Journal of Himalayan Earth Sciences Volume 47, No. 1, 2014, pp. 25-40

Stratigraphic characterization of the Early Cambrian Abbottabad Formation in the Sherwan area, Hazara region, N. Pakistan: Implications for Early Paleozoic stratigraphic correlation in NW Himalayas, Pakistan

Muhammad Qasim[1,2], M. Asif Khan[1] and Muhammad Haneef[1]
[1]National Centre of Excellence in Geology, University of Peshawar
[2]Department of Earth Sciences, CIIT, Abbottabad

Abstract

This paper attempts stratigraphic characterization of the Early Cambrian Abbottabad Formation exposed in the Sherwan area, west of Abbottabad. A regional correlation is carried out with the rest of the Early Paleozoic sequences exposed in northern Pakistan including Abbottabad, Peshawar basin and Salt Range. Stratigraphic sections are measured at Aluli, Pind Khan Khel and Bir villages in the mapped area and at Soban Gali and Muslimabad (Sirbon Hill), Abbottabad. A three-fold subdivision of the Abbottabad Formation has emerged through this study; a) lower arenaceous unit (dominantly quartzite with subordinate pebbly conglomerate, sandstone and siltstone), b) middle dolomitic unit (dominantly dolomite with subordinate quartzite, siltstone, and conglomerate) and c) upper quartzite unit. The three members defined in this study are exclusively preserved in the Sherwan area. Elsewhere, either the only lower two members are preserved such as at the Soban Gali and Sirbon Hill, Abbottabad or only the upper two units are present such as at Swabi in the Peshawar basin. In the latter, the Misri Banda Quartzite that has an Ordovician paleontological age but ~525 Ma age defined by the youngest detrital zircon is possibly an equivalent of the upper quartzite member of the Abbottabad Formation defined in this study. The two are lithologically similar and the detrital zircon age resemble closely with the age of the Abbottabad formation.

Keywords: Stratigraphy; Abbottabad Formation; Sherwan; Hazara; Regional correlation; NW Himalaya.

1. Introduction

Early Paleozoic stratigraphic sequences are dispersed as structurally dismembered isolated pockets in northern Pakistan from Hindu Kush-Karakoram in the north to the Salt Ranges in the south. One of the best known Early Cambrian successions is exposed in the Sirbon Hill, south of Abbottabad that is popularly known as the Abbottabad Formation (Latif, 1970, 1972). However, due to structural disturbances caused by the Abbottabad Thrust and associated tight folding (Latif, 1970), the sequence is inadequately preserved at the type locality. In comparison, equivalent lithologies are exposed in Sherwan area to the west of Abbottabad (Calkins et al., 1975) with better exposures and relatively lesser structural complexities.

In this context, the Early Paleozoic succession of Sherwan area comprising the Early Cambrian Abbottabad Formation is selected for stratigraphic characterization in terms of its constituent lithologies and its correlation with the Early Paleozoic stratigraphic sequences of Abbottabad, Soban Gali, Swabi (Peshawar basin) and Salt Ranges in the northwestern Himalayas.

This study is based on a newly developed map of the Sherwan area between the latitudes 34º 3' 15"-34º 12' 30" and the longitudes 72º 54'-73º 0' 30"(Fig. 1 and 2). The studied area is a part of the southern Tanawal Range (~1500 m above sea level) that occupies the intervening area between the Mansehra basin in the north and the Haripur basin to the south, adjacent and NE of the Tarbela Dam reservoir.

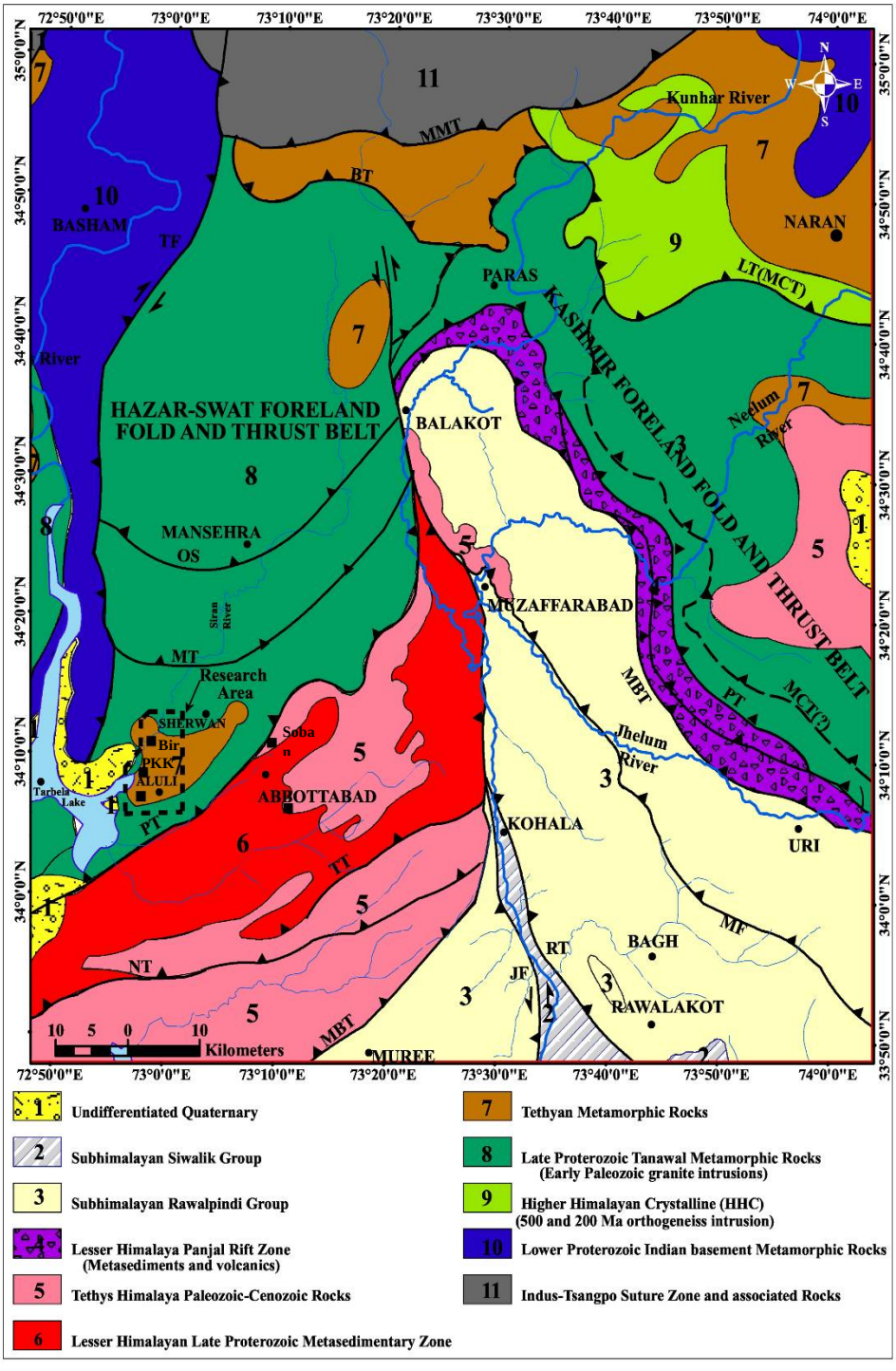

Fig. 1. Modified Geological Map of Hazara Kashmir Syntaxis with major structures of the region. The dotted polygon represents the study area, while the rectangular filled boxes ■ indicate the location of measured sections. PKK: Pind Khan Khail, MMT : Main Mantle Thrust, MBT : Main Boundary Thrust, PT : Panjal Thrust, RT : Riasi Thrust, JF : Jhelum Fault, TF : Thakot Fault, MF : Muzaffarabad Fault, OS : Oghi Shear, MT : Mansehra Thrust, TT : Thandiani Thrust, NT : Nathiagali Thrust. Geology and location of faults modified after Wadia (1928 ; 1931), Latif (1970), Calkins et al.(1975), Kazmi and Rana (1982), Baig and Lawrence (1987), Baker et al. (1988), Bossart et al. (1988), Yeats and Lawrence (1984), DiPietro et al. (2004) and Hussain et al. (2009).

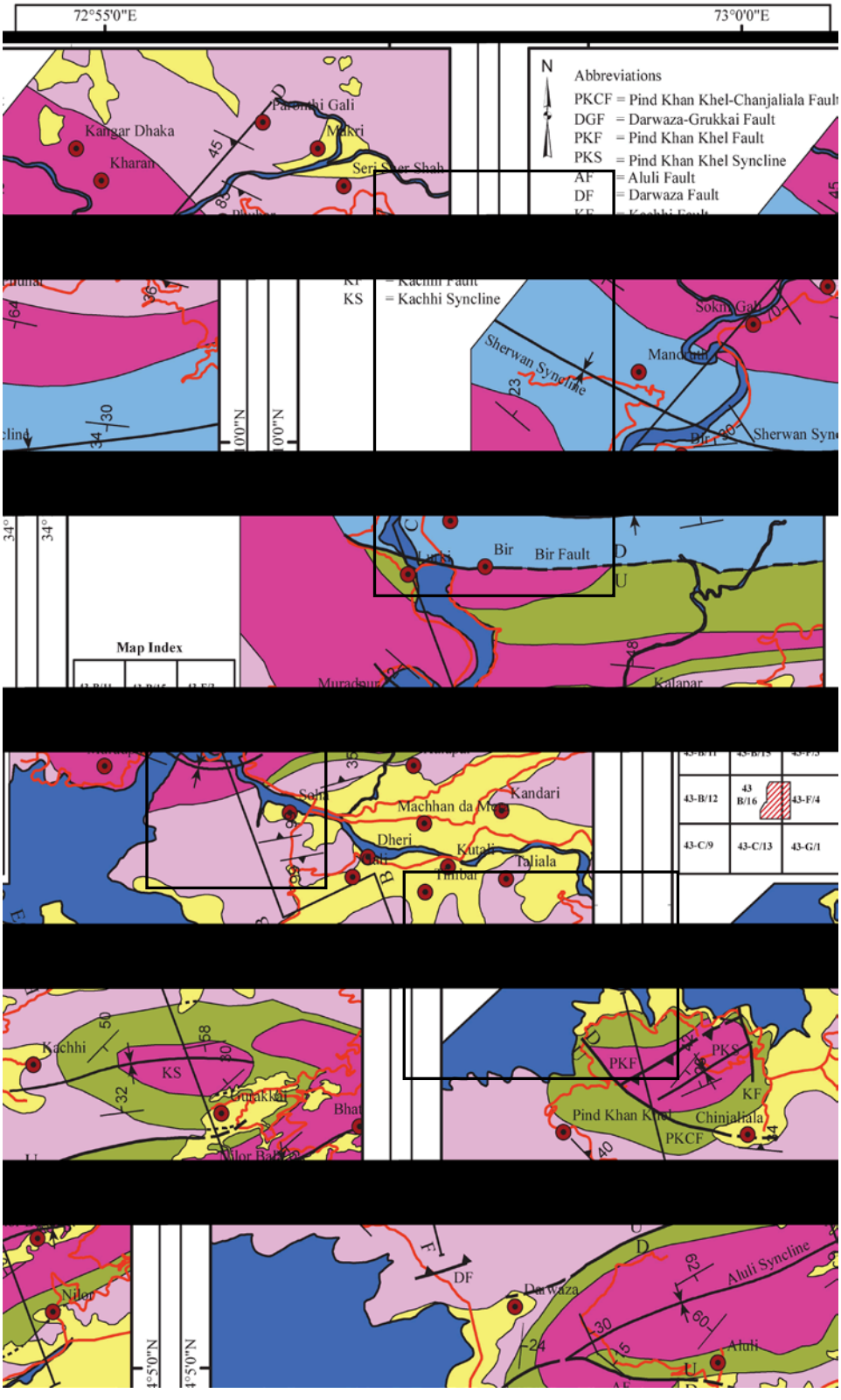

Fig. 2. Geological map of the study area. Black rectangular boxes showing the locations of measured sections in study area.

The study area was previously investigated by different workers on reconnaissance basis to establish the regional stratigraphy for developing regional geological maps (Wynne, 1879; Middlemiss, 1896; Ali, 1962; Ali et al., 1964; Killinger and Richard, 1967; Calkins et al., 1975; Tahirkheli and Majid, 1977). The economic mineral occurrences such as soapstone, barite, laterite and magnesite are also reported by these workers.

In terms of structural setting, the Sherwan area is bounded by the Panjal Fault in the east and southeast and the Mashera Thrust in the north (Fig. 1). To the west, the north-trending Indus syntaxis and the associated faults such as the Darband fault separate the Hazara Range from the Swat Ranges west of the Indus River. The southern Tanawal Ranges are predominantly covered by the Precambrian lithologies, which include the Tanawal Formation in the hanging wall of the Panjal Thrust and the Hazara Slates in the footwall. The Abbottabad Formation unconformably overlies the Precambrian Tanawal Formation in the hanging wall of the Panjal Thrust in the Sherwan area but overlies the Hazara Slates at Soban Gali and Sirban Hill in the footwall of the Panjal Thrust. Pervasive uplift of the Tanawal Ranges in response to the Panjal Thrust and younger faults to the south (e.g., Nathiagali-Hisartang Thrust and the Main Boundary Thrust (MBT)) eroded much of the Paleozoic-Mesozoic successions, with remnants of the Early Cambrian Abbottabad Formation left preserved only in the synclinal fold structures (Latif, 1970; Calkins et al., 1975). With the exception of Permian dolerite sills and dykes and subordinate Quaternary sediments, rocks younger than the Early Cambrian are missing in the hanging wall of the Panjal Thrust (Coward et al., 1988) including the presently studied area. The Tanawal Formation that predominates the studied area was mapped for lithological variations, but usually repetitive lithologies, absence of basal contact and extensive folding and shearing did not allow the stratigraphic characterization of the Tanawal Formation. In comparison, the Abbottabad Formation has well exposed lower contact throughout the studied area, has a variety of constituent lithologies, and the broad, upright synclinal folds allow determination of younging direction in the sequence. For this purpose, road logs were prepared for constituent lithologies at nine locations, which were then used to reconstruct stratigraphy after removing repetitions due to folding and faulting. This led to development of stratigraphic sections at five locations, representing various parts of the succession in the Abbottabad Formation (Fig.1). These stratigraphic sections were ultimately integrated to develop a composite stratigraphic column for correlation on regional basis. For the latter, two stratigraphic sections were measured outside the studied area; 1) at Soban Gali, 10 km west on the Abbottabad-Sherwan road immediately below the Panjal thrust, 2) from Muslimabad (Khota Qabar) to Hazira on Havelian-Abbottabad road. This led to correlation and comparison of the Early Cambrian sequence in the hanging wall and footwall of the Panjal Thrust.

2. Stratigraphy

2.1. Tanawal Formation

Wynne (1879) first described “Tanawal Group” designating dominantly quartzitic rocks with subordinate argillaceous lithologies covering large parts of the Hazara region in northwestern Himalayas. Middlemiss (1896) referred to these rocks as “Tanawal Quartzites” and described them as “feldspathic schistose quartzites”. Mark and Ali (1961) and Ali (1962) studied the Tanawal Formation near Tarbela as well in the presently studied area and described preponderance of well-bedded quartzites with excellent cross bedding and ripple marks. Calkins et al. (1975) described Tanawal Formation from the Ghandghar Range, south of Tarbela as well as from much of the Hazara region. They divided it into four units, which from base to the top included 1) conglomerates, 2) lower quartzite, 3) quartz schist, and 4) upper quartzite. Tahirkheli and Majid (1977) studied Tanawal Formation in the Gadun Amazai (west bank of the Indus River), Ghandghar Range and in the presently studied area near Darwaza, Aluli and Kachhi villages. These authors suggested that the Tanawal Formation occupied a stratigraphic position between the Hazara Slates and the Abbottabad Formation, as was previously suggested by Calkins et al. (1975). Khan and Khan (1994) studied Tanawal Formation exposed north of

Swabi occupying a stratigraphic position between the Precambrian Salkhala Formation and the Cambrian Ambar Dolomite.

In the presently studied area, the Tanawal Formation is found to occupy two-third of the mapped area. Major exposures include northern Sherwan area at the northern limb of the Sherwan Syncline and the Kachchi area, as part of the Kachchi anticlinorium intervening the Sherwan and Aluli synclines. Outcrops of the Tanawal Formation are also present surrounding the Aluli and Pind Khan Khel synclines in the southernmost and southwestern parts of the mapped area.

The Tanawal Formation consists of quartzite, speckled quartzite, quartzose sandstone, argillaceous sandstone, phyllite, shale and quartzose conglomerate. Mutual intercalations between these lithologies are common (Fig. 3). Quartzites and sandstones display well-developed bedding, which range in thickness from 10 to 50 cm. Cyclic sequences comprising alternating dark grey to light grey sandstone and clay interbeds are common (Fig. 3b). Dolerite dykes and sills are commonly found intruding the sequence.

The quartzite is pale tan on the fresh surface that weathers to light brown colors. The quartzite and sandstone are commonly speckled due to weathering of iron grains and nodules (Fig. 3c). The fresh color of the quartzose sandstone is light grey while the weathered color is milky white. The texture of the quartzose sandstone is medium grained. Low angle ripples are very common in the sandstone of the Tanawal Formation. The phyllite of the Tanawal Formation varies in color from light grey to dark grey and brownish.

The lower contact of the Tanawal Formation is not exposed in the studied area, while the upper contact with the Abbottabad Formation is unconformable marked by conglomerate beds (Fig. 3f). The clasts in the conglomerates include quartzite, slates, phyllites, shales and quartz belonging to the Tanawal Formation. These clasts range in size from 2 to 8 cm and fall in the category of pebbles and cobbles. These clasts are mostly elongated but the edges are well rounded. The age of the Tanawal Formation is determined indirectly. Myrow et al. (2009) noticed youngest zircon ages from Tanawal Formation to be clustering around ~500Ma that suggests a Late Cambrian age for the Tanawal Formation. However, Mansehra granite was dated to be 516 Ma by LeFort et al. (1980) that intrudes the Tanawal Formation suggesting an age older than the Cambrian. Crawford and Davies (1975) dated Hazara Slates occupying a stratigraphic position at the base of the Tanawal Formation as 752±20 Ma based on radiometric ages. Based on these considerations, the most likely age for the Tanawal Formation appears to be Late Precambrian.

2.2. Abbottabad Formation

The Abbottabad Formation was named by Mark and Ali (1961) for a set of predominantly dolomitic rocks with subordinate siliceous and argillaceous rocks from the Sirban Hill, Abbottabad. Ali (1962) included similar lithologies exposed in the southern Tanawal region west of Abbottabad into the Abbottabad Formation. Calkins et al. (1975), however, misinterpreted these lithologies to be of Triassic age and mapped them as Kingrialli Formation, a sandstone unit exposed in the Salt Ranges.

2.2.1. Measured stratigraphic sections

In order to characterize variations in the Abbottabad Formation exposed in different parts of the studied area, 9 sections along roads and stream cuts were selected to record rock types, composition, texture, sedimentary structures and thicknesses. The road/stream cut logs were then converted to 5 stratigraphic sections representing lithological distributions in the Abbottabad Formation (Fig. 4). Of these, the Aluli and Pind Khan Khel sections represent the lower two-third, whereas the stratigraphic section constructed at Bir (Sherwan) represents the upper two third of the stratigraphic succession in the Abbottabad Formation.

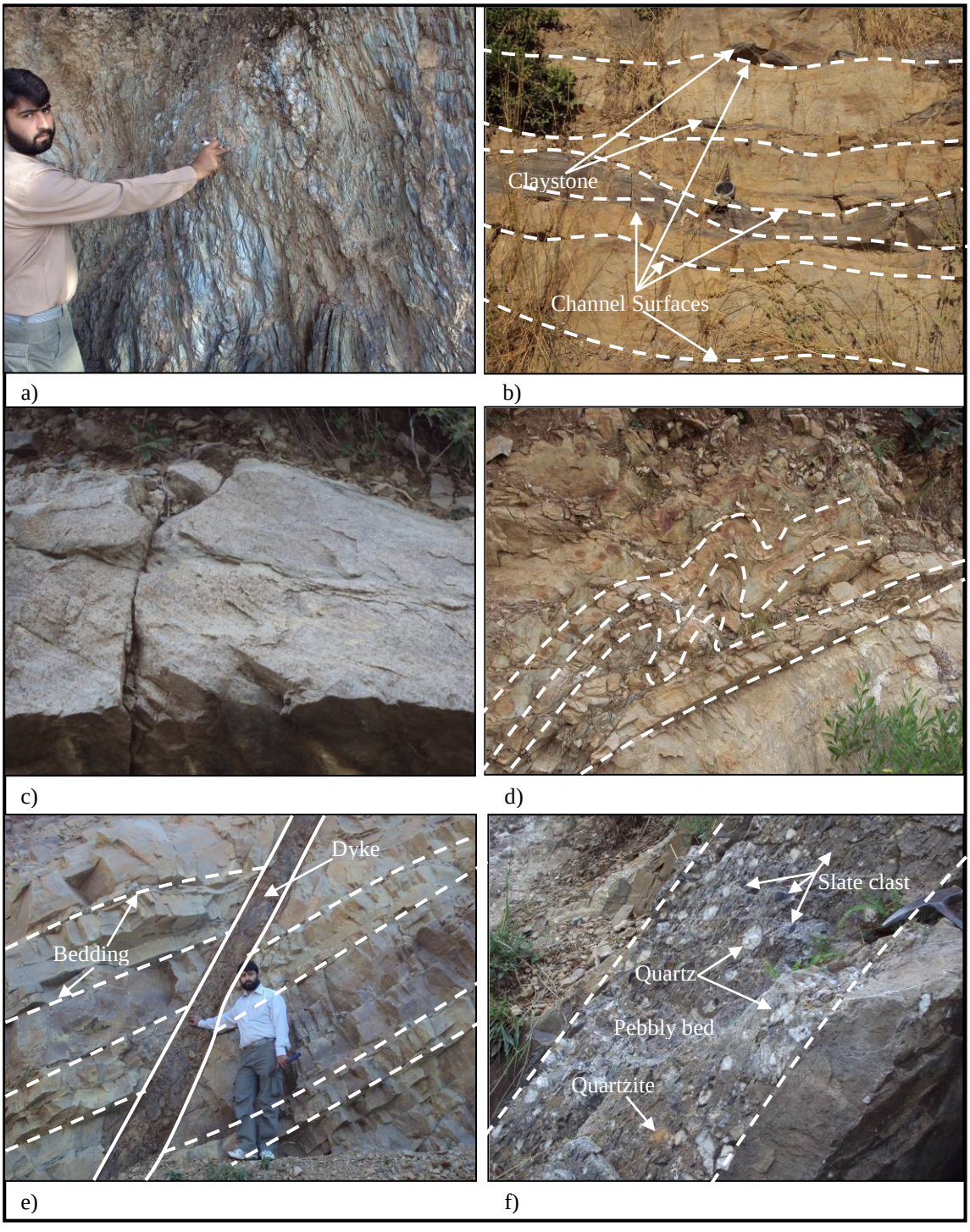

Fig. 3. Field photograph showing the different constituent lithologic units and field features in the Tanawal Formation. a) Phyllites, b) Interbedded quartzite (greyish white), sandstone (pale) and mudstone (dark grey) showing channelized bedding, c) Speckled quartzite, d) Intense folding in thin bedded quartzite and claystone layers, e) Dolerite dyke intruding quartzite and f) Pebbly layers interbedded within siltstone.

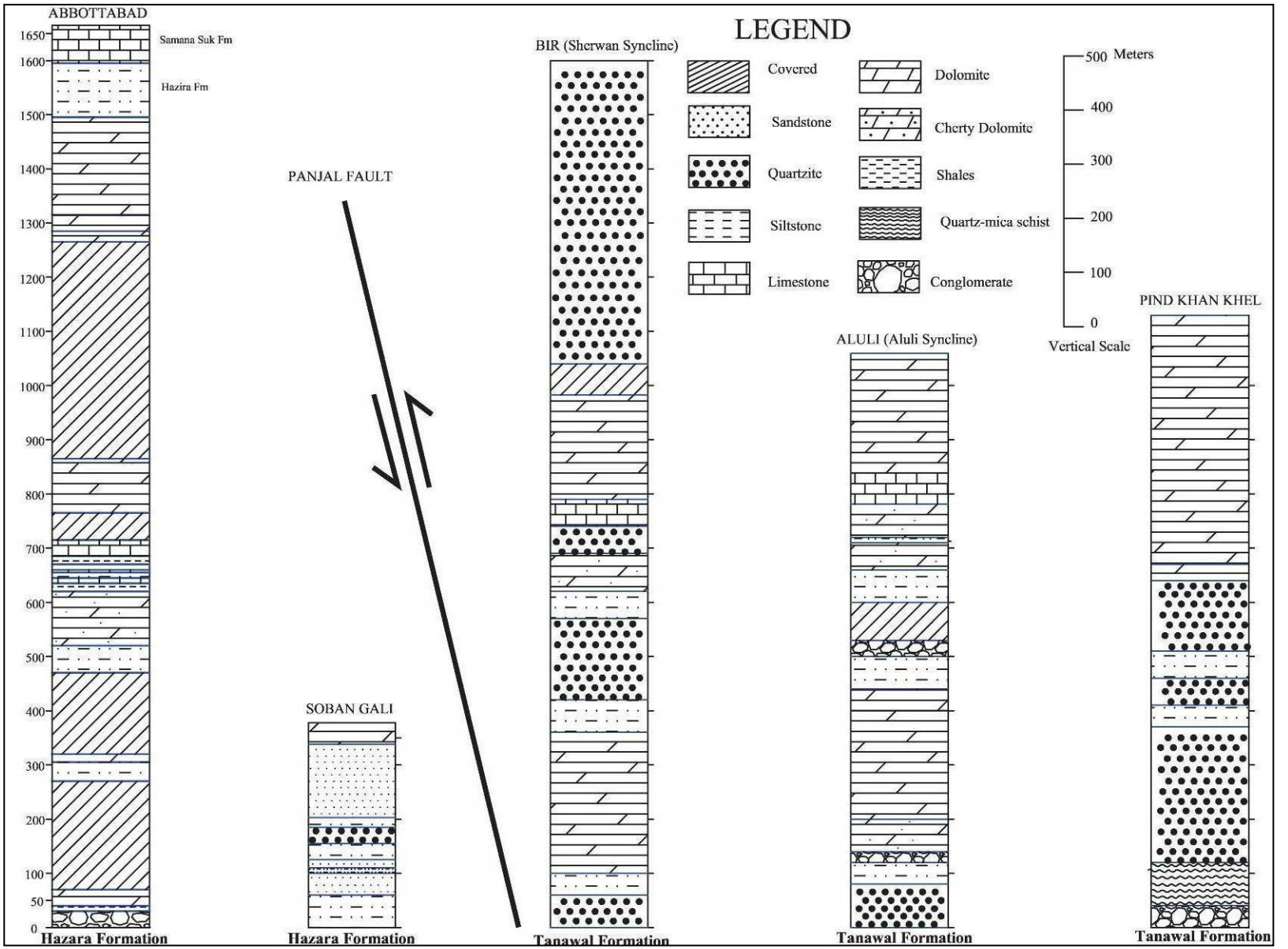

Fig. 4. Stratigraphic sections representing lithological variations in Early Cambrian Abbottabad Formation.

Measured Stratigraphic Section at the Southern limb of the Aluli Syncline: The Aluli syncline forms the 2nd largest synclinal fold structure in the studied area with the Abbottabad Formation exposed in its core. The open upright fold has almost continuous exposures from one limb of the fold to the other, which can be conveniently studied along the Aluli-Bhat-Kakotri road. A 1320 m long road log of lithologies in terms of their compositional variations and sedimentary structures portrays a representative lithostratigraphic setup of the lower part of the formation (Fig. 4). From basal contact with the Tanawal Formation, northward following lithologies are encountered:

1. The base of the Abbottabad Formation at Aluli is arenaceous, comprising (bottom to top) ~80 m thick quartzite, followed by ~ 40 m thick siltstone and finally 20 m thick conglomerate. Quartzite is coarse grained and milky white in color with local intercalations of sandstone beds. It is medium to thick bedded (from 50 cm to 2 m) and has a preponderance of cross bedding. The siltstone is maroon in color, thin to medium bedded (5-50 cm) with common channel beds and slump structures (Fig.5b).
2. Rest of the Abbottabad Formation exposed in the Aluli Syncline is predominantly dolomite. The basal dolomite is ~300 m thick that has cherty dolomite at the base and top (~50 m each). The dolomite is commonly light pinkish to milky white in color and medium to thick bedded. Cherty dolomite with lenticular chert beds is internally brecciated. Followed by a siltstone (with a minor bed of conglomerate) for a thickness of ~50 m, the cherty dolomite reappears for a thickness of over 200 m. A 50 m thick dark-grey limestone bed separates these cherty dolomites from the topmost dolomites.

Measured Stratigraphic Section at Pind Khan Khel: The Early Paleozoic succession in the Pind Khan Khel area starts with basal conglomerates of about 40 m thick, followed by quartz mica schist having a thickness of about 80 m and quartzite, with subordinate siltstone bands in its middle part. It is milky white, speckled and loaded with low angle cross bedding. The bedding is commonly channelized and is 20-100 cm thick. The siltstone is dark grey to maroon in color and has maroon fine clay intercalations. This basal conglomerate, quartz mica schist and quartzite-siltstone sequence is over 600 m thick, and is overlain by a ~30 m thick cherty dolomite sequence. Rest of the sequence exposed in the Pind Khan Khel syncline comprises of massive to thick-bedded dolomite (~400-500 m thick).

Measured Stratigraphic Section at Bir (Sherwan): The contact between the Abbottabad Formation and the Tanawal Formation at the southern limb of the Sherwan Syncline is between quartzite of the Tanawal Formation and dolomite of the Abbottabad Formation. At this point the basal conglomerates are missing. The basal conglomerates are not consistent throughout the contact. The stratigraphic section (Fig. 4) is built using information from a road-log measured along the Bir-Sherwan road. The basal arenaceous sequence as measured in the Bir anticline (a parasite fold in the southern limb of the main Sherwan syncline) is about 100 m thick and comprises of quartzite at the base and siltstone at top directly below the first appearance of dolomite. The dolomite appears three times in the sequence; most basal being 250 m thick, middle 80 m, and upper ~200 m. The dolomite is thin to thick bedded (20-200 cm) and cherty. The internal bracciation is also observed in the dolomite. The color of dolomite is grey. The first and second dolomite units are intervened by over 200 m thick quartzite-silitstone sequence, while the second and third dolomite units are intervened by siltstone and limestone units, each about 50 m thick. The siltstone is light brown in color, and has alternating clayey beds. The quartzite is cross-bedded, channelized and speckled. The limestone is dolomitized and contains sandstone intercalations. It is internally brecciated, dark grey in color and thin to thick bedded.

Unlike rest of the study area, the Sherwan syncline preserves sequence overlying the dolomite unit which is referred to as the Upper Quartzite by Calkins et al. (1975). The Upper Quartzite has a thickness of minimum 550 m. It is coarse grained (locally conglomeratic) with color variation from light brown to milky white having low angle cross bedding and slump structures. The bed thickness in the Upper Quartzite varies from 10 to 200 cm.

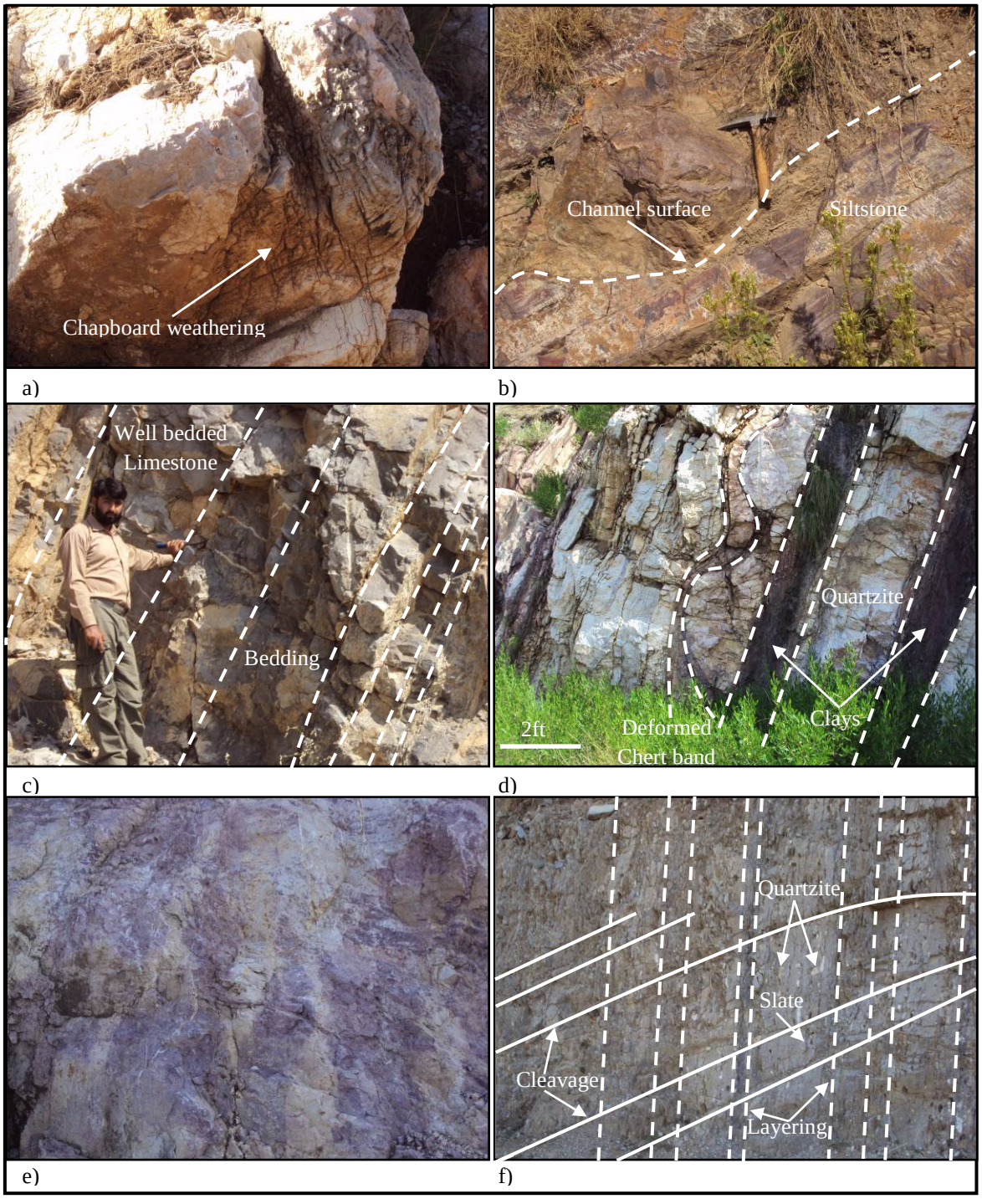

Fig. 5. Photographs showing the different lithological units and features of Abbottabad Formation. a) Chapboard weathering in dolomite, b) Channelized bedding in maroon siltstone, c) Thin to thick bedded grey colour limestone, d) Deformed Chert Bands and Clays, e) Purplish pink cherty dolomite and f) Conglomeratic unit of Abbottabad Formation.

2.2.2. Composite stratigraphy

It is clear from three stratigraphic sections measured in different parts of the study area that the Abbottabad Formation comprises of at least three units; a basal arenaceous unit, an intermediate dolomitic or dolomite-dominant unit and an upper quartzite unit.

The dominant lithologies in the basal arenaceous unit are quartz mica schist, quartzites, sandstones, siltstone and conglomerate (Fig. 5). Ali (1962) identified conglomerates at the contact between the Tanawal and Abbottabad formations ranging in thickness up to 50 m. The present study confirms presence of conglomerate at the Tanawal-Abbottabad contact but finds pebbly beds not only at the base but also interbedded with siltstones at several levels in the sequence both in the basal arenaceous unit as well as in the intermediate dolomitic unit. Calkins et al. (1975) also noted presence of conglomerate both at the base of the Abbottabad Formation as well as intercalations within quartzite and dolomite.

The thickness of the basal arenaceous unit is variable in all the measured sections; ranging from over 600 m at Pind Khan Khel to less than 100 m at Bir and Aluli. Ali (1962) suggested a thickness of ~500 m for the combined basal conglomerate, quartz mica schist, and quartzite members measured at Pind Khan Khel.

The intermediate dolomite unit is the diagnostic component of the Abbottabad Formation and is a characteristic lithology of Cambrian sequence wherever exposed in Pakistan (e.g., Ambar Dolomite, Peshawar Basin; Pogue et al., 1992; Sirban dolomite, Abbottabad; Mark and Ali, 1961; Latif, 1970, 1972; Muzaffarabad Formation; Hussain et al., 2009; Muzaffarabad Formation, Kotli; Ashraf et al., 1983 and Jutana Dolomite; Gee, 1989). In the study area the dolomite member is present in all the four synclinal folds, but its full thickness and upper contact with the overlying upper arenaceous member is only exposed in the Sherwan syncline. The overall thickness of dolomite in this member is between 400 and 500 m, whereas quartzite, siltstone, and conglomerate make the remaining 200-300 m thickness of the member. Although, the arenaceous lithologies are found interbeded with dolomite at several levels, commonly they tend to cluster in the middle part of the sequence between the two principal dolomite sequences.

The upper quartzite member occupies the core of the Sherwan syncline. Compared to the lower arenaceous member, this arenaceous unit is generally monotonous with quartzite as the dominant lithology. The quartzite is highly variable in grain size from fine grained to subconglomeratic. The sequence is characterized by common cross bedding and ripple marks. The thickness of this member in the Sherwan Syncline is over 500 m.

2.3. Quaternary deposits

The quaternary deposits are present in the study area in the form of terraces and plains. These deposits consist of clay, gravels and pebbles. Some terraces along the rivers have some boulder layers which represent the ancient flash flooding. These Quaternary deposits unconformably overlie the Abbottabad Formation as well as the Tanawal Formation.

3. Regional correlation of Early Paleozoic succession

Early Paleozoic rocks are not wide spread but are exposed in several parts of northern Pakistan such as Salt Ranges in the south (Gee, 1989), Peshawar Basin (Pogue et al., 1992) and Spinghar (Kurram) Range in the west (Khan and Abbas, 2011), Muzaffarabad and Kotli in the east (Hussain et al., 2009) and Abbottabad in the close vicinity of the presently studied area. In the following, an attempt is made at comparison of the Early Cambrian Abbottabad Formation from the studied area with those exposed in other parts of northern Pakistan (Fig. 6).

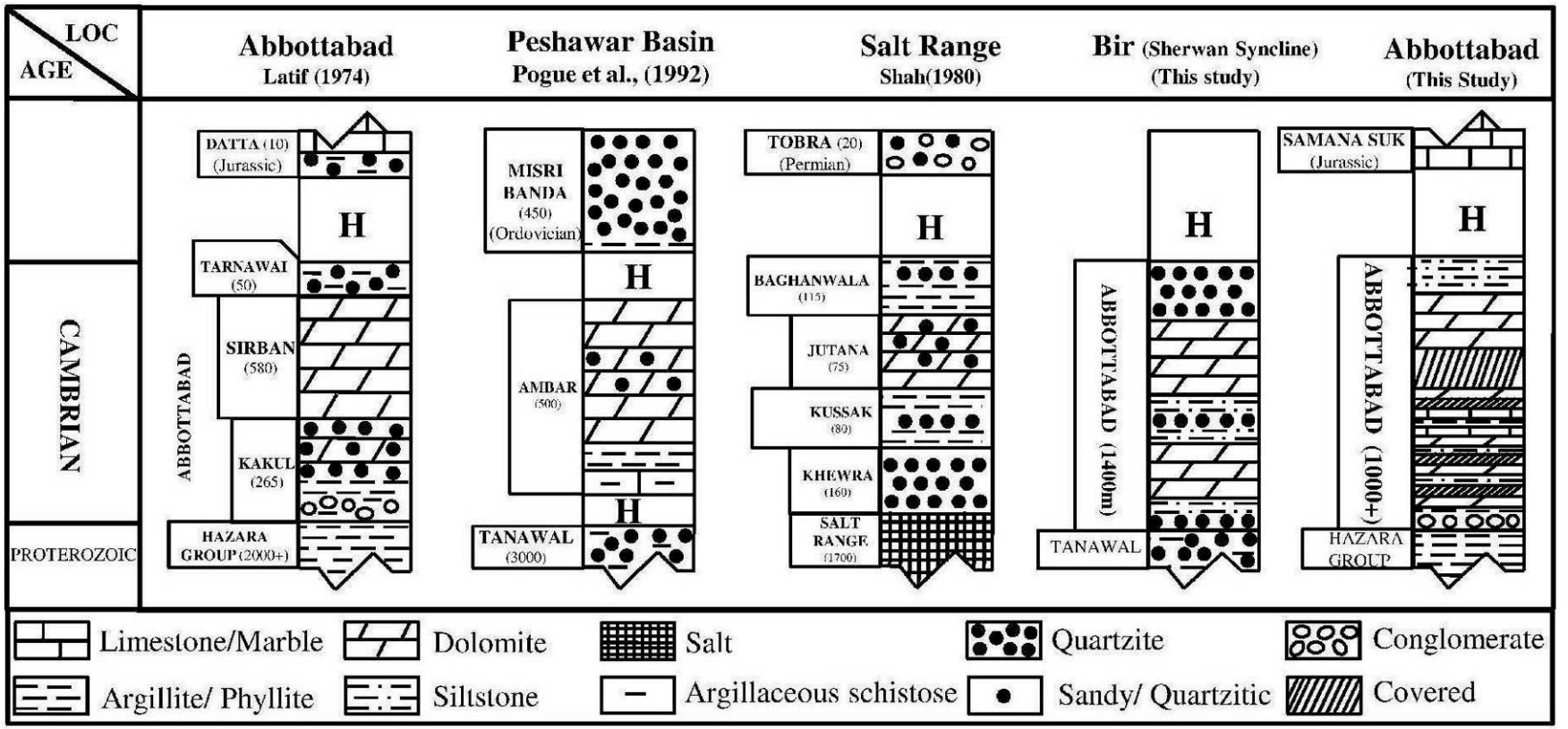

Fig. 6. Regional correlation chart of Paleozoic sequences exposed in Hazara Basin, Peshawar Basin and Salt Range. 'H' indicates major hiatus and number in parentheses represents approximate thickness in meters.

3.1. Comparison with the Soban Gali section

The exposures of the Early Paleozoic rocks nearest to the presently studied area are at Soban Gali on the Abbottabad-Sherwan road (Fig. 1). Here the Early Paleozoic rocks rest on top of the Hazara Formation instead of the Tanawal Formation, opposite to the case in the study area and a situation similar to that at the Sirbon Hill, Abbottabad (Latif, 1970). This section directly lies below the Panjal Thrust that brings Tanawal Formation of the Tanawal block in the studies area to rest directly above the Abbottabad Formation with a faulted contact. The contact of the Hazara and Abbottabad formations at Soban Gali is marked by pebbly slates, instead of conglomerates as the case at the type locality at the base of the Sirbon Hill (Baig and Lawrence, 1987). The basal unit of the Abbottabad Formation at the Soban Gali is ~340 m thick, thin to medium bedded siltstones that contain several beds of sandstone in its middle and upper parts. The sequence has excellent cross bedding and ripples marks and is characterized by a wide variation in bedding thickness from laminations to beds, some with meter scale thickness. The arenaceous-argillaceous basal unite has a transitional contact with overlying dolomites, marked by interbeding between dolomite-quartzite lithologies. The dolomite unit is thick bedded but contains quartzite, siltstone and sandstone beds at several levels. The upper part of the middle dolomite unit and the entire upper quartzite unit is absent at this location due to faulted contact with the overlying Tanawal Formation along the Panjal Thrust.

There is generally a close comparison of the Soban Gali section with Abbottabad Formation exposed in the study area; 1) the siltstone, sandstone, quartzite and dolomite lithologies are closely comparable in composition, sedimentary structures and general appearance; 2) the presence of arenaceous basal members followed by a dolomite member with intercalations of arenaceous lithologies is commonly found at Soban Gali as well as in the studied area.

3.2. Comparison with the Abbottabad section

The Abbottabad Formation exposed at the Havelian-Abbottabad road on the south-western base of the Sirban Hill is probably the most extensively studied sequence by various pioneer workers (Latif, 1970, 1972). For comparisons, a stratigraphic section was measured along the Havelian-Abbottabad road between Muslimabad (Khota Qabar) and Salhad (Figs. 4 and 6). The lower 500 m section directly above the Tanakki conglomerates is mostly covered by debris and overburden of Quaternary deposits and dense vegetation. The two points of bed-rocks exposures are of siltstone composition that suggests the presence of an arenaceous sequence in the basal parts of the formation. Latif (1972) designated this dominantly clastic sequence comprising of siltstone and sandstone with subordinate cherty dolomite as the Kakul Formation with a total thickness of ~250 m.

The measured section during the course of this study has a thickness of ~1000 m covered predominantly by dolomite, except for some shale, cherts, and limestones in the basal parts. Latif (1972) termed this dolomite sequence as the Sirban Formation and noted presence of sandstone, siltstone and chert intercalations throughout the sequence. Latif (1972) measured Sirbon Formation to be ~600 m in thickness. The Sirbon Formation of Latif (1970, 1972) is overlain by a disconformable contact by Hazira Formation. Latif (1972) reported *Hyolithe*s and *Chencelloria* fossils from the Hazira Formation which made the basis of assigning Cambrian age to the Abbottabad Formation (including Kakul and Sirbon formations).

As is clear from the above description of the Abbottabad Formation from its type locality, there is a close similarity in the lower two members i.e., arenaceous and dolomite units from the three areas studied here (i.e., Sherwan, Soban Gali and Sirbon Hill). However, the upper quartzite member present in the core of the Sherwan syncline and described by Calckins et al. (1975) and this study is markedly different from Hazira and Gladanian formations of Cambrian age reported from Sirbon Hill-Abbottabad area (Latif, 1970; 1972).

3.3. Comparison with the Swabi section, Peshawar Basin

West of the Indus River, the Tanawal formation is unconformably overlain by a

dolomitic rich unit termed the Ambar Formation (Pogue and Hussain, 1986; Pogue et al., 1992). The contact is marked by a conglomerate bed comprising well rounded quartzite clasts in an arenaceous matrix. The Ambar Formation is dominated by a massive sandy dolomite with local argillite/phyllite horizons. The formation is overlain by a sequence of quartzites and argillites termed Misri Banda Formation (Pogue and Hussain, 1986; Pogue et al., 1992). The quartzite in the Misri Banda Formation is well sorted, fine to medium grained and feldspathic. It is commonly inter-bedded with fine-grained argillites. The sequence is rich in vertically oriented burrows. Pogue et al. (1992) assigned Early-Middle Ordovician age to the Misri Banda Formation based on the presence of *Cruziana Rugosa* fossils.

The occurrence of dolomites in the Early Paleozoic sequence in the Peshawar basin attracted correlations with the Abbottabad Formation exposed east of the Indus River, especially at Abbottabad (Pogue et al., 1992). The difference is the absence of lower arenaceous member in the Peshawar basin compared to the Abbottabad-Sherwan areas. The upper quartzite member reported by Calkins et al. (1975) and in this study from the Sherwan area is either absent in the Peshawar basin or it is represented by the Misri Banda Formation. The two have identical stratigraphic position with respect to the dolomites and have close lithological resemblance that warrants a mutual correlation. However, absence of fossils in the upper quartzite member in the Sherwan area does not allow confirmation of an Early Ordovician age as is the case in the Peshawar Basin.

3.4. Comparison with the Early Paleozoic sequence, Salt Ranges

In the Salt Range, Early Paleozoic sequence is well established comprising Khewra Sandstone (Purple Sandstone), Kussak Formation, Jutana Formation and Baghanwala Formation (Gee, 1989). Latif (1972), while suggesting the Cambrian age for the Abbottabad Group drew correlation between the Kakul Formation (the arenaceous member of the present study) with that of the clastic rocks (sandstone, siltstone) of the Khewra Sandstone and that of the Sirbon Formation (the dolomite member of the present study) with the Jutana Formation. It is worth mentioning that in the Salt Range, the Early Paleozoic sequence rests on the Precambrian Salt Range Formation instead of the Hazara (Slate) Formation (Abbottabad area) or the Tanawal (Quartzite) Formation (Sherwan area).

4. Discussions

In the study area, Ali (1962) proposed a two fold subdivision 1) lower conglomerates, 2) dolomites. Ali (1962) did not cover the northern parts of the Sherwan syncline. Calkins mapped Sherwan syncline and noted presence of upper quartzite above the dolomite, but misinterpreted them to belong to the Kingriali Formation, a sandstone dominant stratigraphic unit of Triassic age exposed in the Salt Ranges. The present study covers all the three major exposures of the Abbottabad Formation (i.e., Sherwan, Aluli-Kachhi, and Pind Khan Khel synclines) to develop a composite stratigraphic column. On the basis of measured stratigraphic sections, the Abbottabad Formation is divided into three units, which are 1) basal arenaceous unit, 2) Intermediate dolomite unit and 3) upper quartzite unit. The basal arenaceous unit comprises of basal conglomerates, quartz mica schist, quartzites, sandstones and siltstones. The composite thickness of the basal arenaceous unit is ~600 m, but it varies in all the measured sections. The intermediate dolomite unit in the study area is present in all the four major synclinal fold structures, but its upper contact with the overlying upper arenaceous unit is present only in the Sherwan syncline. This intermediate dolomite unit is dominantly comprised of dolomite with quartzite, siltstone and conglomerate as intercalations. The dolomite has a thickness between 400-500 m and other lithologies make the remaining 200-300 m thickness of the member. The arenaceous lithologies are found interbedded with dolomite at several levels, but commonly they tend to cluster in the middle part of the sequence between the two principal thicknesses of dolomites. The upper arenaceous unit occupies the core of the Sherwan syncline. Compared to the basal arenaceous member, this unit is generally monotonous with quartzite as the dominant lithology. The quartzite is highly variable in grain size from fine grained sand size to subconglomeratic. The sequence is

characterized by common low angle cross bedding and current ripple marks. The thickness of the member in the Sherwan syncline is over 500m.

Latif (1972) divides the Abbottabad Group into Kakul and Sirbon formations. The Kakul Formation is further classified into four members, which are Tanakki Conglomerate, Sangargali Member, Mahmdagali Member and Mirpur Sandstone. The composite stratigraphic column shows that the Tanakki conglomerate, Sangargali and Mahmdagali members consist of basal conglomerates, claystone, siltstone, sandstone, quartzite and cherty dolomite. The overall thickness of these three members is ~220 m. The Tanakki conglomerate, Sangargali member and lower part of the Mahmdagali member are correlative with basal arenaceous unit of the Abbottabad Formation of the present study. The Sirbon Formation is predominantly dolomite with some sandstone, shale, limestone and quartzose sandstone. This unit is ~600 m thick and correlative of the intermediate dolomite unit of Abbottabad Formation in the Sherwan area. The upper arenaceous member exposed in the Sherwan syncline is clearly different from the Hazira and Gladanian formations of Cambrian age reported from Abbottabad and probably missing in the Abbottabad area (Latif, 1970; 1972) either through non-deposition or erosion prior to the deposition of the Hazira Formation

The Early Cambrian Ambar Formation, west of the Indus River in the Peshawar basin is a possible equivalent of the Abbottabad Formation (Pogue et al., 1992). The formation is underlain by the Tanawal Formation and the contact is marked by a conglomeratic bed. The dominant lithology in the Ambar Formation is massive sandy dolomite with local argillite/phyllite horizons. It is overlain by quartzites and argillites of the Misri Banda quartzite (Pogue and Hussain, 1986; Pogue et al., 1992). The age assigned to the Misri Banda quartzite is Early-Middle Ordovician (Pogue et al., 1992). Compared to the Hazara region, the Ambar Formation lacks the lower arenaceous member characteristic of the Abbottabad Formation both in the Abbottabad and Sherwan areas. The Misri Banda Quartzite occupies a similar stratigraphic position as the upper quartzites of the Abbottabad Formation exposed in the core of the Sherwan syncline (Calkins et al., 1975; this study). However, absence of fossils in the Sherwan area does not allow confirmation of this correlation. It is worth mentioning that detrital zircons from a sample from the lower part of the Misri Banda Formation yield an age spectrum from 3340 Ma to 525+-5 Ma (Myrow et al., 2010). The youngest of the detrital zircon ages from this sample suggest an Early Cambrian age for the Misri Banda Quartzite that is closely similar to that suggested for the Abbottabad Formation.

5. Conclusions

Detailed measured logs along road and stream cuts have been used to develop stratigraphic characterization of the Abbottabad Formation in the Sherwan area in the southwestern Hazara ranges. Three-fold subdivision of the Abbottabad Formation has emerged through this study; lower arenaceous unit (dominantly quartzite with subordinate pebbly conglomerates, quartz mica schist, sandstone and siltstone), middle dolomitic unit (dominantly dolomite with subordinate quartzite, siltstone, and conglomerate) and upper quartzite unit (almost exclusively quartzite). The lower two units are well defined in the Abbottabad Formation at its type locality at the Sirbon Hill section, Abbottabad (Latif 1970, 1972) but upper quartzite unit of the present study is only described from the Sherwan area (Calkins et al., 1975; this study). Misri Banda Quartzite in Swabi area overlying the Ambar dolomite (Pogue et al., 1992) is possible equivalent, though the latter is Early Ordovician in age based on paleontological evidence, though youngest detrital zircon ages are ~525 Ma are close to that of the Abbottabad Formation.

Acknowledgements

This study was sponsored by the graduate student support program of the National Centre of Excellence in Geology, University of Peshawar. Hammad Hanif is thanked for assistance in the field. Thorough reviews of an earlier draft by Dr. Muhammad Umar, CIIT, Abbottabad and Dr. Raza Shah, Geological Survey of Pakistan are gratefully acknowledged.

References

Ali, C.M., 1962. The Stratigraphy of South Western Tanawal Area, Hazara, West Pakistan. Geological Bulletin Punjab University, 2, 31-38.

Ali, S.T., Calkins, J.A., Offield, T.W., 1964. Mineral Deposits of The Hazara District, West Pakistan. Geological Survey of Pakistan, Record, 13, 1, 38.

Ashraf, M., Chaudhry, M.N., Qureshi, K.A., 1983. Stratigaphy of Kotli area of Azad Kashmir and its correlation with standard type areas of Pakistan. Kashmir Journal of Geology, 1, 1, 19-29.

Baig, M.S., Lawrence, R.D., 1987, Precambrian to Early Paleozoic orogenesis in the Himalaya. Kashmir Journal of Geology, 5, 1-22.

Baker, D.M., Lille, R.J., Yeats, R.S., Jhonson, G.D., Yousaf, M., Zaman, A.S.H., 1988. Development of the Himalayan frontal thrust zone: Salt Range Pakistan. Geology, 16, 3-7.

Bossart, P., Dietrich, D., Greco, A., Ottiger, R., Ramsay, J.G., 1988. The tectonic structure of the Hazara-Kashmir Syntaxis, Southern Himalaya, Pakistan. Tectonics, 7, 273-297.

Calkins, J.A., Offield, T.W., Abdullah, S.K.M., Ali, S.T., 1975. The Geology of the Southern Himalayas in Hazara, Pakistan and adjacent areas. United States Geological Survey Professional Paper, 716c, 29.

Coward, M.P., Butler, R.W.H., Cambers, A.F., Graham, R.H., Izatt, C.N., Khan, M.A., Knipe, R.J., Prior, D.J., Treloar, P.J., Williams, M.P., 1988. Folding and imbrication of the Indian crust during Himalayan collision. Philosophical Transactions of the Royal Society of London, 144, 377-391.

Crawford, A.R., Davies, R.G., 1975. Ages of Pre-Mesozoic formations of the Lesser Himalaya, Hazara District, Northern Pakistan. Geological Magazine, 112, 509-514.

DiPietro, J.A., Pogue, K.R., 2004. Tectonostratigraphic subdivisions of the Himalayas: A view from the west. Tectonics, 23(TC5001), 1-20.

Gee, E.R., 1989. Overview of the geology and structure of the Salt Range, with observation on related areas of northern Pakistan. In: Malinconico, L.L., Lillie, R.J. (Eds.), Tectonics of Western Himalayas. Geological Society America, (Special Paper), 232: 95-112.

Hussain, A., Yeats, R.S., Mona Lisa, 2009. Geological setting of the 8 October 2005 Kashmir earthquake. Journal of Seismology, 13, 3, 315-325.

Kazmi, A.H., Rana, R.A., 1982. Tectonic Map of Pakistan, 1:1,000,000. Geological Survey of Pakistan, Pakistan.

Khan, M.A., Abbas, M., 2011. Interaction between the Himalayan and India-Afghan Collision Tectonics at the NW margin of the Indian Plate in the Kurram Region, NW Pakistan. Journal of Himalayan Earth Sciences, (Abstract Volume), 44, 1, 42-43.

Khan, S.R., Khan, M.A., 1994. Late Proterozoic stratigraphy of the Swabi area, NWFP, N. Pakistan. Geological Bulletin University of Peshawar, 27, 57-68.

Killinger, F.L., Richard, R.L., 1967. Barite in Pakistan: CENTO Symposium on Industrial Rocks and Minerals, Lahore, 1962, Proceedings, 418-428.

Latif, M.A., 1970. Stratigraphy and micropaleontology of Galis group of Hazara, Pakistan. Geological Bulletin of Punjab University, 13, 1-64.

Latif, M.A., 1972. Lower Paleozoic (? Cambrian), Hyolithids from the Hazara shale, Pakistan. Nature, 244, 138, 124-125.

Latif, M.A., 1974. A Cambrian age for the Abbottabad Group of Hazara, Pakistan. Geological Bulletin of Punjab University, 10, 1-20.

Mark, P., Ali, C.M., 1961. The geology of the Abbottabad area with special reference to the Infra-Trias. Geological Bulletin of Punjab University, 2, 47-56.

Middlemiss, C.S., 1896. The Geology of Hazara and the Black Mountains. Geological Survey of India, Memoir 26, 302.

Myrow, P.M., Hughes, N.C., Goodge, J.W., Fanning, C.M., Williams, I.S., Peng, S., Bhargava, O.N., Parcha, S.K., Pogue, K.R. 2010. Extraordinary transport and mixing of sediment across Himalayan central Gondwana during the Cambrian–Ordovician. Geological Society of America Bulletin, 122(9-10), 1660-1670.

Myrow, P., Hughes, N., Fanning, C.M., Banerjee, D., Dipietro, J.A., 2009. Lower Paleozoic Continuity of the East Gondwanan

Margin and Implications for Interpretation of Tectonostratigraphic Zones of the Himalaya. American Geophysical Union, Fall Meeting 2009, abstract, T42A-07.

Pogue, K.R., Hussain, A., 1986. New light on the stratigraphy of Nowshera area and discovery of Early to Middle Ordovician trace fossils in NWFP, Pakistan. Geological Survey of Pakistan, Information Release, 135, 15.

Pogue, K.R., Wardlaw, B.R., Harris, A.G., Hussain, A., 1992. Paleozoic and Mesozoic stratigraphy of the Peshawar Basin, Pakistan: correlations and implications. Geological Society of America Bulletin, 104, 915-927.

Tahirkheli, R.A.K., Majid, M., 1977. Geology of the Tanawals in the southwest Tanawal and Gandghar Range, Hazara, Pakistan. Geological Bulletin University of Peshawar, 9-10, 1-21.

Wadia, D.N., 1928. The geology of Poonch State (Kashmir) and adjacent portions of the northern Punjab. Memoirs of India Geological Survey, 51(2), 185-370.

Wadia, D.N., 1931. The syntaxis of the northwest Himalaya: Its Rocks, tectonics and orogeny. Memoirs of Geological Survey of India, 65 (2), 189-220.

Wynne, A.B., 1879. A geological reconnaissance from the Indus at Kushalgarh to Kurram at thal on Afghan Frontier. Geological Survey India, 12(2), 100-114.

Yeats, R.S., Lawrence, R.D., 1984. Tectonics of the Himalayan thrust belt in northern Pakistan. In: Haq, B.U., Milliman, J.D. (Eds.), Marine Geology and oceanography of Arabian sea and coastal Pakistan. Van Nostrand Reinhold Corporation, New York.