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

M. RIAZ[1], MICHEAL D. HYLLAND[2], SAJJAD AHMED[3] & A.A.K. GHAURI[1]

[1]National Centre of Excellence in Geology, University of Peshawar

[2]P.O. Box 12, Baring, WA 98224, U.S.A.

[3]Department of Geology, University of Peshawar

ABSTRACT

The northern Gandghar Range comprises four structural blocks, separated by the Baghdarra, Sirikot and Darrah faults. In contrast to the southern Gandghar Range none of them shows a complete succession of stratigraphy. The stratigraphy of the northern Gandghar Range is different from that of the southern Gandghar Range in two ways. Firstly, the northern Gandghar Range has an additional stratigraphic unit, the Tanawal Formation which is completely missing from the southern Gandghar Range. Secondly, the Utch Khattak Formation which is so widely developed in the southern Gandghar Range is not found in the northern Gandghar Range.

The deformation of the northern Gandghar Range is accomplished by thrusting and associated folding. The nature of deformation of each block suggests a piggy-back style of thrusting and attitudes of folds indicate two distinct phases of deformation.

INTRODUCTION

The NE-SW trending Gandghar Range is located in the Hazara Division, some 40 km northwest of Islamabad. It forms a partial barrier between the Plio-Pliestocene Haripur and Peshawar basins (Fig. 1). North of the Gandghar Range, in the Hazara Ranges the Tanawal Formation is intruded by the Cambrian Mansehra granite. The Gandghar Range is bound in the east by the Khanpur Hills and in the southeast by the Margala Hills.

The Gandghar Range strata are transitional between the high grade metamorphic and plutonic rocks to the north and unmetamorphosed foreland basin strata to the south. It is structurally continuous with the northern block of the Attock-Cherat Range (Yeats and Hussain, 1987) and records the transition between the Himalayan rocks and foreland basin strata.

Hylland et al. (1988) have described the stratigraphic and structural relationships of the rocks that underlie the southern Gandghar Range. This paper is an attempt to extend the same relationships to the rocks of the northern Gandghar Range.

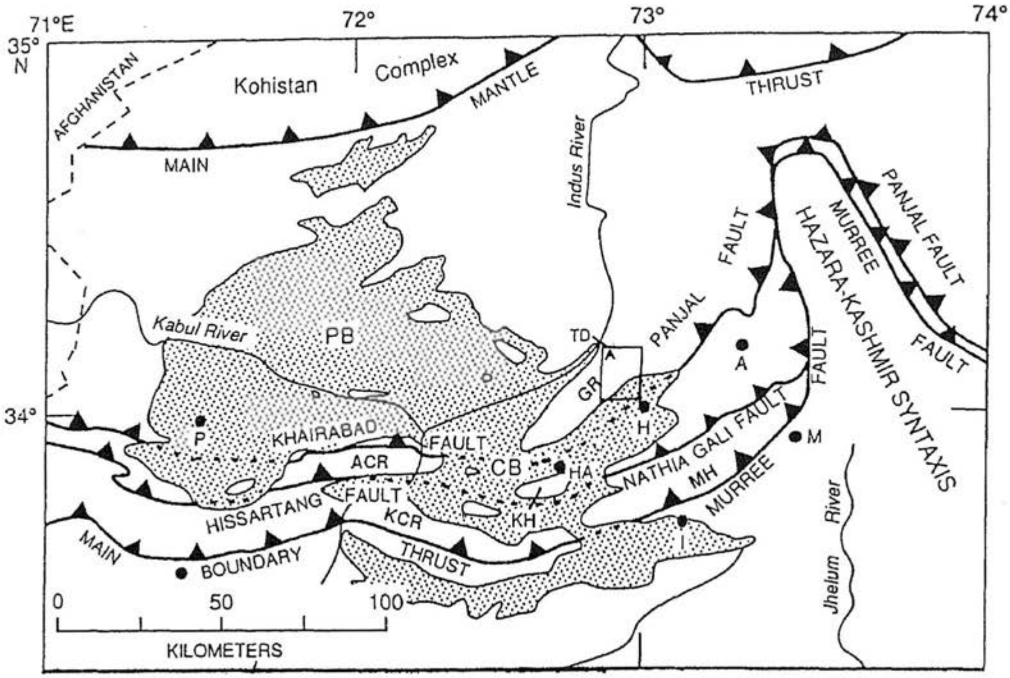

Fig. 1. Tectonic map of northern Pakistan. P = Peshawar; PB = Peshawar basin; AB = Abbottabad; M = Murree; I = Islamabad; H = Haripur; HA = Hasan Abdal; CB = Campbellpur Basin; ACR = Attock-Cherat Range; KCR = Kalachitta Range; KH = Khanpur Hills; CF = Cherat Fault; GR = Gandghar Range; MH = Margala Hills. Area in rectangle A shown in Fig.2.

PREVIOUS WORK

All of the earlier literature on Hazara describe the geology of the Gandghar Range in a regional context (e.g. Waagen & Wynne, 1872; Wynne, 1879; Middlemiss, 1896). They mentioned the infra-Triassic limestone and Paleozoic Slate Series which was correlated with the pelitic rocks of Attock (Cotter, 1933). The limestone units have also been considered to be the part of the Precambrian Hazara Slates (Ali, 1962), whereas Tahirkheli (1971) mapped all of the rocks comprising the Gandghar Range to be of Paleozoic age. The structural relationships of the rocks of the northern Gandghar Range were explained by the existence of large folds and a thrust fault (Calkins et al., 1975).

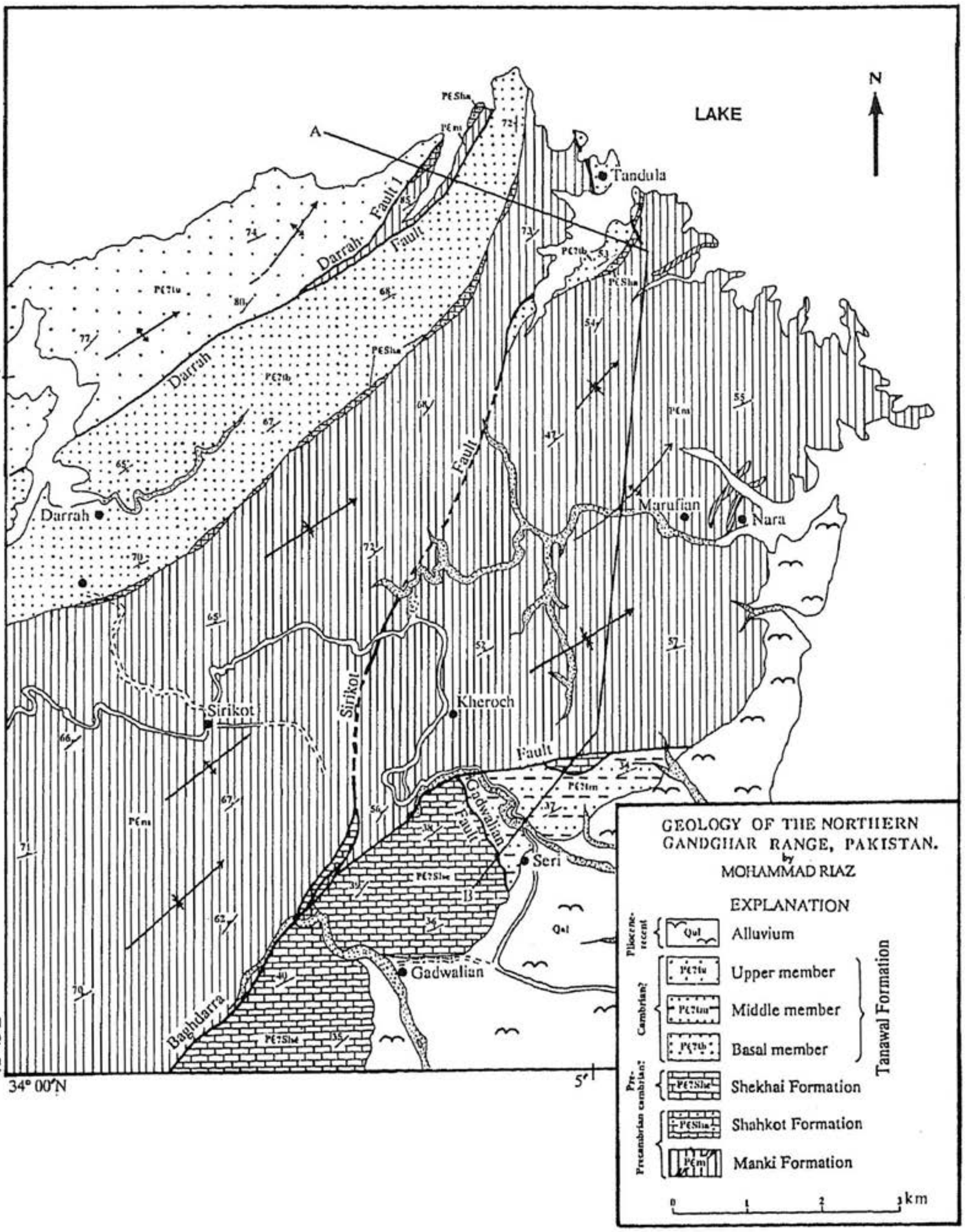

Fig. 2. Geological map of northern Gandghar Range. Line AB is the location of the Fig.4. Thickness of the Shahkot limestone is much exaggerated.

The northern Gandghar Range displays four stratigraphic successions (Fig. 2), the nomenclature of which has been recently revised (Hylland et al., 1988; and Riaz, 1990) The basal sequence (the Manki Formation) is mostly composed of slates and phyllites, which are successively overlain by two carbonate lithologies (the Shahkot and the Shekhai Formations) and an alternating sequence of quartzite and phyllite (the Tanawal Formation). The entire succession is profusely intruded by basic igneous dikes and sills of unknown age. The range is divisible into a western and an eastern structural block (Fig. 3) 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 in itself imbricated into three sub-structural blocks such that all the imbricated slices have the same stratigraphy.

Manki Formation

The Manki Formation is exposed over two third area of the northern Gandghar Range (Fig. 2). The formation is mainly composed of argillites, slates, phyllites, and minor limestone. The argillites are gray, greenish gray, and brown on weathered surfaces, and commonly display two distinct sets of cleavages. The slates are dark gray to black and the phyllites are commonly greenish gray. The graded bedding and cross-bedding are the only sedimentary structures retained in the Manki Formation. In the northern Gandghar Range the upper contact of the Manki Formation is gradational with the overlying Shahkot Formation. Whereas, the lower contact is faulted against the Shekhai and Tanawal Formations.

The Hazara Slates are equivalent to the Manki Formation (Holland et al., 1956), and the Rb/Sr whole-rock age of Hazara is calculated (Crawford and Davies, 1975) to be Precambrian (740$\pm$20 Ma. for one sample and of 930$\pm$20 Ma. for another sample). Similarly 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

In essence the Shahkot Formation consists of limestone, argillite and shale. The limestone occurs at the base of the formation. In the northern Gandghar Range only the basal limestone is exposed (e.g. south of Chontri village). The entire formation is very well exposed in the southern Gandghar Range (Hylland et al., 1988). The limestone is fine to medium grained, medium bedded, yellowish grey on fresh surfaces & brownish

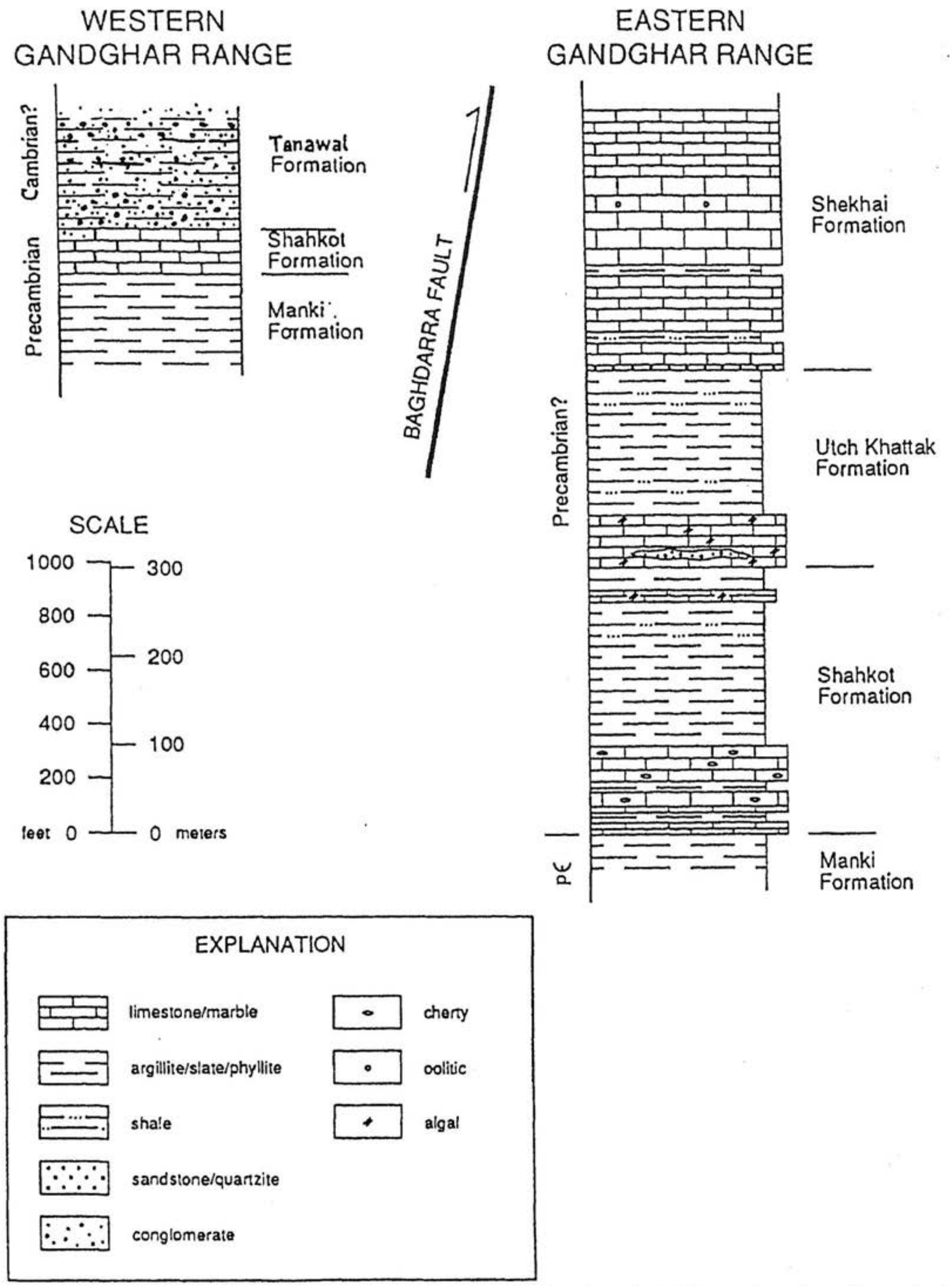

Fig. 3. Stratigraphic column of the eastern (from Hylland et al., 1988) and western Gandghar Range.

grey on weathered surfaces. It contains patches of white chert and is extermely hard. Clasts of the underlying Manki Formation are poorly preserved in it. The maximum thickness of the limestone exposed here is 3 meters. The formation has a gradational contact with the underlying Manki Formation, and an unconformable upper contact with the Tanawal Formation. On the basis of its gradational contact with the underlying Precambrian Manki Formation and an unconformable upper contact with the overlying Cambrian rocks of the Tanawal Formation, the Shahkot Formation is assigned a Pre cambrian age.

Shekhai Formation

The Shekhai Formation is only exposed in the southeastern part of the northern Gandghar Range (Fig. 2). It forms the foot-wall strata of the Baghdarra fault (Figs. 2 & 3). The formation attains its maximum thickness south of the Ali Masjid stream and northwards its outcrop width gets narrower because of slicing by the Baghdarra fault.

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 massive units. The limestone is usually yellowish gray and light gray but brownish gray and light brown or pink beds are also seen. The limestone is locally metamorphosed to white or creamy marble near igneous intrusions.

Argillite and shale are mostly green, greenish gray, thinly laminated and occasionally calcareous.

The base of the Shekhai Formation is not exposed in the northern Gandghar Range. The upper contact of the Shekhai Formation is faulted against the Manki Formation. Based on its relative stratigraphic position in the southern Gandghar Range (Hylland et al., 1988) it is tentatively assigned a late Precambrian(?) age.

Tanawal Formation

The Tanawal Formation is exposed on the southeastern and north western side of the northern Gandghar Range (Fig. 2). 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 conglomerate member is exposed in the western part of the northern Gandghar Range (Fig. 2). The conglomerate consists of pebbles of quartzite and sandstone embedded in a sandy matrix. The quartzite pebbles are dirty white and light green whereas the sandstone pebbles are light green, coarse grained and poorly cemented. The diameter of the pebbles range from 2mm to 30cm. A gradual decrease in the size of the pebbles is observed towards top of the member such that the top most bed is coarse grained sand with no pebbles. Mica flakes have developed around some pebbles in such a manner that they impart an augen structure to the rock. The quantity of mica flakes decreases towards the base of the member. The matrix is mainly composed of coarse quartz grains and fine clay particles.

In northern Gandghar Range, upper contact of basal conglomerate member is faulted against upper quartzite member of the Tanawal Formation (Fig. 2). Whereas, its lower contact is unconformable with basal limestone of the Shahkot Formation.

The middle member is exposed in the eastern part of the northern Gandghar Range. This member consists of an alternating sequence of quartzites and phyllites. The quartzites are white and yellowish white, very hard, medium bedded and cross-bedded in some parts. Occasionally, asymmetric ripple marks are also observed. The phyllites are dark gray, brownish gray and greenish gray.

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. 2). It is dominantly composed of quartzite with shaley partings. The quartzite is medium to thick bedded, white to yellowish white, recrystallized and breaks into sharp angular fragments. It has characteristic brown specks of iron oxide, 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 beds are differentiated by phyllitic partings that are few millimeters to few centimeters thick.

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, the Tanawal Formation is unconformably overlain by the Sherwan Formation (Ahmed, 1990). 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. The whole-rock Rb/Sr age of 516 ± 16 Ma of the Mansehra granite 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, north of Haripur, the Tanawal Formation is unconformably overlain by a sequence of phyllite, quartzite and dolomite of the Sherwan Formation (Ahmed, 1990) 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 along with the country rock. The chemistry of these dikes show that they are the tholeiites of continental flood basalt affinity (Karim and Sufyan, 1989). A similar origin has been proposed for the Panjal Volcanics (Honegger et al., 1982) which are intermediate to basic schistose rocks that occur along the apex and in 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 (K.R. Pogue, pers. comm. 1989) and thus they may be Permian or younger.

STRUCTURE

The structure of the northern Gandghar Range is characterized by three north dipping thrusts (defining a local schuppen structure), a normal fault and two distinct sets of folds.

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. 2). Previously this fault was mapped as a normal contact between the Shekhai and Tanawal Formations (Calkins et al., 1975). 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.

A section exposing the fault in the stream west of the Seri village has some striations and drag folds which indicate that it 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. The Baghdarra fault juxtaposes the Precambrian Manki Formation and the Proterozoic Shekhai and Tanawal Formations (Fig. 2). 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. Drag folds developed in the fault zone indicate that it has a reverse sense of slip. Hylland et al. (1988) have also suggested a reverse-slip dis placement along this fault.

The Sirikot Fault

The Sirikot fault is named after the Sirikot village, which is located approximately 19 km west-northwest of Haripur (Fig. 2). The major portion of the fault juxtaposes Manki vs: 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 is excellently exposed in a section cut by the Tarbela lake water. It is also exposed in a road-cut section, on the Sirikot-Haripur road, about 4 km east of Sirikot. The fault dip varies between 70^{o} to vertical. The associated drag folds indicate a reverse-slip movement. The fault zone is characterized by the black graphitic schistose rocks containing boulders of Shekhai limestone in it.

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 Sirikot (Fig. 2). The fault juxtaposes Manki Formation with the basal conglomerate member of the Tanawal Formation. 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. The fault is nearly vertical, and in one section, i.e., southwest of the Darrah stream, the fault dips in opposite direction.

The Darrah fault 1 (Figs. 2 and 4) 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^{o} 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 (Fig. 4).

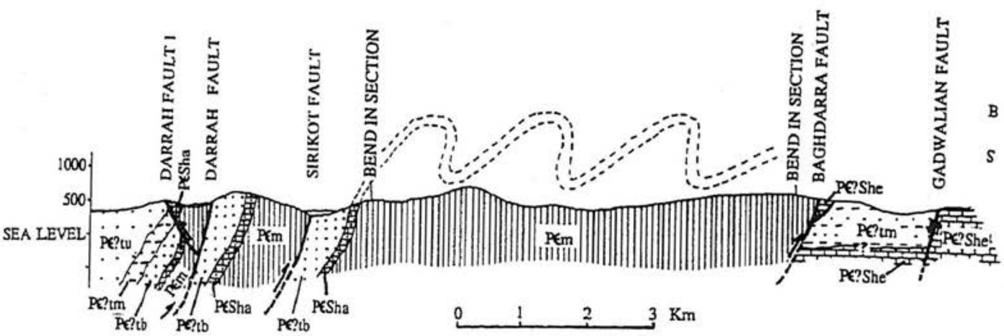

Fig. 4. Cross-sectional view of the northern Gandghar Range along line AB located in Fig. 2. No vertical exaggeration. Symbols are same as in Fig. 2.

Folds

Two distinct sets of folds have been recorded in the northern Gandghar Range. The first set (F_2) includes mesoscopic and macro scopic folds (Fig. 5) which are dominantly developed in the Manki and Tanawal Formations. These folds are northeast oriented and commonly have fractured hinges. These folds are related to a later phase (D_2) of deformation. The other set of folds (F_1) includes microscopic and mesoscopic folds which are exclusively developed in the Shekhai limestone. They are mostly northwest oriented and are considerably more ductile in nature.

A careful examination of the thinly bedded Shekhai Limestone reveals that each bed has some darker bands that are folded within the single bed. This intra-laminar folding shows that the existing bedding surfaces are S_1 instead of S_0. The original bedding surfaces may be the darker bands which now form the fold closures within these bedding surfaces, i.e., S_1. These folds are clearly related to a different deformational phase.

DISCUSSION

Since the Baghdarra fault truncates the northern extension of the Gadwalian fault suggesting that 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.

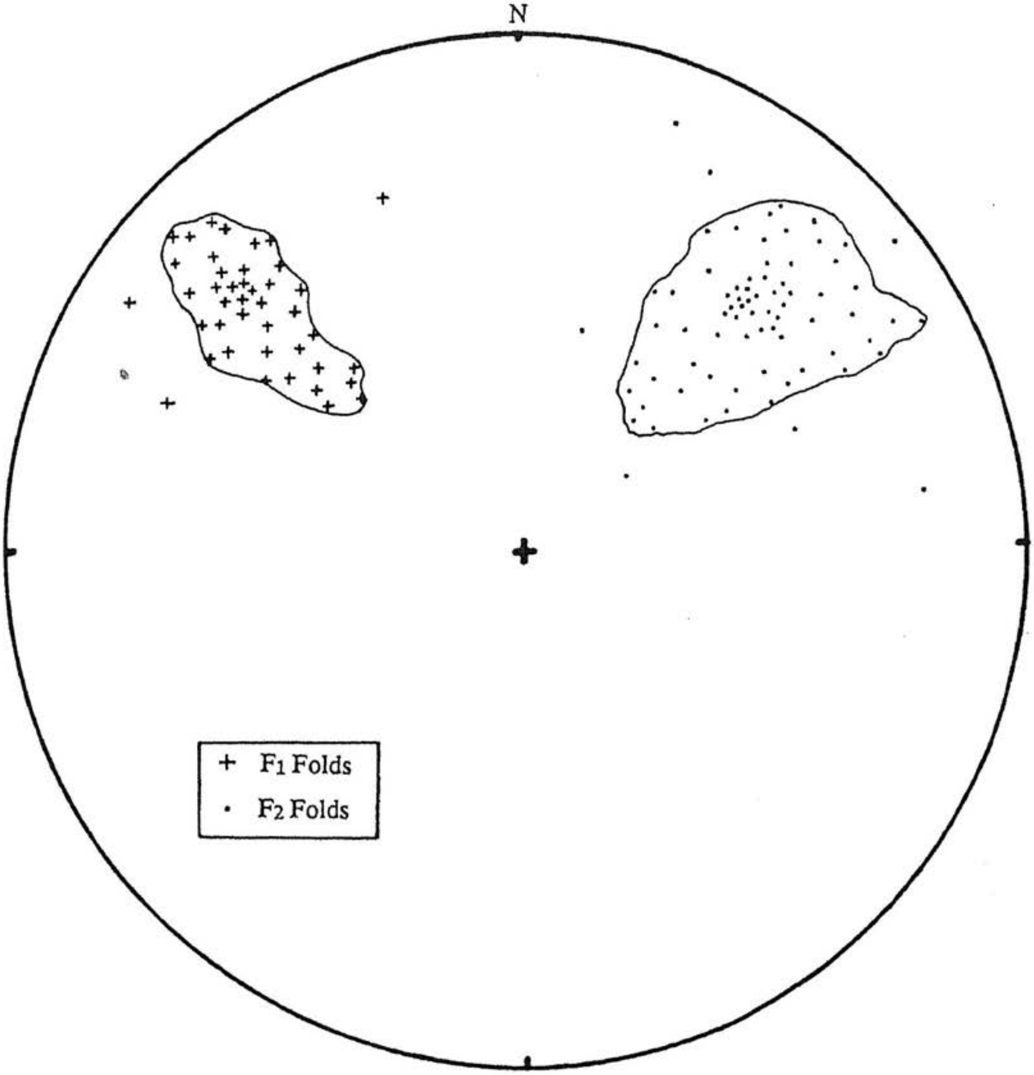

Fig. 5. Equal area stereonet plot of the fold axes of the northern Gandghar Range. F_1 and F_2 are two distinct generations

These faults have a few things in common. Firstly, their attitude is more or less the same. Secondly, the basal sequence of their hangingwalls is always the Manki Formation. And thirdly, they do not cross-cut one another. These features suggest that they are part of an imbricate system, emerging from a common detachment surface that exists at the base of or within the Manki Formation (Fig. 4).

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. This piggy-back style of thrusting in the range is also supported by the geometrical elements (dip angles) of the rocks. The dip angle 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.

The rocks of the northern Pakistan are grouped into the "internal" and "external" zones (Coward et al., 1988) on the basis of their grade of metamorphism. The internal zone is characterized by having the high grade metamorphic rocks with their southern limit at the Panjal fault (Fig. 1). Westward the Panjal fault is represented by the Khairabad fault (Yeats and Hussain, 1987). The external zone is characterized by having unmetamorphosed sediments with their northern limit at the Nathia Gali fault. The Nathia Gali fault is laterally continuous and is equivalent to the Cherat fault (Fig. 1), since both of them are the southern most thrusts which bring the Precambrian basement rocks to the surface.

The rocks between the Khairabad-Panjal fault and Nathia Gali- Cherat fault are either very low in metamorphic grade (green schist facies) or are unmetamorphosed sediments. It is, therefore, suggested that the internal and external zones 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 can be divided into two blocks: the western and the eastern Gandghar Range, and the two are juxtaposed along the Baghdarra fault. The western Gandghar Range is in itself composed of three sub-structural blocks separated by the Sirikot and Darrah faults. The three blocks located north of the Baghdarra fault i.e. the western Gandghar Range, have same stratigraphy. The eastern Gandghar Range is having a complete succession of Precambrian to Cambrian rocks (Hylland et al., 1988) including the basal Manki Formation followed by the Shahkot Formation, Utch Khattak Formation, Shekhai Formation and the Tanawal Formation (Fig. 3). 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. 3).

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