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STRATIGRAPHY AND STRUCTURE OF THE SOUTHERN GANDGHAR RANGE, PAKISTAN

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ABSTRACT

The southern Gandghar Range is composed of a succession of marine strata of probable Proterozoic age, consisting of a thick basal argillaceous sequence (Manki Formation) overlain by algal limestone and shale (Shahkot, Utch Khattak, and Shekhai Formations). These rocks are thrust southeastward over the Kherimar Hills succession along the Panjal fault. The Gandghar Range and Kherimar Hills successions correlate with the northern and central blocks of the Attock-Cherat Range, respectively, indicating that the combined Panjal-Khairabad fault juxtaposes two major, laterally continuous structural blocks.

The rocks of the southern Gandghar Range occur in two structural blocks juxtaposed along the Baghdarra fault. The hanging wall consists entirely of isoclinally-folded Manki Formation, while the footwall consists of the complete Manki-Shekhai succession which has been deformed into tight, northeast-plunging, generally southeast-verging disharmonic folds. The Baghdarra fault is apparently deformed along with the footwall strata, indicating that it is older than, and is being carried piggy-back style on, the Panjal fault. Phyllite near the Baghdarra fault displays asymmetric deformation of foliation around garnet porphyroblasts, kink bands, and a poorly-developed s-c fabric. These features are consistent with conditions of dextral shear, indicating reverse slip displacement along the fault.

INTRODUCTION

The Gandghar Range is located in the fold-thrust belt at the southern margin of the Pakistan Himalaya (Fig. 1). To the south, Mesozoic and lower Tertiary marine strata are thrust over the molassic Murree Formation, which is at least in part of early Miocene age, along the Main Boundary thrust. To the north, the Main Mantle thrust separates Precambrian Paleozoic strata, intruded by granitic rocks ranging in age from Paleozoic to Miocene (Maluski and Matte, 1984), from the Kohistan island-arc sequence still farther north, which forms a vast thrust block delimiting the northern exposure of the Indus suture zone (Lawrence et al ., in press). To the east, the fold-thrust belt of southeastern Hazara forms part of the western limb of the Hazara-Kashmir syntaxis. The Gandghar Range is flanked on the southeast and northwest by the Plio-Pleistocene Campbellpore and Peshawar basins, respectively.

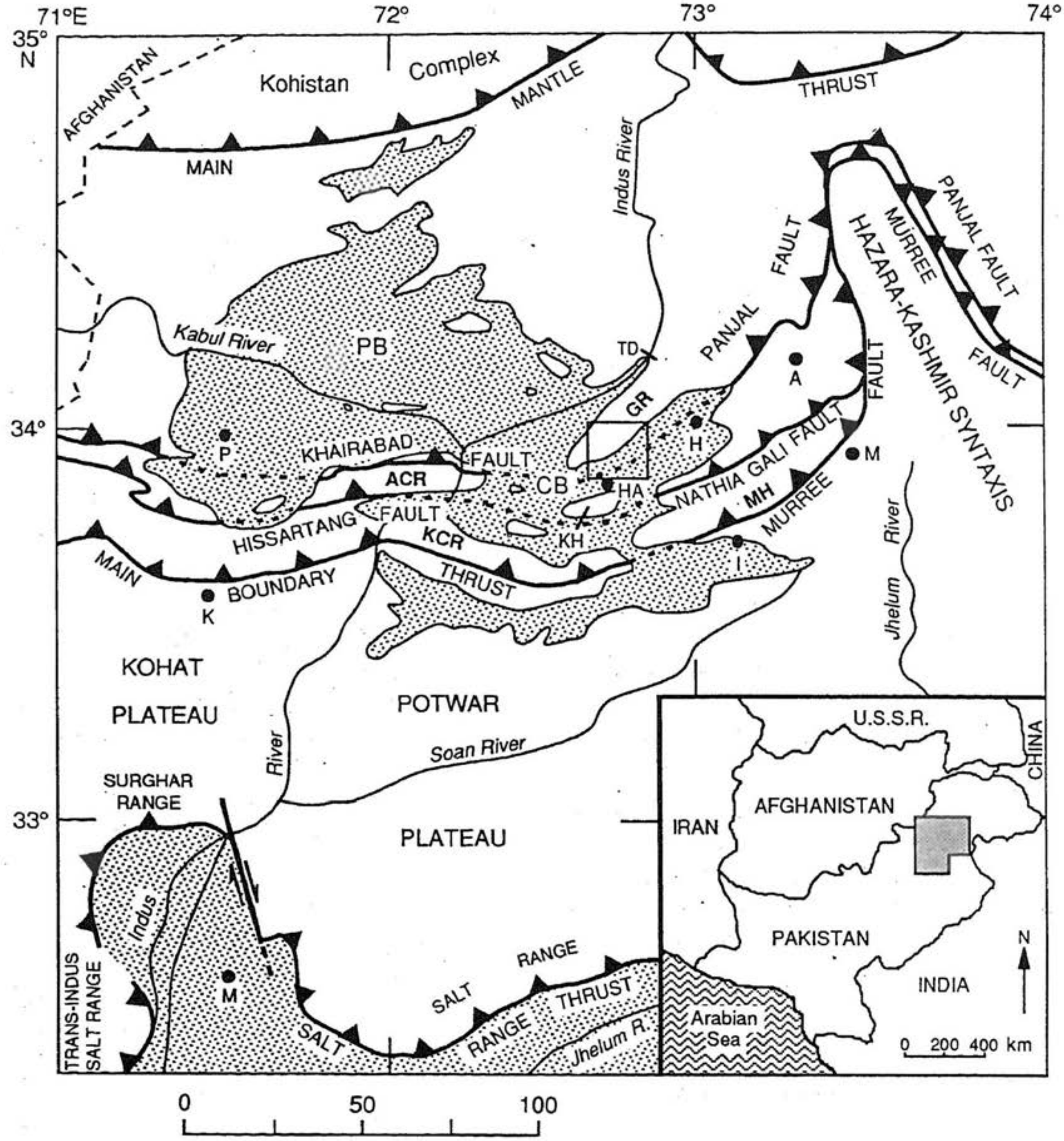

Fig. 1. Tectonic map of northern Pakistan, showing major structural boundaries. P = Peshawar, PB = Peshawar basin; TD = Tarbela Dam; A = Abbottabad; M = Murree; I = Islamabad; MH = Margala Hills; H = Haripur, GR = Gandghar Range, HA = Hassan Abdal; KH = Kherimar Hills; CB = Campbellpore basin; ACR = Attock-Cherat Range; KCR = Kala Chitta Range; K = Kohat; M = Mianwali. Area enclosed in rectangle shown in Figure 2.

The Gandghar Range, Attock-Cherat Range, Kala Chitta Range, and Margala Hills comprise the Hill Ranges, which are separated from each other by alluvial plains (Fig. 1). The rocks of the Hill Ranges, transitional between unmetamorphosed foreland basin strata to the south and high-grade metamorphic and plutonic rocks to the north, have been brought to the surface along major ramp faults (Yeats and Lawrence, 1984) rising from a single detachment surface that based on seismicity, extends beneath the entire area from the Salt Range to the Main Mantle thrust (Seeber et al., 1981). South-directed thrusting and uplift of the Hill Ranges was initiated after deposition of the Murree Formation but prior to 2.8 Ma, the oldest magnetostratigraphic dates of the base of the Peshawar basin fill at the western end of the Attock-Cherat Range (Burbank and Tahirkheli, 1985). Sedimentation in the Campbellpore basin began by at least 1.8 Ma (Burbank, 1982), possibly due to ponding behind the emergent Kala-Chitta Range which was being uplifted along the Main Boundary thrust (D.W. Burbank and R.G.H. Raynolds, written comm., 1986, in Yeats and Hussain, in press), and continued until about 0.6 Ma (Burbank and Tahirkheli, 1985).

This paper summarizes the results of recent mapping in the southern Gandghar Range. The mapping project was undertaken with the intent of determining the stratigraphic and structural relationships of the rocks that underlie the Gandghar Range at both the local and regional scale.

PREVIOUS WORK

The earliest published work describing the geology of the Gandghar Range is that of Wynne (1879), whose paper included a geological sketch map of Hazara at a scale of 1 in = 8 mi and three cross sections through the Gandghar Range. Middlemiss (1896) published a geological map of Hazara from Black Mountain on the west bank of the Indus River eastward to the Kunhar River at a scale of 1/2 in = 1 mi. Both Wynne and Middlemiss made reference to the limestones in the Gandghar Range, but were uncertain of their age and relative stratigraphic positions. In his paper on the geology of the Attock district, Cotter (1933) assigned a pre-Late Carboniferous, possibly Cambrian or Precambrian, age to the slates exposed at the southern end of the Gandghar Range. The northern part of the Gandghar Range was mapped during a detailed geological study of Hazara from 1961 to 1965 by the Geological Survey of Pakistan and the U.S. Geological Survey (Calkins et al., 1975). The Gandghar Range was mapped in its entirety by Tahirkheli (1971), who considered all rock units to be Paleozoic, correlative with lithologically similar units in the Attock-Cherat Range and southeastern Hazara.

STRATIGRAPHY

As shown in Figures, 2, 3 and 4, the stratigraphic succession exposed in the southern Gandghar Range consists of a thick, basal argillaceous sequence (Manki Formation) overlain by algal limestone and shale (Shahkot, Utch Khattak, and Shekhai Formations). A Proterozoic age for this succession, as suggested by Talent and Mawson (1979), is supported by the lack of fossils, a correlation of the Manki Formation with the Hazara Formation, which is of probable Proterozoic age, the commonly graditional nature of the contacts throughout the succession. Age constraints are discussed more fully below in the "Discussion" section. The entire succession contains basic igenous intrusions of uncertain age.

Tahirkheli (1970) applied the names "Manki Slate", "Shahkotbala Formation", "Khattak Limestone", and "Shekhai Limestone" to lithostratigraphic units in the Attock-Cherat Range. Later, Tahirkheli (1971) applied the names "Sirikot Slate", "Mohat Nawan Limestone", "Baghdarra Limestone", and "Pir Than Limestone" to lithostratigraphic units in the Gandghar Range and correlated them, respectively, with the units in the Attock-Cherat Range listed above. In the Attock-Cherat Range, the names "Manki Formation", "Shahkot Formation", "Utch Khattak Formation", and "Shekhai Formation" are modified from the names applied by Tahirkheli (1970), and are currently used by the Geological Survey of Pakistan. Based on the

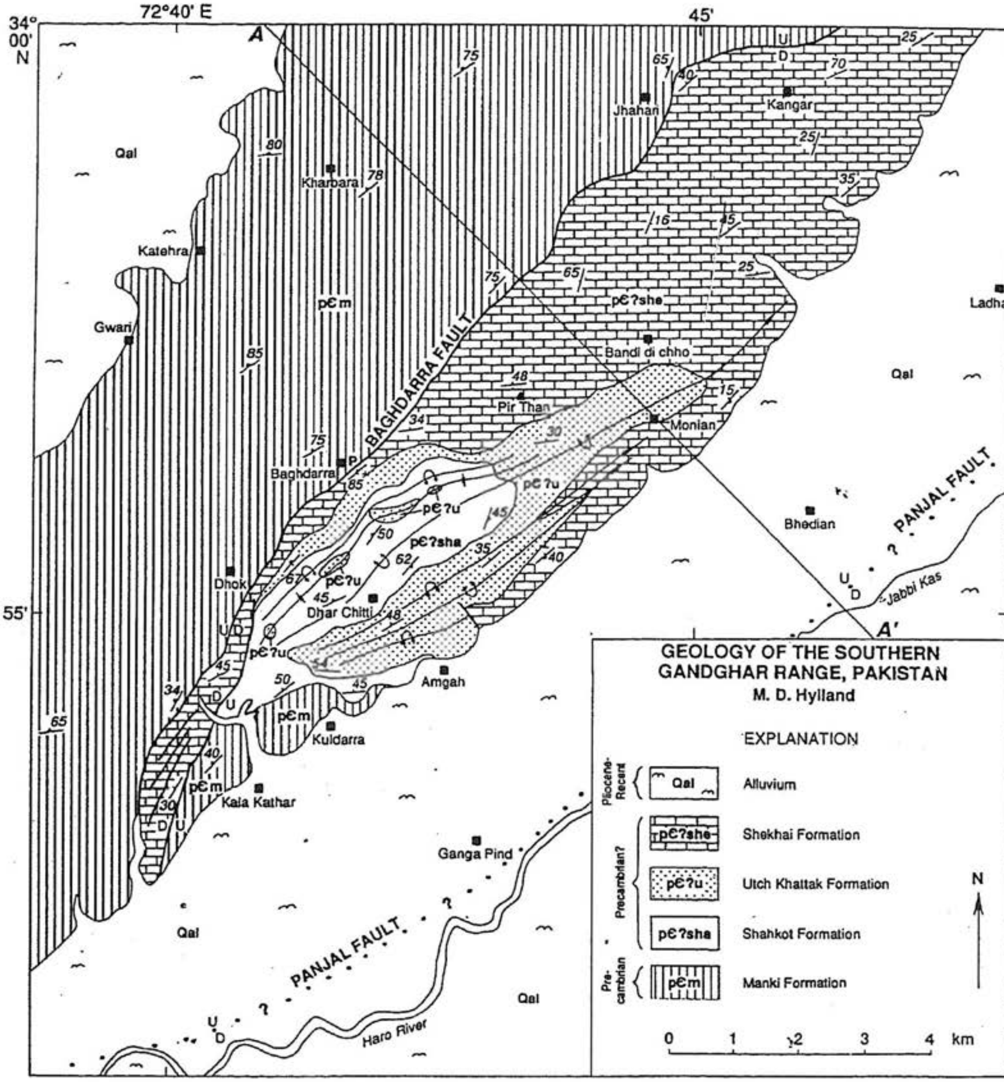

Fig. 2. Simplified geologic map of the southern Gandghar Range. Base from Survey of Pakistan topographic sheets 43 C/9 and 43 C/13. A-A' is line of cross section shown in Figure 5. P = oriented phyllite sample locality discussed in text.

correlations made by Tahirkheli (1971), these modified names are applied to the Gandghar Range in preference to the local names of Tahirkheli (1971) to create a more regionally consistent stratigraphic nomenclature. A comparison of the Gandghar Range lithostratigraphic unit names with those of previous workers is given in Table 1.

Manki Formation

The Manki Formation is continuously exposed over the entire western slope of the southern Gandghar Range in the hanging wall of the Baghdarra fault (Fig. 2). It is also exposed

TABLE 1. COMPARISON OF LITHOSTRATIGRAPHIC UNIT NAMES USED IN THIS REPORT WITH THOSE OF PREVIOUS WORKERS

Wynne (1879)	Middlemiss (1896)	Cotter (1933)	Tahirkheli (1971)	Calkins et al (1975)	This report
Attock Slates	Slate Series	Attock Slates	Pir Than Limestone	Kingriali Formation	Shekhai Formation
			Baghdarra Limestone		Utch Khattak Formation
			Mohat Nawan Limestone		Shahkot Formation
			Sirikot Slate	Hazara Formation	Manki Formation

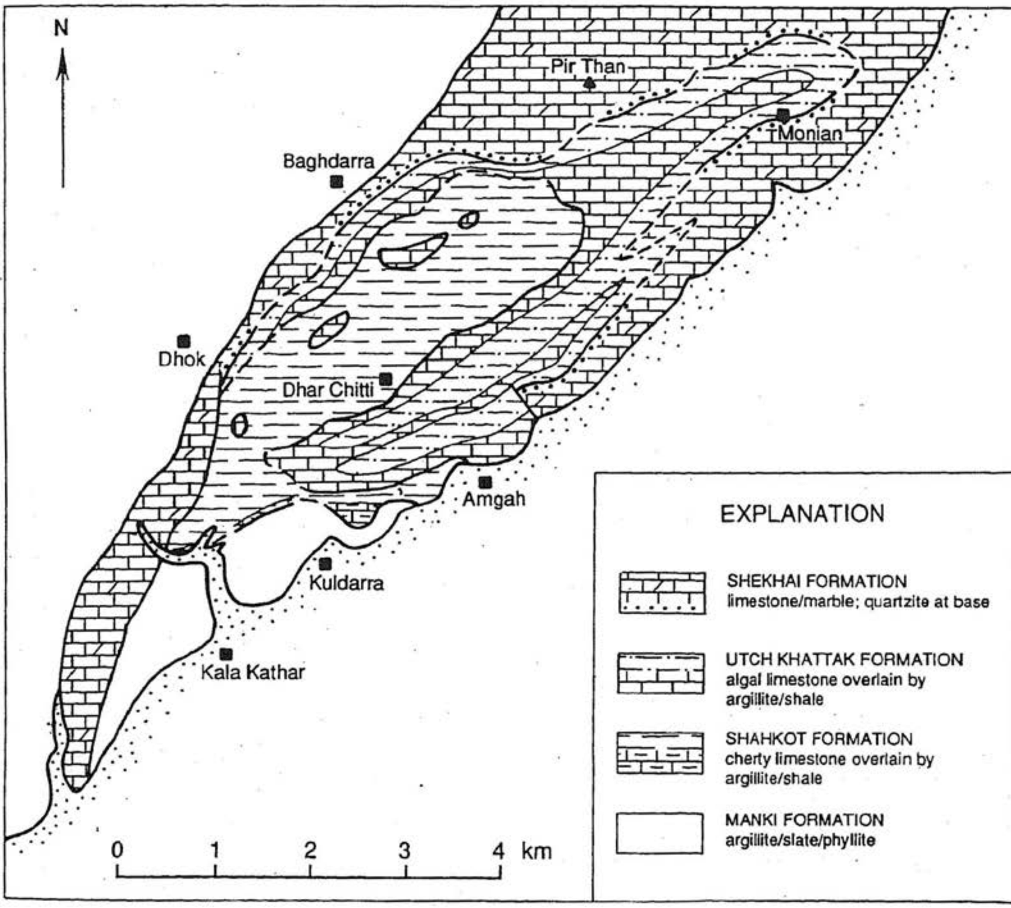

Fig. 3. Lithologic map of the southern Gandghar Range in the vicinity of Dhar Chitti, showing basal Shekhai quartzite and distribution of limestone versus argillite and shale in Shahkot and Utch Khattak Formations. Formation contacts (heavy lines) dashed where approximately located.

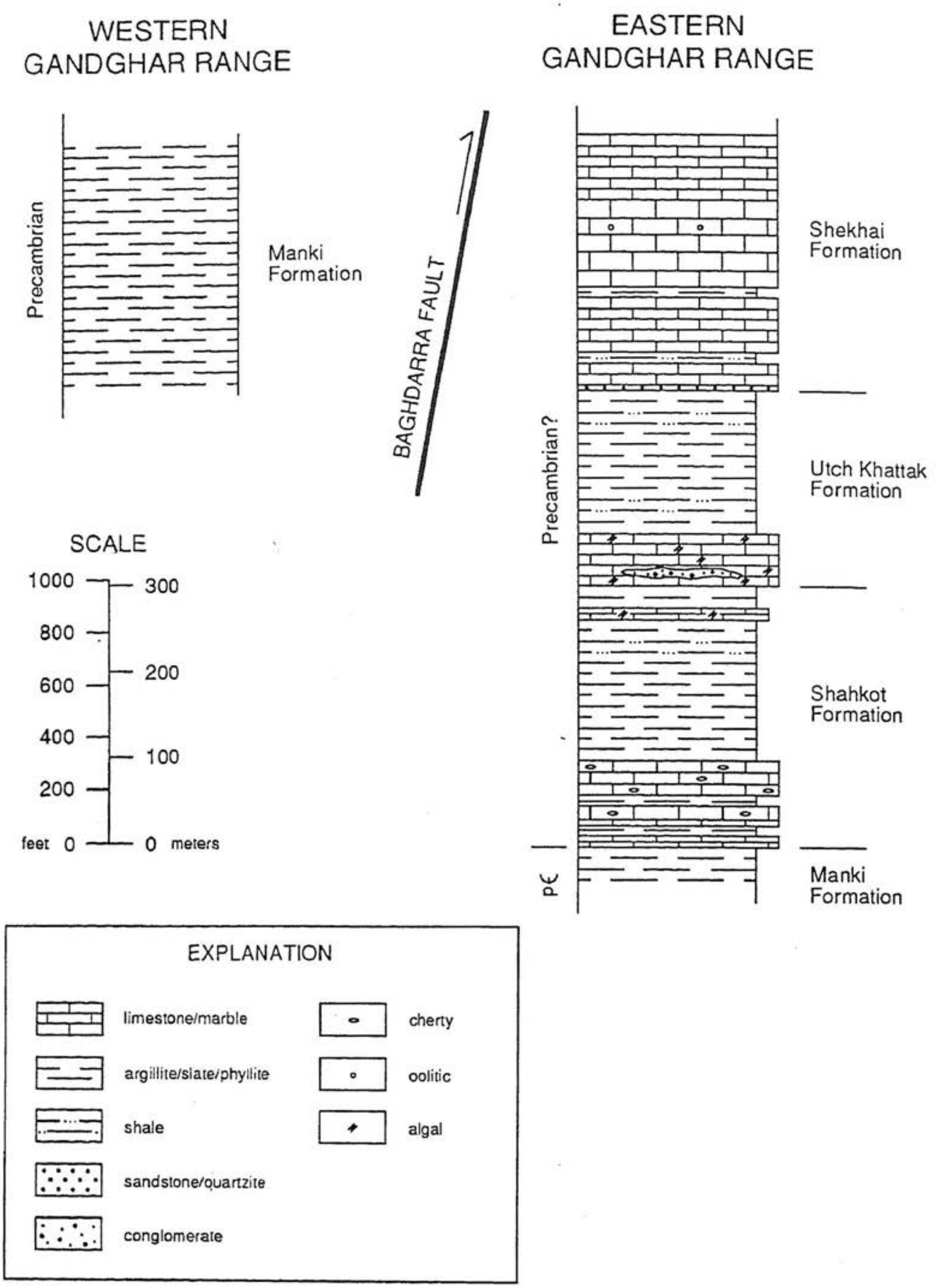

Fig. 4. Composite stratigraphic column showing rock units comprising two structural blocks juxtaposed along the Baghdarra fault in the southern Gandghar Range.

in the footwall of the Baghdarra fault in the vicinity of Kala Katha in the southeastern part of the range. The top of the Manki is gradational into the overlying Shahkot Formation. The relationship of the base of the Manki with underlying rocks is less clear. The base may be exposed adjacent to a 100 m- to 1 km-wide belt of carbonaceous slate and graphitic phyllite in the hanging wall of the Baghdarra fault. Similar lithologies exposed along the Indus River north of the Gandghar Range were assigned by Calkins et al. (1975) to the Salkhala Formation, the type section being a thick sequence of carbonaceous slate, graphitic phyllite, and marble that underlies the Dogra Slates in Kashmir (Wadia, 1934). If the carbonaceous slate and graphitic phyllite of the Gandghar Range are true Salkhala Formation, then the Manki is gradational with the underlying rocks in a relationship analogous to the contact between the Dogra Slates and Salkhala Formation in Kashmir. However, the Salkhala lithologies exposed in the Gandghar Range may be Manki Formation that has been locally metamorphosed by movement along the Baghdarra fault. If the latter is true, the base of the Manki is not exposed. The thickness of the Manki Formation is uncertain due to isoclinal folding. However, outcrop width in the Gandghar Range implies a thickness in excess of 1000 m.

The Manki Formation is composed of argillite, slate and phyllite. The rocks are dark greenish gray or dark gray on fresh surfaces and olive gray, dark gray, or reddish brown on weathered surfaces. Argillite and slate commonly display two sets of cleavage that impart a splintery texture to the rock. One set, which is parallel to bedding, is dominant and may represent bedding fissility, as suggested by Latif (1969). The other set is axial-plane cleavage. Although rare, perfect slaty cleavage is present locally, such as at the exposure of Manki near Kala Katha. Graded bedding was the only sedimentary structure observed in the Manki. An increase in metamorphic grade to the north is indicated by extensive quartz veining and a petrological change from argillite and slate to phyllite. Chevron folds and kink bands occur in the phyllite, indicating compression roughly parallel to foliation.

Shahkot Formation

Exposure of Shahkot Formation are restricted to the southeastern Gandghar Range in the footwall of the Baghdarra fault (Fig. 2). In the vicinity of Dhar Chitti, Argillite of the upper part of the Shahkot is exposed in the core of a north-plunging anticline, and limestone of the lower part of the Shahkot caps the rounded hill approximately 500 m northeast of Kuldarra (Fig. 3). The Shahkot is approximately 300 m thick, and both the lower and upper contacts are conformable with the underlying Manki Formation and overlying Utch Khattak Formation, respectively.

The Shahkot Formation consists of limestone, argillite, and shale (Figs. 3 and 4). A limestone unit approximately 100 m thick at the base of the formation is fine- to medium-grained, thin- to medium-bedded, yellowish gray on fresh surfaces and brownish gray on weathered surfaces, contains patches of white chert, is extremely hard, and has subordinate interbeds of dark greenish gray argillite and shale. Overlying the limestone is dark greenish gray, thinly laminated argillite. The argillite is similar in appearance to argillite of the Manki Formation and has the same splintery texture due to two sets of cleavages. Enclosed within the argillite near the top of the formation is a thin, discontinuous bed of algal limestone.

Utch Khattak Formation

Exposures of Utch Khattak Formation are restricted to the southeastern Gandghar Range in the footwall of the Baghdarra fault (Fig. 2). The Utch Khattak has conformable contacts with the underlying Shahkot Formation and overlying Shekhai Formation, and is 200–250 m thick.

The Utch Khattak Formation is composed of limestone, argillite, and shale (Figs. 3 and 4). Limestone occurs at the base of the formation and is quite distinctive. It is composed of fine- to medium-grained, thin-bedded, blush gray to dark gray limestone enclosed in a wavy meshwork of brown, resistant, clayey material. Calcite veins crosscut both the carbonate and clay material, and dissolution of the calcite has given the surface of the clay material an etched appearance. In places, stromatolites are well developed. The limestone varies in thickness from approximately 10 m to 70 m and is overlain by dark greenish gray, thinly laminated argillite with subordinate interbeds of light gray to light brown thin-bedded shale.

An intraformational conglomerate within the Utch Khattak Formation contains clasts of Manki Formation and Shahkot Formation, indicating that the Utch Khattak is younger than both. This conglomerate is exposed in both the Gandghar Range, at the mouth of the canyon near Amgah, and the Attock-Cherat Range, just west of the Indus River (Tahirkheli, 1970).

Shekhai Formation

The Shekhai Formation is exposed in the footwall of the Baghdarra fault (Fig. 2). North of Pir Than, the Shekhai forms virtually the entire eastern half of the range up to latitude 34° N. Here, the trace of the Baghdarra fault is closer to the range front, resulting in a narrower outcrop width of the Shekhai. The thickness of the Shekhai is uncertain since the top is either truncated by the Baghdarra fault or not exposed. Also, the massive nature of much of the limestone precludes good structural control, so that the intensity of folding is not known. However, outcrop width implies a thickness of at least 300 m. The Shekhai conformably overlies the Utch Khattak Formation.

The Shekhai Formation is composed of limestone and marble with subordinate argillite, shale, and quartzite (Figs. 3 and 4). Limestone is fine- to medium-grained, thin-bedded to massive, and occurs in a variety of colors, including light gray, dark gray, light brown, and pink. The weathered surface is typically light gray or light brown and relatively smooth. Locally, the limestone is oolitic. Small patches of white marble are associated with igneous dikes, suggesting local thermal metamorphism of the limestone. A bed of pink and white quartzite up to 1 m thick occurs at the base of the Shekhai, and intercalations of dark greenish gray, thinly laminated argillite and light gray shale occur throughout the formation.

Intrusive Rocks

The only igneous rocks in the Gandghar Range are basic dikes and sills that intrude all of the strata. The intrusive bodies are generally less than 2 m thick, are composed of diabase, and are structurally deformed along with the country rock. In the adjacent Peshawar basin, diabase intrusions occur in strata as young as Carboniferous (K.R. Pogue, pers. Comm), so it is likely that the age of the Gandghar Range intrusions is post-Carboniferous. These igneous rocks may be correlative with the Panjal Volcanics, intermediate to basic schistose rocks that occur along the limb of the Hazara-Kashmir syntaxis and which are conformably overlain by Triassic marine strata (Bossart et al., 1988).

STRUCTURE

The Gandghar Range strata are thrust over Precambrian flysch and Jurassic and Tertiary limestone of the Kherimar Hills succession along the Panjal fault, which lies beneath alluvium of the Campbellpore basin southeast of the Gandghar Range front. In the southern Gandghar

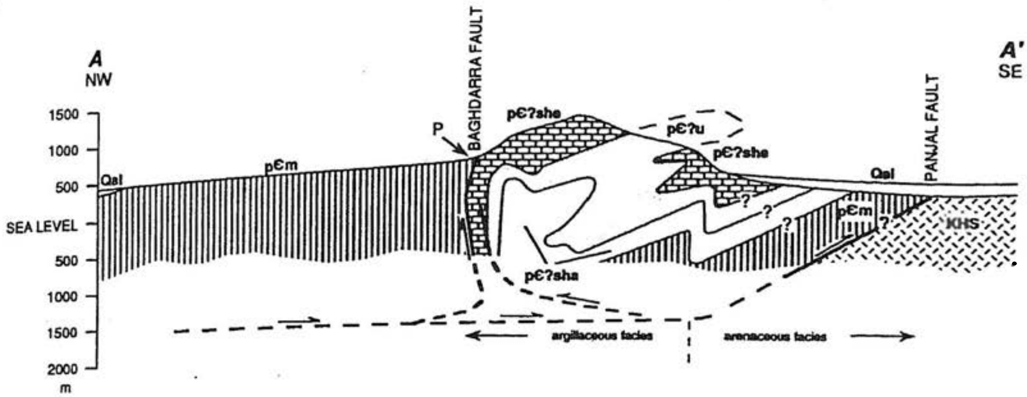

Fig. 5. Structural cross section of the southern Gandghar Range, with structures projecting into section from up-plunge direction. No vertical exaggeration. Ramp-and-flat geometry of Panjal fault shown diagrammatically. Location of ramp based on mechanical strength difference between argillaceous and arenaceous strata as discussed in text. KHS = Kherimar Hills succession; P = oriented phyllite sample locality discussed in text. See Figure 2 for explanation of other symbols and location of line.

Range, the strata occur in two structural blocks that are juxtaposed along the Baghdarra fault, named after Baghdarra village, which is located approximately 3 km southwest of Pir Than (Fig. 2). the hanging wall of the Baghdarra fault is composed entirely of isoclinally-folded Manki Formation. In the footwall of the Baghdarra fault, the complete Manki-Shekhai succession has been deformed into a series of tight, northeast-plunging folds. The disharmonic nature of the folds is likely due to the significant volume of argillite and shale within the Shahkot and Utch Khattak Formations, which has resulted in attenuation of overturned fold limbs and accumulation of material in fold hinges. As shown in the cross section in Figure 5, most of the folds are southeast-vergent, which would be expected if southeast-directed thrusting has occurred along this segment of the Panjal fault. One exception, however, is a northwest-vergent anticline adjacent to the Baghdarra fault. This structure appears to be a fault propagation fold related to a backthrust, movement along which has resulted in overturning of the northwest limb of the anticline. Although no definitive indications of fault dip could be found, the Baghdarra fault must also be overturned if it is assumed that it cuts consistently up dip. Deformation of the Baghdarra fault along with footwall strata suggests that the Baghdarra fault is older than the Panjal fault and is being carried piggy-back style by the latter.

Oriented phyllite samples collected from the narrow zone of carbonaceous slate and graphitic phyllite adjacent to the Baghdarra fault near Baghdarra village (see Figs. 2 and 5 for sample locality) contain small (0.5-1 mm diameter) subhedral to euhedral garnet porphyroblasts. As shown in Figure 6, the primary foliation is deformed asymmetrically around the porphyroblasts. Also, kink bands and a poorly-developed s-c fabric are present. These features are consistent with conditions of dextral shear, indicating reverse slip displacement along the Baghdarra fault. Despite the absence of pinwheel garnets and other indicators of internal deformation in the porphyroblasts, the asymmetry of the deformed foliation suggests that the porphyroblasts may be syntectonic, possibly forming at the same time as the kink bands and s-c fabric in response to movement along the fault.

The amount of displacement along the Baghdarra fault is uncertain. However, a thin limestone unit (Sobrah Formation) that overlies the Manki Formation near Tarbela Dam is considered to be correlative with the Shekhai Formation, Based on lithologic similarties (K.R.

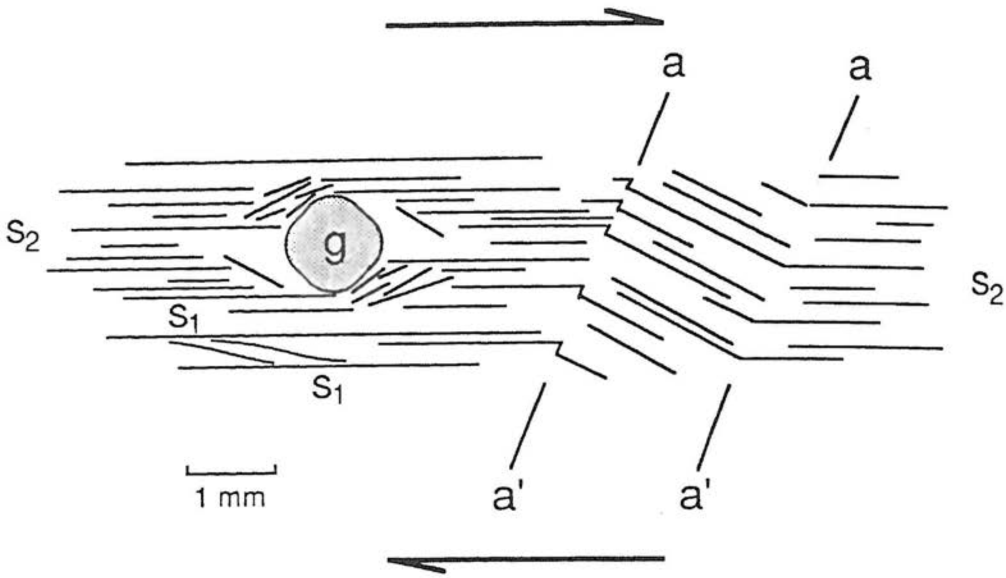

Fig. 6. Simplified line drawing of photomicrograph of oriented (up is to right) phyllite sample from near Baghdarra fault. Shear-sense indicators include asymmetric deformation of primary foliation (S_2) around garnet porphyroblasts (g), kink bands (between boundaries a-a'), and rotation of S_1 between shear planes parallel to S_2, resulting in a poorly-developed s-c fabric. Features are consistent with conditions of dextral shear. See Figs. 2 and 5 for location of sample.

Pogue, pers. comm.). If this is the case, then the great contrast in thickness between the Sobrah and Shekhai Formations could be due to a large amount of displacement along the Baghdarra fault.

DISCUSSION

Previously, the basal sequences on both sides of the Panjal fault were considered to be the same unit. For example, Calkins *et al* (1975) mapped both as "Hazara Formation". However, the two sequences differ markedly in lithology and degree of metamorphism. The sequence in the footwall of the Panjal fault in the vicinity of Hasan Abdal and Haripur is arenaceous and shows no evidence of metamorphism, while the sequence in the hanging wall of the Panjal fault in the Gandghar Range is argillaceous and displays greenschist facies metamorphism. The basal sequence of the Gandghar Range is identical to the Manki Formation of the northern Attock-Cherat Range, whereas the basal sequence of the Hasan Abdal-Haripur area is identical to the Dakhner Formation of the Attock-Cherat Range. Therefore, the basal sequence exposed on the north (hanging wall) side of the Panjal fault should be referred to as "Manki Formation", restricting the term "Hazara Formation" to the basal sequence exposed on the south (footwall) side of the Panjal fault. As suggested by Yeats and Hussain (1987), the Hazara Formation is correlative with the Dakhner, as one can be traced into the other.

Davies (1963) and Latif (1969) have divided the Hazara Formation in the Haripur-Abbottabad area into two separate facies. The southern facies, dominated by arenaceous strata with subordinate algal limestone and gypsum exhibits cross bedding, interference and oscillation ripple marks, and desiccation cracks, and is probably a shallow-water deposit (Latif, 1969).

In contrast, the northern facies is dominated by argillaceous strata, exhibits graded bedding, flute casts,flow casts and fucoids, is devoid of cross bedding, ripple marks, desiccation cracks, algal limestone or gypsum, and is probably a deep-water deposit (Latif, 1969). Tahirkheli (1982) has suggested that the Manki Formation of the Attock-Cherat Range is correlative with the Hazara Slate (Hazara Formation) of the Hazara district, and Yeats and Hussain (1987) have suggested that the Manki and Dakhner Formations are stratigraphically equivalent. The strong similarities between the northern-facies Hazara Formation and the Manki Formation support both of these suggestions.

The age of the Hazara Formation is Precambrian on the basis of Rb/Sr whole-rock model ages of 739 ± 9 Ma and 951 ± 8 Ma (Crawford and Davies, 1975, recalculated in Baig et al., 1988). Additionally, in the vicinity of Abbottabad, basal beds of the overlying Abbottabad Formation, which is Cambrian based on the presence of hyolithids and *Chancelloria* sponge spicules in the upper part of the formation (Latif, 1972; Rushton, 1973), contain clasts of Hazara (Latif, 1974). No definitive fossils have ever been found in the Hazara Formation. "Fossil-like objects" resembling inarticulate brachiopods have been reported to occur in the Hazara (Davies and Ahmad, 1963), but these and similarly cryptic objects in the Hazara reported by Latif (1969) remain to be positively identified and may simply be algae (A.J. Rowell, in Davies and Ahmad, 1963). Pelecypod and gastropod shells found in a limestone within the Attock Shale (Dakhner Formation) by Tahirkheli (1970) were interpreted to occur in Cretaceous or Paleocene limestone that overlies the Dakhner unconformably or is in thrust contact with the Dakhner (Yeats and Hussain, 1987). No fossils of any kind have been reported from the Manki Formation.

Several lines of indirect evidence point to a Proterozoic age for the Shahkot and Utch Khattak formations, and a Proterozoic or possibly early Cambrian age for the Shekhai Formation. First, the only organic features preserved in these rocks are stromatolites and other algal features commonly found in Precambrian rocks. Second, the Sobrah Formation, which is probably correlative with the Shekhai Formation, is unconformably overlain by the Tanawal Formation (K.R. Pogue, pers. comm.) which, in turn, is intruded by the Mansehra Granite. The Mansehra Granite has yielded a Rb-Sr whole rock age of 516 ± 16 Ma (Le Fort et al., 1980), and therefore the Tanawal Formation is Middle Cambrian or older. This leaves open the possibility that the Shekhai and Sobrah Formations could be as young as Cambrian. Third, the quartzite at the base of the Shekhai Formation may represent a disconformity, suggesting that a significant amount of time elapsed between deposition of the Utch Khattak Formation and the Shekhai.

The algal nature of the limestone in the Shahkot and Utch Khattak Formations, the presence of quartzite and oolitic limestone in the Shekhai Formation, and the significant volume of shale in all three formations suggest that they were deposited in relatively shallow water. Since the Manki Formation appears to be a deep-water deposit, the complete succession records a general shallowing of the depositional basin.

In terms of regional metamorphism, the biotite-garnet isograd is located considerably north of the Gandghar Range (Calkins et al., 1975), with Gandghar Range rocks occurring in the chlorite zone of the greenschist facies. Since garnet-bearing rocks in the southern Gandghar Range occur only within the narrow zone adjacent to the Baghdarra fault, it is possible that they are the result of frictional shear heating associated with movement along the fault. Shear heating has been considered to be at least partly responsible for garnet growth in rocks adjacent to the Main Central thrust in Nepal (Arita, 1983) and Alpine fault in New Zealand (Johnston and White, 1983). However, while not precluding local shear heating, recent fission track data indicate that the metamorphic zonation near the Alpine fault is due to differential uplift rates, with maximum uplift occurring adjacent to the fault (Kamp et al., in Press, 1989). A study involving detailed mapping, systematic sampling, and geochemistry could help resolve the question of whether movement along the Baghdarra fault has caused local metamorphism of Manki Formation or brought Salkhala Formation to the surface.

Tahirkheli (1971) correlated the rocks of the Gandghar Range with lithologically similar units in the Attock-Cherat Range and also implied that the two ranges were related structurally. More recently, detailed mapping in the Attock-Cherat Range led Hussain (1984) to reverse the relative stratigraphic positions of the Manki Slate (Manki Formation) and Shahkotbala Formation (Shahkot Formation) established by Tahirkheli (1970), and Yeats and Hussain (1987) have provided a structural framework with which to compare the Attock-Cherat Range and the Gandghar Range. It is now apparent that the stratigraphic successions of the Gandghar Range and the northern block of the Attock-Cherat Range are identical. Furthermore, the central block of the Attock-Cherat Range, separated from the northern block by the Khairabad fault, contains virtually the same sequence as the Kherimar Hills succession. This supports the suggestion by Yeats and Hussain (1987) that the Khairabad fault is the western continuation of the Panjal fault, and indicates that the Panjal-Khairabad fault juxtaposes two major, laterally continuous structural blocks along its combined length.

The Panjal fault likely has a ramp-and-flat geometry beneath the Gandghar Range, as shown diagrammatically in Figure 5. Assuming the detachment surface is located near or at the base of the Manki Formation, suggested by the absence of rocks older than Manki exposed at the surface, then a flat or very gently dipping segment beneath the eastern part of the range is necessary to hold the Manki structurally high and prevent post-Manki strata from being preserved. A ramp would be likely to occur somewhere near the boundary between argillaceous Manki-type rocks and arenaceous Hazara/Dakhner-type rocks, associated with a change in the mechanical strength of the rocks.

The timing of uplift of the Gandghar Range along the Panjal fault is uncertain. However, a heterolithic conglomerate bed within a section of the Campbellpore basin fill along the Haro River contains boulders of diorite and granite up to 3 m in diameter and is directly overlain by normally-magnetized lacustrine sediments (Burbank, 1982). This conglomerate, representing an extra-basinal source area somewhere to the north, was apparently deposited by a fluvial agent more powerful than the modern Haro River. It is possible that the ancestral Indus River flowed through the eastern Campbellpore basin as suggested by Wynne (1879), and was diverted by uplift of the Gandghar Range sometime during the Brunhes chron (Burbank, 1982).

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