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Geology of the Nanga Parbat Syntaxis Along the Astor Valley Transect, Northern Pakistan

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ABSTRACT: *The Nanga Parbat-Haramosh syntaxis represents the youngest phase of thermal, tectonic and metamorphic activity in the Himalaya. The syntaxis is an active crustal-scale antiformal structure comprising Indian plate basement gneisses and cover sequence. The Nanga Parbat rocks in the Indus gorge section have previously been divided into grey Iskere gneiss and pink Shengus gneiss. Along the Astor valley transect, south of Indus valley, several new lithological units have been identified. These include 1) Muskhin grey gneiss 2) Harchu pink gneiss and 3) Rattu formation. The Mushkin gneiss is a medium-grained, locally-porphyroclastic gneiss of grey colour probably representing the basement complex. Harchu pink gneiss is clearly derived from a sedimentary protolith (as suggested by the preserved relicts of quartzite, calc-silicate components and preserved sedimentry structures). The Rattu formation comprises meta-pellites, marbles, calcsilicates pods and lenses and is considered to represent a metamorphosed cover sequence. Structural cross-section from north-west to south-east reveals that the Nanga Parbat sequence consists of two crustal-scale antiformal structures with a tight faulted synform in between. It is noticeble that the Mushkin grey gneiss exhumes with respect to the cover sequence at the margins. Field and petrographic data show that the Rattu formation and Harchu pink gneiss reaches upto kyanite and sillimanite metamorphic grades, whereas the Mushkin grey gneiss lacks these minerals. The Mushkin grey gneiss exhibits a great variety of migmatite structures, indicating that the Mushkin grey gneiss has experienced more severe metamorphic conditions than any other rock unit in the Astor section. Our preliminary studies indicate possibilities of correlation between Mushkin and Harchu gneisses from the Astor valley with the Iskere and Shengus gniesses from the Indus valley, respectively.*

INTRODUCTION

The Himalayas are one of the best examples of an orogenic belts where shortening processes are continuing since collision in mid Tertiary. Within the north-west Himalaya, collision is characterised by Indian plate and the Kohistan-Lakakh island arc (Tahirkheli, 1982). The island arc was sutured to the Eurasia between 100 and 85 Ma ago (Treloar et al., 1989) before Tertiary collision between the Indian and Eurasian plates.

One of the attributes of NW Himalaya is the presence of large-scale, NNE-trending, antiformal structures. These are Nanga Parbat and Hazara syntaxes, developed in the Hinterland and foreland domians of the Pakistan Himalaya, respectively (Treloar et al., 1991; Bossart et al., 1988). As defined by Suess (1901) syntaxes are sharp bends in orogenic belts, within the cores of which exhumation and uplitf rates are high (Zeitler, 1985). The Nanga Parbat syntaxis deforms the Main Mantle Thrust, whereas the Hazara syntaxis deforms the Main Boundary Thrust. Tectonic setup of this area suggests that the crustal-scale strike-slip displacement plays an important role in the development of these syntaxial bends (Treloar et al., 1991). The study of this area is important to provide details about the current processes involved in the reworking of Himalayan crustal lithosphere as well as the regional evolution of the Himalayan tectonics.

The Nanga Parbat Syntaxis comprises Indian plate gneisses which are in tectonic contact with Kohistan terrane on the east and Ladakh terrane on the west. Chronological and structural studies (Zeitler, 1985; Chamberlain et al., 1989; Coward, 1986; Butler et al., 1991; Treloar et al., 1991 and Verplank et al., 1985) suggest that the Nanga Parbat syntaxis is controlled by young crustal scale antiformal structures, leuco-granitic magmatism and uplift with respect to the Kohistan-Ladakh terranes. This is accomplished by a phase of metamorphism, which is far more intense than the early Himalayan metamorphism seen elsewhere in the north-eastern Himalaya.

LITHOLOGICAL UNITS

Two major valleys cut across the massif, i.e., Indus valley in the north and Astor valley in the south. Along the Indus valley, two lithological units have been established (Madin et al., 1989), named Iskere gneiss on the west and Shengus gneiss on the east. Based on the mineral assemblage and radiometric dating (Chamberlian et al., 1989; Zeilter et al., 1989), the Iskere gneisses are generally considered to be a basement orthogneiss complex and are correlated with those of Besham gneisses of northern Pakistan (Treloar et al., 1991). The Shengus gneisses (Madin et al., 1989) are considered to be the supra-crustal series of Nanga Parbat gneisses. These are correlated with those of Tanawal formation of Hazara region (Treloar et al., 1991).

The present study (Fig. 1) deals with the stratigraphic and structural setup of the Nanga Parbat syntaxis along the Astor valley. Predominantly, the Nanga Parbat sequence consists of strongly foliated gneisses of high metamorphic grade. These gneisses are divisible into the basement and cover sequences, on the basis of interpretations about the nature of their protoliths. Along the studied transect, three dominant lithological units were mapped in addition to Kohistan-Ladakh amphibolites on the margins (Fig. 1 & Table A).

TABLE A: SUBDIVISION OF THE NANGA PARBAT SYNTAXES IN ASTOR VALLEY TRANSECTS IN MAPABLE LITHOTECTONIC UNITS

Cover Sequence	Intrusive Rocks
Rattu Formation	Undeformed Granite
Harchu Pink Gneiss	Mylonitic Augen Gneiss
Basement Complex	Felisic Gneiss
Mushkin Grey Gneiss	Megacrystic Augen Gneiss
	Amphibolites
Kohistan-Ladakh Amphibolites	
Fine-grained amphibolites of metavolcanic origin	
Coarse-grained amphibolites derived from gabbroic precursor	

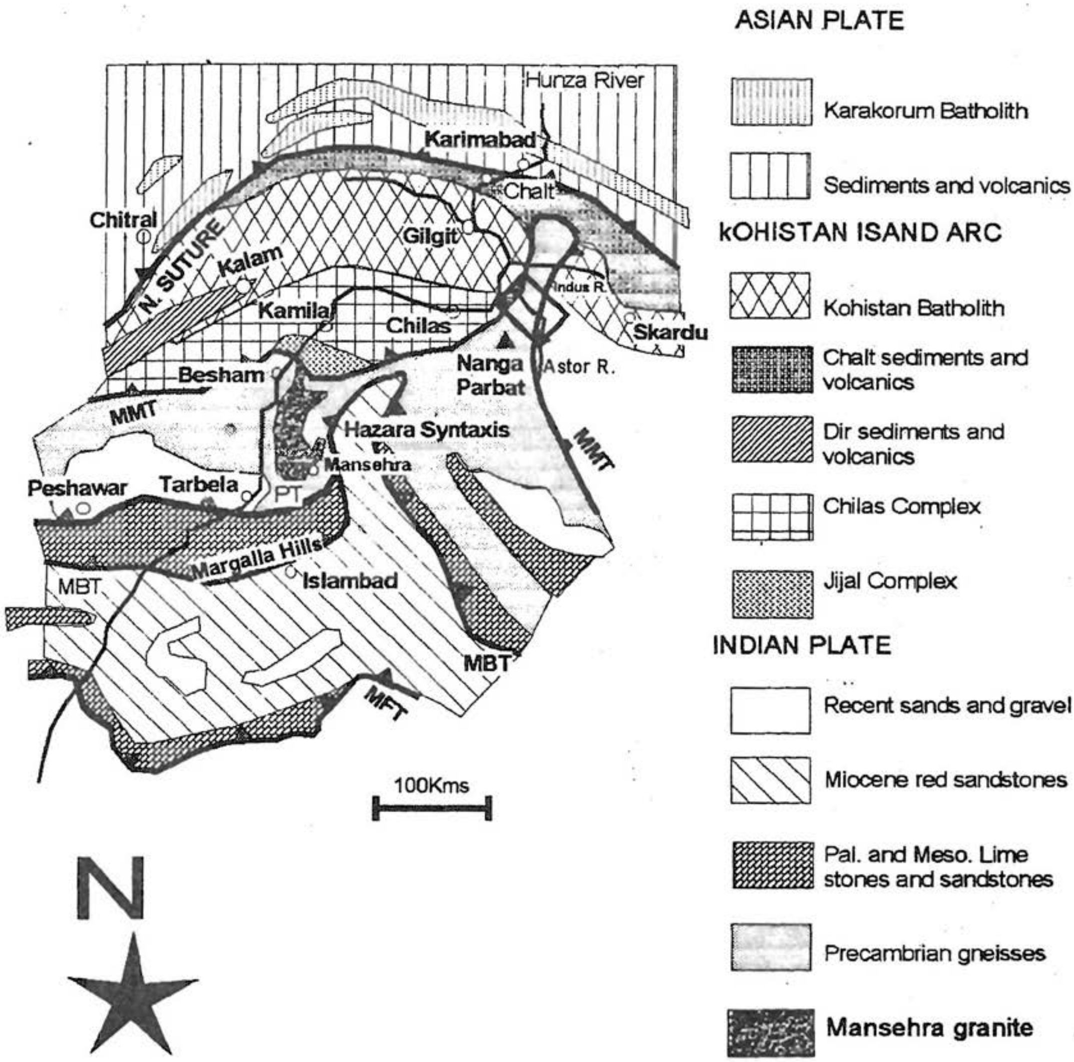

Fig. 1. Geological map of northern Pakistan (after Treloar et al., 1991).

MUSHKIN GREY GNEISS

The Mushkin grey gneiss covers the western half of the massif along the Astor valley. The unit is named after the Mushkin village in the valley. The unit extends from north-west of Mangodoian to south-east of Dushkin. It is bounded by Harchu pink gneiss at its south-eastern contact and Rattu formation at its north-western margin. The contact relation between the Mushkin grey gneiss and the Harchu pink gneiss or Rattu formation are no more preserved and are obliterated by strong shearing. A highly tectonized and attenuated sequence comprising Rattu formation, with amphibolites having characteristics similar to those of Kohistan amphibolites reported form the north-western margin of the massif, occur within the Mushkin gneiss at Dichili-Astor confluence, along a fault zone (Fig. 2).

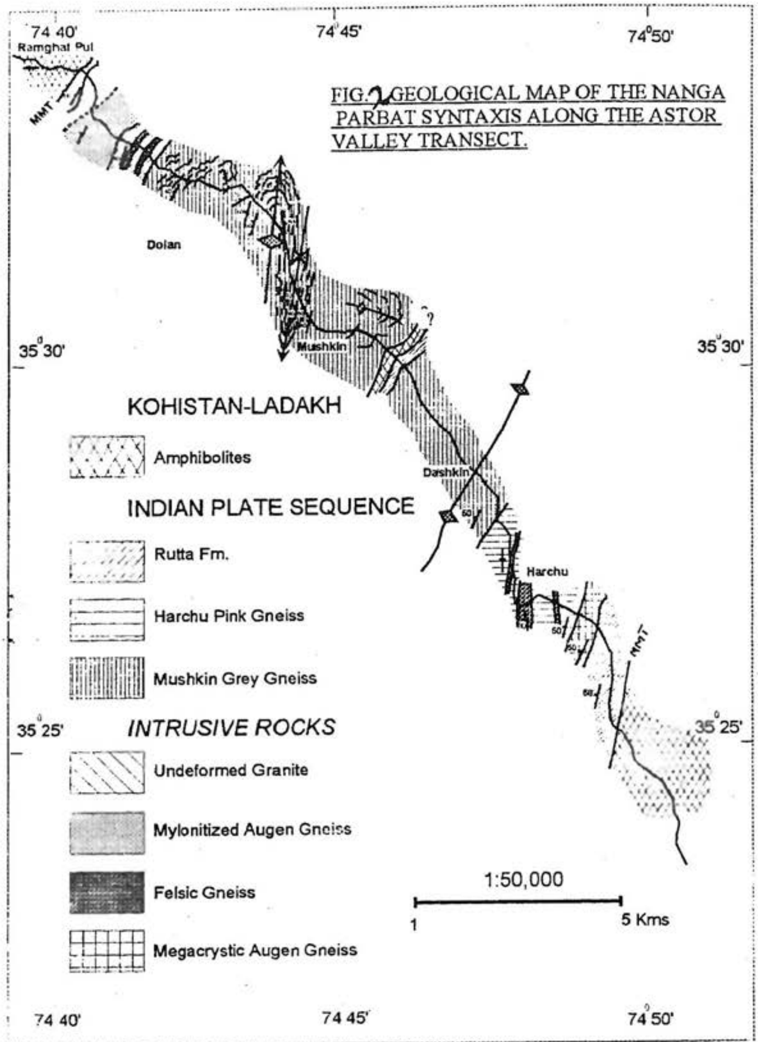

Fig. 2. Geological Map of the Nanga Parbat syntaxis along the Astor Valley transect.

The Mushkin gneisses are strongly foliated and mylonitized part of the Indian plate crustal sequence of a probable Early Proterozoic age. Generally, the rocks are medium - grained, locally - prophyroclastic gneiss of grey colour. The unit consists predominantly of biotite-K-feldspar-quartz gneiss and exhibits a variety of migmatitic structures and insitu melts suggesting that the unit passed through higher-grade of metamorphic conditions than any other rock unit in the Astor section. Typical phlebitic structure is common, and consists of leucosome granitic material in the form of segregations in the gneisses. Rarely, stormatic structure of granitic material is also found. Besides, these segregated structures, the Mushkin grey gneiss also shows homogenous nebulitic structure. Schlieren structure is characterized by biotite-rich segregations, especially at the margins of felsic/granitic streaks and veins. These structures suggests that the Mushkin grey gneiss formed under metatexis conditions. Mushkin grey gneiss is interpreted to be essentially a basement orthogneiss as suggested by its broadly homogenous mineralogy, lack of sedimentary lithologies and close lithological similarity with the Iskere gneiss described from the Indus valley (Madin et al., 1989).

HARCHU PINK GNEISS

The Harchu pink gneiss, that covers a part of the western half of the massif, comprises sillimanite-kyanite-garnet-biotite gneiss with characteristic pinkish-grey colour. The pink colour may be due to the abundance of altered biotite phase and rose to pink coloured garnet. These gneisses are best exposed on the either side of the Harchu river bend, and comprise massive, strongly foliated, pinkish grey, fine-medium grained garnet-biotite gneiss with garnet frequently upto 0.5-1cm in diameter. The gneisses contain abundant felsic veins, which give banded appearance to the gneisses. Mostly, these veins are boudinaged. The north-western contact with the Mushkin grey gneiss is highly shared as indicated by the presence of mylonites. The south-eastern contact with the Megacrystic augen gneiss is covered with debris but is suspected to be intrusive.

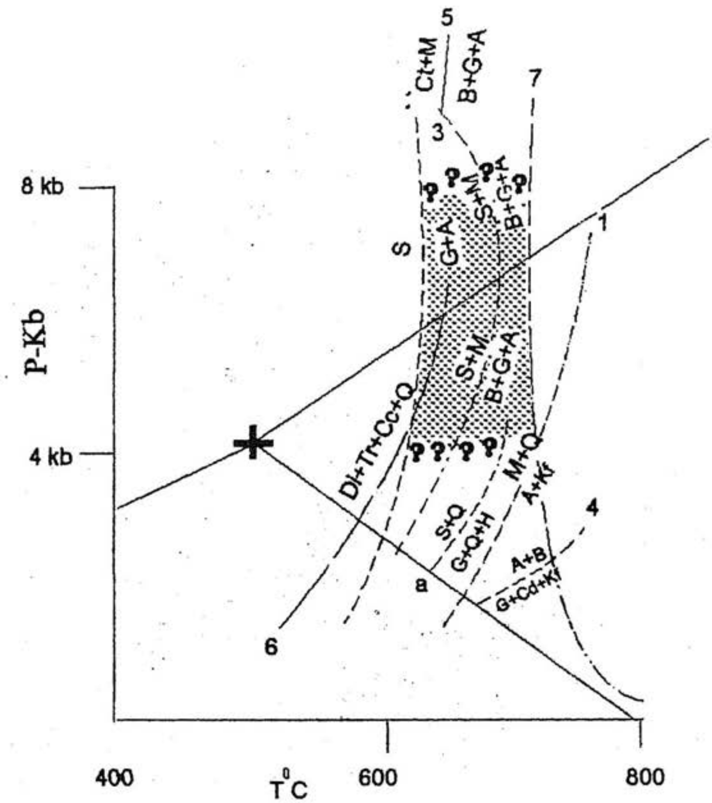

Fig. 3a. Petrogenetic grid for Harchu pink gneiss. The shaded area shows the stability region. Curve 1 from Evans (1965); 2 from Richardon (1969); 3,4 & 5 from Hess (1969); 6 from Mertz (1973); 7 from Tuttle & Bowen (1958); a from Dutrow et al., (1958).
(A) Alumino-silicates, (B) Biotite, (Cc) Calcite, (Cd) Cordierite, (Ct) Choloritoid, (Tr) Tremolite, (Di) Diopside (G) Garnet, (Kf) K-feldspar, (M) Muscovite, (Q) Quartz, (S) Staurolite.

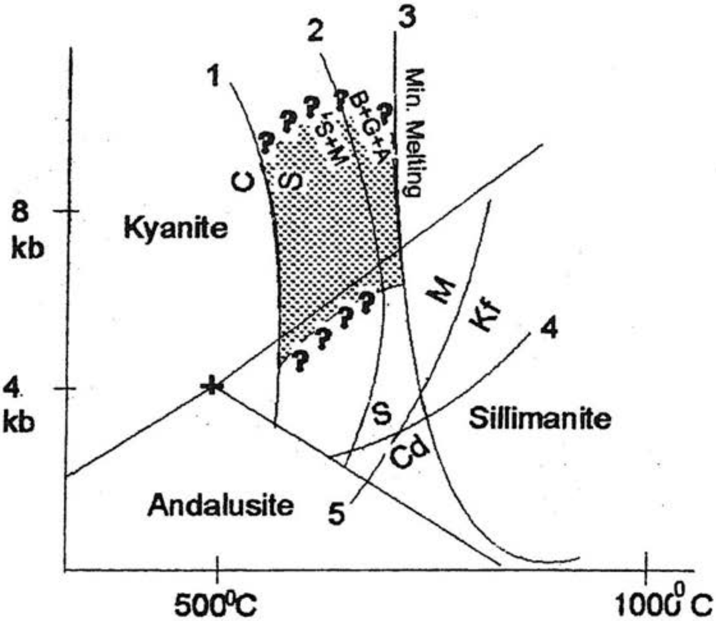

Fig. 3b. Petrogenetic grid for peletic rocks of Rattu formation. Curve 1 from Hoschek (1967); 2 from Holdaway (1971); 3 from Tuttle and Bowen (1958); 4 from Holdaway (1966); and 5 from Evans (1955).
(C) Choloritoid, (S) Staurolite, (B) Biotite, (G) Garnet, (M) Muscovite, (A) Alumino-silicates, (Cd) Cordierite.

The unit contains thinly interbedded metapsammites and calc-silicate pods and lenses. These lenses are generally greenish brown in colour and rarely contain thin graphitic streaks. The psammites are fine-medium grained and have sugary texture; contain tiny garnets and thin biotite flakes. In addition, the unit contains preserved sedimentary structures, such as relict cross laminations, bedding and slump folding. Based on these evidences, the unit is interpreted as a sedimentary cover sequence lying above the Mushkin grey gneiss. Plotting on the pressure/temperature diagrams, it is suggested that the unit formed under 4.5 to 7.5 Kb, at 635^0C to 725^0C (Fig. 3a).

RATTU FORMATION

A succession of schists, paragneisses and marbles defines a mappable unit at the north-western and south-eastern margins of the studied transect in the Astor valley. Tahirkheli (1988) assigned the name Rattu formation to this unit, which is retained in this study. The unit delimits the Main Mantle Thrust (MMT) on the north-western side of the syntaxis near the Ramghat bridge as suggested by the presence of sheared contact with Kohistan amphibolites. Similarly, the south-eastern contact with the Ladakh amphibolites at the Ashraf Shaheed camp, is also defined by MMT (Fig. 2). In addition to these two extremes, the unit also occurs in the middle part of the syntaxis i.e., near the Dichili-Astor confluence, and here it is in contact with amphibolites.

The Rattu formation is typically golden brown in weathering colour and is predominantly composed of kyanite-silllimanite - garnet-staurolite-biotitie-feldspar-muscovite schists and gneisses. Schistosity is well-developed with common prophyroblasts of garnet and rarely those of staurolite and kyanite. The garnet porphyroblasts range in size from 0.4-1.0cm in diameter. In some places, especially at the south-eastern margin of the massif where the unit has reached upto kyanite grade of metamorphism, they are larger and reach up to 2 cm in size. The kyanite in this zone is bluish white in colour and occurs as bladed to prismatic porphyroblasts. Individual kyanite crystals can be seen with unaided eye, some are large with 1 to 2cm length.

The formation contains quartzite, marbles and calc-silicates. This lithological association together with abundance of alumino-silicate minerals suggests derivation from a sedimentary cover succession. The formation experienced metamorphism under upper amphibolite facies (4 to 8 kb pressure, at 550^{0}C to 625^{0}C) (Fig.3b).

INTRUSIVE ROCKS

Four main types of intrusive rocks occur in the crustal sequence along the Astor valley section.

1. Undeformed Granitic Intrusion,
2. Mylonitic Augen Gneiss,
3. Felsic Gneiss,
4. Megacrystic Augen Geniss

In addition, there are number of amphibolite dykes (metabasites) with variable thickness and composition.

1. Undeformed Granitic Intrusion

The unit is a massive, homogenous and undeformed granitic intrusion in the Rattu formation, and only exposed at the north-western margin, little south of Ramghat. The unit is medium to coarse grained, quartz-feldspar-biotite granite. Although the granite is underformed, at some places there is a weak fabric. The north-western contact is sheared with the Rattu formation, while the south-eastern contact is sharp with the mylonitized augen gneiss. (Fig. 2).

2. Mylonitic Augen Gneiss

The mylonitic augen gneiss is characterized by mylonitic to ultramylonitic texture, with elongate felsic porphyroclasts. These porphyroclasts are rotated, typically snow white in colour and, generally, form sharp tails. The granulated fine-grained matrix arranged in foliation consists of quartz and greyish black minerals, mainly biotite. It is in contact with undeformed granite at its north-western contact, which intrudes it with a clear intrusive chilled contact. The south-eastern contact with the lithologies of the Rattu formation is sheared (Fig. 2).

3. Felsic Gneiss

Felsic gneiss occurs at several places in the Astor valley, intrusive into both Rattu formation and Harchu pink gneiss. The unit is in the form of sheets and best exposed at the Harchu river bend (Fig. 2). The thickness of the unit is much variable from few meters to several hundred meters. It is strongly porphyritic garnetiferous gneiss of granitic composition. The unit is generally milky white in colour, strongly sheared in places, and foliated and lineated. It contains tourmaline, garnet, muscovite, biotite, and feldspar porphyroclasts. In addition, felsic bands and pegamatitic veins are abundant.

4. Megacrystic Augen Gneiss

This porphyritic gneiss is restricted to the south-eastern part of the massif, and displays intrusive contact with Rattu formation and Harchu gneiss (Fig. 2). Large augens of feldspar, upto 3-4 cm long and 1-2cm wide, show carlsbad twin, and contain garnet and biotite inclusions. They have been stretched out with undulated tails due to deformation, since most have strongly parallel orientation to schistosity. Garnet inclusions in feldspar are similar to matrix and have distinct rose-pink colour. The matrix is composed of mica, quartz, garnet and feldspar. The matrix material forms anastomosed to wavey foliation around the felsic augens.

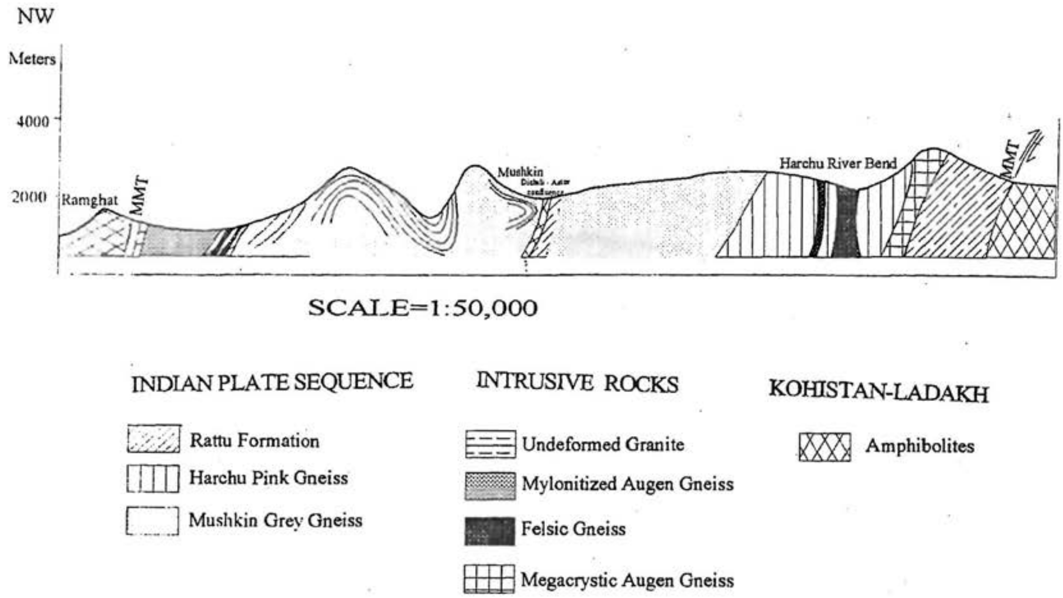

Fig. 4. Structural cross-section of the Indian Plate rocks, along the Astor Valley section.

KOHISTAN-LADAKH AMPHIBOLITES

The massif at the two margins is bordered by amphibolites i.e., Kohistan amphibolites on the north-western margin and Ladakh amphibolites on the south-eastern contact.

The north-western amphibolites fall under two categories: fine-grained amphibolites and medium to coarse-grained amphibolites. The former are strongly foliated, light to dark green in colour and thinly banded. The rocks contain abundant felsic veins and streaks. Generally, thin felsic streaks (<2mm) along and across the foliation are common. These amphibolites contain sufficient epidote and can thus, be classified as epidote-amphibolites. It is generally suggested that the rocks have been derived from volcanic precursor. Amphibolites with similar characteristics from south of Chilas and Indus, Swat and Dir volcanics are interpreted to have been derived from volcanic precursor (Jan, 1990; Khan et al., 1993).

The medium to coarse-grained amphibolites are homogenous and exposed near the Ramghat bridge. However, pegmatite dykes, up to 8-10cm in thickness cutting the foliation, are common. These amphibolites contain red garnet porphyroblasts and classified as garnet-amphibolites. The rocks probably were derived from a gabbroic precursors as suggested by relatively coarser grain size of these amphibolites. Rocks of similar characteristics were also found near Dichili-Astor confluence. These rocks are in sheared contact with Rattu formation along a fault zone.

The Ladakh amphibolites are medium to coarse-grained, foliated, locally sheared, thinly banded amphibolites. Generally, the rocks are light-green in colour. They contain garnet porphyroblasts which are distinctly reddish-pink in colour in a medium grained matrix of amphibole, plagioclase and epidote. Felsic material anastomosed around the garnet grains. Generally, felsic veins contain smaller garnets, whereas the rock contains larger garnet prophyroblasts. These amphibolites are classified as epidote-garnet amphibolites. These amphibolites were probably derived from gabbros.

STRUCTURE GEOLOGY

The Nanga Parbat syntaxis along the studied transect consists of a pair of curstal-scale antifomal folds with a tight, faulted synform in between. Structural cross-section (Fig. 4) of the rock units from north-west to south-east, along the Astor valley, suggests that the Mushkin grey gneiss exhumes at the cores of these antiforms with respect to the cover sequence on the margins. The Harchu pink gneiss is only exposed along the south-eastern margin of the section and, for unknown reasons, is not repeated through folding. The Rattu formation is consistent in the folding sequence. The general trend of the rock units, within the Indian plate is, NNE/60-80^0 NW.

The regional scale antiformal fold in the western part of the massif shows evidence of multiple deformational phases (Fig. 5). For instance, the S_1 fabric is associated with isoclinal fold of intrafolial type and is involved in upright scale fold. This fabric is folded into S_2 fabric on the eastern side of the fold limb as suggested by the overprint of recumbent fold on S_1 fabric. A third fabric, i.e., S_3 is superimposed on the earlier fabrics and consists of tight upright antiforms and synforms exposed in the core of the large fold, and, thus latest in the time sequence. The eastern half of the massif comprises another crustal-scale antiformal fold. The south-eastern side of this fold is again recumbent as suggested by the easterly dips at high altitude and westerly dips near the valley floor.

Geometric analysis of gouge fabric as well as the thrust lineations within the Rattu formation at the south-eastern margin of the massif, reveals that the Rattu formation is thrust over the Ladakh amphibolites. Riedel fabric within the brittle fault zones in the Kohistan amphibolites moves downwards. However, these are local shear zones with normal sense of shear exposed in the north-western part of the Astor valley. These brittle fault zones might be the continuation of Raikot-Liachar thrust fault. More detailed work (Butler et al., 1989, 1991; Treloar et al., 1991) along the western margin of the massif suggests thrust and dextral sense of shearing. These young faults are continued along the massif and displace the trace of Main Mantle Thrust [MMT] on both sides of the syntaxis (Butler et al., 1991; Treloar et al., 1991; Verplank 1985).

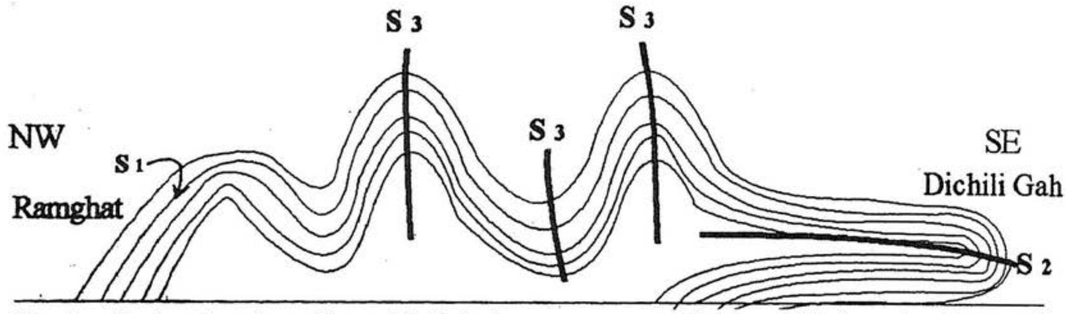

Fig. 5. Regional scale antiformal fold in the western part of the massif along the Astor valley shows multiple deformational phases.

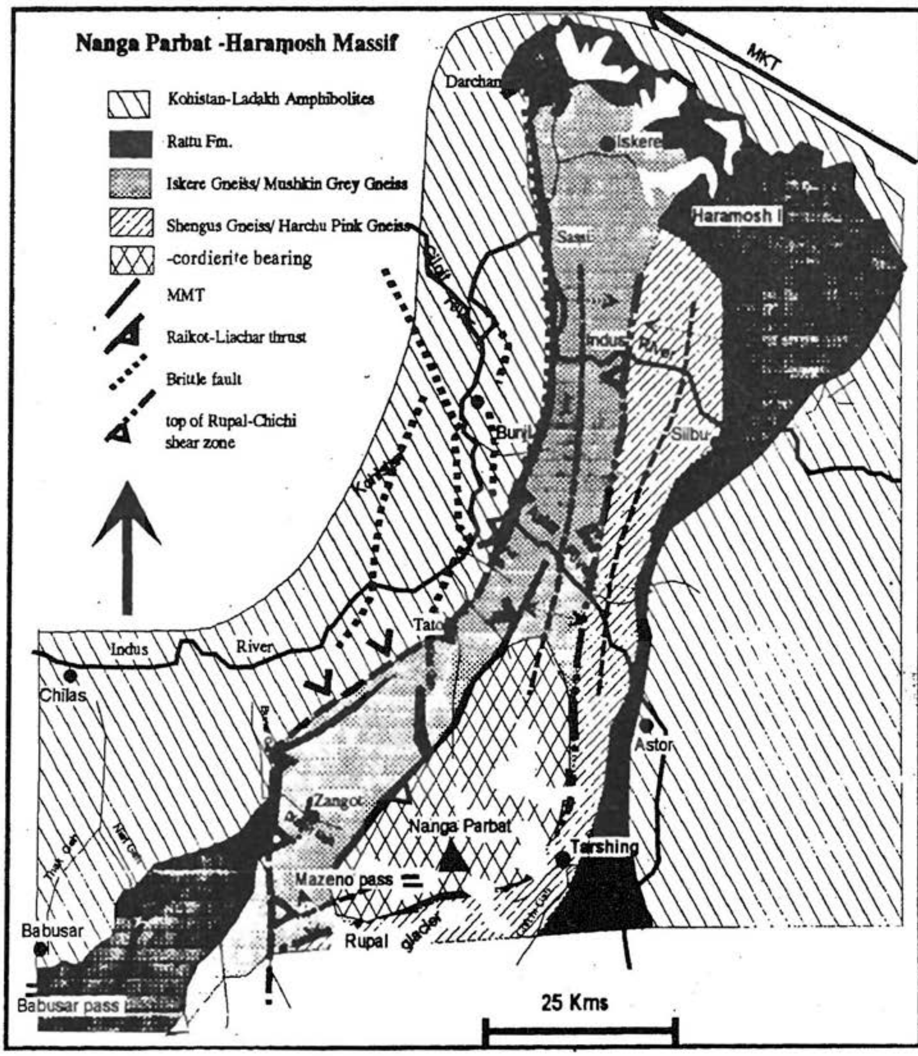

Fig. 6. Geological map of NPHM showing the correlation between Muskhin and Harchu gneisses from the Astor valley with the Iskere and Shengus gneisses from the Indus valley, respectively. (modified from Kidd., 1996).

Based on the lithological similarities the Mushkin grey gneiss and Harch pink gneiss of Astor valley can be correlated with those of Iskere gneiss and Shengus gneiss of Indus valley section, respectively, with a thin veneer of supra-crustal sequence at the margins (Fig. 6).

MAIN MANTLE THRUST

The south-eastern contact of the massif with the Ladakh amphibolites, along the Astor valley, is sheared. However, asymmetric augens of shear zone coupled with thrust relationship of Rattu formation indicate that the Rattu formation of Indian plate sequence have a thrust contact with those of Ladakh amphibolites. Moreover, presence of ultramafic lenses and chlorite-talc schists at the contact between the two domains indicates the distinction of Main Mantle Thrust (MMT). The north-western contact of the Kohistan amphibolites with the Indian plate cover sequence is sheared and poorly exposed, the sense of shearing could not be evaluated. However, the geometric analysis of shear zones within the Kohistan amphibolites indicates that the Kohistan moves downward with respect to Indian plate rocks.

REFERENCES

Bossart, P., Dietrich, D., Greco, A., Otiger, R. & Ramsay, J.G. 1988. The tectonic structure of the Hazara-Kashmir syntaxis, southern Himalaya, Pakistan. Tectonics 7, 273-279.

Chamberlain, C. P., Zeilter, P. K. & Jan, M. Q. 1989. The dynamics of the suture between the Kohistan island arc and the Indian Plate in the Himalaya of Pakistan. J. Metamorphic. Geol., 7, 135-149.

Coward, M. P. 1986. A section through the Nanga Parbat syntaxis, Indus valley, Kohistan. Geol. Bull. Univ. Peshawar, 18, 147-152.

Jan, M. Q. 1990. Petrology and geochemistry of the southern amphibolites of the Kohistan arc, n. Pakistan. In: Sharma, K.K. (ed.). Geology and geodynamic evolution of the Himalayan collision zone. Phys. & Chem. Earth, V. 17, pp. 71-92.

Khan, T., Khan, M. A. S., & Jan, M. Q., 1993. Kohistan, a collage of Island arc and back-arc basin assemblages in the Himalaya of N. Pakistan. Geol. Soc. Amer. Abstracts with Programs, A-122.

Madin, I. P., Lawrence, R.D. & Ur-Rehman, S. 1989. The northwestern Nanga Parbat-Haramosh massif: evidence for crustal uplift at the northwestern corner of the Indian carton. Geol. Soc. Amer. Sp. Paper, 232, 169-182.

Suess, F. E., 1901. Die Herkunft der Moldauite and verwandter Glaser. Austria. Geologisehe Reichsanstalt. Jahrbuch, Bd. 50, H.Z, 193-382.

Tahirkheli, R. A. K., 1982. Geology of Himalaya, Karakuram, Hinduskh in Pakistan. Geol. Bull. Univ. of Peshawar, 15-54.

Tahirkheli, R. A. K., 1988. Pressure of Main Central Thrust in the tectonic domain of northwestern Himalaya in Pakistan. Geol. Bull. Univ. Peshawar, 21, 131-140.

Treloar P. J., Potts, Wheeler J. & Rex D. C. 1991. Structural evolution and asymmetric uplift of the Nanga Parbat syntaxis, Pakistan Himalaya. Geologische Rundchau 80/2, 411-428.

Treloar, P. J., Guise, P. G., Coward, M. P., Searle, M. P., Windley, B. F., Person, M. G., Jan, M. Q. & Luff, I. W. 1989. K-Ar and Ar-Ar geochronology of the Himalayan collision on NW Pakistan, constraints on the timing of suturing, deformation, metamorphism and uplift. Tectonics 8, 881-909.

Verplank,. P. C., Snee, L. W. & Lund, K. 1985. The boundary between the Nanga

Parbat massif and Ladakh island arc terrane, northern Pakistan, a cross fault on the Main Mantle Thrust. Abstract EOS 66, 1074.

Zeitler, P. K. 1985. Cooling history of the NW Himalaya. Tectonics 4, 127-151.