

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

by

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## List of acronyms

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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 II

### General overview of the Himalaya

#### 2.1 Introduction

The Himalayan arc extends about 2400 km from Nanga Parbat (8,138 m) in the west to Namche Barwa (7,756 m) in the east (Le Fort, 1996). This region includes Nepal, Bhutan and as well as parts of Pakistan, India, and China. Since 55 Ma, the Himalayan orogen which began with the collision of India and Eurasia at the Paleocene/Eocene epoch (Rowley, 1996), has thickened the Indian crust to its present thickness of 70 km (Le Fort, 1975). The northwest tip of India after colliding with Asia seems to have met along the full length of the suture by about 40 Ma (Dewey et. al., 1988). Immediately prior to the onset of the Indo–Asian collision, the northern boundary of the Indian shield was likely a thinned margin on which Proterozoic clastic sediments and the Cambrian±Eocene Tethyan shelf sequence were deposited (Le Fort, 1996).

#### 2.2 Tectonostratigraphic division of Himalaya

Heim and Gansser (1939), and Gansser (1964) divided the rocks of the Himalaya into four tectonostratigraphic zones that are characterised by distinctive stratigraphy and physiography. From north to south, these are the Sub Himalayan, Lesser Himalayan, Greater Himalayan, and Tibetan Himalayan zones.

##### 2.2.1 Sub Himalayan zone

The Sub Himalayan zone is the 10 to 25 km wide belt of Neogene Siwaliks (or Churia) Group rocks, that forms the topographic front of the Himalaya. It rises

from the fluvial plains of the active foreland basin, and this front generally mapped as the trace of the Main Frontal Thrust (MFT). The Siwaliks Group consists of upward-coarsening successions of fluvial mudstone, siltstone, sandstone, and conglomerate. The Siwaliks Group in Nepal comprise of three units that are known as lower, middle and upper members. These units can be correlated with the Sub Himalaya of Pakistan and of northern India (Burbank et al., 1996). Palaeocurrent and petrographic data from the sandstone and conglomerate indicate that these rocks were derived from the fold-thrust belt, and deposited within the flexural foredeep of the Himalayan foreland basin (Tokouka et al., 1986; DeCelles et al., 1998)

### **2.2.2 Lesser Himalaya**

The northernmost boundary of the Siwaliks Group is marked by the Main Boundary Thrust (MBT), over which the low-grade metasedimentary rocks of the Lesser Himalaya overlie. The Lesser Himalaya, also called the Lower Himalaya, or the Midlands, is a thick (about 7 km) section of para-autochthonous crystalline rocks comprising of low- to medium grade rocks. These lower Proterozoic clastic rocks (Parrish and Hodges, 1996) are subdivided into two groups. Argillo-arenaceous rocks dominate the lower half of the succession, whereas the upper half consists of both carbonate and siliciclastic rocks (Hagen, 1969; Le Fort, 1975; Stöcklin, 1980). The Lesser Himalaya thrust over the Siwaliks along the MBT to the south, and is overlain by the allochthonous thrust sheets of Kathmandu and HHC along the MCT. The Lesser Himalaya is folded into a vast post-metamorphic anticlinal structure known as the Kunchha-Gorkha anticlinorium (Pêcher, 1977). The southern flank of the anticlinorium is weakly metamorphosed, whereas the northern flank is highly metamorphosed.

### **2.2.3 Main Central Thrust Zone**

The Main Central thrust (MCT) is the single largest structure within the Indian plate that has accommodated Indian-Asian convergence. It extends for nearly 2500 km along strike and has been the site of at least 140 and perhaps more than 600 km of displacement (Schelling and Arita, 1991; Srivastava and Mitra, 1994). Heim and Gansser (1939) defined the MCT in Kumaon based on the difference in metamorphic grade between low to medium-grade rocks of the Lesser Himalaya and higher-grade rocks of the Greater Himalaya. However, the fault originally defined by Heim and Gansser (1939) is not the MCT, but a fault within Lesser Himalaya rocks (Valdiya, 1980; Ahmad et al., 2000). This misidentification symbolizes the challenge that workers have faced in locating the MCT. The metamorphic grade within the Lesser Himalaya increases towards the MCT and at higher structural levels.

In central Nepal, the metamorphic grade increases from low (chlorite + biotite) to medium (biotite + garnet + kyanite  $\pm$  staurolite) towards the MCT over a north-south distance. The highest-grade rocks (kyanite and sillimanite gneisses) are found within the MCT shear zone, i.e. upper Lesser Himalaya. Arita (1983) places two thrusts (MCT I and MCT II) on each side of the MCT shear zone.

### **2.2.4 The Higher Himalaya**

The Higher Himalayan sequence has been variously named. French workers used the term *Dalle du Tibet* (Tibetan Slab) for this unit (Le Fort, 1975; Bordet et al., 1972). Hagen (1969) called them Khumbu Nappes, and Lumbasumba Nappes. Arita (1983) calls it the Himalayan Gneiss Group, and it lies above the MCT II, or the upper MCT.

The HHC are mainly comprised kyanite- to sillimanite-grade gneisses intruded by High Himalayan leucogranites at structurally higher levels (Upreti, 1999a). Throughout much of the range, the unit is divided into three formations (Pêcher and Le Fort, 1986). In central Nepal (Guillot, 1999), the upper Formation III consists of augen orthogneisses, whereas the Middle Formation II are calcsilicate gneisses and marbles, and the basal Formation I are kyanite- and sillimanite bearing metapelites, gneisses, and metagreywackes with abundant quartzite.

The gneiss of Higher Himalayan zone (HHZ) is a thick continuous sequence of about 5 to 15 km (Guillot, 1999). The northern part is marked by North Himalayan Normal fault (NHNF), which is also known as the South Tibetan Detachment system (STDS). At its base, it is bounded by the MCT. The protolith of the HHC is interpreted to be Late Proterozoic clastic sedimentary rocks deposited on the northern Indian margin (Parrish and Hodges, 1996).

### **2.2.5 Tibetan Tethys Sedimentary Series**

The area north of the Annapurna and Manaslu ranges in central Nepal consists of metasediments that overlie the Higher Himalayan zone along the South Tibetan Detachment system. It has undergone very little metamorphism except at its base where it is close to the Higher Himalayan crystalline rocks. The thickness is currently presumed to be 7,400 m (Fuchs et al., 1988). The rocks of the Tibetan Tethys Series consist of a thick and nearly continuous lower Paleozoic to lower Tertiary marine sedimentary succession. The rocks are considered to be deposited in a part of the Indian passive continental margin (Liu and Einsele, 1994).

## **2.3 Previous works**

A number of native and foreign geoscientists have carried out geological investigation in and around the study area and published their finding. In the

ensuing paragraphs brief summary of works and findings on the Stratigraphy, Tectonics and Metamorphism conducted by various workers is presented since 1875.

Auden (1935) noticed the superposition of high-grade metamorphic rocks on low-grade metamorphic rocks in the Mahabharat range.

Hagen (1969) was the first to study the geology of Nepal Himalaya. In his elaborate synthesis, he developed the concept of Nappe structure throughout Nepal Himalaya. He was the first to delineate the Kathmandu Nappe with its root to the Langtang Himalaya through the Gosainkund Tectonic Bridge.

Harrison et al. (1999) scrutinised various models of inverted metamorphism and concluded most of them to be seriously flawed. The model that appealed to the authors is the model in which continuous convergence of plates is manifested by episodic magmatism and out-of-sequence thrusting.

Le Fort (1975) proposed that the inverted geotherm was created by the large-scale underthrusting of the cold Lesser Himalaya under the hot Greater Himalayan Crystallines, along with dissipative heating from high shear stress along the MCT.

The MCT was first defined (Heim and Gansser, 1939) by the occurrence of high- $T$ , upper amphibolite-facies gneisses (Greater Himalayan Sequence, or GHS) above lower- $T$ , greenschist- and amphibolite-facies rocks (Lesser Himalayan sequence, or LHS). The thrust is often described not as a discrete fault, but as a thick ductile shear zone, with a continuous decrease in metamorphic grade and temperature downward (Arita, 1983; Pêcher, 1989). The MCT became active during the early Miocene around 23 Ma (Hubbard and Harrison, 1989; Hodges et al., 1996), and in Nepal it has accommodated at least 160 km of shortening (Schelling and Arita, 1991).

The movement on the MCT occurred synchronously with metamorphism and probably with the motion on the STDS (Macfaralene, 1993 and 1995).

Pêcher (1989) adopted three criteria to identify the MCT in the field: (1) the boundary between hanging wall gneisses and upper carbonate-rich formations of the Lesser Himalaya, (2) where Lesser Himalaya shear fabric (L-S) is replaced by the flattening fabric of the Greater Himalayan Crystallines, and (3) where the rotational deformation that increases progressively through the Lesser Himalaya reaches a maximum.

Stöcklin and Bhattarai (1977) studied the geology of central Nepal. They have divided the rocks of central Nepal into Kathmandu and Nawakot Complex. Nawakot Complex is further subdivided into Lower and Upper Nawakot Group, which have been given an age of Late Precambrian and Palaeozoic respectively. The Kathmandu Complex is grouped into Bhimphedi and Pulchauki Groups, which are of Precambrian and Palaeozoic age respectively.

The map of Trishuli–Kolphu Khola area was the first map to be prepared by the Stöcklin and Bhattarai (1977) under their mapping project. They had reported the presence of kyanite-bearing schist, however fail to mention the presence of sillimanite in the study area.

Stöcklin (1980) mentioned that the crystalline complex of Kathmandu consists primarily of right-way-up sequence of regionally metamorphosed sediments displaying a metamorphic zonation roughly concordant with stratigraphy and a regular decrease in metamorphic grade from highly garnetiferous schist at the base to barely metamorphosed, fossiliferous Palaeozoic sediments on top. The contact of the Kathmandu Crystalline Zone with the underlying metasedimentary rocks is marked by intense shearing and by a stratigraphic, metamorphic and structural discontinuity indicating a thrust plane.

Recent papers revolve around the controversies surrounding the position of the MCT. Recently (Rai et al., 1998; Rai, 2001), MCT has been placed within the Kathmandu Thrust sheet, and it bounds the Sheopuri gneiss on its northern and southern part. But, Johnson et al. (2001) completely refutes the idea that the MCT separates the high-grade rocks of the Kathmandu area from medium to low grade rocks.

Talalov (1972) interpreted the geology of Nepal in terms of vertical movement and believed that the Himalaya is not a geosynclinal folded mountain, but a product of block faulting.

During the Himalayan orogeny, the MCT was followed by the development of the Mahabharat Thrust (MT). Both the MCT and the MT diverged from the same thrust system which merge at depth to the decollement along which the subduction of the Indian plate occurred (Upreti, 1999b).

Mahato (2003) has done extensive mapping in the southern portion of the study area. His petrographic studies have resulted in the presence of staurolite, kyanite, and sillimanite as major metamorphic index minerals in the southern portion of the study area