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Geology of the drainage divide between Kohistan and Kaghan, N. Pakistan

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ABSTRACT: *This paper describes the geology of an area of about 1200 km² in the upper Kaghan valley. The area is traversed by Main Mantle Thrust, which juxtaposes the southeastern part of the Kohistan terrane in tectonic contact with the higher Himalayas of the Indian plate. The Indian-plate sequence in the study area comprises a basement of granitic gneisses (both ortho- and paragneisses) followed by the Domel unit (calcareous schists/paragneisses, garnetiferrous marbles, calc silicates and amphibolites) and the Parla Sapat unit (graphitic quartz-mica to garnet staurolite schists). These rocks are in tectonic contact with the mafic-ultramafic rocks of the Sapat complex along the Main Mantle Thrust. The Sapat complex underplates metabasalts of the Kamila amphibolite belt (i.e., Niat metavolcanic unit) and comprises ultramafic cumulates (dunites, peridotites and pyroxenites) at the base, layered gabbros in the middle and isotropic gabbros in the upper levels. The complex is folded through two phases of folding and metamorphosed under greenschist/lower amphibolite facies. The restored thickness of the complex approaches in excess of 2 kms.*

The Main Mantle Thrust was mapped at several new locations during this study. Our observations show that the MMT at the base of the Sapat complex is younger than the melange/olistostorm preserved in the upper parts of the Parla Sapat unit. The thrust cuts upsection laterally, and to the east of Babusar, occurs at the base of the Niat metavolcanic unit.

INTRODUCTION

The Kaghan valley is the oldest route for access to the interior of the Himalayas in northern Pakistan. The valley provides a unique geological section across the entire width of the Himalayas. Starting from the lower Himalayas in the core of the Hazara-Kashmir syntaxis near Balakot, the valley traverses across the Lesser and Higher Himalayas in its middle and upper reaches, respectively. The drainage divide between the Kaghan valley and southern tributaries of the Indus river in the Kohistan region marks the contact between the Indian plate and the Kohistan terrane, which represented separate geological entities prior to their collision in the Early Tertiary.

This paper is an outcome of our study of the lower crust of the Kohistan terrane exposed along the drainage divide between the Kaghan valley and Kohistan (Fig. 1). In the Indus valley to the west of the presently studied area, the garnetiferous ultramafic-mafic cumulates of the Jijal Com-

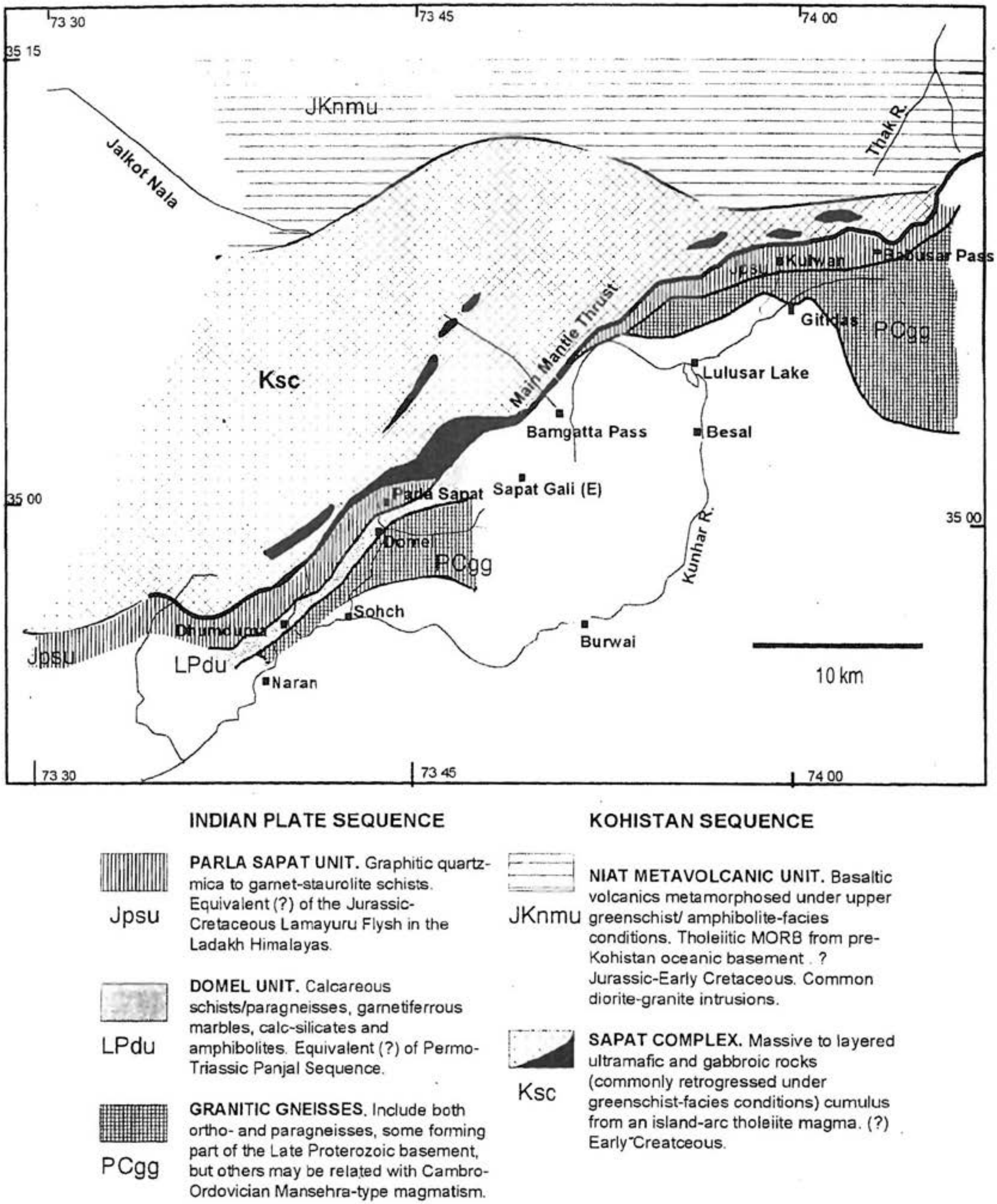

Fig. 1. Geological map of the Sapat Complex and adjacent area (modified after Jan et al. 1993).

plex represent the deepest roots of the middle Cretaceous Kohistan island arc terrane (Jan & Windley, 1990; Miller et al., 1991; Miller & Christensen, 1994). The Jijal complex does not extend into the presently studied area, which instead, comprises a compositionally similar but relatively higher level suite of mafic-ultramafic cumulates which we term as the Sapat Complex (Jan et al., 1993). Besides describing the lower-crust geology of the Kohistan terrane, here we outline the geology of the adjoining Indian plate exposed at the southern slopes of the drainage divide.

GEOLOGICAL FIELD RELATIONS

The Kohistan terrane

The south-eastern part of the Kohistan terrane has been traditionally studied either along the Indus (i.e., Jijal-Kamila-Kandia transect) or the Thak (Babusar-Chilas transect) valleys. A large terrane between these two valleys has remained poorly studied. Following a brief mention of the chemistry of chromite from the Sapat valley by Ahmed (1981), a significant contribution based on the geological mapping of this terrane came from Ghazanfar et al. (1991). Preliminary results of our investigations in SE Kohistan have been outlined in Jan et al. (1993) and Khan et al. (1994).

Our observations in SE Kohistan have revealed the presence of a previously unnoticed mafic-ultramafic complex which we refer to as the Sapat Complex (Jan et al., 1993). The ultramafic bodies and associated amphibolites at the Babusar Pass (Ahmed & Chaudhry, 1976; Khan & Thirlwall, 1988) are considered part of the Sapat Complex. Slicing at the base has exposed the entire complex in the hanging wall of the MMT at the western Sapatgali Pass (Fig. 1). Laterally, both to the SW and NE, the MMT has cut off the basal ultramafic cumulates resulting in the occurrence of gabbroic rocks in its hanging wall. The Sapat Complex occupies approximately 1000 km^2 in SE Kohistan. Western extension of the complex remains totally unexplored, but we suspect that it may continue into gabbroic amphibolites exposed in the Indus valley, which have been locally termed as the Pattan and Kayal complexes (Miller et al., 1991).

The magmatic stratigraphy of the Sapat Complex has been worked out in a measured section in the Ratti Gatti valley (downstream north of the western Sapatgali Pass. Fig. 2). The complex comprises three units; ultramafic cumulates at the base, layered gabbros in the middle and isotropic gabbros at the upper stratigraphic levels. The ultramafic basal part is about half-a-kilometre thick and comprises serpentinised dunites with minor streaks and layers of chromitites. The sole of this body, directly above the MMT, is strongly sheared and transformed into serpentine mylonites. The basal ultramafics are followed by an about 200 meter thick zone comprising layers of dunites, pyroxenites, gabbros and anorthosites. Upsection, layered gabbroic rocks become predominant, comprising pyroxenite and anorthosite layers, which, further up in the section, give way to isotropic gabbros. It may be pointed out that we noticed thin lenticular bodies of pegmatite pyroxenite higher up in the magmatic stratigraphy of the Sapat Complex in the Ratti Gatti valley. Larger bodies of similar composition were noticed extending to the west of Sapatgali. One of such bodies has been mapped in the upper reaches of the Kinari and Nili Nadi valleys by Ghazanfar et al. (1991) as their Maidan Gali pyroxenites. Like Ghazanfar et al. (1991), we only touched the southern parts of this body and could not map its northern contact. However, we believe that this body is a lateral extension of the pegmatitic pyroxenite we observed at higher stratigraphic levels at the ridge west of Ratti Gatti, and is different from the serpentinized basal dunites/peridotites occupying the immediate hangingwall of the MMT at the Sapatgali Pass.

The exposed width of the Sapat Complex does not represent its true thickness. The complex is folded through at least two phases of open

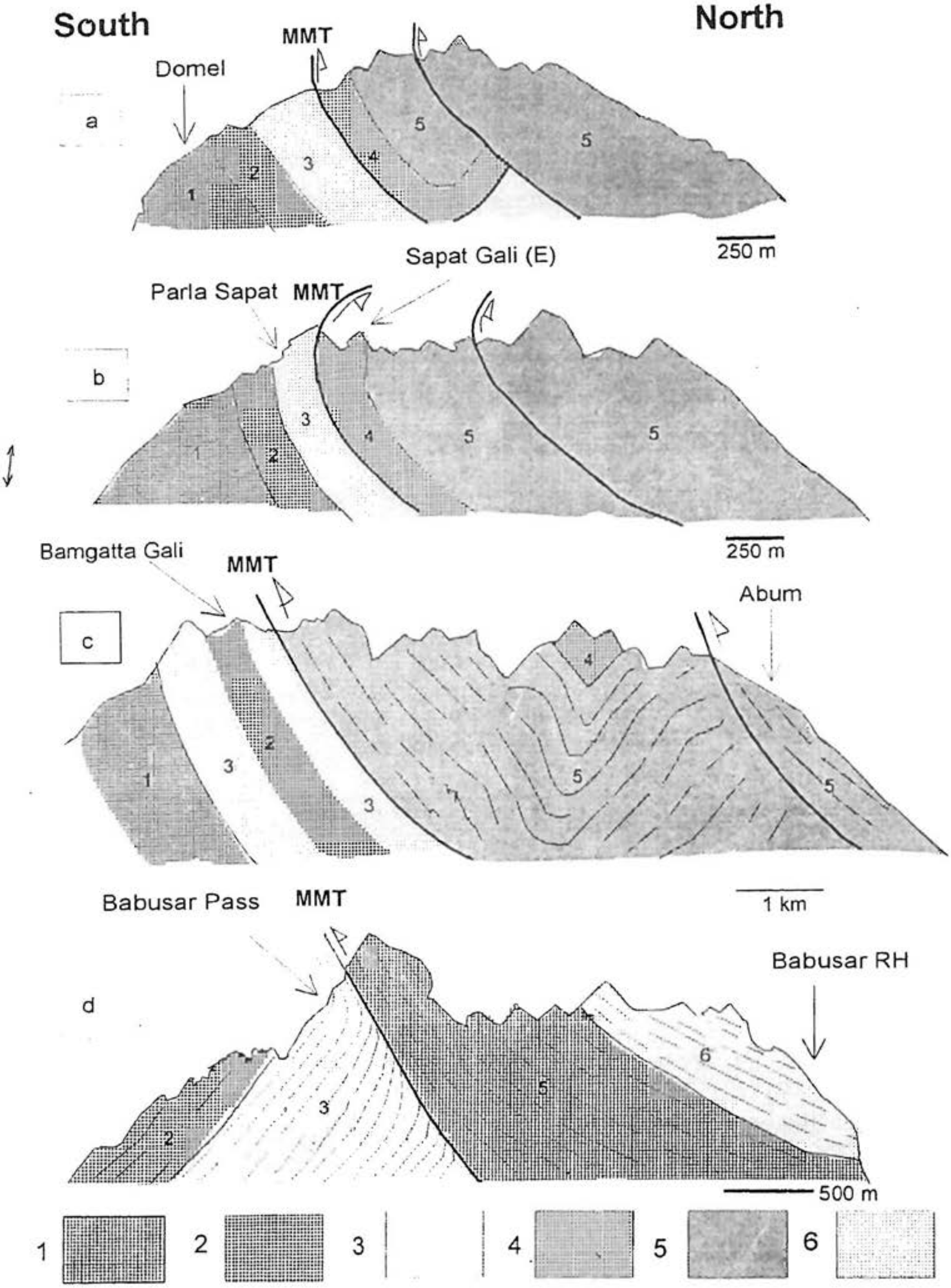

Fig. 2: Cross section across the Indus suture (Main Mantle Thrust), showing hanging wall structures in southern Kohistan **a** and **b** near Sapat gali pass, **c** near Bamgatta pass and **d** near Babusar pass.

folding. The first-phase folding is characterised by upright folds with horizontal fold axes oriented east-west. These fold structures are characterised by large open synclines (half-wavelengths approaching a kilometre or more) and narrow anticlines. The anticlines are commonly breached by south-verging reverse faults. In such areas, the folds verge to the south. Northwards, i.e., away from the MMT, however, the folds of this phase become either upright or verging towards north. A good example of folds of this type is exposed on the eastern slopes of the Bamgatta valley near its confluence with the Ratti Gatti river (Fig. 3). The second phase of folding is again characterised by horizontal fold axes, but unlike the upright or inclined first-phase folds, second-phase folds are open recumbent. These folds are well exposed along the steep valley faces in this high-relief area. Not only they refold the phase-1 folds but fold the MMT and reverse faults located within the complex to the north of the MMT. These folds, like the phase-1 folds, are large scale and characterised by half-wave length of a few hundred meters. Whereas we are uncertain whether or not the phase-1 folds observed in the Kohistan terrane affect the Indian plate, the phase-II folds do affect both the Kohistan as well as the underlying Indian-plate lithologies. The restored thickness of the complex after removing the effect of folding and thrusting approaches about 2 km.

The Indian plate crust

The upper Kaghan region of the Indian plate makes part of the hinterland or the internal zone of the Himalayan orogen, and in the conventional Himalayan division (Gansser, 1964, 1979), is included in the Higher Himalayas. Wadia (1931) made the pioneering contributions, however, the region remained poorly studied until about a decade ago. In recent years, Ghazanfar and Chaudhry (Punjab University, Lahore) carried out a systematic mapping programme in the Kaghan valley leading to some highly valuable contributions (Chaudhry & Ghazanfar, 1987; Chaudhry et al., 1986; Ghazanfar et al., 1992). More recently, a group of Swiss post-graduate students carried out detailed work on the Higher Himalayas of the Kaghan region (Greco et al., 1989; Spencer, 1993). Other contributions include those of Chamberlain et al. (1991), Smith et al. (1994) and Jan et al. (1993). Our map covering the southern face of the Sapat drainage divide is meant to supplement the existing maps of the Kaghan region (Chaudhry & Ghazanfar, 1987; Greco et al., 1989; Spencer, 1993; Smith et al., 1994), which somehow lack details about this particular area.

The lithologies of the Indian plate exposed at the southern slopes of the Sapat-Bamgatta ridge comprise more or less equal proportions of metasediments and granitic gneisses. The interrelationship between these two rock-types are obscured by deformation, therefore, intrusive and/or depositional relationships between the two are no more preserved.

Metasedimentary Rocks: Two units of metasedimentary rocks are exposed at the southern face of the Sapat ridge. One of these, locally named here as the Domel unit, consists predominantly of garnet carbonate schists and amphibolites. The second unit of the metasediments is locally named here as the Parla Sapat unit and comprises metapelites with garnet-quartz-mica schist as the predominant lithology.

Domel Unit: This unit is squeezed between two sheets of granitic gneisses and is best exposed in the middle reaches of the Sohch valley, at and to the south of Domel. The unit has a NE-SW regional trend and extends towards Naran in the SW and towards Eastern Sapatgali Pass in the NE (Fig. 1). Compositionally, the Domel unit is divisible into three subunits. The southern subunit is predominated by commonly banded

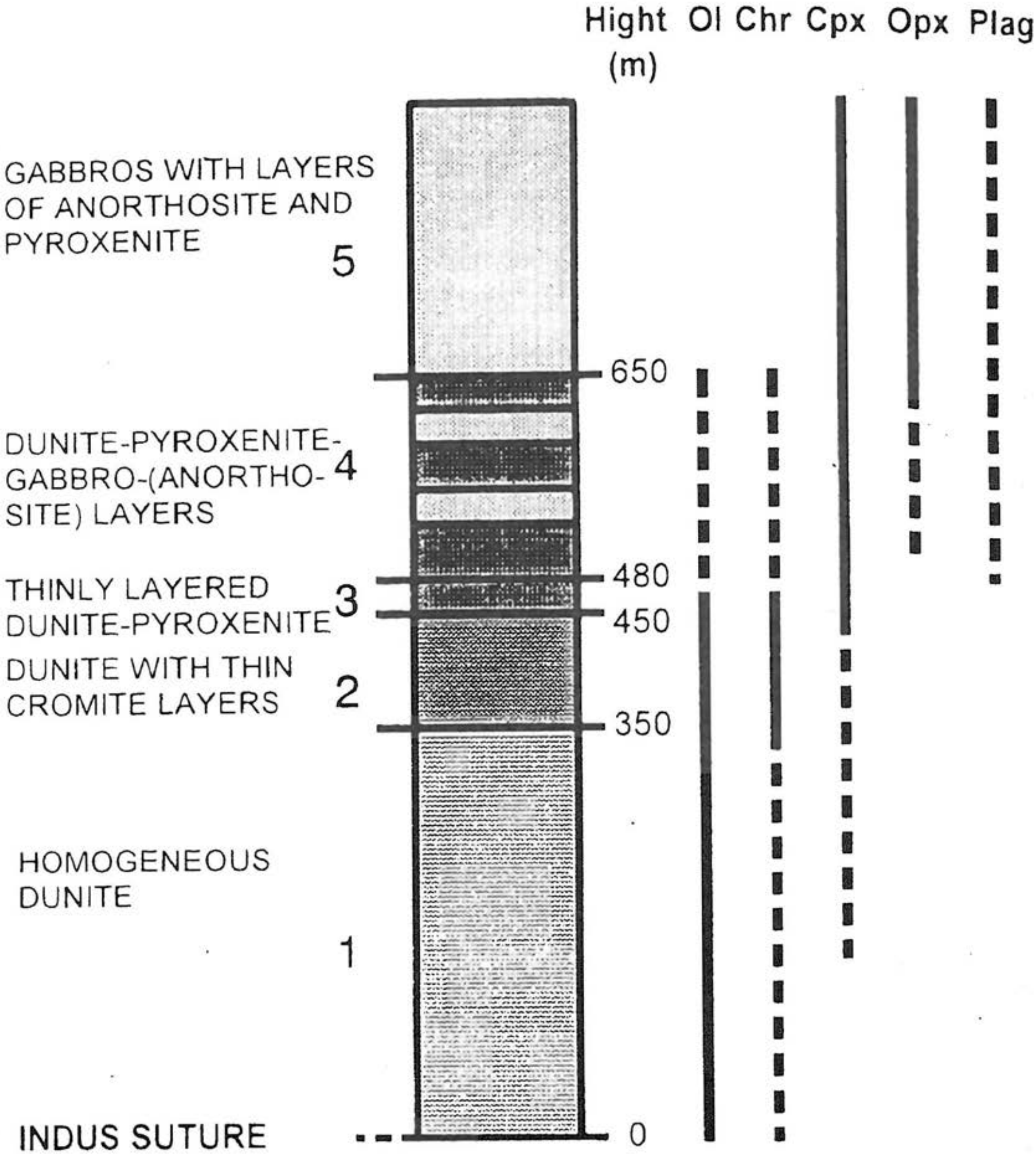

Fig. 3. Stratigraphic column of the lower part of Sapat layered complex, 2.5 km south of Ratti Gatti.

amphibolites comprising garnet-rich compositions alternating with garnet-poor or garnet-free bands. The absence or presence of garnet is attributed to compositional control, which in turn points to the origin of these amphibolites as volcanogenic (irrespective of flows, pyroclastic or epiclastic nature) as opposed to intrusive. The intermediate subunit comprises calc-silicates. The rock is thinly banded, comprising alternating bands rich or poor in carbonates. The carbonate-poor bands are characteristically rich in quartz, biotite and garnet. Garnet porphyroblasts in certain bands are > 1 cm in diameter and are clearly rotated, suggesting a pre-tectonic metamorphic origin. The northern subunit is predominated by marbles with abundant, though subordinate, bands of metapelites. The marble is variable in composition; brown marble loaded with coarse-grained garnet, micaceous marble with rounded grains of garnet and white marble devoid of garnet. A large part of this subunit, in its northern parts, comprises garnet-mica schist with distinctly high carbonate content, and local horizons of brown garnetiferous marble. The Domel unit is commonly intruded by leucogranites and pegmatites. Some of the pegmatites are sheared and clearly pretectonic, others are boudinaged when involved in the shear zones but otherwise remain undeformed suggesting syntectonic origin, while there are still others which post-date deformation and cut across fabric in the unit. Basic sheets, commonly containing garnet, are present throughout the unit, but it is difficult to ascertain their mode of emplacement, i.e., whether intrusive or volcanogenic.

Parla Sapat Unit: This unit has been previously mapped by Ghazanfar et al. (1991) under the name of Babusar mylonites, and the rocks were identified as garnetiferous-graphitic schists. Greco et al. (1989), too, showed this unit on their regional map of the upper Kaghan valley as graphitic schist. Smith et al. (1994) mapped this unit as grey phyllites with marble and considered it to be a thrust sheet of the MMT zone.

This unit occupies the upper reaches of the Kinari and Sapat valleys in a NE-SW regional trend, preferentially located along and to the south of the MMT. Westward the unit swings first to an E-W trend and then to a WNW-ESE trend in the upper reaches of the Nili Nadi valley. Eastwards the unit squeezes between the ultramafic mylonites of the Kohistan plate and the Dhumduma gneisses (see later) and pinches out before reaching the northern slopes of the Eastern Sapatgali. From here towards the northeast, the unit is missing for about 12 km, and the ultramafic mylonites of the Kohistan plate overlies Dhumduma gneisses directly. The Parla Sapat Metapelites reappear at the ridge to the northeast of the Bamgatta Pass. Our observations in the upper reaches of the Lhoeylul Nar, at the Shutta Pass and at the Babusar Pass, confirm regional northeasterly distribution of this unit along and to the south of the MMT.

The Parla Sapat Metapelites, as observed in the upper reaches of the Sapat valley north of Domel, are grossly homogeneous but strongly foliated. They are black in appearance and contain minor graphite. Other minerals include quartz, biotite and muscovite, thus broadly, the rock may be named graphitic schist or more precisely graphitic quartz- mica schist. The unit is hetrogeneously sheared; the horizons escaping the shear, retain higher-grade minerals like garnet and staurolite (and may thus be termed garnet-staurolite schists, or garnet mica schists), while those retrogressed during shearing in greenschist facies conditions no more contain garnet or staurolite. Immediately below the ultramafic mylonites, garnetiferous and non-garnetiferous rocks are found in close association, suggesting a lack of penetrative deformation. Nonetheless the unit is extensively sheared and the application of terms mylonites or blastomylonites is not inappropriate (Ghazanfar et al., 1991). In the vicinity of the contact with the ultramafic mylonites of the Kohistan plate, the metapelites are extensively crenulated with a strong lineation oriented E-W, and plunging steeply towards west.

The Parla Sapat metapelites in the Kinari valley, north of Dhumduma, are in contact with the Dhumduma granitic gneiss near the village of Kinari. In this valley, they are divisible into a southern schistose unit and a northern phyllite unit. The schistose unit is a type garnet-quartz-mica schist with a strong foliation while garnet is absent in the phyllite subunit. As noted in the Sapat valley, the phyllites are probably derived from the garnetiferous schists through greenschist-facies ductile-brittle shearing associated with the MMT. We noted several bands of greenschists and talc-carbonate schists intercalated with the graphitic phyllites. These rocks were possibly derived from ultramafic or volcanic precursors, as is the case in the Shangla melange (Kazmi et al., 1984), but we cannot distinguish the nature of their incorporation, i.e. whether depositional like in an olistostorm or tectonic slices as is the case in the melanges. Minor amounts of marble bands are present in the Parla Sapat unit both in the Kinari valley as well as to the west in the Nili Nadi valley (Smith et al., 1994). Marbles and calcareous garnet-mica schists are also observed in the Parla Sapat unit in the upper reaches of the Lhoeylul valley (at the Kulwan confluence), and short of the Babusar pass. A notable absence is that of the basic igneous rocks as dykes or sills which are very common in all the other lithologies of the region.

Granitic Gneisses: Granitic gneisses are abundant in the studied part of upper Kaghan. They are predominantly in the form of sheets, ranging in size from a few centimetres to a km or more. Two sheets of the granitic gneisses are prominent in the studied area. The southern sheet, which we locally refer to as the Sohch granitic gneiss, occupies the lowermost reaches of Sapat valley and its confluence with the Kaghan river. This granitic gneiss is predominantly fine-medium grained and strongly gneissose. However, at several places, the gneiss retains augen structures, suggesting tectonic derivation from a megacrystic granite. The second sheet of the granitic gneisses occupies, from west to east, the Kaghan-Kinari confluence at Dhumduma, upper reaches of the Sapat valley north of Domel, and at the northern faces of the Sapatgali (eastern)-Bamgatta ridge. This granitic gneiss, locally named here as the Dhumduma granitic gneiss, is considered as a separate entity rather than a folded limb of the Sohch granitic gneiss as portrayed by Greco et al. (1989). The Dhumduma granitic gneiss is typically fine-medium grained and strongly foliated with well-developed mm-scale gneissic banding. The gneiss may originally have been fine-medium grained with no signs of megacrysts or augens. Compositionally it comprises quartz, plagioclase, microcline, muscovite and biotite. Zircon, sphene and tourmaline are in trace amounts. Observations in the Bamgatta valley (north of the Bamgatta Pass) suggest that the Dhumduma granitic gneiss itself is composite, comprising alternating sheets of very felsic and less felsic compositions. The less felsic variety contains greater proportions of biotite and muscovite. In the same area, 2-10 meter thick sheets of granitic gneiss alternate with sheets of similar sizes but comprising paragneisses. These paragneisses are internally banded with alternating quartzofeldspathic and micaceous bands both containing abundant garnet. The Dhumduma granitic gneiss contain sheets of garnetiferous amphibolites, both in the Noor Jamal Di Bahk area as well as to the north of the Bamgatta pass. Locally, these gneisses are intercalated with calc-silicate bands. These are medium grained and consist of plagioclase, quartz, clinopyroxene, calcite, biotite, carbonates, with traces of zircon, rutile and sphene.

STRATIGRAPHIC CORRELATIONS

The crustal geology of the Higher Himalayas of the Kaghan region is complicated by several episodes of magmatism, ductile and brittle deformation and regional metamorphism. Yet attempts have been made to workout a stratigraphic order amongst the constituent lithologies. The stratigraphic schemes of Greco et al. (1989) and Spencer (1993) remain broadly similar. These authors believe that all the granitic gneisses are Cambrian in age and are correlative of the 516 Ma Mansehra granite of the Hazara region (LeFort et al., 1980). Spencer (1993) identifies a sequence of metapelites (garnet-mica schists) from near the Gitti Das village, which he believes to be the host to the intruded granites (now gneisses) and thus Precambrian in age. Two cover sequences are identified. The lower is considered to be Lower to Middle Paleozoic in age and consists of a sequence of paragneisses derived from greywacks with minor marbles and quartzites (Naran Formation = Lulu Sar Formation). The upper cover comprises a succession of amphibolites, marbles, calc-pelites, garnet-mica schists and dolomites (the Burwai Formation) and is correlated with the Permo-Triassic Panjal volcanics and sediments of the Lesser Himalayas. An extensive sequence of carbonate garnet schists exposed around and to the south of Naran is identified to be a basement component by Smith et al. (1994) rather than a structural repetition of the Burwai Formation as proposed by Greco et al. (1989). Chaudhry et al. (1987) and Ghazanfar et al. (1992), in contrast, classify all the lithologies of the Upper Kaghan region to be part of the Indian plate basement of mid Proterozoic to Archean age. They believe that the granitic gneisses are derived mainly from two sheets of granites intruded and emplaced at two stratigraphic levels in a basement sequence of paragneisses (called Sharda Group) and are divided into units like Naran-, Besal-, Burwai-, Lulu Sar-gneisses on the basis of their gross composition rather than stratigraphic order. A succession of garnet-mica schists (locally graphitic), forming a 500-800 m wide belt in the immediate footwall of the MMT is distinguished by Ghazanfar et al. (1991), Greco et al. (1989) and Smith et al. (1994) to be part of the MMT melange rather than that of the Indian-plate crust.

As far as the lithologies of the presently studied area are concerned different interpretations exist in the previous work regarding their geological affinities in the above-stated stratigraphic setup. For instance the Domel unit of the present study is considered to be part of the Burwai Formation by Greco et al. (1989) while Smith et al. (1994) include it in the basement gneisses. The Domel unit of this study has gross lithological similarities both with the Burwai Formation as well as with the carbonate-garnet schists unit exposed at and around Naran. At the moment we tend to equate our Domel unit with the Burwai Formation of Greco et al. (1989) on the basis of presence of volcanoclastic amphibolites and predominance of metamorphosed marbles. The southern contact of the Domel unit is directly with the Sohch gneisses. If the Domel unit is equivalent of the Burwai Formation, the Naran Formation, which intervenes between the two elsewhere, is missing in the studied area. However, as noted both by Greco et al. (1989) and Spencer (1993), the Burwai Formation represents a transgressive sequence and is commonly in direct contact with the granitic gneisses equivalent of the Sohch gneisses.

The Parla Sapat unit is distinct from the Domel unit, comprising pelitic rather than carbonate lithologies. In the area north of Besal, Spencer (1993) has included the equivalent rocks into his Triassic metasediments making part of the upper cover, while Ghazanfar et al. (1991) and Smith et al. (1994) include them in the MMT melange. In the studied area, these metasediments are separated from those of the Domel unit by the sheet-like mass of the Dhumduma granitic gneisses, which appear to occupy the contact between these two units. The distinct lithological differences between the Domel and Parla Sapat units and absence of amphibolites in the Parla Sapat metapelites suggests that the Parla Sapat Unit represents a distinct stratigraphic entity. On a regional basis the Parla Sapat metapelite may be an equivalent of the Saidu Formation in Swat (Kazmi et al., 1984; DePietro et al., 1993). Both these lithological units are graphitic, comprise quartz-mica phyllites and schists (±garnet), and occupy the highest stratigraphic levels in their respective areas. The Parla Sapat metapelites and the Saidu Formation of Swat may be remnants of the Jurassic Tethyan flesh similar to that mapped in detail from the Ladakh area (Robertson & Degnan, 1994).

As far as the granitic gneisses are concerned, their suggested correlation with those of Mansehra, is difficult to confirm on the basis of data at our hand. Only the megacrystic granites, like those of Sohch have chances of being equivalent to those of Mansehra. The fine-medium grained, garnet and tourmaline-bearing granites, like those of Dhumduma have nothing comparable to the Mansehra granite. Similar granites, however, occupy the contact between the Swat (Ilam) granitic gneisses and overlying metasediments of the Alpurai Formation at the Karakar Pass (SE of Mingora). Nonetheless, all these granitic gneisses (except for the leucogranites such as those described by Smith et al., 1994) are intruded by basic dykes and thus older than the metabasalts in the area. We see a great scope for U-Pb (zircon) dating of the granites and granitic gneisses in the Indian plate for sorting out the outstanding stratigraphic problems.

THE MAIN MANTLE THRUST

At the time of publication of the first geological map of Kohistan (Tahirkheli & Jan, 1979), the location of MMT in the SE Kohistan was known only at two places, i.e., Jijal and Babusar Pass. Since then, the MMT has been mapped at several locations between these two points (Chaudhry and Ghazanfar, 1987; Ghazanfar et al., 1991; Greco et al., 1989; Jan et al., 1993). The trace of the MMT was mapped during the coarse of this study near Lidi in the Kinari valley; Sapatgali (western), Noor Jamal the Bahk, Bamgatta pass, south of the Butogali, Shutta Pass and Babusar Pass. As mentioned above, the Parla Sapat metapelites do contain lenses of talc-carbonate schists and greenstone, suggesting an olistostorme or melange nature. However, the base of the Sapat Complex is emplaced onto the Parla Sapat metapelites along a very sharp thrust. Furthermore, in the area between the Noor Jamal the Bahik and Bamgatagali, the base of the Sapat Complex is directly emplaced onto granitic gneisses of the Indian plate. These observations suggest that the thrust at the base of the Sapat complex is younger than the melange/olistostorm formation in the Parla Sapat unit. Therefore, at the moment, we retain the name of MMT for this tectonic interface rather than encompassing the Parla Sapat metapelites too.

The serpentinite mylonites along the MMT are strongly foliated but lack any lineation. The quartz-mica phyllites directly below the MMT are strongly banded, comprising bands of ribbon quartz alternating with bands rich in muscovite and biotite. These phyllites are extensively crenulated at a microscopic to mesoscopic scale (an area of 10 cm^2 contains several dozens of crenulations). Considering that these crenulations are restricted to the vicinity of the MMT, we interpret them to be sheath folds in nature rather than being parasitic to major fold. The attitude of fold axes (EW and 50-60 plunge towards the west) suggests an ESE direction of thrusting for MMT in the Sapat area.

The trace of the MMT at the Sapat drainage divide is clearly folded. The folding is typically open recumbent type with subhorizontal fold axes. The trace of the MMT, as shown on the map, dips towards the north in the lower reaches of the valleys, but dips towards the south at the high-altitude ridges, forming a southwards-closing recumbent fold (Fig. 3). This phase of folding is observed to affect both the Kohistan and the Indian plate rocks equally. In the deep-cut valley just to the west of the Parla Sapat, there are even indications that the Parla Sapat unit is folded into a northward closing open-recumbent fold, complimentary to the southward-closing open recumbent fold at the high-altitude ridges.

It is interesting to note that a northward-closing open recumbent fold is also observed at the Babusar Pass within the quartz-mica schists (= Parla Sapat unit) (Fig. 3C), which, at least superficially, resembles with the similar fold west of the Parla Sapat village. The structure at the Babusar Pass, however, is controlled by ductile shearing associated with the southward thrusting of the MMT rather than with a post-MMT folding event. The garnet-mica schists of the Parla Sapat unit approaching the Babusar Pass are characterised by a strong F1 fabric with an attitude of EW/50°S. At the pass, however, the predominant fabric is EW/30°N. A closer observation suggests that this N-dipping fabric transposes the S-dipping foliation into spectacular meso- and microscopic crenulations. This superimposition of the two fabrics is observed at a scale of several tens of meters, with a net effect that the MMT (which marks a south-verging shear zone), causes a spectacular transposition of the south-dipping quartz-mica schists into north-dipping mylonites (Fig. 2), forming a northward-closing open recumbent fold.

Another aspect of the MMT which we wish to bring into notice is the lateral variation in its level of propagation with respect to its position in the magmatic stratigraphy of the Kohistan terrane. The MMT at Jijal in the Indus valley carries garnetiferous ultramafic rocks at its hangingwall which represent the petrological Moho (Tahirkheli et al., 1979; Miller et al., 1991). In the Sapat area at the Kohistan-Kaghan drainage divide, the MMT runs through the basal ultramafics of the Sapat Complex, which we consider a relatively higher level magmato-stratigraphic unit in the Kohistan crust. Further to the east, in the area between the Noor Jamal the Bahik and the Bamgatta Pass, the MMT climbs upsection laterally and carries the layered to isotropic gabbroic rocks of the Sapat Complex. Eastward, towards the Babusar Pass, the MMT follows more or less this stratigraphic level. However, before reaching the Niat Gah, it once again climbs upsection, and rests along the contact between the Sapat Complex and the overlying metavolcanic basement (unpublished data; Ahmed Khan in preparation). Finally, near Hala (Buner Gah), the MMT once again cuts upsection and rests along the base of the Kamila Amphibolite unit, from where onward towards Gilgit, it retains this stratigraphic level. A similar, lateral staircase geometry is followed by the MMT, to the west of the Indus valley in the Swat and Dir valleys.

DISCUSSIONS AND CONCLUSIONS

The drainage divide between Kohistan and Kaghan in the area to the north and northeast of Naran forms a part of the higher Himalayas marking the tectonic contact between the middle Cretaceous Kohistan island-arc terrane and the Indian plate. The studied area exposes the basal part of the obducted Kohistan terrane, comprising a >2 km thick complex of strati-form and isotropic ultramafic and gabbroic rocks belonging to the Sapat ultramafic-mafic complex. This complex has an origin probably similar to that of the Jijal Complex, exposed to the west in the Indus valley. Yet, the two have drastic differences in the constituent mineral assemblages. Whereas the Jijal Complex has distinctly higher grade mineral assemblage appropriate to granulite facies, the Sapat Complex is metamorphosed under the green schist or lower amphibolite facies. We interpret that whilst the Jijal Complex formed the very base of the Kohistan island arc crust, the Sapat Complex occupied relatively higher stratigraphic levels. In order to account for their equivalent tectonic position in the hangingwall of the MMT, we suggest that the MMT ramped upsection laterally away from Jijal, so that it exposes successively higher stratigraphic levels in its west to east lateral profile (Khan et al., 1994).

The underthrust Indian plate comprises a basement of granitic gneisses and a cover sequence of metamorphosed intercalated carbonates and pelites in the lower part and a metapelite in the upper. There are no fossils preserved and the radiometric age data is lacking (except for the Tertiary leucogranites of post-tectonic origin; Zeitler et al., 1993). The ages assigned to various units, both in this work and those of the previous authors, are highly tentative and are based on very loose correlation. There is a tendency to lump all the granitic rocks (including the gneisses) into Early Cambrian Mansehra type. Similarly, it is compelling to equate the metamorphosed carbonates and amphibolites with those of the Permo-Triassic Panjal Formation. Yet, the entire sequence of the Higher Himalayas of Kaghan may be Proterozoic or earlier as preferred by Chaudhry and Ghazanfar (1987) and Tahirkheli (1982). In this context, the example of eastern Kashmir may be kept in mind, where, in contrast to earlier belief that all the basic rocks are of Panjal affinity, Bhat and Le Fort (1992) found presence of basic rocks as old as 1500 Ma.

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