

PALEOZOIC STRATIGRAPHY OF THE PESHAWAR BASIN, PAKISTAN

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ABSTRACT

*An almost complete Paleozoic sequence of sedimentary rocks is exposed in the ranges fringing the Peshawar basin. The present study establishes a revised stratigraphy and modifies the stratigraphic nomenclature of the previous workers. The Precambrian - Cambrian Tanawal Formation forms the base of the sequence and is overlain unconformably by the Ambar Formation (Cambrian?). The Misri Banda Quartzite unconformably overlies the Ambar Formation and contains *Cruziana* ichnofossils which indicate an Early to Middle Ordovician age. The limestone at the base of the Panjpir Formation contains siluricus zone conodonts (Ludlovian) and unconformably overlies the Misri Banda Formation. The Early to Late Devonian Nowshera Formation overlies the Panjpir and contains a reef facies first recognized by Stauffer in 1968. The youngest recognized Paleozoic unit is the Jafar Kandao Formation from which Carboniferous conodonts have been obtained. The section outlined above has possible correlatives in the Khyber and Hazara regions, but differs dramatically from the Paleozoic sequence of the Salt Range to the south. The tectonic setting of the area is transitional between a sedimentary fold-thrust belt to the south and a metamorphic terrane to the north.*

INTRODUCTION

The Peshawar intermontane basin lies at the southern margin of the Pakistan Himalaya (Fig. 1). It is bounded on the south by the Attock-Cherat Range and on the east and west by Gandghar and Khyber Ranges respectively, both of which contain rocks transitional between metasediments of the lesser Himalaya and unmetamorphosed foreland basin sediments of Kohat-Potwar Plateau of the outer Himalaya. To the north and northwest of the Peshawar basin the strata includes metasediments

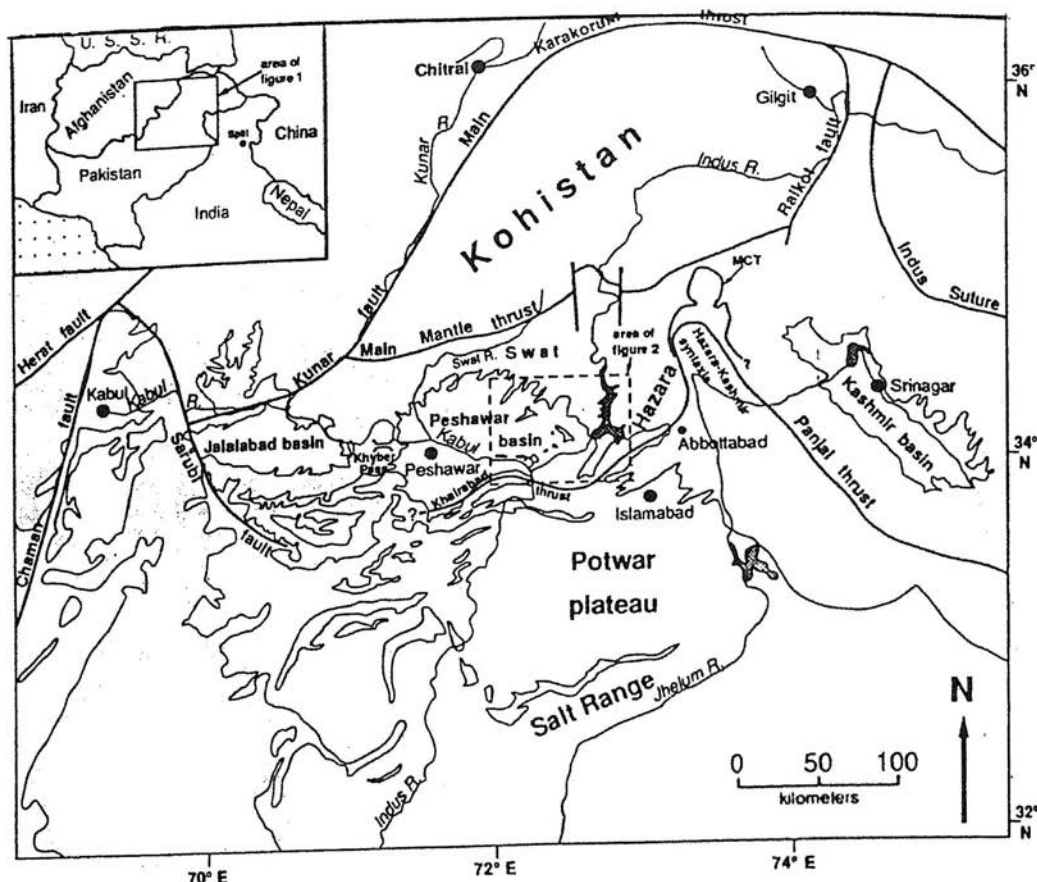


Fig. 1. Location map of the Peshawar Basin with selected major Himalayan faults. Location of faults from Gansser (1981), Yeates & Lawrence (1984). MCT = Main Central Thrust of Greco & others (1989).

intruded by the granitic rocks belonging to the marginal mass of the Indian plate. The tectonic setting of the basin is transitional between a sedimentary fold- and-thrust belt to the south and metamorphic terrane to the north. The unlithified sediments of the Peshawar basin are predominantly lacustrine silts with fluvial sand and gravel. The basin came into existence in Plio-Pleistocene time when more than 300 metres of sediments were deposited in response to ponding of drainage by the rising Attock-Cherat Range (Burbank & Tahirkheli, 1985). Exposures of the Paleozoic and older strata are limited to small outcrops within the basin (Fig. 2).

The first geological account of the rocks of the southern Peshawar basin was given by Coulson (1936) who included these rocks in the 'Attock Slate' sequence and assigned Precambrian age. Martin and other (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 Paleozoic age. Teichert and Stauffer (1965) made in first discovery of Siluro-Devonian reef rocks near the town of Nowshera. Stauffer (1968a) described the reef complex and also reported other probable localities of Paleozoic rock 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 Swabi and Nowshera area. Pogue and Hussain (1986) established a revised stratigraphy and modified the previous stratigraphic nomenclature of the southern Peshawar basin based on systematic geological mapping and discoveries of trilobite trace fossils of Early to Middle Ordovician age. As a result of their work the revision of stratigraphy of Peshawar basin became apparent. To establish the stratigraphic and structural setup, the area was remapped and fossiliferous horizons were sampled. Bulk samples from the rocks units were also processed for conodonts studies.

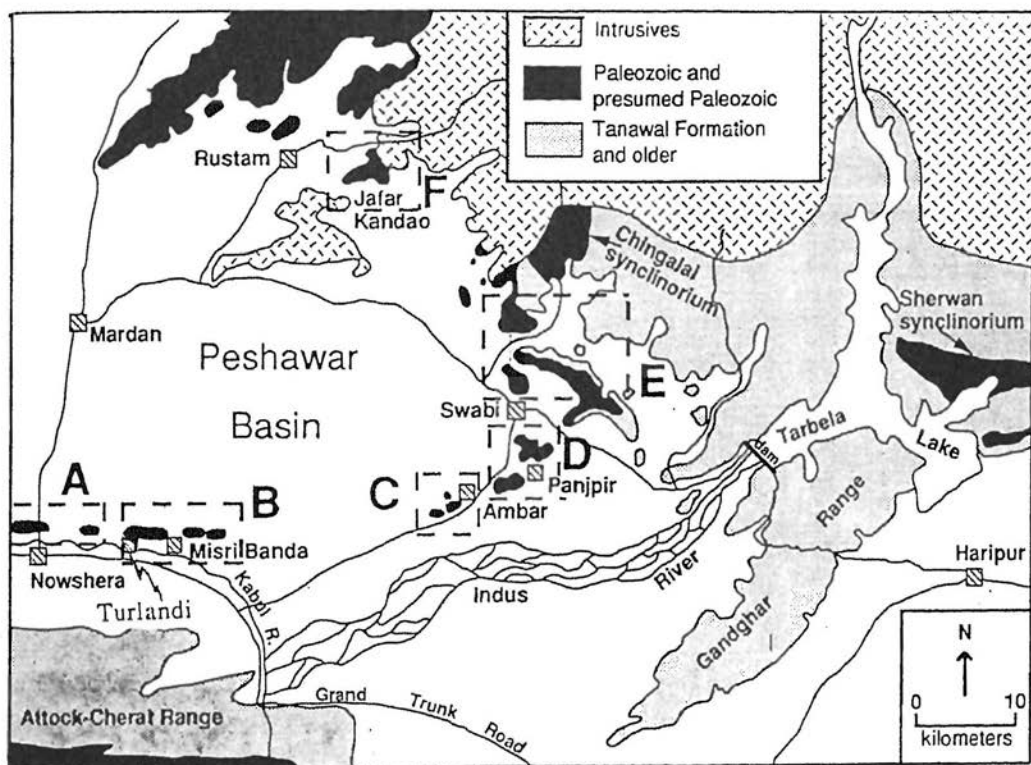


Fig. 2. Generalized geologic map of the eastern Peshawar Basin showing areas for composite stratigraphic columns (fig. 3).

STRATIGRAPHY

In the southern part of Peshawar basin the presence of Paleozoic rocks were first confirmed by Teichert and Stauffer (1965). These rocks were dated as Late Silurian to Early Devonian based on conodont zonation (Barnett et al., 1966). The following rock sequence was proposed in Nowshera area by Stauffer (1968a).

Misri Banda quartzite	Post Early Devonian
Nowshera formation	Late Silurian to Early Devonian.
Kandar phyllite	Late Silurian

Latif (1970) found an ampleximorph corals of carboniferous age in the upper part of Nowshera Formation and introduced the term "Pir Sabak Formation" to these rocks. This age was rejected by Talent & Mawson, (1979) on the basis of identification of Early Devonian conodonts from stratigraphically highest beds of the Nowshera Formation.

Pogue and Hussain (1986) based on systematic mapping and discovery of Cruziana ichnofossils revised and modified the stratigraphic sequence of Nowshera area as follows:-

Nowshera Formation	Early Devonian
Panjpir Formation	Middle Ordovician to Late Silurian
Misri Banda Quartzite	Early to Middle Ordovician
Ambar Dolomite	Cambrian?

The rocks of the northeastern part of the Peshawar basin were assigned the name "Swabi-Chamla Sedimentary Group" by Martin and Others (1962). They further subdivided the group into the following rock formations:-

1. Kala Limestone and Dolomite
2. Swabi Quartzite
3. Swabi Pebbly Shale
- Unconformity-----
4. Chamla Quartzite
5. Chamla Shale and Phyllite.

Davies and Ahmed (1963) reported orthoconic nautiloids from the Kala Limestone to the south of Swabi and assigned it a Silurian - Devonian age.

As a result of the present study, especially the new finds of conodonts, the geology of the area was further modified and the contact relationships of the rock units were elaborated. Unconformities were identified between Ambar Dolomite and Misri Banda Quartzite and between Misri Banda Quartzite and Panjpir Formation. The rocks of Nowshera area were traced towards Swabi on the basis of similar lithology and conodonts revelations. In addition, in Swabi area, conodonts of Late Devonian and

Carboniferous age have also been identified. The revised Paleozoic stratigraphic sequence established in the Peshawar basin as a results of the present study is given below.

Jafar Kandao Formation	Carboniferous (Kinderhookian-Atokan)
-----	Unconformity -----
Nowshera Formation	Devonian (Lochkovian-Frasnian)
Panjpir Formation	Silurian (Llandoveryan-Pridolian)
-----	Unconformity -----
Misri Banda Quartzite	Early-Mid (Tremadoc-Ordovician Llandeilo)
-----	Unconformity -----
Ambar Formation	Cambrian?

Ambar Formation

Pogue and Hussain (1986) proposed the name Ambar Formation for the carbonate rocks found in isolated outcrops of Peshawar basin between Turlandi and Swabi. Stauffer (1968a) described the rock of this formation exposed near Turlandi area in Nowshera Formation. Martin and others (1962) included all the outcrops of Ambar Formation in Swabi area in their "Kala Limestone and Dolomite". The section exposed at Ambar village (Lat. 34° 03' 02"N; Long. 72° 24' 46"E) along 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 Tanawal Formation in Swabi area. The contact is locally marked by a conglomerate bed with cobble and pebble size in a matrix of dolomitic quartzite and argillite. South of Swabi, the lower contact of the formation is covered under the alluvium of Peshawar basin. The upper contact of the formation is also unconformable with Misri Banda Quartzite and is marked by 5-10 metres of maroon coloured shale. In Chingalai area, however, the unconformity is represented by about 10 metres 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 Ambar section. It has been tentatively placed in Cambrian because of its stratigraphic position resting above the Tanawal Formation of Precambrian age and below the Misri Banda Quartzite of Ordovician age. The formation is correlated with 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 Nowshera Formation of Early Devonian age. Pogue and Hussain (1986) restricted the name "Misri Banda Quartzite" to dominantly arenaceous sequence lying between Ambar Dolomite and Panjpir Formation (Kandar Phyllite of Stauffer). 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 Peshawar basin was named by Martin and others (1962) as "Swabi Quartzite" and "Chamla Quartzite" in the respective areas. The type section is designated near Misri Banda (Lat. 34° 01' 02"N; Long. 72° 06' 05"E) located 10 kilometers 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 bedding are commonly found in the quartzite. In some parts of the quartzite sequence vertically oriented tube-shaped burrows (*Skolithus*) are preserved (Table 1, nos. 1,11). A dark grey thinly laminated argillite is commonly associated in the upper part of 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 Turlandi village (Fig. 2). A bulk sample of the calcareous quartzite from this conglomerate horizon yielded *Ozarkodina excavate* and *Ozarkodina remscheidensis* conodonts of late Ludlovian-Pridolian age (Table 1, no.3).

Pogue and Hussain (1986) reported *cruziana rugosa* (Table 1, no. 2) in the interbedded argillite and quartzite of upper part of 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 Sherwan area exposed to the west of Panjal thrust.

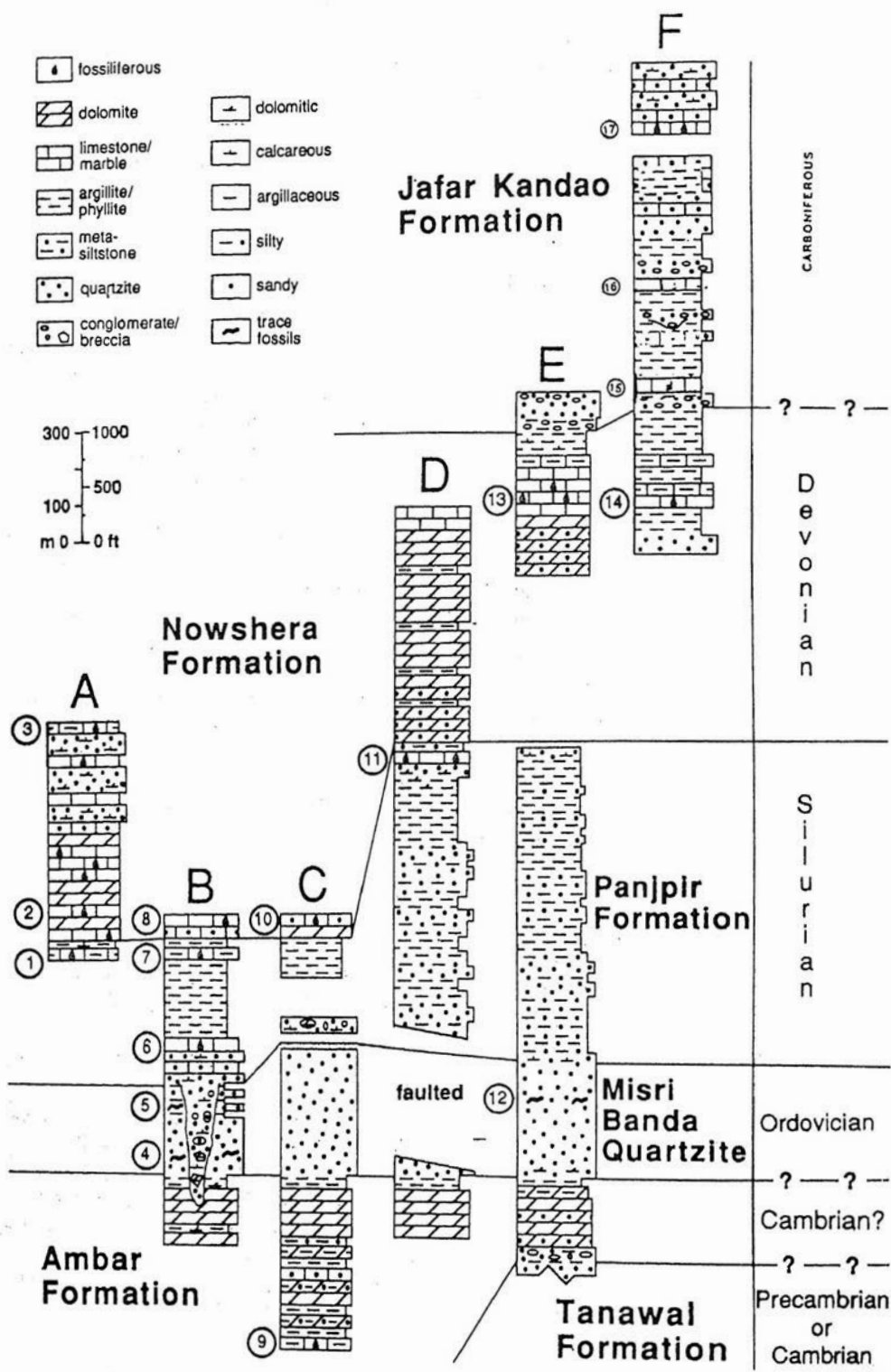
Panjpir Formation

The name Panjpir Formation 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 and other (1962) termed "Swabi Shale" and "Chamla Shale" for the similar rocks in the respective area. The type section is located near the village Panjpir (Lat. 34° 05' 32"N; Long. 72° 29' 49"E) 4 km to the southeast of Swabi town.

TABLE 1. FOSSIL LIST

CAI = Conodont alteration index, Location = Survey of Pakistan toposheet lat., long.

1. *Skolithus*, 43 B/4, 34° 01' 00" N, 72° 06' 48" E.
 2. *Cruziana rugosa*; age: Early-Middle Ordovician; 43 B/4, 34° 01' 29" N, 72° 09' 13"E.
 3. *Ozarkodina excavata*, *Ozarkodina remscheidensis*, *Ancryodelloides omnis* (contaminant); age: Silurian, late Ludlovian-Pridolian; USGS# 11980-SD; CAI=5, 43 B/4, 34° 01' 05"N, 72° 06' 33"E.
 4. *Distomodus* sp.; age: Silurian, Llandoveryan-early Wenlockian; USGS# 11983-SD; CAI=5.5-6.5, 43 B/4, 34° 01' 12"N, 72° 09' 07"E.
 5. *Ozarkodina excavata*, *Ozarkodina remscheidensis remscheidensis*, *Walliserodus* sp.; age: Silurian, *siluricus* Zone-late middle to early late Ludlovian (sample is stratigraphically below sample no. 6); USGS# 11775-SD; CAI=5.0-5.5, 43 B/4, 34° 01' 22' N, 72° 09' 13 "E.
 6. *Kockelella variabilis*, *Oulodus* sp., *Ozarkodina excavata*, *Ozarkodina remscheidensis remscheidensis*, *Panderodus* sp., *Polygnathoides siluricus*, *Walliserodus* sp.; age: Silurian, *siluricus* Zone-late middle to early late Ludlovian; USG# 11774-SD; CAI=5.0-5.5, 43 B/4, 34° 01' 15"N, 72° 09' 14"E.
 7. *Ozarkodina excavata*, *Ozarkodina remscheidensis*, *Ozarkodina crispa*, *Oulodus elegans*, *Panderodus unicostatus*; age: Silurian, lower *eastinhornensis* Zone-latest Ludlovian; USGS# 11975-SD; CAI=5.5-6.5, 43B/4, 34 o 01'15"N, 72° 08' 13"E.
 8. *Ozarkodina excavata*, *Ozarkodina remscheidensis*, *Oulodus* sp.; age: Late Silurian-Early Devonian, middle Ludlovian-early Pragian; USGS# 11981-SD; CAI=5-5.5, 43 B/4, 34° 01' 50"N, 71° 59' 55"E.
 9. *Ozarkodina confluens*, *Ozarkodina excavata*, *Ozarkodina remscheidensis* or *Kockelella variabilis*, *Kockelella* ? sp.; age: Silurian *crassa* into *costeinhornensis* Zones - late Wenlockian to early Pridolian; USGS# 11974-SD; CAI=5-6, 43 B/8, 34° 04' 55"N, 72° 24' 50"E
 10. *Oulodus*? sp., *Ozarkodina* aff. *O. confluens*, *Ozarkodina excavata*, *Ozarkodina remscheidensis*; age: Late Silurian-early Devonian; USGS# 11772-SD; CAI=5.0-7.0, 43 B/8, 34° 05' 40"N, 72° 29' 05"E.
 11. *Skolithus*, 43 B/12, 34°08' 20"N, 72° 37' 08"E.
 12. *Icriodus corniger/struvei* plexus, *Polygnathus* sp., *Dvorakia* sp., *Belodella devonica*; age: Devonian, late Emsian-Eifelian; USGS# 11978-sd, CAI=5.0-6.5, 43 B/8, 34° 09' 36" N, 72° 28' 00"E.
 13. *Ancyrodella* cf. *A. buckeyensis*, *Polygnathus* cf. *P. webbi*; age: Devonian, Frasnian, Middle asymmetric to Upper gigas Zones; USGS# 11982-SD; CAI=7.0, 43 B/8, 34° 03' 07"N, 72° 25' 00"E.
 14. *Icriodella* sp., *Carniodus* sp., age: Silurian, Llandoveryan to early Wenlockian; USGS# 11977-SD, CAI=8.0, 43 B/11, 34° 16' 37"N, 72 o 35' 22"E.
 15. *Protognathodus* sp.; age: Late Devonian-Early Mississippian, late Famennian to Kinderhookian; USGS# 31036-PC, 31038-PC, CAI=5.5, 43 B/7, 34° 18' 37"N, 72° 17' 53"E.
 16. *Gnathodus pseudosemiglaber*, *Gnathodus semiglaber*, *Eotaphrus* sp.; age: Mississippian, Osagean; USGS# 31035-PC, 30660-PC, CAI=5.5-8.0, 43 B/7, 34° 20' 05"N, 72° 19' 10"E.
 17. *Neogondolella* cf. *N. donbusica*, *Rhachistognathus* sp., age: Pennsylvanian, Atokan; USGS# 31039-PC, CAI5.5-6.0, 43B/7, 34° 26' 03"N, 72° 21' 56"E.
- The Conodont identifications were made by Robert G. Stamm, Bruce R. Wardlaw and Anita G. Horris of US-Geological Survey, Reston, Virginia.



The formation is composed of argillite and phyllite with interbeds of crinoidal limestone, metasiltstone and argillaceous and calcareous quartzite. These rocks are generally dark grey to greenish-grey, silty, fissile and chloritic. The upper part of the formation is characterized 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 samples of crinoidal limestone from the upper part of Panjpir Formation have yielded Late Silurian (Pridolian) conodonts (Talent & 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 lens in the basal part of the panjpir Formation yielded *Distomodus sp.* of Llandoveryan-early Wenlockian age (Table 1, no. 4). 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 & 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 Nowshera Formation was based on the presence of Early Devonian (Lochkovian) lime stone stratigraphically above and below the quartzite. In Swabi area Martin et al. (1962) termed the similar outcrop of Nowshera Formation as "Kala Limestone" and "Maneri Marble". The type locality of the Nowshera Formation lies 3.5 km north of Nowshera (Lat. 34° 01' 54"N; Long. 71° 59' 40"E) along 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 fossils. 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

Fig. 3. Correlation of composite stratigraphic columns for selected areas of the eastern Peshawar Basin. Numbers indicate approximate stratigraphic horizons for fossils in Table 1.

carbonate horizon followed by medium to coarse-grained carbonate-cemented sandstone and quartzite. It constitutes the youngest Paleozoic 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 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 (Table 1, no. 13). The formation thus ranges in age from Early to early Late Devonian. The Nowshera Formation is correlated with the Ghundai Sar "reef complex" of the Khyber area described by Stauffer (1968), Khan (1969) and Shah et al. (1980).

Jafar Kandao Formation

The name Jafar Kandao Formation was proposed by Pogue and Hussain (1988) for rocks dominated by argillite with lenses of limestone lying above the Nowshera Formation in Rustam area. Martin and others (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 (Lat. 34° 18' 40"N; Long. 72° 17' 56"E) along Machai Canal, about 5 Km southeast of Rustam.

The principal 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. The formation is overlain by greenschist which is the southern extension of an amphibolite which was interpreted as a metamorphic tholeiitic basalt based on geochemical analysis by Ahmed and others (1987).

The formation has yielded *Protognathodus* sp., of Late Devonian-Early Mississippian age, *Gnathodus psedosemiglaber*, *Gnathodus Semiglaber*, *Eotaphrus* sp. of Mississippian age and *Neogondolella* cf. *N. donbasica*, *Rhachistognathus* sp. of Penn-

sylvanian age (Table 1 nos. 15, 16 & 17). The age of the Panjpir Formation is thus Carboniferous (Kinderhookian-Atokan). The formation is correlated with overlying reef complex of Ghundai Sar in the Khyber area.

DISCUSSION

Prior to the work of Pogue & Hussain (1985) 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 & others, 1966). For the first time, a fairly complete Paleozoic sequence has been identified in the ranges fringing the Peshawar basin. The existence of a complete Paleozoic sequence in the Peshawar basin serves to bridge the gap in the stratigraphy between India and Afghanistan where a relatively well-established Paleozoic sequence is identified. The new finds 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 Main Karakrum Thrust (MKT).

The Paleozoic sequence of the Peshawar basin extends towards the northeast in 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 Paleozoic sequences have also been reported from Chitral and Salt Range which lies on different continental blocks to the north of Main Karakorum Thrust (MKT) and to the south of Main Boundary Thrust (MBT) respectively.

The major episodes of tectonism can be depicted for the stratigraphy and sedimentology of Peshawar basin. The first Late Cambrian? event is indicated by erosion of Ambar dolomite and its deposition in the form of conglomerate bed at the basal part of Misri Banda Quartzite along with the clasts of underlying Tanawal Formation. The feldspathic quartzite of Misri Banda may represent the erosional products of granitic highland. This event coincides with the intrusion of Cambrian? Mansehra Granite of Hazara (Le Fort & others, 1980). The second tectonic episode occurred in Early Carboniferous and is marked by granite clast cobble conglomerate in the Jafar Kandao Formation. The granite clasts could be derived from the Cambrian? Swat Granite. The intrusion of Ambela Granite Complex during the Carboniferous period coincides with this event. The Late Cambrian and Early Carboniferous episodes of tectonism reveals that the Peshawar Basin received sediments periodically from tectonic highland to the north and slowly eroding craton to the south.

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