STRUCTURE AND STRATIGRAPHY OF THE NORTHERN GANDGHAR RANGE, HAZARA DISTRICT, PAKISTAN.

M.PHIL. THESIS

by

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ABSTRACT

The structure of the northern Gandghar Range is shown to be controlled by the folding and faulting processes. Folding and faulting has apparently exaggerated the true thicknesses of the strata. The majority of folds (F_2) are southeast vergent indicating a southeast-directed thrusting. The other group of folds (F_1) is oriented perpendicular to the F_2 folds, and indicate a compression direction from the NE, distinctly different from those of the F_2 folds which is from the NW. The thrusting system developed in the northern Gandghar Range locally defines a small schuppen or imbricate zone.

The stratigraphic status and ages of all the rocks of the northern Gandghar Range have been revised. This study indicated that all the rocks of the northern Gandghar Range are of the Proterozoic or early Paleozoic age.

CHAPTER-1
INTRODUCTION

The NE-SW trending Gandghar Range is located in the Hazara district some 40 km northwest of Islamabad, forming a partial barrier between the Haripur and Peshawar basins (Figs.1 & 2). The range is the southwestern extension of the rocks of Hazara district. The Campbellpur basin is stretched on its south whereas the western boundary is marked by the alluvium of the Peshawar basin. To the north lies the Tanawal territory, exposing dominantly the Tanawal Formation which is intruded by the Mansehra granite of Cambrian age. The Margala and Khanpur Hills are located to the southeast and east respectively.

The Gandghar Range, Attock-Cherat Range, Margala Hills and Kalachitta Range are collectively termed the Hill Ranges separated from each other by alluvial plains (Fig.2). The rocks of the northern Hill Ranges, i.e. the Gandghar Range and Attock-Cherat Range are transitional between the high grade metamorphic and plutonic rocks in the north and unmetamorphosed foreland basin strata to the south. Rocks of the Hill Ranges are brought to the surface along major ramps branching from a single detachment surface (Yeats and Lawrence,1984). The Gandghar Range was probably uplifted along the Panjal fault (Fig.2). The Panjal fault was originally recognized by Wadia (1957) in the area constituting the Hazara-Kashmir syntaxis. He considered it to be the basal sliding plane of a large nappe, called the Kashmir nappe. Later, Calkins *et al.*,(1975) mapped the same fault to the west of the syntaxis, and have shown that the fault is a combination of reverse-slip and strike-slip motions, with dip angles from 59°E or W to vertical. They also showed that northwest of Haripur it cuts through the eastern front of the Gandghar Range. Hylland *et al.*,(in prep.) argue that southwest of Abbottabad the Panjal fault is buried beneath the alluvium of the Campbellpur and Haripur basins and is not cutting through the eastern Gandghar Range.

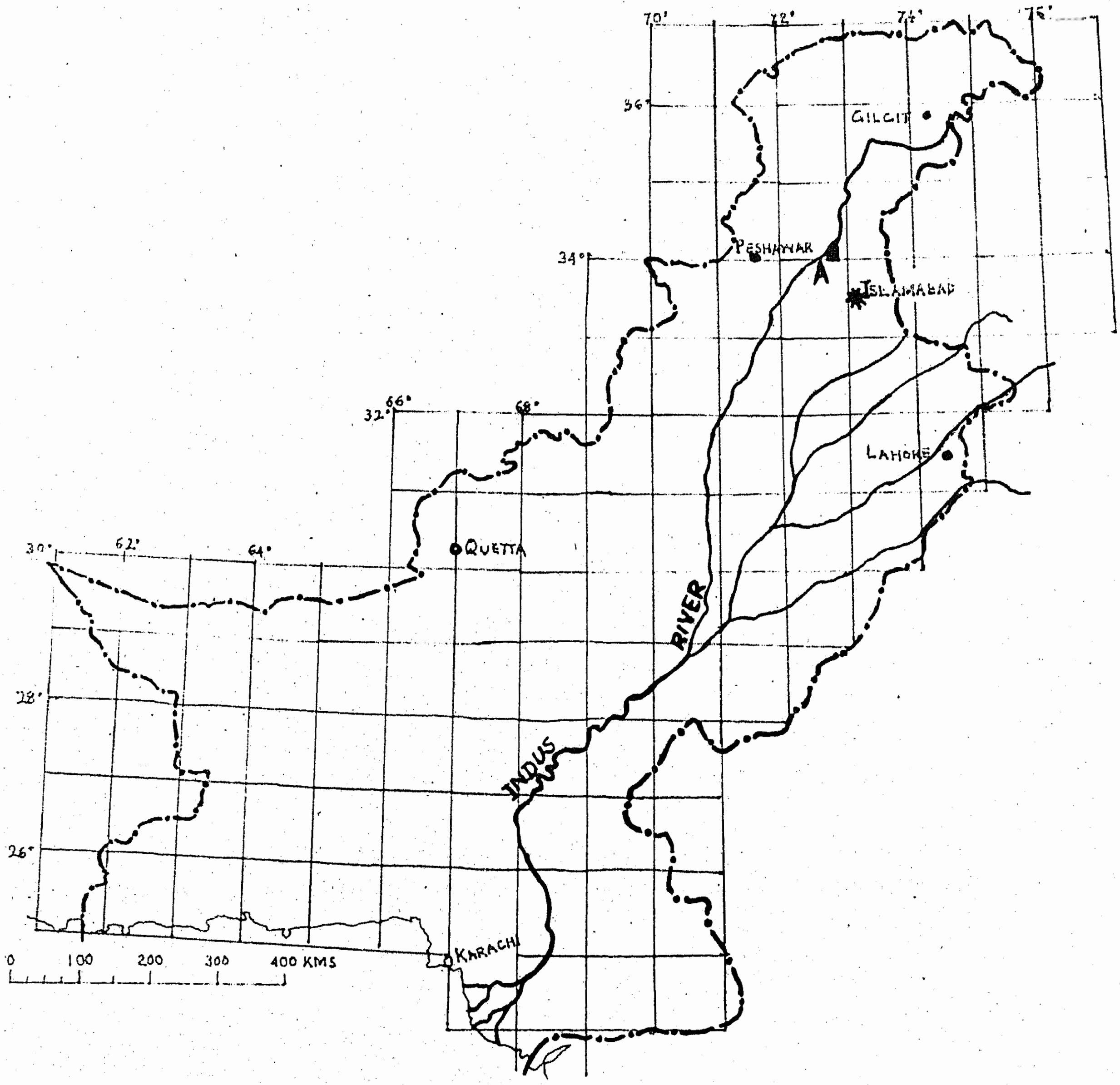


Figure 1. Index map of Pakistan showing the location (A) of the study area.

REGIONAL GEOLOGY

The collision of Indian and Eurasian plates had shortened the crust, which was accommodated by the development of an extensive southward directed thrust system and associated folding (Coward *et al.*,1982; Yeats and Lawrence,1984; Coward and Butler,1985; Coward *et al.*,1988; Bossart *et al.*, 1988; Greco *et al.*,1989). These thrusts include; the Main Karakoram Thrust (MKT), the Main Mantle Thrust (MMT), the Main Boundary Thrust (MBT) and the Salt Range Thrust (SRT).

The MKT separates the rocks of the Asian landmass from the Kohistan island arc complex. The Asian landmass is composed of gneisses, slates, marbles and quartzites that range in age from late Paleozoic to early Tertiary (Tahirkheli,1979). The Kohistan island arc is a mass of dominantly amphibolites followed by diorites, metanorites (pyroxene granulites) and associated volcanic rocks (Tahirkheli,1979).

The Kohistan island arc is separated from the Indian plate by the MMT. The Indian landmass displays the entire succession of a geological column, which is disrupted at various intervals by thrust faults, e.g. the Panjal Fault, the MBT and the SRT.

The MBT separates the pre-collisional Paleozoic and Mesozoic sedimentary rocks of the Indian plate from the younger post-collisional Himalayan mollase sediments.

Seebers *et al.*,(1981) have shown that the rocks to the south of MMT are underlain by a single "detachment surface" which extends beneath the entire Potwar plateau and emerge south of the Salt Range as Salt Range Thrust (SRT). The SRT brings the entire Salt Range sequence over the late Quaternary deposits (Yeats *et al.*,1984).

The Panjal fault juxtaposes the rocks of Precambrian and Cambrian age to Carboniferous age (Wadia,1957; Latif,1970; Calkins *et al.*,1975) and marks the western limit of the Hazara-Kashmir syntaxis.

The Gandghar Range is located north of the Panjal fault (Fig.2) and was probably uplifted along this fault delimiting the southern extension of the "internal" zone (Coward *et al.*,1988). The transition of the Himalayan hinterland rocks to the foreland

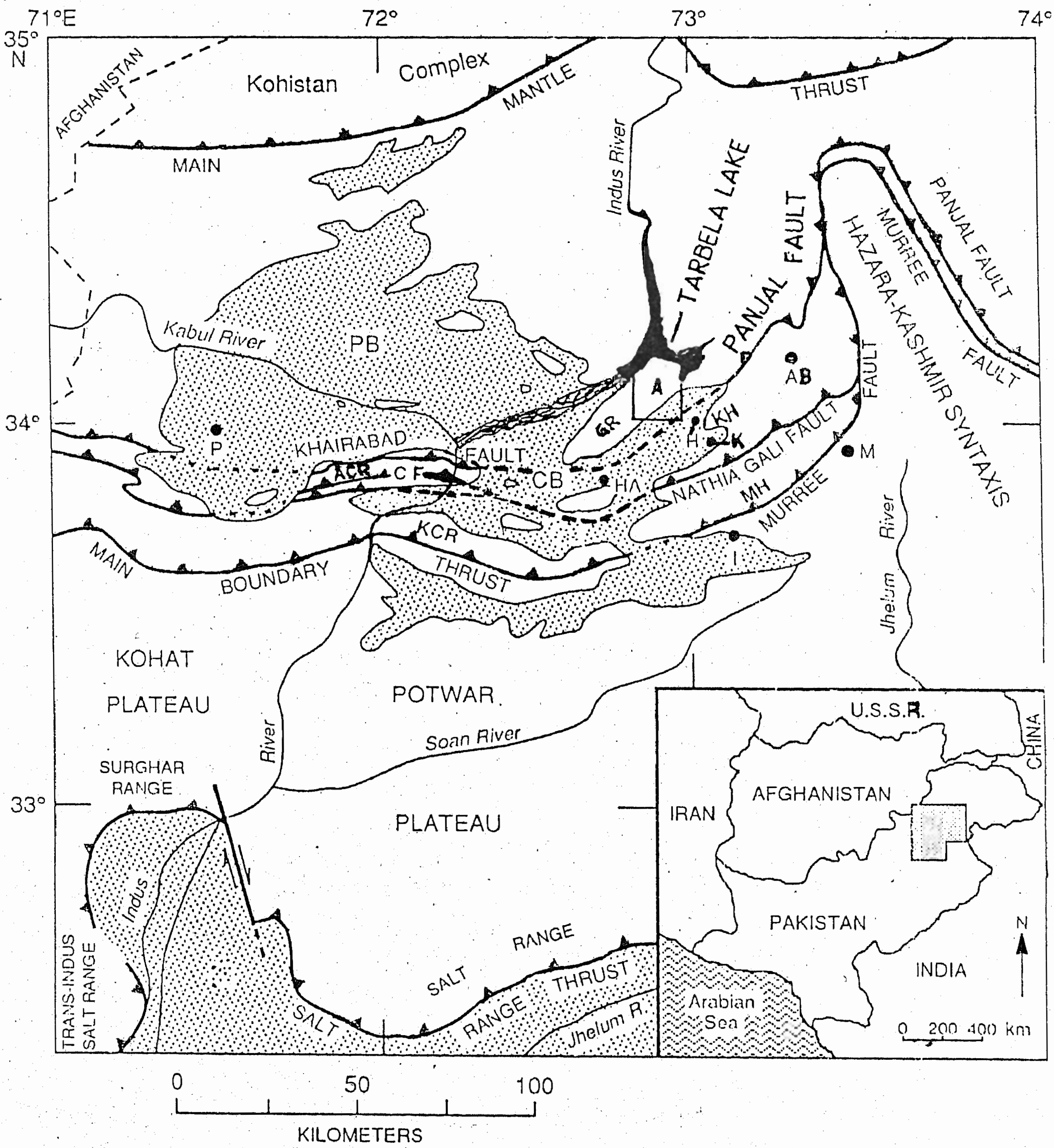


Figure 2. Tectonic map of N.Pakistan, showing major structural boundaries: P=Peshawar; PB=Peshawar basin; AB=Abbottabad; M=Murree; I=Islamabad; H=Haripur; HA=Hasanabdal; CB=Campbellpur basin; K=Khanpur; ACR=Attock-Cherat Range; KCR=Kalachitta Range; KH=Khanpur Hills; CF=Cherat fault; GR=Gandghar Range; MH=Margala Hills. Area in rectangle A shown in Figure 4.

strata is marked by the rocks of the Hill Ranges. The Gandghar Range is the northern most of the Hill Ranges, and in the west it is laterally continuous with the northern block of the Attock-Cherat Range (Yeats and Hussain,1987). The range is therefore, very important in studies involving the Himalayan hinterland-foreland relationship as its structural and stratigraphic features will help to understand the transition in a much better way.

PREVIOUS WORK

The earliest published work available on the geology of the Gandghar Range is that of Waagen and Wynne (1872), who described the geology of the Hazara area. Later, Wynne (1879) prepared a geological map of the Hazara area at scale of 1 inch = 8 miles, which contained three cross-sections through the Gandghar Range. Middlemiss (1896) ,also published a geological map of Hazara from Black Mountain on the west bank of Indus River eastward to the Kunhar River at a scale of 1/2 inch = 1 mile. Both Wynne and Middlemiss referred to various limestones in the Gandghar Range but could not ascertain their age and relative stratigraphic positions.

Cotter (1933) while working in the Kalachitta Range also visited the southern tip of the Gandghar Range and specially mentioned the Slate Series, which he correlated with the pelitic rocks of Attock. He assigned a Pennsylvanian, possibly Cambrian or Precambrian age to these slates. Khan *et al.*,(1949) described three lithological units in the Gandghar Range (a) the Hazara Slate Series (b) the Infra-Triassic limestones and (c) the Tanol Quartzites. Ali (1962) while working in southwestern Tanawal area, also mapped the extreme northern part of the Gandghar Range. In the geological map of Pakistan, Bakr and Jackson (1964) showed the Gandghar Range to have Precambrian rocks on its eastern side whereas the western half is consisting of Silurian-Devonian rocks.

The first detailed map of the entire Gandghar Range was published by Tahirkheli (1971). He considered all the rock units exposed in the Gandghar Range to be of Paleozoic age and correlated them with lithologically similar units in the Attock-Cherat Range and southern Hazara. Later, Calkins *et al.*, (1975) published a geological map of the northern Gandghar Range and described three rock units from the northern Gandghar Range (i) the Precambrian(?) to Ordovician(?) Hazara Formation, (ii) the Ordovician(?) to Devonian(?) Tanawal Formation and (iii) the Triassic Kingriali Formation. They have also shown the Panjal Fault passing through the eastern Gandghar Range, separating Hazara Formation to the west from the Kingriali Formation to the east.

RATIONALE

Though the work of Calkins *et al.*,(1975) sufficiently explained the geology of the northern Gandghar Range (Fig.3) but there were still some questions that remained unanswered. For example, what is the status of the Hazara Formation? What is the exact age of the Tanawal Formation? What is the nature of the contact between the Hazara and Tanawal Formations? Whether the status of the Kingriali Formation is justified here? How did the Gandghar Range deform? Can the various phases of deformation of Hazara be also established in the Gandghar Range? What is the significance of the Panjal fault in the deformation of the Gandghar Range?

The present study is an attempt to answer the above questions. The study was based on the work of Calkins *et al.*, (1975)(Fig.3).

ACCESSIBILITY

Calkins and his fellow workers had the advantage of the old Tarbela-Haripur road that ran along the northern end of the range. After the Tarbela dam was built the lake water rose to an altitude of about 500 meter, thus making the northern end more difficult to approach but the critical areas can be visited in a boat. The Ghazi-Sirikot-Haripur road exposes a thorough section through the middle of the area. Similarly all villages are interconnected either by unpaved roads or foot tracks.

Two very large streams cross-cut the southeastern part and expose very good sections. Elsewhere the continuous and

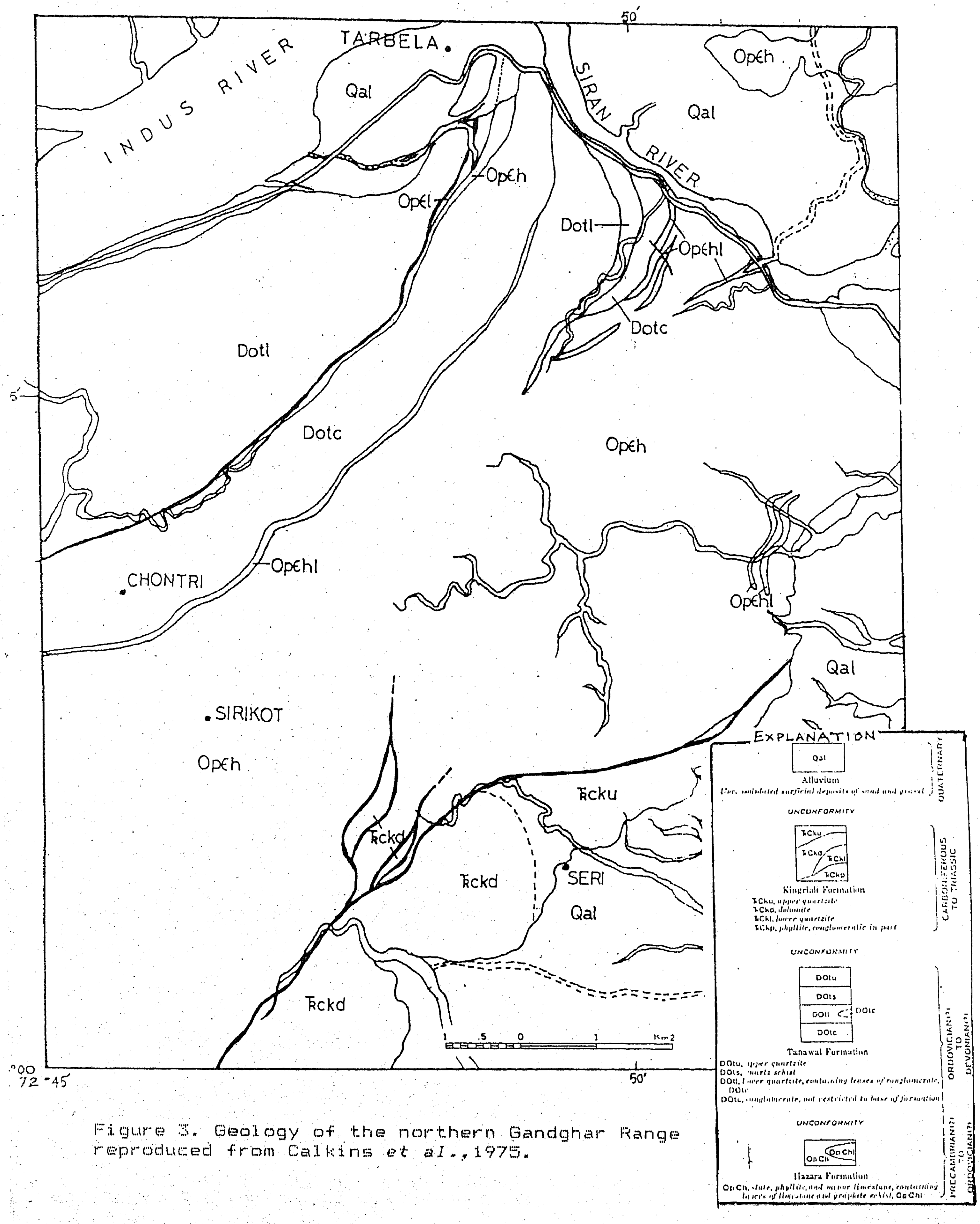


Figure 3. Geology of the northern Gandghar Range reproduced from Calkins *et al.*,1975.

excellently exposed rocks with little vegetation further facilitate the field work.

METHODOLOGY

The present work is restricted to the northern part of the Gandghar Range, between Lat. 34°N and 34°8 N and long. 72°45 E and 72°53 E. The total area covered is approximately 160 sq.km. The base map was part of the Survey of Pakistan quadrangle No. 43 B/16.

The Gandghar Range study was a part of an ongoing co-operative project between Oregon State University, University of Peshawar and the Geological Survey of Pakistan. For this reason the southern Gandghar Range was studied by M.D.Hylland, an M.S. student of the Oregon State University, and the northern part by the writer. The aim of the project was to determine the local and regional structural and stratigraphic relationships of the rocks comprising the northern Gandghar Range.

To answer the above mentioned questions the writer carried out the present investigations as follows:

* studied the lithological characters and contact relationships of the Hazara Formation (Manki Formation) in the Gandghar Range, in the area east of Haripur and in Abbottabad area.

* investigated the lower and upper contacts of the Tanawal Formation in its type area (Tanawal Territory) and in the northern Gandghar Range.

* Attention was particularly focused on the nature of the contacts between various lithologies during their mapping.

* The Kingriali Formation of Calkins *et al.*,(1975) was studied lithologically and stratigraphically in the northern Gandghar range and in the Sherwan area.

* The area was mapped on 1:50,000 scale, and all the major and most of the minor structures were also mapped.

* Orietations of small and large folds were recorded carefully and were later plotted on an equal area stereonet for the possible establishment of the various phases of deformation.

CHAPTER-2

STRATIGRAPHY

The northern Gandghar Range displays four stratigraphic successions (Fig.4). The basal sequence (Manki Formation) is mostly composed of slates and phyllites, which are successively overlain by two carbonate lithologies (Shahkot and Shekhai Formations) and an alternating sequence of quartzite and phyllite (Tanawal Formation). The entire succession is profusely intruded by basic igneous dikes of unknown age. The range is divisible into a western and an eastern block (Fig.5) separated by the Baghdarra fault. The eastern block shows an almost complete succession of the strata, whereas in the western block two limestone lithologies are missing (marked by an unconformity). The western block is imbricated (not shown on Fig.5) and all the imbricated slices have the same stratigraphy.

Tahirkheli (1971) described three lithologies from the Gandghar Range; the Mohat Nawan Limestone (Upper Ordovician to lower Silurian), the Sirikot Slate (lower to middle Silurian) and the Tarpakhi Quartzite (upper Silurian to Devonian) and correlated them with similar lithologies exposed in the Attock-Cherat Range. Later, Calkins *et al.*,(1975) mapped the Sirikot Slates as the Hazara Formation (Precambrian? to Ordovician?), the Tarpakhi Quartzite as the Tanawal Formation (Ordovician? to Devonian?) and the Mohat Nawan Limestone as the Kingriali Formation (Carboniferous to Triassic) and correlated them with rocks of the Khisor and Kalachitta Ranges.

As a result of present study the nomenclature and status of these rocks is revised, because of two reasons. Firstly, the stratigraphic positions of these lithologies and identical lithologies in the adjacent areas (Hazara & Attock-Cherat Range) with which they have been previously correlated (e.g. Tahirkheli, 1971), are exactly similar. Secondly, being the same lithologies with almost similar characters in all the three areas i.e. Gandghar Range, Attock-Cherat Range and southern Hazara, it is appropriate to use the same names in order to create regional consistency in nomenclature.

Hence it is suggested that the dominantly slate/phyllite

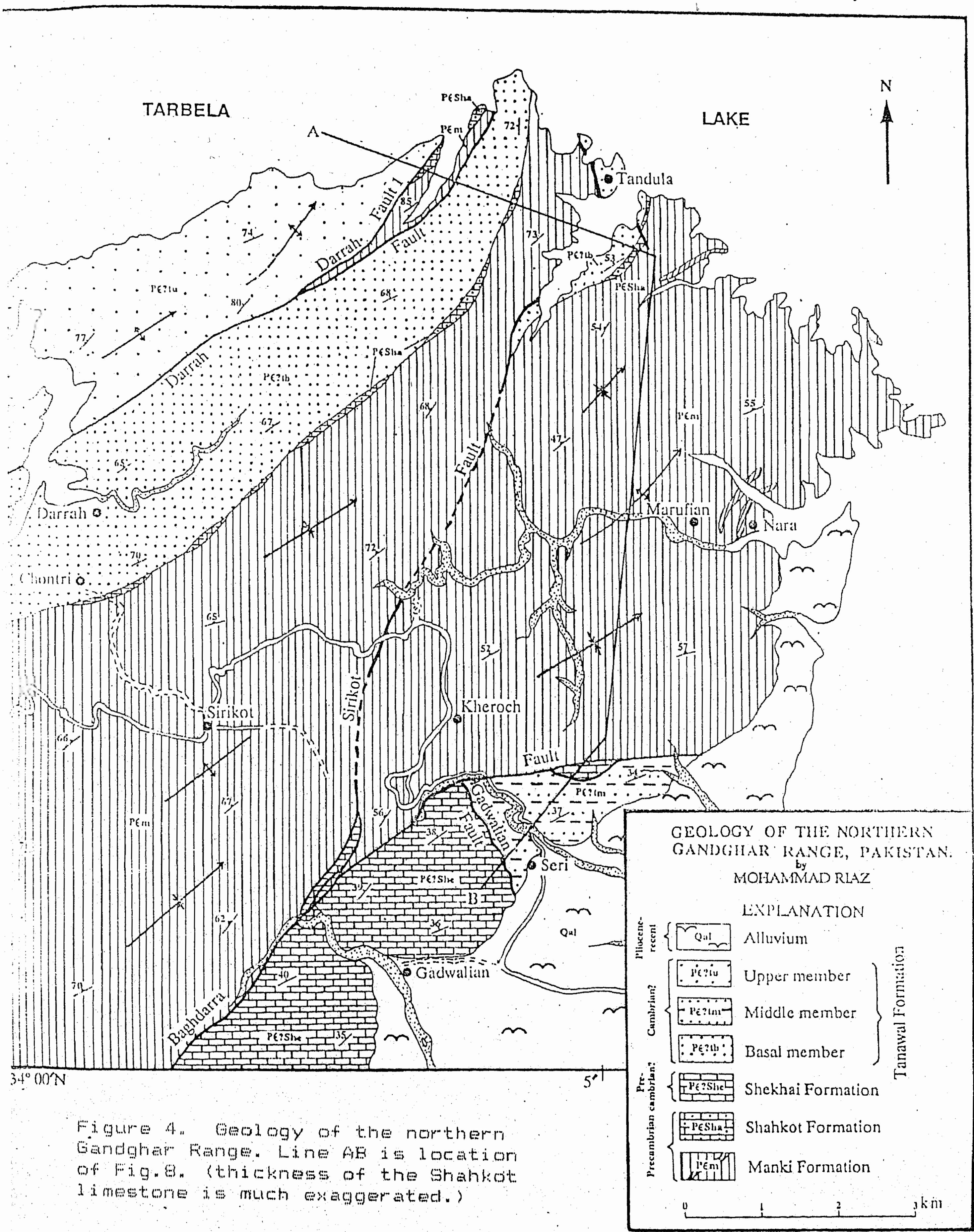


Figure 4. Geology of the northern Gandghar Range. Line AB is location of Fig.8. (thickness of the Shahkot limestone is much exaggerated.)

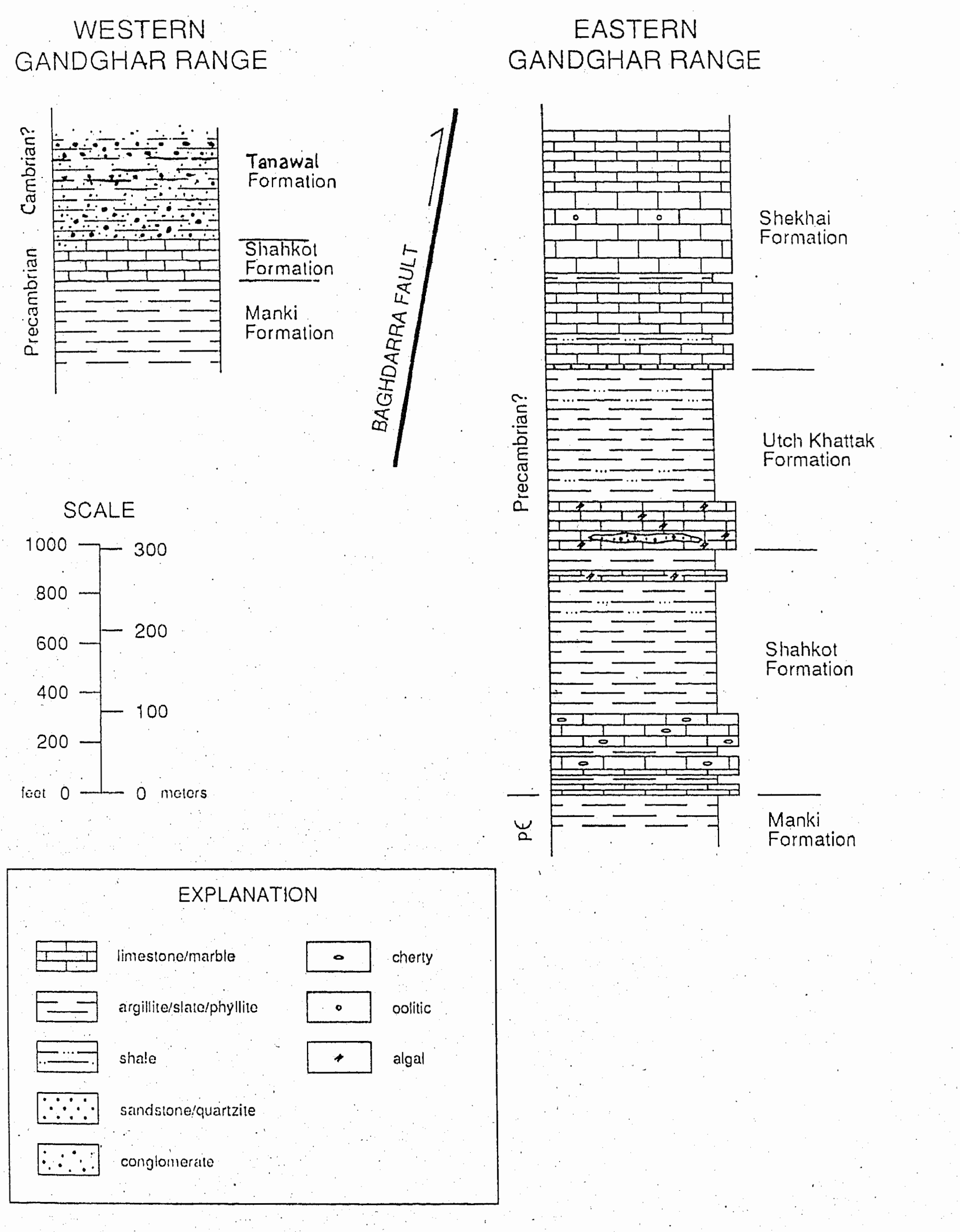


Figure 5. Stratigraphic column of the eastern (modified from Hylland, in prep.) and western Gandghar Range.

sequence of the Gandghar Range should be called the "Manki Formation" instead of Sirikot Slates (Tahirkheli,1971) or Hazara Formation (Calkins *et al.*,1975). The invalidity of the term Hazara Formation for these rocks is discussed in chapter 4. The misinterpreted Kingriali Formation is now shown to be the Shekhai Formation. Similarly the term Tarpakhi Quartzite is abandoned and the name Tanawal Formation is adopted. The Shahkot Formation is a new lithology which was never reported before, from the northern Gandghar Range. A comparison of the names of the rocks of the northern Gandghar Range by various authors is given in table 1.

The various lithological units comprising the northern Gandghar Range are:

ROCK UNIT	AGE
Intrusive rocks	Permian(?)
Tanawal Formation	Early to middle Cambrian(?)
Shekhai Formation	Late Precambrian(?)
Shahkot Formation	Precambrian
Manki Formation	Precambrian

MANKI FORMATION

The Manki Formation is exposed approximately over two third of the total area of the present study. It forms a major bulk of the strata comprising the hangingwall of the Baghdarra fault (Fig.4). The formation is mainly composed of argillites, slates, phyllites, sandy phyllites and minor limestone. The argillites are gray, greenish gray, and brown on weathered surfaces. They are fine grained and give earthy odor when wet. The slates are dark gray to black and fine grained. Phyllites are commonly greenish gray and on weathered surfaces they are olive green or brown. The argillites and slates are characterized by splintery texture because of the presence of the two distinct sets of cleavages. One of these sets, is dominant and parallel to bedding. Latif (1969) has suggested that this set may represent the bedding fissility. The other set is axial plane cleavage. Perfect slaty cleavage is rarely present.

Tahirkheli, 1971.	Calkins *et al.*, 1975.	this report
Tarpakhi quartzite late Silurian to Devonian	**Tanawal Formation** Ordovician(?) to Devonian	**Tanawal Formation** Early to middle Cambrian(?)
Mohat Nawan L.st. late Ordovician to early Silurian	**Kingriali Formation** Carboniferous to Triassic	**Shekhai Formation** Late Precambrian (?)
		Shahkot Formation Precambrian
Sirikot Slates early to middle Ordovician	**Hazara Formation** Precambrian(?) to Ordovician(?)	**Manki Formation** Precambrian

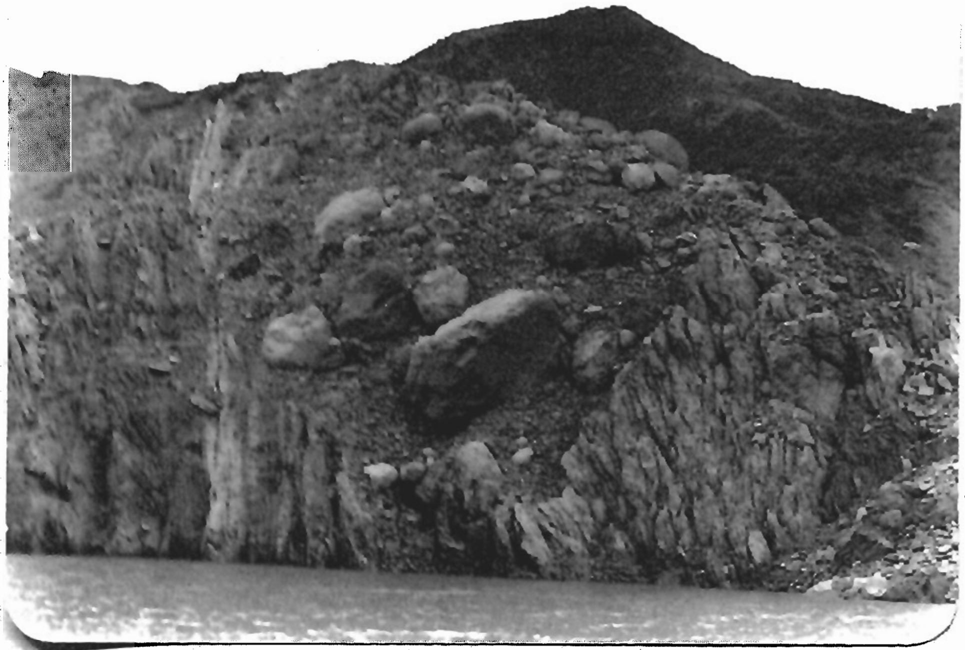
Table 1. Comparison of various nomenclatures for the rocks of the northern Gandghar Range.

Dark gray to black, very fine grained, 2 to 30cm thick, quartzite bands are also rarely found. The limestone bands interbedded with the slates and phyllites are yellowish brown, very hard, and coarsely crystalline (Photo.1). They are rarely continuous and the maximum thickness of a single bed is rarely more than 2 meters. The principal occurrence of the limestone is between Marufian and Nara villages on the eastern flank of the Gandghar Range.

The grade of metamorphism changes towards north, and is marked by the extensive quartz veining and a gradual petrological change from argillite to slate to phyllite.

In the northern Gandghar Range the upper contact of the Manki Formation is gradational with the overlying Shahkot Formation. Whereas, the lower contact is either not positively identified or is not exposed. Southward, the Manki Formation is in thrust contact (Fig.4) with the Shekhai and Tanawal Formations along the Baghdarra fault. The base of the Manki Formation may be exposed close to the Baghdarra fault zone. The thrust zone is exclusively marked by carbonaceous slates and graphitic phyllites. Similar lithologies exposed north of the Gandghar Range along the Indus River, were described as the Salkhala Formation (Calkins *et al.*, 1975). The Salkhala Formation at its type locality in Kashmir consists of a thick sequence of carbonaceous slates, graphitic phyllites and marbles and have a gradational contact with the Dogra Slates (Wadia, 1934). If the carbonaceous slates and graphitic phyllites exposed all along the Baghdarra fault are taken to be part of the Salkhala Formation, then the base of the Manki Formation is gradational with the underlying rocks; a contact relationship similar to that between Dogra Slates and Salkhala Formation. Alternatively these thrust-zone rocks may actually be a part of the Manki Formation locally metamorphosed to higher grades by the movement along the Baghdarra fault. If this is the case then the base of the Manki Formation is not exposed.

Due to isoclinal folding the true thickness of the Manki Formation is difficult to determine. However, outcrop width in the Gandghar Range indicate that it is more than 1200 m thick. A



Photograph 1. The limestone unit of the Manki Formation interbedded with the Manki phyllites, which are also exposed in the background. The limestone is badly eroded by the Tarbela Lake water.

common feature of the Manki Formation is the small scale folding. Generally chevron folds and kink bands occur in the more metamorphosed part of the formation, and indicate a compressional force roughly parallel to foliation.

According to Crawford and Davies (1975), the age of Hazara Slates, which are equivalent to the Manki Formation (Holland *et al.*,1956), is Precambrian based on the Rb/Sr whole-rock ages of 740±20 Ma. for one sample,and of 930±20 Ma. for another sample. The basal beds of the overlying Cambrian Abbottabad Formation contain clasts of Hazara Slates (Latif,1974) suggesting a Precambrian age of the Hazara Formation.

SHAHKOT FORMATION

The small patches of limestone occurring all along the contact of the Manki and Tanawal Formations (Fig.4) are remnants of the basal limestone of the Shahkot Formation. Previously these limestone patches were mapped as part of the Hazara Formation (Manki Formation) by Calkins *et al.*,(1975). Based on its stratigraphic position and lithological similarity with the basal limestone of the Shahkot Formation exposed in the Attock-Cherat Range, they are considered to be equivalent to the basal limestone of the Shahkot Formation. The maximum thickness of the limestone exposed here is 3 meters. The entire formation is very well exposed in the southern Gandghar Range (Hylland, in prep.) and in the Attock-Cherat Range (Hussain,1984; Yeats and Hussain,1987).

In essence the Shahkot Formation consists of limestone, argillite and shale. The limestone occurs at the base of the formation. In the present study area only the basal limestone is exposed (e.g. south of Chontri village).

The limestone is fine to medium grained, medium bedded, yellowish grey on fresh surfaces and brownish grey on weathered surfaces. It contains patches of white chert and is extermely hard. Clasts of the underlying Manki Formation are poorly found in it.

The formation has a gradational contact with the underlying Manki Formation, and an unconformable upper contact with the

Tanawal Formation.

Based on its stratigraphic position in the Attock-Cherat Range, Yeats and Hussain (1987) have tentatively assigned a Precambrian age to this formation. The gradational contact with the underlying Precambrian Manki Formation and lack of fossils supports the suggestion of Yeats and Hussain (1987).

SHEKHAI FORMATION

Tahirkheli (1970) designated a small outcrop of dolomitic limestone, quartzite and shale as "Shekhai Formation" after the Shekhai village on the northern slopes of the Attock-Cherat Range, about 16 km west of Nowshera. He correlated it with the Abbottabad Formation and assigned a Permo-Carboniferous age. Yeats and Hussain (1987) considered the Shekhai Formation to be of late Precambrian(?) age. Tahirkheli (1971) mapped a very similar lithology in the Gandghar Range as the early Paleozoic Mohat Nawan Limestone. Whereas Calkins *et al.*, (1975) mapped the same unit in the northern Gandghar Range as the Kingriali Formation of Triassic age. Based on the stratigraphic position and lithological similarities between the Shekhai Formation of the Attock-Cherat Range and the limestone unit exposed south of the Seri village in the northern Gandghar Range, noted by the writer and Ahmed Hussain of Geological Survey of Pakistan (pers. comm.,1989) it is suggested that this lithology be distinguished as "Shekhai Formation".

The Shekhai Formation is only exposed in the southeastern part of the northern Gandghar Range. It forms the foot-wall strata of the Baghdarra fault (Fig.4). The formation attains its maximum thickness south of the Ali Masjid stream and towards north its outcrop width gets narrower because of slicing by the Baghdarra fault which runs close to the eastern front of the range.

The Shekhai Formation is composed of limestone and marble with subordinate argillite, shale and quartzite. The limestone is fine grained, crystalline, thin to medium bedded, with occasionally thicker beds or massive units. Mostly the bed thickness range between 3 to 20 cm. It is usually yellowish gray to light and dark gray but brownish gray and light brown or pink colored beds are also seen. A few beds show parallel alignment of iron streaks that produce a lineation. The weathered surfaces are typically light gray or light brown and are relatively smooth. The limestone is locally metamorphosed to white or creamy marble in the close vicinity of basic igneous intrusions.

Argillite and shale occur as intercalations. They are mostly green, greenish gray, thinly laminated, occasionally calcareous and weather to greenish brown powdery stuff.

The base of the Shekhai Formation is not exposed in the northern Gandghar Range. However, in the southern Gandghar Range the Shekhai Formation has a conformable lower contact with the Utch Khattak Formation. The upper contact of the Shekhai Formation is faulted against the Manki Formation.

The formation is about 450 meters thick and is devoid of fossils. Based on its relative stratigraphic position in the Attock-Cherat Range (Yeats & Hussain,1987) and southern Gandghar Range (Hylland,in prep.), it is tentatively assigned a late Precambrian(?) age.

TANAWAL FORMATION

Wynne (1879) named the alternating quartzite and phyllite sequence of the Tanawal area (SW Hazara) as "Tanol Group", and extended the same name for the rocks exposed on the northwestern and eastern sides of the northern Gandghar Range. Middlemiss (1896) included these rocks in the lower part of the Infra-Trias as the "Tanol Quartzites". Both, Wynne and Middlemiss were not able to determine its stratigraphic position relative to the other formations of Hazara.

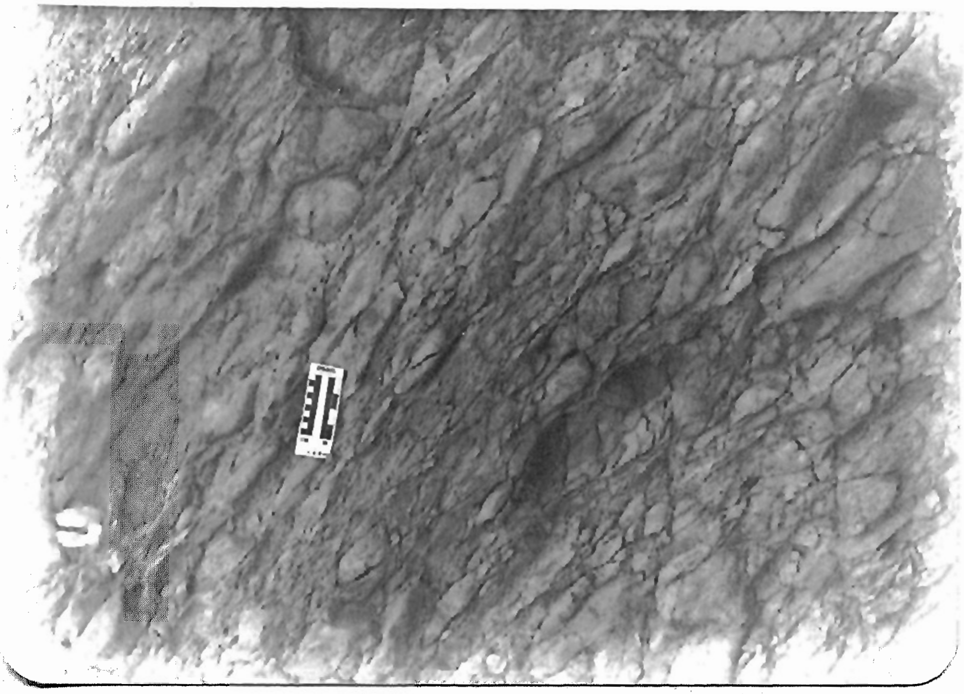
The term "Tanol" is the name of a tribe, living in the north and nothwest of Haripur and Tanawal is their territory. The "Tanol" were first spelt "Tanawal" by Wadia (1931), and included "strongly arenaceous and quartzitic sediments" occurring within the Infra-Trias in the Tanawal Formation. Ali (1962) resurrected the term "Tanol" and restricted it to the clastic sequence between the Hazara Slate Formation (Manki Formation) and the Abbottabad Formation. Identical lithologies on the west bank of the Indus River were mapped as "Chamla Quartzites" by Martin *et al.*,(1962). The same lithology throughout Hazara and west of Indus River was mapped by Calkins *et al.*,(1975) as Tanawal Formation. Tahirkheli (1971) mapped these rocks in the Gandghar Range as Tarpakhi Quartzites. The name Tanawal Formation is adopted here to create a regional consistency in nomenclature.

The Tanawal Formation is exposed on the southeastern and northwestern side of the northern Gandghar Range (Fig.4). In the Gandghar Range the Tanawal Formation consists of three members: the basal conglomerate member, the middle quartzite-phyllite member and the upper quartzite member.

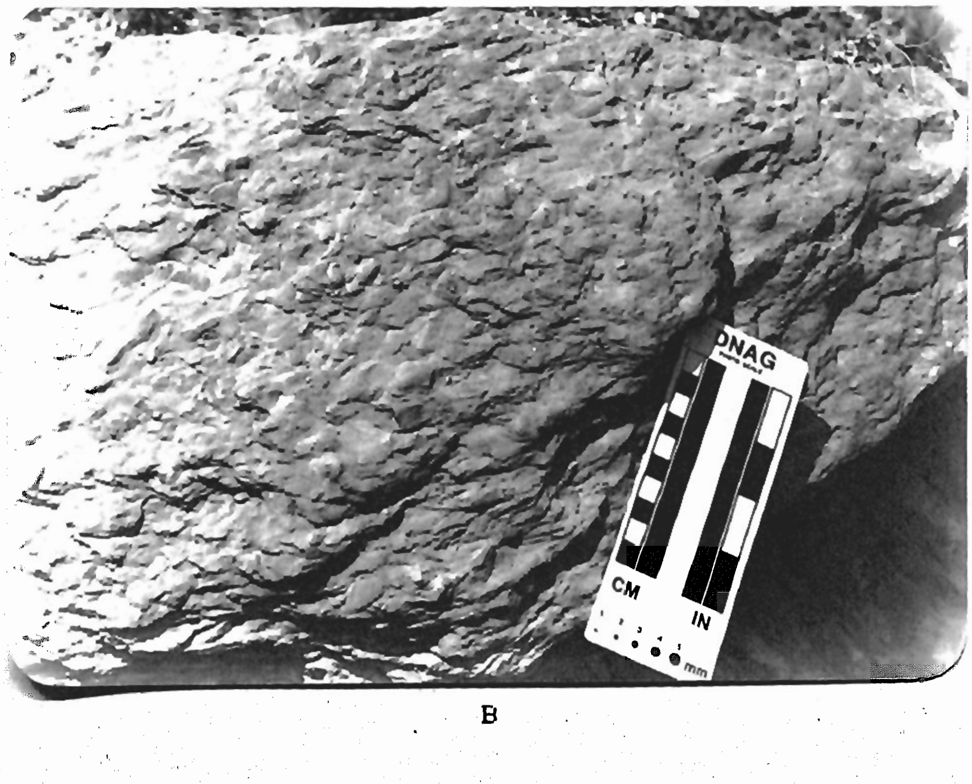
The basal conglomerate member represents an unconformity between the underlying Shahkot Formation and the overlying Tanawal Formation. The conglomerate member is exposed only in the western part of the northern Gandghar Range (Fig.4).

The conglomerate consists of pebbles of quartzite and sandstone embedded in a sandy matrix. The quartzite pebbles are dirty white, light green and brownish on weathered surfaces. Sandstone pebbles are light green on fresh surfaces and brown on weathered surfaces and are coarse grained and poorly cemented. The pebbles range from 2mm to 4cm in diameter, but occasionally pebbles having diameters of 20 to 30cm are also found (Photo.2 A & B). A gradual decrease in the size of pebbles is observed towards top of the member. The top most bed is very coarse grained sand and has no pebbles. The pebbles are elongate and aligned parallel to the beddings. Mica flakes have developed around some pebbles in such a manner that they impart an augen structure to the rock. The matrix is mainly composed of coarse quartz grains and fine clay particles, roughly having a ratio of 70% and 30%. The abundance of mica flakes not only imparts a micaceous sheen but also a slippery or soapy touch to the bedding surfaces. The quantity of mica flakes decreases downward in the member. Similarly the ratio of the coarse quartz grains to the fine clay particles decreases towards the bottom of the member.

In the northern Gandghar Range, the upper contact of the basal conglomerate member is faulted against the upper quartzite member of the Tanawal Formation (Fig.4). Whereas, its lower



A



B

Photograph 2. The basal conglomerate of the Tanawal Formation. A=in situ, B= a close look at a boulder.

contact is unconformable with the basal limestone of the Shahkot Formation.

The middle member is only exposed in the eastern part of the northern Gandghar Range (Fig.4). This member consists of an alternating sequence of quartzites and phyllites. The quartzites are white, yellowish white and brown on weathered surfaces. They are very hard, compact, recrystallized, medium bedded and cross-bedded in some parts. West of Siri village, asymmetric ripple marks were observed which indicate a current direction from southwest to northeast. The phyllites are dark gray, brownish gray and greenish gray and weather to brownish white powdery stuff. Cleavages are poorly developed and at some places they have kink bands and chevron folds.

The upper contact of the middle member is faulted against the Manki Formation and the lower contact is not exposed.

The upper member is exposed in the northwestern part of the northern Gandghar Range (Fig.4). It is dominantly composed of quartzite with shaley or phyllitic partings. The quartzite is medium to thick bedded, white to yellowish white and weathers to brownish white. The quartzite is recrystallized and breaks into sharp angular fragments. The beds are differentiated by phyllitic partings that are few millimeters to few centimeters thick. It has characteristic brown specks of probably iron or magnesium oxide. The quartzite is exclusively cross-bedded and the interfaces between beds are commonly ripple-marked. Another characteristic and often diagnostic feature is the presence of tourmaline as an accessory mineral.

The upper contact of the Tanawal Formation is not exposed in the Gandghar Range. However, in the southern Tanawal area, north east of the Gandghar Range and north of Haripur, the Tanawal Formation is unconformably overlain by the Sherwan Formation (Ahmad,in prep.). The lower contact of the Tanawal Formation is unconformable with the basal limestone of Shahkot Formation.

Tanawal Formation was assigned different ages by early workers. The most reliable age of the formation comes from the radiometric dating of the Mansehra granite which intrudes the Tanawal Formation in northern Hazara. The whole-rock Rb/Sr age of

516±16 Ma as reported by LeFort *et al.*,(1980) restricts the age of the Tanawal Formation from middle to late Cambrian or older. In the southern Tanawal area (Fig.6), north of Haripur, the Tanawal Formation is unconformably overlain by a sequence of phyllite, quartzite and dolomite of the Sherwan Formation (Ahmad,in prep.) which resemble the Abbottabad Formation of Cambrian age thus restricting the Tanawal Formation to early Cambrian or older. The dolomite member of the Sherwan Formation is identical to the late Cambrian Ambar Dolomite of the Peshawar basin (K.R.Pogue, pers.comm.,1989), in which case the Tanawal Formation will belong to the middle Cambrian or older.

INTRUSIVE ROCKS

The entire Gandghar Range is intruded by basic igneous rocks which are in the form of sills and dikes. The same kind of dikes have also been reported from the Attock-Cherat Range (Hussain, 1984; Karim and Sufyan,1989), from the western Hazara Ranges (Shams and Ahmed, 1968; Ahmed,1985) and from the Peshawar basin (K.R.Pogue, pers.comm.,1989). The intrusive bodies are generally less than 5 meter thick. They are diabasic in nature and are structurally deformed alongwith the country rock. Karim and Sufyan (1989), on the basis of chemistry of these dikes, have shown that they are the tholeiites of continental flood basalt affinity. A similar origin has been proposed for the Panjal Volcanics (Honegger *et al.*,1982). The Panjal Volcanics are intermediate to basic schistose rocks that occur along the apex and the eastern limb of the Hazara-Kashmir syntaxis and are conformably overlain by Triassic marine strata (Bossart *et al.*,1988). The diabase dikes of the Gandghar Range may be correlative with the Panjal Volcanics. The age of these rocks is not certain, but in the Peshawar basin, diabase intrusions of similar affinity have been found to occur in strata as young as Carboniferous (Pogue,K.R. pers.comm.,1989) and thus they may be Permian or younger.

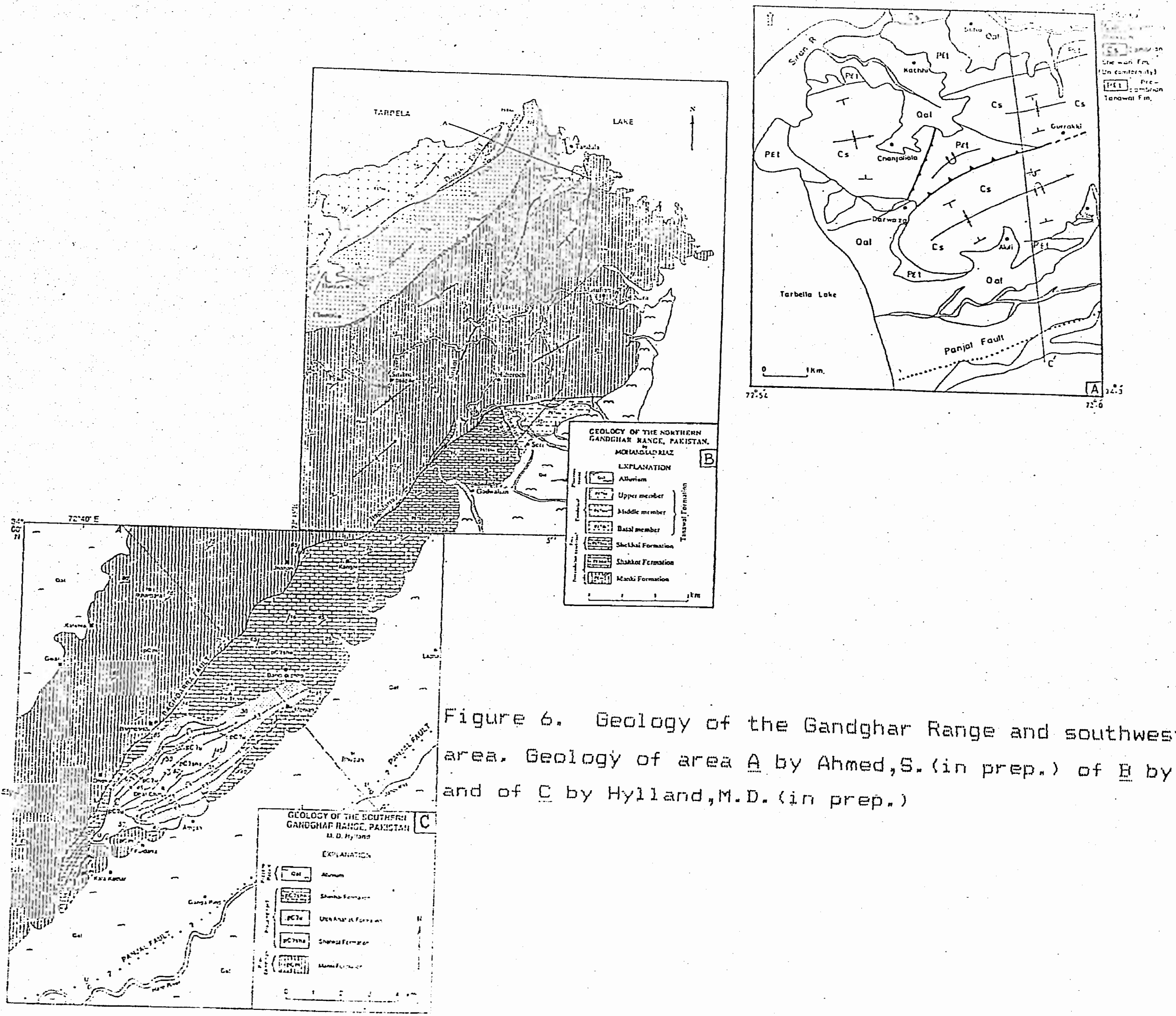


Figure 6. Geology of the Gandghar Range and southwestern Tanawal area. Geology of area A by Ahmed, S. (in prep.) of B by the writer and of C by Hylland, M.D. (in prep.)

SUMMARY

The present study reviewed the status of the carbonate lithology exposed around Gadwalian village (Fig.4) on the eastern flank of the Gandghar Range. The rocks are similar in all characters to the carbonates of the Shekhai Formation exposed in the Attock-Cherat Range. Therefore, in the northern Gandghar Range, the Kingriali Formation of Calkins *et al.*,(1975) is now interpreted to be the Shekhai Formation. Furthermore this lithology is not dolomitic in character but is dominantly a limestone lithology with few dolomitic beds at various stratigraphic intervals.

The Shekhai Formation did not yeilded any megafossils. Samples of the Shekhai limestone were analyzed by Dr.B.R.Wardlaw (pers. comm.,1989) for conodonts, but couldn't get any microfossils. The Precambrian age assigned to it is based on its relative stratigraphic position i.e. it underlies the early to middle Cambrian Tanawal Formation.

The alternating quartzite-phyllite sequence exposed north of Seri village (Fig.4) is identical to the quartzite-phyllite part of the Tanawal Formation exposed in the southern Tanawal area. This unit is therefore, interpreted as the middle member of the Tanawal Formation. Previously, the same unit was mapped by Calkins *et al.*,(1975) as the upper part of the Kingriali Formation.

Similary the limestone unit between the Manki and the Tanawal Formations is considered to be the part of the basal limestone of the Shahkot Formation. The same limestone was formerly included in the Hazara Formation (Manki Formation) by Calkins *et al.*,(1975).

CHAPTER-3

STRUCTURE PART I DATA

The structural setting of the Gandghar Range in relation to the major structures of northern Pakistan is shown in Figure 2. The Gandghar Range strata are thrust over the Precambrian, Paleozoic and Tertiary rocks exposed in the Khanpur Hills and small outcrops within the Campbellpur basin along the Panjal fault (Hylland *et al.*,in prep.). The range is deformed by an imbricate structure, the frontal thrust of which is the Panjal fault. The strata of the southeastern part of the Gandghar Range are folded into a northeast plunging overturned anticline,the Pirthan anticline, (Hylland *et al.* in prep.) whose normal limb is in part faulted by the Baghdarra fault (Fig.6 area C). The outer most beds of the overturned limb are covered by the alluvium of the Haripur basin. The deformation of the range as a whole is attributed to the movements on the Panjal and associated faults.

The northern Gandghar Range is a small imbricate zone characterized by three north dipping thrusts and a number of south verging folds of two distinct generations. In several sections small structures like cleavages, foliations etc. have also been observed.

FAULTS

The important faults recognized in the northern Gandghar Range (Fig.4) include:

1. The Gadwalian Fault
2. The Baghdarra Fault
3. The Sirikot Fault
4. The Darrah Fault

The Gadwalian Fault

The Gadwalian fault is a small fault, named after the Gadwalian village, which is located about 14 km west of Haripur (Fig.4). Previously this fault was mapped as a normal contact between the Shekhai and Tanawal Formations (Calkins *et al.*,1975). It brings the Shekhai limestone (footwall) against the Tanawal Formation (hangingwall). The fault is not visible as a discrete line or zone but there are some positive indications of faulting. For instance, the "contact" is very sharp and southwest of the Seri village, some calcite and quartzite veins in the Shekhai Formation are truncated by the strata of the Tanawal Formation. Also a thin-section of the Shekhai limestone from the "contact" between the Shekhai and Tanawal Formations, revealed shearing and crushing of the calcite grains. Similarly the limestone which is otherwise light gray, gets bluish near the "contact", probably because of shearing and increased content of graphitic matter.

The fault could partly be mapped because of the steepness of the strata and rugged topography. The section exposing the fault in the stream west of the Seri village has some striations and drag folds that show that the fault is a dip-slip normal fault.

The Baghdarra Fault

The Baghdarra fault is named after the Baghdarra village, which is located approximately 3 km southwest of the Pirthan ,the highest peak in the southern Gandghar Range (Fig.6 area C). The Baghdarra fault juxtaposes the Precambrian Manki Formation and the Proterozoic Shekhai and Tanawal Formations (Fig.4). The Manki Formation is exposed in the hangingwall of the Baghdarra fault and the footwall is composed of Shekhai and Tanawal Formations. Though no definitive measurements of the fault dip were possible to get, yet at most places the fault is nearly vertical. Hundreds of drag folds developed in the fault zone indicate that the fault had a reverse-slip movement.

Hylland (in prep.) mapped the southern Gandghar Range and studied oriented phyllite samples from the Baghdarra fault zone, in the vicinity of the Baghdarra village. His study reveals presence of small (0.5-1mm diameter) subhedral to euhedral garnet porphyroblasts, around which the foliation was deformed asymmetrically and also the presence of kink bands and a poorly developed s-c fabric. These features are suggestive of a reverse-slip displacement along the Baghdarra fault.

The Sirikot Fault

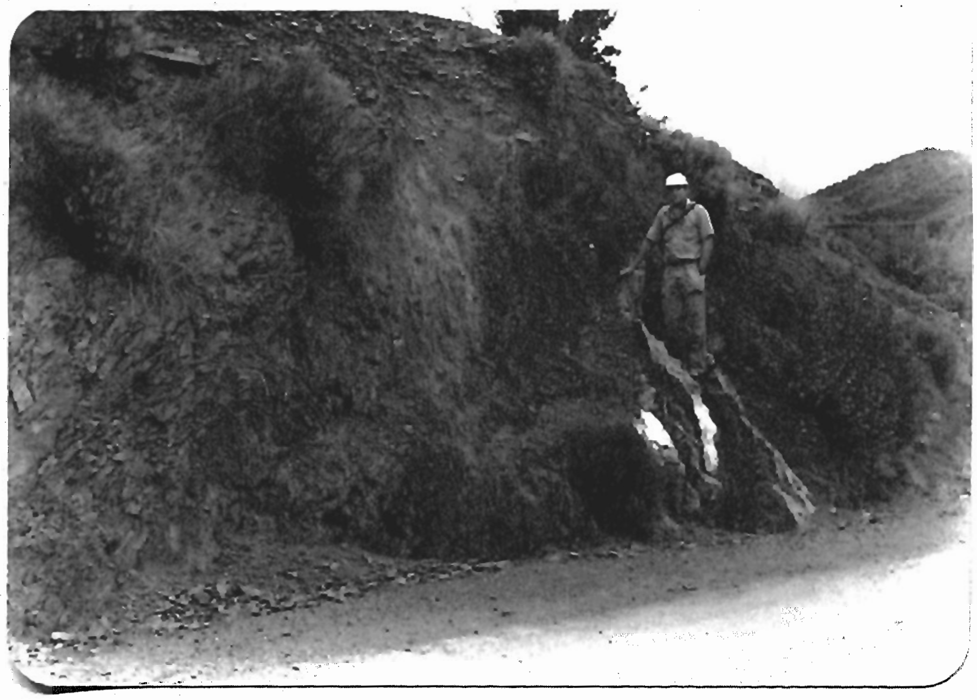
The Sirikot fault is named after the Sirikot village, which is located approximately 19 km west-northwest of Haripur (Fig.4). The major portion of the fault runs through the Manki Formation, but the northern part of the fault brings the Manki Formation against the basal conglomerate member of the Tanawal Formation. The northern tip of the fault because of the erosion by the Tarbela lake water, exposes an excellent section of the fault zone where one to two meter thick black fault gouge can be seen (Photo.3). The fault gouge consists of black graphitic schist with crushed pebbles of quartzite and limestone. The fault gouge zone is broader at the base and gradually gets narrower towards the top i.e. near the surface. This wedge shaping of the fault gouge explains why the fault is not exposed at the surface, but is clearly visible in the cross-sections. There are two places where this fault can be seen, one is about 1/2 km west of Tandula village and the other is in a road-cut section, on the Sirikot-Haripur road, about 4 km east of Sirikot (Fig.4 & Photo.4). The fault gouge also has big blocks of the Shekhai limestone, which still retain their fine laminations, intra-laminar fold closures and microfolds. These blocks range in size from 25 cm to 3 meter in diameter.

The Sirikot fault exposed in the section west of the Tandula village, is vertical, but dips more than 70 to the northwest in the section on Sirikot-Haripur road (Photo.4). The sense of movement on the fault plane is reverse-slip, which is indicated by the associated drag folds and kink bands.

The Darrah Fault

This fault is located in the extreme northwest of the Gandghar Range. It is named after the Darrah village, which is located about 4 km northwest of the Sirikot village (Fig.4). Some of the striations observed on the surface of a quartzite bed in the Darrah stream, indicate a dip-slip component of movement and the drag folds in the limestone and argillites immediately below the fault zone indicate a reverse-slip sense of shearing. This fault is subvertical, and in one section i.e. southwest of the Darrah

Photograph 3. The Sirikot fault gouge, exposed along the Tarbela Lake. To the left is the Tanawal Formation and to the right is the Manki Formation.



Photograph 4. The Sirikot fault zone on the Sirikot-Haripur road section. The light color rocks are the Manki phyllites and the darker rocks make the fault gouge. Kevin is holding onto a block of Shekhai limestone embedded in the fault gouge.

stream, the fault plane dips in opposite direction (Photo.5).

The Darrah fault 1 (Figs.4 and 8) is a small fault developed in the hangingwall of the Darrah fault. It juxtaposes the basal Manki Formation and the upper quartzite member of the Tanawal Formation. The fault is dipping at more than 85° towards south. Slickensides observed on its hangingwall and footwall strata indicate a dip-slip motion. Some vaguely developed drag folds in the argillites of the Manki Formation indicate a reverse-slip movement, suggesting that it is a back-thrust.

FOLDS

The Gandghar Range is dominated by the southeast directed thrusting, which is typical of the Himalayas. As a result the entire Gandghar Range is deformed into south/southeast verging folds. For example, the Pirthan Anticline is developed in the hangingwall of the Panjal fault (Hylland, in prep.) in response to the movement along this fault (Fig.6).

The Manki Formation being argillaceous is more prone to folding. The Manki Formation has developed from large to mesoscopic and even microscopic size folds. The great thickness of the Manki Formation is due to the isoclinal folding of the rocks. The Manki Formation is folded into numerous anticlines, synclines, chevron folds and kink bands. The folds are commonly fractured or faulted along their hinges. In the vicinity of the major faults, the Manki Formation developed drag folds, which help in deducing the sense of shearing on the associated fault.

The Shekhai Formation which is dominantly a carbonate lithology, produced eye catching folds. Close to the Baghdarra fault the Shekhai limestone displays numerous folds, which are oriented parallel to the NE-SW direction (Fig.7). Similarly the Pirthan Anticline and hundreds of folds developed on its limbs are all oriented parallel to the NE-SW direction (see area C in Fig.6). The strike of the Baghdarra fault is parallel to the attitudes of these folds suggesting a possibility that these folds may have formed in response to the movement along the Baghdarra fault. Two phases of deformation have been established by interpreting the stereonet plots of these folds.

Photograph 5. The Darrah fault, exposed in the Darrah stream (looking towards southwest). The fault is dipping in the opposite direction in this section. The basal conglomerate of the Tanawal Formation (to left) is juxtaposed with the upper quartzite member (to right) of the same formation.

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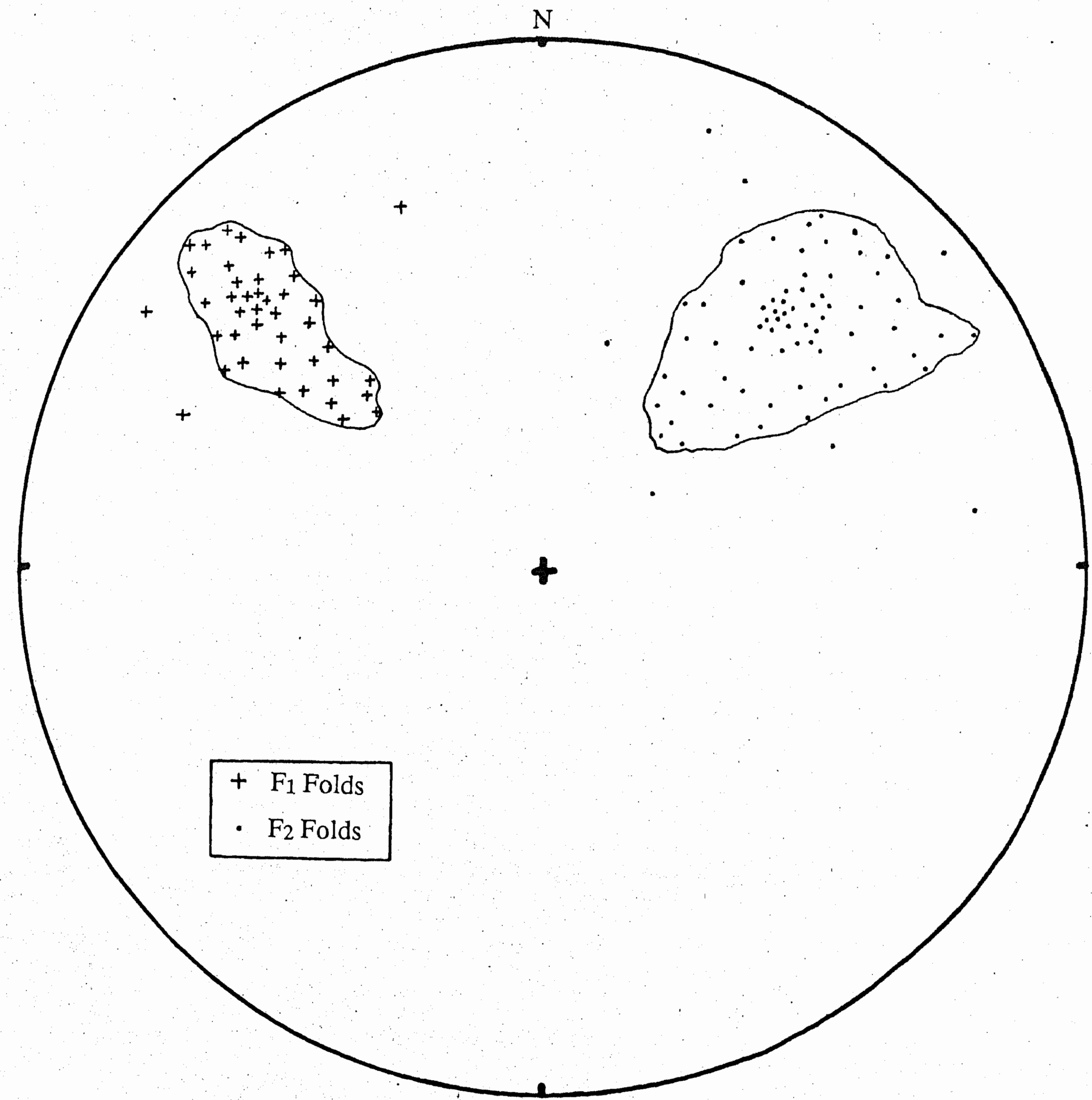

Figure 7. Fold axes of F_1 and F_2 generations, plotted on an equal area net.

On closely examining the thinly bedded Shekhai limestone, it becomes evident that each bed has some darker bands that are folded within the single bed (Photo.6a). This intra-laminar folding shows that the apparent bedding surfaces are S_1 instead of S_0. The original bedding surfaces may be represented by the present darker bands which now form the fold closures within these apparent bedding (S_1) surfaces. These folds are termed as F_1 folds (Fig.7) produced by the deformation phase D_1. The other phase of folding (F_2) is the one in which the S_1 are folded (Photo.6b & Fig.7). The F_2 folds are associated with the D_2 phase of deformation. The F_2 folds include the Pirthan Anticline, and hundreds of mesoscopic folds developed on the limbs of the anticline. All of these F_2 folds are southeast verging and plunge towards northeast.

The Tanawal Formation is mostly quartzite and thus it didn't deform directly. Some folds which are developed in the Tanawal Formations are few meters across and have fractured hinges. They can be seen on the road side just west of the Seri village.

MICROSTRUCTURES

The argillites and phyllites of the Manki Formation commonly display two sets of cleavages. The splintery texture of the rocks of the Manki formation is due to these cleavages.

One set of these cleavages is dominant and parallel to bedding. This set may be representing the bedding fissility of these rocks, as is suggested by Latif (1969). The other set of cleavage is the axial plane cleavage. Perfect slaty cleavage is rarely developed.

The Shekhai limestone does not exhibit any cleavages. However, at few places, for example in the Gadwalian stream, the limestone has some fractures that are filled with secondary minerals (mostly calcite). In some of the beds iron specks are aligned in straight lines that define mineral lineation.

The phyllite of the Tanawal Formation also show some poorly developed cleavages.

a

b

Photograph 6 a. The Shekhai limestone with its darker bands (S_0) folded into F_1 folds; b. The S_1 surfaces of the same limestone folded into F_2 folds.

STRUCTURE

PART II SYNTHESIS OF DATA

The data gathered from the present work in the northern Gandghar Range and also from field-work in the southern Gandghar Range, together with the data from previous literature is all put together to model the systematic development of the structure of the northern Gandghar Range.

The Gadwalian fault may be a part of the series of north-south trending faults in the vicinity of the Tarbela area (Kazmi,1979; Seeber and Armbruster,1979). A number of earthquake epicenters are located along these faults, mainly near the northern end of the fracture zone. Based on the seismicity and subsequent fault plane solutions, Armbruster *et al.*,(1978) have shown that these faults are steeply dipping and are characterized by reverse and strike slip motions. The abrupt northward truncation of the Gandghar Range may be because of a strike slip movement along one of these faults. It may be possible that the Gadwalian fault along with other faults (described by Kazmi,1979) may have formed as tear faults to compensate the differential rate of movement of the thrust sheet along a major basal detachment surface (Seeber *et al.*,1981).

Deformation of the Baghdarra fault alongwith the footwall strata suggest that the Baghdarra fault is older than the Panjal fault, because the hangingwall of the Panjal fault is also the footwall of the Baghdarra fault. The possibility of the Gadwalian fault being a lateral ramp is ruled out by the fact that it does not cross the Baghdarra fault. Instead the Baghdarra fault terminates the northern end of the Gadwalian fault. In such a case the Gadwalian fault must be older than the Baghdarra fault. Similarly the Sirikot fault is either branching from the Baghdarra fault or is terminated by the Baghdarra fault. If the former is true then they may be of the same age or closely following each other. And if the latter is true then the Sirikot fault must be older than the Baghdarra fault. No age constraints were possible to get on the Darrah fault. But the geometric set-up of these faults suggest that the Gadwalian fault is the

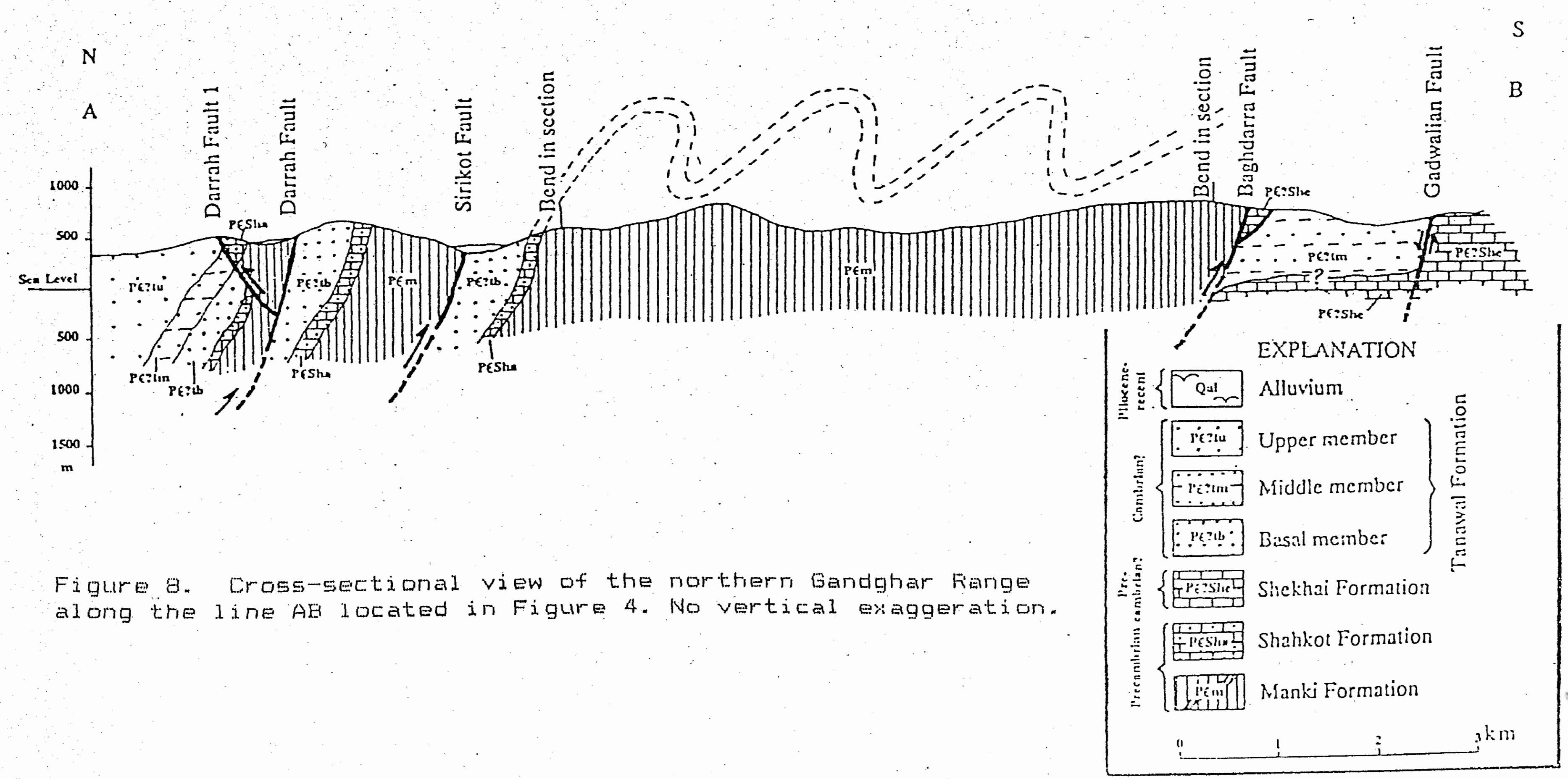

Figure 8. Cross-sectional view of the northern Gandghar Range along the line AB located in Figure 4. No vertical exaggeration.

oldest, followed by the Darrah fault, Sirikot fault, Baghdarra fault and lastly by the Panjal fault.

All these faults have few things in common. Firstly, all of them trend more or less in the same direction i.e. NE-SW. Secondly, the basal sequence of their hangingwalls is always the Manki Formation. And thirdly, they do not cross-cut one another. All these features suggest that they are part of an imbricate system, emerging from a common detachment surface that is existing at the base of or within the Manki Formation (Fig.8).

The Gandghar Range is separated from the rocks of the Khanpur and Kherimar Hills by the Panjal fault (Fig.4). The entire Gandghar Range strata form the hangingwall of the Panjal fault and the footwall strata is composed of the rocks of the Khanpur and Kherimar Hills. The steeper dips of the hangingwall strata of the Panjal fault as compared to that of its footwall strata and the deformation of the structures of the hangingwall rocks suggest that the Panjal fault is younger than all other faults of the Gandghar Range.

The order of development of these faults suggest that the deformation is foreland-directed, and the entire Gandghar Range is being carried in a piggy-back style by the Panjal fault. The piggy-back style of thrusting in the range is also supported by the geometrical elements (dip angles) of the rocks. The dip angles of the hangingwall rocks of each individual thrust are steeper than those of their respective footwall strata, which is consistent with the geometry of a piggy-back thrusting style.

PHASES OF DEFORMATION

Two phases of deformation i.e. D_1 and D_2 are recognized in the Gandghar Range strata. Evidence (two distinct sets of folds) for these two phases of deformation is recorded by the carbonate rocks of the Shekhai Formation.

The D_1 phase of deformation is documented by the presence of the F_1 folds. The development of the F_1 folds involves the folding of the S_0 surfaces. The orientation of the F_1 folds define a distinct domain (Fig.7). This domain owes its existence to a force which is different from the one that caused the

Baghdarra faulting event. As the F_1 folds involve folding of S_0 surfaces, which suggests that the D_1 phase must be older than the Baghdarra faulting event. The very distinct nature of the S_1 surfaces, which are now the apparent bedding surfaces, may indicate Precambrian deformation of the S_0 surfaces, as is also suggested by Baig *et al.*,(1988). However, the exact nature and age of the D_1 phase of deformation is not known.

The D_2 phase of deformation is documented by the F_2 folds (Fig.7), which were formed by the folding of the S_1 surfaces. The vergence and the mutual parallelism of the F_2 folds suggest a compressional force from the northwest. The deforming force of the Baghdarra fault, Panjal fault and of the F_2 folds appears to be the same, i.e. they owe their formation to a force from the northwest. Similarly the intensity of occurrence of the mesoscopic F_2 folds increases near the Baghdarra fault, which suggest that both of them were formed under a single deforming force. The movement on the Panjal fault folded the entire footwall strata (hangingwall of the Panjal fault) of the Baghdarra fault into a huge southeast verging and northeast plunging anticline (the Pirthan Anticline).

CHAPTER-4

DISCUSSION

The Panjal fault is recognized by the fact that it brings the Precambrian basement rocks over the upper Paleozoic or younger strata (Wadia,1957). The fault separating the Manki Formation and the carbonates which were formerly thought to be part of the Triassic Kingriali Formation, was mapped as the Panjal fault (Calkins *et al.*,1975). The present study interpret these carbonates as the Precambrian Shekhai Formation and therefore, precludes the existence of the Panjal fault in the Gandghar Range. Hylland *et al.*, (in prep.) argue that the Panjal fault is buried beneath the alluvium of the Haripur and Campbellpur basins.

All the thrust faults of the Gandghar Range have the Manki Formation as the basal detachment level, from which these thrusts branch and imbricate the range. In this imbricate structure the Panjal fault is the frontal thrust.

Kazmi (1979) with the help of satellite imageries mapped several strike-slip faults trending NS in the Tarbela area. Similarly the seismic data also supports their existence (Seebers and Armbruster,1979). The northward abrupt truncation of the Gandghar Range is probably because of one of such faults.

The relative ages of the various fault of the northern Gandghar Range are open to question. The Gadwalian fault which is considered to be the oldest fault may actually be the youngest fault if it is assumed that it is a lateral ramp developed in the hangingwall of the Panjal fault. Though apparently the Baghdarra fault truncates the northern end of the Gadwalian fault suggesting that the former is older than the latter.

The rocks of the northern Pakistan can be grouped into the "internal" and "external" zones (Coward *et al.*,1988). The internal zone is characterized by having the high grade rocks with their southern limit at the Panjal fault. The external zone is characterized by having unmetamorphosed sediments with their northern limit at the Nathia Gali-Cherat fault. The Nathia Gali and Cherat faults are laterally continuous and are equivalent in that they are the southern most thrusts that bring the Precambrian basement rocks to the surface. Similarly Yeats and Hussain (1987) have suggested that the Khairabad fault is the western continuation of the Panjal fault and laterally juxtapose the Gandghar Range with the Attock-Cherat Range. The rocks south of the Khairabad-Panjal fault and north of the Nathia Gali-Cherat faults are either slightly metamorphosed to greenschist facies or are unmetamorphosed sediment. I suggest that the internal and external zones should be separated by a transitional zone, which is characterized by having the least metamorphosed Precambrian basement rocks, overlain by virtually unmetamorphosed sediments.

The Gandghar Range is located immediately to the north of the Panjal fault at the fringe of the internal and transitional zones, which suggests that the regional metamorphism of the rocks of the Gandghar Range will be of very low grade. This is supported by the fact that the biotite-garnet isograd is located considerably north of the Gandghar Range (Calkins *et al.*,1975) with the Gandghar Range strata occurring in the chlorite zone of the greenschist facies. The only garnet bearing rocks reported from the Gandghar Range (Hylland, in prep.) occur within a narrow zone adjacent to the Baghdarra fault. In which case it is possible that they are the result of frictional shear heating associated with movements along the fault.

Previously the basal sequences on either side of the Panjal fault were considered to be the same i.e. the Hazara Formation. The present study showed that the two have major differences. The basal sequence in the footwall of the Panjal fault is arenaceous and has no evidence of metamorphism. Whereas, the basal sequence in the hangingwall of the Panjal fault is argillaceous and displays greenschist facies metamorphism. The basal sequence of the Gandghar Range (in the hangingwall of the Panjal fault) is identical to the Manki Formation of the northern block of the Attock-Cherat Range, and the basal sequence in the footwall of the Panjal fault is similar to the Dakhner Formation of the central block of the Attock-Cherat Range. It is therefore, suggested that the basal sequence in the hangingwall of the Panjal fault be called as "Manki Formation" and reserve the term

Hazara Formation for the one in the footwall of the Panjal fault.

The carbonate lithology south of Seri village (Fig.4) in the Gandghar Range was previously mapped as the upper Ordovician to lower Silurian Mohat Nawan Limestone (Tahirkheli,1971) and the Triassic Kingriali dolomite (Calkins *et al.*,1975). The present study shows that the said lithology is dominantly of limestone with few beds of dolomite in it, and is in no way related to the Kingriali Formation. Tahirkheli (1971) mapped two limestone units (the Mohat Nawan Limestone and the Pirthan Limestone) between Seri village and the Pirthan. He correlated the Pirthan Limestone with the Shekhai Limestone of the Attock-Cherat Range. The combined lithological description of the Mohat Nawan and Pirthan Limestones (Tahirkheli,1970) and that of the Shekhai Limestone (Tahirkheli,1970) of the Attock-Cherat Range are exactly similar; a fact which is also supported by the field observations. It is therefore suggested that the dominantly carbonate lithology between the Seri village and the Pirthan, on the eastern flank of the Gandghar Range should be treated as the Shekhai Formation.

The age of Shekhai Formation was interpreted to be Permo-Carboniferous (Tahirkheli,1970). This was based on his correlation of this formation with the Abbottabad Formation. If the same correlation is valid, then the Shekhai Formation will have an early Cambrian age, because the Abbottabad Formation is now proved be of early Cambrian age (Latif,1974). Furthermore, in the Attock-Cherat Range (Yeats and Hussain,1987) and in the southern Gandghar Range (Hylland, in prep.), the Shekhai Formation has a quartzite bed at its base which suggests that a considerable amount of time lapsed between the deposition of the underlying Precambrian Utch Khattak Formation and the Shekhai Formation.

The alternating quartzite-phyllite sequence north of the Seri village was previously mapped as the Tarpakhi Quartzite (Tahirkheli,1971) and upper quartzite of the Kingriali Formation (Calkins *et al.*,1975). Field observations in the southern Tanawal area has shown that identical lithologies exist in this area as part of the Tanawal Formation. Hence it is appropriate to consider this lithology as part of the Tanawal Formation.

Furthermore, Calkins *et al.*,(1975) had mapped them as upper quartzites of the Kingriali Formation, because they thought that the Shekhai Formation is a dolomite of the Kingriali Formation. The field description of these quartzites does not match with the lithological description of the Kingriali Formation (Shah,1977).

The lower contact of the Tanawal Formation has been reported to differ at various places (Calkins *et al.*,1975). At Sobrah Gali it is marked by a conglomerate, whereas south of Garhi Habibullah it is gradational with the underlying Hazara Formation (Calkins *et al.*,1975). The unconformable lower contact of the Tanawal Formation with the Precambrian Salkhala Formation was also reported by Wadia (1931). In the study area the Tanawal Formation is separated by a conglomerate bed from the underlying limestone of the Precambrian Shahkot Formation. Earlier workers (Calkins *et al.*,1975) have considered this limestone bed as part of the Hazara Formation (Manki Formation). Whereas, the writer maps it as the basal limestone of the Shahkot Formation because of its lithological similarity and stratigraphic position with that formation.

The Gandghar Range can be divided into four structural blocks that are juxtaposed along the Baghdarra, Sirikot and Darrah faults. The three blocks north of the Baghdarra fault have the same stratigraphy and constitute the western Gandghar Range separated from the eastern Gandghar Range by the Baghdarra fault. The eastern Gandghar Range is having a complete succession of Precambrian to Cambrian rocks (Fig.5) including the basal Manki Formation followed by the Shahkot Formation, Utch Khattak Formation, Shekhai Formation and the Tanawal Formation. Whereas, in the western Gandghar Range the stratigraphy is interrupted by an unconformity between the basal limestone of the Shahkot Formation and the overlying Tanawal Formation. Here not only most of the Shahkot Formation is missing, but the whole of the Utch Khattak and Shekhai Formations are also missing. The sequence of various lithologies of these blocks suggest that their basin of deposition was gradually getting shallower towards west (Fig.5). The timing of uplift of the Gandghar Range along the Panjal fault is not known. However, a heterolithic conglomerate bed within a section of the Campbellpur basin fill along the Haro River contains boulders of diorite and granite up to 3 meter in diameter and is directly overlain by normally-magnetized lacustrine sediments (Burbank,1982). This conglomerate had been deposited by a fluvial agent more powerful than the modern Haro River (Fig.7 area C). It is possible that the ancestral Indus River flowed through the eastern Campbellpur basin, as suggested by Wynne (1879), and was diverted by uplift of the Gandghar Range some time during the Brunhes chron (Burbank,1982).

CONCLUSION

1. The deformation of the Gandghar Range is not only due to the folding processes, but also involves imbrication.
2. The imbricate zone is characterized by the Baghdarra, Sirikot, and Darrah faults.
3. The imbricated zone makes up the hagging wall of the Panjal fault.
4. Two distinct sets of folds have been recorded which indicate two separate phases of deformation.
5. The carbonate lithology (Triassic Kingriali Formation of Calkins *et al.*,1975) is here proved to be the Precambrian Shekhai Formation.
6. The alternating quartzite/phyllite unit occurring north of Seri village, which was previously shown to be part of the Kingriali Formation (Calkins *et al.*,1975) is now interpreted to be the middle member of the Cambrian(?) Tanawal Formation.
7. Ages of all the rocks of the Gandghar Range have been completely revised.

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