GEOLOGY OF SOUTHERN TANAWAL AREA, NORTH OF HARIPUR, N.W.F.P; PAKISTAN.

A THESIS SUBMITTED TO THE NATIONAL CENTRE OF EXCELLENCE IN GEOLOGY, UNIVERSITY OF PESHAWAR IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF PHILOSPHY IN GEOLOGY.

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ABSTACT

The southern Tanawal region exposes a suite of metasedimentary rocks comprising , conglomerate, argillite, quartzite and dolomite.The basal sequence of unfossiliferrous quartzites of Precambrian age belongs to Tanawal Formation and is unconformably overlain by thick succession of argillite, quartzite and dolomite of Cambrian age . This assemblege of younger metasediments is named as Sherwan Fomation.

The southern tanawal area lies on the hanging wall side of the Panjal fault and is largely influenced by the deformational pattern associated with this fault. On large scale ,a series of northeast- trending overturned anticlines- synclines establish the structural style of the region.

The fault crossing the area are north- dipping thrust and reverse faults.A small scale back thrust which is part of the system is present in the central part of the area.

The overturned folds invariably verge southward.The orientation of thrust and the fold vergence indicates southward directed tectonic transport.Since the major structure in the vicinity of the area is the Panjal fault , it can be inferred that the stucture of this part of the region took shape during the development of this fault.

INTRODUCTION

INTRODUCTION

GEOGRAPHIC DESCRIPTION

The study area encompasses 68 sq.km. of the southern Tanawal region (plate 1).It lies in the survey of Pakistan topographic sheet No. 43 B/16 between latitudes $34^{\circ} 4' 20''$ and $34^{\circ} 8' 0''$ N and longituted $72^{\circ} 53' 30''$ and $73^{\circ} 0' 0''$ E.The base map was prepared by enlarging two times the quarter degree sheet.

The major city of the Tanawal area is Haripur which lies 8 km.to the south of the area proper. A newly surfaced road named Chapper road leads to the southern Tanawal area from Haripur.It runs all along its southern and western periphery and provides good sections for study . Some paths connecting local villages allow deeper penetration in the area. In ,addition several stream courses bisecting the hilly terrain provides good access to the remote parts of the area.

The relief is moderate and ranges from 500 m. above the sea level at valley floors to about 1080 m. above sea level at the highest peak in the area .The ridges are mostly formed by dolomite.

The whole drainage is captured by the Siran river which demarcates the western boundry of the area and join the Tarbela lake near the southern margin of the area.

PURPOSE OF INVESTIGATIONS

The area under study remained neglected till 1975. During the last 15 years lot of work has been carried out by local and foreign geologists in Hazara and adjoining areas. The primary aim of this investigation is to map various lithologies in detail and work out the stratigraphic order. It is believed that detailed investigations in small area of this structurally complicated and topographically rugged terrain of mountains will be usefull in establishing the stratigraphic framework of southern Hazara and continuation of similar lithologies in Peshawar basin.

The project was taken up to concentrate on the role of Panjal fault on the the structural geometry of the area and to construct a structural model showing the tectonic transport direction in relation to the adjoining areas. Additionally, the present investigations will provide a sound base for the future investigations of the region.

PREVIOUS INVESTIGATIONS

The initial geologic observations in the southern Tanawal area were made by Waagen and Wynne (1872).Their work include a geological sketch map of Hazara describing the detailed stratigraphy of the region. Later, Middlemiss (1896) published a geological sketch map of Hazara from Black Mountains on the west bank of Indus river eastward to Kunhar river. Both Waagen and

Middlemiss mentioned thick sequence of quartzites (Tanol Quartzites) unconformably overlain by thick cabonate succession.

Wadia (1931) carried out detailed stratigraphy of Hazara including the study area. Ali (1962) published a paper on the stratigraphy of the southern Tanawal area. He did detailed stratigraphic and structural study of the area.

During 1961- 1965 , the Tanawal area was mapped in detail as a part of a joint US-Pakistan study of the geology of Hazara (Calkins *et al*; 1975). They rejected the previous nomenclature for the rock sequences exposed in southern Tanawal area and assigned new names and ages to the quartzite and carbonate succession exposed in the area. Publication of the results from this study was delayed for ten years, during which lot of work has been carried out in Hazara region.

Finally, Tahirkheli and Majid (1977) did a detailed petrographic study of the "Tanawal Formation" exposed in the northern part of Gandghar range and southern Tanawal area.

CHAPTER :1 STRATIGRAPHY

STRATIGRAPHY

INTRODUCTION

The Lesser Himalayas of Hazara exposed in Tanawal and Abbottabad areas consist of a thick sequence of dolomites and qquartzites. The dolomite-quartzite sequence is unconformably underlain by Precambrian metasediments. The unconformity is represented by a well developed conglomerate bed throughout Hazara and Kashmir. Similar rock sequences are present west of river Indus,in Rustam-Swabi area (Pogue, 1989). The age of the dolomite- quartzite sequence was uncertain till 1972, when Latif forthe first time reported Cambrian fauna '*Hyolithids*' from the overlying 'Hazira Shale', near Abbottabad area.

Two formations crop out in the study area ; Tanawal Formation unconformably overlain by the Sherwan Formatin. The two formations are tentatively assigned Precambrian and Cambrian ages respectively.The dominent lithologies in the area are quartzites, dolomites and argillites. As a result of the present study, the revised stratigraphic sequence for the southern Tanawal area is proposed as under.

Name of Formation		Age
Sherwan Formation	Dolomite member	
	Quartzite unit	Cambrian?
	Quartzite member	
	Argillite member	
	Unconformity	
Tanawal Formation		Precambrian?

HISTORICAL REVIEW

The earliest attempt to establish the stratigraphy of Hazara was made by Waagen and Wynne (1872). They described a series of unfossiliferrous, partly metamorphosed slates, conglomerates, schists and quartzites under the name 'Tanol Series', unconformably overlain by a thick succession of carbonates which they called 'Below the Trias'. Middlemiss (1896) working in Hazara, renamed the 'Tanol Series' as 'Tanol quartzites' and described them as feldspathic schistose quartzites. He also changed the name of Waagen and Wynne (1872) 'Below the Trias' as 'Infra Trias'. Firstly, he believed that the Tanol quartzites forms the lower part of the 'Infra Trias' and are metamorphic equivalent of the 'Infra Trias' but latter on changed his opinion when faced some difficulties in constructing a map and section on the basis of this assumption. He mentioned the possibility that the 'Infra Trias' are equivalent partly or wholly of the Carboniferous-Permian of the Salt range.

Wadia (1931) spelled the Tanol quartzites as Tanawal quartzites and correlated them with Muth quartzites of Kashmir, Simla and Garhwal areas of India. Wadia (1957) correlated the boulder bed of Hazara area with the Talchir boulder bed of eastern peninsular India and suggested a Paleozoic, probably Permo-Carboniferous age for the 'Infra Trias series'.

Marks and Muhammad Ali (1961) worked out the detailed stratigraphy of Abbottabad area and renamed the 'Infra Trias' as

'Infra Trias Group'. They divided the group into two formations, consisting of a lower clastic sequence followed by an upper calcareous sequence. They described the Tanol quartzites as Tanol Formation. In 1962, the same authors decided to change their previous nomenclature and called the Infra Trias Group as Abbottabad Formation with a five- fold subdivision.

Ali (1962) in a paper about the geology of southwestern Tanawal area, named the carbonate sequence as Abbottabad Formation, unconformably underlain by 'Tanol Formation'.

Latif (1970) working near Abbottabad area, rearranged the stratigraphy and gave group rank to the Abbottabad Formation. He described the lower clastic sequence as Kakul Formation and the upper calcareous sequence as 'Sirban Formation'. Latif (1972) and Rushton (1973) found Cambrian fauna from the overlying Hazira Shale near Abbottabad and suggested a lower Cambrian age for the Abbottabad Group. Latif (1972) has correlated the Abbottabad Group with the post Blaini sequence of Simla, Garhwal, Kumaon of India and Western Nepal.

Calkins and others (1975), while mapping the southern Himalayas of Hazara, spelled the Tanol as Tanawal, which is written on the topographic sheets. They called the 'Abbottabad Formation' (Ali, 1962) as Kingriali Formation of Triassic age on the basis of lithological similarities of the Abbotabad Formation with the Kingriali Formation.

REVISED STRATIGRAPHY

The revised and previous stratigraphic schemes proposed for the southern Tanawal area are shown in Table 1. Previously the dolomite-quartzite sequence of the Tanawal and Abbottabad area was named as Abbottabad Formation (Ali,1962) and Kingiriali formation (Calkins *et al.*, 1975). As a result of the present investigations the dolomite-quartzite sequence exposed in Tanawal area is separated from that of the Abbottabad area. New ages are assigned to the formations on the basis of recent research, carried out in the Tanawal and adjacent areas. The reasons which convinced the author to separate the Tanawal area rocks from that of the Abbottabad area, are based on the following observations.

Hazara can be divided into two stratigraphic-tectonic zones, which are from north to south as Tanawal zone thrust over the Abbottabad zone (Fig.1). The Tanawal zone consists of thick sequence of Tanawal Formation , unconformably overlain by dolomite-quartzite sequence. Recently Pogue (1989) has reported a quartzite unit overlying the dolomite-quartzite sequence exposed in the core of Sherwan syncline (Calkins *et al*; 1975), north of the mapped area (Fig.1). He considered this quartzite unit to be the equivalent of Misri Banda Quartzite of Rustam-Swabi area.

The Abbottabad zone starts with Hazara Formation at the base, unconformably overlain by the Abbottabad Formation which is in turn overlain by the Tarnawai group (Latif; 1970). The Tanawal Formation is completely missing in the Abbottabad zone (Fig. 1).

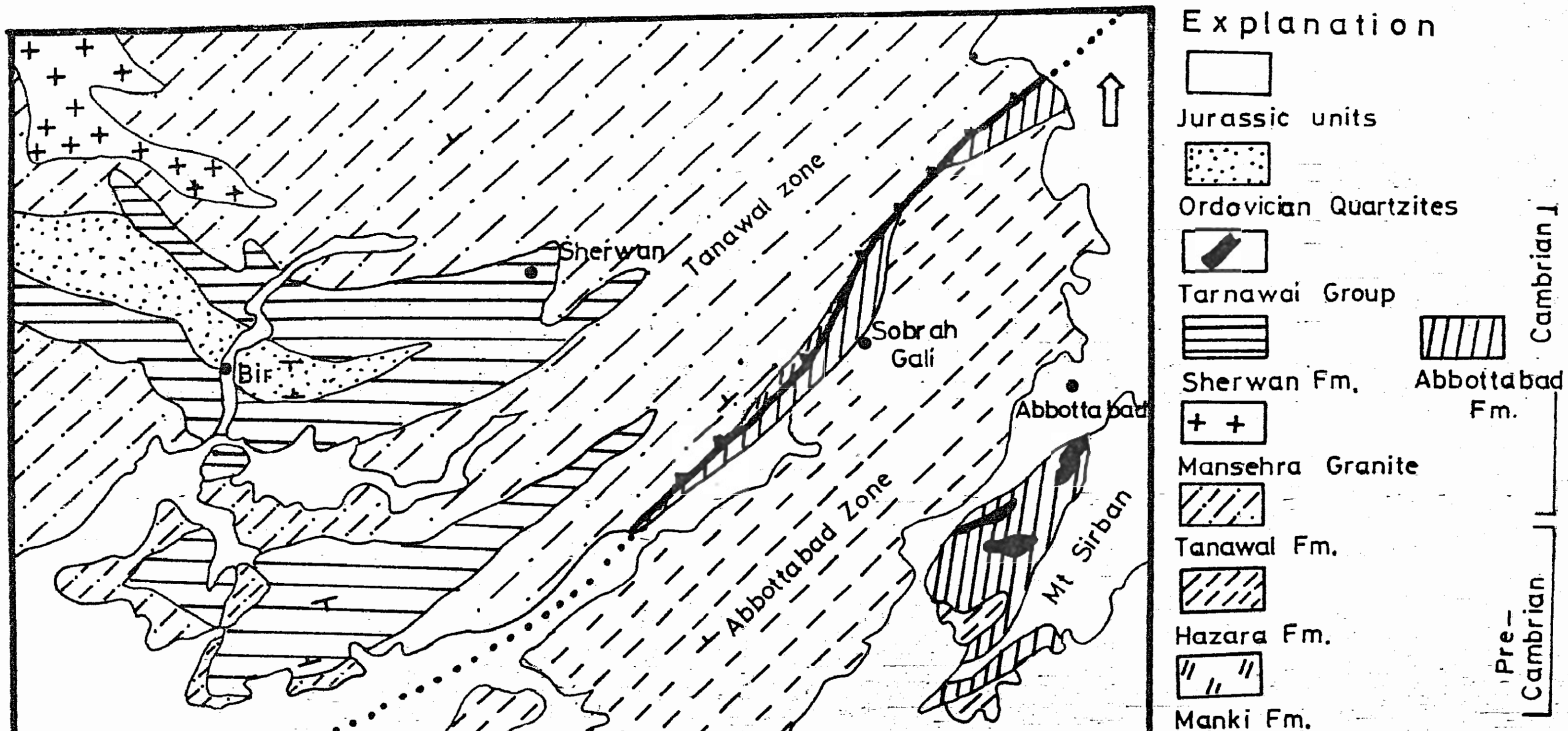

Fig.1. Geological sketch map of Tanawal and Abbottabad areas(modified& interpretted after Latif,1972;Calkins & others,1975;G.Fuch,1975).

Middlemiss(1896)	M.Ali(1962)		Calkins & Others (1975)		Suggted by author		
Infra-Triass	Abbottabad Formation	Dolomite member	Kingriali Formation	Dolomite unit	Sherwan Formation	Dolomite member	Cambrian ?
		Quartzite member		Lower quartzite unit		Quartzite member	
		Quartz mica schist member		Phyllite unit		Argillite member	
		Basal conglomerate member					
Unconformity	Unconformity		Unconformity		Unconformity		
Tanol Quartzites	Tanol Formation		Tanawal Formation		Tanawal Formation		Precambrian

Tab.1. Stratigraphic schemes for the southern Tanawal area, as proposed by various authors.

The Tanawal zone is located in the hanging wall of the Panjal Fault which is the boundary between the two zones and is characterised by a displacement with both thrust and strike-slip components (Calkinset *al*; 1975). Along Panjal fault considerable displacement of various facies has occured .

Comparing the stratigraphic position of the dolomite-quartzite sequence of Tanawal zone with that of the Abbottabad zone, a remarkable dissimilarity can be observed (Tab. 2). Additionally the lithological comparison of the two zones shows that a higher grade metamorphic rocks are exposed in the Tanawal zone.

On the basis of above mentioned observations the nomenclature and ages of the Tanawal zone rocks is revised in order to separate the rocks of the two zones.

Tanawal zone(Suggested by author&Pogue,1989)	Abbotabad zone(Marks&Ali, 1962;Latif,1970)
Misri banda quartzite	Tarnawai group
Sherwan Formation (Dolomite-Quartzite)	Abbottabad Formation (Dolomite-Sand stone)
Unconformity	Unconformity
Tanawal Formation	Hazara Formation

Tab.2. Stratigraphic position of the dolomite sequence exposed in Abbottabad and Tanawal zones.

FORMATIONAL DESCRIPTIONS

Tanawal Formation

Stratotype

The type locality is named after a former tribal area called Tanawal, which is located east of river Indus and north of Haripur.

Lithology

In the study area, the formation mainly consist of medium-bedded, light grey to yellowish-White quartzite which weathers to faintly reddish and yellowish-white colours. The quartzite is interbedded with grey argillites in places. The grain size of the quartzite range from fine to coarse. In the upper stratigraphic levels, the quartzite is subconglomeratic in places (Fig. 2). The quartzite is profusely cross-bedded (Fig. 3) and ripple marks are found rarely on the interfaces between quartzite and argillite (Fig. 4). Iron specks can be seen in the quartzite beds of the formation.

Relation to adjacent rocks.

In the study area the lower contact of the Tanawal Formation is not exposed whereas its upper contact is unconformable with the overlying Sherwan Formation

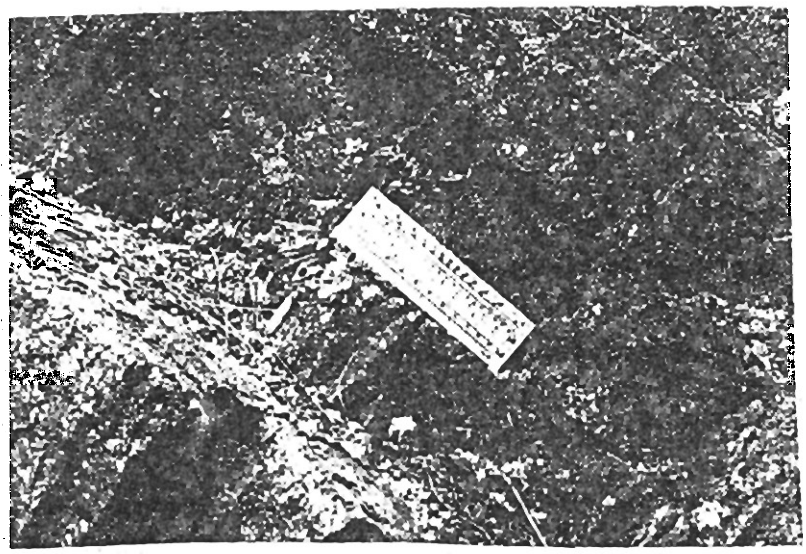

Fig.2. Subconglomerritic layers within the quartzite of Tanawal Formation.

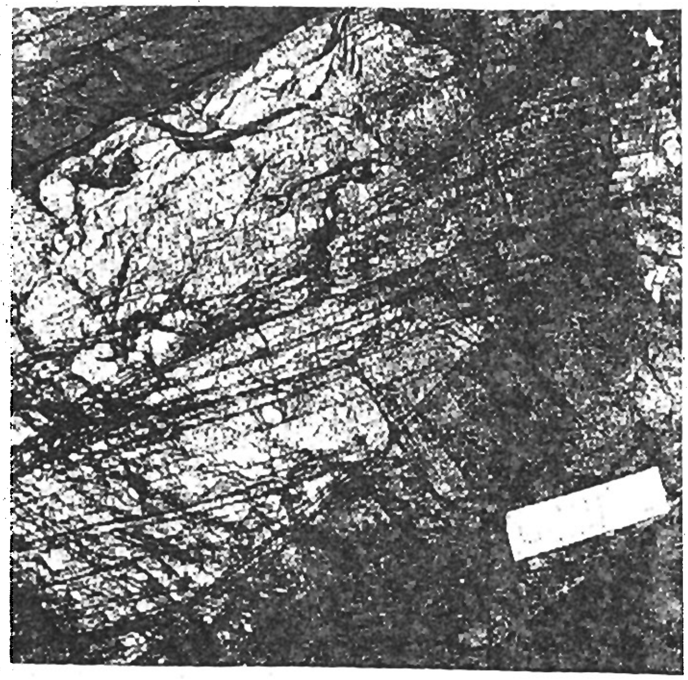

Fig.3. Cross-bedded quartzite of Tanawal Formation showing right side up.

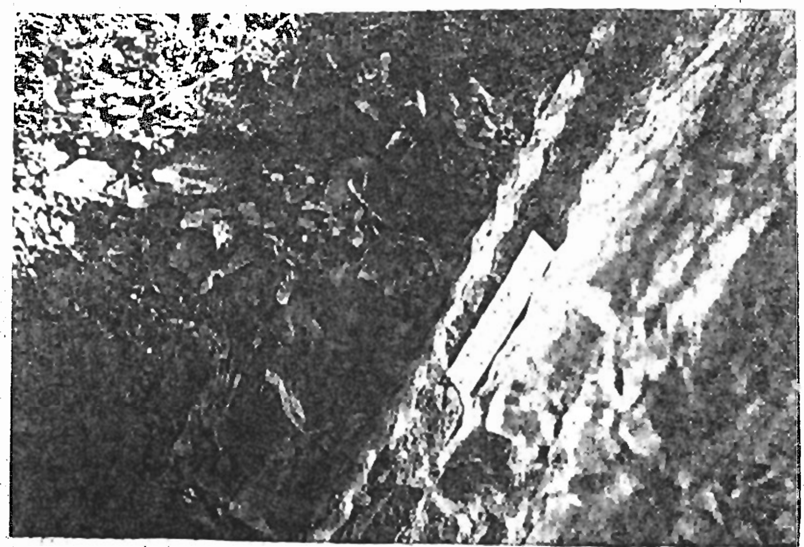

Fig.4. Oscillation ripple marks in the quartzite ofTanawal Formation showing right side up.

Distribution and Thickness

The formation crops out along an extensive belt, streching from Haripur to Darband and Mansehra through Sherwan area which forms the Tanawal territory of Hazara. It is also exposed to the west of river Indus upto Swabi area (Pogue;1989). The formation is intensely folded and faulted, so it is very difficult to measure the thickness. The estimated thickness is about 300 meters in the study area.

Note: As no sections are measured, so the thicknes measurements are based on trignometric calculations using outcrop width measurements.

Age and Correlation

No fossils have been reported so far from the Tanawal Formation. The age assigned to the Formation by the previous workers is mainly based on its stratigraphic position and lithological similarities with other rocks in Hazara . and adjoining areas. Latif (1972) reported Cambrian fauna from the Hazira Shale which underlies the Abbottabad Formation. In the study area the Tanawal Formation is overlain by Sherwan Formation which is correlative with the Abbottabad Formation . So a Precambrian age can be inferred for the Tanawal Formation. In northern Hazara, the Mansehra granite intrudes the Tanawal Formation. Le Fort and others (1980) reported a whole rock Rb/Sr age of 516 Ma for the granite body, thus restricting the Tanawal Formation to Precambrian age. The formation is correlated with Muth quartzite of Kashmir by earlier workers (Wadia,1931; Latif, 1970; Calkins and others, 1975).

Sherwan Formation

Stratotype

The name 'Sherwan' is introduced here to denote the dolomite and quartzite sequence above the Tanawal Formation in the Tanawal area. The type locality is designated Sherwan because the formation is best exposed in Sherwan area though the present study was carried out south of Sherwan area. Reference section in the study area is located east of Darwaza village (Lat. 34° 5′ N, Long. 72° 57′ E), 10 km north of Haripur City.

Lithology

Lithologically the formation is divided into three members which are from bottom to top as argillite member, quartzite member and dolomite member. The dolomite member has quartzite unit in the form of lenses (Fig. 5).

Argillite member

The basal part of the member at several localities consist of conglomerate bed which has poorely sorted clasts. The conglomerate is not restricted to the base of the member. The

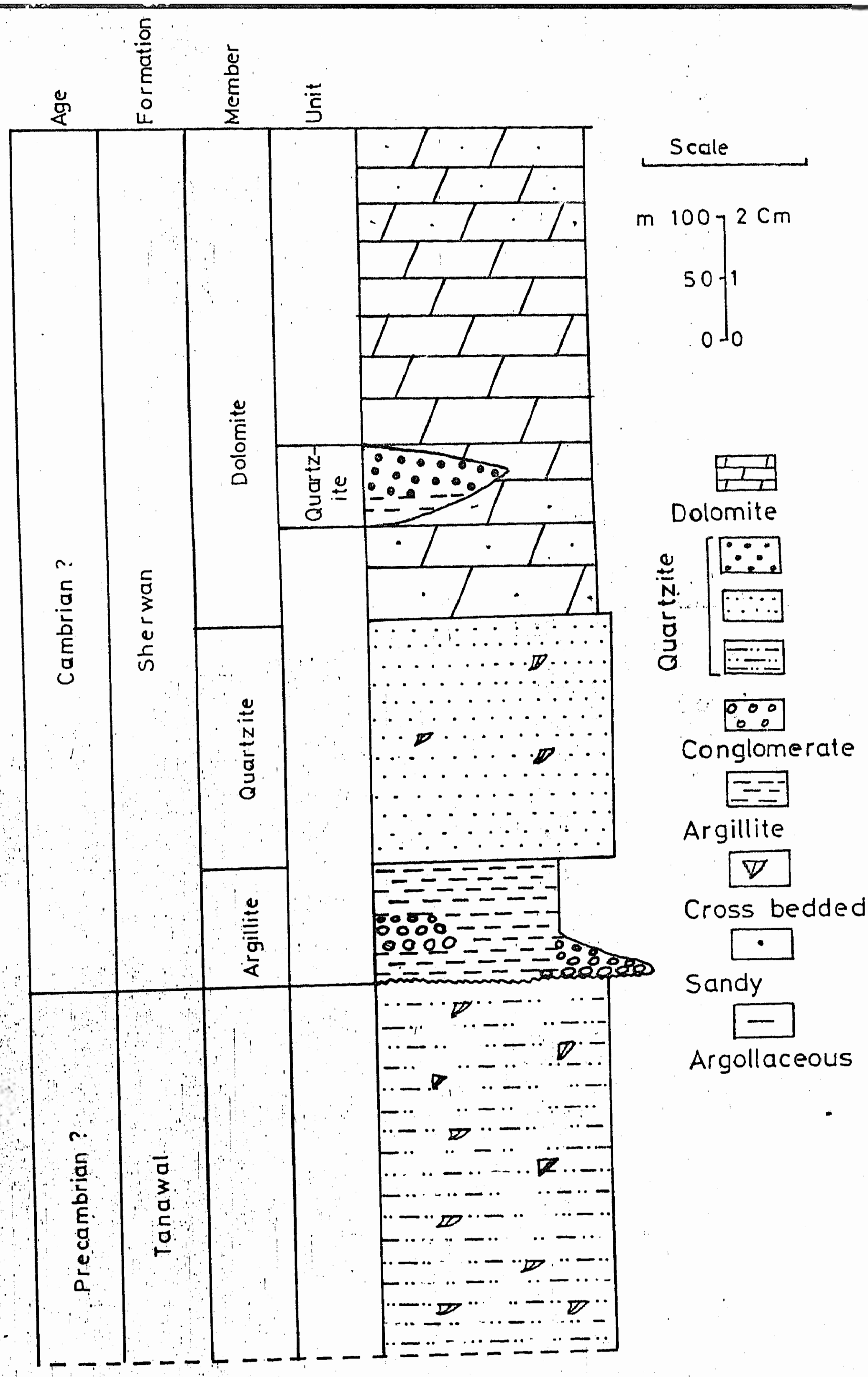

Fig.5. Stratigraphic column of the southern Tanawal area,north of Haripur.
(Lat.34° 5′ N,Long. 72° 57′ E)

clasts mainly consist of white to grey quartzites and grey argillite, embedded in argillaceous and sandy matrix. The clasts ranges in size from a few cm to about 40 cm in diameter and are commonly elogated parallel to the bedding (Fig. 6). The conglomerate is about 30 meter thick in places. It gradually passes upward into dark grey argillites. The argillites contains sandy and silty intercalations at various stratigraphic levels. The estimated thickness of the member ranges between 100 and 120 meters. It passes sharply upward into the next member.

Quartzite member

It mainly consist of medium to thick-bedded quartzites. It starts from its lower contact with light grey, fine-grained quartzite, followed by greenish-grey quartzite and at the top it grades into coarse-grained yellowish-white quartzites. The grain size ranges from fine to coarse. The upper yellowish-white quartzite is very coarse-grained and on weathering produces rubbly material. The quartzite is cross-bedded (Fig. 7) and argillaceous laminations are common. The thickness of this member is variable and ranges from 150 to 210 meters. It attains meximum thickness south of village Chanjaliala (Plate 1). Its upper contact with the overlying dolomite member is sharp and about a one meter thick bed of dolomitic quartzite is observed which can be called as gritstone.

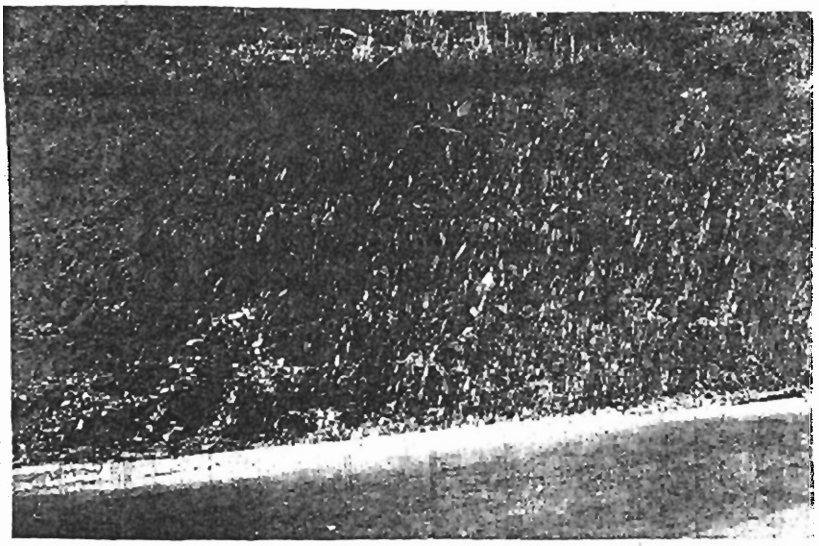

Fig.6. Conglomerate bed at the base of the argillite member of Sherwan Formation.

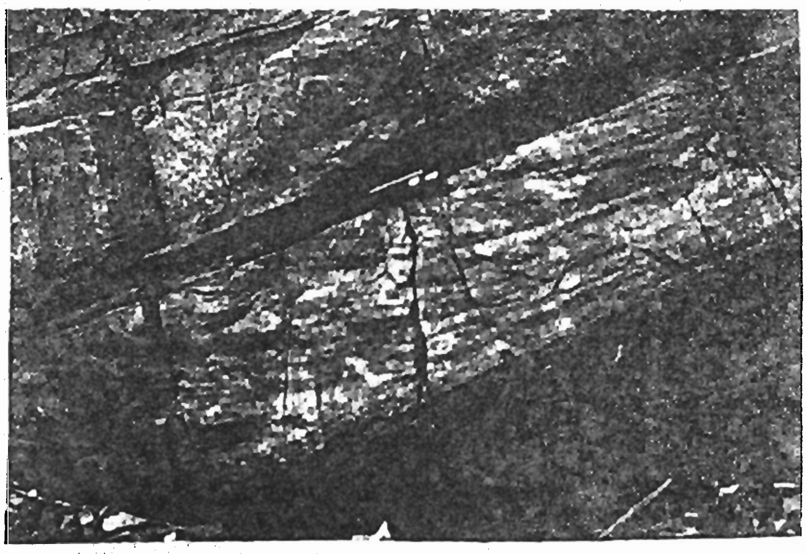

Fig.7. Cross-bedded quartzite of the Sherwan Formation showing right side.

Dolomite member

This member starts at the base with brown weathering, coarsely recrystallized, medium-bedded dolomite which is sandy and have chert nodules and lenses. This grades upward into thin to medium-bedded, white, grey and pinkish dolomite which is fine recrystallized and has argillaceous laminations, resembling stramatolites locally. At about a 60 meter height from the base, the dolomite has a quite persistant bed of quartzite-argillite in the form of lenses and is designated as quartzite unit. Above the quartzite unit, the dolomite is medium-grained, grey in colour on fresh surfaces and weathers to brownish-grey colour. The weathered surfaces resemble butcher's chopping board. In the upper horizon of the member cherty (Fig.8) and argillaceous layers are common (Fig.9). Also dark grey limestone beds are found in few places. Its thickness is estimated about 400 meters. The lower contact with the quartzite member is sharp. Its uper contact is not exposed in the study area. However, a 60 meter thick lense of conglomerate is seen in the core of the largest syncline of the area, north of village Aluli (Lat. $34^{\circ} 5' 30''$ N, Long. $72^{\circ} 58' 0''$ E) (Plate 1). The conglomerate consists of 80% argillite, 10% quartzite and 5% dolomite clasts. The quartzite clasts are grey to white, well rounded, embedded in coarse-grained quartzite or argillaceous quartzitic matrix. The quartzite clasts are sometimes so densely packed that it may be called as clast supported.

Quartzite Unit

The dolomite member has thick and quite persistant lenses of quartzite-argillite at an approximate stratigraphic height of 70 to 80 meters at various places. The unit has about 20 meters thick argillites at the base followed upward gradationally by a 60 meter thick grey coloured quartzite. The quartzite is medium-bedded, fine-grained and occasionally cross-bedded. Pyrite cubes are present rarely

Distribution and thickness

The Sherwan Formation is widely distributed in the lower and upper Tanawal region. The thickness is estimated to be 750 meters in the study area.

Age and correlation

Recently,Pogue (1989) has reported Ordovician quartzites(Misri Banda Quartzite) overlying the Sherwan Formation, north of the study area in the core of Shewan syncline (Fig.1).Thus a Cambrian age cane be inferred for the Sherwan Formation.The formation can be correlated with the Ambar Formation of Rustam- Swabi area on lithological basis.

Remarks

It is very difficult to differentiate between the Tanawal

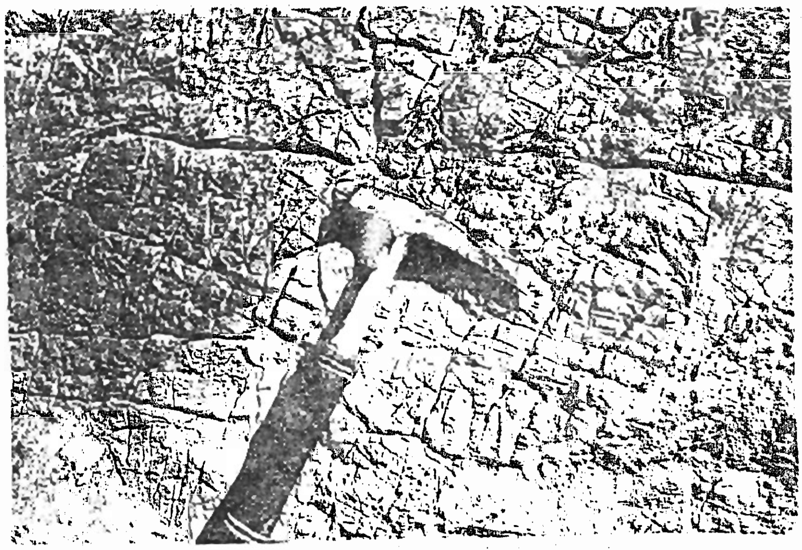

Fig.8. Butcher chop weathering feature in the dolomite member of Sherwan Formation.

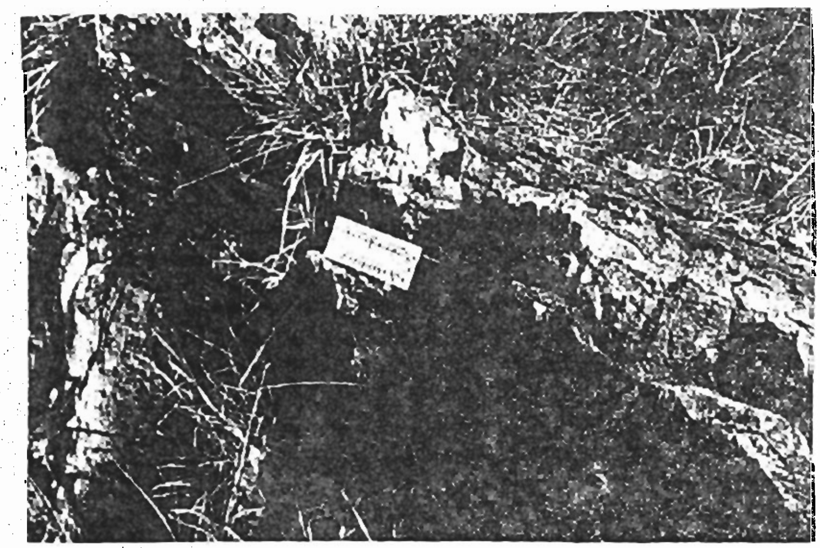

Fig.9. Chert layers within the dolomite member of the Sherwan Formation.

Rustam-Swabi area (Pogue, 1989)	Southern Tanawal area (suggested by author)	
Ambar Formation	Sherwan Formation	Dolomite member
		Quartzite member
		Argillite member
Unconformity		Unconformity
Tanawal Formation		Tanawal Formation

Table No 03. Proposed correlation of the rocks of southern Tanawal area with Rustam-Swabi area.

quartzite and the quartzite member of the Sherwan Formation in outcrop. They are nearly identical in colour, grain size and bedding. The only difference is that, the argillite interbeds are very regular in Tanawal quartzites and iron specks are more prominent which lack in the Sherwan Formation.

CHAPTER:2 STRUCTURAL GEOLOGY

STRUCTURAL GEOLOGY

TECTONIC SETTING

The Tanawal area is located in the Hazara foreland fold-and-thrust belt of Himalayas. The Himalayan mountain chain is the result of collision between the convergent plates of India and Asia (Fig.4). The collision of plates and the resulting Himalayan range dates back to 40 Ma (Molnar and Tapponier, 1975). The north moving Indian. Plate and the south moving Asian plate had a wedge of island arc terrain which was sandwiched in between the two plates towards their western part. The shortening processes resulting from the collision are partly accomodated by the thickening of crust and partly by thrusting (Molnar, 1984). These processes are still continuining and an active foreland fold-and-thrust belt has formed along the southern margin of the Himalayas. This foreland fold-and-thrust belt consist of the deformed and metamorphosed rocks of the northern margin of Indian plate and largely comprise of Precambrian elements (Gansser, 1964; Le Fort, 1975; Valdiya, 1984; Ahmad and Alam, 1978).

The tectonic style of the Hazara foreland fold-and-thrust belt is controlled by three structural elements i.e Main Mantle thrust lying towards north, Hazara-Kashmir syntaxis towards north-east and Main Boundary thrust located towards south (Fig.1).

Along the Main Mantle Thrust the Kohistan island arc sequence over-rides the northern edge of the Indian plate which

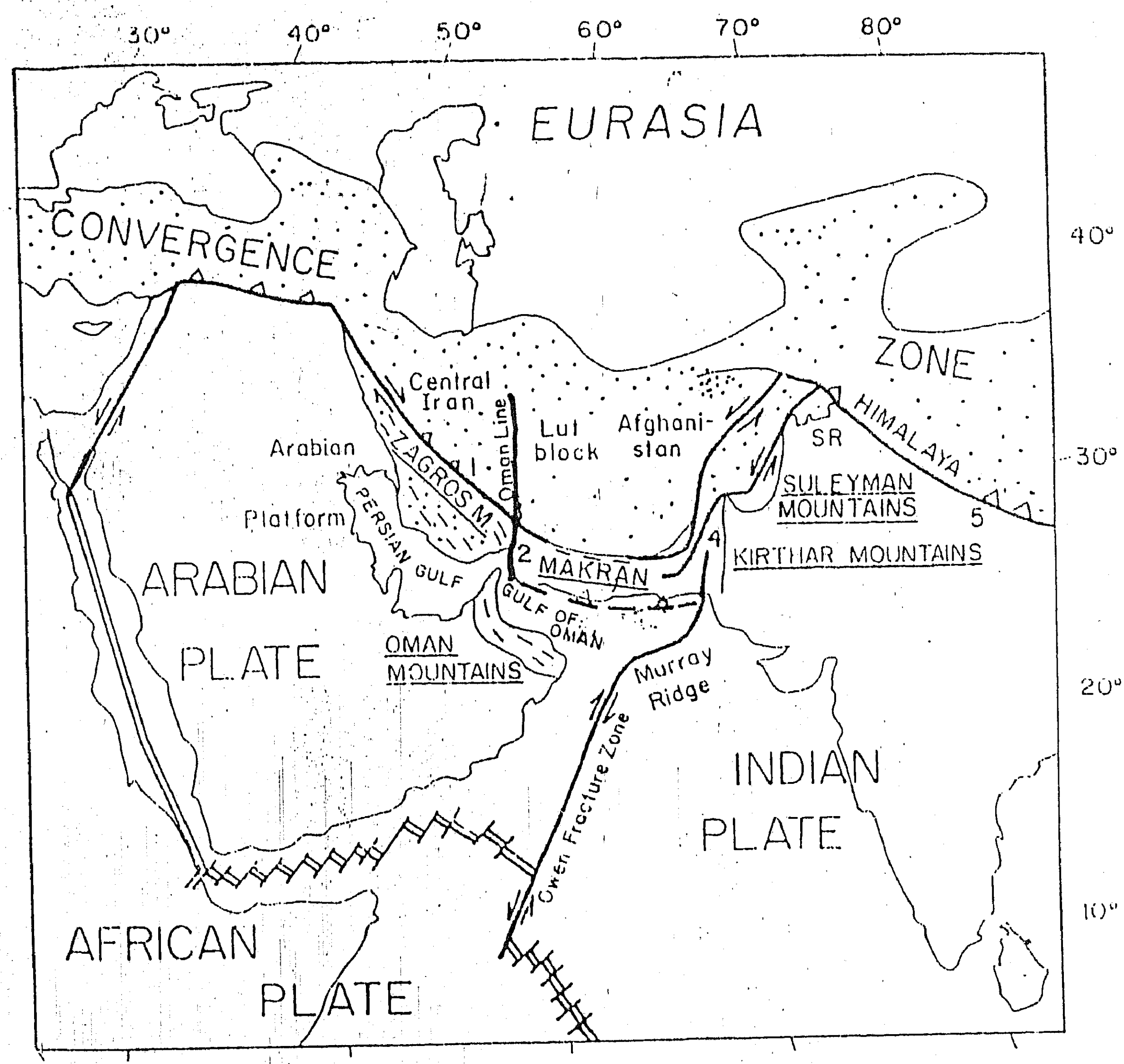

Fig. 10. Plate tectonic setting of Pakistan (after Jacob and Quittmeyer, 1979)

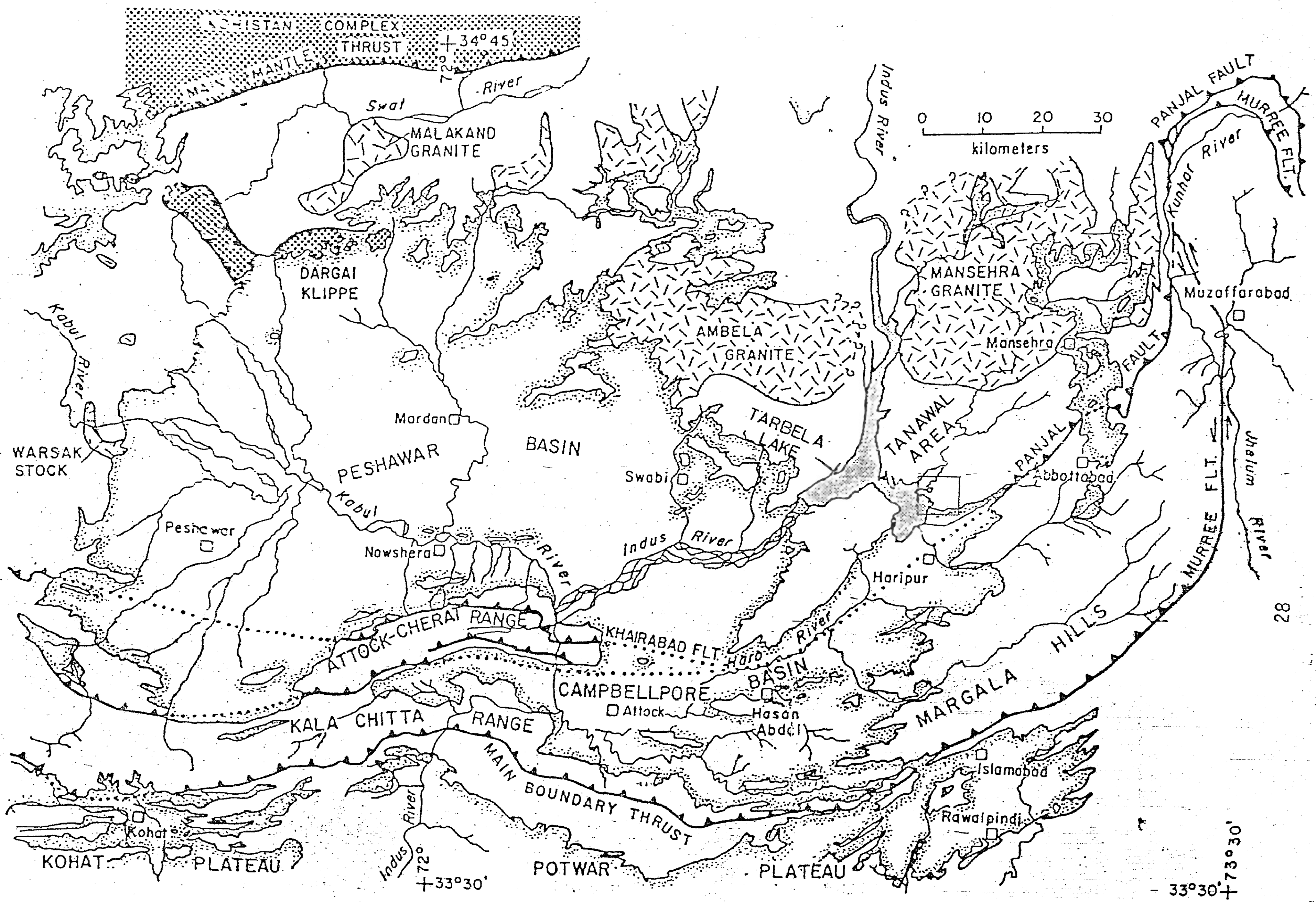

Fig.11. Map of Peshawar basin and adjacent areas.Area enclosed in box is shown on plate 1.(After Yeats & Hussain,1987)

consist of Precambrian pelites intruded by Cambrian granites (Le Fort *et al.*, 1980). The suture is highly deformed and in places it is a zone of south directed thrust systems with associated melanges (Lawrence and Kazmi, 1984). In Hazara the southern boundary of this zone of intense deformation can be extended upto Oghi shear zone (Coward *et al.*, 1986) (Fig.5)

In the Tanawal area Precambrian rocks are thrust over the Paleozoic sequence of Abbottabad area along the Panjal fault (Fig.2). Further south the same rocks are thrust over the Murree Formation (Eocence and Miocene molasse sediments) along the Main Boundary thrust.

In Hazara and western Kashmir, the structral trends are greatly influenced by the deformation patterns associated with the Hazara-Kashmir syntaxis. The northwetern Himalayas runs in a gentle curve across northern India and Kashmir and the geologic structures abruptly turn back upon themselves in Kashmir and Hazara area forming a tight loop which penetrates deep in the Himalayan range. Wadia (1931) for the first time reported this inflextion in the geologic strike and named it "The Syntaxis of northwest Himalaya". He mapped two, nearly parallel and persistant thrust faults wrapping all around the syntaxis (Fig.1). The outer one which he called Panjal fault considered to be the basal sliding plane of a large nappe "The Kashmir nappe". Along this fault the Precambrian rocks of the Lesser Himalayas are thrust to the south over the Carboniferous-Eocene systems of

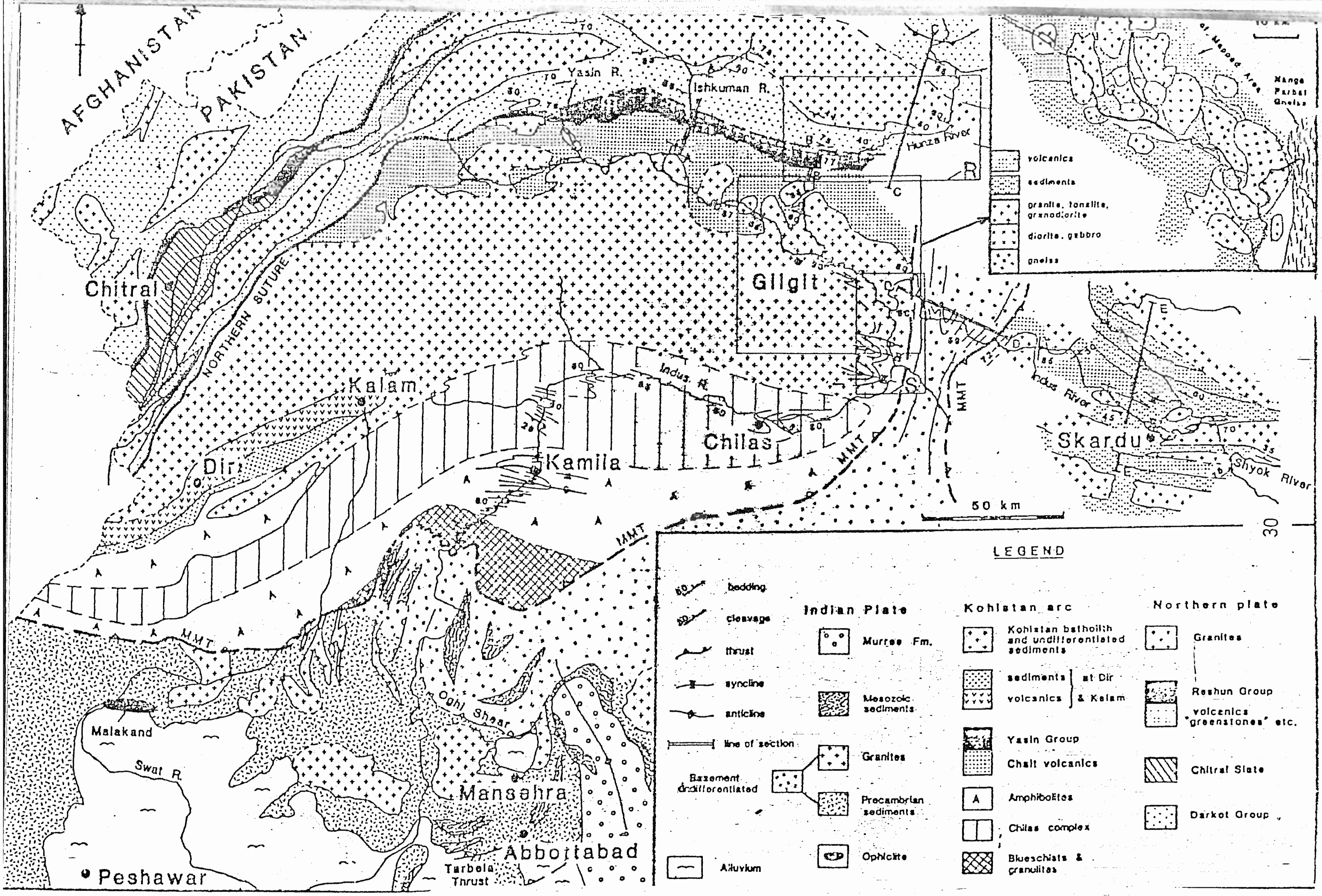

Fig.12. Lithological and structural map of northern Pakistan.(After Coward & others,1986)

Hazara and Kashmir. The inner one, Murree fault, along which the carboniferous to Eocene systems are thrust over the Eocene-Miocene molasse of Murree Formation.

The axis of the syntaxis is oriented slightly west of north and have severely deformed the rocks of the Hazara area. The Murree molasse in the syntaxis is itself folded indicating a southward propagatin. The two main boundary faults loop around the syntaxis and along the western flank, north of Balakot, they join each other. South of Balakot they again separate, the Panjal fault follows a southwestward direction towards the Haripur plain and separate the Tanawal area rocks from that of Abbottabad (Fig.1). The Murree fault (Main Boundary thrust) from Balakot follows a southward direction and runs all along Margalla hills. Latter it turns west towards Kalachitta range and can be traced upto Kohat area.

Along the Main Boundary thrust, thrusting of the folded and imbricated Cambrian-Eocene sequence over the Eocene-Miocene molasse sediments, suggests the collision and uplift by end Eocene times (Coward et al., 1986).

STRUCTURAL GEOMETRY

The deformation features of the area are characteristics of the foreland fold-and-thrust belt of northern Pakistan. This belt has developed during the main tectonic events of the Himalayan orogeny. All the major faults in the study area and north of it are dipping north. The majority of folds have developed along east-west axes and verge southward. These features indicate a southward tectonic transport which is typical of the foreland fold-and-thrust belt of the Himalayas.

Folds

Calkins *et al* (1975) was the first to map the southern Tanawal area in detail. He mentioned numerous east-west trending large scale, gentle to open, symmetric and asymmetric folds which gently plunge north-east.Two distinct style of folding have been recognised in the study area i.e. Large scale asymmetric folds and overturned folds. The Tanawal and Sherwan Formations are folded into a subparallel system of overturned anticlines and synclines and open asymmetric synclines.

Overturned Folds

The overturning in the folds is best represented where only Tanawal Formation is exposed or where the upper dolomite member of the Sherwan Formation has been removed by erosion. The only place where dolomite beds are overturned is near the village upper Nilor, along the north-western flank of the largest syncline in the area (Plate 1).

The Tanawal quartzites, south of village Soha are folded into a series of nonplunging overturned anticlines and synclines trending north-east and east-north-east. These folds are overturned towards south-east which is in conformity with the general tectonic behaviour of the area. Further south-east near village Gurakki, between the two major synclines of the area, the quartzite member of Sherwan Formation is tightly overturned towards south-east and marks the termination of the only thrust fault of the area (Plate1). The axis of this anticline is parallel to that of other overturned folds in the north-west. Further south, the whole Sherwan and the underlying Tanawal Formation is folded into a major overturned syncline verging south. The fold runs parallel to the other folds and its axis plunges shallowely (about 10) in the north-eastern direction.

East of village Chanjaliala, there is an overturned anticline in the Tanawal Formation. This fold is bounded by thrust fault in the south-east and a back thrust towards north-west. The trend of the hinge of this anticline is east-west to north-east.

<u>Other Folds</u>

The mapped area is characterised by three major synclines. The two northern synclines are nearly of equal wavelength and are comparatively smaller than the third (southern) one. There is a distinct structural discontinuity between these folds and the southern syncline (Plate 1). This discontinuity is a thrust along which the rocks exposed towards north-west of the area are pushed southward.

The two northern synclines are produced by the folding of both the Tanawal and Sherwan Formations. Both of these are nearly equal in size. These are open, asymmetric and non plunging. The troughs of the two synclines trend north-east.

The largest syncline of the region lies at the south-eastern edge of the mapped area (PLate 1). It is open and asymmetric near its nose i.e at its south-west part, but towards north-east it generally gets overturned. A very interesting phenomenon is observed during the traverse from the nose towards north-east along the northern limb of this syncline i.e the gently dipping beds get steeper. Dips ranging from 45 to 60 south-east are common in the western part. At the middle of the syncline vertical bedding is common and in the extreme east, the beds dip steeply but distinctly towards north-west. The axis of the syncline trends N50°E and plunges shallowely towards north-east.

Small scale foldss associated with large folds

Small scale overturned and other folds are common on the limbs of lagre folds, specially in thin bedded dolomite. They range in amplitude from 30-60 centimeters. The trend of these smaller folds and their geometry is remarkably similar to that of the large folds.

Faults

The major faults of the mapped area are thrust and reverse faults. Few minor faults indicated by offset beds have also been mapped.

Major faults

Three major faults have been identified in the area. Two of these are north - west dipping and the third one is south-east dipping back thrust (PLate 1). Following is a brief description of the major faults.

Thrust fault

This fault is the most prominent structure of the area. It appears on the surface at the eastern side of Darwaza village where it follows a north-eastern direction and finally merges into an overturned anticline near village Gurakki. The fault strikes north-east and dip north-west at moderate angle. Along this fault the Precambrian Tanawal Formation is thrust over the Cambrian Sherwan Formation.

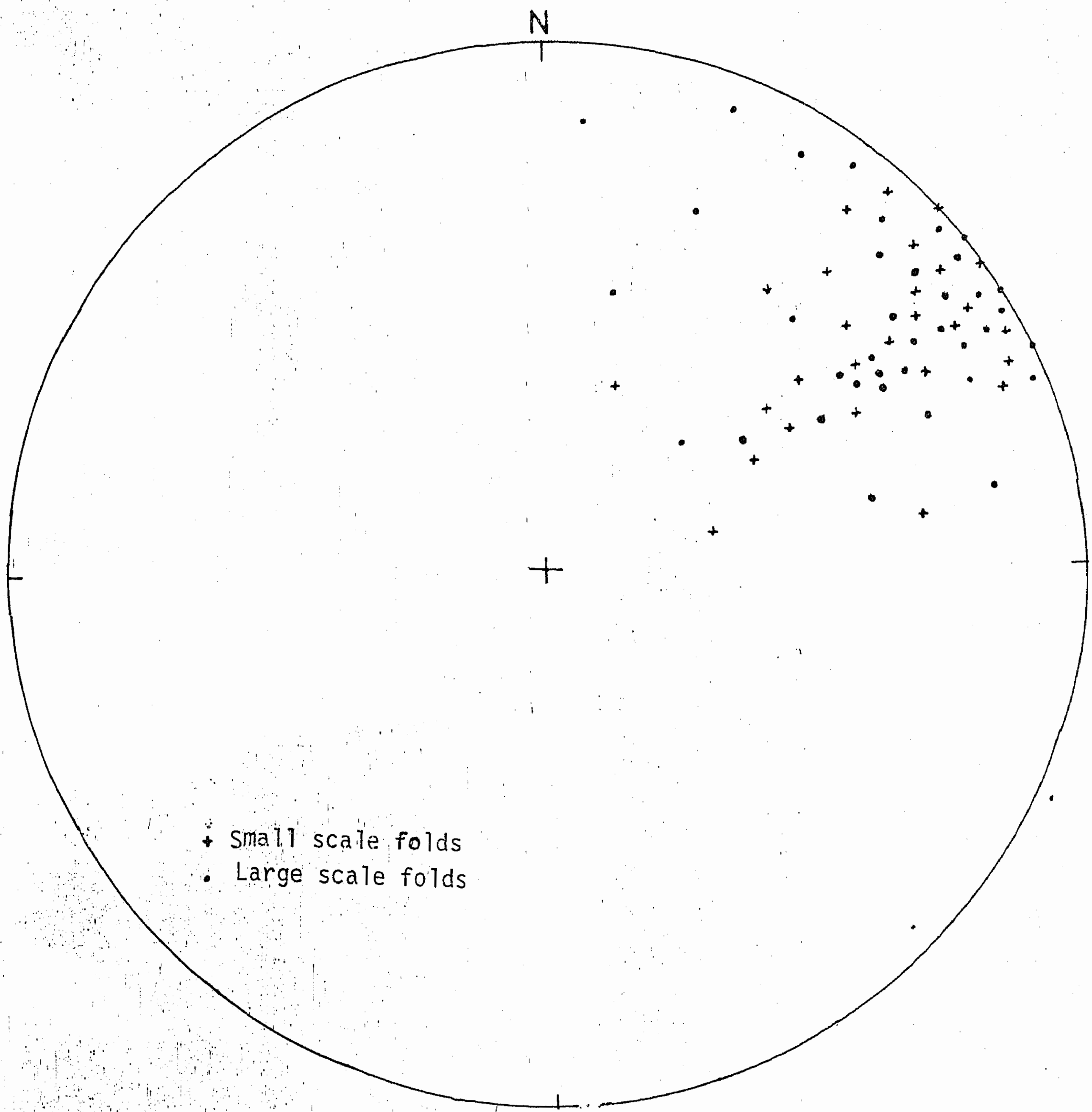

Fig.13. An equal area plot showing the orientation of fold axes of small and large scale folds.

Back Thrust

It is located on the western side of Darwaza village. It strikes north-south and dip east at modeate angle. Along this fault the overturned Tanawal quartzite is pushed northward over the Sherwan Formation. The overturned Tanawal quartzite looks like a pop-up structure in between two opposite dipping faults. This fault is of local extent.

Reverse fault

This fault is located west of Chanjaliala village. It strikes east-west and dips toward north with high angle. Since the fault is located within quartzite member of the Sherwan Formation, no offsetting is visible. However, the effect of faulting can be seen in the enormous thickness of quartzite exposed south of village Chanjaliala. This quartzite is exposed on the two limbs of the adjacent syncline. Although the dips of the northern limb of this syncline are steeper, the difference between the outcrop thickness of the two limbs is far much to be explained without a fault (Plate 1).

Minor faults

Two minor faults are mapped in the area including a reverse and normal fault.

The reverse faults is located south of village Kachhi along the north-western edge of the adjacent syncline (Plate 1).

It brings the quartzite member of the Sherwan Formation over the dolomite member of he same Formation.

A minor normal fault is mapped north of vilage Aluli along the main stream. Along this fault the dolomite member of the Sherwan Formation is in contact with the quartzite member of the same Formation (PLate 1). Its trend is north-south and its east side is up.

SYNTHESIS OF STRUCTURAL GEOMETRY

The study area is located in the foreland fold - and - thrust belt of Hazara Himalayas (Fig. 10). In the following pages the inferences drawn by the organization and synthesis of field data are given. The interpretation of stresses responsible for producing the deformational pattern of the area has been done.

The rock formations of the area strike north-east and dip towards northwest (Plate 1). The axes of the major folds are parallel to regional strike. The overturned fold have consistant southward vergence . A major thrust traced in the area runs northeast - southwest and dips northwest. North of Darwaza village a local back thrust is mapped (Plate 1). It strikes north- north-east and dips towards southeast at moderate angle. The attitude data on major and minor fault planes is plotted on equal area net and proccessed to find the precise orientation of stresses operating in the area at the time of their formation (Fig.14).

The direction of compressional stresses is oriented N45°W and is horizantal. The southward directed asymmetry of the structures indicate a south-eastward directed tectonic transport of the region. The above mentioned pattern and symmetry of the structures matches with characteristic deformational style of the foreland fold-and-thrust belt of Himalayas.

The mapped area is located along the southern margin of Tanawal zone, which comprises the hanging wall rock sequences of

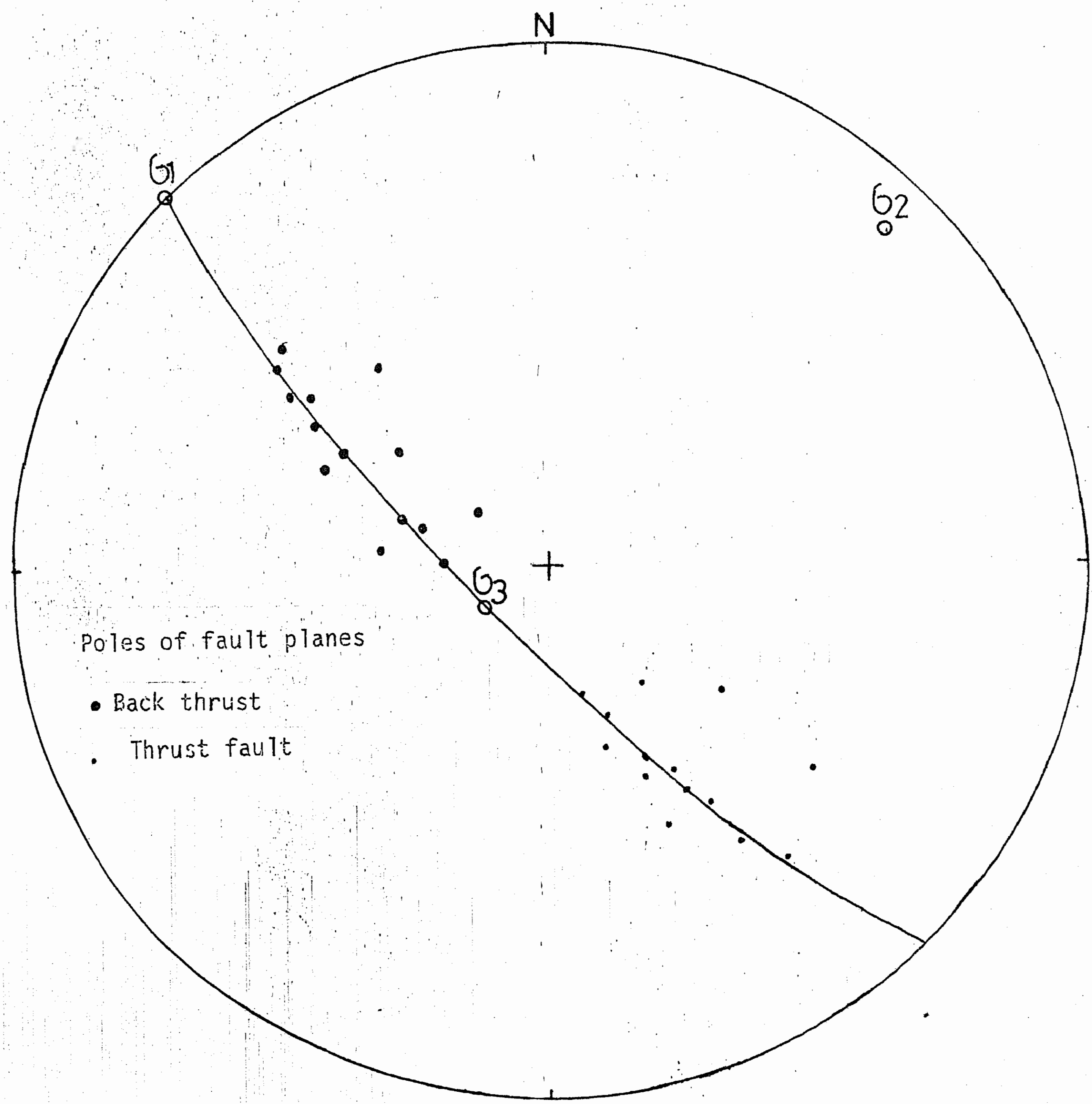

Fig14. An equal area plot showing the poles of the major faults and orientation of stress axes.

the Panjal fault (Fig. 1). Along the Panjal fault the Tanawal zone is pushed south-eastward over the Abbottabad zone. The surface traces of Panjal fault is not exposed in the study area. It is burried beneath the Haripur plain towards south-east but the effects of this major structure can be felt and seen in the major part of the region. The relationship of the deformation of the study area and the Panjal fault is largely based on the observations made by the previous workers (Calkins *et al*; 1975, B.Fuch; 1975, Hylland *et al*; In press).

Calkins *et al* (1975) considered that the basal sequence of rocks exposed on both sides of the Panjal fault was similar and was mapped as Hazara Formation. However, during recent investigations (Hylland *et al* ; In press) it is found that the two sequences differ greatly in the lithology and degree of metamorphism. The squences in the footwall of the Panjal fault in the vicinity of Hasan Abdal and Haripur is arenaceous and shows no degree of metamorphism. The hanging wall rocks of this fault observed in the Gandghar range are argillaceous and display greenschist metamorphism. The basal sequence of Haripur and Hasan Abdal area is similar to the Dakhner Formation of the Attock-Cherat range which is correlative with the Hazara Formation (Yeats & Hussain; 1987). The argillaceous sequence of the Gandghar range is similar to the Manki Formation of Attock-Cherat range.

The deformational history of the area is closely associated with the evolution and developement of Panjal fault

(Fig.1). This block of the fault has greatly deformed the rock sequences present in it. A structural model showing the sequence of events that occured during the movements on the Panjal fault is shown in figure 15 a,b, & c.

The structural style of the southern Tanawal area has devloped during the Himalayan orogeny . As the deformation proceeded south of the Main Mantle Thrust a basal shearing plane developed beneath the Tanawal area.The Panjal fault is the result of a major ramp in the basal decollomemt exposed south-east of the study area (Fig.16 & 17).This fault brings argillaceous facies (Manki Formation) over arenaceous facies (Dakhner Formation)in the vicinity of Hasan Abdal(Hylland *et al*;In press).The Panjal fault is not studied in the mapped area.

The basal shearing plane is assumed to be located at or near the base of argillaceous facies.It is suggested that first the movements occured along the basal shearing plane beneath the Tanawal area,which got exposed south of it and later due to the continuous movements along the Panjal fault the Tanawal area was deformed.The mapped structures in the study area shows that the Panjal fault exhibit ramp and flat geometry beneath it (Fig.17).

The only thrust fault mapped in the study area is believed to be a ramp segment from the basal shearing plane.This ramp segment cut up-section the competent quartzite of the Tanawal Formation and brings these older rocks over the younger Sherwan Formation (Fig.17).Furthermore, it is suggested that this

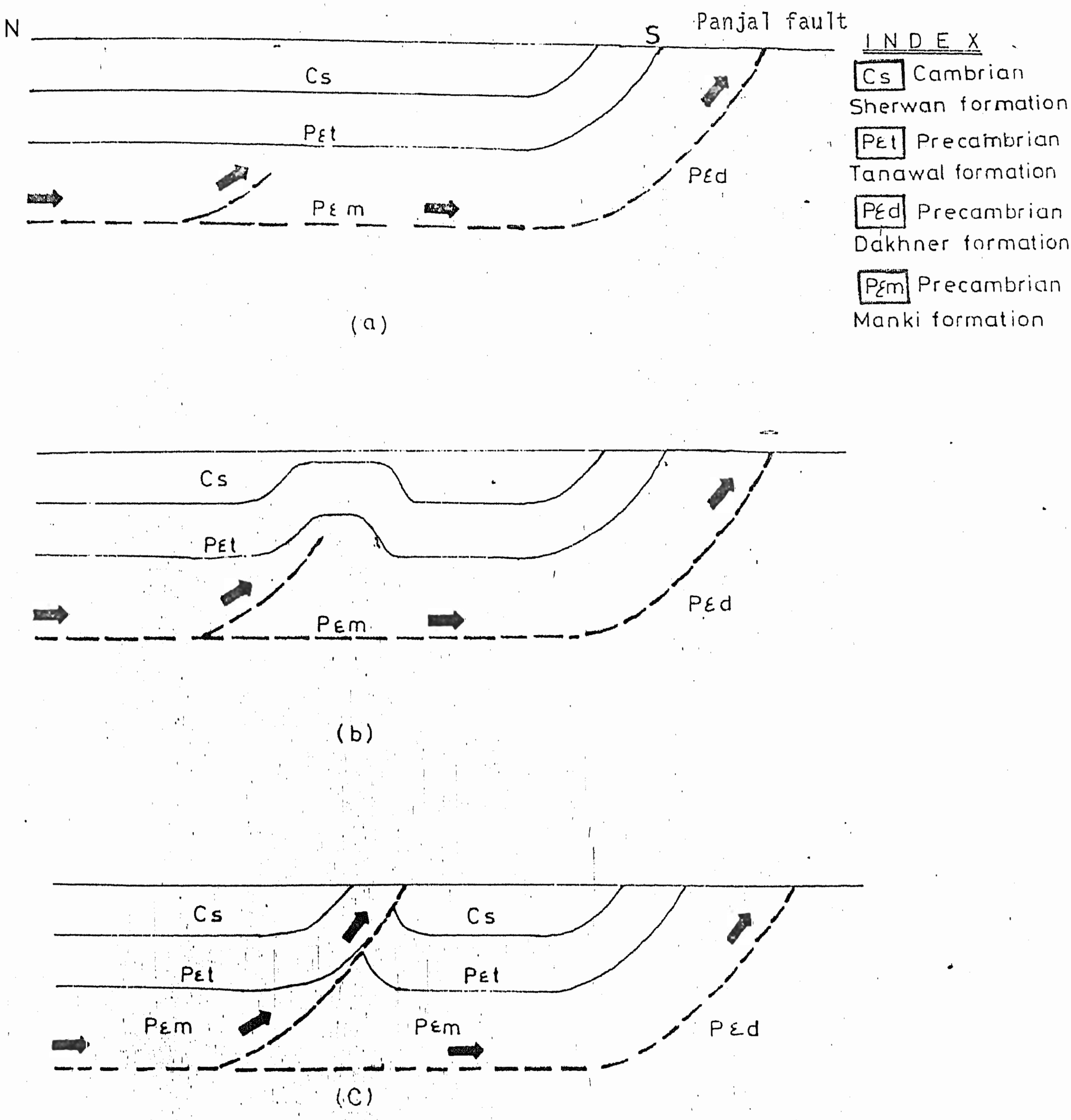

Fig.15. Proposed structural model showing the sequential development of various a.b & c) surface structures in relation with the Panjal fault.

ramp segment has developed later in the hanging wall of the Panjal fault. Had this ramp segment produced earlier than the Panjal fault it might have brought the argillaceous facies (Manki Formation) to the surface. This ramp therefore developed later and was responsible for release of the severe strain condition caused by the continuous movements on the Panjal fault.

The large scale folds mapped in the area are in conformity with the above mentioned ramp and flat geometry (Fig.16 & 17).The major anticline is located above the ramp segment whereas the synclines are located above the flat segments and all these folds were developed as a result of this subsidiary fault that detached from the basal shearing plane(Fig.15 a,b&c).

The timing of uplift along the Panjal fault is uncertain. The overturned folds in the area are south vergent,which would be expected if a south-east directed thrusting had occured along the Panjal fault.

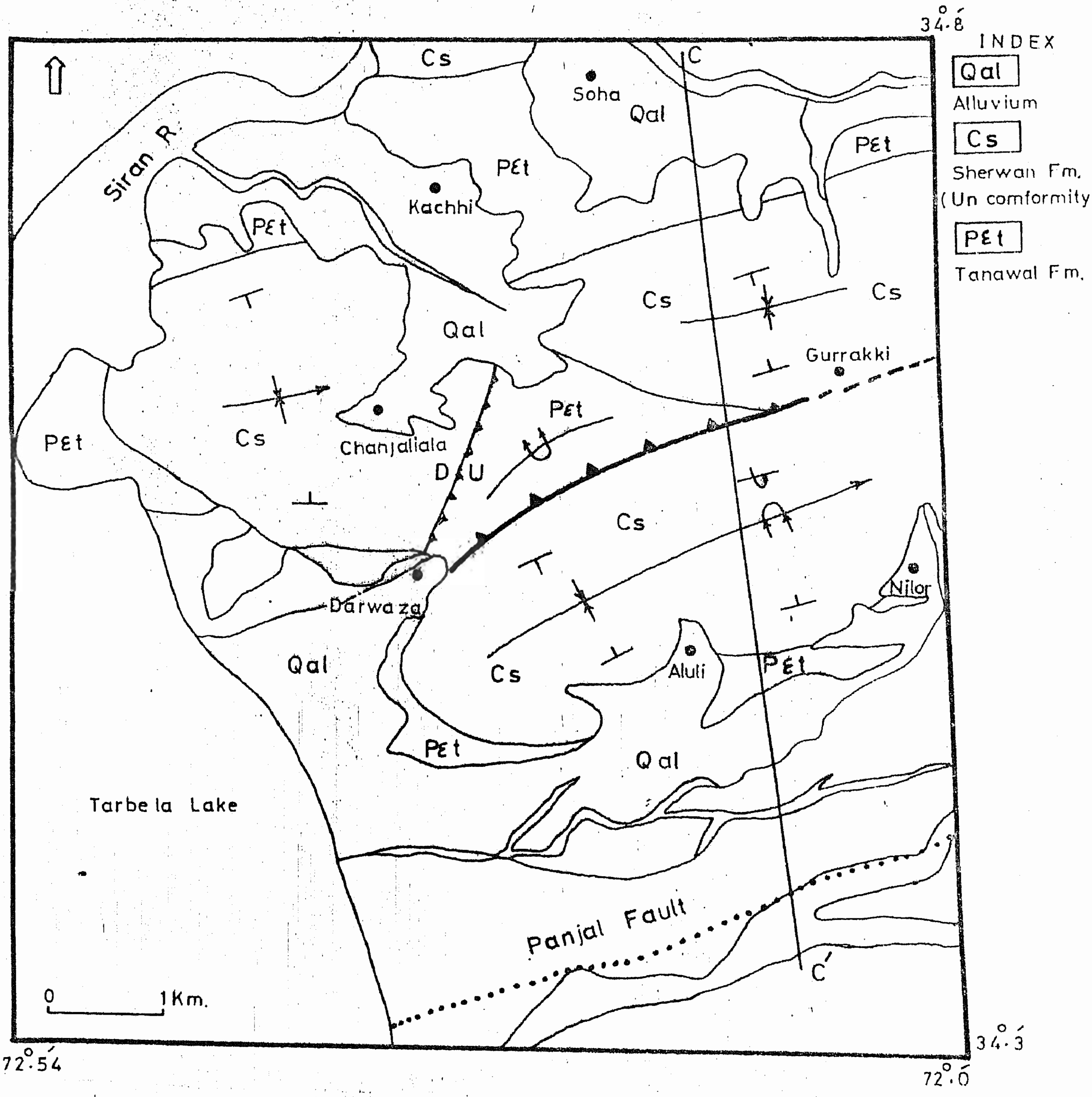

Fig.16. Sketch map of the southern Tanawal area, north of Haripur. C C′ is the cross-section line.

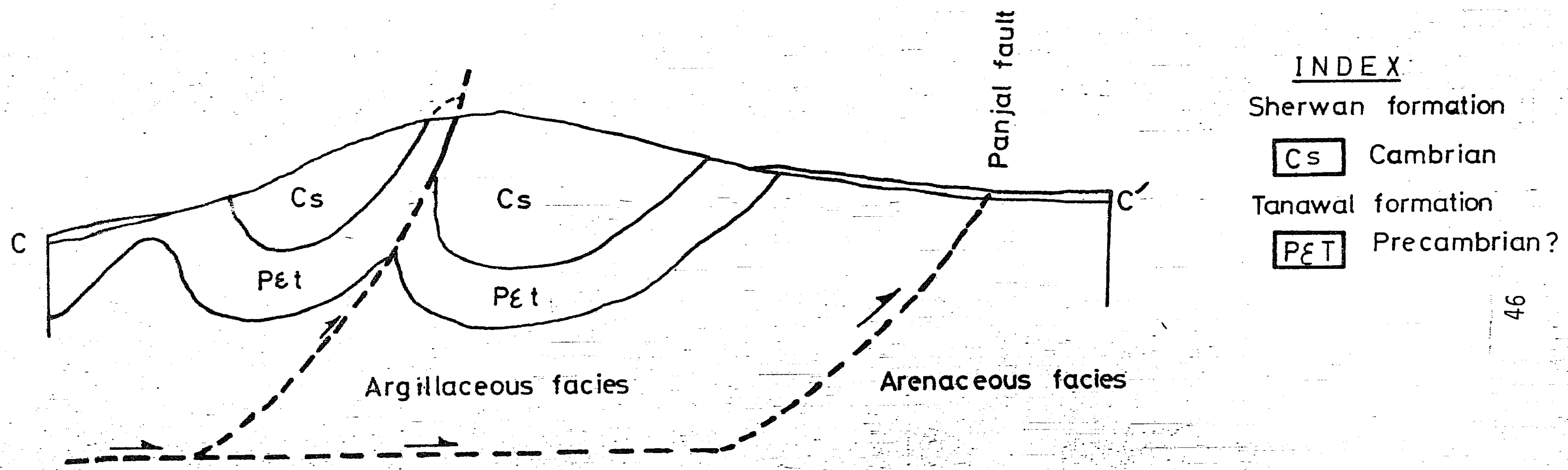

Fig. 17. Cross-sectional sketch along line CC' of figure 16.

CONCLUSIONS

On the basis of present work , the following main conclusions are drawn concerning the stratigraphy and structure of the area.

It is generally believed that the dolomite - quartzite sequence (Sherwan Formation) of Tanawal area can be correlated with the dolomite sequence (Abbottabad Formation) exposed in Abbottabad area. The present work shows that the rock sequences of southern Hazara can be divided into two tectono-stratigraphic zones i.e Tanawal zone and Abbottabad zones ; the former is thrust over the later along Panjal fault. Thus the Tanawal zone which comprises the hanging wall of the fault is entirely different from the Abbottabad zone.

The rock sequences of Tanawal zone are correlative with the stratigraphic order established recently by Pogue (1989) in Rustam-Swabi area.

A distinct south-eastward vergence of the structures of the area is observed which is in conformity with the regional structural style of the Hazara Himalaya.

Panjal fault which runs south of the area has a great structural control over this part of Hazara. Thus the deformational pattern of the area i.e folds axes, fault traces and vergence directions are in direct conformity with this major structure of the region.

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