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Tectonic Reinterpretation Constraints of the Western Most Kohistan Complex in Timargara, Dir District, Pakistan

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ABSTRACT: *No detailed tectonic and structural studies were carried out in the western most extremity of the Kohistan area. People have been concentrating mostly along Indus canyon and Swat valley for geotectonic, structural, petrological and geochronological studies. Present investigation is the first study to thoroughly work out tectonic reinterpretation constraints of the western most Kohistan complex particularly in Timargara quadrangle and adjoining area of Warai consisting of 673 sq.km. The concept of underplating for the emplacement of major plutonic complexes is advocated in this area as well, as was also found out in Swat and Indus canyons, i.e., the Balambat norite and Timargara gabbronorite which are different from Chilas complex magma type underplated the Dir tholeiitic amphibolites. These plutonic rock types are more evolved than those of main Chilas complex. The latter underplated Dassu metaplutonic complex of Kamila amphibolites.*

The Kamila amphibolites are further subdivided into Kamila group metaplutonic calc-alkaline amphibolites and Dir metavolcanic tholeiitic amphibolites or precisely as Kamila amphibolites and Dir amphibolites which are advocated to be adopted due to their different provenances.

INTRODUCTION

A detailed geological and tectonic investigation of 673 sq. km of Timargara-Lal Qila-Wari area of Dir district was envisaged on the context, that no such work was taken in hand after the one presented by Chaudhry et al. (1974a,b, 1983, 1984). Recently some work was initiated by Shah et al. (1994), Shah and Hamidullah (1994) and Jan and Tahirkheli (1990) on the magmatism and mineralogical constraints of northern metavolcanics and Tora Tigga mafic-ultramafics in the surrounding areas but that was not related to the tectonic framework of the western most Kohistan Complex in the Dir district. However the work of Butt et al. (!980), Butt(1983) and Chaudhry et al. (1984) have some relevance to the present work and is further evaluated and presented by reinterpreting.

The norite, gabbronorite, diorite and amphibolites of the area have been renamed as Balambat norite, Timargra gabbronorite, Panjkora diorite, being not related to Chilas magma type. The Dir amphibolites consisting of metavolcanics and metasediments are separated from Kamila amphibolites being metaplutonic calk-alkaline in nature and underplated the Dir amphibolite in Babusar area.

Present study shows that Dir amphibolite is a separate entity from Kamila amphibolites and Balambat norite is a different magama type and not related to Chilas magma rather is derived from independent source.

The project area is located between longitudes 71 45' to 72 2'E and latitude 34 45' to 35 0'N of toposheet No 38 N/13 and 43 B/1 of the Survey of Pakistan.

TECTONIC FRAMEWORK

Plate tectonic models for the collision of the Indian and Eurasian plates have been proposed by a number of geoscientists. Dewey and Bird (1970), Crowford (1974), Powell and Conaghan, (1973), Gansser (1974) etc. Most of the proposed models deal with the rock relationships in the eastern and central Himalayas, whereas the western Himalayas were neglected by most of the workers. However, Tahirkheli et al. (1979) and Powell (1979), discussed tectonic events in the north western Himalayas. Tahirkheli et al. (1979) postulated the Kohistan sequence (36,000 Km^2 of amphibolites, metagabbros, and associated volcanics) as the oceanic crust of an ancient calc-alkaline island arc, which was obducted on the Paleozoic cover of India and Asia during suturing.

Tahirkheli et al. (1979) also discussed tectonic events in the north western Himalayas according to which the northwards movement of India leads to an initial oceanic-oceanic plate collision resulting in the formation of island arc. Later on the Island arc was sutured to the north with the Eurasian continents and to the south with the India. The sequence of rocks consisting of this island arc system is now located between two major thrusts, the Main Mantle Thrust (MMT) in the south and the Main Karakoram Thrust (MKT) in the north (Fig. 1).

Chaudhry et al. (1983, 1984) proposed another tectonic model for north western Himalayas in contrast to Tahirkheli which was based on situation of the rock types as they actually existed on the ground using petrotectonic approach. According to these workers the Kohistan area between Indian and Eurasian plates is not a single island arc sequence but comprises at least two and possibly three island arc sequences and associated trenches. The extensive amphibolite complex is separate and does not represents the lower part of a single Kohistan Island Arc sequence, but comprises at least three distinctive belts, two belts of obducted melanges with a central belt consisting of possibly trapped portion of the Tethys oceanic crust. Finally southward subduction of the Tethyan lithosphere is postulated under the Indian plate in contrast to north directed subduction of the Indian plate.

Coward et al. (1986) suggested the Kohistan Island Arc was essentially a crustal pop-up with southward-upright and northward-verging structures developed above a thick ductile decoupling zone (the Indus suture). This pop-up formed by a two stage process, closure of northern suture followed by the closure of the southern suture.

The concept of underplating for the emplacement of major plutonic complexes in Kohistan Island Arc was introduced by Ashraf and Loucks (unpublished report, 1990). According to them the stacked complexes (i.e. Dasu complex, Kayal complex-Chilas complex, Patan complex and Jijal complex) represent successive episodes of crustal underplating by dense magma that stalled at or near Moho and fractionated ultramafic and mafic cumulates until residual liquids acquired enough buoyancy to resume ascent to higher level magma chambers that produced the diorite sheets and batholithic plutons. As each of the layered intrusion was emplaced along the ultramafic-mafic cumulate boundary of the pre-existing metamorphosed complex, the Moho stepped downward to the ultramafic-mafic cumulate contact of the newest intrusion, and the entire stack underwent dynamic metamorphism before the emplacement of the next complex in the series (Ashraf and Loucks unpublished, 1990) and Miller et al. (1991).

Butt et al. (1980) describe plutonic rocks of the project area as the Tethys crust, consisting of volcanics, norites to noritic gabbros and diorites. Chaudhry et al. (1984) also reported blocks, patches and sills of hornblendites, containing peridotites or dunites, as core and eclogites which occurs as exotic screens within amphibolites.

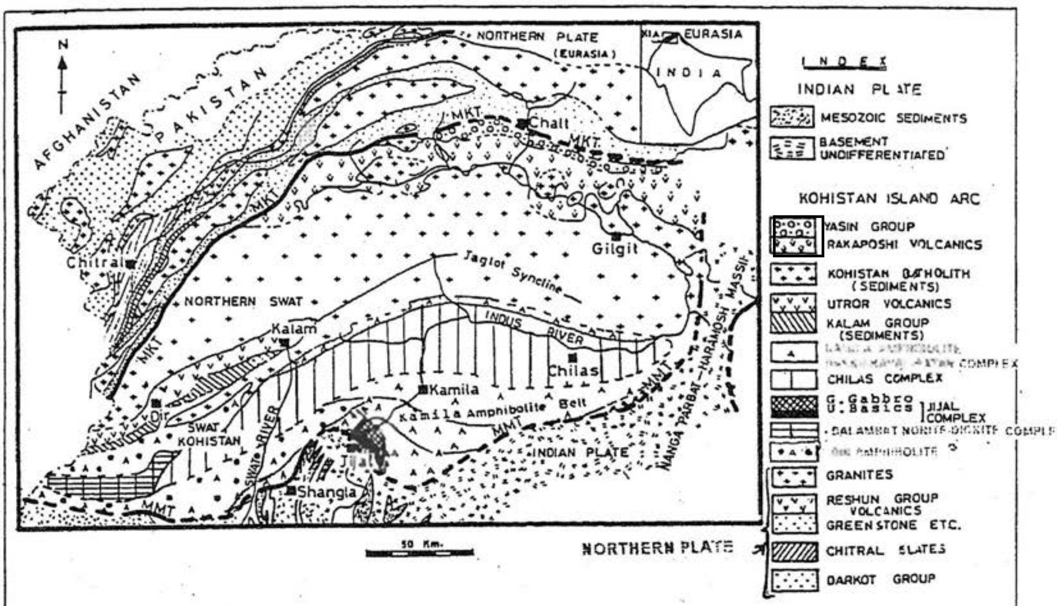

Fig. 1. Geological map of Kohistan Island Arc Complex showing occurrence of Kamila Amphibolite Belt in Indus and Swat Valleys and Dir Amphibolite in Timargara (modified after S. Hamidullah, 1992).

During this study the rock associations present north of Main Mantle Thrust zone were remapped; structural, petrographical as well as geochemical analyses were made. The field evidences as well as structural, petrographical and geochemical evidences show that the northern and southern Dir amphibolites are not much different on the basis of their original unmetamorphosed material. They can be correlated on the basis of their primary igneous structures, metasedimentary stuff and crystal rich volcaniclastic pyroclastic materials (which is found present in both rock units i.e. at Burhani and at Shamozai near MMT). In northern exposure of Dir amphibolites the ratio of metasedimentary stuff is relatively higher which increase northwards out of project area with thick sequence of quartzite, volcanics, impure pelites and impure carbonates. The northern and southern amphibolites are part of a single ocean floor in which the younger Balambat norites, Timargra gabbronorites, Panjkora diorites and more evolved rocks either intruded or underplated. Roof pendants of amphibolites occur in plutonic bodies in the form of small fragments and even large bodies, as against the idea postulated as xenolith and screens (Chaudhry et al., 1974a).

The southern part of Dir amphibolite contains abundant lava flows with pillow structures with thin interbeds of argillaceous and arenaceous materials along with carbonates which possibly were deposited near MOR as was evident by the presence of ophiolitic klippe near Dargai-Malakand (Awan 1989). Those volcanoclastic and metasediments later on metamorphosed to amphibolites facies while moving down the outer slope of the hot MOR onto the ocean floor. The metamorphism to epidote-amphibolite facies and amphibolite facies depended on the prevailing temperature along the slope of the ridge. It is evident that the thickness as well as concentration of metasediment is relatively thinner in southern part of Dir amphibolites and thicker in northern part. Carbonates are more abundant in southern part of Dir amphibolites, their concentration decreases northwards, however, huge roof pendants of carbonates were observed in Panjkora diorite which comprises the central part of the mapped area. The pillow lavas and basaltic flows are in the form of thick layers in southern Dir amphibolites, while in northern Dir amphibolites the meta-volcanic stuff is relatively less and thin bedded as compared to metasedimentary stuff. It is also assumed that the upper sequence of rocks from southern Dir amphibolites were probably eroded after uplifting followed by collision. In the further north towards Dir city the volcanic stuff decreases to thin stringers of andesitic to rhyolitic composition.

The amphibolites sequence was intruded by calc-alkaline rocks of the composition of norites, diorites, tonalites, trondhjemite, adamellites, granites, aplites/pegmatites, quartz porphyries, etc. Most of these intrusive rocks shows agmatitic contact with the amphibolites which served as a roof.

Field and petrographic evidences show a complete differentiation trend of the magma from norite/ gabbronorite (basic) at the base, diorite (intermediate) at the centre and adamellite, trondhjemites, granites, porphyries, aplites & pegmatites at the top roof portion.

THE MAIN MANTLE THRUST

The Main Mantle Thrust (MMT)/Indus Suture Zone demarcates a tectonic contact between the Indian continental plate and Kohistan Island Arc. The collision of India with Kohistan block has exposed a variety of rock types which were obducted from different structural levels of oceanic crust of Kohistan and continental basement of India, due to difference in the intensity of uplift along the suture.

In the Indus Kohistan region the Indus Suture Zone has been folded occasionally around the Nanga Parbat gneisses and is referred to as Main Mantle Thrust Zone

(Tahirkheli and Jan, 1979). The rocks of Jijal complex are the only mantle rock proved by Ashraf and Loucks (unpublished, 1990) and Miller et al. (1991) in the Kohistan (see also Jan et al., 1980; Jan and Howie, 1981 and Bard, 1983 for another interpretation). The Jijal complex is exposed there in contact with the Besham basement complex. In Shanglapar Swat district and Shin Qamar (Baig,1989) Kohistan district blues schist melanges are prominent feature along the Main Mantle Thrust.

In the project area a 150-200m thick greenschist melange zone is exposed along the Main Mantle Thrust which is sandwiched between the para/ortho gneisses of Indian plate and southern part of Dir amphibolite.It is possible that this greenschist melange zone might be host for blue schist (trench environment) which is yet to be discovered.

Here we will restrict to call these ocean floor rocks as Dir amphibolites of volcanosedimentary origin. They are not comparable to Kamila amphibolite of Jan (1988) exposed along KKH near Patan to Kamila having plutonic origin (Loucks et al., 1992). The Dir amphibolites are possibly completely eroded from area along KKH while some relicts are in the Babusar area.

TECTONICS OF THE AREA COMPARED TO THE REGIONAL TECTONICS

The collision of Indian plate with Kohistan block has formed most of the structures. The intensity of deformation, uplift and metamorphism is different at different places along the suture, zone therefore different rocks present at different structural levels are exposed, most of the cover rocks were eroded giving a complex geological picture. The modification produced due to collision should also be kept in mind while reconstructing the tectonic history of the area, and while correlating the rock units exposed at different places in Kohistan Island Arc.

The Indus Suture zone extends from Ladakh to northern Pakistan (where it is mostly referred to as Main Mantle Thrust) and eastern Afghanistan (Tahirkheli et al., 1979; Gansser, 1981 and Chaudhry et al., 1983). The Main Mantle Thrust Zone contains several groups of rocks, mostly it is expressed as a schistosity parallel, but intensely deformed tectonic contact between Dir amphibolites, amphibolites of Kamila belt and para/orthogneisses of Indian plate. Ophiolitic, layered ultramafics, blue schist and greenschist melanges are also exposed at different places along the suture zone (Ashraf 1997, Ashraf et al., 1989; Kazmi et al., 1984). In Dir area the Main Mantle Thrust is well marked and highlighted by Shamozai greenschist melange, which is exposed as a tectonic slice between the para/ortho gneisses of the Indian plate and southern part of Dir amphibolites.

Melange Zones

The melanges of different tectonic affinity were juxtaposed along MMT during progressive suture development as a result of late Cretaceous to Eocene closure of the Neotethys ocean between the Indian plate and Kohistan Island Arc terrain. These melanges are exposed all along the Main Mantle Thrust.

Various types of fault bounded melange units are present in Swat; these are the Mingora and Shangla blueschist melanges (Kazmi et al., 1984). In Allai-Kohistan area there are Baleja ophiolitic melange, Shin-Qamar blueschist melange and Matai greenschist melange (Baig 1989). In Bajaur Agency is Titobai ophiolitic melange (Hussain et al., 1989).

During our field remapping program a greenschist melange was mapped along the Main Mantle Thrust in Dir district which is herein called the Shamozai melange. Although it is only 150 to 200 m thick and about 5 km long strip as exposed in the project area, yet it has great significance in the tectonic history of the area. The melange zone consists of phyllites, carbonates and metacherts along with talc carbonate and exotic blocks of ultramafic rocks.

The Shamozai melange could be correlated with the Matai greenschist melange, Charbagh greenschist melange of Swat district and with the Titobai ophiolitic melanges of Bajaur agency present in the vicinity of the project area. Some unconfirmed reports of emerald mineralization in this area were made by locals.

Amphibolites

The amphibolite facies rocks exposed north of Main Mantle Thrust are regarded as the Kamila amphibolite belt (Tahirkheli and Jan, 1979; Coward et al., 1986, Jan et al., 1988). It has been suggested that the origin of Kamila amphibolites was either oceanic crust on which the arc was built (Bard et al., 1980) or a highly deformed sequence of arc type plutons and volcanics (Coward et al., 1986). Along the Indus valley the main part of the amphibolite belt that separates the Jijal complex to the south and the Chilas complex in the north, is termed as Kamila shear zone, which is 38 km wide at Kamila but narrows eastwards to only 3.5km (Searle et al., 1991). The Kamila shear zone is regarded as Dassu, Kayal and Patan complexes by Loucks et al. (1992). The Dassu complex is polymetamorphosed isoclinally folded banded amphibolite gneisses that grade from metatonalites at its top downwards to melanocratic garnet amphibolites at its base some 5 to 6 km down section. Khan et al. (1997) believe Kamila amphibolite belt as a composite mass dominated by amphibolite facies metaplutonic and metavolcainc rocks. Where they have not tried to separate the former from latter in the field as being underplated.

In Dir area the amphibolite facies rocks present north of Main Mantle Thrust were regarded as southern Dir amphibolites by Chaudhry et al. (1974b). We regard these rocks as a metamorphosed volcano-sedimentary rocks of ocean floor (of tholeiitic affinity) which serves as a roof to the magmatic activity during the building of the arc. The uplifting and erosion in Dir area are not so intense as compared to Indus canyon area due to which the metamorphosed ocean floor rocks are exposed mostly. The top most portion of the oceanic crust was most probably eroded. However, the upper portion of ocean floor which contains dominantly metasedimentary stuff is exposed in the north of the area and was regarded as northern Dir para amphibolites by Chaudhry et al. (1974b). These amphibolites were under plated by norites, gabbronorites, diorites, tonalites, trondhjemites and acid minor bodies which were most probably emplaced in a single episode of magmatic activity forming a completely differentiated products. The ultramafics are mostly found in Dir amphibolites as exotic blocks. The ultramafics are also present on the surface of norites/gabbronorites as roof pendants along with minor to insignificant amphibolitic stuff.

Intrusive Sequence

The plutonic sequences at the northern contact of southern amphibolite belt was regarded equivalent to Chilas complex which croped out across much of the southern central Kohistan and comprised a very thick (>10 km) mafic ultramafic stratiform plutonic complex dominated by norite, two pyroxene gabbros and diorite (Chaudhry et al., 1984, Jan 1979; Jan and Howie 1980; Coward et al., 1986 and Khan et al., 1989). These workers extend the Chilas complex to Dir from Indus valley (Fig.1).

The petrographical and geochemical studies of intrusive sequences show that they are mostly (Balambat) norite and (Panjkora) diorite and minor associate as (Timargara) gabbronorite and also support that these rocks are not similar to the rocks of Chilas Complex. The only difference is that Dir plutonic sequences are mostly norite with minor associates of gabbronorite and are more evolved rocks (as tonalites, tronjhemites, adamallites, granites, pegmatites/aplites and quartz porpheries) and are present more near to the roof i.e. below the oceanic crust (Dir amphibolite) of the Neotethys and is not a Chilas magma type which is dominantly gabbronorite with layered ultramafic associates (Ashraf, 1997 and Khan et al., 1989). The oceanic crust under which all the plutons were formed does extend to Swat/Indus water-shed as much deformed rocks are thinning out and ultimately being eliminated in the Indus valley around KKH, which is rather the deepest part of Kohistan Island Arc exposing the metaplutons (i.e. Dassu amphibolites, & Kayal amphibolites and patan amphibolites) and Jijal & Chilas complexes (Loucks et al., 1992).

Another important feature about the plutonic sequence is that the above mentioned workers believe that the rocks of Chilas complex were crystallized from a single magma chamber. However, we believe that the origin of magma for Chilas complex may be of same type but it was feeded from different magma chambers which were formed due to development of Kohistan Island Arc. The Balambat norite/Timargara gabbronorite magma types was still different.

NATURE & STYLE OF EMPLACEMENT OF ULTRAMAFIC ROCKS

The ultramafic rocks present in the area are of three types regarding to there origin and style of emplacement.

i) Wehrlite and Pyroxenite Bodies in Amphibolites

These includes wehrlites exposed in the northern part of Dir amphibolite near Manial 5 km northwest of Lal Qila. The wehrlite and corundum bearing pyroxenite exposed at Ursak 3 km southeast of Timargara in southern part of Dir amphibolite.

These bodies were probably emplaced in oceanic crust during its development at MOR (which is now in the form of amphibolites). These bodies were later altered and metamorphosed and their original chemical composition was changed due to metasomatism.

Wehrlite exposed near Manial were previously referred to as exotic blocks of eclogite by Chaudhry et al. (1983) but from our field and petrographic observation it is clear that these bodies are not exotic blocks of eclogite rather these were part of oceanic crust which are now in the form of amphibolites and were emplaced on ocean floor during its development at MOR.

ii) Wehrlites and Websterites in Plutonic Sequence

Two bodies of wehrlites are exposed in granites near Manial. A small unmappable body is present in adamellite and a body of wehrlite is exposed near Shidas. The above mentioned bodies of wehrlites mostly trends NS. These bodies were also seemed to be emplaced during the formation of oceanic crust.

The exposure of these bodies in plutonic rocks is questionable and appear to be non-cumulus. The field relations and the trend of these rocks show that they might be part of the roof or roof pendant of the oceanic crust under which these plutonic rocks were underplated.

A small unmappable body of websterite was observed in Panjkora diorite near Gurgu. Sheared phyllite bands were observed at the contact with diorite which proved that it might also be the part of the roof of oceanic crust. Also its trend is similar to the body of corundum bearing pyroxenite at Ursak.

iii) Hornblendites

Three types of hornblendites occur in the Dir area both types are exposed in the amphibolites and in plutonic rocks.

First type of hornblendite (small and unmappable bodies) were probably produced due to contact metamorphism and metasomatism of amphibolites and roof pendants of amphibolites in plutonic rocks. These type of hornblendite bodies are exposed with tonalites near Khongi and in amphibolites near Kuz Nagari The presence of similar type of small bodies of hornblendites were also evident near the agmatitic structures formed at the contact of plutonic bodies with amphibolites.

The second type of hornblendites are intruded in amphibolites near Watangai Darra and near Dobera, with norite near Jabagai and Barmalakand, on diorite near Lajbok Darra and on tonalite near Bandagai. These hornblendites were probably fractionated from the hydrous magma produced due to the partial melting of the oceanic crust and fractionation left out after the crystallization of major basic plutons of Dir. These rest magmaic fluids ascended to higher levels being buoyant and deposited as hornblendite bodies near the roof rocks (i.e. amphibolites), (Ashraf & Loucks, 1990 unpublished work).

The third type of hornblendite bodies are those occuring near Tora Tigga and Rabat Khwar. These are zoned bodies with wehrlite and dunite in the core and which are subsequently extensively hornblenditized by aqueous Mg-Ca-silicate solutions forming large mantle of varying thickness (Jan & Tahirkheli, 1990 and Ashraf & Loucks, 1990). These bodies appear to have developed as ophiolite sequence and emplaced in the ocean floor.

DISCUSSION

The three petrotectonic units (i.e. Indian mass, Shamozai melange and Kohistan Island Arc) juxtaposed along the Main Mantle Thrust after collision. The timing of collision in the western Himalayas is poorly constrained, Paleocene time is recommended by a group of workers (Baig et al., 1984) which is evident by the presence of Paleocene unconformity in the north western Himalayas, Eocene timing is suggested by another group of workers (Coward et al., 1986). Timing of 40 Ma (Priabonian i.e. Late Eocene) for collision of India and Asia is suggested by Molnar & Tapponier. (1975) and Klootwijk & Radhakrishamurty (1981). The last movement along Main Mantle Thrust is 15 Ma as recorded by fission track data of the rocks along the Main Mantle Thrust (Zeitler et al., 1982).

The gneisses exposed on the southern side of Main Mantle Thrust represent the basement rocks of Indian mass and are exposed due to high uplift produced as a result of collision. The Indian basement rocks have recorded several episodes of orogeny yet the effect of Indian-Asian collision occurred during Himalayan orogeny had transposed over the previous orogenic deformational records evident by the prominent gneissic foliation in the rocks unit which is nearly parallel to the Main Mantle Thrust.

The greenschist melange in the mapped area (i.e. Shamozai greenschist melange) along the Main Mantle Thrust is being reported for the first time by us, which consists of blocks of metasediments and blocks of ultramafic metamorphosed to greenschist facies (chloride grade) evident by the petrographical studies of various rocks units. The structural and metamorphic history of this petrotectonic unit is very complex, no fossil record or geochronological data is available which could be helpful in dating the time of emplacement of this petrotectonic unit. It is in the form of lenses of rocks that have caught up in between Indian basement rocks and amphibolites of Kohistan Island Arc. The presence of tension gashes in carbonate blocks which were filled by quartz veins, evident some strike slip movement along the Main Mantle Thrust which might have occurred along the suture zone. The presence of minor scale drag folds in phyllites also support the strike slip sense of movement.

The amphibolites of Kohistan Island Arc were basically a metamorphosed ocean floor under which the arc was build. These rocks were deformed by at least two phases of folding. The first phase of isoclinal or recumbent folding has developed S_1 foliation in metavolcanics and S_0/S_1 bedding cleavage in pillow lavas and metasedimentary layers within metabasites and metasediments respectively. This S_1 foliation is basically the axial planner cleavage of earlier formed isoclinal or recumbent fold. The isoclinal phase of folding in amphibolites were also suggested by Coward et al. (1982 b). In the second phase the amphibolites were again folded into north wards dipping south wards verging structures which are tight in the southern part of Dir amphibolites and generally opens northwards. The earlier phase of isoclinal or recumbent folding was probably subduction related (i.e. subduction of Kohistan under Asian continent). The metamorphism of these rocks might have probably happened in this phases of deformation. The second phase of folding seems to be collision related it might have occurred in two stages. In the first stage the rocks were folded in response to crust shortening happened due to collision of Kohistan block with Eurasian continent. In the second stage when the Indian continent collided with Kohistan blocks these folds became tight into northward dipping southward verging isoclinal folds.

The influence of deformation produced in the southern extremity of southern part of Dir amphibolites can be easily judged by the regional trend of these rocks along the Main Mantle Thrust. The frequency distribution of the poles of S_1 and S_0/S_1 foliation in southern Dir amphibolites (Fig.2 &3) show that most of the data lie in the SE quadrant showing that the dip of rocks is mostly NW.

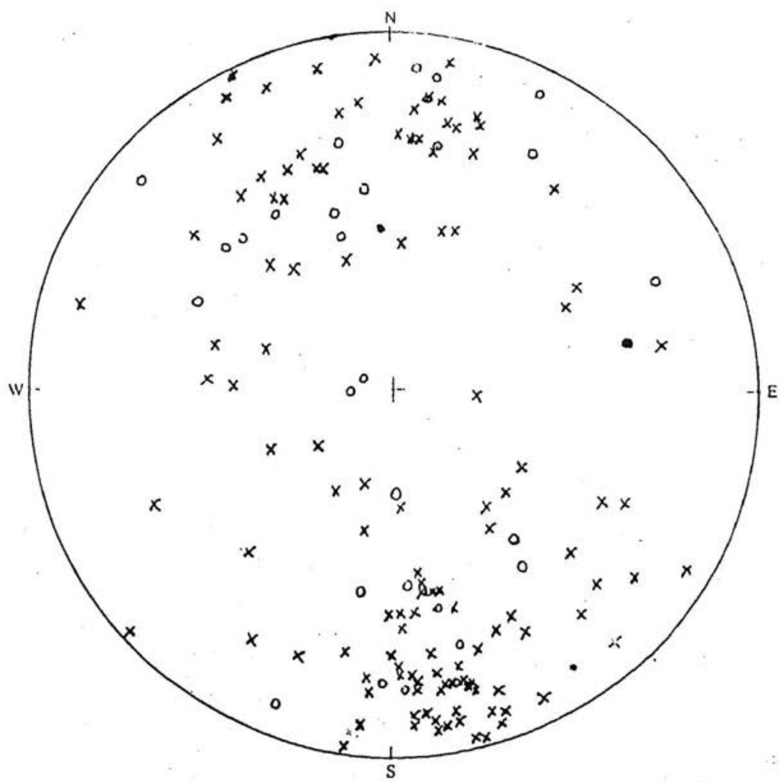

Fig. 2. Lower hemisphere equal area projection to the poles of S_0/S_1 and S_1 foliations in southern part of Dir amphibolites trend EW and dip northwards.

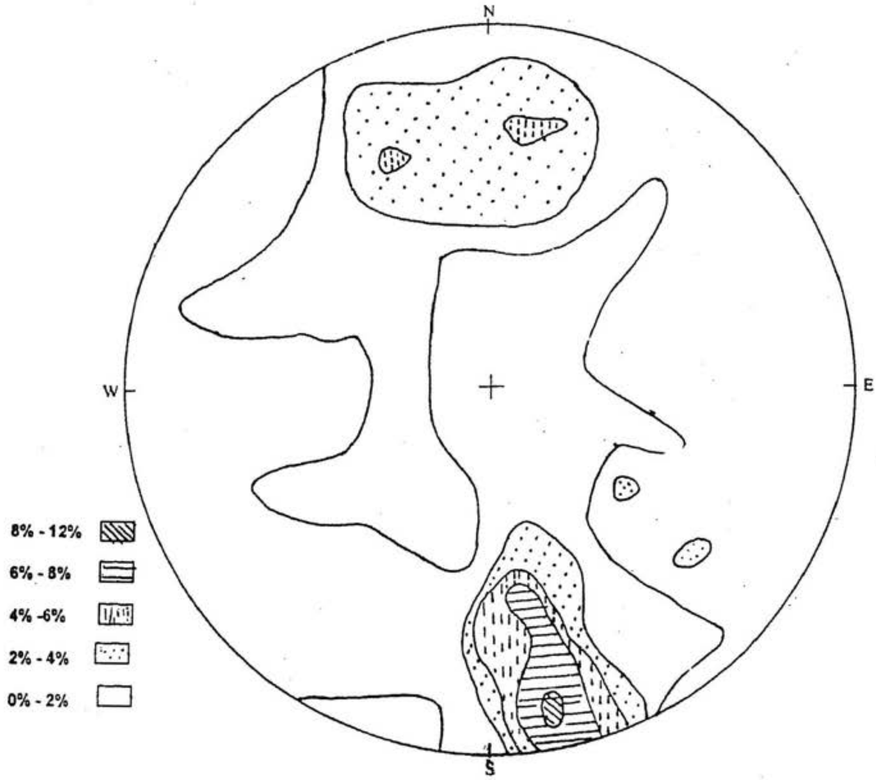

Fig. 3. Frequency distribution of the poles of S_0/S_1 and S_1 foliation in southern part of Dir amphibolites showing that most of the southern part of Dir amphibolites trend EW and dip northwards (i.e. parallel to M.M.T).

The rocks of Kohistan Island Arc have been subjected to a third phase of deformation which might has been produced due to the crustal adjustments (i.e. crustal shortening due to continuous northward drag of Indian plate which still moves 4 cm/year) after collision (Powell, 1979). This phase is evident by the presence of shear zone (i.e. Panjkora shear zone and Wach Khwar shear zone) in both amphibolites and plutonic rocks. Most of the shear zones in amphibolites were observed as phyllite bands which often serves as best ductile material during such sort of deformational activities. The retrograde metamorphism to chlorite grade was observed along these shear zones (i.e. Panjkora shear zone and Wach Khwar shear zone) both in the field and in the petrographic study. Retrograde metamorphic overprint is also evident in amphibolites near MMT.

The plutonic rocks of Kohistan Island Arc are also effected by the collision and is evident by the strong straining effect in quartz which shows the effect of post emplacement deformations. The fold axis in Balambat norite and Panjkora diorite are also parallel to each other and are seemed to be influenced by the collision.

CONCLUSIONS

1. The Dir amphibolites (metavolcano-metasedimentary rocks) are not related at all with Kamila type locality amphibolites. The former represent ocean floor materials with supply source Dargai MOR. It is therefore recommended to adopt Dir amphibolite as separate.

2. The Kamila amphibolites/ Kamila shear zones are metaplutonic rocks consisting of Dassu and Kayal complexes of basic protolith while Patan complex consists of ultrabasics to basic rocks which are amphibolatized along shear zones. It does have igneous structures and igneous pyroxene and hornblende minerals.

3. The basic igneous complex of Dir consists of major norite/diorite with minor gabbronorite and their complete differenciates of tonalite, trondjhemite, adamalite granite, aplite/pegmatites and quartz porphyries. They are not related to Chilas magma type rocks as Chilas complex consists of major gabbronorites and ultramafic associates and no norites.

4. The ultramafic rocks are exotic blocks of wehrlites, pyroxenites formed at Dargai MOR and carried away alongwith volcanosedimentary rocks to the present position and are lying in Dir amphibolites and on the intrusives.

5. The metamorphism of Dir amphibolites to epidote amphibolite and amphibolite facies occurred on MOR slope with varying temperatures there favouring for respective facies.

6. A new melange zone called Shamozai melange is like other melanges juxtaposed along MMT which may be having blue schist rocks.

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