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Metamorphic mineral assemblages south of the Malakand and adjoining areas, northern Pakistan

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ABSTRACT: *The mineral assemblages (calcite + muscovite + hornblende + quartz + plagioclase + zoisite + garnet) indicate epidote amphibolite facies conditions in the north near Mora Kandao south of the Malakand, north Pakistan. With the reported occasional occurrence of kyanite indicate that the metamorphism is probably of the medium pressure i.e., Barrovian type. Based on the mineral assemblages, temperatures of 580°C are assumed for the epidote amphibolite facies and pressures about 5.5 kb in the north.*

The greenschist facies rocks in the south near Takht-e-Bhai, Rustam and surrounding, the mineral assemblage actinolite + biotite + muscovite + quartz + albite + magnetite and color index of conodont 5.5 to 7 suggesting peak metamorphic temperatures between 300 and 400 °C and pressures up to 3 kb. Temperature and pressure for the melange blocks and matrix are assumed between 200 and 570 °C with pressure 3 kbar.

INTRODUCTION

Early structural and petrographic studies by Chaudhry et al. (1976), Hamidullah et al. (1991), DiPietro (1990), and Ahmad and Lawrence (1992) proposed that metamorphic mineral assemblages in schistose rocks of the Malakand, Chakdarra and Saidu areas show a regional metamorphic gradient, which increases from south to north. The gradient is from biotite to Kyanite grade. The temperature calculated in Swat, north of the Jowar and near Chakdarra areas ranges 600-700°C and 9-11 kbar (DiPietro, 1990).

This paper describes the metamorphic mineral assemblages and their P-T conditions south of the Malakand and adjoining areas (Fig.1).

GEOLOGICAL SETTING

South of the Malakand, the study area (Fig. 1) is consists of granitic and metasedimentary rocks. Martin et al. (1962) divided these rocks into the Swabi-Chamla sedimentary group and Lower Swat Buner schistose group. DiPietro et al. (1999) reinterpreted the stratigraphy from the base upward as the Jafar Kandao formation, Duma, Kashala and the Nikanai Ghar formation. Ahmad (1999) revised the startigraphy south of the Malakand as Jafar Kandao formation, Ambela/Shewa granite, Mora granite gneiss, Marghazar formation, Chakdara Granite gneiss, Kashala formation, Saidu formation and Nikanai Ghar formation.

Near Malakand pass and surrounding the Dargai ultramafics and mélange blocks of diverse nature are thrusted over the Indian shelf rocks (Fig. 1). A comparative stratigraphy from Lower Swat and Peshawar basin area is presented in Table 1.

TABLE 1. COMPARATIVE STRATIGRAPHIC COLUMNS FROM LOWER SWAT - PESHAWAR BASIN

	Martin et al., 1962	Kazmi et al., 1984	DiPietro et al., 1993	Pogueet al., 1992a.	This study
C			Tourmaline Granite Gneiss **Alpurai Group**		
Late Paleozoic Mesozoic	Swabi Chamla Group Lower Swat-Buner Schistose Group	Saidu Graphitic Schist Alpurai Calc-mica-Schist	Nikanai Ghar Fomration Saidu Formation Kashala Formation Marghazar Formation	Nikanai Ghar Formation Kashala Formation Karapa greenschist Ambela/Shewa granite Jafar Kandao Formation	Nikanai Ghar Formation Saidu Formation Kashala Formation Chakdara Granite Gneiss Marghazar Formation Mora granite gneiss Ambela/Shewa granite Jafar Kandao Formation
		u	Jobra Formation?	Nowshera Formation Panjpir Formation	
Early-Middle Paleozoic			u	Misri Banda Formation	
		Swat Granite Gneiss	Swat Granite Gneiss	Ambar Formation	
			u	Tanawal Formation	
PC		Manglaur Formation	Manglaur Formation		

PC = Precambrian C=Cenozoic u = Unconformity

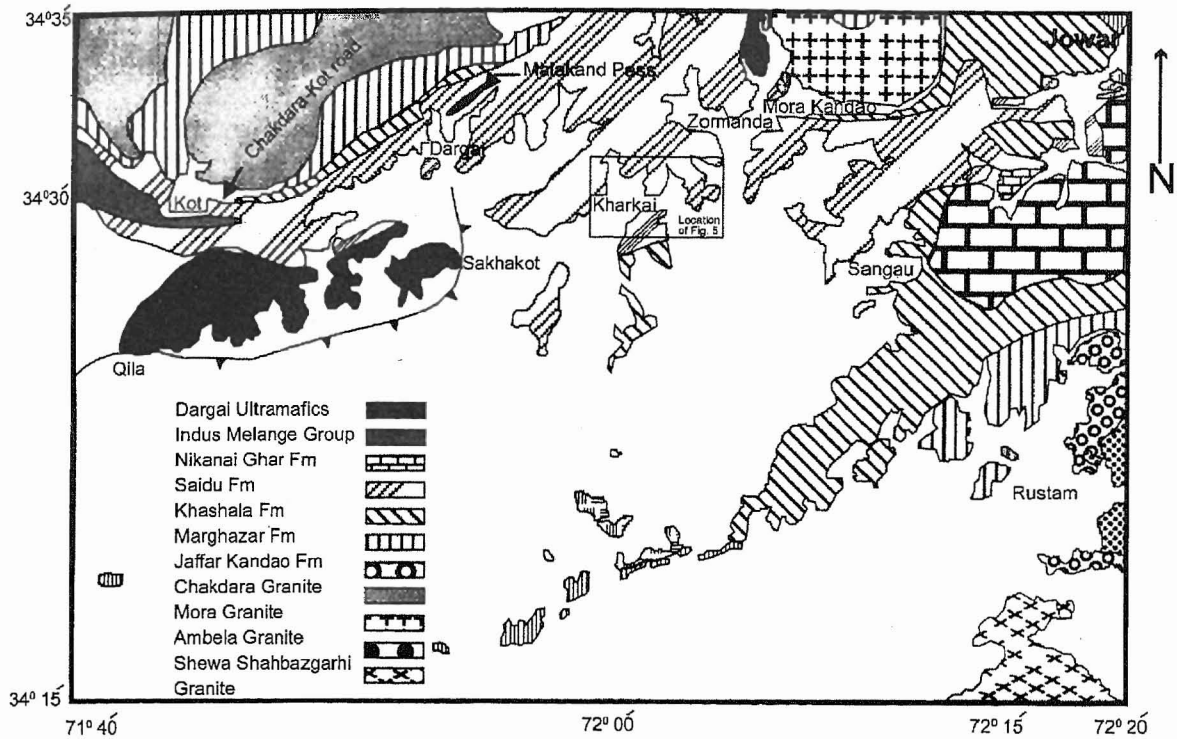


Fig. 1. Geological map south of the Malakand and adjoining areas.

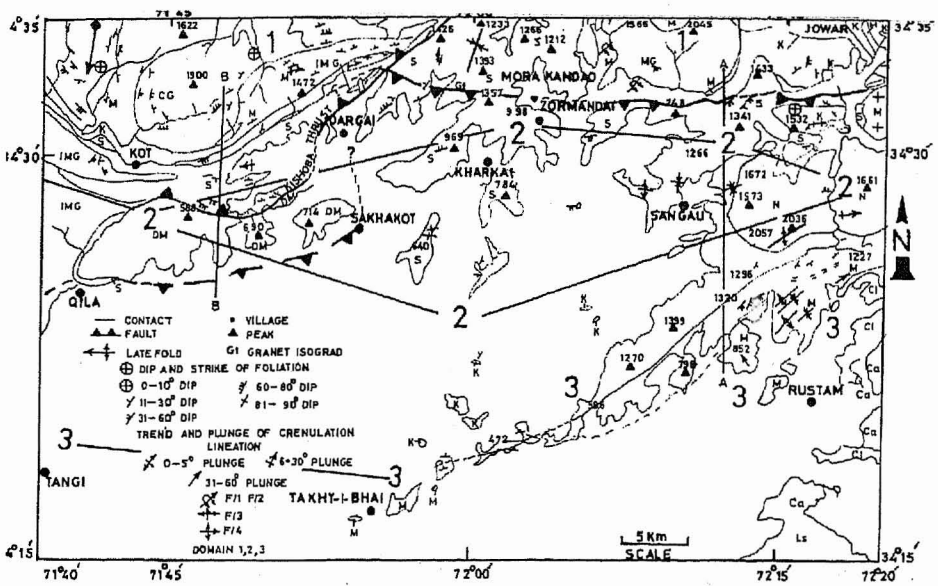


Fig. 2. Structure and domains map south of the Malakand and adjoining areas.

CONDITIONS OF METAMORPHISM

Based on structure, metamorphism and rock types, the study area can roughly be divided into three domains. The Indian plate rocks represent domain 1 and 3, whereas the ophiolitic melange domain 2. The mineral assemblage in domain 3 in the south lies in the chlorite zone, whereas the domain 1 in the north is in garnet (almandine zone). There is an abrupt change in the grade from chlorite to almandine zone or (greenschist to epidote amphibolite facies) near Zormandai village seperated by a back thrust (Fig. 2). Only garnet isograd can be mapped through the area. The ophiolitic mélange Domain 2 and the matrix show a transition from chlorite to biotite, and the mineral assemblage represents greenschist facies conditions. Mineral assemblages and the related rock types south of the Malakand and adjoining areas are listed in Table 2.

TABLE 2. REPRESENTATIVE MINERAL ASSEMBLAGES OF THE ROCKS SOUTH OF MALAKAND AND ADJOINING AREAS

Formation	Mineral assemblage	Rock type	Metamorphic- Grade
Nikanai Ghar	Cal-Do	Calcite Marble	Greenschist
	Do-Cal	Dolomitic Marble	
Saidu	Ms-Qtz-Pl-Chl-Z-Gr-Grt Qtz-	Graphitic schist	Ep-Amphibolite
	Ms-Pl-Chl	Quartz-mica schist	Greenschist
	Pl-Qtz-Tr-Ep-Chl	Diabase sills and dykes	Greenschist
Kashala	Cal-Ms-Hb-Qtz-Pl-Grt-Z	Calc-mica-garnet schist	Ep-Amphibolite
	Cal-Ms-Qtz-Pl	Calc-mica schist	Greenschist
	Cal-Ms-Qtz	Marble	Greenschist
Marghazar	Hb-Pl-Qtz-Ep-Cal-Rt-Ilm	Amphibolite	Ep-Amphibolite
	Pl-Qtz-Ms-Bt-Grt-Ep	Psammitic schist	Ep-Amphibollite
	Pl-Qtz-Bt-Ms-Grt	Quartz-feldspathic schist	Ep-Amphibolite
	Bt-Chl-Pl-qtz-Ac-Ilm	Biotite-Chlorite schist	Greenschist
	Chl-Ac-Pl-Qtz-Ep	Greenschist	Greenschist
	Cal-Ms-Qtz-Pl-Chl	Crinoid bearing Calcschist	Greenschist
	Qtz-Pl-Ms	Quartzite	Greenschist
Mora Granite	Kfs-Pl-Qtz-Ms-Bt-EP	Granite gneiss	Ep-Amphibolite
Chakdarra	Kfs-Pl-Qtz-Ms-Bt-Mt	Granite gneiss	Ep-Amphibolite
Ambela	Kfs-Pl-Qtz-Ms-Bt-Hb	Granite and gneiss	Ep-Amphibolite + Greenschist
Ophiolitic	Chl-Pl-Ep-Ms-Cal	Greenschist	Greenschist
melange rocks	Do-Tc-Chl-Mt	Talc-carbonate schist	Greenschist
	Kfs-Pl-Qtz-Bt	Plagiogranite	Greenschist
	Tc-Ac-Chl	Talc-actinolite schist	Greenschist

Each assemblage with the most abundant mineral listed first. Trace minerals are not shown. Mineral abbreviations after Kretz (1983): Ac-actinolite, Bt-biotite, Cal-calcite, Chl-Chlorite, Do-dolomite, Ep-epidote, Gr-graphite, Grt-granet, Hb-hornblende, Ilm-ilminite, Kfs-K-feldspar, Ms-muscovite, Mt-magnetite, Pl-plagioclase, Qtz-quartz, Tc-talc, Tr-tremolite, Z-zoisite.

METAMORPHIC CONDITIONS OF THE INDIAN SHELF META-SEDIMENTS

Rocks of Domain 1 and 3 are divided into three groups based on mineral composition: (1) calcpelitic (calc-mica schist and calc-mica-garnet schist), (2) psammopelitic (psammitic schist, quartzo-feldspathic schist and graphitic schist), and (3) metabasites (basaltic lava flows, sills and biotite-chlorite schist).

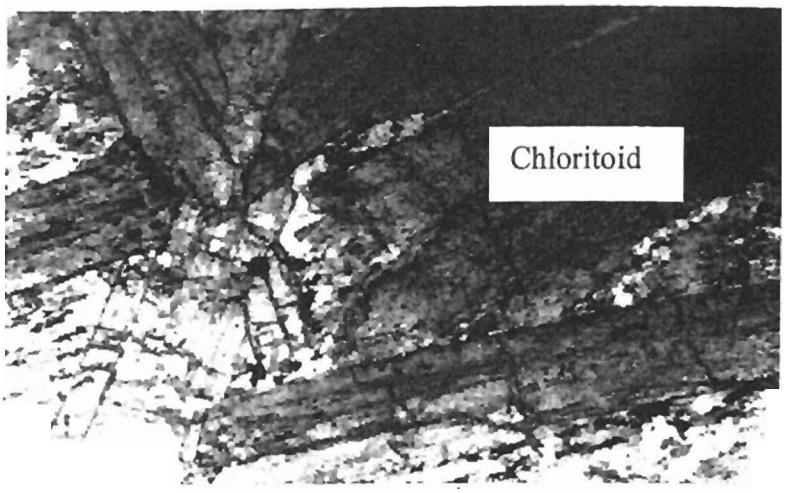
The calcpelitic, psammopelitic rocks, lava flows and sills range from greenschist facies to epidote-amphibolite facies conditions. Near Mora Kandao the rock sequence crops out as a dome that resulted from the superposition of east-west trending F_4 folds on generally north-south trending earlier folds (Fig. 2). The highest grade rocks are in the core of the dome where aluminosilicate minerals (principally kyanite) occur in trace amounts at isolated localities (Imtiaz Ahmed, pers. comm. 1997).

Metamorphic grade decreases toward the peripheries of the dome from Zormandai to Takht-e-Bhai. Rocks of the Alpurai group surrounding the Mora granite gneiss are in the garnet zone. A garnet isograd is mapped in the calcareous schist of the Kashala formation (Fig. 2). This isograd is based on the first appearance of the garnet. The isograd assemblage is calcite + muscovite + hornblende + quartz + plagioclase + zoisite + garnet. The psammitic schist has more or less the same mineral assemblage and it is more-rich in the quartzo-feldspathic minerals. Immediate to the south of the garnet isograd the rocks are in chlorite grade with mineral assemblage calcite + siderite + muscovite + quartz + albite. The colour alteration index of conodonts from the Kashala formation in the south near Rustam is between 5.5 and 7 (Pogue et al., 1992a suggesting peak metamorphic temperatures between 300 and 400 °C (Epstein et al., 1977).

The metabasites in the south have the mineral assemblage actinolite + biotite + muscovite + quartz + albite + magnetite and represent greenschist facies metamorphism. A chloritoid-chlorite with a matrix of chlorite + quartz + ore (probably ilmenite) and plagioclase assemblage is found as a thin layer in the greenschist rock and suggests greenschist facies metamorphism (Fig. 3; see Rafiq & Jan, 1991). The amphibolite in the north near Mora Kandao has the mineral assemblage hornblende + oligoclase + quartz + biotite + muscovite + garnet. This mineral assemblage indicates an epidote amphibolite facies metamorphism.

METAMORPHIC CONDITIONS OF OPHIOLITIC MELANGE BLOCKS

The mineral assemblage dolomite + magnetite + talc + quartz + plagioclase + fuchsite of the talc-carbonate rock indicate conditions of at least greenschist facies. The mineral assemblage of the greenstone chlorite + albite + quartz + epidote + magnetite + ilminite suggests low grade greenschist facies condition.


Chloritoid

shown that temperature > 200 °C are necessary to coarsen pelitic sediments and obtain phyllitic and schistose rocks. Temperature above to 200 °C is indicated by fine to medium-grained size (0.1to 3 mm) of quartz, albite and mica (muscovite and paragonite) of the matrix of the present melange. P-T estimates based on the present mineral assemblages, including some non-equilibrium assemblages, are presented in figure 5.

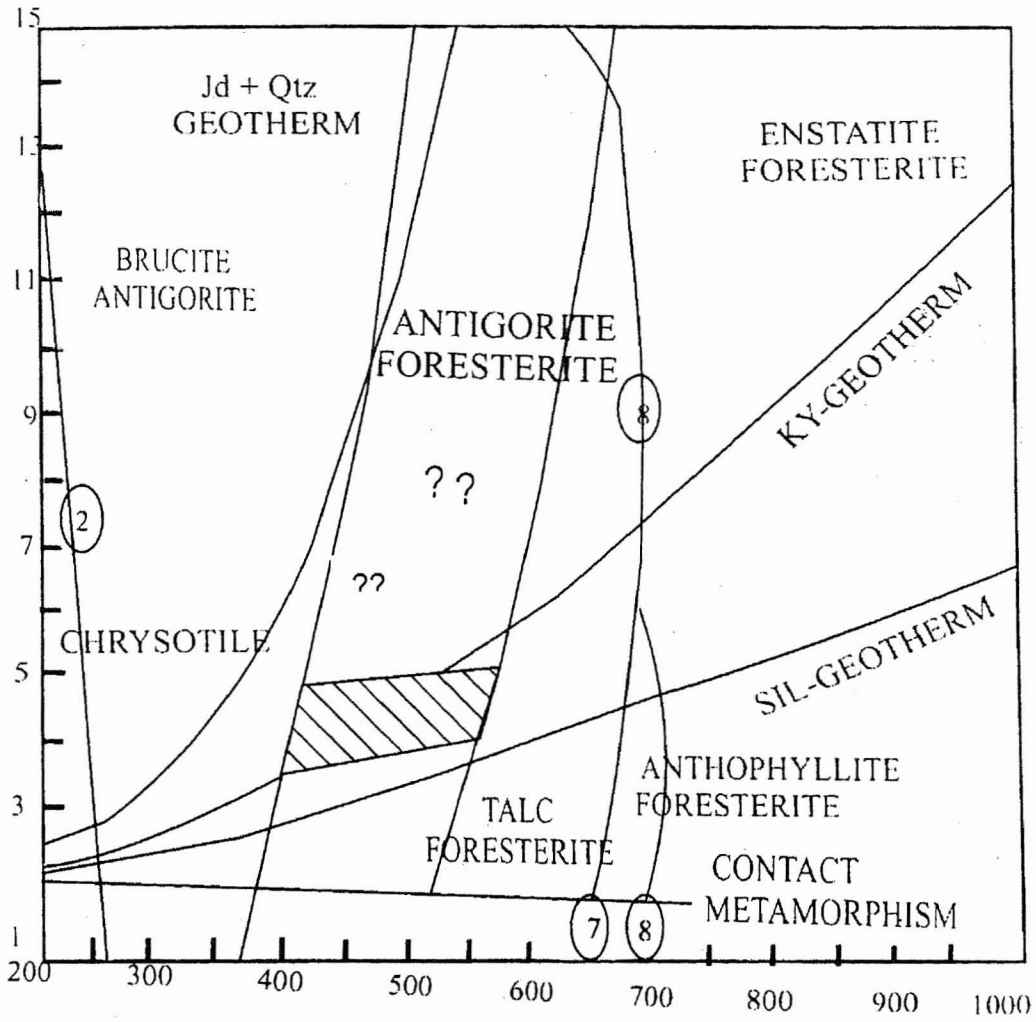


Fig. 4. Pressure and temperature diagram for equilibria in the MSH (Harzburgite) system after Bucher and Frey (1994). Oblique lines represent the assemblages of the study area.

Epstein, A.G. Epstein, J.B. & Harris, L.D., 1977. Conodont color alteration - an index to organic metamorphism. USGS Professional Paper 915.

Hamidullah, S., Jabeen, N., Bilqees, R. & Jamil, K., 1986. Geology and petrology of the Malakand granite, gneiss and metasedimentary complex. Geol. Bull. Univ. Peshawar, 25, 17-22.

Kazmi, A.H., Lawrence, R.D., Dawood, H., Snee, L.W., & Hussain, S.S., 1984. Geology of the Indus suture zone in the Mingora Shangla area of Swat, N. Paksitan: Geol. Bull. Univ. Peshawar, 17, 127-144.

Martin, N.R., Siddiqui, S.F.A., & King, B., 1962. A geological reconnanssaince of the region between the lowre Swat and Indus River of Pakistan. Geol. Bull. Univ. Punjab, 2, 1-14.

Miyashiro, A., 1973. Metamorphism and metamorphic belts: New York, Harper and Row, 514p.

Pogue, K.R., Wardlaw, B., Harris, A., & Hussain, A., 1992a. Paleozoic and Mesozoic stratigraphy of the Peshawar Basin, Pakistan: correlation and implications: Geol. Soc. Am. Bull. 104, 915-927.

Rafiq, M. & Jan, M.Q., 1991. Titanium content of a chloritoid-quartz-ilmenite band in ophiolitic mélange near Prang Ghar, NW Pakistan. Geol. Bull. Univ. Peshawar, 24, 127-132.

Turner, F.J., 1981. Metamorphic Petrology: Mineralogical Field and Tectonic Aspects (Second edition): New York McGraw-Hill, 524p.

Wick, F.J. & O' Hanley, D.S., 1988. Serpentine minerals: structure and petrology. Mineral. Soc. Am., 19, 91-167.