

## Stratigraphy and structure of the Peshawar basin, Pakistan

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### ABSTRACT

The Peshawar intermontane basin is a broad, oval shaped and low-lying depression at the southern margin of the Himalaya. It lies to the north of the Attock-Cherat Range and contains rocks transitional between the sedimentary fold-thrust belt to the south and a metamorphic terrane to the north. The basin came into existence as the Kalachitta Range was faulted south on the Main Boundary Thrust (MBT) pushing the Siwalik foreland basin still farther south. The basin sediments predominantly comprise of the lacustrine, deltaic and fluvial deposits, which are overlain by loess, flood plain and alluvial fans of younger age. As a result of the present study, especially the findings of conodonts, the bedrock sequence of the Peshawar basin established previously, has been modified and revised. An almost complete sequence of rocks ranging from the Precambrian to Triassic age has been established for the first time in the Peshawar basin.

The study of the Landsat data, aerial photographs and subsequent field studies indicate presence of zone of late Quaternary deformation that extends across the southern margin of the Peshawar basin. Lacustrine, fluvial and alluvial fan deposits, which are dated at 2.8 to 0.6 Ma are tilted, folded and faulted along the four left-stepping pressure ridges that extend for nearly 60 km. Alluvial-fan and fluvial sediments are also folded and faulted in the Ghazi area where the base of the Indus River appears to be displaced by a reverse fault with its northwest side up. Additional minor lineaments and faults occur parallel and oblique to the major fault structures.

### INTRODUCTION

The Peshawar basin is superimposed on a fold-thrust belt at the Himalayan foothills of Pakistan (Fig. 1). The unlithified sediments of the Peshawar basin are predominantly lacustrine sediments with fluvial sediments. Exposures of the Mesozoic and older strata are limited to small inliers of bedrock within the basin and to ranges north and east of the Peshawar basin fill.

The first geological account of the southern Peshawar basin was given by Coulson (1937) who included these rocks in the 'Attock Slate' sequence and assigned the Precambrian age. Martin et al., (1962) subdivided the rock sequence of the northeastern Peshawar basin into "Swabi-Chamla sedimentary Group" and "Lower Swat-Buner Schistose Group". Davis and Ahmed (1963)

described orthoconic nautiloids from the hills south of Swabi indicating a Palaeozoic age. Teichert and Stauffer (1965) discovered Siluro-Devonian reef rocks near the town of Nowshera. These rocks were dated as late Silurian to early Devonian based on the conodont zonation (Barnett et al., 1966). Stauffer (1968a) described the reef complex and also reported other probable localities of Palaeozoic rocks from northern Pakistan. Ali and Anwar (1969) described the stratigraphy of the Nowshera reef complex. Latif (1970) collected corals from the Nowshera Formation at Pir Sabak hillock and suggested the possibility of Carboniferous age. Fuchs (1975) described the stratigraphy of rocks exposed near the Swabi and Nowshera area. The study of the conodont from the carbonate rock of Nowshera (Molloy, 1979) has provided the most detailed biostratigraphic information on Peshawar basin. Pogue and Hussain



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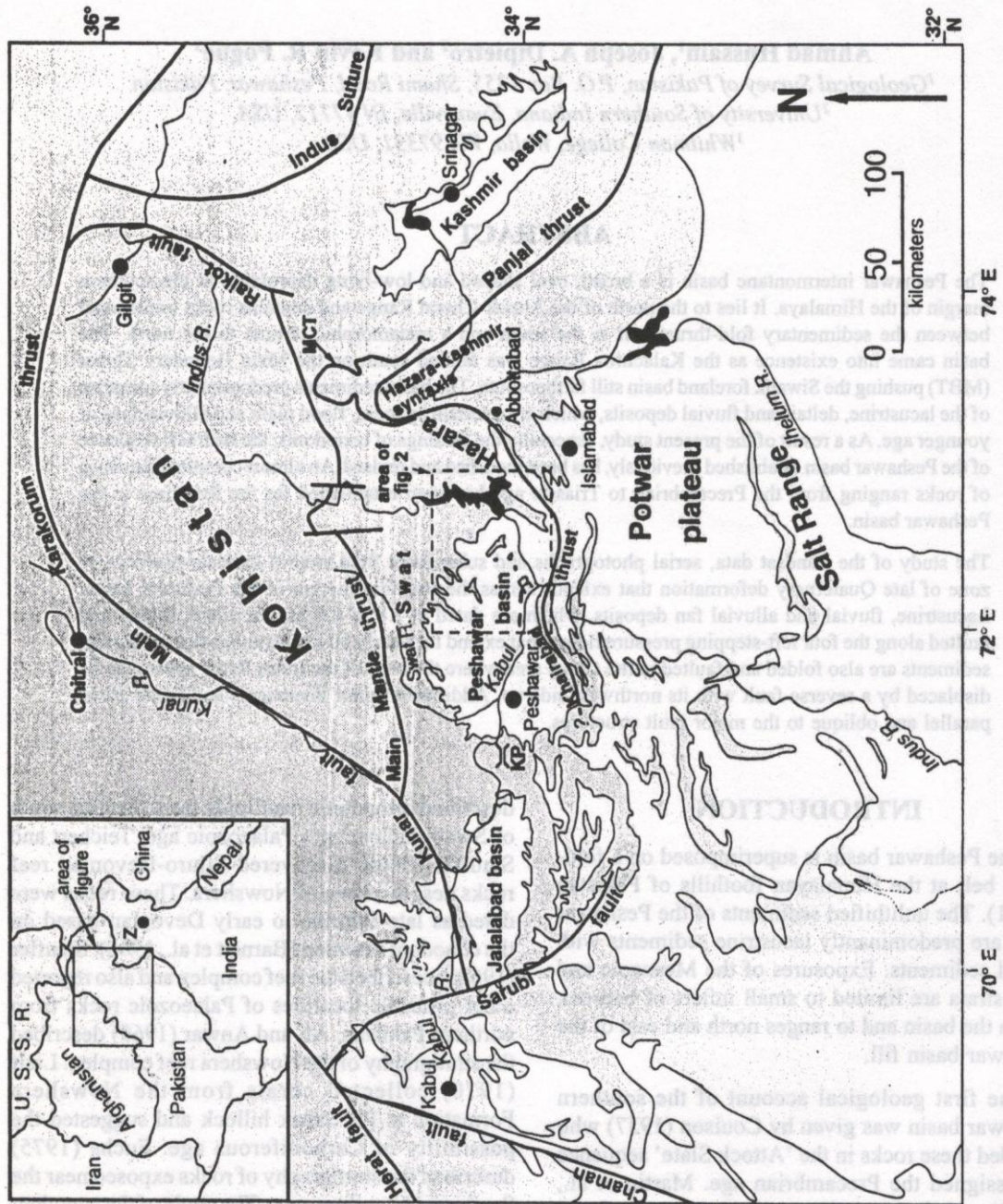


Fig. 1: Index map of Peshawar basin showing selected major Himalayan faults. Shaded areas are pre-Quaternary rocks. Location of faults from Gansser (1981) and Yeats and Lawrence (1984). Z = Zanskar, KP = Khyber Pass, MCT = Main Central Thrust of Greco et al. (1989).



(1986) established a revised stratigraphy of the southern Peshawar basin based on systematic geological mapping and discovery of trilobite trace fossils (*Cruziana rugosa*) of early to middle Ordovician age in the upper part of the Mishri Banda Quartzite. Pogue et al. (1992) for the first time established the Palaeozoic and Mesozoic rock sequence in the Peshawar basin on the basis of stratigraphic interrelationship and conodont identification.

The present study, especially the new find of conodonts has further modified the geology of the area. The rocks of the Nowshera and Swabi area were traced towards Lower Swat area on the basis of similar lithology and conodonts revelations. In addition, conodonts of late Devonian, Carboniferous and Triassic age have also been identified. The revised stratigraphic sequence established in the Peshawar basin as a result of the present study is given below.

Kashala Formation	Late Triassic
Karapa Greenschist	Late Carboniferous (Westphalian) to Late Triassic (Carnian)
Jafar Kandao Formation	Carboniferous (Kinderhookian-Atokan)
----- Unconformity -----	
Nowshera Formation	Devonian (Lochkovian-Frasnian)
Panjpir Formation	Silurian (Llandoveryan-Pridolian)

#### Ambar Formation

Pogue and Hussain (1986) proposed the name Ambar Formation for the carbonate rocks found in isolated outcrops of the Peshawar basin between Turlandi and Swabi. Stauffer (1968a) described the rock of this formation exposed near the Turlandi area in the Nowshera Formation. Martin et al. (1962) included all the outcrops of the Ambar Formation in the Swabi area in their "Kala Limestone and Dolomite". The section exposed at the Ambar village (latitude 34°03'02"N; longitude 72°24'46"E) along

the Swabi-Jehangira road has been designated as the type section.

The formation is comprised of dolomite, dolomitic limestone, calcareous quartzite and subordinate argillite. Chert in the form of veinlets, nodules and stringers is found at places. The dolomite contains algal laminations and poor development of stromatolites. The lower contact of the formation is unconformable with the Tanawal Formation in the Swabi area. The contact is locally marked by a conglomerate bed of cobbles and pebbles in a matrix of dolomitic quartzite and argillite. South of Swabi, the lower contact of the formation is covered by the alluvium of the Peshawar basin. The upper contact of the formation is also unconformable with the Misri Banda Quartzite and is marked by 5-10 m of maroon coloured shale. In the Chingalai area, however, the unconformity is represented by about 10 m of conglomerate consisting of pebbles and cobbles of quartzite and dolomite in quartzite matrix.

The formation has not revealed any fossils except microscopic shell debris in the interstices of pisoliths from the Ambar section. It has been tentatively placed in the Cambrian age because of its stratigraphic position resting above the Tanawal Formation of Precambrian age and below the Misri Banda Quartzite of Ordovician age (Fig. 2). The formation is correlated with the Abbottabad Formation in Hazara on the basis of its stratigraphic position and lithological similarity.

#### Misri Banda Quartzite

The term Misri Banda Quartzite was proposed by Stauffer (1968a) for calcareous quartzite overlying the Nowshera Formation of early Devonian age. Pogue and Hussain (1986) restricted the name "Misri Banda Quartzite" to dominantly arenaceous sequence lying between the Ambar and Panjpir formations (Kandar Phyllite of Stauffer, 1968a). The quartzite at Misri Banda is lithologically distinct from the calcareous quartzite overlying Nowshera and also contains *Cruziana* ichnofossils of Ordovician age. The extension of the quartzite outcrop towards the eastern part of the Peshawar Basin was named by Martin et al. (1962) as "Swabi Quartzite" and "Chamla Quartzite" in the respective



areas. The type section is near Misri Banda (latitude 34°01'02"N; longitude 72°06'05"E) located 10 km northeast of Nowshera.

The quartzite is light grey to pinkish-grey and contains fine to medium grained quartz and feldspar in siliceous and calcareous matrix. Cross-bedding, ripple marks and graded beddings are commonly found in the quartzite. In some parts of the quartzite sequence, vertically oriented tube-shaped burrows (Skolithus) are preserved. A dark grey thinly laminated argillite is commonly associated in the upper part of the Misri Banda Quartzite. The upper contact of the Misri Banda Quartzite is unconformable with the Panjpir Formation. The unconformity is marked by discontinuous conglomerate bed composed of rounded to subrounded cobbles and pebbles of quartzite and dolomite in calcareous quartzite matrix. The unconformity is well exposed at about 1 km east of the Turlandi village. A bulk sample of the calcareous quartzite from this conglomerate horizon yielded *Ozarkodina excavate* and *Ozarkodina remscheidensis* conodonts of late Ludlovian-Pridolian age.

Pogue and Hussain (1986) reported *Cruziana rugosa* in the interbedded argillite and quartzite of upper part of the Misri Banda Quartzite, which reveals an early to middle Ordovician age (Tremadoc to Llandeilo). The Misri Banda Quartzite is tentatively correlated with the quartzite member of the Abbottabad Formation in the Sherwan area exposed to the west of the Panjal Thrust.

### Panjpir Formation

The name Panjpir was proposed by Pogue and Hussain (1986) for the dominantly argillaceous sequence lying below the Nowshera Formation and above the Misri Banda Quartzite. This sequence was previously referred to by Stauffer (1968a) as "Kandar Phyllite". The new name was introduced by Pogue and Hussain (1986) due to the greater thickness of the unit and presence of lithologies other than the phyllite at its type section. Martin et al. (1962) termed "Swabi Shale" and "Chamla Shale" for the similar rocks in the respective areas. The type section is located near the village Panjpir (latitude 34°05'32"N; longitude 72°29'49"E) 4 km to the southeast of the Swabi town.

The formation is composed of argillite and phyllite with interbeds of crinoidal limestone, metasilstone and argillaceous and calcareous quartzite. These rocks are generally dark grey to greenish grey, silty, fissile and chloritic in nature. The upper part of the formation is characterised by interbedded argillite and crinoidal limestone. The formation has a conformable contact with the overlying Nowshera Formation. The contact can be placed at the base of massive limestone overlying the interbedded argillite and limestone of the Panjpir Formation.

The crinoidal limestone from the upper part of the Panjpir Formation have yielded late Silurian (Pridolian) conodonts (Talent and Mawson, 1979). The fossiliferous horizon has widespread exposure and late Silurian conodonts have also been reported at the Misri Banda, Ambar, and Panjpir outcrops. To the northwest of Misri Banda, a crinoidal limestone lense in the basal part of the Panjpir Formation yielded *Distomodus* sp. of the Llandoveryan-early Wenlockian age. This discovery provides the first evidence for the rock of early and middle Silurian age from Pakistan. On the basis of previous and present conodonts finds, the age of the Panjpir Formation is regarded as early to late Silurian (Llandoveryan-Pridolian). The formation strongly resembles the phyllite and interbedded limestone sequence exposed below the Ghundai Sar "reef complex" (Khan, 1969) located at about 17 km northwest of Peshawar.

### Nowshera Formation

Stauffer (1968a) proposed the term Nowshera Formation for fossiliferous carbonate rocks lying above his "Kandar Phyllite" and below "Misri Banda Quartzite"; Pogue and Hussain (1986) redefined the Nowshera Formation as the youngest stratigraphic unit in the Nowshera area and also included calcareous and dolomitic quartzite mapped by Stauffer as "Misri Banda Quartzite". The inclusion of this quartzite sequence within the Nowshera Formation was based on the presence of the early Devonian (Lochkovian) limestone stratigraphically above and below the quartzite. In the Swabi area, Martin et al. (1962) termed the similar outcrop of Nowshera Formation as "Kala Limestone" and



Age	Lithology	Present study	Stauffer (1968a) (area A)	Martin and others (1962) (areas C-F)	Fuortz (1878) (areas A-D)	
Jurassic(?) and Triassic		Nikanai Ghar Formation		Lower Swat-Buner Schistose Group		
Triassic		Kashala Formation				Marble and Calcareous schist
Permian(?)		Karapa Greenschist				Amphibolite horizon
Carboniferous		Jafar Kandao Formation				
						Kala Limestone
						Swabi Quartzite
Devonian		Nowshera Formation	Misri Banda Quartzite	Swabi Shale	Tanol Quartzite (area D)	
					Maneri Marble (area D)	Maneri Marble (area D)
					Kala Limestone (area C)	Kala Limestone (area C)
Silurian		Panjpir Formation	Kandar Phyllite	Chamla Shale (area D)	Nowshera Fm (area A)	
					Swabi Shale (area C)	Kandar Phyllite (area A)
						Dogra (Hazara) Slate (area C)
Ordovician		Misri Banda Quartzite	Misri Banda Quartzite	Chamla Quartzite (area D)	Turlandi Cgl (area A)	
					Swabi Quartzite (areas B,C)	Tanol Quartzite (area D)
Cambrian(?)		Ambar Formation	Nowshera Formation	Kala Limestone (area B)	Misri Banda Quartzite (area A)	
						Nowshera Formation (area A)
Proterozoic(?)		Tanawal Formation		Chamla Quartzite Chamla Shale	Tanol Quartzite	

Fig. 2: History of stratigraphic nomenclature for the eastern Peshawar basin, northern Pakistan.

“Maneri Marble”. The type locality of the Nowshera Formation lies 3.5 km north of Nowshera (latitude 34°01'54"N; longitude 71°59'40"E) along the Nowshera-Risalpur road.

The Nowshera Formation is composed of limestone and dolomitic limestone (marble), calcareous quartzite and sandstone, and subordinate argillite. Stauffer (1968a) subdivided the formation into reef core, carbonate containing reef breccia or fossil debris, and carbonate containing fewer or no fossil. This subdivision is valid locally around

Nowshera and does not extend to the other outcrops of the southern and eastern Peshawar basin. At its type locality, the formation contains a fossiliferous carbonate horizon followed by medium to coarse grained carbonate-cemented sandstone and quartzite. It constitutes the youngest Palaeozoic sedimentary formation exposed between the Nowshera and Swabi areas. North of Swabi, the Nowshera Formation has an unconformable contact with the overlying Jafar Kandao Formation. The unconformity is marked by a discontinuous conglomerate bed composed of



pebble and cobbles of argillite in quartzite-argillite matrix.

The lower part of the formation in the Nowshera area yielded corals, brachiopods, gastropods, cephalopods, stromatoporoids and conodonts that reveal an early Devonian (Lochkovian) age. In the upper parts of the Nowshera Formation in Pir Sabak hillock, Latif (1970) assigned a Carboniferous age based on ampleximorph corals. Talent and Mawson (1979) rejected this age based on the identification of conodonts of early Devonian age from the stratigraphically highest beds of the hillock. North of Swabi, the upper part of the formation has yielded *Ancyrodella* cf. *A. buckeyensis*, *Polygnatus* cf. *P. webbi*, which indicate a Frasnian age. The formation, thus, ranges in age from early to late Devonian. The Nowshera Formation is correlated with the Ghundai Sar "reef complex" of the Khyber area described by Stauffer (1968b), Khan (1969) and Shah et al. (1980).

#### Jafar Kandao Formation

The name Jafar Kandao Formation was proposed by Pogue and Hussain (1986) for rocks dominated by argillite with lenses of limestone lying above the Nowshera Formation in the Rustam area. Martin et al. (1962) included these rocks in the "Swabi Shale", which is equivalent to the Panjpir Formation of Pogue and Hussain (1986). The stratigraphic inference that the sequence is youngest than Swabi Shale was confirmed by discovery of Carboniferous conodonts from this formation. The type locality of the formation is Jafar Kandao section (latitude 34°18'40"N; longitude 72°17'56"E) along the Machai Canal, about 5 km southeast of Rustam.

The main lithology of the formation is argillite with subordinate interbeds of limestone, argillaceous quartzite and conglomerate. On the basis of lithology, the formation is subdivided into lower, middle, and upper parts. The lower part consists of argillite with lenses of limestone, argillaceous quartzite and conglomerate. The conglomerate occurs in channels and contains clasts of granite and quartzite. The middle part is dominated by interbedded argillite, calcareous quartzite, and sandy limestone. The upper part contains argillite with lenses of argillaceous

quartzite and conglomerate. This formation is overlain by greenschist which is the southern extension of an amphibolite, a metamorphic tholeiitic basalt.

The formation has yielded *Protognathodus* sp. of late Devonian-early Mississippian age, *Gnathodus psedosemiglaber*, *Gnathodus semiglaber*, *Eotaphrus* sp. of the Mississippian age and *Neogondolella* cf. *N. donbasica*, *Rhachistognathus* sp. of Pennsylvanian age. The age of the Panjpir Formation is Carboniferous (Kinderhookian-Atokan). The formation is correlated with overlying reef complex of Ghundai Sar in the Khyber area.

#### Karapa Greenschist

The Karapa Greenschist was described as metamorphosed tholeiitic basalt on the basis of geochemical analyses. The unit overlies the Jafar Kandao Formation with sharp contact and is well exposed near the Karapa village, 30 km northeast of the Baroch village. The type section crops out along the south-facing slope of Gumbat Sar between the villages of Karapa and Sonigram (Survey of Pakistan Topographic Sheet, 43B/7). The Karapa Greenschist is restricted to late Carboniferous (Westphalian) to late Triassic (Carnian) by conodonts in the underlying and overlying formations.

#### Kashala Formation

The Karapa Greenschist is overlain by about 1,500 m of interbedded marble and phyllite to the north of Rustam. These rocks were described by Martin et al. (1962) as marbles and calcareous schists of the Lower Swat-Buner Schistose Group. Kazmi et al. (1984) reassigned the Lower Swat-Buner Schistose Group of Martin et al. (1962) as Manglaur Schist, Alpurai Schist, and Saidu Schist. Dipietro (1990) renamed the Manglaur schist as the "Manglaur Formation" and the "Saidu Schist" as the Saidu Formation. The Kashala Formation is comprised of over 100 m of brownish grey marble and interbedded calcareous phyllite. The marble sampled from the middle part of the Kashala Formation yielded Late Triassic (Carnian) conodonts.



### **Nikanai Ghar Formation**

The name Nikanai Ghar was first used by Palmer-Rosenberg (1985) and Ahmad (1986) to the massive dolomite and marble exposed on the Nikanai Ghar mountain in southern Swat. These rocks comprised the upper one-third of the marble and calcareous sequence described by Martin et al. (1962) of the Lower Swat-Buner Schistose Group.

The Nikanai Ghar Formation is comprised of white to grey thick-bedded to massive, finely to coarsely crystalline marble and dolomitic marble. The sequence also includes thin beds of calcareous schist, schistose marble, and calcareous quartzite. The age of the Nikanai Ghar formation is tentatively restricted to late Triassic and Jurassic by the age of the underlying Kashala Formation and the presence of palaeoniscoid fish teeth.

### **Basin Fill Sediments**

The Peshawar basin fill sediments are mainly lacustrine sediments with interbedded fluvial sands and gravels containing clasts of the Kohistan provenance. The sediments may have been ponded by uplift of the Attock-Cherat Range related to movement on the Hissartang Thrust and MBT (Yeats and Hussain, 1987). Younger sediments in the Peshawar basin include catastrophic flood deposits (Burbank and Tahirkheli, 1985) and alluvial fan and fluvial deposits. The younger deposits along with older rocks are faulted and folded.

### **LATE QUATERNARY DEFORMATION**

Evidence for late Quaternary tectonics is found in four left-stepping, en echelon pressure ridges formed within the Peshawar basin parallel to its southern margin (Fig. 3). Additional evidence is found 50 km farther east at Tarbela Dam, although this area is off trend, being right-stepping rather than left-stepping. The pressure ridges are, from west to east, the Garhi Chandan, Uch Khattak, Walai, and Misri Banda ridges named for villages located in the vicinity.

The four left-stepping pressure ridges extend within the Peshawar basin, parallel and close to its

southern margin. Additional lineaments found in the Attock-Cherat Range have the same east-northeast trend as individual faults on the pressure ridges. The lineations are discordant to the low-angle, generally east-trending thrust structures of the Attock-Cherat Range (Yeats and Hussain, 1987). The linear, south-facing front of the Attock-Cherat Range at the western end of the Nizampur basin at Mir Kalan marks a north-dipping reverse fault between Jurassic limestone and alluvial fan gravels of the Nizampur basin. If the deformation zone includes the entire Attock-Cherat Range, then the Tarbela exposure could well represent part of the same zone, and the gap in exposures may be caused by the shifting course of the Indus braided stream between Tarbela and the Attock-Cherat Range. Furthermore, the straight southwest trend of the Indus in this area may be influenced by the deformation zone, which would have the same trend.

It is possible that the Attock-Cherat Range is a large scale version of the pressure ridges to the north, faulted on the south against the sediments of the Nizampur basin. Like the smaller ridges, the Attock-Cherat Range is asymmetric in profile with a steeper south slope. The Indus River may be antecedent to uplift of the range, analogous to the small streams cutting gorges through the pressure ridges. Uplift of the Attock-Cherat Range and ponding of the Peshawar and Campbellpore basin sediments may be related to thrusting on the Main Boundary Thrust to the south beginning about 2.1 Ma (Burbank et al., 1988). If so, this uplift and entrenchment of the Indus River would be coeval with early uplift on at least the Garhi Chandan ridge (as dated by flanking sediments) and possibly the other as well.

Except for the Tarbela Lake Fault, evidence for strike-slip on this zone of deformation is limited to low-angle slickensides on the fault at Misri Banda. A left-slip component is suggested by the en echelon, left-stepping pattern of the ridges, but the ridges are discontinuous, and total left slip in subjacent bedrock must be too small for the ridge-bounding faults to coalesce into a single fault zone. Evidence for left-lateral displacement is present only on the north-trending fault at Tarbela Lake, suggesting that the strike of this fault is closest to that of the slip vector between the main Peshawar basin block and the Attock-Cherat and Gandghar Ranges. Except for



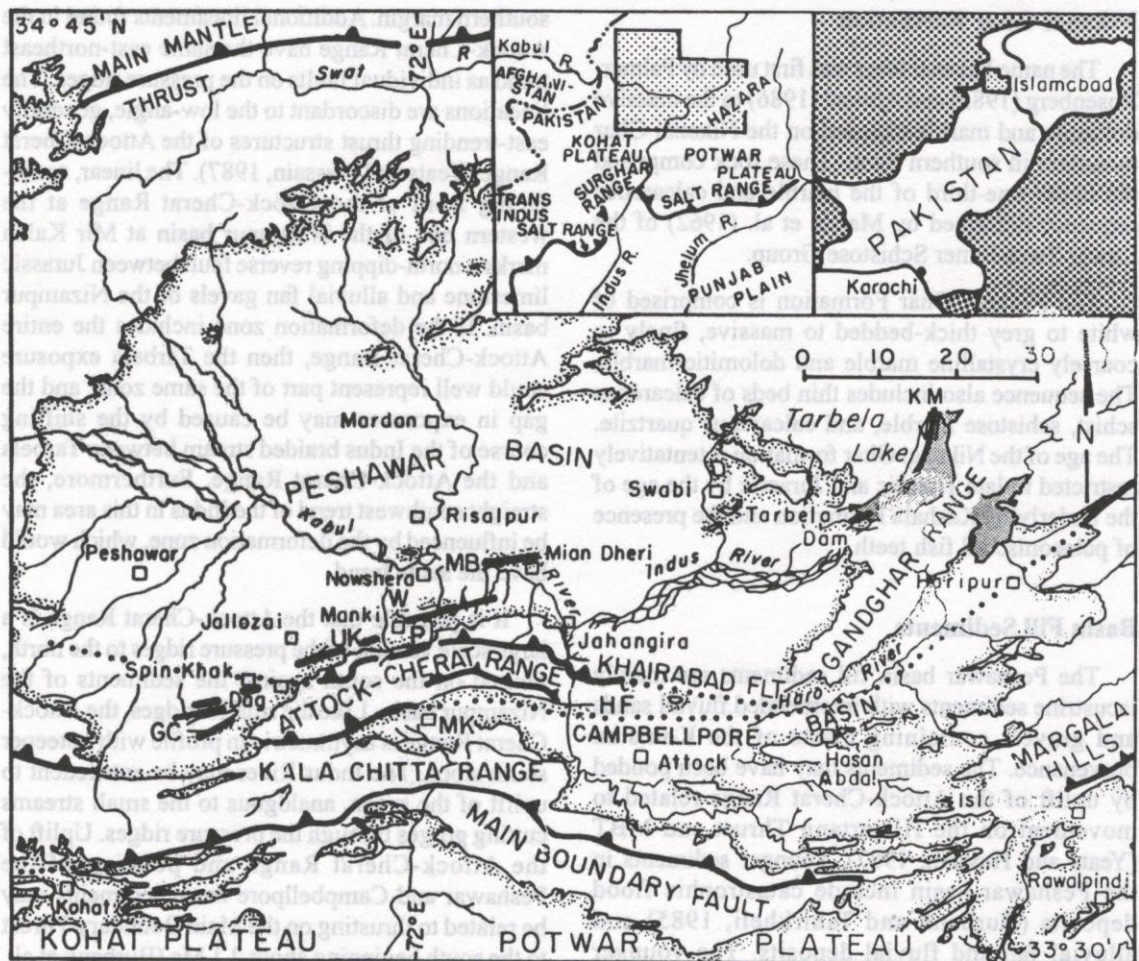


Fig. 3: Map of the Peshawar basin showing late Quaternary fault traces (heavy solid lines) and older regional thrust faults (heavy lines with teeth): Main Mantle thrust, Khairabad-Panjal thrust, and Main Boundary thrust. H.F. = Hissartang fault. Pressure ridges: GC = Garhi Chandan; UK = Uch Khattak; W = Walai; MB = Misri Banda. Villages: P = Pallosai, MK = Mir Kalan.

the Tarbela Lake fault, all faults have north side up, like the older thrusts, but these faults have linear map traces and are not lobate as is the Salt Range thrust (Yeats et al., 1984).

### DISCUSSION

Prior to the work of Pogue and Hussain (1986) and their subsequent studies the age of the rocks of the southern Peshawar basin was all considered to range from late Silurian to early Devonian (Barnett et al., 1966). For the first time, a fairly complete Palaeozoic sequence has been identified

in the ranges fringing the Peshawar basin (Fig. 4). The existence of a complete Palaeozoic sequence in the Peshawar basin serves to bridge the gap in the stratigraphy between India and Afghanistan where a relatively well-established Palaeozoic sequence is identified. The new findings of Ordovician ichnofossils in the Misri Banda Formation and conodonts of early to middle Silurian in Panjpir Formation, late early to middle Devonian in Nowshera Formation, and Carboniferous in the Jafar Kandao Formation are the first evidence of these ages in rocks south of the Main Karakrum Thrust (MKT).



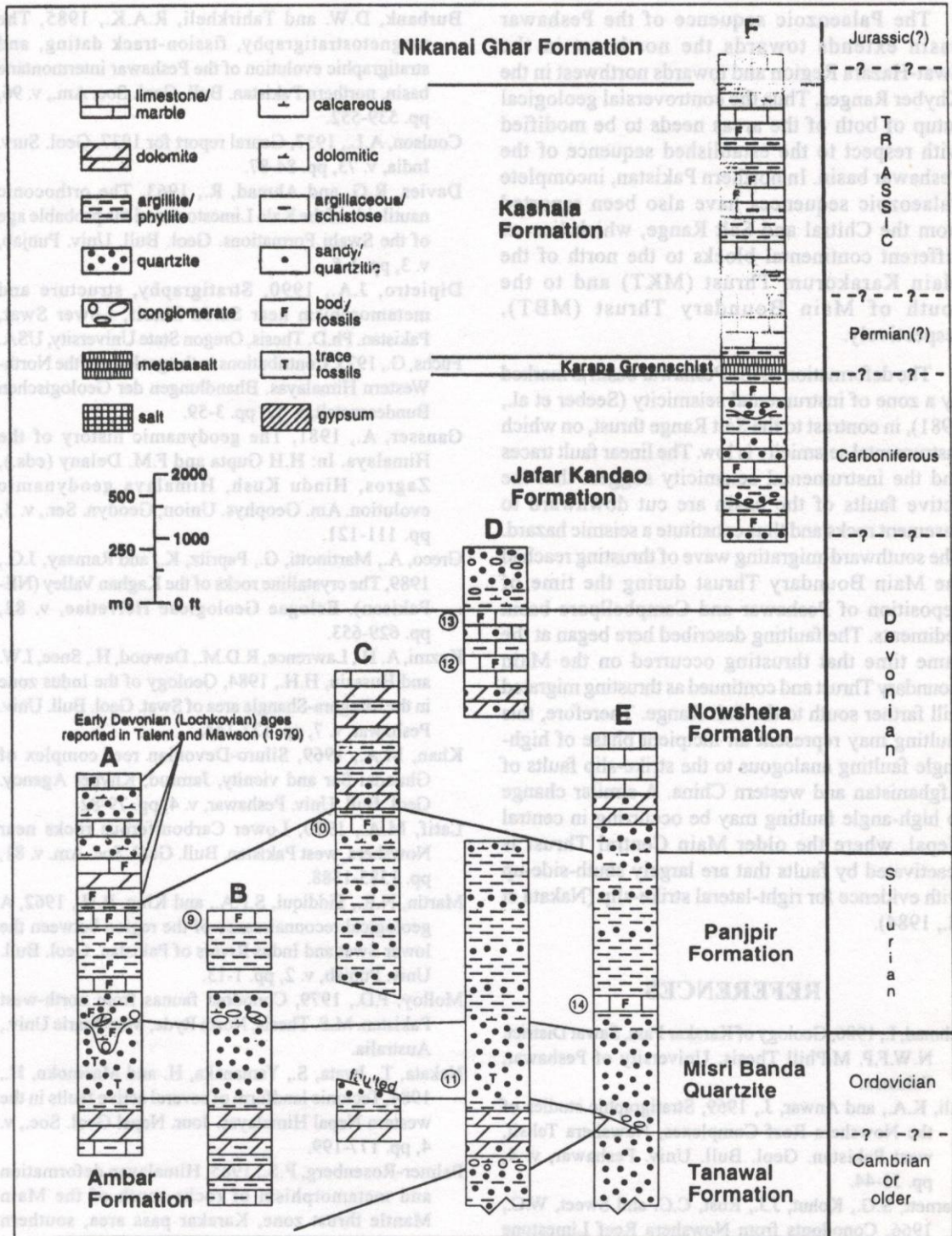


Fig. 4: Correlation of composite stratigraphic columns for selected areas of the eastern Peshawar basin.



The Palaeozoic sequence of the Peshawar basin extends towards the northeast in the Swat-Hazara Region and towards northwest in the Khyber Ranges. Thus the controversial geological setup of both of the areas needs to be modified with respect to the established sequence of the Peshawar basin. In northern Pakistan, incomplete Palaeozoic sequences have also been reported from the Chitral and Salt Range, which lies on different continental blocks to the north of the Main Karakorum Thrust (MKT) and to the south of Main Boundary Thrust (MBT), respectively.

The deformation of the Peshawar basin is marked by a zone of instrumental seismicity (Seeber et al., 1981), in contrast to the Salt Range thrust, on which instrumental seismicity is low. The linear fault traces and the instrumental seismicity suggest that the active faults of the basin are cut downward to basement rocks and thus constitute a seismic hazard. The southward-migrating wave of thrusting reached the Main Boundary Thrust during the time of deposition of Peshawar and Campbellpore basin sediments. The faulting described here began at the same time that thrusting occurred on the Main Boundary Thrust and continued as thrusting migrated still farther south to the Salt Range. Therefore, this faulting may represent an incipient phase of high-angle faulting analogous to the strike-slip faults of Afghanistan and western China. A similar change to high-angle faulting may be occurring in central Nepal, where the older Main Central Thrust is reactivated by faults that are largely south-side-up with evidence for right-lateral strike-slip (Nakata et al., 1984).

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