TECTONIC ANALYSIS OF THE SOUTHERN KOHAT PLATEAU, N.W.F.P. PAKISTAN

BY

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PESHAWAR
1995

بسم الله الرحمن الرحيم

IN THE NAME OF

ALLAH

THE MOST BENEFICENT

THE MOST MERCIFUL

And He is alone the Helper

United Printing Press Sheri Hotel Stadium Chowk Pesh. Cantt.

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ABSTRACT

The studied area constitutes a part of the southern Kohat Plateau and exposes a suite of sedimentary rocks which includes evaporites, shelf sediments and a thick sequence of mollase sediments. The rocks in the area belong to the Eocene age and consists of Panoba Shale, Bahaderkhel Salt and Jatta Gypsum, followed by Kuldana and Kohat Formations. These units are overlain by mollase sediments of Miocene to Pleistocene age which comprises Kamlial Formation of Rawalpindi group overlain by the complete stratigraphic sequence of the Siwalik group.

The studied area constitutes the western half of the southern structural boundary of the Kohat Plateau, herein named as " Kohat Plateau Boundary Zone". It is about 120 km long with width ranging from 5-10 km and trends east-west. The studied area is characterized by the large scale east-west trending open , synclinal and tight anticlinal trends. These compressional structures are superimposed by a Plio-Pleistocene phase of strie-slip deformation. This deformation is displayed on the surface of the formation of two large scale strike-slip faults with apperent dip-slip movements. The Zarwam fault is the northern most structural discontinuity and is beleived to be a strike-slip fault with left lateral movement. The Bannu-Surdag fault lies south of Zarwam fault and is also characterized by strike-slip movement with the sense of movement being right lateral. Both these faults are Rheidal shears which eminates from the Kurram fault.

ACKNOWLEDGMENT

I extend my most sincere and profound thanks to my supervisor, Prof. Arif Ali Khan Gauri, NCE in Geology University of Peshawar, for his invaluable guidance and very kind supervision throughout the work.

My greatest gratitude is extended to my co-supervisor Mr. Sajjad Ahmad, Lecturer Department of Geology University of Peshawar, for his invaluable guidance, continuous support, advice and encouragement.

I am also greatful to Mr. Amjad Ali Khan, Assistant Director in Direcor General Petroleum Concessions, Islamabad for his help in providing the seismic data.

Thanks are also due to Mr. Fayaz Ali, Lecturer Department of Geology University of Peshawar for nice company and assistance in the field.

CHAPTER-1

1.1- INTRODUCTION

The area of study is located northeast of Bannu city and constitutes western half of the southern Kohat Plateau. It lies in the Survey of Pakistan topographic sheet no 38K/12 and 38K/16. The area is restricted between the longitudes 70° 30′ 45" and 70° 45′ 71"E and latitudes 33° 00′ 00" and 33° 15′ 00"N encompassing 1300 sq.km area (Fig. 1.1) and is bounded by Main Boundary Thrust (MBT), Surghar Range Thrust and Kurram Fault towards the north, south and west respectively. Towards the east, the plateau is marked by the Indus River which seprates it from the Potwar Plateau (Fig. 3.3).

The area is accessible by the mettaled Bannu-Kohat road. Several secondry dirt roads and stream courses provide an easy approach to most parts of the area.

Stratigraphically, the rocks identified in the area of investigation can be broadly divided into the following three major groups (Fig 1.2).

3. Siwalik Group - Plio-Pliestocene.
2. Rawalpindi Group - Miocene.
1. Chharat Group - Eocene.

Chharat group is composed of Eocene evaporites i.e. Bahaderkhel Salt and Jatta Gypsum at the base, overlain conformably by marine clay and sandstone of Kuldana Formation. It is in turn overlain conformably by massive Kohat Formation.

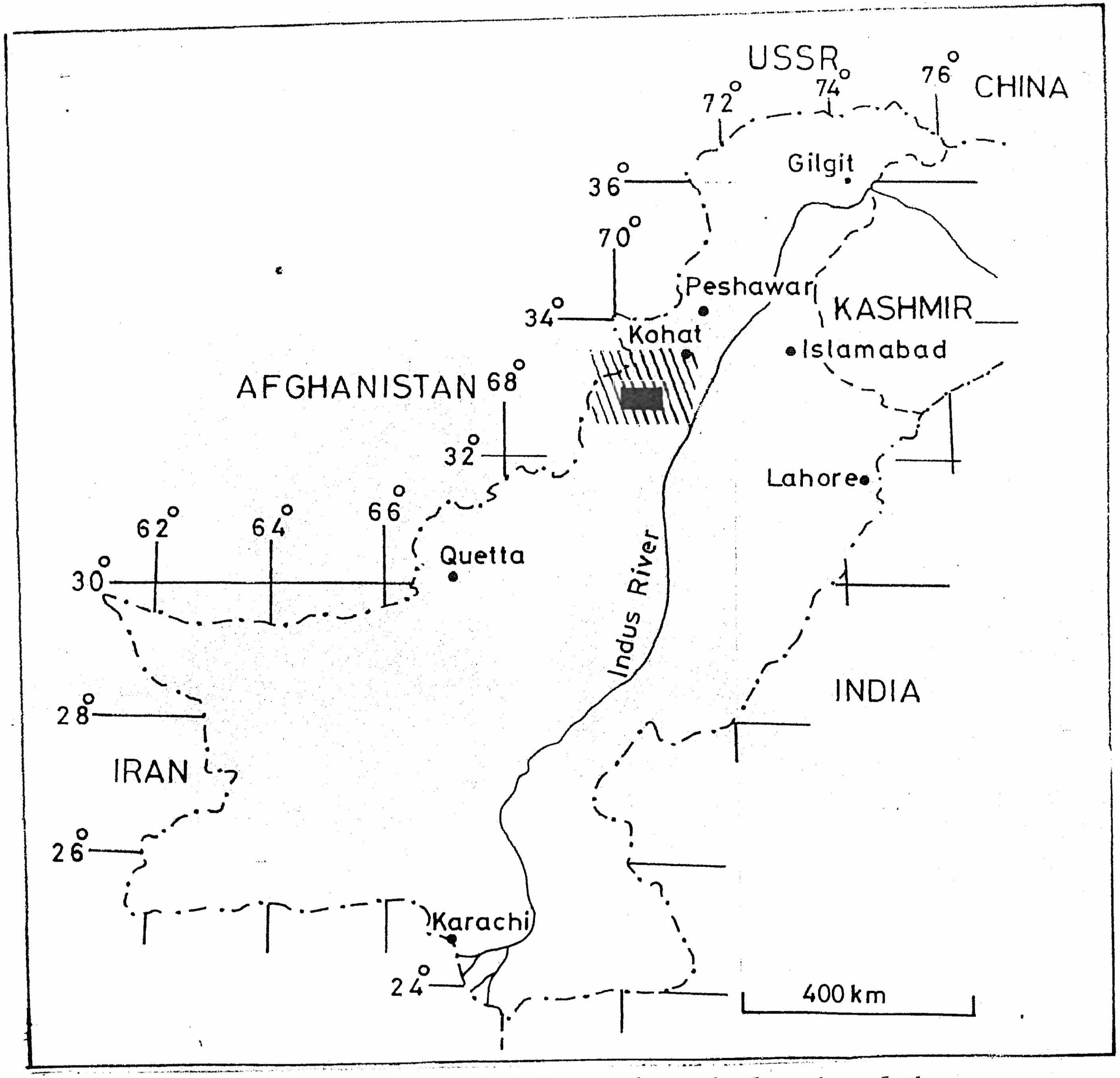


Fig.1.1. Index map of Pakistan. Shaded area shows the location of the Kohat Plateau. The black rectangular area shows the location

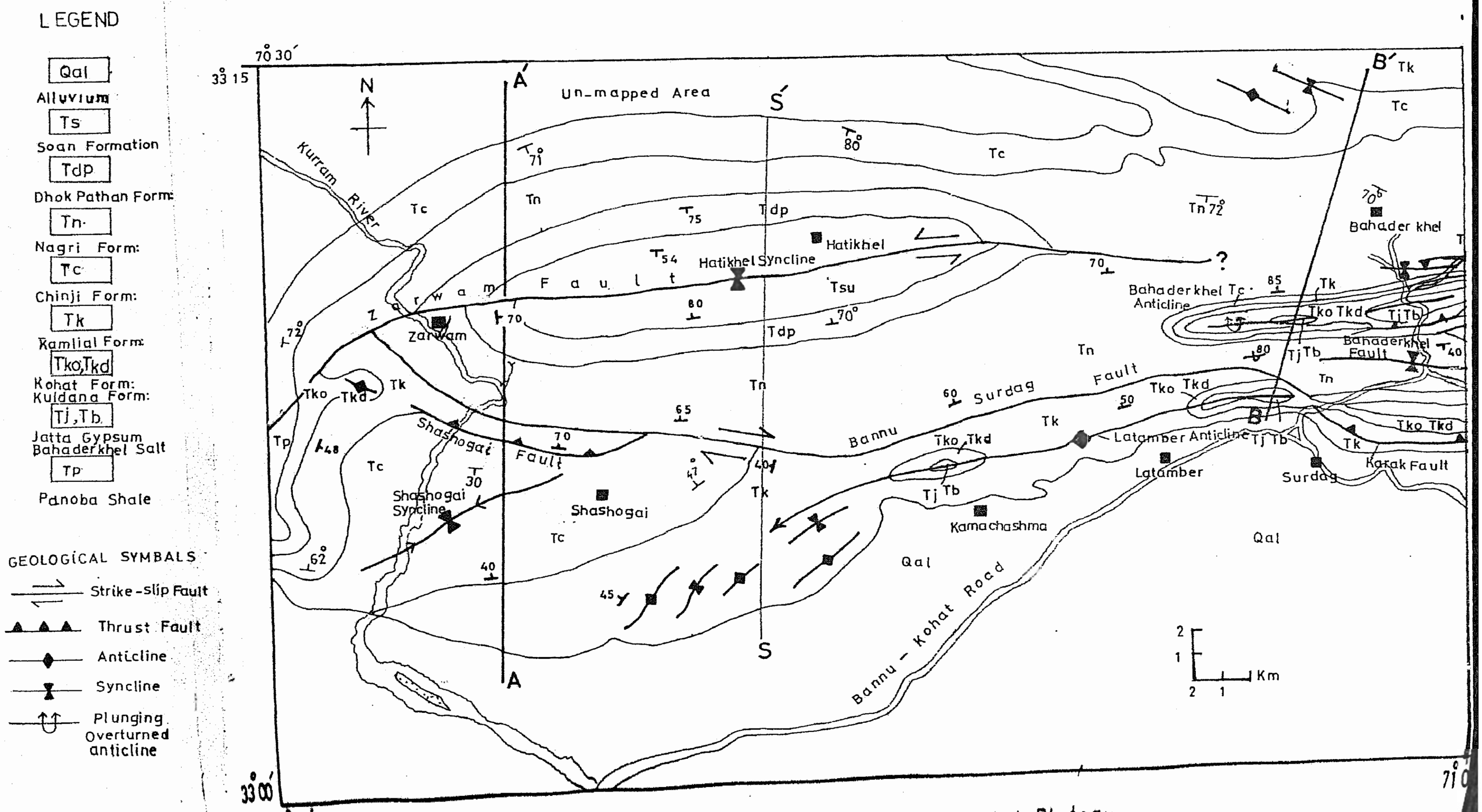


Fig.1.2 Geological map of southern part of the Kohat Plateau.

LEGEND

KK= Karak

NP=Naripanos

BA=Banda Asar

NPF=Naripanos Fault

BKF=Bahadur khel Fault

KKF=Karak Fault

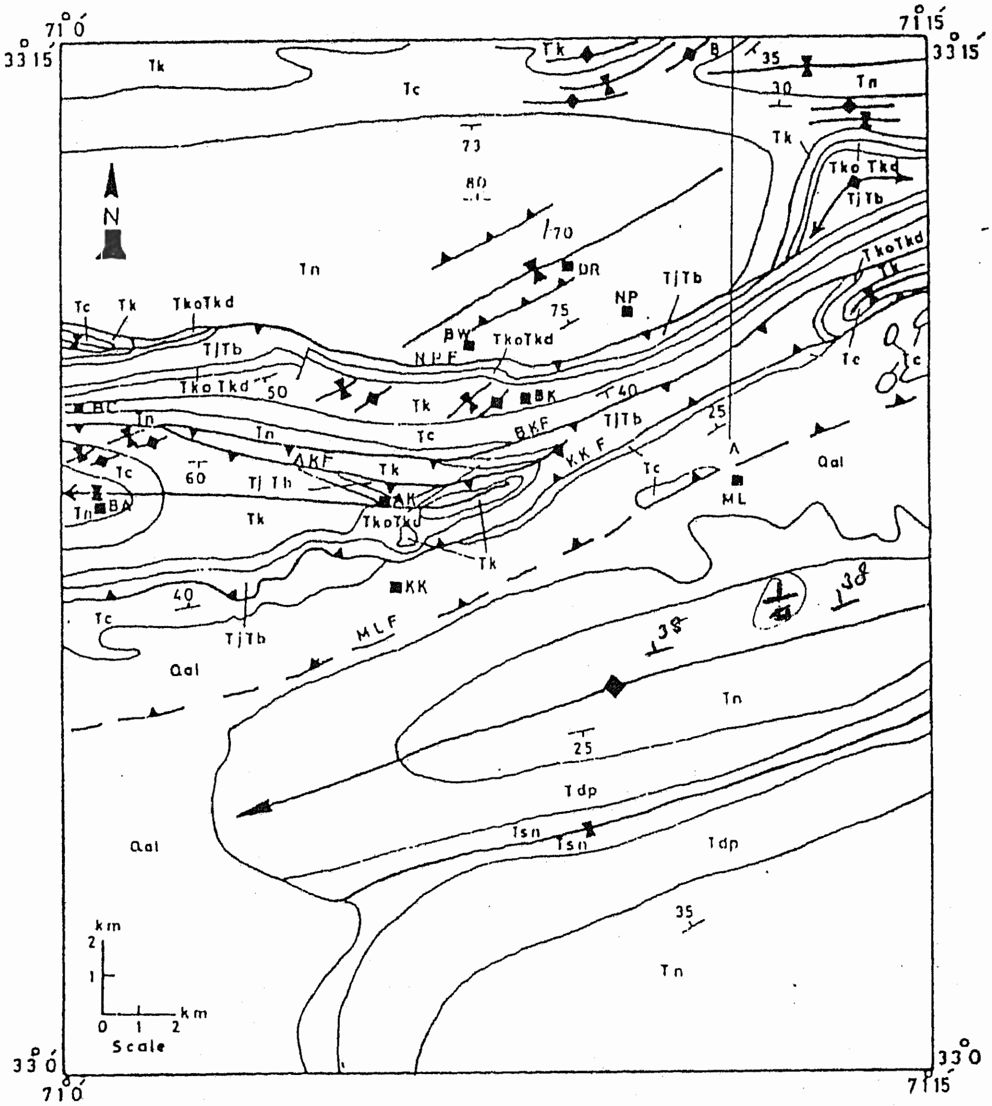


Fig.1·3 Geological map of Karak quadrangle.

FAYAZ (1994).

The Rawalpindi group includes purple grey and dark brick red sandstone of Kamlial Formation and grey to reddish grey sandstone of Murree Formation which has not developed in the mapped area. The Kamlial Formation lies unconformably on the Kohat Formation. The Siwalik group is mostly constituted by Chingi and Nagri, Dhok pathan and Soan Formations. Chingi Formation is dominantly composed of sandstones, clay and siltstone of grey to brownish grey colour. The formation lies conformably on the Kamlial Formation. It is overlain by greenish grey, massive to thick bedded sandstone of Nagri Formation. On top of Nagri Formation lies the Dhok Pathan Formation and Soan Formation which dominantly are composed of sandstone, clay, siltstone and conglomerates.

The studied part of the southern structural boundary of the Kohat Plateau is characterised by strike-slip deformation and is named as "Kohat Plateau Boundary Zone".

1.2- PREVIOUS WORK

Being a region rich in salt deposits and the possibility to be the potential source for hydrocarbon, the Kohat Plateau has been the focus of attention since a long time. It has also attracted the attention of the structural geologists due to its tectonic significance.

The earliest report on the salt deposits in Kohat Plateau was published by Burnes (1832). Oldham (1864) was the first to mention the salt mines in Kohat -Potwar Plateau. Wynne (1874), Pinfold (1918), Davies (1930) and Gee (1945) have contributed in establishing the stratigraphy of the Kohat Plateau and surrounding areas.

After partition of the subcontinent, the geologists of GSP and the foreign geologists working in collaboration with them have produced significant work in this area. Fatmi (1973) established the lithostratigraphic sequence of the Kohat region. Meissner et al. (1974) prepared the geological map of the Kohat quardangle on a regional scale (1:250,000) for the first time mostly with the help of aerial photographs. He and his associates have also worked out the detailed stratigraphy and structure of the region. Khattak (1983) published a comprehensive geological map of the Karak area on 1:50,000 scale. Fayaz (1994) carried out the structure and tectonic analysis of the area north-west of Karak for M.Phil thesis. He interpreted the area as an east-west trending positive flower structure which exhibits strike-slip deformation in addition to the thrusting (Fig. 1.3).

1.3- PURPOSE OF INVESTIGATION

The present work is carried out with the following objectives:

1- To carry out the detailed mapping of the study area on scale 1:50,000 with special emphasis on the structural geometry.

2- To work out the style of deformation of the area.

3- To determine the various phases of deformation.

CHAPTER-2

STRATIGRAPHY

The rocks exposed in the study area include a sequence of evaporites and shelf sediments of Eocene age overlain by a thick molasse sequence ranging in age from Early Miocene to Early Pleistocene (Table 1). The formation names and descriptions used here, are mostly derived from the works of Meissner et al. (1974), Gardezi et al. (1976) and Shah (1977).

2.1- Eocene Succession

There are following five formations of Eocene rocks exposed in the study area:

5. Kohat Formation
4. Kuldana Formation
3. Jatta Gypsum
2. Bahaderkhel Salt
1. Panoba Shale

1. Panoba Shale

Panoba Shale was initially named by Eames (1952) and the Stratigraphic Committee of Pakistan has approved formally this name. The formation is only exposed in the western most part of the mapped area (Fig 1.2).

The formation consists of shale with subordinate bands of sandstone. The shale is greenish grey to light grey, slightly

Age		Stratigraphy	Thickness in study area (m)	Abb	Lithology
Pliocene	Siwalik Group	Soan Formation	1000	Ts	
Miocene	Siwalik Group	Dhok Pathan Form:	700	Tdp	
Miocene	Siwalik Group	Nagri Formation	1000-6000	Tn	
Miocene	Siwalik Group	Chinji Formation	1000	Tc	
Miocene	Rawalpindi Group	Kamlial Formation	500	Tk	
		Unconformity			
Eocene	Chharat Group	Kohat Formation	5-12	Tko	
Eocene	Chharat Group	Kuldana Formation	40	Tkd	
Eocene	Chharat Group	Jatta Gypsum	50	Tj	
Eocene	Chharat Group	Bahaderkhel Salt	?	Tb	
Eocene	Chharat Group	Panoba Shale	?	Tp	

Table 1. Composite stratigraphic column of the study area.

silty, soft and calcareous towards the base. In places, the shale is ferruginous and calcareous with veins of Gypsum.

The upper contact of the formation is conformable with Kuldana Formation. The lower contact is faulted with Nagri Formation. Various types of foraminifers have been reported from the formation (Meissner et al.1968). The foraminiferal evidence indicates Early Eocene age of the formation (Shah. 1977).

2. Bahaderkhel Salt

Meissner et al. (1968) revised the name of Kohat Saline Series of Gee (1945) as "Bahaderkhel Salt" from exposures in the Bahaderkhel salt querry. In the study area Bahaderkhel salt is exposed in the south of Bahaderkhel village (Fig 1.2). The salt represents a diapiric anticlinorium that mainly crops out along thrust faults. Clear halite crystals are also common in this part. At some localities, it is interbedded with clay and green shale layers.

The lower contact being unexposed, the exact thickness of the formation is uncertian. The upper contact is conformable with Jatta Gypsum. Some well preserved fossils like plant leaves and bands of sandstone and clay have been reported from the formation. The age assigned to the formation is Early Eocene (Shah. 1977).

3. Jatta Gypsum

Gee (1945) formerly placed it in "Kohat Saline Series". Meissner et al. (1968) renamed it as Jatta Gypsum and considered it to be the upper part of the "Kohat Saline Series". In the study area the formation is exposed in the south of Bahaderkhel village and is crossed by Bannu-Kohat road. Jatta Gypsum crops out along thrust faults. The formation is charactarised by the interbedded bentonitic clay and gypsiferous shale. Gypsum is massive to thick bedded with white or greenish whit to grey colour.

The formation is also characterised by grey and white bands with sharp edges. The clay is greenish grey to bluish grey in colour with plastic nature. Average thickness of the formation is about 50 meters. Small scale assymetric folds of various sizes and shaps have originated as a result of thrusting and diapirism. Both the upper and lower contacts of the formation are conformable with the Kuldana Formation and Bahaderkhel Sat respectively. The formation is non-fossiliferous, however, its conformable contacts with the Eocene Formation above justify its Early-Eocene age (Shah. 1977).

4. Kuldana Formation

The first name to the formation was given as "Kuldana Beds" by Wynne (1874), The "Kuldana Series" by Middlemiss (1896) and "Mamikhel Clay" by Meissner et al. (1968). Latif (1970a) revised the name as "Kuldana Formation". Kuldana Formation can be easily identified by its characteristic red to brownish red coloured clay with interbedded sandstone layers. Being highly soft in nature, Kuldana Formation forms minor zigzag features in between the Kohat Formation and relatively resistant Jatta Gypsum. It conformably overlies the Jatta Gypsum. The upper contact with the Kohat Formation is also conformable. The formation is of Middle Eocene age (Shah. 1977).

5. Kohat Formation

The Kohat Formation of Eames (1952) and the Kohat Limestone of Meissner et al. (1968) was formally renamed as the Kohat Formation by the stratigraphic Committee of Pakistan (1974).

The formation is generally composed of interbedded limestone and shale. It is mainly developed to the south of Bahaderkhel village and the thickness is recorded to be 5-12 meters (Fig 1.2). The shale is greenish grey to grey in colour, soft and calcareous with fossiliferous beds. Limestone is fine grained, medium bedded, jointed and fosiliferous with abundant foraminifers and nummulites.

The formation overlies Kuldana Formation with sharp distinct and conformable contact. The upper contact is unconformable with Kamlial Formation. The fauna indicates the Early to Middle Eocene age (Shah. 1977).

2.2-Rawalpindi Group

2.2.1-Kamlial Formation

The "Kamlial Beds" of Pinfold (1918) was formally approved by the Stratigraphic Committee of Pakistan (1974). The formation consists of purple grey to dark brick-red sandstone which is thick bedded medium grained, cross bedded with subordinate shale, siltstone and conglomerate lenses. The siltstoe is reddish brown, compact, fine grained thin bedded and interbedded with thin clay layers. The shale is dominently composed of brownish-red and purple silty clay.

The formation is unconformably overlying the Kohat Formation, while the upper contact with the Chingi Formation of the Siwalik

Group is conformable. The age to the formation is proposed to be Middle-Miocene to Late-Miocene on the basis of a number of vertibrate fossils recorded from the formation. (Pascoe.1963).

2.3- Siwalik Group

The term "Siwalik" was first introduceed by Meddlicot (1868), derived from the name of Siwalik Hills of India. Holland et al. (1913) used the term "Siwalik System" for the "Siwalik Series" of Pilgrim (1913). Pilgrim (1913) suggested the three-fold division of the Siwalik System.

The Stratigraphic Committee of Pakistan approved the "Siwalik Group" for the "Siwalik System" including the following formations:

4- Soan Formation

3- Dhok Pathan Formation

2- Nagri Formation

1- Chinji Formation

2.3.1- Chinji Formation

Lewis (1937) used the name "Chinji Formation" for the "Chinji Zone" of Pilgrim (1913). Being softer than the other formations of the Siwalik Group, it forms low relief features in undulating manner. Thickness of the formation is about 1,000 meters.

The formation comprises of sandstone interbeded with subordinate clay and siltstone. The sandstone is reddish to reddish grey, occasionally crossbedded, fine to medium grained and soft .The formation represents argillaceous facies. The lower contact of the formation with Kamlial Formation is conformable. It is conformably overlain by the Nagri Formation. Abundant vertebrate fossils have been recorded from the formation. The age of the formation is considered to be Middle Miocene (Shah. 1977).

2.3.2- Nagri Formation

Lewis (1937) renamed Nagri Zone of Pilgrim (1913) as Nagri Formation which was accepted by the Stratigraphic Committee of Pakistan (1977). A major portion of the investigated area is occupied by Nagri Formation. The formation is mainly composed of sandstone with subordinate clay and conglomerate beds. The sandstone is greenish grey medium to coarse grained, crossbedded, massive, moderate to poorly cemented and "salt and pepper" pattern. The clay is silty and chocolate brown in colour with occsional siltstone interbeds. The composition and thickness of conglomerate beds is variable from place to place.

The formation conformably overlies the Chinji Formation while the upper contact with Dhok Pathan Formation is transitional. Vertebrate fossils have been recorded from the formation which assign the age of the formation to be Early Pliocene (Shah. 1977).

2.3.3- Dhok Pathan Formation

The name "Dhok Pathan" was first introduced by Pilgrim (1913). Cotter (1913) renamed it as "Dhok Pathan Formation". In the study area the formation is exposed in the core of Hathikhel syncline (Fig 1.2). Thickness of the formation varies from 50m to 700m. The formation is characterized by cyclic alternation of sandstone and clay beds. The upper part of the formation is constituted by lenses and layers of conglomerates. The sandstone is light grey to greenish grey, thick bedded, soft, calcareous, cross bedded, course grained and moderately cemented. Clay is orange brown to reddish brown, calcareous and sandy. Conglomerate is in the form of lenses and layers composed of pebbles of igneous and sedimentry origin, poorly cemented in sand and silty clay matrix.

The formation has conformable contact with the underlying Nagri Formation. The upper contact with Soan Formation is disconformable.

A very rich vertibrate fauna has been recorded from the formation that indicates an Early to Middle Pliocene age (Shah 1977).

2.3.4- Soan Formation

The "Tatrot" and "pinjor" stages of Pilgrim (1913) have been formally named as Soan Formation by the Stratigraphic Committee of Pakistan (1974). The formation occypies the central core of the Hathikhel syncline with thickness 1000 meters (Fig 1.2). The formation mainly comprises of massive conglomerate with subordinate interbeds of gneiss, greenish grey sandstone, grey limestone, quartzite and various types of sedimentry and metamorphic rock fragments, cemented in soft sandy matrix.

The formation is underlain disconformably by Dhok Pathan Formation marked by a sharp coarsening of clastics and by the appearance of massive and densely packed conglomerate.

The formation is poorly fossiliferous. Age of the formation is suggested to be Early Pliestocene (Kravetchenko 1964).

CHAPTER-3

REGIONAL TECTONIC AND STRUCTURAL GEOLOGY

3.1-REGIONAL TECTONIC SETTING

The Himalayan Mountain belt came into origin as a result of the collision of the Cimaride (Dipietro 1994) and Indian contenents with Asia. The cimaride continent represents a series of crustal fragments that have been detached from Gondwana in the Late Paleozoic, drifted northward, and collided with Asia in the Jurasic-Early Cretaceous (Sangor 1984). The first block collided with the southern margin of the Eurasian Plate, was Karakoram, followed by Afghan Block and finally the Kohistan Island arc came in contact with the system (Gassner,1964, and Lefort,1975). India broke from Gondwana in Late Jurasic-Early Cretaceous and made a head on collision with the southern margin of the Eurasian Plate along the Indus-Tsangpo Suture (Fig 3.1). The continuation of this suture in north-west Pakistan separates the Indian Plate from Kohistan Island arc and is called Main Mantle Thrust (Thirkheli 1979, 1982).

The initial contact with Asia began between 65 and 50 Ma along the north-western margin of Indian Plate in Pakistan territory. (Molnar and Topponnier 1975, Patriat and Archache 1984). After the initial contact, the Indian Plate rotated anti clockwise which led to the northward subduction of the same underneath the Asia and also the obduction of the Kohistan Island arc. The island arc is demarcated from Karakoram Plate in the north by Main Karrakorum

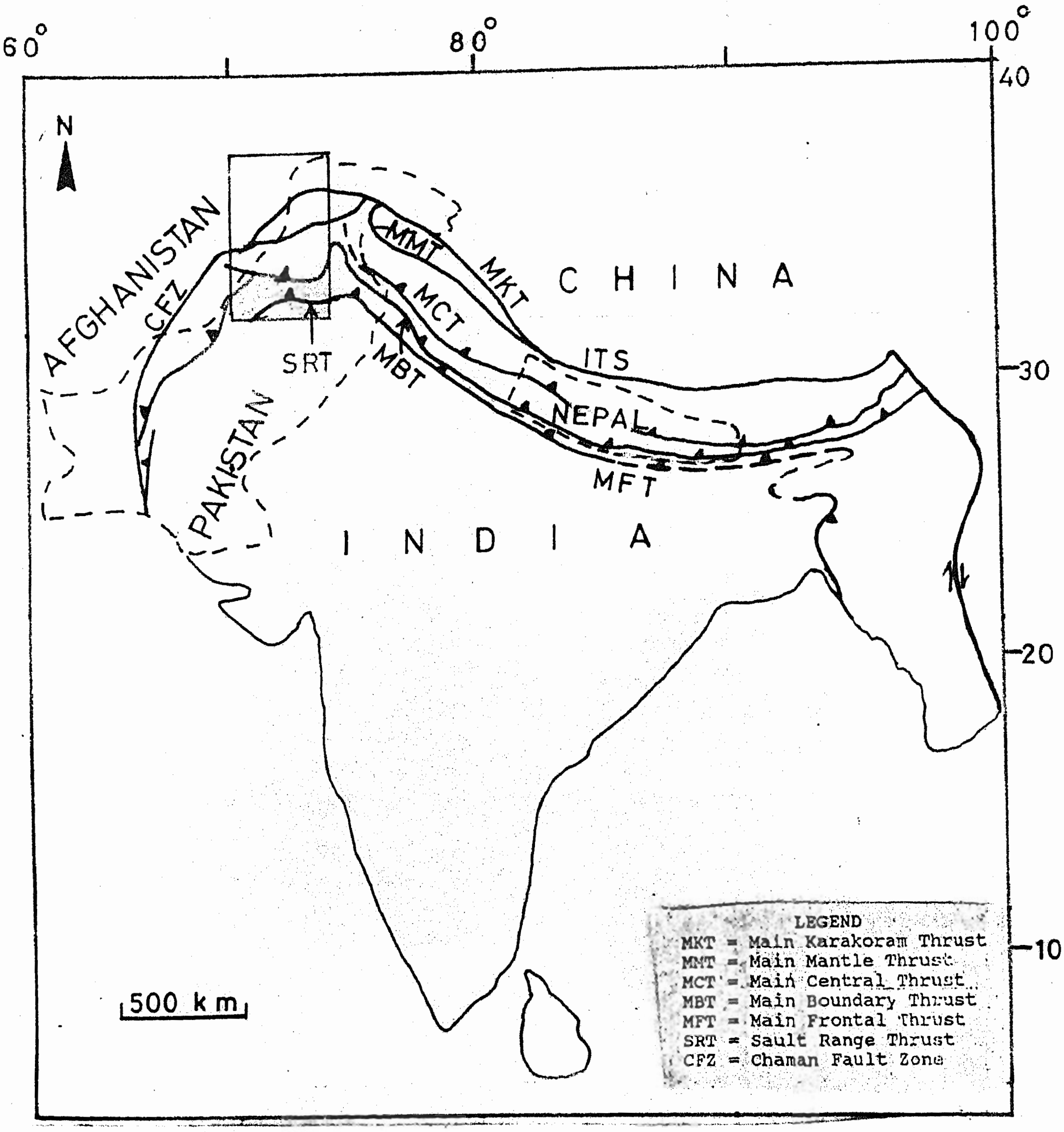


Fig.3.1 Generalized Tectonic map of the Himalayan orogenic belt (After Peter Blisnik, 1994). Inset shows area of figure 3.2

Thrust(MKT) and to the south from Indian Plate by Main Mantle Thrust(MMT). MKT was formed as a result of collision between the Karakoram Plate and Kohistan Island arc (Tahirkheli 1979,1982 and 1983) during Late Cretaceous (Coward et al. 1986). MMT was formed as a result of collision and subduction of the Indian Plate underneath the Kohistan Island arc during Eocene time (Tahirkheli 1979, 1982, and Gassner 1981). To the south-west, in northern Pakistan the MKT and MMT join together to form left lateral Sarobi-Chaman Fault (Fig 3.1).

The rocks along the northern edge of the Indian Plate in the north-west Pakistan record the complete history from Late Paleozoic drifting of micro continents to the obduction of the Kohistan Island arc. The Karakoram Plate, to the north of MKT consists of high grade metamorphic rocks with granitic intrusion (Searle,1991). while in the south of MKT lies metamorphic, basic and ultrabasic rocks of the Kohistan Island Arc (Bard, 1983).

The subduction of the Indian plate did not cease with the formation of MMT and is continued since Eocene at the rate of 5mm/year (Patriat & Archache,1984). This convergence resulted in the internal deformation of the Indian crust giving rise to the Himalayan foreland fold and thrust belt of the Northern Pakistan, which led to the formation of a series of south younging faults. The major faults of this fault system are the MBT and Salt Range Thrust which bound the Kohat and Potwar Plateau in north and south respectively.

The Main Boundary Thrust (MBT) runs east-west along most of the foreland basin , turns northward, west of Jehlum River, forming a major bend known as Hazara Kashmir Syntaxis (Fig 1.1). The Salt Range Thrust is the southern most thrust of the north west Himalayas and is the lateral equivalent of the Main Frontal Thrust (MFT) of central Himalaya (Fig 3.2).

The Potwar Plateau constitutes the eastern part of the Himalayan foreland basin. The Potwar Plateau is developed by a less deformed fold and thrust belt having a width of approximately 150 kms in N-S direction. The Plateau is bounded in the south by Salt Range Thrust and in north by Hazara Kalachitta Ranges. Most of the deformation is restricted to the northern part of the plateau (Aabbasi and Mc Elroy, 1991).

The Kohat Plateau constitutes the western part of the Himalayan fold and thrust belt with a N-S width of approximately 70 km (Fig 3.3). It is bounded in the north by Main Boundary Thrust and in the south by Surghar Range and Khisor Range Thrusts. The eastern limit extends to the Indus River while the western boundary is marked by Kurram Fault.

3.2- STRUCTURAL GEOLOGY

In order to study the structural behaviour of Kohat Plateau one has to refer to the geological map of Kohat quardangle prapared by Meissner et al.(1974). This map is on 1:50,000 scale and gives only broad lithology and structural features. However, it is one of the best available maps to date for regional studies in the Kohat Plateau.

The present work is carried out on a small area north-east of

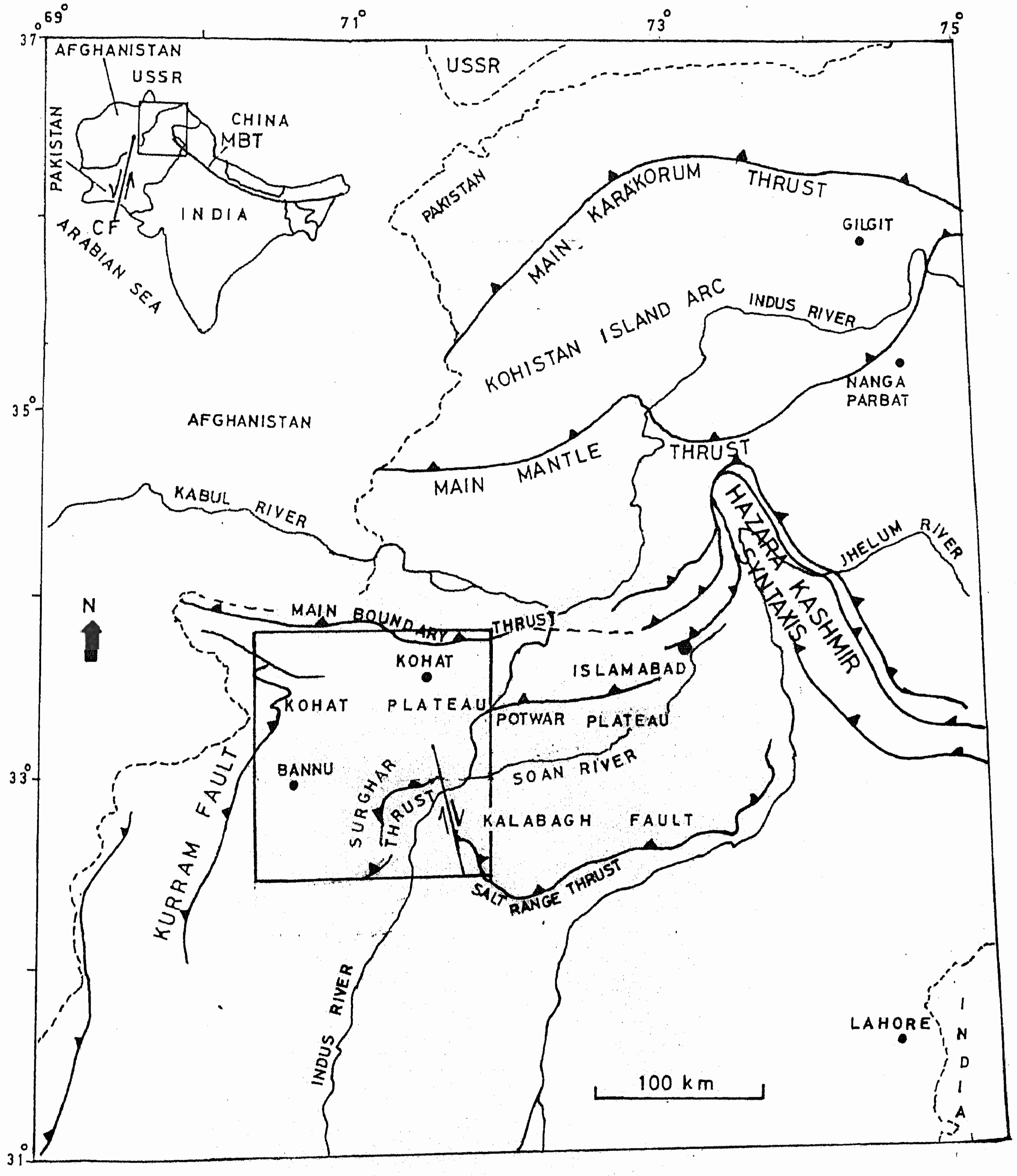


FIG:3.2 REGIONAL SKETCH MAP OF PAKISTAN SHOWING MAJOR TECTONOMORPHIC TERRAINS. (After Kazmi & Rana 1982),

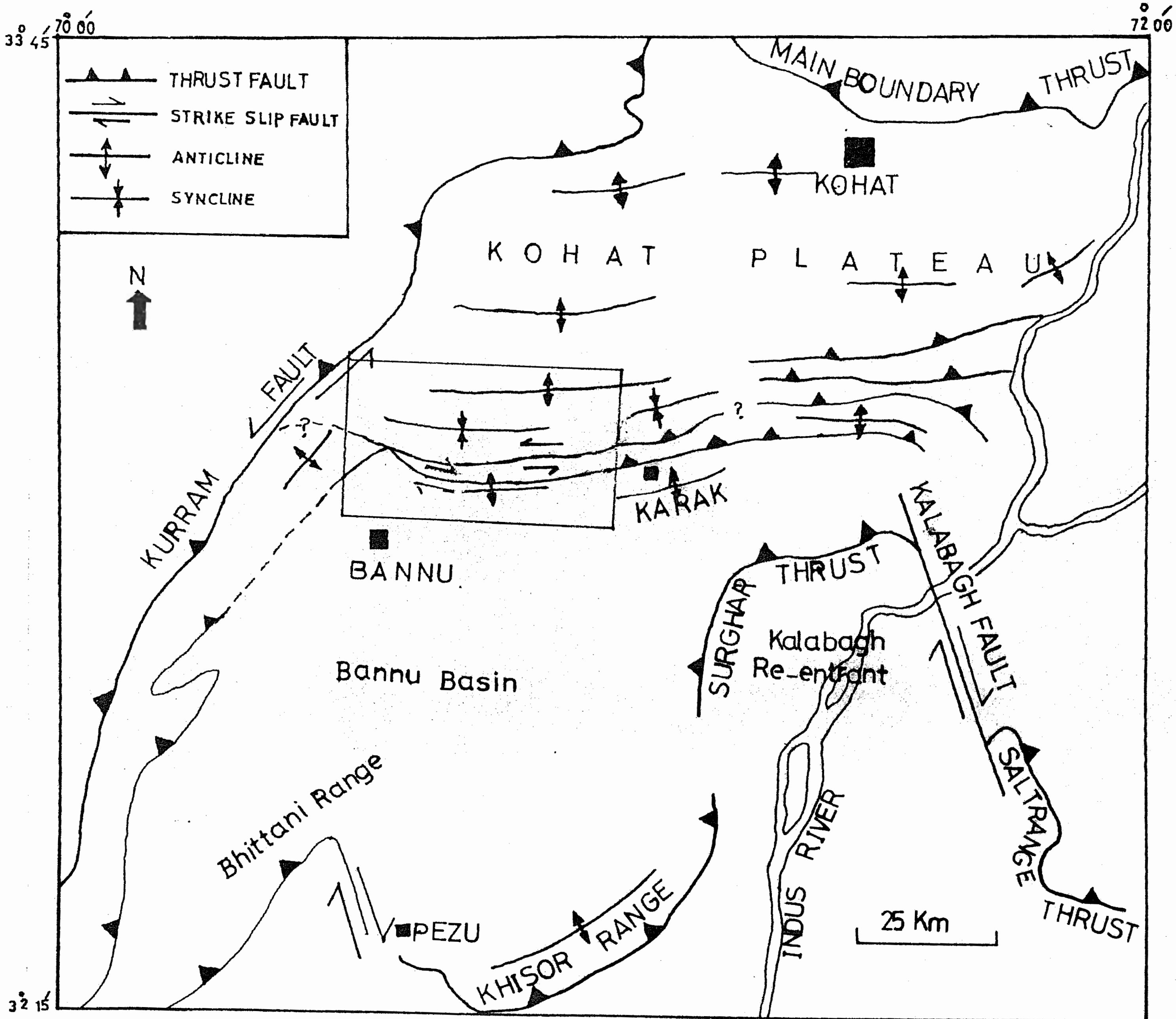


Fig .3.3 TECTONIC MAP OF KOHAT PLATEAU MODIFIED AFTER MEISSNER ET AL.(1974).

Bannu between Lat 33° 00′ 00", 33° 15′ 00" N and Long 70° 30′ 45", 70° 45′ 71" E. This study is part of a project under taken by the Center Faculty to produce a detailed map of Bannu-Karak area giving lithological boundaries and structural trends of formations and finally work out the geometric setting in the tectonic frame work of this part of the country. The area is dominated by large scale east-west trending faults and folds (Fig 1.2). The major and more continuous faults are strike-slip faults with apperent normal sense of movement in sectional view, while the smaller and localized ones are thrust faults. The apperent normal sense of movement has been detected by the study of seismic line No YXT-19, (1991) provided by the Pakistan Petroleum Concession and interpreted by several geophysists and experts in seismic data interpretation, working in different organizations (Fig 4.2). The presence of strike-slip faulting is confusing in the context of regional tectonic setting which is characterized by the thrusting. The adjacent area to the east is regarded as a positive flower structure bounded by steep thrusts (Fayaz 1994). Thrust faults though on a smaller scale are also observed and mapped in the area but they do not extend for long distances and have secondary status in this part. The most intriguing fact is that Karak fault which is recognized and confirmed by seismic interpretation to be a thrust fault in the east, switches to strike-slip fault in the study area (Fig 1.2).

3.3-FAULTS

As mentioned above, the investigated area is characterized by two distinct groups of faults i.e. thrust and strike-slip faults.

All the faults trend east-west and dip north. The strike-slip faults which are distinct, more continuous and are exposed over a major proportion of the mapped area, are steeply dipping towards north in the eastern part and show moderate dip towards western part of the area. The thrust faults are smaller in extent and restricted to localized zones. These faults crop out mostly in the eastern part of the mapped area. The thrust faults are moderately dipping towards north.

3.3.1-STRIKE-SLIP FAULTS

The large scale strike-slip faults mapped in the area (Fig 1.2) are named on the basis of villages and other localities where these are best exposed. The following are the names of these faults starting from north to south:

1- Zarwam Fault

2- Bannu-Surdag Fault

1- Zarwam Fault

It is the northern most major fault in the study area trending north-east toward its western trace. It swings east-west as it crosses Zarwam village. The fault is steeply north dipping with the dip angles ranging from 70° to 85°N. The trace of this fault runs parallel to the axial trend of Hathikhel syncline which is the largest folded structure in the area.

The fault exposure can be traced along the entire mapped area. Towards east, the fault runs within Nagri Formation (Fig 3.4) whereas towards west it off-sets Kuldana Formation, Kohat Formation, Chinji Formation , Nagri Formation, Dhok Pathan

Formation and Soan Formation (Figs 3.5, 3.6). The displacement of the formations across the fault can be observed in the area.

2- Bannu-Surdag Fault

It is the second largest structural discontinuity of the area. It lies south of the Zarwam fault and steeply dips towards north in the western part of the map. Its dip becomes gradually moderate eastward beyond Zarwam village. Bannu-Surdag fault runs almost east-west and along most of its trace, it juxtaposes Kamlial Formation with Nagri Formation (Fig 3.7). Towards west near Zarwam village it joins the Zaram fault. Its general trend is east-west (Fig 1.2).

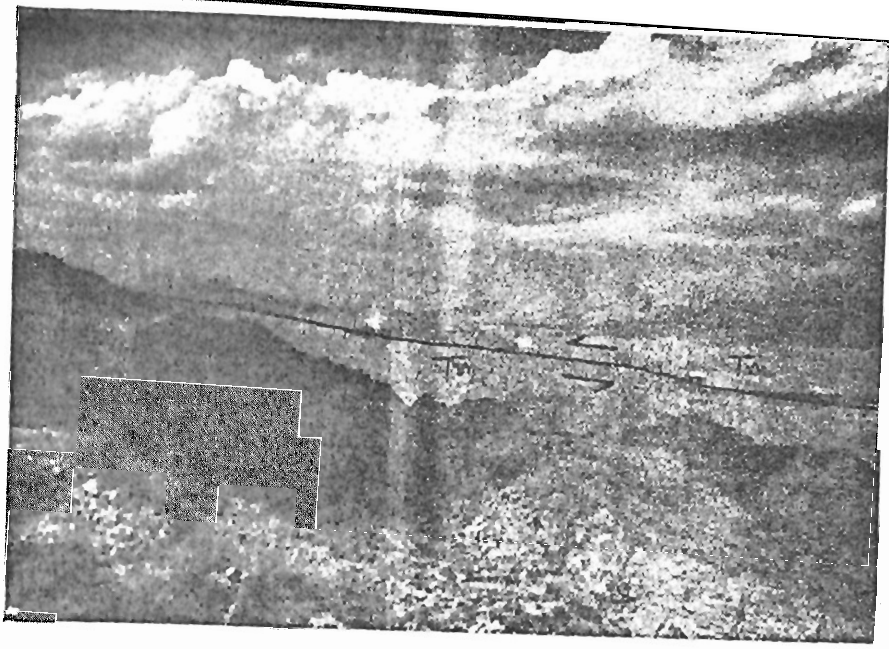


Fig 3.4 A view of the Zarwam Fault exposed within Nagri Formation north of Niaz Kili.

Tn= Nagri Formation Tc= Chinji Formation

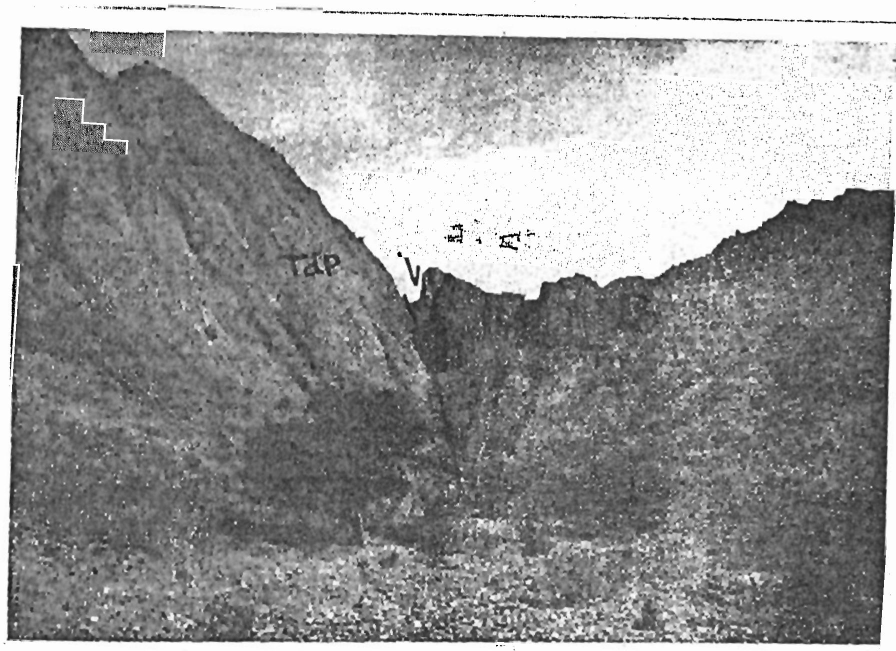


Fig 3.5 An eastward looking view of Zarwam Fault to the east of Zarwam Village showing the juxtaposition of the Nagri Formation with Dhokpathan Formati

Tn= Nagri Formation Tdp= Dhokpathan Formation

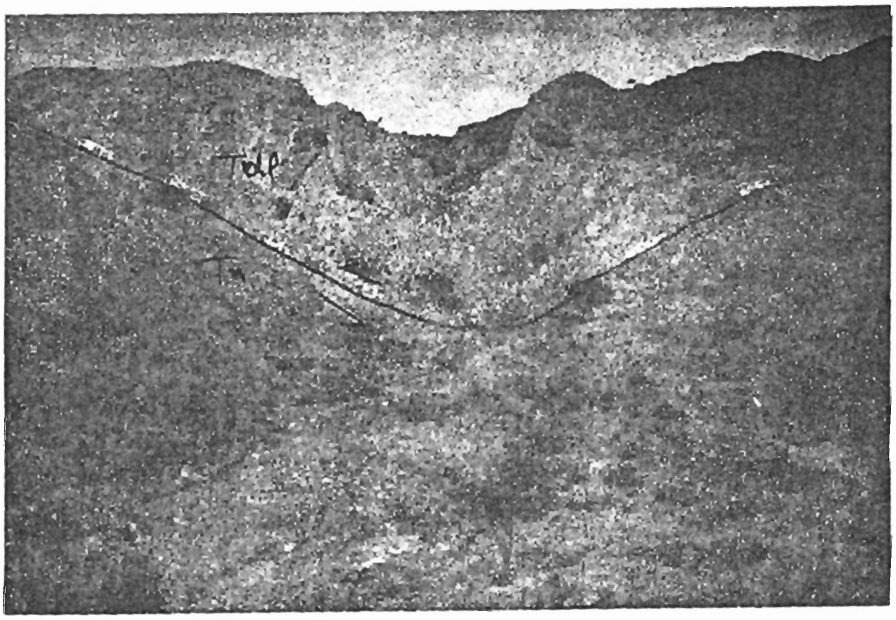


Fig 3.6 Northward looking view of Zarwam Fault, near Zarwam Village.

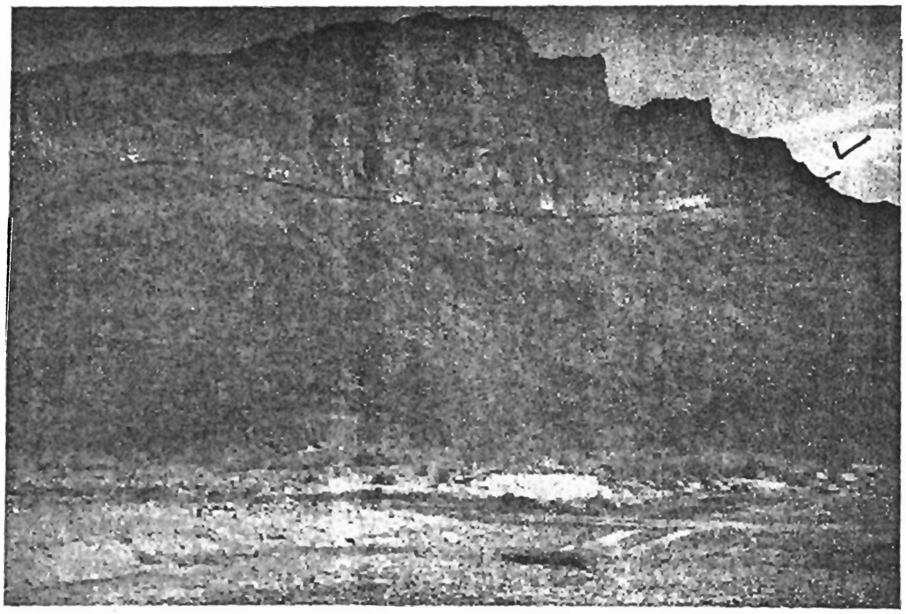


Fig 3.7 A view of north dipping Bannu-Surdag Fault.

Tn= Nagri Formation

Tk= Kamlial Formation

3.3.2-THRUST FAULTS

Thrust faulting on smaller scale is a common phenomenon in this area. Regional scale thrust faults are not present in the area of study. However, two low angle thrust faults mapped in the eastern part of the area and one steeply dipping fault is mapped in the western part of the area which are:

1. Bahaderkhel Thrust
2. Karak Fault
3. Shashogai Fault

1. Bahaderkhel thrust

It is well exposed along Bannu-Kohat road section south of Bahaderkhel village. The fault steeply dips towards north and trends east-west. The trace of the fault is marked along the contact of Jatta Gypsum and Chinji Formation (Fig 3.8) where the former is thrust over the younger Chinji Formation exposed in the foot wall. The fault is localized within the Bahaderkhel anticline and exposes Jatta Gypsum all along its hanging wall.

2. Karak Fault

Although Karak fault is a major fault in Kohat Plateau Boundry Zone, it looses its significance in the area and can only be regarded as a minor thrust fault. In the adjoining area towards east, it is shown to be a continuous fault for about 30kms (Fayaz 1994). However, in the area under discussion, it is exposed in a small part towards east of the area and moderately dips towards north. Karak fault is traced upto the core of Lathamber anticline from where onwards it looses its trace North-west of Surdag village, the fault exposes Jatta Gypsum in the hanging wall which is thrusted southward over the Kamlial Formation in the foot wall (Fig 3.9).

3. Shashogai Fault

It is a minor fault which branches out from Bannu-Surdag fault towards south in the western most part of the area. It is an east-west trending and north dipping steep fault. It juxtaposes Kamlial Formation in the hanging wall with Chinji Formation in the foot wall (Fig 3.10).

Though the stratigraphic succession is normal across the fault, it can be identified in field by the steeply dipping Kamlial Formation of the hanging wall in contact with gently dipping Chinji Formation in the foot wall (Fig 1.2).

3.4- FOLDS

The trends, locations and style of folds in the area have a significant role in the structural geometry of the region. A variety of folded structures at different scales have been observed.

The folds present within the limits of the study area can be classified into two main types i.e. Macroscale and Mesoscale folds.

3.4.1- Macroscale Folds

Four major folds have been mapped in the area. These folded structures are named after the villages which are close to their localities. Following are the names of the folds mapped in the area from north to south:

1. Hathikhel Syncline

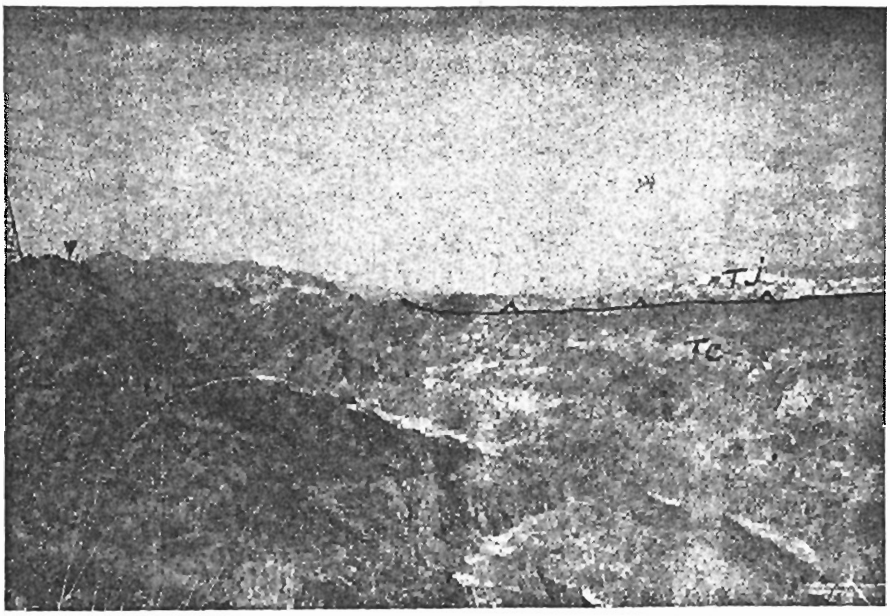


Fig 3.8 A view of north dipping Bahaderkhel Thrust having Jatta Gypsum in the hanging wall thrust over the Chinji Formation in the foot wall.

Tj= Jattá Gypsum Tc= Chinji Formation

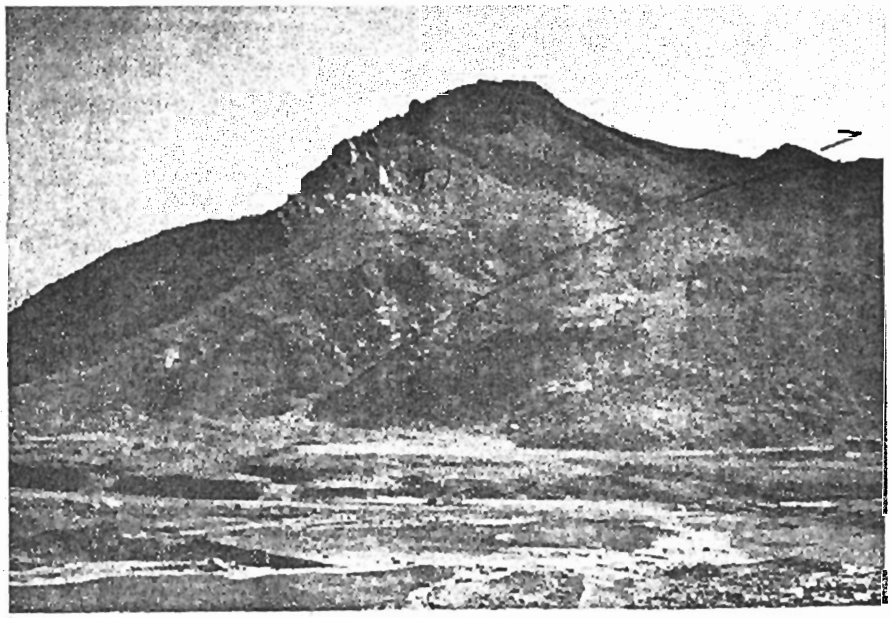


Fig 3.9 A view of Karak Fault, north-west of Surdag Banda, showing the faulted contact between Jatta Gypsum and Kamlial Formation.

Tj= Jatta Gypsum Tk= Kamlial Formation

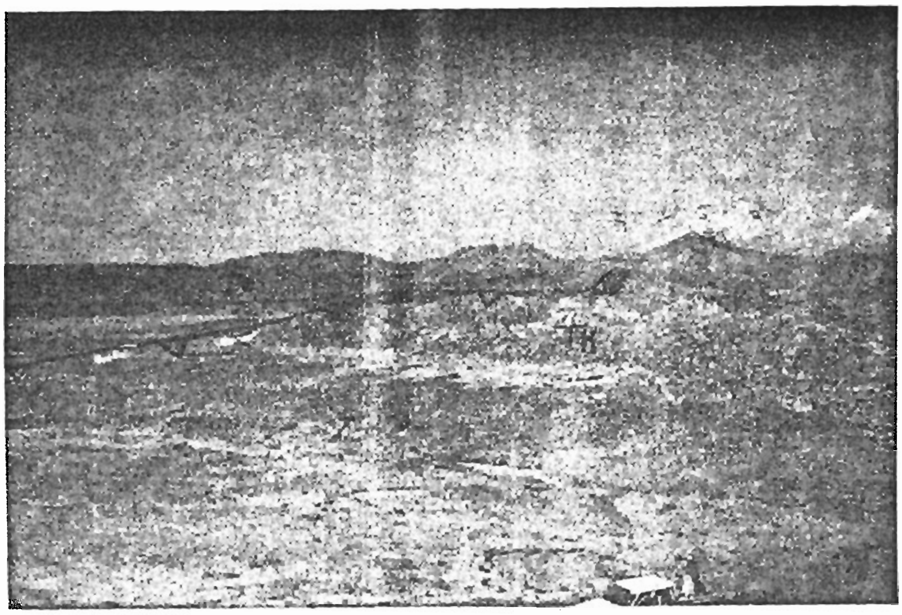


Fig 3.10 A view of north dipping Shashogai Fault having Chinji Formation in the foot wall and Kamlial Formation in the hanging wall. Beds of Chinji Formation are gently south dipping and those of Kamlial Formation are steeply north dipping.

Tc= Chinji Formation

Tk= Kamlial Formation

2. Shashogai Syncline

3. Bahaderkhel Anticline

4. Lathamber Anticline

1- Hathikhel Syncline

It is exposed in the northern part of the study area and can be traced all along the map running in east-west direction (Fig 1.2). The attitude data collected from various segments of folded surface shows that it is tightly folded syncline which exposes the Soan Formation in its core. It is an assymmetric fold with both the limbs steeply inclined. The dip values range from 75° to 85°. The axial trend of the fold and the trace of Zarwam fault runs along the same line throughout the area under discussion. The southern limb of the syncline is truncated by another east-west normal fault i.e. Bannu-Surdag fault, along which a part of the northern limb has gone down.

2- Shashogai Syncline

It is another large synclinal structure of the area and is well exposed in south-western part of the mapped area (Fig 1.2). It is located south of the Bannu-Surdag fault and its northern limb is truncated by Shashogai fault. The northern limb of the syncline dips moderately (about 30° to 35°) specially along the fault contact and gradually becomes gentle to about horizontal near its core. The fold is assymetric and doubly plunging. The youngest rocks exposed in its core belong to the Chinji Formation of the Siwalik Group.

3- Bahaderkhel Anticline

It is located in eastern part of the mapped area and its both limbs are well exposed along the Bannu-Kohat road section (Fig 1.2). The two limbs of the anticline are quite steep with dip angles ranging from 75° to 85°. In sectional view, it can be classified as an overturned anticline verging south. Its axis trends east-west and plunge eastward at a shallow angle. Bahaderkhel anticline exposes the oldest rocks of the plateau in its core i.e Bahaderkhel Salt. Furthermore, its southern limb is offset by Bahaderkhel fault along which Jatta Gypsum is thrust southward over Chingi Formation in the foot wall.

4- Lathamber Anticline

It is the largest anticlinal structure exposed in the area. It constitutes the foot-wall sequence of the Bannu-Surdag fault (Fig 1.2). The complete stratigraphic succession of the region is exposed towards east specially north of Surdag and Kamachashmai villages, where it exposes Bahaderkhel Salt and Jatta Gypsum in its core. However, west of Lathamber village the anticline exposes only Kamlial Formation. This feature indicates that the Lathamber anticline is gently plunging towards west.

3.4.2- Mesoscale Folds

In addition to the large scale folds, a number of small anticlines and synclines can be seen on outcrop scale in different part of the mapped area (Fig 1.2).

North of Bahaderkhel village a couple of anticlinal and synclinal structures are present. The axis of these folds are oriented north-west. The anticlines mostly expose Kamlial Formation in the core whereas the synclines have invariably the younger Chinji Formation covering the older sequence. Furthermore, south of the Bahaderkhel anticline a small synclinal fold can be seen which has developed within Nagri Formation. Its axial trend is again east-west.

In addition to the above mentioned folds a series of mesoscale north-east oriented anticlines and synclines are present north of Shadikhel village. Some of the smaller folds have curvilinear axial trends. All these folds are restricted within the outcrop of Kamlial Formation in the western part of the area.

To the west of Shashogai Syncline, two anticlinal folds have developed with north-west axial trends. The northern anticline exposes Kohat Formation in its core but the similar southern structure has exposure of Panoba Formation in the central part (Fig 1.2). Some of the mesoscopic scale folded structures are shown in the Figs 3.11, 3.12, 3.13, 3.14.

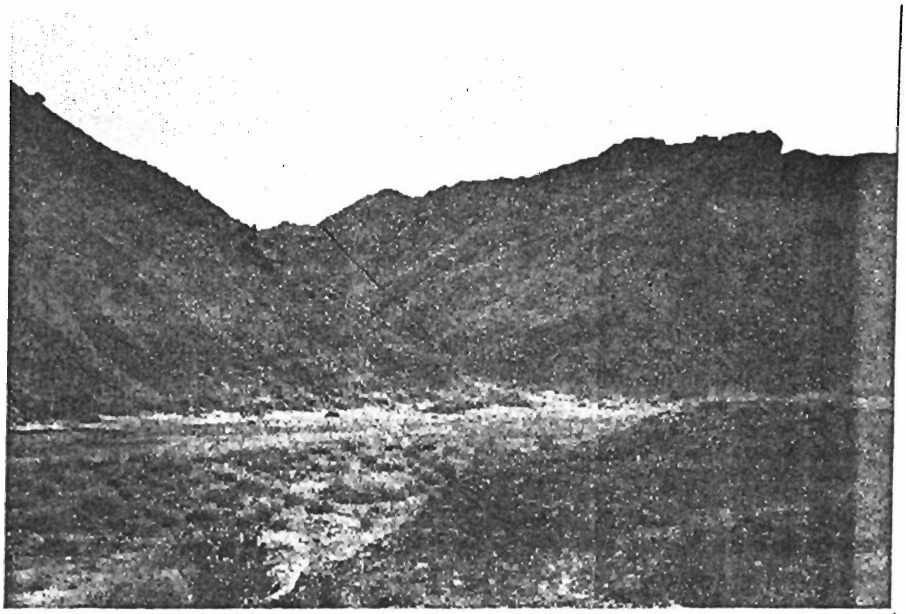


Fig 3.11 A small synclinal fold within Nagri Formation along Changhose algad.

Fig 3.12 A meso scopic scale overturned anticline within the Kohat Formation along Bannu-Zarwam Road.

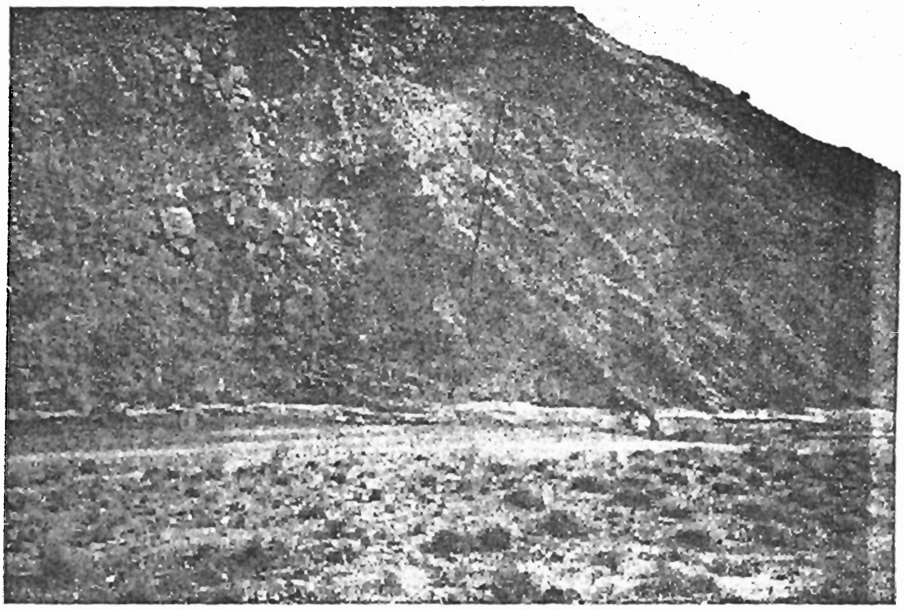


Fig 3.13 A mesoscopic scale anticlinal fold within Kamlial Formation , north of Aral Banda.

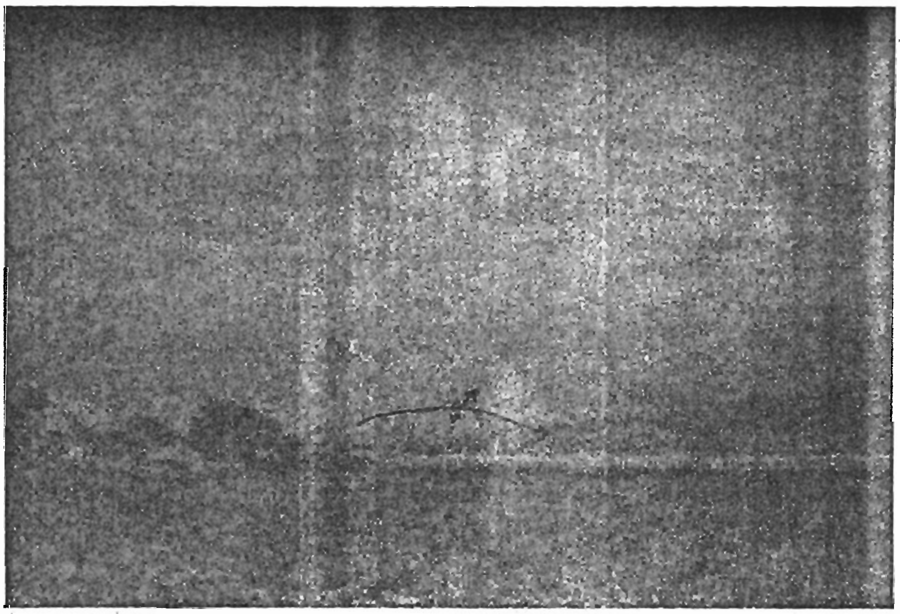


Fig 3.14 A view of a small anticlinal fold cropped out north of Kama Chashai Village.

CHAPTER-4

4.1- PROPOSED STRUCTURAL MODEL AND SYNTHESIS OF STRUCTURAL DATA

All the previous workers have interpreted the Kohat Plateau being exclusively a compressional regime characterized by low angle imbricates with the detachment horizon localized in Panoba Shale in the north and Jatta Gypsum and Bahaderkhel Salt in the south.

Pivnik and Sercombe (1993) have emphasised the role of transpressional deformation in addition to the main compressional deformation. Recently Fayaz (1994) have mapped the Karak quardangle and established the structure as positive flower structure being characterized by right lateral strike-slip deformation.

The present area was selected to establish this strike-slip deformational zone west of Karak quardangle and to look for further evidences to confirm this interpretation. Besides it was expected that this work may help in establishing the southernmost structural boundary of the Karak Plateau.

The proposed structural model has been prepared by studying the seismic section prepared by Amoco (1991) combined with the detailed surface mapping. Two cross-sections are constructed taking into consideration the best possible interpretation of the seismic data (Figs 4.1a, 4.1b). Both the models are identical with small variations. These models suggest that this part of the region is characterized by strike-slip faults with apperent normal movements in the sectional view.

LEGAND

SF=Shashogai Fault

BSF=Bannu-Surdag Fault

ZF=Zarwam Fault

BkF=Bahaderkhel Fault

Qal=Alluvium

Ts=Soan Form:

Tdp=Dhokpathan Form:

Tn=Nagri Form:

Tc=Chinji Form:

Tk=Kamlial Form:

Tko=Kohat Form:

Tkd=Kuldana Form:

Tj=Jatta Gypsum

Tb=Bahaderkhel Salt

Tp=Patala Shale

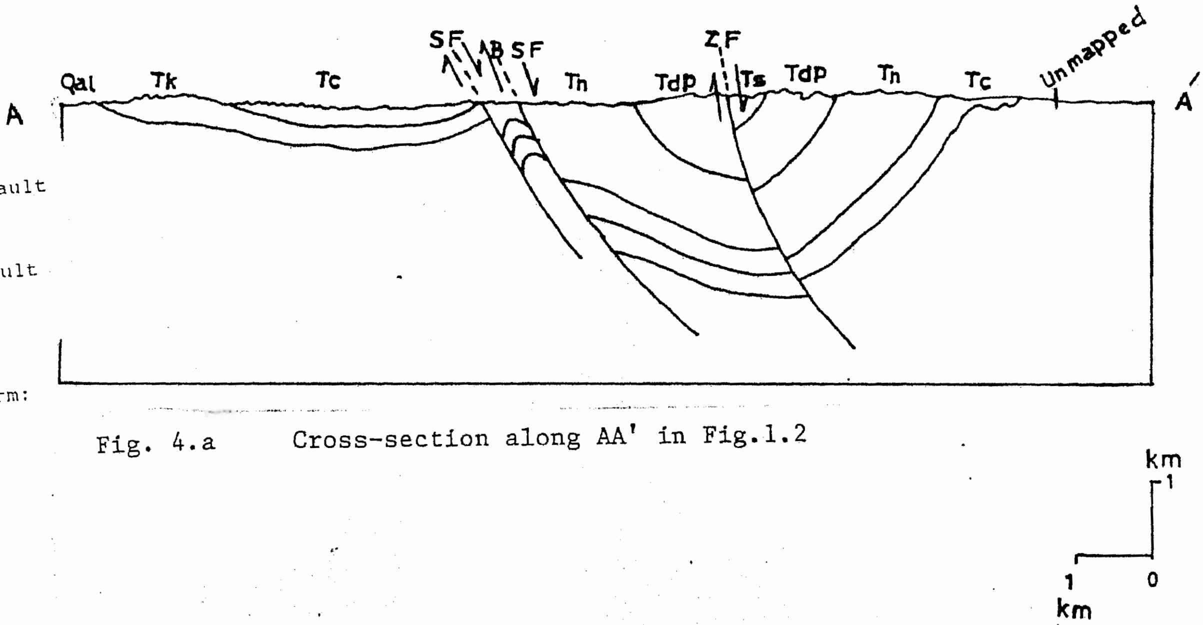


Fig. 4.a Cross-section along AA' in Fig.1.2

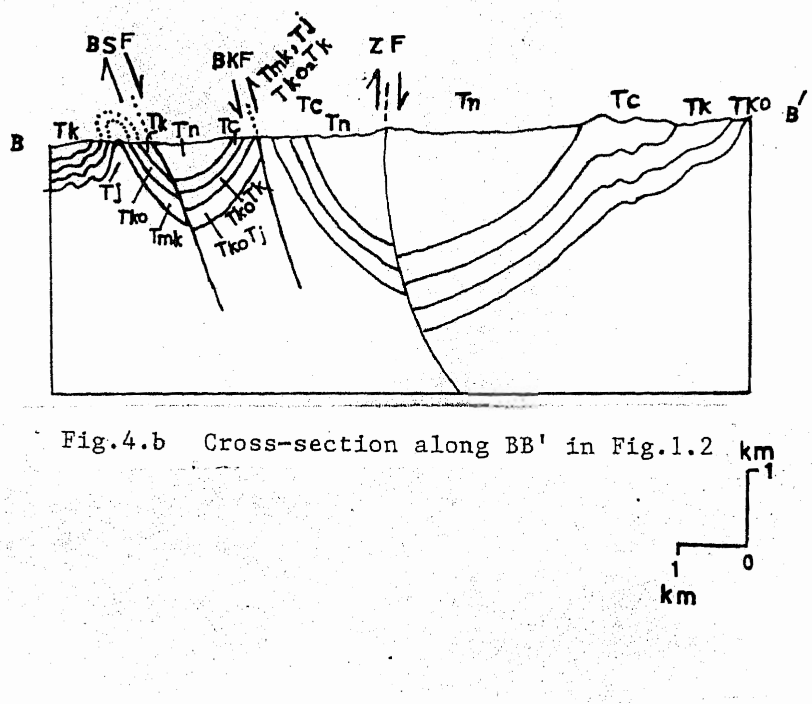


Fig.4.b Cross-section along BB' in Fig.1.2

In addition to these large scale faults, numerous macro-scale folds also control the structural geometry of the area. Along Zarwam Fault which is the northern most fault of the area, little vertical displacement is associated. All along its trace, it is intraformational i.e. within Soan Formation. In comparision, the Bannu-Surdag Fault shows greater vertical displacement. Along this fault, the Kamlial Formation is in contact with Nagri Formation. The entire Chinji Formation has been removed as a result of faulting. The Chinji Formation is slightly less than one Km thick in the study area. Thus an apperent normal displacement of around one km can be assigned to this fault. The availible seismic data is poor in the sense that one can not study the faults in depth. The options of these faults involving basement, joining at a shallow depth or major emergent faults starting from moderate depth are purely conjectural.

4.2- PROBLEMS WITH THE EXISTING MODEL

As mentioned earlier that all previous models emphasise on the low angle imbricates with shallow detachments in the Panoba Shale and Bahaderkhel Salt. This idea is superimposed on the present worker's model with high angle apperent strike-slip faults with apperent normal movements in sectional view but the problem with this model is the explanation of the presence of such large scale strike-slip faults in an entirely compressional regime. The faults are classified as strike-slip faults after very careful field study which is well supported by seismic data.

These faults can be traced upto the eastern boundary of the area, north of Surdag and give way to the thrust fault which are well exposed to the east of the mapped area in Karak quardangle (Fig 1.3). It seems that the Bannu-Kohat road section is the place from where the transpressional environments change to compressional environments.

4.3- EVIDENCES OF STRIKE-SLIP DEFORMATION

The main pattern of deformation in the area is characterized by strike-slip faulting. This idea is based on the overall tectonic set up of Kohat Plateau and the work carried out in adjacent area. Following is a brief account of the arguments to support the idea of transpressional deformation in the area.

1. The faults mapped in the area are steep as observed at the outcrop as well as interpreted in the sub-surface which can be seen in the seismic profile (Fig 4.2). The high angle faults are very common feature of the regime which are characterized by strike-slip deformation.

2. The Kohat plateau is unique in sense that it is surrounded by tectonic boundaries which are major thrusts and strike-slip faults of the region. The rationale of the strike-slip deformation lies in this tectonic set up of the plateau.

Towards north, the plateau is bounded by MBT along which Mesozoic rock sequence is thrust southward over the Eocene-Miocene sediments. The western boundary is demarcated by the Kurram Fault, which has recently been acknowledged as transpressional boundary that has undergone a 100 km sinistral strike-slip movement (Beck and Richard 1995). Towards south-east lies the Kalabagh Fault which

LEGEND

BSF= Bannu-Surdag Fault
ZF= Zarwam Fault

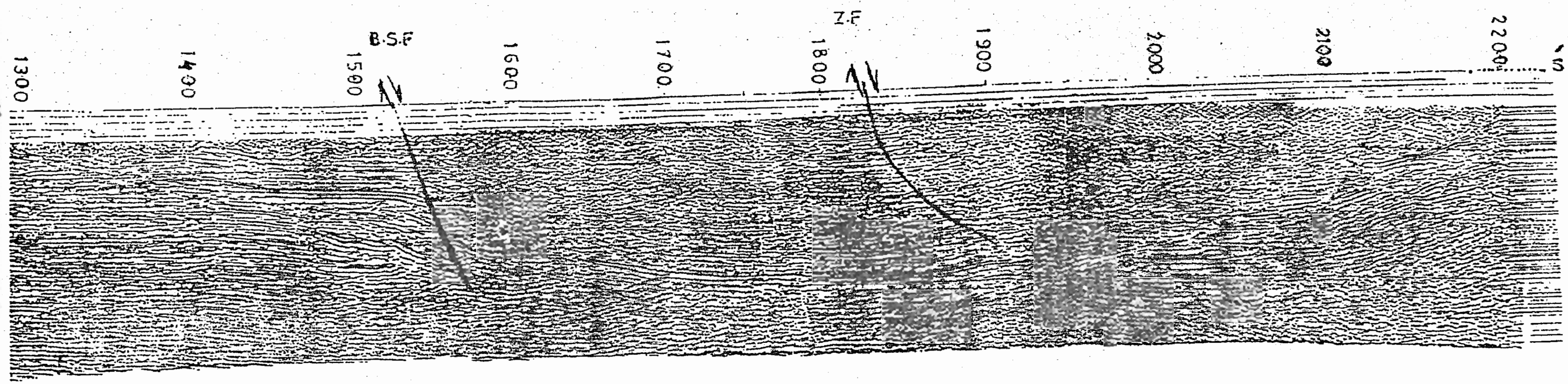
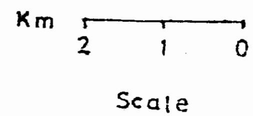


Fig 4.2: Seismic Profile (S5'). YXT-19 (Migrated)



is established as a right lateral fault with considerable strike-slip movement (McDougall, 1993).

Towards south it is bounded by the Surghar Range Thrust and Khisor Range Thrust. The Surghar Range Thrust runs east-west in the eastern part and swings in its western continuation to become almost north-south. This segment of the fault shows a strike-slip movement which is due to Kalabagh reentrant pushing its way towards north and the adjacent Bannu Basin creeping to the south (Fig 3.3). The Khissor Range Thrust is located way south of the area (about 75 to 80 km). Although work is needed to establish the relationship, if any, between Surghar Thrust and Khissor Range Thrust, it appears that these two faults initiated as a single fault which was later separated due to differantial movement between Kalabagh Re-entrant and Bannu Basin.

3. Slickenlines data has been observed and measured in the field. These lineations are quite common on surfaces of smaller faults exposed within the zones of major faults (Fig 4.3). The most common orientation of the slickenlines is oblique making an acute angle of 25 to 45 with the strike of their surfaces. However, a sufficient number of readings are parallel to the strike of the bedding surfaces (Table 2).

This feature indicates that the latest movement along these faults are strike-slip which as discussed above, fits in the regional tectonic scenario of this part of the country.

4. As mentioned earlier Fayaz (1994) have demonstrated the transpressional deformation towards east while mapping the eastern

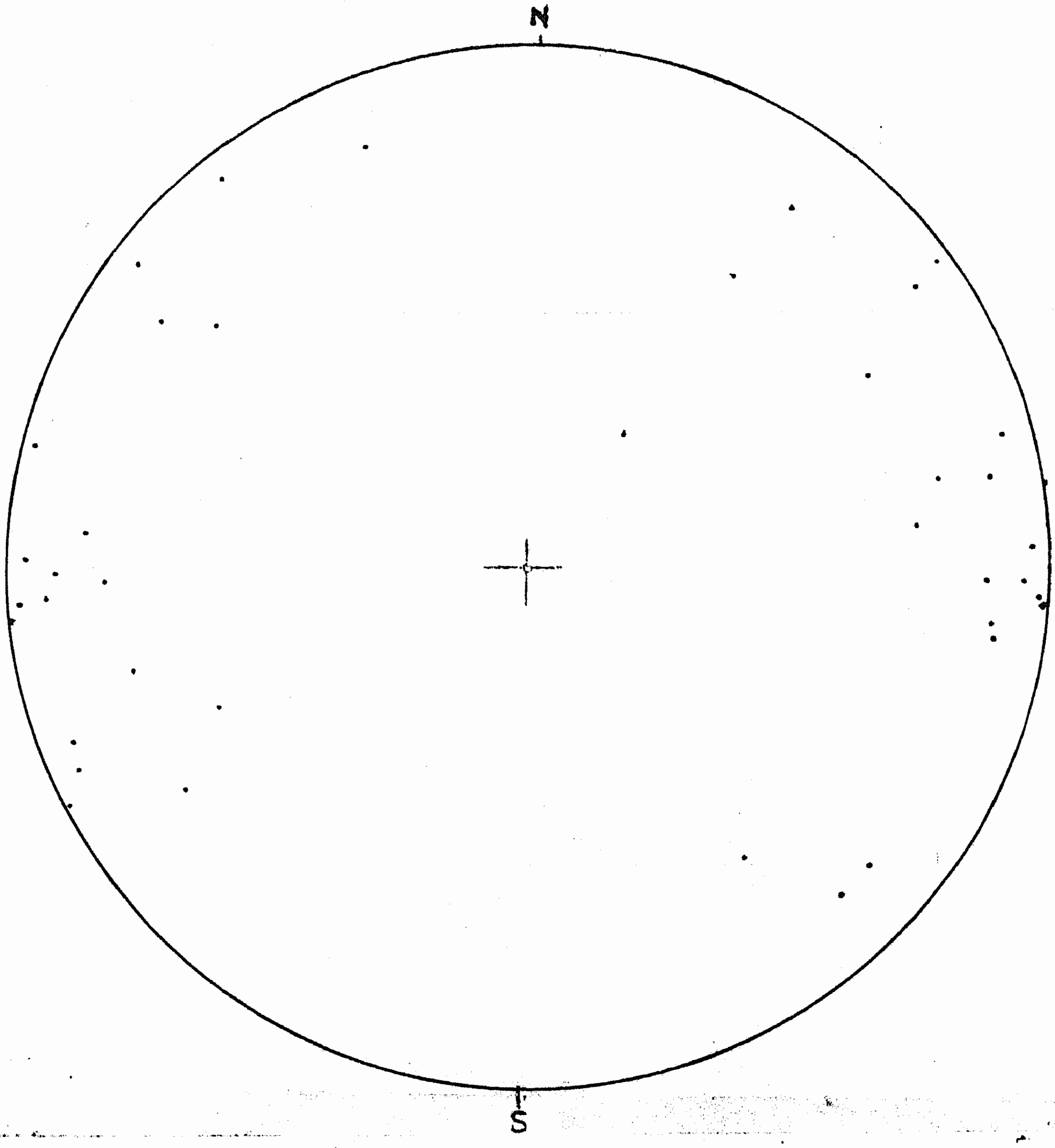


Fig.4.3. Equal area plot of the Slikenline data along different fault surfaces of the study area.

1.	3°	N52°E	21.	5°	N39°W
2.	12°	S84°E	22.	5°	N53°W
3.	10°	N53°E	23.	1°	S62°W
4.	2°	S87°E	24.	13°	S89°E
5.	25°	N52°W	25.	27°	N60°E
6.	16°	N56°W	26.	6°	S89°E
7.	6°	S65°W	27.	7°	S69°W
8.	4°	N87°E	28.	0°	S84°W
9.	8°	S86°W	29.	2°	N87°E
10.	27°	N83°E	30.	2°	S86°W
11.	20°	S88°W	31.	11°	N82°E
12.	10°	S89°W	32.	0°	N80°E
13.	4°	N89°W	33.	16°	N86°W
14.	21°	N77°E	34.	2°	N76°W
15.	7°	N74°E	35.	11°	N78°E
16.	23°	S57°W	36.	14°	S49°E
17.	16°	N35°E	37.	14°	N22°W
18.	35°	S65°W	38.	23°	S75°W
19.	31°	S37°E	39.	64°	N34°E
20.	32°	N34°E	40.	14°	S44°E

Table.2: Slikenline data along different fault surfaces of the area.

Karak quadrangle which is the continuation of the mapped area. This whole structural complex is extended east-west from north of Bannu upto Indus River where it is truncated by the Kalabagh Fault.

5. Several mesoscopic scale enechelon folds are developed on the southern side of the Bannu-Surdag fault, north of Khalboi village (Fig 1.2). All these folds have a north-east oriented linear to curvi-linear axial trends. Such fold geometries are characteristic of the areas which have been subjected to strike-slip deformation.

4.4- DISCUSSION

As a result of the present field work and the literature study of the eastern continuation of the area, this structural complex is named as "Kohat Plateau Boundary Zone". This boundary runs east-west and east-northeast for about 120 km and is about 6km wide. It is joined towards the west with north-south trending folded and faulted belt of the Mesozoic and Tertiary sediments which connects this zone with the Sulaiman Fold Belt. Towards east this zone can be traced upto the Kalabagh Fault. It is characterized by large scale strike-slip faults,minor anticlines, synclines and east-west trending thrust faults that intersect and truncate the early folds of the area.

The Kohat Plateu Boundary Zone is characterized by strike-slip deformation. It is unique in the sense that its eastern part is characterized by transpressional deformation whereas its western part has undergone strike-slip deformation.

The strike-slip deformation in the area is accompanied by apperent normal and thrust-slip movements in places along the Zarwam and Bannu-Surdag Faults. The sense of movement along the Zarwam Fault is left lateral which is evident from its map relationship. The offset of the rocks juxtaposed along this fault can be seen in map view (Fig 1.2). Towards the eastern closure of Hathikhel Syncline the left lateral movement is evident by the offset of the rocks and this sense of motion is well supported by the same type of offset at the western closure of Hathikhel Syncline to the north of Zarwam.

The Bannu-Surdag Fault which lies south of the Zarwam Fault is characterized by right lateral sense of movement. The evidence for the opposing sense of movement along this fault is the development of small scale enechelon folds in the Kamlial Formation south of this fault. All these minor enechelon folds are right stepping which indicates a right lateral sense of movement along this fault. It is believed that both these faults are Rheidal shears which branches from the Kurram Fault which lies west of the studied area (Fig. 3.3). The Kurram Fault is established as a left lateral strike-slip fault with a 100 Km sinistral displacement along it (Beck 1995).

There are no good constraints upon the amount of displacement along these faults. The timing of deformation is beleived to be Plio-Pleistocene as these faults incorporate rocks of Plio-Pleistocene age.

CHAPTER-5

CONCLUSIONS

1. Ten distinct lithostratigraphic units have been recognized in the study area which ranges in age from Eocene to Pleistocene. These units are listed below in the order of superposition:

   J) Soan Formation

   I) Dhok Pathan Formation

   G) Nagri Formation

   F) Chinji Formation

   E) Kamlial Formation

   D) Kohat Formation

   C) Kuldana Formation

   B) Jatta Gypsum

   A) Panoba Shale

2. The major faults mapped in the area are steeply north dipping strike-slip faults with apperent normal slip movements in the sectional view.
3. The area has undergone an earlier NS compressional phase of deformation giving rise to folds and thrust faults which is over printed by a north-west oriented phase of transpressional deformation which have resulted in the formation of largescale strike-slip faults.

4. The strike-slip adjustments are evident from the development of small scale, NE oriented enechelon folds in the rocks juxtaposed along the Zarwam and Bannu-Surdag Fault.

5. The availible constraints upon the timing of deformation suggest a Plio-Pleistocene age for the NW oriented transpressional phase of deformation.

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