Chapter III

Lithostratigraphy

3.1 Introduction

The stratigraphy of central Nepal is well established, and has been mapped by Stöcklin and Bhattarai (1977). In central Nepal, Stöcklin and Bhattarai (1977) have coined the term Nawakot Complex to include all the formations of the Lesser Himalayan rocks whereas the Kathmandu Complex incorporates all the rocks lying within the Kathmandu nappe, including the crystallines below and the overlying fossiliferrous metasedimentary rocks. This nomenclature is followed in the present study area.

3.2 Lower Nawakot Group

The Nawakot Complex is subdivided into the Upper and Lower Group by an unconformity lying between the stromatolitic Dhading dolomite and the argillaceous Benighat Slates. The Upper Nawakot Group include the argillaceous Benighat Slate, Malekhu Limestone, and Robang Formation, in the order of older to younger age. In the study area, both the Upper and Lower Nawakot Group are observed in the northern portion, i.e. north of the Kolphu River.

The Lower Nawakot Group is of Late Precambrian age (Stöcklin and Bhattarai, 1977). In the study area, only the Dhading Dolomite and Nourpul Formation can be observed. The dolomite and quartzite of both these formation forms a distinctive topographic relief in the northern part of Galchhi.

Table 3.1 Tectonostratigraphic subdivision of Galchhi

Unit	Main lithology	Approx. thickness (m)	Age (Stöcklin and Bhattarai, 1977)
Bhimphedi Group			
Kulikhani Formation	Quartzitic schists, mica schists	>1060	Precambrian
Chisapani Quartzite	White and grey quartzite	340	
Kalitar Formation	Aphanitic to medium grained, white to grey quartzite	820	
Raduwa Formation	Garnetiferous schist	80	
———	Main Central Thrust	———	
Upper Nawakot Group			
Robang Formation	Phyllite, quartzite	510	Paleozoic
Malekhu Limestone	Siliceous limestone, dolomitic limestone	480	
Benighat Slate	Slates	790	
- -	?Unconformity	- -	
Lower Nawakot Group			
Dhading Dolomite	Dolomite	1320	Late Precambrian
Nourpul Formation	Phyllite, quartzite	> 1240	

3.2.1 *Nourpul Formation*

This unit is characterised by having a mixed lithology of phyllitic, quartzitic and calcareous rock types. The quartzite and phyllite can be observed along the foot trail following Ratmate from Bhairavkunda Dada. However, the outcrops are quite weathered. At most places, the exposures are obliterated by vegetation. Along Koshi Khola section, the phyllite is pale grey-coloured due to the weathering. Quartzite has been weathered to dirty yellowish colour. The contact between Nourpul Formation and the overlying dolomites of Dhading Dolomite is

transitional. This distinctive character can be observed along the Galchhi-Devighat road section. Alternating sequence of phyllite with fractured dolomite beds marks the transition.

3.2.2 *Dhading Dolomite*

The best exposures are along the Galchhi-Devighat road section. The dolomites are grey to light grey in colour. The rocks of Dhading Dolomite can be observed in Khahare Khola. In Ramkuwa Jyamire, the exposures of dolomites are exhibit fracturing, and along Koshi Khola as well. The dolomites along Kalleri also show fracturing patterns. The transitional contact between Nourpul Formation and Dhading Dolomite persist throughout the unit. This can be observed in Bhairavkundadada. However, at most places the residual soil deposits obliterate the exposures. Along the Kalleri—Gahate section, the alteration of grey phyllite with the dolomite can be observed.

3.3 Upper Nawakot Group

The rocks of Upper Nawakot Group are of Paleozoic age (Stöcklin and Bhattarai, 1977). In the study area, Benighat Slates, Malekhu Limestone and Robang Formation can be observed.

3.3.1 *Benighat Slates*

The slates are well exposed mostly in the part along the Khahare Khola. The distinguishing black slate of Benighat slate can be observed on the riverbank of Trishuliganga River in Keureni. However, at most places, the slates have weathered and given way to characters similar to phyllite. The direction of the Khahare Khola follows along the strike of the slate.

The slates are dark in fresh exposures, and the graphitic bands of these slates can be identified. They have a tendency to exhibit light yellowish colour in weathered outcrops. These slates strike SW-NE, and dips steeply (about 60^{O}) towards SE. Further west, in Dumrichaur, the slates are dark grey with occasional quartz veins sub-parallel to the foliation plane.

3.2.3 *Malekhu Limestone*

The Malekhu Limestone is well exposed along the newly constructed road section from Galchhi to Devighat. The road section shows grey coloured fractured limestone. They can be observed along the Kallerighat-Gahate section as well. Here, the exposures show light grey dolomitic limestone.

This formation is mainly composed of dolomite and limestone. Fine, massive, milky white dolomite and dolomitic limestone form the basal part of the formation. Dark grey and often laminated siliceous dolomite with 0.1 to 1.0 mm pink lamina within 5 to 15 mm dark grey bands, exhibit fine foliation. The dolomitic limestone forms the upper part of the formation. Fine, distinct grey and dark grey thin laminas characterize the rock.

3.2.4 *Robang Formation*

In the study area, this formation is well exposed along the Galchhi–Devighat road. The outcrop can be studied in Kallerighat. This formation is further subdivided in to two members; the phyllite is known as the Robang Phyllite, and the quartzite is known as Dunga Quartzite. The graphitic phyllite of Robang Phyllite constitutes the basal part of the formation. It is dark, lacking any black streak and does not soil the hand. Fine-grained grey lamina (about 2 mm) with silky lustre intercalates with the graphitic phyllite. Quartz lenses can be

Figure 3.1 Photograph of garnetiferrous schist of Raduwa Formation observed in Chiraundi Khola.

observed parallel with the foliation of the phyllite. The fine- to medium-grained greenish grey Dunga Quartzite overlies this phyllitic sequence. They are often intercalated with grey phyllite.

3.4 Bhimphedi Group

The name Bhimphedi Group was borrowed from the Indian geologists, who introduce it in the form of Bhimphedi Formation in central Nepal (Stöcklin and Bhattarai, 1977). It consists of seven formations in central Nepal. In the study area, only three formations are observed. Schist, quartzite, and gneiss characterize this group.

3.4.1 *Raduwa Formation*

The rocks of Raduwa Formation rest over the low-grade metasedimentary rocks of the Upper Nawakot Group along the MCT. However, in Galchhi, it is exposed

only at the far west part of the study area. The Raduwa Formation is not exposed in the eastern portion. It is mainly concentrated as a thin band around Chiraundidobhan, and Mashtar. The rocks of Raduwa Formation are represented by garnetiferrous schist, with garnet – biotite – muscovite schist. The schist has abundant garnet porphyroblasts, which ranges in size from 0.50 to 10.00 mm.

3.4.2 *Bhaisedobhhan Marble*

In the study area, this formation is not seen anywhere. In a recent study by Mahato (unpublished thesis, 2003), there is a report of a thin bed of this unit. However, the present study could not justify the presence of marble within the study area.

3.4.3 *Kalitar Formation*

The Kalitar Formation includes mica schist and quartzite. Dark green grey, aphanitic- to medium-grained micaceous quartzite occurs as intercalation with the dark grey phaneritic coloured micaschist. Micaschist in the lower part of the formation have abundant biotite mineral. The micaceous quartzite has inequidimensional anhedral grains of quartz with biotite and chlorite. Such micas dominate the pervasive sub-parallel imperfect fine surfaces.

The rocks are well exposed in Galchhi, and in Bhaltar. In Galchhi, at the initial part of the Devighat road section, the micaceous schist has abundant sillimanite in them. This is due to the presence of the MCT, which underlies this unit. The ductile thrusting of the MCT have resulted in high metamorphic minerals. The lowermost portion of Kalitar Formation near the MCT shows the presence of garnet bearing schist. This garnet-biotite-schist can be observed all along the Kolphu Khola.

Figure 3.2 Highly foliated garnet-biotite schist alternating with mica schistose quartzite in a section along Kolphu Khola. This is a typical outcrop of Kalitar Formation.

Figure 3.3 Alternating of dark and white bands of schist and quartzite of Kalitar Formation observed at the bridge over Mahesh Khola in Galchhi.

3.4.4 *Chisapani Quartzite*

Chisapani quartzite is exposed along the Chiraundi Khola. Due to the injection of the gneisses, much of the unit has been consumed, and the section observed in Chiraundi Khola is a small. The quartzite outcrops within a small narrow zone. Chisapani quartzite comprises of white to grey quartzite. They are aphanitic to medium-grained, hard and compact with sharp fracture edges. Inequidimensional quartz grains with white mica and chlorite streaks are more common. The quartzite shows tiny golden flaky inclusions, which are usually, mica and sericite.

3.4.5 *Kulikhani Formation*

This formation is essentially composed of mica and quartz and show banding in varying proportion to form mica schist, quartzitic schist, and shistose quartzite. These rocks are exposed along the Mahesh Khola, and as well as along the Chiraundi Khola. This unit is extensively intruded by gneisses, which have largely resulted in the migmatisation of the local structures. In the Mahesh Khola, the migmatitic gneisses are foliated and show a history of intense folding. This unit shows differentiated layering of dark and light coloured minerals, which can be observed along the Mahesh Khola. The gneissic complex shows an interfingering pattern, especially in the western part of the study area. Augen gneiss is observed upstream of the Mahesh Khola. The granular feldspar and quartz minerals with large flaky micaceous layer characterize the schistose gneiss, which is observed in the Chiraundi Khola section.

3.5 Magmatic and Migmatitic rocks

The intrusion of gneissic rocks covers a large portion of study area. The gneissic complex can be observed to form an interfingering pattern. The gneiss appears to

be a product of migmatisation, and they are only confined to the rocks of Kathmandu Complex. Beside that, a linear body of basic rocks is also distinguished in the northeastern part of the study area. This includes the amphibolite, which have intruded Robang Formation in the northeastern part of the study area.

3.5.1 *Gneiss*

The gneisses are intimately associated with biotite and tourmaline granites and must be considered in the context of migmatisation. The area consists of a) banded gneiss in which dark bands of biotite schist alternate with light bands of granitic and tourmaline-rich pegmatitic minerals, b) Augen or porphyroblastic gneiss in which feldspar crystals may attain enormous size and c) Migmatitic gneiss. There are small bands of hornblende gneiss as well.

At the confluence of the Mahesh Khola and Trishuliganga River, a lithologically mixed, banded gneiss zone composed of fine-grained biotite quartzite and schist can be observed. The gneisses are of granitic or pegmatitic composition, with muscovite, biotite, tourmaline, and porphyroclasts or augen of feldspar.

Hornblende gneiss can be observed along the Chiraundi Khola, and as well in Kolphu Khola. At Kolphu Khola, they are characterised by alternating bands of green and white veins, whereas in Chiraundi Khola, hornblende minerals are scattered in the matrix.

Schistose gneiss is observed along the Chiraundi Khola section. It is a phaneritic rock with large grain size. The feldspar and quartz grains are coarse. It is somewhat akin to pegmatitic rock.

Figure 3.4 Augen Gneiss observed at the confluence of Bhote Khola, and Kolphu Khola.

Figure 3.5 Hornblende gneiss observed in Chiraundi Khola.

Augen gneiss is observed at the confluence of Bhote Khola and Kolphu Khola. It is basically composed of medium to coarse-grained quartz, feldspar, plagioclase, biotite, muscovite and tourmaline. The gneiss interfinger through the rock sequences and this can be observed along the Mahesh Khola, Bhote Khola, and Kolphu Khola. The gneiss has annihilated some portion of the Chisapani Quartzite and Kulikhani Formation in the north of Aduwabari. Similarly, the gneiss has consumed some portions of the Chisapani Quartzite and Kalitar Formation around Maheshdobhan area. The size of potassic feldspar megacryst ranges up to 4 cm in the Kheste Bazaar along the Mahesh Khola. The recent U-Pb age determination of Zircons from this augen gneiss gave 471±12 to 423±41 Ma (Johnson et al., 2001).

3.5.2 *Amphibolite*

Amphibolite is a basic rock that is found in the study area. The characteristic dark green, crystalline nature of amphibolite can be observed in Thulo Khola, where the sequence overlies the slates of Benighat Slate. It is also observed on the road section, at the confluence of Chiraundi Khola with Trishuliganga River. However, the outcrop is very small. The green colour is due to the high presence of amphibole minerals, which comprise it. Some portion of the amphibolite in Thulo Khola shows a folding pattern, which is probably indicative of a deformation phase. Amphibolite is always associated with the MCT, therefore such deformational patterns are obvious.

Another outcrop of amphibolite can be observed in Keurenipani, Dahalthok. Fresh outcrops are difficult to locate as the amphibolite has weathered much.

Figure 3.6 Outcrop of amphibolite in Thulo Khola.