

Geology and petrographic study of the area from
Chiraundi Khola to Thulo Khola, Dhading/Nawakot
district, central Nepal

by

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A dissertation submitted to the Central Department of Geology
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for

Partial fulfillment of the requirements
for the Master's degree in Science for Geology
(Mapping and Analysis stream)

August 2003

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List of acronyms

HHC	Higher Himalayan Crystallines
HHZ	Higher Himalayan zone
IUGS	International Union of Geological Sciences
MBT	Main Boundary Thrust
MCT	Main Central Thrust
MFT	Main Frontal Thrust
MT	Mahabharat Thrust
NHNF	North Himalayan Normal Fault
PPL	Plane polarised light
P/T	Pressure/Temperature
SCMR	Subcommission on the Systematics of Metamorphic Rocks
STDS	South Tibetan Detachment system
XPL	Crossed polarised light

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Chapter V

Metamorphism

5.1 Metamorphism in the study area

Metamorphism is a subsolidus process leading to changes in mineralogy and/or texture (for example grain size) and often in chemical composition in a rock. These changes are due to physical and/or chemical conditions that differ from those normally occurring at the surface of planets and in zones of cementation and diagenesis below this surface. They may coexist with partial melting. (IUGS-SCMR, 2003)

The rocks of the study area show low- to medium-grade metamorphism, and it have the characteristics of a barrovian-type metamorphism, with occurrences of kyanite, sillimanite, garnet, and biotite. The rocks of Bhimphedi Group have attained medium-grade metamorphism, whereas those of the Nawakot Complex show low-grade metamorphism. Structural inhomegenities with respect to the foliation, slaty cleavage, schistosity, gneissocity, and shearing of rock strata and meso-scale folds are found in the area which reveal that the area has undergone regional metamorphism.

5.2 Mineral assemblage

Minerals, which coexist in equilibrium during metamorphism of rock, is known as "Mineral assemblage" (Best, 1986). It depends on pressure, temperature, and composition of the rock. The paragenesis of the co-existing mineral phases in the present study area are presented in the table 5.

Table 5 Mineral assemblages of the rocks in the study area

Unit	Main lithology	Mineral assemblage
Bhimphedi Group		
Kulikhani Formation	Quartzitic schists, mica schists	Qtz + plag + bt + mus + chl qtz + ky + grt + bt + mus + plag
Kalitar Formation	quartzite, gneiss, sillimanite schist, cordierite schist	qtz + bt + mus + plag qtz + sil + grt + bt + mus + plag qtz + crd + grt + bt + mus + plag
Chisapani Quartzite	White and grey quartzite	Qtz + mus + bt + chl
Raduwa Formation	Garnetiferous schist	Qtz + grt + mus + chl + plag
Upper Nawakot Group		
Robang Formation	Phyllite, quartzite amphibolite	Qtz + mus + seri + bt + plag hbl + bt + mus + plg + chl
Malekhu Limestone	Limestone	Qtz + cal + dol cal + dol + qtz
Benighat Slates	Slates	Qtz + seri + chl + mus
Lower Nawakot Group		
Dhading Dolomite	Dolomite	dol + cal + qtz + ser
Nourpul Formation	Quartzite, Phyllite	Qtz + mus + chl + ser

5.3 Metamorphic grade

Pressure and temperature are the measures of conditions under which the metamorphism occurs. The terms lower and higher grade which are used in metamorphism, are ambiguous as they may relate to either increasing temperature or increasing pressure, or most often both. Therefore, the IUGS–SCMR has restricted the use of metamorphic grade by referring only to the temperature of metamorphism, which are very low, low, medium, high, very high grade of metamorphism.

In the present study area, the rocks of different units and their mineral assemblages provide information on the relative degree of metamorphism which

can be expressed in terms of low-grade to medium-grade. However, the presence of anhydrous mineral phases of kyanite and sillimanite shows that the metamorphism has reached high grade.

The metasedimentary rocks of Lower Nawakot group show low-grade metamorphism, and the Upper Nawakot group shows a gradual increase in metamorphic grade towards the MCT. The Nawakot Complex is generally in the greenschist facies, with sericite and chlorite as the main index minerals (Stöcklin & Bhattarai, 1977). The metamorphism in Bhimphedi group is right-way up (Johnson et al., 2001). In the study area, the presence of sillimanite and kyanite in gneisses indicates a high-grade metamorphism.

Along the Kolphu Khola near the MCT, chlorite-schist and biotite-schist with tiny garnet porphyroblasts can be observed. Further away from the MCT, and towards the gneissic intrusion, metamorphic grade increases. The first appearance of kyanite, is observed near the confluence of Bhote Khola, and Kolphu Khola in the banded gneiss. Further upstream, both kyanite-sillimanite is present in the schist, along with a kyanite bearing pematitic vein. South of Kolphutar, along the Galchhi—Devighat Highway towards the Galchhi, sillimanite-bearing schist can be observed. However, no kyanite is observed along this section. Kyanite is observed further upstream of the Mahesh Khola, indicating a slight decrease in metamorphic grade away from the MCT.

5.4 Metamorphic zonation

A metamorphic zone is *a mappable part of a metamorphic body in which rocks are of similar grade* (Best, 1986). Zonation of metamorphic terrane has been done by the first appearance of an index mineral and they are separated by is a surface across the rock sequence, represented by a line on a map, joining points at which

metamorphism proceeded at similar values of temperature, pressure and chemical activities of elements (T, P and X), known as isograd.

In the present study area, the metasedimentary rocks of the Nawakot Complex falls in the Chlorite zone (Fig 5.1). However, the upper part of the Robang Formation is placed in Biotite zone. The Garnet zone begins from the Kalitar Formation, which shows a mixture of biotite schist and chlorite schist with the presence of garnet. It also includes the Raduwa Formation. Kyanite appears near the gneissic intrusion, but it immediately overcome by the appearance of sillimanite. The Sillimanite zone is concentrated within a narrow zone of the gneissic complex, However, detailed mapping further northeast into the gneiss complex might reveal a higher concentration of sillimanite. Further south, towards the rocks of the Kulikhani Formation, Kyanite reappears again. The appearance of staurolite can be traced outside of the study area in Dandunge Khola, towards far southeast, which has been documented in earlier works (Stöcklin and Bhattarai, 1977; Mahato, 2003).

5.5 Metamorphic facies

A **Metamorphic facies** is a set of metamorphic mineral assemblages, repeatedly associated in time and space and showing a regular relationship between mineral composition and bulk chemical composition, such that different metamorphic facies (sets of mineral assemblages) appear to be related to the metamorphic conditions, in particular temperature and pressure, although other variables, such as P_{H_2O} may also be important (IUGS-SCMR).

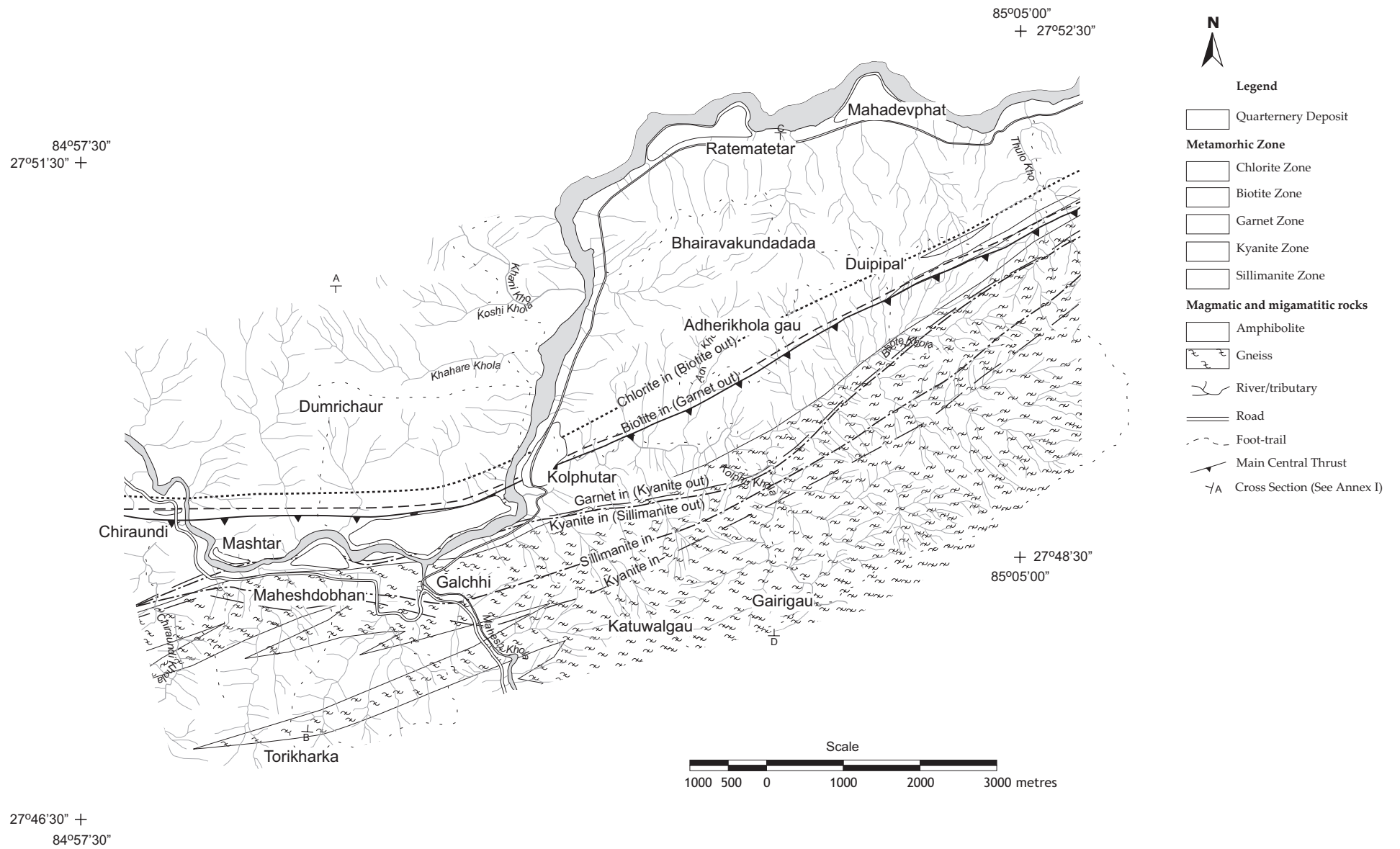


Fig. 5.1 Metamorphic Zonation map of the study area

Metamorphic facies are commonly found in different regular sequences, which led to the concept of metamorphic facies series (Miyashiro 1961). Miyashiro (1961) defined **metamorphic facies series** as a sequence of metamorphic facies developed under the same range of P/T ratios, thus represented by a radial sector in the P-T diagram. Miyashiro distinguished five facies series. Later (Miyashiro 1973) he related them to **baric types of metamorphism**: low pressure I, low pressure II (intermediate), medium pressure (Barrovian), high pressure I (intermediate) and high pressure II (Fig. 5.1)

The mineral assemblages found in the metapelitic sequences of the present study area suggest greenschist facies, transitional facies, amphibolite facies, and upper amphibolite facies (Fig. 5.2).

Metamorphic Facies	Greenschist	Transitional	Amphibolite		Upper Amphibolite Facies
Albite	-----				
Plagioclase	-----				
Hornblende	-----				
Muscovite	-----				
Chlorite	-----				
Biotite	-----			
Feldspar	-----				
Garnet	-----				
Kyanite	-----				
Sillimanite	-----				
Zone	Chlorite Zone	Biotite Zone	Garnet Zone	Kyanite Zone	Sillimanite Zone
Stratigraphy	Nourpul Formation Dhading Dolomite Benighat Slates Malekhu Limestone Robang Formation	Robang Formation	Robang Formation Raduwa Formation Kalitar Formation Kulikhani Formation	Kalitar Formation Kulikhani Formation	Kalitar Formation

Figure 5.2 Distribution of metamorphic minerals in the study area.

The metasedimentary rocks of the Nawakot Complex fall within the Chlorite zone, except for the upper part of the Robang Formation, due to its position near the MCT. Garnets appear in the Raduwa Formation as garnetiferous schist. Kyanite starts to show up in the Kulikhani Formation. Sillimanite appears in the schist, and in the gneisses of Kalitar Formation.