STRATIGRAPHY AND STRUCTURAL SET-UP OF SWABI AND ADJOINING AREAS NWFP, PAKISTAN

BY

SAID RAHIM KHAN

NATIONAL CENTRE OF EXCELLENCE IN GEOLOGY,
UNIVERSITY OF PESHAWAR
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Said Rahim Khan

National Centre of Excellence in Geology,
University of Peshawar.
1992

Approved by

(Dr. M. Asif Khan)
Internal Examinar

(Prof. Arif Ali Khan Ghauri)
(Internal Examinar)

(Dr. Aslam Awan)
External Examinar

(Dr. M. Qasim Jan)
Director
NCE in Geology
University of Peshawar

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ABSTRACT

The present work has resulted in the recognition of a well developed stratigraphic succession of the Tethyan Himalayas exposed in the mountain ranges fringing the northeastern Peshawar basin (Swabi, Mardan, and Buner districts of the NWFP, Pakistan). The rocks range in age from Precambrian through Paleozoic to Early Mesozoic and are composed of igneous, metamorphic and sedimentary rocks. A Precambrian succession comprising of Salkhala and Tanawal formations makes a basemenet to about 400 metres thick Paleozoic succession, comprising Ambar Formation (Cambrian), Misri Banda Quartzite (Early to Late Ordovician), Panjpir Formation (Late Silurian), Nowshera Formation (Early Devonian), and Jafar Kandao Formation (Early Carboniferous). These metasedimentary rocks provide evidence for Late Paleozoic (Caboniferous-Permian) intracontinental rifting, the onset of which is indicated by north-derived clasts in the Jafar Kandao Formation and together with extrusion of riftrelated volcanism in the form of alkaline acid porphyries and theiilite to alkaline basalt horizons. A much greater variety of hypabyssal and plutonic rocks including carbonatite, ijeolite etc., are associated with this phase of magmatism. Post Permian thermal subsidence and marine transgression led to the deposition of the Early Mesozoic carbonate rocks which unconformably overly the Karapa Greenschist.

The whole stratigraphic succession is considered to be developed in a northward dipping epicontinental basin while the magmatism is related to the rifting episode. Most of the rocks have yielded fossil evidences regarding their ages, while a few have been dated by radiomatric determination. The present work describes some of the new evidences relating to the Paleozoic-Mesozoic rocks of the study area and their interpretation and implication in the reconstruction of the regional geological framework of this part of Tethyan outer Himalayas.

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CHAPTER ONE

INTRODUCTION

1.1. Location and Accessibility

The present work describes the stratigraphic and structural set-up of about 1600 square kilometres area lying in the Swabi, Mardan and Buner districts, NWFP, Pakistan. The study area is covered by Survey of Pakistan topographic sheet nos. 43 B/7, 8, 11 and 12 (Fig. 1). It is divided into two parts (Fig. 2). The Swabi area (Map 1) is bounded by long. 72 to 72 45 E and lat. 34 6 19 to 34 20 N. while the Rustam area (Map 2) is bounded by long. 72 15 to 72 30 E. and lat. 34 15 to 34 30 N. In terms of regional geological setting the study area forms a part of the "Swat nappe" (Treloar, 1989), which is bounded on the north by Kohistan Arc and on the south by the Attock-Cherat range. The western limits of this nappe are still not clear, while in the east the Darband-Oghi Thrust Fault separates it from the Hazara nappe.

A network of metalled and unmetalled roads gives an easy access to most of the outcrops in the investigated area (Fig.3). The area is approachable from Jehangira in the south, Tarbela Dam in the east, Mardan in the southwest and Mingora in the north.

1.2. Purpose and Objective

The study area is mostly covered by sedimentary, metamorphic and igneous rocks. The present work summarizes the results of a detailed geological mapping around Swabi and Rustam areas on a 1:50,000 scale (Map 1 & 2). This mapping was undertaken with the intent of establishing the stratigraphic and structural set-up of the area and their correlation at both local and regional scale. Since the area makes the outer limits of the internal zone of the Indian plate (Coward et al., 1988), both metamorphic and unmetamorphosed sedimentary successions are encountered in this area. A relatively lesser degree of internal deformation has enabled the author to recognize, map and document a Precambrian to Early Mesozoic succession which is comparable in its completness with that of the Salt Range (Gee, 1989).

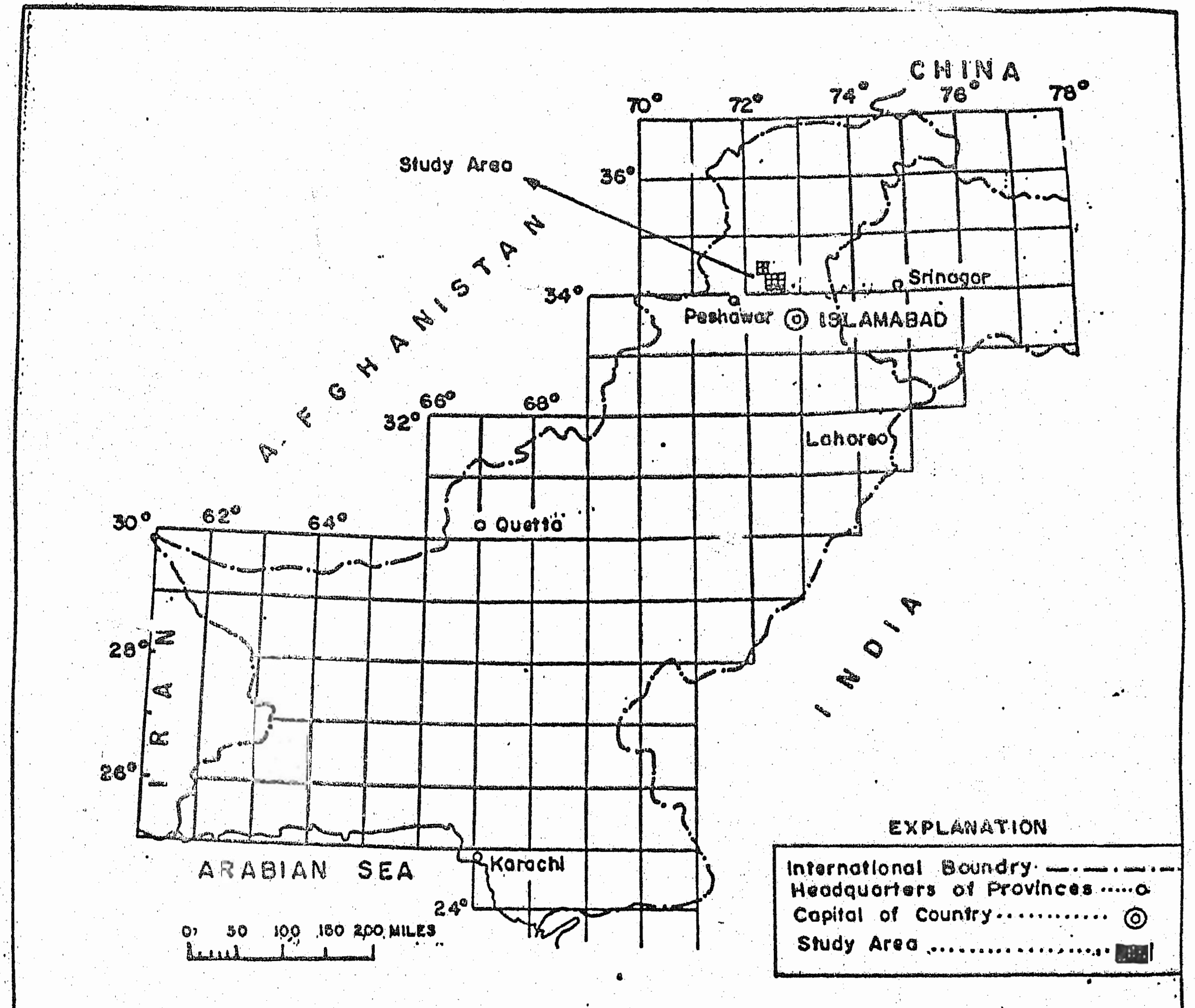


Fig. I: INDEX MAP OF PAKISTAN SHOWING THE LOCATION OF STUDY AREA.

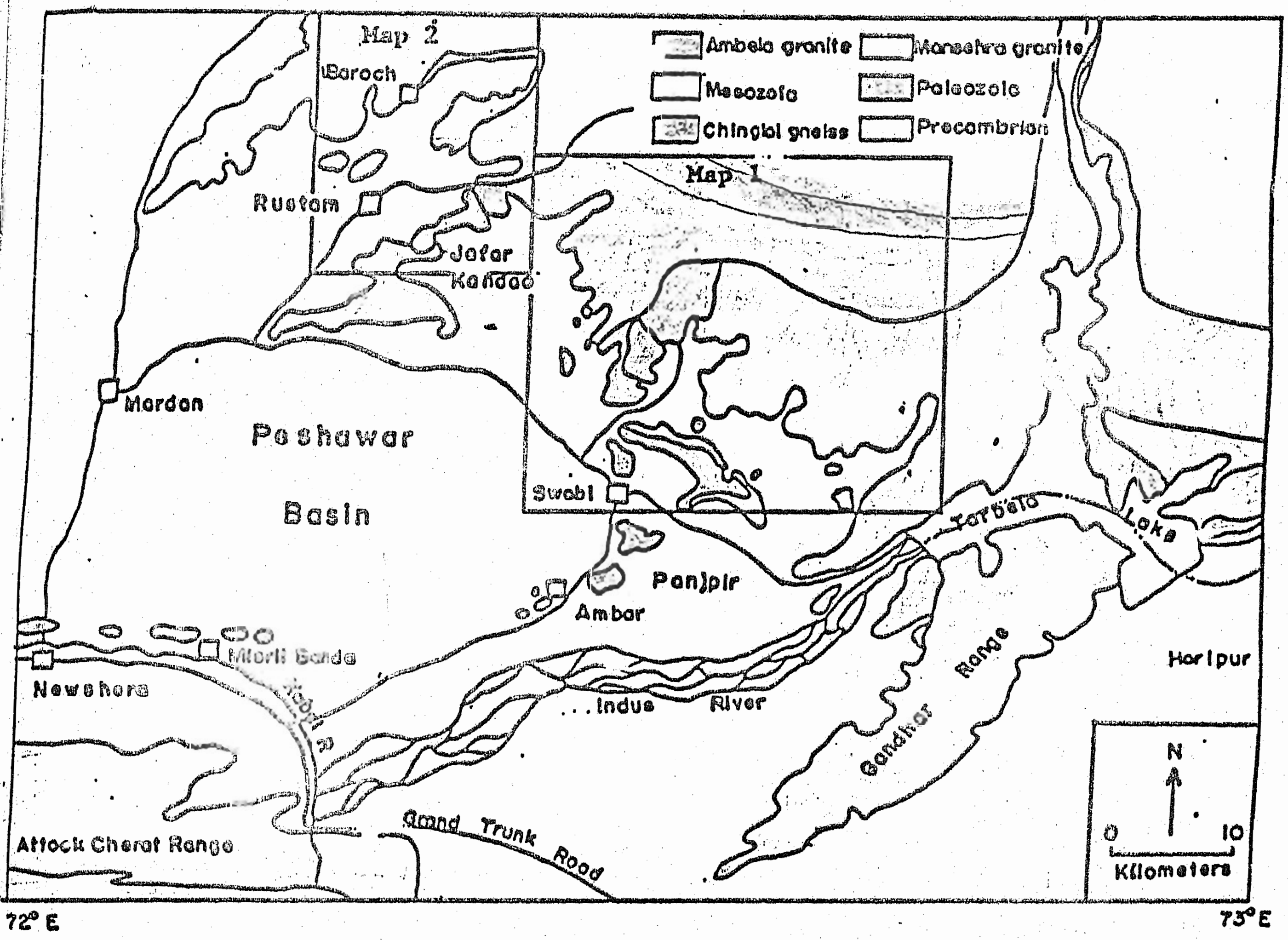


Fig 2: Simplified geological map showing the location of study area (after Pogue et al. 1992)

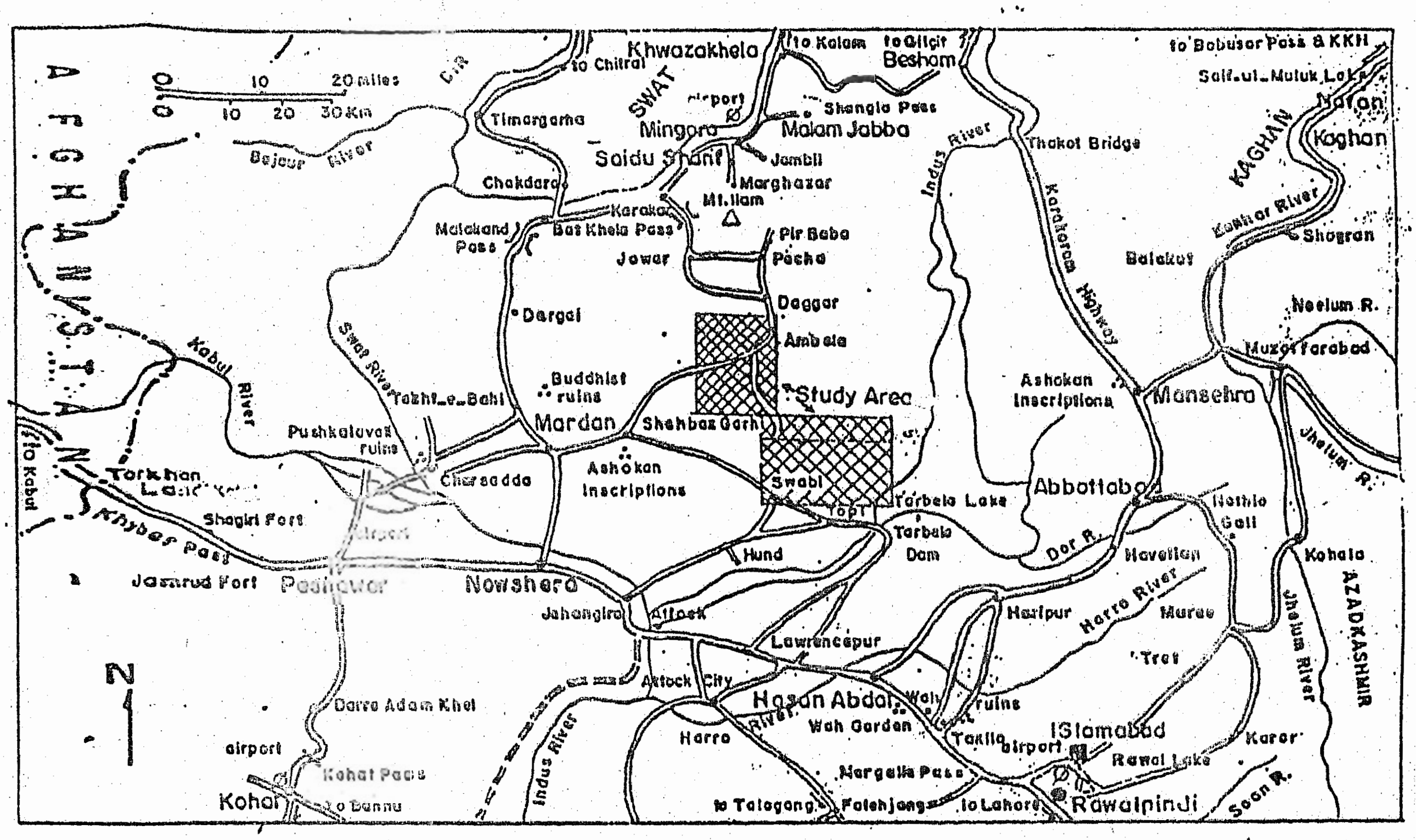


Fig.3: Road accessibility map to the Swabi and adjoining areas.

1.3. Geography

The area has a dry to subtropical climate with hot summers and moderate winters. The maximum temperature during summer is 105 F (40 c) and minimum temperature during winter is 43 F (1 C).

The rainfall usually occures from January to March and July to September, Which are considered to be the rainy seasons.

The area is thickly populated and the average concentration of pulation is about 500-559 persons per square kilometre (Survey of Pakistan, 1985). Pushto is their mother language, while they can also understand and speak Urdu.

1.4. Method of Mapping

Detailed geological mapping was carried out on 1:50,000 scale and was based on close spaced traverses from place to place. First, the aerial photographs (1:40,000 scale) were studied under stereoscope in the laboratory and were later on checked in the field. The geological details marked on the aerial photographs were later on transferred to the topographic sheets (1:100,000 scale).

1.5 Local Geological Setting

The study area forms the northeastern flank of the Peshawar basin and comprises a sequence of sedimentary and metasedimentary rocks, ranging in age from Precambrian through Paleozoic to Early Mesozoic. The Precambrian and Early Paleozoic (Cambrian) rocks are devoid of fossils, while the Paleozoic-Mesozoic (from Ordovician to Triassic) contain fossils. To the north, the study area is bounded by a granitic body of batholithic dimension called the "Ambela Granite Complex" (Rafiq and Jan, 1989). Martin et al. (1962) have named the cover sequence as "Chamla Sedimentary group". The present studies have proved that the cover sequence is similar to that exposed in the Rustam area and is Late Paleozoic to Early Mesozoic in age. Further more, the cover sequence is neither separated by a fault from the "Swabi sedimentary group", nor it is as old as Cambrian as suggested previously by Martin et al. (1962). To the west the geology exposed in the Tangi and Jamrud areas is almost identical to that found in the study area Shah et al. 1980; Khan A, and Aslam,M 1990). To the south, a well established Early Paleozoic sequence is exposed in the Nowshera area (Stuaffer, 1968; Pogue and Hussain, 1986) which is a continuation of the same sequence exposed in the presently studied area. To the east, the study area is separated from the Ghandghar range and Hazara nappe by the Darband-Oghi Thrust Fault. The Precambrian basement rocks of the study area (i.e., Salkhala and Tanawal formations) on which the Paleozoic-Mesozoic fossiliferous succession of the Tethyan Himalaya rests, are very much similar to those found in the basal parts of the Hazara nappe and different from those croping out in the Attock-Cherat and Ghandghar ranges. The rocks exposed in the Alpuri-Saidu areas, Swat, including Manglaur Crystalline Schist, Alpuri siliceous schist, Saidu calcareous graphitic schist (Kazmi et al., 1984) and Nakani Ghar marble (Palmer-Rosengberg, 1985) are believed to be the high grade metamorphic equivalents of the Tanawal Formation, Misri Banda Quartzite and Baroch Formation (Nakani Ghar marble), respectively (Pogue et al. 1992). Similarly the Swat Granite Gneiss and amphibolite can be correlated with the Chinglai Gneiss and Karapa Greenschists exposed in the study area (Pogue et al. 1992).

It is, therefore, suggested that the rocks exposed in the Nowshera, Swabi, Swat (Buner, Saidu & Alpuri) areas are similar, forming a separate tectonic block known as Swat nappe. The geology of the Swat nappe is distinct from the adjacent Attock-Cherat and Gandghar ranges and comparable with that of the Hazara area but may be broadly correlated with that of the Hazara area (Treloar, 1989).

CHAPTER TWO

STRATIGRAPHY

2.1 Introduction

The hill ranges to the north and northeast of Swabi consist predominantly of stratified sedimentary and metamorphic rocks ranging in age from Precambrian to Jurassic. A suite of igneous rocks comprising both acidic and basic compositions occurs either as intrusions cutting across the older formations or as extrusion interstratified with the Carboniferrous strata (Map 1 & 2). A detailed appraisal of the magmatic rocks is given in chapter 3.

Earliest attempts on stratigraphic analyses of the Swabi and adjoining areas was that of Martin et al. (1962). They classified the metasedimentary rocks of the area into two groups e.g., a) Swabi- Chamla sedimentary group and b) Lower Swat-Buner schistose group. They recognised additional stratigraphic units in this previously unknown area which included the Swat Granitic Gneiss, the Ambela Granite and the Shewa porphyries. Until then, however, nothing was known about the age of these rocks. Davies and Ahmed (1963) described orthoconic nautiloids from the hills south of Swabi which indicated for the first time presence of Paleozoic rocks in this part of the Himalayas. Tiechert and Stauffer (1965) confirmed this by describing a Paleozoic reef complex from near Nowshera which contained a fossil assemblage of Devonian age. Stauffer (1968) divided the sequence in the Nowshera area into three formations which range in age from Late Silurian to post Early Devonian.

Calkin and Ahmed (1969) recognized a Paleozoic sequence in the area east of the Indus river in the Hazara which they assigned to the Tanawal and Abbottabad formations (Table 1, column 1). It was realised that the Paleozoic sequence rests unconformably on Precambrian metasediments which they divided into Hazara and Salkhala formations. Hussain (1985) carried out regional geological mapping in the Attock-Cherat area and established the stratigraphic order (Table 1, column 2). Pogue and Hussain (1986) revised the stratigraphy of the Nowshera area (Table 1, column 3) on the basis of further findings of Paleozoic fossil assemblages. Khan et al. (1988), while carrying out regional geological mapping around the Tarbela dam divided the area into "western block and eastern block" (Table 1, column 4). They correlated the Paleozoic rocks of the Tarbela area with those rocks exposed in the Nowshera area. The Proterozoic rocks were correlated with those outcroping in the Hazara area. Later on Khan et al. (1990) and Hussain et al.(1990) found the upper Paleozoic and Early Mesozoic rocks in the Rustam area (Map 2).

The present work on the stratigraphic analysis results in the recognition of a complete sequence from Precambrian to Early Mesozoic (Table 1, column 5). It has been shown that the Nowshera sequence of Pogue and Hussain (1986) rests unconformably on the Tanawal Formation which has been assigned a Precambrian age in present study on the basis of its stratigraphic position below the Cambrian Ambar Formation. This work has also resulted in (1) delineation of the spatial distribution of the Precambrian sequence in the Swabi and adjoining areas which was previously unknown and (2) subdivision of both the Salkhala and the Tanawal formations into units which define the complete litho-stratigraphic spectrum within these formations Table 2 & 3). It is to be noted that such information was previously lacking because of the common involvement of the Precambrian successions in the Himalayan tectonics in the rest of the internal zone of the Indo-Pakistan continantal plate (Coward et al., 1988). In the context of the Paleozoic succession, this work has succeeded in the recognition of the stratigraphy younger than the Nowshera Formation, completing the sequence upto Jurassic (Table 1, column 5). In the following, a detailed description of the various stratigraphic formations is presented in terms of their distribution, lithological variation, contact relationships and basis for the assigned ages.

2.2 Precambrian Succession

The Tethyan Himalayas (Gansser, 1964; Searle et al., 1987) are characterized by a thick Phanerozoic succession which is commonly fossiliferrous. This rests on a Precambrian basement which is mainly argillaceous but carries significant amount of other lithologies including arenites and carbonates. In the NW Himalaya, the Precambrian basement has commonly been divided into a lower Salkhala Formation, which is overlain by Dogra or their equivalent Hazara Slates. These in turn are overlain by the Tanawal Formation (Calkins et al., 1975). The Salkhala and Tanawal formations are exposed in the study area, while the Hazara Formation is missing. The Darband-Oghi Thrust Fault is a regional lineament following the course of the Indus river, which separates the area into two tectonic blocks in the vicinity of the Tarbela dam (Khan et al., 1988). The NW.

block, of which the presently studied area is a part, contains Precambrian Salkhala Formation which is tectonically overlain by the Tanawal Formation. These Precambrian rocks are unconformably overlain by a Paleozoic succession. In the tectonic block SE. of the Darband-Oghi Thrust Fault, however, the Salkhala Formation is missing, while the Hazara Formation is overlain by the Precambrian Sobra Formation and the Tanawal Formation. Obviously this discrepancy in the Precambrian succession is due to the interaction of tectonics which has been analysed in details in the chapter on regional tectonics. In the following a detailed account of the Precambrian succession exposed in the Swabi and adjoining areas is presented. The Precambrian rocks from the Swabi area mapped during this study are amongst the least metamorphosed rocks of their equivalents in northern Pakistan. Although, they are commonly folded, but are stratigraphically coherent and less deformed internally than their counterparts elsewhere in the northern Pakistan (e.g., Besham, Hazara, Kaghan, and Kashmir areas). In this section a detailed description of the lithological characteristics of the Precambrian rocks is presented together with a new lithostratigraphic subdivision (Table 2 & 3). It is expected that a comparison with the Precambrian rocks of the Swabi area may solve several of the stratigraphic and tectonic problems associated with the Precambrian strata in the internal zone of the northwestern Himalaya.

2.2.1 Salkhala Formation

2.2.1.1 Field Distribution

Calkin and Ahmed (1969) mapped a complex lithological assemblage comprising phyllites, schists, limestone and quartzite at the right bank of the Indus river near the Tarbela dam site, to which, they reffered to as the Salkhala Formation. They showed it to be extending northward along the Indus river in the Amb-Utmanzai area, flanked on the either side by the Tanawal Formation. This disposition of the Salkhala Formation was interpretted to be due to its position in the core of a large northward-Plunging antiform to which they termed as the Indus re-entrant. The extreme northern tip of this north-verging fold structures has recently been mapped by Williams (1989) confirming that the Salkhala Formation extends up to north of Darband where it plunges northward under the Hazara nappe comprising of Tanawal Formation and the Mansehra Granite. An important feature, noted both by Calkin et al. (1975) and Williams (1989) is the tectonic nature of the contact between the Salkhala and Tanawal formations.

During the course of this work, it has been found that fold structures other than the Indus reentrant may also contain Salkhala Formation in their cores. The Swabi-Rustam areas in the notheastern parts of the Peshawar Plain, are folded into a series of NW-SE striking cylindrical fold structures, which are at a right angle to the trend of the Indus reentrant (see chapter 4). In one of the anticlines called the "Kundal antiform", which trends NW-SE and runs for over 15 Kilometres between the right bank of the Indus river and upto the village Ghurghushtu, the core is occupied by the Salkhala Formation with the Tanawal and younger formations occurring at the flanks (Map 1). In this anticline the lower stratigraphic levels of the Salkhala Formation are exposed at the right bank of the Indus river in the vicinity of the village Gandaf. The successively upper stratigraphic levels of the Salkhala Formation are exposed westward in the plunging direction of the anticline.

2.2.1.2 Lithological Subdivision

The Salkhala Formation in the study area is divided into three units (Table 2). The lower most unit consists of graphitic schist, recrystallized limestone, phyllite and flaggy quartzite. The graphitic schist is dark to dark-grey, fine grained and contains disseminated quartz grains. The graphitic schist grades into limestone, which is dark-grey to grey, medium to coarse grained, thin to medium bedded and unfossiliferous. It is interbeded with phyllite. The quartzite is flaggy, brownish-grey to light-grey, thin to medium bedded and is highly ferruginous, iron staining along bedding planes and sheared surfaces are commonly observed. Sedimentary structures like ripple marks and cross bedding are frequently found in the quartzitic part of the formation. Hematite mineralization is found in the lower parts of the formation south of Gandaf. The lowest exposed unit is usually associated with pyrite, indicating an aerobic condition during the deposition of this part of the formation. The exposed part of the lower unit of the Salkhala Formation may range upto 600 metres in thickness.

The middle unit is composed of phyllite, which is brownish-grey to greenish-grey on weathered surface and greenish-grey to olive-grey on fresh surfaces. It is fine grained and thinly laminated with well developed slaty cleavage. Graphitic schist is locally present in the phyllites of this unit. Its thickness is about 100 metres.

The upper most unit of the Salkhala Formation consists of green-coloured chlorite-bearing quartz-mica schists and minor quartzites (Table 2). The best exposures of this unit are exposed near the village of Kundal in the hinge line of the westward plunging Kundal antiform. The basal part comprises alternating horizons of brownish-grey and green-grey phyllites, while in the upper most part of the unit there are minor horizons made up of quartzites, interbedded with the phyllites. A charcteristic feature of this unit is the occurrence of rounded to subrounded "pebbles" of quartz, embedded in the green chlorite-schist matrix. There is a gradual but distinct increase in the number of these quartz "Pebbles" towards the top of this unit, where upto 70% of some of the horizons may consist of them. An important point regarding these "quartz pebbles", is their composition which is distinct from the quartzites occurring in the overlying Tanawal Formation. They are made up of medium to coarse (upto 4 cm.) clear quartz crystals similar to those commonly occurring in the quartz veins but unlike those constituting the quartzites. The quartz pebbles may be originally the quartz veins which attained the present shape following intense shearing and boundinaging. The unit is approximately 300 metres thick.

2.2.1.3 Contact Relations

The lower contact of the Salkhala Formation is nowhere exposed in the studied area. As far as the upper contact with the Tanawal Formation is concerned, it is lined by a fault both in the parts of the studied area as well as in the area around and north of the Tarbela dam (Calkin et al., 1975; Williams, 1989). Local presence of pebbly beds at the contact with the Tanawal Formation has induced some workers to suggest that the Salkhala-Tanawal contact is depositional. The composition of the "pebbles" in these so called conglomerate beds is however, suggestive of derivation from quartz veins probably through tectonism rather than by erosion of quartzite lithologies. The quartzite lithologies could not be derived by erosion anyway, since the quartzites of the Tanawal Formation were yet to be deposited and there is very little quartzite component in the Salkhala Formation itself. Therefore, the contact between the Salkhala and the Tanawal formations may be tectonic all along its extension (Calkin et al., 1975; William, 1989).

2.2.1.4 Age

No direct evidence either palaeontological, radiometric or even

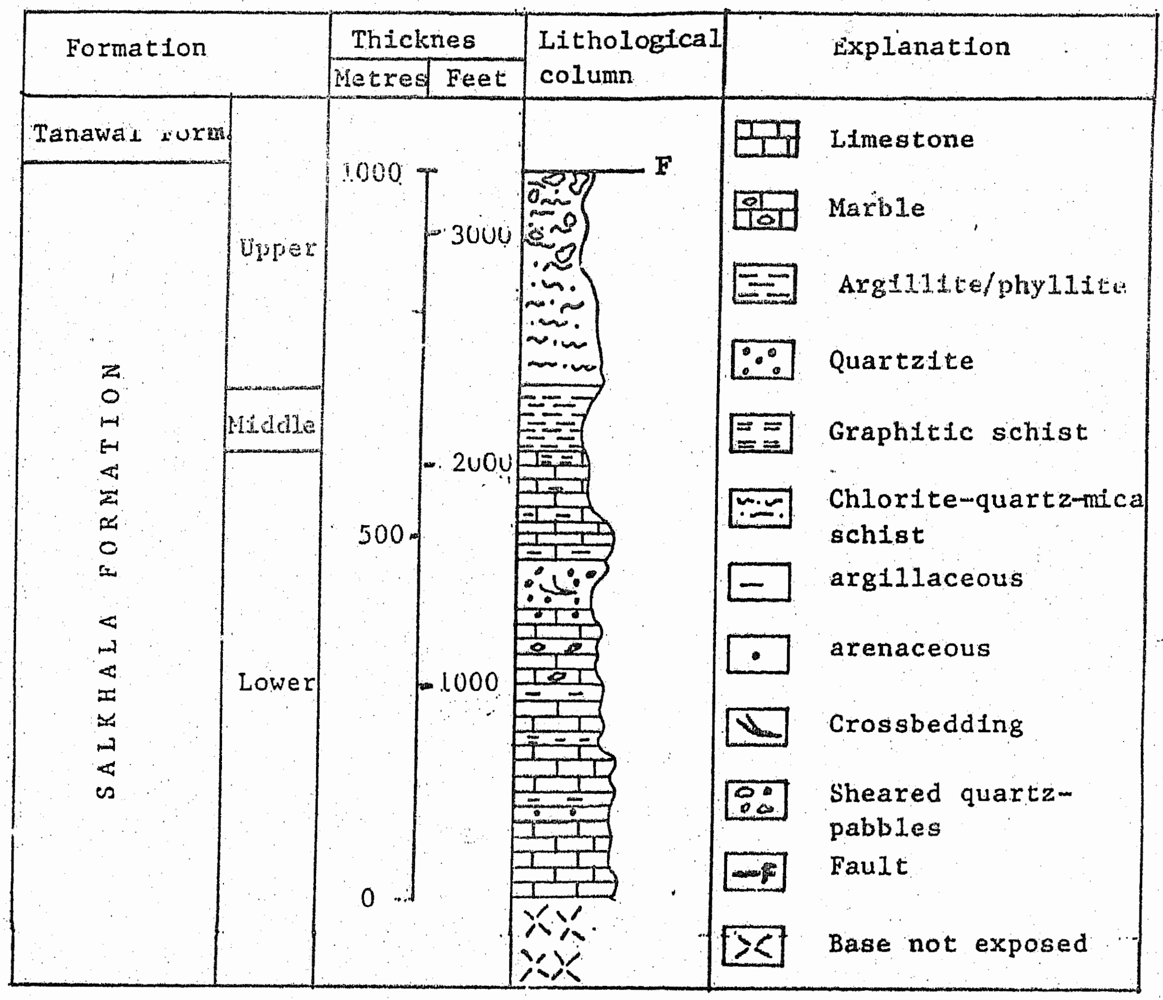


Table 2: Generalized Columnar Section showing the varied lithologies of Salkhala Formation exposed in the study area.

statigraphic is available for the age of the Salkhala Formation in the study area and its surroundings. In Kashmir, Wadia (1928 and 1931), recognised a sequence in which a thick unit of slates, termed the " Dogra Slates", conformably overlie the Salkhala Formation. Calkin et al. (1975) correlated the Dogra Slates with the Hazara Formation for which there is a radiometric age of 750 Ma available (Crawford and Davies, 1975). On the basis of this indirect correlation a Precambrian age is assigned to the Salkhala Formation.

2.2.2 Tanawal Formation

The widely distributed arenaceous sequence in the Hazara area of Northern Pakistan has commonly been included in the Tanawal Formation (Latif, 1970; Calkin et al., 1975). Calkin and Ahmed (1969) has shown the Tanawal Formation extending into the area west of the Indus river, near the Tarbela dam. The Present work has been able to trace out the complete distribution of the Tanawal Formation west of the Indus river in the hill ranges north and northeast of Swabi. More than two-third of the presently study area is occupied by the Tanawal Formation (Map 1). In the eastern parts of the mapped area, the Tanawal Formation is interfolded together with the underlying Salkhala Formation and overlying Paleozoic rocks.

2.2.2.1 Lithological Description

The lower most part of the formation is composed of brownish-grey to light-grey and white, coarse grained, medium to thick bedded, hard and compact quartzite (Table 4). Sedimentary structures like cross bedding and gradded structure are well developed. Iron staining along the bedding planes, joints and fractured planes is commonly found. Dark-grey, thick bedded to massive, unfossiliferous and recrystalised limestone is found in the form of lenses. The limestone also contains intercalations of graphitic schist. Thickness of this unit is about 1200 metres.

The middle unit consists predominantly of argillite with minor quartzite. The argillite is greenish-grey to olive-grey, fine grained, thinly laminated and cleavage is poorly developed or lacking. The quartzite is found in the form of lenses and is light-grey, fine grained, thin bedded, and hard. This unit is approximately 500 metres in thickness.

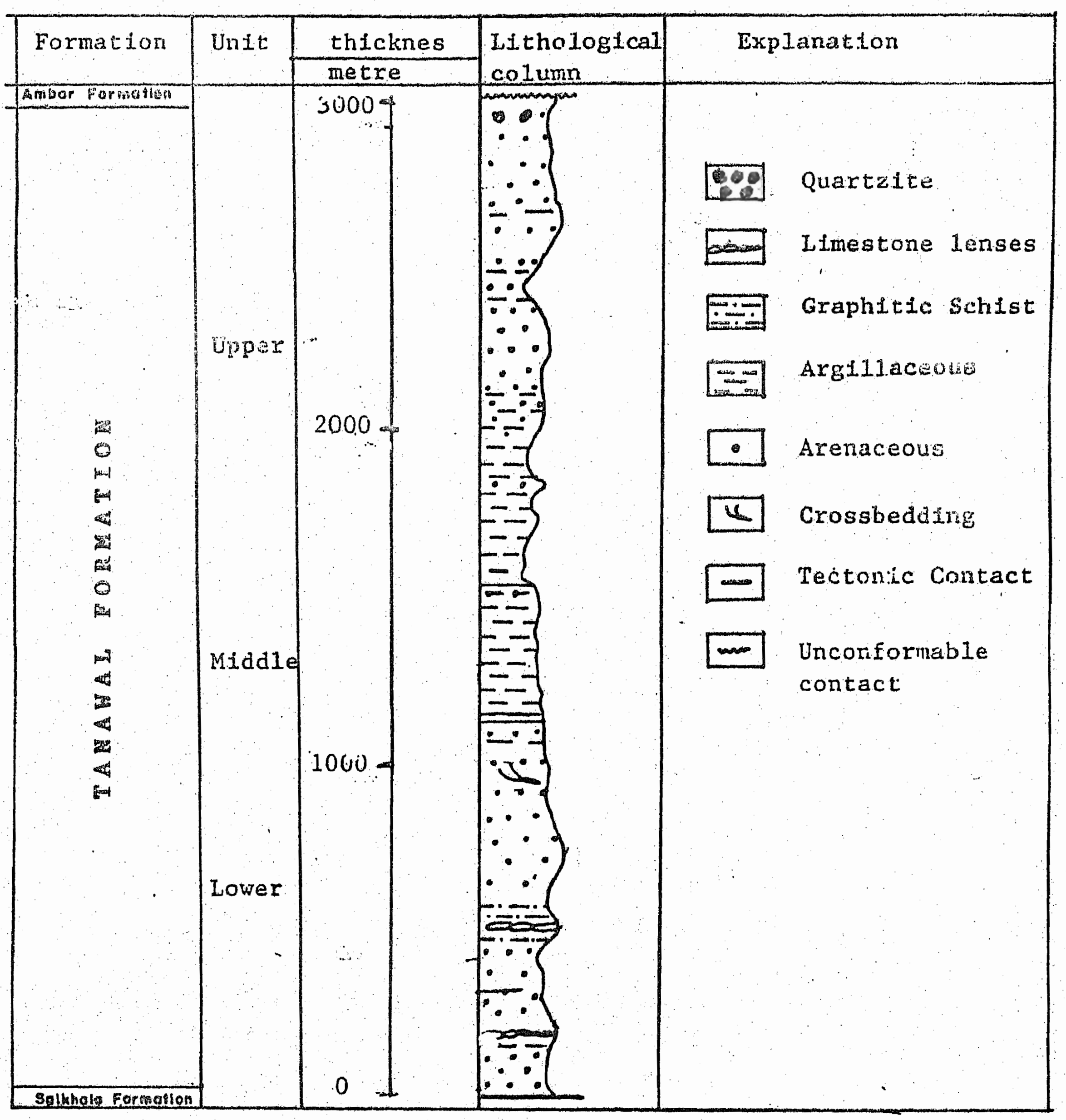


Table 3: Generalized columnar Section showing the varied lithologies of Tanawal Formation exposed in the study area.

The upper most unit of the Tanawal Formation comprises mostly of quartzite with phyllite intercalations. The quartzite is brownish-grey, thick-bedded, cross bedded, hard, compact and forms high ridges. Barite and magnetite mineralization is restricted to this unit mostly along the shear zones and faults. Its thickness is approximately 1500 metres.

2.2.2.2 Contact Relations

The Tanawal Formation is unconformably overlain by the Ambar Formation of Cambrian age. This is indicated by a 18-21 metres thick conglomerate bed occupying the contact between the two formations, consisting of pebbles and cobbles of quartzite embedded in a groundmass of quartzite and phyllite. The lower contact with the Salkhala Formation, as discussed above, is probably tectonic.

2.2.2.3 Age

The Tanawal Formation is devoid of fossils and thus lacks any direct evidence of age. Its extension in the Hazara area, east and northeast of the presently studied area is extensively intruded by a granite of batholithic dimension, which has been radiometrically dated to be 516 Ma (LeFort et al., 1980). This implies a Cambrian or older age for the Tanawal Formation. Starigraphically, the Tanawal Formation in the Hazara area is overlain by the Abbottabad Formation which is in turn, overlain by the Tarnawai Formation. The Hazira member of this formation has yielded an Early Cambrian fauna (Fuchs and Mostler, 1972; Rushton, 1973; Talent and Mawson, 1979) which implies a Late proterozoic age for the Tanawal Formation.

2.2.3 PALEOZOIC SUCCESSION

2.2.3.1 Ambar Formation

The name Ambar Dolomite was introduced by Stauffer (1968) for the basal parts of the Lower Devonian Nowshera Formation. Pogue and Hussain (1986) however, suggested that the Ambar Dolomite occurs as a discrete formation beneath the Misri Banda Quartzite. The present study has resulted in the recognition that the Ambar Dolomite occurs as a formation between the Tanawal

Formation and Misri Banda Quartzite. The name has been also changed to "Ambar Formation" as the formation not only contains Limestone and dolomite but includes calcareous quartzite and subordinate phyllite. In the Presently mapped area, the Ambar Formation is exposed in the limbs of large syncline known as the "Maneri synclinorium" just north and northeast of Swabi and in the cores of tight anticlines west and northwest of village Totalai (map 1).

The dolomite of the Ambar Formation is light-grey to pinkish-grey, medium to thick bedded and massive at places. The dolomite contains algal laminations and poor development of stromatolite. Chert in the form of veins, nodules and stringers is found commonly. Calcite veins and veinlets are quite common. It contains greenish-grey and maroon coloured, thinly laminated phyllite in the upper part and thin bedded, fine grained, flaggy calcareous quartzite in the lower part.

The lower contact of the Ambar Formation is unconformable with the Tanawal Formation and is marked by cobble conglomerate. The clasts of quartzite are embedded in a groundmass of dolomitic quartzite and phyllite. The upper contact of the formation is also unconformable with the Misri Banda Quartzite. In the Dander and Chinglai areas, the unconformity is marked by a conglomerate bed which consists of pebbles and cobbles of quartzite with dolomite in matrix. It has to be noted that the Ambar Formation is not consistent in its lateral extent. For instance, in the Swawai synclinorium in the northern parts of the presently mapped area (Map 1), the formation may or may not exist between the Tanawal Formation and the Misri Banda Quartzite. Where Ambar Formation is absent, the Misri Banda Quartzite rests unconformably on the Tanawal Formation. The thinckness of the formation is about 550 metres just southwest of Boka village.

The Ambar Formation has similar lithologies and occupies the same stratigraphic position as the Abbottabad Formation in Hazara (Latif, 1970). In particular the Sherwan and associated synclines contain dolmite with butcher-chap weathering (Plate 1), which is overlain by Skolithus-bearing feldspathic quartzite (Pogue et al. 1992), which together form a sequence closely resembling the Ambar Formation and Misri Banda Quartzite sequence of the Swabi area. The upper part of the Abbottabad Formation in Hazara area has yielded hylolithes, which indicate an Early Cambrian age (Fuchs and Mostler, 1972). The Misri Banda Quartzite which overlies the Ambar Formation has yielded fauna of Early to Middle Ordovician age. The stratigraphic position of the Ambar Formation below the

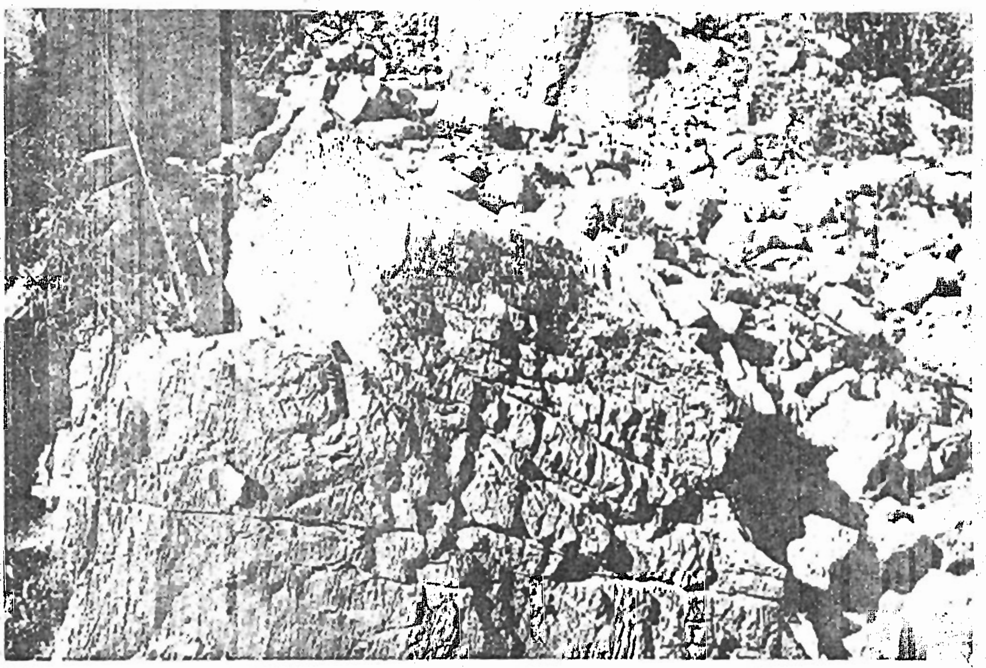


Plate 1: Photograph showing butcher-chap weathring found in the dolomite of Ambar Formation.

Misri Banda Quartzite suggests a Cambrian age.

2.2.3.2 Misri Banda Quartzite

The term "Misri Banda Quartzite" was first applied by Stauffer (1968) for the calcareous and dolomitic quartzite overlying reef bearing limestone of the Nowshera Formation (Table 5). Later, Poque and Hussain (1986) restricted the name for the unconformably bounded arenaceous sequence between the Ambar and Panjpir formations (the then Kander Phyllite of Stauffer, 1968). The type section of the Misri Banda Quartzite is located near Misri Banda village about 10 kilometres northeast of Nowshera, (lat. 34 01 N.and long. 70 06 05 E.).

Stauffer, 1968	Pogue and Hussain, 1986
Misri Banda Quartzite	
Nowshera Formation	Nowshera Formation
Kandar Phyllite	Panjpir Formation
	Misri Banda Quartzite
Ambar Dolomite	Ambar Dolomite

Stratigraphic set-up of the Nowshera area established by Stauffer,1968 and Pogue and Hussain, 1986.

In the present study area, Martin et al. (1962) mapped the outcrops of the Misri Banda Quartzite south of Swabi as "Swabi Quartzite" and north of Swabi in the Chamla valley as "Chamla Quartzite". The formation is dominantly composed of quartzite with subordinate argillite and contains conglomerate horizons in the basal part. The quartzite is brownish-grey to light-grey, fine grained, thin to thick bedded, hard, compact, calcareous and dolomitic. Cross bedding (Plate 2), gradded structures and riple marks are well preserved. At places tube-shaped burrows are also found. Ferruginous encrustation along the bedding planes, joints and fracture surfaces are commonly observed. The intercalated argillite is greenish-grey to brownish-grey, thinly laminated, and foliations are lacking or poorly developed. The Misri Banda Quartzite can be easily distinguished from the rest of the formations on the basis of its typical reddish-brown weathering topography. Its thickness is about 600 metres.

Within the lower part of the formation two conglomerate horizons occur locally (e.g., these occur southeast and southwest of the Dandar village). The lower

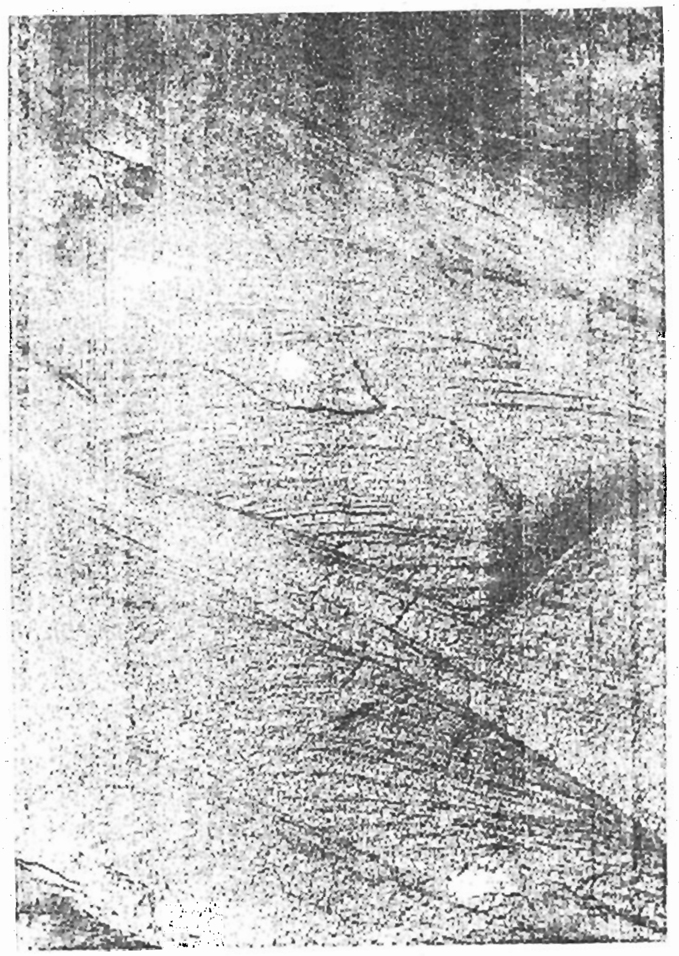


Plate 2: Photograph showing cross stratification found in the Misri Banda Quartzite, which are up-side down.

conglomerate bed is composed of rounded, subrounded and angular clasts of quartzite embedded in a matrix of quartzite. This conglomerate bed is very hard, compact and of local nature. The upper conglomerate bed is composed of rounded to subrounded quartzite clasts in a phyllite matrix.

The Misri Banda Quartzite unconformably overlies the Ambar Formation. This is indicated by a conglomerate bed which is composed of subrounded to angular clasts of limestone, while the cementing materials are calcareous quartzite. In the study area, the formation is devoid of fossils, while the upper part of the formation in the Nowshera area contains ichno fossil "Cruziana rugosa" indicating its age to be Early to Middle Ordovician (Pogue and Hussain, 1986).

2.2.3.3 Panjpir Formation

The term "Panjpir Formation" was introduced by Pogue and Hussain (1986) for the argillaceous sequence below the Nowshera Formation and above the Misri Banda Quartzite. The upper most 60 metres of the Panjpir Formation exposed beneath the Nowshera Formation just north of Nowshera town was mapped by Stauffer (1968) as "Kandar Phyllite". Martin et al. (1962) mapped the outcrops of the Panjpir and Jafar Kandao formations as "Swabi Shale" and "Chamla Shale" respectively as members of Swabi-Chamla sedimentary group in the study area. Its type locality is located near Panjpir village about 5 Kilometres [illegible]east of Swabi town at. 34 05 32 N. and long. 72 29 42 E.).

The formation is well exposed in the southern, western and northern parts of the study area (map 1). It is composed dominantly of argillites with interbedded crinoidal limestone, metasiltstone and argillaceous quartzite. These rocks are generally dark-grey to brownish-grey, silty, fissile and chloritic. Slaty cleavage is poorly developed. Baking effects in the argillites are observed where it is in contact with the Ambela Granite (e.g., north of Naugram). Its thickness is about 900 metres northwest of Dakara.

In the study area its lower and upper contacts with the Misri Banda Quartzite and Nowshera Formation respectively are transitional, while in the Nowshera area both the contacts are unconformable (Pogue and Hussain, 1986). The limestone lenses of the formation bear conodonts of Late Silurian Age (Pogue and Hussain, 1986).

2.2.3.4 Nowshera Formation

The name " Nowshera Formation" was given by Stauffer (1968) for the fossiliferous carbonates above the Kandar phyllite and below the Misri Banda Quartzite. Pogue and Hussain (1986) restricted the name for the fossiliferous carbonate rocks above the Panjpir Formation. The Panjpir Formation is overlain by a thick carbonate sequence of reef type with subordinate quartzite and phyllite, which has been included in the Nowshera Formation by Pogue abd Hussain (1986). Previously, Stauffer (1968) considered only the reef carbonate as the Nowshera Formation. Martin et al. (1962) named similar outcrops in the Swabi area as "Kala Limestone" and "Maneri Marble". The type locality of the formation lies 3.5 Kilometres north of Nowshera (lat. 30 01 34 N. and long. 71 59 40 E.) along the Nowshera-Risalpur road.

The Nowshera Formation is well exposed in the western and northern parts of the study area (Map 1). In the Swawai synclinorium, it occupies the core of the syncline and is intruded by the Ambela Granite. It is also found in the form of xenoliths (e.g., Bagh marble) in the Ambela Granite.

The formation is composed of limestone, dolomite, marble, calcareous quartzite and subordinate argillite. The limestone and marble are highly jointed, fractured and fossiliferous. Chloritization is found along the fractured surfaces at places. The marble is light-grey on weathered surface and white, dark and green on fresh surfaces. Diabase dykes/sills are sparsely distributed. The upper part of the formation contains coarse grained, friable, crossbedded, carbonate-cemented sandstone. The cross-beddings are upside-down indicating overturning of the strata and coincide with the northern overturned limb of the Maneri Synclinorium (Map 1).

Its upper contact with the Jafar Kandao Formation is unconformable as indicated by a conglomerate bed, which consists of pebbles of quartzite embedded in a carbonate cemented matrix. The Nowshera Formation has been assigned Early to Late Devonian age on the basis of conodont studies (Pogue and Hussain, 1986).

2.2.3.5 Jafar Kandao Formation

Khan et al. (1990) proposed the term "Jafar Kandao Formation" for both the argillites and the Shewa-shahbazghari porphyries exposed along the western and northwestern peripheries of the Ambela Granite in the Rustam area. These two units of different origin are so much intercalated that it is difficult to separate them. The same nomenclature is retained in the present work. The type locality is Jafar kandao about 5 kilometres southeast of Rustam on the left side of lower Swat canal (lat. 34 18 40 N. and long. 72 17 56 E.). Beside the type locality and the better known Shewa- shahbazaghari area, the formation is also exposed east of Baroch, Banda and Karapa areas of Mardan and Buner districts respectively (Map 2). The present studies have shown that contrary to the previously thought structurally restricted extent (Martin et al., 1962; Kempe, 1973), the Shewa-Shahbazghari porphyries have a much larger aerial extent showing cyclic intercalation with the argillites. This suggests that the deposition of the argillites and the emplacement of the porphyries took place simultaneously in a basin. As such the whole sequence is treated as a separate, distinct and mappable time-rock unit. Martin et al. (1962) named these argillites as "Swabi pebbly shale".

The formation comprises dominantly of argillites, limestones, quartzites and conglomerates. The argillite is rusty-brown to greenish-grey and olive-grey, fine grained with poorly developed cleavage. The limestone found in the form of lenses contains abundant conodonts. The sandstone found about 1 kilometre north of Maneri, along the Swabi-Salim Khan road, is coarse grained, calcareous, friable and crossbedded. The cross stratifications is upside down, coincident with the northern overturned limb of the Maneri synclinorium (Map 1). Its thickness is about 1500 metres.

The porphyry is volcanic to subvolcanic in origin and has a cyclic intercalation with the argillites. It contains columnar joints which are well developed and preserved (Plate 4). At places it is tuffaceous, soft, friable with kaolinization restricted to the shear zones and fractures. The contact between the intercalating porphyries and the argillites is very sharp (Plate 3). Xenoliths of the porphyry are found in the Ambela Granite just east of Rustam and northeast of Jafar Kandao, indicating that the Ambela Granite is younger than the porphyries (Jafar Kandao Formation). The formation is overlain by Karapa Greenschist which is well exposed in the Karapa pass.

Besides the type locality, the greenschist is also exposed in the Banda and Malandrai Kandao. The volcanics which are now metamorphosed to amphibolite grade may be equivalent to the Panjal trap volcanic below the Permo-Triassic rocks in northwestern India and Kashmir.

On the basis of conodonts collected from the limestone from the type locality, the formation has been assigned Early Carboniferous age (Pogue, pers. Comm.). This age is further confirmed by its stratigraphic position above the Nowshera Formation of Early to Middle Devonian age.

2.2.4. MESOZOIC SUCCESSION

2.2.4.1 Baroch Formation

The name "Baroch Formation" is proposed for the widely distributed carbonate sequence exposed in the northwestern parts of the study area (Map 2. Its type locality is designated at Baroch about 7 kilometres north of Rustam (lat. 34 26 N. and log. 72 17 50 E). These rocks were mapped by Martin et al. (1962) as "Marble and Calcareous schist" of the Lower Swat-Buner Schistose Group. Stauffer (1968) correlated these rocks with the Nowshera Formation on the basis of poorly preserved corals. Kazmi et al. (1984) named these rocks as "Kashala Formation" a member of Alpuri Group. The name "Baroch Formation" is suggested here because it is well exposed at this location with an easy access.

The formation comprises of limestone, marble, dolomitic limestone and calcareous schist. The limestone is grey in colour, fine grained, thin to medium bedded. The marble is grey to light-grey on weathered surface and white to green and black on fresh surface. Cream coloured, medium to thick bedded, fine grained dolomitic limestone is also intercalated with the limestone which gives a bituminous smell when hitted with a hammer. The calcareous schist found in the basal part of the formation is thinly laminated, fine grained and intercalated with thin bedded limestone. This formation is characterized by tight isoclinal folding, whose axis are running northeast to southwest. The thickness of the formation is about 1200 metres.

Its contact with the overlying Tor Kamar Dolomite is gradational. On the basis of the condonts Late Triassic age has been assigned to the formation (Pogue, Pers. Comn.).

2.2.4.2 Tor Kamar Dolomite

The name "Tor Kamar Dolomite" is proposed for the dolomite found above the Baroch Formation. Its type locality is designated at Tor Kamar about 3.5 kilometres west of Karapa pass (lat. 72 17 50 N. and long. 34 27 E.). Martin et al. (1962) mapped the limestone, marble, dolomite and calcareous schists collectively as the upper most part of the "Lower Swat-Buner schistose group". Palmer-Rosenburing (1985) named the marble and the limestone member of the Lower Swat - Buner schistose group collectively as the Nakani Ghar marble. Later on Ahmed et al.(1987) gave it the formation status. It is the youngest rock unit in the study area and is always found in the cores of synclines (Map 2).

The dolomite is light-grey on weathered surface and milky white on fresh surface, fine grained, thick bedded, massive, hard and resistant, thus makes high ridges in the area under investigation. It can easily be distinguished from other formations on the basis of its typical white topography even from a long distance. Calcite veins and veinlets are commonly observed. Due to metamorphism the corals are poorly preserved. The thickness of the formation is approximately 1500 metres.

The Tor Kamar Dolomite has been assigned Late Triassic-Jurassic age purely on the basis of its satigraphic position above the Baroch Formation of Late Triassic (Pogue, pers. comm.).

DEPOSITIONAL HISTORY AND TECTONICS

The study area consists of a fairly continous marine succession of Paleozoic and some Early Mesozoic rocks resting unconformabley over the Precambrian basement comprising Salkhala and Tanawal formations. The sedimentary record of the Tethyan Himalyan zone characterizes the geosynclinal stage of the evolution of the Himalayan Orogen. The Himalayan geosyncline appeared over a Precambrian basement at the beginning of the Phanerozoic time and it was closed during the Tertiary Orogenic phase. This geosynclinal history is marked by certain breaks in the deposition. These breaks are represented by unconformities found at the contacts of different litho-stratigraphic units.

The Salkhala Formation consists of various types of schists, marble, crystalline limestone and subordinate quartzite and phyllite. It is the oldest metasedimentary unit representing deep marine sedimentation. The Salkhala Formation has undergone greenschist-facies metamorphism and has a penetrative foliation marked by slaty cleavage. These features have not been observed in the overlying Paleozoic- Mesozoic succession. This indicate deformation of the Salkhala sediments after the culmination of their deposition. Note a tectonic event of Late Precambrian age is already recorded in the northern Pakistan (Baig et al., 1988; Williams, 1989). In the study area the Salkhala Formation is overlain tectonically by the Tanawal Formation, while in the Hazara area it is overlain by Hazara Formation (equivalent to Manki Formation), Calkin et al. (1975). After the deposition of the Salkhala Formation, the marine environment reestablished itself in the Late-Precambrian period, during which quartzite and argillite of Tanawal Formation were deposited in a shallow-marine environment.

After a short but pronounced upheaval represented by an unconformity at the top of the Tanawal Formation, a deep marine environment restored itself during Early Cambrian period and resulted in the deposition of dolomitic limestone and quartzite of Ambar Formation.

Soon after the deposition of the Ambar Formation the area was emerged indicated by a conglomerate bed, which is composed of pebbles and cobbles of quartzite embedded in a quartzite groundmass. This was soon followed by the depositon of pure quartzite of Misri Banda Quatzite during Early to Late Ordovician period in the shallow marine environment. Small lenses of conglomerate of local nature are found in the basal part of formation indicating rapid upheaval and submergence of the area during this period. The Misri Banda Quartzite is followed by the deposition of argillites with minor limestone lenses of Panjpir Formation indicating a deep sea environment during Late Silurian period. The Panjpir Formation is succeeded by the deposition of reef limestone of Nowshera Formation in a shallow marine environment during Early Devonian.

After the deposition of the Nowshera Formation the area was resubmerged and resulted in the deposition of argillites and emplacement of porphyries (Martin's Shewa-Shahbazghari porphyritic microgranite) of Jafar Kandao Formation during Early Carboniferous period. During Early to Late Carboniferous and even in Permo - Triasic time, the area was subjected to severe tectonic activity and rifting that resulted in the intrusion of alkaline to peralkaline igneous rocks along the northern margin of the Peshawar basin (Pogue et al., 1992). This was followed by the deposition of limestone, marble, argillite of Baroch Formation in a deep marine environment during Triassic period. The deposition of the Tor Kamar Dolomite which is the youngest lithological unit in the study area, took place during Late Triassic - Jurassic.

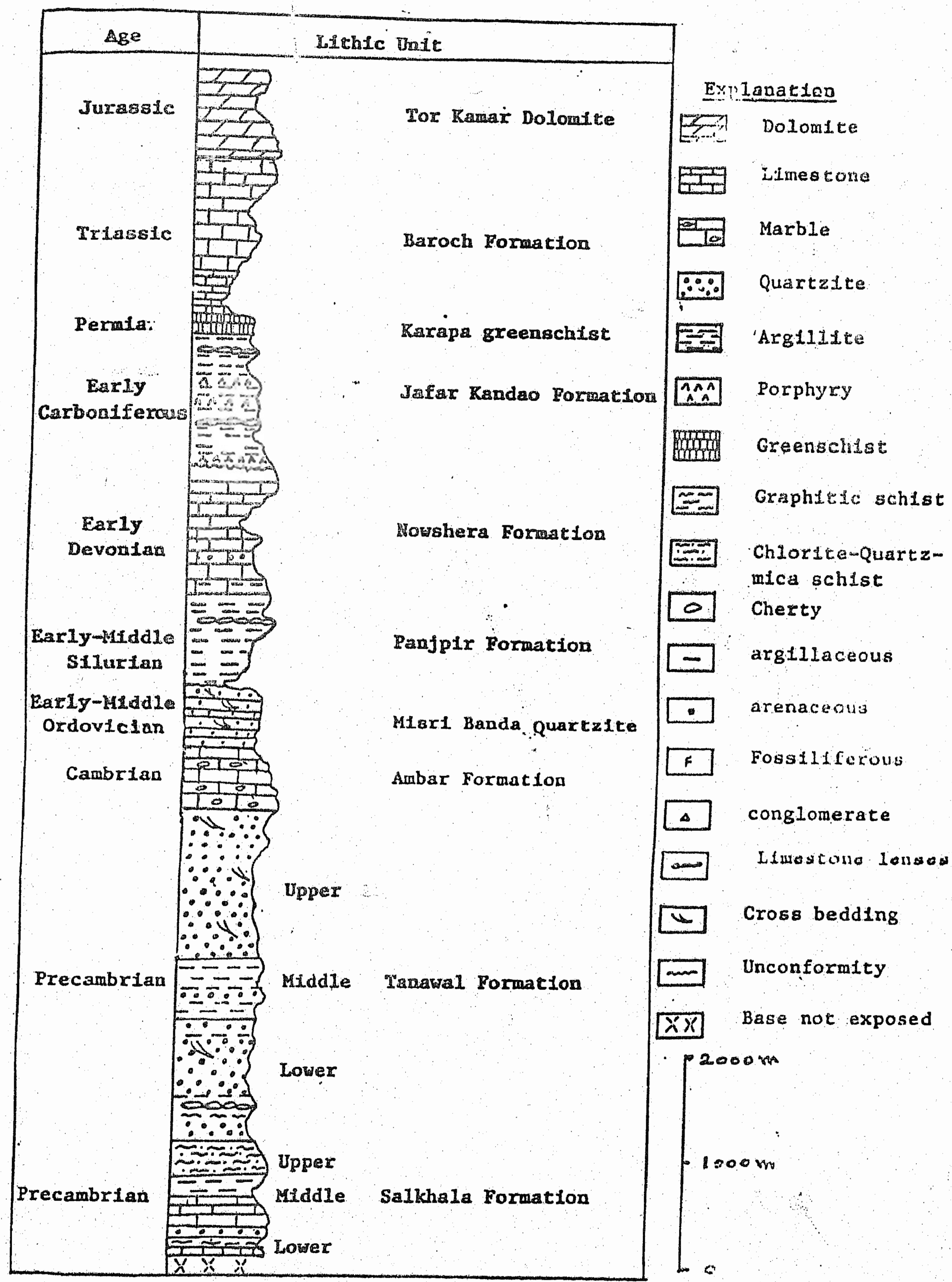


Table 4: Columnar Section showing the detailed lithologies of the different stratigraphic Units exposed in the study area.

TABLE 1: STARTIGRAPHIC CORRELATION OF HAZARA, ATTOC-CHERAT, NOWSHERA, TARBELA & THE STUDY AREAS

Age	Hazara Area (Calkin et at., 1975)	Attock Cherat Area (Hussain, A. 1985)	Nowshera Area (Pogue et al., 1986)	Tarbela Area (Khan et al., 1988)		STUDY AREA
				Western Block	Eastern Block	
	1	2	3	4		5
						Tor Kamar Dolomite
Jurassic						
	Panjal Formation	Kingriali Formation				
						Baroch Formation
Triassic						
	Kingriali Formation	Mianwali Formation				
						Karapa Greenschist
Permian						
						Ambela Granite Complex
						Jafar Kandao Formation
Carboniferous	Abbottabad Formation					
		Inzari Limestone	Nowshera Formation	Nowshera Formation		Nowshera Formation
Dovonian						
		Hisartang Formation				
		Darwaza Formation	Panjpir Formation	Panjpir Formation		Panjpir Formation
Silurian						
Ordovician			Misri Banda Quartzite	Misri Banda Quartzite		Misri Banda Quartzite
			Ambar Dolomite	Ambar Dolomite		Ambar Fromation
Cambiran						
		Dakhner Formation		Tanawal Formation	Tanawal Formation	Tanawal Formation
		Uckkhattak Formation				
					Sobra Formation	
Precambrian		Shahkot Formation				
	Hazara Formation				Hazara Formation	
	Salkhala Formation			Salkhala Formation		Salkhala Formation

CHAPTER THREE

MAGMATISM

3.1 Introduction

A restricted part of the internal zone of the Indian continental plate in NW. Himalayas comprising Peshawar Plain and lower Swat valley is characterized by an assemblage of plutonic igneous rocks which define an alkaline igneous province (Kempe and Jan, 1970, 1980; Kempe, 1973, 1983; LeBas et al., 1987; Jan and Karim, 1990). The various igneous complexes of the province include Shilman, Warsak, Tarbela, Shewa-Shahbazghari, Ambela, Koga, Malakand and Silai Pattai and comprise a diverse assemblage of rocks including peralkaline to alkaline granites, syenites, feldspathoidal syenites, carbonatites, ijeolites, melteigites and albitites. A phase of tholeiitic basic magma is closely associated, both in space and time with the alkaline magmatic activity in the Peshawar Plain alkaline province. This basic magmatism occurs in both plutonic and hypabyssal bodies in the form of intrusive plugs, dykes and sills (e.g., Warsak, Tarbela). Hitherto, no extrusive equivalents of either alkaline or basic composition have been reported, though Kempe (1973) considered some of the basic rocks at Warsak to be metamorphosed tuffs and lava flows.

Detailed stratigraphic analysis carried out in parts of the Swabi, Mardan and Buner districts, at the northeastern edge of the Peshawar Plain, indicate closely spaced, both in space and time, bimodal volcanism from this part of the Peshawar Plain. Data is presented for satigraphic control on the age and nature of the emplacement for these igneous rocks. I consider that the acid volcanics reported here are extrusive equivalents of the subvolcanic Shewa-Shahbazghari and Warsak microporphyries (porphyritic microgranites of Kempe, 1973). Whereas the basaltic volcanics are correlative with Panjal volcanics of Kashmir and Kaghan valleys and the extensive suite of tholeiitic basic dykes spread over the most part of the internal zone of the Indian plate in Peshawar plain, Swat, Hazara and Kashmir areas (e.g., dykes in the Precambrian slates, Warsak and Tarbela basic intrusions). The occurrence of these volcanics at a specific stratigraphic position in the Late Paleozoic succession of the Peshawar Plain and lower Swat has strong implications for the age and nature of the magmatism in the alkaline province.

3.2 Geological Setting

The area discussed here lies at the junction of the Swabi, Mardan and Buner districts (Fig. 3). The southwestern part of the mapped area (Map 2), comprises about 35 square kilometres isolated outcrop of microporphyries of Shewa-Shahbazghari (Martin et al. 1962., Kempe, 1973). The foothills to the Swat Himalaya in the northeast comprise a large lopolithic body of A-type granites called the Ambela Granite Complex (Rafiq and Jan, 1989). The Ambela Granite intrudes a succession of predominantly metasedimentary rocks which are exposed at its northern, western and southern contacts. The volcanic rocks being reported in this paper are part of this stratigraphic succession.

A systematic stratigraphic analysis of the Peshawar Plain and lower Swat including the country rocks of the Ambela Granite Complex have recently been carried out by Khan et al. (1990) and Hussain et al. (1990). They divide the rocks exposed at the western contact of the Ambela Granite into three formations which include Jafar Kandao and Baroch formations and Tor Kamar Dolomite. Among these formations the first one is Late Paleozoic, while the remaining two are Early Mesozoic (Map 2), envisaged to have been deposited in a subsiding (rifting) basin which gave way to the Tethys ocean. On the southern side, the Ambela Granite is in contact with the Tanawal Formation, Misri Banda Quartzite, Panjpir and Nowshera formations (Map 1).

2.2.3.1 Chinglai Gneisses:

The Chinglai Gneisses are exposed on the northern border of the study area (Map 1) between Chinglai in the West and Dhand in the east. It is in contact with the Ambela Granite Complex and Koga Syenites. The contact between the Chinglai Gneisses and the Ambela Granite Complex is marked by a regional shear zone. This shear zone is anastomosing in nature, in which the sheared syenite contain lensoids of relatively undeformed syenite. However the distinct petrological and mineralogical differences between the Chinglai Gneiss and syenite suggest that prior to their shearing the contact was intrusive in which the Ambela Granite was intruded.

The Chinglai Gneisses are two micas augen gneisses. These are leucocratic, medium to coarse grained and well gneissosed. The gneissosity is expressed by an alignment of mica and feldspar minerals. It is mainly composed of feldspar, quartz, biotite, muscovite, amphibole/pyroxene and some iron ore. The iron bearing minerals are oxidised on the weathering surfaces. The phenocrysts of microcline are mostly randomly oriented and occassionally roughly aligned to give a possible direction of flow and characterized by carlsbad twining. When involved in the cm-scale shearing, the phenocrysts are converted to augen-shaped porphyroclasts.

The Chinglai Gneiss is traditionally grouped with the Ambela Granite Complex (Rafiq, 1987). However, the present study shows that the Chinglai Gneisses are distinct from all phases of the Ambela Granite Complex in terms of texture, mineral composition and gneissosity. The closest analogy of the Chinglai Gneisses is exposed in the Lower Swat and Hazara areas in the form of Swat and Mansehra granites respectively. These granits, as in the case of Chinglai Gneisses, are biotite and muscovite bearing together with large pheoncrysts and porphyroclasts of feldspar. The Ambela Granite on the other hand is leucocratic, equigranular and non foliated.

On the basis of the the above described similarities the Chinglai Gnisses may be assinged a Cambrian age similar to the Mansehra Granite (LeFort et al., 1980).

SATURATED AND UNDER SATURATED ALKALINE AND PERALKALINE MAGMATISM

2.2.4.1 Jafar Kandao Formation

The porphyries were previously considered as a fault bounded isolated outcrop exposed in the Machai, Shewa and Shahbazghari triangle (Martin et al., 1962; Kempe, 1973; Kempe and Jan, 1970 and Rafiq, 1987). The present study has shown that porphyries are also exposed in the Jafar Kandao, Malandrai, Banda and Karapa areas of Mardan and Buner districts and show cyclic intercalations with the argillites of the Jafar Kandao Formation (Plate 5). This suggests that the emplacement of porphyritic rhyolites and deposition of argillites took place contemporaneously. As such the whole sequence is treated as separate, distinct and mappable time-rock unit.

The porphyries are subvolcanic in origin and are composed of porphyritic rhyolite, tuffs and quartz veins. The porphyritic rhyolite is leucocratic, fine grained, porphyritic and commonly foliated. Columnar joints (Plate 4) and flow

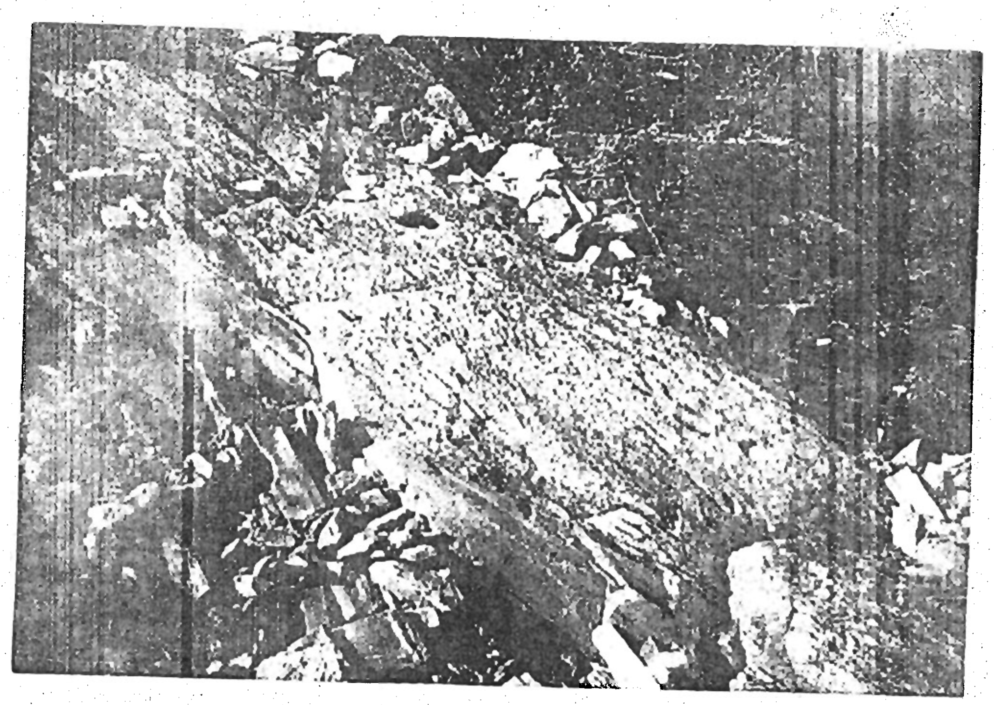


Plate 3: Photograph showing sharp contact between the porphyries and argillites of Jaffar Kandao Formation.

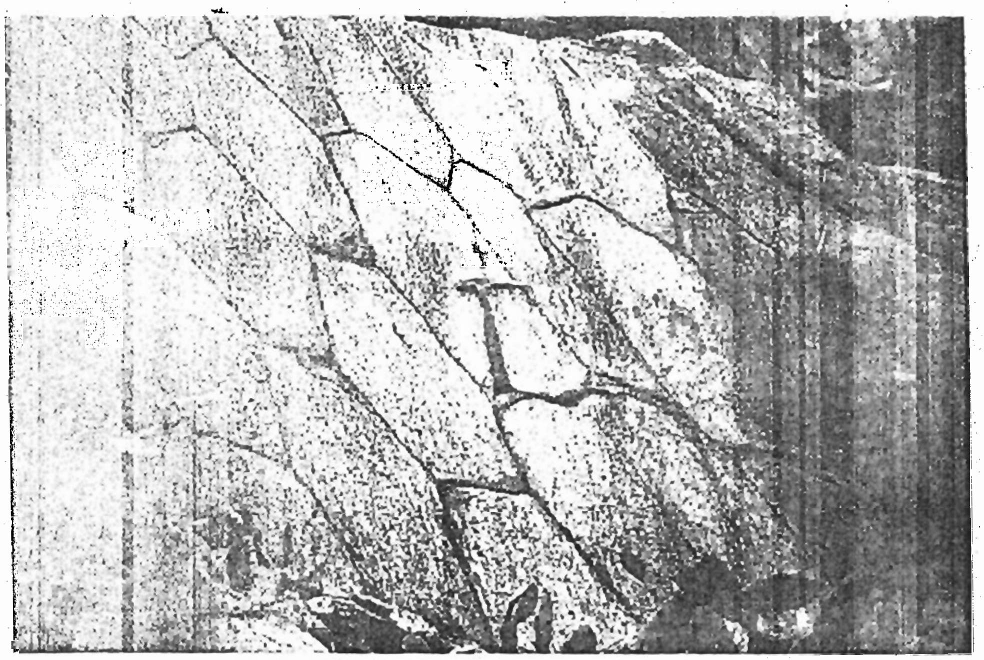


Plate 4: Typical hexagonal Columnar joints found in the porphyries of Jafar Kandao Formation.

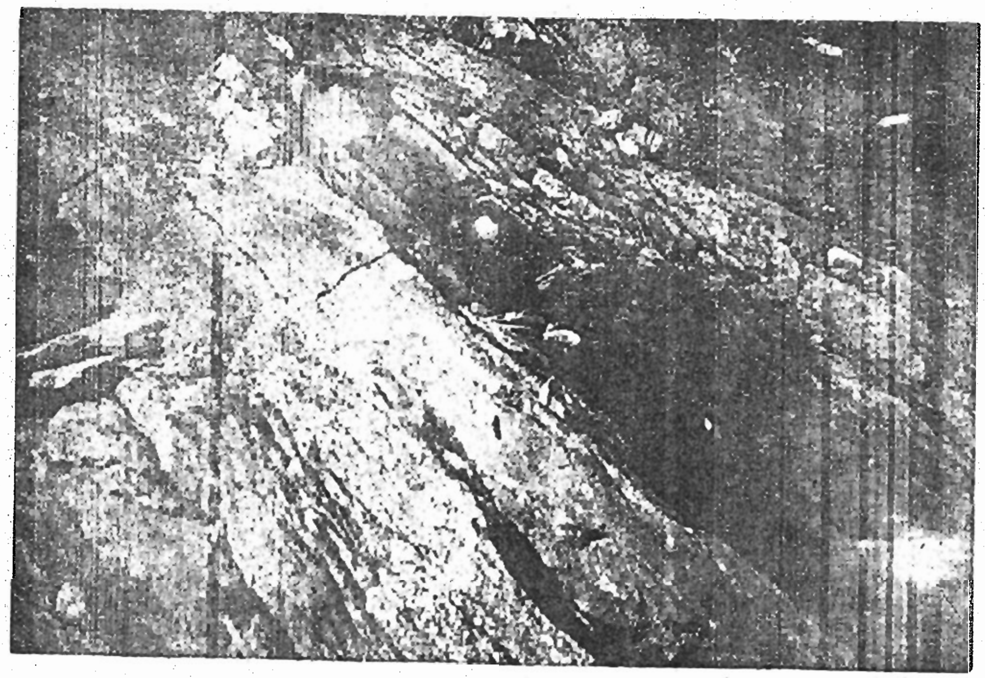


Plate 5: Intercalation between rhyolite porphyry (white) and argillite (greenish-white) of Jafar Kandao Formation.

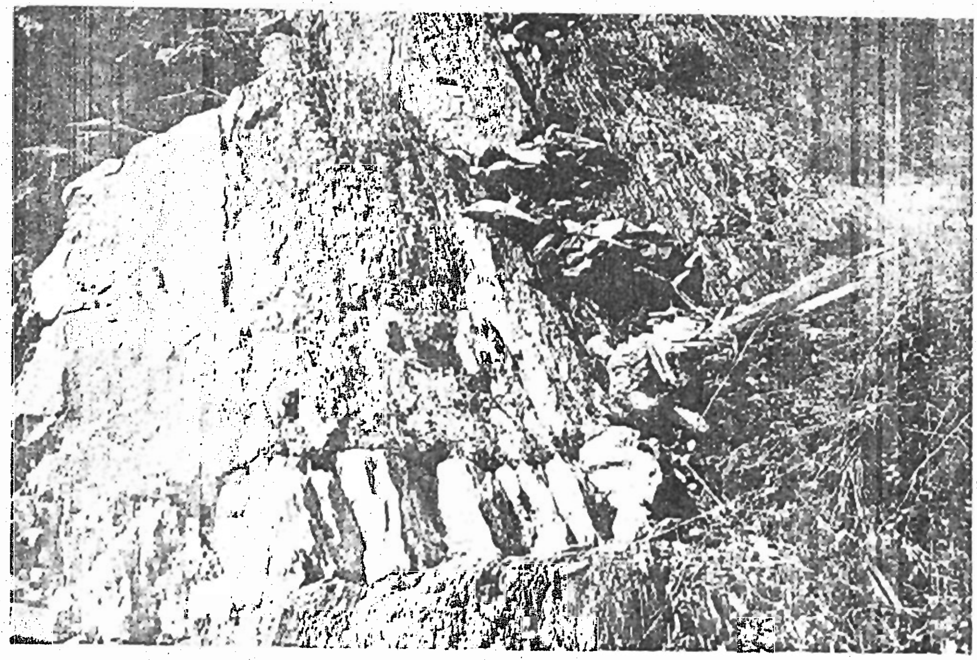


Plate 6: An horizon of fine grained porphyritic rhyolite (creamy-white) interbedded with argillites (pinkish-grey) of Kandao and a quartz vein cutting across the pophyry.

textures are well developed and preserved. At places, it is tuffaceous, soft and friable. Quartz veins from few centimetre to 2 metre thick are commonly observed within the porphyritic rhyolite and argillite of Jafar Kandao Formation. Locally quartz vein is cutting across the porphyries and does not extend into the overlying and underlying argillites (Plate 5). Kaolinization is restricted to the sheared zones. Xenoliths of the porphyries are found in the Ambela Granite just southeast of village Rustam indicating that the Ambela Granite is younger than the porphyries. The Porphyries have been considered as a part of the Jafar Kandao Formation and are thus assigned an Early Carboniferous age to it.

2.2.4.2. Ambela Granite Complex

The name "Ambela Granite" was introduced by Martin et al. (1962) and later on it was renamed as, "Ambela Granite Complex" by Siddiqui (1965) and Rafiq (1987). The Ambela Granite Complex has many phases of intrusions and ranges in composition from alkaline to peralkaline (Rafiq and Jan, 1989). The granite is leucocratic, relatively finer grained, fractured, jointed, porphyritic and locally foliated. The foliation in the granite is expressed by alignment of phenocrysts of feldspar and mica. It is mainly composed of quartz, oligoclase, tourmaline, biotite, and accessory magnetite, sphene and tourmaline.

The granite is further intruded by aplites, pegmatities, syenites, carbonatites and diabasic dykes. All these younger intrusions are fresh, hard and standing out due to their resistance to weathering, while the older granite is highly weathered. The granite has an intrusive contact with the Tanawal, Panjpir, Nowshera, and Jafar Kandao formations. Xenoliths of the porphyries and Nowshera Formation (i. e.,

Bagh marble) are found in the Ambela Granite indicating that the former two are older than the later. Intrusion of the Ambela Granite Complex took place during Late Carboniferous. The Ambela granite has been assigned (+_316 Ma) age on the basis of Rb/Sr whole rock isochron data (LeBas et al., 1987).

2.2.4.3 Koga Nepheline Syenite

The nepheline syenite intrudes the Ambela Granite Complex through out but is more concentrated in the area around Koga. This is dark-grey to rusty-brown on wheathered surface, while the fresh colour is grey to geenish-grey. It is fine to coarse-grained, hard, fresh and characterized by spheroidal weathring. It is mainly composed of albite, microcline, calcite, nepheline, quartz and black coloured minerals. At places fluorite and needle like yellowish-brown crystals of sphene/apatite are present.

2.2.4.4. Narangi Carbonatite

The carbonatite has a close genetic relationship with the subsilicic alkaline igneous rocks such as nepheline syenite. It is found in the Narangi Kandao and northeast of Surai Malandrai (Map 2).

The Narangi Kandao Carbonatite occur in the form of lenses, pockets and veins and confined to the western part of the syenite body. The carbonatite is rusty-brown on weathered surface and white on fresh surface, coarse-grained and lacks foliation. It is composed of calcite, microcline, pyroxene and magnetite. Finitization has also taken place near the contacts of carbonatite and nepheline syenite. The carbonatite found near Surai Malandrai (Map 2) is coarse grained and massive.

BASIC MAGMATISM

2.2.4.5 Dolerite Dykes

Dolerite intrusions in the form of sills, dykes and irregular bodies are randomly distributed in the stratified and igneous rocks older than Permian in age. These intrusions are highly altered and deeply weathered and display baked zones along the contacts. These are coarse grained toward centre and become fine grained toward peripheries. They occur widely near Banda Kandao, Dheri, southeast of Boka Kandao, north and northwest of Naugram (Map 1). The dolerite dykes are light-grey to greenish-grey in colour, fine to medium grained and massive. The main mineral constituents are plagioclase, calcite, and iron oxide in chlorite-clay groundmass. These intrusions are further intruded by quartz veins and veinlets which are mostly stained with ferruginous materials. The dolorite dykes of the studied area are considered to be feeders to the Karapa Greenschist (metavolcanics) and thus assigned a Permian age .

2.2.4.6 Karapa Greenschist

The Karapa Greenschist occupies a well defined stratigraphic position on top of the Jafar Kandao Formation and below the Baroch Formation. It is well exposed in the Karapa pass (lat. 34 29 30 N. and long. 72 28 20 E.), about 1-kilometer south of Daggar, the district headquarter of Buner, Swat (Fig. 3). It is also exposed in the Banda, Malandrai Kandao and Malandrai areas. The greenschist occupies the same stratigraphic position as the Panjal volcanics in Kashmir and India below the Permo-Triassic limestone (Pogue et at., 1992). Such types of rocks are more widely distributed and are found in the Kaghan and Kashmir areas as compared to the alkaline igneous rocks which are restricted to the area between the Indus river in the east and Warsak in the west (Khan et al., 1990).

IMPLICATIONS

Whereas the external zone of the Himalayan thrust fold belt is completely devoid of magmatic rocks, they are not uncommon in the Coward's internal zone (Fig. 6). Leaving apart the basement gneisses, such as those exposed in the Nangaparbat and Besham syntaxis, there are at least two major phases of granite magmatism since Cambrian (LeFort et al. 1980., Jan et al. 1981., Shams, 1983). The first type include the peraluminous, porphyritic two micas augen gneisses. They include Chinglai Gneisses, Swat and Mansehra Granites which are of a Cambrian age (LeFort et al., 1980). The Chinglai Gneisses are exposed in the northern parts of the study area (Map 1) separated on the east from the Mansehra Granite by the gorge of Indus river and from the Swat Granite in the north by a normal fault (Pogue et al., 1992). All these plutons are considered correlative based on their textural, pertrological, geochemical composition and intrusive relationship. The second type is distinctly alkaline to peralkaline in chemistry and resembles closely with post orogenic A-type granites (Whalen et al., 1987). These granites are typically distributed in a semicircle around the western, northern and northeastern fringes of the Peshawar Plain and include Warsak, Shewa-Shahbazghari, Ambela, and Malakand granite occurrences. They are spatially associated with a suite of undersaturated to mildly oversaturated alkaline to peralkaline magmatism which gives rise to a diverse assemblage of rocks ranging from carbonatites, through ijeolites, meltiegites, feldspathoidal syenites to syenites and quartz syenites. They have been considered to define an alkaline province in the area occupied by Peshawar Plain and its surroundings. The alkaline to peralkaline magmatism in the Peshawar Plain is accompanied by basic magmatism which occurs in the form of an extensive suite of basic dykes, sills and minor intrusive bodies of a plutonic character. This magmatism may be less voluminous than the A-type granites, but unlike the latter, is much more wide spread in its distribution from Attock-Cherat range in the south to the Upper Kaghan and Kashmir valleys in the north.

All these igneous rocks are subject of detailed petrological studies for last several decades. However, little was known, until recently about the stratigraphy of the host rocks, except for those inter-stratified with the Panjal basic volcanics which yield Permian fossils. This led to a reliance solely on the radiometric data for the age of the magmatism in the Peshawar Plain alkaline province, which was often misinterpreted. For instance, Kempe (1973) reported K/Ar ages of 41, 50 and 100 Ma determined on reibeckite, biotite and nepheline minerals separated from the Warsak Granites and Koga Syenites, and arbitrarily selected 50 Ma as the age of emplacement of the alkaline province magmatism. Maluski and Ma[illegible] (1984) presented Ar 40/ Ar 39 data on amphiboles and biotite from the Warsak Granites yielding ages of 43.5, 40 and 42 Ma which they interpreted to be tectono-metamorphic, but their age of emplacement for the Malakand Granite (23 Ma) turned out to be much less than that determined by Zeitler,(1988) on Zircon as Carboniferous. LeBas et al. (1987) presented Rb/Sr whole-rock isochron data for the Ambela Granite yielding ages of 300 Ma, but considered the Sillai pattai Carbonatite to be emplaced at 31 Ma based on a K/Ar age on biotite, which is highly questionable in the light of existence of a tectonometamorphic event of this age in the same area (Treloar et al., 1989).

A detailed reappraisal of stratigraphy in the recent years in the parts of Peshawar Plain and lower Swat valley have resulted in opening new avenues for dating the Peshawar Plain alkaline magmatism with a much greater reliability than before (Khan et al., 1988, 1990 ; Hussain et al., 1990 and Pogue et al., 1992).

The occurence of basalt as a distinct stratigraphic horizon in the upper parts of the Jafar Kandao Formation confirms their Late Carboniferous-Permian age, which coincides closely with the age of the Panjal volcanics from northern Pakistan. Interestingly, whereas the strata older than this age is almost always cross cut by basic dykes, there is a sharp lack of basic dykes and sills in the younger i.e., post Permian strata. We assign all the plutonic and hypobassal rocks in the Peshawar Plain to this event of basic magmatism in Carboniferrous-Permian. It has to be noted that a suite of dykes and sills in the Kaghan area has been considered by Papritz and Ray (1989) to be intrusive equivalents of the Permian Panjal volcanics. This would imply a wide spread basic magmatic activity at the northern margin of the Indian plate in Late Carboniferous-Permian time.

There is a strong indication that the acid volcanism was erupted more or less simulataneously with the basic volcanics, but intercalations at several horizones, in the Jafar Kandao Formation, both below and within the greenschist unit, suggest a wider span of the magmatic activity than that of the basic magmatism. Unlike in the case of basic magmatism, there is an indication that the plutonic equivalents of the acid volcanics may be of the same age or younger. A lack of deformation in the Ambela and Warsak granites compared to the tectonised acid volcanics of the Jafar Kandao Formation favours a younger age of some of the phases of the A-type granites in the Peshawar Plain. It has to be noted that a similar relationship exists in the Warsak Igneous Complex where sheared microporhyries are cut across by relatively undeformed peralkaline granites (T.Tahirkheli,1990). We suggest that there was a Carboniferous to Permian acidic magmatic activity (the magma was peraluminous but had A-type geochemical character), which was both erupted and emplaced in lower level plutons (e.g., sheared garnetiferous microporphyries in Warsak, T.Tahirkheli, 1990) and Shewa-Shahbazghari, early phase peraluminous-metaluminous granites in the Ambela complex (Rafiq and Jan, 1989). This was followed by a phase of peralkaline granites in Late Carboniferous-Permian which included the peralkaline microporphyries of Warsak and Shewa-Shahbazghari, main Warsak Granite and some late phases in the Ambela complex.

There have been suggestions that the alkaline and peralkaline magmatism in the Peshawar Plain is related with Permian-Triassic rifting of the Gondwana [Jan and Karim, 1990). Despite a contrasting composition a more or less similar tectonic setting of origin is suggested by the basic magmatic rocks (T.Tahirkheli, 1990). This is however, not understood that why the A-type granites and peralkaline saturated to undersaturated rocks are restricted only to the Peshawar plain, whereas basic magmatic rocks are widespread througout the Indian plate north of the Panjal fault.

The stratigraphic, radiometric and structural evidence indicate a major rifting during Late-Paleozoic. A model is presented in (Fig. 4), which exhibits the interacalation of tectonics, sedimentation and magmatism in the Peshawar Plain. The pre- rifting sedimentary rocks were deposited as late as the Late Devonian in a northward-deeping epicontinental sea (Fig. 4a). The uplifting and emergence of the epicontinental basin was accompanied by the normal faults and emplacement of porphyritic alkaline rhyolitic flows, dykes, sills and basalt flows (Fig. 4b). This bimodal, both acidic and basic volcanism continued in to the Late Carboniferous-Permian period as did the erosion of the Early Carboniferous highlands, which were largely submerged by Early Carboniferous (Fig. 4c). The area was again uplifted and accompanied by the inception of the alkaline magmatism (Ambela Granite Complex) in the Late Carboniferous period (Fig. 4d). This rifting was soon followed by subsidence which resulted in the marine sedimentation during Late Triassic-Jurassic (Fig. 4e). This rifting sequence provide direct evidence for the Late Carboniferous-Permian fragmentation of the northern Gondwana for the first time from Pakistan.

Fig. 4: A model showing temporal intercalation between tectonics, sedimentation and magmatism in the parts of the Peshawar plain (After Pogue et al., 1992).

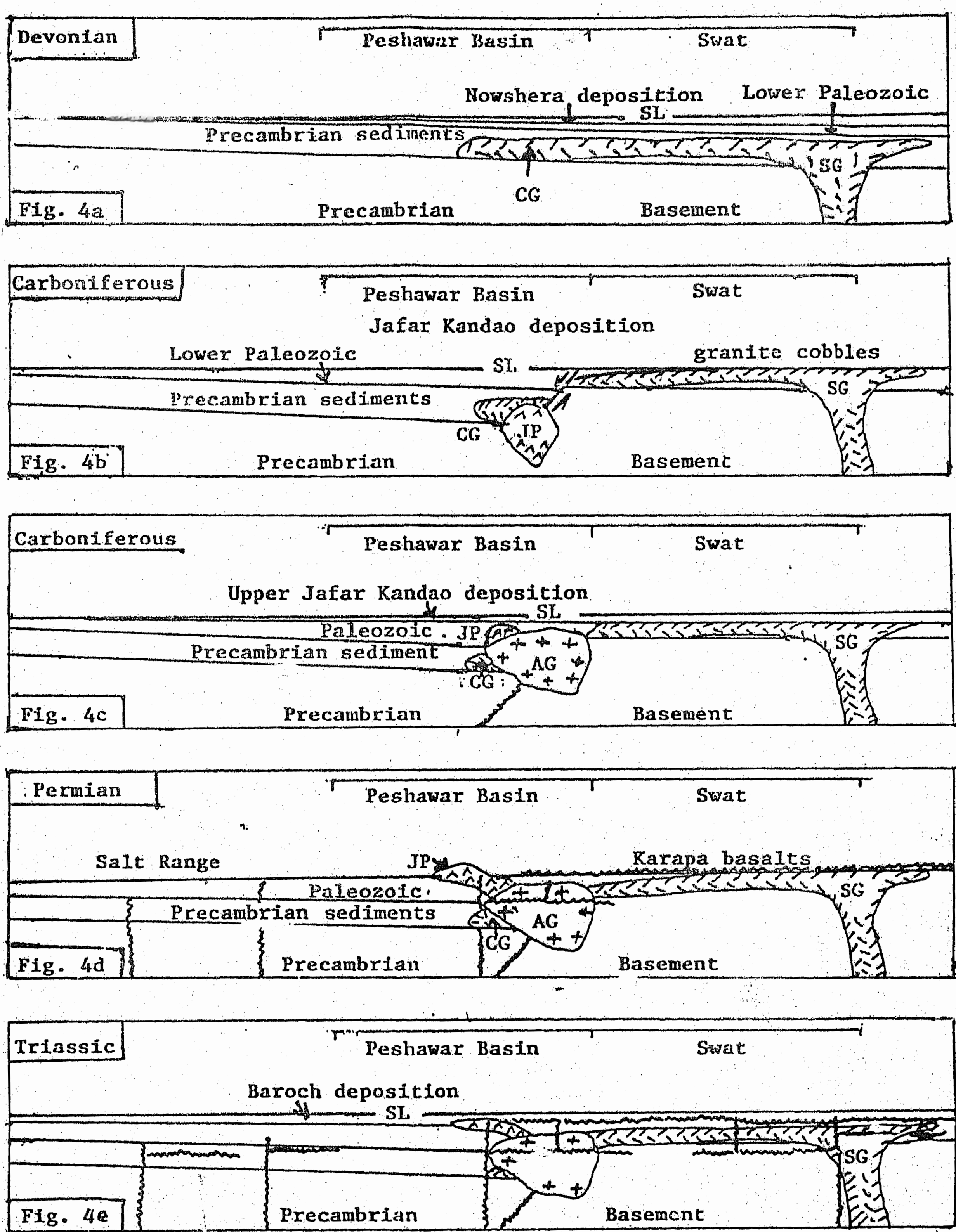
a). Paleozoic marine sedimentation on a Precambrian basement previously intruded by Swat Granite (SG) and Chinglai Gneisses (CG).

b). Normal faulting associated with Late Paleozoic rifting separates the Chinglai Gneisses from the swat Granite. Intrusion and emplacement of acid volcanics and plutons equivalent to Shewa-Shahbazghari porphyries (JS).

c). Intrusion of Ambela Granite (AG) and basic dykes.

d). Emplacement of Karapa basalts.

e). Early Mesozoic marine sedimentation on the Karapa basalts.


Devonian
Peshawar Basin
Swat
Nowshera deposition
Lower Paleozoic
SL
Precambrian sediments
SG
CG
Fig. 4a
Precambrian
Basement
Carboniferous
Peshawar Basin
Swat
Jafar Kandao deposition
Lower Paleozoic
granite cobbles
SL
SG
Precambrian sediments
JP
CG
Fig. 4b
Precambrian
Basement
Carboniferous
Peshawar Basin
Swat
Upper Jafar Kandao deposition
SL
Paleozoic . JP
SG
Precambrian sediment
AG
CG
Fig. 4c
Precambrian
Basement
Permian
Peshawar Basin
Swat
Salt Range
JP
Karapa basalts
Paleozoic
SG
Precambrian sediments
AG
CG
Fig. 4d
Precambrian
Basement
Triassic
Peshawar Basin
Swat
Baroch deposition
SL
SG
Fig. 4e
Precambrian
Basement

CAPTER FOUR

STRUCTURE

The inernal zone of the Indian plate, northern Pakistan has been divided in to six major tectonic blocks, known as Bana, Besham, Hazara, upper & lower Kaghan and Swat nappes (Treloar, 1989). The present study area makes the southern part of the Swat nappe. The Swat nappe is separated to the south from the Attock-Cherat range and to the east from the Hazara nappe by the Darband-Oghi Thrust Fault. The western extension of the Swat nappe is still not known, however, Paleozoic rocks similar to that of the swat area are well exposed in the Jamrud area, Khuber Agency.

4.1 Structure of the study area:

4.1.1 Folds

The major folds mapped in the study area defines an arcute pattern. The fold axes of the major folds trend Nw-SE in the eastern part of the study area, E-W in the central part (Map 1) and changes to NE-SW in the western part (Map 2), resulting in the development of an arc shape structure, similar to the indus re-entrant, Hazara-Kashmir syntaxis and the Besham syntaxis. Small folds are commonly encountered in the limbs of the major folds. Both the major and small scale folds are asymetrical, tight, overturned, south verging and their axes are parallel to each other. The folds found in the western part (Map-2) are open and upright.

In addition to the folds defining an arcute pattern in the Swawai area (Map 1), a N-S oriented syncline has been mapped. It is typically an open fold of local nature. Arcuation may be result of a N-S compression, while the N-S oriented Swawai synclinorium may have developed due to a later E-W compression.

4.1.2 FAULTS

Faults found in the study area could be classified into 1) thrust faults or reverse faults and 2) strike-slip faults.

4.1.2.1 Thrust Fault

The most important thrust fault mapped in the area is the, "Darband-Oghi Thrust Fault". first reported by Calkin and Ahmed (1969). Noth of Tarbela dam, the fault trends NE-SW, while in the area between Tarbela dam in the east and Nowshera in the west, it runs in the E-W direction along the Kabul river. This E-W trending part could be consider as frontal ramp of the Swat nappe, where the sense of movement is right lateral. The age of the Darband-Oghi Thrust Fault is not known, however, according to seeber and Ambuster (1980) it is seismically active, suggest a recent age for it Further, the seismogrph installed at Tarbela damsite also indicate epicentre of the earthquake along this fault.

Other thrust fault recognized in the study area is named as, "Kundal Fault". This fault is folded by later folding and towards east meets with Darband-Oghi Thrust Fault. Folding suggests that is could be older than the Darband-Oghi Thrust Fault

4.1.2.2 Strike-Slip Faults

Two set of strike-slip faults are recognized in the study area and are right lateral. One of these trend between NE-SW and other trend NW-SE and have left lateral sense of slip.

A major right lateral NE-SW trending fault runs along the Totalai khawar and displaces the folded strata of the Manc i synclinorium and Kundal antiform. The right lateral displacement is clear on the map. A displacement of about 1.5 kilometre is estimated. Other right lateral NE-SW trending fault is located just west of Chinglai (between the Ambela Granite and the Chinglai Gneiss). These faults could be secondary riedal shear of Darband-Oghi Trust Fault (Fig. 5a)

4.1.3 Structural Analysis and Discussion

If we condsider that major fold defining an arcute pattern developed due to a N-S compression, they could be correlated with the southward transported Swat nappe. The folds could be detachment folds in this nappe (Fig.5b) or fault propagation folds at the tips of blind splays of Darband-Oghi Thrust Fault (Fig 5c). Acruation may be result of N-S compression against rigid Ambela Granite or due to a later E-W compression as suggested for Hazara-Kashmir Syntaxis and Besham syntaxis (Treloar, 1989). The Swawai synclinorium, with a north-south fold axis can also be correlated on a regional scale with the Indus re-entrant, Hazara-Kashmir syntaxis and Besham syntaxis or may be secondary product of arcuation itself.

The Kundal fault which marks the contact between the Salkhala and Tanawal formations is itself folded along phase-1 isoclinal folds and thus can not be responsible for the large scale fold structures observed in the study area and is older than folding.

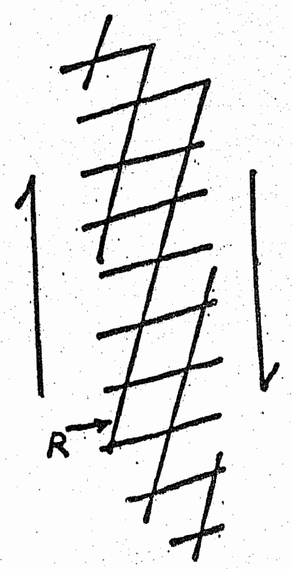


Fig.5a: Model showing Orientation of riedal shears (R)

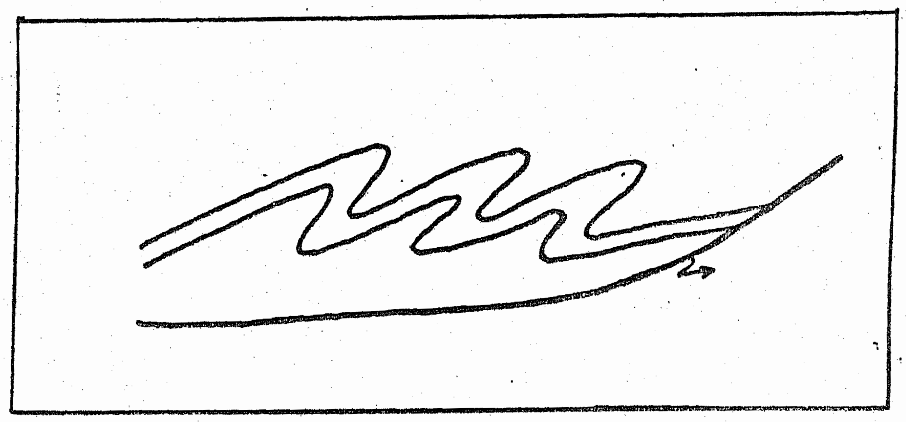


Fig.5b: A cartoon section showing folds in a thrust nappe

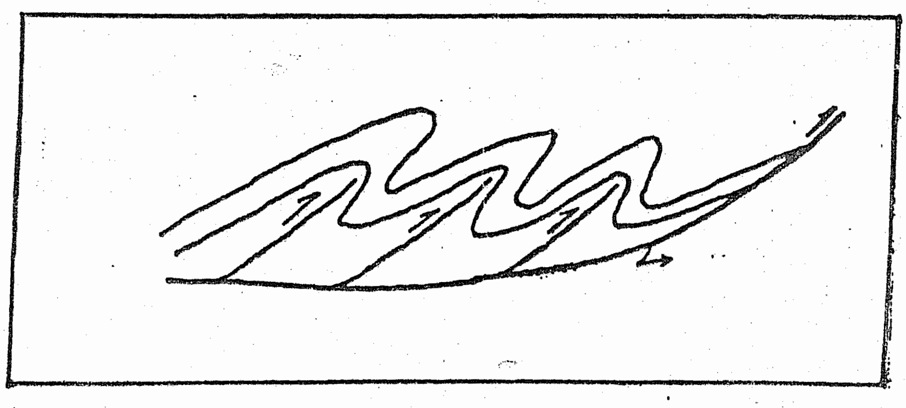


Fig.5c: A Cartoon showing fault propagation folds in a thrust nappe.

REGIONAL TECTONICS

The northern Pakistan has been divided into three broad regions on the basis of stratigraphic successions, grade of metamorphism and igneous activities (Coward et al., 1988). The three regions from north to south are the Asian continantal plate, Kohistan arc and the Indian continantal plate, separated by the Main Karakoram thrust (MKT) and the Main Mantle Thrust (MMT) respectively. The Indian plate is further divided into two zones (Coward et al., 1988) by the Hissartang fault. The northern zone between the Hissartang fault and MMT is known as Internal zone while the southern zone is called as external zone. Treloar et al. (1989) has recognised six major crustal nappes in the Coward's Internal zone between Panjal Fault and the Main Mantle Thrust (MMT) (Fig. 12). Each nappe is internally imbricated, separated by major thrusts and stratigraphically distinct from those adjacent to it. The six major thrust sheets are the Banna, Besham, Hazara, Upper Kaghan, Lower Kaghan and the Swat nappe. The present study area makes the southern part of the Swat nappe.

The Swat nappe to the north, is separated from the Besham nappe by a shear zone known as Alpuri Thrust (Trelaor et al., 1989), while its southern boundary is not yet been exactly marked. Kazmi, (1984) and Lawrence et al., (1989) are of the opinion that the Swat nappe is composed of Precambrian Manglaur crystalline schists (equivalent to Tanawal Formation), which are intruded by Swat Granite and unconformably overlain by siliceous and argillaceous schists, amphibolites, marbles and calcareous schists/marbles of the Alpuri Group. These siliceous/argillaceous schists, marble, and amphibolites may be equilant to the Jafar Kandao and Baroch formations and Karapa Greenschist respectively. Hamayun (1986) describes this cover group as Paleozoic.

The present opinion is that there is a continous stratigraphic succession ranging in age from Precambrian to Jurassic in the area between Nowshera to the south and Alpuri to the north including the present study area. As such, the Swat nappe is separated from the Besham nappe in the north and Hazara nappe in the east by the Alpuri and Darband-Oghi thrusts. The geology of the Swat nappe is different from the adjacent Hazara and Besham nappes as well as the Gandghar and Attock-Cherat ranges. In Nowshera and Tarbela areas, the Darband-Oghi Thrust Fault separates the Swat nappe to the east from Gandghar range and to the south from the Attock-Cherat range. This is suggested on the basis of distinct lithologies of the Attock-Cherat and Gandghar ranges from those exposed in the Swat nappe as well as in the study area. Furthermore, the rocks exposed in the Gandghar and Attock-Cherat ranges are less metamorphosed and devoid of fossils. No igneous rocks except doleritic intrusions are reported from these ranges. In contrast the Precambrian sequence constituting the basement for the Paleozoic-Mesozoic succession of the Tethyan Himalaya is comprising of Salkhala and Tanawal formations. In the study area the Salkhala Formation is tectonically overlain by Tanawal Formation, which is unconformably overlain by an almost complete paleozoic and Early Mesozoic succession. This sequence is intruded by numerous plutonic (like Swat Granite and Chinglai Gneiss) rocks during Cambrian. The Shewa porphyries, Ambela Granite, Warsak Granite, the Tarbela alkaline granite, Koga Syenites and Narangi Carbonatites were intruded during Carboniferous as a result of Late Paleozoic intracontinantal rifting. Similar stratigraphic evidences for Paleozoic rifting have been documented in Zansker and Spiti areas of India, where Permian marine sediments unconformably overly the fault bounded highlands (Gaetani et al., 1990).

Accordingly, the timing and geochemistry of the Panjal volcanics in Kashmir and Zansker also support their association with Late Paleozoic rifting (Bhat et al., 1981; Sengor, 1984). Sengor (1984) proposed that the Panjal volcanics were genetically related to the rifting.

The Internal zone is further characterized by folds, imbricated basement-cover sequence, back thrusts and strike slip faults. The sedimentary and metasedimentary rocks of the Swat nappe including the present sutdy area, are fossiliferous, more metamorphosed and intruded by numerous igneous rocks. The exeternal zone consists of non-metamorphosed Precambrian to Recent sediments. No igneous intrusions have been found in this zone. There is another thrust south of Hissartang fault, known as "Main Boundary Thrust" (MBT). There is a thick imbricated sequence of Miocene to Quaternary molasse known as" Siwalik Group". This forms part of the foreland basin of western Himalayan ranges and Kohistan arc.

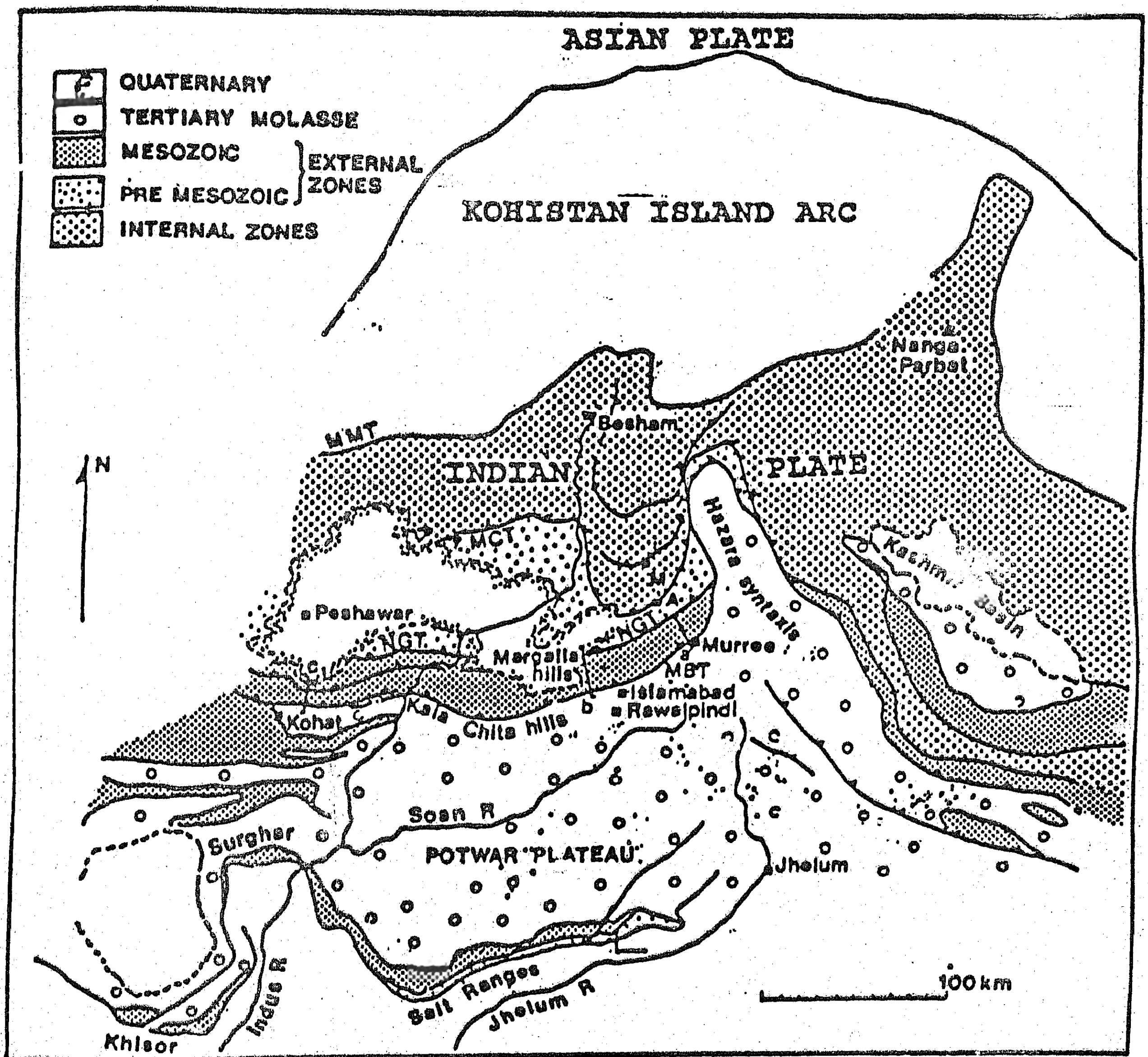


FIGURE 6·Location map for northern Pakistan, showing the distribution of the main thrusts (MMT, Main Mantle Thrust; MCT, Main Central Thrust; MBT, Main Boundary Thrust; NGT, Nathia Gali Thrust), the Kohistan island arc and the internal and external zones: (after Coward et al. 1988)

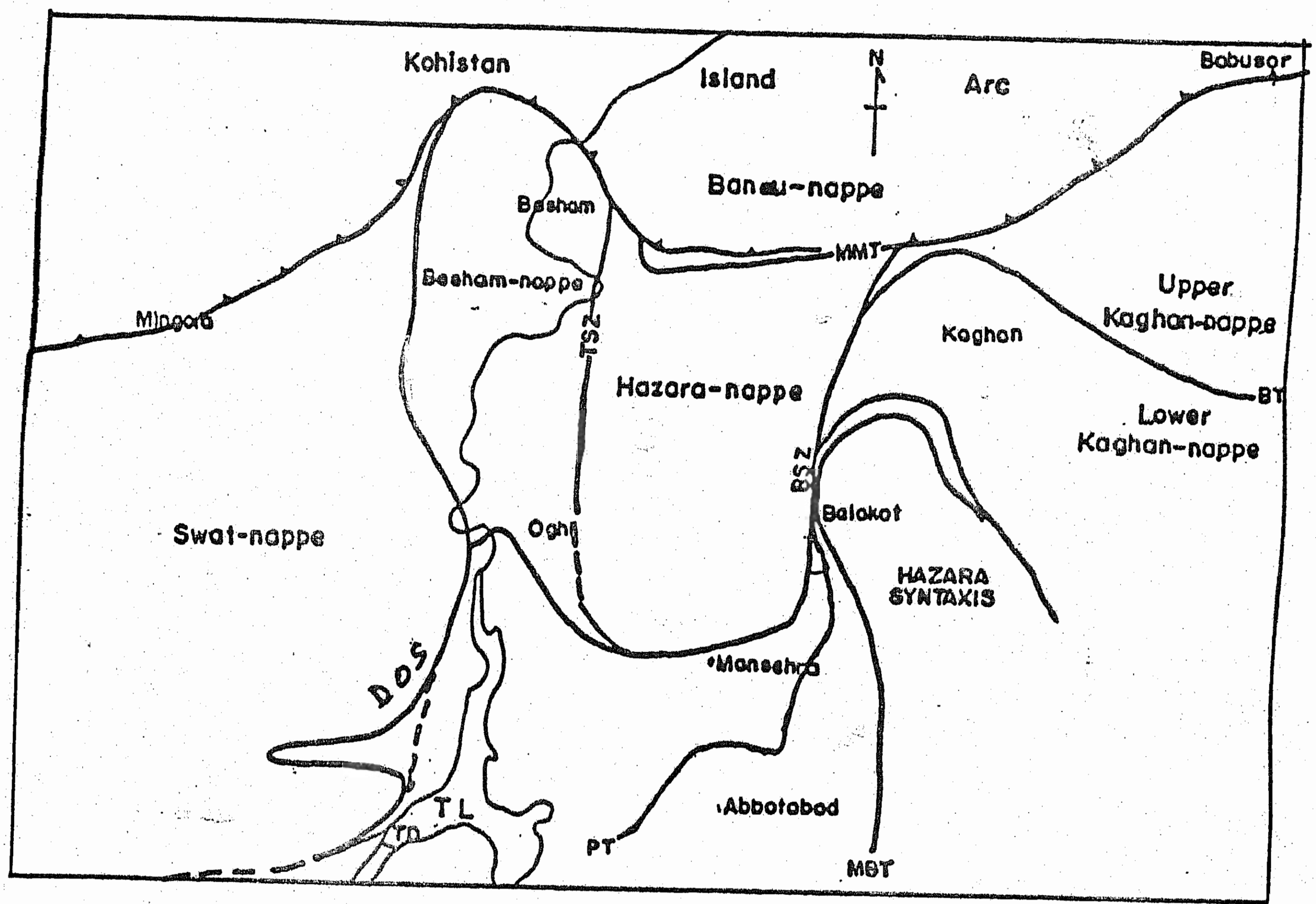


Fig 7: Map showing the location of the major crustal nappes in the internal zone of the Indian plate. MMT: Main Mantle Thrust, BT: Batal Thrust, AT: Alpuri Thurst, MBT: Main Boundary Thrust, PT: Panjal Thrust, BSZ & TSZ: Balakot and Thokot Shear zones, DOT: Darband-Oghi Thrust, T.D: Tarbela Dam, T.L: Tarbela Lake (after Treloar, 1989).

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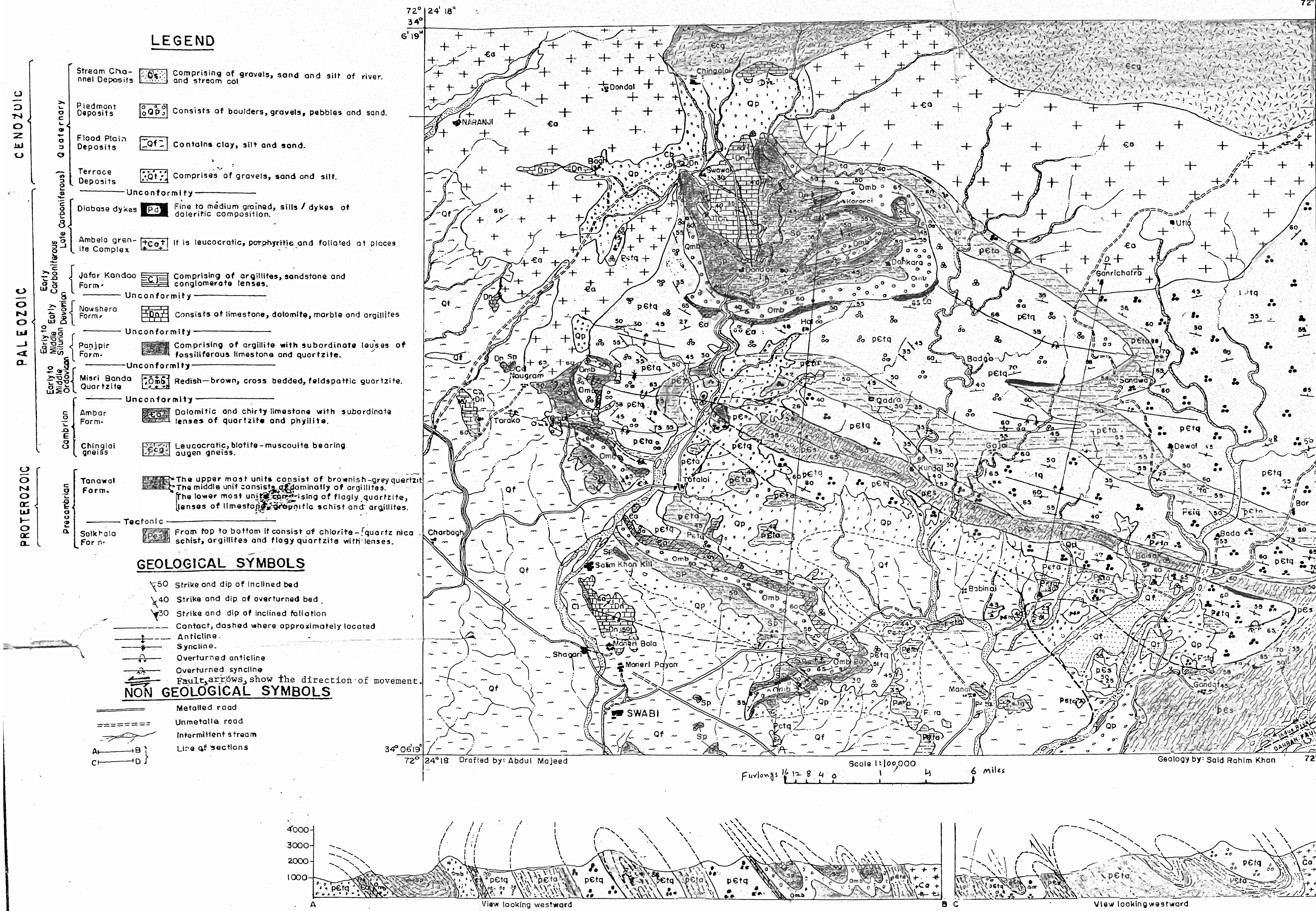
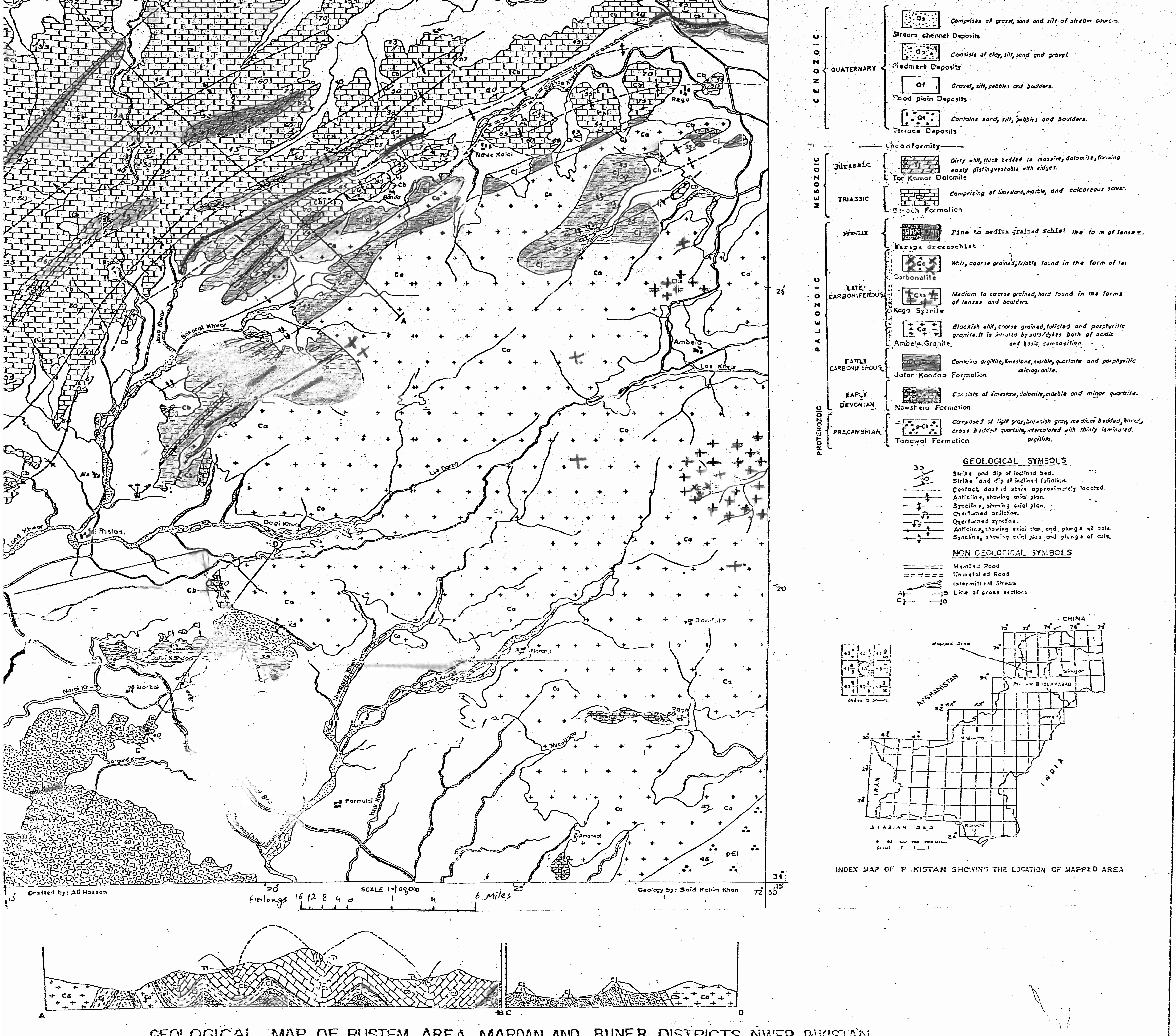


FIG GEOLOGICAL MAP OF SWABI AND ADJOINING AREAS, SWABI AND BUNER DISTRICTS, NWFP, PAKISTAN.



GEOLOGICAL MAP OF RUSTEM AREA, MARDAN AND BUNER DISTRICTS, NWFP, PAKISTAN.