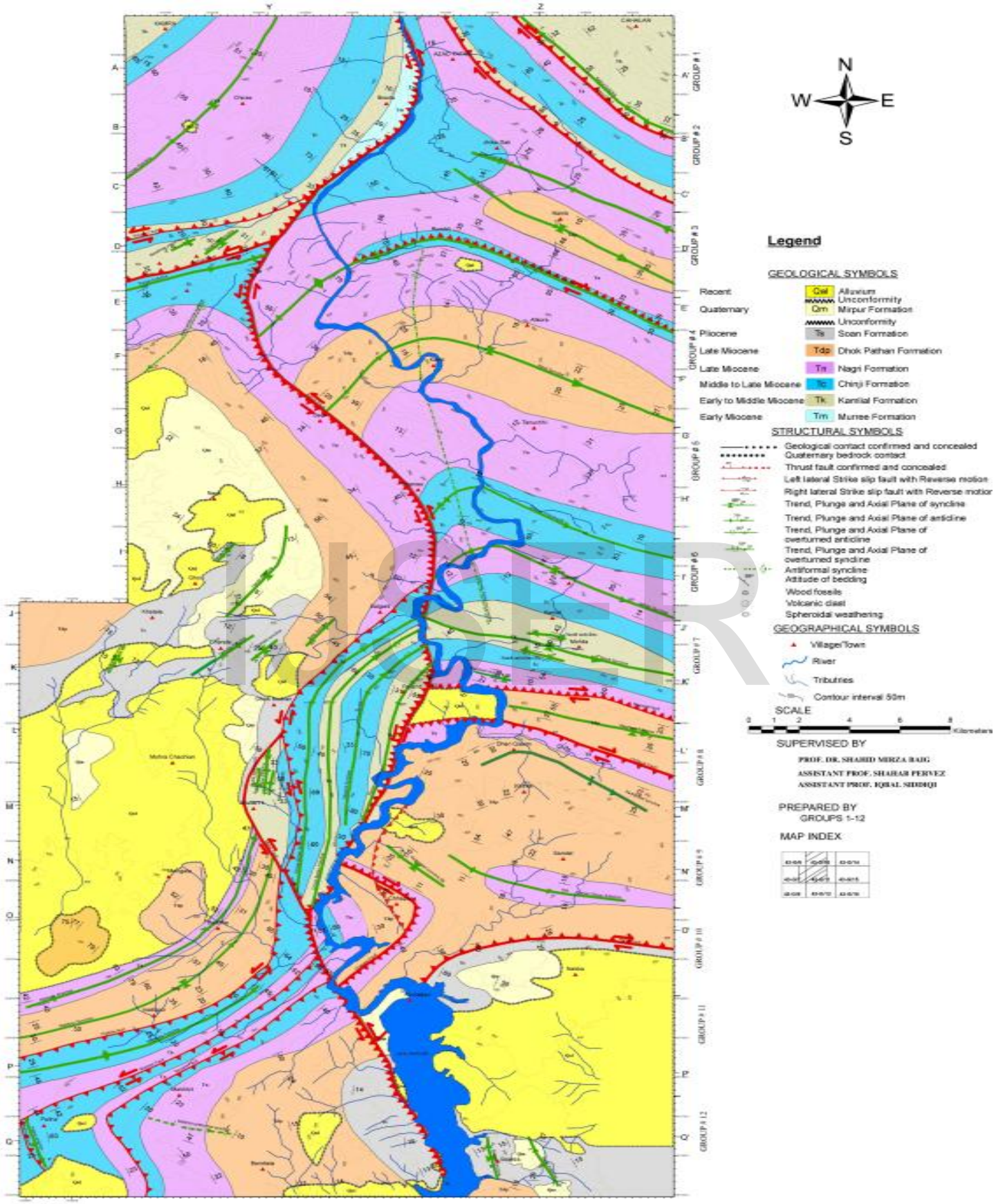


Plate 1: Geological map of studied area.

STRUCTURE

As Hazara Kashmir Syntaxes is the part of Himalayan Fold and thrust belt situated in sub- Himalayan and the studied lies between its limbs. The structures of the studied areas are consequence of Indian and Eurasian plate's collision. These are described as under:

a) FOLD

There are 41 folds present in the studied area. The structural data is represented in π and β diagrams and shows that these are tight to gentle in nature.

1 Chiras syncline

This syncline is created by the folding of Nagri Chinji, Kamlial and Murree Formation (Plate 2). The Nagri Formation situated in the core whereas on the limbs Chinji, Kamlial and Murree Formation are present (Plate 4a; cross section AA'). The southeastern limb of syncline is cut by the Jhelum fault. The attitude of northwestern limb ranges from N30°E/15°SE to N60°E/55°SE.The attitude of southeastern limb varies from N20°E/15°NW to N25°E/20°NW. The NW limb is relatively steeper than the SE limb. The attitude of axial plane of syncline ranges from N24°E/89°NW to N50°E/68°NW. The trend and plunge of fold axis ranges from 2°/205° to 6°/230°. The interlimb angle of syncline varies from 110° and 150° (Table 2; Figure 2 and 3). The structural data show that Chiras syncline is asymmetrical, southeast verging and open to gentle fold (Plate 3a; cross sections AA' and BB').

2 Kakrul anticline

The Kakrul anticline is formed by the folding of Kamlial and Murree Formation (Plate 2). The Kamlial Formation situated on limbs whereas Murree Formation in core. This anticline is hanging wall anticline of the Kakrul fault. The western limb of Kakrul anticline is cut by the Kakrul Fault. The attitude of northeastern limb is N50°W/32°NE to N50°W/33°NE whereas the attitude of southwestern limb is N45°W/35°SW. The axial plane has attitude from N48°W/88°NE to N48°W/89°NE. The fold axis of anticline is 2°/312° to 2°/313° (Table 2; Figure 11). The interlimb angle of anticline is 111° and 113°. The structural data show that Kakrul anticline is a southwest verging open fold (Plate 2 and Plate 4a; cross-section AA'). .

3 Jhika Gali anticline

The Nagri and Chinji Formayion folded to form this anticline (Plate 2).The northeastern limb of JhikaGali anticline is faulted by Pattan fault. Chinji Formation situated in core and limbs Nagri Formation is present. The attitude of the southwestern limb is N05°W/14°SW whereas the attitude of the northeastern limb is N60°W/25°NE. The axial plane has attitude N38°W/86°SW. The fold axis of anticline is 9°/322° (Table 2; Figure 17). The interlimb angle of anticline is 141°. The structural data show that the Jhika Gali anticline is an asymmetrical, northeast verging and gentle fold (Plate 2 and Plates 3a and 3g; cross-sections CC' and ZZ').

4 Namb syncline

Namb syncline is created by the folding of Dhok Pathan, Nagri, Chinji, Kamlial and Murree Formation (Plate 2). It has Nagri Formation in the core and Chinji and Kamlial Formations. The southwestern limb of the syncline is cut by the Rumbli Fault. The Namb syncline is truncated to the west by northwest dipping Jhelum Fault. The attitude of the northeastern limb is N25°W/09°SW-N68°W/55°SW whereas the attitude of the southwestern limb is N45°W/14°NE - N56°W/58° NE. The axial plane has attitude from N37°W/88°NE- N64°W/89°SW. The fold axis of syncline is 2°/142°-10°/116°. The interlimb angle of syncline is 67° and 157°. The structure data show that Namb syncline is an asymmetrical, southwest verging and close to gentle fold (Plate 2 and Plates 3a,3b and 3g; cross-section CC', DD' and ZZ').

5 Rumbli anticline

Rumbli anticline is created by the folding of Nagri and Chinji Formation (Plate 2). Chinji Formation situated in core and limbs the Nagri Formation is present. Rumbli anticline is cross fold and core faulted anticline i.e Rumbli Fault cuts core of this anticline. In southeastern part of the Rumbli anticline, the attitude of

northeastern limb is N58°W/35°NE - N81°W/54°NE whereas attitude of the southwestern limb is N81°W/37°SW - N70°W/50°SW. The Rumbli anticline fold axis trending northwest bends to the southwest direction. The attitude of the northwestern limb is N59°E/70°NW, whereas the attitude of southeastern limb is N81°E/40°SE - N70°E/33°SE. The axial plane, fold axis and interlimb angle are N60°E /75°NW,02°/239° and 70° respectively. The structure data shows in the southwestern part it is an asymmetric, southeast verging close fold. The southeastern part of the Rumbli anticline is fault core anticline (Plate 2 and Plates 3b and 3g; cross-sections DD', EE' and ZZ').

6 Panjar anticline

The Panjar anticline is created by the folding of Chinji, Kamlial, Muree, Paleocene-Eocene rocks, Muzaffarabad and Dogra Formation, The Dogra Formation situated in core and on limbs the Chinji Formation is present. To the east Panjar anticline is truncated by the left lateral Jhelum strike slip Fault (Plate 2). The northwestern limb of the Panjar anticline is cut by the Kahuta Fault. The attitude of the northwestern limb is N70°E/50°NW, whereas the attitude of southeastern limb is N68°E/40°SE. The NW limb is relatively steeper than the SE limb. The attitude of the axial plane, fold axis and interlimb angle are N70°E/85°SE, 02°/251° and 90° respectively. The structure data shows the Panjar anticline is an asymmetric, northwest verging open fold (Plate 2 Plate 3g; cross-section YY').

7 Barathian anticline

The Barathian anticline is created by the folding of Kamlial, Muree, Paleocene-Eocene rocks, Muzaffarabad and Dogra Formation (Plate 2 and Plate 4b; cross-section DD'). The Dogra Formation situated in core and Kamlial Formation occurs along the limbsThe attitude of the northwestern limb is N56°E/20°NW, whereas the attitude of the southeastern limb is N50°E/29°SE. The SE limb is relatively steeper than the NW limb. The attitude of the axial plane, fold axis and interlimb angle of the fold are N54°E/86°NW, 02°/234° and 131° respectively. The structure data shows, that the Barathian anticline is an asymmetric and southeast verging gentle fold (Plate 2 and Plate 3b; cross-section DD').

8 Barathian syncline

Barathian syncline is formed by the folding of Kamlial, Murree, Paleocene-Eocene rocks, Muzaffarabad and Dogra Formation (Plate 2).The Dogra Formation present in the core and on limbs the Kamlial Formation is present. Kahuta Fault cut southeastern limb of the Barathian syncline.The Kamlial Formation is thrusted over Chinji Formation (Plate 3b; cross-section DD'). The attitude of northwestern limb is N56°E/29°SE, whereas the attitude of southeastern limb is N31°E/31°NW. The SE limb is relatively steeper than the NW limb. The attitude of the axial plane, fold axis and interlimb angle of fold are N42°E/86°NW, 08°/222° and 120° respectively. The structure data shows, that the Barathian syncline is an asymmetric and southeast verging gentle fold. (Plate 2 and Plate 3b; cross-section DD').

9 Karot syncline

Karot syncline is created by the folding of Dhok Pathan and Nagri Formation. Dhok Pathan Formation is present in core whereas the Nagri Formation is on limbs (Plate 2). Western part of the Karot syncline cut by the Jhelum Fault. The Karot syncline is cross folded. On the southeastern side of syncline the attitude of NE limb is N70°W/22°SW, whereas attitude of SW limb is N60°W/20°NE. The attitude of axial plane, fold axis and interlimb angle are N67°W/89°SW, 01°/ 113°and 138° respectively. On the northwestern side of syncline the attitude of northwestern limb of Karot syncline varies from N36°E/22°SE to N45°E/27°SE, whereas attitude of southeastern limb varies from N24°E/20°NW to N40°E/18°NW. The attitude of axial plane varies from N28°E/88°NW to N43°E/87°NW. The fold axis varies from 01°/223° to 02°/211°. The interlimb angle varies from 135° to 138° and northeastern and southeastern verging (Table 2; Figure 4 and 5). Interlimb angle showed that Karot syncline is gentle fold (Plate 2 and Plates 3b and 3g; cross-sections FF' and YY').

10 Kangarh antiformal syncline

Kangarh antiformal syncline is formed by the folding of Chinji, Nagri and Dhok Pathan Formation (Plate 2). The Dhok Pathan Formation lies in core whereas Chinji Formation at the limbs. Eastern limb of Kangarh antiformal syncline is cut by the Jhelum Fault. The attitude of northwestern limb is N50°E/45°SE whereas the attitude of southeastern limb is N40°E/40°NW. The NW limb of Kangarh antiformal syncline is relatively steeper than the SE limb. The attitude of axial plane , fold axis and interlimb angle are N45°E/88°NW,04⁄ 225°and 95° respectively and southeastern verging. Interlimb angle showed that the Kangarh antiformal syncline is open fold (Plate 2 and Plate 3b; cross-section FF').

11 Chanas antiformal syncline

Chanas antiformal syncline is created by the folding of Nagri and Dhok Pathan Formation (Plate 2) The Nagri Formation present in core whereas the Dhok Pathan Formation lies on the limbs .The attitude of northeastern limb is N78°W/26°SW. The attitude of southwestern limb is N60°E/34°SE. The attitude of axial plane , fold axis and interlimb angle are N8°E/ 61°NW, 27°/194° and 75°, 120° and northwestern verging (Table 2; Figure 12). On the basis of interlimb angle, it is classified as a close fold (Plate 2 and Plate 3b; cross-section EE').

12 Jabran syncline

Jabran syncline is created by the folding of the Nagri and Chingi Formation. The Nagri Formation present in core of syncline whereas the Chinji Formation is exposed on limbs, (Plate 2). The attitude of northeastern limb is N42°W/19°SW and the attitude of southwestern limb is N40°W/12°NE. The NE limb is relatively steeper than the SW limb. The attitude of axial plane, fold axis and interlimb angle areN43°W/86°NE, 0°/137°and 149° (Table 2; Figure 15). The structural data show that the Jabran syncline is a non plunging gentle fold and southwestern verging (Plate 2 and Plate 3c; cross-section II′).

13 Haveli syncline

Haveli syncline is created by the folding of Soan, Dhok Pathan and Mirpur Formation (Plate 2). The Mirpur Formation present in core whereas the Dhok Pathan and Soan Formation occur along the limbs of the syncline .The attitude of northwestern limb of fold is N29°E/8°SE and the attitude of southeastern limb is N24W°/46°SW. The attitude of axial plane, fold axis and interlimb angle are N18°E/70°NE. 4°/162° and 128° respectively. The structural data show that the Haveli syncline is a gentle fold and southwestern verging (Plate 2 and Plate 3c; cross-section II′).

14 Band anticline

The Band anticline is created by the folding of Soan Formation (Plate 2). Soan Formation present in core whereas Mirpur Formation lies at the limbs. The attitude of northwestern limb of fold is N30°E/6°NW and the attitude of southeastern limb is N29°E/8°SE. The attitude of axial plane, fold axis and interlimb angle are N28°E/89°NW, 0°/210°and 164°. The structural data show that Band anticline is a gentle fold and southeastern verging (Plate 2 and Plate 3c; cross-section II′).

15 Chanas anticline

The Chanas anticline is created by the folding of Chinji and Nagri Formation (Plate 2). Nagri Formation present on limbs and Chinji Formation lies in core (Plate 2; Plates 3c, cross-section HH′ and II′). The attitude of northeastern limb is N45ºW/63°NE and the attitude of southwestern limb is N40ºW/55°SW. The attitude of axial, fold axis and interlimb angle are N43ºW/88ºSW, 4º/315º and 62º (Table 2; Figure 16). The structural data show that Chanas anticline is a close fold and northeastern verging.

16 Gharala syncline

It is a northeast-southwest trending fold. The Gharala syncline is created by the folding of Soan Formation (Plate 2). The Soan Formation is in core and the Dhok Pathan Formation is on limbs of the syncline. The attitude of northwestern limb is N18oE/60oNW whereas the attitude of southeastern limb is N20ºE/35ºSE. The attitude of axial plane, fold axis and interlimb angle are N17ºE/77ºSE,

1°/197° and 85° respectively. On the basis of structural data, the Gharala syncline is a close and northwest verging fold (Plate 2 and Plate 3d; cross sections KK′ and JJ′).

17 Gharala anticline

It is a northeast-southwest trending fold. The Gharala anticline is formed by the folding of Soan Formation (Plate 2). The Dhok Pathan Formation is in the core in the subsurface. The attitude of northwestern limb is N28°E/50°NW whereas the attitude of southeastern limb is N30°E/80°SE. The attitude of axial plane, fold axis and interlimb angle are N29°E/75°NW, 2°/210° and 50° respectively. On the basis of structural data, the Gharala anticline is a close and southeast verging fold (Plate 2 and Plate 3d; cross section KK′).

18 Barine syncline

It is a northeast-southwest trending fold. The Barine syncline is created by the folding of Soan and Dhok Pathan Formation (Plate 2). The Soan Formation is in core whereas the Dhok Pathan Formation present on limbs. The attitude of southeastren limb is N36°E/50°NW whereas the attitude northwestren limb is N30°E/75°SE. The attitude of axial plane, fold axis and interlimb angle are N34°E/76°NW, 5°/212° and 54° respectively. Barine syncline is classified as a southeast verging and close fold on the basis of structural data (Plate 2 and Plate 3d; cross section KK′).

19 Chouk Borjan syncline

The Chouk Borjan syncline is an overturned syncline created by the folding of Chinji and Kamlial Formation (Plate 2). The Kamlial Formation present on limbs whereas as Chinji Formation present in core. Western limb is cut by Malikpur-Diljabba fault. The attitudes of northwestern and western limb are N50°E/60°SE and N30°E/33°SE respectively. The attitudes of southeastern and eastern limb are N35°E/40°SE and N22°E/50°SE respectively. The attitude of axial plane, fold axis and iterlimb angle are N26°E/45°SE- N42°E/50°SE, 22°/222°- 11°/204 ° and 17 ° and 70° respectively (Table 2; Figure 18).The Chouk Borjan syncline is a northwest verging, tight to close and overturned fold (Plate 2 and Plates 3d and 3e; cross section KK′, LL', MM' and NN′).

20 Chouk Borjan anticline

The Chouk Borjan overturned anticline is created by folding of Chinji, Kamlial and Murree Formation (Plate 2). Chinji Formation present on limbs whereas Murree Formation present in core. The Murree Formation lies in the core in subsurface whereas the Chinji Formation lies on the limbs. On the surface this anticline is an intraformational fold. The attitudes of northwestern and western limb are N36°E/44°SE and N15°E/47°SE respectively, whereas the attitudes of southeastern and eastern limb are N50°E/72°SE and N25°E/52°SE respectively. The attitude of axial plane, fold axis and interlimb angle are N44°E/56°SE-N20°E/40°SE, 18°/224°-40°/200° and 28° and 84° respectively (Table 2; Figure 19). The Chouk Borjan anticline is a tight to close overturned fold and northwestern verging (Plate 2 and Plate 3d, 3e and 3g; cross section KK′, LL', YY′ and MM').

21 Panjand syncline

The Panjand overturned syncline is created by folding of Chinji and Kamlial Formation (Plate 2). The Kamlial Formation present on limbs whereas Chinji Formation present in core. The attitudes of northwestern and western limb are N30°E/50°SE and N15°E/54°SE respectively, whereas the attitudes of southeastern and eastern limb are N40°E/60°SE and N30°E/48°SE respectively. The attitude of axial plane, fold axis and interlimb angle are N37°E/56°SE-N23°E/50°SE, 38°/216°-44°/ 202° and 6° and 70° respectively (Table 2; Figure 20). Panjand syncline is classified as a northwest verging overturned isoclinals to close fold on the basis of structural data, (Plate 2 and Plates 3d and 3e; cross section KK′, LL' and MM′).

22 Panjand anticline

It is northeast-southwest trending fold. The Panjand overturned anticline is created by folding of Chinji, Kamlial and Murree Formation (Plate 2). Murree Formation present in core in subsurface whereas Chinji and Kamlial Formation lies on the limbs. The Panjand anticline is truncated by the Jehlum Fault. The attitudes of northwestern and western limb are N50°E/64°SE and N35°E/59°SE respectively, whereas the

attitudes of southeastern and eastern limb are N25°E/60°SE and N20°E/55°SE respectively. The attitude of axial plane, fold axis and interlimb angle are N38°E/61°SE- N30°E/57°SE, 55°/198° -60°/217°and 4° and 119° respectively (Table 2; Figure 21). The Panjand anticline is northwest verging and overturned isoclinals to open fold (Plate 2 and Plates 3d and 3e; cross section KK′, LL' and MM').

23 Toter anticline

The Toter anticline is created by folding of Dhok Pathan, Nagri and Chinji Formation (Plate 2). Chinji Formation is in core and Dhok Pathan Formation present on limbs. It is the northeast-southwest trending fold. The attitude of southeastern limb of the anticline is N35°E/60°SE whereas the attitude of the northwestern limb is N30°E/75°NW. The attitude of axial plane, fold axis and interlimb angle are N32°E/80°SE , 6°/212° and 45° respectively. Toter anticline is classified as a southwest verging and close fold on the basis of structural data (Plate 2; Plate 3e; cross-section JJ′)

24 Sandi anticline (A)

The Sandi Anticline (A) is the northwest-southeast trending fold. The Sandi Anticline (A) is created by folding of Kamlial and Chinji Formation (Plate 2). Kamlial Formation present in core whereas Chinji Formation lies on the limbs .The attitude of northeastern limb is N80oW/65°NE and attitude of southwestern limb is N74°W/60°SW. The attitude of axial plane, fold axis and interlimb angle are N77°W/85°SE , 6°/274° and 55° respectively. On the basis of structural data, the Sandi anticline (A) is classified as a close fold (Plate 2 and Plate 3d; cross section JJ′).

25 Sandi syncline

The Sandi syncline is created by folding of Kamlial Formation (Plate 2). Chinji Formation present in core whereas Kamlial Formation lies on the limbs. This is a northwest-southeast trending fold .The attitude of northeastern limb is N75°W/60°SW and attitude of southwestern limb is N70°W/62°NE. The attitude of axial plane, fold axis and interlimb angle are N72°W/88°SW, 6°/288° and 58° respectively. The structural data show that Sandi syncline is a close fold (Plate 2 and Plate 3d; cross section JJ′).

26 Sandi anticline (B)

The Sandi anticline (B) is the northwest-southeast trending fold. The Sandi anticline (B) is created by folding of Kamlial and Chinji Formation (Plate 2). The Kamlial Formation is present in core whereas Chinji Formation lies on the limbs .The attitude of northeastern limb is N72°W/55°NE whereas the attitude of southwestern limb is N60°W/65°SW. The attitude of axial plane, fold axis and interlimb angle are N66°W/79°SW, 10°/245° and 50° respectively. The structural data show that the Sandi anticline (B) is a close fold (Plate 2; Plate 3g; cross-section ZZ′).

27 Maliar anticline (A)

The Maliar anticline (A) is created by the folding of Kamlial Formation (Plate 2). Kamlial Formation present on limbs whereas in subsurface the Murree Formation present in core, This anticline is an intraformational fold on the surface, The western limb of the Maliar anticline (A) is cut by the Maliar fault. The attitude of eastern limb is N10°W/63°NE and the attitude of western limb is N15°W/40°SW. Eastern limb is relatively steeper than western limb. The attitude of axial plane, fold axis and interlimb angle are N12°W/80°SW, 4°/169° and 77° respectively. Maliar anticline (A) is classified as a northeast verging close fold on the basis of the structural data, (Plate 2 and Plate 3e; cross-section MM').

28 Maliar syncline

The Maliar syncline is an intraformational fold created by folding of Kamlial Formation (Plate 2). The attitude of eastern limb is N12°W/56° SW and the attitude of western limb is N10°W/40°NE. The attitude of axial plane, fold axis and interlimb angle are N11°W/82°NE, 1°/169° and 84°.Maliar syncline is classified as a southwest verging close fold On the basis of the structural data (Plate 2 and Plate 3e; cross-section MM').

29 Maliar anticline (B)

The Maliar anticline (B) is an intraformational fold created by folding of Kamlial Formation (Plate 2 and Plate 4e; cross-section MM'). The

attitude of the eastern limb is N8°W/60°NE and the attitude of western limb of the fold is N12°W/56°SW. The attitude of axial plane, fold axis and interlimb angle are N10°W/88°SW, 4°/170° and 64° respectively. Maliar anticline (B) is classified as a northeast verging close fold on the basis of structural data (Plate 2 and Plate34e; cross-section MM').

30 Sadiqabad syncline

The Sadiqabad syncline is created by folding of Dhok Pathan Formation (Plate 2). The Dhok Pathan Formation present in core and Nagri Formation lies on limbs. The attitude of the northeastern limb is N50°W/20°SW whereas the attitude of the southwestern limb is N52°W/25°NE. While attitude of northwestern limb is N60°W/28°SE and the attitude of southwestern limb is N50°W/20°NE.The attitude of the axial plane, fold axis and interlimb angle are N50°W/85°SW-N55°W/88°NE, 2°/135°- 3°/124° and 132° and 140° respectively (Table 2; Figure 6 and 7). This fold is classified as gentle fold on the basis of the interlimb angle. Vergence of Sadiqabad syncline is southwest (Plate 2 and Plates 3d, 3e and 3g; cross-sections LL', MM' and ZZ').

31 Rajdahni syncline

The Rajdahni syncline is created by folding of Dhok Pathan and Nagri Formation (plate 2). The Dhok Pathan Formation present in core and Nagri Formation lies on limbs, Bhalawal fault cut northeastern limb of the Rajdahni syncline and the southwestern limb of the syncline is cut by the Chillayar fault.

The attitude of northeastern limb is N60°W/55°SW whereas the attitude of southwestern limb is N55°W/27°NE. The attitude of the axial plane, fold axis and interlimb angle are N58°W/76°NE, 2°/121° and 98° respectively (Table 2; Figure 13). This fold is classified as an open fold on the basis of interlimb angle, Vergence of Rajdahni syncline is southwest (Plate 2; Plate 3d; cross-section KK').

32 Malikpur anticline

It is created by folding of Dhok Pathan and Nagri Formation (Plate 2). The Nagri Formation present in core and Dhok Pathan Formation is present on limbs. The bedding attitude of the northwestern limb is N50°E/42°NW and southeastern limb is N65°E/30°SE. The attitude of the axial plane, fold axis and interlimb angle are N56°E/88°SE, 4°/237° and 18º and 108° respectively (Table 2; Figure 10). The structural data shows that the Malikpur anticline is tight to open asymmetric fold and (Plate 2 and Plates 3e and 3g; cross-sections OO', NN' and YY').

33 Pheran Dinpur anticline

The Pheran Dinpur anticline is formed by the folding of Nagri and Dhok Pathan Formations (Plate 2). The Dhok Pathan formation present on limbs and Nagri Formation lies at core of anticline. The attitude of northeastern limb is N50°W/22°NE whereas the attitude of southwestern limb is N40°W/11°SW. The attitude of axial plane, fold axis and interlimb angle are N47°W/88°SW, 1°/313° and 147° respectively (Table 2; Figure 14). The fold is classified as gentle fold (Plate 2 and Plate 3g; cross-sections NN' and ZZ').

34 Malikpur syncline

The Malikpur syncline is created by folding of Dhok Pathan and Nagri Formation (Plate 2). The Dhok Pathan Formation is in the core whereas the Nagri. The southeastern limb of the Malikpur syncline is cut by the Malikpur-Diljabba fault. The attitude of the northwestern limb is N29ºE. 65ºSE and attitude of the southeastern limb is N31ºE/ 48ºNW. The NW limb is relatively steeper then SE limb. The attitude of the axial plane, fold axis and interlimb angle are N30°E/81°NW, 2º/031° and 67° respectively (Table 2; Figure 8) so classified as a close fold. The Malikpur syncline is the southeast verging asymmetric fold (Plate 2 and Plates 3e and 3g; cross-sections NN', OO' and YY').

35 Diljaba anticline

The Diljaba anticline is intraformational anticline formed by the folding of the Chinji formation (Plate 2). The southeastern limb is cut by the Makhlot fault.The attitude of northwestern limb is N45°E/20°NW. The attitude of southeastern limb is N42°E/20°SE. The attitude of the axial plane, fold axis and interlimb angle are N44ºE/89ºSE, 0º/44º and 139º respectively (Table 2; Figure 9). The

structural data show that Diljaba anticline is a gentle fold (Plate 2 and Plates 3e and 3f; cross-section PP′).

36 Palina anticline

The Palina anticline is an intraformational fold created by folding of Chinji Formation (Plate 2). Southwestern limb of the anticline is cut by the Makhlot Fault. The attitude of the northeastern limb is N2°W/65°NE and attitude of the southwestern limb is N14°W/50°SW. The NE limb is steeper than SW limb. The attitude of axial plane, fold axis and interlimb angle are N6°W/86°SW, 4°/174° and 65°. On the basis of structural data the Palina anticline is classified as the close fold (Plate 2; Plate 3f; cross-section QQ'). The Palina anticline is a hanging wall anticline. It is developed along drags of the hanging wall of the Makhlot fault (Photo 15).

Photo 15: Palina anticline in Chinji Foramtion (Figure 4; station Palina-6). Photo facing southwest.

37 Balatera syncline

The Balatera syncline is an intraformational fold formed by the folding of Soan Formation on the surface and by folding of Dhok Pathan Formation in the subsurface (Plate 2) The attitude of northeastern limb is N34°W/16°SW and the attitude of southwestern limb is N24°W/10°NE. The attitude of axial plane, fold axis and interlimb angle are N29°W/88°NE, 2°/150° and 154° respectively. The structural data show that the Balatera syncline is an asymmetric, southwest verging and gentle fold (Plate 2 and Plates 3f and 3g; cross-section QQ' and ZZ').

38 Siakh anticline

The Siakh anticline is a fold formed by the folding of Soan Formation on the surface and by the folding of Dhok Pathan Formation in the subsurface (Plate 2). The attitude of northeastern limb is N33°W/16°NE and the attitude of southwestern limb is N34°W/16°SW. The attitude of axial plane, fold axis and interlimb angle are N36°W/89°NE, 1°/149° and 148° respectively. The structural data shows that the Siakh anticline is an asymmetric, southwest verging and gentle fold (Plate 2 and Plate 3f; cross-section QQ').

39 Makhlot syncline

The Makhlot syncline is created by the folding of Nagri and Chinji Formation (Plate 2). Nagri Formation occurs at core and Chingi Formation along limbs. The attitude of the northeastern limb is N40°W/23°SE and the attitude of southwestern limb is N40°W/47°NE. The SW limb is steeper than the NE limb. The attitude of axial plane, fold axis and interlimb angle are N68°W/74°SW, 23°/116° and 110° respectively. On the basis of structural data the Makhlot syncline is an asymmetrical, northeast verging and open fold (Plate 2 and Plate 3g; cross-section YY').

40 Sadiqabad syncline (B).

It is created by folding of Dhok Pathan Formation (Plate 2). The attitude of the northeastern limb N45°W/15°SW and southwestern limb is N52°W/25°NE. The attitude of the axial plane, fold axis and interlimb angle are N50°W/85°SW, 2°/135° and 140° (Table 2; Figure 7). So the fold is classified as gentle fold and northeastern verging (Plates 2, 3d, 3e and 3g; cross-sections LL′, MM′, NN′ and ZZ′).

41 Rajdahni syncline (B)

The Rajdahni syncline is created by folding of Nagri and Chinji Formation (plate 2). The Nagri Formation present at core whereas Chinji Formation lies on the limbs of the Rajdahni syncline (B). Bhalawal fault cut the northeastern limb of the Rajdahni syncline and southwestern limb of the syncline is cut by the Chillayar fault. The attitude of northeastern limb is N60°W/55°SW whereas the attitude of southwestern limb is N55°W/27°NE. The attitude of the axial plane, fold axis and interlimb angle are N58°W/76°NE, 2°/121° and 98° respectively (Table 2;). This fold is classified as an open fold on the basis of interlimb angle. Vergence of Rajdahni syncline is southwest (Plate 2; Plate 3d; cross-section KK′).

B FAULT

The faulting are also present in the areas. The structures are mostly northwest southeast or southwest northeast trending. The faults are mostly thrust behaviour and their fault planes are southwest, northeast, northwest and southeast dipping. Topographic fronts, fault controlled gullies are present. The faults encountered in the areas are as follows:

1 Jhelum Fault

It is regional fault running through the area and shows the oblique behavior at some places. In the studied area, it is running along the river Jhelum. The Jhelum Fault trends south to north direction (Plate 2).The Jhelum Fault is a left lateral strike slip fault with subordinate reverse motion. The Shearing, crushing, gouge, drag folds and slickenside, topographic front are common along Jhelum Fault. The attitude of fault plane is N15˚E/68˚NW, whereas in adjacent areas the attitude of fault plane is N60°W/45°SW and different at other areas. Jhelum Fault cuts different lithologies The Soan Formation thrusted over the Recent Alluvium and show the active behaviour of Jhelum Fault at Baletra area. At some places, the Jhelum Fault is concealed due to alluvial cover. The major structures on the western side and eastern side of the Jhelum Fault truncate against the Jhelum Fault. Jhelum Fault abruptly truncate the fold and thrust belt along the eastern and western banks of the Jhelum river (Plate 2; 3a, 3b, 3c, 3d, 3e, 3f and 3g; cross-sections AA′, BB′, CC′, DD′, EE′, FF′, GG′, HH′, II′, JJ′, KK′, LL′, MM′ NN, OO′, PP′, QQ′, YY′ and ZZ′). In the project area different splays of Jhelum fault are present. The Jhelum Fault is identified on the basis of change in strike direction and triangular facets at some places (Photo 16, 17, 18, 21and 35).

2 Pattan fault

The Pattan fault is reverse fault running northwest-southeast (Plate 2). The Kamlial Formation is thrusted over the Nagri Formation. The Pattan fault is northwest-southeast trending fault. The Kamlial Formation is exposed at hanging wall block and Nagri Formation on foot wall block (Plates 3a and 3g; cross section AA', BB′, CC' and ZZ'). The attitude of fault plane is N35°W/55°NE. The shearing, crushing and drag folds are present in the fault zone.

3 Kakrul fault

The fault is reverse fault running northwest-southeast (Plate 2). The Kakrul fault is marked between Nagri Formation and Kamlial Formation. The Kamlial Formation is exposed at hanging wall block whereas the Nagri Formation on foot wall block (Plates 3a and 3g; cross section AA' and ZZ'). The hanging wall is folded and the Kakrul hanging wall anticline is formed. The attitude of fault plane is N35°W/45°NE

4 Kaloian fault

The Kaloian fault is a reverse fault and exposed in the upper western corner of the project area. (Plate 2).The Kaloian fault is northeast-southwest trending and northwest dipping fault. In this fault Kamlial Formation is thrusted over the Chinji Formation in the project area. However, in the adjacent area the Kaloian fault is marked within the Kamlial Formation. In the northeast, the Kaloian fault is truncated against the Jhelum Fault (Plate 2 and Plate 3g; cross-section YY').The attitude of the fault plane is N70°E/85°NW. The shearing and crushing are present along the fault zone. The fault breccias and gauge can also be identified in the project area along the Kaloian fault. The drag folds are common along this fault.

5 Rumbli fault

The Rumbli fault is a reverse fault and northwest-southeast trending fault. It bends to the southwest due to the folding of Rumbli anticline (Plate 2 and Plate 3b and 3g; cross-sectionDD′,EE′ and ZZ').). The Rumbli fault cuts the core of Rumbli anticline. It runs parallel to the fold axis of Rumbli anticline. The Rumbli fault lies within the Chinji Formation which occurs in the core of Rumbli anticline. The attitude of the fault plane is N58°W/65°NE.The shearing, crushing and drag folds are present along the fault zone. The fault breccias and gauge can also be identified in the project area along the Rumbli Fault (Photo 19).

6 Kahuta fault

It is northeast-southwest trending fault. It is the splay fault of the Jhelum Fault (Plate 2 and Plate 3b, 3g; cross-section DD″ and YY').). In this fault, the Kamlial Formation is thrusted over the Chinji Formation. Hanging wall anticline is developed at hanging wall block of Kahuta fault. The attitude of the fault plane is N70°E/70°NW. The Kahuta fault is a reverse fault. The shearing and crushing is present along the fault zone. The fault breccias and gauge can also be identified in the project area along the Kahuta Fault. The drag folds are common along this fault (Photo 20).

7 Diljaba fault

The Diljaba fault is the splay fault of Jhelum Fault running in northeast-southwest direction (Plate 2). The Diljabba fault is a thrust fault. The Chinji Formation is thrusted over the Nagri Formtion. However in some areas Chinji Formation is thrusted over Dhok Pathan Formation and in adjacent areas Chinji Formation is thrusted over Soan Formation and in some areas Chinji Formation is thrusted over Kamlial Formation along the Diljaba fault. In some areas it is marked within the Chinji Formation in such a way that the lower part of the Chinji Formation is thrusted over the upper part of the Chinji Formation The Chinji Formation is exposed at hanging wall block and the Nagri, Dhok Pathan, Soan, Kamlial Formation on footwall block of the fault (Plate 2 and Plates 3d, 3eand 3g; cross-section JJ′, KK′, LL′, MM′, NN′, OO′ and YY′). The attitude of the fault is N40°E/68°SE. The rocks are highly sheared along fault. The fault gouge and breccias are present along fault. The triangular facets are also present along the Diljaba fault (Photo 24, 27, 28 and 30).

8 Bhalawal Fault

The Bhalawal fault is running southeast-northwest in the project area (Plate 2). The fault is running between the Nagri and Dhok Pathan Formation upto the Jhelum River and joins the Jhelum Fault at Banahal village along the Jhelum river. The Nagri Formation thrusted over the Dhok Pathan Formation in area. The attitude of fault plane is N58°W/68°NE. Drag folds, landslides, gouge and slickenside were observed along the fault in the field area (Photo 23).

9 Chillayar fault

The Chillayar fault is a northwest-southeast trending reverse fault (Plate 2). The Nagri Formation is exposed at hanging wall block whereas Dhok Pathan Formation is exposed on footwall block of the fault (Plate 2 and Plates 3d and 3g; cross-sections LL'and ZZ'). In the project area, the Chillayar fault is truncated by the Jhelum Fault near Banhil. The attitude of hanging wall block is N31°W/20°SW and attitude of foot wall block is N39°W/24°NE. The attitude of fault plane of the Chillayar fault in the project area is N40°W/50°SW. The fault gouge, shearing and crushing is observed along the fault zone. The Chillayar fault is a back thrust (Photo26).

10 Maliar fault

The Maliar fault is a splay fault of Diljaba fault. This fault is a reverse fault. The Kamlial Formation thrusted over the Soan Formation and in adjacent areas the Kamlial Formation thrusted over the Dhok Pathan and Nagri Formation. The Kamlial Formation at hanging wall while Soan, Nagri, and Dhok Pathan Formation at footwall of Maliar Fault at Maliar area. The Kamlial Formation occurs in the hanging wall and the Soan Formation in the footwall of the Maliar fault. In south the attitude of fault plane is N25°W/61°NE. This fault extends southeast-northwest and it bend to northeast. The fold axis of Malikpur anticline and Malikpur syncline is truncated by the Maliar Fault (Plate 2 and Plate 3e; cross-sections MM′ and NN′). This fault is interpreted as back thrust (Photo 29).

11 Chappar fault

The Chappar fault is splay fault of Jhelum Fault. It present at the eastern side of the Jehlum Fault in the project area. The Chappar fault lies to the east of the Jhelum Fault. The Chappar fault is truncated by the Jehlum fault near Andarwal. It runs in northeast-southwest. Near Chappar it bends and it trends in northwest-southeast direction (Plate 2and Plate 3e; cross-sections NN′ and OO′). In Chappar fault, the Nagri Formation is thrusted over Dhok Pathan Formation. The Nagri

Formation is exposed in hanging wall while the Dhok Pathan Formation in footwall. The attitude of the hanging wall is N50°W/31°NE while the attitude of the foot wall is N25°W/25°NE.

12 Makhlot fault

It is a reverse fault .The Makhlot fault lies on the western side of the Jehlum fault. It is a northeast-southwest trending fault In the southwestern part of the area, the fault is intraformational running through the Chinji Formation and trend northwest-southeast (Plate 2 and Plates 3f and 3g; cross-sections PP′, QQ′ and YY′). The Makhlot fault is a reverse fault in which the Chinji Formation is thrusted over the Nagri Formation. The Chinji Formation is at hanging wall block and Nagri Formation is in the footwall block of the fault. The attitude of hanging wall block is N47ºE/50°SE while the attitude of the foot wall is N40°E/52ºSE. The fault is identified on the basis of stratigraphy, shearing, crushing and omission of strata. The attitude of fault plane of Makhlot fault is N25°E/81°SE whereas in adjacent areas the attitude of fault plane is N25°W/81°NE (Photo31 and 33).

13 Tanyam fault

The Tanyam fault is a reverse fault and northwest-southeast trending fault on western side of the Jhelum Fault, It bends to northeast-southwest (Plate 2 and Plates 3f and 3g; cross-sections PP′, QQ′ and YY′). This fault is running through center of the project area. The Chinji Formation thrusted over the Nagri Formation along the fault. Chinji Formation is at hanging wall block and Nagri Formation is on footwall block. The attitude of the hanging wall block is N47ºE/55°SE while the attitude of footwall block is N45ºE/64ºSE. The attitude of fault plane is N35ºE/51ºSE, whereas in adjacent area the attitude of the Tanyam fault is N25°W/86°NE. The Tanyam fault is truncated by the Jehlum fault on the northeastern side. The Tanyam fault is a reverse fault running almost parallel to the Makhlot fault. The shearing, crushing and omission of strata are observed along the Tanyam fault (Photo 32 and 34).

14 Ratta Fault

The Ratta fault is a reverse fault passing through the project area. The Ratta fault is a northeast-southwest trending fault (Plate 2 and Plate 3g; cross-section ZZ′). The Dhok Pathan Formation thrusted over Soan Formation. The Dhok Pathan Formation is at hanging wall block while the Soan Formation is on foot wall block. The attitude of the hanging wall block is N52°E/26°SE while the attitude of footwall block is N58°E/85°SE.

Photo 16: Murree Formation (A) Chinji Formation (B) and Nagri Formation (C) near Azad Pattan.(Plate 2; station Azad Pattan-1). The Jhelum Fault present between the Murree Formation (A) and Chinji Formation (B). Photograph facing southeast.

Photo 17: Slickenside surface in the sandstone of Murree Formation along the Jhelum fault (Plate 2; station Azad Pattan-2).Photograph facing southeast.

Photog 18: Drag folds in Chinji Formation in the foot wall block of Jhelum Fault (Plate 2; stationLasaniati-1). Photograph facing southeast.

Photog 19: Shearing and crushing along the Rumbli fault. Note Z-type drag fold in the middle right corner of the photograph. Rumbli fault in Chinji Formation (Plate 2; station Rumbli-2). Photograph facing southwest.

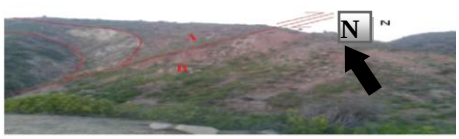


Photo 20: Kahta fault between Kamlial Formation (A) and Chinji Formation (B). Note hanging wall anticline in the hanging wall of the Kahuta fault (Plate 24; station Panjar-6). Photograph facing southwest

Photo 21: Fault gouge along the Jhelum Fault in Nagri Formation (Plate 2; station Nala Khair-2). Photograph facing southwest.

Photo 22: Slickensides of Bhalawal fault (Plate 2; station Luna-2). Photograph facing southwest.

Photo 23: Shearing along the Bhalawal fault (Plate 2; station Banahal-1). Tn= Nagri Formation, Qal= Quaternary alluvium. Photograph facing southeast.

Photo 24: Gouge and shearing of Malikpur-Diljabba fault (Plate 2; station Sehar-3). Tc= Chinji Formation, Tdp= Dhok Pathan Formation. Photograph facing southwest.

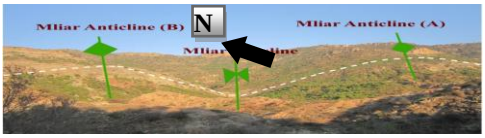


Photo 25: Maliar anticline (A), Maliar syncline and Maliar anticline (B) (Plate 2; station Khad-2). Photograph facing northeast.

Photo 26: Crushing along Chillayar fault between Nagri Formation (Tn) and Dhok Patha Formation (Tdp) (Plate 2; station Bela Bhadarshah-2). Photograph facing southeast.

Photo 27: Shearing along Malikpur-Diljaba fault between lower Chinji Formation (Tc) and upper Chinji Formation (Tc) (Plate 2; station Khad-4). Photograph facing east.

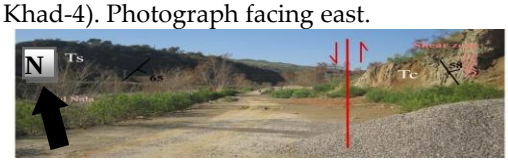


Photo 28: Chinji Formation (Tc) thrusted over Soan Formation (Ts) in Malikpur-Diljaba fault (Plate 2; station Khad-5). Photograph looking north-northwest.

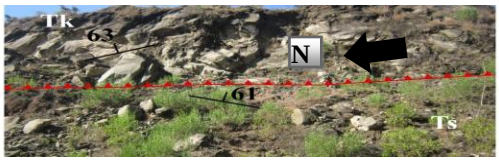


Photo 29: Maliar fault between Kamlial Formation (Tk) and Soan Formation (Ts) (Plate 2; station Maliar-2). Photograph facing northeast.

Photo 30: Highly sheared sandstone of Dhok Pathan Formation along Malikpur-Diljabba

Fault (Plate 2; station Palal Mallah khan-2). Photograph facing southeast.

Photog 31: Makhlot Fault near Makhlot. Note; (A) Chinji Formation, (B) Nagri Formation (Plate 2; station Makhlot-4) Photograph facing northwest.

Photo 32: Tanyam Fault. Note; (A) Chinji Formation, (B) Nagri Formation (Plate 2; station Tanyam-1). Photograph facing southeast.

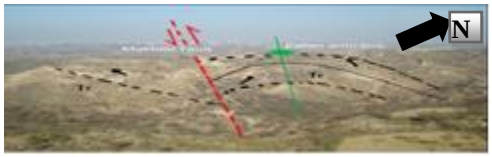


Photo 33: Makhlot fault within Chinji Formation having wall anticline (Plate 2; station Palina-6). Photograpgh facing southeast.

Photo 34: Tanyam fault between Nagri Foramation (Tn) and Chinji Formation (Tc). Facing southeast.

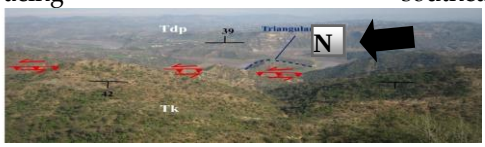


Photo 35: Jhelum fault between Dhoke Pathan Formation (Tdp) and Kamlial Formation (Tk). The degraded triangular facet is developed along the fault (Plate 2; station Pajand-2). Photograph facing east.

PLATE 3a. STRUCTURAL CROSS-SECTIONS OF PALANDRI, AZAD PATTAN AND TEHSIL KAHUTA AREAS OF AZAD KASHMIR AND PAKISTAN.

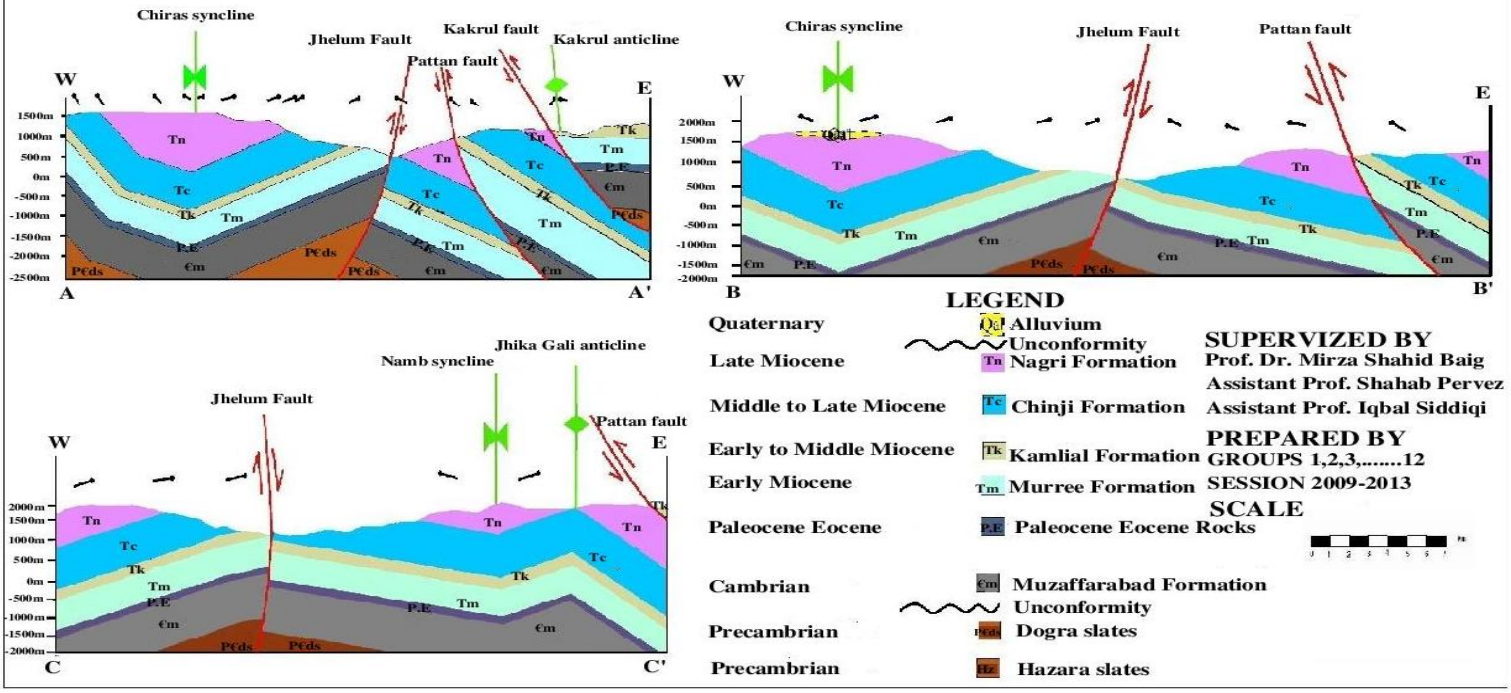
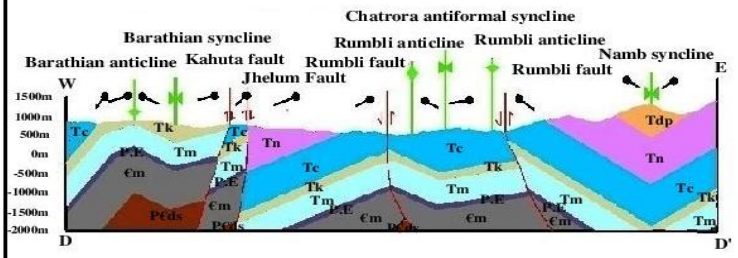
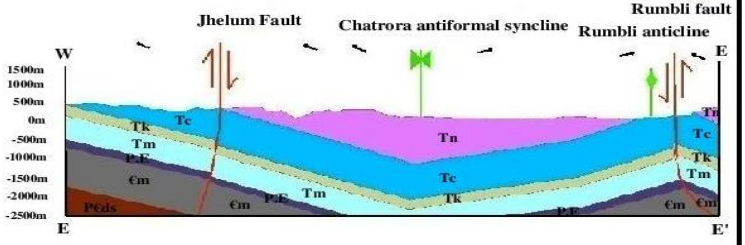
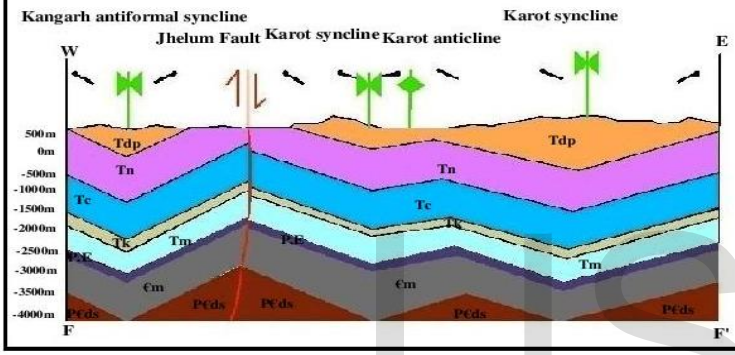


PLATE 3b. STRUCTURAL CROSS-SECTIONS OF PANJAR, RUMBLI, KAROT, TARALA AND ATKORA AREAS OF AZAD KASHMIR AND PAKISTAN.







LEGEND

Late Miocene	Tdp	Dhoke Pathan Formation
Late Miocene	Tn	Nagri Formation
Middle to Late Miocene	Tc	Chinji Formation
Early to Middle Miocene	Tk	Kamlial Formation
Early Miocene	Tm	Murree Formation
Paleocene Eocene	P.E	Paleocene Eocene Rocks
		Unconformity
Cambrian	€m	Muzaffarabad Formation
		Unconformity
Precambrian	P€ds	Dogra Slates

SUPERVIZED BY:
Prof. Dr. Mirza Shahid Baig
Assistant Prof. Shahab Pervez
assistant Prof. Iqbal Siddiqi

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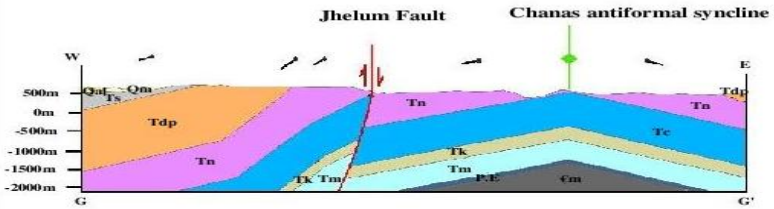
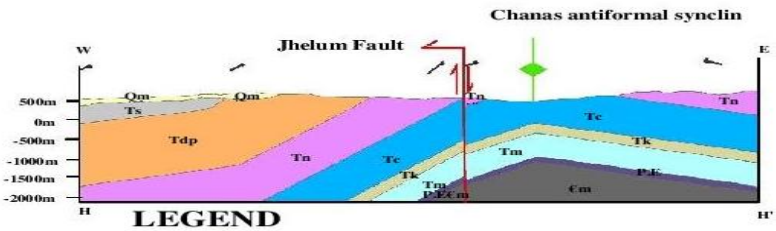
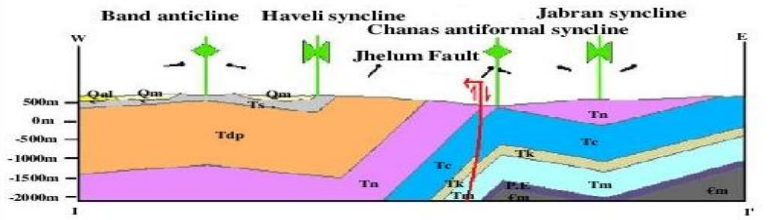
PLATE 3c. STRUCTURAL CROSS-SECTION OF NARA, TANUCHI, BEOR, NAWAN, AND JABRAN AREAS OF AZAD KASHMIR AND PAKISTAN.







LEGEND

Quaternary	Qal	Alluvium
		Unconformity
Pliestocene	Qm	Mirpur Formation
		Unconformity
Pliocene	Ts	Soan Formation
Late Miocene	Tdp	Dhoke Pathan Formation
Late Miocene	Tn	Nagri Formation
Middle to Late Miocene	Tc	Chinji Formation
Early to Middle Miocene	Tk	Kamlial Formation
Early Miocene	Tm	Murree Formation
Paleocene Eocene	P.E	Paleocene Eocene Rocks
Cambrian	€m	Muzaffarabad Formation

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Prof. Dr. Mirza Shahid Baig
Assistant Prof. Shahab Pervez
Assistant Prof. Iqbal Siddiqi

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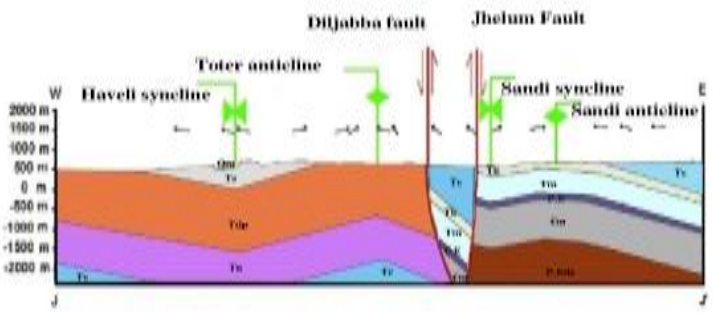
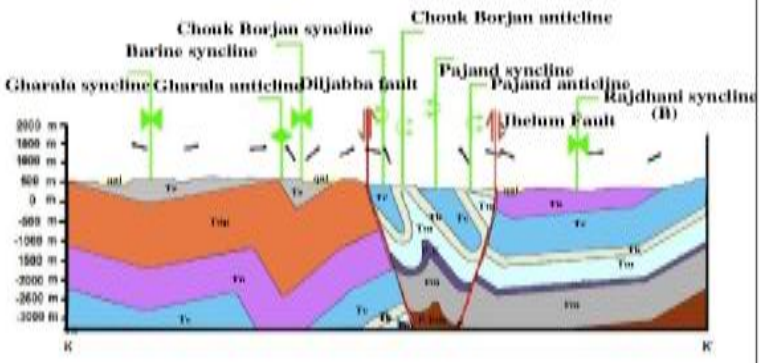
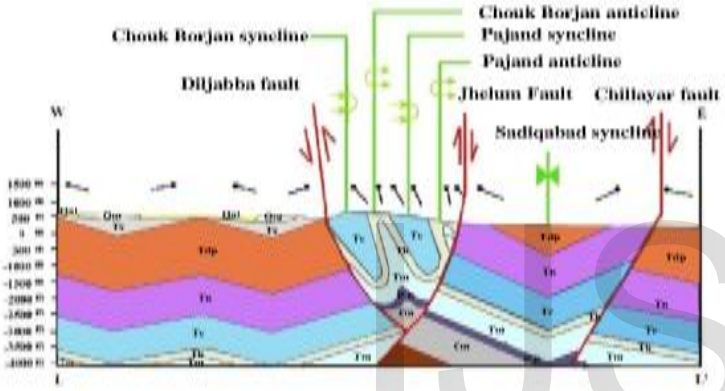
PLATE 3d. STRUCTURAL CROSS-SECTION OF SEHAR, BANHIL, PANJAR AND DHERI QASIM AREAS OF AZAD KASHMIR AND PAKISTAN.







LEGEND

Recent	Qal	Quaternary Alluvium
		Unconformity
Pleistocene	Qm	Mirpur Formation
		Unconformity
Pliocene	Ts	Soan Formation
Late Miocene	Tdp	Dhok Pathan Formation
Late Miocene	Tn	Nagri Formation
Middle to Late Miocene	Tc	Chinji Formation
Early to Middle Miocene	Tk	Kamlial Formation
Early Miocene	Tm	Murree Formation
Paleocene-Eocene	PE	Paleocene-Eocene Rocks
		Unconformity
Cambrian	Cm	Muzaffarabad Formation
Precambrian	PCm	Dogra Slates

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Prof. Dr. Mirza Shahid Baig
Assistant Prof. Shahab Pervez
Assistant Prof. Iqbal Siddiqi

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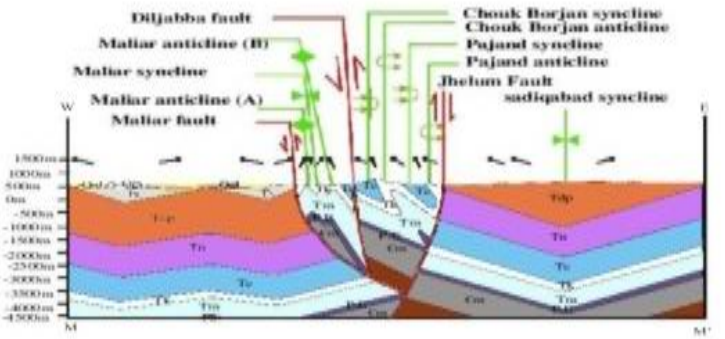
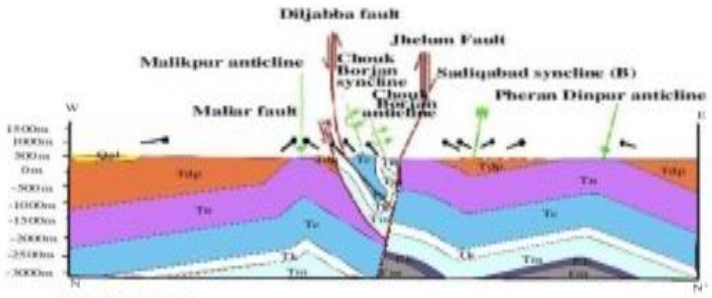
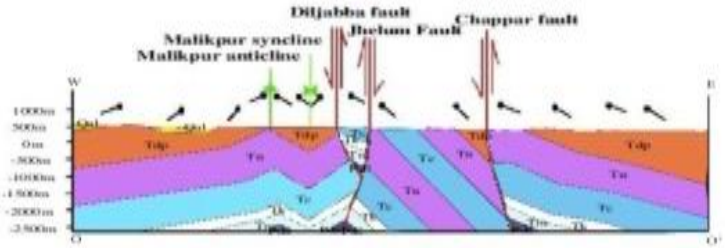
PLATE 3e. STRUCTURAL CROSS-SECTIONS OF KATHAR, MOHRA CHACHIAN, SANDAL, CHAPPAR AREAS OF AZAD KASHMIR AND PAKISTAN.







LEGEND

Quaternary	Qal	Alluvium
		Unconformity
Pliestocene	Qm	Mirpur Formation
		Unconformity
Pliocene	Ts	Soan Formation
Late Miocene	Tdp	Dhoke pathan Formation
Late Miocene	Tn	Nagri Formation
Middle to Late Miocene	Tc	Chinji Formation
Early to Middle Miocene	Tk	Kamlial Formation
Early Miocene	Tm	Murree Formation
Paleocene - Eocene	PE	Paleocene Eocene Rocks
		Unconformity
Cambrian	Cm	Muzaffarabad Formation
		Unconformity
Precambrian	PCm	Dogra Slates

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Assistant Prof. Shahab Pervez
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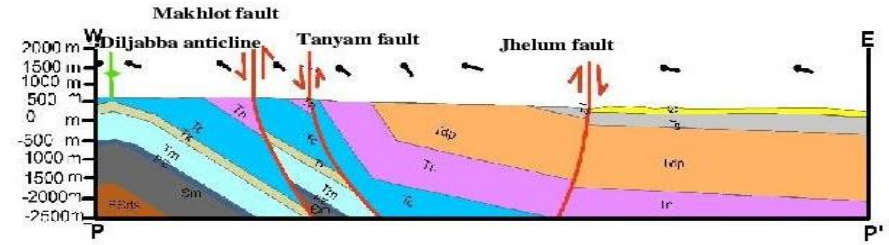
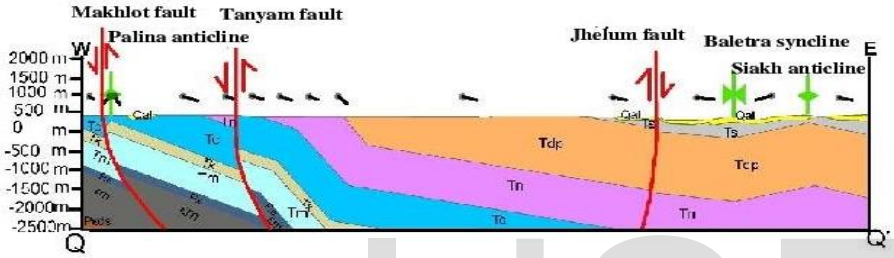
PLATE 3f. STRUCTURAL CROSS-SECTION OF CHATROH, TANYAM,MAKHLOT, BEGHAM, BANDIALA, SIAKH, AND PALINA AREAS OF AZAD KASHMIR AND PAKISTAN.





Legend

Quaternary	Qal	Alluvium
		Unconformity
Pleistocene	Qm	Mirpur Formation
		Unconformity
Pliocene	Ts	Soan Formation
Late Miocene	Tdp	Dhak Pathan Formation
Late Miocene	Tn	Nagri Formation
Middle to Late Miocene	Tc	Chinji Formation
Early to Middle Miocene	Tk	Kamlial Formation
Early Miocene	Tm	Murree Formation
Paleocene-Eocene	PE	Paleocene-Eocene Rocks
Eocene		Unconformity
Cambrian	Em	Muzaffarabad Formation
		Unconformity
Precambrian	PCds	Dogra Slates

SUPERVISED BY

Prof. Dr. Mirza Shahid Baig
Assistant Prof. Shahid Baig
Assistant Prof. Iqbal Siddiwi..

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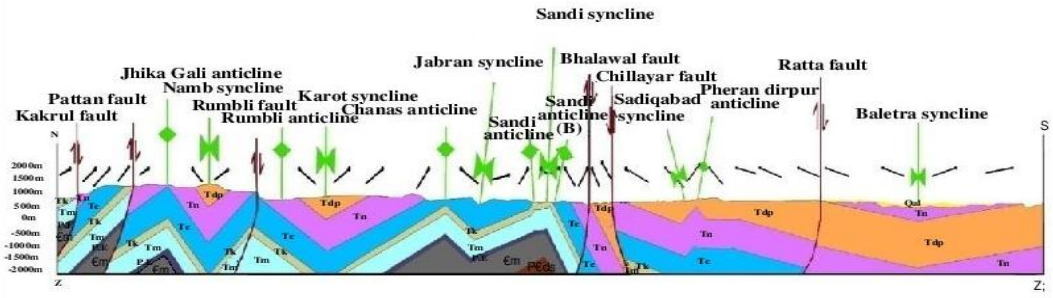
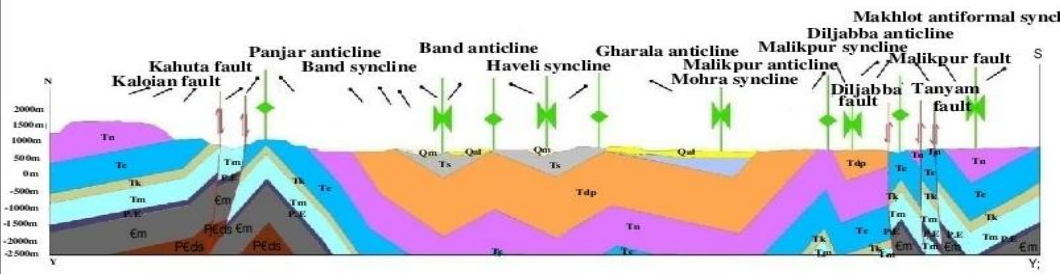
PLATE 3g. STRUCTURAL CROSS-SECTION OF CHHALAR, NAMB, ATKORA, TANUCHI, JABRAN, NAKKA, MOHILA, KATHAR, BALETRA, MAKHLOT, MALIAR KHATALA,PANJAR AND CHIRAS AREAS OF AZAD KASHMIR AND PAKISTAN





LEGEND

Quaternary	Qal	Alluvium
		Unconformity
Pliestocene	Qm	Mirpur Formation
Pliocene	Ts	Soan Formation
Late Miocene	Tdp	Dhoke Pathan Formation
Late Miocene	Tn	Nagri Formation
Middle to Late Miocene	Tc	Chinji Formation
Early to Middle Miocene	Tk	Kamlial Formation
Early Miocene	Tm	Murree Formation
Paleocene Eocene	PE	Paleocene Eocene Rocks
		Unconformity
Cambrian	Em	Muzaffarabad Formation
		Unconformity
Precambrian	PCds	Dogra Slates

SUPERVISED BY

Prof.Dr.Mirza Shahid Baig
Assistant Prof. Shahab Pervez
Assistant Prof. Iqbal Siddiqi

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Table 2: Structural data of major folds of studied area.

S.No.	Folds	Attitude of bedding		Axial plane	Fold axis	Interlimb angle	Fold type
		NW Limb	SE limb				
1	Chiras syncline	N30°E/15°SE	N20°E/15°NW	N24°E/89°NW	2°/205°	150°	Gentle
		N60°E/55°SE	N25°E/15°NW	N50°E/68°NW	6°/230°	110°	Open
2	Karot syncline (SE Part)	N45°E/27°SE	N40°E/18°NW	N43°E/87°NW	1°⁄223°	135°	Gentle
		N36°E/22°SE	N24°E/20°NW	N28°E/88°NW	2°⁄211°	138°	Gentle
3	Sadiqabad syncline)	N60°W/28°SE	N50°W/20°NE	N55°W/88°NE	3˚/124˚	132°	Gentle
4	Malikpur Syncline	N29ºE/65ºSE	N31ºE/48ºNW	N30°E/81°NW	2º/031°	67°	Close
5	Diljaba Anticline	N45°E/20°NW	N42°E/20°SE	N44ºE/89ºSE	0º/44º	139º	Gentle
6	Malikpur anticline	N50°E/42°NW	N65°E/30°SE	N56°E/88°SE	4°/237°	18º-108°	Tight- open

S.No.	Folds	Attitude of bedding		Axial plane	Fold axis	Interlimb angle	Fold type
		NE Limb	SW limb				
7	Kakrul anticline	N50°W/32°NE	N45°W/35°SW	N48°W/89°NE	2°/312°	113°	Open
		N50°W/33°NE	N45°W/36°SW	N48°W/88°NE	2°/313°	111°	Open
8	Karot syncline (SE Part)	N70°W/22°SW	N60°W/20°NE	N67°W/89°SW	1°⁄113°	138°	Gentle
9	Chanas antiformal syncline	N78°W/26°SW	N60°E/34°SE	N8°E/ 61°NW	27°/194°	75°-120°	Gentle
10	Sadiqabad syncline(SE part)	N50°W/20°SW	N52°W/25°NE	N50°W/85°SW	2°/135°	140°	Gentle
11	Rajdahni Syncline	N60°W/55°SW	N55°W/27°NE	N58°W/76°NE	2°/121°	98°	Open
12	Pheran Dinpur Anticline	N50°W/22°NE	N40°W/11°SW	N47°W/88°SW	1°/313°	147°	Gentle
13	Jabran syncline	N42°W/19°SW	N40°W/12°NE	N43°W/86°NE	0°/137°	149°	Gentle
14	Chanas anticline	N45ºW/63°NE	N40ºW/55°SW	N43ºW/88ºSW	4º/315º	62º	Close
15	JhikaGali anticline	N60°W/25˚NE	N05˚W/14˚SW	N38˚W/86˚SW	9°/322°	141°	Gentle

S.No.	Folds	Attitude of bedding		Axial plane	Fold axis	Interlimb angle	Fold type
		NW and Western Limb	SE and Eastern limb				
16	Chouk Borjan Syncline	N50°E/60°SE-N30°E/33°SE	N35°E/40°SE-N22°E/50°SE	N26°E/45°SE-N42°E/50°SE	22°/222°-11°/204°	17° - 70°	overturned tight-close
17	Chouk Borjan Anticline	N36°E/44°SE-N15°E/47°SE	N50°E/72°SE-N25°E/52°SE	N44°E/56°SE-N20°E/40°SE	18°/224°-40°/200°	28°- 84°.	overturned tight-close
18	Panjand Syncline	N30°E/50°SE-N15°E/54°SE	N40°E/60°SE-N30°E/48°SE	N37°E/56°SE-N23°E/50°SE	38°/216°-44°/ 202°	6°- 70°	overturned isoclinals-close
19	Panjand Anticline	N50°E/64°SE-N35°E/59°SE	N25°E/60°SE-N20°E/55°SE	N38°E/61°SE-N30°E/57°SE	55°/198° - 60°/217°	4°- 119°	Overturnd isoclinal-open

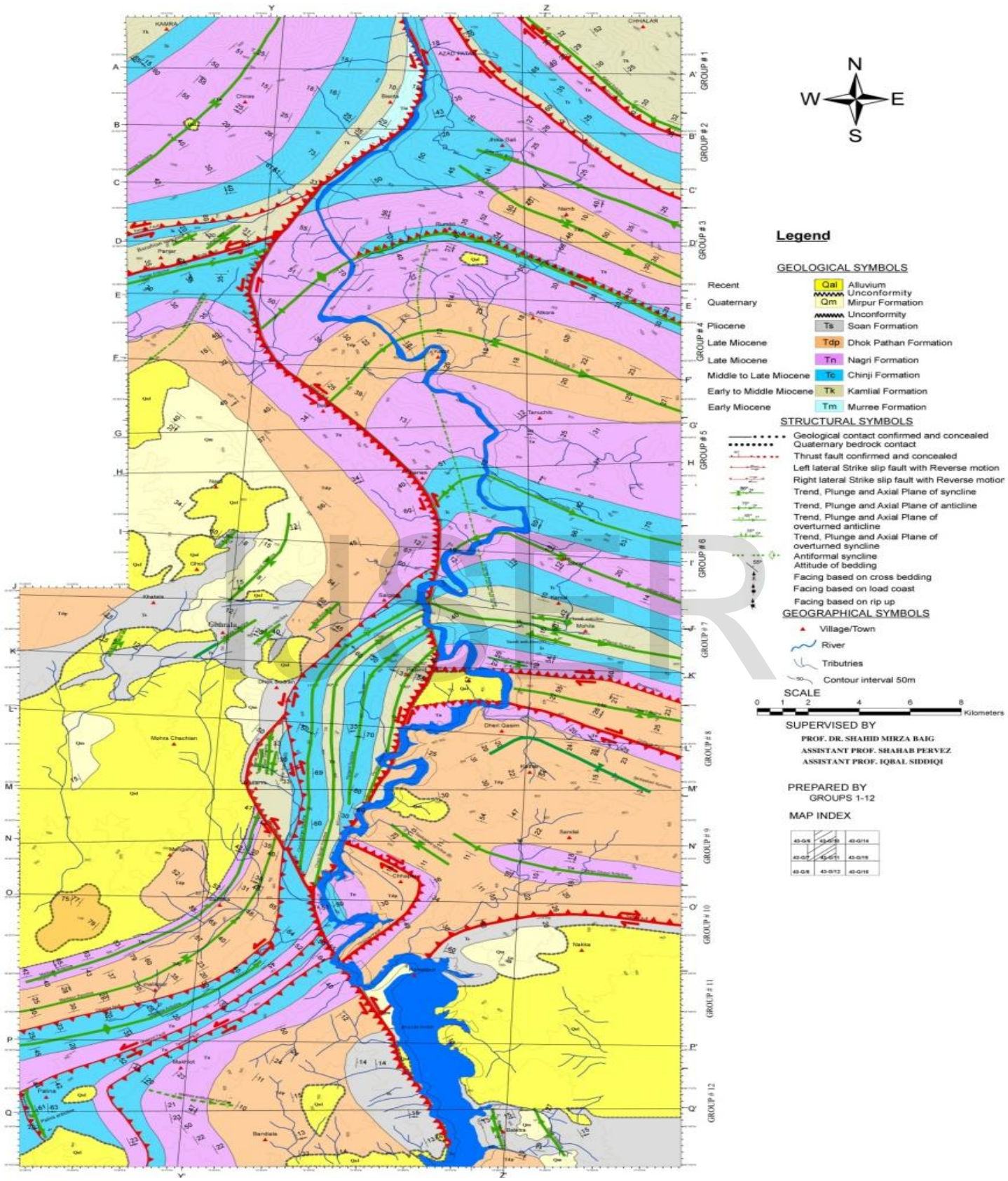
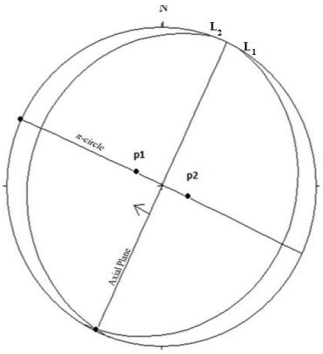
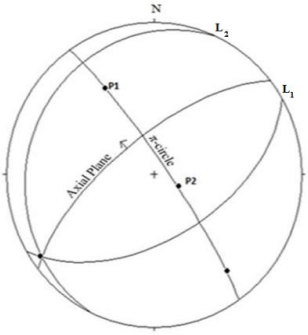
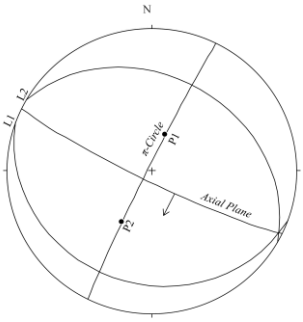
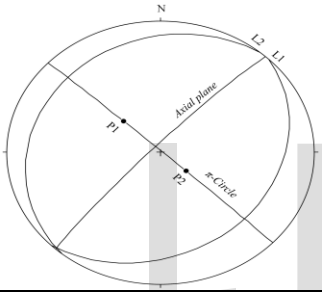
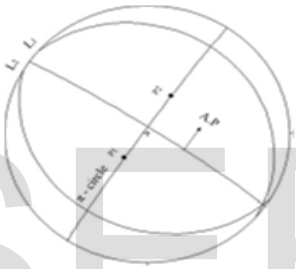
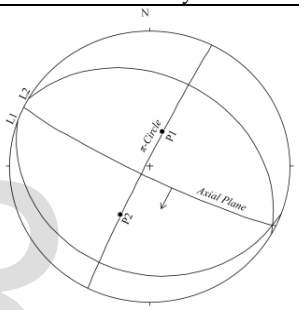
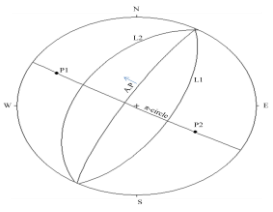
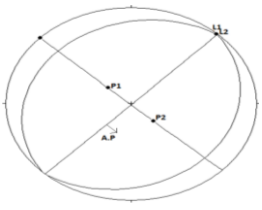
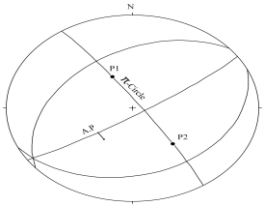
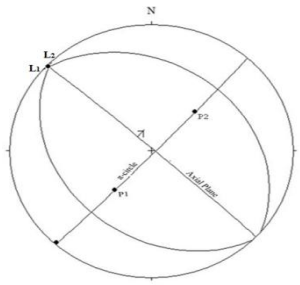
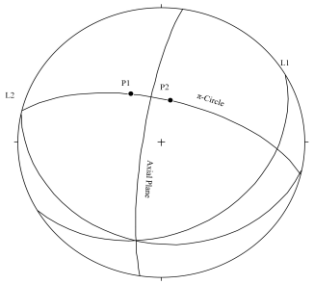
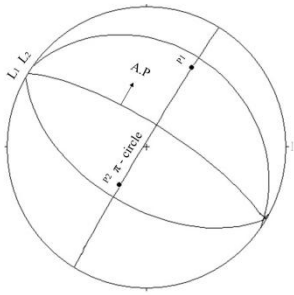
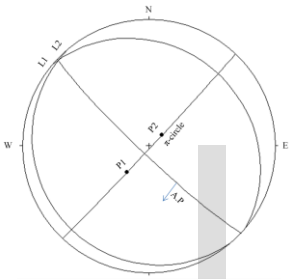
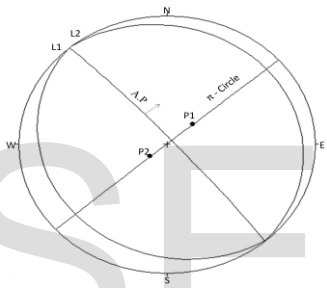
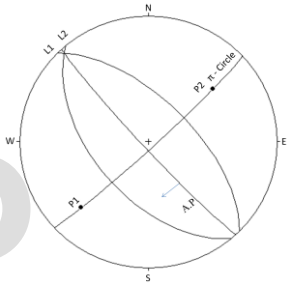
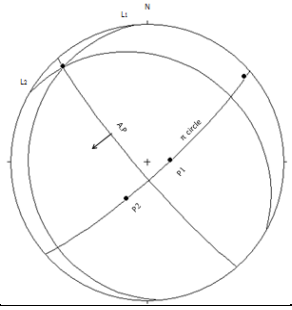
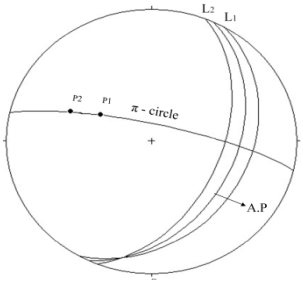
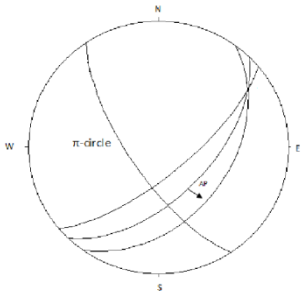
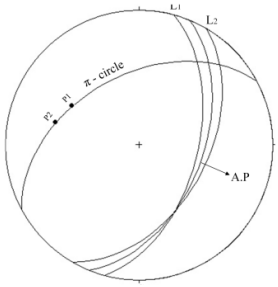
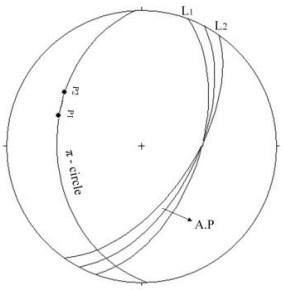


Plate 2: Structural map of studied area.

		
Limb1=N30°E/15°SE Limb 2=N20°E/15NW F.A = 2°/205° A.P = N24°E/89°NW I.A = 150°	Limb1= N60°E/55°SE Limb 2= N25°E/15°NW F.A = 6°/230° A.P = N50°E/68°NW I.A = 110°	Limb1=N70°W/22°SW Limb 2=N60°W/20°NE F.A = 1°/113° A.P = N67°W/89°SW I.A = 138°
Figure 2. π and β Diagram of Chiras syncline	Figure 3. π and β Diagram of Chiras syncline	Figure 4. π and β Diagram of Karot syncline
		
Limb1=N45°E/27°SE Limb 2=N40°E/18°NW F.A = 1°/223° A.P = N43°E/87°NW I.A = 135°	Limb1= N60°W/28°SE Limb 2= N50°W/20°NE F.A = 3°/124° A.P = N55°W/88°NE I.A = 132	L_1 =N45°W/15°SW L_2=N52°W/25°NE F.A=2°/135° A.P=N50°W/85°SW I.A=140°
Figure 5. π and β Diagram of Karot syncline	Figure 6. π and β Diagram of Sadiqabad syncline	Figure 7 π and β Diagram of Sadiqabad syncline(B).
		
Limb1= N29ºE/65ºSE Limb 2= N31ºE/48ºNW F.A = 2º/031° A.P = N30°E/81°NW I.A = 67°	Limb1=N45°E/20°NW Limb 2=N42°E/20°SE F.A = 0º/44º A.P = N44ºE/89ºSE I.A = 139º	Limb1=N50°E/42°NW Limb 2=N65°E/30°SE F.A = 4°/237° A.P = N56°E/88°SE I.A = 108°
Figure 8. π and β Diagram of Malikpur Syncline	Figure 9. π and β Diagram of Diljaba anticline	Figure 10. π and β Diagram of Malikpur anticline

		
Limb1=N50°W/32°NE Limb 2=N45°W/35°SW F.A = 2°/312° A.P = N48°W/89°NE I.A = 113°	Limb1=N78°W/26°SW Limb 2=N60°E/34°SE F.A = 27°/194° A.P = N8°E/ 61°NW I.A = 120°	Limb1=N60°W/55°SW Limb 2=N55°W/27°NE F.A = 2°/121° A.P = N58°W/76°NE I.A = 98°
Figure 11. π and β Diagram of Kakrul anticline	Figure 12. π and β Diagram of Chanas antiformal syncline	Figure 13. π and β Diagram of Rajdahni Syncline
		
Limb1=N50°W/22°NE Limb 2=N40°W/11°SW F.A = 1°/313° A.P = N47°W/88°SW I.A = 147°	Limb1=N42°W/19°SW Limb 2=N40°W/12°NE F.A = 0°/137° A.P = N43°W/86°NE I.A = 149°	Limb1=N45ºW/63°NE Limb 2=N40ºW/55°SW F.A = 4º/315º A.P = N43ºW/88ºSW I.A = 62º
Figure 14. π and β Diagram of Pheran Dinpur Anticline	Figure 15. π and β Diagram of Jabran syncline.	Figure 16. π and β Diagram of Chanas anticline..
		
Limb1=N60°W/25°NE Limb 2=N05°W/14°SW F.A = 9°/322° A.P = N38°W/86°SW I.A = 141°	Limb1=N30°E/33°SE Limb 2=N22oE/50oSE F.A = 11º/204 º A.P = N26oE/45oSE I.A = 17 º	Limb1=N36ºE/44ºSE Limb 2=N50ºE/72°SE F.A = 18º/224º A.P = N44oE/56oSE I.A = 28°
Figure 17. π and β Diagram of JhikaGali anticline	Figure 18. π and β Diagram of Chouk Borjan Syncline	Figure 19 π and β Diagram of Chouk Borjan Anticline

	
Limb1=N30°E/50°SE Limb 2=N40°E/60°SE F.A = 38°/216° A.P = N37°E/56°SE I.A = 6°	Limb1=N35°E/59°SE Limb 2=N20°E/55°SE F.A = 55°/198° A.P = N30°E/57°SE I.A = 4°
Figure 20. π and β Diagram of Panjand Syncline.	Figure 21. π and β Diagram of Panjand anticline.

CONCLUSION/ RECOMMENDATIONS

Based on above discussion following conclusions are made:

1. In Azad Pattan, Karat, Chanas, Dangali, Dadyal, Kahuta and Malikpur areas of discricts Mirpur, Sudhnoti and Rawalpindi, only sedimentary rocks are present that is ranging from Early Miocene to Recent ages. These deposits originated from higher Himalayas and transported by paleo-river from north and are cover sequence of Indian plate
2. The folds and faults in the studied areas show structural deformation. All these structures have a general northwest –southeast trending or southwest-northeast trending. The folds are southwest or northeast and southeast or northwest verging, southwest or northeast and southeast or northwest plunging and Gentle to isoclinals in nature.
3. Jhelum Fault present in area show Left lateral strike slip behaviour with subordinate reverse motion.
4. A detailed mapping i.e geological and structural of the areas is recommended for the economic evaluation of the Hazara Kashmir Syntaxes and adjoining area.

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